25.

LAKE SEDIMENT CORING ALONG SMITH SOUND, ELLESMERE ISLAND AND GREENLAND

Project 750063

W. Blake, Jr.
Terrain Sciences Division

Blake, W. Jr., Lake sediment coring along Smith Sound, Ellesmere Island and Greenland; in Current Research, Part A, Geological Survey of Canada, Paper 81-1A, p. 191-200, 1981.

Abstract

During the 1979 and 1980 field seasons, cores of bottom sediments have been recovered from six lakes on the Ellesmere Island side of Smith Sound and from three lakes in Inglefield Land, northwestern Greenland. Radiocarbon age determinations on basal organic material from a lake at 390 m on Pim Island and from a lake at 295 m above Ekblaw Glacier, innermost Baird Inlet, indicate that both areas were free of glacier ice by 9000 years ago. The basal moss-rich sediment from a pond at 300 m in a moraine above Baird Inlet is slightly younger, perhaps because dead ice may have persisted at that locality.

Introduction

Studies of lake sediments in the Canadian Arctic Archipelago are few and far between, especially those carried out with the specific purpose of establishing absolute chronologies by radiocarbon dating or other means. The scattered investigations that have been undertaken over this vast area have all been done during the last two decades. The earliest attempts at recovering lake sediment samples for ^{14}C age determinations were those in northern Ellesmere Island of G. Hattersley-Smith (Defence Research Board) and staff of the Smithsonian Institution (Long and Mielke, 1967; Hattersley-Smith, 1969; Mielke and Long, 1969). Caflisch (1972) cored lakes, including an ice-dammed lake, on Axel Heiberg Island, and Barnett (1977) cored Generator Lake, an ice-dammed lake in central Baffin Island. More recently, J.C. Ritchie and R.J. Mott have, independently, cored organic lake sediments on Banks Island, and ^{14}C ages have been obtained from five sites (see Vincent, 1980). Bradley and England (1977) have recovered four cores from a lake near the Mer de Glace Agassiz in northeastern Ellesmere Island, and Davis (1978, 1980a, b) has carried out an extensive lake coring program in southern Cumberland Peninsula, Baffin Island.

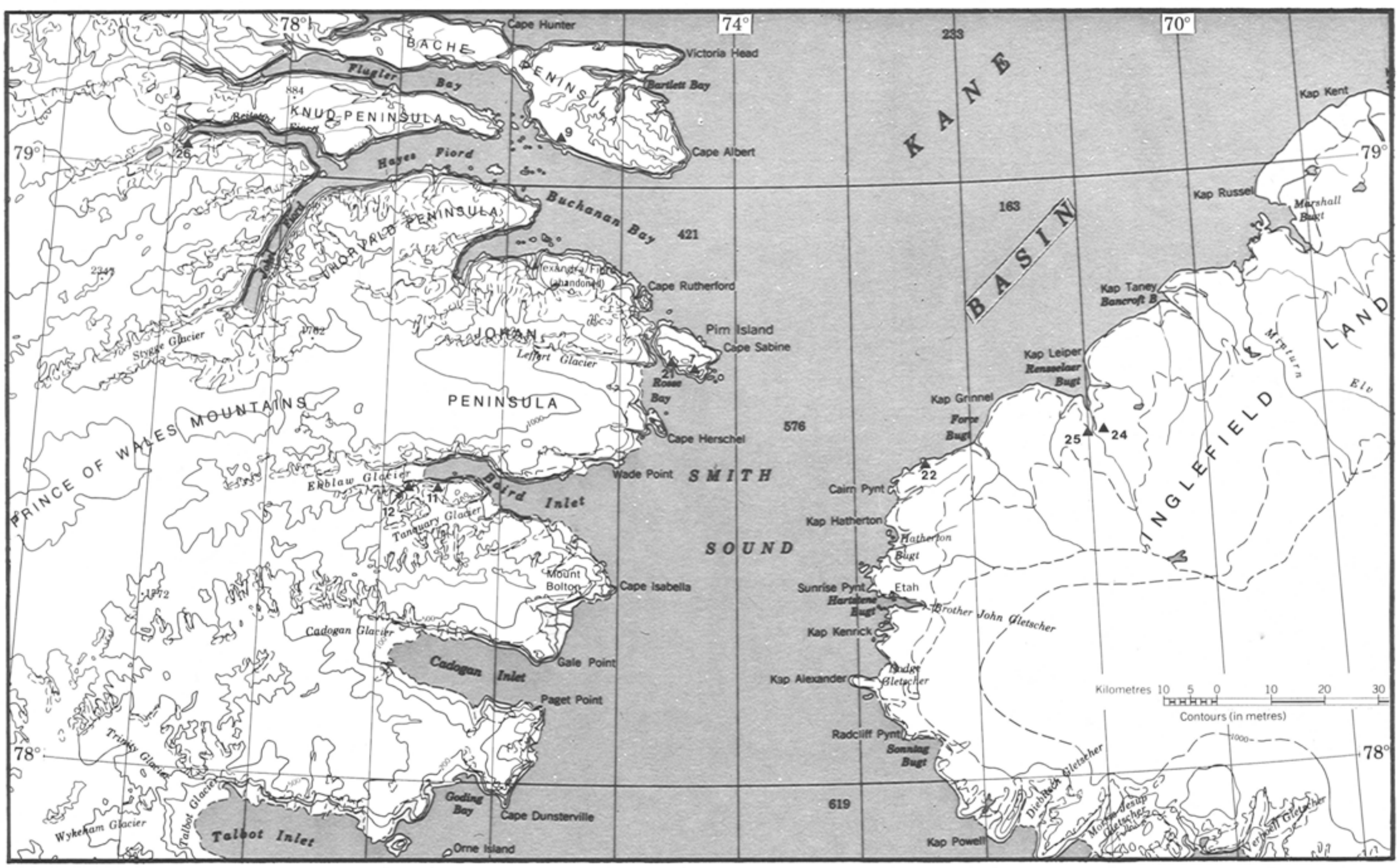

Figure 25.1. *Location map of eastern Ellesmere Island and northwestern Greenland showing lakes cored. Numbers beside triangles correspond to sites in Table 25.1. Contours, spot elevations, and depths are in metres.*

Blake (1978) described the technique of recovering cores of sediments from shallow ponds that freeze to the bottom each winter on Cape Herschel peninsula, eastern Ellesmere Island (Fig. 25.1). This work, which was continued successfully in 1979 and 1980, was carried out primarily to obtain data bearing on the rate of Holocene emergence, and nearly all the ponds cored are situated below the Holocene marine limit, which is at approximately 90 m a.s.l. on the north side of Cape Herschel. Now the emphasis has shifted to larger and deeper lakes, utilizing conventional coring equipment, i.e., a modified Livingstone corer. The present report is a preliminary account of the lake coring program, the main purpose of which is to obtain chronological data bearing on glacial history. It is also hoped that study of the cores will provide information on changes in climate through time by means of analysis of the sediments themselves as well as by investigations of the contained pollen, diatoms, and plant macrofossils.

