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NOTES ON GLACIAL GEOLOGY, NORTHEASTERN DISTRICT OF MACKENZIE

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Weston Blake Jr.

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By

Weston Blake, Jr.

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Illustration

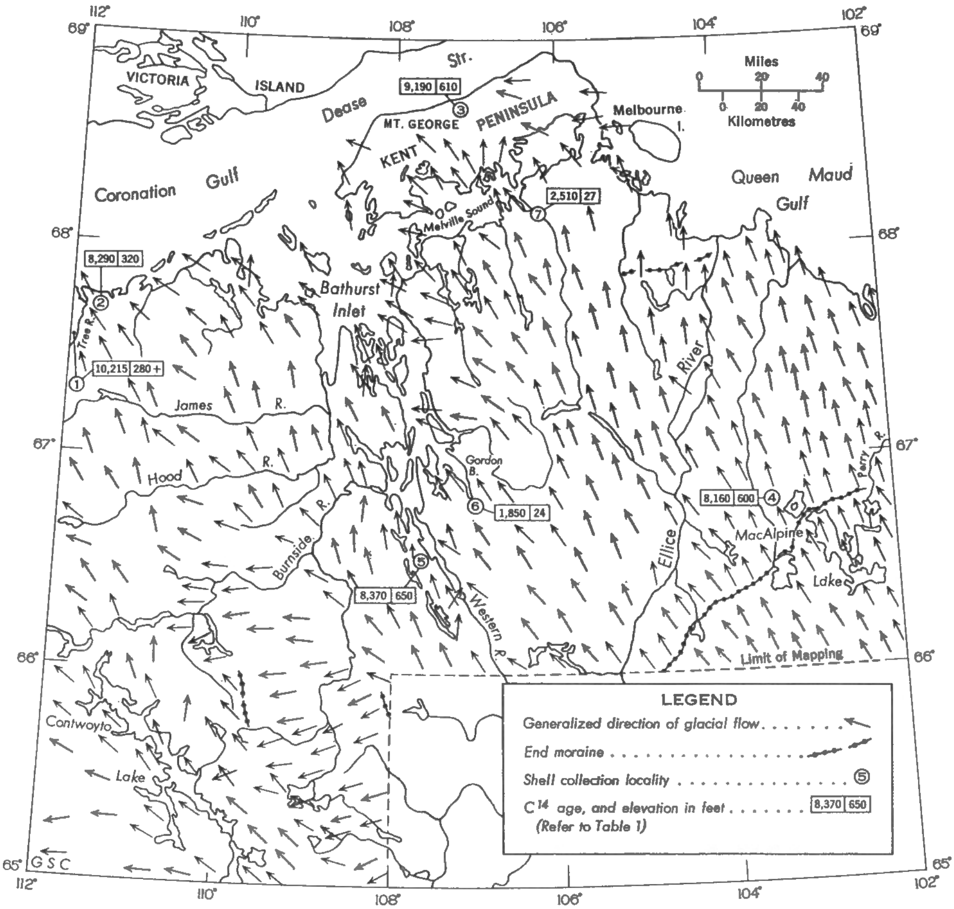

Figure 1. Directions of glacial flow, end moraines, and location of radiocarbon dated marine samples near Bathurst Inlet

NOTES ON GLACIAL GEOLOGY, NORTHEASTERN DISTRICT OF MACKENZIE

INTRODUCTION

The area described in this report extends southward from the Arctic coast of Canada and is centred about Bathurst Inlet. The map-area of approximately 55,000 square miles is bounded on the east and west by the 102nd and 112th meridians, respectively. In the western part of the area the southern boundary lies along the 65th parallel; east of the 108th meridian it lies along the 66th parallel.

The data upon which this report is based, in addition to airphoto interpretation, were collected between June 5th and August 17th, 1962, during the course of 'Operation Bathurst'. Observations throughout the area were made by the bedrock geologists on helicopter traverses. More detailed studies of selected sites were made by the writer on ground traverses, often with the assistance of R.N. McNeely.

