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DEPARTMENT OF ENERGY,
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PAPER 71-34

QUATERNARY GEOLOGY OF SOUTHWEST NEW BRUNSWICK WITH PARTICULAR REFERENCE TO FREDERICTON AREA

N. R. Gadd

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(21G)

N. R. Gadd

(Report, 14 figures and Map 12-1971)

DEPARTMENT OF ENERGY, MINES AND RESOURCES

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ABSTRACT

Data acquired in the mapping of some 6,000 square miles in southwest New Brunswick provide a basis for the interpretation of Pleistocene history of that region. Inherent in the data is some suggestion that two major ice lobes may have met more or less along a line between the cities of Saint John and Fredericton. However, the pattern of distribution of ice-contact deposits and the sequential development of glacially controlled and modern drainage indicate a retreat of the ice margin towards the northwest, a retreat that probably occurred earlier than had been previously assumed.

RÉSUMÉ

Les données recueillies au cours des levés cartographiques d'environ 6,000 milles carrés dans le sud-ouest du Nouveau-Brunswick fournissent une base pour l'interprétation du Pléistocène de cette région. Ces données amènent à présumer que deux importants lobes glaciaires ont pu se rencontrer suivant, plus ou moins régulièrement, une ligne passant entre les villes de Saint-Jean et Frédéricton. Toutefois, le modelé des dépôts de contact glaciaire et la délimitation des réseaux hydrographiques d'origine glaciaire et moderne, indiquent une régression de la limite des glaces en direction du nord-ouest, probablement à une époque plus ancienne que supposée au préalable.

QUATERNARY GEOLOGY OF SOUTHWEST NEW BRUNSWICK WITH PARTICULAR REFERENCE TO FREDERICTON AREA

INTRODUCTION

In 1967 and 1968 the surficial deposits of the St. George (21 G/2) and St. Stephen (21 G/3) map-areas were mapped and the data deposited on open file at the Geological Survey of Canada. This, and previous work by Lee (1957, 1962) in the Fredericton (21 G/15) and Canterbury (21 G/14) map-areas, formed the basis for the present study. This report contains a geological map showing the distribution of unconsolidated glacial and nonglacial deposits at a scale of 1:250,000 and the interpretation of the glacial and postglacial history of the Fredericton area.

ACKNOWLEDGMENTS

Field assistants in 1967 were R. Héroux, H. Jacobs, and G. Jones, and in 1968 N. Szabo, L. McIntyre, and R. Bowlby. The air photo mosaic (Fig. 11) was prepared by Mrs. E.A. Fleming of the Surveys and Mapping Branch of the Department of Energy, Mines and Resources.

PREVIOUS WORK

The literature on the physiography and surficial geology of New Brunswick began at the time when the concept of continental glaciation was introduced in North America. Therefore, although the work of Matthew (1872, 1875) is mainly an eloquent defence of continental glaciation, others such as Ganong made valuable identifications and comments on glacial phenomena in widely spaced writings. For instance, in 1896 Ganong noted the unusual occurrence of a delta at the outlet of Lake Utopia, near St. George, but mentioned almost parenthetically that the lake itself owed its existence to "the glacial dam between it and Letang". He did not, however, investigate the morainic system of which the dam forms an important part. On the other hand, his article "On the Division of New Brunswick into Physiographic Districts" (Ganong, 1899) serves as a model for current physiographic subdivision of the region (Bostock, 1970).

In the period 1881 to 1905, R. Chalmers (1885, 1887, 1888, 1890, 1895, 1900) produced maps of the entire province and evolved a concept of glaciation by radial flow from an ice cap in the highland area of north-central New Brunswick. He depended mainly on glacial striations as indicators of glacial flow, but some of his published striation lists that also show orientation of striated bedrock slopes suggest that he commonly adopted the down-slope direction as that of glacial flow. Other criteria applied to the same regions prove up-slope movements equally credible.

Other phenomena observed by Chalmers in this area have alternative interpretations. For example, some of his "moraines", although certainly

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composed of glacial till, are better interpreted as drumlins, and his "kames" and "marine kames" include deposits that this writer would interpret to be fluviatile delta or terrace deposits, and marine beach sand and gravel. Chalmers' use of the term "marine kames" leads one to suggest that there may have been an element of compromise in his early writing between the two principal concepts of glaciation current in his professional lifetime.

Recent geological work, in and near the area, by Lee (1954, 1955, 1957, 1959, 1962), and Melvin (1966) and soil studies by Wicklund and Langmaid (1955) and Langmaid (1953) deal with the nature, origin and glacial and postglacial history of the area in modern context. This paper is an attempt to provide a regional setting for such work. Many other publications having local or incidental reference to glacial deposits and history are listed in the bibliography produced by the New Brunswick Research and Productivity Council (1965).

BEDROCK LITHOLOGY, TOPOGRAPHY AND DRAINAGE

The area constitutes a triangular structural basin of low relief (the Maritime Plain) occupied by flat-lying sediments and bordered on the northwest and south by ranges of hills (the New Brunswick Highlands). Immediately adjacent to the Bay of Fundy there is an apron of relatively low-lying terrain that is underlain by gneissic and granitic rocks of ages variously assigned between Precambrian and Devonian[1], and by sediments and minor volcanics of Pennsylvanian and Triassic ages.

Nearly two-thirds of the map-area, along the western and southern boundaries, has relief of as much as 1,000 feet. Devonian granite batholiths intruding deformed lower Paleozoic rocks occupy the two principal hilly regions of the map-area. The one trending south-southwest across the northwest corner of the map-area contains hills in the vicinity of Skiff Lake that exceed 1,200 feet above sea level. The second, trending southwesterly and thus converging towards the southwest on the first, more or less parallels the north shore of Bay of Fundy in the area between Hampstead and the north side of Passamaquoddy Bay. Its highest hill, Mont Champlain, is 1,462 feet a.s.l. These two areas are linked, between the towns of McAdam and St. Stephen, by a belt of folded Silurian to Cambro-Ordovician sediments and metasediments whose smooth, glacially streamlined hills attain elevations of about 700 feet. These areas are grouped physiographically as the New Brunswick Highlands by Bostock (1970).

The remaining third of the area is a somewhat dissected plain of low relief. This area east of Lake George and Oromocto Lake and including the city of Fredericton and the northern part of Canadian Forces Base Gagetown, is underlain by "carboniferous coarse-grained sediments mostly undisturbed and locally including basic and acidic volcanic rocks" (Anderson and Poole, 1959). Elevations range to about 600 feet and relief is low, generally less than 100 feet. This area is part of the Maritime Plain physiographic region as designated by Bostock (1970). The cuesta-like range of hills along the north margin of this plain, between Harvey Station and Fredericton, is

[1] For detailed descriptions of the geology of parts of the Fredericton map-area, see: Anderson and Poole, 1959; Hay, 1967; Ruitenberg, 1968a, b; and earlier work by Alcock, 1938, 1959, 1960a, b, c; 1964a, b. All these publications include pertinent bibliography.

intruded in places by volcanic rocks and has "anomalously high dips" that "may indicate faults and/or folds" (Anderson and Poole, 1959).

A geological traverse northwest from Bay of Fundy in the direction of ice-margin retreat would show the following topographic features: a coastal area of low relief; a high range of granitic hills extending from Passamaquoddy Bay to the south end of Camp Gagetown; a belt of relatively flat terrain and low relief fringed along its northwest margin by a cuesta-like ridge that extends from McAdam through Harvey Station to Fredericton; and a high range of granitic hills with maximum relief towards the north along a line from Fosterville to Canterbury Station. Thus there were three principal barriers controlling the pattern of ice-margin retreat and the development of postglacial drainage in southwest New Brunswick.

Modern drainage of the map-area in large part reflects ice-controlled late-glacial drainage. In the southern half of the region, i.e. south of Oromocto Lake, southward drainage is by means of such streams as Digdeguash, Magaguadavic, Lepreau, and Douglas, all of which are parallel to major glacial outwash and esker systems. Modern streams are underfit in much greater former outwash channels. The run-off from the northwestern highland area between Canterbury Station and McAdam collects in large lakes near the height of land which drain southward via St. Croix River. This appears to reflect a late-glacial condition when these waters were prevented by ice from flowing northward into Saint John River. Drainage of the central lowland area (Maritime Plain) eastward and northward into Saint John River in part reflects glacial ice-margin drainage, but is chiefly due to the re-establishment of preglacial drainage systems controlled by the bedrock structure.

SURFICIAL GEOLOGY

Abundant evidence of glacial abrasion and deposition testifies to the complete glaciation of the map-area. Parts of the area were covered by the sea in late-glacial time, as a result of isostatic-eustatic interaction, but are now as much as 240 feet a.s.l. Results of the study of glacial and nonglacial Pleistocene sediments of the area are shown on the accompanying map.