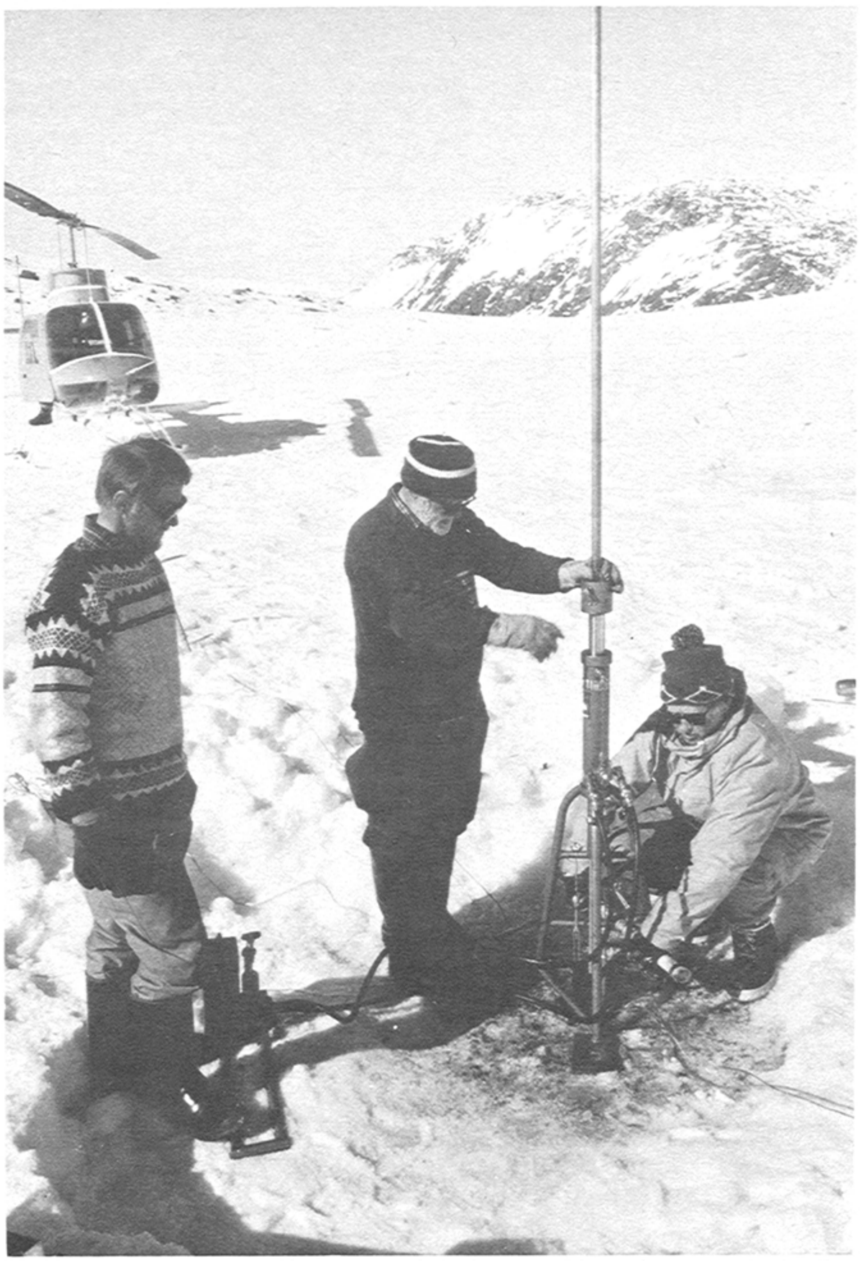

Figure 25.2. *Detail of the hydraulic unit and the foot-operated pump and reservoir used for jacking the plastic coring tubes into the lake sediments. View northwest toward the highest part of Pim Island from lake no. 7 at 390 m. June 12, 1980. GSC 202823-H*

Coring was carried out in June, between the 12th and the 19th in 1979 and between the 3rd and the 16th in 1980. By that time air temperatures were close to 0°C and yet the intact ice cover on the lakes provided a stable platform to operate from. Another advantage to coring at this time of year is that the bays and fiords along the coast are still frozen. The presence of the ice permits the helicopter, necessary to reach the coring sites, to be equipped with skids rather than floats, thus allowing faster travel and heavier loads.

Methods

Three or four people participated in the coring. The first trip to each lake was to transport personnel, the second trip was to bring in the bulk of the equipment. On most occasions the equipment was transported in a cargo net, but in 1980 the Bell 206B helicopter (supplied by Okanagan Helicopters, Ltd., through the Polar Continental Shelf Project) could be converted easily into an ambulance. In this configuration the front left seat folds to the side towards the pilot, permitting the storage of coring tubes (2.4 m long), rods, and casing lengthwise inside. Elimination of the cargo net on long distance flights, such as to Inglefield Land or to the head of Beitstad Fiord (Fig. 25.1), simplified transport and saved flying time, especially in windy conditions.

In 1979 a 6 inch (15 cm) diameter and 41 inch (105 cm) long hand auger (manufactured by K.J. Eriksson's Knivfabrik, Mora, Sweden) was used for drilling through the ice. This tool, designed primarily for use as an aid to ice fishing in more southerly latitudes, worked well on lakes where the ice was of the order of 150 cm thick. Once the ice thickness exceeded 150 cm, it proved difficult to continue augering because of the accumulation of chips in the hole; the auger is flighted only for the first 50 cm of its length, and the extension rods are not flighted. The problem was solved by utilizing an empty plastic coring tube equipped with a cutting edge and a core retriever on the lower end, a coring head and extension rods on the top. The tube was jammed into the hole and the ice chips were forced inside where they were held by the retriever, then the head was removed, the chips were emptied out, and the process was repeated until the hole was cleared, after which augering could proceed. In this way it proved possible to core through more than 3 m of ice at the high level lake on Pim Island.

In 1980, in addition to the hand auger, a power-driven 8 inch (20 cm) diameter auger (Model 51, manufactured by General Equipment Co., Owatonna, Minnesota) was tried. Attachments included a 48 in (122 cm) long auger, flighted for 46 inches (117 cm) of its length, two flighted extensions, each 36 inches (91 cm) long, and a non-flighted extension of the same length. A few holes were drilled successfully with this unit, most of them at the lake with the thickest ice at ca. 390 m elevation on Pim Island (Locality 7 in Fig. 25.1). However, difficulties were encountered with both the cutting edge and with the operation of the power unit itself; the latter ultimately refused to start despite all efforts at repair. For the rest of the 1980 season most holes were drilled with the same 6 inch (15 cm) diameter hand auger that had been used in 1979.

Although complete recovery of the basal organic material in each lake sampled in 1979 was achieved, it had not proved possible to penetrate more than a few centimetres into the underlying inorganic sediment. For this reason a hydraulic unit to aid in driving down the coring tubes was employed in 1980. The device used, a Portasampler Model DR-2000 (manufactured by Soiltest, Inc., Evanston, Illinois), is made up of two components (Fig. 25.2): (1) a hydraulic cylinder mounted on a tripod, and (2) a foot-operated pump and reservoir which are connected to the cylinder by rubber hoses (these can be disconnected from the cylinder for transport). The complete unit weighs 45 kg, stands about 120 cm high, and the piston has a play of 30 cm. Direction of movement of the piston within the cylinder is controlled by a valve. The hollow piston, which is clamped onto the rods attached to the coring tube by means of four large bolts, can accommodate rods up to 3.5 cm in diameter; those used were a magnesium/zirconium alloy 1.5 m long and 2.7 cm in diameter.

