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Weston Blake, Jr., Mary M. Boucherle, Bent Fredskild, Jan A. Janssens and John P. Smol

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The geomorphological setting, glacial history and Holocene development of 'Kap Inglefield Sø', Inglefield Land, North-West Greenland

WESTON BLAKE, JR., MARY M. BOUCHERLE, BENT FREDSKILD, JAN A. JANSSENS and JOHN P. SMOL

Blake, W., Jr., Boucherle, M. M., Fredskild, B., Janssens, J. A., and Smol, J.P. 1991. The geomorphological setting, glacial history and Holocene development of 'Kap Inglefield Sø', Inglefield Land, North-West Greenland. Meddr Grønland, Geosci. 27, 42 pp, Copenhagen 1992-04-03.

A 115 cm-long core was raised from an irregularly shaped lake informally named 'Kap Inglefield Sø', 1.5 km southeast of Kap Inglefield, North-West Greenland, at an elevation of 150 m. A 49 cm-thick organic sequence is underlain by banded sediment (sand alternating with clay/silt), deposited in an ice-dammed lake. Today the lake is held up at the outlet by bouldery till containing marine shells. The presence of till containing shells with low D/L ratios for aspartic acid at several inland sites, together with well preserved glacial sculpture along the coast (mirrowing features on nearby Ellesmere Island) and over 80 m of Holocene emergence, provides convincing evidence that an ice stream, draining from coalesced Greenland and Innuitian Ice Sheets over Kane Basin, filled Smith Sound at the last (late-Wisconsinan) glacial maximum. Four ^{14}C age determinations have been made on Core 80–18, and the age of the basal organic sediment is 7210 ± 130 conventional radiocarbon years.

The minerogenic sediment in Core 80–18, rich in rebedded pollen, is lacking in contemporary algae and zoological remains, whereas their number varies throughout the organic part of the core, giving some indication of climate and trophic fluctuations. In the organic sequence only 20 diatom species were recorded, and of these only five taxa were ever present at greater than trace levels. The diatom assemblage was dominated by small *Fragilaria* species, typical of early postglacial environments from most glaciated lakes, regardless of location or geologic substrate. Their continued abundance throughout the history of this lake reflects the extreme climate of the region. These harsh conditions are also reflected in the fossil Cladocera (Crustacea). Fragments of mosses occurred throughout the organic sequence; *Calliergon giganteum* dominated at most levels between 5 and 40 cm. A pollen- and microfossil diagram can be divided into five zones. From the bottom upward they are: A. *Poaceae* pioneer plant zone; B. *Salix arctica* – Polypodiaceae zone with many pioneer plants; C. *Salix arctica* zone with high pollen influx; D. Cyperaceae zone with *Dryas*, *Oxyria* and *Salix*; and E. *Saxifraga oppositifolia* – *Papaver* zone with many pioneer (fell-field) plants. In this uppermost zone up to 250,000 *Pediastrum*/ml indicate a slow sedimentation rate, as do the age determinations, probably caused by the development of a nearly permanent ice cover over the central part of the lake. Detailed analysis of the top 7.6 cm of sediment in a second core revealed drastic changes in the chlorophycean (green algae) fossils. *Scenedesmus* is dominant below 4.7 cm, whereas *Pediastrum* is dominant above 4.6 cm. An AMS date of 4050 ± 110 conventional radiocarbon years pinpoints the time at which the cover of lake ice became more permanent.

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Introduction

WESTON BLAKE, JR.

'Kap Inglefield Sø' is the informal name given to a lake 1.5 km southeast of Kap Inglefield in Inglefield Land, North-West Greenland (Figs. 1 to 5; Plate I), at 78°31.8'N, 72°21.0'W. As part of a study of Quaternary deposits, geomorphology and glacial history along Smith Sound and around the southern part of Kane Basin, coring was undertaken at 'Kap Inglefield Sø'. The chronological and paleoecological data were intended to supplement similar information being obtained at various localities along the coast of Ellesmere Island and on Pim Island, on the opposite side of Smith Sound (e.g., Blake 1981a, 1987b; Smol 1983; Hyvärinen 1985). The paleolimnological investigations constitute one facet of the 'Cape Herschel Project', as this long term research program of the Geological Survey of Canada has come to be named, after the location of our base station (Fig. 2). 'Kap Inglefield Sø' was cored because: 1) it is small, has a restricted drainage basin and is close to the network of canyons which characterizes this corner of Inglefield Land; 2) it lies at an elevation of approximately 150 m (not 250 m as listed in Blake 1987b), i.e., it is above the limit of Holocene marine submergence; and 3) it is situated in close proximity to the coast, hence it is easy to reach using a helicopter based at Cape Herschel, by flying around the northern edge of the 'North Water'.

The primary reason for carrying out a program of coring in Inglefield Land was to obtain information about the time of deglaciation, by dating the basal organic sediments. However, because of the great cost of carrying out field operations in the High Arctic and the general scarcity of paleolimnological data (no coring had been done in Inglefield Land prior to 1980), we have attempted to extract as much information from the cores as possible. Thus the studies of pollen, diatoms, Cladocera and bryophytes have been carried out, and the analysis of each of these constituents constitutes a section in the present report.

The nearest site which has been analyzed thoroughly is at 'Rock Basin Lake' in innermost Baird Inlet, Ellesmere Island, approximately 100 km due west of 'Kap Inglefield Sø' (Fig. 1). For that lake Smol (1983) reported on the diatoms in a 56 cm-long core which spanned 9000 years, Hyvärinen (1985) analyzed the pollen content of the sediments, and Duff and Smol (1988) studied the distribution of chrysophycean stomatocysts.

In Greenland the nearest site for which a complete pollen diagram is available is Qeqertat, an island near the head of Inglefield Bredning, where 135 cm of organic sediment represented nearly 7000 years (Fredskild 1985b). This site is 170 km southeast of 'Kap Inglefield Sø' (Fig. 1). Aside from that locality, a significant amount of work has been carried out in Peary Land (Fredskild 1969, Bennike 1983), in eastern North Greenland (Funder and Abrahamsen 1988), and in North-East Greenland (Björck and Persson 1981). Farther south along the west coast a number of peat samples have been collected on the north side of Foulke Fjord and elsewhere in North-West Greenland (Malaurie et al. 1972), and two lakes have been investigated at Tugtuligssuaq in the Melville Bugt area (Fredskild and Bay 1980; Fredskild 1985b).

Coring at 'Kap Inglefield Sø' was carried out on June 8th, 1980 by W. Blake, Jr. and T. W. Anderson, both of the Geological Survey of Canada (GSC), and S. Funder, of the Geological Museum, University of Copenhagen. The core obtained on this occasion is the one which has been analyzed for the present report (Blake et el. 1985). A second core was taken on June 4th, 1984 by W. Blake, Jr., F. M. Nixon and R. J. Thibedeau, all of the GSC, using newly constructed coring equipment with which we hoped to obtain longer cores. Numerous other sites in Inglefield Land were visited during June 1984, and a final trip to 'Kap Inglefield Sø' was made on July 4th, 1984, together with J. P. Smol, in order to collect vascular plants and mosses around the lake nearer to the peak of the growing season. At the same time the lake was resurveyed for limnological variables, and samples for water chemistry were collected. Because many plants were still not in bloom on this occasion, another trip to the lake was made on July 18th, 1986. Although 1986 was not a particularly warm summer, a number of new vascular plants were found during a traverse around the lake (personal communication from B. Fredskild, October 1986), and in addition new collections of algae, invertebrates, and water were made for J. P. Smol by M. S. V. Douglas.

Despite the time spent in this corner of Inglefield Land, the reconnaissance nature of the geomorphological work must be stressed. Emphasis was placed on investigating the environs of 'Kap Inglefield Sø' and a few other sites, nearly all of them along the coast. Many more helicopter landings at critical localities on the plateau, and many more foot traverses to search for striae, till, datable materials, etc., would be highly desirable.

In the text of this paper responsibility for the different chapters is indicated at each main heading. Place names for the major settlements (Fig. 1) follow the current Greenlandic spelling; *i.e.*, Iita instead of Etah. Local names in Inglefield Land, many of them given by expeditions, follow the spelling given in Laursen (1972). Unofficial names are set off by single quotation marks.

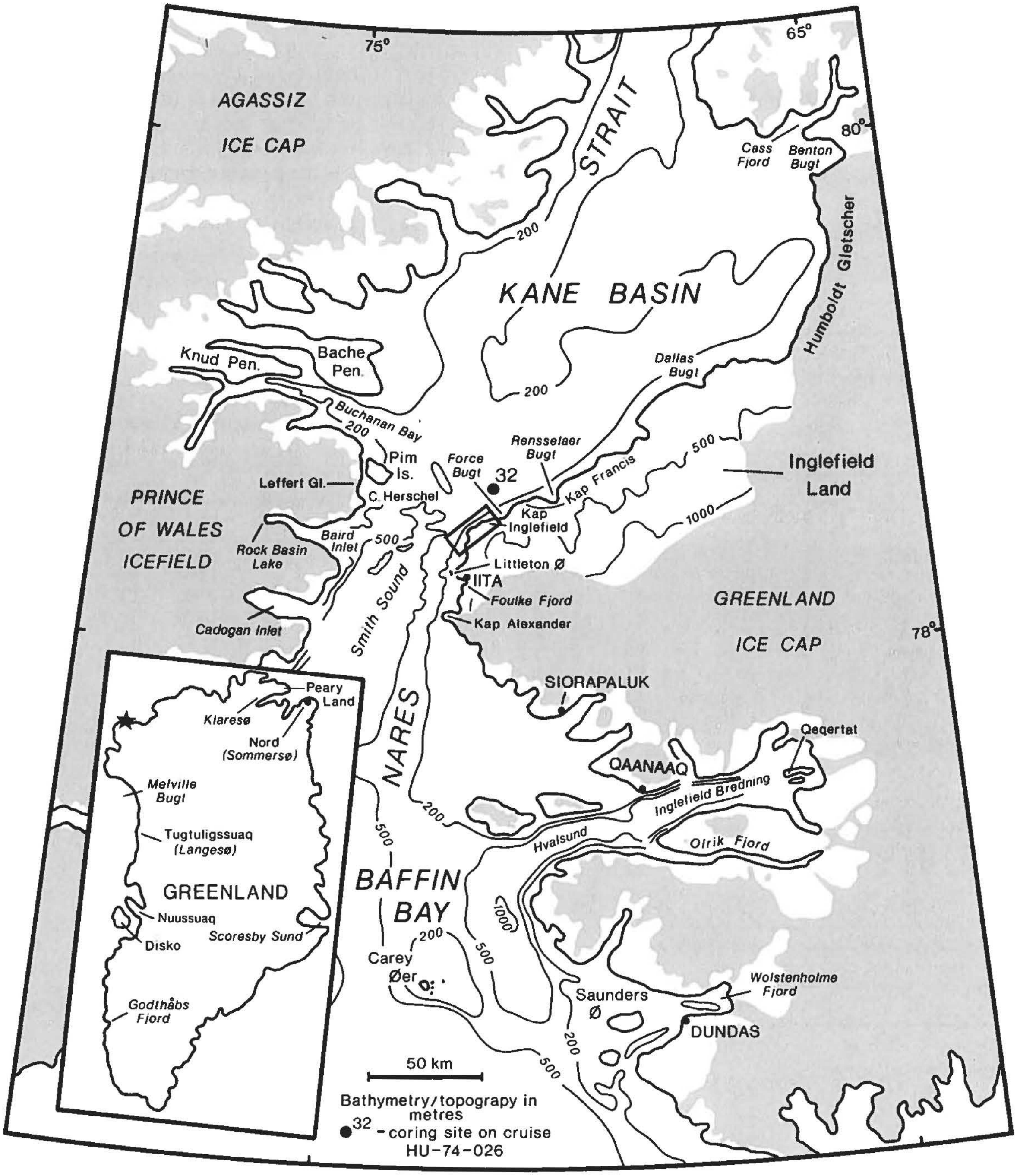

Fig. 1. Location map for the Smith Sound – Kane Basin region, North-West Greenland and east-central Ellesmere Island. Adapted from 'Baffin Bay Bathymetry', sheet 817-A (1:2 000 000), Canadian Hydrographic Service, 1980 (Bathymetric contours interpreted by D. Monahan). The rectangle enclosing Kap Inglefield shows the area covered by Plate I.

