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Holocene Emergence of the South and East Coasts of Melville Island, Queen Elizabeth Islands, Northwest Territories, Canada

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ABSTRACT. Twenty-five radiocarbon dates from the coast of Melville Island show that there has been up to 100 m of Holocene emergence. This evidence of post-glacial rebound suggests there was significant late-Wisconsin glacier cover on or near the island. The Winter Harbour moraine on the south coast is thought to mark the maximum northward advance of the Laurentide Ice. However, emergence for this area appears to be essentially complete, whereas the northeast coast is still recovering at a rate of approximately 0.35 cm/yr. Ice cover in the region to the northeast must, therefore, have been thicker and/or lasted longer than in the peripheral areas of the Laurentide Ice, lending support to the concept of an Innuitian Ice Sheet, rather than local ice masses over the central Queen Elizabeth Islands. Unfortunately, there is an absence of fresh glacial landforms and stratigraphy that can be attributed to the Innuitian Ice Sheet. We suggest that this ice sheet may have had a thermal regime below the pressure melting point, thus depriving the ice of much of its erosive and depositional capabilities, but with a sufficient mass to account for the observed pattern of emergence.

RÉSUMÉ. Vingt-cinq datations au carbone 14 effectuées sur la côte de l'île Melville indiquent qu'une émergence de plus de 100 mètres s'est produite au Quaternaire récent. Cette preuve de détente post-glaciaire suggère la présence d'une couverture glaciaire importante datant de la fin du Wisconsin sur l'île même ou à proximité de celle-ci. La moraine de Winter Harbour sur la côte sud signale, croit-on, le point d'avance maximale vers le nord de la couverture de glace Laurentide. Toutefois, l'émergence dans cette zone semble être essentiellement complète, tandis que la côte nord se remet toujours à un rythme d'environ 0,35 cm par année. La couverture de glace dans la région, vers le nord-est, doit avoir été, en conséquence, plus épaisse et/ou plus durable que dans les zones périphériques de la couverture Laurentide ce qui appuie l'hypothèse d'une couverture de glace Innuitienne, plutôt que le concept de masses locales de glace recourvrant les îles centrales Reine-Elisabeth. Malheureusement, on doit noter l'absence de formes de terrain et de stratigraphie glaciaires récentes qui pourraient être attribuées à la couverture de glace Innuitienne. Nous suggérons que cette couverture de glace pourrait avoir eu un régime thermique inférieur au point de fusion par pression, privant ainsi la glace de son pouvoir d'érosion et de déposition, tout en lui conservant une masse suffisante pour rendre compte du mode observé d'émergence.

INTRODUCTION

Through the efforts of the International Geological Correlation Programme (IGCP) an Atlas of Sea Level Curves has been compiled to provide "the raw material for subsequent analyses by geophysicists, oceanographers, climatologists, archaeologists and many other scientists and engineers"

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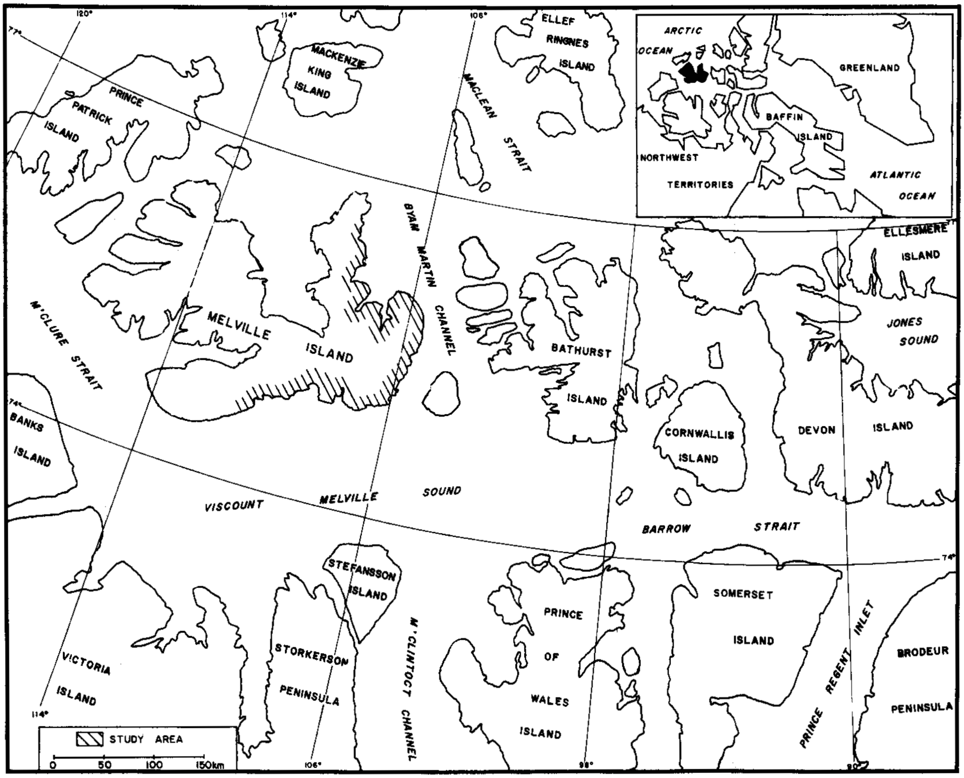

