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PAPER 67-66

GEOLOGY OF MOUNT STEWART — SOURIS MAP-AREA, PRINCE EDWARD ISLAND (11 L/7, L/8)

(Report, 17 figures and Map 1260A)

G. H. Crowl

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GEOLOGY OF MOUNT STEWART — SOURIS MAP-AREA, PRINCE EDWARD ISLAND

G. H. Crowl

DEPARTMENT OF ENERGY, MINES AND RESOURCES

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CONTENTS

Page

Abstract v
Introduction 1
Acknowledgments 1
Bedrock geology. 1
Lithology 1
Sandstones. 2
Mudstones 2
Conglomerates 2
Conditions of deposition 3
Stratigraphic succession 3
Geomorphology and structure 3
Glacial deposits 7
Ground moraine 7
Ablation moraine 10
Glaciofluvial deposits 10
Eskers and crevasse fillings 10
Kames 12
Undifferentiated ice-contact deposits. 15
Postglacial deposits 15
Alluvium and colluvium 15
Swamp deposits. 17
Salt marsh 17
Beaches and dunes 17
Soils 17
Glacial history. 19
Glacial direction indicators 19
Fluted topography 19
Eskers. 19
Striae 20
Erratics 21
Miniature crag-and-tail. 21
Till fabrics 21
Directions of ice flow 23
Deglaciation 23
Postglacial history 24
Economic geology 24
Sand and gravel 24
Peat. 24
References 24

Table I. Typical soil profile 18
Table II. Till fabric data 22

Illustrations

Figure 1. Generalized stratigraphic column 4
Figure 2. Rock shoulder near Springton 5
Figure 3. Till over bedrock on north shore. 7
Figure 4. Esker depression southeast of St. Theresa West 9

Page

Figure 5. Esker southeast of St. Theresa West 9
Figure 6. Esker north of Morrell 11
Figure 7. Esker at Windon 11
Figure 8. Esker at West St. Peters 12
Figure 9. Kames at Fortune 13
Figure 10. Kames southwest of Mount Stewart 13
Figure 11. Kame at West St. Peters 14
Figure 12. Kame terrace west of St. Theresa West 14
Figure 13. Beach ridges at Basin Head. 16
Figure 14. Podsol profile at Cherry Hill 18
Figure 15. Striae on north shore 20
Figure 16. Glacial direction indicators, eastern Prince Edward Island . . . . in pocket
Figure 17. Topographic lineaments, eastern Prince Edward Island . . . . . in pocket

Map 1260A Surficial geology Mount Stewart - Souris,
Prince Edward Island . . . . . in pocket

ABSTRACT

The Mount Stewart – Souris area comprises the northern half of Prince Edward Island east of Charlottetown. Permian bedrock forms a homocline dipping uniformly northeast. The cuestiform topography is partly masked by Wisconsin deposits. Thin sand-till covers the upland. Anastomosing glaciofluvial deposits occupy the valleys and connect with one another through cols in the divides.

The till was deposited over most of eastern Prince Edward Island by an ice advance from New Brunswick. This ice-sheet stagnated and down-melted in place; a later ice advance from the Cobequid Mountains of Nova Scotia covered a narrow strip along the south shore of the island.

GEOLOGY OF MOUNT STEWART — SOURIS MAP-AREA, PRINCE EDWARD ISLAND

INTRODUCTION

The Mount Stewart – Souris map-area covers about 650 square miles and comprises the northern half of Prince Edward Island east of Charlottetown. Elevations range from sea level to about 275 feet.

Broad rolling plains form a large part of the land surface; valleys are wide and shallow, and the hills are broadly rounded. A few rivers, such as the Pisquid and Morell, have cut deep valleys below the upland surface; steep dissection is usually confined to short stream valleys in coastal areas.

The entire area was covered by ice during the Wisconsin glaciation. Thin till covers the uplands and thicker glaciofluvial and alluvial deposits floor the valleys. Swamps occupy many of the depressions on the surface.

Much of the area is forested, and in Souris map-area abandoned farmland is reverting to forest at a rapid rate. Cultivated land is devoted principally to hay and potatoes.

Frankel (1966) has summarized previous geologic work in Prince Edward Island, and the reader is referred to that paper.

Field work was carried on in the summers of 1955, and 1957 to 1960. Primary emphasis was given to mapping glacial deposits; bedrock geology received less attention. Aerial photographs were used to locate and define glacial features and bedrock shoulders which indicate cuestas. Examination of road-cuts, borrow pits, and natural exposures along the shore provided most of the information; augering and pitting supplemented this information.

ACKNOWLEDGMENTS

The writer is indebted to P. A. Murnaghan and B. Graham Rogers of the Provincial Government of Prince Edward Island for many courtesies. Beverly Patten, Arthur Hughes, Garth McLean, Dugald Carmichael, Franz Anderson, and Kenneth Lauterer ably assisted in the field. Anderson and Lauterer were supported by research grant G-8170 from the National Science Foundation of the United States Government in 1959. Numerous discussions and field conferences with V. K. Prest and L. Frankel have helped to clarify doubtful points.

BEDROCK GEOLOGY

LITHOLOGY

Prince Edward Island is underlain by a series of gently dipping, red to brown mudstones and crossbedded sandstones, with calcareous lenses of mudstone

breccia and pebble-conglomerate, the latter composed of stones foreign to the island. Inland, exposures of bedrock are widely scattered and poor. Exposures are more numerous along the coast where locally they are continuous for long distances.

Pennsylvanian rocks are exposed on Governors Island, and Lower Permian rocks at Gallas Point on Hillsborough Bay, on the south coast (Langston, 1963; Frankel, 1966). Rocks in Montague map-area, to the east of Hillsborough Bay, overlie these and are presumably of Permian age, although this is not definitely established. Rocks in the Mount Stewart - Souris map-area are equivalent to part of those in the Montague area.

Sandstones

Sandstone, sometimes with very minor conglomerate, siltstone, and mudstone alternate irregularly in the section. The lenticular character of the deposits is well displayed on any large outcrop. Nearly all the rocks are dark red to brown; irregular white and green patches are presumably the result of reduction of the iron oxide colouring agent.

The sandstones range from fine- to coarse-grained; and from thin-bedded (sometimes almost leaf-like in thinness) to thick-bedded and massive layers. The grains are cemented by mixed hematite and clay into a soft sandstone. Rarely, calcium carbonate or hematite may cement the sediment into a hard rock. Usually the weathered surface is a little lighter in colour than the fresh surface. Characteristically, the sandstones are crossbedded. The crossbedding ranges from high angle, torrential type, to low angle, which, even on large exposures, is difficult or impossible to distinguish from true bedding. The crossbedding is seldom planar, and on wide wave-cut benches festoon crossbeds may be observed (Knight, 1953). Sometimes the crossbeds have quaquaversal primary dips, and slight domes or basins result.

Mudstones

Mudstones (claystone and fine siltstone) include shale layers with well-developed fissile parting, and massive irregularly jointed layers. The shales occur in layers up to 20 feet thick; the claystone or 'keel' is seldom more than 2 feet thick. The claystones occur as irregular bodies or blebs within the thick-bedded or massive sandstones. The irregularity of these bodies can be attributed to loading and the resulting squeeze of unconsolidated sediments.