The hydraulic unit, which was anchored to the underside of the ice by means of two deadmen attached to opposite sides of its frame by 3 mm steel cables, worked well. The use of this equipment saved a great deal of effort and allowed somewhat deeper penetration into the inorganic sediments, although lower suites of organic deposits (if, in fact, such materials exist) were not reached. Perhaps the rods utilized need to be stronger, for on a few occasions the casing broke (or became cross-threaded at the joints) as a result of the pressure exerted by bending of the rods as the corer was jacked downward.

Most of the core tubing was 8 foot (2.4 m)-long cellulose acetate butyrate tubing having an outside diameter (O.D.) of 2 7/8 inches (7.3 cm) and an inside diameter (I.D.) of 2 5/8 inches (6.7 cm). In 1979 some slightly smaller diameter tubing also was tried – O.D. 2 1/2 inches (6.4 cm), I.D. 2 1/4 inches (5.7 cm). The advantage of using clear plastic tubing is that it is not necessary to extrude a core in the field in order to see what has been obtained; in fact extrusion would not have been possible in many cases because of the watery nature of the uppermost organic sediments as well as the lack of cohesiveness in sand.

For casing ABS plastic drainpipe was used, cut into 6 foot (1.8 m) lengths. In 1979 the casing was 3 inches (7.6 cm) I.D., but as this was too small to use with the larger diameter plastic core tubes, in 1980 the next size larger was tried. The 4 inch (10.2 cm) I.D. casing could still be accommodated in the hole drilled with the 6 inch (15 cm) auger, together with the cables necessary to anchor the hydraulic tripod.

Results

Two of four lakes cored in 1979 were revisited in 1980 to obtain new cores, and in addition five other lakes were cored during the second season. The locations of the lakes are indicated in Figure 25.1, and details of snow thickness, ice thickness, water depth, and maximum amount of sediment recovered are summarized in Table 25.1. With the exception of the sites on Bache Peninsula (No. 9) and near Kap Inglefield (No. 22), coring has been restricted to areas underlain by granite or gneiss to avoid the 'hard water effect' characteristic of lakes on carbonate terrane.

A great variety of sediments has been encountered in the lakes, and the thickness of organic sediment has proved to be equally variable. For example, at the high level lake (No. 7) on Pim Island only 50 to 60 cm of gyttja and moss was obtained above inorganic material, but in the lower lake (No. 21) 179 cm of organic-bearing sediment was recovered above grey sand and silt. Concentrations of mosses occur at

Table 25.1

Data on lake coring, Smith Sound

	Year	Baird Inlet		Pim Island		Bache Peninsula	Beitstad Fiord	Kap Inglefield	Rensselaer Bugt	
Lake/pond designation (Fig. 25.1)		11	12	7	21	9	26	22	24	25
Approximate elevation m a.s.l.*		300	295	390	260	415	200	250	220	220
Maximum snow thickness at coring sites (cm)	1979	36	40	< 25		40				
	1980	70		32	>20		25	25	30	30
Maximum ice thickness at coring sites (cm)	1979	89	101	304		143				
	1980	91		290	220		140	165	200	190
Depth to sediment/water interface from ice surface (m)	1979	2.7	15.6	10.9						
	1980	2.6		8.1	9.8	6.3	12.8	3.95	2.9	8.0
Number of coring drives attempted	1979	4	3	12		4				
	1980	5		7	2		1	1	1	2
Maximum amount of sediment recovered (cm)	1979	122	95	80		84				
	1980	165		85	255		64	132	19**	209
Sample designations	1979	BS-79-45	BS-79-47	BS-79-27		BS-79-38				
	1980	BS-80-17		BS-80-16	BS-80-21		BS-80-46	BS-80-18	BS-80-24	BS-80-25

* Altimeter determinations, rounded off to the nearest 5 m. Most elevations are based on more than one reading (helicopter traverses), but are uncorrected for temperature or pressure changes.

** Only slight penetration achieved, as sediments were frozen at shallow depth.

Table 25.2

Radiocarbon age determinations, basal organic sediment

Location	Lake number (Fig. 1, Table 1)	Sample No. of core	Depth below sediment/water interface (cm)	Laboratory dating no.	Uncorrected age[1]	$\delta^{13}C$	Corrected age[1]	Organic carbon content (%)[2]	Inorganic carbon content (%)[2]	Dry sample weight (g)	Gas yield, CO_2 (cm)	Counter (L)	Pressure (atm)	Counting time (days)	Comments
Southeastern Pim Island	7	BS-79-27 Core 2	45-50	GSC-2934	9060 ± 190	-30.8	8970 ± 190	25.38	-	5.0	6.1	2	2	4	Only moss utilized for dating.[3]
	7	BS-79-27 Core 12	50-53	GSC-3042	8600 ± 90	-26.1	8580 ± 90	5.44	0.54	34.1	25.2	2	2	3	Basal gyttja – moss (much less common here than in Core 2) was not utilized.[4]
Inner south side of Baird Inlet	11	BS-79-45 Core 2	98-102	GSC-3009	8530 ± 170	-24.3	8540 ± 170	6.00	1.36	14.8	7.5	2	2	3	Moss-rich peaty sediment.
Above Ekblaw Glacier	12	BS-79-47 Core 3	46-51	GSC-3051	9070 ± 160	-31.2	8970 ± 160	3.85	0.43	24.7	13.4	2	2	4	Laminated sediment.[4]

[1] All age determinations from the Radiocarbon Dating Laboratory, Geological Survey of Canada, are based on a ^{14}C half-life of 5568 ± 30 years and 0.95 of the activity of the NBS oxalic acid standard. Ages are quoted in conventional radiocarbon years before present (B.P.) where 'present' is taken to be 1950. All finite age determinations from this laboratory are based on the 2σ criterion; i.e., there is a 95% probability that the correct age in conventional radiocarbon years lies within the stated limits of error. $^{13}C/^{12}C$ ratios were determined at the Department of Earth Sciences, University of Waterloo, under the direction of Professor P. Fritz and R.J. Drimmie (DSS contract OSU79-0045) and by Waterloo Isotope Analysts, Inc. (R.J. Drimmie; DSS contract OSQ80-00018).

[2] The carbon determinations were carried out by W.E. Podolak on a Leco IR12 carbon determinator. Two separate runs were made for each sample, and each run is the average of 2 or 3 determinations. The first run is to determine total carbon on the untreated sample; the second run is on a portion of the original sample which has been digested in 10% HCl and dried – this gives the amount of organic carbon. Inorganic carbon content is the difference between these two values. For GSC-2934 the value obtained for total carbon was 25.42; i.e., essentially no inorganic carbon is present.