FIG. 1. Queen Elizabeth Islands and location of study area.

(Bloom, 1977, p. 3). As part of this program Blake (1976) has summarized the sources of radiocarbon age determinations and the general pattern of emergence for the Queen Elizabeth Islands (Fig. 1). Curves showing the relation between time and elevation have been constructed for a number of localities and recent studies on Melville Island supply raw information from an area of substantial emergence and enhances the work of an earlier study by Henoch (1964). This paper presents data used to derive emergence curves for the east and south coasts of Melville Island and discusses implications as they relate to the pattern of deglaciation in the Queen Elizabeth Islands.

HOLOCENE EMERGENCE

Marine shells and, less commonly, peat, organic detritus and driftwood have been collected to obtain radiocarbon dates on Melville Island. Olsson and Blake (1962) discuss numerous geological and analytical problems associated with radiocarbon dating of emerged beaches. The greatest difficulty is in relating sea level to the time of death of the organism. In the case of marine shells, the most common species is *Hiatella arctica* which can live from the intertidal zone to depths of over 100 m (Olsson and Blake, 1962).

Therefore, it is probable that a marine limit derived from shells embedded in a raised beach deposit is somewhat higher than the elevation of the beach in which they were found. The same is true for driftwood since time must be allowed for the wood to float ashore, during which sea level may be lowering with respect to land.

Twenty-five post-glacial radiocarbon dates have been documented from Melville Island (Table 1). From these, three tentative emergence curves have been constructed (Figs. 2, 3 and 4). An early curve (Fig. 2) produced by Henoch (1964) is based on 6 dates (1-6, Table 1) which was a first attempt to assess the general emergence for the island as a whole. Two dates (5 and 6, Fig. 2 and Table 1) from archaeological sites at McCormick Inlet (Fig. 5) caused Henoch to believe that emergence during the last 2,000 years has been negligible. This may well be true for this location which is 120 km north of the Winter Harbour moraine (Fig. 5), the supposed site of maximum late Wisconsin Laurentide ice advance (Fyles, 1967) and 171 km east of Towson

