# Late Foxe glaciation of southern Baffin Island, N.W.T., Canada

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## ABSTRACT

A continental outlet glacier terminating in outer Frobisher Bay, southern Baffin Island, Arctic Canada, deposited the Hall moraine immediately prior to 10,760 yr B.P. (dated by $C^{14}$). This moraine and associated $C^{14}$ dates provide the first documentation of a pre-Holocene late Foxe (late Wisconsin) ice advance from the eastern Canadian Arctic. A second moraine system deposited near the head of the bay is of Cockburn age (8,000 to 9,000 yr), and it correlates with the maximum late Foxe advance farther north on Baffin Island. A compilation of $C^{14}$ dates related to the maximum late Foxe advance and marine paleoclimatology along 2,500 km of eastern Arctic coastline suggests a parallel but time-transgressive latitudinal relationship. There is considerable evidence for dominantly local ice accumulation centers and a prominent glacial advance between 11,000 and 10,000 yr B.P. from widely scattered sites surrounding the North Atlantic Ocean.

## INTRODUCTION

The purpose of this paper is to report new data from Frobisher Bay, southern Baffin Island (Fig. 1), that provides the first documentation of a pre-Holocene late Foxe (late Wisconsin) ice advance in the eastern Canadian Arctic (25,000 km of coastline). Evidence for this advance, as well as at least one younger and two older advances, is derived from moraines, weathering data, and sea-level stratigraphy with radiocarbon and amino-acid dating control. These new data demonstrate the fundamental time-transgressive latitudinal relationships of the last glacial maximum and associated climatic shifts that occurred along the eastern Canadian Arctic at the close of the last glaciation. It also suggests that broadly similar glaciological events have occurred on many of the land masses bordering the North Atlantic Ocean.

Despite nearly two decades of research on glacier fluctuations in the eastern and high Canadian Arctic, an unequivical late Foxe

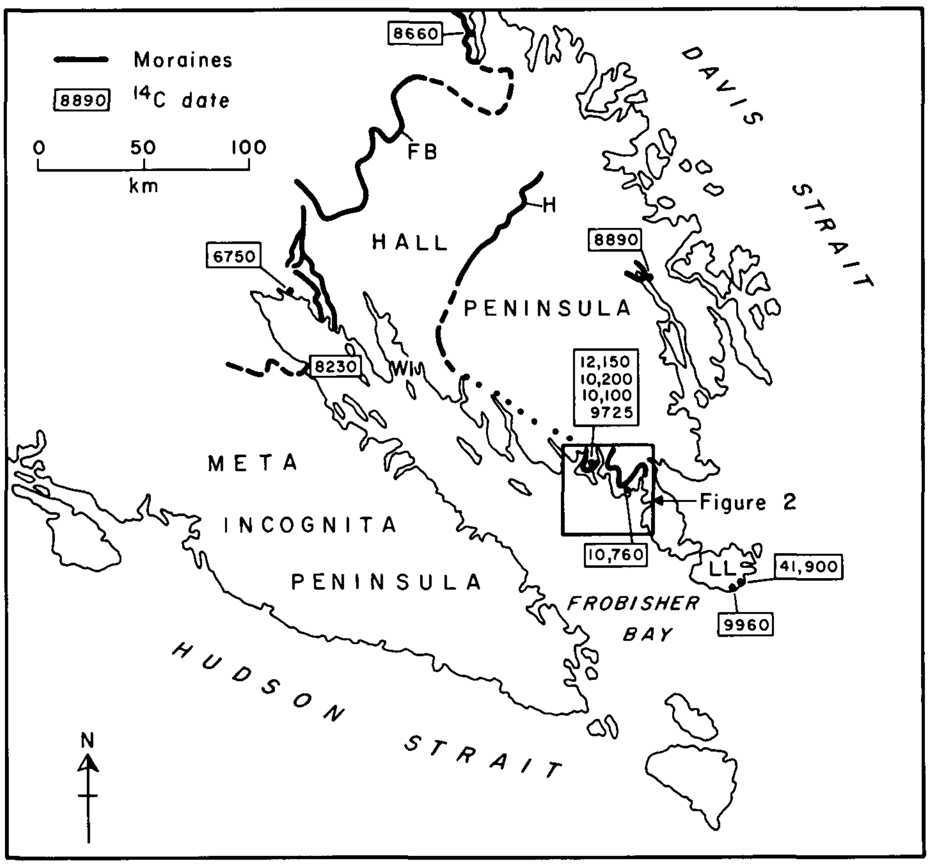


Figure 1. Southern Baffin Island with the location of major moraine systems and pertinent radiocarbon dates. Moraines are dashed where inferred or indistinct and dotted where interpolated. FB = Frobisher Bay moraine; H = Hall moraine; WI = Ward Inlet; LL = Loks Land.