[3] The moss at the base of the cores from Pim Island has proved to be difficult to identify but is a member of the Amblystegiaceae (J.A. Janssens, personal communication, 1980). The basal organic material in the Baird Inlet cores contains **Drepanocladus lycopodioides** var. **brevifolius**, whereas the surface of the sediment today is characterized by **Drepanocladus exannulatus** (both determinations by J.A. Janssens; unpublished Bryological Reports JJ 409b, -410b, -411, and -412, Boreal Institute, University of Alberta).

[4] GSC-3042 is the only sample of the four which was not mixed with dead gas for counting. NaOH leach omitted in the pretreatment of GSC-3042 and -3051.

various horizons in a number of cores, and such concentrations appear to be especially prevalent near or at the base of a given organic sequence. Similar basal moss layers have been observed by Funder (1978) in two of five lakes that he sampled in central East Greenland, and data on mosses in lake sediment cores from southernmost Greenland and from Peary Land are given in Fredskild et al. (1975) and Fredskild (1977).

Radiocarbon age determinations on basal organic material are now available for three of the lakes along the western side of Smith Sound, as summarized in Table 25.2. The results indicate that the lake basin at ca. 390 m in the southern part of Pim Island was ice free by approximately 9000 years ago, for the basal moss in one of the cores is 8970 ± 190 years old (GSC-2934). This lake (No. 7), situated in a rock basin with abundant evidence of scouring by south-flowing ice (cf. Blake, 1977), is one of the highest on the island (Fig. 25.3); within 1.5 km to the east-northeast is a patch of dead ice at the head of a col, and 2 km to the northwest is a small (and presumably thin) ice cap which is in a lee position relative to moisture-laden southerly winds blowing across the highest part of the Pim Island plateau. The dimensions of this carapace ice cap 9000 years ago are unknown. Dating the basal organic sediment from the lake (No. 21) at ca. 260 m, together with future coring and dating of other lakes on Pim Island, should make it possible to define the glacier boundaries in early Holocene time more precisely.

Equally interesting to the results from Pim Island is the age of the basal organic sediment (8970 ± 160 years; GSC-3051) from a rock basin lake (No. 12) above Ekblaw Glacier, some 3 km west of the head of Baird Inlet and 50 km west of Cape Herschel (Fig. 25.4). A somewhat younger age than that obtained for the basal moss from Pim Island was expected, since the lake (elevation 295 m) occupies a deep basin excavated by glacier ice in the middle of a rock bastion surrounded by valley glaciers. The rock surfaces 40 m and more above the level of the lake show unmistakable signs of overriding by ice (Fig. 25.5). Thinning of an enlarged Ekblaw Glacier apparently proceeded rapidly enough that organic accumulation could commence at approximately the same time as it did at the higher and much more exposed Pim Island site. Today the south-facing ledges above the rock basin lake are characterized by rather lush vegetation for this latitude, including **Empetrum nigrum** and **Vaccinium uliginosum** in addition to the more widespread **Cassiope tetragona.** The changes in vegetation from the outer coast (Pim Island and Cape Herschel, where the first two plants do not occur) to the innermost fiord areas (Baird Inlet and Beitstad Fiord) mirror those reported long ago from Svalbard (Elton, 1925; Summerhayes and Elton, 1928).

The third water body for which an age determination is available is a small pond (No. 11), elevation 300 m, situated in the moraine (Fig. 25.6) that occupies a col above Baird Inlet, about 5.5 km east of the rock basin lake just described. The age obtained for basal organic material from this pond is 8540 ± 170 years (GSC-3009). Well developed moraines, such as the one in which this pond lies, are rather rare in the Queen Elizabeth Islands, and it is even more unusual to find one that contains a pond or lake suitable for coring. The configuration of the moraine shows that it formed in an interlobate situation, between ice in the valley (Fig. 25.4), now occupied by a northern branch of Tanquary Glacier, and an enlarged Ekblaw Glacier which formerly extended farther east in Baird Inlet. The position of the moraine in the col shows that the major push must have come from Ekblaw Glacier, which was, and is, one of the main outlet glaciers from the ice cap to the west. The crest of the moraine, which now forms the drainage divide in the col, rises 13 m above the level of the adjacent pond. An interlobate moraine is forming nearby today (Fig. 25.4), but at a lower elevation, in the same way as is envisaged for the moraine above Baird Inlet.

Figure 25.3. *Aerial view north at lake no. 7 at 390 m elevation, southeastern Pim Island. Coring in both 1979 and 1980 was carried out in the northwestern part of the lake (arrow). June 19, 1979. GSC 202823-O*

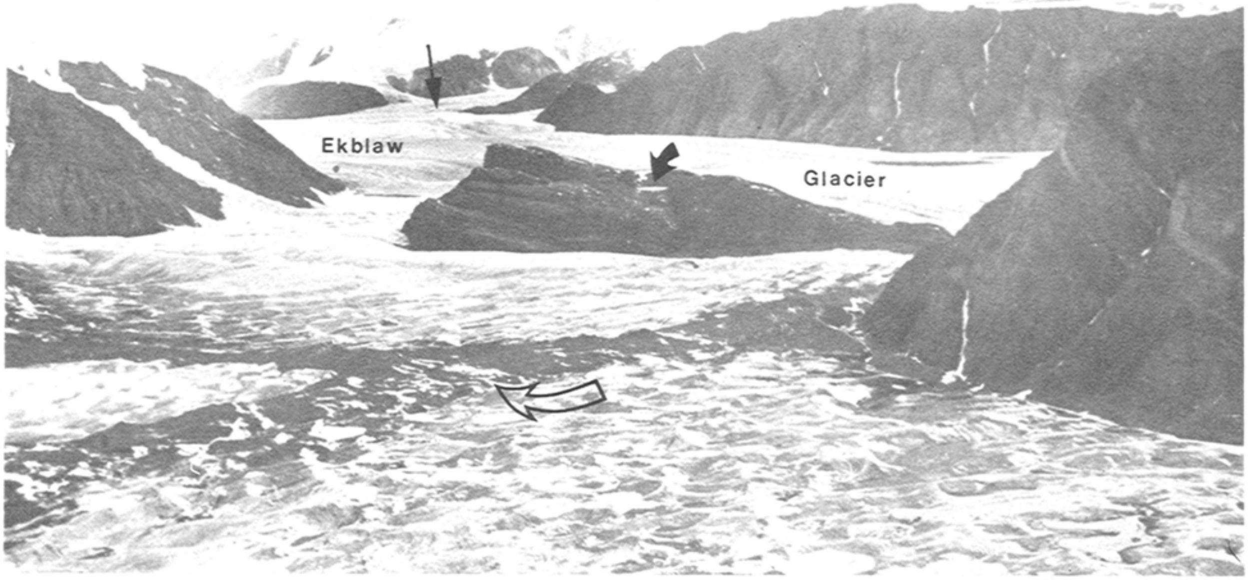

Figure 25.4. Aerial view northwest at the rock basin lake (no. 12 – curved black arrow) at 295 m elevation, above Ekblaw Glacier. Glacier in foreground is a northern arm of Tanquary Glacier; note the interlobate moraine (open arrow) between it and an unnamed glacier descending from the ice cap to the south (left of photo). In the distance (straight black arrow) Isachsen Glacier joins the main outlet, Ekblaw Glacier. July 25, 1977. GSC 174432

