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PAPER 66-26

END MORAINES AND DEGLACIATION CHRONOLOGY IN NORTHERN CANADA WITH SPECIAL REFERENCE TO SOUTHERN BAFFIN ISLAND

(Report, 6 plates and 2 figures)

W. Blake, Jr.

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CONTENTS

Illustrations

ABSTRACT

An extensive system of end moraines near Frobisher Bay and on Foxe Peninsula, in southern Baffin Island, are described for the first time. The section crossing Frobisher Bay can be traced for some 325 miles (525 km). The high level "strandlines" described from the southwest side of Frobisher Bay by several workers are in reality a combination of kame terraces, lateral moraines, and marginal lake terraces - all related to the moraine system and formed beside a major ice lobe entering Frobisher Bay from the northwest.

Numerous radiocarbon dates show that: 1) ice from Hudson Strait impinged on the south coast of Baffin Island during the last glaciation, carrying marine shells far above the level of marine submergence; 2) all or nearly all of Hudson Strait was filled by ice 9,000 years ago, but was ice free by 8,000 years ago, and the sea had reached the limit of submergence south of James Bay a short time after 8,000 years B.P.; 3) the major moraines crossing Frobisher Bay, near Rae Isthmus at the south end of Melville Peninsula, and at MacAlpine Lake, District of Mackenzie, were forming some 8,200 years ago, but parts of the moraine system in northern Baffin Island probably formed earlier; 4) moraine formation continued for several hundred years after 8,200 B.P.; 5) innermost Frobisher Bay and Foxe Basin were ice free by 6,900 to 6,700 years ago; and 6) Amadjuak Lake was free of ice before 4,500 B.P., although the last mass of ice, which lay northeast of this lake, may have still been in existence then.

The orientation of the moraines in southern Baffin Island and radiocarbon dates from widely spaced areas in northern Canada show the need for reappraisal of the "Cockburn Glacial Phase" hypothesis and the postulated position of the ice-edge 9,500 or 9,000 to 8,000 years ago (cf. Falconer et al., 1965a, 1965b).

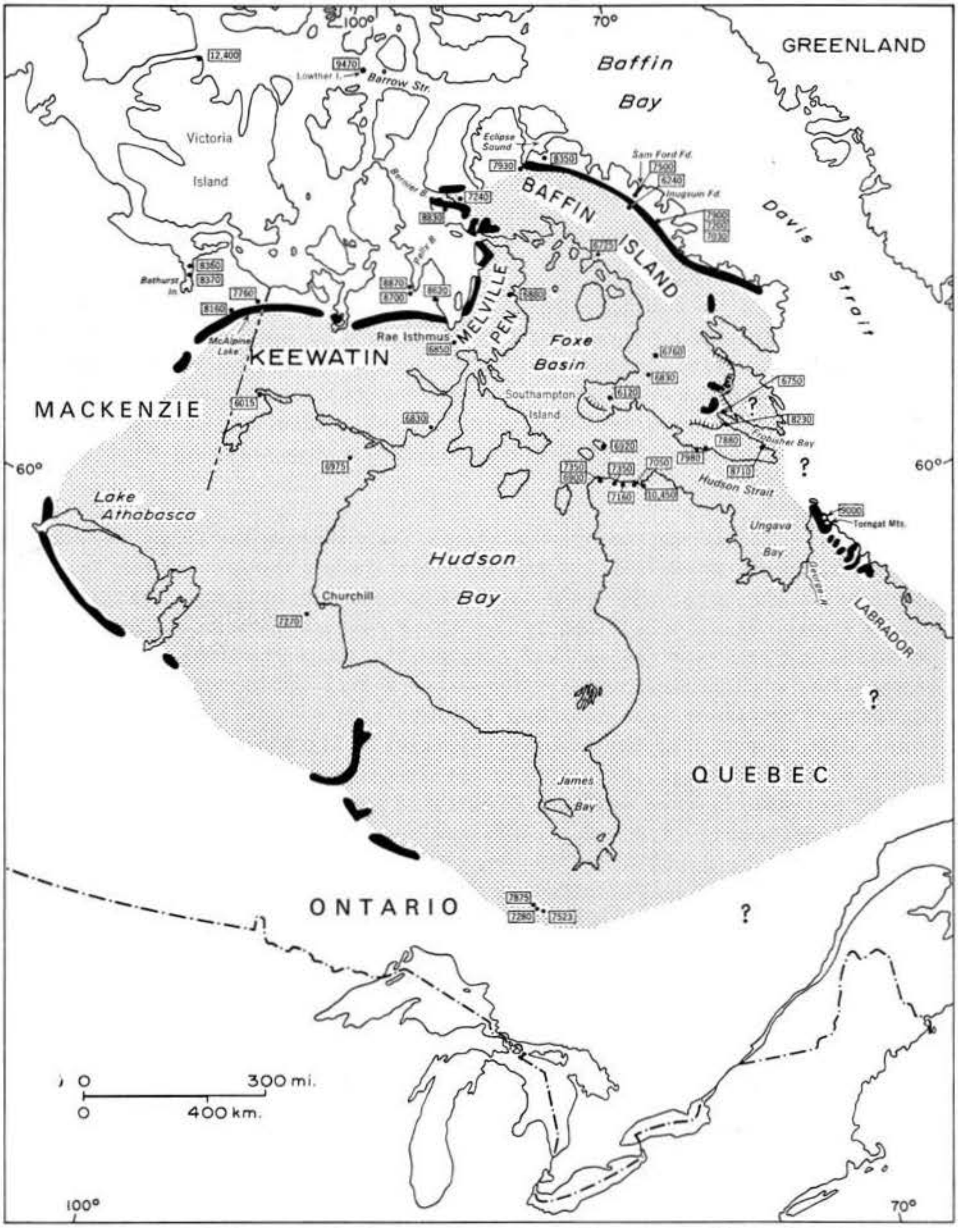

Figure 1. "Generalized outline of the Cockburn moraine system and the perimeter of the ice sheet 8,000 to 9,000 years ago, representing the Cockburn Glacial Phase" (after Falconer, Ives, Løken, and Andrews, 1965 b, Fig. 7, p. 147). The major moraines (hachured line) in southern Baffin Island, the critical radiocarbon dates on marine shells, and localities discussed in the present paper are superimposed on the original map.

END MORAINES AND DEGLACIATION CHRONOLOGY IN NORTHERN CANADA, WITH SPECIAL REFERENCE TO SOUTHERN BAFFIN ISLAND

INTRODUCTION

In two recent articles Falconer et al. (1965a, 1965b) proposed the existence of a late-Wisconsin ice-sheet centred over Foxe Basin and Hudson Bay 9,500 or 9,000 to 8,000 years ago. The main evidence put forward for the existence of this ice-sheet, during what is termed the "Cockburn Glacial Phase", is a major system of moraines, named the "Cockburn Moraine System". According to the authors, the system is traceable, with minor gaps, for over 1,300 miles (2,100 km) from northeastern District of Mackenzie, across Keewatin to Melville Peninsula and Baffin Island. A number of radiocarbon dates, obtained on samples collected by Falconer et al. and by B.G. Craig and the writer, of the Pleistocene Section, Geological Survey of Canada, are used to demonstrate the contemporaneity of certain parts of the moraine system. Possible correlation with moraines in the vicinity of Lake Athabasca, in northern Ontario, and in northern Labrador is suggested, but no moraines at all are shown in Quebec on which to base the outline of an ice-sheet.

During the summer of 1965 the writer carried out field work in southern Baffin Island, an area in which moraines had not been studied previously and for which no radiocarbon dates bearing on the time of deglaciation were available. The first season's field work involved a reconnaissance study of glacial geology from Nettilling Lake south to Hudson Strait; more detailed work in selected localities is planned for the future. In the present paper the distribution of end moraines in southern Baffin Island as mapped from air photographs is described, a tentative chronology for the deglaciation of this region is given, and the hypothesis of Falconer et al. is examined in light of the new dates from southern Baffin Island and published and unpublished dates from elsewhere in northern Canada.

Figure 1 shows moraines and the outline of the late-Wisconsin ice-sheet according to Falconer et al. (1965a, 1965b); major end moraines in southern Baffin Island and most dates and localities discussed in the present paper are superimposed on it. Figure 2 is a more detailed map showing directions of ice flow, end moraines, and radiocarbon dates in southern Baffin Island.

