69-33

GEOLOGICAL SURVEY OF CANADA

DEPARTMENT OF ENERGY, MINES AND RESOURCES

PAPER 69-33

RETREAT OF THE LAST ICE SHEET FROM THE MARITIME PROVINCES — GULF OF ST. LAWRENCE REGION

(Report and 4 figures)

V. K. Prest and D. R. Grant

GEOLOGICAL SURVEY
OF CANADA

CANADA

PAPER 69-33

RETREAT OF THE LAST ICE SHEET FROM THE MARITIME PROVINCES — GULF OF ST. LAWRENCE REGION

V. K. Prest and D. R. Grant

DEPARTMENT OF ENERGY, MINES AND RESOURCES

Available by mail from the Queen's Printer, Ottawa,

from the Geological Survey of Canada
601 Booth St., Ottawa
and at
Canadian Government bookshops in
HALIFAX - 1735 Barrington Street
MONTREAL - 1182 St. Catherine Street West
OTTAWA - Corner Mackenzie and Rideau
TORONTO - 221 Yonge Street
WINNIPEG - 499 Portage Avenue
VANCOUVER - 657 Granville Street
or through your bookseller

Price: $1.50 Catalogue No. M44-69-33

Price subject to change without notice

The Queen's Printer
Ottawa, Canada
1969

CONTENTS

Illustrations

ABSTRACT

The popular concept of overriding Laurentide ice (Labradorean sector) in the Maritime Provinces-Gulf of St. Lawrence region is examined in terms of regional ice-flow patterns and other supporting data - and is found wanting. A re-interpretation of the data, the glacial lineations and other features presents a picture of localized, more or less radial outflow from certain upland and lowland areas. The pattern of ice-flow features and end moraines is shown to relate to a rising sea level over the period from about 18,000 to 11,000 years B.P. The maritime climatic regime enabled various parts of an Appalachian ice complex to remain active as the sea encroached on the depressed land masses. The deeper-water parts of the submerged coast served as 'leads' into the ice fronts, with consequent development of calving bays and ice drawdown.

It is concluded that Laurentide ice was not as active over the Maritime Provinces as has generally been believed and that the growth of Appalachian glaciers during the build-up of the last continental ice sheet may have effectively barred Laurentide ice from some parts of the region. Laurentian Channel served as an outlet that diverted Laurentide ice through Cabot Strait to Atlantic Ocean, so that Prince Edward Island and Cape Breton Island do not show a pattern of Laurentide ice flow, and the Magdalen Islands remained unglaciated.

RETREAT OF THE LAST ICE SHEET FROM THE MARITIME PROVINCES — GULF OF ST. LAWRENCE REGION

INTRODUCTION

There has long been controversy as to the extent and mode of glaciation in the Maritime Provinces (Fig. 1). This has involved differences of opinion as to the Maritime centres of accumulation or outflow and the pattern of glacier retreat. Also, there has been some question as to whether the Magdalen Islands in the Gulf of St. Lawrence were glaciated. The configuration of the ice front during recession of the last ice sheet or ice-sheet complex is a matter of prime concern. In studying these problems, the present authors have made field observations in, and have studied the air photos of, most parts of the regions. This paper is a summary of their conclusions regarding the extent and movement of the last ice-sheet complex, both at its maximum and during subsequent recessional stages. The views presented here are at some variance with the generally-held concepts of glaciation and deglaciation in the Maritimes, particularly on the question of the extent and influence of the Laurentide ice in the region and the pattern of glacier recession.

Before discussing the last glaciation it is perhaps appropriate to mention briefly the records of older or earlier Pleistocene events in the Maritimes. Organic-bearing sediments beneath one or two tills are reported only from Nova Scotia. A summary account of these deposits is given by Prest (in press) and detailed accounts by Mott and Prest (1967).

Organic materials from several sites on Cape Breton Island were radiocarbon dated and found to be beyond the range of the given standard analyses. Pollen studies of these materials indicated only cool climatic conditions. The deposits are considered to relate to early and mid-Wisconsin interstadial periods.

Organic sediments from a drillhole at Leitches Creek, Cape Breton Island, may relate to an interglacial deposit but pollen studies of the organic layers are at present incomplete. Interglacial deposits, however, are reported from near Milford in central mainland Nova Scotia; these bear record of at least two climatic periods comparable with the present.

Marine shells found in a stony clay or till at the southwest end of the Scotian Peninsula are further evidence of events prior to the last

---

Project Numbers 530030, 660036
Original Ms. submitted by authors 5 September, 1968
Authors' address: Geological Survey of Canada,
601 Booth Street,
Ottawa, Canada.