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Geological Society of America Bulletin, Part I, v. 91, p. 399–405, 5 figs., 2 tables, July 1980, Doc. no. 00705.

radiocarbon-dated site that defines a former ice-marginal position older than about 9,200 yr has yet to be reported, and most such sites are less than 8,700 yr old. The late Foxe glacial history prior to 10,000 yr B.P. remains hotly debated for some areas (see Patterson, 1977). However, on east-central Baffin Island, numerous studies have documented that outlet glaciers were restricted for the most part to the inner fiord regions throughout late Foxe time. Moraines formed between 8,000 and 9,000 yr B.P. (Cockburn Substage, Andrews and Ives, 1978) apparently represent the maximum late Foxe ice limits (Andrews and Ives, 1972; Miller and Dyke, 1974; Dyke, 1979).

## MORAINAL EVIDENCE

Blake (1966) suggested that a disjunct but largely continuous end moraine complex traceable from the head of Meta Incognita Peninsula across the inner reaches of Frobisher Bay and trending northwesterly across Hall Peninsula was a single moraine system that formed during early Holocene time. This moraine system, here named the "Frobisher Bay moraine," can be traced with only minor breaks to the head of Cumberland Sound, where it is correlated with the Ranger moraine (Dyke, 1979).

A previously unrecognized moraine system, much less continuous, but locally of well-preserved morphology, terminates along the outermost northeast shore of Frobisher Bay, ~ 170 km southeast of the terminous of the Frobisher Bay Moraine (Fig. 1). The moraine system is best preserved between Gold Cove and Warwick Sound (Fig. 2), where it occurs as a series of disjunct lateral moraines on gently sloping hillsides. Glacio-fluvial deposits and dead ice topography are commonly associated with the moraines, which in some areas are composed of a mixture of till and fluvially reworked sediments with typical kame terrace morphology. These deposits have undergone only limited post-depositional modification from fluvial and cryoturbation processes. This moraine system is here named the "Hall moraine," after the peninsula on which it is found.

Limestone erratics are abundant in the drift about the marine limit in the outer reaches of Frobisher Bay, but diminish in abundance toward the head of the bay. In the Gold Cove area, limestone pebbles locally account for 10% to 20% of the till pebbles, whereas at the mouth of Hamlen Bay 30 km up-bay, limestone pebbles have diminished to less than 1%, and in till another 40 km up-bay, no limestone erratics were found. Outliers of Paleozoic limestone that underlie outer Frobisher Bay (B. McClean, 1978, oral commun.) are presumed to be the source of the erratics. The distribution of limestone-bearing till, coupled with the down-bay slope of the moraine crests, indicates that the Hall moraine was deposited by an outlet glacier that advanced out Frobisher Bay from the west.

Thick patches of till and scattered moraine remnants found along the east flank of Ward Inlet (Fig. 1) are presumed correlatives of the Hall moraine. Inland from the head of Ward Inlet, a prominent moraine system has been identified from aerial photographs trending roughly northeast-southwest across central Hall Peninsula. This moraine, lying some 50 km beyond the Frobisher Bay moraine, was formed by continental ice impinging on the peninsula from the northwest. The ice dammed a complex series of proglacial lakes as much as 35 km in length. Shorelines and lacustrine deltas associated with these lakes are as well preserved as similar deposits in proglacial lake basins fronting the Frobisher Bay moraine. The trace of the moraine is lost to the northeast, and although it cannot be traced unambiguously to the south and east into the moraines terminating in the Warwick Sound region, the two segments are considered correlative (Fig. 1).