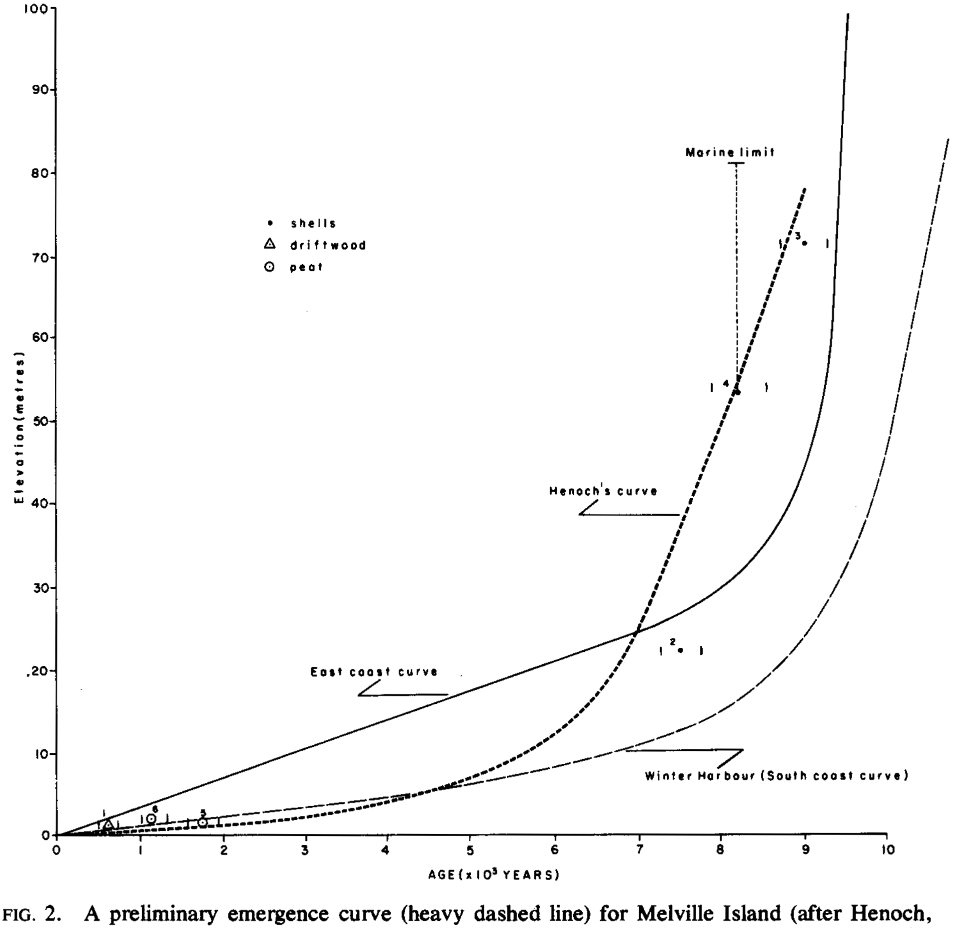

FIG. 2. A preliminary emergence curve (heavy dashed line) for Melville Island (after Henoch, 1964) showing relevant radiocarbon dates and their errors (Table 1). The authors' curves for eastern and southern Melville Island are shown for comparison.

TABLE 1. Radiocarbon dates from post-glacial deposits, Melville Island

Location No. (see Figures 2,3,4,5)	Laboratory dating number	Elevation (m)	Age (years B.P.)	Site Information	Reference
1. Winter Harbour	I-842	1.6[1]	625±100[2]	Driftwood in raised beach	Henoch (1964) Trautman (1964)
2. Ross Point, S.E. coast Melville Island	I-841	22[1]	7,565±235	Mollusca (unidentified) from surface of sandy marine terrace	Henoch (1964) Trautman (1964)
3. West end of Weatherall Bay	I-730	71.5[1]	9,075±275	Marine shells *(Hiatella arctica)* Marine limit unknown	Henoch (1964) Trautman (1964)
4. West arm of Weatherall Bay	I(GSC)-21	53.5[1]	8,275±320	Marine shells (*Hiatella arctica*) collected from marine terrace	Henoch (1964)
5. McCormick Inlet Hecla and Griper Bay	I-840	1.8[1]	1,740±190	Peat under floor of Eskimo archaeological site	Henoch (1964) Trautman (1964)
6. McCormick Inlet Hecla and Griper Bay	GSC-148	1.8[1]	1,150±160	Charred peat from Eskimo archaeological site	Henoch (1964)
7. Cape Providence	GSC-664	?	11,310±150	Marine shells *(Hiatella arctica)* from highest shell bearing beds on inland (distal) side of Winter Harbour moraine	Lowdon and Blake (1968)
8. Winter Harbour	GSC-278	52[3]	10,340±150	Marine shells *(Hiatella arctica)* from beach on inland (distal) side of Winter Harbour moraine; no relation to marine limit	Fyles (1967)
9. Winter Harbour	GSC-786	79[3]	10,900±150	Marine shells *(Hiatella arctica)* from inland (distal) side of Winter Harbour moraine	Lowdon and Blake (1968)
10. Winter Harbour	GSC-339	19[3]	9,550±160	Marine shells *(Hiatella arctica)* from shelving slope on seaward (proximal) side of Winter Harbour moraine below highest beach which is at 30 m.	Fyles (1967)

TABLE 1. – (Cont'd.)