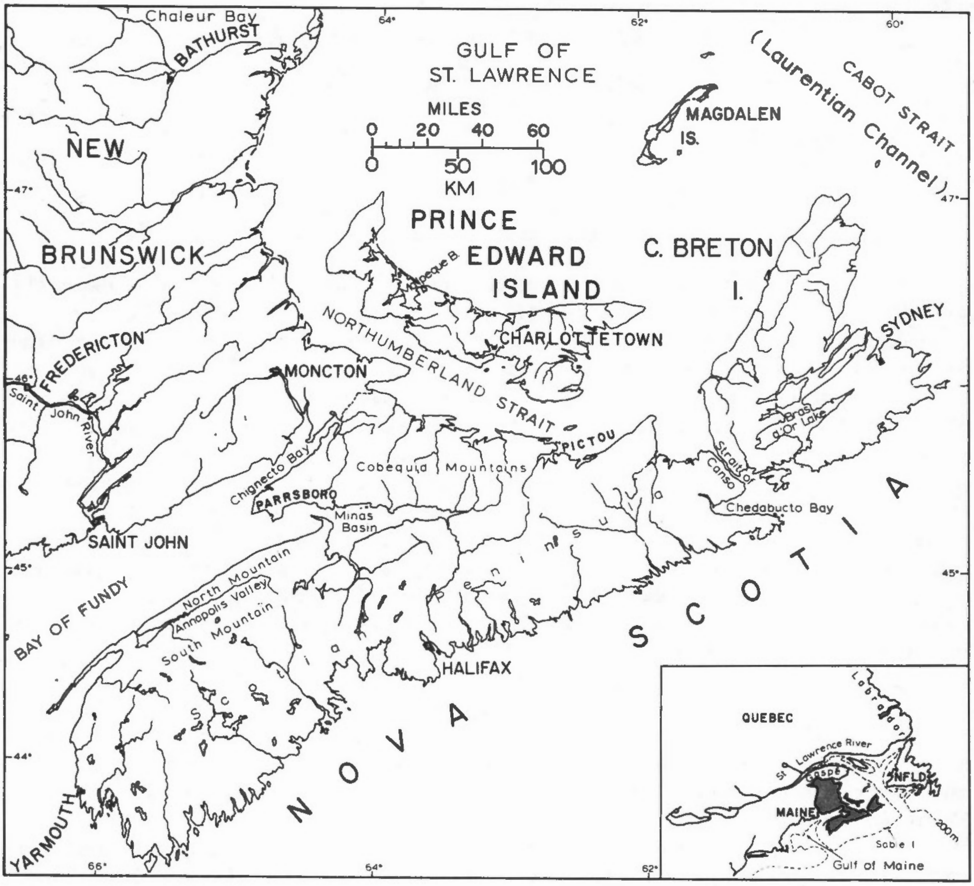

Figure 1. Maritime Provinces-Gulf of St. Lawrence region

glaciation. The shells were probably derived from sea-bottom sediments, by a glacier that crossed the Bay of Fundy. The shells were radiocarbon dated and found to be beyond the range of the given analyses.

The 'Bridgewater Conglomerate' may be another record of older Pleistocene events. This conglomerate is a cemented gravelly material that generally underlies till. It outcrops sporadically across the Scotian Peninsula from near Yarmouth to northeast of Halifax.

THE LAST GLACIATION

Terminal ice positions

The terminal positions of one or more ice sheets off the Nova Scotian coast have generally been believed to lie near the edge of the continental shelf and to pass through or near Sable Island, about 100 miles (160 km) from the shore. Crystalline erratics, either incorporated in offshore sediments or deposited on them, have been accepted as supporting evidence for this concept. From an analysis of boulder distribution, drift-ice patterns and surface currents, however, Grant has concluded that the erratics are mainly due to ice rafting in postglacial times.

King (1969) reported that the entire Scotian Shelf which extends seaward to the limits of the continental shelf along the entire southeast coast of Nova Scotia, had been glaciated. Precision depth profiling and reconstruction of accurate, sea-bottom morphology revealed an inner shelf bordering the land and terminating offshore at approximately the 100-metre contour, an outer zone of complex mesa-like forms, and a central zone of longitudinal and transverse depressions. The central and inner zones have a decidedly glaciated character. In the central zone, King has mapped an end-moraine system that has been traced from northeast of Halifax to southeast of Yarmouth. The moraine has been cored, and a small sample of amorphous organic material in mud, obtained from marine sediments intimately associated with the moraine, has been radiocarbon-dated at 18,800 years B.P. From this, King concluded that the end-moraine system represents a major late-Wisconsin glacier limit – either a recessional stand during the retreat of the ice from the edge of the continental shelf or the terminus of the last ice sheet. The present authors hold with this latter view because of the morphological differences between the outer and the central and inner zones of the shelf, and in view of the radiocarbon age of the organic matter. Channels, believed to be proglacial meltwater channels, connect the glaciated basins of a central zone with terraces fringing the outer banks at depths of as much as 400 feet (121 m) below sea level. One such channel is cut along the proximal side of the southwestern part of the end moraine that extends into the Gulf of Maine.

Regional Ice Flow

The regional southeasterly trend of eskers and other ice-flow features in the state of Maine and adjoining parts of southwestern New Brunswick, and the continuation of this trend in southern Nova Scotia, has contributed to the generally-held concept of a regional radial flow of Laurentide ice (Labradorean sector) across the Maritime Provinces and on to the Scotian Shelf (Fig. 2). This concept has been further strengthened by the presence in Nova Scotia of glacial erratics considered to be New Brunswick 'indicators' (Goldthwait, 1924). Precambrian boulders derived from the Laurentian physiographic province in Quebec, however, have not been recognized in Nova Scotia. The absence over northern Nova Scotia, Cape Breton Island, Prince Edward Island and eastern New Brunswick of the southeasterly ice-flow trends that might be expected from a major flow of Laurentide ice, has been attributed to erasure by later recessional lobations of the relatively inactive ice. Presumably, these lobations were controlled by topography and by drawdown toward the Gulf of St. Lawrence subsequent to the presumed main flow of Laurentide ice from the northwest and/or from the Acadian Bay lobe (Goldthwait, 1924) of this ice sheet from the north (Fig. 2). The present authors recognize the importance of these recessional drawdown effects but they also draw attention to the east-southeast direction of the main ice flow indicated over Prince Edward Island (Fig. 3); this flow would not be in accord with the presumed southeast flow of Laurentide ice nor with the southward flow of an Acadian Bay lobe. Furthermore, they point out that there is little