MORAINES IN SOUTHERN BAFFIN ISLAND

The distribution of moraines in southern Baffin Island, Figure 2, is unlike that presented on the "Glacial Map of Canada" (1958), by Bird (1958, p. 135) or in certain of the papers resulting from the work of the Geographical Branch on Baffin Island since 1961 (Ives, 1963b, p. 348; Ives and Andrews, 1963, p. 18; Falconer et al., 1965b, Fig. 1). Considerable sections of moraines are absent from all these maps, and most show moraines where none exist. This is due in part to the unavailability, before 1959, of complete air photograph coverage of southern Baffin Island.

interpretation and suggested instead that after Frobisher Bay became ice-free, glaciers entering it from the sides might have dammed up the head of the bay, thus creating a lake which could form the strandlines as it fluctuated in level. This seems unlikely if not impossible on the scale necessary in Frobisher Bay. Water depths of over 600 feet (183 m) occur "up-bay" from Cape Rammelsberg (Dunbar, 1958, p. 161; Canadian Hydrographic Service, Chart 7122, 1965), necessitating ice more than 2,000 feet (610 m) thick in order to dam up a lake 1,400 feet (427 m) above sea-level. Furthermore, there are no traces in the form of moraines or ice-motion indicators that such an ice dam ever existed. Bird (1958, pp. 351-352) proposed a third alternative, namely the existence of marginal lakes formed when the uplands and side valleys leading to Frobisher Bay had been deglaciated, but when an ice mass still occupied the bay itself. Bird is correct concerning the existence of marginal lakes, although the writer does not agree with his (Bird, 1958, p. 329) sketch maps showing phases of deglaciation in which the whole of Frobisher Bay is depicted as being filled by ice at a late stage (see discussion in the second part of this paper regarding chronology).

Rather than any of the above hypotheses, the writer submits that the high-level 'strandlines', as well as some of those at lower altitudes, are in reality a combination of lateral moraines and kame and lake terraces (Plates I and II). They were formed along the irregular margin of an ice-lobe entering Frobisher Bay from the northwest (Fig. 2), and the succession of features was produced during thinning and retreat of this lobe. From Eggleston Bay to beyond the head of Frobisher Bay a valley parallels the coast and lies between the steep hills overlooking the bay and the even higher scarp fronting the plateau to the southwest. Thus the topography is ideally suited for the development of subsidiary ice-lobes and small marginal lakes, and for the accumulation of marginal outwash deposits. Because of the low gradient of the former ice surface the lateral moraines and kame terraces appear nearly horizontal when viewed from a distance. In several places the disposition of moraines shows that after the inner valley became ice-free, tongues from the main ice-lobe in Frobisher Bay pushed southwestward into this valley through gaps in the coastal hills. These tongues also dammed up small lakes. Some of the drainage from the inner valley reached the sea at Eggleston Bay, where a large delta, whose surface is now over 300 feet (91 m)[1] above sea-level, was built.

The variation in the altitude of the marine limit between the distal and proximal sides of the moraine system suggests that the ice-front stood at the positions represented by the moraines for a considerable period of time, although by this it is not meant to imply stillstands only. On the contrary, slight readvances undoubtedly took place; the fact that tongues from the main ice-lobe in Frobisher Bay pushed southwestward through the coastal hills after the valley parallel to the coast had become ice-free is one

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[1] All altitudes in this paper are referred to the level of the ice-foot surface, which is close to mean high-tide level. Some altitudes were obtained by hand level, most by surveying altimeter. No corrections have been made for barometric changes or temperature, but several determinations have been made at all sites discussed, usually within a few minutes of the time of sea-level checks.

indication of this, and such renewed activity must also have been reflected elsewhere along the glacier margin. In addition to the 300-foot (91 m) delta in Eggleston Bay, marine shells were found at an altitude of 285 to 290 feet (88 m) in silt directly in front of the easternmost moraine ridge on a peninsula 2.5 miles (4 km) south of Cape Rammelsberg. The washing limit[1] 7 miles (12 km) southeast of this moraine and some 12 miles (19 km) southeast of the outermost moraine of the moraine system on the opposite side of Frobisher Bay, was close to, but nowhere over, 400 feet (120 m). By contrast, on the proximal (northwest) side of the moraine system at a number of localities around the head of Frobisher Bay, no evidence was found of marine action above about 100 feet (30 m) (cf. Farrand and Gajda, 1962, Fig. 1; Ives, 1963a, pp. 120-121).

Foxe Peninsula

The moraine that crosses Foxe Peninsula is a single ridge in most places; elsewhere it is merely a zone of unusually thick till. Near the western side of the peninsula several shorter sections of moraine are also present (Fig. 2). The main ridge has as much as 200 feet (61 m) of relief. The moraine is oriented at right angles to all features that indicate the direction of ice flow, and strandlines formed in an ice-dammed lake, along a north-flowing river on the north side of the moraine, show that the ice retreated northward. In western Foxe Peninsula, along the projected course of the moraine, there is a noticeable drop in the altitude of the marine (washing) limit, from between 500 and 600 feet (152 to 183 m) inland from Harkin Bay to about 400 feet (122 m) farther to the northeast[2]. The implication is that more than 100 feet (30 m) of uplift occurred while the ice-front was at the moraine. This figure is considerably less than the comparable figure for Frobisher Bay, 300 feet (91 m). Thus it can be assumed that the moraine on Foxe Peninsula was built in a somewhat shorter time than the moraine system crossing Frobisher Bay.

RADIOCARBON DATES AND CHRONOLOGY OF DEGLACIATION[3]

Frobisher Bay

The available radiocarbon dates indicate that much of Frobisher Bay was ice-free by 8,000 years ago. Dates of 8,840 ± 160 (GSC-463) and

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[1] This is the limit below which till and perched boulders have been washed away by the sea. In much of southeastern Baffin Island, where steep slopes face the sea and fiord topography is common, this is the only criterion by which the former limit of marine submergence can be determined (cf. Plates III and IV). It was first applied by Weeks (1928, pp. 90-91) in Cumberland Sound.

[2] This was determined by a study of air photographs in conjunction with the 1:250,000 topographic map (Sheet 36 C & D, Cape Dorset) with a 100-foot (30 m) contour interval. Unfortunately Foxe Peninsula was not reached during the 1965 field season, but it is planned to study this area in detail in the future.

[3] Refer to Tables I to IV.

8,710 ± 180 (GSC-463-2)[1] were obtained on shells from the large delta at the head of York Sound (Locality 6, Fig. 2). The shells were collected from a 6-inch-thick layer 65 feet (20 m) above sea-level; the top of the delta is at 125 feet (38 m). Nearly 100 miles (160 km) to the northwest, near Cape Rammelsberg in the inner part of Frobisher Bay (Locality 7, Fig. 2), a date of 8,230 ± 240 years (GSC-462) was obtained on shells at 285 to 290 feet (88 m) above sea-level, collected from silt in juxtaposition with the outermost moraine system. The ice-front must have been at this moraine, or only a short distance to the northwest, when these molluscs were living.

Dates have also been obtained on three shell samples collected on the proximal side of the innermost moraine crossing Frobisher Bay (Locality 8, Fig. 2). Two of the samples, from a delta at Apex Hill 2.5 miles (4 km) southeast of the town of Frobisher are 6,750 ± 170 (GSC-464) and 6,140 ± 170 (GSC-503) years old, respectively. An age determination on shells 10 feet (3 m) above sea-level in a delta at Frobisher settlement gave 6,440 ± 160 years (GSC-553). The possibility that the sea may have penetrated inside the innermost moraine at an earlier date is not excluded, however, for the surface of the delta from which GSC-464 and GSC-503 were collected is 70 to 80 feet (21 to 24 m) above sea-level, whereas the marine (washing) limit in the vicinity is close to 100 feet (30 m) above sea-level. Furthermore, the shells in GSC-464 were collected from sandy talus apparently being derived from layers near the top of the delta, and the lower strata must be slightly older. In any event it seems reasonable to conclude, from the data at hand, that the various moraine ridges which make up the moraine system crossing Frobisher Bay were formed over a period of several hundred years, perhaps as much as 1,000 years.

South coast of Baffin Island

The chronology along the south coast of Baffin Island is somewhat more complicated than in Frobisher Bay, although events in the two areas are interrelated. However, before discussing deglaciation brief mention must first be made of one aspect of the glaciation of Hudson Strait, the impingement of Hudson Strait ice on Baffin Island.

The till on Big Island contains fragments of Palaeozoic limestone (see Barton, 1896, p. 381; Kindle, 1896, pp. 455-456), and such fragments are also characteristic of the till in a narrow zone along the south coast of Baffin Island (localities visited were between Crooks Inlet and Nannuk Harbour). This till, apparently deposited by ice flowing in Hudson Strait and impinging on the island, also contains marine shells in a number of places. In fact, the distribution of limestone-rich till and striae shows that ice flowed northeastward across the tip of Meta Incognita Peninsula. The lack of limestone erratics inland from the north shore of Hudson Strait indicates that the erratics along the coast did not originate in the area of Palaeozoic rocks northwest of Frobisher Bay. A similar lack of shells inland, even at altitudes below those near the coast, permits the conclusion that the molluscs did not live at the levels where they now occur. Two dates,

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[1] Two separate age determinations were made on the same sample (see Table I).