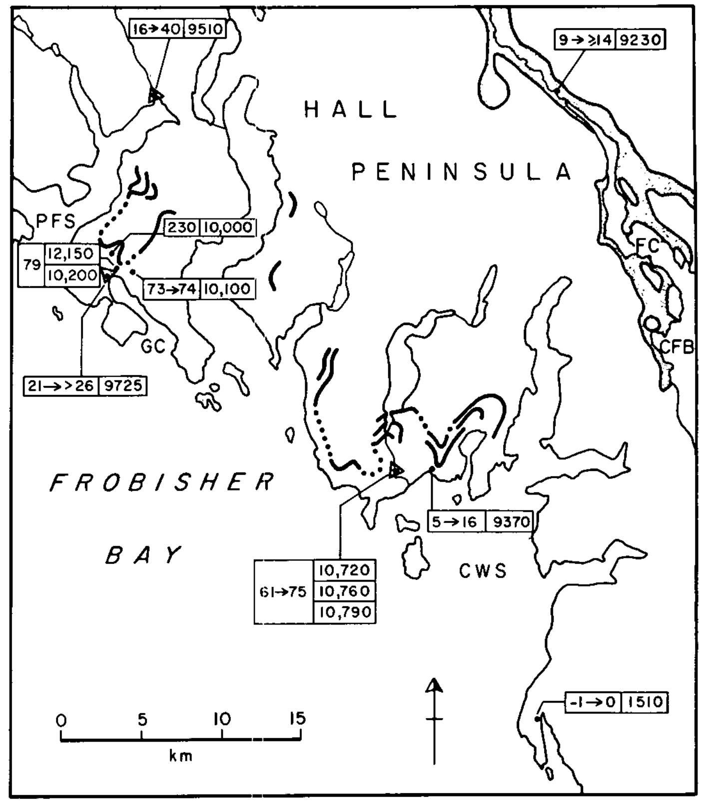


Figure 2. Major moraines and marine deposits along the outer northeastern coast of Frobisher Bay (see Fig. 1 for location). Numbers in rectangles refer to the following (in order of appearance): (a) the elevation of the sample (maht), (b) the inferred relative sea level at the time the sample lived, and (c) the radiocarbon date (yr B.P.). Hachured areas represent marine deposits; triangles are fossiliferous marine deltas. Moraines denoted by heavy solid line where traceable in the field or on air photos, dotted where inferred. Place names abbreviated as follows: PFS = Peter Force Sound, GC = Gold Cove, WS = Warwick Sound, FC = Frenchman Cove, CFB = Cyrus Field Bay.

An earlier, more extensive ice advance is recorded by moraines above and/or beyond the Hall moraine along the outer northeast coast of Frobisher Bay. The moraines descend down-bay and contain limestone erratics, indicating that they are also related to a major outlet glacier that occupied Frobisher Bay. Erratic boulders above the uppermost lateral moraines suggest that an even earlier glaciation affected the bay, although no geomorphological evidence of this advance remains.

## WEATHERING

On substrate above the local marine limit (20 to 120 m aht[1] in Frobisher Bay) proximal to the Frobisher Bay moraine, only incipient bedrock weathering has occurred. Glacial striae, chatter marks, grooves, and polish are commonly preserved on fine-grained rock; perched boulders are abundant. Soil development is limited to a thin organic horizon over an oxidized zone whose

[1] All elevations were determined by surveying altimeter and are given in metres above mean high tide (m aht). The tidal range in Frobisher Bay varies between 3 and 13 m.

depth is primarily a function of grain size. Depths of 20 to 50 cm are attained in coarse sand and gravel deposits, whereas the depth of oxidation is considerably shallower in finer grained sediments (Birkeland, 1978).

Similar soil development occurs on substrate between the Frobisher Bay and Hall moraines. Glacial polish and striae are more limited, although perched boulders and roche mountonnée are nearly as abundant as within the younger moraine system. Limestone erratics exposed at the surface are generally smooth and contrast markedly with the highly pitted surficial limestone erratics in till farther north and Baffin Island, known to be ≥ 40,000 $C^{14}$ yr old. Macropitting in crystalline rocks has not occurred within either moraine system.

In constrast to the limited weathering that has occurred within the two moraine systems, marked weathering changes have been observed in hillslope traverses in the outer reaches of the bay. A transect up a summit at the head of Peter Force Sound (Fig. 2) revealed a till veneer as much as 1 m in thickness with unpitted crystalline boulders and only limited oxidation of the sediment. At about 420 m aht, an abrupt change occurs in the character of the surficial deposits. Above this level, erratic boulders are extensively pitted (macro-pits 10 to 20 cm in diameter and 3 to 5 cm deep are common), corner rounding has progressed to an advanced level, and weathered bedrock residuals crop out near the summit areas. In areas devoid of till, the surficial deposits are dominated by shattered bedrock. No glacial polish, striae, or perched boulders were found in this area. A pit excavated to a depth of 80 cm in a well-drained, level site in sandy till 480 m aht revealed 25 cm of highly oxidized sediment beneath which a slightly less intense oxidation extended below the base of the pit. The intensity and depth of oxidation in this pit greatly exceeds that encountered below 420 m aht (10 to 20 cm of light oxidation). A similar weathering break was noted on eastern Hall Peninsula between 350 and 450 m aht.

The weathering data suggest that the surfaces within the Frobisher Bay and Hall moraines are of similar ages, but that these surfaces do not extend to the higher summits in the outer portion of the bay. Mercer (1956) noted that the summits along southeastern Frobisher Bay (600 to 900 m aht) were mantled by a mature felsenmeer without any evidence of glacial overriding. He also noted a limestone-bearing drift across the bay from Gold Cove that extended to about 250 m above sea level (asl). Although moraines corresponding to the Hall moraine have not yet been identified along southeastern Frobisher Bay, the limestone-bearing drift is a probable equivalent to the Hall moraine.

## SEA-LEVEL STRATIGRAPHY

In a region of continuous deglaciation and reduction in ice-sheet mass, the marine limit surface should display a steady decrease in elevation away from the center of the ice sheet. Perturbations in that trend provide evidence of fluctuations in glacier recession. Marine limit determinations for sites in Frobisher Bay are plotted on Figure 3. Between 270 and 200 km, the marine limit rises regularly at about 0.8 m $km^{-1}$, but at 200 km, coincident with the terminous of the Hall moraine, this trend is reversed, and the marine limit decreases up-bay. This abrupt alteration in the trend suggests a stillstand of the ice at the Hall moraine long enough for a substantial amount of glacio-isostatic recovery to occur. Between 180 and ~ 120 km, the marine limit again rises inland (0.6 m $km^{-1}$), implying continuous ice recession to the Frobisher Bay moraine. The highest marine feature located within the Frobisher Bay moraine is an ice-contact delta 39 m aht, whereas Blake (1966) reported the marine limit on the distal side to be ~ 120 m aht. Ice must have remained in the vicinity of the Frobisher Bay moraine for several centuries, during which time about 80 m of emergence occurred.

