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FORMER ICE SHELVES IN THE CANADIAN HIGH ARCTIC

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ABSTRACT. Moraines deposited by the outermost ice advance across Judge Daly Promontory, north-eastern Ellesmere Island, reflect thin, topographically controlled ice lobes extending to sea-level. The termini of two ice lobes were investigated and both produced ice shelves where they flowed into isostatically depressed embayments along western Kennedy Channel. Morphological evidence for these ice shelves occurs at the entrance to these valleys where steeply descending lateral moraines become abruptly horizontal for 2 km. In addition, both the horizontal moraines and associated pro-glacial terraces are fossiliferous down-valley from the apparent grounding line. Based on the differences in elevation between the horizontal moraines and the valley bottoms, the two ice shelves had estimated thicknesses of *c.* 110 and 150 m. A pro-glacial outwash terrace at 175 m a.s.l. is considered to represent the approximate relative sea-level during the formation and break-up of the ice shelves. This relative sea-level is consistent with the water depths required to float the calculated ice thicknesses in both valleys. Associated with these ice margins are finite ^{14}C dates of 28 000–30 000 B.P. and amino-acid age estimates of >35 000 B.P. The importance and likelihood of additional past ice shelves in the Canadian High Arctic is discussed.

RÉSUMÉ. *Anciens glaciers dans le Grand Nord Canadien.* Des moraines déposées par l'avance extrême de la glace à travers le Judge Daly Promontory, au Nord-Est de l'Île d'Ellesmere, sont l'indice de lobes de glace peu épais contrôlés par la topographie et s'étendant jusqu'au niveau de la mer. On a examiné les extrémités de deux lobes de glace et tous deux ont engendré des platformes de glace lorsqu'elles flottaient dans des baies rendues plus profondes par l'isostasie le long de Kennedy Channel occidental. Des preuves morphologiques de l'existence de ces platformes subsistent à l'entrée de ces vallées lorsque les moraines latérales jusque là en pente prononcée deviennent brusquement horizontales sur 2 km. De plus, les moraines horizontales et les terrasses pro-glaciaires associées sont fossilifères à l'aval de la ligne de rivage apparente. En se basant sur la différence d'altitude entre les moraines horizontales et les fonds de la vallée, les deux glaciers avaient des épaisseurs estimées à 110 et 150 m. Une terrasse pro-glaciaire alluviale à 175 m au-dessus du niveau de la mer est considérée comme représentant le niveau relatif approximatif de la mer pendant la formation et la disparition des glaciers. Ce niveau de la mer est cohérent avec les épaisseurs d'eau requises pour permettre que flotte l'épaisseur de glace calculée dans les deux vallées. A ces formations périglaciaires sont associées des datations au carbone 14 de 28 000 à 30 000 ans avant le présent et des amino-acides âgés de 35 000 ans. L'importance et la vrai semblance de l'existence de glaciers supplémentaires dans le passé du Grand Nord Canadien sont discutées.

ZUSAMMENFASSUNG. *Frühere Schelfeise in der Kanadischen Hoch-Arktis.* Moränenablagerungen vom äussersten Vorstoss des Eises über das Judge Daly-Vorgebirge im Nordosten von Ellesmere Island lassen auf dünne Eisloben schliessen, die sich dem Gelände anschmiegten und bis zur Küste reichten. Die Untersuchung der Ränder zweier solcher Eisloben ergab, dass sie beide dort, wo sie in isostatisch abgesenkte Buchten längs des westlichen Kennedy-Kanals flossen, Schelfeise bildeten. Der geomorphologische Nachweis für diese Schelfeise lässt sich am Eingang zu diesen Senken führen, wo steil absteigende Seitenmoränen plötzlich auf 2 km horizontal verlaufen. Ausserdem enthalten sowohl die horizontalen Moränen wie die zugehörigen Vorfeld-terrassen talabwärts von der erkennbaren Aufsetzlinie Fossilien. Auf Grund des Höhenunterschiedes zwischen den horizontalen Moränen und den Talsohlen lässt sich die Dicke der beiden Schelfeise auf etwa 110 m und 150 m abschätzen. Eine Schwemmterrasse im Vorfeld mit 175 m Seehöhe scheint annähernd den relativen Meeresspiegel während der Bildung und des Abbruchs der Schelfeise anzugeben. Diese relative Höhe steht in Übereinstimmung mit den Wassertiefen, die für das Aufschwimmen von Eisschelfen der berechneten Dicke in beiden Tälern erforderlich ist. Verknüpft mit diesen Eisrändern sind zuverlässige ^{14}C-Datierungen von 28–30 000 Jahren vor der Gegenwart und Altersschätzungen an Aminosäuren von mehr als 35 000 Jahren. Die Bedeutung und Wahrscheinlichkeit weiterer früherer Schelfeise in der Kanadischen Hoch-Arktis wird diskutiert.