Table I

Radiocarbon Dates, Southern Baffin Island

Locality No. (Fig. 2)	Laboratory Dating No.	Approx. alt. of sample ft. (m) a.s.l.	Dated material[1]	Age (radiocarbon years before 1950)[2]
1	GSC-468	25 (8)	marine shells	> 25,900
2	GSC-426	210 (64)	marine shells	34,800 ± 1,100
3	GSC-414	210-235 (64-72)	marine shells	30,200 ± 1,500
6	GSC-463	65 (20)	marine shells[3]	8,840 ± 160
6	GSC-463-2	65 (20)	marine shells[3]	8,710 ± 180
7	GSC-462	285-290 (88)	marine shells	8,230 ± 240
4	GSC-425	245 (75)	marine shells	7,980 ± 220
5	GSC-433	210 (64)	marine shells	7,880 ± 140
5	GSC-504	140 (43)	marine shells	7,480 ± 160
8	GSC-464	45-55 (14-17)	marine shells	6,750 ± 170
8	GSC-503	50 (15)	marine shells[4]	6,140 ± 170
8	GSC-533	10 (3)	marine shells[4]	6,440 ± 160
9	GSC-498	390 (119)	organic debris[5]	4,460 ± 140
9	GSC-498	390 (119)	organic debris[5]	4,550 ± 220
10	GSC-465	315-330 (96-100)	marine shells	6,830 ± 150
10	GSC-553	285-300 (87-91)	marine shells[6]	6,270 ± 140
10	GSC-553	285-300 (87-91)	marine shells[6]	6,590 ± 140
11	GSC-466	285-305 (87-93)	marine shells	6,760 ± 140
12	GSC-561	>200, <300 (>61, < 91)	marine shells	6,120 ± 140
13	GSC-560	140 (43)	marine shells	6,920 ± 150

[1]The standard pretreatment of shells includes a 20% acid leach. Because of the small size of the samples this was reduced to 10% for GSC-414 and GSC-425, and omitted altogether for GSC-462, GSC-464, and GSC-503. Also, again because of small size, all samples except GSC-426 and GSC-433 were mixed with dead gas for counting.

[2]All finite age determinations from the Geological Survey of Canada, as reported in this table and elsewhere in this paper, are based on the 2σ criterion, indicating that there is a 95% probability that the age falls within the limits of error. 'Greater than' ages, such as GSC-468, are based on the 4σ criterion; i.e., there is a 99% probability that the age is greater than that indicated.

[3]This sample was split into two parts. For GSC-463 the standard 20% acid leach was used, but for GSC-463-2, 50% was removed in the acid leach. The results agree well within the limits of error.

[4]These two shell samples were collected by B. Matthews.

[5]The first determination is on the fraction less soluble in NaOH, the second on the fraction (humic) more soluble in NaOH.

[6]After an initial 10% leach the first age determination for GSC-553 is on the outer fraction (10-55% leach), the second is on the inner fraction (56-100% leach).

30,200 ± 1,500 years (GSC-414) and 34,800 ± 1,100 years (GSC-426), have been obtained on shells in the till, and one, >25,900 years (GSC-468), from shells in beach material presumably reworked from the till (Localities 3, 2, and 1, respectively, in Fig. 2). Although two of the dates are finite, it seems better for the present to regard them as minimum age values also (cf. Olsson and Blake, 1962, pp. 49-53). The best interpretation would seem to be that during the last interglacial, or some early Wisconsin interstadial, Hudson Strait was open, after which an ice advance scraped material from the sea bottom or carried it from an area of Palaeozoic outcrop to the south or west, and deposited it along the south coast of Baffin Island.

The presence of deltas and strandlines inland from Pritzler Harbour, at altitudes of as much as 1,200 feet (365 m) and on the southwest side of the drainage divide, indicates that ice must have occupied Hudson Strait in order to hold up lakes at such levels. The existence of an ice-dammed lake or lakes in this area was first suggested by Mercer (1956, p. 568) as a mechanism for providing enough water for the excavation of two enormous gorges that cut across Meta Incognita Peninsula toward York Sound (Plate V)[1].

The dated shells from the delta in York Sound (Table I) provide information about the time of deglaciation of eastern Hudson Strait as well as Frobisher Bay. The material in the delta (Plate VI) was derived from the excavation of the gorges by water spilling over from the ice-dammed lakes on the Hudson Strait side of the drainage divide, and the molluscs are believed to have lived when the delta was forming. Thus an outlet glacier still must have filled Hudson Strait, with the possible exception of the extreme eastern end, some 8,700 or 8,800 years ago. Although the existence of ice in Hudson Strait at that time does not necessarily mean that Ungava Bay was also filled by ice, such probably was the case. The concept of ice in Ungava Bay 8,700 or 8,800 years ago agrees with the suggestion by Løken (1962, pp. 51-52) that the moraines on the east side of Ungava Bay were formed more recently than 9,000 years ago. Løken's suggestion was made because shells from the proximal side of an end moraine farther east, at the head of Eclipse Channel, northeastern Labrador, are 9,000 ± 200 years old (L-642). Ice in Ungava Bay would also provide the barrier necessary to hold up the large ice-dammed lakes on the western side of the Torngat Mountains, Labrador (Ives, 1957, 1958) and along the George River in northern Ungava (see Ives, 1960a, 1960b; Matthew, 1961; Barnett and Peterson, 1964; Peterson, 1965). The existence of ice in Ungava Bay does not conflict with the observation by Matthew (1961, p. 26) that the last flow of ice in the vicinity of the George River estuary was northward. It would be natural to expect a large calving bay to have developed at the mouth of Hudson Strait and Ungava Bay, a calving bay that would have tended to enlarge itself

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[1] The size of the gorges, both of which are about 13 miles (21 km) long and in places over 1,000 feet (305 m) deep, suggests that they were formed during more than one glaciation and that they may have served as spillways for the outflow from ice-dammed lakes during both advance and retreat stages of glaciation; cf. Mercer (1956, p. 568) who suggests that the gorges formed completely during 'postglacial' time. The precise locations of the gorges is probably controlled by lines of structural weakness.

toward the west and south. Ice that lay over the lower reaches of the George River would have flowed northward toward this calving bay.

However, although ice remained in the eastern part of Hudson Strait later than in southeastern Frobisher Bay[1], once retreat commenced in the former area it apparently proceeded rapidly. Dated shells on Big Island (Locality 4, Fig. 2) and near the Soper River 2.5 miles (4 km) north of Lake Harbour (Locality 5, Fig. 2) are 7,980 ± 220 (GSC-425) and 7,880 ± 140 (GSC-433) years old, respectively. When the configuration of the end moraine system in southern Baffin Island is taken into account, these dates suggest that much, if not all, of Hudson Strait was ice-free by 8,000 years B.P.; however, the deglaciation of Hudson Strait will be discussed in more detail later when the dates from the south side of the strait are considered.

The dates from Big Island and near Lake Harbour also indicate that deltas and strandlines above the level of the shells and farther north in the Soper River valley, up to a point within at least 25 miles (40 km) of the moraine system, are 7,900 years old. In fact the sea may have penetrated to within 13 miles (21 km) of the moraine system by this time, judging by the present altitude of the Soper River valley. The dates thus provide indirect confirmation for the age of the moraine system as determined in Frobisher Bay.

The data presented above are based on 1965 field work in southern Baffin Island. They necessitate considerable changes in the location of the ice edge during the time of the "Cockburn Glacial Phase", as defined by Falconer et al. (1965a, 1965b; compare Figures 1 and 2 in the present report). Nor do the new radiocarbon dates fit into the scheme proposed by these authors. The following sections deal with the age of certain other segments of the moraine system in northern Canada.

MacAlpine Lake, District of Mackenzie[2]

A major end moraine in the northeastern part of the District of Mackenzie was studied by the writer in 1962. Because of its excellent development near MacAlpine Lake it has been named the "MacAlpine Moraine" by Falconer et al. (1965b, p. 137). Shells collected some

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[1]A fact also indicated by the variation in altitude of marine features on either side of Meta Incognita Peninsula. For example, at Nannuk Harbour on the south coast, only 15 miles (24 km) from the southeast tip of Baffin Island, the washing limit is at about 65 feet (20 m), and at Pritzler Harbour, 35 miles (56 km) to the northwest, it is at about 115 feet (35 m). On the other hand, at York Sound the surface altitude at the front of the delta is 125 feet (38 m), with the marine limit being at an unknown higher level, and at Watts Bay, 21 miles (34 km) to the northwest, traces of beaches were found at 240 feet (73 m).