Previous observations on the glacial and postglacial history of parts of the area have been made by O'Neill (1924, pp. 29, 33-35), Washburn (1947, pp. 49, 110-113, 117-118), and Bird (1954, p. 462; 1955a, pp. 8-13; 1955b, pp. 7-12; 1959, p. 162; and 1961, with M.B. Bird, pp. 18-32). The glacial geology of adjacent areas has been described in Geological Survey reports as follows: east (Craig, 1961); south (Fyles, 1955; Craig, 1957, and in press); west (Craig, 1960); and north (Fyles, in press). South of Contwoyto Lake some glacial observations are included on maps by Folinsbee (1949) and Lord and Barnes (1954). Finally, the map-area is within the region discussed by Craig and Fyles in their "Pleistocene Geology of Arctic Canada" (1960).

PHYSIOGRAPHY

With the exception of Melbourne Island and parts of Kent Peninsula, the entire map-area is underlain by Precambrian rocks; of these gneisses and granites occupy the largest areas (_see_ Fraser, in press).

The land surface in the map-area is a plateau of low relief that slopes gently to the north and northeast. The even surface is broken by steep-walled valleys near Bathurst Inlet, but over large areas drainage follows ill-defined 'lows' in the plateau. Some of the river valleys are in part structurally controlled, as is Bathurst Inlet itself, a major indentation along the Arctic coast. The inlet extends

140 miles inland, and its continuation, the 'trench' in which the Western River flows, continues beyond the southern edge of the map-area. For a detailed description of the physiography of part of the map-area the reader is referred to Bird and Bird (1961, pp. 34-42).

The highest elevation near Contwoyto Lake is slightly over 2,000 feet, but most of the lakes on the plateau surface west and southwest of Bathurst Inlet are between 1,100 and 1,700 feet above sea-level[1]. East of the inner part of the inlet a few lakes are over 1,000 feet in elevation, but farther east around MacAlpine Lake most lakes are between 500 and 700 feet above sea-level. In only a few places, notably near Bathurst Inlet, does the relief exceed a few hundred feet, and over large areas it is less than 200 feet.

Bedrock is exposed over much of the map-area, and felsenmeer is widespread, although landforms related to glaciation are abundant also.

GLACIAL GEOLOGY

The entire map-area was glaciated during Wisconsin time, and all the glacial features, which are abundant and well developed throughout this part of the 'barren lands', are related to the last glaciation. Evidence for glaciation includes many erratics, but continuous deposits of ground moraine are rare. A significant thickness of till was observed in only one valley, that of the Burnside River, a few miles west of Bathurst Inlet.

Drumlins are by far the most common sort of depositional landform, and the general category of drumlins includes a wide variety of streamlined drift forms. Minor moraine ridges are present in a few areas, as are zones of hummocky moraine. A few major end moraines are present, and their locations are given in Figure 1. Eskers are plentiful throughout the map-area; some of them are continuous for several tens of miles. Kames and deltas are associated with the eskers in many places. Large areas are covered by outwash, particularly near MacAlpine Lake and in river valleys.

An abundance of drainage channels and abandoned gorges attests to the erosive activity of meltwater during ice recession, and in some areas lakes were impounded by the retreating ice. The largest lake formed in the Contwoyto Lake basin, where abandoned shorelines are well developed about 100 feet above the present lake level of 1,460 feet.

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[1] At the time of writing most of the available elevations, obtained by radar-altimetry, are for the lakes.

Immediately upon deglaciation large areas were inundated by the sea. As a result of the uplift of the land, which has occurred since then, raised beaches are common along the shores of Bathurst Inlet and the Arctic coast, as well as on the flanks of eskers farther inland. In terrain with less relief extensive deposits of silt containing marine shells indicate the former presence of the sea. The silts mantle everything except the tops of bedrock hills and eskers in much of the area south of Queen Maud Gulf.