Introduction

Ice shelves in the Canadian and Greenland High Arctic are presently formed by either land-fast sea ice or floating glacier margins. Ice shelves created by the accretion of land-fast sea ice are well documented from northernmost Ellesmere Island (cf. the Ward Hunt Ice Shelf; Koenig and others, 1952; Hattersley-Smith and others, 1955; Crary, 1960; Lyons and Mielke, 1973). Radiometric dates on the youngest driftwood trapped behind the Ward Hunt Ice Shelf and on organic debris incorporated within it suggest initial formation *c.* 3 000–4 000 B.P., hence, following the Holocene Climatic Optimum (Crary, 1960; Hattersley-Smith, 1969; Lyons and Mielke, 1973). The build-up of land-fast sea ice is due to the freezing of low-salinity sea-water at its base and, to a lesser extent, to the periodic surface accumulation of iced firn (Marshall, 1955). The growth of such ice shelves is favoured by severe winter cold, low precipitation, and limited summer melting (Hattersley-Smith, 1960). Depositional features along the landward margins of these ice shelves have been briefly described and are restricted to shattered boulders transported down ice ramps from the adjacent land (Hattersley-Smith and others, 1955) or to "debris-laden ice ridges" where the ice shelf is grounded (Lyons and Mielke, 1973, p. 315). Morphological evidence for more extensive, pre-Holocene ice shelves has not been cited either due to its absence or a lack of systematic investigation. It seems likely that such land-fast sea ice was more extensive in the past, perhaps during the cold phase between 65 000 and 10 000 B.P. as recorded in the "Camp Century" and Devon Island ice cores (Dansgaard and others, 1973; Paterson and others, 1977).

Ice shelves, formed by floating glacier ice discharging from land-based ice sheets, have been extensively reported from Antarctica (Swithinbank, 1957; Crary and others, 1962; Swithinbank and Zumberge, 1965; Budd, 1966; Holdsworth, 1969; Thomas, 1973, 1976). In addition, the occurrence of present-day, floating glacier termini in arctic Canada and Greenland is widely recognized (Koch, 1928; Sorge, 1933; Krinsley, 1961; Carbonnel and Bauer, 1968; Feazel and Kollmeyer, 1972; Løken and others, 1972). The dimensions of such features are generally limited by the rate of ice flow from the adjacent land, rates of melting and calving, submarine topography, and additional forces such as the bending stresses at the hinge line (Holdsworth, 1969). Their principal morphological distinction is a comparatively flat upper surface with a limited amount of freeboard (ratio of total ice thickness to front height is *c.* <8.5 (Budd, 1966; Reeh, 1968, 1969; Thomas, 1973)).

Several authors have speculated on the presence of extensive ice shelves during former glaciations of the High Arctic (Hattersley-Smith, 1960; Mercer, 1969, 1970; Grosval'd, 1972; Broecker, 1975; Hughes and others, 1977). Stratigraphic evidence has also been cited which suggests the presence of shelf ice bordering the Magdelen Islands, Gulf of St. Lawrence, during the Wisconsin glaciation (Prest and others, 1976). Although submarine and near sea-level moraines have been described from arctic Canada and Greenland (Crary, 1956; Løken, 1973; Ten Brink and Weidick, 1974; Blake, 1977), no documentation of former ice-shelf moraines has been made. In addition, Smith (unpublished) showed that the moraines in Sam Ford Fiord, eastern Baffin Island, descended to sea-level with a gradient of 1 : 100.

