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Raised Marine Features, Radiocarbon Dates, and Sea Level Changes, Eastern Melville Peninsula, Arctic Canada[1]

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ABSTRACT. Radiocarbon dates from eastern Melville Peninsula indicate that deglaciation of western Foxe Basin occurred about 6900 years ago, although late ice persisted in an area northwest of Hall Lake and on the central plateau. Relative sea level was as high as 144 m above present at that time. Two new well-controlled sea level curves depict emergence as an exponential decay function. Marine limit elevations and nested curves indicate a major ice-loading centre in south-central Foxe Basin. These data and archaeological dates suggest a secondary recent rebound centre in the northern part of the basin. Flights of raised beaches, prevalent in the area, are composed of angular limestone fragments and suggest that frost-riving occurs in shallow foreshore environments. The prominent wash line near the marine limit suggests that Foxe Basin had less sea ice cover prior to 6000 years ago but that coastal processes have been similar to present since that time.

Key words: Arctic, coasts, archaeology, radiocarbon dating, glacial history, emergence, sea level, geomorphology

RÉSUMÉ. Des datations au carbone radioactif dans la presqu'île Melville orientale indiquent que la déglaciation du bassin Foxe s'est produit vers 6900 ans, bien que la glace ait persisté dans une zone situeé au nord-ouest du Lac Hall et sur le plateau central. A cette époque, le niveau de la mer s'élevait à 144 m au-dessus du niveau actuel. Deux nouvelles courbes du niveau marin bien étayées illustrent l'émergence comme une fonction de décroissance exponentielle. Les élévations du niveau marin et les courbes emboîtées indiquent un important centre de chargement glaciaire dans le centre-sud du bassin Foxe. Ces données et des datations archéologiques laissent supposer qu'un soulèvement isostatique secondaire a eu lieu récemment dans le nord du bassin. Les séries de plages soulevées, nombreuses dans la région, sont composées des fragments de calcaire anguleux indiquant que la gélifraction est un phénomène courant dans les bas de plage peu profonds. La ligne d'érosion qui prédomine près de la limite marine laisse présumer que la couverture glacielle dans le bassin Foxe était moindre avant 6000 ans, mais que les processus littoraux n'ont pas changés depuis cette époque.

Mots clés: l'Arctique, côtes, archéologie, datation au carbone radioactif, histoire glaciaire, niveau marin, geomorphologie

INTRODUCTION

Melville Peninsula lies on the western side of Foxe Basin (Fig. 1), a shallow inland sea in the Eastern Arctic that is ice covered for much of the year. Landfast ice persists along the Melville coast until the end of June, and drifting pack ice occupies much of the basin until mid-August. Sea ice reforms in October. The present coast of Melville Peninsula is therefore exposed to shoreline processes for a very short period of time. Raised marine deposits indicate that the coastline has been emerging since deglaciation due to postglacial isostatic rebound and that ice conditions may have been different from those of today for part of the time. This paper examines the marine features on eastern Melville Peninsula and the record of coastal conditions and sea level change since the last glaciation. It describes the variety of raised marine forms for the first time, lists new radiocarbon data, presents well-constrained emergence curves for the area, and supplements earlier concepts of postglacial submergence and uplift developed by Sim (1960a), Farrand and Gajda (1962), Dyke (1974), and Andrews (1989).

The main landscape elements of eastern Melville Peninsula are the lowlands, which extend inland as much as 60 km, the Shield upland area, and a major escarpment that separates the two terrains (Fig. 2). The coastal lowlands are underlain by Paleozoic carbonate strata, as is most of Foxe Basin. Bedrock is generally not far below the surface, and the flat-lying aspect of the strata accounts for the lack of major relief. The lowlands are wetlands covering most of the terrain lying between sea level and about 50 m elevation. Slopes range between 0.5 and 1.6 m/km. The main topographic features in the lowlands are raised beaches, the swales between them (Fig. 3), and the low mesas and stepped limestone outcrops, which interrupt the otherwise flat terrain. The raised strands form gravelly unvegetated berms whose spacing is determined by the slope of the land and proximity of outcrop. Grassy swales between ridges are poorly drained and are occupied by ephemeral ponds and shallow lakes whose outlines change throughout the season and from year to year.

The lowlands are bounded by normal faults, along which Precambrian rocks have been uplifted relative to the Paleozoic strata (Bolton *et al.*, 1977). The fault escarpment is a prominent feature traceable for more than 150 km. It rises abruptly either from the coast to 150 m, as at Roche Bay, or from the lowland terrain (about 40 m elevation asl), as at Hall Lake. The slope of the escarpment varies between 10 and 30 cm/m. The upland region west of the escarpment and north of Quilliam Bay consists of igneous and metamorphic rocks of the Precambrian Shield. It rises inland gradually from the escarpment to an elevation of between 250 and 300 m in the centre of the peninsula at a rate of about 5 m/km. This terrain consists of rolling hills and plains of till-covered or bare rock knobs and rock basins. The Ajaqutalik, Kingora, and Hall rivers are major streams flowing across the Shield terrain and are incised into the bedrock in their lower reaches. They empty into Roche Bay and Hall Lake at the edge of the escarpment and do not continue out across the lowlands. The lower parts of the river valleys were inundated by postglacial seas. It is in these valley embayments that most of the fossils used in radiocarbon dating were found.

The main events in the glacial history of the area that pertain to this paper have been determined by Sim (1960c,d) and Craig (1965b) and by field mapping by the author for the Geological Survey between 1985 and 1988. The direction of major ice flow during the last glaciation was westward from a grounded ice centre in Foxe Basin. Carbonate till (Andrews and Sim, 1964) was dispersed westward across the

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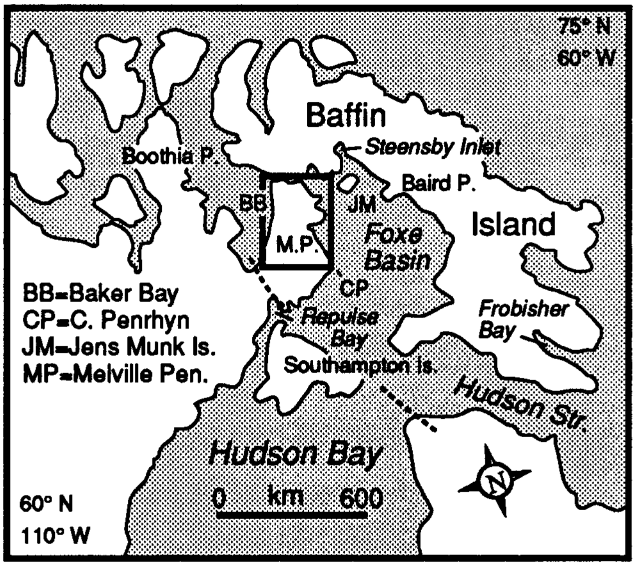

FIG. 1. Regional location map, Eastern Arctic. Boxed area is shown in Figure 2. Dashed line indicates the trend of the Bell Structural Arch.

peninsula far beyond the contact between Paleozoic and Precambrian rocks. Late in the glacial cycle ice also flowed southwestwards across Fury and Hecla Strait onto the northern part of the peninsula, and a separate ice cap developed over the centre of the peninsula farther south. Hummocky till deposits and eastward-flowing eskers on the Shield and lowlands between Lailor and Hall lakes (Fig. 2) mark the area of a late-disintegrating ice mass on the lowlands as well. When ice had retreated from Foxe Basin, the carbonate lowland areas and limited parts of the uplands were inundated by a high-level sea, which subsequently regressed to the position of the present coast. Pre-Dorset, Dorset, and Thule archaeological sites representing coastal hunting communities located on raised beaches on Igloolik Island and the nearby mainland (Meldgaard, 1960, 1962) augment the geological record of recent sea level change.