## CHRONOLOGY

Radiocarbon dates on marine mollusks[2] in deposits associated with the Frobisher Bay and Hall moraines provide chronological

[2]The reported $C^{14}$ ages are either uncorrected for isotopic fractionation (QL and QC dates) or corrected to $\delta$ $C^{13}$ = 0 (GSC dates).

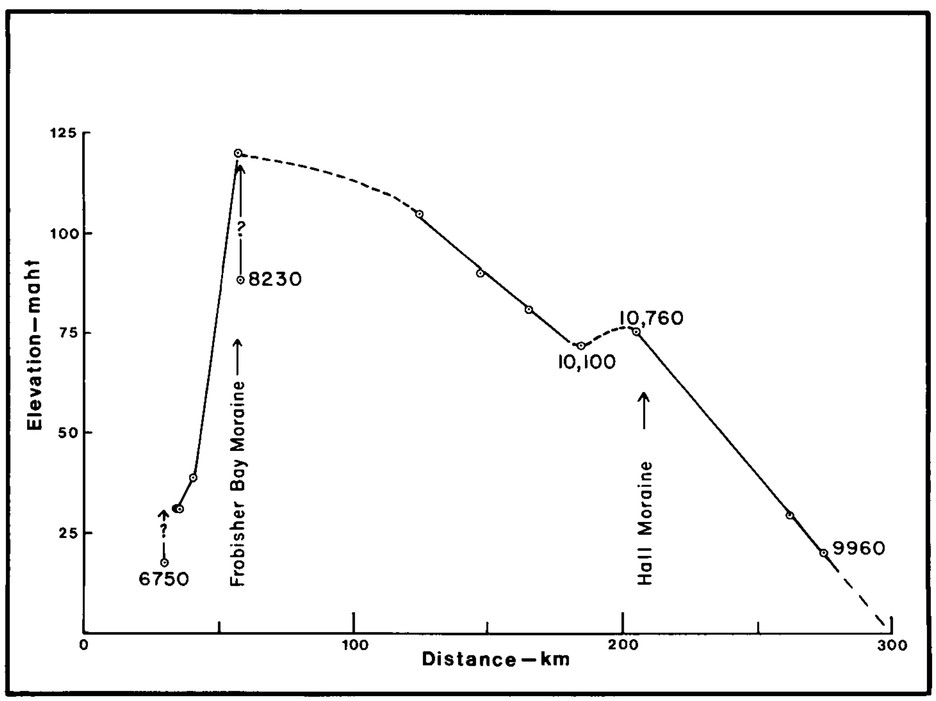


Figure 3. Variation in marine limit elevations along the axis of Frobisher Bay, and relevant dates on shells associated with marine limit deposits. Distances are in kilometres from the head of the Bay. Major breaks in slope of the marine limit surface coincide with terminal positions of the Hall and Frobisher Bay moraines.

TABLE 1. RELEVANT RADIOCARBON DATES FROM THE FROBISHER BAY REGION

| Date (yr B.P.) | Lab ID | Comments |
|---|---|---|
| 6,750 ± 170 | GSC-464 | Minimum date for deglaciation of the head of Frobisher Bay (Blake, 1966). |
| 8,230 ± 240 | GSC-462 | Date on shells from distal side of the Frobisher Bay moraine. Moraine was being deposited at this time (Blake, 1966). |
| 8,750 ± 100 | GSC-2508 | Shell date; fauna includes *Chlamys islandicus,* northern Hall Peninsula. |
| 9,725 ± 120 | QC-450 | Shell date from Gold Cove (Fig. 2), includes such subarctic indicator species as *C. islandicus.* |
| 9,960 ± 230 | GSC-2752 | Marine limit date from eastern Loks Land. Exclusively large, thick *Mya truncata.* |
| 10,100 ± 110 | GSC-2725 | Marine limit shells from Gold Cove (Fig. 2). Exclusively massive valves of *M. truncata.* |
| 10,200 ± 210 | GSC-2778 | Shells in till immediately above the local marine limit, Gold Cove (Fig. 2). Recollection of QC-543. Single whole valve of *M. truncata* dated. |
| 10,720 ± 140<br>10,760 ± 150<br>10,790 ± 70 | QC-480A<br>QC-480C<br>QL-1173 | Massive paired valves of *M. truncata* in deltaic sediments deposited immediately after recession from the Hall Moraine, Warwick Sound (Fig. 2). |
| 12,150 ± 140 | QC-543 | 17 fragmented valves of *M. truncata* collected from till immediately above the local marine limit, Gold Cove. Date is superseded by GSC-2778. |
| 41,900 $^{+7,100}_{-3,700}$ | QC-446 | Paired valves of *Macoma calcarea* from foreset deltaic beds, eastern Loks Land. Dates a period of isostatic uplift following a pre-late Foxe ice advance. Not overridden during late Foxe time. |