Evidence for former ice shelves

During 1975–76, studies were conducted on the surficial geology of Judge Daly Promontory, north-eastern Ellesmere Island (Fig. 1). In this area, moraines deposited by the outermost Ellesmere Island ice advance cross-cut an older and more extensive zone of Greenland till (England and Bradley, 1976). The distribution and gradients on the Ellesmere Island moraines indicate the presence of thin, topographically controlled ice lobes draining south-eastward across the promontory to sea-level along western Kennedy Channel. The termini of two ice lobes were investigated, one originated from the interior of Judge Daly Promontory and extended to Cape Defosse, whereas the second, 20 km to the north-east, represented tributary ice flowing south-eastward out of Lady Franklin Bay into lower "Beethoven Valley"* (Fig. 1). Both ice lobes crossed an interior lowland (*c.* 200–300 m a.s.l.) before descending into narrow valleys, 2–3 km in width, which lead to Kennedy Channel. Relief in the valleys is >500 m and bathymetric soundings 5 km offshore show water depths of >360 m (Canada. Hydrographic Service, 1973). Due to glacio-isostatic depression of these valleys, both outlet glaciers were forced to float in the resulting embayments along western Kennedy Channel. Under these conditions, it is suggested that small ice shelves developed but it is not known to what extent these would have been sustained by bottom accretion of ice or by surface accumulation. Evidence in support of such ice shelves is based on morphology, stratigraphy and the relative sea-level at the time of their formation. The chronology of these ice shelves is also discussed.