METHODS

The marine features described in this paper are based on ground site investigations combined with air photo interpretation and are an extension of the work of Sim (1960d). They are used to interpret Holocene coastal conditions.

Sim (1960a,b) used a Paulin altimeter and radar altimetry profiles to determine elevations. Additional elevations from helicopter and foot traverses during the 1985-88 mapping project were made by the author using a Wallace and Tiernan altimeter with a 2 m precision, with frequent checks against readings at sea level. The altimeter data were supplemented by new topographic maps that show contours at 10 m intervals. With the new maps marine limits and other elevations could be determined to an accuracy of ± 5 m from air photo interpretation in places not measured with the altimeter. The extent and elevation of marine submergence was used to reconstruct the geological history of the area, including the record of sea level change. In this area marine limit patterns could be further used to establish centres of isostatic unloading because the Foxe Ice sheet disintegrated in a short time period; the regional marine limits therefore reflect the response of the crust to glacial unloading.

Organic materials were collected for radiocarbon dating in order to establish the time of deglaciation and reconstruct the emergence record. They were chosen from the foreset beds of small deltas from the sides of two valleys that were once marine embayments. These deltas are sufficiently small that the organics were within 2 m elevation of the apices: the dates obtained could thus be precisely linked to a marine waterplane elevation. The samples selected for dating were primarily marine molluscs, although algae, detrital sticks, and leaves were also retrieved from some deltas. The main species dated was *Hiatella arctica*, although *Mya truncata* and *Mya arenaria* were used in a few places. Although these were the most common species, *Macoma calcarea*, *Serripes groenlandicus*, *Clinocardium* sp., and *Balanus* sp. were also encountered.

In several places the valves were partly coated with secondary calcite, and some surface collections had lichen specks; in these cases the extraneous material was thoroughly removed prior to dating, as were all iron stains. The shells were dated at the GSC lab following acid treatment, and the results were corrected for isotopic fractionation of ∂C13 to 0‰, as described by Lowdon (1985). The terrestrial detrital organics were corrected to ∂C13=−25‰. Delta 13 values are shown in Table 1, along with the "corrected" dates. The

TABLE 1. Radiocarbon dates, eastern Melville Peninsula (ML = marine limit elevation in metres above sea level)

Site locn	Sample el (m)	^{14}C age (corrected)	Lab reference	∂C13 ppt	Comments
Hall Beach					
1	7	1020 ± 30	GSC-691		Shells in beach
2	8	1120 ± 60	GSC-3802	−23.0	Bowhead tissue
3	8	1130 ± 60	GSC-3850	−15.1	Bowhead bone
Lailor/Tremblay					
4	75	5510 ± 70	GSC-4453	+1.3	Hummocky till; ML 90
5	72	5470 ± 60	GSC-4536	+2.8	Surface, SL up to 109
6	55	5330 ± 80	GSC-4397	+2.8	Surface, about 81 m level
7	32	5320 ± 60	GSC-4449	+2.7	Section, sublittoral; ML 93
West Hall Lake					
8	100	6240 ± 90	GSC-4809	+1.6	ML 110 m
Kingora					
9	113	6530 ± 110	GSC-4693	+1.4	Delta section; ML 120
10	53	5640 ± 80	GSC-4720	−0.9	Delta section
11	43	6170 ± 100	GSC-4743	+0.9	Delta section, silts
12	35	5080 ± 90	GSC-4702	+1.2	Delta
13	21	3970 ± 70	GSC-4426	+0.2	Upper sand, section
14	8	2380 ± 60	GSC-4452	+3.0	Beach section
Ajaqutalik					
15	90	6200 ± 100	GSC-4413	+1.4	Delta section, top 100; ML 110
16	60	4980 ± 80	GSC-4803	+1.5	Delta section. ML 115
17	35	4610 ± 80	GSC-4814	+1.8	Delta section
18	26	4210 ± 60	GSC-4416	+1.9	Offlap; ML 140
19	14	3600 ± 60	GSC-4451	+1.4	Delta foresets, top 20 m
20	5	1590 ± 60	GSC-4759	−21.8	Organic detritus in topset beds
Amitoke					
21	122	6620 ± 70	GSC-4792	+0.8	Waterplane at 123 m
22	92	6260 ± 90	GSC-4798	+1.4	Delta; NTS says 85 m
23	76	5850 ± 80	GSC-4627	+3.4	Surface fragments, ML 134
Cape Jermain					
24	141	6420 ± 90	GSC-4750	+1.4	Sublittoral sand
25	134	6880 ± 180	GSC-291		Craig (1965) ML 146
26	104	6170 ± 80	GSC-4812	+1.5	Delta
Fury and Hecla					
27	121	6520 ± 70	GSC-4378	+1.5	Surface shells
Rae Isthmus					
28	120	6850 ± 140	GSC-286		Craig (1965) ML 140

difference between the raw "machine" dates and those corrected for a ∂C13 value of 0‰ are generally less than 40 years. The archaeological dates appear as they were originally reported in the literature and have no ∂C13 correction. None of the dates used has been adjusted for reservoir effects, since the use of, and amount of, the reservoir correction is controversial and is known to be areally variable (*cf.* McGhee and Tuck, 1976; Arundale, 1981). Dates from modern beaches in northern Canada indicate that the the reservoir time may be in the order of 0 to 400 years for this area (*cf.* Blake, 1987, 1988; field data). Interpretive problems associated with numerous adjustments to archaeological and other dates are summarized in Arundale, 1981.