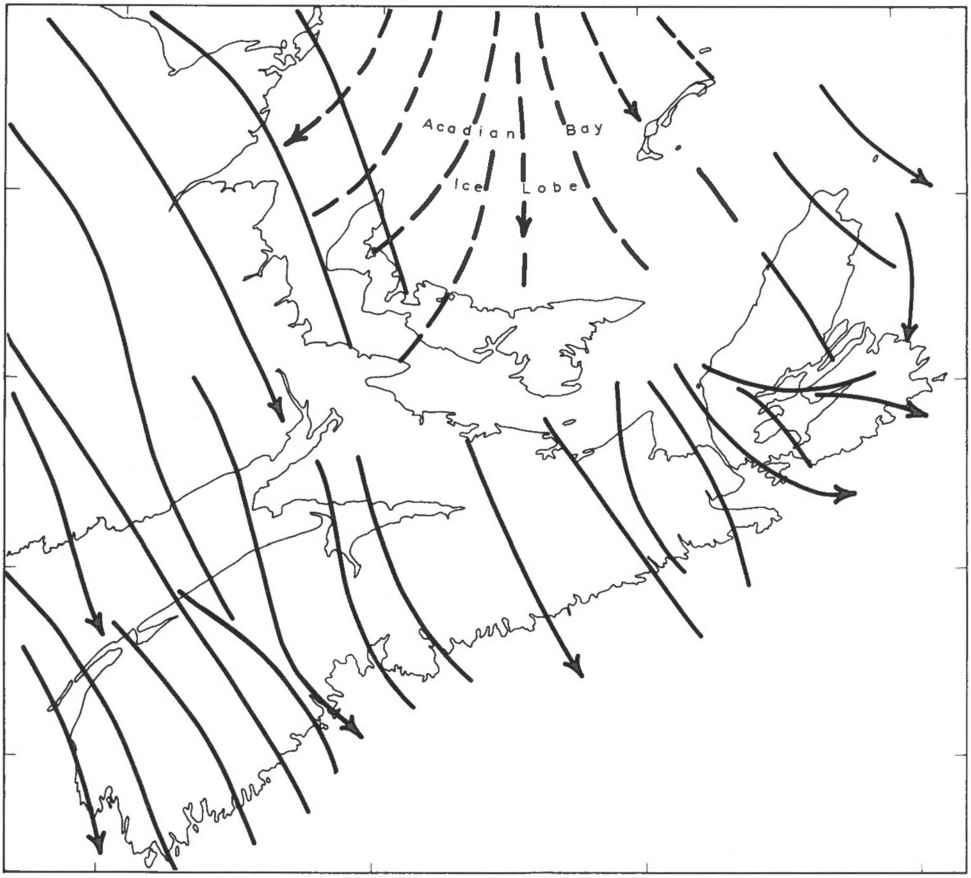

Figure 2. Popular concept of Laurentide ice flow

or no evidence on Cape Breton Island of the southeast-trending ice-flow lineation, characteristic of southeast Nova Scotia. Yet, Cape Breton Island lies closer to the Laurentide centre of outflow than does mainland Nova Scotia and would be unprotected by highland areas from any such ice flow across the Gulf of St. Lawrence. The ice flow pattern on the island is, in fact, markedly discordant with the concept of an overriding Laurentide ice sheet.

General Deductions

The period of snow cover in the Maritimes extends into the spring season longer than in comparable latitudes farther west in the interior. An already-existing ice cover, with its added height and locally developed climate would prolong the life of the ice cover over the land masses. The climate and topography of the Maritimes is such that local ice caps might form in some regions prior to the advance of a continental ice sheet. The authors believe that, during the process of deglaciation, parts of the region were

Figure 3. Glacial features indicative of ice flow.

areas of excessive snowfall and that the recessional ice-sheet complex maintained active areas of outflow as calving took place into the encroaching sea.

The ice-flow pattern in the Maritime Provinces, and the distribution of erratics, reflect a drawdown and calving process related to rising sea level during the deglaciation process. At the last glacial maximum, the Maritime ice and the Laurentide ice were confluent but the latter was not as influential in this region as has formerly been assumed.

DISCUSSION OF EVIDENCES OF GLACIATION IN DIFFERENT SECTIONS OF THE REGION

Significant features and geological data pertinent to the problem of ice-flow directions in specific parts of the Maritime Provinces are as follows:

Atlantic side of the Scotian Peninsula

In Nova Scotia, the till mantle has been studied in somewhat more detail in the central and northeastern parts of the Atlantic side of the Scotian Peninsula than it has elsewhere (Grant, 1963). The till-covered areas display a marked glacial lineation due to the presence of groups of drumlins. These are composed of a fine-grained, red-brown, clay till that is both texturally and mineralogically anomalous to the bedrock geology of the areas and is responsible for geochemical anomalies throughout the region. The till between the drumlins is yellowish grey and of strictly local derivation. Grant studied the problems of both these tills and related their stone content to bedrock sources. In so doing, he outlined dispersion fans that appear indicative of major ice lobations and strong ice-flow currents. The reddish materials are believed to have been largely derived from red estuarine and marine muds of upper Bay of Fundy, Minas Basin and Northumberland Strait, and the till is believed to represent the advance phase of the Classical Wisconsin Glaciation.