Location No. (see Figures 2,3,4,5)	Laboratory dating number	Elevation (m)	Age (years B.P.)	Site Information	Reference
11. Winter Harbour	GSC-665	21[3]	9,620±150	Marine shells *(Hiatella arctica)* from delta deposit on seaward (proximal) side of Winter Harbour moraine within 9 m of marine limit	Lowdon and Blake (1968)
12. Winter Harbour	GSC-2060	27[4]	8,980±400	Algal deposit in raised beach on seaward (proximal) side of Winter Harbour moraine	Collected by M. Kuc, 1971 (unpublished)
13. Nelson Griffith Point, S.E. coast Melville Island	GSC-2089	14.6[1]	5,400±410	Organic debris from exposed uplifted delta section. Below marine limit by undetermined amount	McLaren (1977)
14. Consett Head, E. coast Melville Island	GSC-2092	13[1]	5,940±150	Organic debris *(Salix)* sp. from exposed section of uplifted delta foreset beds. Below marine limit by undetermined amount	McLaren (1977)
15. Consett Head, E. coast Melville Island	GSC-2114	6[1]	6,630±100	Organic detritus *(Salix)* sp. From same section as GSC-2092, 7 m below this sample	McLaren (1977)
16. E. coast Melville Island	GSC-1826	0.15[5]	70±80	Driftwood (*Picea* sp.)	Collected by D.M. Barnett 1973 (unpublished)
17. Towson Point, E. coast Melville Island	GSC-1981	98[5]	9,640±90	Marine shells *(Hiatella arctica)* from high level delta	Collected by D.M. Barnett 1973 (unpublished)
18. Domett Point E. coast Melville Island	GSC-1991	4[6]	770±60	Driftwood (*Picea* sp.) Partially buried, 80 m from shore	Collected by D.M. Barnett 1973 (unpublished)
19. Weatherall Bay, E. side of W. arm	GSC-1721	1.5[6]	830±130	Driftwood (*Larix* sp.) 7 m inland from present beach back slope	Collected by D.M. Barnett 1971 (unpublished)

TABLE 1. – (Cont'd.)

Location No. (see Figures 2,3,4,5)	Laboratory dating number	Elevation (m)	Age (years B.P.)	Site Information	Reference
20. Weatherall Bay, E. arm	GSC-1688	4[6]	2,090±140	Driftwood (*Picea* sp.)	Collected by C.N.D. Hotzel for D.M. Barnett 1971 (unpublished)
21. Sherard Bay	GSC-1652	16[5]	4,880±140	Driftwood (*Picea* sp.) Buried in raised beach	Collected by D.M. Barnett 1971 (unpublished)
22. Sherard Bay	GSC-1708	52[5]	9,040±160	Moss peat, from surface of deltaic sands	Barnett (1973)
23. Sherard Bay	GSC-1636	55[5]	9,750±690	Single valve of marine shell *(Hiatella arctica)*	Barnett (1973)
24. Sherard Bay	GSC-1752	55[7]	10,200±150	Marine shells *(Hiatella arctica)* close to marine limit	Barnett (1973)
25. Sherard Bay	GSC-1624	24[5]	7,890±140	Driftwood (*Picea* sp.) Partly buried in deltaic sands	Barnett (1973)

1: Elevation determined with a Zeiss N-2 automatic level from high tide mark.
2: The error estimate of Isotope Inc. dates (indicated by I) is only one standard deviation. All GSC dates are two standard deviations.
3: Elevation determined by levelling; rounded to nearest metre.
4: Determination of elevation unknown.
5: Elevation determined with altimeter.
6: Elevation determined with Abney level.
7: This elevation of 55 metres is corrected from 50 metres as shown in Barnett (1973). Elevation determined with altimeter.

Point, the area of maximum emergence on the east coast (Fig. 5). It probably is not true, however, for the whole island.

Apart from the lack of data between 2,000 and 7,000 years B.P., the chief problem with Henoch's curve lies in the uppermost portion based on date numbers 3 and 4 at 9,075 ± 275 and 8,275 ± 320 years and elevations of 11.5 and 53.5 m respectively (Fig. 2). Both these dates from the Weatherall Bay area (Fig. 5) are anomalous when compared with dates collected later from nearby Sherard Bay by Barnett (1973). Dates 22, 23 and 24 (Table 1, Fig. 3) shift the curve significantly back in time such that Henoch's dates (date numbers 3 and 4) appear to be too young by approximately 1,700 years. The new dates are considered to be more reliable for two reasons. First, careful assessment of possible contamination of samples was undertaken, and in