Description of Map-Units

Bedrock (R)

This includes those areas in which rock exists at or near the surface; small areas of drift thicker than a few feet may be included in pockets among dispersed outcrops. Bedrock is most commonly veneered by till and the products of till weathering such as lag boulder gravel and individual boulders. In one area in particular (shown as 2/R on the map; see also Fig.7) bedrock is strewn with or completely buried beneath a heavy accumulation of large blocks of rock (some 20 feet in diameter), mainly grey porphyritic granite. The area shown south of South Oromocto Lake is the most spectacular example of this, but other smaller areas are similarly strewn with granite blocks. This is common in the terrain underlain by coarse-grained and coarsely porphyritic granite north and west of McAdam and Magaguadavic Lakes. The town of McAdam and the southeast end of McAdam Lake are easily accessible areas in which large blocks dominate the surface. Similar features are common in the belt extending northward from McAdam through Canterbury Station to Meductic and Pokiok, the latter two localities being on the Trans-Canada Highway along the south bank of Saint John River.

Deep weathering of several rock types has produced granular regolith (residual soil) which, in some areas, is exploited as gravel. Porphyritic grey granite on the road to Charlie Lake (Fig. 1) is excavated to a depth of about 8 feet, the weathered rock being overlain in places by glacial till. On the peninsula between French and Indian Lakes (Sheffield Parish) in the northeast corner of the map-area, in several places south of the town of Oromocto as well as within the limits of C. F. B. Gagetown, Carboniferous conglomerate (Fig. 2) is sufficiently friable to be used as gravel to depths of as much as thirty feet. Fissile rocks such as basalt, some types of acid volcanic rocks, schists and slates, are granulated by the development of very closely spaced fault and fracture systems. These too are exploited as granular fill material and road ballast in parts of the area.

<u>Glacial features of the bedrock surface</u>: Glacial groovings and striations are well preserved on competent rocks such as some granites, fine-grained volcanics and sediments (Figs. 3, 4). There are two major trends; southeast in the western half of the area and south in the eastern half of the area. Striations alone record only the orientation of movement of a glacier, not its direction of flow, and may record any stage, or all stages, of glaciation. Superposed striae may record more than one glacial episode or variations in the pattern of flow during various phases of a single glaciation. Crescentic markings on some outcrops (Fig. 4) support the concept of the principal flow of continental glaciers in the area from northwest and north towards southeast and south.

"Bevelled flutings" (Fig. 5) were observed in two places on the Letang Peninsula. It appears that the rock surface was fluted by glacial abrasion into a series of alternate parallel ridges and troughs (amplitude about 8 inches) both of which were striated in the regional southeasterly pattern, and was subsequently abraded by glacial movement at an angle of about 45 degrees to the original direction of flow. The second abraded surface intersects the first in such a way as to leave a bevelled edge on the upstream side of the original fluting. Because the bottom of the flute bears only striations parallel to the groove, and because it would seem that a depression would be protected from erosion by a thin cover more readily than would a ridge, it is inferred that the depression was protected from secondary abrasion by material such as till.

Where this phenomenon occurs it is concluded that there were two phases of glacial erosion, the first producing the glacial fluting and the second the tangential striation and bevelling. Because the more easterly flow direction on Letang Peninsula is compatible with late ice lobation in Passamaquoddy Bay, it is assumed that the bevelled edge in these features is on the upstream side of the groove. Thus the phenomenon has been used to identify the sequence of both glacial abrasion and direction of flow during the last glacial event. Where the sequence has been determined by this means, the relevant crossing striation symbols are numbered chronologically 1 and 2 on the map.

Divergent striations in most other parts of the area are commonly within a twenty degree range of the most common or principal direction but, in a few places such as Sand Point north of St. Andrews and the Fundy shore

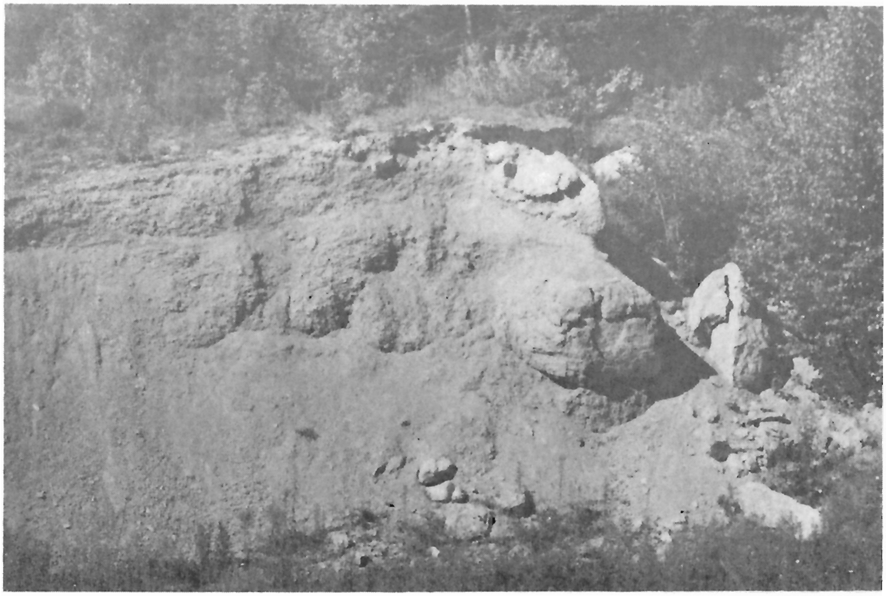

Figure 1. Weathered granite; gravel pit in the vicinity of Charlie Lake. Highest part of section approximately 8 feet. GSC Photo 159365

Figure 2. Carboniferous conglomerate exploited for gravel in Sheffield Parish. Exposure at centre of photo is about 15 feet high. GSC Photo 159372

Figure 3. Striations and crescentic fractures on glacially eroded surface of fine-grained volcanic rock. Camera faces south; crescentic fractures are concave downstream glacially; glacial flow towards top of picture (Sand Point, east bank of St. Croix River). GSC Photo 159367

near Pocologan, striations are found that are nearly at right angles to the regional pattern. In these cases, the divergent flow is confined and parallel to linear troughs produced by differential erosion along dykes (Sand Point) or fault or fracture systems (Pocologan). The troughs range in depth from about three to nearly ten feet. Since there are some intermediate striations along their mutual boundaries, striations of the trough and surrounding bedrock surface seem compatible rather than sequential. It is assumed, therefore, that they were formed contemporaneously and that flow of the basal part of the ice sheet was deflected locally by these relatively minor troughs.

Glacial till

Areas mapped as unit 1 are generally underlain by glacial till, but do include small areas of bedrock. Composition of the till ranges from silty to sandy or gravelly, depending on the nature and proximity of underlying local bedrock from which it was largely derived. For the same reason, unweathered till has a range of consistency from compact to loose and friable. Where it lies directly on conglomerate bedrock, only poor sorting and lack of stratification will distinguish the till from gravel or from weathered bedrock. Lee (1957) has noted that, in the Fredericton area (21 G/15), till is generally from three to five feet thick but that, in one section through a drumlin, it is reported to be 156 feet thick. Observations over the wider area encompassed by this report suggested that, typically, the till cover ranges from three to ten feet in till plains and attains thicknesses of as much as 50 feet in moraines and probably over 100 feet in drumlins.

The concentration of loose boulders on the surface of the till (Fig. 6) and the variable thicknesses of loose, poorly sorted boulder gravel and sandy gravel that grades downward into compact till, are attributed to soil-forming processes and ablation. Unlike Lee (1957, etc.) who classified the loose surface debris as 'ablation till' and 'colluvium', the author attributes much more of this material to soil-forming processes, including the erosion of slopes by running water. Because the author feels that the material is, in most cases, an erosional lag deposit, he disagrees with the usage of the term 'colluvium' as it appears in Lee's reports and has some reservations on the degree to which the term 'ablation till' may apply locally.

There are basically two till colours; grey-brown-olive shades such as greyish brown to light olive brown (Munsell 2.5Y 5/2, 2.5Y 5/4) and darker shades ranging to olive grey and olive (Munsell 5Y 5/2, 5Y 5/3) and, secondly, reddish brown shades such as dark reddish brown (Munsell 2.5YR 3/4) and reddish brown (Munsell 2.5YR 4/4). The grey-brown-olive shades dominate the western and southwestern parts of the area that are underlain by slates, schists, and argillites of dark grey to dark green colour, and the reddish brown shades are common in the central and northeastern parts underlain by sedimentary rocks of predominantly dark red colour. Variants on these colours are produced locally by the addition of grey, pink or salmon pink of