[2]The approximate locations of samples discussed in this and the following sections are shown in Figure 1, and the radiocarbon dates are listed in Tables II and III.

13 miles (21 km) northwest of the moraine, at an altitude of 600 feet (180 m), are 8,160 ± 140 years old (GSC-110), an age which is similar to that of 8,230 ± 240 years (GSC-462) for shells on the distal side of the moraine system in Frobisher Bay. The field evidence near MacAlpine Lake, discussed in a previous paper (Blake, 1963, pp. 7-8), indicates that the moraine was forming when the molluscs were living.

How long before 8,200 B.P. the moraine started to form is not known exactly, although the available evidence suggests a situation analogous to that in Hudson Strait, where it has been shown that a considerable and rapid recession of the ice must have taken place in the few hundred years following 8,700 B.P. In the case of the "MacAlpine Moraine", the highest shells in the region, at 670 feet (205 m) near Bathurst Inlet, are 8,370 ± 100 years old (GSC-115), and no older marine organisms have been found as yet in the vicinity of this inlet. A date of 8,360 ± 150 years (GSC-344) has been obtained on shells at 480 feet (145 m) farther north in Bathurst Inlet, and this serves to corroborate the fact that the inlet was open about 8,400 years ago. At the same time deltas close to 700 feet (215 m) above sea-level were being formed where the waters from ice-dammed lakes entered the sea at the south end of Bathurst Inlet, i.e., toward the "MacAlpine Moraine". The relations between these spillways and the location of other, lower drainageways (especially the Ellice River; see Fig. 1 in Blake, 1963), show that the ice must have lain to the northwest of the "MacAlpine Moraine" 8,400 years ago.

Indeed, the entire sequence of dates from northwestern Victoria Island, where shells are 12,400 ± 320 years old (I(GSC)-18), to the vicinity of the "MacAlpine Moraine", is one of progressively younger age (Craig and Fyles, 1960, p. 10; Craig, 1960, p. 6; Dyck and Fyles, 1962, p. 22; Fyles, 1963, pp. 35-36; Blake, 1963, p. 7; Dyck et al., 1965, p. 39). Similarly, another sequence of dates also obtained on marine shells, extends from Lowther Island (9,470 ± 150 years, GSC-322) in Barrow Strait to west and south of Pelly Bay (8,870 ± 140 years, GSC-44; 8,700 ± 120 years, GSC-47) on the mainland (Craig, 1961, p. 4; 1964, p. 6; Dyck and Fyles, 1962, p. 24; Craig and Fyles, 1965, p. 21). In both regions a number of shell samples near the limit of marine submergence have been dated, and because of the progressively younger ages toward the south and southeast it is believed that the sea was in contact with the receding ice front. If this assumption is correct, it follows that in the vicinity of Bathurst Inlet and MacAlpine Lake, as well as farther east along the arctic mainland, the ice-margin was nowhere near the "Cockburn Moraine System" 9,000 years ago, and the ice-margin was even farther from the moraines of this system at 9,500 years B.P. A similar conclusion has been reached, apparently, by Andrews, one of the co-authors of the papers in which the "Cockburn Glacial Phase" is proposed. At one point in his doctoral dissertation he mentioned "a major stillstand of the Laurentide ice about 8,200 B.P.", later he suggested that the "Cockburn Phase" occurred "about 8,000 to 8,300 years ago", and still later in the same paper he suggested 8,400 years for the age of the "Cockburn-MacAlpine Moraines" (Andrews, 1965, pp. 203, 234, 453-454, respectively).

Little can be said regarding the time at which the ice withdrew from the "MacAlpine Moraine". It seems certain that the ice remained at the moraine longer to the west and southwest of MacAlpine Lake, where the

Table II

Selected Radiocarbon Dates on Marine Shells, elsewhere in Northern Canada

Laboratory Dating No. [1]	Locality	Approx. alt. of sample ft. (m) a.s.l.	Collector or Reference	Age (radiocarbon years before 1950)
L-642	N. Labrador	95 (29)	Løken, 1962	9,000 ± 200
GSC-110	NE. Dist. of Mackenzie	600 (183)	Blake, 1963	8,160 ± 140
GSC-337	NE. Dist. of Mackenzie	355-360 (110)	Blake, unpubl.	7,760 ± 140
GSC-115	NE. Dist. of Mackenzie	650-670 (198-204)	Blake, 1963	8,370 ± 100
GSC-344	NE. Dist. of Mackenzie	480 (146)	Blake, unpubl.	8,360 ± 150
I(GSC)-18	NW. Victoria Island	230 (70)	Fyles, 1963	12,400 ± 320
GSC-322	Lowther Island, Barrow Strait	370-390 (113-119)	Blake, unpubl.	-9,470 ± 150
GSC-44	N. Dist. of Keewatin	510 (155)	Craig (Dyck & Fyles, 1962)	8,870 ± 140
GSC-47	N. Dist. of Keewatin	560 (171)	Craig (Dyck & Fyles, 1962)	8,700 ± 120
GSC-288	N. Dist. of Keewatin	624 (190)	Craig, 1965	8,620 ± 140
GSC-286	N. Dist. of Keewatin	397 (121)	Craig, 1965	6,850 ± 140
GSC-183	NW. Baffin Island	392 (119)	Craig, 1965	8,830 ± 170
GSC-304	NW. Baffin Island	293 (89)	Craig, 1965	7,240 ± 150
I-1246	N. Baffin Island	200 (61)	Falconer et al., 1965a, 1965b	7,930 ± 300
I-724	N. Baffin Island	249 (76)	Falconer et al., 1965a, 1965b	8,350 ± 300
I-1553	NE. Baffin Island	207 (63)	Falconer et al., 1965b	7,500 ± 200
I-1556	NE. Baffin Island	151 (46)	Falconer et al., 1965b	6,240 ± 140
I-1602	NE. Baffin Island	108 (33)	Barnett (Løken, 1965)	7,900 ± 210
I-1598	NE. Baffin Island	135 (41)	Løken, 1965	7,200 ± 150
I-1554	NE. Baffin Island	85 (26)	Falconer et al., 1965b; Løken, 1965	7,030 ± 190

[1] In addition to the Geological Survey of Canada (GSC), the abbreviations used here refer to the following laboratories: L – Lamont; I and I(GSC) – Isotopes, Inc.

Table III

Radiocarbon Dates, Deglaciation of Hudson Bay Region[1]

Laboratory Dating No. [2]	Locality	Approx. alt. of sample ft. (m) a. s. l.	Collector or Reference	Age (radiocarbon years before 1950)
		SOUTHERN BAFFIN ISLAND		
GSC-425	Big Island	245 (75)	Blake, unpubl.	7,980 ± 220
GSC-433	Soper River valley	210 (64)	Blake, unpubl.	7,880 ± 140
GSC-504	Soper River valley	140 (43)	Blake, unpubl.	7,480 ± 160
		ISLAND IN HUDSON STRAIT		
GSC-560	Salisbury Island	140 (43)	Blackadar (Blake, unpubl.)	6,920 ± 150
		NORTHERN UNGAVA		
I-488	Deception Bay	281 (86)	Matthews, 1962	10,450 ± 250
I-729	Sugluk Inlet	365 (111)	Matthews, 1964	7,650 ± 250
L-702A	Kugluk Cove	365 (111)	Robitaille, unpubl.	7,050 ± 150
I-726	"Baie Oblongue"	365 (111)	Matthews, 1964	7,160 ± 250
L-702D	Unnamed bay 24 miles (39 km) east of Erik Cove	150 (46)	Robitaille, unpubl.	6,800 ± 150
L-702B	Unnamed bay 20 miles (33 km) east of Erik Cove	255 (78)	Robitaille, unpubl.	7,350 ± 150
GSC-327	Erik Cove	360 (110)	Nichols (Dyck et al., 1966)	7,350 ± 150
NPL-58	Erik Cove	271 (83)	Matthews (Callow et al., 1965)	6,900 ± 130
		HUDSON BAY AND JAMES BAY		
GSC-289	W. of Southampton Island	415 (126)	Craig, 1965	6,830 ± 170
I(GSC)-8	SW. of Chesterfield Inlet	210 (64)	Lee, 1959, 1960b	6,975 ± 250
GSC-92	SW. of Churchill	465 (142)	Dyck & Fyles, 1964	7,270 ± 120
I(GSC)-14	SW. of James Bay	400 (122)	Terasmae & Hughes, 1960; Hughes, 1965	7,875 ± 200
Gro-1698	SW. of James Bay	300+ (91+)	Terasmae & Hughes, 1960	7,280 ± 80
I-1256	SW. of James Bay	370 (113)	Hughes, unpubl.	7,523 ± 200
GSC-487	S. of James Bay	800+ (244+)	Terasmae (Dyck et al., 1966)	7,660 ± 140
GSC-309	S. of James Bay	800+ (244+)	Terasmae (Dyck et al., 1966)	7,150 ± 140
		FOXE BASIN		
GSC-286	SW. side - (Rae Isthmus)	397 (121)	Craig, 1965	6,850 ± 140
GSC-291	W. side - (Melville Peninsula)	441 (134)	Craig, 1965	6,880 ± 180
I-406	NE. side - (Ikpik Bay)	291 (89)	Sim, 1964, Ives, 1963a	6,725 ± 250
GSC-466	E. side - (Nettilling Lake)	285-305 (87-93)	Blake, unpubl.	6,760 ± 140
GSC-465	SE. side - (Putnam Highland)	315-330 (96-100)	Blake, unpubl.	6,830 ± 150
GSC-553	SE. side - (Putnam Highland)	285-300 (87-91)	Blake, unpubl.	6,590 ± 140
GSC-561	S. side - (Foxe Peninsula)	>200, <300 (>61, <91)	Kwak (Blake, unpubl.)	6,120 ± 140

[1] All determinations are on marine shells, except for GSC-487, wood, and GSC-309, peat.

