

## Glacial and Sea Level History of Lowther and Griffith Islands, Northwest Territories: A Hint of Tectonics

## Histoire glaciaire et évolution des niveaux marins aux îles Lowther et Griffith, Territoires du Nord-Ouest : quelques indices de tectonique

## Glazialgeschichte und Entwicklung des Meeresspiegels auf den Insein Lowther und Griffith, Northwest Territories: Ein Hinweis auf die Tektonik

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Article abstract

Lowther and Griffith islands, in the centre of Parry Channel, were overrun by the Laurentide Ice Sheet early in the last glaciation. Northeastward Laurentide ice flow persisted across at least Lowther Island until early Holocene déglaciation. Well constrained postglacial emergence curves for the islands confirm a southward dip of raised shorelines, contrary to the dip expected from the ice load configuration. This and previously reported incongruities may indicate regionally extensive tectonic complications of postglacial rebound aligned with major structural elements in the central Canadian Arctic Islands.

# GLACIAL AND SEA LEVEL HISTORY OF LOWTHER AND GRIFFITH ISLANDS, NORTHWEST TERRITORIES: A HINT OF TECTONICS

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**ABSTRACT** Lowther and Griffith islands, in the centre of Parry Channel, were overrun by the Laurentide Ice Sheet early in the last glaciation. Northeastward Laurentide ice flow persisted across at least Lowther Island until early Holocene deglaciation. Well constrained postglacial emergence curves for the islands confirm a southward dip of raised shorelines, contrary to the dip expected from the ice load configuration. This and previously reported incongruities may indicate regionally extensive tectonic complications of postglacial rebound aligned with major structural elements in the central Canadian Arctic Islands.

**RÉSUMÉ** Histoire glaciaire et évolution des niveaux marins aux îles Lowther et Griffith, Territoires du Nord-Ouest: quelques indices de tectonique. Les îles Lowther et Griffith, situées au centre du chenal de Parry, ont été recouvertes par l'Inlandsis laurentidien tôt au cours de la dernière glaciation. Un écoulement glaciaire vers le nord-ouest a persisté à l'île Lowther, tout au moins, jusqu'à la déglaciation au début de l'Holocène. Les courbes d'émersion bien identifiées de l'île confirment une inclinaison des plages soulevées vers le sud, contrairement à l'inclinaison prévue à partir de la configuration de la charge glaciaire. Ce fait ainsi que d'autres anomalies déjà signalées pourraient indiquer des complications d'ordre tectonique à l'échelle régionale au moment du relèvement isostatique postglaciaire correspondant aux principaux éléments structuraux des îles du centre de l'Arctique canadien.

**ZUSAMMENFASSUNG** Glazialgeschichte und Entwicklung des Meeresspiegels auf den Inseln Lowther und Griffith, Northwest Territories: Ein Hinweis auf die Tektonik. Die im Zentrum des Parry-Kanals gelegenen Inseln Lowther und Griffith wurden zu Beginn der letzten Vereisung durch die laurentidische Eisdecke bedeckt. Der laurentidische Eisfluß in Richtung Nordosten hat zumindest über die Insel Lowther hinweg bis zur frühen Holozan-Enteisung gedauert. Die deutlich erkennbaren postglazialen Auftauchkurven der Inseln bestätigen eine Neigung der angehobenen Küstenlinien nach Süden, entgegen der Neigung, die man entsprechend der Eismassenkonfiguration erwartet hätte. Dies und zuvor schon aufgezeigte Anomalien könnten auf regional extensive tektonische Komplikationen beim postglazialen isostatischen Rückprall hinweisen, entsprechend den wichtigsten strukturellen Elementen der Inseln im Zentrum der kanadischen Arktis.

## INTRODUCTION

This paper presents new radiocarbon-dated emergence curves for Lowther and Griffith islands in an attempt to better define the apparently incongruous crustal deformation pattern in that area (Dyke *et al.*, 1991). Additional observations of the glacial geology of the islands extend earlier conclusions.

## REGIONAL CONTEXT

Islands south of Barrow Strait, the central segment of Parry Channel (Fig. 1), were strongly affected by the Late Wisconsinan Laurentide Ice Sheet, but the islands north of the strait are thought to show evidence of glaciation by either the (still hypothetical) Innuitian Ice Sheet or by local ice caps during the Late Wisconsinan (Blake, 1970; Dyke and Prest, 1987; Dyke and Dredge, 1989; Hodgson, 1989). Laurentide erratics occur on the northern islands (Barnett *et al.*, 1976) but have been considered to date from an earlier advance possibly because no Laurentide ice frontal deposits of Late Wisconsinan age are recognized in the region. Lowther and Griffith islands rise from Barrow Strait. Lowther Island is near the middle of the strait whereas Griffith Island is near the northern side.

Although they have received only cursory attention, the Late Wisconsinan Laurentide Ice Sheet limit has been placed between Lowther and Griffith islands. Prest *et al.* (1968) arbitrarily drew the Laurentide "Classical Wisconsin" limit between the islands, but both islands might well have been placed either within or beyond the limit as no observations were available on the glaciation of either at that time (V.K. Prest, personal communication, 1992). The intention was merely to indicate that the limit lay north of Prince of Wales and Somerset islands and south of Bathurst and Cornwallis islands. However, the speculation that the limit lay between Lowther and Griffith islands was bolstered when Barnett *et al.* (1976) reported evidence of "fresh" Laurentide glaciation on Lowther Island in the form of generally northward trending striae and of till rich in shield erratics; similar evidence was not reported from Griffith Island (Barnett *et al.*, 1976). Consequently, a Late Wisconsinan limit between the islands fitted comfortably with Dyke's (1978; *cf.* Edlund, 1991) interpretation of the limit of Laurentide glaciation on Somerset Island.

## INCONGRUOUS CRUSTAL DEFORMATION PATTERNS

Recent work on the pattern of postglacial emergence in the central Arctic Islands (Dyke *et al.*, 1991) stimulated the need for additional data from Lowther and Griffith islands. Dyke *et al.* presented 14 emergence curves for Prince of Wales and neighbouring smaller islands based on 130 new radiocarbon dates. Most dates are on driftwood logs and bowhead whale bones from raised beaches. These are the ideal materials for documenting sea level history because they are well preserved, both float for a long time, have high stranding potentials, and are immobilized by burial in the beach upon stranding. The wood and bone dates are supplemented by dates on shells mainly from ice-proximal glaciomarine sediments, hence associated with marine limit. An

additional 14 emergence curves from the adjacent central Arctic region and numerous isolated radiocarbon samples, mainly of early Holocene (deglacial) age, completed the data base for a series of isobase maps.

Dyke *et al.* concluded that all emergence curves for Prince of Wales Island follow a smooth exponential decay form with a half-response time of 2000 years, and thus resemble most other curves published for Arctic Canada (*e.g.* Blake, 1975). But the spatial pattern of postglacial crustal deformation in the central Arctic deviates from a normal glacioisostatic pattern due to tectonic complications (Fig. 2). These tectonic anomalies most strongly affect early postglacial shorelines in the area of best dating control. They comprise: (1) a ridge-like deformation over the structural Boothia Arch on Somerset Island and Boothia Peninsula with an amplitude of 60-120 m, and (2) a lack of delevelling on Prince of Wales Island that resulted in a large "isobase plateau". The isobase ridge dissipated quickly but the plateau persisted throughout the Holocene. Further explanation of the data, as well as of assumptions and sources of error in both radiocarbon dates and elevation measurements, are in the original paper. But the features of importance here are far too large in extent and amplitude to result from any fortuitous convergence of errors in either dating or elevation in such a large data base.

In contrast to the well controlled emergence pattern on and east of Prince of Wales Island, isobase patterns north of Prince of Wales Island were poorly constrained. But the general pattern (Fig. 2) pointed to a further element that was incongruous with the known or inferred pattern of glacial loading and that, therefore, may suggest further tectonic complication. Dyke *et al.* pointed out that the northern uplift cell, which either is centred on or has the southern end of its axis on northern Bathurst Island, is problematic and bears consideration in this regard.