Glacial Features and Their Significance

Drumlins and striae indicate the trends of glacial flow, whereas accompanying crag-and-tail hills and minor gouges and fractures in bedrock indicate that the last movement was dominantly toward the north and northwest. However, glacial flow may have been in a similar direction throughout much of the time that the area was ice-covered. The general pattern of flow is shown in Figure 1. East-west oriented striae on the east side of Bathurst Inlet may indicate the presence of a 'calving bay' (see Hoppe, 1948, pp. 37-41) during ice recession, or they may reflect merely the channeling of ice toward the topographic depression of Bathurst Inlet, where the rate of glacier flow would tend to be faster. The lack of end moraines makes it impossible to determine which striae formed synchronously.

Lobation of the receding ice is indicated on Kent Peninsula. A swarm of drumlins and crag-and-tail hills in the central southern part indicates ice moving northward with peripheral motion toward both the northeast and northwest. The glacial features at the eastern end of the peninsula, however, indicate that the last ice flow there was to the west, or even slightly toward the southwest (see Washburn, 1947, Plate 3).

The discontinuity in the flow pattern northeast of Contwoyto Lake is a result of the difference in activity between ice on the plateau and ice flowing into the Bathurst 'trench'. This discontinuity has been discussed recently by Craig and Fyles (1960, p. 7), and its existence to the southeast was indicated earlier by Wilson (1939, p. 122 and Fig. 2), Fyles (1955), and Craig (1957, and in press). As Figure 1 shows, the striae, drumlins, and associated features on both sides of Contwoyto Lake indicate that the last ice movement was toward the northwest, whereas similar features to the east and northeast indicate flow toward the southwest. Although the details of the sequence of events and the manner in which the ice receded have not been worked out fully, it is evident that the ice flowing into the Bathurst 'trench' was more active. The drumlins on the southwest side of the discontinuity are probably older than the adjacent drumlins on the northeast side, although stagnant ice may have persisted in the area southwest of the discontinuity while the drumlins on the northeast side were being formed; withdrawal of the ice and readvance from the northeast do not appear to be necessary to explain the existing features.

The discontinuity in the flow pattern can be distinguished north of Contwoyto Lake also, although it gradually becomes less distinct northward and is not apparent at the coast.

End moraines are among the most impressive features in the map-area. They formed during pauses, or perhaps slight readvances, in the general course of ice recession. They have not been mapped previously, and as Craig and Fyles (1960, p. 7) have pointed out, large end moraines are, in general, absent in the central zone of the area covered by ice in Wisconsin time. The two north-south oriented segments of end moraine east of Contwoyto Lake are related to the more active ice mentioned above. The western of these two moraines lies close to, or along, the discontinuity in the flow pattern, and it represents, apparently, the terminal position reached by part of the ice moving toward the southwest. This moraine is by far the most prominent topographical feature in the area, and the 'peaks' along its crest are used by local pilots for navigation. Locally the ridge rises nearly 400 feet above the surrounding countryside. The eastern moraine, lying along the 108th meridian, is a recessional moraine left by the same ice lobe.

A few short segments of end moraine occur on the mainland southeast of Kent Peninsula, but by far the best developed end moraine lies north and west of MacAlpine Lake. This end moraine extends almost continuously across the southeast corner of the map-area; it continues with several interruptions to the northeast, where it has been mapped by Craig (1961, p. 2 and map), and to the south-west. Including breaks it is over 200 miles long. In some places the moraine is a sharp ridge only a few tens of feet in width, in other localities it is a broad zone up to 4 miles wide. It rises 10 to 250 feet above the adjacent terrain, and its crested ridge is the dominant feature in an otherwise gently rolling landscape of low relief. There is no evidence that the moraine is locally rock-cored, as has been suggested by Hanson, Queneau, and Scott (1956, p. 16).