[2] In addition to the Geological Survey of Canada (GSC), the abbreviations used here refer to the following laboratories: I and I(GSC) - Isotopes, Inc.; L - Lamont; NPL - National Physics Laboratory; Gro - Groningen.

started sometime prior to 7,900 years ago and may still have been going on about 7,000 years ago.

Finally, in the writer's view it is most reasonable to expect that on the plateau of northeastern Baffin Island, where the moraine system is represented by multiple ridges in many places and where the retreating ice was not in contact with the sea, some of the ridges could have formed 9,000 years ago, or even earlier, as suggested by Falconer et al. (1965a, p. 609).

Hudson Strait, Hudson Bay, and James Bay

In addition to the new dates on shells from the south coast of Baffin Island, mentioned previously, dates are available from the south side of Hudson Strait, from the west side of Hudson Bay, and from southwest of James Bay; all are listed in Table IV.

The dates from southern Baffin Island show that much of Hudson Strait was open by 8,000 years B.P., and if the moraine athwart Foxe Peninsula corresponds to the moraine crossing Frobisher Bay, it is clear that the whole strait was open by this time. Furthermore, it should be noted that the shell samples from Big Island (7,980 ± 220, GSC-425) at 245 feet (75 m) and the Soper River valley (7,880 ± 140, GSC-433) at 210 feet (64 m) are about 120 feet (37 m) and 90 feet (27 m) below the marine (washing) limits in their respective areas. Both samples were from silt and clay preserved in present-day ponds; i.e., the shells were not found in beach deposits[1]. Thus there is a good possibility that shells nearer the marine limit would be more than 8,000 years old. Likewise, the shells from Salisbury Island, only 6,920 ± 150 years old (GSC-560) are in silt at an altitude of only 140 feet (43 m) (personal communication from R.G. Blackadar, 1966), so that shells nearer the marine limit, presumed to be at 500 feet (150 m) or more as on nearby Mill Island (Gould, 1928, p. 29), could be expected to date from 8,000 B.P. or earlier.

The date of 10,450 ± 250 (I-488) on shells from Deception Bay, northern Ungava, does not fit the general pattern of dates from Hudson Strait; i.e., it is some 3,000 years older than a number of other dates on shells which also relate to high beaches in the same general area (Table III). Falconer et al. (1965b, p. 149) state that this date does not conform to their concept of deglaciation. Nor is it compatible with the writer's suggestion that ice still occupied nearly all of Hudson Strait 8,700 or 8,800 years ago. In view of the configuration of Hudson Strait, and because Deception Bay lies near the western end and is west of the narrowest part of the strait, it is difficult to visualize ice being restricted to the north side while the sea entered along the south shore. In addition, as Andrews (1965, p. 230) pointed out, this date does not fit into the normal pattern of uplift. Possibly the sample was contaminated in some way, perhaps by the mixing of 'old'

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[1] High level beaches were scarce along those parts of the south coast visited by the writer in 1965, and where beaches did occur shells were rarely found. No evidence was seen, in the vicinity of Lake Harbour, of marine action up to an altitude of 600 feet (180 m) or even 500 feet (150 m) (cf. Polunin, 1948, p. 136; Ives, 1963, p. 120, citing unpublished observations by B. Robitaille).

shells, of interstadial or interglacial age[1], with postglacial shells. Obviously more dating of shells along Hudson Strait is needed, but there is certainly no reason to use this isolated date, as Ives (1963b, pp. 347, 353) has done, to suggest that Hudson Strait may have been open as long ago as 18,000 years B.P. Ives himself has apparently discarded this idea, as a co-author of two more recent papers (Falconer et al., 1965a, 1965b), but in these papers no reference is made to the earlier hypothesis or to why it was abandoned.

In Hudson Bay proper, only a limited number of dates bearing on the time of deglaciation are available (see Table III), and unfortunately, at the time of writing no dates at all are available on material near the marine limit along the entire east coast of Hudson Bay (cf. Lee, 1960a; Dyck and Fyles, 1962, p. 22) or from Southampton Island (cf. McCallum, 1955, p. 34; Bird, 1953, pp. 21-28). However, the three dated shell samples from southwest of James Bay, supported indirectly by dates on wood and peat (GSC-487 and GSC-309, Table III)[2], and a single date on shells from southwest of Churchill, Manitoba, indicate that the sea had reached these areas by about 7,900 and 7,300 years B.P., respectively, an incursion named the "Tyrrell Sea" by Lee (1960b). The dates from James Bay also imply that Hudson Strait may have been open slightly before 8,000 years ago, particularly when the distance of nearly 900 miles (1,630 km) from Cape Wolstenholme at the entrance of Hudson Bay to the southern limit of the area once submerged southwest of James Bay is taken into consideration. In this regard Hughes' estimate of 8,275 years as a minimum value for the time of the Cochrane maximum in Ontario is of considerable interest (see Hughes, 1965, p. 563; also Terasmae and Hughes, 1960, p. 1446). Obviously the readvance that deposited the Cochrane till must have culminated well before the sea invaded James Bay from the north, and the figure of 400 years which Terasmae and Hughes allow for this period of retreat and downwastage seems most reasonable to the writer. In fact, a pertinent question is how much time elapsed after deglaciation before marine pelecypods succeeded in migrating to south of James Bay, for it must be remembered that the inflow of freshwater into the Hudson Bay–James Bay area must have been tremendous. This freshwater, flowing out via Hudson Strait, would have hindered the entry of sea water and its accompanying fauna, whereas localities in eastern Baffin Island or Labrador, for example, are open to the Atlantic Ocean and could have been colonized much more quickly after withdrawal of the ice. Thus there is considerable evidence to suggest that ice was in retreat from the Cochrane maximum by 8,200 years B.P., close to the time at which the moraines in Frobisher Bay and near MacAlpine Lake were just starting to form.

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[1] The reader will recall that "old" shells occur in both till and in postglacial (?) beach deposits on the north side of Hudson Strait.

[2] Date GSC-487 (7,660 ± 140 years) is on wood from sediments in a residual pond post-dating Glacial Lake Barlow-Ojibway, which drained northward to James Bay. Date GSC-309 (7,150 ± 140 years) is on basal peat overlying sediments of this glacial lake (see comments by J. Terasmae in Dyck et al., 1966). James Bay must have been partially open before the glacial lake could drain.

Foxe Basin

A number of dates from Foxe Basin indicate that deglaciation occurred later there than in the Hudson Bay–James Bay region. The date of 6,850 ± 140 years (GSC-286) from Rae Isthmus is from the extreme southwest corner of Foxe Basin, and dates on shells from four other localities around the basin are very similar (see Table III and Localities 10 and 11, Fig. 2). The shells were collected close to the marine limit in their respective areas[1], and therefore they are presumed to indicate the approximate time at which the sea invaded Foxe Basin. One other sample, from Foxe Peninsula, is only 6,120 ± 140 years old (GSC-561), but as the shells were collected at an altitude between 200 and 300 feet (61 to 91 m) above sea-level (personal communication from R.G. Blackadar, 1966), and the marine limit in the area may be as much as 500 feet (152 m), the young age is not surprising. It appears that there was a rapid disintegration of the ice in the Foxe Basin region shortly after 7,000 years B.P., the same time the ice retreated from the moraine in Frobisher Bay. None of the dates presently available support Andrews' (1965, p. 216) suggestion that the southern third of Foxe Basin was open as early as 7,400 years ago.