There are two contrasting current models of the last glaciation of the Bathurst Island area. One model proposes that Bathurst Island lay beneath the south-central part of an Innuitian Ice Sheet, which is thought to have covered all or most of the islands north of Parry Channel (Blake, 1970; Prest, 1969; McLaren and Barnett, 1978; Mayewski *et al.*, 1981); the other model proposes that Bathurst Island, along with Melville, Cornwallis, Devon, Ellesmere and Axel Heiberg islands, supported large local ice caps that were partly coalescent (England, 1976; England and Bednarski, 1989; Dyke and Prest, 1987).

Local ice caps (model 2) on Melville, Bathurst, Cornwallis and Devon islands would have constituted merely an extension of the Laurentide Ice Sheet load because they were close to and largely coalescent with the Laurentide margin. They would not, therefore, have generated a separate uplift centre like that illustrated on Figure 2 unless their retreat were delayed greatly after Laurentide deglaciation; judging from available radiocarbon dates (Hodgson, 1989; Dyke and Prest, 1987), this does not seem to have occurred. Even a pervasive Innuitian Ice Sheet (model 1) over the islands north of Parry Channel would not have generated a separate uplift centre (with closure of isobases) unless its southern axial part were thicker than the coalescent axial part of the Laurentide Ice Sheet.

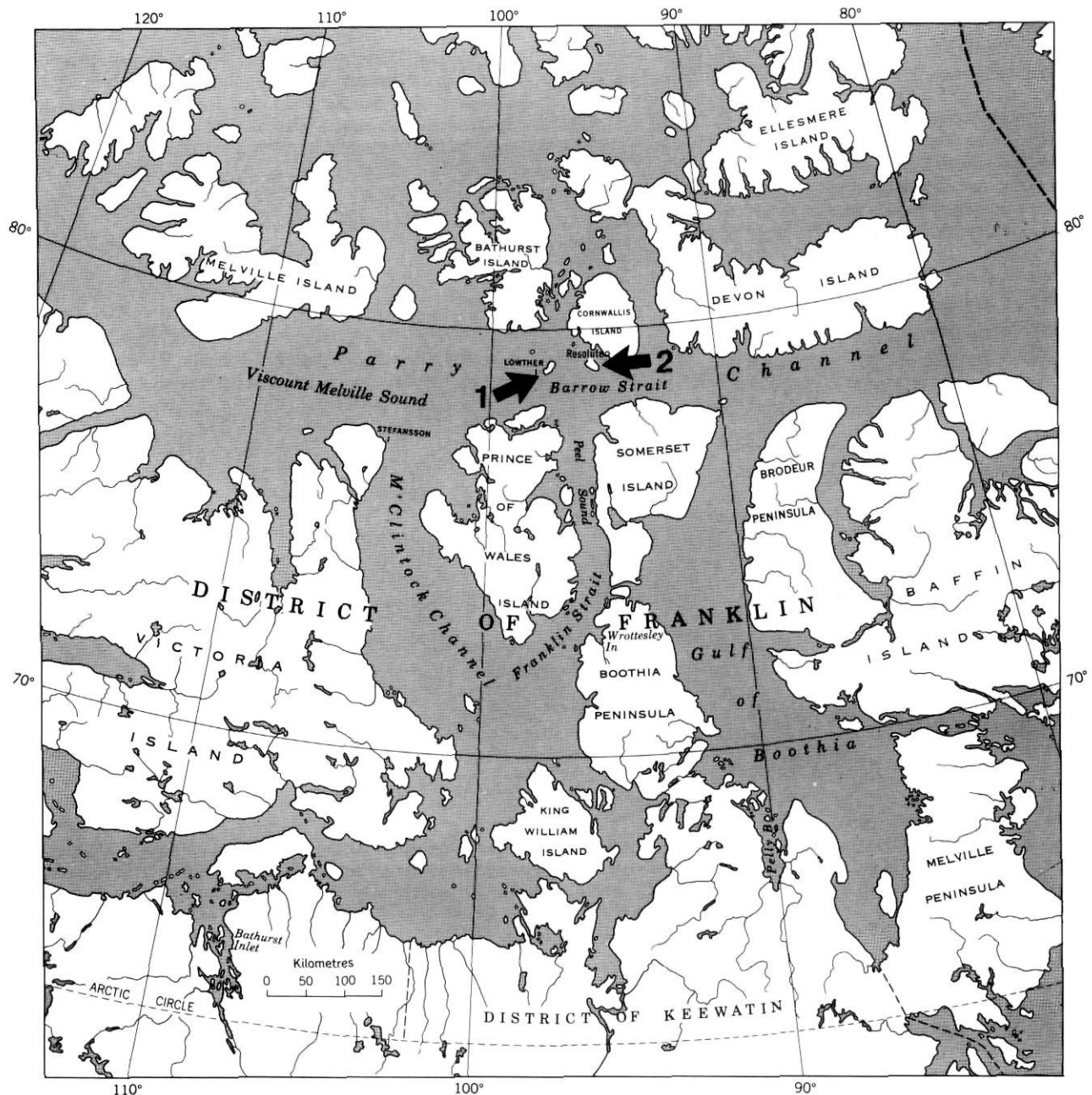


FIGURE 1. Location of the study area in the central Canadian Arctic Archipelago. Arrows 1 and 2 locate Lowther and Griffith islands, respectively.

Localisation de la région à l'étude au centre de l'archipel arctique canadien. Les flèches 1 et 2 identifient les îles Lowther et Griffith, respectivement.

Isobase values, as shown by Dyke *et al.* (1991; Fig. 2), decline from central Bathurst Island to Prince of Wales Island, remain low across Prince of Wales Island, and then ascend to the southern (Laurentide) uplift south of Prince of Wales Island. A straightforward interpretation would place the boundary between the dominant glacioisostatic effects of the Laurentide and Innuitian ice sheets east to west across central Prince of Wales Island. However, this is unacceptable because of clear evidence that the Laurentide Ice Sheet extended into and across western Parry Channel (Viscount Melville Sound; Hodgson *et al.*, 1984). Hence, the ice load

increased southward across Prince of Wales Island, not northward from Prince of Wales Island to northern Bathurst Island. There is no evidence that any archipelago-centred ice sheet ever flowed southward across Parry Channel or Prince of Wales Island, let alone during the Late Wisconsinan (Dyke *et al.*, 1992).

Thus, it appeared that the northern postglacial uplift cell may not be simply glacioisostatic; there appeared to be a serious mismatch between the southward slope of the northern uplift, as reconstructed by Dyke *et al.* (1991; Fig. 2), and the known and inferred Late Wisconsinan glacial history.