RAISED MARINE FEATURES, RADIOCARBON DATES, AND SEA LEVEL CHANGES

Raised Marine Features

Raised beaches: Raised strandlines are widely distributed across the eastern part of Melville Peninsula, where they range geographically all across the lowlands and the flank of the

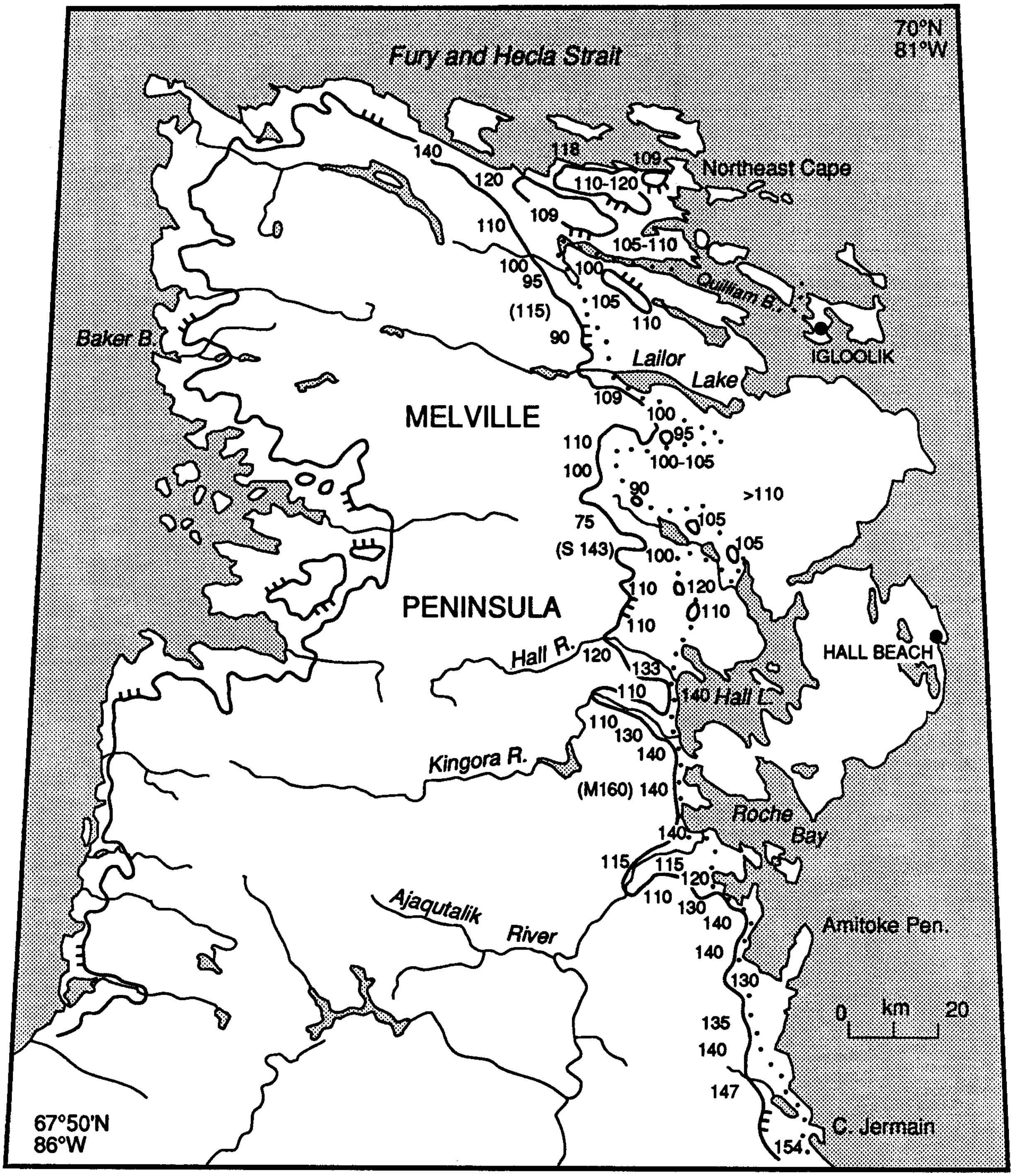

FIG. 2. Marine limit, eastern Melville Peninsula. Solid pecked lines show the limit of marine submergence on northern Melville Peninsula, and numbers give the marine limit elevation in metres asl. Dotted line denotes the contact between Precambrian and Paleozoic rocks.

FIG. 3. Emerged and modern strandlines with intervening lagoons and pond-studded swales on the north coast of Igloolik Island; view westwards. NAPL photo T255R-104.

uplands and from sea level to as high as 140 m asl. They occur both as continuous stepped flights of beaches (Fig. 4) and as individual ridges separated by swales or broad, level areas dotted with shallow tundra ponds. The spacing of the ridges depends on the slope of the land and the proximity of available material. They are more widely spaced on flatter areas than on those that are slightly sloped, in accordance with the steady emergence of the lowlands from the sea. They tend to be more prevalent near limestone outcrop, which forms very low scarps or closely underlies the land surface in many places, than in areas of till or Precambrian outcrop. In places the beaches are built on flat limestone bedding planes, and the rectilinear joint pattern of the rock is visible between the ridges (Fig. 5). The ridges are commonly 2–4 m high and consist of limestone flags or angular, fist-sized lenticular limestone cobbles (Fig. 6), along with occasional rounded ice-rafted granitic boulders. It is suggested that frost action is important for breaking up limestone bedrock along bedding planes and exposed joints and around small scarps in littoral and foreshore areas, and that these riven products are then used to create the beach ridges. The angularity of the beach material, also noted here by Sim (1960d) and Taylor (1980) on Somerset Island, further suggests that wave abrasion and longshore transport is minimal, due to the short open-water season. While the beaches consist mainly of coarse material, fine material is present in the swale areas as disaggregation products of the broken rock, as till, or as overwash deposits from the beach-forming processes.

Some ridges have conical pits scattered along the suface (Fig. 7). Because similar depressions are present in shore berms at sea level where patches of sea and landfast ice have been buried into the ridge, the melting of buried ice blocks is thought to account for the conical features in the raised berms as well. (An alternative explanation would be that they are collapse structures resulting from localized dissolution of the underlying limestone.)

FIG. 4. Flights of raised beaches east of Hall Lake. GSC 204141-G.

FIG. 5. Sharply defined rectilinear joint pattern on broken limestone bedrock, partly obscured by gravelly marine deposits. The joints are preferential sites for frost heaving. Small curved marks on the right side of the photo are probably pressure-ridge grooves. Photo taken from an altitude of 500 m: approximate scale 1:10 000. GSC 204141-J.

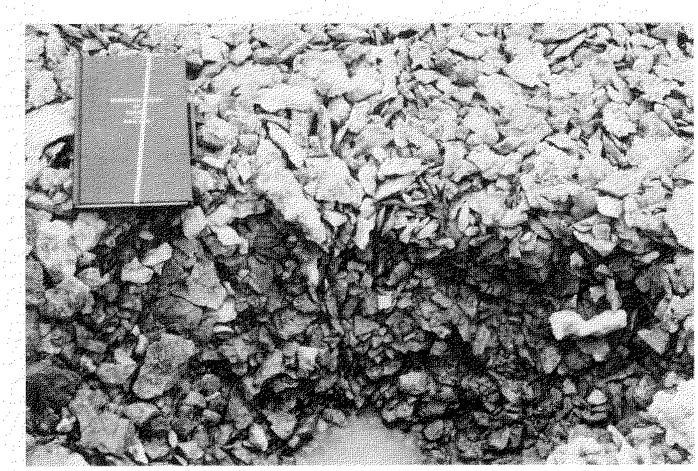

FIG. 6. Angular lenticular limestone gravel in a beach ridge. Notebook is 20 cm long. GSC 204141-L.