control for the periods of moraine formation. Blake (1966) dated shells collected from silt 88 m asl associated with the outermost crest of the Frobisher Bay moraine at 8,230 ± 240 yr B.P. (GSC-462). The marine limit is 120 m aht 12 km down-bay from this site. Because the shells were not ascribed to a given sea level, it must be concluded that the Frobisher Bay moraine was being formed by 8,230 yr B.P., and that it possibly began forming several centuries earlier. The oldest date on the proximal side of the moraine is from the town of Frobisher Bay where shells in a delta 7 to 10 m below the marine limit (31 m aht) date 6,750 ± 170 yr B.P. (GSC-464).

In Warwick Sound (Fig. 2), paired valves of *Mya truncata* with attached siphons were collected in growth positions 61 m aht in a dissected delta that was deposited immediately after deglaciation from the Hall moraine. The apex of the delta lies 76 m aht, whereas the washing limit in the same area is 79 m aht. Three dates on shells from this collection average 10,760 ± 70 yr B.P. (Table 1). At Gold Cove, 20 km up-bay, robust paired valves of *M. truncata* from marine limit deposits 73 m aht yielded a date of 10,100 ± 110 yr B.P. (GSC-2725). The shells are considered to date the deglaciation of Gold Cove. Smaller and thinner *M. truncata* associated with a diverse Subarctic molluscan fauna were collected 21 m aht from the same area and yielded a $C^{14}$ age of 9,725 ± 120 yr (QC-450). The transition to relatively favorable marine environmental conditions must have occurred shortly after deglaciation of Gold Cove. Fragments of *M. truncata* collected from till 6 m above the marine limit at the head of the cove gave an apparent $C^{14}$ age of 12,150 ± 140 yr (QC-543). Because of the potential significance of this age, the site was re-collected in 1978 from which a single whole valve of *M. truncata* yielded a date of 10,200 ± 210 yr B.P. (GSC-2778). This date supersedes the former determination and is statistically indistinguishable from the marine limit date of 10,100 ± 100 yr B.P. It is possible that the first sample contained shells of more than one age, although amino-acid ratios (Table 2) suggest that all shells are <25,000 yr old. Fragments of *M. truncata* with amino-acid ratios similar to those in shells at the marine limit (Table 2) are found in the till to an elevation of 250 m aht, suggesting that the outlet glacier was at least 250 m thick in the Gold Cove area. A single large fragment (8 g) of *M. truncata* collected from the surface of a frost boil in till ~ 220 m aht gave a $C^{14}$ age of 10,000 ± 200 yr (GSC-2813). The small sample size led to relatively large counting errors. Statistically, the age of this sample cannot be differentiated from either the marine limit or lower till dates above. These data indicate that the outlet glacier in Frobisher Bay withdrew from the Gold Cove area by about 10,100 yr B.P., readvanced briefly within two centuries of initial deglaciation, depositing till to at least 250 m aht before final withdrawal to the Frobisher Bay moraine 130 km up the bay. The readvance in Gold Cove was a relatively minor event during a period of general deglaciation, and subsequent ice recession proceeded continuously as indicated by the steady rise in marine limit elevations up bay from Gold Cove (Fig. 3).

A date on in situ paired valves of *Macoma calcarea* collected from undisturbed deltaic foreset beds (delta surface 5 m aht) on easternmost Loks Land was 41,900 (+ 7,100 −3,700 yr) (QC-

TABLE 2. ISOLEUCINE EPIMERIZATION RATIOS IN MARINE MOLLUSCS FROM HALL PENINSULA

| Amino acid ratios* | | Lab ID | Comments |
|---|---|---|---|
| Total | Free | | |
| 0.023 | <0.1 | AAL-412 | *M. truncata* dated 10,760 yr B.P. Same collection as QC-480 and QL-1173. |
| 0.024± | <0.1 | AAL-461 | *M. truncata* from same collection as QC-543. |
| 0.023 | <0.1 | AAL-754 | *M. truncata* from same collection as GSC-2778. |
| 0.024<br>0.026±<br><0.03 | 0.1<br>0.1<br>0.1 | AAL-462<br>AAL-747<br>AAL-752 | *M. truncata* from till above 130 m aht in Gold Cove area (three different collections). Ratios indicate these shells are all of late Foxe age. |
| 0.06 | 0.30 | AAL-650 | *Hiatella arctica* from ice-contact mid-Foxe glaciomarine delta, eastern Hall Peninsula. Contrast with late Foxe ratios above. |

* Ratio of D-alloisoleucine to L-isoleucine in the free and total (free plus peptide bound) amino-acid fractions. Figures are the mean of analyses on three valves from each collection.