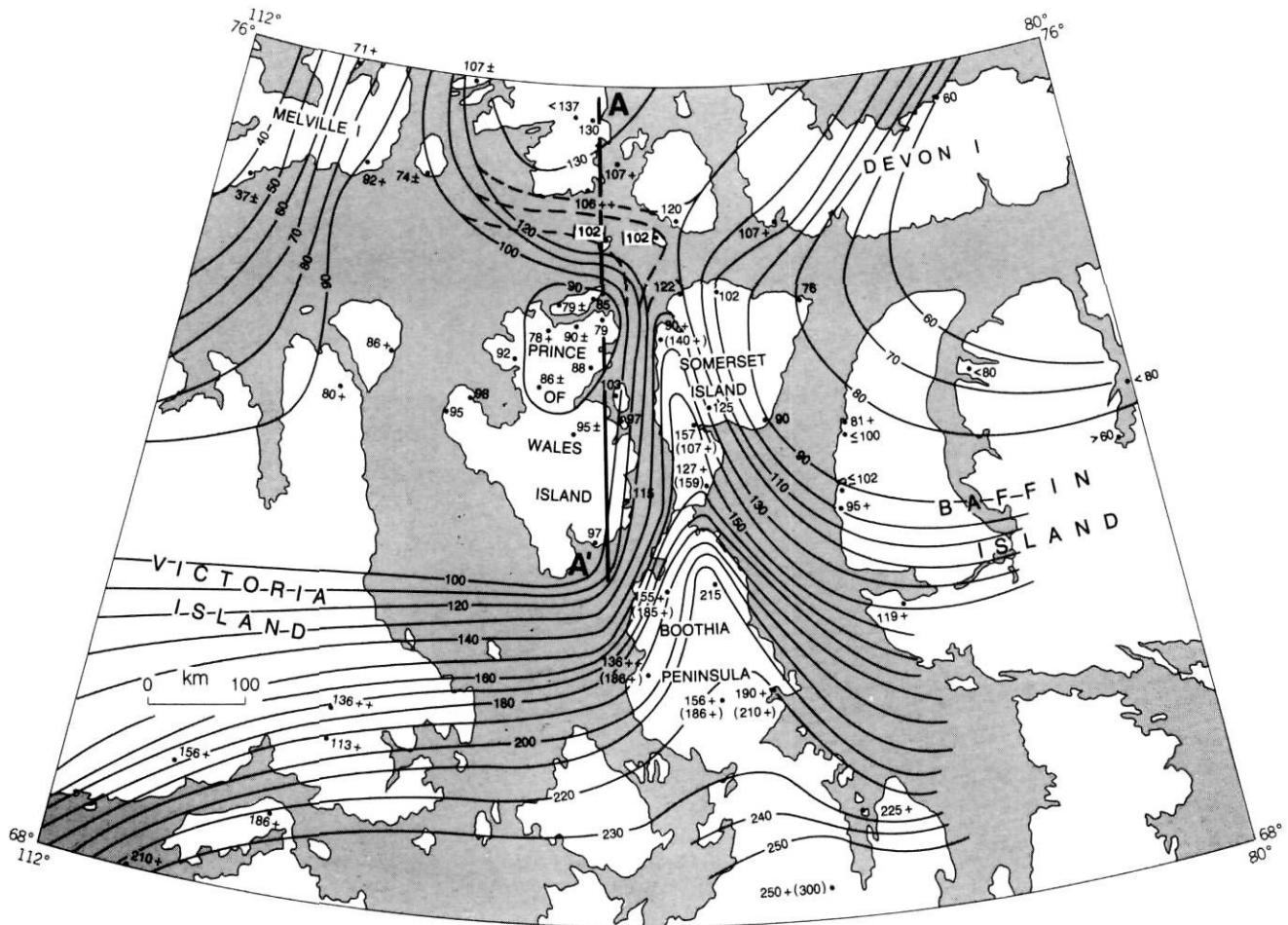


FIGURE 2. Isobases on the present elevation (metres) of the 9300 BP shoreline in the central Canadian Arctic, from Dyke et al. (1991) with modification (broken isobases) for new data. Elevations given without qualifications are from well controlled relative sea level curves; elevations from minimum emergence curves are followed by a plus sign (+); and elevations from poorly controlled, extrapolated curve segments are followed by a plus or a minus sign ( $\pm$ ). Elevations followed by a double plus sign (++) are those of shell samples that date substantially younger than 9.3 ka. The line of profile (A-A') is used for Figure 8.

*Isobases du littoral de 9300 BP appliquées aux altitudes actuelles au centre de l'Arctique canadien, tirées de Dyke et al. (1991) et comprenant de nouvelles données (tiretés). Les altitudes identifiées non accompagnées de signes proviennent de courbes relatives du niveau marin sûres; accompagnées d'un +, les altitudes proviennent de courbes d'émersion minimales; accompagnées d'un  $\pm$ , elles proviennent de segments extrapolés non vérifiés; les altitudes accompagnées de ++ proviennent d'échantillons de coquilles dont la datation est nettement inférieure à 9,3 ka. Le tracé A-A' sert à la figure 8.*

Furthermore, the much greater uplift on Bathurst Island, just beyond the Laurentide limit, than on Prince of Wales Island, well inside the Laurentide limit, seemed odd in light of either model of glaciation of Bathurst Island. Therefore, Lowther and Griffith islands, which lie in the critical area of the mismatch, were visited to better define their glacial and sea level histories. Two central questions are addressed: (1) were the islands overridden by Laurentide ice during the last glaciation, and (2) do shorelines rise northward across all of Barrow Strait or does the Prince of Wales isobase plateau extend farther northward than previously shown?

## GLACIAL GEOLOGY

### LOWTHER ISLAND

Lowther Island has an extensive till cover and bears evidence of moderately strong glacial scouring. Many bedrock-

basin lakes occur in the limestone and dolomite, and ice moulding of bedrock has created asymmetric linear forms in three areas indicating pervasive northeastward flow (Fig. 3). The ice moulding is apparent on airphotos and striae are in the same direction on stossed outcrops at three other sites. A fourth striae set as plotted on northeastern Lowther Island has the same general direction. Its slight deviation could represent a deglacial shift in flow or merely the inherent inaccuracy of azimuth determinations near the magnetic pole.

Superimposed striae measured at two sites record shifts in flow direction that likely date from deglaciation. Near the northwest corner of the island, the strong northeastward striae are lightly overprinted by striae with a nearly east-west orientation. The younger flow did not reshape the outcrop nor leave other directional indicators. On the south-central part of the island, D.M. Barnett (GSC, unpublished field notes) observed light north-south oriented striae superimposed on