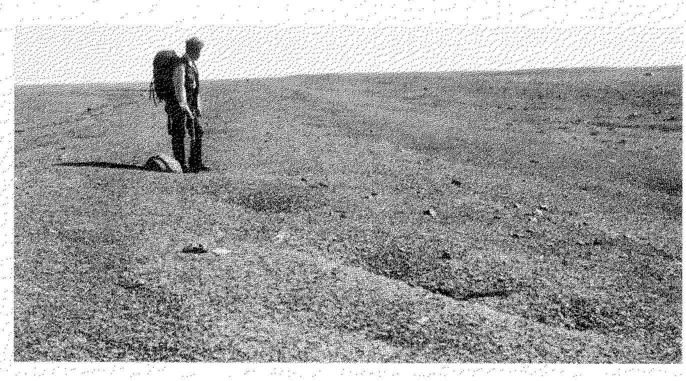

FIG. 7. Raised beaches composed of limestone gravel, with scattered ice-rafted erratics. The berms contain ice block depressions. GSC 204141-E.

Individual strandlines are traceable for several kilometres (Figs. 3, 4). In many instances, their ends bifurcate or hook, and these aspects led Sim (1960d) to suggest that some of the ridges formed as underwater bars rather than as beach features and that the bars emerged from the sea as the land rose. However, King's (1969) work on Baffin Island and Taylor's (1980) observations on Somerset Island suggest that these ridges were built as storm beaches despite the short season of open water. A prograding set of ridges would develop as the land emerged and successive ridges were abandoned. If the largest ridges represent major storm events, then the emergence record suggests that the recurrence interval for major storms is about once per hundred years. Taylor attributed the spits and hooks to wave refraction across topographic obstructions in the foreshore and the resulting variation in wave approach. On Melville Peninsula, hooked forms are most prevalent on raised beaches where limestone mesas would have formed islands or underwater wave obstructions during emergence. The presence of buried ice in modern beaches and related conical forms in the raised strandlines mentioned above suggest that ice-push processes are also involved in the creation of the ridges.

Since the beaches descend uninterrupted down to present sea level, it is clear that strandlines are continuing to form even though there is only a brief period of open water in Foxe Basin.

Along with the limestone beaches that dominate the lowlands are more limited flights of sand and rounded gravel beaches. These beaches have mixed shield and carbonate lithologies. They occur along the flanks of the escarpment and are most common in areas where streams from the upland area flowed into the high-level sea. They are thought to be formed as storm ridges. The rounding of the component clasts may have occurred during glacial or stream transport or from wave activity.

Till surfaces below marine limit: Between Lailor and Hall lakes are areas of washed carbonate till. In many places the limit of washing is clearly discernible (Fig. 8). Where marine processes have been active, the topography is more subdued

FIG. 8. Marine limit (accentuated by the dashed line) shown as a trimline separating bare rock and carbonate till (A), separating washed and unmodified till (B), and separating marine deposits from till (C). Foreground shows carbonate lowland terrain, whereas the background is Shield upland. View westwards from Lailor Lake.

than the terrain above and areas between till hummocks are infilled with fine material that supports vegetation: the carbonate till alone is hostile to plants. Although marine fossils were not found in till above the limit of postglacial marine submergence, shell fragments do occur on the till surface below marine limit and are sometimes frost-churned into the upper part of the till. In a few places, very small beach ridges have also developed on the till surface. Large ice-wedge polygons have also developed on tills in this area, whereas they are rarely encountered elsewhere.

Marine sediments: Thin marine deposits blanket glacial material and outcrop in lowland areas where beach ridges are widely separated. The blanket deposits consist mainly of angular limestone gravel mixed with calcareous silt. Silt and fine sand are limited to areas lying seaward of raised deltas and offshore from Hall River.

Deltas: Raised marine deltas are present in two situations: a) Several outwash deltas at the marine limit mark the location where anastomosing outwash streams entered the sea. These features are large and are composed of boulder gravel consisting predominantly of Precambrian lithologies. b) The remaining deltas are small features, triangular in plan, that developed where normal streams entered the high-level sea. They are common features where side streams flowed into the embayments now occupied by the Ajaqutalik (Fig. 9), Kingora, and Hall river valleys. These deltas consist of grey, silty, poorly stratified lower units capped by stratified sandy topsets. Progressively lower deltas were built as sea level receded. Where they are fossiliferous the little deltas provide good control for dating sea level stands, because their limited vertical extent allows the dated shells within them to be related closely to a base-level position.

Trimlines: In a number of places along the escarpment the upland till surface is separated from marine deposits by a zone of bare rock (Figs. 10, 11). This type of feature is

FIG. 9. Delta sets on the Ajaqutalik River at site 15 near marine limit. The sediments contain marine molluscs, algal mats, and terrestrial detrital organics. Section is 10 m high. GSC 204141-K.

FIG. 10. Ground view of a trimline showing the limit of unmodified till (T) against bare washed rock (R) and washed ground moraine (W). Vertical bar along the trimline is 1 m high. Photo near the Kingora River. GSC 204141.