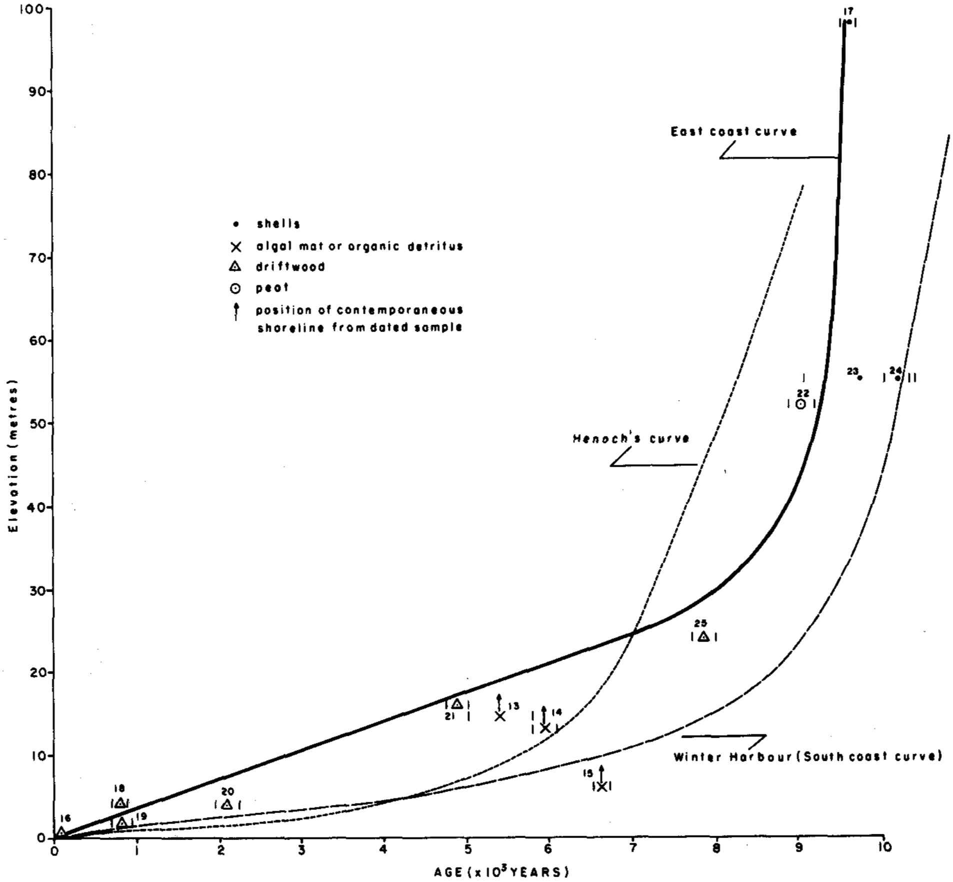

FIG. 3. A preliminary emergence curve (heavy solid line) for the east coast of Melville Island showing relevant radiocarbon dates and their errors (Table 1). The curve derived by Henoch (1964) and the authors' curve for southern Melville Island are shown for comparison.

sample #23 a single pelecypod valve was dated to determine if the larger sample (24) might contain shells of more than one age. Second, the new dates lie within a reasonably small elevation-time zone, yet they include both maximal (marine shells) and minimal (terrestrial peat) estimates for emergence. The upper part of the east coast curve (Fig. 3) is, therefore, considered to be more acceptable than Henoch's curve (Fig. 2).

A curve for the Winter Harbour area (Fig. 4) was constructed from samples collected mainly by J.G. Fyles (Fyles, 1967; Lowdon and Blake, 1968). The curve uses date 1 (Henoch, 1964) and dates 8 and 12 (Table 1, Figs. 4 and 5). Date number 7, although from the same area, is missing on the graph since the altitude is not know. These dates indicate that the inland (distal) side of the Winter Harbour moraine was ice free at least 11,310 years B.P. (number 7, Table 1), whereas the seaward (proximal) side was not ice free until 9,620 years B.P. (numbers 10 and 11, Table 1). There is too great a hiatus between