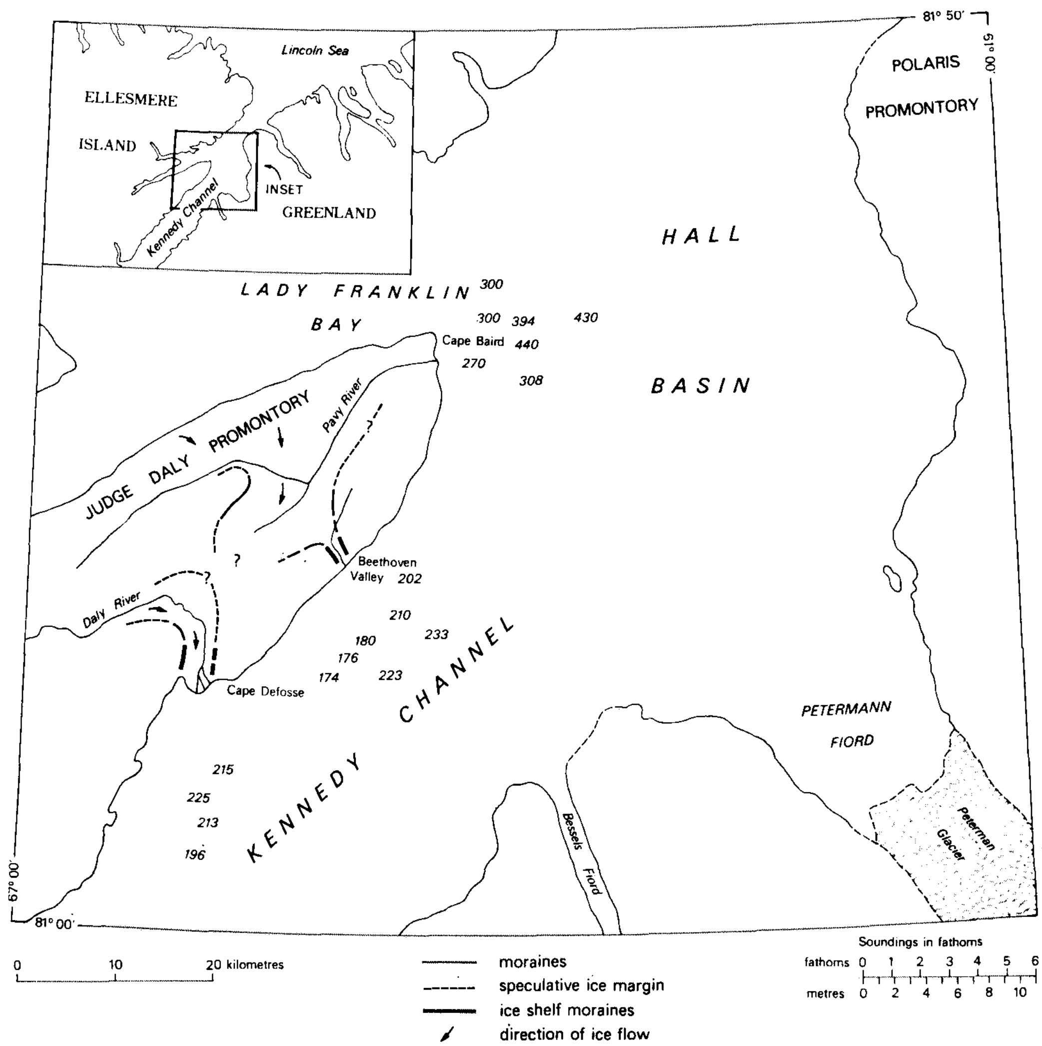

Fig. 1. Map of Judge Daly Promontory, north-eastern Ellesmere Island and adjacent Greenland coast. Outermost Ellesmere Island moraines, ice-flow directions and the location of former ice shelves are indicated. Water depths are shown in fathoms.

* Unofficial place-name under consideration by the Canadian Permanent Committee on Geographical Names.

Morphology

The uppermost Ellesmere Island moraines in the interior of Judge Daly Promontory occur at *c.* 500 m a.s.l. and descend to *c.* 260 m a.s.l. at the entrance to lower "Beethoven Valley" (Fig. 1). Within 0.5 km of this latter point, a well-developed system of conical kames and lateral moraines descends steeply down-valley to an elevation of 200 m a.s.l., where they become abruptly horizontal for a distance of *c.* 2 km. Immediately up-slope from these horizontal lateral moraines one encounters a sharp break in weathering characterized by deeply oxidized bedrock, tors, and a sparse distribution of crystalline erratics previously deposited by the Greenland ice sheet. The horizontal moraines are considered to represent the lateral margin of a floating outlet glacier whose grounding line was located at the lower-most sector of steeply sloping lateral moraines up-valley. Vertical and ground-level view of

Fig. 2. Air photograph of "Beethoven Valley" showing the horizontal ice-shelf moraines (black arrows) and the approximate grounding line (black circle). Dotted line shows the approximate outer limit of this ice shelf based on morphologic evidence. (Copyright Canadian Government, air photograph A-16680-107.)

these moraines on the south-west side of "Beethoven Valley" are shown in Figures 2 and 3, respectively. The slope of the moraines shown in Figure 3 compares with observations made on the Ross Ice Shelf, Antarctica, whose profile is characterized by "(i) the abrupt increase in elevation as one goes from the ice shelf on to the continental ice sheet and (ii) the depression associated with the juncture of the ice shelf and ice sheet" (Theil and Ostenso, 1961, p. 825). Several altimeter transects, corrected for both temperature and pressure, were run along the entire horizontal sector of the "Beethoven Valley" moraines and no elevation differences >1 m were detected. Similar, but less extensive, lateral moraines occur on the opposite side of the valley and suggest an ice-shelf width of *c.* 2 km.