Climate

WESTON BLAKE, JR.

The climate of Inglefield Land is high arctic, although the location of Kap Inglefield near the northern end of the 'North Water' (Dunbar 1969; Nutt 1969; Ito 1982) means that the presence of this polynya has an ameliorating effect throughout the winter months. Müller *et al.* (1976, p. 56) stated, "The isolines for the winter months indicate the existence of an especially warm area in the eastern part of Smith Sound, *i.e.*, on the Greenland side of the polynya" (cf. also Steffen & Ohmura 1985).

The nearest permanent weather station is at Qaanaaq, 135 km to the southeast of Kap Inglefield (Fig. 1). Monthly and yearly temperature data for 1964 through

Table 1. Meteorological observations at Qaanaaq, Iita and Refuge Harbour.

A. Temperature (°C) – monthly and yearly mean values

Year	J	F	M	A	M	J	J	A	S	O	N	D	Mean
Qaanaaq (77°29'N, 62°12'W)[1]													
1964	−21.8	−20.4	−24.6	−19.2	−6.8	2.6	3.3	3.9	−0.6	−14.4	−19.4	−19.1	−11.4
1965	−22.8	−17.2	−22.2	−17.6	−0.6	1.4	3.7	5.9	−6.2	−7.8	−9.2	−20.4	−9.6
1966	−25.8	−20.4	−24.4	−18.4	−6.4	1.2	3.5	5.7	−1.1	−6.9	−13.7	−23.3	−10.8
1967	−21.4	−24.6	−19.9	−15.2	−1.8	0.9	4.4	3.7	−1.5	−9.7	−16.1	−16.7	−9.8
1968	−25.2	−24.4	−24.7	−13.0	−3.1	1.2	5.4	4.3	−1.7	−6.2	−12.6	−20.2	−10.0
1969	−18.4	−20.1	−25.3	−16.8	−3.8	1.0	4.3	6.2	−0.7	−8.8	−14.5	−20.4	−9.8
1970	−24.0	−19.9	−22.4	−16.1	−8.4	1.2	3.8	4.1	−0.1	−5.2	−13.7	−21.0	−10.1
1971	−25.7	−25.0	−22.1	−15.5	−5.7	3.2	4.9	3.6	−0.5	−8.4	−17.5	−26.2	−11.3
1972	−23.7	−23.5	−24.0	−18.4	−5.7	0.5	2.5	3.4	−0.1	−5.9	−15.1	−25.1	−11.3
1973	−20.4	−28.7	−26.9	−17.3	−7.8	1.5	3.8	5.0	−0.7	−5.6	−13.6	−17.4	−10.7
1974	−23.9	−24.0	−23.2	−16.3	−7.5	0.6	3.5	5.4	−0.4	−6.2	−17.9	−23.5	−11.1
1975	−25.1	−23.8	−23.1	−17.6	−4.9	3.7	5.9	4.5	−2.8	−6.1	−16.2	−22.0	−10.6
1976	−21.4	−20.8	−19.3	−17.3	−6.7	0.9	4.6	3.7	0.4	−9.6	−15.4	−17.1	−9.8
1977	−14.1	−22.9	−21.4	−13.1	−3.8	1.2	5.2	4.9	−2.1	−5.8	−15.3	−24.3	−9.3
1978	−21.8	−22.1	−23.7	−17.8	−4.4	0.1	5.0	5.0	−1.8	−10.5	−20.9	−13.3	−10.5
1979	−20.2	−29.5	−22.1	−13.2	−6.7	1.5	4.2	4.0	−0.9	−7.7	−17.2	−21.8	−10.8
ALL	−22.2	−23.0	−23.1	−16.4	−5.3	1.4	4.3	4.6	−1.3	−7.8	−15.5	−20.7	−10.4
Iita (78°20'N, 72°42'W)[2]													
1937	–	–	–	–	–	–	–	–	−3.8	−11.4	−15.3	−22.1	–
1938	−25.7	−24.9	−21.9	−17.3	−5.2	3.8	–	–	–	–	–	–	–
Refuge Harbour (78°30'N, 72°38'W)[3]													
1923	–	–	–	–	–	–	–	–	−4.8	−13.9	−19.4	−26.4	–
1924	−29.6	−31.8	−23.6	−19.3	−2.8	–	–	–	–	–	–	–	–

B. Precipitation (mm) – monthly and yearly sums

Year	J	F	M	A	M	J	J	A	S	O	N	D	Mean
Qaanaaq (77°29'N, 62°12'W)[1]													
1964	10.2	9.6	3.5	0.3	0.0	0.0	72.8	3.5	11.6	12.2	3.3	1.2	128.2
1965	19.5	17.3	2.5	4.8	10.5	14.1	18.1	14.0	8.2	5.0	0.0	0.0	114.0
1966	8.5	3.3	1.0	3.5	11.0	13.5	3.1	61.9	67.9	20.1	6.3	5.4	205.5
1967	12.0	22.6	0.5	2.0	4.7	0.0	26.8	2.2	1.1	3.3	8.0	10.9	94.1
1968	0.0	4.4	1.3	7.9	8.7	8.4	4.9	0.5	0.8	2.0	2.5	0.5	41.9
1969	0.8	18.1	5.7	5.1	3.4	4.1	32.3	11.3	8.8	0.0	5.0	5.4	100.0
1970	1.7	4.3	6.8	8.1	2.3	6.2	15.2	12.4	9.3	13.0	1.5	8.2	89.0
1971	6.8	2.9	1.7	0.8	4.6	6.6	17.7	31.7	16.8	4.6	0.7	0.2	95.1
1972	5.4	0.0	3.9	13.2	5.7	0.0	13.3	34.8	20.0	6.2	1.4	0.0	103.9
1973	1.0	0.4	1.1	0.0	4.1	4.4	35.3	43.9	5.9	11.9	5.7	0.8	118.5
1974	0.2	7.1	2.8	7.4	2.7	16.0	32.8	52.6	1.0	6.1	1.0	0.1	129.8
1975	2.6	2.3	3.4	2.4	0.0	8.8	51.3	23.2	12.0	7.4	0.1	0.0	113.5

[1]Data from Bay (in press.)
[2]Data from MacGregor (1939)
[3]Data from MacMillan (1927). The latitude is taken from the 1978 1:250 000 topographic map (Bache Peninsula, N.T.S. No. 49N½ & 39N½). MacMillan (1927) gives the latitude as 78°31'N.

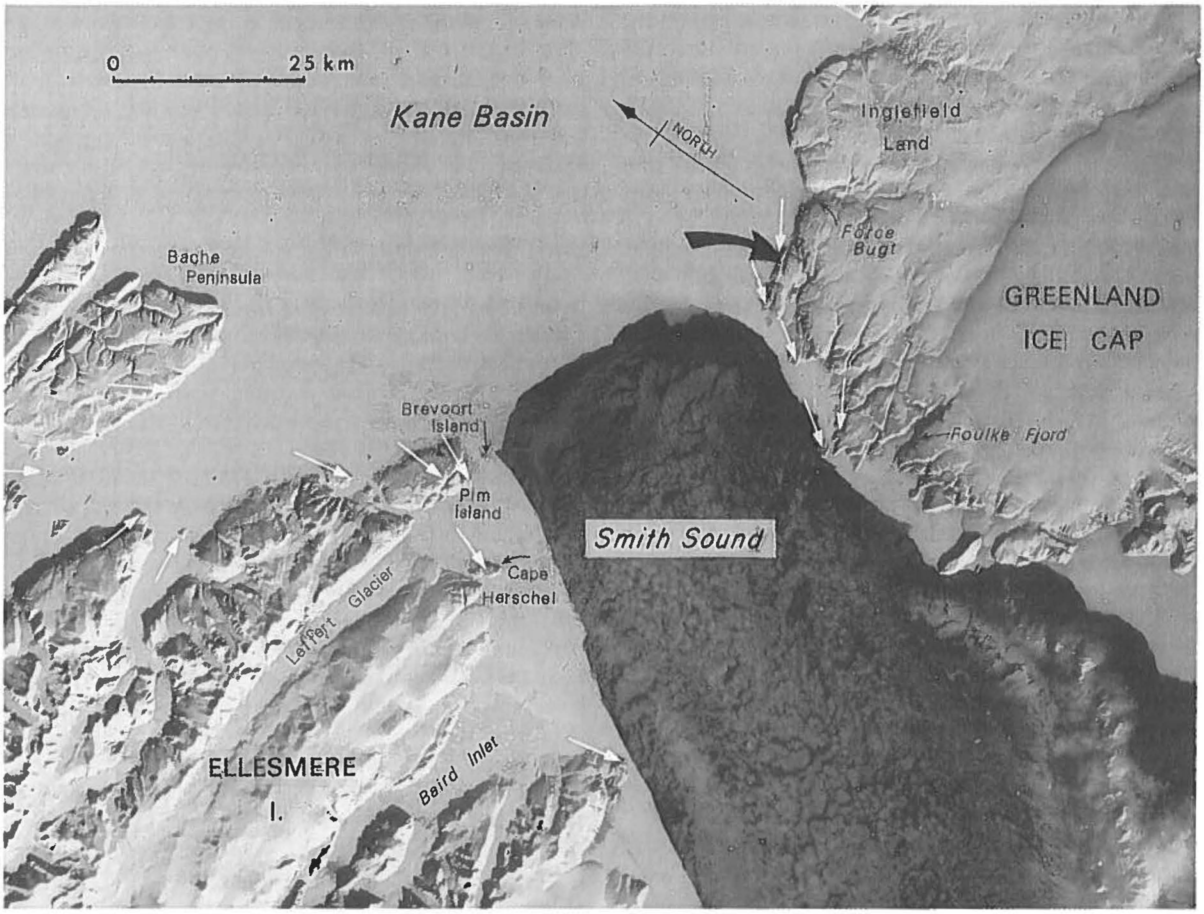

Fig. 2. LANDSAT image of Smith Sound and southern Kane Basin. The location of 'Kap Inglefield Sø' is indicated by the black arrow. The former direction of ice flow through Smith Sound is shown by the white arrows. Note the development of the North Water on April 4, 1973 (image E-10255–18054, spectral band 7).

1979 are given in Table 1, with the mean annual temperature for this 16-year period being −10.4°C. The mean for the coldest month (March) for these years is −23.1°C, but February is nearly identical, with a mean value of −23.0°C. The lowest mean monthly value was −29.5°C, for February 1979.