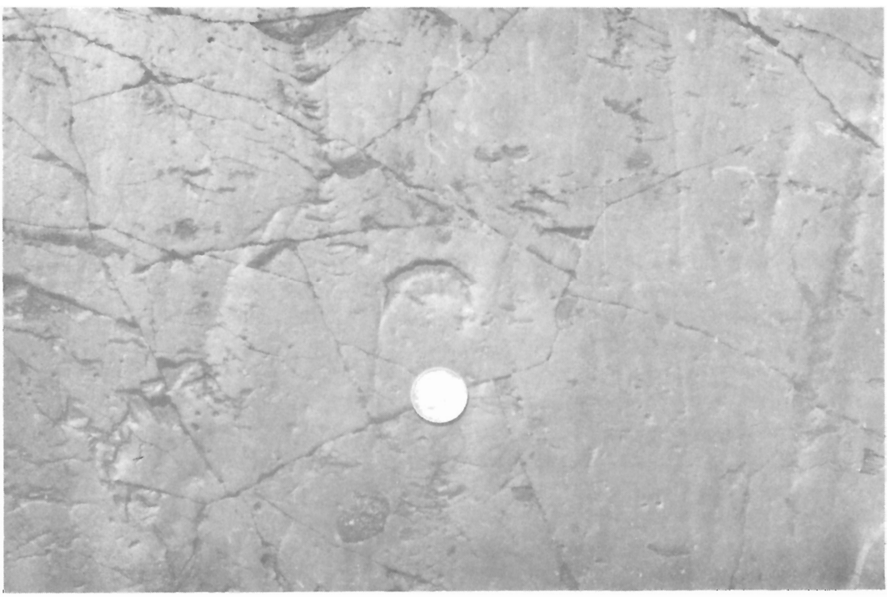

Figure 4. Crescentic gouge at centre of photo (above coin) shows, by the conchoidal fracture of its floor, that a chip has been removed from otherwise glacially polished volcanic rock. The gouge is terminated by a vertical crescentic fracture which is concave upstream glacially. Tension cracks of the opposite orientation, i.e. concave downstream, are shown both above and below the featured percussion form. Flow towards the top of the picture is confirmed by nearby crag-and-tail features (Sand Point, east bank of St. Croix River; same outcrop as Fig. 3). GSC Photo 159368

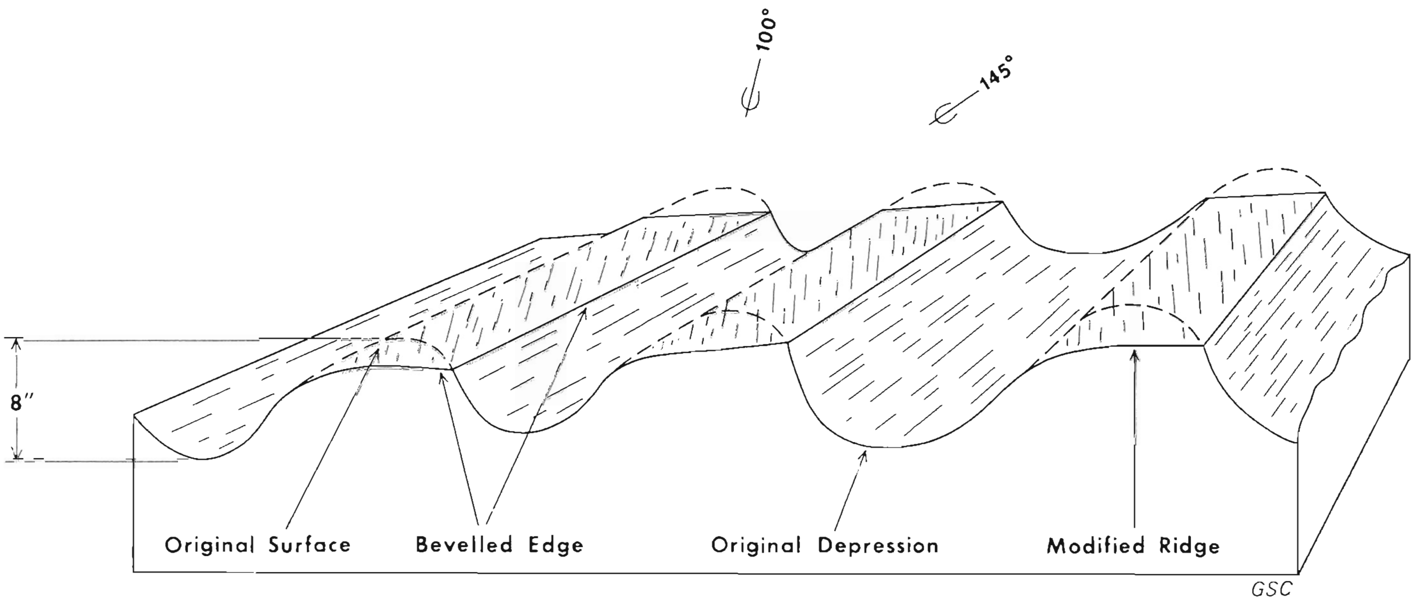

Figure 5. Three-dimensional diagram of bevelled fluting.

Figure 6. Typical sandy till with surface concentration of boulders in granitic terrain, vicinity of McAdam. Surface disturbed by road-building. Deposit of till approximately 10 feet thick at this place. GSC Photo 159369

Figure 7. Glaciated bedrock with thin veneer of glacial debris; map-unit 2/R. Till thickness 1-1.5 feet. GSC Photo 159370

the granites and by the addition locally of dark to light grey and light olive grey of some facies of the sandstone and conglomerate rock units. Presence of coal seams in some of the rock units in the extreme northeast part of the area and of graphitic schists and slates in the southwest is reflected by local darkening of the till colours.

Streamline features of till and/or bedrock: Ice-moulded streamline features on till and/or bedrock are most common in the western third of the area and most of them are primarily composed of till. Drumlins and crag-and-tail are two common features of that area, both of which demonstrate by their shape that the flow of glaciers across the area was from northwest to southeast. On the geological map they are shown by means of symbols. In the same belt of streamline features one finds rock drumlins (Flint, 1957, p. 68), rock-cored drumlins and roches moutonnées. With the majority of drumlinoid hills, where bedrock is not exposed, it seems possible to equate height of the hill with thickness of till, but it is not always possible to judge whether or not the feature is rock-cored.

Till is present in minor amounts in ridges included in map-unit 2, but is not distinguished on the map from associated gravel and sand.

Gravel-till complex

Classification of areas under map-unit 2 is based on both materials and landforms. Included are thick accumulations of ice-generated sediment, both glacial and glaciofluvial, commonly found in the form of mounds and elongate ridges (moraines). Moraine ridges recognized on the ground and on air photographs have been designated by lines labelled 'M'. These ice-marginal or ice-contact sediments are dominated by gravel and sand, but include till commonly buried within the bouldery gravel matrix of a minor moraine, although a few moraine ridges are basically till. Several large areas are densely covered by very large blocks and boulders. Angular blocks of as much as 50 feet are known and sizes ranging up to 20 feet are common. Boulders of all sizes are very abundant, most particularly in, and glacially downstream from, regions underlain by coarse-grained granite rocks (Fig. 8).

Much of the material of map-unit 2 is accumulated in discontinuous morainic ridges ranging from a few yards to several miles in length and form ten to over one hundred feet in height (Fig. 8). Such ridges are oriented more or less at right angles to the local direction of ice flow as represented by the orientation of drumlins and striations. Morainic ridges greater than fifty feet in height are restricted to the Fundy coastal area between St. George and Saint John, N.B.; moraines in other parts of the area are generally smaller. Some of the large coastal moraines have been modified by wave action resulting in deposition of marine gravel on their crests and in the development of marine spits, bars, and other marine shore features along their flanks. Such modified features are designated on the map by 6/2.

Closely spaced minor moraines commonly occupy broad flat depressions and are similar to minor moraines of the 'DeGeer', 'annual', 'washboard' (Prest, 1968), or 'Rogen' (Lundquist, 1969) type. They are interpreted as accumulations of glacial debris at or near the active ice margin. Because they have a fairly regular, lobate distribution across the area, they are believed to indicate the retreat of the ice margin.

Also included in map-unit 2 are large areas of ice-contact stratified drift in irregular, hummocky or knob-and kettle topography. These deposits, produced at the ice margin during rapid melting, are most abundant in the belt extending along the north side of a range of granitic hills in the area south of McDougall Lake, between Mosquito Lake and the village of Elmsville on Digdeguash River. Deposits of this type, extending northward along Magaguadavic valley, have been modified by superposition of younger outwash gravel and sand that have partly buried the ice-contact deposits. These and other areas of similar composition are designated 4/2 on the map. Morainic ridges are not common, or the connections of one to the other are obscured by the blanket of overlying sediment and by related outwash channels, so that ice-marginal positions cannot be traced readily in this central area of concentrated ice-marginal deposition. No data are available on the thickness or granulometry of these deposits although they would appear, nonetheless, to be significant commercial sources of sand and gravel. Their distribution across the map-area emphasizes the lobate character of the ice margin.

Figure 8. Morainic ridge of boulders, gravel, some till in vicinity of Big Kedron Lake. Top of ridge in background is about fifteen feet above road level from which photo was taken. Large boulder at left side of roadway is approximately 6 feet in diameter. Although this relatively small feature does not show well on a surface photograph it is easily recognized as a distinct morainic ridge on air photographs where the concentration of grey to white granite boulders shows up as a white arcuate line. GSC Photo 159373

Esker complex

Characteristic sediment is variously sorted, angular to subrounded sand and gravel, with silt and boulders (Fig. 9, 10). It is interpreted as ice-contact sediment on the basis of form, range and variability of sedimentary structure, and association with masses of ice-contact drift in typical hummocky or knob-and-kettle topography. The latter are minor features. not distinguished on the map, that occur in several places such as McDougall Lake area, Pokiok River-Mud Lake area and Mazerall Settlement area. Sinuous, sharp-crested ridges are characteristic. The esker ridges range in height from about 5 feet to nearly 250 feet, the most prominent being that portion of an esker system extending south from McDougall Lake. Eskers of the area are more or less continuous over distances of up to ten or more miles. Some portions of eskers near First Eel Lake (northwest corner of the map-area), Dead Brook, Mud Lake, and Rusagonis River exceed 100 feet in height.