Siltstones are usually so broken by bedding plane joints that the rock appears to be medium- to thin-bedded, i.e. beds one to three inches thick. They grade into claystone on one hand and fine-grained sandstone on the other.

Conglomerates

A quartzite-chert conglomerate outcrops irregularly along the north shore from Tracadie Bay eastward to Bayfield and North Lake. It is thought to extend about a mile inland. At Bayfield the conglomerate is fresh, unweathered, and hard. The pebbles are cemented in a sand matrix, are rarely in contact with one another, and comprise about 40 per cent of the rock. Thin stringers of sand occur between the pebble-rich layers. At North Lake the conglomerate is weathered and soft. Pebble-rich layers are fewer and thinner in this exposure than at Bayfield.

A few outcrops of angular-pebble conglomerate have been noted along the north shore and at Souris Head, but their relationships as yet are obscure.

CONDITIONS OF DEPOSITION

The highly crossbedded character of the sandstones, the lenticularity of all the deposits, the abrupt facies changes, and the red colour of the rocks are good indicators of a deltaic or low alluvial plain depositional environment for these sediments.

A warm, and probably seasonally dry climate is indicated by the red colour of the rocks. Various shades of red in sediments are due to small amounts of hematite. Oxidation of iron occurs most readily in a warm and seasonally dry (Savanna) climate where soils are strongly leached and oxidized. Sediments derived from such soils retain their red colour unless deposited in a reducing environment rich in organic material. They may perhaps be further oxidized if deposited above a permanent water table.

A few beds in the section are grey; this results from the reduction of ferric oxide to ferrous oxide. These sediments may have been deposited in a reducing environment, such as a swamp, or may have contained a sufficient amount of plant detritus to alter the colour to grey. Where a grey or green colour follows the joint or bedding planes, it is clearly the result of percolating ground water.

STRATIGRAPHIC SUCCESSION

In the short time devoted to bedrock study it has not been possible to establish a detailed stratigraphy based upon any reasonably continuous series of exposures. Furthermore, facies changes are commonly abrupt, and individual beds cannot be traced for any great distance. The attitude of the sandstone is often impossible to determine because of large scale crossbedding at low or rarely very high angles to the bedding.

A generalized stratigraphic column is shown in Figure 1. The column is based upon regional structural trends deduced from the geomorphology, regional dips that average about 1.5°, outcrop width of 34 miles across strike, and topographic inequalities which suggest where massive sandstone or mudstone and thin sandstone predominate. The section begins at the shore at Crown Point on Hillsborough Bay and 'steps' across country to East Point.

The calculated thickness of the section is 5100 feet. The 'thickness of section' figures deviate from a strict foot-per-mile relationship; corrections for topographic relief have been added.

The stratigraphic column (Fig. 1) shows the principal sandstone horizons responsible for topographic highs and coastal promontories, and also indicates the weak zones (mudstone and thin sandstone) responsible for major depressions. Undoubtedly there are many more sandstones than are shown in the column; they do not all form prominent topographic 'breaks', and thus have not been plotted.

The middle part of this section is best controlled; the strong trellis drainage between the Pisquid River - Cardigan River line and the St. Peters Bay - Fortune River line (see Map 1260A, in pocket) indicates clearly the regional strike. Strike indicators are less abundant on Souris Peninsula, and there is a divergence in strike between Tea Hill and the Pisquid River - Cardigan River line in the southwest; thus these two parts of the section are less reliable.

GEOMORPHOLOGY AND STRUCTURE

A trellis drainage pattern, indicative of tilted beds, is well developed in the Mount Stewart map-area and extends into the northeast corner of the Montague map-area and the southwest third of the Souris map-area. The subsequent streams trend N60°W. (See Fig. 17).

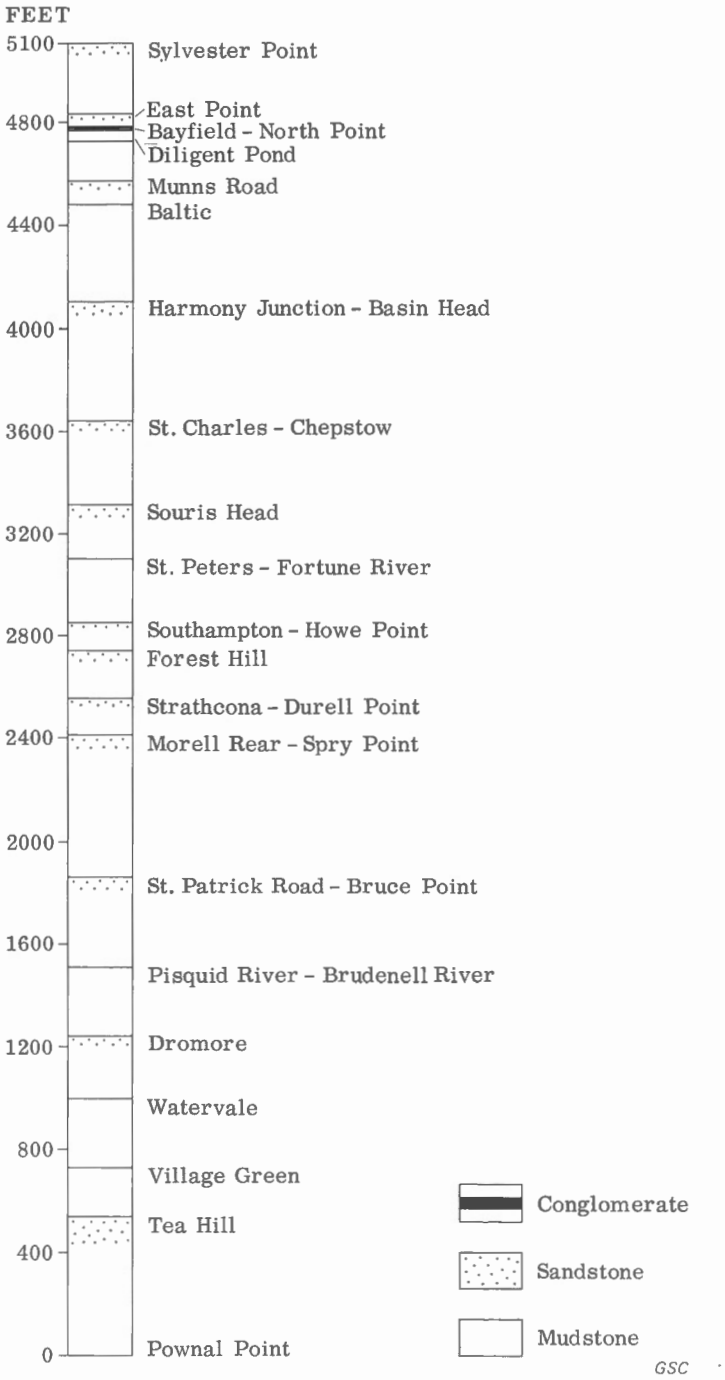

Figure 1. Generalized stratigraphic column.