The general uniformity and parallelism of direction characteristic of ice-flow features along the whole southeastern side of the Scotian Peninsula (Fig. 3) reflects, in large part, the last major flow of ice. Examination of air photos and of surficial geology and soils maps reveals, however, some variation in the detail of ice-flow trends. Also, crossing striae have been observed, especially in the southernmost part of the province. It would appear that, at two different periods, the ice flow followed a southeasterly course toward the Atlantic Ocean, but as the sea encroached forming bays in the ice front, drawdown was hastened, and there were minor variations in the direction of the later ice flow.

Bay of Fundy side of the Scotian Peninsula

Examination of air photos reveals two main sets of ice-flow features over a broad zone along Bay of Fundy side of the Scotian Peninsula. It is believed that one set, largely obliterated in places, indicates the main Wisconsin flow and that the other is the result of a later recessional movement. This younger set of features trends westward in the southwestern part of the peninsula and northward a little farther to the north (Fig. 3). In both cases, the indicated direction of ice flow is toward the Bay of Fundy. Such outward flow from an interior ice cap on the Nova Scotian upland of the Scotian Peninsula was recorded by Dawson (1855). He noted granitic erratics on the southeastern side of the Annapolis Valley, at elevations of less than 200 feet, that he considered had been derived from the South Mountain batholith of the upland area south of the valley. He also noted boulders of what he believed to be South Mountain granite on the northern side of the valley on the slopes of North Mountain – a cuesta of Triassic basalt with elevations up to 900 feet. His observations were confirmed by Chalmers (1895), Bailey (1898), Prest (1898) and Walker and Parsons (1923). Goldthwait (1924), however, believed that most of the erratics were transported from New Brunswick by Laurentide ice that flowed across Bay of Fundy and the Scotian Peninsula while some erratics were possibly derived from local, unmapped bodies of South Mountain granite lying north of the known occurrences. The concept of northward transport was revived by MacNeill (1951) who also noted South

Mountain granitic materials on the top of North Mountain and on the Fundy shore. By both field and petrographic comparisons of South Mountain and New Brunswick granites, Hickox (1962) showed that they were readily distinguishable and he confirmed the northward dispersion of South Mountain erratics.

In interior parts of the Scotian Peninsula, MacNeill observed drumlins, crag-and-tail hills, eskers and outwash, indicative of former westerly and northerly ice flows. Hickox reports two sets of striae south of central Annapolis Valley, an older set trending about N130°E, and a younger set trending nearly north-south. The former probably relates to the main ice flow and the latter to a later northward flow. Kame terraces and kame deltas on the southwest side of the northern part of the Annapolis Valley indicate recessional ice stemming from the South Mountain region. Thick morainal deposits along the coast north of Yarmouth appear to mark the ice-marginal position of an upland ice cap at a time when higher relative sea levels reworked only the distal side of the deposits.

MacNeill and Hickox envisaged a postglacial climatic change as responsible for the build-up of an upland ice cap in Nova Scotia. The present writers, on the contrary, consider that the upland ice represents a remnant of the former more extensive ice sheet that became isolated on the Scotian Peninsula as a result of incursion of the sea into Bay of Fundy. Radial flow and meltwater drainage toward the bay would be a natural consequence of this invasion and was probably in progress by 14,000 years B.P., as shells from close to the marine limit on the New Brunswick side of the bay have been dated 13,200 $\pm$ 200 years B.P. (GSC-965). The maritime environment enabled active, outlying, ice masses to persist in Nova Scotia during the period of sea-level rise resulting from the thinning of ice sheets and ice caps throughout the world. Radial outflow was maintained during and for some time following the period of marine overlap.

Northern Nova Scotia

The presence of another late, upland ice mass is indicated in north-central Nova Scotia. In the area east and southeast of Minas Basin, glacier advance was from the northwest but retreat was toward the northeast rather than the northwest (Hughes, 1957). This late ice appears to have stemmed from the uplands of northeastern mainland Nova Scotia including part of the Cobequid Mountains. There are numerous reports in the literature of northward ice flow from the eastern end of these mountains (Dawson, 1855; Fletcher, 1893; Poole, 1904). The present authors have confirmed some of these observations and, in addition, have noted north-pointing drift tails, branching eskers and valley trains, all extending north toward Northumberland Strait. The extent of this active flow of late ice is shown by the abundance of Cobequid erratics near Pictou and on Pictou Island, ten miles offshore. A large area of kames and other ice-marginal features in the north-central lowland east of both Pictou and the Cobequid Mountains, is probably the site of the last remnants of this late ice mass. Here, as in the Bay of Fundy area, is evidence of ice retreat to a local upland area with drawdown in several directions towards the transgressing sea.

The western part of Cobequid Mountains presents a different picture of glacier retreat. Borns (1965) maintains that this part of the upland "... was not a centre of radial outflow after the dissipation of the last ice sheet to cover the region". He reports that the last ice in this area "... dissipated primarily by down-wasting, probably by downmelting". Borns and Swift (1966) state "As the ice thinned, it remained active on the north side of the Cobequids and built end moraine complexes in the higher passes as the ice continued to flow through the lower passes".