Final dissolution of the ice-sheet, southern Baffin Island

Although the moraines discussed in this paper were formed along the margins of an ice-sheet which may well have been continuous from Baffin Island and Foxe Basin to the eastern District of Mackenzie, presumably a number of topographic highs, or centres of outflow, existed within the boundaries of the ice-sheet. For instance, even at the time that the moraine crossing Frobisher Bay was forming, there seems to have been a local "high" on the ice-sheet a short distance to the west. Ice from Foxe Basin or from a dome over the western part of the island adjacent to Foxe Basin flowed eastward across the Nettilling Lake basin to Cumberland Sound and southward across the low eastern part of Foxe Peninsula to Hudson Strait. Probably some flow occurred toward Frobisher Bay to the southeast.

However, unlike northern Baffin Island (cf. Ives and Andrews, 1963, pp. 24-25, 43; Andrews and Sim, 1964; Sim, 1964, pp. 71-73), no evidence, either in the form of erratics or in the carbonate content of the silt-clay fraction in till[2], was found of Palaeozoic limestone and dolomite

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[1] Craig's samples from Rae Isthmus and the west side of Foxe Basin are about 65 feet (20 m) and 40 feet (12 m), respectively, below the marine limit (personal communication, 1966). Sim's (1964, Map 2; Ives, 1964, pp. 61-62) sample from northeastern Foxe Basin is about 60 feet (18 m) below the marine limit, and the writer's sample from west of Nettilling Lake and the higher sample in the Putnam Highland are both within 30 feet (9 m) of the marine limit.

[2] Five samples of till from areas underlain by granite along the east side of Amadjuak Lake and north of the lake all contain less than 3% carbonate, as determined in the Chittick apparatus (cf. Andrews and Sim, 1964), whereas 12 till samples from south, west, and northwest of Amadjuak Lake in areas underlain by Palaeozoic rocks all contain from 30 to 90% carbonate.

Table IV

Radiocarbon Dates, Final Dissolution of Ice-sheet

Laboratory Dating No.[1]	Material Dated	Locality	Collector or Reference	Age (radiocarbon years before 1950)
		SOUTHERN BAFFIN ISLAND		
GSC-498	organic debris[2]	Amadjuak Lake	Blake, unpubl.	4,460 ± 140
GSC-498	organic debris	Amadjuak Lake	Blake, unpubl.	4,550 ∓ 220
		CENTRAL LABRADOR - UNGAVA		
SM-354	organic carbon in sediment	Ashuanipi River	Grayson, 1956; Bray & Burke, 1960	5,250 ± 800
SM-355	organic carbon in sediment	Greenbush Lake	Grayson, 1956; Bray & Burke, 1960	5,300 ∓ 800
SM-356	organic carbon in sediment	Marymac Lake	Grayson, 1956; Bray & Burke, 1960	6,400 ± 900
I-880	peat	Churchill Falls area	Morrison, 1963	5,255 ± 200
I-853	peat	Churchill Falls area	Morrison, 1963	5,450 ∓ 220
I-728	peat	Churchill Falls area	Morrison, 1963	5,575 ∓ 250
		WESTERN KEEWATIN		
I-1224	marine shells	Beverly Lake	Dyck _et al._, 1966	6,015 ± 150

[1] In addition to the Geological Survey of Canada (GSC), the abbreviations used here refer to the following laboratories: SM - Socony Mobil; I - Isotopes, Inc.

[2] The first determination is on the fraction less soluble in NaOH, the second of the fraction (humic) more soluble in NaOH.

having been carried eastward across Amadjuak Lake onto the Precambrian granite terrain, although the two areas are only a few miles apart. On the contrary, tails of till from Palaeozoic outliers and countless highly smoothed and plucked outcrops within the area of Precambrian rocks indicate westward ice motion (Fig. 2), and the ground surface above the limestone cliffs, which in places rise 100 feet (30 m) above the west side of Amadjuak Lake, is littered with granitic erratics. Possibly the ice did move eastward across Amadjuak Lake at some stage during the last glaciation, but if so it seems curious to the writer that no traces of such movement were found, despite many low-level helicopter flights and ground checks in the area just east of the lake. The absence of limestone erratics is especially remarkable.

The available radiocarbon dates indicate that by about 6,800 to 6,700 years B.P. the ice had receded from the head of Frobisher Bay and from the Foxe Basin coast west of Nettilling and Amadjuak Lakes. The highest marine features occurring along the southeastern Foxe Basin coast are rarely above 350 feet (107 m); no indication was seen that the sea entered the basin now occupied by Amadjuak Lake, at about 370 feet (113 m), a suggestion also put forward by Bird (1958, pp. 336, 348) in contrast to the area of marine inundation shown on the "Glacial Map of Canada" (1958). It is not known whether marine waters reached Nettilling Lake first from the east or from the west, as no dates are available from Cumberland Sound, but when the high level beaches were forming Foxe Basin and Cumberland Sound were joined. At the same time the low eastern part of Foxe Peninsula was inundated by the sea, leaving western Foxe Peninsula and that part of Baffin Island south of Nettilling Lake as separate islands.

The last main mass of ice in southern Baffin Island was apparently located in a crescent-shaped area to the northeast, east, and southeast of Amadjuak Lake. This area, except for a zone near Sylvia Grinnell Lake, is distinguished by the complete lack of drumlins or other landforms indicating ice flow that are large enough to be visible on air photographs. Most of this featureless area is at altitudes above 1,000 feet (305 m). Eskers and deltas south of the eastern part of Amadjuak Lake all indicate flow of water toward the lake. Lateral drainage channels near the headwaters of Hone River and along the scarp south of Amadjuak Lake, a scarp that separates the lower area of Palaeozoic rocks from the higher Precambrian terrain toward Hudson Strait, also indicate that meltwater flowed toward the northwest.

The crescent-shaped mass of ice no doubt broke up into several smaller remnants at a still later stage. Numerous strandlines, formed in ice-dammed lakes along the north-flowing McKeand River and its tributaries, indicate that one of the last masses of ice was situated on the plateau northeast of Amadjuak Lake but south of the area inundated by the sea between Nettilling Lake and Cumberland Sound. The writer found no evidence supporting Bird's (1958, pp. 329-331; 1960, p. 8) contention that during deglaciation, at a time when all the area west of the east sides of Nettilling and Amadjuak Lakes was ice-free, ice still filled Frobisher Bay and Cumberland Sound and covered much of the peninsulas adjoining these troughs; in fact, the available radiocarbon dates invalidate this hypothesis.

The only date available bearing on the time of disappearance of the main remnant ice mass is a bog bottom sample collected on an island in the southeastern corner of Amadjuak Lake (Locality 9, Fig. 2). The basal organic material, in a cliff exposure along an esker, is 4,460 ± 150 years old (GSC-498)[1]. However, experience in many other glaciated areas has shown that several hundred years, or more, may elapse after ice melts away before organic accumulation commences. Therefore the date can only be regarded as providing a minimum age for the deglaciation of southeastern Amadjuak Lake; ice still may have existed farther east along the McKeand River when this organic material was accumulating.

By way of comparison it is interesting to note that numerous dates on bog bottom samples from the central part of Labrador-Ungava show that deglaciation there occurred more than 5,000 years ago (Grayson, 1956, pp. 205-209; Bray and Burke, 1960, p. 110; Morrison, 1963, p. 274)[2]. West of Hudson Bay a date of 6,015 ± 150 years (I-1224) obtained recently on marine shells from west of the Keewatin Ice Divide, at Beverly Lake in the Thelon River valley, indicates that the sea had penetrated westward through the remnant ice mass by about 6,000 years B.P. (see comment by Craig and Fyles in Dyck et al., 1966).

No definite information is available yet as to whether the present-day ice-caps disappeared during any part of 'postglacial' time, or whether they are remnants from the ice-sheet as it existed prior to 8,200 years ago, i.e., at a time when the ice lay east of the major moraine system crossing Frobisher Bay. The two most southerly ice-caps, the Grinnell and Terra Nivea, are separated by the gorges leading to York Sound from the Hudson Strait side of Meta Incognita Peninsula. For this reason the ice-caps must also have been separated 8,700 or 8,800 years ago, when the gorges were occupied by major rivers and when the delta at the head of York Sound was being built. No evidence was seen to suggest that the ice-caps have coalesced since that time.

SUMMARY AND CONCLUSIONS

The main points of the present paper can be summarized as follows:

1. A major end moraine system, some 325 miles (525 km) in length, which crosses Frobisher Bay in southeastern Baffin Island, has been mapped accurately for the first time. The high level 'strandlines' reported by earlier workers from the southwest side of Frobisher Bay (Wengerd, 1951; Mercer, 1956) are in reality a part of this moraine system; i.e., they are a combination of lateral moraines, kame terraces, and marginal lake terraces.

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[1] This date was obtained on the fraction of the organic matter that was less soluble in NaOH. A date of 4,550 ± 220 years (GSC-498) was obtained on the more soluble (humic) fraction, indicating that contamination by younger material was at a minimum.