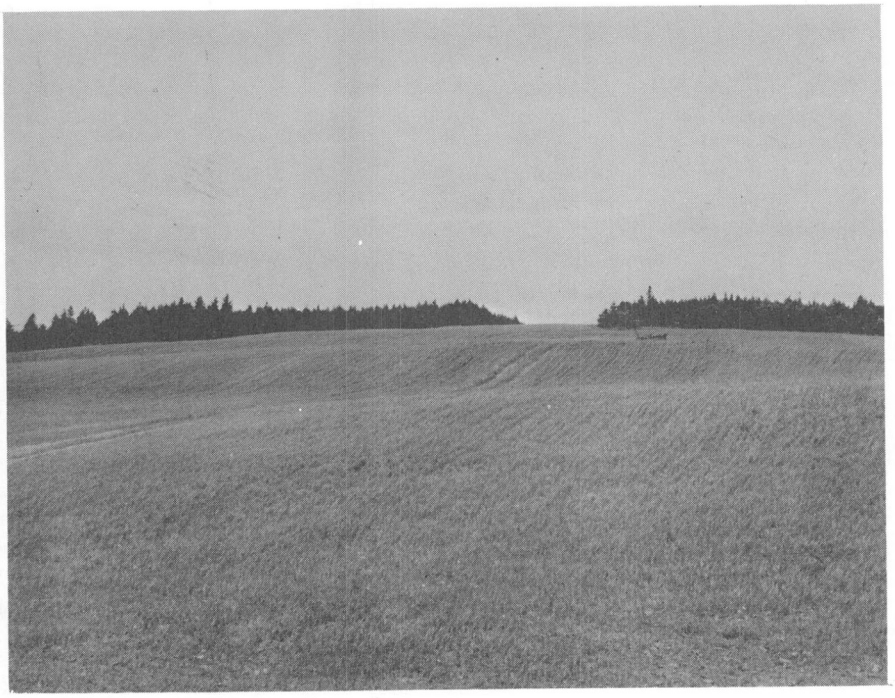

Figure 2: Rock shoulder near Springton (125204).

Structural control of pre-Glacial stream erosion has not been obliterated by glaciation and is apparent in many of the smaller stream courses, in Cardigan River, and in the major bends of East (Hillsborough) River. Similar control is evident in the northwest-trending bays on the southeast coast from Cardigan River to Rollo Bay, and in St. Peters Bay on the north coast.

A few hills are cuestiform, and many hillsides are stepped as they descend over sandstone ledges that outcrop or are partly masked by a thin cover of drift (Fig. 2). These ledges, commonly more clearly discernible on aerial photographs than in the field, are the scarp slopes of minor cuestas which trend west to N60° W. Dip slopes of the cuestas, measurable in a few instances, are 1° to 2° north.

The trellis drainage pattern is not well-developed east of a line through St. Peters and Rollo Bays. In fact, some stream courses are parallel to the northeast-trending south coast of the peninsula. However, scarp slopes are discernible in the area, and have a southeast trend like those in the Mount Stewart area to the west.

Many of the divides are low ridges. The combination of ridges and trellis drainage emphasizes the structural control of the topography. The pattern of ridges and small scarps extends beyond the limits of the trellis drainage pattern and thus indicates continuity of structure over the eastern part of the island.

The conglomerate which outcrops along the north shore in the Souris area, and presumably extends only a short distance inland, is comparable to Frankel's Unit C in the Montague area (Frankel, 1966). Frankel points out that his Unit C is unconformable on older beds, and that the drainage patterns in the two areas are different. On Souris Peninsula, streams probably established their courses on the conglomerate unit, and since its removal, they have eroded hill slopes in the older formation and developed the usual minor scarp slopes.

No certain reversals of dip are indicated by cuestas, so the structure of the Mount Stewart - Souris map-area is interpreted as a homocline, the north limb of the Gallas Point anticline whose axis trends northeastward in Hillsborough Bay and thence swings eastward and southeastward down Georgetown Peninsula. The fold plunges eastward at a very low angle.

Prominent north-south stream courses in the Mount Stewart area are, from east to west, parts of the Boughton, Midgell, Marie, Morell Rivers, and Bristol Creek, Pisquid River, and Clarks Brook. It is tempting to interpret the north-south portions of these stream courses as the result of faulting. There is, however, no clear evidence to support such a conclusion, and it appears that many cuesta ridges and related stratigraphic zones may be traced across the valleys with no marked shift in position. Thus, the author believes that no cross-faulting has occurred, and that the present streams occupy preglacial transverse stream valleys.

Geomorphology is a better guide to structure (and thus to overall stratigraphy) than dips obtained on poorly exposed outcrops of crossbedded sandstones. Lithologic trend lines, as deduced from drainage, hill crest lines, and scarp slopes, are more consistent than attitude measurements on bedding planes. As most of the observed dips are measurements on crossbedded sandstones, and as the directions in any one area are so highly variable and their relationships to true bedding so uncertain that they cannot be used as a reliable guide to structure, none are shown on the map.

Detailed studies of crossbedding have been made at four locations; two are on Hillsborough Bay at Prim Point and Crown Point, the third is at Spry Point, and the fourth is at Durell Point; both the latter are southwest of Souris.

At Prim Point and at Crown Point the predominant dip directions of the crossbedding are parallel to dip directions derived from a study of the geomorphology of the area. At Spry Point and Durell Point, however, the predominant attitude of crossbedding is at a high angle to the geomorphic trend. Furthermore, aerial photographs show underwater ledges trending parallel to the general strike of what appears to be large-scale crossbedding units. Thus, even where abundant data are available, crossbedding is not related in any systematic manner to the attitude of the beds.

There is no necessary correspondence between the structure of the surface beds of eastern Prince Edward Island and that of the underlying bedrock formations. There are prominent unconformities within and beneath the Pennsylvanian and Mississippian systems in the Maritime Provinces (Gussow, 1953). Exploratory drilling by Imperial Oil Company in central Prince Edward Island has demonstrated the presence of prominent unconformities in the subsurface section. Frankel (1966) has indicated unconformities within the section exposed at the surface in southeastern Prince Edward Island.

Frankel (1966) has summarized structural interpretations by earlier workers in eastern Prince Edward Island and has advanced his own, based upon lithologic mapping. He is unconvinced that the Gallas Point anticline continues eastward beyond Perth, but the structural lineaments of Brudenell River and Cardigan River, and the area to the north, and the area west of Vernon River strongly suggest an anticlinal axis trending eastward down the Georgetown peninsula.

There are several other points of disagreement between Frankel (1966) and the author. In places Frankel's lithologic boundaries are at a high angle to the geomorphic trends which show a consistent pattern throughout most of the area but neither has an answer to this problem at present. Until detailed mapping, like that of Frankel, is done in the Mount Stewart - Souris area, the stratigraphy and structure must remain uncertain.