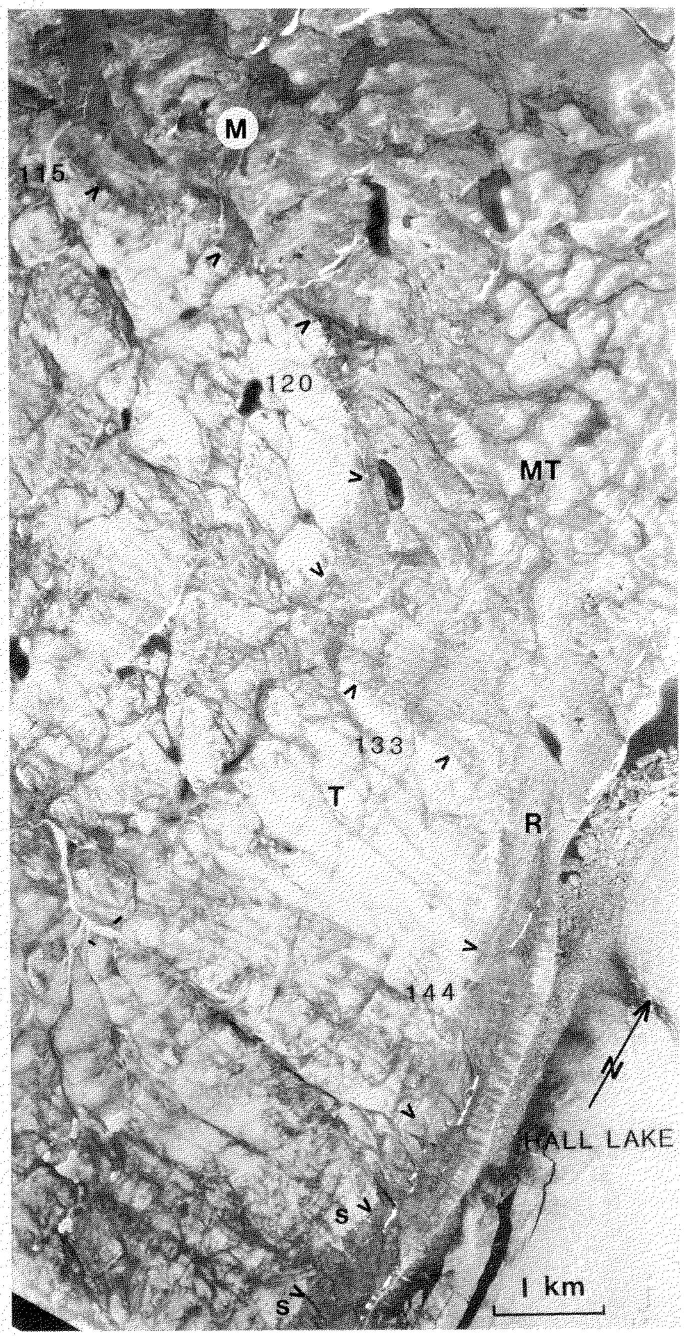

FIG. 11. Trimline (carets) on the escarpment on the west side of Hall Lake. Numbers give the elevation of the marine limit in metres. The trimline clearly separates unmodified till (T) from washed rock (R), subdued modified till (MT), and marine deposits (M). (S) marks an area of solifluction lobes. A15740-17.

traceable for considerable distances on the air photos (Fig. 8). Its breadth and vertical extent depend on the local terrain geometry. It is characteristically 60–100 m wide and commonly extends through a vertical interval of 5–25 m. The upper edge of the bare rock is thought to be a marine trimline, marking the upper limit of postglacial marine erosion. The rock/till interface is abrupt (Fig. 10) and there is no storm beach separating the two materials. Similarly, the bare area is generally totally free of boulders or other marine lag deposits. The trimline and bare zone is most common along the upper parts of the escarpment in fairly steep areas that may not have had a great amount of till on them. However, not all relatively steep areas of the escarpment, or steep areas lower down, are marked by trimlines; rather, they are limited to places that would have been open, unprotected coastlines in early postglacial times when relative sea level was 100–140 m above present. Trimlines are not present in areas that would have been protected by offshore islands at the time. The existence of the trimline and erosion zone would seem to require intense wave or ice-scouring activity because the rock has been cleared of all glacial debris, including boulder lags. Sea-ice scouring is a mechanism that would account for the absence of a storm beach at the top of the rock/till interface. Because similar wash zones are not observed at lower elevations, the existence of the trimline suggests that coastal conditions were somewhat different in early postglacial times. There might have been differences in oceanic circulation, as suggested by Dyke and Morris (1990); climatic differences during the Hypsithermal, resulting in less landfast ice; or more vigorous coastal processes along the escarpment, where wave energy could be expended totally at the shore rather than being dispersed in a shallow foreshore, as is the case for much of the more gently sloping lowland terrain. It is also possible that tidal effects were different and that landfast ice was lifted and removed earlier in the season. The fact that trimlines and bare zones are not present even on steep slopes at low elevations indicates that terrain geometry and slope were not the only factors.

Ice scours: Criss-crossing, intersecting shallow grooves created by the scraping of pressure ridges across the sea floor or the piling of ridges at the shore are present in the area west and northwest of Hall Beach but occur sparingly and are restricted to elevations below 40 m. Smaller linear and parabolic scars are observed near present sea level where ice pans and piled floes are pushed onto the shore.

Fossils: Holocene marine fossils are found on and in beaches and deltas as paired or separate valves and as fragments on some till surfaces below marine limit. Shells were not found as transported clasts in till above the marine limit. Whale remains are restricted to the Hall Beach area. One large bowhead whale was found buried in a beach 8 m above present sea level. Because the depth of beach gravels overlying the carcass was greater than the active layer, both the fleshy parts and skeleton were well preserved. Although no other intact specimens were found, piles of dismembered whale bones at archaeological sites in the area of the DEW line installation indicate that whales were more common in Foxe Basin about 1000 years ago.

Marine Limit

The upper limit of postglacial marine submergence was determined using the highest elevation of marine features described above. In the case of the trimline, although there has been some solifluction of the unwashed till onto the rock, the solifluction lobes can be easily seen and accounted for when determining the limit of submergence.

Figure 2 shows elevations of marine limit and delimits the area inundated by the postglacial sea. The data combines the determinations from recent mapping projects with those of Sim (1960a) and one determination of Mathiassen (1933; M prefix on Fig. 2). The entire lowland area was submerged except for one mesa south of Quilliam Bay. The sea also covered low Precambrian rocks around Northeast Cape and penetrated into valleys such as those of the Hall and Kingora rivers.

The many marine limit elevations obtained from recent mapping agree basically with those of Sim (1960a) except for the area west of the north arm of Hall Lake. He reported a strandline at 143 m (denoted as S143 on Fig. 2) and shells as high as 131–135 m, whereas the limit determined in this study using strandlines and the limit of washed till is closer to 110 m. Using the new maps, no marine deposits could be found at the elevations Sim reported. Since there are no radar altimetry profiles for this area, it is possible that Sim's altimeter was reading too high.

In a north-south direction, marine limits range from about 105 to 110 m in the north, down to about 75 m between Lailor and Hall lakes, and then up again to a height of 140–150 m in the south. There is also a noticeable rise in marine limit in several places from west to east, as seen by the elevation of beaches on limestone mesas south of Quilliam Bay and north of Hall Lake. Along the escarpment near Hall River (Fig. 11), the Kingora River, and south of Roche Bay there is an appreciable rise in marine limit along a southeast direction; marine limits there rise from 115 m to greater than 140 m, with a gradient of about 2.5 m/km.

Marine limits are generally lower throughout this area than on the west coast of the peninsula, where they are as high as 235 m (Dredge, 1990). This difference is attributed to: a) earlier deglaciation of the west side, where radiocarbon ages indicate that deglaciation occurred by about 9100 ± 100 B.P. (GSC-4324), and b) different loading histories. The limits here are also lower than at Cape Penrhyn (152 m), outer Repulse Bay (173 m; Sim, 1960b), and Southampton Island (180–190 m; Bird, 1954). Marine limits on Baird Peninsula (110 m; Ives, 1964) and Steensby Inlet (95 m), both Baffin Island, are similar to or lower than those on northern Melville Peninsula. The regional marine limit pattern suggests that the centre of loading of the Foxe ice sheet was in south-central Foxe Basin. That some part of Foxe Basin, and not the landmass, was the load centre has been known from till dispersal patterns for several decades (e.g., Ives and Andrews, 1963). This line of evidence is supported by the marine limit data and by the nesting of emergence curves from west to east across the peninsula (see discussion below).