[2] Grayson's dates were obtained on sections of core one foot (30 cm) in length and the errors are ±800 to 900 years, thus they are approximate at best (cf. Table IV).

2. A second end moraine which crosses Foxe Peninsula in southwestern Baffin Island has been delineated. Although radiocarbon dates bracketing this moraine are not available as yet, on morphological grounds it is thought to correlate with the moraine system crossing Frobisher Bay.

3. The existence of these moraines necessitates a considerable change in the outline of a diminished Laurentide Ice Sheet during the so-called "Cockburn Glacial Phase" of Falconer et al. (1965a, 1965b).

4. Analysis of the time of formation of various moraines assigned to the "Cockburn Moraine System", and of other dates bearing on the time of deglaciation, indicates that the ice margin did not remain at the position indicated by Falconer et al. (1965a, 1965b) for the period 9,500 or 9,000 to 8,000 years B.P. Instead, major changes in the configuration of the ice-sheet occurred during this 1,000 to 1,500-year period.

5. Certain, but not all, segments of the "Cockburn Moraine System", as well as the moraine system crossing Frobisher Bay, appear to have been forming about 8,200 years B.P. Only in northwestern and northern Baffin Island is there evidence that parts of the moraine system may have started to form as much as 9,000 years ago.

6. Moraine formation continued for several hundred years after 8,200 years B.P. The oldest dates on the proximal sides of the moraine system are: 7,240 ± 150 (GSC-304) for northwestern Baffin Island (Bernier Bay), 6,850 ± 140 (GSC-286) for the southwest corner of Foxe Basin (Rae Isthmus), and 6,750 ± 170 (GSC-464) for southeastern Baffin Island (Frobisher Bay).

7. Dates on marine shells from south of James Bay indicate that the sea had reached this region by about 7,900 years B.P. Since the sea must have reached James Bay by way of Hudson Strait (and then the shortest route would be along the east coast of Hudson Bay), it follows that the strait must have been open slightly before 8,000 years ago. This conclusion is in agreement with the date of about 8,200 years B.P. for the beginning of moraine formation in southeastern Baffin Island and with the suggested correlation of the Foxe Peninsula moraine with the moraine system crossing Frobisher Bay.

8. By 8,000 years ago, the sea had penetrated very close to the centre of the area postulated by Falconer et al. (1965a, 1965b) as then being an ice-sheet, and the ice had retreated from the limit reached during the Cochrane advance, but at the same time the moraines on Baffin Island and the arctic mainland were in the process of forming. Rather than this having been a "healthy" time for an entire ice-sheet, moraine-building activity seems to have been concentrated around the northern margins. Several domes, or centres of outflow, already had developed, and the ice-sheet was about to disintegrate into separate ice masses.

9. Ice remained in Foxe Basin later than in Hudson Bay; the dates available from five localities around the basin, on shells near the marine limit, are all close to 6,900 to 6,700 years B.P.

10. The last main ice-mass in southern Baffin Island persisted in a crescent-shaped area southeast, east, and northeast of Amadjuak Lake, and

no evidence was found of ice ever having flowed eastward across the lake. Amadjuak Lake was free from ice some time before 4,500 years B.P.

In conclusion, the concept of a "Cockburn Glacial Phase", as presented by Falconer et al. (1965a, 1965b) is a most interesting hypothesis, one which merits attention and which has stimulated much thought and discussion. In the writer's opinion, however, more critical examination of the hypothesis is needed, after further study and after more radiocarbon dates become available. It would be desirable for future work to be concentrated in those fiords and lowland areas where moraine ridges are more widely spaced and where dating of individual ridges may be possible. Only in this way can an accurate chronology of events be established, and only this chronology will prove exactly which parts of the moraine system are contemporaneous.

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REFERENCES

Andrews, J.T.
1965: Glacial geomorphological studies on north-central Baffin Island, Northwest Territories, Canada; Ph.D. dissertation, Univ. of Nottingham, 2 vol., 476 pp. (Limited distribution).

Andrews, J.T., and Sim, V.W.
1964: Examination of the carbonate content of drift in the area of Foxe Basin, N.W.T.; Can. Dept. Mines Tech. Surv., Geog. Bull., No. 21, pp. 44-53.

Barnett, D.M., and Peterson, J.A.
1964: The significance of Glacial Lake Naskaupi 2 in the deglaciation of Labrador–Ungava; Can. Geographer, vol. 8, pp. 173-181.

Barton, G.H.
1896: Evidence of the former extension of glacial action on the west coast of Greenland and in Labrador and Baffin Land; Am. Geol., vol. 18, pp. 379-384.

Bird, J.B.
1953: Southampton Island; Can. Dept. Mines Tech. Surv., Geog. Br. Mem. 1, 84 pp.

1958: A report on the physical environment of southern Baffin Island, Northwest Territories, Canada; The Rand Corporation, Santa Monica, California (U.S. Air Force PROJECT RAND), Research Memorandum RM-2362, 375 pp. (reprinted 1963 with same pagination as Memorandum RM-2362-1-PR).

1960: The scenery of central and southern Arctic Canada; Can. Geographer, No. 15, pp. 1-11.

Blackadar, R.G.
1960: Geology, Hobart Island, Baffin Island, District of Franklin, Northwest Territories; Geol. Surv. Can., Map 55-1959.

1961: Geology, Mingo Lake, Baffin Island, District of Franklin, Northwest Territories; Geol. Surv. Can., Map 43-1960.

1962: Geology, Andrew Gordon Bay–Cory Bay, Baffin Island, District of Franklin; Geol. Surv. Can., Map 5-1962.

Blake, W., Jr.
1963: Notes on glacial geology, northeastern District of Mackenzie; Geol. Surv. Can., Paper 63-28, 12 pp.

Bray, E.E., and Burke, W.H.
1960: Socony Mobil radiocarbon dates I; Am. J. Sci. Radiocarbon Supp., vol. 2, pp. 97-111.

Callow, W.J., Baker, M.J., and Hassall, G.I.
1965: National Physics Laboratory radiocarbon measurements III; Radiocarbon, vol. 7, pp. 156-161.

Canadian Hydrographic Service
1965: Culbertson Island to Koojesse Inlet; Marine Sci. Br., Chart 7122, Edition 4.

Craig, B.G.
1960: Surficial geology of north-central District of Mackenzie, Northwest Territories; Geol. Surv. Can., Paper 60-18, 8 pp.

1961: Surficial geology of northern District of Keewatin, Northwest Territories; Geol. Surv. Can., Paper 61-5, 6 pp.

Craig, B.G. (cont'd.)
1964: Surficial geology of Boothia Peninsula and Somerset, King William, and Prince of Wales Islands, District of Franklin; Geol. Surv. Can., Paper 63-44, 8 pp.

1965: Notes on moraines and radiocarbon dates in northwest Baffin Island, Melville Peninsula, and northeast District of Keewatin; Geol. Surv. Can., Paper 65-20, 7 pp.

Craig, B.G., and Fyles, J.G.
1960: Pleistocene geology of Arctic Canada; Geol. Surv. Can., Paper 60-10, 21 pp.

1965: Quaternary of Arctic Canada, in Markov, F.G., et al., eds., Anthropogene Period in the Arctic and Subarctic; Trans. U.S.S.R. Res. Inst. Geol. Arctic, vol. 143, pp. 5-33 (in Russian with English summary).

Davison, W.L.
1959a: Geology, Lake Harbour, Baffin Island, District of Franklin, Northwest Territories; Geol. Surv. Can., Map 29-1958.

1959b: Geology, Foxe Peninsula (eastern part), Baffin Island, District of Franklin, Northwest Territories; Geol. Surv. Can., Map 4-1959.

Dunbar, M.J.
1958: Physical oceanographic results of the "Calanus" expeditions in Ungava Bay, Frobisher Bay, Cumberland Sound, Hudson Strait and northern Hudson Bay; J. Fisheries Research Board Can., vol. 15, pp. 155-201.

Dyck, W., and Fyles, J.G.
1962: Geological Survey of Canada radiocarbon dates I; Radiocarbon, vol. 4, pp. 13-26.

1964: Geological Survey of Canada radiocarbon dates III; Radiocarbon, vol. 6, pp. 167-181.

Dyck, W., Fyles, J.G., and Blake, W., Jr.
1965: Geological Survey of Canada radiocarbon dates IV; Radiocarbon, vol. 7, pp. 24-46.

Dyck, W., Lowdon, J.A., Fyles, J.G., and Blake, W., Jr.
1966: Geological Survey of Canada radiocarbon dates V; Radiocarbon, vol. 8.

Falconer, G., Andrews, J.T., and Ives, J.D.
1965a: Late-Wisconsin end moraines in northern Canada; Science, vol. 147, pp. 608-610.