A number of eskers lead up to the end moraine from the southeast; most of them end in deltas and sandurs, which have been built out from the distal (north) side of the moraine. Near MacAlpine Lake beaches are preserved on a number of the deltas and at a few places along the north side of the moraine itself, which is perhaps the reason why the end moraine is mistakenly indicated as a 'prominent marine shoreline' on the "Glacial Map of Canada" (Geol. Assoc. Canada, 1958).

Marine Submergence

Beach ridges, and other features indicating former shorelines, such as wave-cut cliffs and benches, occur throughout much of the map-area. Beaches are best preserved in relatively coarse material, such as that constituting eskers, deltas, and the steeper rocky slopes around Bathurst Inlet, whereas cut features are well preserved on drumlins. Together with extensive deposits of silt and clay containing marine shells, these features indicate that upon deglaciation large areas were covered by the sea. In a few places, notably on the east side of Bathurst Inlet and east of the mouth of Tree River, it was possible to map the marine limit accurately by changes in the nature of the drift cover. In both localities a level exists above which erratics are extremely common and many of the boulders are perched, in contrast to lower elevations where erratics are rare and perched boulders are absent. Bird (1954, p. 459; 1955b, pp. 8-9), Sim (1960, pp. 183-185; 1961, pp. 241-242), and Craig (1961, p. 3) have described this phenomenon for other areas in northern Canada.

Craig (1960, p. 6) has stated that the marine limit on the west side of the mouth of Tree River is about 700 feet above sea-level, and the writer's observations at two localities on the east side confirm this. Because the land south of Coronation Gulf is relatively high, only a narrow coastal zone a few miles wide was inundated by the sea. The same can be said in general for the west shore of Bathurst Inlet, but on the east side inundation was much more extensive. As Bird (1955b, pp. 8-12) and Bird and Bird (1961, pp. 26-30) have pointed out, in Bathurst Inlet itself there is evidence of marine action at approximately 700 to 750 feet above sea-level in several localities.

Eastward from Bathurst Inlet a zone extending at least 70 miles south from the coast was inundated, and locally the sea reached even farther inland. Near MacAlpine Lake the marine limit is slightly lower than farther west, being close to 650 feet.

Muddy lakes and beaded streams are two other features that are characteristic of the area once covered by the sea south and southwest of Queen Maud Gulf. These phenomena are mentioned here because their distribution in similar situations elsewhere may be helpful in determining the marine limit. Where the gentle regional slope of the land is toward the sea, and where the ice retreated up this slope, thus making it most unlikely that glacial lakes of any size could develop, it seems safe to assume that an abundance of silt-filled lakes indicates a former marine environment. These lakes may appear milky in colour or various shades of brown, red, yellow, or green when viewed from the air.

Beaded streams, the name given to streams containing strings of pools or ponds, also apparently develop in areas of fine-grained sediments, and they are often associated with denser vegetation and peat deposits. Beaded streams are a thaw phenomenon in the permafrost. In the map-area, with a few minor exceptions, they are restricted to the zone of marine silts.

CHRONOLOGY

A number of radiocarbon dates are available from the map-area, and the results are summarized in Table I. The main objectives of the dating program have been to determine:

1) the age of the highest beaches, and thus indirectly when the various parts of the map-area became ice-free;

2) the age of the end moraine near MacAlpine Lake;

3) the rate at which uplift of the land relative to the sea has progressed, and in particular what uplift, if any, has occurred recently.

As Table I indicates, all C^{14} determinations except one were made on marine shells.

The shells that are 10,215 ± 220 years old from the Tree River valley (Locality 1) were collected from marine clay 280 feet above sea-level in an area where the limit of marine submergence is close to 700 feet. Craig (1960, p. 6) has noted that the date does indicate that this section of the present coast was ice-free 10,000 years ago. Because shells from the same area (Locality 2) at 320 feet are 8,290 ± 330 years old, the older shells must date beaches that are between 320 and 700 feet above sea-level. Furthermore, although some differential tilt probably has occurred, shells at an elevation of 495 feet about 35 miles west of the Tree River valley are 9,100 ± 180 years old (Craig, 1960, p. 6). Thus it does not seem unreasonable to assume that the 10,200-year old shells give an approximate value for the age of the highest beaches near the mouth of Tree River.