The present authors concur that the ice remained active and that it receded northward. This is indicated by (1) end moraines in the valley north of Parrsboro that transect the Cobequid Mountains; (2) outwash, extending southward from the Parrsboro Valley to a calving bay in Minas Basin and graded to a sea level higher, relative to the land, than the present one; (3) south-trending striations and eskers preserved on the Cobequid Upland; (4) hillside meltwater channels incised into the north flank of the Cobequid Upland; and (5) abundant, well-developed southerly and southwesterly oriented ice-flow features in the Chignecto Bay Lowland. Active, south-flowing ice must have abutted against the north side of the western end of the Cobequid Mountains, whereas, for some time after the main ice sheet had receded and dissipated from Nova Scotia, the eastern end of the upland supported a late, independent, radially-spreading glacier.

Cape Breton Island

The eastern lowlands of Cape Breton Island show little evidence of the marked southeastward ice-flow pattern characteristic of mainland Nova Scotia. In its place Cape Breton Lowland bears mainly northeast-southwest lineations. Along the southeastern coast there are marked, rock-inscribed glacial features that show unmistakable evidence of ice flow onto the island. Goldthwait (1924) concluded that the ice responsible for these features came either from the northeastern tip of Nova Scotia or, more probably, from New Brunswick via Northumberland Strait, Strait of Canso and Chedabucto Bay. The present authors concur with this latter view.

Northeasterly-directed ice-flow markings also occur in interior parts of Cape Breton Lowland, both on the shores of Bras d'Or Lake and on adjacent upland slopes. The whole of eastern Cape Breton appears to have been scoured by ice from northern Nova Scotia or New Brunswick. There were only minor additions of ice from Cape Breton Highland, and there is no evidence of Laurentide ice.

The fault-line scarp along the south side of Chedabucto Bay partly controlled the flow of ice onto the continental shelf and the ice splayed northward onto Cape Breton Island. Offshore studies in Cabot Strait shed some light on the extent of eastern Cape Breton ice. Sea bottom morphology suggests that the ice moved northeastward from northern Cape Breton Lowland as well as eastward along the extension of Chedabucto Bay and became tributary to the vast Laurentian Channel glacier. Similar conditions are evident in respect to Newfoundland ice on the northern side of the Channel. The Laurentian Channel ice flowed eastward past the exposed areas of the continental shelf, plugging tributary valleys with morainal debris.

In eastern Cape Breton Lowland, there is also evidence of younger, diverse ice-flow trends. The present authors believe that, as a calving basin formed in Chedabucto Bay, rising sea level severed the Bras d'Or Lowland ice from its source of supply in the southwest or west. The northern part of the lowland ice mass continued to flow northeastward toward the encroaching sea in Cabot Strait, forming drumlins and at least one small end moraine (not shown on map) with a steep, south-facing proximal side. Eskers parallel the trend of the ice-flow features. The southern part of the ice mass in the Bras d'Or Lake area, however, was now free to flow southward into the Chedabucto calving basin. The south-flowing ice reworked older morainal ridges into drumlins and lightly striated coastal outcrops that had been earlier scoured by northeastward-flowing ice. It also deposited a red till, derived from red rocks in the Bras d'Or Basin, on top of local crystalline tills. Still later, the lowland ice appears to have been confined within the limits of the Bras d'Or Basin where it left striations on outcrops and deposited small morainal elements and drumlins in some of the bays.

Whereas Cape Breton Lowland abounds in constructional glacial features, the highland plateau does not. Here, ice-flow features are relatively uncommon and such as are found are discordant with those of the lowlands. Some southeast-trending features along the eastern side of the highland have fostered the popular concept that Laurentide ice overrode the highlands (Goldthwait, 1924). The present writers do not consider such a conclusion justified. To date, airphoto study of the plateau has revealed only a few flights of hillside meltwater channels and small areas of hummocky, lineated drift. The few striae and roches moutonnées reported in the literature as indicative of Laurentide ice, may be equally well-explained as the effects of a local ice mass. The present writers favour the hypothesis of a highland ice cap that was neither extensive nor very active judging by the pattern of ice marginal channels, the probable absence of raised marine shorelines, and the fact that only valleys penetrating deeply into the plateau have been ice sculptured. Further, valley train deposits in Margaree Valley of west-central Cape Breton Island originate in the southern end of the highland and are indicative of late ice from the highland.

There are signs, however, that a major glacier impinged on the western flank of the highlands. This was formerly believed to be Laurentide ice from the northwest, but it appears to have flowed northward and was responsible for the north-sloping kame terraces and meltwater channels, and for the northward dispersal of erratics reported in the literature (Honeyman, 1890; Fletcher, 1893; Norman, 1935). This glacier built moraines across at least two major valleys and created proglacial lakes in them. It probably stemmed from the glacier that flowed eastward along Northumberland Strait and over Prince Edward Island.

Magdalen Islands

Prest (1957; in press) does not consider that the Magdalen Islands, in the central part of Gulf of St. Lawrence, were scoured by overriding Laurentide ice during the Classical Wisconsin Glaciation. Richardson (1881) and Chalmers (1895) also believed this, and Coleman (1920) reported that only floating ice had reached these islands. The occurrences of till, commonly sited as evidence of glaciation, were not deposited by basal glacier ice but rather by floating ice. The till is intercalated with, and locally underlies or overlies marine gravels, and is present up to altitudes of about 120 feet.