By way of comparison, a series of temperature observations from Iita (Fig. 1), and only 26 km to the south-southwest of Kap Inglefield, made during a 10-month period from September 1937 through June 1938 by the MacGregor Arctic Expedition (MacGregor 1939), are also listed in Table 1. During that period the mean temperature of the coldest month (January) was −25.7°C, and the mean temperature for February was −24.9°C.

The wintering site closest to 'Kap Inglefield Sø' from which meteorological data are available is Refuge Harbour, 6.5 km west-southwest of the lake. The original harbour is the unnamed bay inside of Cache Point (Plate I, Fig. 3), rather than the larger bay indicated on modern maps. Observations were made from September 1923 to early June 1924 by an expedition under the leadership of D. B. MacMillan (1927) in the ship *Bowdoin*. The temperature data, summarized in Table 1, show that February was the coldest month, with a mean temperature of −31.8°C.

One other set of data provides information on the climate in Inglefield Land. The 'Second Grinnell Expedition in Search of Sir John Franklin', led by E. K. Kane, made meteorological observations at their base in Rensselaer Bugt from June 1853 through April 1855 (Kane 1856, Appendix XII). During this 23-month period, the two coldest months were March and December 1854, at −39.4°C and −38.7°C, respectively. Rensselaer Bugt is some 30 km northeast of Kap Inglefield.

Additional information is available from the series of maps in Ohmura's (1987) compilation of monthly mean surface temperatures for the whole of Greenland. The data used on his maps were reduced to the standard decade of 1951 to 1960. A measure of the severity of the climate at 'Kap Inglefield Sø', despite the presence of the 'North Water' polynya, is that the lake lies close to the isothermal line for −25°C for January, between the lines for −25° and −30°C for February, and astride the

−30°C line for March. For July, the warmest month, the isothermal line for 5°C does not reach as far north as Iita or Kap Inglefield, although it is situated to the north of Qaanaaq.

The precipitation records from Qaanaaq for the 12-year period 1964 through 1975 give a mean annual precipitation of 111.1 mm, with the yearly sums varying from a low of 41.9 mm in 1968 to a high of 205.5 mm in 1966 (Table 1). July and August are the months with by far the most precipitation, the mean values being 26.97 mm and 24.33 mm, respectively. Unfortunately the two months missed by the MacGregor Arctic Expedition during their 10-month stay at Iita were July and August (MacGregor 1939), and the appendix dealing with weather in MacMillan (1927) does not contain details of precipitation.

Winds over the southern part of Kane Basin and Smith South are dominantly northerly or southerly (Ito 1981). At 'Kap Inglefield Sø' some topographic influence is presumably exerted by the local topography, as the lake lies in a valley oriented northeast-southwest.

Geomorphology and glacial history

WESTON BLAKE, JR.

Traverses across various parts of Inglefield Land and along the Kane Basin coast have been made by a number of geologists who were primarily interested in mapping the bedrock, notably Koch (1926, 1928, 1933), Bentham (1936), Troelsen (1950) and Cowie (1961). All of them commented on the geomorphic development of the landscape as well. Three studies that dealt especially with geomorphology, glacial history, soils and weathering phenomena were those of Malaurie (1955, 1968), Nichols (1969) and Tedrow (1970). Weidick (1976a) provided an extensive summary of the Quaternary of Greenland, and the most recent summary of the Quaternary geology of North Greenland has been compiled by Funder (1989).

Modern work on the bedrock geology of Inglefield Land, by staff members of Grønlands Geologiske Undersøgelse, is summarized by Dawes (1971, 1976, 1988). A number of other important papers are contained in the volume arising from the 1980 'Nares Strait Symposium' (Dawes and Kerr 1982).

Precambrian Shield rocks outcrop along the coast of southwestern Inglefield Land from Foulke Fjord to Force Bugt. The basement rocks in the vicinity of Kap Inglefield are part of the Etah meta-igneous complex (Dawes 1972). According to Dawes (1976, p. 255), "The rocks vary from black, dark grey and brown gabbro through diorite, quartz norite, quartz diorite and hypersthene tonalite to pink and red granodiorite and granite". It is the reddish granite-family rocks which dominate along the coast at Kap Inglefield (from Force Bugt to Cairn Pynt; Dawes 1979). A succession of unmetamorphosed Proterozoic and basal Cambrian platform strata overlie the basement. The lower units, the redefined Rensselaer Bugt Formation, is composed of multicoloured sandstone and siltstone with minor shale and stromatolitic dolomite; the upper unit, the Dallas Bugt Formation, is composed of red and white sandstone with dolomitic sandstone and siltstone at the top (Peel et al. 1982). The rock making up part of the peninsula which juts out into the southern end of 'Kap Inglefield Sø' is a pebbly sandstone, but dolomite outcrops near the stream entering the north side of the lake (Fig. 5). As seen from the air, basement rocks are exposed in a channel a short distance to the west-southwest of 'Kap Inglefield Sø'.

At nearby 'Stromatolite Sø' (78°31.1'N, 72°17.5'W; Figs. 3, 4 and 7), the granitic basement is overlain unconformably by brightly-coloured red and green shales and well exposed beds of spectacular stromatolitic dolomite of the Rensselaer Bay Formation (hence the origin of the informal name for the lake). These rocks also outcrop sporadically along the coast between Kap Inglefield and Force Bugt, and presumably it is from here that many of the numerous erratics around 'Kap Inglefield Sø' derive.

As Cowie (1961, p. 36–37) has correctly pointed out, "The nature of the land surfaces and coasts of S. W. Inglefield Land is closely related to the solid geology: the basement rocks produce a rugged, irregular topography and an indented coastline while the younger sediments produce featureless upland plateaus and smooth coastlines with steep cliffs... The smooth scree-aproned coastline north-east of Kap Inglefield contrasts with the rugged small bays and headlands running south from that point, reflecting the nature of the bed-rock... In the coastal area between Littleton Ø and Kap Inglefield the sandstone plateau ends in cliffs standing above the coastal basement area. The dolerite sills which are prominent features of the cliffs no doubt largely account for their steepness and resistance to erosion. Between Kap Inglefield and Cairn Pynt an outlier of sandstone is preserved and in this sector the coast rises steeply in low cliffs. The plateaus are terminated in the north coast by steep cliffs with extensive screes; small outwash fans are produced by the streams draining the uplands."

From a glacial geological point of view, the most interesting feature of the geological map (1:700 000) in the report by Koch (1933) is that he shows the southern part of Inglefield Land as having a cover of 'glacial deposit'. The width of the drift-covered zone is shown as being over 20 km in the area south and southeast of Rensselaer Bugt, much narrower to the southeast of Kap Inglefield. The Rensselaer Bugt segment of this map, labelled "Northern Extent of Glacial Drift (Koch)" is reproduced with additions as Figure 7 in Tedrow (1970). There is relatively little in Koch's text to

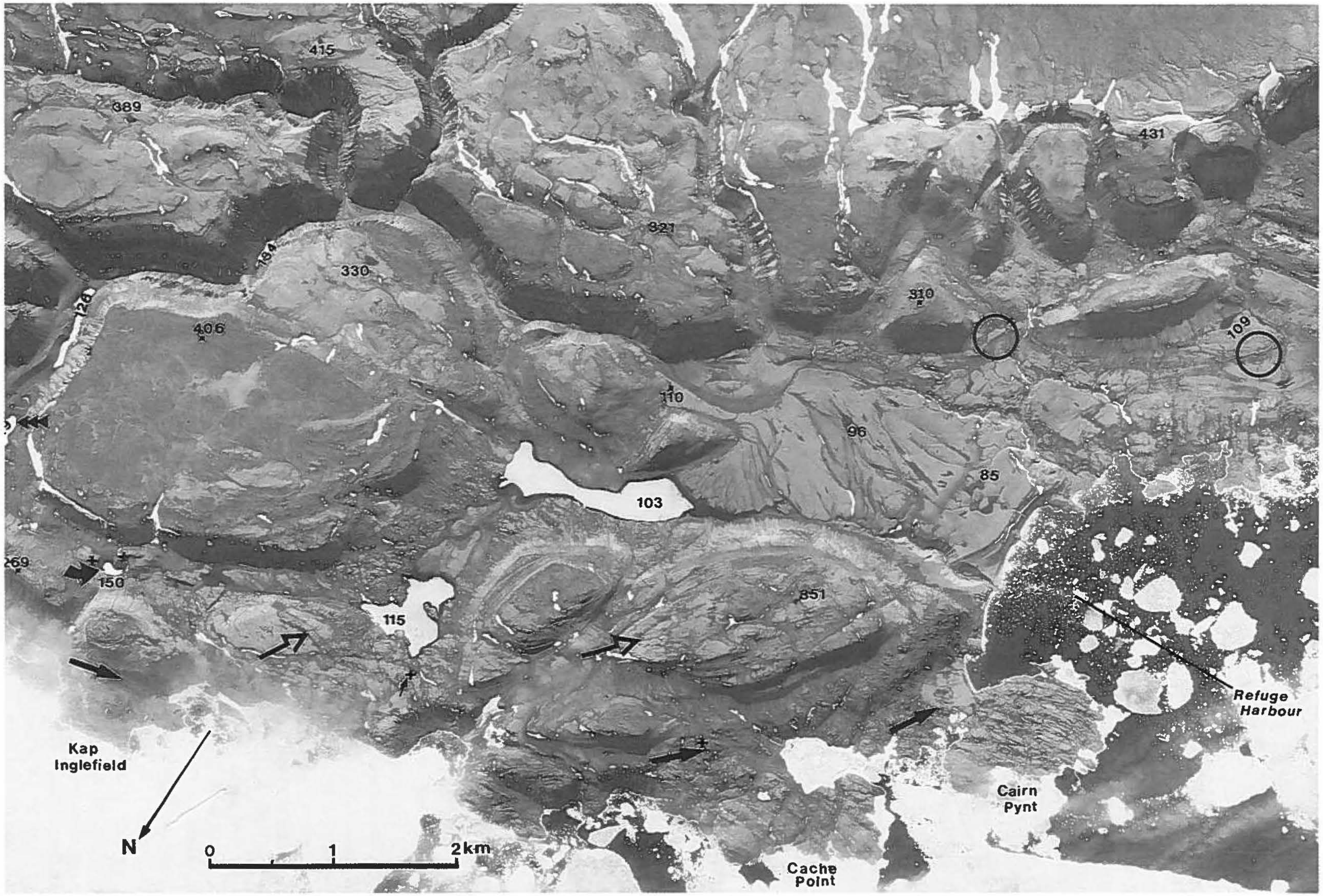

Fig. 3. Vertical aerial photograph of the coast of southwestern Inglefield Land, between Kap Inglefield and Refuge Harbour. 'Kap Inglefield Sø' is indicated by the curved black arrow, 'Stromatolite Sø' by the barbed black arrow. Former directions of ice flow are indicated by the straight black arrows, with the main arrows showing flow along the coast and the smaller arrows indicating where the ice pushed inland into embayments. The open arrows show the inferred direction of ice flow across the coastal hills. Note the network of canyons leading from the north (some heading at the coast) to the delta at Refuge Harbour. Spot elevations are in metres, sites at which shelly till occurs are marked by a + sign, and two areas of lateral moraines and associated features at close to 100 m a.s.l. are circled. Photograph 239B/497, July 7, 1959, 28 000 ft. (8535 m). Published with permission from Kort og Matrikelstyrelsen, Copenhagen.

tell us the basis for his drift limit, but he does state, under the section on topography (p. 7): "From east to west the gneiss plain may be divided into a series of minor areas, viz...

d) The western gravel plain south of Cape Francis and Rensselaer Harbour (= Bugt). The underground is exposed in the entire eastern part of the area, and only a strewing of boulders indicates that the ice has moved across the country. Towards the west, however, the ground is planed by large masses of diluvial gravel. Rivers are rare, but small shallow lakes are exceedingly numerous. Moraine ridges, 10 to 20 metres high, may occasionally be observed.
e) Behind Anoretok (= Anoritôq), in the direction of Etah, the gneiss plain rises again, and the morainic material is less dominant. Sediments in connection with diabases make the ground more broken, and deep valleys cut down into the gneiss surface to a depth of 100 metres or even more. Raised beaches, extraordinarily beautifully developed, occur in the mouth of the valleys, frequently up to an altitude of 150 metres above sea level."