Discussion

Although there is no reason to doubt, as yet, the validity of the few ^{14}C ages available on lake sediments from the west side of Smith Sound, investigations elsewhere have shown that severe difficulties may arise with the dating of basal organic materials or of sediments containing finely disseminated organic matter (e.g., see Lundqvist, 1973; Donner and Jungner, 1974; Mott, 1975; Karrow and Anderson, 1975; Schroeder and Bada, 1978). Recently, the papers of Lowe and Walker (1980) and Sutherland (1980) treated the dating of basal organic sediments, especially as related to the chronology of deglaciation in Scotland, and Davis and Davis (1980) described problems encountered with attempts to date basal bog and pond-bottom sediments in Maine. In addition, the significance of $\delta^{13}C$ values with regard to source of organic matter has been touched on briefly by Funder (1978). A detailed discussion is beyond the scope of the present paper and would be premature until additional age determinaitons have been obtained, but a few points are worth emphasizing.

The two age determinations from the Pim Island lake (cf. Table 25.2), carried out on separate cores, are in proper sequence, for the gyttja stratigraphically overlies the moss in Core 2. At this site the inorganic sediment underlying the organic layers contains an average (8 determinations) of 1.65% inorganic carbon, a value equivalent to 13.8% $CaCO_3$. This value is similar to the values for carbonate content obtained on a number of till samples from the Cape Herschel – Pim Island area. The moss unit at the base of the core does not suffer from the problem of low organic content (Table 25.2) which often characterizes basal organic sediments in newly deglaciated terrain (cf. Olsson, 1979; Sutherland, 1980), and the $\delta^{13}C$ value of -30.8‰ falls in the general range of terrestrial plants (Olsson and Osadebe, 1974; Stuiver, 1975). If the moss is of terrestrial origin, rather than being a submerged aquatic species, and its $\delta^{13}C$ value is well outside the typical range (-18.3 to -8.6 ‰) of submerged aquatic plants such as **Chara**, **Potamogeton**, **Myriophyllum**, and **Nitella** (cf. Stuiver, 1975)[1], it seems curious that it is such a pure layer. If it had been washed into the lake basin from the adjacent slopes one would expect detritus derived from vascular plants or fragments of other mosses to be present as well. Pertinent evidence is also provided by the diatoms present in the same increment of Core 2 that was used for dating. The assemblage is characterized by distinct bloom of **Fragilaria construens** var. **venter**; other species present are **F. construens**, **F. pinnata**, and **F. pinnata** var. **intercedens.** The dominance of **F. construens** var. **venter** "strongly reflects a well-oxygenated, cool water biotope and the presence of aquatic vegetation" (S. Lichti-Federovich, unpublished GSC Diatom Reports 79-2 and 79-3).

In the case of the coring sites above Baird Inlet and Ekblaw Glacier the inorganic carbon content of the sediments beneath the dated basal organic horizons is even lower than on Pim Island – 0.01% for the moraine pond and 0.11% for the rock basin lake. The bedrock in the vicinity is dominantly granulite gneiss, and carbonate rocks were not observed in the area drained by Ekblaw Glacier (cf. Frisch et al., 1978; T. Frisch, personal communication, 1980). Two samples of bedrock from above the rock basin, however, were analyzed for their carbon content, and small amounts are indeed present. The untreated samples contained an average of 0.085% carbon, and after treatment with 10% HCl an average value of 0.06% was obtained. Thus it is clear that the potential for a small amount of contamination by 'old' carbon exists at all three lakes, but whether or not contamination has actually occurred is another question. For the time being it seems reasonable to accept the dates as valid ages for the basal increments (5 cm or less) of the organic sediments.

[1] A recent $\delta^{13}C$ determination on **Drepanocladus exannulatus,** a submerged moss collected from holes in the ice of the moraine pond above Baird Inlet, gave a value of -21.0‰ (GSC-3128).

At the time that the moraine in the col above Baird Inlet was being constructed, ice must have covered the 'up-glacier' site of the rock basin lake. At the coring site the elevation of the moraine is above 300 m, and it rises up the mountain slope to the west (Fig. 25.6). If a gradient similar to that of the present-day Ekblaw Glacier were maintained, then the ice would have been roughly 150 m higher in elevation at the site of the rock basin lake (Fig. 25.4) than at the moraine pond. This amount would be sufficient to inundate the bedrock knobs that surround the lake (cf. Fig. 25.5).

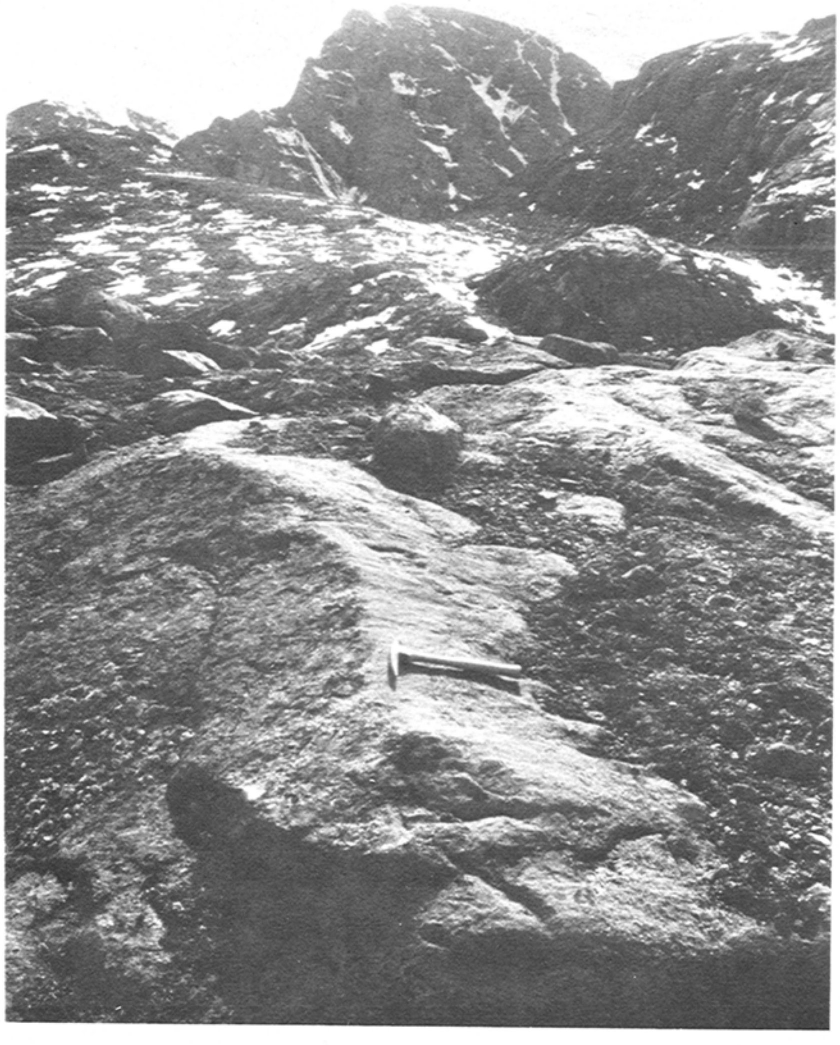

Figure 25.5. Detail of glacially sculptured surface on hilltop (gneiss) to the east of the rock basin lake (no. 12). View toward the southwest. Ice flowed across this hill from west to east (right to left in the photograph). Note the form of the highest part of the bastion, showing how an enlarged Ekblaw Glacier once flowed eastward through the valley shown in Figure 25.4 (the reverse direction to today). July 20, 1979. GSC 202823-F