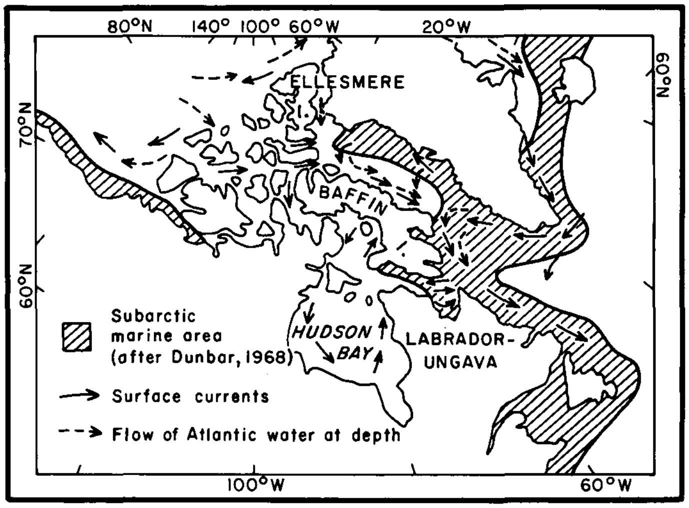


Figure 4. Oceanic circulation and limits of subarctic surface water along the eastern Canadian seaboard (from Dunbar, 1968).

446). Although this should be considered a minimum age, it suggests that the outer reaches of Frobisher Bay have not been inundated by actively eroding ice for more than 40,000 yr.

## Paleoclimatology and Eastern Arctic Glacial Chronology

The response of outlet glaciers fringing the eastern Arctic coastline involves a complex interaction between temperature, precipitation, and glacier activity index (rate of mass turnover). The regional oceanic-atmospheric circulation pattern over the North Atlantic is quite probably the greatest single variable controlling the extent of glacierization along the eastern Canadian seaboard. The present oceanic circulation pattern for this region (Fig. 4) has been dramatically different during the last 20,000 or so years. From the last sea level minimum until 13,000 yr B.P., the polar front lay southeast of the Labrador Sea (Ruddiman and McIntyre, 1973). Subsequently, the polar front migrated to the northwest, accompanied by increased meridional transport of relatively warm Atlantic surface waters into the Labrador Sea and eventually Davis Strait and Baffin Bay. The time-transgressive retreat of the polar front may be expected to be reflected in the timing of the last glacial maximum along the eastern Canadian coast.

The oldest dates reported for deposits unambiguously associated with a former late Foxe ice margin (generally shell dates from ice-contact glacio-marine deltas) along the eastern Arctic margin are plotted in Figure 5. The deposits are noticeably time-transgressive, with the oldest documented glacial advance being that reported herein on southern Baffin Island (63°N), where it appears that outlet glaciers may have begun receding by 9300 yr B.P. (Blake, 1975); on northern Ellesmere Island (81°N), with the exception of one ambiguous deposit, the oldest ice-contact deltas are all between 8,200 and 8,400 yr in age (England, 1978).

A similar trend can be seen in the timing of the incursion of relatively warm subarctic water along the eastern Arctic coastline. Previous studies (Andrews, 1972; Miller, 1973) have indicated that subarctic marine surface waters reached 67°N on eastern Baffin Island about 8,400 yr B.P. Older fossiliferous late Foxe marine units contain an impoverished wholly arctic bivalve assemblage, dominated by *Hiatella arctica, Mya truncata,* and *Portlandia arctica,* whereas younger deposits contain a more diverse faunal assemblage, including such subarctic watermass indicator species as *Chlamys islandicus* and *Mytilus edulis.* In contrast, similarly diverse bivalve assemblages including abundant *C. islandicus* are found in deposits dated as old as 9,725 ± 120 yr (QC-450) in Frobisher Bay (63°N) and 8,750 ± 100 yr (GSC-2508) along northern Hall Peninsula (65°N). Deposits in Frobisher Bay older than 9,900 yr contain impoverished exclusively arctic faunas dominated by massive valves of *M. truncata.* These data indicate that the incursion of subarctic surface waters reached southern Baffin Island at the head of the Labrador Sea more than a millennium before reaching the central east coast of the island. However, the extension of subarctic water into Davis Strait and Baffin Bay must have proceeded rapidly. Faunal evidence from Henry Kater Peninsula (70°N) (unpub. data) and the influx of driftwood in the Queen Elizabeth Island (Blake, 1972) both suggest warmer marine conditions by 8,300 to 8,400 yr B.P. A similar change toward greater faunal diversity on northern Ellesmere Island (81°N) occurred between 7,700 and 8,200 yr B.P. (J. H. England, 1979, oral commun.).