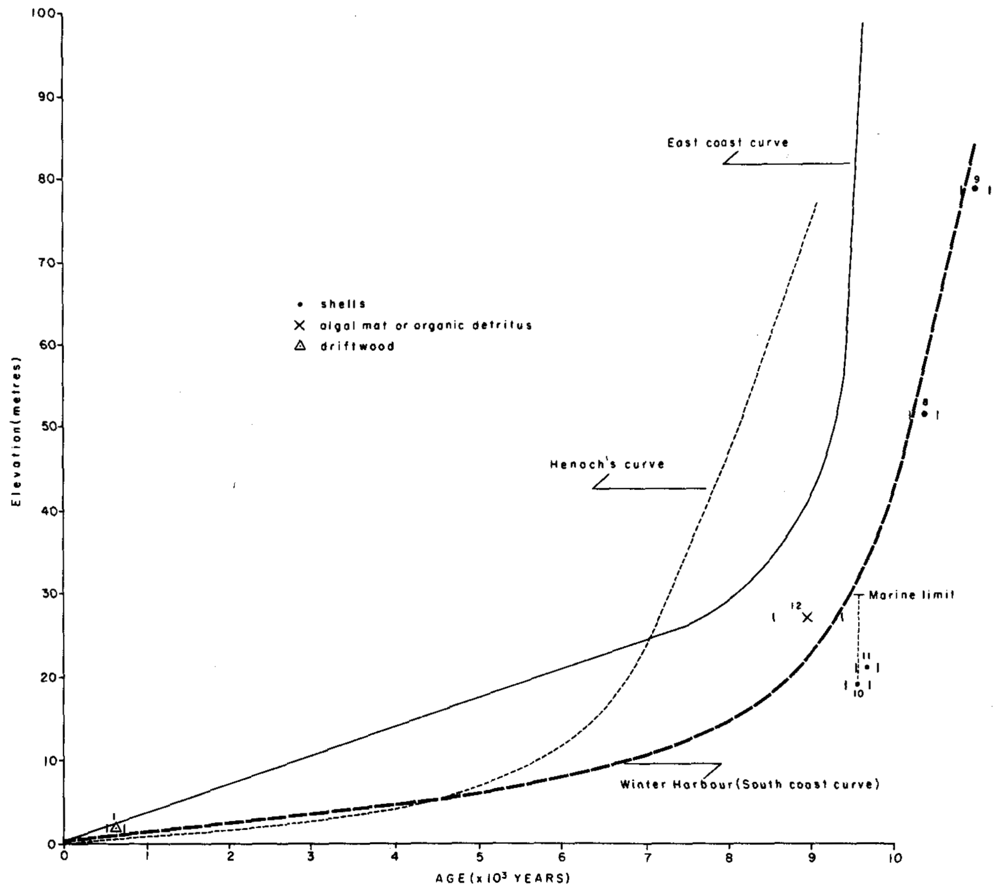

FIG. 4. A preliminary emergence curve (heavy dashed line) for the south coast of Melville Island showing relevant radiocarbon dates and their errors (Table 1). Henoch's curve and the east coast curve are shown for comparison.

number 12 (8,980 ± 400) and number 1 (625 ± 100) to speculate on the detailed shape of the curve in this area. It is quite possible to draw the curve much flatter for the first 3,000 years and Henoch (1964) may be correct in his supposition that there is little or no present emergence.

The third curve (Fig. 3) has used data derived from the northeast and east coasts of Melville Island (numbers 13 to 25, Fig. 3 and Table 1), the majority from the Sherard Bay and Weatherall Bay areas. The oldest date (number 24; 10,200 ± 150) collected by Barnett (1973) was close to the post-glacial marine limit. Submergence was apparently short-lived since peat collected from within 5 km and above deltaic sands at approximately the same elevation yielded an age of 9,040 ± 160 years (number 22). Date numbers 21 and 25 (Fig. 3) fill in the large gap of the other two curves at 4,880 ± 140 and 7,890 ± 140 years respectively. Combined with number 20 at 2,090 ± 140 years, they support a slope for the last 8,000 years of emergence that is steeper than either of the other two curves. It is possible to construct the curve with an even greater slope by passing the line above number 18 (Fig. 3). To do so poses difficulties in the construction of the curve beyond 8,000 years B.P. It is reasonable to suggest that the elevation of number 18 is anomalously high and may be the result of storm waves or, more likely, ice push. Date numbers 13, 14 and 15 (Fig. 3) have been taken from uplifted delta foreset beds and are, therefore, expected to be below the contemporaneous sea level.

GLACIAL HISTORY

Early Glaciation

Although the western and central Queen Elizabeth Islands are generally characterized by a lack of glacial landforms, several glacial events have been distinguished (Craig and Fyles, 1960). Tozer and Thorsteinsson (1964) summarize the evidence for a complete ice cover over Melville Island during Pleistocene time. Apart from the Table Hills, 11 km west of Winter Harbour (Fig. 5), where a thickness of 46 m of till was observed, the island supports an almost ubiquitous weathered drift containing erratics. The most common are red, white and brown quartzite, gabbro, red granite, gneiss and chert. The nearest known source for the quartzite is the Precambrian of Victoria Island (Tozer and Thorsteinsson, 1964) and the gneiss and granite were probably derived from the continental mainland. These erratics have been found at