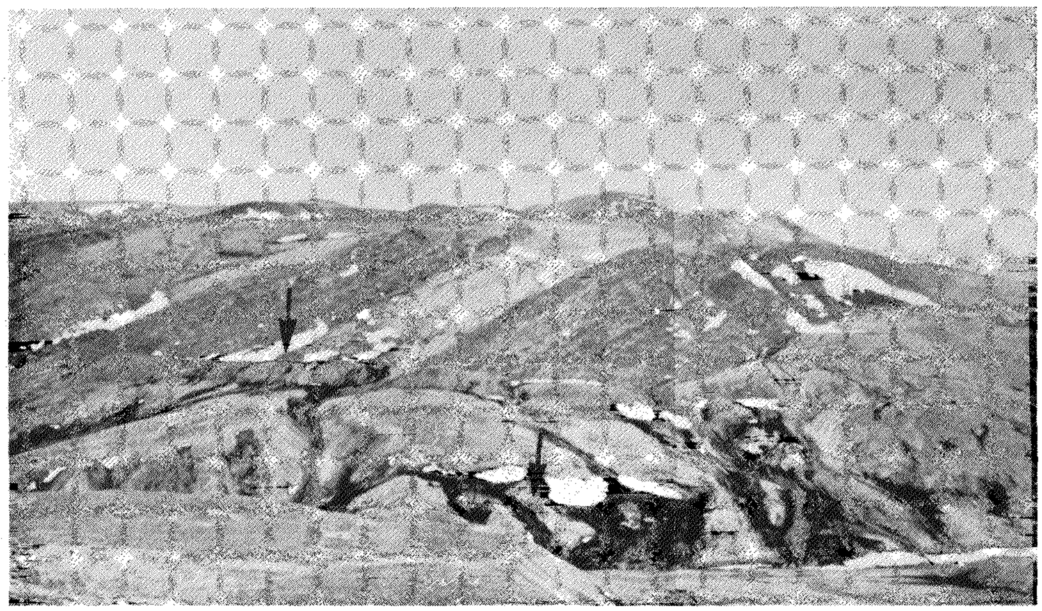

Fig. 3. View looking southward across upper "Beethoven Valley" showing segment of horizontal ice-shelf moraines (c. 200 m a.s.l.) and the steeply sloping lateral moraines extending into the interior of Judge Daly Promontory (c. 260 m a.s.l., right background). Note slight depression in the moraines at the contact with the former ice shelf. Associated pro-glacial marine terraces occur down-slope from ice-shelf moraines. Locations of dated shell samples are shown by black arrows.

20 km to the south-west of "Beethoven Valley" an outlet glacier from the interior of Judge Daly Promontory formerly reached Kennedy Channel via the lower Daly River valley (Fig. 1). Along the western slope of this valley another prominent horizontal moraine system occurs at *c.* 195 m a.s.l. and is bordered up-slope by the same deeply weathered bedrock and sparse Greenland erratics. This moraine system and the morphology of its upper surface are shown in Figures 4 and 5, respectively. The surfaces of the horizontal moraines in both valleys show little relief (<0.5 m), are 5 m in width and covered by a highly frost-shattered lag gravel lying on a stony/sand weathering profile. On the basis of the valley size and the distribution of depositional features, the ice shelf in lower Daly River was not more than 2 km in length and width.

Stratigraphy

In "Beethoven Valley", the ice-shelf moraines are occasionally fossiliferous, containing fragments of marine shells. That these shells have not been ice-transported across the interior of Judge Daly Promontory is clearly evidenced by their termination up-valley at a point coinciding with the apparent grounding line. In addition, no shells were found in the interior of Judge Daly Promontory despite extensive traverses of this area. The manner by which these shells have been incorporated in the moraines is unclear; they may have been scoured up by the advancing ice at its grounding line or, alternatively, they may have been gradually transferred to the surface by the accretion of freezing sea-water at the base of the floating glacier. This latter process has been well documented from the 40 m thick Ward Hunt Ice Shelf where organic material (siliceous sponges, sea worms, pelecypods, and remains of Arctic cod) has been transported to the surface (Lyons and Mielke, 1973). Lyons and Mielke (1973, p. 315) also reported a rich biota in both the ice shelf's debris ridge and in the ice moat between this ridge and the shore. As regards glacier flow as a mechanism for transporting these shells into the moraines, it is of interest that particle trajectories through the Brunt Ice Shelf, Antarctica, do not reveal basal flow lines returning to the surface (Thomas, 1973).