Significant differences in marine limit occur even within the limited area of Melville Peninsula described in this paper: a) The very low marine limits of 75–90 m between Hall and Lailor lakes correspond to areas of eskers and hummocky till containing more ice wedges than other deposits and to relatively young radiocarbon dates. It is thought that a late ice mass disintegrated in this area and that the sea lay against or partially flooded the remnant ice here, so that high limits were not recorded. b) There is an increase in marine limit elevation southeastwards along the escarpment reported in several areas; this increase could have several interpretations. Firstly, if deglaciation began essentially with the disappearance of the ice centre in Foxe Basin, then ice may have persisted somewhat longer near the land where the ice sheet was more stable; elevations of marine limit strandlines would thus decrease inland, in accordance with progressive deglaciation from the middle of the basin. From the data in Table 1, this would mean that it actually took from about 6880 ± 180 B.P. to 6530 ± 110 B.P. to remove glacier ice from exposed embayments around Foxe Basin and that 40 m of emergence had occurred during that time. One problem with this explanation is that the observed changes occur over a short distance, and it is unlikely that one point less than 10 km from another would have a delay in deglaciation of almost 400 years when both points are along open stretches of coast. Another problem is that the Amitoke shell date at site 22 corresponds with the Ajaqutalik site 15, farther inland, suggesting that points along the coast and inland both have the same emergence history. A second explanation is that the elevation gradient reflects load differences; if so, then the vectors here indicate that the load centre is in Foxe Basin somewhere off Cape Penrhyn.

While this explanation agrees generally with the regional load picture, the differences in elevations observed over short distances indicate loading differentials greater than expected from a purely viscoelastic crustal response (Walcott, 1970, 1972); it would mean that the isobases are very steep. One modification of this idea is to suggest that some other crustal response is operating in addition to the viscoelastic one, such as faulting or tilting of a block of the crust. If the Melville block were tilted upwards to the northwest, then there would be a greater observed rise in marine limits than that observed from a viscoelastic response alone.

Three lines of indirect evidence support the idea that tilting may be a factor: a) Although there is no evidence of reactivation of faults on Melville Peninsula, there is an indication of movement along Fury and Hecla Strait, where some glacially moulded bedrock features appear to have been faulted. b) The southern periphery of the Foxe ice dome corresponds to a structural zone extending from Hudson Strait across northern Southampton Island to Boothia Peninsula. Basham *et al.* (1977) consider this region to be seismically active, and they have suggested that Foxe Basin responded to postglacial uplift as a block. c) Dyke *et al.* (1990) have documented cases of postglacial tilting of other parts of the central Arctic.

Radiocarbon Dates on Marine Fossils

Fossils were collected from small deltas in order to determine the onset of deglaciation and the pattern of emergence. Shells were found to be restricted to certain environments. They were plentiful in some river valleys that were once embayments, such as the Kingora, whereas they were absent in others, such as the Hall. They were found more often in river valley settings than along the exposed coast. Also, they were found more often in and on deltas than on strandlines. This last aspect may be related either to their preferential occurrence near fresh water or to greater preservation in these environments. At present, calcite dissolves readily in the area, as is seen in the way that beach pebbles are etched and pitted on their top sides and are covered with small calcite accretions on their bottom sides. Shells therefore can be expected to be better preserved in sections than on exposed berms. Shells collected from strandlines tended to be fragments or single valves rather than paired valves. They were dated only where they were the highest shells and lay near the marine limit. Most collections are from small deltas, and these are best for estimating sea level positions. In general, the shells were well preserved and clean and occurred in clusters or colonies; many were paired valves. They were usually found at the contact between the topset sand and the siltier foreset beds. Because the deltas are generally very small, the shells can be related to a specific waterplane.

Sites that have been radiocarbon dated are shown on Figure 12. The corrected dates, ∂13C values, and elevations are shown on Table 1. The dates are on marine shells except for site

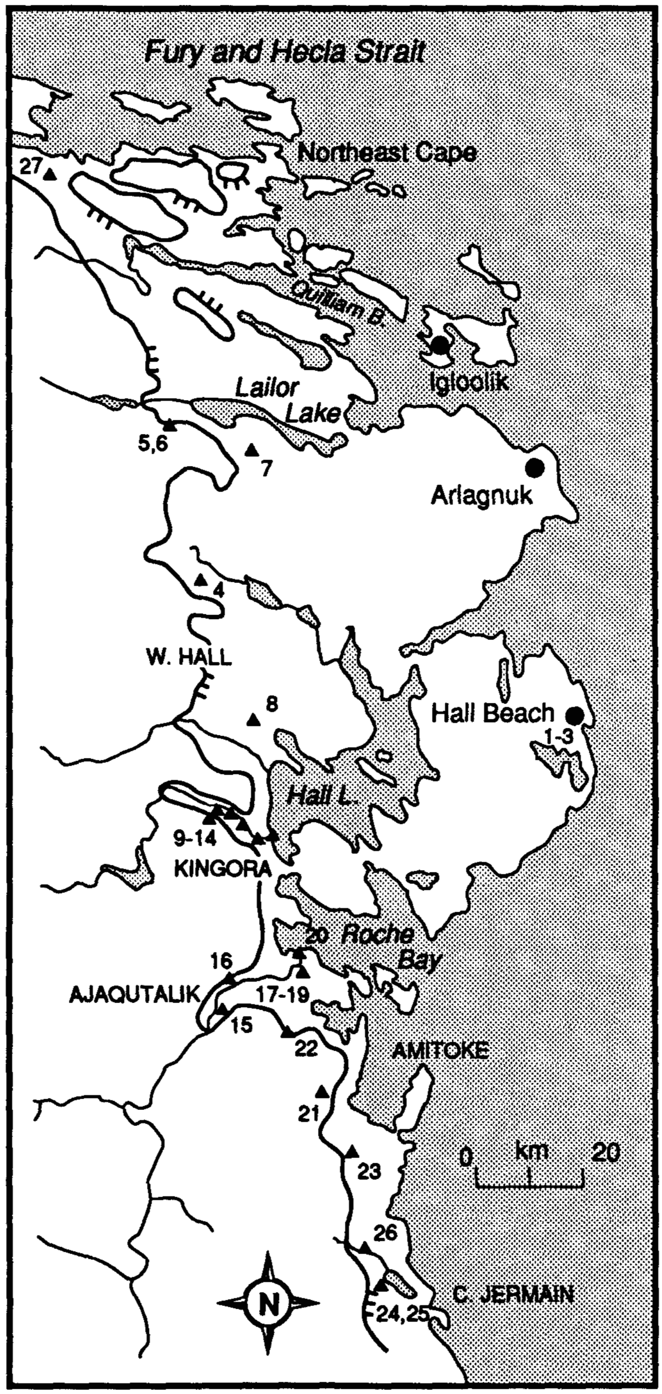

FIG. 12. Radiocarbon-dated shell sites. Dates are shown on Table 1.