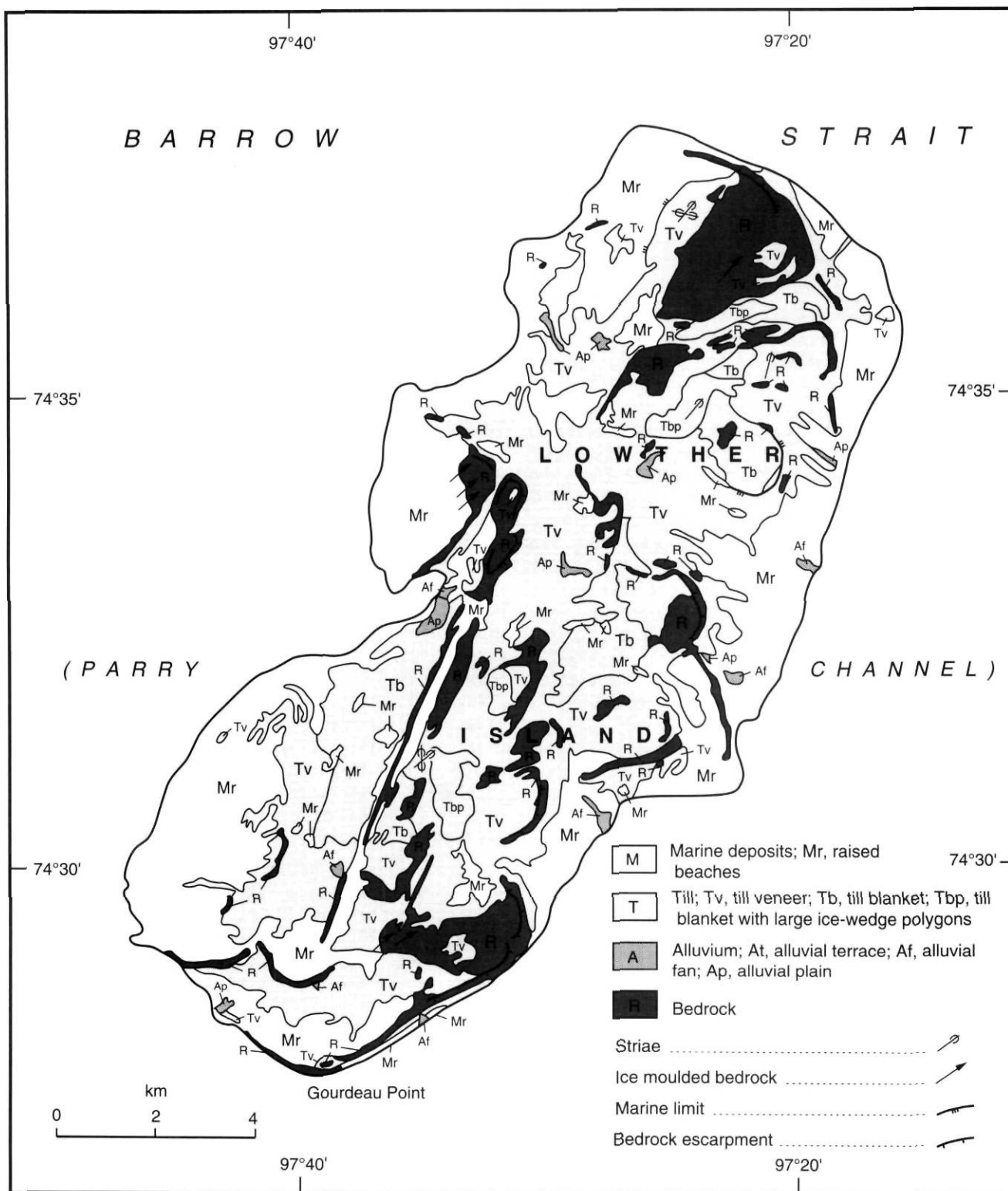


FIGURE 3. Surficial geology of Lowther Island.

*Géologie des formations superficielles de Lowther Island.*

strong northeast striae. Here again the sense of the younger flow could not be determined.

The younger striae at the northwest site could have been formed either by coastward flow of a local ice cap, isolated on the island during deglaciation, or by onshore flow of an outlet glacier flowing along Barrow Strait. The former is more probable in that the striae are so light. The south-central site suggests flow of a local ice cap in that the striae are oblique to the strait. Because there are no clear ice marginal features on the island, better resolution of the pattern of deglaciation will have to await more extensive striae mapping.

The till sheet resembles till on similar bedrock elsewhere in the region, both north and south of Parry Channel. Sand/silt/clay ratios of the matrix fraction are approximately 40/30/30 and the material typically is moderately stony (10-50% stones by volume). Stones are dominantly local carbonate rock. Red sandstone clasts are locally abundant to dominant in the vicinity of the only known area of outcrop of red sandstone on the island (Thorsteinson, 1986). Elsewhere red sandstone appears to be the most common erratic, slightly exceeding granite and gneiss, although all combined comprise only a few percent of clasts. Granite and gneiss erratics are widespread and are undoubtedly of Laurentide origin. The red sandstone erratics, other than those in the vicinity of the one red sandstone outcrop area, are more likely of southern than local provenance; red sandstone crops out broadly on northern Prince of Wales and neighbouring islands (Blackadar, 1967; Dyke *et al.*, 1992) and extends an unknown distance offshore toward Lowther Island. These sandstones were crossed by the northeastward Laurentide flowlines recorded by striae and ice moulded rock on Lowther Island. Hence, the last (and only recorded) advance of Laurentide ice across the island can fully account for the observed erratics. There is no evidence on the island of any southward flow from an Innuitian Ice Sheet.

#### GRIFFITH ISLAND

Griffith Island bears evidence of weak glacial scouring in the form of small rock-basin lakes in limestone and dolomite on its south and west flanks, but its extensive till cover indicates complete glaciation (Fig. 4). There are no large ice moulded forms to indicate a direction of ice flow, but the preferential scouring of the southwest part may indicate that the flow came from that direction. Striae were observed at a single site, near Dyers Cove, on rock protruding from raised beach gravel, which is likely but not certainly bedrock. The large valley that is partly submerged to form Dyers Cove lies along a Tertiary graben (Thorsteinsson, 1986) but may have been glacially modified by northwestward ice flow as suggested by the striae and by the oversized form of the valley.

Griffith Island till closely resembles till on Lowther Island in both lithic composition and texture. Granite, gneiss, and red sandstone erratics of southern (Laurentide) provenance are sparse but widespread. The red sandstone erratics here could have come from Prince of Wales and neighbouring smaller islands, from northwestern Somerset Island or from offshore extensions of either of these large occurrences. Pink-weathering siltstone (or muddy limestone) and black

shale erratics occur locally and possibly came from bedrock on the island. Rare, comminuted, Pleistocene marine shells also occur as erratics on the till surface above marine limit.

Erratic shells offer a means of constraining the timing of the last ice advance. Washburn and Stuiver (1985) radiocarbon dated *Hiattella* fragments from till above marine limit on the northern plateau of Griffith Island at  $41\,000 \pm 1200$  BP (QL-1870). Radiocarbon dates on shells in this age range, even those reported as finite, are normally taken as minimum age estimates.

Amino acid ratios from erratic *Hiattella arctica* shells near Resolute Bay, Cornwallis Island (Washburn and Stuiver, 1985) and from sites on Prince of Wales Island (Dyke *et al.*, 1992) indicate that a range of ages of shells occur in the till, as might be expected. But the youngest erratic shells, those with the lowest ratios, fall in group 2 of Dyke and Matthews (1987), which they interpreted to be of Sangamonian age. Paired *Hiattella arctica* shells with group-2 amino acid ratios in ice-proximal glaciomarine sediment below Wisconsinan Laurentide till on northeastern Prince of Wales Island yielded a uranium-series age of about 80 ka (Dyke *et al.*, 1992). This age estimate supports the Sangamonian age assignment of amino-acid group 2 and places the Laurentide ice advance in the region in the Early Wisconsinan. This chronological framework suggests that Laurentide ice crossed Griffith Island (hence also Lowther Island) and at least southern Cornwallis Island after the Sangamonian, before 41 ka, and likely around 80 ka. This advance may have enveloped all of Cornwallis and Bathurst islands for Laurentide erratics are widespread on both and there is as yet no stratigraphic basis to warrant assigning Laurentide erratic dispersion north of Barrow Strait to more than one event. Indeed, current stratigraphic and chronological information does not preclude a massive Laurentide advance during the Early Wisconsinan to the northwestern continental shelf.

The placement of the Late Wisconsinan Laurentide ice limit between Lowther and Griffith islands (e.g. Prest *et al.*, 1968) does not contradict observations, including those outlined above. But it is also not confirmed by observation, especially as the postulated limit does not follow any mapped ice marginal feature. Till on both islands is very similar, and is at least in part of Laurentide origin on both. For the present, till on both islands should be taken as being of the same age because there is no appreciable difference in morphology or weathering. A Laurentide ice flow pattern is well imprinted on Lowther but not on Griffith island, except perhaps in the preferential scouring of the southwest side. This difference may indicate, but does not demonstrate, later Laurentide ice cover of Lowther.