Adjacent to the ice-shelf moraines in lower "Beethoven Valley" are massive pro-glacial terraces at *c.* 175 m a.s.l. (Fig. 3). These terraces are capped with coarse till and/or ice-rafted debris overlying thickly bedded and poorly sorted outwash sands. The terraces occur at similar elevations on both sides of the valley and they are considered to represent rapid sedimentation along the retreating Ellesmere Island ice margin following the removal of the ice shelf. These terraces are fossiliferous throughout; although most shells are fragmented, complete valves also occur. Terraces up-valley from the former grounding line, however, are not fossiliferous.

Along the west side of lower Daly River, a massive section of unconsolidated material occurs down-slope from the ice-shelf moraines (Fig. 4). The truncated face of this 50 m thick section reveals till overlying bedded sands containing preserved plant debris. The till is fossiliferous and its deposition is considered to have taken place during the formation of the ice shelf. The underlying fluvial (?) sands stratigraphically pre-date the till and their preservation puts maximum limits on the depth to which the floating ice shelf extended. Adjacent to this section are fossiliferous pro-glacial terraces which occur up to *c.* 105 m a.s.l. (Fig. 4). Additional fossiliferous terraces and raised beaches occur at the same elevation farther down-valley (England, 1974). The uppermost post-glacial marine deposits, on the other hand, occur below these features at 90 m a.s.l. These fossiliferous terraces from "Beethoven" and Daly River valleys have been dated both by ^{14}C and the amino-acid method, and are discussed under the section on chronology.

Former relative sea-level

Estimates can be made on the thickness of these former ice shelves and, hence, the water depths required to float them. In "Beethoven Valley", a maximum estimate of ice thickness is based on the difference in elevation between the bedrock floor (*c.* 90 m a.s.l.) and the horizontal moraines (200 m a.s.l.). This suggests a maximum thickness of <110 m for the ice shelf since it is assumed to be floating. As a result, the associated water depth must also be somewhat less than 0.88×110 m (Reeh, 1969) or <97 m above the bedrock. This results in a maximum relative sea-level of <187 m a.s.l. As discussed under the section on stratigraphy, pro-glacial terraces *c.* 175 m a.s.l. occur adjacent to these ice-shelf moraines in "Beethoven Valley". The elevation of these graded terraces suggests water depths of *c.* 85 m above bedrock which would be capable of floating an ice thickness of *c.* 100 m. Such an ice thickness would extend from the horizontal moraines to within 10 m of the bedrock floor. It is suggested that these 175 m terraces, containing fragments of marine shells, represent the approximate relative sea-level that existed during the formation and break-up of the associated ice shelf. The deposition of these terraces clearly necessitated the removal of this ice shelf from the valley.

Along lower Daly River a maximum estimate on the ice thickness is *c.* 150 m based on the difference in elevation between the preserved bedded sands (containing organic debris at *c.* 45 m a.s.l.) and the horizontal moraines (195 m a.s.l.). This would suggest a required water depth of *c.* 130 m above the bedded sands (*c.* 45 m), hence a similar relative sea-level of *c.* 175 m at the time of ice-shelf formation. The absence of terraces at this elevation in the valley may be due to the fact that (1) they never formed, (2) they have been removed by subsequent erosion, or (3) the ice tongue stagnated in the lower valley, i.e. if the ice shelf remained in place during *c.* 15–20 m of emergence, it would have become grounded. Moraines on the valley sides at 150 m a.s.l. (below the horizontal moraines) may reflect such stagnation and grounding as the sea-level dropped from the ice-shelf stage. Following the deglaciation of lower Daly River valley, there is evidence of a pre-Holocene shoreline at 105 m a.s.l. (Fig. 4) which occurs above the upper post-glacial marine deposits at *c.* 90 m a.s.l.