The shells on top of Mt. George, the highest point (elev. 610 feet) on Kent Peninsula (Locality 3), are the remains of pelecypods that can live in varying water depths. Hence they do not necessarily date the beaches at that level, but they do indicate that Kent Peninsula was ice-free about 9,200 years ago. If higher beaches were present, they would probably not be much more than 700 feet above sea-level, so the shells are assumed to be within 100 feet of the marine limit.

Table I

List of Radiocarbon Dates

Locality No. (Fig. 1)	Dating No.	Approx. Elev. of sample (ft. a.s.l.)	Dated Material[1]	Age (years B.P.)
1	I(GSC)-17[2]	280	*Macoma calcarea* (Gmelin)	10,215 ± 220
2	I(GSC)-13[3]	320	*Hiatella arctica* (L.) and *Mya truncata* L.	8,290 ± 330
3	GSC-125	610	*Mya truncata* L.	9,190 ± 210
4	GSC-110	600	*Hiatella arctica* (L.)	8,160 ± 140
5	GSC-115	650-670	*Hiatella arctica* (L.), *Mya* sp., and *Macoma balthica* (L.)	8,370 ± 100
6	GSC-137	24	*Mytilus edulis* L.	1,850 ± 140
6	GSC-138	19	Leaves and twigs of birch, alder, and willow.	2,170 ± 140

[1]Shells identified by Frances J. E. Wagner, Geological Survey of Canada, except for I(GSC)-13 (see W.H. Dall, *in* O'Neill, 1924, p. 31).

[2]Collected by Craig in 1959, reported by Craig (1960, p. 6) and Craig and Fyles (1960, p. 12).

[3]Collected by O'Neill (1924, p. 33, Sta. No. 5289) in 1915, reported by Craig (1960, p. 6) and Craig and Fyles (1960, p. 12).

Shells 8,160 ± 140 years old at an elevation of 600 feet near MacAlpine Lake (Locality 4) are within about 50 feet of the marine limit. They were collected in marine silts, but at the time the animals were living the higher beaches on the nearby eskers and along the deltas in the end moraine must have been forming. Yet at the time the outwash in the deltas was being deposited the ice must have been at the moraine, for three reasons: 1) the steep sides of the raised deltas, which are locally mesa-like, indicate that they were formed between ice walls; 2) the absence of river channels upstream (south) from the deltas, but instead a series of eskers (topographically lower) leading up to the deltas, also indicates the presence of ice; and 3) the lack of well developed beaches along much of the front of the moraine suggests that till was actively being deposited by the ice. Thus, although the size of the moraine indicates that it was forming over a considerable length of time, it can at least be stated that the ice was at the moraine 8,200 years ago.

Because the shells on Mt. George and near MacAlpine Lake bear approximately the same relation to the assumed marine limits, it follows that the ice took something of the order of 1,000 years to recede about 175 miles. It is possible that recession took place more rapidly, for as noted above the ice stood for a considerable length of time at the position now occupied by the end moraine at the north end of MacAlpine Lake.

Another collection of shells was made in a zone 650 to 670 feet above sea-level on the west side of Bathurst Inlet (Locality 5). These were the highest shells found in the map-area, and they were close to the southernmost of the high shell localities reported by Bird (1955b, p. 11) and Bird and Bird (1961, p. 25). Here, too, the shells were in silts, not shoreline deposits, but they are believed to give an approximate age for the highest beaches, which are between 700 and 750 feet above sea-level in Bathurst Inlet. The difference in age between these shells and those near MacAlpine Lake is not great enough, when the possible errors inherent in the dating are considered, to permit any conclusions to be drawn as to the relative time of deglaciation of the two areas.