Milligan (1949) could find no direct evidence for the eastward prolongation of the Gallas Point anticlinal axis, but projected it northeastward along the south shore

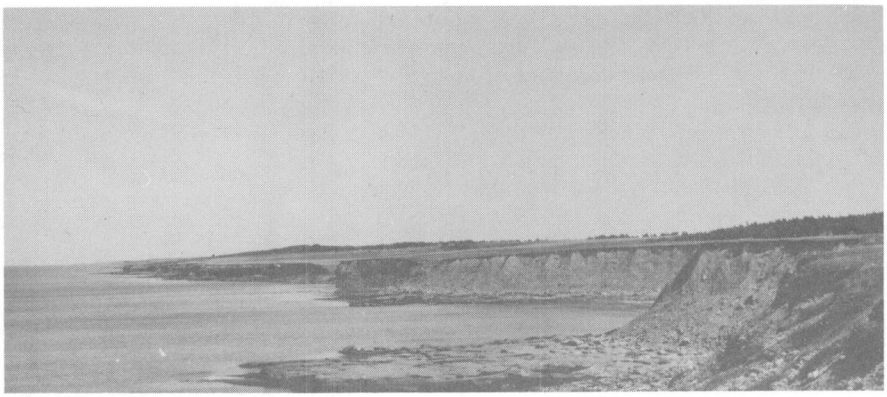

Figure 3: Till over bedrock on north shore (125210).

of the Souris Peninsula on the basis of northward dips along the coast. He apparently regards this as a strike shore whereas the author believes it cuts across the strike. Milligan also traces a synclinal axis from Southport through Peakes, Bangor, and St. Peters. He apparently was not impressed by the trellis drainage pattern of the area.

GLACIAL DEPOSITS

The area is covered by drift that is as much as 70 feet thick; the greatest observed thickness is 45 feet in the sea cliffs (Fig. 3), but shallow-depth seismic work indicates 70 feet of cover in some places (George Hobson, Geol. Surv. Can., pers. comm.). The glacial cover is usually 5 to 10 feet thick. Ground moraine and ablation moraine cover hilltops and slopes, glaciofluvial deposits cover lowland areas and extend through cols from one valley to another.

Only in two small areas northwest of Rollo Bay is bedrock mapped as exposed at the surface; there the drift is absent or less than 3 feet thick. It is often difficult to distinguish a thin mantle of drift from weathered bedrock, for soil depth is 1 foot to 1.5 feet and weathering may extend to a greater depth. Slightly weathered mudstone or sandstone grades downward through flat-lying fragments into solid rock; deeply weathered sandstone is covered by a mantle of 'sharp' micaceous sand. Till, on the other hand, usually has a small amount of clay.

The drift is derived from local sandstones and mudstones, and is therefore reddish in colour. Most tills in northeastern Prince Edward Island are varieties of sand till; clay tills occur in places on mudstone outcrop areas. The glaciofluvial deposits consist of sands with varying amounts of clay and silt. Erratic boulders of igneous and metamorphic rocks are rare except on St. Peters Peninsula. The largest erratic measures 3 feet by 3 feet by 4 feet.

GROUND MORAINE

Ground moraine covers a large portion of the upland surface of eastern Prince Edward Island. The major topographic features are bedrock controlled and only the minor surface features are glacial. The surface is flat to gently rolling; rarely does the relief of the moraine exceed 10 feet. Natural lakes are uncommon, and bogs and swamps are widespread.

The ground moraine is composed of sand till which has a low percentage of pebbles except where thick-bedded sandstones or conglomerates are near the surface. In such cases sandstone fragments and pebbles from the conglomerate have been incorporated into the till.

For purposes of field classification, the sand till on Prince Edward Island has been divided into sand- and clay-rich phases. The clay-rich phase is not mapped within the Mount Stewart-Souris map-area because its exposure areas are too small, and are apparently restricted to areas underlain by clayey mudstones. It is exposed in the Pownal Bay district southwest of the map-area (Frankel, 1966) but even here the phases grade into one another.

The sand phase in the present map-area shows all gradations from a loose textured, nearly clean sand till to firm or clayey till. These are descriptive terms; the field distinction between the tills is literally by rule of thumb – the behaviour of the till when crushed in the hand, and its appearance under a hand lens. The intermediate members of the series are obviously difficult to classify, and there is some doubt that consistency has always been maintained in field determinations. In preliminary reports on eastern Prince Edward Island (Crowl, 1960a, 1960b; Frankel, 1960) an attempt was made to distinguish an intermediate clay-sand phase, but this three-fold classification has been abandoned in this report as being too inconsistent. Size of sand grain influences one's judgment of the amount of clay. Sand grains are, of course, more apparent when large or numerous in the till. The crushing behaviour depends upon the amount of moisture in the till. When the ground is moderately moist, distinctions are usually reliable. During a drought, till appears more sandy than normal; just after a heavy rain the clay content is accentuated.

As yet, standard mechanical analyses do not confirm the field classification suggested by Frankel and the writer. Thoroughly dried material, crushed and sieved in the laboratory, generally gave an obviously high proportion of sand as sandstone fragments were crushed and treated as matrix. A wet method of analysis that does not require crushing gives promise of results more in line with field experience (Prest, pers. comm.). Samples preserved with natural moisture content are sieved in water. It seems that sandstone particles and clay aggregates are not broken down to their component parts and a more accurate analysis of the till matrix may be obtained.

The typical sand phase till has the following characteristics: pebbles in the till are sandstone, the matrix is mostly sand and contains few fines. On a freshly broken surface, sand grains are clearly visible under a hand lens, and sometimes appear as an almost loose aggregate. When crushed in the hand, the clay material either collapses into grains or dust, or breaks into chips that have little cohesive strength. When the till is wet, it will first fracture into fragile chips; the plasticity is low. Cut banks are highly susceptible to earth flow in a layer about one inch thick; the wrinkled 'flow layer' is common at the base of the cut in old ditches.

As the clay content of the till increases, sandstone pebbles continue to predominate, but there is an appreciable number of mudstone pebbles; the matrix contains a moderate proportion of fines. Sand grains are less visible under a hand lens, and clay 'skins' around pebbles or large sand grains become more common. When dry, the till breaks into chips that have moderate cohesive strength; when wet, the till is moderately plastic. It may have a moderate clay 'shine'. Cut banks hold up moderately well.

The -200 mesh fractions of three different till samples were analyzed by Differential Thermal Analysis. No difference in clay minerals was found (J. Brady, Mines Branch, pers. comm.) that might explain differences between till phases. More work must be done to define these tills adequately.

Figure 4: Esker depression southeast of St. Theresa West (l252l3).

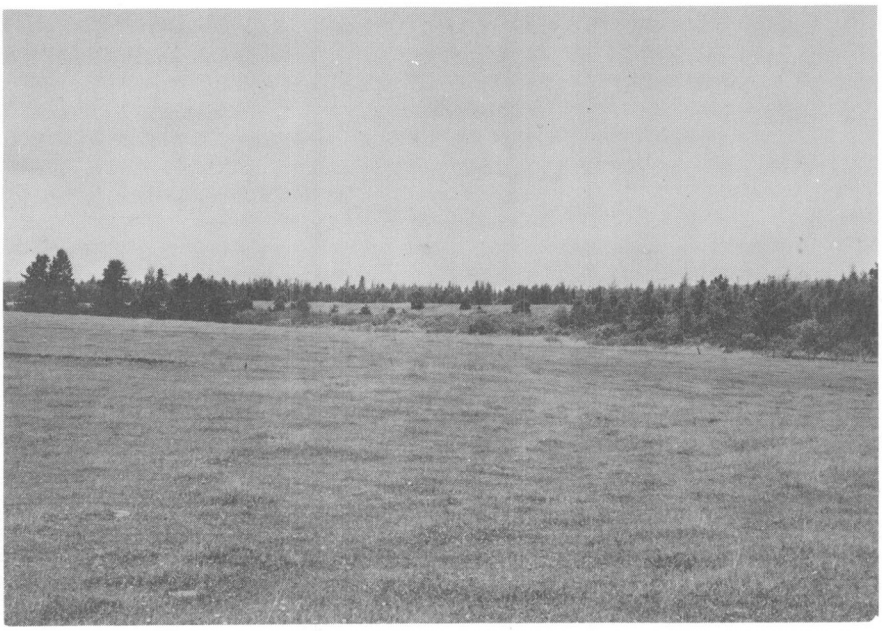

Figure 5: Esker southeast of St. Theresa West (l252l2).