This surprising amount of overlap, relative to the absence of raised marine shorelines of Cape Breton and on eastern Prince Edward Island, is presumably due to the islands' proximity to the combined Laurentide and Newfoundland ice sheets to the north. Ice from these sheets flowed strongly eastward along the immediately adjacent Laurentian Channel. The end moraine reported by Alcock (1941) on Coffin Island in the northeastern part of the islands is actually an eroded mass of fine-textured, well-bedded, ice-contact, stratified drift, overlain by a bouldery mantle deposited during the postglacial marine transgression. The whole feature might perhaps be termed kame moraine. It would appear to have been deposited from a southward bulge of Laurentian Channel ice into the depression between the Magdalen Islands and Cape Breton Island.

Prince Edward Island

Prince Edward Island is unique among the land masses of the Maritime region in that it is composed entirely of Pennsylvanian and Permian age 'red beds' - sandstone, mudstone, conglomerate and intraformational mudstone breccia. The occurrence of foreign rock is, therefore, both noticeable and meaningful in determining the source of the ice which inscribed glacial features and left deposits on the island.

The western end of Prince Edward Island is strewn with a great variety of large igneous and metamorphic erratics, and the tills contain smaller rocks of the same materials. Most of these 'foreign' stones are similar to those found in eastern New Brunswick and which become more numerous the nearer one approaches their source areas in the New Brunswick Highland. Even though striae are extremely rare in the western parts of the Island, it must be concluded that the major ice flow came from the west in view of the distribution of erratics. Two gneissic boulders, found in north-central Prince Edward Island and thought to have been derived from the Precambrian Shield, perhaps by confluent Laurentide New Brunswick ice, were dated by the K-Ar method and shown to be Devonian in age like the granitic intrusives and associated gneisses of the New Brunswick Highland. On the other hand, an anorthosite boulder from the north-central part of the Island is similar in appearance to large intrusive masses in the Grenville subprovince of the Precambrian Shield north of St. Lawrence River. It is unlike the smaller bodies of anorthosite known in Cape Breton Island, and anorthosite is not known to occur in New Brunswick. It is considered probable that the anorthosite boulder was transported by Laurentide ice into the northern end of Matapedia Valley in the Gaspé; then it was carried by mainly Appalachian-derived ice across part of eastern New Brunswick and western Prince Edward Island to its resting place. Alternatively, they may have been implanted on the Island by a lobe of Laurentide ice flowing around the eastern tip of Gaspé Peninsula, but this is considered unlikely.

Glacial striations abound along the west-central part of Northumberland Strait and the south and east shores of Malpeque Bay. Commonly, they exhibit a characteristic nail-head shape, and, less commonly, a wedge shape. The pointed end of these striae is directed eastward along the Northumberland Strait section and east, northeast and north in the Malpeque Bay area. According to accepted theory, therefore, ice movement was south and west - though the latter appears incongruous in view of the distribution of New Brunswick erratics as far east as Malpeque Bay. Wedge striae in the eastern parts of the Island and along its north shore, however, generally point west and broaden toward the east, and miniature crag-and-tail features associated with these striae in a few places confirm the inferred eastward ice flow.

Upon re-examination of some of the better striated surfaces in Northumberland Strait and Malpeque Bay, miniature crag-and-tail features were found that substantiated the seemingly incongruous southward and westward ice flow. It would appear that much ice may have lain in the Gulf of St. Lawrence north of Prince Edward Island as well as on the Island itself when the sea encroached into the western end of Northumberland Strait - an event that occurred prior to 12,410 ± 170 years B.P., the age given to shells that relate to a sea level well below the marine limit. Some of this ice must have flowed southward through Malpeque Bay and westward along Northumberland Strait where an active calving bay formed. Glacier ice also moved southwestward off the higher central part of the Island and then west along Northumberland Strait. Blockage of the eastern end of the Strait by the movement of late ice from Nova Scotia mentioned earlier, may have initiated this westward flow. Possibly, the southward movements were partly a continuation of the earlier southward flow across the lowland area between Northumberland Strait and Chegnecto Bay and into the calving bay formed somewhat earlier in Bay of Fundy. Finally, the Prince Edward Island ice, on the northern side of the highland areas, stagnated and formed the anastomosing system of ice-contact deposits characteristic of the eastern end of the Island (Frankel, 1966) but absent in the western end.

New Brunswick

New Brunswick affords evidence of markedly diverse ice-flow trends. Regional southward and southeastward ice-flow lineations occur in the area adjacent to the Saint John Valley (Lee, 1962). If southeast-flowing ice crossed the New Brunswick Highland, all evidence has been removed by the last ice flow from the highland which fanned out to the east and into Chaleur Bay in the northeast. In the meantime, however, ice appears to have flowed southward from Chaleur Bay around the eastern side of the highlands. There is also evidence of southward ice flow in the east-central lowlands where an end moraine and extensive outwash were deposited. Late ice appears also to have flowed radially from the south-central lowlands, calving first into Bay of Fundy and later into Northumberland Strait.