Several explanations may help to account for the younger age of the basal organic material in the moraine pond:

1. The depression now occupied by the pond is assumed to have originated by the melting in situ of a block of ice that had become isolated from the main ice mass. The melting process would have taken a period of time, perhaps several hundred years, thus delaying the start of organic accumulation.
2. Vegetation was slower to invade this area, more exposed as it is, and today its environs are not characterized by the rich vegetation found around the rock basin lake. Also, the morainic substrate was unstable as the ice melted away.
3. Fortuitously the oldest organic sediment was obtained from the rock basin lake but not from the much smaller moraine pond. In neither case were soundings taken nor is any sort of bathymetric map available; coring was attempted as near to the middle of the lake and the pond as possible, and air photographs show that the pond is deepest in the middle.
4. The peaty, moss-rich material used for dating in the moraine pond consisted of distinct layers that could be clearly seen to extend right across the core. The same moss-rich material extended 3 cm lower on one side of the core but this material was not used for dating as it was feared it might be an artifact of the coring process; possibly it merely reflected an uneven bottom, and had this lowermost organic material been dated, an older age would have been obtained.
5. The ice surface may still have been above the level of the rock basin lake but the surrounding rock bastion prevented the ice from filling the basin; i.e., the lake was originally deeper in an early phase when ice blocked its outlet and when ice still covered the site of the moraine pond to the east.

The sequence of events at this pond is further complicated by the fact that the moss, **Drepanocladus lycopodioides** var. **brevifolius,** at the base of the core is not a true aquatic species (J.A. Janssens, personal communication, 1980). Unlike the luxurious growth of **Drepanocladus exannulatus** (aquatic modification) which is present in the centre of this 2.6 m-deep pond today, **D. lycopodioides** var. **brevifolius** is a typical fen species; it appears to develop especially well on calcareous substrates. **Drepanocladus brevifolius** (synonymous with **D. lycopodioides** var. **brevifolius** (Ireland et al., 1980)) is common, for example, in hummocky sedge-moss meadows and wet sedge-moss meadows on the Truelove Lowland, northern Devon Island (Muc and Bliss, 1977; Vitt and Pakarinen, 1977), and in central Bathurst Island it is widespread at the edges of ponds and pools and in wet tundra meadows (Miller and Ireland, 1978). Both areas are characterized by Paleozoic carbonate rocks

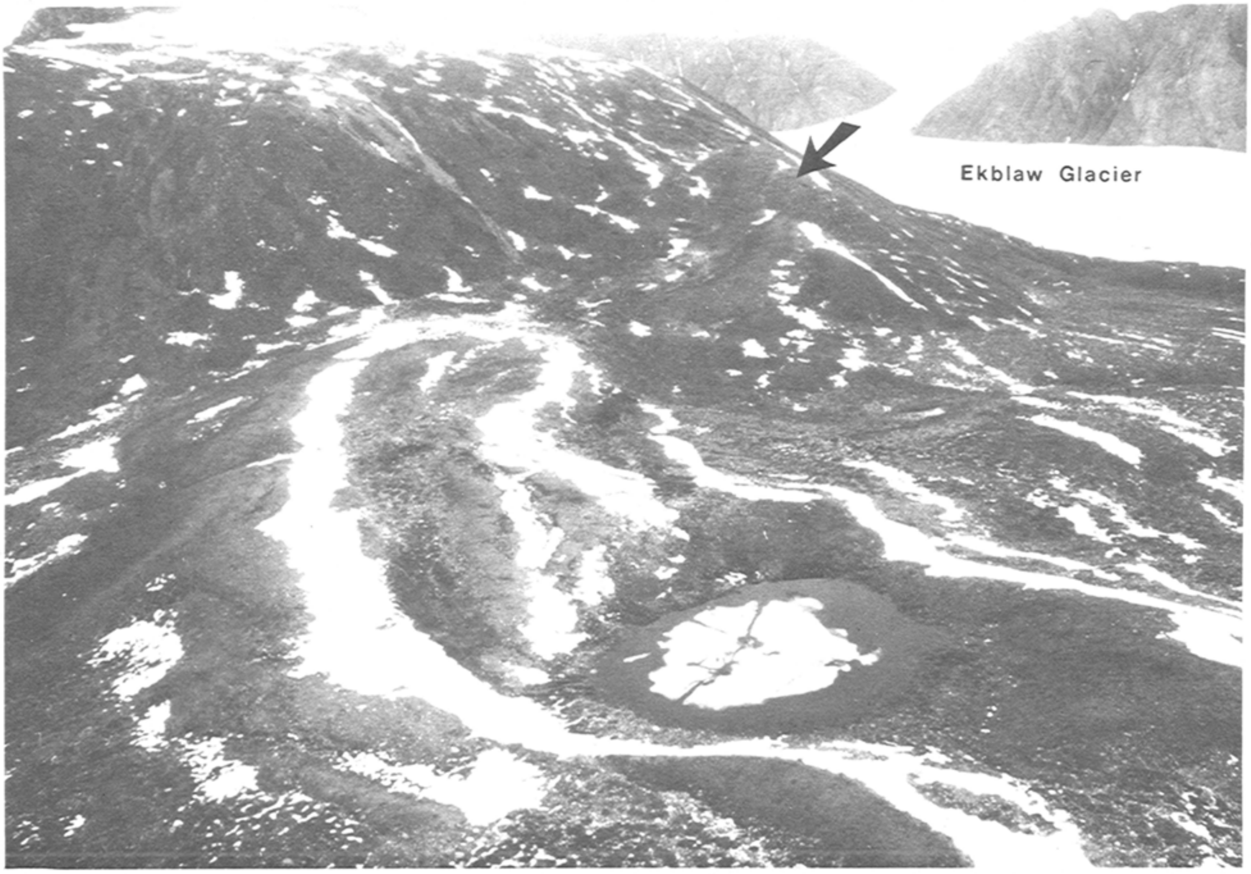

Figure 25.6. Aerial view west at the moraine pond (no. 11) at an elevation of 300 m on the south side of Baird Inlet. The hole in the centre of the ice is where coring was carried out June 18, 1979. Note how the moraine ascends the mountain slope (arrow) on the far side of the pond (in an up-glacier direction). July 20, 1979. GSC 202823-M

outcropping nearby, and the same is true in Peary Land, North Greenland, where Holmen (1960, p. 78) cited it as "a very important species in calcareous marshes and meadows. . ." (cf. also Brassard (1971) for data on this moss community in northern Ellesmere Island). Although, as noted earlier, no carbonate rocks are known to exist at the head of Baird Inlet (T. Frisch, personal communication, 1980), and the underlying inorganic material does not react with dilute HCl, at the level of the dated sample in Core 2 from this pond 1.36% of inorganic (carbonate) carbon is present.