ABLATION MORAINE

Ablation moraine occurs in patches on hilltops and divides in the Mount Stewart district. This moraine is usually more irregular and rolling than ground moraine; the microrelief is about 2 to 4 feet.

Ablation till is more sandy than normal basal sand till and may be washed to such an extent that there are barely sufficient fines to bind the fragments. Texture is its most distinctive trait. The till is loose and streaked with layers of sand and gravel. In deep cuts or auger holes there is an abrupt change with depth to the normal, compact, more clayey basal till. This change occurs beneath the B soil horizon, is therefore unrelated to soil forming processes, and is thus regarded as a change from ablation till to basal till.

GLACIOFLUVIAL DEPOSITS

Glaciofluvial deposits underlie the valleys and extend through cols in the divides from one drainage basin to another. The anastomosing pattern of the deposits is remarkable. The materials range from non-sorted ice-contact debris sloughed against valley walls to kame and esker deposits which exhibit a wide range of sorting. The form of the deposits is sometimes their most characteristic feature.

Eskers and crevasse fillings

Eskers are rare on the uplands, and occur there in the glaciofluvial connecting links between valleys. They are more abundant on slopes leading into valleys, and are common in the valleys. Eskers on the upland and on the valley walls tend to be aligned in a northwest direction, and as will be shown later, are parallel to the general direction of ice movement. Valley-bottom eskers follow the courses of the valleys.

Usually the sand ridges are irregular in profile; a few have notably flat, 'railroad embankment', tops. The flat-topped ridges indicate deposition by a graded stream in a crevasse; irregular ridges may result from deposition in a tunnel or from later irregular compaction and slump. Characteristically, the larger eskers and crevasse-fillings are bordered by shallow depressions on one or both sides, and these are commonly swampy if the esker is in a valley (Figs. 4, 5). Eskers range from 3 to 20 feet in height and usually have a winding course across country (Fig. 6).

Some eskers have been opened for borrow pits. The materials range from well-washed sand and gravel to till. Sand forms a large proportion of the esker material and gravel is relatively rare. The local sandstone is not hard enough to withstand transport for any great distance, and is quickly broken down to sand size. Many of the eskers splay out at one end into an irregular kame deposit, indicating deltaic deposition in ponded water. An esker at Windon (Fig. 7), another a mile southwest of St. Peters, and a kame complex at Swallow Point on the north shore are unusual in that they have a large amount of local sandstone gravel as well as sand.

The esker at West St. Peters (Fig. 8) is about $1\frac{1}{2}$ miles long, and rises sharply from the ground moraine on its flanks in the upper part of its course south of the highway. To the northwest it becomes low and rounded, almost kame-like in appearance. It is termed an esker because of its linear pattern and ridge-like form at the ends. The southeast end of this esker is till cored.

The prominent esker extending across the road corner 2 miles south of St. Theresa West shows well-developed marginal depressions along its flanks (Figs. 4,5). So far as known it is not till cored, although the esker between Rollo Bay and Bear River, west of Souris, shows both the till core and marginal depressions.

Figure 6: Esker north of Morrell (125197).

Figure 7: Esker at Windon (201263).

Figure 8: Esker at St. Peters west (125215).

The occurrence of till cores in the eskers, and the marginal depressions alongside many of the eskers indicate that many of these may be ice-pressed forms (Hoppe, 1952; Stalker, 1960). An ice tunnel or a crevasse provided an opening into which unfrozen, saturated till might have been squeezed from the sides by the weight of the overlying ice. The depressions at the sides of the eskers mark the sites from which the till was removed. Subsequent sorting of the till materials in the eskers depended upon the flow of water in the channel.

Topographic position indicates that the eskers drained into adjacent valleys and down valley, but there are three notable exceptions:

(1) a small esker in a group on the east bank of Cross River south of Big Pond on the north shore; crossbedding indicates that the flow of water was northeastward, up and out of the valley under hydrostatic head.

(2) an esker-kame system 1.5 miles south of New Acadia, northwest of Rollo Bay; this esker splays out southward into a small kame complex; the indicated southward direction of water flow is opposite to that of present drainage.

(3) the crevasse-filling 1.5 miles south of St. Theresa West at the south margin of the map. This is the southernmost part of a system of eskers in the valley draining northward to Morrell River; it lies just north of the broad divide between the Morrell and Cardigan drainage systems. Cross-bedding indicates that this glacial stream drained opposite to present drainage, and southeast to the Cardigan or Brudenell Rivers.

Kames

Kame deposits of various types are distributed widely over the area; they are concentrated in the valleys and extend onto the uplands. In many cases there is no

Figure 9: Kames at Fortune (125217).

Figure 10: Kames southwest of Mount Stewart (125216).

Figure 11: Kame at West St. Peters (125214).

Figure 12: Kame terrace west of St. Theresa West (125196).

clear distinction between an elongate kame and an esker. A few isolated kames are more irregular than the typical moulin kame. Kames are the most characteristic feature of the drainage complex and include valley-side kames, short, narrow kame terraces, and kame complexes. These kame deposits are characterized by their poorly developed forms and by the rapid changes in sorting of materials (Fig. 9). Gradations from well-sorted sand and gravel to ice-contact debris and washed till are common. Washed till is more sandy and looser than the adjacent normal till.

An excellent example of a kame is situated on the north bank of East (Hillsborough) River about 1.2 miles southwest of Mount Stewart (Fig. 10). It is a low, smooth knob about 600 feet in diameter and 30 feet high. Another kame, on Boughton Bay east of Poplar Point, shows massive beds of dirty sand. In fact, were it not for the form and the bedding of the deposit, one might be tempted to term the material 'very sandy till'.

Small valley side kames form terraces at many places (Fig. 11). They are generally an eighth to a half mile in length and range from 3 to 15 feet in height at their outer edge. The material is usually fairly well sorted.

Perhaps the most unusual kame terrace is that in the valley west of St. Theresa West (Fig. 12). The upstream end of the terrace rests directly upon bedrock; the sand cover is about 2 feet thick. Downstream, where the rock floor is deeper and covered by till, the terrace maintains its grade, the deposits are much thicker, and the surface slopes gently upward to the valley walls.