CONCLUSIONS

There is undoubted evidence of Wisconsin Laurentide ice in various parts of the Maritime Provinces-Gulf of St. Lawrence region, but there is no actual proof of its presence throughout the entire region. It appears that the development of local ice in some parts of the region was sufficiently early and extensive to hold off the Laurentide ice flood or, at least, to direct it along defined channels such as the Saint John and Matapedia valleys. Furthermore, the great Laurentian Channel effectively served to draw down the northern ice eastward through Cabot Strait toward the edge of the

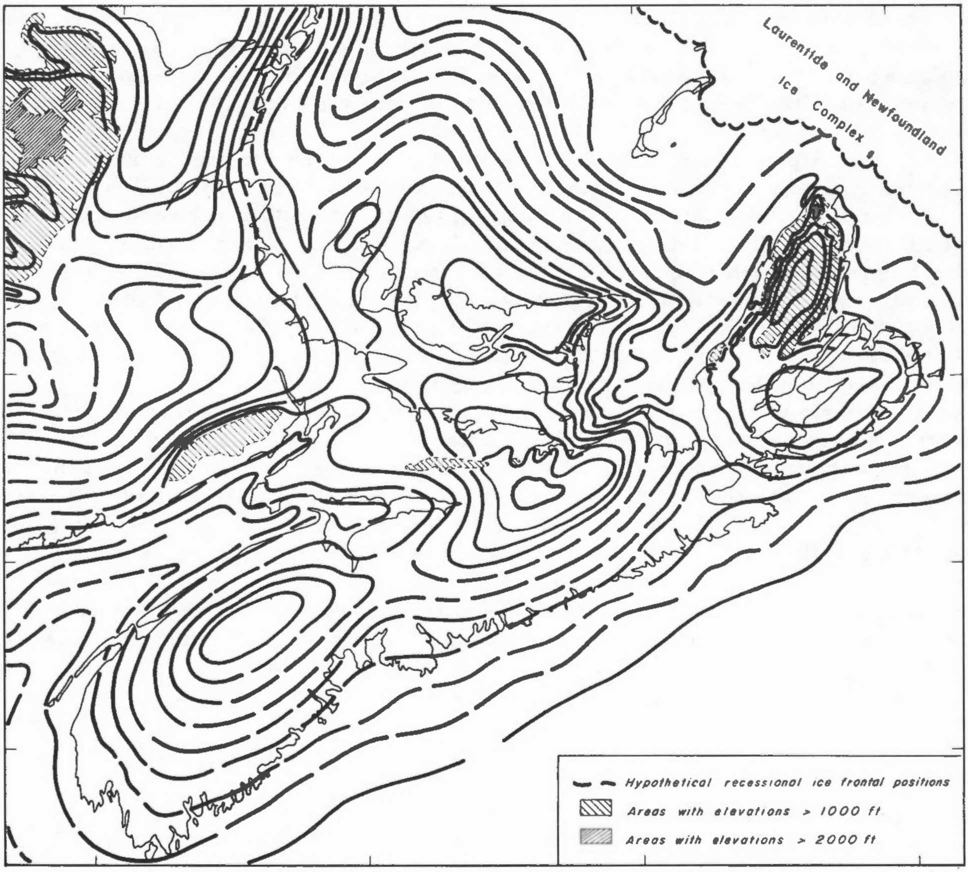

Figure 4. Hypothetical ice-marginal positions during recession of Wisconsin ice.

continental shelf, and there is but scant evidence of Labradorean sector ice south of Laurentian Channel in the Gulf of St. Lawrence. Great as this channel is - some 60 miles wide by 1,500 feet deep - it could not have accommodated the full Labradorean ice flood necessary to glaciate the entire Maritimes. Rather, it is felt that Laurentide ice sheet was not as active in the Maritimes as it was in the south and southwest, toward the continental interior. Instead, the locally nourished Appalachian complex dominated the Maritimes.

During glacier recession there was undoubtedly much local ice activity in the Maritimes. The pattern of glacial lineations, the location of end moraines, and the distribution of erratics is clearly indicative of changing ice-flow directions in response to topography, climatic change, and sea-level rise. A hypothetical configuration of the receding Wisconsin ice is shown in Figure 4. The implied synchroneity between areas of late or local radial flow is highly speculative but the actual areas are considered valid in terms of the data presented above.

About 14,000 years ago, as Wisconsin ice waned and the sea encroached into Gulf of St. Lawrence, floating ice fringed the shores of the Magdalen Islands on the east and south, and marine sand and gravel together with thin layers of till were deposited along the coasts up to an elevation of about 120 feet. The sea invaded the southwestern part of Newfoundland about 13,600 ± 180 years ago (GSC-968), the northwestern part of Prince Edward Island prior to 12,410 years B.P. (GSC-101) and had encroached some 250 miles up St. Lawrence River by 12,720 ± 170 years B.P. (GSC-102). Also, it had flooded into Bay of Fundy before 13,200 years B.P. (GSC-956). In all cases there is evidence of glacier ice near at hand and the rapid rise of sea level had caught the active Maritime glaciers in an unstable position. Active glacier ice remained over Prince Edward Island and on the floor of the Gulf of St. Lawrence to the north of its shores. As the sea penetrated up deep 'leads' into Northumberland Strait both east and west of the Island, ice flowed towards the 'leads' in response to active calving. The last active ice on the Island flowed south and southwest through Malpeque Bay into Northumberland Strait. The remaining ice on the north side of the uplands stagnated, leaving a system of anastomosing eskers, kame terraces, ice-sloughed debris, and ablation moraine.