20, which is on detrital organics in the Ajaqutalik delta, and the bone and tissue dates from the whale buried in a beach berm at Hall Beach. The whale dates are for comparison only and were not used to generate emergence curves. The shells taken from deltas have fairly low ∂13C values, suggesting that they lived in brackish water conditions. Those collected from open coastal situations have higher ∂13C values.

Emergence Curves

The Kingora glacioisostatic emergence curve is constructed from shells extracted from small deltas along the sides of the present river valley. These deltas were created where small streams flowed into the Kingora embayment, and they developed at progressively lower levels as the land emerged. The suite of shells was collected from a small area about 9 km long; therefore, all shells have undergone the same emergence history. The size of the symbols on Figure 13 accommodates the counting error in the assigned shell dates. Sites 9, 10, and 12 are from silty foreset sands directly below the topset beds and lying 2–5 m (vertically) below the apices of the deltas, i.e., the waterplanes. Site 13 is from topset sands and site 14 is from a sandy littoral section where the Kingora entered the sea. The curve for the Kingora area is well controlled. The points indicate continuous emergence of the area from at least 6500 B.P. The date from site 11 is thought not to represent a waterplane because the shells were single valves buried deeply in the lower deltaic facies. The shell dates from west of Hall Lake and from Fury and Hecla Strait fall on the Kingora curve. Even though the marine limit is different northwest of Hall Lake, the emergence history appears to be similar.

Sites 15, 16, 17, 18, and 19 are from foreset beds of silty sand lying 2–10 m below the waterplanes of small deltas formed by streams entering the Ajaqutalik embayment. Site 20 is from topset sand. The sea level curve (Fig. 14) constructed for the Ajaqutalik River about 25 km farther south has upper and lower parts that are coincident with the Kingora curve. Also, the plot of Amitoke site 22 coincides with the Ajaqutalik site 15, farther inland, suggesting that points along the coast and inland both have the same emergence history.

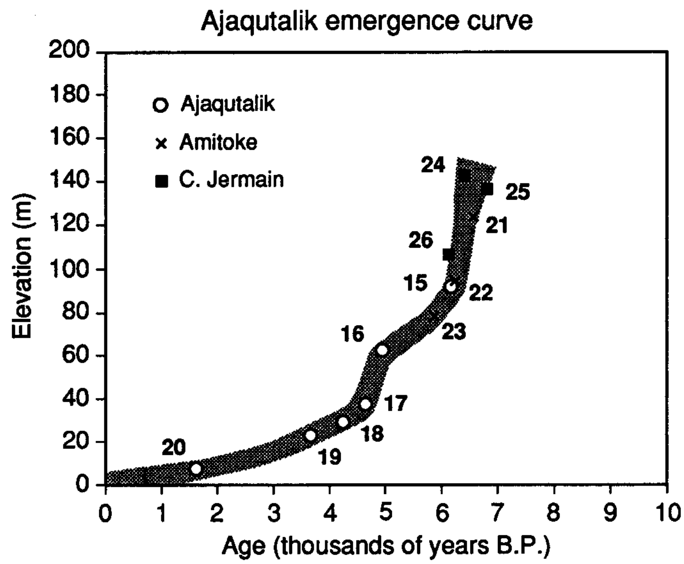

FIG. 14. Emergence curve, Ajaqutalik River.

Site 16, however, creates a bend in the exponential curve. This site is from delta topsets whose elevation was measured with the altimeter and confirmed by the topographic map. If the date and elevation are valid, then there was a period when emergence or uplift slowed down. The difference from the Kingora curve might relate to the late ice cap that developed in the centre of the peninsula in the Ajaqutalik area and may have caused the rate of uplift to slow down for a period of time. We know from west coast dates and the pattern of meltwater channels that a substantial ice mass remained over the central part of Melville Peninsula for some time. If, however, the date is discarded, then the Ajaqutalik and Kingora curves are essentially the same. Dates from the Cape Jermain area appear to fit the Ajaqutalik curve. It is not known how Craig (1965a) determined the elevation at site 25, although he likely used a (helicopter?) altimeter.

The shells at Hall Beach may fall along a curve nested above and to the left of the Kingora and Ajaqutalik curves, although the data are very limited (Fig. 15). The shells are considerably younger than those at similar elevation on the Kingora River

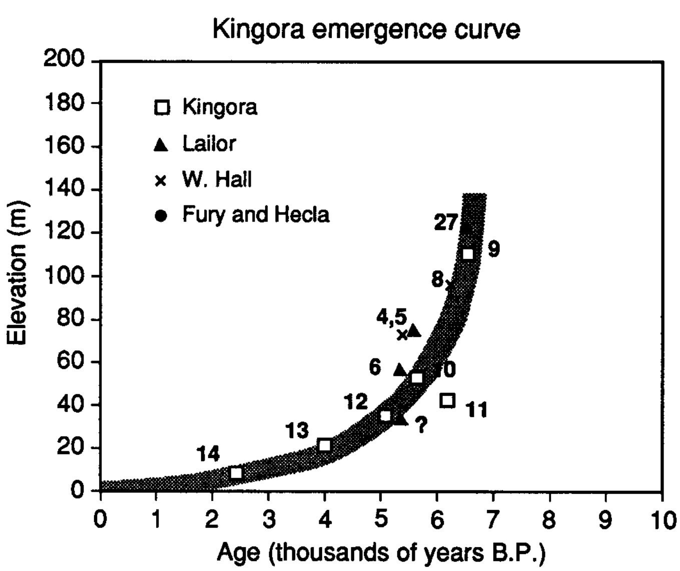

FIG. 13. Emergence curve, Kingora River.