The presence of **Drepanocladus lycopodioides** var. **brevifolius** indicates that shallower water conditions prevailed 8700 to 8400 years ago, for this species does not live in 2+ m-deep water such as exists in this pond today. As mentioned earlier the basin containing the moraine pond was created by the melting of a block of ice. Although the presence of dead ice would have resulted in shallower water, it is by no means certain that the moss grew in this environment. Alternatively, if the permafrost table was originally lower, drainage through the bouldery, morainic debris to the north may have occurred in early postglacial time. As the outlet gradually became blocked by fines derived from the moraine ridges on the other sides of the pond, by the growth of vegetation, and by a rise in the permafrost table, the pond that we see today could have developed from what was originally a meadow-bordered pool. This alternative would explain the change in moss species without the necessity of washing material in at an early stage in the pond's history.

Although the correct explanation may be a combination of several of the factors mentioned, it is interesting to note that in a comparative situation at Nakervare in Swedish Lapland, Karlén (1979) appeared to favour the interpretation that a moss peat/gyttja sequence could result if peat had accumulated in shallow water above ice; then, as the ice melted, a deeper body of water would be formed, and gyttja would be deposited. Wright (1980), too, has stressed the importance of dead ice as a way of explaining similar sequences – coarse organic detritus overlain by deep-water organic lake mud – that are common in Minnesota; cf. also Florin and Wright (1969), Rampton (1970), and Watson (1980) for illustrations of the development of a cover of vegetation on top of dead ice.

The age determinations from innermost Baird Inlet also bear on the question of ice cap symmetry, a topic that has been discussed by Koerner (1977) as a result of his studies of mass balance and ice thickness on several ice caps in the eastern Queen Elizabeth Islands. He presented a series of profiles, based on radio echo sounding, which showed that the ice is significantly thicker on the eastern and southern sides of the Devon Island and central Ellesmere Island ice caps, the latter being the one from which Ekblaw Glacier drains (Fig. 25.1). The present asymmetry of these ice caps is primarily a result of the greater accumulation of snow on the slopes towards Baffin Bay (Koerner, 1966, 1970). Questions posed by Koerner (1977) were: when had the asymmetry developed and was the ice now as thick as, or thicker than, in late Wisconsinan time?

Although the period of time during which the moraine was being constructed cannot be determined precisely on the basis of the available data, there is no reason to doubt that it represents a marginal position of Ekblaw Glacier in late Wisconsinan time, or possibly even in the earliest Holocene as well. Ekblaw Glacier has not reattained the position occupied by the moraine since the inception of organic sedimentation.

Finally, the two oldest age determinations, those from the rock basin above Ekblaw Glacier and from the lake at 390 m on Pim Island, are nearly identical with one in a similar situation on the plateau of Nordvestø, the main island in the Carey Øer, 225 km to the south-southeast of Pim Island. There, although the coring site was a frozen peat mound instead of a lake, and the elevation was lower (ca. 124 m a.s.l.), the basal peat was 8940 ± 90 years old (GSC-2440, at 99-104 cm depth; Brassard and Blake, 1978). It will be of interest to see if age determinations on the basal organic sediment in any of the other lakes sampled fall into the same period of time, and whether any ages are obtained to match the oldest obtained so far on lake sediments from Greenland, i.e., 10 050 ± 150 years (K-2034) from Scoresby Sund, East Greenland, and 9840 ± 170 years (K-1149) in southern West Greenland (Kelly and Funder, 1974).

Acknowledgments

Logistical support was provided by the Polar Continental Shelf Project (G.D. Hobson, Director), and thanks are extended to the staff of that organization in Resolute for expediting our work in every way possible. Assistance with the coring program in 1979 was provided by R.J. Richardson (GSC), R.N. McNeely (on secondment from the Water Quality Branch, Inland Waters Directorate, Environment Canada; responsible for chemical analysis of water samples), and H. Hyvärinen (University of Helsinki; palynology of the cores from Pim Island and Baird Inlet). In 1980 the coring group consisted of T.W. Anderson and I.M. Robertson (both GSC), and S. Funder (University of Copenhagen; palynology of the cores from Greenland); J.P. Bridgland served as general assistant in addition to conducting his own studies of the present-day moss flora at Cape Herschel. The carbon content of the rocks and sediments was analyzed by W.E. Podolak and the radiocarbon age determinations were carried out under the supervision of J.A. Lowdon. J.A. Janssens (University of Alberta) determined the mosses, and S. Lichti-Federovich (GSC) identified the diatoms. T.W. Anderson provided a most helpful critical review of the manuscript.

References

Barnett, D.M.
1977: Glacial geomorphology in a sub-polar proglacial lake basin: a process-response model; unpublished Ph.D. dissertation, University of Western Ontario, London, 302 p.

Blake, W., Jr.
1977: Glacial sculpture along the east-central coast of Ellesmere Island, Arctic Archipelago; in Report of Activities, Part C, Geological Survey of Canada, Paper 77-1C, p. 107-115.

1978: Coring of Holocene pond sediments at Cape Herschel, Ellesmere Island, Arctic Archipelago; in Current Research, Part C; Geological Survey of Canada, Paper 78-1C, p. 119-122.

Bradley, R.S. and England, J.
1977: Postglacial activity in the High Arctic; Department of Geology and Geography, University of Massachusetts, Amherst, Contribution No. 31, 184 p.

Brassard, G.R.
1971: The mosses of northern Ellesmere Island, Arctic Canada. I. Ecology and phytogeography, with an analysis for the Queen Elizabeth Islands; The Bryologist, v. 74, p. 233-281.

Brassard, G.R. and Blake, W., Jr.
1978: An extensive subfossil deposit of the arctic moss **Aplodon wormskioldii**; Canadian Journal of Botany, v. 56, p. 1852-1859.

Caflisch, T.
1972: Limnological investigations on Colour and Phantom Lakes; in 22nd International Geographical Congress (Montreal), Guidebook to Field Tour Ea2, ed. F. Müller; Axel Heiberg Island Research Reports, McGill University, Miscellaneous Papers, p. 49-56.

Davis, P.T.
1978: Pangnirtung and Kingnait Fiord area; The Canadian Alpine Journal, v. 61, p. 73-76.

1980a: Holocene vegetation and climate record from Iglutalik Lake, Cumberland Sound, Baffin Island, N.W.T., Canada; American Quaternary Association, 6th Biennial meeting (Orono, Maine) Abstracts, p. 61.

1980b: Late Holocene glacial, vegetational, and climatic history of Pangnirtung and Kingnait Fiord area, Baffin Island, N.W.T., Canada; unpublished Ph.D. dissertation, University of Colorado, Boulder, 366 p.