Undifferentiated ice-contact deposits

The deposits at the base of many valley slopes and irregular kame slopes usually have no distinctive form, but continue the normal slopes. Characteristically these deposits show a wide range and a heterogeneous assortment of materials – till which is almost comparable to basal till, sand streaks and pockets, 'washed till', and a great number of angular bedrock cobbles and boulders. The boulders are commonly much larger than those usually seen in basal till. The character of the material is best shown in road-cuts and sea-cliffs. The transition to adjacent basal till usually occurs within a few feet and the two materials are distinctly different in overall size-range and appearance. The materials are regarded as the result of ice-margin melting. Basal till, and supraglacial debris which slid off the ice, were mixed and partially sorted, losing some of the fines. Boulders slid off the surface of the ice and were incorporated into the mass. This interpretation is corroborated by several till fabrics in these areas. The fabrics (see Fig. 16) show little or no orientation.

It is difficult, and impossible in many cases, to trace the contact between ice contact deposits and basal till along the valley slopes, but in road-cut after road-cut across a valley these deposits can be distinguished, and their essential continuity seems established. As might be expected, these materials are difficult to distinguish from ablation till, for in origin they are closely comparable. In fact, sometimes the distinction on the map has to be arbitrary. Ablation till generally seems to have little or no fine material comparable to basal till as does ice contact debris. Ice contact debris is usually thicker, and located in valley bottoms and flanks.

The recognizable ice contact deposits are usually too small to be mapped independently of neighbouring kame deposits, particularly those of complex character.

POSTGLACIAL DEPOSITS

ALLUVIUM AND COLLUVIUM

Alluvial deposits in the valleys cannot be distinguished from glaciofluvial materials, and the amount of alluvium is judged to be small.

Figure 13: Beach ridges at Basin Head.

Little colluvium has been identified. The total amount of material that has moved downslope under the influence of gravity, frost heave, and surface wash, particularly under a coniferous forest cover, is judged to be small.

SWAMP DEPOSITS

Swamps are widespread over eastern Prince Edward Island and are probably more abundant in the forested areas than is shown on the map. They could not always be recognized by colour or pattern changes on aerial photographs. Some swamps are in kettle-holes, others have formed where drainage has been impeded by growth of vegetation.

No systematic effort has been made to distinguish between peat and muck deposits. Where field work or aerial photographs so indicated, they were identified, otherwise they are undifferentiated. There are two raised peat bogs; one about two miles north of Red Point, east of Souris; the other is in the Marie River lowland between Ruskin and Corraville about 6 miles south of St. Peters Bay.

SALT MARSH

Small salt marshes are found at a number of points along the coasts. The most extensive area of salt marsh is in the tidal flats along East (Hillsborough) River. A deposit of buried sphagnum peat at the head of Boughton Bay indicates recent submergence. This occurrence is comparable to others in the eastern part of Prince Edward Island (Frankel and Crowl, 1961).

BEACHES AND DUNES

Beaches and small associated dune deposits that rival the well known features of Prince Edward Island National Park are found on the south shore at South Lake, Basin Head, and Little Harbour; on the north shore from St. Peters Peninsula to Savage Harbour and Tracadie Bay.

Beaches and spits on both the north and south shores indicate their construction by westward-moving longshore currents; the beach ridges at Basin Head (Fig. 13) record in remarkable fashion the constructional history of the spit. After deglaciation the area between Basin Head and Bothwell sloped more gently to the sea than the headlands, and probably ended in a shelving shore. Wave attack has carved cliffs on all this shore from headland to headland. As sediment supply became more abundant, beach ridges began to form close to shore, and built seaward in succession. The beach ridges are a few feet higher at the shore than inland, and some of the swales inland are flooded by sea level ponds. It seems that both the high seaward beach ridges and the ponded swales may be consequent upon a late rise of sea level or slight down tilting of eastern Prince Edward Island (Frankel and Crowl, 1961).

Howe Point, south of Rollo Bay, marks the division between north-flowing currents from Cardigan Bay and south-flowing currents derived from westward currents along the coast to the north and east.

Dune areas are small, and for the most part are stabilized by dune grass; they show successive stages of growth by buried surfaces now exposed in blowouts. Shore dunes are advancing over contiguous forest at two points on St. Peters Peninsula.

SOILS

Eastern Prince Edward Island is underlain by podsol soils developed under the influence of cool, moist climate and a deciduous and coniferous climax forest (Fig. 14).

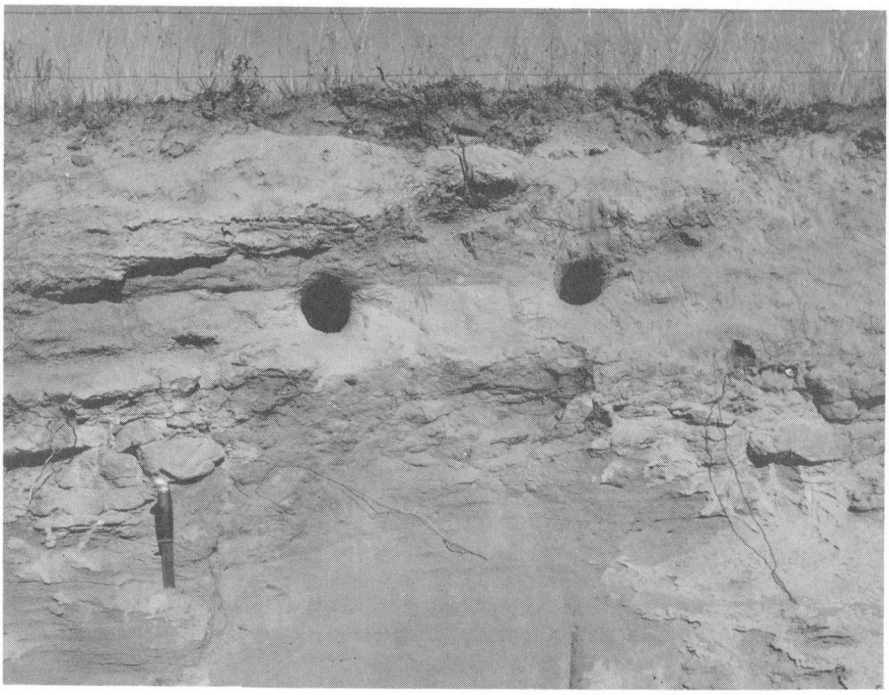

Figure 14: Podsol profile at Cherry Hill (125192).

Soil profiles are best developed on flat or gently sloping land where erosion is at a minimum and leaching predominates. A typical soil profile is given in Table I.

Table I

Typical Soil Profile

Zone	Thickness (inches)	Composition
A_0	1-2	partially decomposed humic material
A_1	0-2	mixed organic and inorganic soil materials
A_2	4-12	grey sand with a small amount of clay
B	3-6	very clayey red sand
C		red sand till

Organic soils are developed in swampy areas and characteristically have a very thick and bleached A_2 zone as a result of strong leaching by percolating waters rich in organic acids. Grey-podsols develop in areas of poor drainage, and occasionally ortstein layers – sand cemented with limonite to form a hardpan – may develop in the B zone.

In cultivated areas these light soils are subject to serious erosion, and most profiles are truncated or destroyed by ploughing and erosion.