This part of Inglefield Land has been classified by Sugden (1974, p. 186) under his "linear ice sheet erosion" category, characterized by "trough and unmodified plateaux", whereas the remainder of the region, from west of Rensellaer Bugt to Humboldt Gletscher, is typified by "areal scouring by ice sheet".

By far the most striking element of the landscape in this part of Inglefield Land is the network of canyons and channels which dissects the plateau (Plate I; Figs. 3 and 6 to 8). These features are especially well developed between Force Bugt and Refuge Harbour. As indicated above under (e), the canyons were noted by Koch when he sledged along the coast in 1917, 1920 and 1922, and they are shown on the maps and diagrams produced by Malaurie (1968). The canyons were not commented upon by Nichols (1969), however, as he started his walking traverse a few kilometres southwest of Force Bugt, worked northeastward along the coast and then headed inland from Rensselaer Bugt.

The most important feature of much of the canyon and channel network is that it only could have formed if glacier ice lay on the seaward side. The presence of an ice stream in southern Kane Basin and Smith Sound forced rivers draining along, and under, the ice margin to flow inland on their way to the coast farther south, i.e., at Refuge Harbour (Fig. 3). Because the general elevation of the plateau surface rises inland (cf. Plate I; Fig. 3), water from ice on the inland (southeast) side alone could not have created a series of canyons and channels parallel to, or heading at, the present coast. Lateral drainage channels are particularly well developed on the plateau between Force Bugt and the canyon leading inland from 'Stromatolite Sø', and all of them decrease in elevation toward the west and southwest (cf. Plate I; Fig. 8). Many of these channels lead into the heads of tributary canyons which drain towards the major canyon in which 'Stromatolite Sø' and the adjacent unnamed long lake to the south are situated.

The size of the major canyons, some of which are more than 200 m deep, suggests that they may have been excavated during the course of several glacial/deglacial cycles. Although they were originally created by meltwater, they have been modified, undoubtedly, by the erosive action of glacial ice. A perched delta complex is associated with one of the major drainage channels (Plate I; Fig. 3). For this feature to have formed on the plateau at an elevation of over 350 m ice had to lie on the seaward (downhill) side, and the intervening canyon must have been filled by ice, thereby indicating that at least part of the canyon-cutting was achieved prior to the last glaciation. An alternative explanation is that the canyon-cutting took place after the delta and accompanying deposits up-valley were deposited. However, this alternative seems less likely, simply because of the volume of material which would have had to have been excavated in a relatively short period of time, *i.e.*, during the Holocene. The important point is that had this corner of Inglefield Land only been covered by northwestward flowing ice from an expanded Greenland Ice Sheet, the existing network of canyons could not have been created. There would have been no reason for massive amounts of water to flow southwestwards, at right angles to the direction of ice flow, despite the fact that lines of structural weakness have undoubtedly helped to localize some of the canyons, especially near Kap Hatherton.

The glacial history of this corner of Inglefield Land is inextricably bound up with the history of glaciation on the Ellesmere Island side of Smith Sound. Not only does the network of canyons in southern Inglefield Land require the presence of glacier ice in Kane Basin and Smith Sound, but the beautifully sculptured and striated red granite and associated Shield rocks along the coast indicate that during the maximum of the last glaciation, southward-flowing ice filled Smith Sound (Blake 1977), one of the narrowest parts of Nares Strait.

This massive ice stream, which served as an outlet glacier from coalesced Greenland and Innuitian Ice Sheets impinged on, and overrode, the coastal terrain on both sides of Smith Sound. On Pim Island, the highest point on the island, at approximately 550 m a.s.l., was sculptured by the southward flowing ice. On the Greenland side the granitic rocks do not rise as high above sea level, and because observations on striae were restricted, for the most part, to this rock type (because of the helicopter landing sites that were chosen), the highest glacial features observed here were at an elevation of approximately 160 m. Striae orientations were recorded along the coast at 1) Littleton Ø, 2) Kap Hatherton, 3) Cairn Pynt, 4) Cache Point, and 5) Kap Inglefield (Figs. 3, 9, and 10; Plate I). The striated and shaped rock surfaces, many of them situated where a protective cover of till could not have been removed, are also characterized by an abundance of perched boulders (Fig. 11). In addition, the elongated shape of the line of coastal hills between Kap Inglefield and Refuge Harbour, and south of Refuge Harbour, strongly suggests sculpturing by ice. This section of the coast, which juts furthest to the west, would have been most subject to the force of the 'Smith Sound Ice Stream'. The top of the largest of these hills, inland from Cairn Pynt and Cache Point, appears to have a thin cover of drumlinized till (and/or glacially-modified bedrock) at its northeast end, at elevations above 350 m (cf. Plate I and Fig. 3). The plateau further inland, at a site visited east-northeast of Kap Hatherton, does not display readily evident ice sculptured features, although erratics are present (Fig. 12). Presumably the erosive effects of the 'Smith Sound Ice Stream' were not felt or were less intense at this elevation (above 400 m) and some 2.5 km from the coast.

Had there not been an ice stream filling Smith Sound, draining from Kane Basin, there would have been no reason for glacier ice entering Kane Basin from Force Bugt, say, to turn and flow southwestward and then southward along the coast. It would be much easier for such an outlet glacier to flow northwestward into the deep water (over 400 m) of southern Kane Basin (cf. Monahan and Johnson 1982), which in turn leads to the deepest part of Smith Sound, more than 600 m in places (Tooma 1978). The evidence for former glacier flow along the coast matches the inferred direction of glacier ice movement in southern Kane Basin, as deduced by Kravitz (1982) from his analysis of a number of sedimentological and mineralogical parameters in 30 cores and three grab samples. However, Pelletier's (1966) original analysis of the submarine topography led him to propose an ice divide in Kane Basin, from which ice flowed both north and south in Nares Strait, and Funder's (1989) conceptual model of the Late Wisconsin Independence Fjord glaciation also has an ice divide in Kane Basin. Verification of the flow of glacier ice northward in Nares Strait from northern Kane Basin has been provided recently by de Freitas (1990).

The 'Smith Sound Ice Stream' evidently pushed southeastward and eastward into all pre-existing embayments along the coast. For example, southward flowing ice pushed through the ENE-WSW oriented valley in which 'Kap Inglefield Sø' lies, as the till-covered bedrock ridge on the northeast side of the lake contains abundant fragments of marine pelecypod shells, especially *Hiatella arctica* and *Mya truncata*, but also including *Astarte* sp., *Macoma* sp. (probably *M. calcarea*) and *Clinocardium ciliatum*. One gastropod, *Tachyrhynchus* sp. (probably *T. reticulatus,* cf. Macpherson 1971) also was recovered from the till at this site. In addition, shell fragments are present in the veneer of bouldery till on the ridge that extends out into the lake on its southern side (Fig. 5), and the lake itself is held up at the outlet by bouldery till. This second ridge was interpreted as an end moraine at first, on the basis of the obvious presence of till and the overall shape of the ridge. On a later visit bedrock was discovered along the west side of the ridge or, if it is not bedrock, a block several metres in diameter has been transported by ice. In any event the bulk of the material in the ridged area around the southern end of 'Kap Inglefield Sø' is till, and the shape of the ridge facing the lake (which may be controlled, in part, by bedrock) suggests that a lobe of ice may have pushed inland through the gap in the coastal hills. If that is the case then glacier ice entered the lake basin from two directions.

The presence of sculptured and striated bedrock outcrops, together with shelly till, on the drainage divide at the northern end of 'Peninsula Sø', the informal name for a larger lake 2.5 km southwest of 'Kap Inglefield Sø', is another indication of the onshore flow of ice (Fig. 3). At this site the shell species in the till included *Mya truncata, Hiatella arctica, Chlamys islandica, Astarte* sp., and *Balanus* sp. Malaurie (1968, Fig. 43) shows a recessional moraine created by ice on the landward side in the vicinity of 'Peninsula Sø, but no evidence for this feature or for this direction of ice flow was seen in 1984. On the other hand, and here the general position of the lobe depicted by Malaurie (1968) seems reasonable, ice appears to have flowed through the valley now occupied by 'Peninsula Sø' and on to Refuge Harbour. As this ice thinned and fluctuated during retreat from its Late Wisconsinan maximum position, moraines were built along its southern margin, at the base of the scarp to the plateau. The topographically highest moraine reaches above the 200 m contour in places (Plate I and Fig. 3).

Although sculptured and polished surfaces occur along the bedrock ridge at the seaward end of 'Stromatolite Sø', the evidence for the direction of flow was not as convincing as at the other two sites. Nor were shell fragments discovered in the till mantling the ridge, perhaps because of the more extensive cover of vegetation here than in the vicinity of 'Kap Inglefield Sø'. The absence (or scarcity) of shells at this site is not really surprising, however, for the dominant ice flow was southwestwards, into and through the valley in which 'Kap Inglefield Sø' lies, and therefore this would have been the main direction in which marine sediments, including shells, were also transported (cf. Figs. 3 and 4).