Finally, two age determinations have been made on material collected close to sea-level in an attempt to trace the recent fluctuations of the shoreline. At the head of Gordon Bay (Locality 6), on the east side of Bathurst Inlet, a 31-foot section of sediments is exposed. Clayey silts occur at sea-level, but the sediments become progressively coarser upward, and nearly flat-lying deltaic beds of sand and gravel are present at the top of the water-laid deposits, 29 feet above sea-level. Overlying the gravel is 2 feet of peat. Marine shells occur from sea-level to the 24-foot level in the section. The shells at 24 feet, 5 feet below the surface of the deltaic beds, are *Mytilus edulis*, a shallow-water pelecypod, associated with fragile shells of *Macoma balthica* in living position. *Mytilus edulis* and *Macoma balthica* do not occur at lower levels in the more silty parts of the section. Thus, both the change in fauna and the increasing coarseness of the sediments upward in the section suggest the imminent approach of the shoreline, and the 2 feet of peat at the top must have accumulated after the marine deposits had emerged from the sea. As there is no evidence of channeling or other erosion of the surface, the pelecypods are believed to have lived when the sea was at, or close to, the level now represented by the sediments 29 feet above sea-level.

The Mytilus shells are 1,850 ± 140 years old. Twigs and leaves of willow, birch, and alder interbedded with silt and sand 5 feet lower in the section (19 feet above sea-level) are 2,170 ± 140 years old. No conclusions as to the rate of uplift can be drawn from the difference in age of these two samples 5 feet apart, but it does seem reasonable to assume that the uppermost sediments were being deposited approximately 2,000 years ago. If, in addition, a constant sea-level is assumed, uplift of the land has averaged 1.5 feet per century for this 2,000-year period. Since the rate of uplift presumably is decreasing, it is probably less than 1.5 feet per century at the present time.

POSTSCRIPT

After the manuscript of this paper was completed three additional radiocarbon age determinations became available. The samples were collected from deltaic beds in an unnamed bay on the south side of Melville Sount (Locality 7 in Figure 1). The section there is similar to that described above from Gordon Bay. At sea-level silt predominates, but the beds become progressively more sandy toward the top of the 31-foot section. The uppermost sand beds are about 29 feet above sea-level, and are overlain by 2 to 3 feet of peat. Whole shells and fragments of Macoma balthica, Macoma calcarea, and Mya truncata 1 foot to 3 feet below the uppermost sand layers and 26 to 28 feet above sea-level are 2,510 ± 180 years old (GSC-158). As at Gordon Bay some of the fragile Macoma shells are in living position. A black-coloured organic layer composed of moss fragments, twigs, and leaves about 5 feet below the uppermost sand (2 to 4 feet below the shells and 24 feet above sea-level) is 3,070 ± 140 years old (GSC-152).

The dates are of interest in regard to both the development of patterned ground and the recent rate of land uplift. The organic layer and the overlying sand beds have been deformed in one place by the growth of an ice-wedge, which has formed since the delta emerged from the sea. This ice-wedge, and others at similar elevations in the same area, have formed sometime within the last 2,500 years. Yet the peat mantling the surface of the delta and covering the ice-wedge is undisturbed, indicating that the ice-wedge has undergone no significant additional growth since the peat started to accumulate approximately 470 years ago (GSC-172, preliminary date on basal peat 3 feet below the surface and overlying the ice-wedge).

Both here and at Gordon Bay nearly 100 miles to the south-southwest the uppermost sand beds are about 29 feet above sea-level, and the dated samples are above the 19-foot level. Nonetheless the samples near Melville Sound are 700 to 800 years older than those at Gordon Bay. Possible explanations for the age difference between the two localities are: 1) the pelecypods near Melville Sound lived in deeper water, although there is nothing in the nature of the sediments to indicate this; 2) the shells and/or organic layer may include older material washed in from higher levels, but the fact that some individuals of Macoma are in living position and one Mya still has its siphon attached makes the shells less suspect in this regard; and 3) uplift during the last 3,100 years has been slightly slower at Melville Sound than at Gordon Bay.

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