GLACIAL HISTORY

The direction of ice advance over Prince Edward Island was an open question during much of the field work. Directional criteria were studied intensively in an effort to solve the problem, but they have not provided unequivocal evidence for direction of ice movement. Western Prince Edward Island was covered by an ice advance from New Brunswick as indicated by numerous erratics ascribed to that province (Chalmers, 1895; Owen, 1949; Prest, 1957, 1962). A single ice sheet covered most of Prince Edward Island east and southeast of New London Bay on the north shore as indicated by the reasonably uniform alignment of glacial direction indicators; a few crag-and-tail in eastern Prince Edward Island indicate the ice flowed east and southeast. Apparently after deglaciation of the main part of the island, ice advanced eastward in Northumberland Strait, up Hillsborough Bay and along the south shore as indicated by distorted till fabrics and by crag-and-tail features.

No moraines mark the boundaries of these drift sheets, nor can the drifts of these ice advances be distinguished from one another. The boundary between the main ice sheet and the Northumberland tongue is drawn on the basis of glacial direction indicators (Fig. 15).

No glacial stratigraphy has yet been discovered on the island. Presumably the Late Wisconsin ice sheet incorporated any older deposits into the present drift whose recent age is attested by thin soil profiles developed thereon.

GLACIAL DIRECTION INDICATORS

Fluted topography, eskers, striae, erratics, and miniature crag-and-tail, the primary indicators of the direction of ice flow, are widely scattered over the area. A large number of till fabrics supplement this information. All these data are shown on Figure 16. It is clear that the ice moved along an east to east-southeast alignment, but the evidence for sense direction of movement along this line is contradictory and confusing.

Fluted topography

A number of low drumlinoid hills and shallow grooves in till are scattered over the area, and there is one small area of fluted topography southeast of Dundas (Fig. 16). All have a west to northwest alignment. One drumlin near Dundas forms a ridge 4 to 5 feet high at its eastern end and grades westward down a long gentle slope into a till cored esker 20 feet high; the esker is surrounded by ablation till. This esker is most probably an ice-pressed form (Stalker, 1960). The westward change from till, to gravel and till indicates westward drainage downslope. This esker-drumlin is parallel to striae on the bedrock surface beneath its western end.

The fluted topography is parallel to the general trend of striae and till fabrics in the Mount Stewart - Souris map-area. Frankel (1966) has mapped fluted topography in the northern part of the Montague area. It is noteworthy that the trends in these two areas diverge eastward; the trend in the Montague area is more toward the southeast.

Eskers

Eskers on the upland and on valley slopes have a general southeast trend and mark channels developed along longitudinal fractures inherited from moving ice. Eskers are common in, and often parallel to the valleys; these latter are ice drainage features controlled by topography, rather than by fracture systems in the ice.

Figure 15: Striae on north shore (125209).

Striae

Striae are widely distributed over the area (Fig. 16). As might be expected they are more numerous on sandstone exposures along the shore where winter storms clear the till from the underlying rock. They have also been uncovered at a number of places inland where hard unweathered sandstone ledges are at the base of the till. They are highly variable in direction, even on the same outcrop (Fig. 15).

The sense of movement along most striae cannot be determined, for they are simple line-scratches on the rock surface. Prest (1964) reported that most nailhead striae, with a platey depression at one end, appeared to indicate movement from the head end toward the point. He abandoned this concept, however, when miniature crag-and-tail features were found associated with nailhead striae (pers. comm.). Lewis (1885) stated that wedge striae on flat outcrops indicate movement toward the blunt end of the wedge, i.e. they widen in the direction of ice flow. This remains the accepted interpretation. Nailhead striae appear to be a variety of wedge striae. A count of nailhead striae on the north shore in the Mount Stewart-Souris map-area showed nine with their head end toward the east and seven toward the west. A count of wedge striae along the same coast showed six wedges widening east and one widening west. Thus, along this coast, wedge striae appear more consistent than nailhead striae and, if Lewis be correct, are indicative of ice flow toward the east. This deduction is in harmony with observations made by Frankel (1966) in southeastern Prince Edward Island.

In interior parts of the island, observed striae show little variation from the simple line-scratch, and in Mount Stewart-Souris map-area they parallel the east-southeast trend of both bedrock and topography. The same trend is displayed by fluted

topography in adjacent parts of Montague map-area. This regional ice-flow trend is continuous westward into the northern part of Rustico map-area, though here more east-west in its orientation. All these striated and fluted areas lie north of the hill country of the island (around Hartsville in Rustico area and Caledonia in Montague area), and they appear to indicate a single period of ice flow eastward from New London Bay on the north-central coast toward the eastern end of the island.

Along the coast, variation in the trend of striae is more common and some crossing striae have been observed, but relative age determinations of these are unsatisfactory. At a number of locations along the coast, striae have been observed at a high angle to the general striae trend and to the shore. Some of the aberrant striae near sea level may readily be attributed to shove by present-day shore ice (these have not been recorded) but others are clearly beyond the reach of such ice. These latter may indicate local changes in direction of ice flow as the island was being deglaciated under the influence of rising sea level.

Erratics

No erratics whose source area could be positively identified were found in eastern Prince Edward Island. Granite boulders are much more numerous in the extreme western part of the island than elsewhere and are believed derived from the unmetamorphosed Devonian intrusives of New Brunswick (Prest, 1962).

Within the Mount Stewart-Souris map-area, boulders are fairly numerous in the north coastal area of Souris Peninsula and St. Peters Peninsula. The highest concentration is in St. Peters Peninsula. They are practically absent in Mount Stewart area and only a few have been found to the south in Montague area near the southeast corner of the island and to the west in the Orwell area.

Miniature crag-and-tail

Miniature crag-and-tail, formed in association with rare small pebbles in the sandstone, is usually perceived only by minute examination of the exposure. Two occurrences have been found within the map-area, and three more just beyond its limits. These latter are: (1) on the west shore of Tracadie Bay south of Winter Bay, (2) at Perth, northwest of Montague, and (3) two miles southeast of Montague. All are within the area of southeast-trending striae and till fabrics. One other occurs on the south shore, at Stewart Point, west of Wood Islands. Some have been destroyed by weathering since they were first observed, and most were poor examples when discovered.

These occurrences deserve discussion because their evidence is internally inconsistent and conflicts with that from striae and till fabrics. The inland crag-and-tail consistently indicate ice movement to the southeast. The north shore examples are contradictory: crag-and-tail on the west shore of Tracadie Bay indicates eastward movement whereas another east of Big Pond indicates westward movement. Neither example is first class, but both were acceptable. The westward crag-and-tail near Big Pond cannot be readily explained. A local eddy in ice flow during deglaciation might give rise to aberrant crag-and-tail comparable to aberrant striae. The crag-and-tail at Stewart Point west of Wood Island on the south shore clearly indicate eastward movement parallel to the shore and to striae in the vicinity.

Till fabrics

Sixty-five till fabric studies (Holmes, 1941; Wright, 1957) have been made in central and eastern Prince Edward Island. Some of these are shown in Figure 16.

Table II

Till Fabric Data

Azimuth	No. of Stones	Total in 10° Interval	Group Total	/3= Moving Average
270	0	8		
275	8			
280	3	8	27	9 (280)
285	5			
290	6	11	24	8 (290)
295	5			
300	3	5	18	6 (300)
305	2			
310	0	2		
315	2			

The attitude of stones whose axial ratio was 1.5:1 or greater was recorded. Stones were not subdivided into various subclasses – prolate, oblate, etc. One hundred stones were measured at most localities. Directions of long axes of pebbles were measured to the nearest 5 degree interval. Later in the course of the work, measurements included the direction of axial plunge of the pebble.