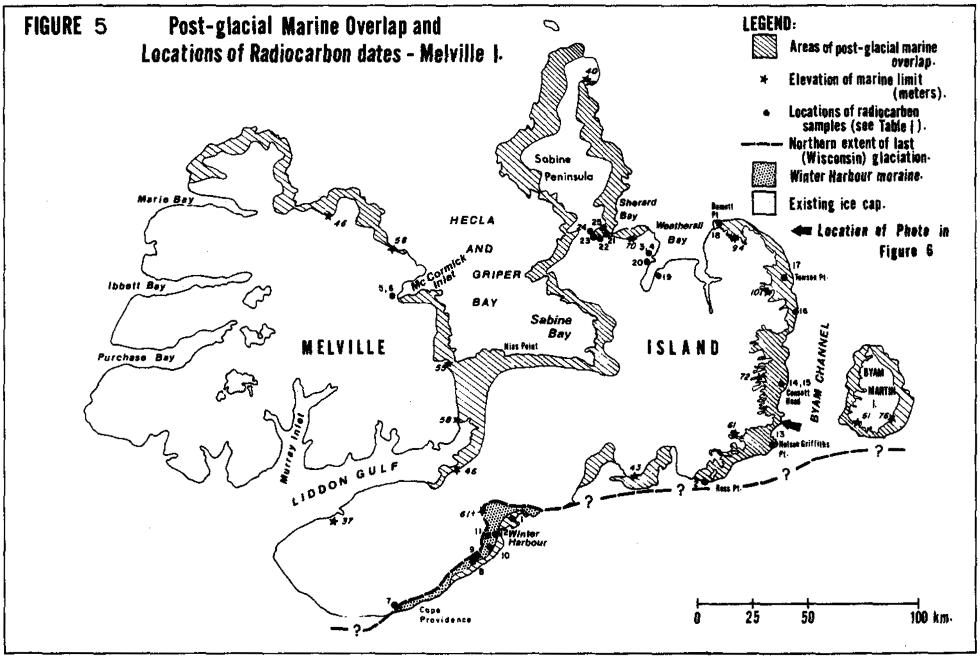

FIG. 5. Postglacial marine overlap and locations of radiocarbon dates, Melville Island.

summit elevations of 700 m and their distribution indicates glaciation of the entire island.

To the south of Melville on Victoria and Stefansson Islands, fresh glacial landforms are found that are quite unlike the old residual till deposits of Melville Island. The former are considered to be formed by Laurentide ice during late Wisconsin time (Craig and Fyles, 1960). It is concluded that the surficial drift of Melville Island must represent an earlier, Laurentide glaciation.

Late Wisconsin Glaciation

The northern extent of late Wisconsin Laurentide ice has been placed at the outer limits of fresh glacial landforms (Craig and Fyles, 1960). Features such as moulded rock surfaces, crag and tail hills, drumlinoid forms, esker complexes and moraines, many of which are shown on the Glacial Map of Canada (Prest *et al.*, 1967), are seen to radiate from the Precambrian Shield west of Hudson Bay northwards across Victoria and Prince of Wales Islands. The Winter Harbour moraine (Fig. 5), on the south coast of Melville Island marks a segment of the northwest margin of the late Wisconsin Laurentide ice sheet (Fyles, 1967), probably formed during its maximum stand. Older erosional remnants of Laurentide drift occur to the north.

In spite of the apparent absence of Laurentide ice cover over Melville Island, the spectacular evidence of marine transgression (Fig. 6), and Holocene emergence indicates the substantial influence of nearby ice. Marine limit elevations (Fig. 5) clearly increase from southwest to northeast across Melville Island (Glacial Map of Canada, Prest *et al.*, 1967). In the south, submergence occurred to depths of approximately 43 to 61 m whereas to the northeast, in the vicinity of Towson Point, the marine limit is placed at 101 m

FIG. 6. A raised beach sequence (location shown in Fig. 5) on the east coast of Melville Island illustrates the effects of Holocene marine transgression followed by emergence. GSC Photo 202953-y.

(Fig. 5). This increase in emergence towards the north and east precludes the supposition that a tongue of Laurentide ice protruded into Byam Channel from the south as suggested by J.G. Fyles in Tozer and Thorsteinsson (1964). However, there are at least two possibilities that can account for the observed emergence.