Earlier, ice was similarly trapped on Cape Breton Island and probably flowed outward from the highland in all directions. Lowland ice continued to flow toward the sea on the northeast but elsewhere reversed the direction of its former flow and moved south and east toward the sea. In both northern and southern Nova Scotia, ice was trapped on the uplands and, under the Maritime climatic regime, flowed actively seaward, in places reversing or nearly reversing the direction of its former flow. Complex ice lobations resulted over New Brunswick as confluent Laurentide and Appalachian ice receded. Both highland and lowland ice caps appear to have been active during the postglacial marine phase. Late ice was also very active over Gaspé, and, as marine transgression extended up St. Lawrence Valley, there was, over a lengthy period, active northward flow into that part of the sea.

REFERENCES

Alcock, F.J.
1941: The Magdalen Islands; *Trans. Can. Inst. Mining & Metallurgy*, vol. XLIV, pp. 623-649.

Bailey, L.W.
1898: Geology of southwest Nova Scotia; *Geol. Surv. Can.*, Ann. Rept., vol. IX, Pt. M, 1896.

Borns, H.W., Jr.
1965: Late glacial ice-wedge casts in northern Nova Scotia, Canada; *Science*, vol. 148, No. 3674, pp. 1223-1226.

Borns, H.W., and Swift, D.J.P.
1966: Surficial geology, north shore of Minas Basin, Nova Scotia; *in* Guidebook-Geology of parts of Atlantic Provinces, Ed. W.H. Poole; *Geol. Assoc. Can.*

Chalmers, R.
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., vol. VII, Pt. M, 1894.

Coleman, A.P.
1920: The glacial history of Prince Edward Island and the Magdalen Islands; *Trans. Roy. Soc. Can.*, Ser. 3, vol. 13, pp. 33-38.

Dawson, Sir J.Wm.
1855: Acadian Geology, Macmillan and Co., London, pp. 50-51.

Fletcher, H.
1893: Geological surveys and explorations in the counties of Pictou and Colchester, Nova Scotia; *Geol. Surv. Can.*, Ann. Rept. 1890-91, Pt. P, Surface Geology, pp. 144-147.

Frankel, L.
1966: Geology of southeastern Prince Edward Island, Part II; *Geol. Surv. Can.*, Bull. 145.

Goldthwait, J.W.
1924: Physiography of Nova Scotia; *Geol. Surv. Can.*, Mem. 140, 179 pp. and map.

Grant, D.R.
1963: Pebble lithology of the tills of southeast Nova Scotia, unpublished Masters thesis, Dalhousie University, Halifax.

Hickox, C.F., Jr.
1962: Pleistocene geology of the central Annapolis Valley, Nova Scotia; *Nova Scotia Dept. Mines*, Mem. 5.

Honeyman, Rev. D.
1890: Glacial geology of Cape Breton Island; *Proc. Nova Scotia Inst. Nat. Sci.*, vol. VII, Pt. 4, Art. 1, pp. 337-344.

Hughes, O.L.
1957: Surficial geology of Shubenacadie map-area, Nova Scotia; *Geol. Surv. Can.*, Paper 56-3.

King, L.H.
1969: Submarine end moraines and associated deposits on Scotian Shelf; *Bull. Geol. Soc. Am.*, vol. 80, pp. 83-96.

Lee, H.A.
1962: Surficial geology of Canterbury, Woodstock, Florenceville and Andover map-areas, York, Carleton and Victoria counties, New Brunswick; *Geol. Surv. Can.*, Paper 62-12.

Loring, D.H., and Nota, D.J.G.
1966: Sea-floor conditions around the Magdalen Islands in the southern Gulf of St. Lawrence; Jour. Fisheries Res. Bd., Canada, vol. 23, No. 8.

MacNeill, R.H., and Purdy, C.A.
1951: A local glacier in the Annapolis-Cornwallis Valley; (Abstr.) *Proc. Nova Scotia Inst. Sci.*, vol. XXIII, Pt. 1, p. 111.

Mott, R.J., and Prest, V.K.
1967: Stratigraphy and palynology of buried organic sediments from Cape Breton Island, Nova Scotia; *Can. J. Earth Sci.*, vol. 4, pp. 709-723.

Norman, G.W.H.
1935: Lake Ainslie map-area, Nova Scotia; *Geol. Surv. Can.*, Mem. 177, pp. 62-63.

Poole, H.S.
1904: Report on the Pictou coalfield, Nova Scotia; *Geol. Surv. Can.*, Ann. Rept., vol. XIV, 1901 (New Series).

Prest, V.K.
1957: Pleistocene geology and surficial deposits; *in* Geology and Economic Minerals of Canada, Ed. C.H. Stockwell; *Geol. Surv. Can.*, Econ. Geol. Series, No. 1, 4th Ed., chap. 7.

in press: Quaternary geology of Canada; *in* Geology and Economic Minerals of Canada, Ed. R.J.W. Douglas; *Geol. Surv. Can.*, Econ. Geol. Series, No. 1, 5th Ed., chap. 12.

Prest, W.H.
1889: Glacial succession in central Lunenburg; *Trans. Nova Scotia Inst. Sci.*, vol. 9, pp. 158-170.

Richardson, J.
1881: The Magdalen Islands; *Geol. Surv. Can.*, Ann. Rept. 1879-80, Pt. G.

Walker, T.L., and Parsons, A.L.
1923: The North Mountain basalt of Nova Scotia; Glaciation; *in* Contributions to Canadian Mineralogy, 1923; *Univ. Toronto Studies*, Geol. Series No. 16, pp. 5-8.