There is further argument for placing the Late Wisconsinan Laurentide limit well north of Lowther Island. Late Wisconsinan Laurentide ice impinged on Melville and Byam Martin islands to the west, laying down Winter Harbour Till (Hodgson *et al.*, 1984). It is not known to have impinged on Bathurst Island, but little work has been done there. The strong, parallel (non diverging) flow of warm-based ice across Lowther Island indicates that the ice was thick and, therefore, that it extended well north of the island. It could not have

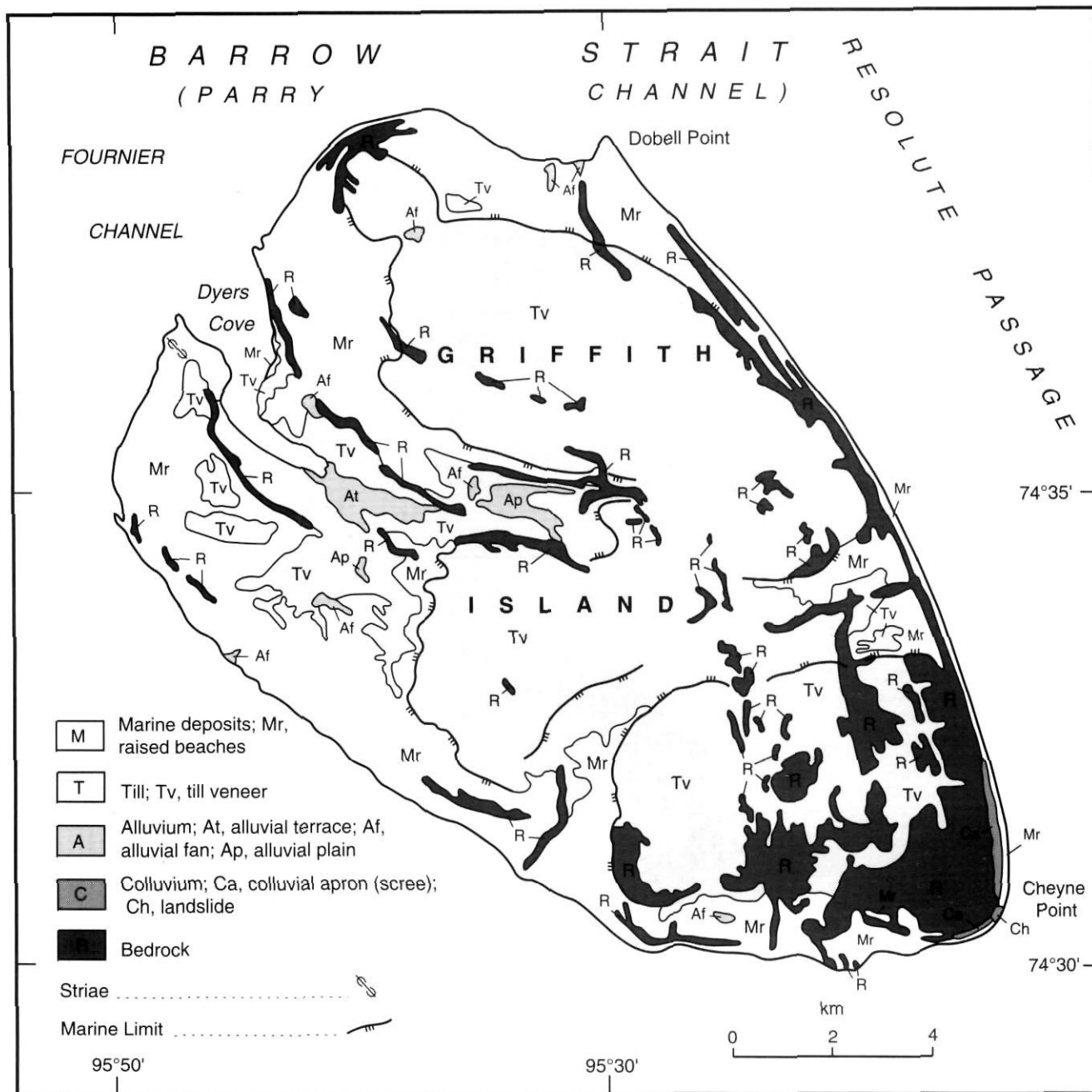


FIGURE 4. Surficial geology of Griffith Island.

*Géologie des formations superficielles de Griffith Island.*

stopped much short of the south coast of Bathurst Island, which is only 40 km farther down flow.

Still the patterns of ice retreat are profoundly different on either side of central and western Parry Channel. South of the channel, the ice retreat landforms indicate systematic withdrawal of Laurentide ice, abutted on northern Somerset Island by a large local ice cap (Dyke, 1983, 1984; Dyke *et al.*, 1992). North of the channel, the ice retreat landforms indicate only retreat of large island-centred local ice caps. The striae

record of Lowther Island suggests that it lay under warm-based Laurentide ice until the early stages of deglaciation, when a local ice cap may have formed and briefly persisted. The apparent rarity of striae on Griffith Island and lack of a clear Laurentide flow pattern possibly indicate that the ice cover there was less erosive or cold based; furthermore, the ice cover there may have been reconfigured earlier to that of a local ice cap, centred either on Griffith Island itself or on Cornwallis Island.



## SEA LEVEL HISTORY

### MARINE LIMITS

#### Lowther Island

Most of Lowther Island is rimmed by raised beaches. The beaches extend to various elevations but the highest at several localities plot at the 105 m level as read from newly available 1:50 000 scale topographic maps (Fig. 5). The highest beach on northwestern Lowther Island was measured by altimeter at 106.5 m. Till above this level shows no evidence of modification by waves, so it appears to represent marine limit. D.A. Hodgson (GSC, unpublished field notes, 1983) measured by altimeter the elevation of a break in slope that lies at or just below the highest faint beach traces on north-eastern Lowther Island at 103 m.

Still one previous observation indicates that the marine limit may be higher than 107 m. W. Blake, Jr. collected *Hiatella arctica* fragments in 1963 from the surface of till-like

material on northwestern Lowther Island (74°33'N, 97°31'W, as reported), at an altitude of about 112-119 m (370 to 390 ft, as reported; Lowdon *et al.*, 1967). These shells dated  $9470 \pm 150$  BP (GSC-322) and came from above the highest obvious beaches near the site, about 5-12 m lower. The lower end of the reported shell sample elevation range is not significantly higher than the feature thought here to represent marine limit elsewhere on northwestern Lowther Island, given a reasonable inaccuracy of 5% in altimetry, but the upper end is. Dyke *et al.* (1991) took Blake's stated elevation range to represent the vertical extent of the shell collection area, and hence assigned the sample a minimum relative sea level of 119 m (Fig. 2). However, the elevation range instead represents two altimeter measurements of the elevation of the same point (W. Blake, Jr., personal communication, 1992) and the 7 m discrepancy (370 vs 390 ft) is a minimum for the possible error on that measurement. Hence, a lower value should be used for the minimum relative sea level to which the dated shells pertain.