No shells from the till have been dated by ^{14}C as yet, for past experience has shown that samples of this kind tend to produce finite ages in the 30 000 to 40 000 year-range, nearly all of which are difficult to interpret (Olsson and Blake 1962; Blake 1985). Five determinations on shells in till from the Ellesmere Island side of Smith Sound have been carried out, however. The results, each on an individual shell fragment, range from 28 900 ± 240 years (TO-1268; *Mya truncata*) to 50 230 ± 1330 years (TO-1225; *Chlamys islandica*). In addition, D/L ratios for aspartic acid on shells in till at 'Kap Inglefield Sø' and 'Peninsula Sø' (Plate I; Fig. 3) have

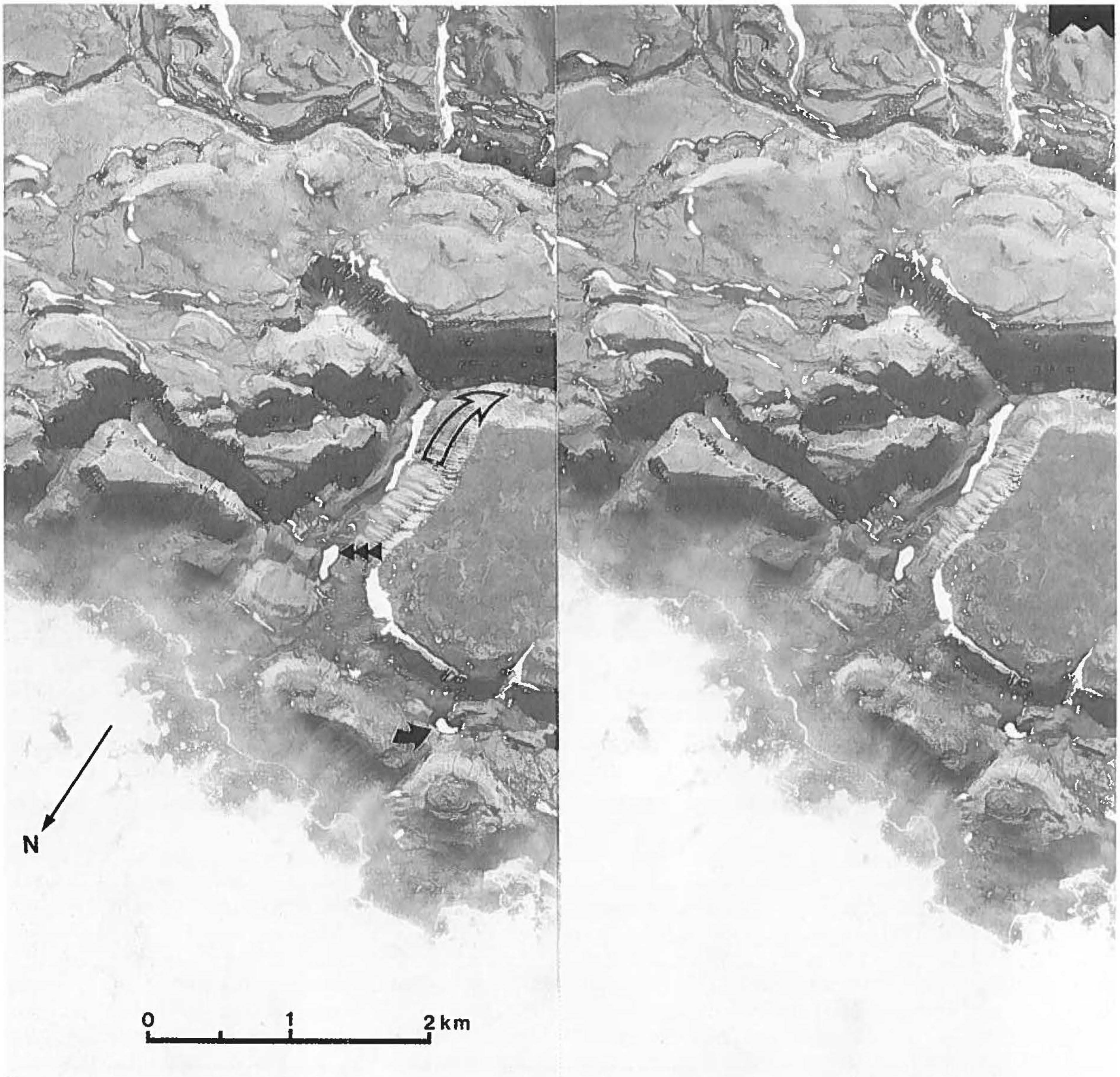

Fig. 4. Vertical aerial photographs (stereopair) of the environs of 'Kap Inglefield Sø' (curved black arrow). The lake retains a significant cover of ice, including the site where coring was carried out. Note the major canyons heading at the coast and the position of 'Stromatolite Sø' (barbed black arrow) at the head of the largest one, which leads to the delta north of Refuge Harbour (cf. Fig. 3). The direction of water flow when an ice stream occupied Smith Sound is indicated by the open arrow. Photographs 239 B/495 and 496, July 7, 1959, 28 000 ft. (8535 m). Published with permission from Kort og Matrikelstyrelsen, Copenhagen.

been determined, and they are listed in Table 5. Comparative ratios for samples from stratigraphic sections at two sites further south in North-West Greenland and from one section and two surface till collections on Ellesmere Island, as well as Holocene control samples from both areas, are included in this table (cf. also Sejrup (1990) for additional amino acid data from Saunders Ø). The site on the Cape Herschel plateau for which a ^{14}C date of 28 900 ± 240 years (TO-1268) was obtained yielded D/L ratios for aspartic acid of 0.215 (UA-1408) and 0.214 (UA-3112) on samples of *Hiatella arctica* fragments (Table 5). The three ratios on individual *Hiatella arctica* fragments from till in Inglefield Land bracket the range of ratios obtained from previously analyzed samples. In fact, UA-3108 (0.173) represents the lowest D/L ratio for aspartic acid yet obtained for either *Hiatella arctica* or *Mya truncata* of pre-Holocene age in the Smith Sound region. Although the aspartic acid ratios cannot be translated into precise ages, and it would be desirable to analyze many more individual

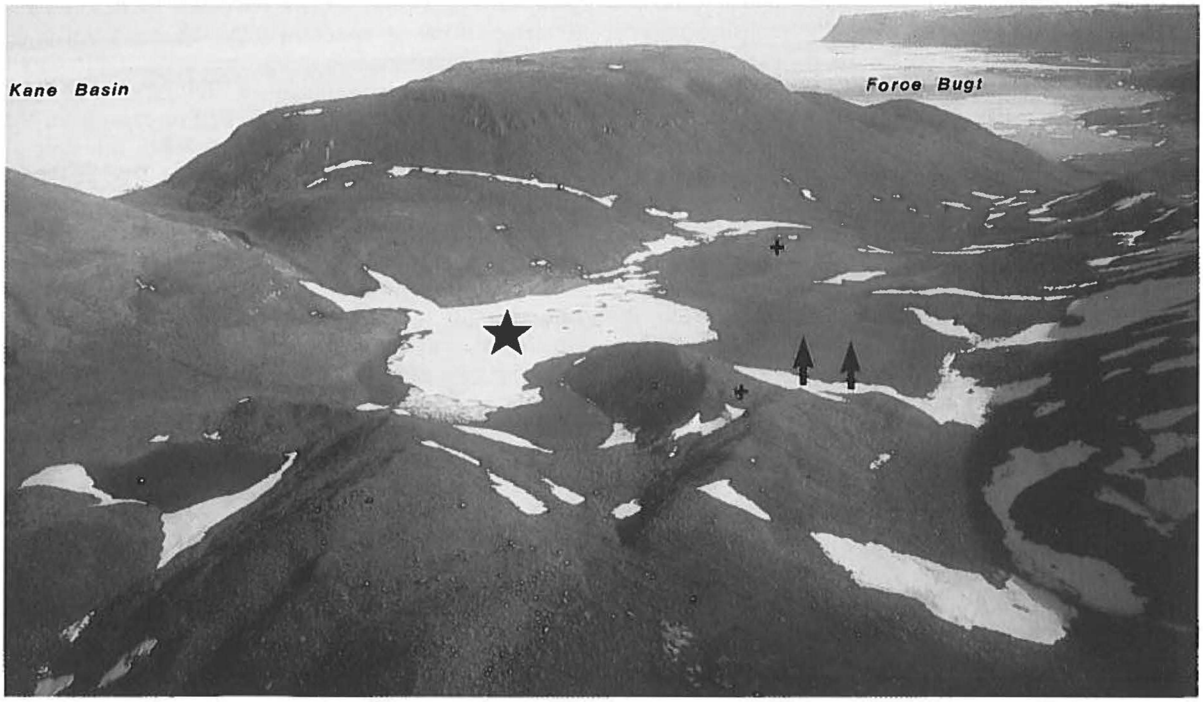

Fig. 5. Oblique aerial photograph looking northeastward across 'Kap Inglefield Sø' to Kane Basin and Force Bugt. The approximate site at which coring was carried out in 1980 is indicated by the black star on the lake ice. The 1984 core was recovered a short distance to the southwest of the 1980 site. The shallow area near the outlet is indicated with black arrows; sites with marine shells in till are marked by a + sign. July 18, 1986. GSC Photograph 204415-U by W. Blake, Jr.

Fig. 6. View southward into the upper end of the northernmost canyon heading at the coast. This canyon joins a second canyon at 'Stromatolite Sø' (Figs. 3 and 4). June 15, 1984. GSC Photograph 205033-F by W. Blake, Jr.

fragments, nevertheless the results obtained so far do not contradict the hypothesis that the enclosing till is of late Wisconsinan age. Quite clearly the surface till from this part of Inglefield Land, and from adjacent Ellesmere Island, contains shells that are younger than those in the till which outcrops just above sea level on Saunders Ø. (Table 5; Sejrup 1990; Houmark-Nielsen *et al.* 1990; Funder & Houmark-Nielsen 1990).

Other evidence for the presence of glacier ice along the coast is found in the vicinity of 'Stromatolite Sø'. This lake now drains northeastward to the sea, and it receives the outflow from an unnamed lake over 1 km in length which is situated 'down-channel' to the southeast (Figs. 3, 4 and 7). Yet both lakes lie near the head of the 10 km-long canyon system which leads to the apex of the huge delta built into the sea at Refuge Harbour. When this delta was being constructed the flow of water throughout the entire length of the channel system in which 'Stromatolite Sø' and the unnamed lake are situated was in the opposite direction, *i.e.*, north to south (and west), and the surface of the terrace along the east side of the unnamed lake is inclined downward in the same direction (Fig. 7). The fact that there is now a drainage divide at approximately 148 m in the main canyon is interpreted as being the result of the continuing deposition of sediment in Holocene time. This deposition occurred after the ice had receded from the canyon entrance at 'Stromatolite Sø', but the flow of water continued from the landward side. The drainage divide is located at the point where the stream from the major tributary canyon (which has by far the largest drainage basin) debouches into the main canyon. In addition, the build-up of talus cones along the steep canyon walls has caused the damming up of several smaller lakes and ponds.

In the case of 'Kap Inglefield Sø' itself, which now drains eastward and northeastward to the sea, the lobe of ice which pushed up this valley blocked the normal drainage. As this lobe receded, for a period of time a lake was dammed between the ice front and the higher ground to the southwest, and the existence of this lake is reflected in the presence of glaciolacustrine sediments in the lower part of the core. Alternatively, the ice-dammed lake may have been held up at its southwest

Fig. 7. View southward at 'Stromatolite Sø' and the head of the canyon leading to the delta at Refuge Harbour. The long lake (large white arrow) beside the terrace now drains toward 'Stromatolite Sø' and then toward the sea in the lower right-hand corner of the photograph. The surface of the terrace (small white arrows) slopes 'down-canyon' away from the viewer. Note the incipient moat at the near end of 'Stromatolite Sø' (black arrow). June 20, 1984. GSC photograph 205033-B by W. Blake, Jr.

Fig. 8. View eastward at the outermost channel incised in the plateau a little over 6 km east of Kap Inglefield. The pond in the foreground is at 309 m a.s.l. (cf. Plate I). June 15, 1984. GSC photograph 205232-A by W. Blake, Jr.