Eskers occur mainly west of Oromocto River and Lepreau River; farther east, glacial drainage seems to have occurred in outwash channels along the deep valleys of the Oromocto, Nerepis and Saint John rivers and of Back Creek. The western part of the area is characterized by a discontinuous system of ice-controlled drainages represented by eskers which, from the dips of strata in relatively few exposures and from the regional network pattern of the eskers, appear to have carried water southward across the easterly trending Saint John valley. Between the Saint John River and the Bay of Fundy, eskers trend southeasterly parallel to the regional trend of glacial flow. It is possible that the entire system was active at one time but, the segmented nature of the system, the association with apparently succesive major outwashes on the coast and along principal valleys, and the fact that esker ridges are found oriented more or less at right angles to moraine and minor moraine systems, where the relationship may be seen, all suggest that the abandonment of esker segments was sequential and controlled by topography and thus emphasizes the lobate configuration of the ice margin at different times. Some major eskers apparently were at some time continuous across major transcurrent valleys such as the Saint John; smaller eskers parallel to such valleys, and apparently younger than the major eskers, represent the transition from glacial to nonglacial drainage during the last local phase of ice-controlled glacial drainage. The esker network of southwest New Brunswick is continuous with that of adjacent areas of Maine. A few representative eskers across the International Boundary south and west of St. Stephen are redrawn from the maps of Leavitt and Perkins (1935) to show parallelism and similarity of discontinuities common to eskers in the two areas.

One esker in the vicinity of Oak Bay has been modified by marine submergence and has been partially buried by shore and near-shore sediments; it is designated 6/3 on the geological map.

Eskers contain large volumes of fluvial gravel and sand and, as such, have great potential for commercial exploitation as sources of granular materials. Weathering to depths of 10 feet or more of carbonate-bearing rocks producing pebbles that are 'shadows' composed of insoluble residues, and the presence of large amounts of schist and slate in certain deposits in the southwestern part of the area, appear, from local experience, to be limited in their use for specialized purposes such as road surfacing and concrete aggregate materials.

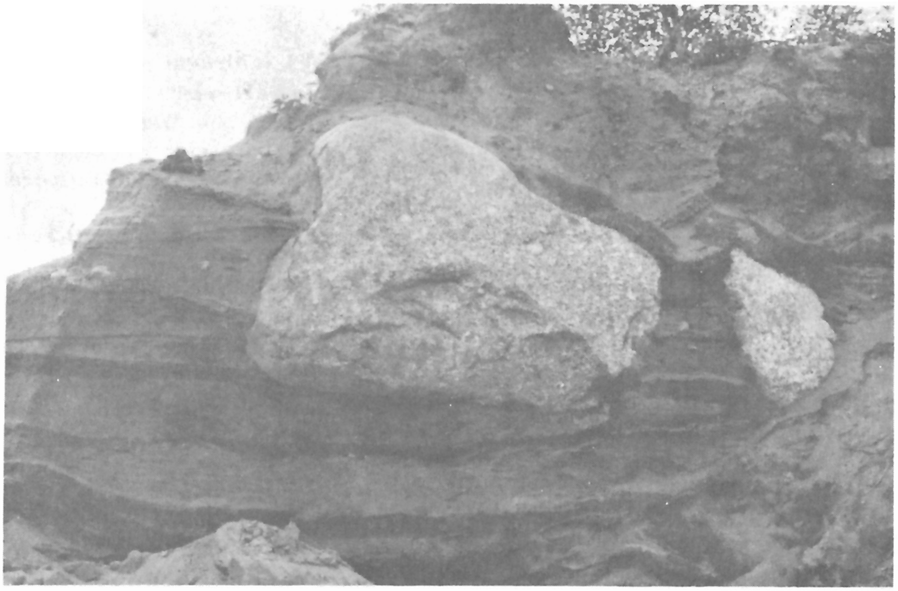

Figure 9. Four-foot granite porphyry boulder enclosed in silty sand, fine sand, and gravel of Otter Brook Eskers. GSC Photo 159371

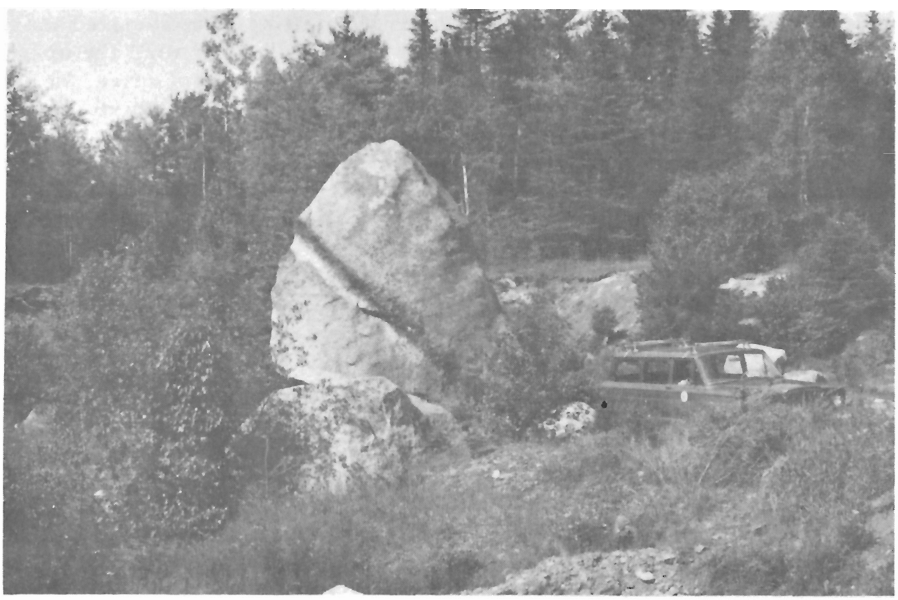

Figure 10. **Boulder**, approximately 12 feet in diameter, in esker, vicinity of Graham Corner. Podzol profile etched on boulder marks position of side slope of esker before removal of gravel. GSC Photo 159366

Outwash plain, fan and channel deposits

By far the largest amount of glaciofluvial sediment of map-unit 4 is included in channel and river terrace deposits in valleys. The largest of these outwash channel deposits are in the valleys of the Digdeguash, Magaguadavic (particularly near Brockway), Oromocto (vicinity of Fredericton Junction), and Saint John rivers. In the first two, esker segments alternate with glaciofluvial channels in which outwash is well developed. In the Saint John valley, masses of outwash are associated with moraines and other ice-marginal features at Welsford, Upper Hampstead, Gagetown and Fredericton. The Little, Keswick, and Nackawic rivers and Nashwaaksis stream are southward-flowing tributaries of the Saint John River. Each of them, as glacial streams, carried coarse outwash to that section of the valley upstream from Marysville and Fredericton and produced in the Saint John valley a more or less continuous and regular outwash unit of great depth that has been incised and redistributed by the modern Saint John River.

Glaciofluvial sediments deposited at or at a short distance beyond the glacier margin are also included in map-unit 4; they comprise gravel with clasts of all sizes (including boulders), sand, and minor silt. Sorting of the material is fair to good and granules are mostly subangular to subrounded with roundness and abundance of resistant particles increasing rapidly with distance from source. Fans and delta-like deposits are prominent in the coastal area and constitute sand and gravel deposits up to 150 feet thick at Maxwell (north of St. Stephen), at and northeast of Bethel (between Digdeguash and St. George on Highway 1), at Pennfield Ridge and Utopia Centre, and in the vicinity of Pocologan and New River Stations. Several of the gravel deposits are deeply pitted by kettles formed by melting of associated masses of glacial ice. The northern portion of Pennfield plain, forming the apex of a triangular mass of gravel about 1 1/2 miles east of Utopia Centre, is pitted in a spectacular fashion by irregular depressions as much as thirty feet deep. Some of the depressions contain lakes (Fig. 11, in pocket).

Marine sediments

Late-glacial marine submergence of the Fundy coastal areas of the Fredericton map-area (21 G) is represented by two facies of marine sediments, a silty facies (map-unit 5) and a sand and gravel facies (map-unit 6). The sand and gravel facies sediments are interpreted as shore sediments and are most extensive in the raised beaches north and northeast of Maces Bay between New River Beach and Lepreau where vertical sections of between 10 and 20 feet, mainly of sand, are exposed along the highway and in shore cliffs. Also included in the shore facies are the products of older glacial deposits reworked by wave action during periods of immersion and during offlap episodes; coarse boulder gravel and lag boulder concentrations produced in this way are variously shown on the map as follows: 6/3 - wave-modified esker; 6/2 - wave-modified moraine and ice-contact material; 6/4 - wave-modified outwash fan and delta deposits. Only the latter of these wave-modified units is known to be fossiliferous, but in most places the others do grade laterally into off-shore facies silt and clay deposits that are abundantly fossiliferous.