The axial direction varies widely, and a high percentage of the axes dip at a high angle contrary to many published accounts (e.g., Wright, 1957). However, the direction of axial plunge is not consistent – pebbles plunge both upstream and downstream in relation to ice flow, and the predominant plunge varies from site to site. This high angle of plunge has been inferred to indicate deposition of till by active ice (Glen, Donner, and West, 1957), but an alternative explanation may be suggested – these tills have been so affected by frost action that the fabric has been disturbed but not obliterated. This may explain the large horizontal divergence of axes in this area and the high dips. It would seem that the pebbles have been more strongly rotated about a horizontal axis to give steeper dips than about a vertical axis to give greater variability in strike.

In some cases simple compass rose plots showed remarkably good alignment, but in most cases there was a wide scattering. Because ice flow is nearly streamline, the readings were grouped by the method of moving averages (James and James, 1959) by 10 degree intervals to indicate clearly the predominant orientation of the pebbles.

Table II shows a partial arrangement of data from which fabric diagrams might be drawn.

Table II shows that averages based on 10 degree intervals may shift slightly, depending upon which 5 degree readings are paired (270 + 275 vs. 275 + 280, etc.). This results in a 10 degree shift of the peak of the diagram. So far as the author has determined by several checks, peaks will shift in either direction and there is nothing systematic about the shift.

Examination of these till fabrics discloses that they can be divided into four types (see Fig. 16). Fabric 15 shows a strong orientation parallel with ice flow; the transverse axis is slightly developed (Holmes, 1941; Glen, Donner, and West, 1957). Fabric 21 shows a pronounced transverse axis. Similar fabrics have been interpreted by MacClintock and Dreimanis (1964) to indicate reorientation of fabric by later ice advance; this interpretation is supported here by striae at a high angle to the usual trend.

Fabric 11 shows an orientation transverse to the main flow of the ice. This is thought to result from a rolling of pebbles about their long axes (Holmes, 1941; Glen, Donner, and West, 1957). Such fabrics are rare. Fabric 18 shows little preferred orientation of pebbles. Fabrics like this are believed to indicate slumping of ice contact deposits or, in rare cases, possible frost action. Sample localities were chosen to avoid, so far as possible, recent downslope movement.

Three-dimensional analyses of pebble orientations were made at about one third the localities in an attempt to deduce the sense of movement in the direction of the long axes of the rose diagrams as plotted on the map. First, the plunge of the long axes of the pebbles was plotted on an equal-area net, and the resulting point diagram contoured (Billings, 1954). These stereo-net diagrams were not satisfactory because the contoured maximum was commonly close to the centre because of steep plunge of the pebble axes, or the diagrams were highly irregular. Additional analyses on an IBM 1620 computer failed to indicate a consistent direction of plunge along a southeast axis as an indicator of ice movement.

DIRECTIONS OF ICE FLOW

To sum up the evidence, indicators point to ice movement along a northwest-southeast line in most of eastern Prince Edward Island. The evidence for sense of movement along this line is contradictory. Crag-and-tail in the interior and, to a lesser extent wedge striae, indicate a southeastward flow of ice. It is unlikely that the problem will be solved on the island; the solution must await mapping of Pleistocene deposits in Nova Scotia. Prest and Grant (1967) have recently summarized evidence from the Maritimes and deduced a mainly southeastward flow complicated in late stages by radial flow from local ice caps; Muller (pers. comm. 1966) has found no evidence to support the idea of outflow from a plateau ice-cap on the Cape Breton Highlands.

Along the south shore of the island from the Charlottetown area to Murray Harbour, striae, crag-and-tail and distribution of erratics indicate a late eastward movement of ice down Northumberland Strait. Most striae along the south shore trend nearly east-west; crag-and-tail at Stewart Point indicates eastward movement; the occurrence of erratics in the Orwell area is best explained as the result of eastward movement up Hillsborough Bay.

The till fabrics in the Murray Harbour district are judged to be transverse to ice flow; fabrics with strong transverse axes in the vicinity of Pownal Bay and Orwell Bay indicate disturbance and partial reorientation of earlier fabrics by later ice in Northumberland Strait. They are closely comparable to fabrics in demonstrably overridden till (MacClintock and Dreimanis, 1964).

Till of these ice advances cannot be distinguished on lithologic or textural bases, and the boundary shown on Figure 16 is drawn on the basis of direction indicators.

DEGLACIATION

As there are no end moraines in eastern Prince Edward Island, no retreatal stages of deglaciation are visible. Instead, the anastomosing complex of glaciofluvial deposits in the valleys and their connections across divides indicate the wastage of a rapidly thinning stagnant ice sheet that melted down in place with no significant amount of movement.

Abundant meltwater is indicated by the numerous kames and eskers. Presumably eskers first formed along extension fractures in the ice, and later as parts of the valley bottom drainage system. Abundant, small, valley-side kames mark the position of temporary ponds. None of the kames has been identified as a part of a

system of kame terraces. Ice contact debris, sloughed from the ice, is commonly associated with these kames.

Meager evidence, i.e. three eskers with crossbedding indicating eastward drainage indicates that ice may have been removed from the eastern Gulf of St. Lawrence prior to its disappearance from the island, perhaps by a rise of sea-level consequent upon general deglaciation.

Two radiocarbon dates on mollusc shells from marine deposits in the Tignish map-area in western Prince Edward Island give minimum dates for deglaciation of that area: 12,410 ± 170 years B. P. (GSC 101, Dyck and Fyles, 1963) and 12,670 ± 340 years B. P. (GSC 160, Dyck and Fyles, 1964). Presumably eastern Prince Edward Island was deglaciated about the same time.

POSTGLACIAL HISTORY

Raised marine terraces in western Prince Edward Island indicate maximum postglacial uplift of about 75 feet (Owen, 1949; Prest, 1957, 1962); recent submergence in eastern Prince Edward Island, possibly by eustatic rise of sea level, is indicated by peat and tree stumps (about 6 feet below high tide level) and is dated 915 ± 70 years B. P. (I-GSC-23, Frankel and Crowl, 1961). Evidences of this submergence are widespread along the southeast coast of the island, and trees and peat have also been found below high tide level on the west shore of Tracadie Bay.

ECONOMIC GEOLOGY

SAND AND GRAVEL

Glacial sand gravel deposits are widely exploited for road materials in this area. Even more commonly, the soft sandstones are quarried at numerous borrow pits and hauled a short distance for road fill.

The best gravel deposits are the weathered bedrock conglomerates at Bayfield and North Lake; these hard-pebble conglomerates have been exploited for road materials for highways in the area. As pointed out earlier, these deposits may be at approximately the same stratigraphic horizon, and additional pit sites may be discovered by drilling between the two localities.

PEAT

A number of peat deposits are indicated on Map 1260A. They have not been sampled in this investigation. Before any one of them is used for commercial purposes it should be sampled for quality and its depth determined at a number of places.

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