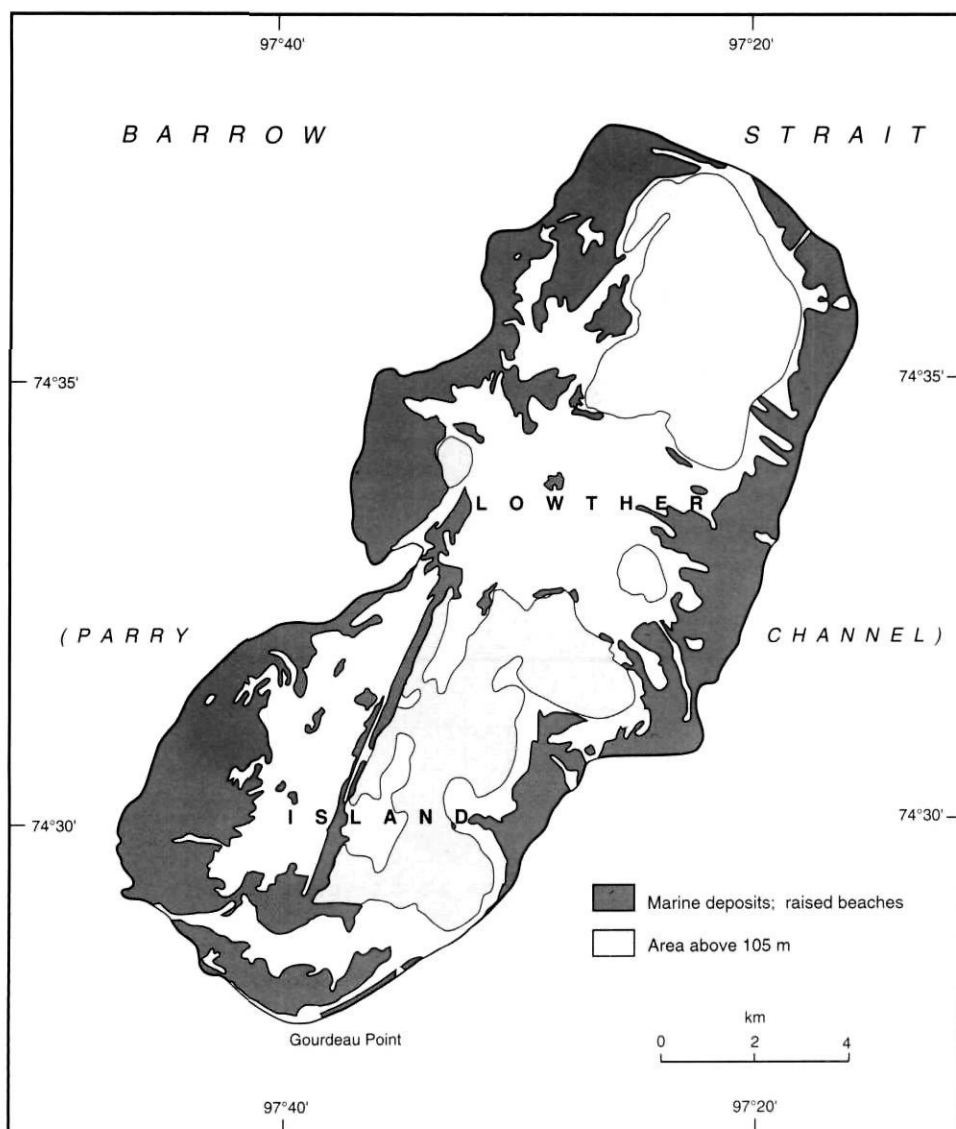


FIGURE 5. Distribution of raised beaches with respect to the 105 metre contour (taken from a 1:50 000 scale topographic map) on Lowther Island.

Répartition des plages soulevées en fonction du niveau de 105 m (à partir d'une carte topographique à 1/50 000) de Lowther Island.

Attempts to verify this sample elevation failed. No original plotting of the sample on an airphoto is available. Plotting the reported coordinates on the new 1:50 000 scale topographic map with a 10-metre contour interval is unhelpful because the location does not fit the description with regard to either position on the island or to elevation. This simply results from inaccurate horizontal control on the preliminary map of much smaller scale available in 1963. Given this uncertainty, for the purpose of this paper, I regard the Lowther Island marine limit to be at 107 m, the age of which is closely limited by GSC-322 ( $9470 \pm 150$  BP).

#### Griffith Island

Marine limit has a much stronger morphological expression on Griffith Island than on Lowther Island. Raised beaches on Griffith Island rise so consistently to the 105 m level (Fig. 6), with apparently unmodified till upslope from there, that this level almost certainly represents the limit of submergence. Elsewhere, where high beaches do not occur, a sharp airphoto lineament on till follows the same contour. This lineament, a common feature throughout the central Arctic, represents the limit of wave modification of till, the so-called washing limit.

The clearer expression of the marine limit shoreline on Griffith than on Lowther Island is due to the slightly higher and

simpler topographic form of central Griffith Island. When the marine limit shoreline was forming, Griffith Island consisted of two large islands in deep to moderately deep water; Lowther Island, in contrast, consisted of several smaller islands with much of their coastlines rising from shallow water because marine limit is just above the surface of much of the island.

The coincidence, within reasonable precision, of the clear marine limit on Griffith Island with the upper limit of beaches on Lowther Island, measured at 106.5 m, suggests that the latter is also a valid determination of marine limit. The similarity of marine limit elevations on the two islands suggests similar dates of deglaciation.

#### RELATIVE SEA LEVEL CURVES

##### Lowther Island

Aside from the unavoidable ambiguity about the exact marine limit elevation and the pertinent relative sea level for shell date GSC-322 ( $9470 \pm 150$  BP), the Lowther Island emergence curve is well controlled and among the best available for the central Arctic Islands (Fig. 7a, Table I). Eight accordant dates on driftwood plot, with negligible scatter, along a smooth exponential curve. Another date on the dense, well-preserved, ear bone of a bowhead whale fits the wood-based curve, without correction. All these dated materials were found shallowly buried, partly exposed, in raised

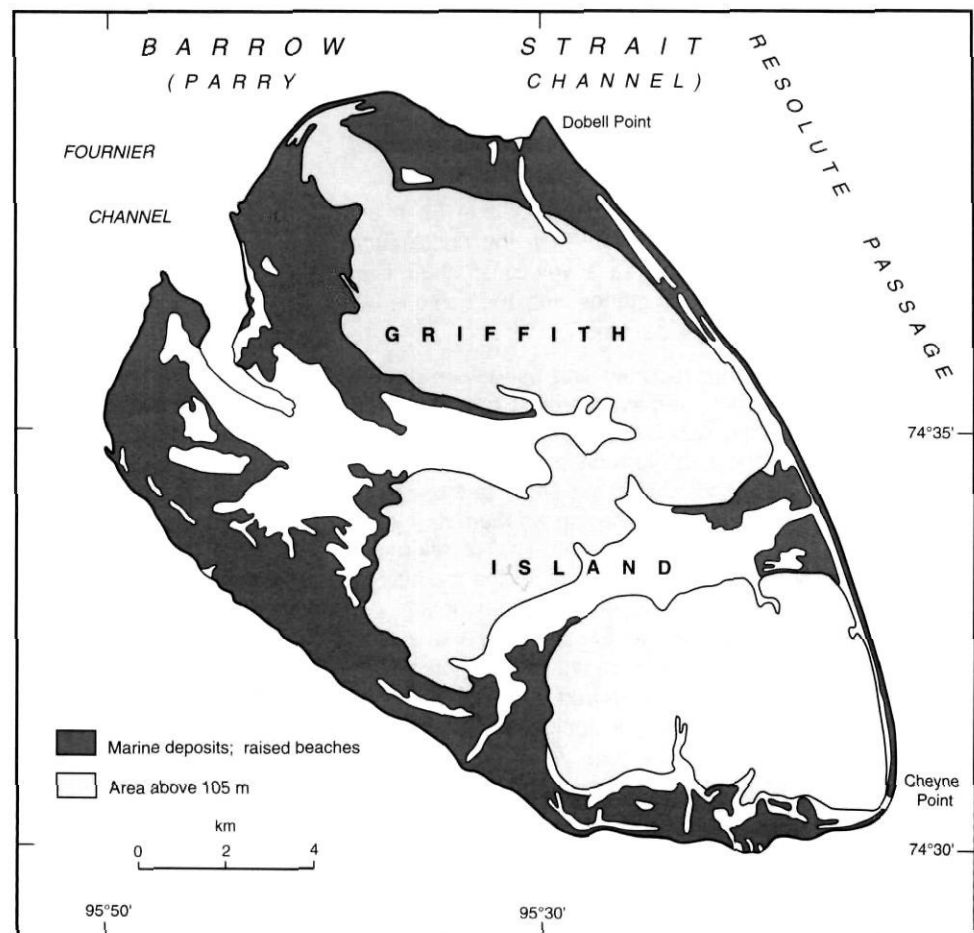


FIGURE 6. Distribution of raised beaches with respect to the 105 metre contour (taken from a 1: 50 000 scale topographic map) on Griffith Island.