Chronology

In lower Daly River valley, fragmented shells collected from a pro-glacial terrace at 105 m a.s.l. dated 27 950±5 400 B.P. (St. 4325; England, 1974). Amino-acid age estimates on the same shell sample, and from a subsequent collection from the same site, yielded ages >35 000 B.P. (Table I). 3 km up-valley there is an exposed section of fossiliferous till overlying bedded sand along the west side of the Daly River. The fossiliferous till is considered to represent deposition in a marine environment as it occurs below both the local ice-shelf moraine (Fig. 4) and the former relative sea-level at 175 m. In addition, no shells were observed up-valley from the ice-shelf moraines which precludes transport and re-deposition of these shells by ice from the interior of the promontory. Shell fragments from this marine till dated $28\,610^{+1\,710}_{-2\,180}$ B.P. (DIC-550). The bedded sands underlying this till contain remnants of the locally extinct plant species *Dryas octopetala* (personal communication from J. Packer, 1976), a sample of which dated >25 000 B.P. (DIC-584). Adjacent to this section is a second fossiliferous terrace at *c.* 105 m a.s.l. (Fig. 4) containing shells dated at >35 000 B.P. by the amino-acid method.

Along the south-western slope of "Beethoven Valley" two samples of fragmented shells were collected in 1975. The first sample, incorporated in the horizontal ice-shelf moraines, dated $23\,110^{+660}_{-720}$ B.P. (DIC-544), whereas the second, collected down-slope and washing out of the 175 m terrace, dated $22\,780^{+810}_{-900}$ B.P. (DIC-546). X-ray analysis of both shell samples, however, revealed that they were encrusted with 50% calcite and 50% silica. These contaminants could not be completely removed and may date from the recrystallization of the shells following their initial deposition. Hence, it was concluded that both dates were *minimum* estimates. Amino-acid analyses of the same samples indicated ages >35 000 B.P. (Table I).

During 1976 the 175 m terrace was re-visited and a second sample was collected. These shells occurred in the same location as sample DIC-546; however, they were not encrusted by contaminants. This sample dated $29\,670^{+830}_{-930}$ B.P. (DIC-738) and it takes precedence over the first date of $22\,780^{+810}_{-900}$ B.P.* This most recent date closely coincides with the other

* It has been shown that the apparent ^{14}C age of shells increases with increased sample leach (personal communication from M. Stuiver, 1977). In terms of the 175 m terrace, the sample which provided the youngest date (DIC-546) had only 15% leach, whereas in the older sample (DIC-738) leaching increased to 25%. It seems likely that these shell samples would more closely approximate the amino-acid age estimates (>35 000 B.P.) if leaching were allowed to exceed 25%.

TABLE I. ^{14}C DATES AND AMINO-ACID AGE ESTIMATES

Site location	*Deposit*	*Dated material*	*% leach*	*Available ^{14}C date* B.P.	*Lab. No.*	*Amino-acid age estimate** B.P.	*Allo/Iso free*	*Allo/Iso total*
1. Lower Daly River	Pro-glacial terrace *c.* 105 m a.s.l.	Marine shells (*Mya truncata*)	— —	27 950±5 400	St. 4325	>35 000 >35 000	0.23 0.25	0.040 0.050 0.054
2. Lower Daly River	Same terrace as above	Marine shells (*Hiatella arctica*)	—	—	—	>35 000	0.18	0.064
3. Lower Daly River	Pro-glacial terrace 3 km up-valley from site 1. Elevation *c.* 105 m a.s.l.	Marine shells (*Hiatella arctica*)	—	—	—	>35 000	0.20	0.037
4. Lower Daly River	Fossiliferous till	Marine shells (*Hiatella arctica*)	None	$28\,610^{+1\,710}_{-2\,180}$	DIC-550	—	—	—
5. Lower Daly River	Bedded sands (fluvial?)	Organic layer (*Dryas octopetala*)	None	>25 000	DIC-584	—	—	—
6. "Beethoven Valley"	Ice-shelf moraine	Marine shells (*Hiatella arctica*)	15	$23\,110^{+660}_{-720}$	DIC-544	>35 000	0.28	0.048
7. "Beethoven Valley"	Pro-glacial terrace 175 m a.s.l.	Marine shells (*Hiatella arctica*)	15	$22\,780^{+810}_{-900}$	DIC-546	—	—	—
	Same terrace as above	Marine shells (*Mya truncata*)	25	$29\,670^{+830}_{-930}$	DIC-738	>35 000 >35 000	0.28 0.22	0.073 0.040