Silty to clayey facies of the marine sediments (map-unit 5) are interpreted as off-shore sediments and occur over a wider area than the

Figure 13: Fossiliferous red silty marine clay (dark bands) interfinger with poorly sorted gravel reworked from underlying glacial deposit. Beds dip south towards Bay of Fundy. Height of section approximately 12 feet. Sheldon Point, Saint John Harbour, N. B. GSC Photo 159374

shore-facies sediments, but their total area is small. (Lacustrine sediments probably of glacial origin have a very limited surface distribution in the vicinity of Lake Utopia and St. George and have been included in map-unit 5 in those areas.) The marine silty sediments are most common in flat areas adjacent to the sea coast and at elevations commonly not more than 50 feet above present sea level. Thicknesses of up to 40 feet have been observed in actively eroding shore cliffs. Silt, silty clay, and clay in thin horizontal layers of one-half inch to several inches thick are common. In some of these there is colour banding with alternate dark grey to black bands; interbedding and interfingering relationships with sand and gravel deposits lying landward of the clayey deposits are exposed in a few localities. The most striking example of interfingering is exposed in road-cuts along service roads leading towards the modern beach in the large gravel pits at Sheldon Point. There, fossiliferous clay beds pinch out shoreward over a distance of about one thousand feet up the gradient of foreset beds of gravel and sand with which they are associated (Fig. 13).

Like the glacial tills of the area, the Pleistocene and modern marine clays have two principal colours, grey in the coastal areas west of Pennfield Station, and reddish brown in the areas eastward at least as far as the harbour of Saint John. These distinctive colours of similar sediment, apparently deposited simultaneously in the same marine basin, must reflect the provenance of the material and not differences in the marine environment of the Bay of Fundy.

The two facies of marine sediment are generally limited to a narrow zone extending no more than five or six miles north of Passamaquoddy and Fundy bays. Lee has reported the occurrence of fossiliferous marine clay in the vicinity of Fredericton, but no other occurrences along the Saint John River are known. Although marine deposits are rarely more than 100 feet above present sea level, shore facies sediments occur up to 240 feet above sea level. This maximum is based on the fact that, on the Pennfield plain, glacial outwash fan deposits at and below 240 feet contain few open kettles and few sections in gravel pits show collapse structures bridged by horizontal strata, indicating that depressions of kettles have been filled during wave planation of the surface. Also, the surface of the same deposit above 240 feet is deeply pitted with large kettles. In some of these kettles, bogs and lakes hold organic sediments; one such lake, Little Lake, has organic matter older than the oldest known marine sediments of the area and contains only elements of fresh-water environments. Little Lake has a present water surface elevation of approximately 208 $\pm$ 5 feet[2] above sea level (Fig. 11), and is rimmed by sand deposits at least 240 feet above sea level. There are at least two possible interpretations of this information - one, that late-glacial sea level never exceeded the 240-foot mark above present or, two, that formation of kettles occurred after subsidence of the sea from a level higher than 240 feet.

All dated shell materials of the area (see Table I) lie below 150 feet a.s.l. and only one of the dates (GSC-886) represents shore facies sand and gravel deposits; the others are from off-shore clay and silt facies but which, because of their lamination, stratification and interfingering relationships with shore facies sediments, are considered to represent a shoreward, shallow-water environment rather than a deep-water environment.

Most of the fossil remains observed record near-shore and intertidal environments. Some species, particularly gastropods, possibly represent deeper water and may have been introduced into the assemblage as floating material. It is suggested that dominance of several species such as Hiatella arctica, Macoma balthica, Portlandia arctica in Pleistocene sediments may represent colder water conditions than those of the present coast where these genera, though present, are relatively less common. Modern warmer water forms common to the Fundy coast such as oysters, scallops and sea urchins have not been observed in the fossil material.

Ostracods identified by U.S. Geological Survey paleontologist Joseph E. Hazel (pers. comm., June 1971), listed in Table II, he interpreted as suggesting "deposition in quite shallow, very cold (subfrigid to frigid) waters of normal salinity".

Alluvial deposits

Map-unit 7 comprises sediments that occur in terraces flooded, or recently abandoned, by modern streams. They consist of sand and silt with small amounts of gravel and disseminated organic matter. Areas of this material large enough to map (greater than one-quarter mile wide) occur on

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[2] This elevation and other data on contours and elevations of Pennfield Plain shown on Figure 11 were determined by Mrs. G. Mizerovsky and mapped using a Zeiss sterotope. Her original contour map, which contains much more detailed information than shown on Figure 11, has been placed on open file at the Geological Survey of Canada.

Table I

Locality	Approx. Elevation (ft. a. s. l.)	Geologic Setting	Macrofossils	Lab. No.	C^{14} Date
Benson Corner	85	Wave-modified kame	*Mytilus edulis* *Macoma* spp.	GSC-886	12,300 ± 160
Sand Point	50	Marine silt on kame terrace overlain by off-lap gravel	*Hiatella arctica* *Macoma calcarea* *Serripes groenlandicus* *Mya truncata* *Balanus* sp. *Mytilus edulis* *Lunatia* sp. *Neptunea* sp. *Buccinum* sp. other unident. pelecypods, gastropods, crustaceans	GSC-795	12,300 ± 160
Pennfield	130	Toe of slope at south margin of Pennfield plain (modified outwash fan ?)	*Portlandia arctica* *Macoma balthica*	GSC-882	13,000 ± 240
Saint John (Sheldon Point)	10 25	Red marine clay interfingering up-slope with gravel of modified moraine	*Macoma balthica* *Macoma calcarea* *Portlandia arctica* *Balanus* sp. *Mya truncata* *Serripes groenlandicus* *Hiatella arctica* Several gastropods, ophiuroid starfish	I(GSC)-7 GSC -965 GSC-1340	13,325 ± 500 13,200 ± 200 13,000 ± 170

Table II

Ostracods of Sandy Cove (Sheldon Point), N. B.

Sample No.	Location	Identification	Comments
MC-12	700' east of gravel pit road, 40' above beach level	(C) [1] Leptocythere machesneyi Brady and Crosskey, 1871 (C) Normanicythere concinella Swain, 1963 (R) "Acanthocythereis" cuspidata (Brady and Crosskey, 1871) (R) Cytherura granulosa Brady and Crosskey, 1871 (R) Cytheropteron nodosum Brady, 1868 (R) Paradoxostoma cf. P. variabile (Baird, 1850) (R) Cytheropteron pyramidale Brady, 1868	Very organic, sandy, reddish clay containing also: brittle stars, snails including Buccinum cf. B. hancocki Mørch, and bivalves including Seripes groenlandicus (Bruguière).
MC-14	At east side of gravel pit road, 20' stratigraphically below MC-12	(R) Leptocythere machesneyi (R) Cytheropteron nodosum (R) "Acanthocythereis" cuspidata	Red, shelly clay; same locality as collection of shells for GSC-965 (13,000 ± 200 B.P.) and GSC-1340 (13,000 ± 170 B.P.).

[1] C-common; R-rare

the lower Magaguadavic, in the lower parts of Oromocto and Douglas valleys and, most extensively, in the Saint John River valley. In the latter, alluvial terraces in the vicinity of Maugerville and Jemseg are subject to frequent flooding. This produces broad natural levees along the river bank broken at many places by channels branching towards the inner, low parts of the terraces. Swamps and lakes on the terrace are being filled gradually by inorganic and organic sediment.

Bog deposits

Most areas designated as map-unit 8 are raised bogs in poorly drained depressions, either in glacial deposits or in bedrock. Some are developed by partial or complete filling of lake basins. As no complete exposures or borings are available, the dimesnions of the deposits are not known.

The chief material on the surface of the bogs is sphagnum peat. In many cases the peat grades downward through several types of organic detritus (including diatomite in several small lakes in the headwaters of Little New River (McMullen and Wright, 1938)) into soft grey lacustrine clay.

Tidal marsh along the Fundy coast is of limited extent, occupying two principal areas: Musquash Harbour at the mouth of Musquash River, and Lorneville Harbour north of the village of Lorneville. It has not been shown as a map-unit on the geological map. Salt marsh mats of up to four feet thick have been observed in many places along the coast.

INTERPRETATION OF GLACIAL HISTORY

Because no evidence of glacial and nonglacial events older than Wisconsin is available for this region, events related to continental glaciation are assumed to be of probable Wisconsin or late-Wisconsin age.

Ice-flow directions

Two principal directions of ice flow have been noted in the map-area, that of the western half of the area recorded by southeasterly-trending drumlins and other streamlined features and by striations (see above). and that of the eastern part of the area recorded primarily by southerly-trending striations. The geological map shows the existence of a large outwash fan at Pennfield, the convergence of moraines into an apparent re-entrant of the ice margin north of the Pennfield fan, and a major development of a complex of eskers, ice-contact, morainic, and outwash deposits in Magaguadavic drainage basin between McDougall and Kedron lakes; all these are factors that may be considered as supporting evidence of lobation, since they all lie in the boundary zone between the two principal flow patterns. They may represent lobation of the ice, when its margin stood at or near the north side of the Bay of Fundy, with two broad lobes converging along a line between Fredericton and Pennfield. Bevelled glacial flutings (Fig. 5) on Letang Peninsula support the concept of a late-glacial ice lobe in Passamaquoddy Bay.