*Répartition des plages soulevées en fonction du niveau de 105 m (à partir d'une carte topographique à 1/50 000) de Griffith Island.*

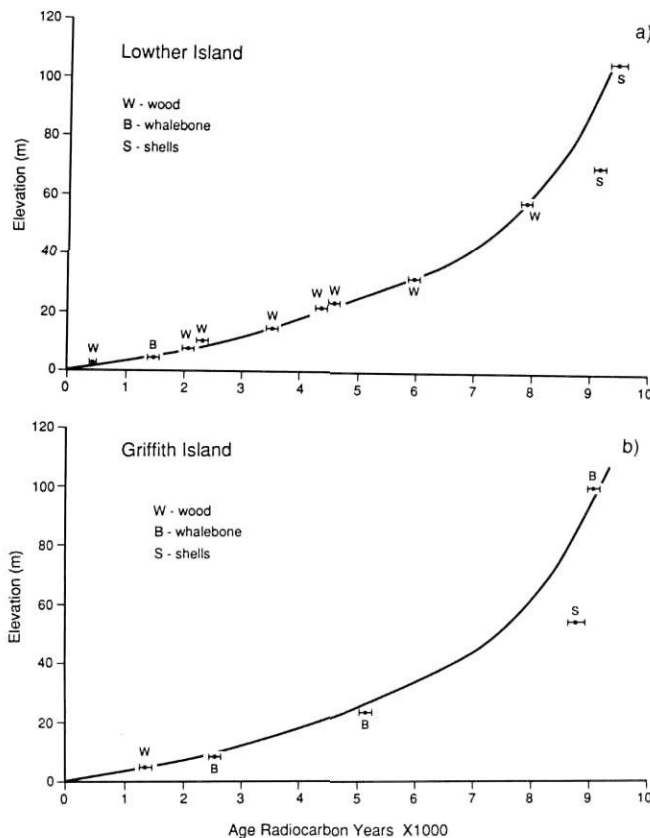


FIGURE 7. a) Emergence curve for Lowther Island. b) Emergence curve for Griffith Island; this curve is a trace of that for Lowther Island.

a) Courbe d'émergence de Lowther Island. b) Courbe d'émergence de Griffith Island: cette courbe est calquée sur celle de Lowther Island.

beaches. The oldest driftwood was collected at 58 m and dated  $7910 \pm 70$  BP (GSC-4841). Thus, the entire curve below 60 m and younger than 8 ka is well constrained. If we accept the 107 m shoreline as marine limit, the curve is well constrained for all of postglacial time.

Radiocarbon dates are reported and used here as they have been in most earlier studies of Arctic Canada in order to maintain compatibility within the region. Wood dates are corrected for  $^{13}\text{C}$  fractionation to a base of  $-25$  per mil with respect to the PDB standard. Marine shell dates are corrected to a base of 0 per mil, which makes them 410 years younger than if corrected to  $-25$  per mil. The intention is to apply a uniform correction of this amount for the marine reservoir age. Mangerud and Gulliksen (1975) suggested that the present reservoir age in the Ellesmere Island area is about 750 years, although this is based on only three samples. If correct, reported shell ages from this region are still slightly too old. But the choice of appropriate corrections, especially during the early Holocene when oceanographic circulation patterns in the central Arctic were quite different than now (Dyke and Morris, 1990), remains open. Whale bone dates are reported here in uncorrected form. No radiocarbon dates are available on whales harvested from this region at documented times before atomic bomb testing. If the same corrections are appropriate for molluscs and

whales, the bone dates (mean  $\delta^{13}\text{C}$  of  $-16$  per mil) are about 250 years too old in comparison to shell dates from the region, if other sources of error are ignored. These considerations would have little effect on the Lowther Island curve because it is based mostly on driftwood.

Due to weather conditions, terrain above 60 m was not extensively prospected for shells, wood or bone, so future work may add useful control there. The highest shells (*Hiatella arctica*) collected in a single traverse across the centre of the island occurred as surface litter on thin beach gravel at 70 m and dated  $9160 \pm 90$  BP (GSC-4890). This date confirms that marine limit and deglaciation predate 9.2 ka. But it does not further constrain the top of the curve because there is no constraint on the depth of water in which the shells lived. Most shells collected from the surface well below marine limit fall far below any reasonable curve position as repeatedly demonstrated (see curves in Dyke *et al.*, 1991).

#### Griffith Island

We were less fortunate in recovering samples for radiocarbon dating from Griffith than from Lowther Island. The only driftwood found on the island was at 4.5 m elevation and dated  $1380 \pm 60$  BP (GSC-5074). However, remains of eleven bowhead whales (*Balaena mysticetus*) were located in raised beaches and four ear bone samples were collected; ear bones were missing from the others. Three bowhead ear bone samples were dated (Table I), yielding ages within the expected ranges. The highest sample at 98.5 m, about 7-10 m below marine limit, gave an uncorrected age of  $9110 \pm 110$  BP (S-3310), only about a century younger than expected based on the ages from Lowther Island and Resolute Bay (Washburn and Stuiver, 1985). Washburn also collected shells (*Hiatella* fragments) from the surface of a broad bedrock bench at the north end of the island at 53 m. This sample dated  $9230 \pm 140$  BP (QL-1866) with a fractionation correction normalized to  $\delta^{13}\text{C}$  of  $-25$  per mil with respect to the PDB standard. The equivalent age normalized to 0 per mil is  $8820 \pm 140$  BP and the sample is thus plotted on Figure 7b and recorded in Table I. Here again, this date does not helpfully constrain the top of the curve because there is no independent way of assessing the depth of water that the shells lived in.

Other bowhead whale remains were of poor quality and would likely have yielded radiocarbon ages seriously too young judging from previous experience (Dyke, 1980; Dyke *et al.*, 1991). This problem is further illustrated by a previous radiocarbon date from Griffith Island. James Bockheim collected bowhead whale bone from a raised beach on the southwestern part of the island at 91 m (bringing to 12 the number of known bowhead occurrences on this small island) and obtained a "collagen" date of  $6040 \pm 60$  BP (P-2141; reported in Washburn and Stuiver, 1985). As pointed out by Washburn and Stuiver, this date is much too young for a relative sea level at that elevation and should be discarded. The date, along with others (Dyke, 1980), illustrates that "collagen" extracted from bones for radiocarbon dating can remain significantly or severely contaminated by younger material. The effect of this contamination can be several times the opposing reservoir effect. We were unable to relocate this

TABLE I  
Radiocarbon dates on postglacial emergence of Lowther and Griffith islands

Laboratory number	Material dated	Elev (m)	Age <sup>1</sup> in <sup>14</sup> C years	Lat	Long
Lowther Island					
GSC-322	shells	112?	9470 ± 150	74°33'	97° 31'
GSC-4890	shells	70	9160 ± 90	74° 33.4'	97° 24'
GSC-4841	wood	58	7910 ± 70	74° 34'	97° 35'
GSC-4940	wood	32	6000 ± 70	74° 34'	97° 35.5'
GSC-4956	wood	23.5	4620 ± 80	74° 34.9'	97° 35'
GSC-2224	wood	21.5	4410 ± 70	74° 34'	97° 35.5'
GSC-4977	wood	14.5	3540 ± 60	74° 36.7'	97° 30.5'
GSC-4971	wood	10	2340 ± 60	74° 30.9'	97° 25.5'
GSC-4981	wood	7.5	2120 ± 60	74° 29.4'	97° 46'
S-3134	bone	4.5	1510 ± 80	74° 35.8'	97° 30.2'
GSC-4976	wood	2.5	430 ± 50	74° 35.4'	97° 32.7'
Griffith Island					
S-3310	bone	98.5	9110 ± 110	74° 35.7'	95° 46.5'
QL-1866	shells	53	8830 ± 140	74° 38'	95° 40'
P-2141	bone	91	6040 ± 60	74° 33'	95° 30'
S-3288	bone	23	5170 ± 80	74° 33.8'	95° 46.8'
S-3289	bone	7.5	2530 ± 70	74° 36.4'	95° 48.2'
GSC-5074	wood	4.5	1380 ± 60	74° 38.6'	95° 34'

<sup>1</sup> GSC-322, not corrected for isotopic fractionation; all other GSC dates corrected for <sup>13</sup>C fractionation to a base of -25 per mil with respect to the PDB standard for wood and 0 per mil for marine shells. S- dates, not corrected for isotopic fractionation. Measured <sup>13</sup>C fractionations are -15.2 per mil for S-3288, -15.7 per mil for S-3289, and -16.7 per mil for S-3310.

sample to see if ear bones or other good quality bone could be recovered.