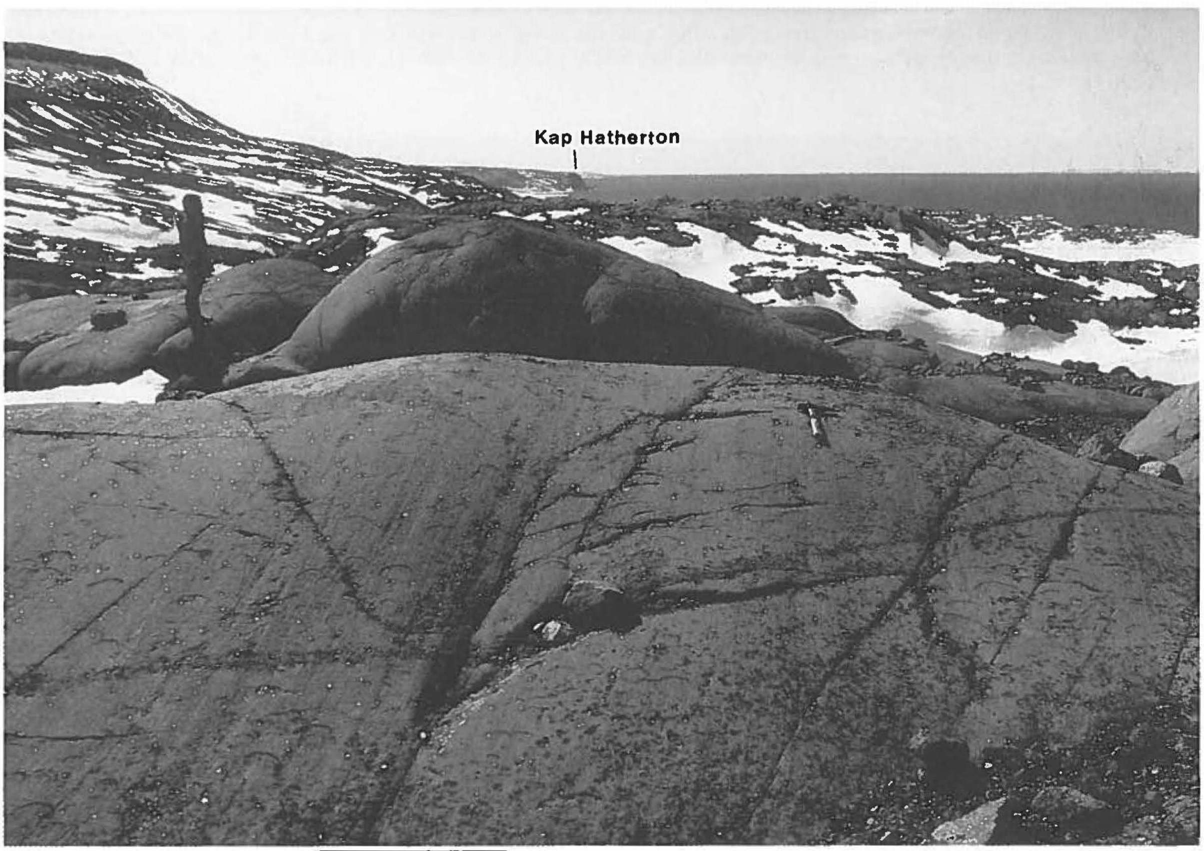

Fig. 9. Striated basement rocks at approximately 160 m a.s.l. on the peninsula leading to Cache Point. Orientation of the striae is NNE-SSW. Kap Hatherton and Littleton Ø (beyond) are visible in the distance. June 11, 1984. GSC photograph 205033-A by W. Blake, Jr.

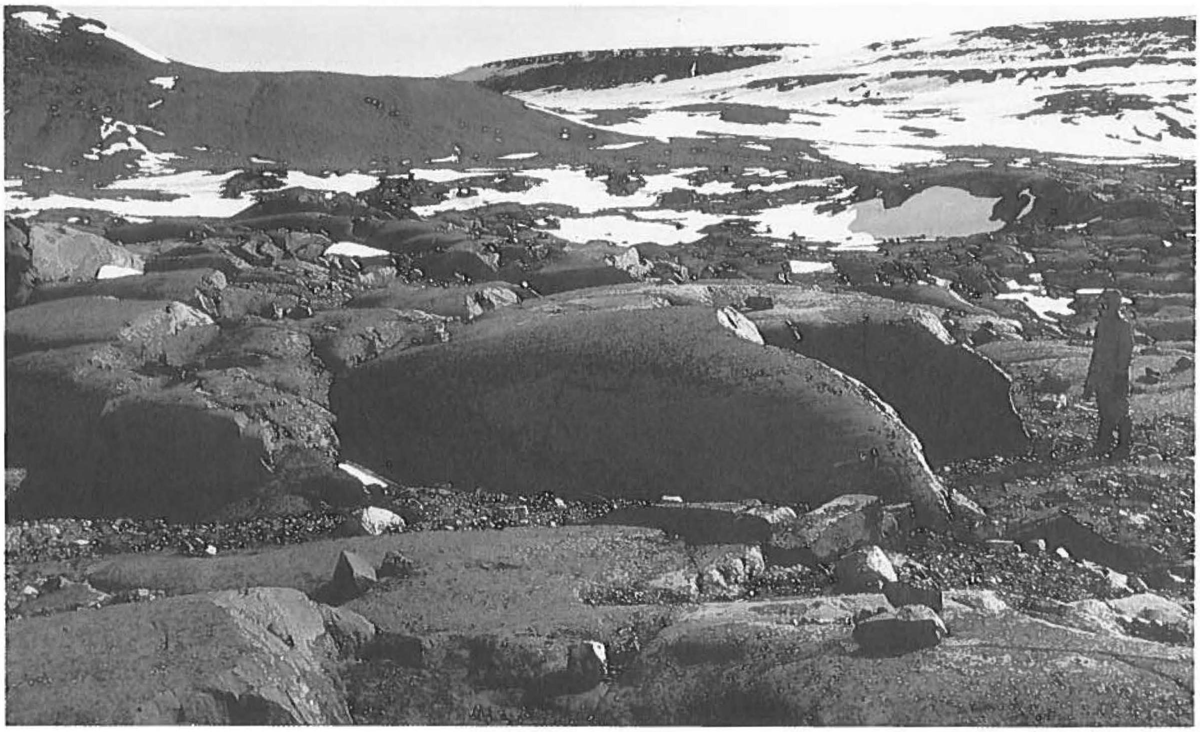

Fig. 10. View southeastward at sculptured bedrock at the same site as Fig. 9. Ice flow here was from the north-northeast toward the south-southwest, roughly parallel with the coast of Smith Sound (cf. Fig. 3). June 11, 1984. GSC photograph 205033-C by W. Blake, Jr.

Fig. 11. Perched boulder (white arrows indicate support rocks) and erratics at the same site, 150 m a.s.l. The helicopter has landed on a flat area of till, in which a few shell fragments were found. June 11, 1984. GSC photograph 205033-H by W. Blake, Jr.

Fig. 12. View inland (southeastward) at a large sandstone erratic on diabase which caps the plateau at ~420 m a.s.l., 4.3 km east of Kap Hatherton (cf. Plate I). Scale is provided by the helicopter in the distance and by the 30 cm-long box in the foreground. June 9, 1984. GSC photograph 1991–049 by W. Blake, Jr.

end by the lobe of ice which pushed inland into the valley now occupied by 'Peninsula Sø' (at 115 m a.s.l., cf. Fig. 3).

The dilemma about the glacial history of Inglefield Land is the same as that which has emerged in many High Arctic areas. As Weidick (1976a, p. 438) has stated succinctly, "...in general the theory of a small expansion of the Inland Ice during the last glacial period (Wisconsin-Weichsel) conflicts with the fact that the late and rapid Holocene glacio-isostatic uplift of the whole of northern Greenland can only be explained as a reaction from the retreat of a young, presumably Wisconsin-Weichsel glaciation over the whole area extending to the outer coasts." Certainly no field evidence supports the position of the 'minimum portrayal limit' of Prest (1984), in which the entire area investigated in this study is indicated as being ice-free in Late Wisconsinan time. Nor does the field evidence provide verification for the series of maps produced by Dyke and Prest (1987), in which the whole of Nares Strait is depicted as being open continuously since 18 000 years ago (as far back in time as the maps show the distribution of glacier ice, land, and water). Four of their maps are reproduced in a review article by Bradley (1990), who apparently accepts the point of view that Nares Strait was open and much of Inglefield Land (including the site of 'Kap Inglefield Sø') was ice-free by 10 000 BP. Finally, to state, as England *et al.* (1981, p. 88) have done, that "...expansive late Wisconsin/Würm ice flowing southward from Kane Basin and Smith Sound is problematic in terms of the limited Holocene emergence presently reported from the Carey Islands..." is to completely ignore the field evidence from Smith Sound. The reconstructions of Reeh (1984, Figs. 3B & 3C), on the other hand, even when the shallow 200 m depth contour is taken as the grounding line (for ice sheet/ice shelf transition), are much more compatible with the observations on ice flow documented in the present report, and this viewpoint is favoured in the recent summary by Funder (1989).

Flora

BENT FREDSKILD & JAN A. JANSSENS

Vascular plants and lichens

BENT FREDSKILD

The flora of Inglefield Land is high arctic, consisting mainly of widespread arctic species found all over Greenland. These plants are, for the most part, alpine and rare farther south, but some are decidedly high arctic species, extending south to Melville Bugt or Nuussuaq-northern Disko on the west coast and Scoresby Sund on the east coast (Fig. 1). A total of 109 species of higher plants are known so far (Bay 1983; in press).

During short stays on July 3, 1984 and July 18, 1986, W. Blake, Jr. collected plant material from the wet area with shallow flowing water at the outlet of 'Kap Inglefield Sø' (Fig. 13), the only place near the lake with a high degree of vegetation cover, including mosses. Collections were also made from rocks and dry slopes with much more open vegetation, especially on the gentle slope at the northeast end of the lake, and on the rocky promontory which extends into the southern end of the lake. Typical species of the mossy vegetation are *Alopecurus alpinus, Arctagrostis latifolia, Eriophorum triste, Salix arctica, Braya purpurascens, Draba adamsii, D. alpina, Ranunculus sulphureus, Melandrium apetalum* and many species of *Saxifraga: cernua, foliolosa, nivalis* and *rivularis* (a new northern limit for the last-named species). *Pleuropogon sabinei* grows at the shore of the lake. Dry sites on till or bedrock are characterized by *Dryas integrifolia, Carex nardina, Poa abbreviata, P. arctica, Saxifraga caespitosa, S. oppositifolia, S. tricuspidata, Draba subcapitata, D. bellii, D. macrocarpa* and *Cassiope tetragona. Salix arctica*, having a wide ecological amplitude, is also common on the drier sites. Species found in a variety of habitats are *Luzula arctica, L. confusa, Papaver radicatum, Saxifraga tenuis, Stellaria crassipes, S. edwardsii, Cerastium arcticum* ssp. *hyperboreum, Potentilla hyparctica, Oxyria digyna*, and *Pedicularis hirsuta*. The list of higher plants thus includes 35 species.

E. S. Hansen of the Botanical Museum, University of Copenhagen, has determined eight species of lichens in these collections: *Physconia muscigena, Thamnolia vermicularis, Cetraria islandica, C. nivalis, Alectoria nigricans, A. ochroleuca, Bryocaulon divergens* and *Lecanora epibryon*.

Bryophytes

JAN A. JANSSENS

Surface samples containing mosses, liverworts, and lichens were collected by W. Blake, Jr. on July 18, 1986. Collections (19) were made from shallow water, in nearby seepage areas (in the sense of non-peat forming systems) and on wet rocks along the outlet stream, as well as in the single inlet channel to the lake (north side). Ten additional collections were made on dry slopes to the southeast and on the bedrock ridge jutting into the southern end of 'Kap Inglefield Sø'. Table 2 lists all 31 species identified from the collections, including a habitat classification. Two additional genera were represented – *Distichium* sp. and *Lophozia* sp. – but the poor preservation of the material did not allow specific identification.