First, based largely on the pattern of emergence throughout the eastern and central Queen Elizabeth Islands, Blake (1970) has supplied convincing evidence of a high arctic ice cap which he named the Innuitian Ice Sheet. Areas that experienced maximum emergence and were, therefore, associated with the centre of this ice sheet follow a northeast-southwest trending axis that extends from central Ellesmere Island to eastern Bathurst Island. The amount of emergence decreases both to the northwest and southeast of the central axis (Blake, 1970). There is a possibility, therefore, that the Innuitian ice approached the northeastern coast of Melville Island. If this were the case, the greatest submergence occurring in the Towson Point area (Fig. 5) combined with decreasing elevations of the marine limit towards the south and north can be explained in terms of isostatic depression associated with the Innuitian ice sheet rather than that of the Laurentide ice.

The second possibility, and not necessarily mutually exclusive of the first, is that there were local ice caps originating on Melville Island in the area between Sabine Bay and Weatherwall Bay (Fig. 5). Fyles (1965) describes several glacial features that suggest local glaciers. These include an esker several miles long in northwest Melville Island between Ibbett Bay and Hecla and Griper Bay, and a group of subdued drumlinoid ridges on the northwestern tip of Sabine Peninsula. Although several small ice caps presently exist in western Melville Island (Fig. 5), these are thin and appear to be a relatively recent growth rather than the remains of a larger ice sheet (Tozer and Thorsteinsson, 1964).

DISCUSSION

The existence of a late-Wisconsin, Innuitian Ice Sheet over the central Queen Elizabeth Islands is a subject of some controversy. England (1976a, b) and (England and Bradley, 1978) have suggested that the pattern of emergence over the Queen Elizabeth Islands, as put forward by Blake (1970), is primarily the result of an enlarged Greenland Ice Sheet and the role of any discrete ice mass over the arctic archipelago is of lesser importance. Paterson (1977, p. 184-186) has reviewed the argument and declined an opinion, but pointed out that some assumptions on both sides may be invalid.

The emergence curve for the east coast of Melville suggests the presence of a substantial thickness of ice increasing to the northeast. Furthermore, the east coast curve (Fig. 3) clearly lies above the south coast curve (Fig. 4) and descends with a relatively steep slope to present sea level. The slope indicates that emergence may still be in progress at the rate of approximately 0.35 cm/year and that this rate is considerably greater than present emergence on the south coast which appears to be very slow or non-existent. The two curves show that at any one time during the Holocene, the east coast has more recovery still to go than the south coast, a fact that implies two possibilities. One, deglaciation occurred earlier in the south, a contention supported by dates on the north side of the Winter Harbour moraine; or two, the ice thickness was greater to the northeast and supplied a larger isostatic load than the marginal zone of the Laurentide Ice.

The former alternative contradicts Blake (1972, p. 77): "Numerous radiocarbon dates show that by 10,000 years ago the disintegration of the Innuitian Ice Sheet was well underway in the western part of the Queen Elizabeth Islands, although a lobe of the Laurentide Ice Sheet still impinged on the south coast of Melville Island at the time". Although the oldest date (number 9, 10,900 ± 150 years) is found on the Winter Harbour curve, this does not prove that deglaciation of the south coast occurred first since older dates may exist on the east coast. It seems probable that decay of the two ice sheets commenced at approximately the same time, but their rates of wastage may have been different. Paterson (1977) points out that uplift does not begin on deglaciation, rather it starts as soon as the ice begins to thin. Perhaps a greater percentage of the total uplift took place beneath the Laurentide Ice than beneath the Innuitian Ice before deglaciation occurred. On the basis of the apparent differential rates of emergence between the east and south coasts of Melville Island, it appears likely that the ice in the northeast was more than a "noncontiguous" cover termed the Franklin Ice Complex (England, 1976b). Rather our evidence suggests an ice sheet of substantial thickness, probably the Innuitian Ice Sheet.

Unfortunately, evidence in the form of glacial deposits and landforms clearly associated with such an ice mass of late Wisconsin age does not occur to support this conclusion. A possible answer to this contradiction may be that the thermal regime of the ice was below the pressure melting point. This would deprive the ice mass of much of its erosive and depositional capabilities but of course retain the mass necessary to account for the isostatic depression and subsequent emergence.

Cold based ice must, however, be melted with at least, the subsequent formation of glacial drainage channels. Although not abundant on Melville Island, they are present and they have also been reported from Bathurst Island (Blake, 1964) and observed in subsequent work on Cornwallis Island. However, they cannot be reliably assigned to any one particular glacial episode. Clearly there is a need for further field study and hypothesis testing.

ACKNOWLEDGEMENTS

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