Bowhead whale skeletons from southern Ellesmere Island (76°N) that date between 9,000 and 9,400 yr B.P. (Blake, 1975, p. 22 and Table 2) indicate at least seasonally open water, and a shell collection from the same area dated about 9,000 yr B.P. (Blake, 1975) contains a relatively diverse bivalve fauna. The perturbation in the curve around southern Ellesmere Island may indicate that the pene-

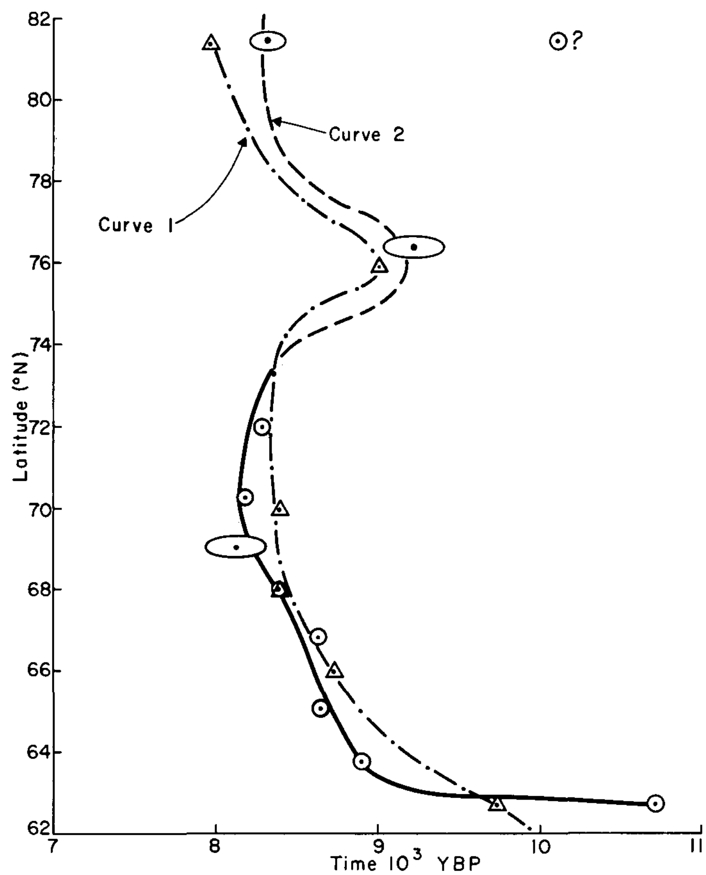


Figure 5. Time-transgressive nature of the incursion of subarctic water (triangles, curve 1) and maximum dates on late Foxe moraines (circles, curve 2) for the eastern Canadian Arctic. Data are from this paper: Miller, 1973 and unpub.; Blake, 1970, 1975; England, 1978 and oral commun.; Dyke, 1979; Andrews and Ives, 1978.

tration of the west Greenland Current and re-establishment of the north water at the head of Baffin Bay occurred prior to 9,000 yr B.P., several centuries before subarctic water reached the central-east coast of Baffin Island. At present, subarctic water extends up the coast of west Greenland to 76°N, but it is restricted to the regions south of 66°N on the Canadian side of Davis Strait (Fig. 4). A slight intensification of the West Greenland Current could result in subarctic surface waters penetrating the southeastern Queen Elizabeth Islands. The distribution of marine bivalves with subarctic affinities in postglacial marine deposits throughout the Canadian Arctic implies a greater extension of subarctic waters during the early and middle Holocene than at present (Andrews, 1972).

The clear time-transgressive trends in the timing of both the (apparent) last glacial maximum and incursion of subarctic marine waters in the eastern Canadian Arctic (Fig. 5) suggest that a simple glacio-climatic model cannot explain the observed glaciological responses across this region. The oldest dates on the Baffinland Drift (Andrews and Ives, 1978) now range from nearly 11,000 yr B.P. in the Frobisher Bay area to less than 8,000 yr B.P. in the Home Bay area (69°N), and it is doubtful that the northeastern sector of the Laurentide Ice Sheet was characterized by outflow from a single accumulation center. Rather, it may be more realistic to consider a series of possibly contiguous ice dispersal centers along the axis of Baffin Island and along the eastern High arctic archipelago that, during a time of rapid but time-transgressive climatic change, responded independently to changing temperature and precipitation regimes, moderated by the particular response times of each system. A similar model has been proposed by Andrews and Miller (1980) based on the distribution of limestone erratics.

The possibility of ice-sheet complexes both contiguous with and independent of the Laurentide Ice Sheet has been recently proposed for portions of southeastern Canada. The Wisconsin glacial history of the Atlantic Provinces is summarized by Grant (1977a), who argues that Newfoundland, Nova Scotia, and much of New Brunswick were glaciated solely by locally accumulated ice caps throughout late Wisconsin time. An earlier glacial episode, during which the region was enveloped by continental Laurentide ice, occurred prior to 40,000 yr B.P. Grant (1977b) has suggested that the independent ice-dispersal centers were maintained by reversed easterly flow from the North Atlantic. Available radiocarbon dates indicate two episodes of glacial expansion for the area, dated at about 12,700 and 11,000 yr B.P. Gadd (1976) summarized evidence for northward-flowing ice from an independent ice cap in the Appalachian region of southeastern Quebec. The timing of this phenomenon is as yet unclear, but it must have occurred prior to the incursion of the Champlain Sea (12,800 yr B.P.). The glacial history of the Canadian High Arctic remains unresolved, but England (1978) proposed that the Queen Elizabeth Islands were characterized by a series of independent ice-sheet complexes throughout the late Wisconsin Glaciation, whereas Blake (1972, 1975) favors a continuous ice sheet cover.