All species listed in Table 2 have been recorded for the Canadian Arctic Islands or for Greenland (Schuster & Damsholt 1974, Brassard 1971, Vitt 1975, and Ireland *et al.* 1987) and are widespread or scattered but locally abundant in circumpolar regions. Nomenclature for the most part follows Anderson *et al.* (1990).

Table 2. Bryophytes from the environs of 'Kap Inglefield Sø'[1].

Taxon	Stream & Seepage	Dry Upland
Aneura pinguis (L.) Dum.	●	
Aulacomnium acuminatum (Lindb.) Kindb.	●	
Aulacomnium turgidum (Wahlenb.) Schwaegr.	●	
Bryum cyclophyllum (Schwaegr.) B.S.G.	●	
Bryum neodamense Itzig.	●	
Bryum pseudotriquetrum (Hedw.) G.M.S.	●	
Calliergon giganteum (Schimp.) Kindb.	●	
Cinclidium arcticum (B.S.G.) Schimp.	●	
Cyrtomnium hymenophyllum (B.S.G.) Kop.	●	
Dicranum elongatum Schleich.		●
Dicranum groenlandicum Brid.		●
Distichium sp.	●	●
Ditrichum flexicaule (Schwaegr.) Hampe	●	●
Drepanocladus aduncus (Hedw.) Warnst.	●	
Drepanocladus brevifolius (Lindb.) Warnst.	●	
Hylocomium splendens (Hedw.) B.S.G.		●
Hypnum revolutum (Mitt.) Lindb.		●
Hypnum vaucheri Lesq.		●
Isopterygiopsis pulchella (Hedw.) Iwats.	●	
Limprichtia revolvens (Sw.) Loeske	●	
Lophozia sp.		●
Meesia triquetra (Richt.) Ångstr.	●	
Mnium ambiguum H. Müll.		●
Orthothecium chryseum (Schwaegr.) B.S.G.	●	
Orthotrichum speciosum Nees		●
Philonotis fontana var. *pumila* Brid.	●	
Pohlia cruda (Hedw.) Lindb.		●
Pohlia sp.		●
Polytrichastrum alpinum (Hedw.) Smith	●	
Racomitrium canescens (Hedw.) Brid.		●
Racomitrium lanuginosum (Hedw.) Brid.		●
Sanionia uncinata (Hedw.) Loeske	●	●
Timmia austriaca Hedw.	●	●
Tortula ruralis (Hedw.) G.M.S.		●

[1]Voucher specimens in Jan A. Janssens' herbarium.

Present limnology

JOHN P. SMOL

As with most lakes in the region, 'Kap Inglefield Sø' is ultra-oligotrophic. The lake is further characterized by extended periods of ice cover. For example, when the site was visited on June 8, 1984, the lake was completely ice-covered. By July 3rd, when the lake was re-visited, only about 20% of the lake surface was clear of ice. Not surprisingly, it was the shallow, southeastern end of the lake that had thawed. The lake was next visited two years later on July 18, 1986. Even at this late date, the lake still supported a large central ice float that covered about 60% of the lake's surface (cf. Fig. 5). Under present climatic conditions some ice persists over the deepest part of the lake for much of each summer. For instance, on July 7, 1959, when the aerial photographs were taken (cf. Figs. 3 and 4; Plate I), although less than half the lake was covered, ice was present in the area where coring was carried out in 1980 and 1984.

A small creek flows into the lake from the col on the plateau to the north, otherwise the only inflow is from slopewash, especially along the south side (Figs. 5, 13 and 14). A relatively broad (10 m) but shallow (approximately 20 cm deep on July 3, 1984) outlet drains the lake. Although it was not possible to survey the entire lake basin, it appeared that much of the lake floor in the shallow, open water parts is covered by cobble-sized rocks, with a few aquatic mosses. A green alga (*Rhizoclonium* sp.; personal communication to B. Fredskild from T. Christensen, February 1990) is present on the stony lake bottom at the shallow end near the outlet.

Because the lake's drainage basin contains a small amount of calcareous till, it is not surprising that field pH measurements were somewhat alkaline (Table 3). Specific conductivities were, however, relatively low for this area. The somewhat lower conductivity recorded in the 1984 field sampling may reflect the fact that much of the water in the shallows at this early stage of the lake's thaw was more heavily influenced by spring snow and ice melt.

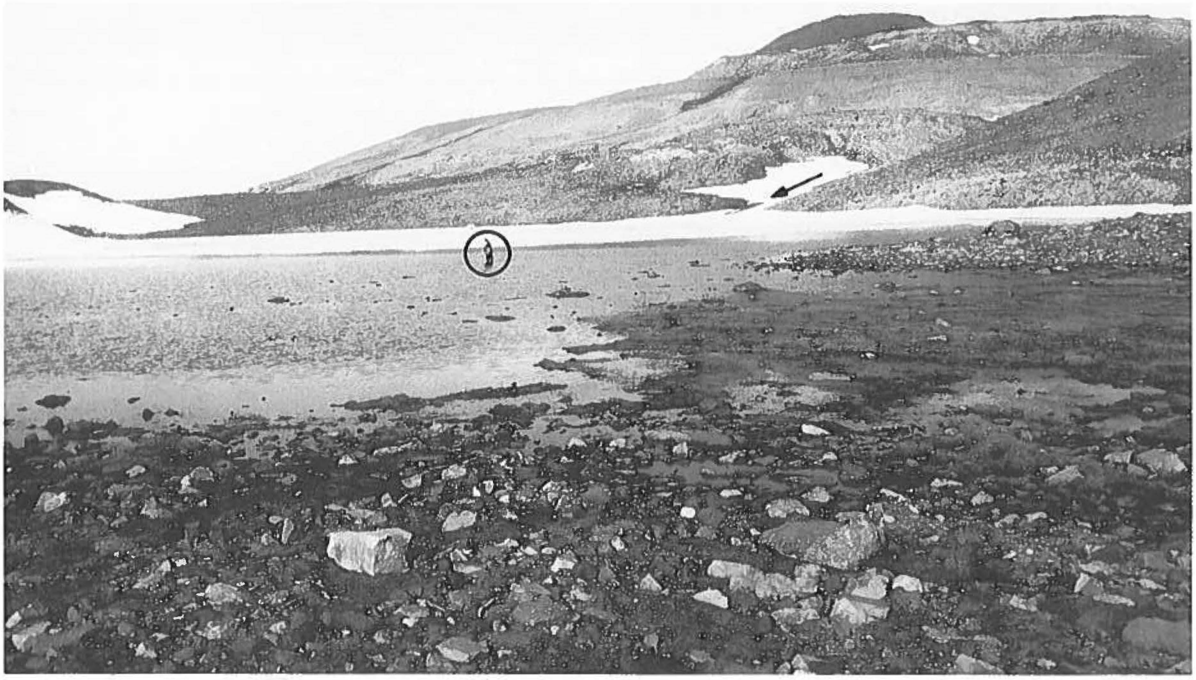

Fig. 13. View northwestward across 'Kap Inglefield Sø' from the south side of the outlet stream. Note the relatively abundant vegetation in the shallow water. The main inflow into the lake is via the snow-filled gully on the opposite side of the lake (arrow). M. S. V. Douglas (circled) is collecting in the shallow, open water area on July 18, 1986. GSC photograph 205033-D by W. Blake, Jr.

Fig. 14. View northeastward over the shallow end of 'Kap Inglefield Sø' to the outlet (black arrows), and with the sea (Force Bugt) in the distance. Note the extent of ice cover on the lake. The helicopter (circled) provides scale. Marine shells occur on the slope around the helicopter and on the till-mantled bedrock ridge in the foreground. July 18, 1986. GSC photograph 204963-G by W. Blake, Jr.

Water samples for detailed major ions analyses were also collected during the 1984 and 1986 field seasons, and the results are presented in Table 4. In general, these data also reflect the relatively dilute but slightly alkaline nature of these waters.

A 50 μm mesh plankton net was pulled through the open moat region on each sampling date. On July 3, 1984 the only species of zooplankton recovered from the net samples was the phyllopod *Branchionecta palludosa*. However, on July 18, 1986 the more open water conditions supported a much richer fauna, including some *Daphnia pulex, Chydorus* cf. *sphaericus*, chironomid larvae, copepods, and ostracods, as well as more *B. palludosa*.

Table 3. Field measurements of water temperature, pH and specific conductivity, 'Kap Inglefield Sø'.

Date	Temperature (°C)[1]	pH	Specific Conductivity (μS/cm)[2]
June 4, 1984 (A)	0.5	–	183
(B)	1.7	–	317
July 3, 1984	5	7.4	54
July 18, 1986	6	7.4	111

[1]Two temperature readings were taken as soon as a hole was drilled through the ice, preparatory to coring on June 4, 1984. The readings were taken using the temperature/salinity probe on a YSI Model 33 S-C-T Meter. Readings on line (A) were immediately under the ice (147 cm thick) at 150 cm below the ice surface. Readings on line (B) were at 350 cm below the ice surface (5 cm above the bottom). The temperature readings on July 3, 1984 and July 18, 1986 were taken by hand-held thermometer in the littoral zone of the lake.

[2]All specific conductivity readings were taken with the YSI Meter.

Table 4. Major ion water chemistry analyses[1].

Variable	July 3, 1984	July 18, 1986
Ca	4.8	7.0
Mg	2.7	4.6
Na	3.2	3.07
K	0.38	0.34
SO_4	2.5	0.9
Cl	6.2	4.66
SiO_2	0.78	1.2
F	0.15	not determined
Alk ($CaCO_3$)	15	31

[1]Provided by W. Gummer, Canada Centre for Inland Waters, Burlington, Ontario. All concentrations are in mg/L.

Coring and sediments

WESTON BLAKE, JR.

The first attempt at coring 'Kap Inglefield Sø' on June 8th, 1980 was made in the eastern part of the lake, not far from the outlet. Only a few centimetres of water were present under 240 cm of ice, and a number of filaments of the green alga *Rhizoclonium* sp., as noted above but no cores, were recovered from the stony lake bottom. Later visits revealed that it is this part of 'Kap Inglefield Sø' that becomes ice-free earliest, because it is so shallow (cf. Figs. 5, 13 & 14). From the volume of *Rhizoclonium* sp. recovered on the auger, and many of the clumps exceeded 30 cm in length, it would appear that a luxuriant algal growth carpets the bottom of this part of the lake.