The currently available dates from Griffith Island indicate an emergence history that is indistinguishable from that of Lowther Island. The curve of Figure 7b is a trace of the curve of Figure 7. It intersects or passes close to the four critical bone and wood samples while passing, as expected, well above the shell sample. More intensive searching of the raised beaches may yet improve this curve; the areas not searched, or least well searched, are at the north end east of Dyers Cove, the south coast, and the southeast coast.

## DISCUSSION

The purpose of this research was to improve data control for reconstructing the pattern of raised shoreline deformation in the area of Barrow Strait because of the apparent incongruity of southward dipping raised shorelines in an area thought to have been isostatically loaded by northward flowing Laurentide ice during the Late Wisconsinan. Observations of the glacial geology confirm earlier inferences regarding ice load configuration within Barrow Strait: the strait and its islands were overridden by Laurentide ice, likely during the Early Wisconsinan. The islands within the strait were deglaciated in the early Holocene, about 9.4 ka, with northeastward Laurentide ice flow persisting across at least Lowther Island until shortly before deglaciation when a local ice cap configuration may have developed.

The new relative sea level curves require local modification of the isobase patterns (e.g. Fig. 2) presented by Dyke *et al.* (1991). The modification involves mainly a compression of isobases northward toward southern Bathurst Island, steepening the apparent southward dip of shorelines on the northern side of Barrow Strait and extending the Prince of Wales Island "isobase plateau" northward. The revised isobases are thus brought into alignment with the north shore of Barrow Strait and with the Parry Islands Fold Belt (Dyke *et al.*, 1991).

The southward dip of raised shorelines well within the limit of northward flowing Laurentide ice remains an incongruous but apparently real phenomenon (Fig. 8). The shoreline gradients shown on Figure 8 across Barrow Strait are the lowest that presently available data allow. On this view, this is an extreme interpretation. The alternative, at the other extreme, is that the relatively low and horizontal early Holocene shorelines extend north of Lowther Island to the coast of Bathurst Island, where they rise abruptly.

Postglacial shorelines of all ages are uplifted substantially more just north of the zone of coalescence of Laurentide and northern ice (only 10-50 km behind the limit of northern ice) than at sites as much as 400 km south of the Laurentide limit. Yet sites hundreds of kilometres behind the Laurentide limit must have been much more heavily loaded than sites only a few tens of kilometres behind the limit of northern ice. Even in the vicinity of the Late Wisconsinan Laurentide limit in



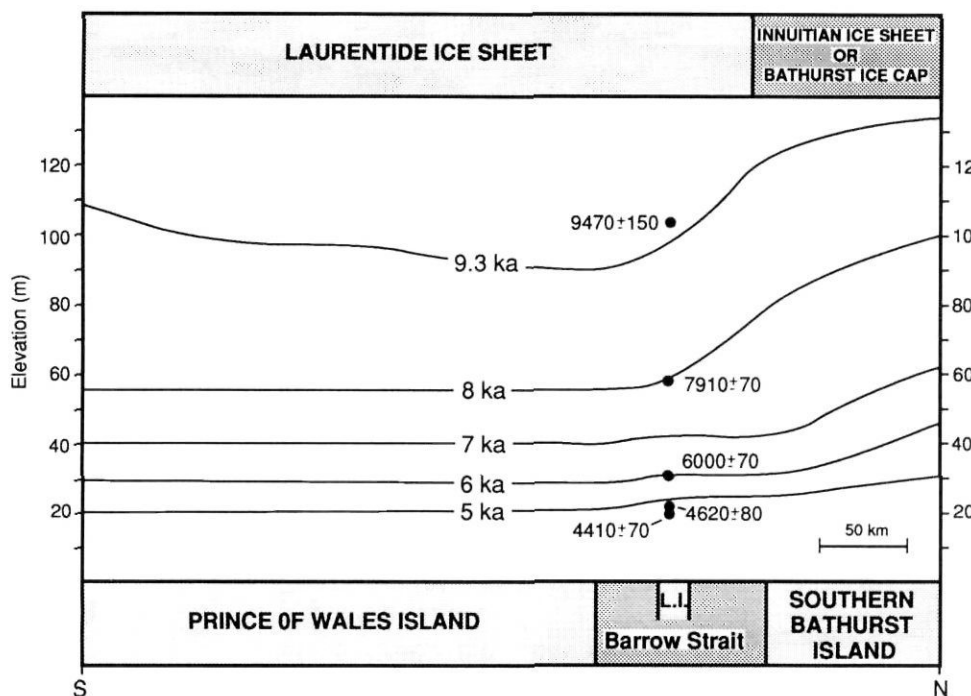


FIGURE 8. Shoreline profiles plotted along a north-south transect from Bathurst Island to Prince of Wales Island (Fig. 2); based on isobase maps in Dyke *et al.* (1991) modified to accommodate the new radiocarbon dates from Lowther and Griffith islands.

*Profils de littoraux relevés le long d'un transect nord-sud, de Bathurst Island à Prince of Wales Island (fig. 2); profils fondés sur les cartes d'isobases de Dyke et al. (1991) modifiées en fonction des nouvelles datations provenant des îles Lowther et Griffith.*

northern Barrow Strait, where Laurentide ice was necessarily at its thinnest, it must still have been thicker than the local ice on the plateau of southern Bathurst Island. Laurentide ice extended vertically from the floor of the strait to at least the level of the plateau 400 m above. Above that level, in the zone of coalescence, the two ice masses were equally thick. Why then does the 8 ka shoreline, for example, lie at 80-100 m elevation on southern Bathurst Island but at only  $55 \pm 3$  m on and south of Lowther Island?

There is no simple or satisfactory glacioisostatic explanation for this pattern that can presently be offered with any basis in observation. Even if the ice over Bathurst Island had a very steep surface gradient, such that its thickness a short distance to the north greatly exceeded that in the zone of coalescence, the isostatic effect of this thicker load would extend well south of Lowther Island because normal crustal rigidity spreads the effect more than 100 km beyond the load itself (Walcott, 1970; Farrell and Clark, 1976). Furthermore, there is no evidence of any Innuitian Ice Sheet advance across or south of Barrow Strait early in the last glaciation. Such an advance might explain greater uplift to the north provided that the subsequent Laurentide advance was only very late in the last glaciation and only brief. Given a half-response time of 2000 years (Dyke *et al.*, 1991), the shoreline deformation patterns likely do not include a memory of ice configurations much before the last glacial maximum. On the contrary, there is good evidence that Laurentide ice advanced across Barrow Strait and at least partly overlapped Cornwallis Island, likely early in the last glaciation. It is even possible, though by no means proven, that the advance enveloped all of Cornwallis and Bathurst islands. Certainly, shield erratic dispersion indicates that when Laurentide ice advanced entirely across the islands on the north side of Barrow Strait it was able to com-

pletely overwhelm and incorporate any island-centred local ice caps that it may have encountered.

It is too early to postulate a mechanism to explain the incongruous shoreline deformation pattern other than to re-emphasize that it may hint at tectonic complication of the general postglacial rebound process. The modified isobases along western Barrow Strait (Fig. 2) not only extend the Prince of Wales isobase plateau farther to the north but they now trend parallel to the Parry Islands Fold Belt (Dyke *et al.*, 1991), just as the isobases to the east trend parallel to the Boothia Arch. But data are still too sparse in the region to the north to properly evaluate this apparent correlation. Further progress in resolving this enigma will rely on a much expanded Holocene sea level data base for all islands along the north side of Parry Channel so that any further correlations between Holocene crustal deformation patterns and possible tectonic influences can be evaluated.

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