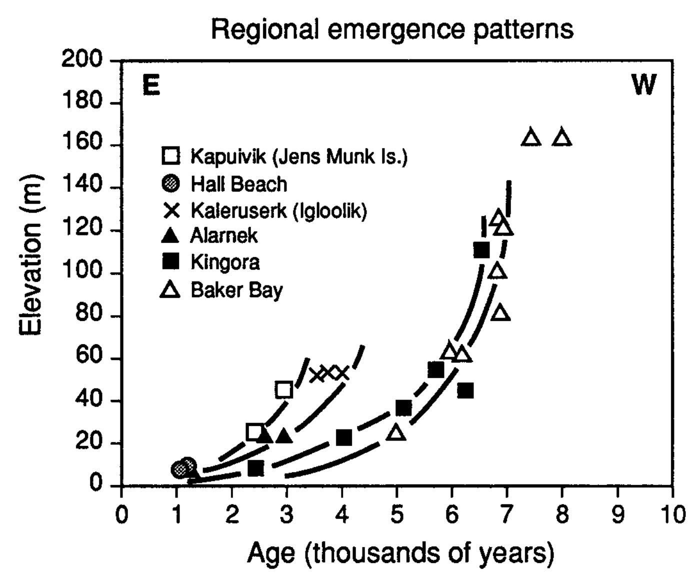

FIG. 15. Regional sea level curves.

and also younger than the organic detrital date from the Ajaqutalik delta, even with correction factors allowed. This suggests that Hall Beach is presently emerging faster than the other areas, at about 70 cm per century. That the Hall Beach emergence curve is nested above the Kingora is supported by the archaeological data (Table 2) from the Kaleruserk site on Igloolik Island and the Alarnek site (Fig. 12), which contain house ruins and bone and ivory artifacts of the Pre-Dorset, Dorset, and Thule cultures. The Pre-Dorset artifacts lie between 54 and 23 m above sea level (asl); the Dorset sites lie between 22 and 8 m asl, and Thule sites lie from 8 to 5 m above present sea level (Meldgaard, 1960, 1962). The archaeological sites represent former coastal hunting communities that were situated just above sea level when they were occupied (Andrews *et al.*, 1971). Although the archaeological dates cannot be compared exactly with the marine shell dates because of contamination of samples and different correction methods (possibly 400 years difference), the data still plot too far above the Kingora curve to be from that uplift region. However, they would fit closer to the hypothetical curve proposed for Hall Beach. Similarly, the Pre-Dorset archaeological site of Kapuivik on Jens Munk Island (Rainey and Ralph, 1959; Meldgaard, 1962) may belong to another curve that could be nested above the Hall Beach curve. The nested pattern suggests a late local secondary rebound centre in northern Foxe Basin, near Baffin Island.

SUMMARY AND DISCUSSION

Radiocarbon dates presented in Table 1 indicate that the west side of Foxe Basin was deglaciated about 6900 years ago. The Kingora and Ajaqutalik dates have been used to construct the first well-controlled emergence curves for the area. The Kingora curve indicates a simple exponential type of emergence that can be explained by the traditional viscoelastic rebound model of crustal response. One interpretation of the Ajaqutalik curve suggests that a late massive ice cap on the centre of the peninsula changed the rebound pattern somewhat in the southern part of the area shown on Figure 2. Hummocky till forms, melt-out depressions, and esker patterns between Hall and Lailor lakes suggest that a stagnating remnant ice mass also persisted in that area, and radiocarbon dates indicate that this ice remained for about 700 years after other areas were deglaciated. The Hall Lake date suggests that stagnant ice in that area was not of sufficient thickness to affect rebound/emergence, because the date fits well onto the Kingora curve.

The oldest Melville dates, compared with other dates from around Foxe Basin, such as 6930 ± 150 (GSC-782) and 6890 ± 210 (GSC-838) (Lowdon *et al.*, 1971) from northern Southampton Island and 6725 ± 250 (I-406; Ives, 1964) from Baird Peninsula on Baffin Island, indicate that all areas peripheral to Foxe Basin were deglaciated at about the same time and suggest rapid removal of the marine-based part of the ice sheet there. Regional marine limit patterns from Melville Peninsula and around Foxe Basin related to this event indicate that the centre of unloading was in south-central Foxe Basin. This fits regional ice flow patterns, which indicate that Foxe Basin was a major dispersal area. The loading centre deduced from marine limit data is similar to the one shown by Dyke (1974) and Walcott (1972), who predicted that there would have been a major gravity undercompensation zone over Foxe Basin about 6000 years ago and that this was subsidiary to a larger anomaly in Hudson Bay. The nesting of sea level curves from west to east across Melville Peninsula suggests in a slightly different way that the present centre of uplift lay to the east of the peninsula. These curves and dates from archaeological sites on Igloolik and Jens Munk islands invite speculation that there is a late secondary rebound centre in the northern part of Foxe Basin, near the Baffin coast. Walcott (1972) shows present-day free air gravity lows north of Prince Charles Island near Baird Peninsula, which may also indicate this residual uplift area. The present rate of uplift at Hall Beach is about 70 cm per century over the last 1000 years.

The changes in marine limit observed along the escarpment in areas that should have been deglaciated simultaneously lead to speculation that there may be some tilting of a segment of the crust up to the northwest. The idea that parts of Foxe Basin are responding to postglacial rebound as a block is given some support by observations of seismicity along the Bell Arch (Basham *et al.*, 1977; Fig. 1), by possible postglacial faults cutting glaciated outcrop along Fury and Hecla Strait, and by the block tilting and faulting inferred in other parts of the central Arctic discussed by Dyke *et al.* (1990).

At the time of deglaciation, deep-water (> 50 m) conditions characterized the coastal environment. This factor, tidal differences, or Hypsithermal climatic conditions favouring less landfast ice and sea ice than present produced a high-energy coastal environment, as evidenced by a remarkable zone of erosion along the escarpment. The highest deltas formed along the open coast where glacial streams emptied into the sea and dropped their bouldery bedloads. Series of lower deltas developed in embayments where small streams entered the sea progressively as the land emerged. Long strandlines of limestone rubble developed over lowland terrain and continue to form at present, despite more than nine months of sea-ice cover per year. They originate as storm beaches, emerged bars, and spits. The angularity and shape of the beach material indicate that waves and ice-push activity have piled frost-shattered limestone into berms, with little reworking by waves (King, 1969). Frost-shattering is probably an active, ongoing process in shallow foreshore areas.

TABLE 2. Radiocarbon dates from archaeological sites, Eastern Melville Peninsula and Jens Munk Island

Site	Elevation (m)	Material	^{14}C age	Laboratory number	Reference*
Alarnek					
Dorset	22	ivory	2910 ± 129	P-213	2,3
Dorset	22	antler	2404 ± 137	P-212	2,3
Thule	2-6	?	1100		1
Kaleruserk (Igloolik)					
Pre-Dorset	52	ivory	3958 ± 168	P-207	2,3
Pre-Dorset	52	antler	3560 ± 123	P-208	2,3
Pre-Dorset	51	ivory	3906 ± 133	P-209	2,3
Pre-Dorset	51	antler	3700 ± 300	K-505	2,4
Kapuivik (Jens Munk)					
Pre-Dorset	44	antler	2898 ± 136	P-210	2,3
Pre-Dorset	24	antler	2354 ± 135	P-211	2,3

*References: 1) Andrews *et al.*, 1971; 2) Rainey and Ralph, 1959; 3) Ralph and Ackerman, 1961; 4) Tauber, 1960.

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