Pattern of Retreat of the Last Ice Sheet

Ice-margin positions related to the wasting of the last ice sheet in this map-area are recorded by: 1) major end moraines in the coastal areas between St. George and Saint John; 2) minor moraines and ice-marginal drainage systems that developed in succession from southeast to northwest across the area; and 3) orientation and distribution of eskers. There is some suggestion of minor recessional halts of the ice margin or perhaps, more correctly, of fluctuations in the rate of melting of the ice sheet as its margin moved northward out of the area. There is no evidence to date of significant readvance of the ice-margin in this part of New Brunswick. Because moraines of the entire region are discontinuous, all ice-margin positions showing possible correlation of ice-marginal features are speculative.

Early Phase

Wave-modified remnants of what appear to be the oldest moraines preserved on land are exposed south of Highway 1 at Sheldon Point and Taylor Peninsula in the Saint John Harbour area and between Lorneville and Musquash harbours. A small mass of morainic material at Seely Cove may be a related feature. It is unkown whether ice stood north, south, or on both sides of these ridges during their formation.

The moraine of Sheldon Point is modified by wave action and its sediments interfinger with marine clay containing shells dated 13,000 to 13,325 years B. P. This date serves as a minimum age for the formation of the original morainic feature.

Ice-marginal features in the area north of Highway 1 were formed by ice lying to the north of the features. The sequence of events related to ice-margin retreat between Saint John and Fredericton is shown in a series of seven diagrams that constitute Figure 12; local names are used for the selected phases of this retreat in order to emphasize the sequence of glacial and nonglacial events.

Pennfield Phase

(Fig. 12-1, see also Fig. 11) The principal feature of this phase of ice-margin retreat is a triangular apron of glacial outwash with its base near Highway 1 between Pennfield Corner and Pennfield Station. Its apex, at the railway crossing on the Old Saint John road about 1.5 miles east of Utopia Centre, occupied a re-entrant in the ice margin that then lay against the west side of Letang River valley and extended northeasterly through Pennfield Corner to the apex of the Pennfield outwash plain, thence southeastward, possibly to the vicinity of Pennfield Station, where it appears to have swung eastward, possibly across the north end of Maces Bay through Little Lepreau and South Musquash, where strong morainic features exist, and thence connected with the very well defined moraine occupied by Highway 1 between Spruce Lake and the Lancaster area of Saint John.

West of Pennfield, because of the absence of strong morainic features, and because of strong easterly flow pattern shown by striations and bevelled flutings on the peninsula near Mascarene, it is assumed that the ice margin formed a bulbous lobe centred on Passamaquoddy Bay, with its margin within this map-area extending southerly through Blacks Harbour.

The present Little Lake on the Pennfield outwash plain (Fig. 11) contains freshwater lake organic sediment, the base of which was dated at 16,500 $\pm$ 370 C^{14} years B. P. (GSC-1063). The lake occupies a kettle in the unmodified glacial outwash deposit lying more than 240 feet a. s. l., the level assumed to be the maximum of marine submergence of this area. Little Lake, whose rim rises a few feet above this assumed marine limit contains material of freshwater affinity only. Little Lake was available for accumulation of organic sediment from the time of recession of the ice margin, plus time necessary to melt ice blocks in the outwash deposit and to form the kettle lake basins there. Perhaps organic sediment began to accumulate as early as 16,500 years B. P. Provided this is a valid radiocarbon date, we may use it as a minimum age for the presence of glacial ice at Pennfield and for the formation of the Pennfield outwash plain. The age of marine submergence and its possible significance is discussed in a separate section that follows.

Utopia Phase

(Fig. 12-2) Following the formation of Pennfield plain, the ice margin retreated a short distance to the vicinity of St. George where it built a major moraine through the site of the town of St. George, produced the barrier across the south end of Lake Utopia and occupied a northeasterly orientation through Utopia Centre. The re-entrant established at the Pennfield stage persisted and the eastern lobe lay with its margin on high ground between Pocologan River and Utopia Centre, and presumably swung eastward parallel to the Old Saint John road through Pocologan and New River stations to Lepreau; east of Lepreau the ice margin may have lain along the present Highway 1 from Lepreau to Saint John. A pitted outwash apron formed at Utopia Centre with flow east and southeast towards an arcuate meltwater channel that flowed south, then west to the Letang Valley, which was at this time free of ice. New River Beach area, also probably ice-free at this time, may have begun to receive outwash sediment.

Termination of the moraines just west of St. George and the persistent evidence of easterly flow on the peninsula near Mascarene, plus evidence of southerly flow of meltwater across the peninsula between Mascarene and Letang indicate that an ice lobe also persisted in Passamaquoddy Bay at this time.

Recession from Lake Utopia to Second Falls

During the time required for the ice margin to retreat from the south end of Lake Utopia to the vicinity of Second Falls on the Magaguadavic River, it was transferred from the north coast of Bay of Fundy to the north side of the St. George granite batholith complex and thus lay north of the first of the regional barriers to southward flow.

In the Passamaquoddy Bay area, it is assumed that a broad lobe shrank from a position seaward of Deer Island to a narrow lobe confined to the estuary of St. Croix River as probably defined by ice-contact deposits on the west side of Oak Bay near Benson Corner, possibly similar deposits along the same west shore between Red Beach and Robbinston, Maine, and kame terrace deposits at Sand Point on the east side of the river, in the vicinity of Lower Bayside. Superposition of fossiliferous marine off-shore sediments on kame deposits at Benson Corner and Sand Point attest to the Passamaquoddy

Bay area being open to the sea, and therefore free of ice, by 12, 300 years B. P. (GSC-886, GSC-795, Table I).

Recessional moraines in Lake Utopia basin indicate that a narrow lobe retreated northward, opening up drainage into the east side of Lake Utopia and consequently diverting drainage from the Utopia-Letang outwash channel into a system now occupied by Messenett Stream. Thus, drainage from the re-entrant zone that previously supplied sediment to both Pennfield and Utopia outwash plains now flowed into the east side of Lake Utopia. For a time water ponded in the southern half of the Lake Utopia basin flowed through a channel that crosses Highway 1 about 2 miles west of St. George, but this was abandoned when the present course of Magaguadavic River was established through the gorge at St. George.

During this time a major change also took place in the glacial drainage system now represented by the system of eskers extending from the north side of McDougall Lake, through Sparks Lake and probably extending, at one time, as far south as the small esker segment 1.5 miles west of Utopia Centre that terminates in a small lake called Jerry Pond. This latter esker segment carried meltwater to Pennfield plain. As the ice margin retreated, drainage in this area was split, with a minor part diverted into Lake Utopia (see above), and the major part being carried by eskers through Sparks and Clear Lakes to the headwaters of Pocologan River. As ice thinned over the higher hills near Red Rock Lake, eskers were replaced by an outwash channel system in the headwater area of the Pocologan; at the same time New River, Lepreau and Musquash channels opened and flowed southward carrying glacial outwash.

Bethel-Pocologan Phase

(Fig. 12-3) Ultimately, with the ice margin north of the New Brunswick Highland (the range of hills dominated by the St. George granite batholith), the large esker system over the range ceased to function and a new one formed parallel to the north side of the range along the McDougall Lake road, about 3 miles south of McDougall Lake. At this time the ice margin is thought to have had a narrow lobe in the Oak Bay-St. Croix valley area (see above), to have continued along the north side of hills between Waweig and the south end of Lake Digdeguash, through Second Falls, and then easterly through Mosquito Lake, the south end of Loch Alva to the south shore of Kennebecasis Bay at the northern outskirts of the city of Saint John.

Outwash from this position of the ice went mainly into the St. Croix, Digdeguash, Magaguadavic, New and Lepreau river valleys. Large masses of sand and gravel accumulated on the south side of the bedrock barrier at such places as Bethel plain and the area east of Pennfield Station including Pocologan Station, New River Station and New River Beach. It is possible that the deposits of the latter area were laid in the sea, for fossiliferous red clays similar to the regional marine clays are exposed beneath sands of Pocologan and New River valleys.

During this same time it would appear that parts of the Saint John River valley above Saint John became ice-free. Masses of ice-contact gravel near Epworth Park and near the ferry landing at Hardings Point possibly outline an ice lobe in that area.

McDougall Lake Phase

(Fig. 12-4) It is inadequate to use a single line to illustrate the so-called McDougall Lake Phase of ice-margin recession, for it was a time during which the ice-margin recession was rapid, a very large number of small recessional moraines was produced in a broad belt centred on McDougall Lake and large volumes of outwash were produced that accumulated mainly in that area. Moraines in the vicinity of that lake were partially or completely buried by outwash so that it is truly impossible to trace any particular ice-marginal position with any degree of accuracy.

The diagram also shows a significant change in ice-marginal drainage. Up to this time all drainage from the ice margin had been southward, more or less directly to the Bay of Fundy using the glacial equivalents of the major modern streams and some additional outwash channels. When ice retreated to the vicinity of Westfield, the first significant eastward drainage towards Saint John valley occurred. This was along a linear channel extending southeastward from Queens Lake, as shown in Figure 12-4.