Davis, P.T. and Davis, R.B.
1980: Interpretation of minimum-limiting radiocarbon dates for deglaciation of Mount Katahdin area, Maine; Geology, v. 8, p. 396-400.

Donner, J.J. and Jungner, H.
1974: Errors in the radiocarbon dating of deposits in Finland from the time of deglaciation; Bulletin of the Geological Society of Finland, No. 46, Part 2, p. 139-144.

Elton, C.S.
1925: The biology in relation to the geography; Appendix 1 in The Oxford University Arctic Expedition, 1924; Geographical Journal, v. 66, p. 111-113.

Florin, M-B. and Wright, H.E., Jr.
1969: Diatom evidence for the persistence of stagnant glacial ice in Minnesota; Geological Society of America Bulletin, v. 80, p. 695-704.

Fredskild, B.
1977: The development of the Greenland lakes since the last glaciation; in Danish Limnology – Reviews and Perspectives, ed. C. Hunding; Folia Limnologica Scandinavica, v. 17, p. 101-106.

Fredskild, B., Jacobsen, N., and Roen, U.
1975: Remains of mosses and freshwater animals in some Holocene lake and bog sediments from Greenland; Meddelelser om Grønland, Band 198, Nr. 5, 44 p.

Frisch, T., Morgan, W.C., and Dunning, G.R.
1978: Reconnaissance geology of the Precambrian Shield on Ellesmere and Coburg Islands, Canadian Arctic Archipelago; in Current Research, Part A; Geological Survey of Canada, Paper 78-1A, p. 135-138.

Funder, S.
1978: Holocene stratigraphy and vegetation history in the Scoresby Sund area, East Greenland; Grønlands Geologiske Undersøgelse, Bulletin 129, 66 p.

Hattersley-Smith, G.
1969: Glacial features of Tanquary Fiord and adjoining areas of northern Ellesmere Island, N.W.T.; Journal of Glaciology, v. 8, no. 52, p. 23-50.

Holmen, K.
1960: The mosses of Peary Land, North Greenland; Meddelelser om Grønland, Band 163, Nr. 2, 96 p.

Ireland, R.R., Bird, C.D., Brassard, G.R., Schofield, W.B., and Vitt, D.M.
1980: Checklist of the Mosses of Canada; National Museum of Natural Sciences, Publications in Botany, No. 8, 75 p.

Karlén, W.
1979: Deglaciation dates from northern Swedish Lappland; Geografiska Annaler, v. 61A, p. 203-210.

Karrow, P.F. and Anderson, T.W.
1975: Palynological study of lake sediment profiles from southwestern New Brunswick: Discussion; Canadian Journal of Earth Sciences, v. 12, p. 1808-1812.

Kelly, M. and Funder, S.
1974: The pollen stratigraphy of late Quaternary lake sediments of South-West Greenland; Grønlands Geologiske Undersøgelse, Rapport Nr. 64, 26 p.

Koerner, R.M.
1966: Accumulation on the Devon Island ice cap, Northwest Territories, Canada; Journal of Glaciology, v. 6, p. 383-392.

1970: The mass balance of the Devon Island ice cap, Northwest Territories, Canada, 1961-66; Journal of Glaciology, v. 9, p. 325-336.

1977: Ice thickness measurements and their implications with respect to past and present ice volumes in the Canadian High Arctic ice caps; Canadian Journal of Earth Sciences, v. 14, p. 2697-2705.

Long, A. and Mielke, J.E.
1967: Smithsonian Institution radiocarbon measurements IV; Radiocarbon, v. 9, p. 368-381.

Lowe, J.J. and Walker, M.J.C.
1980: Problems associated with radiocarbon dating of the close of the Lateglacial period in the Rannoch Moor area, Scotland; in Studies in the Lateglacial of North-West Europe, ed. J.J. Lowe, J.M. Gray, and J.E. Robinson; Pergamon Press, Oxford, p. 123-137.

Lundqvist, J.
1973: Isavsmältningens förlopp i Jämtlands Län; Sveriges Geologiska Undersökning, Series C, Nr. 681, Årsbok 66, Nr. 12, 187 p.

Mielke, J.E. and Long, A.
1969: Smithsonian Institution radiocarbon measurements V: Radiocarbon, v. 11, p. 163-182.

Miller, N.G. and Ireland, R.R.
1978: A floristic account of the bryophytes of Bathurst Island, Arctic Canada; Occasional Papers of the Farlow Herbarium of Harvard University, No. 13, 38 p.

Mott, R.J.
1975: Palynological studies of lake sediment profiles from southwestern New Brunswick; Canadian Journal of Earth Sciences, v. 12, p. 273-288.

Muc, M. and Bliss, L.C.
1977: Plant communities of Truelove Lowland; in Truelove Lowland, Devon Island, Canada: A High Arctic Ecosystem, ed. L.C. Bliss; The University of Alberta Press, Edmonton, p. 143-154.

Olsson, I.U.
1979: A warning against radiocarbon dating of samples containing too little carbon; Boreas, v. 8, p. 203-207.

Olsson, I.U. and Osadebe, F.A.N.
1974: Carbon isotope variations and fractionation corrections in ^{14}C dating; Boreas, v. 3, p. 139-146.

Rampton, V.N.
1970: Neoglacial fluctuations of the Natazhat and Klutlan Glaciers, Yukon Territory, Canada; Canadian Journal of Earth Sciences, v. 7, p. 1236-1263.

Schroeder, R.A. and Bada, J.L.
1978: Aspartic acid racemization in Late Wisconsin Lake Ontario sediments; Quaternary Research, v. 9, p. 193-204.

Stuiver, M.
1975: Climate versus changes in ^{13}C content of the organic component of lake sediments during the Late Quaternary; Quaternary Research, v. 5, p. 251-262.

Summerhayes, V.S. and Elton, C.S.
1928: Further contributions to the ecology of Spitsbergen; Journal of Ecology, v. 16, p. 193-268.

Sutherland, D.G.
1980; Problems of radiocarbon dating deposits from newly deglaciated terrain: examples from the Scottish Lateglacial; in Studies in the Lateglacial of North-West Europe, ed. J.J. Lowe, J.M. Gray, and J.E. Robinson; Pergamon Press, Oxford, p. 139-149.

Vincent, J-S.
1980: Les glaciations quaternaires de l'île de Banks, Arctique canadien; thèse de doctorat non-publiée, Université de Bruxelles, 248 p.

Vitt, D.H. and Pakarinen, P.
1977: The bryophyte vegetation, production, and organic components of Truelove Lowland; in Truelove Lowland, Devon Island, Canada: A High Arctic Ecosystem, ed. L.C. Bliss; The University of Alberta Press, Edmonton, p. 225-244.

Watson, R.A.
1980: Landform development in moraines of the Klutlan Glacier, Yukon Territory, Canada; Quaternary Research, v. 14, p. 50-59.

Wright, H.E., Jr.
1980: Surge moraines of the Klutlan Glacier, Yukon Territory, Canada: Origin, wastage, vegetation succession, lake development, and application to the Late-Glacial of Minnesota; Quaternary Research, v. 14, p. 2-18.