Falconer, G., Ives, J.D., Løken, O.H., and Andrews, J.T.
1965b: Major end moraines in eastern and central Arctic Canada; Can. Dept. Mines Tech. Surv., Geog. Bull., vol. 7, pp. 137-153.

Farrand, W.R., and Gajda, R.T.
1962: Isobases on the Wisconsin marine limit in Canada; Can. Dept. Mines Tech. Surv., Geog. Bull., No. 17, pp. 5-22.

Fyles, J.G.
1963: Surficial geology of Victoria and Stefansson Islands, District of Franklin; Geol. Surv. Can., Bull. 101, 38 pp.

Geological Association of Canada
1958: Glacial Map of Canada; Geol. Assoc. Can.

Gould, L.M.
1928: Report on the physical geography, in Putnam, G.P., The Putnam Baffin Island Expedition; Geog. Rev., vol. 18, pp. 27-40.

Grayson, J.F.
1956: The postglacial history of vegetation and climate in the Labrador – Quebec region as determined by palynology; Ph.D. dissertation, Univ. of Michigan, 252 pp.

Hoppe, G.
1948: Isrecessionen från Norrbottens kustland, i belysning av de glaciala formelementen; Geographica (Skrifter från Uppsala Universitets Geografiska Inst.), No. 20, 112 pp.

1957: Problems of glacial morphology and the ice age; Geografiska Annaler, vol. 39, pp. 1-17.

1959: Glacial morphology and inland ice recession in northern Sweden; Geografiska Annaler, vol. 41, pp. 193-212 (published 1960).

Hughes, O.L.
1965: Surficial geology of part of the Cochrane District, Ontario, Canada, in Wright, H.E., Jr., and Frey, D.G., eds., International Studies on the Quaternary; Geol. Soc. Am., Special Paper 84, pp. 535-565.

Ives, J.D.
1957: Glaciation of the Torngat Mountains, northern Labrador; Arctic, vol. 10, pp. 66-87.

1958: Glacial geomorphology of the Torngat Mountains, northern Labrador; Can. Dept. Mines Tech. Surv., Geog. Bull., No. 12, pp. 47-75.

1960a: Former ice-dammed lakes and the deglaciation of the middle reaches of the George River, Labrador – Ungava; Can. Dept. Mines Tech. Surv., Geog. Bull., No. 14, pp. 44-70.

1960b: The deglaciation of Labrador – Ungava; Cahiers de Géographie de Québec, No. 8, pp. 323-343.

Ives, J.D. (cont'd.)

1963a: Determination of the marine limit in eastern Arctic Canada; Can. Dept. Mines Tech. Surv., Geog. Bull, No. 19, pp. 117-122.

1963b: Field problems in determining the maximum extent of Pleistocene glaciation along the eastern Canadian seaboard - a geographer's point of view, in Löve, A., and Löve, D., eds., North Atlantic Biota and their History: Oxford, Pergamon Press, pp. 337-354.

1964: Deglaciation and land emergence in northeastern Foxe Basin; Can. Dept. Mines Tech. Surv., Geog. Bull., No. 21, pp. 54-65.

Ives, J.D., and Andrews, J.T.

1963: Studies in the physical geography of north-central Baffin Island, N.W.T.; Can. Dept. Mines Tech. Surv., Geog. Bull., No. 19, pp. 5-48.

Kindle, E.M.

1896: On some Palaeozoic fossils from Baffinland; Am. J. Sci., 4th ser., vol. 2, pp. 455-456.

Lee, H.A.

1959: Surficial geology of southern District of Keewatin and the Keewatin Ice Divide, Northwest Territories; Geol. Surv. Can., Bull. 51, 42 pp.

1960a: Surficial geology, Sakami Lake (Fort George - Great Whale River area), New Quebec; Geol. Surv. Can., Map 52-1959.

1960b: Late glacial and postglacial Hudson Bay sea episode; Science, vol. 131, pp. 1609-1611.

Løken, O.H.

1962: The late-glacial and postglacial emergence and the deglaciation of northernmost Labrador; Can. Dept. Mines Tech. Surv., Geog. Bull., No. 17, pp. 23-56.

1965: Postglacial emergence at the south end of Inugsuin Fiord, Baffin Island, N.W.T.; Can. Dept. Mines Tech. Surv., Geog. Bull., vol. 7, pp. 243-258.

Matthew, E.M.

1961: The deglaciation of the George River Basin, Labrador - Ungava, in Geomorphological studies in northeastern Labrador - Ungava; Can. Dept. Mines Tech. Surv., Geog. Br., Paper No. 29, pp. 17-29.

Matthews, B.

1962: Glacial and post-glacial geomorphology of the Sugluk - Wolstenholme area, northern Ungava, in Field Research in Labrador - Ungava; McGill Sub-Arctic Research Papers, No. 12 (Annual Report, 1960-61), pp. 17-46.

Matthews, B. (cont'd.)
1964: The late Pleistocene glaciation and deglaciation of northernmost Ungava, Quebec; unpublished report to the Arctic Institute of North America and the Air Force Cambridge Research Laboratory, 94 pp.

McCallum, K.J.
1955: Carbon-14 age determinations at the University of Saskatchewan; Trans. Roy. Soc. Can., 3rd ser., Sect. 4, vol. 49, pp. 31-35.

Mercer, J.H.
1956: Geomorphology and glacial history of southernmost Baffin Island; Bull. Geol. Soc. Am., vol. 67, pp. 553-570.

Morrison, A.
1963: Landform studies in the middle Hamilton River area, Labrador; Arctic, vol. 16, pp. 272-275.

Olsson, I.U., and Blake, W., Jr.
1962: Problems of radiocarbon dating of raised beaches, based on experience in Spitsbergen; Norsk Geografisk Tidsskrift, vol. 18 (1961-1962), pp. 47-64.

Peterson, J.A.
1965: Deglaciation of the Whitegull Lake area, Labrador - Ungava; Cahiers de Géographie de Québec, No. 18, pp. 183-196.

Polunin, N.
1948: Botany of the Canadian Eastern Arctic, Part III, Vegetation and Ecology; Natl. Mus. Can., Bull. No. 104, 304 pp.

Riley, G.C.
1959: Cumberland Sound, Baffin Island, District of Franklin, Northwest Territories; Geol. Surv. Can., Map 1061A.

Sim, V.W.
1964: Terrain analysis of west-central Baffin Island, N.W.T.; Can. Dept. Mines Tech. Surv., Geog. Bull., No. 21, pp. 66-92.

Terasmae, J., and Hughes, O.L.
1960: Glacial retreat in the North Bay area, Ontario; Science, vol. 131, pp. 1444-1446.

Ward, W.H.
1952: A note on the elevated strandlines of Frobisher Bay, Baffin Island; Geog. Rev., vol. 42, p. 651.

Weeks, L.J.
1928: Cumberland Sound area, Baffin Island; Geol. Surv. Can., Summ. Rept., 1927, Part C, pp. 83-95.

Wengerd, S.A.
1951: Elevated strandlines of Frobisher Bay, Baffin Island, Canadian Arctic; Geog. Rev., vol. 41, pp. 622-637.

Plate I. Aerial view southeast along valley parallel to Frobisher Bay, near Cape Rammelsberg. Note complex of lateral moraines and kame terraces in centre foreground. The location of Plate II is shown by the arrow. July 18, 1965.

Plate II. View southeast along lateral moraine - kame terrace shown from the air in Plate I. Deposit rises over 50 feet (15 m) above the adjacent flat area (left in photograph). Sloping moraines in distance (arrows) were formed by ice that flowed through gaps in the coastal hills from Frobisher Bay. July 19, 1965.

Plate III. Marine (washing) limit on west side of Barrier Inlet, south coast of Baffin Island. The arrows indicate the level, here at about 230 feet (70 m), below which erratic boulders and the thin till cover have been washed away by wave action. The presence of such a line is typical for much of the rough and irregular coast of southern Baffin Island. June 14, 1965.

Plate IV. Raised beaches on low-lying terrain northwest of the Putnam Highland. Beaches are common and well developed in the areas near Foxe Basin that are underlain by Palaeozoic sedimentary rocks. Compare with Plate III. July 30, 1965.

Plate V. Aerial view northeast toward York Sound along largest gorge crossing Meta Incognita Peninsula. Terra Nivea Ice-cap in right distance, coastal mountains and Frobisher Bay beyond. Gorge is over 1,000 feet (305 m) deep near the ice-cap. July 3, 1965.

Plate VI. Delta at head of York Sound, where river in gorge of Plate V once debouched into the sea. View west at fore-set beds of sand and silt. Shells collected 65 feet (20 m) above sea-level, about half-way up the face in the foreground, are 8,700 years old. Helicopter on surface of delta provides scale. August 29, 1965.