As the ice margin retreated through the McDougall Lake area, corresponding retreat in the Saint John valley caused additional drainage to open up towards Nerepis River valley and then to Douglas River valley. Short-lived southward glacial drainage across high ground at the south end of Camp Gagetown produced outwash accumulated and distributed in the Long Reach section of the Saint John valley. Subsequently, as the ice retreated northward, ice-contact features were produced at Upper Greenwich, Evandale, Hampstead, and Central Hampstead; these formed the central masses of gravel deposits later redistributed by the Saint John River. Farther west, the Nerepis River for a time became a major outwash channel and Douglas valley, between Welsford and Wirral, became the principal glacial outwash channel for much of the eastern half of the area. This was so particularly when the ice margin cleared the south end of South Oromocto Lake and water previously routed down the esker system to the headwaters of New and Lepreau Rivers was diverted into major ice-marginal channels flowing northeastward into the Douglas River system near Wirral. Simultaneously, Patterson Brook carried significant amounts of meltwater from the northeast. The ice margin could not have been far away, for the Wirral area channels enter the valley very near the present height of land between the northward-flowing Back River and the south-flowing Douglas River.

Retreat of the ice margin in western parts of the area is represented by apparent alternations between development of outwash and of esker systems as the margin retreated northwestward up the valleys. Accumulations of morainic material in areas flanking the valleys appear to correspond with the esker segments and the till plains with the segments dominated by outwash. Digdeguash and Magaguadavic valleys give the best examples.

Shin Creek Phase

(Fig. 12-5) There seems to have been a fairly significant halt of the ice margin halfway between the Bay of Fundy and the Fredericton-Meductic section of Saint John River. Although no continuous major moraine was produced, several well-developed features would seem, on the basis of physical similarity alone, to have some kind of regional relationship. These are, firstly, eskers west and east of Canoose Lake, near Rolling Dam station on the Digdeguash River, along Otter Brook (east of Oromocto Lake); secondly, morainic developments near Tryon Settlement, in the vicinity of the Kedron Lakes, near Hoyt Station in the Back Stream valley, and in the central part of Camp Gagetown, particularly in the vicinity of Upper Hampstead and Otnabog Lake and, thirdly, significant ice-marginal drainages along Otnabog River, Mersereau Stream and, most particularly, in the major channel that extends from Peltoma Lake, along Shin Creek to the vicinity of Hoyt Station.

Ice masses in areas west of Oromocto Lake drained via the major well-developed river system (e.g. St. Croix, Digdeguash, and Magaguadavic), but those east of Oromocto Lake drained mainly to the Back Stream valley in the area between Wirral and Hoyt Station. Large volumes of ponded sediment occur there, and apparently drainage of this large glacial reservoir was southward via Douglas River.

There followed another period of ice-margin recession during which masses of ice-contact and outwash gravel and sand were deposited in the Saint John valley between Upper Hampstead and Upper Gagetown. Simultaneously the ice retreated from Hoyt Station to the vicinity of Fredericton Junction, thus expanding the glaciolacustrine basin in that area and opening the east-flowing section of Oromocto River to glacial meltwater.

Oromocto-Gagetown Phase:

(Fig. 12-6) Moraines built in the northern part of Camp Gagetown between Babbit and Farnham Settlement, features near Waasis, Rusagonis and Beaver Dam, lobate moraines around Oromocto Lake and massive boulder moraines in the vicinity of McAdam are associated here in an ice-marginal position of some importance. Significant outwashes developed at this time in the Upper Brockway sector of Magaguadavic River, in the Upper Gagetown section of Saint John valley and the above-mentioned extension of ponded sediment deposits took place into the Fredericton Junction area (the lower Oromocto valley remaining blocked and regional drainage still flowing southward via Back and Douglas valleys).

The next episode of ice-margin recession saw the opening of the easterly-flowing section of Saint John River between Upper Gagetown and Fredericton with the consequence that lower Oromocto River developed as a tributary of the Saint John, drainage was reversed in the former outwash channel, and Back River flowed northward, becoming separated form the Douglas River system by the low morainic ridge that now fortuitously provides a drainage divide between these two rivers. With this fundamental change of drainage, the modern drainage system for the Maritime Plain sector of the map-area, with minor exceptions, came into being for the first time.

Ice lying west of Fredericton at the Oromocto-Gagetown phase fed large esker systems draining into the large lakes of that region (e.g. Spednik, McAdam, Magaguadavic, Cranberry) and meltwater thence flowed southward via established south-flowing outwash systems (primarily St. Croix, Digdegaush, Magaguadavic).

Canterbury-Marysville Phase

(Fig. 12-7) At this stage, drainage of the northwest corner of the map-area was confined to southward glacial channels and the ice margin lay in a position between Fosterville and Canterbury, extending through Allandale towards Prince William and Kingsclear. In the vicinity of the latter two places the ice may have defined a lobe basically in the Saint John valley with related eskers now flowing parallel to the valley. Up to this point, drainage had traversed the Saint John valley developing esker systems like that extending from the vicinity of Allandale (south of Pokiok) through Mud Lake to Prince William Station. Another major esker, which formerly flowed southward between Shogomoc and Kilburn lakes, at the Canterbury phase took a topographically controlled orientation parallel to the modern Dead Brook. The parallelism of this esker and esker segments in the Saint John valley suggest that ice now remaining occupied a lobe in the Saint John-St. Croix valley with flow from northwest towards southeast and east. A fairly strong moraine east of Marysville with an associated west-flowing ice-marginal drainage channel is probably of related age, but may represent a separate lobe in the Nashwaak valley. Large deposits of glaciofluvial sand at the mouths of Keswick, Nashwaak and Nackawick rivers may be from an interlobate zone.

Northward and eastward drainage of the Eel River drainage basin in the northwest corner of the map-area developed only after complete removal of ice from that part of the map-area, and the development of a gorge in the Pokiok River represents the reversal of drainage that occurred at the cessation of the glacier-esker relationship in the Little Pokiok valley a few miles east of Allandale.

The bulk of sand and gravel in terraces and flood plains of the Saint John River, particularly in that area between Mactaquac and Evandale, is considered to be basically glacial outwash produced at the ice margin, or carried to the Saint John by glacial meltwater tributaries. It has been modified by fluvial action of the Saint John River in its various stages of development that were controlled by changes of base level due to postglacial eustatic and isostatic change.

Problems of Chronology and Correlation

Ice margins (Fig. 12) have been drawn across the Saint John valley more or less at right angles to lie against the south flanks of such major depressions as Kennebecasis Bay, Long Reach, Washademoak Lake and Grand Lake. The work of Melvin (1966) in the area immediately adjacent to the east and covering a smaller area around Ben Lomond, east of Saint John, suggests a complicated lobate form of the ice margin that is related to the well-developed regional bedrock structure. It may be, then, rather than as shown in Figure 12, that sparse ice-marginal features of areas east of Saint John valley may indeed be related to a more complex pattern of recession of small ice lobes originating from different (northeastern) sources. Nonetheless the sequence of development of glacial and postglacial drainage appears to have been more or less as stated for the areas west of Saint John River and a modification of the concept of deglaciation of structural basins north and east of Saint John can have little effect on the pattern described for most of the map-area.

Another problem is that of an apparent discrepancy between the chronology of deglaciation and that of marine submergence. Earlier work (e.g. Borns, 1967) suggests that ice-margin retreat and maximum marine submergence of the area were simultaneous 13,000 years B.P. Shell dates on marine sediments of the Fredericton map-area (Table I) are compatible with this concept. The interpretation by Lee (Walton, Trautman and Friend, 1961) of the Sheldon Point locality was that sea and ice were contemporaneous 13,325 ± 500 years B.P. (I(GSC)-7) in a glacio-marine association. New exposures show gravels interfingering with marine sediments now exposed on both north and south sides of a central ridge and dipping both north and south away from a central core mass that is glacial end moraine (Fig. 14). Therefore, a moraine existed and was modified by the sea but, in the writer's opinion, the building of the moraine and the wave modification were not necessarily contemporaneous. The difference between this and Lee's interpretation lies in the identification of the interfingering gravel unit. Lee calls the sediment glaciofluvial or glacio-marine whereas the present writer sees it as reworked glacial, hence marine.

It has been suggested above that a major moraine lying north of Sheldon Point is associated with moraines and glacial outwash at Pennfield (Fig. 12-1) – the so-called Pennfield phase of deglaciation. The age of formation of these glacial features is given a minimum age of 16,500 C^{14} years B.P. by association with dated freshwater organic material of Little Lake. The Sheldon Point moraine may be somewhat older than that of Pennfield. In both places, however, marine shell material taken from deposits at or near the present surface is of the order of 13,000 B.P. (Table I). If the two sets of dates (kettle lake and shell) are valid, then there is an apparent discrepancy of more than 3,000 years between the ages of glacial and marine events that is unexplained.

Figure 14: Glacial till and ice-contact gravel at centre of photo is a remnant of end moraine overlain by gravels dipping north (left) and south; section shown in Figure 13 is on same exposure about 200 yards south of this locality. Height of section approximately 18 feet. Sheldon Point, Saint John Harbour, N.B. GSC Photo 201731-A

Let us consider the possibility that materials dated from the base of Little Lake core are anomalously old because of contamination. Graphite and coal are known in the map-area, but occur at distances of 25 to 40 miles northwest and northeast of the sample site and are therefore not seriously considered potential contaminants. The dated material at the base of Little Lake core contained free carbonates, but this was removed by pre-treatment leaching. As a further check on this aspect, noncalcareous material 10 cm above the base of the section was dated. It gave a radiocarbon age of 14,300 $\pm$ 270 years B.P. (GSC-1272). This date would tend to corroborate the older date from the base of the core and is, incidentally, older than shells dated from adjacent parts of the Fundy and Maine coasts. Therefore, it seems reasonable to accept as a working hypothesis that the Fundy coast may have become ice-free at least 16,500 years before present.