* Amino-acid age estimates are based on a relative scale in which older shells have a higher ratio of D-alloisoleucine to L-isoleucine (Allo/Iso) in both the free and total (free plus peptide-bound) fractions. The rate of amino-acid racemization is temperature-dependent, decreasing for colder temperatures. *Mya truncata* and *Hiatella arctica* samples from eastern Baffin Island with minimum ^{14}C ages between 40 000 and 50 000 B.P. (after 80% leach) have Allo/Iso ratios of *c.* 0.29 (free) and 0.045 (total) (Miller and others, 1977). The climate of eastern Baffin Island is currently warmer than that of north-eastern Ellesmere Island, hence the Ellesmere Island shells are thought to be at least as old as those from eastern Baffin Island.

finite ^{14}C dates along the ice margin at Cape Defosse (27 950±5 400 and $28\,610^{+1\,710}_{-2\,180}$ B.P.; St. 4325 and DIC-550, respectively). However, as there are problems in obtaining reliable dates on marine shells >20 000 B.P. (Olsson and Blake, 1961; personal communication from M. Stuiver, 1977), it is most realistic to treat these ^{14}C dates as minimum estimates. Amino-acid age estimates on the same samples are all >35 000 B.P. (Table I) and their true age may be as old as 70 000 B.P. Consequently, these *c.* 28 000–30 000 B.P. dates on pro-glacial terraces should be considered as minimum estimates on initial recession from the ice margin which previously formed the ice shelves. On the other hand, the 175 m sea-level appears to be consistent with the water depths required to float the calculated ice thicknesses in both valleys and, hence, the ice shelves may not be substantially older than the pro-glacial terraces. Finally, it is apparent that the 175 m sea-level associated with these former ice shelves is substantially older than the highest post-glacial marine deposits (110 m a.s.l.) observed on northern Judge Daly Promontory (8 380±105 B.P.; DIC-737).

Discussion

During the maximum ice advance on north-eastern Ellesmere Island, outlet glaciers formed ice shelves along western Kennedy Channel when the relative sea-level was *c.* 175 m above present. Evidence in support of these ice shelves is principally morphological and is based on the horizontality of two separate moraine systems which extend for 2 km beyond steeply descending moraines up-valley. These ice shelves are useful stratigraphically in that they delimit the extent of former ice margins and, chronologically, because they formed in a marine environment which favours the deposition of dateable fossiliferous units. In addition, these ice shelves provide estimates on the former relative sea-level at the time of their formation, since this can either be observed (pro-glacial terraces) or calculated, given the local ice thickness. On the basis of both the amino-acid and ^{14}C datings, it is presently concluded that the maximum north-eastern Ellesmere Island ice advance occurred within the period of the Wisconsin/Würm glaciation. Because of the known problems in dating inorganic shell carbonate >20 000 B.P., we favour the amino-acid age estimates which place this ice advance at >35 000 B.P.

Throughout the Canadian and Greenland Arctic, numerous outlet glaciers descend from upland icefields into prominent fiords and embayments. In addition, glacio-isostatic depression during former glaciations resulted in the inundation of many low coastal valleys that are presently above sea-level. Therefore, during the advance of Arctic glaciers in the past, many ice shelves similar to those described from eastern Judge Daly Promontory must have formed. Where such ice shelves were constrained between steep valley sides, remnant depositional features, such as horizontal moraines, should be preserved. Air-photograph analysis of the coastline south of Cape Defosse, Judge Daly Promontory, indicates the presence of additional ice-shelf moraines. At present the extent of former ice shelves in the North American Arctic is open to considerable speculation (Mercer, 1970; Broecker, 1975; Hughes and others, 1977) and hence the mapping, dating and analysis of their related deposits is pertinent to the understanding of high-latitude Quaternary environments.

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