The Hall moraine has chronological and stratigraphical correlatives in other Arctic regions. Funder (1972) and Funder and Hjort (1973) recognized a major late Weichselian terminal moraine complex in the Scoresby Sund region of central East Greenland. The deposition of these moraines is bracketed by $C^{14}$ dates of 11,000 and 9,500 yr B.P., which defines the Milne Land Stadial. The ice extent during the Milne Land Stadial marked the most extensive position of outlet glaciers along the east coast of Greenland in the past 30,000 or more years. On west Spitzbergen, Boulton and Rhodes (1974) and Boulton (1979) identified a glacial advance bracketed by $C^{14}$ dates of about 11,000 and 9,700 yr B.P. This event, termed the Billefjorden Advance, marks the only identifiable late Weichselian glaciation on western Spitzbergen, and marks the most extensive ice advance in that area in the past 35,000 or more years. The Younger Dryas chronozone of northern Europe (about 11,000 to 10,000 yr B.P.) was also a prominent period of glacial readvance for both local cirque and outlet glaciers.

## CONCLUSIONS

A newly recognized moraine system in outer Frobisher Bay, southern Baffin Island, here named the "Hall moraine," marks the apparent maximum extension of late Foxe ice in the bay. Radiocarbon ages on in situ molluscs that date deglaciation from the Hall Moraine average 10,760 yr and provide the first unequivical documentation of a pre-Holocene, late Foxe moraine in the eastern Canadian Arctic. General deglaciation was punctuated by a minor readvance about 10,000 yr B.P. that transported marine shells of that age up to 230 m aht. A major moraine system at the head of Frobisher Bay, here named the "Frobisher Bay moraine," and previously dated at 8,230 yr B.P., can be traced to the head of Cumberland Sound where it is correlated with the Ranger moraine (Dyke, 1979), also of late Foxe age.

The degree of weathering (bedrock and soils) is similar within the Frobisher Bay and Hall moraine systems, but altitudinal transects in the outer reaches of the bay revealed a sharp transition to a more advanced state of weathering above 350 to 450 m. Deeply weathered erratics, felsenmeer, and advanced soil development on these higher summits indicate that the peninsulas adjacent to Frobisher Bay were not completely inundated by actively eroding ice during the last glaciation.

In marked contrast to prevailing concepts of only a decade ago, it is now postulated that the entire eastern Canadian seaboard has been dominated by local, possibly independent ice-dispersal centers *throughout* late Wisconsin (or late Foxe) time. These local ice centers, nourished from nearby moisture sources, responded rapidly to climatic events. As the polar front in the North Atlantic retreated after 13,000 yr B.P., the oceanic-atmospheric circulation pattern in the Labrador Sea, Davis Strait, and Baffin Bay exerted the primary control on the glacial histories of the adjacent ice bodies. The available radiocarbon dates suggest that the last glacial maximum was attained earliest in the maritime provinces, and at progressively later dates at higher latitudes. Along eastern Baffin Island, the oldest dates associated with ice-marginal deposits display a steady decrease from 62°N to 70°N latitude. To the north, the data are more sparse, but a clear reversal of this trend is shown by the data from southern Ellesmere Island. This exception is as would be predicted by the present oceanic circulation pattern. The incursion of relatively warm surface waters into the eastern Arctic coast shows a parallel time-transgressive latitudinal relationship.

A major glacial advance dated between 10,000 and 11,000 yr B.P. has now been recognized around most of the North Atlantic. At low Arctic regions (southern Baffin Island, East Greenland, western Spitzbergen), this advance marked the maximum extension of ice during the last glacial stade, whereas at lower latitudes (northern Europe, Maritime Canada), it marks a major readvance during general deglaciation.

## ACKNOWLEDGMENTS

This project was financed by the National Science Foundation Grants (EAR-74-01857 and EAR-77-24555), with additional logistical support from the Arctic Petroleum Operators Association (APOA Project 138). Field assistance was provided by H. Moulton. During the 1978 summer, Dr. J. D. Jacobs, University of Windsor, shared base camp facilities. Dr. W. Blake, Jr., Geological Survey of Canada, and Dr. M. Stuiver, University of Washington, kindly supplied radiocarbon dates for critical samples. Drs. P. Calkin and J. T. Andrews reviewed the manuscript and provided constructive comments. Amino-acid data were determined at the Amino Acid Geochronology Laboratory, INSTAAR, University of Colorado.

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Manuscript Received by the Society April 13, 1979
Revised Manuscript Received October 16, 1979
Revised Manuscript Accepted October 24, 1979

Printed in U.S.A.