The absence from this area of evidence of glacio-marine conditions at or near the coastal moraines makes it possible to speculate that the area may have been ice-free for a period of over 3,000 years (i.e. ca. 16,500 to ca. 13,500 B.P.) before marine submergence to the local maximum level of approximately 240 feet a.s.l. Marine submergence then may have taken place as a relatively slow on-lap that reached its maximum only 13,500 years B.P. This concept seems all the more plausible if it is considered that sea-weed collected by Grant (1971) from marine clay at Gilbert Cove on the south side of the Bay of Fundy, has been dated at 14,100 $\pm$ 200 years B.P. (GSC-1259).

If the Pennfield area was deglaciated at 16,500 or more years before present, it is probable that eustatic sea level was well below present levels (see, for example, Mörner, 1971, Fig. 1, p. 133). The great unkown is the state of isostatic change at the same point in time. Accordingly, the present Bay of Fundy may or may not have been occupied by the sea as early as 16,500 B.P. This is a problem that must be investigated by examination, where possible, of the base of the marine sequence with a view to discovering the age of earliest marine occupation and also by examination of material underneath the marine sequence, possibly by off-shore drilling, to investigate the possible existence of nonglacial material in an age range between 14,000 and 16,500 years or a little more.

REFERENCES AND SELECTED BIBLIOGRAPHY

Alcock, F. J.

1938: Geology of Saint John region, New Brunswick; Geol. Surv. Can., Memoir 216, 65 p.

1959: Geology; Musquash, Charlotte, Kings, and Saint John Counties, New Brunswick; Geol. Surv. Can., Map 1084A.

1960a: Geology; St. Stephen, Charlotte County, New Brunswick; Geol. Surv. Can., Map 1096A.

1960b: Geology; St. George, Charlotte County, New Brunswick; Geol. Surv. Can., Map 1094A.

1960c: Geology; Rolling Dam, Charlotte County, New Brunswick; Geol. Surv. Can., Map 1097A.

Anderson, F. D. and Poole, W. H.

1959: Geology; Woodstock-Fredericton, York, Carleton, Sunbury and Northumberland Counties, New Brunswick; Geol. Surv. Can., Map 37-1959.

Borns, H. W., Jr.

1967: Field trip guide for the friends of the Pleistocene; 30th Ann. Reunion, Machias, Maine, May 20-21, 1967.

Bostock, H. S.

1970: Physiographic regions of Canada; Geol. Surv. Can., Map 1254A.

Chalmers, R.

1884: Report on the surface geology of western New Brunswick with special reference to the area included in York and Carleton Counties; Geol. Surv. Can., Rept. of Progress 1882-84, section GG, 42 p.

1887: Report to accompany quarter-sheet maps 3 S. E. and 3 S. W. Surface geology. Northern New Brunswick and southeastern Quebec; Geol. Surv. Can., Ann. Rept. 1886, v. II, Rept. M, 34 p.

1888: Report on the surface geology of northeastern New Brunswick; Geol. Surv. Can., Summ. Rept. 1887 and 1888, v. III, Pt. N.

1890: Report on the surface geology of southern New Brunswick; Geol. Surv. Can., Summ. Rept. 1889, v. IV, Rept. N, 87 p.

1895: Report on the surface geology of eastern New Brunswick, northwestern Nova Scotia, and a portion of Prince Edward Island; Geol. Surv. Can., Ann. Rept. 1894, v. VII, Rept. M, 144 p.

Chalmers, R. (cont.)
1902: Report on the surface geology shown on the Fredericton and Andover quarter-sheet maps, New Brunswick; Geol. Surv. Can., Ann. Rept. 1899, v. XII, Rept. M, 36 p.

Flint, R.F.
1957: Glacial and Pleistocene geology; New York, John Wiley & Sons.

Gadd, N.R.
1970: Quaternary geology, southwest New Brunswick (21G); Project 670037; Geol. Surv. Can., Paper 70-1, Pt. A, p. 170-172.

Ganong, W.F.
1896: Notes on the natural history and physiography of New Brunswick; 2; The outlet-delta of Lake Utopia; Bull., N.B. Nat. Hist. Soc., no. XIV, p. 43-47.

1899: On the division of New Brunswick into physiographic districts; Bull., N.B. Nat. Hist. Soc., no. XVIII, p. 233-236.

Grant, D.R.
1971: Glacial deposits, sea level changes and Pre-Wisconsin deposits in southwest Nova Scotia; in Report of Activities: November 1970 to March 1971; Geol. Surv. Can., Paper 71-1, Pt. B; p. 110-113.

Haw, P.W.
1967: Sedimentary and volcanic rocks of the St. Andrews-St. George area, Charlotte County, New Brunswick; N.B. Dept. Nat. Resources, Mineral Resources Branch, Map series 67-1.

Langmaid, K.K.
1955: The geology of New Brunswick soils; in Proc. of the First Maritime Soil Mechanics Conf., Fredericton; Natl. Res. Council, Assoc. Comm. on Soil and Snow Mech., Tech. Memorandum no. 35, p. 4-5.

Leavitt, H.W. and Perkins, E.H.
1935: Glacial geology of Maine; Maine Technology Exp. Sta., Bull., no. 3.

Lee, H.A.
1954: Two phases of till and other glacial problems in the Edmundston-Grand Falls region, New Brunswick, Quebec and Maine; Univ. Chicago, unpubl. Ph. D. Thesis.

1955: Surficial geology of Edmundston, Madawaska and Temiscouata Counties; New Brunswick and Quebec; Geol. Surv. Can., Paper 55-15, 14 p.

1957: Surficial geology of Fredericton, York and Sunbury Counties, New Brunswick; Geol. Surv. Can., Paper 56-2, 11 p.

Lee, H.A. (cont.)
1959: Surficial geology, Grand Falls, Madawaska and Victoria Counties; New Brunswick; Geol. Surv. Can., Map 24-1959.

1962: Surficial geology of Canterbury, Woodstock, Florenceville and Andover map areas; York, Carleton and Victoria Counties, New Brunswick; Geol. Surv. Can., Paper 62-12, 8 p.

Lundquist, Jan
1969: Problems of the so-called Rogen moraine; Sveriges Geologiska Undersokning, Ser. C., Nr. 648, Årsbok 64, Nr. 5; Stockholm.

MacKenzie, G.S.
1964a: Geology; Saint John, New Brunswick; Geol. Surv. Can., Map 1113A.

1964b: Geology; Hampstead, New Brunswick; Geol. Surv. Can., Map 1114A.

Matthew, G.F.
1872: On the surface geology of New Brunswick; Can. Naturalist, new series, v. 7, p. 433-454.

McMullen, W.E. and Wright, W.J.
1938: Non-metallics of New Brunswick, with special reference to diatomite; Bull., Can. Inst. Mining Met., v. 31, no. 316, p. 373-384.

Melvin, Robert L.
1966: The surficial geology of Ben Lomond area, Saint John and Kings Counties, New Brunswick; Univ. New Brunswick, M.Sc. thesis.

Mörner, N.A.
1971: The position of the ocean levels during the Interstadial at about 30,000 B.P. – A discussion from a climatic-glaciologic point of view; Can. J. Earth Sci., v. 8, no. 1, p. 132-143.

Munsell Color Company, Inc.
1954: Munsell soil colour charts; Munsell Color Company, Inc., 2441 N. Calvert St., Baltimore, Md., 21218, U.S.A.

New Brunswick Research and Productivity Council
1965: Bibliography of New Brunswick geology; N.B.R.P.C. Mineralogical Group, Record 2, Part C; Fredericton, March 1965.

Prest, V.K.
1968: Nomenclature of moraines and ice-flow features as applied to the Glacial Map of Canada; Geol. Surv. Can., Paper 67-57, 32 p.

Prest, V.K., Grant, D.R. and Rampton, V.N.
1967: Glacial Map of Canada; Geol. Surv. Can., Map 1253A.

Ruitenberg, A.A.
1968a: Geology, St. Stephen-Pleasant Mountain area, New Brunswick; Geol. Surv. Can., Map 20-1966.

1968b: Geology and mineral deposits, Passamaquoddy Bay area; N.B. Dept. of Nat. Resources, Mineral Resources Branch, Rept. of Invest. no. 7.

Walton, A., Trautman, M.A. and Friend, J.P.
1961: Isotopes Inc., Radiocarbon Measurements I; Am. J. Sci., Radiocarbon supplement, v. 3, p. 47-59.

Wicklund, R.E. and Langmaid, K.K.
1953: Soil survey of southwestern New Brunswick; N.B. Soil Survey, Rept. no. 4.

Wolfe, W.J., Mason, M. and Mazerolle, G.J.
1967: The Cu, Pb, Zn, Ni, Ag, Mn, Sn, Mo, and As contents of stream and spring sediments, southwestern Charlotte County, New Brunswick; Min. Res. Br., N.B. Dept. Nat. Resources, Rept. of Invest. no. 4.