The next coring attempt was made later on June 8th to the northwest, roughly halfway between the bedrock peninsula that juts out into the lake and the opposite shore (Fig. 5). At this site 25 cm of snow and 165 cm of ice were present above 3.95 m of water, and a 106.5 cm-long core was recovered, using a modified Livingstone corer (6.7 cm inside diameter). Details of lake-coring procedures and equipment are given in Blake (1981a). The 1980 core was used for most of the analyses reported in this paper, including pollen, diatoms, Cladocera, mosses, grain size and organic carbon content, as well as for all but one of the radiocarbon age determinations (see below). One centimetre-thick increments of sediment were extracted every 5 cm, except at the top of the core, where samples were taken at 2 to 3 cm as well as at 5 to 6 cm depth. Also, at the base of the organic sequence, samples were taken at 45 to 46, 48 to 49, 50 to 51, 52 to 53 and 55 to 56 cm. On the basis of a physical examination of the core, as well as the determination of organic carbon content, the ^{14}C sample to date the base of the organic sequence was extracted from a depth of 45 to 49 cm. Below this level there was a striking decrease in organic carbon content (cf. Table 6). At first, a cursory examination of the core through the transparent plastic coring tube had indicated the presence of a moss-rich layer at what was believed to be the base of the organic sequence, but this material turned out to have been dragged downward during the coring process. The moss fastened around a particularly thick clay-rich layer (dry colour, pinkish gray: 7.5YR 6/2 on the Munsell scale; Munsell Color Co., Inc. 1954) at 58 to 60.5 cm depth. The other striking decrease in organic carbon content (to 5.7%) was at the top of the core, at 2 to 3 cm depth. This decrease coincided with an increase in abundance of inorganic detritus, including the presence of several pebbles >4 mm in diameter. The pebbles and sand may have been frozen onto the bottom of the lake ice at the shore, then dropped as this ice drifted around the lake and melted during the following summer.

The core can be divided conveniently into four stratigraphic units, of which the upper two represent the organic sediments and the lower two, the inorganic. The depths given are in centimetres below the lake bottom:

0–36 cm — Organic sediment, watery at the top but otherwise jelly-like gyttja with varying amounts of moss stems and *Nostoc* balls (in general where *Nostoc* is more abundant, there is less moss; and vice-versa). Pebbles were observed at 2–3, 5–6, and 35–36 cm depth, as well as sand at 23–24 and 37–38 cm depth; *Dryas* leaves at 15–16, 20–21 and 25–26 cm. Dry colour at 2–3 cm: 2.5Y 4/4 – olive brown. Samples for ^{14}C at 3–7, 17–21 and 30–36 cm (Fig. 15).

36–49 cm — Organic sediment, in general with more moss than the uppermost unit, and less *Nostoc* (except at 42.5–43.5 cm). Dry colour at 40–41 cm: 2.5Y 5/2 – grayish brown; at 45–46 cm: 2.5Y 6/2 – light brownish gray; and at 48–49 cm: 10YR 6/3 – pale brown. Base of organic sequence at 49 cm. Sample for ^{14}C at 45–49 cm (Fig. 15).

49–60.5 — Layers of silt- and clay-rich sediment (all contain 5% or less sand) alternating with sand-rich layers, e.g. at 52–53 cm (Figs. 15 and 16). Dry colour at 50–51 cm: 7.5YR 6/2 – pinkish gray; 52–53 cm: 10YR 6/2 – light brownish gray; and 58–59 cm: 5YR 6/2 – pinkish gray. Sediment at 50–51 cm and 52–53 cm exhibits a steady slow reaction with 7% HCl.

60.5–106.5 cm — Laminated sediment, dominantly sand, but with thin (1–2 mm) layers with more clay, such as at 89–91 cm (Fig. 15). The percentage of sand in most horizons ranges from 54 to 78% (Fig. 15). Dry colour at 61–62, 73–74, 83–84 and 89–91 cm is 7.5YR 7/2 – pinkish gray; at 95–96 cm: 5YR 5/3 – reddish brown; and at 100–106.5 cm: 7.5YR 6/2 – pinkish gray.

The laminated nature of the core below 49 cm (Fig. 15) suggests that this body of sediment was deposited in an ice-dammed lake. This lake would have been held up by the lobe of ice which pushed inland from Kane Basin, as shown by the presence of shells in the surface till. The effect of this lobe, as it later receded downvalley to the east, was to block the outlet of the lake. The saddle on the ridge at the west end of the lake is several metres above the present level of 'Kap Inglefield Sø', thus the

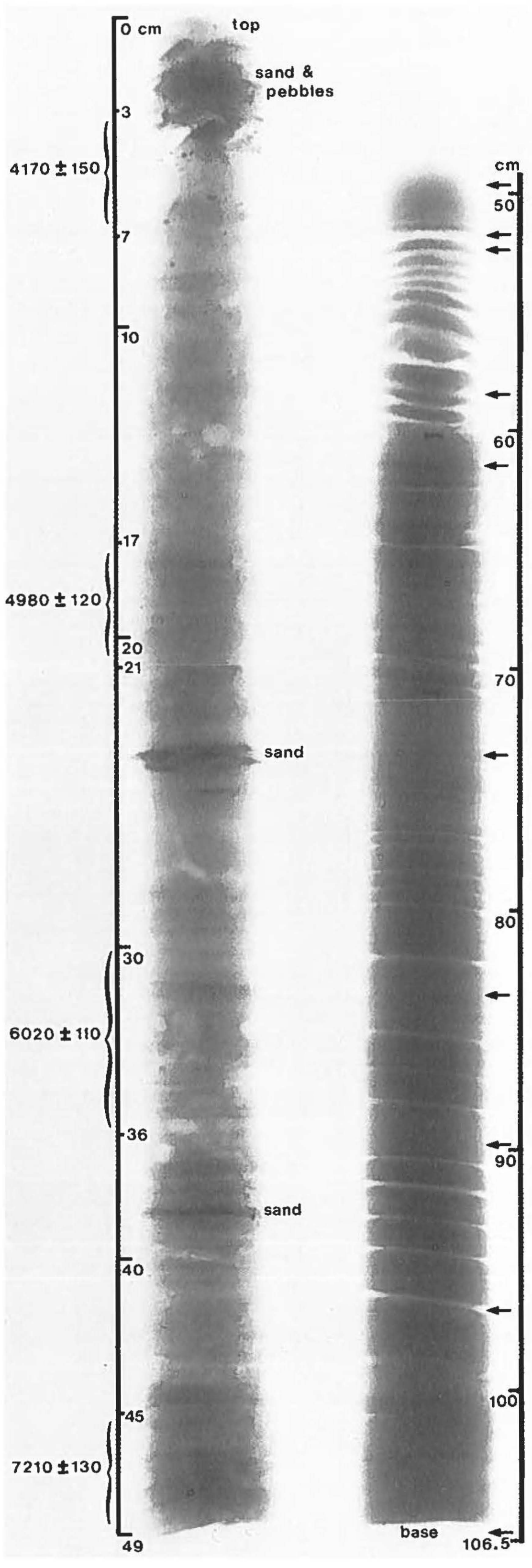

Fig. 15. X-ray of Core 80–18 from 'Kap Inglefield Sø'. The vertical scales differ because the upper organic part of the core (on the left) underwent considerable settling between September 1980, when the X-rays were taken, and October 1983, when sub-sampling was carried out. The three wedges of sand in the upper part of the core correspond to the three main sand 'peaks' plotted in the pollen diagram (Plate II). Increments used for radiocarbon dating are indicated along the left-hand side of the diagram; increments from which sediment was extracted for grain size analysis are indicated by arrows along the right-hand side (cf. Fig. 16). The lowermost sample analyzed, at 106–106.5 cm depth, does not show on the X-ray because it extended beyond the end of the coring tube and was bagged separately at the time of collection.

ice-dammed lake was deeper than the present lake by *at least* this amount. However, the lobe of ice that pushed inland via the valley in which 'Peninsula Sø' lies (Fig. 3; Plate I) would have dammed the drainage from the series of ponds and lakes west of 'Kap Inglefield Sø' (the drainage divide is formed by the ridge at the west end of the lake). Assuming that these two lobes receded in synchronous fashion an ice-dammed lake would have filled the valley between 'Kap Inglefield Sø' and 'Peninsula Sø' for an unspecified interval of time, and the laminated sediments recovered by coring may have been deposited in this larger water body. Laminated sediments such as those in 'Kap Inglefield Sø' have not been recovered from any of the lakes cored on the Ellesmere Island side of Smith Sound, but none of the latter were in topographic situations comparable to that of 'Kap Inglefield Sø'.

Sand: silt: clay ratios for ten increments from the lower, inorganic part of Core 80–18 are plotted on a triangular diagram (Fig. 16), and the locations of the samples in the core are shown in Fig. 15. The striking changes in grain size between silt- and clay-rich layers such as those at 49–50, 51–52, and 58–59 cm and the thicker, sand-rich layers are readily apparent. The fact that a sample such as the clay-silt band at 96.5 to 97.0 cm did not fall into the lower group may be in part because it was difficult to extract sediment from such a thin band, and some of the adjacent sand-rich sediment was probably included.

In the top half of core the influx of sand at approximately 38 cm, 24 cm, and in the top 3 cm of the core is shown in Fig. 15 and in Plate II. In addition, Fredskild recorded the presence of some sand in nearly every increment that he examined for pollen (Plate II).

On June 4th, 1984, using a corer newly constructed by R.J. Thibedeau (also of 6.7 cm inner diameter), a second core was raised, close to the 1980 coring site. On this occasion 30 to 40 cm of snow was present above 147 cm of ice, and the water depth was 3.55 m. Core 84–30 measured 114 cm in length when it was examined in the laboratory in October 1985, but considerable settling had occurred in the time since the core was collected. This core contains a much longer increment of coarse sand (gravel in places) than did the original core, and this coarse sand is characterized by numerous brightly coloured fragments derived from the Rensselaer Bugt Formation. The till-like sediment at the base of the core is pinkish gray (5YR 6/2 on the Munsell scale), and it exhibits a weak reaction with HCl. The 1984 core was used for detailed sampling (17 slices, all except one only 2 mm thick) of the upper 7.5 cm, and then dating by accelerator mass spectrometry (AMS), in order to define more precisely the time that a change in the lake's ice cover occurred (see discussion under the chapter on pollen by B. Fredskild).

The surface till samples collected in the environs of 'Kap Inglefield Sø', and as far afield as Kap Alexander and inland from Rensselaer Bugt, show considerable variability in grain size composition (Fig. 17). The variability is not surprising in view of the presence of a wide range of bedrock types in the area. All of the samples are from sites above the limit of Holocene marine submergence. The finer nature of the material in the till-covered ridge at the northwest end of 'Stromatolite Sø' may be because silt from an ice-dammed lake was incorporated into the till as the ice margin oscillated at the entrance to one of the major canyons. It is of interest to note that the samples from the base of the core in Kane Basin (Station 32), to the north-northeast of Kap Inglefield, fall in the middle range of the samples

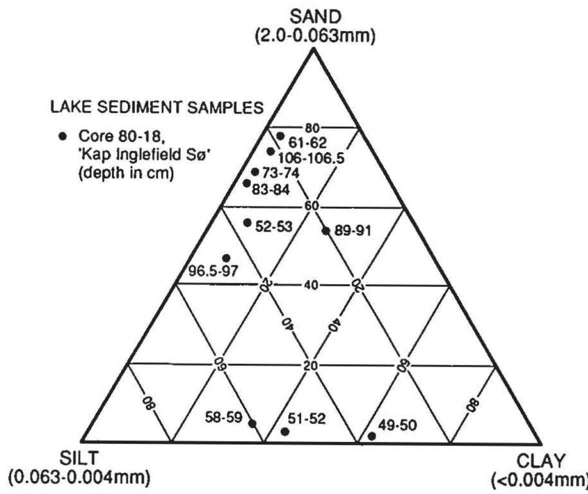

Fig. 16. Triangular diagram showing sand: silt: clay ratios for 10 samples from the lower, inorganic part of Core 80–18, 'Kap Inglefield Sø' (cf. Fig. 15).

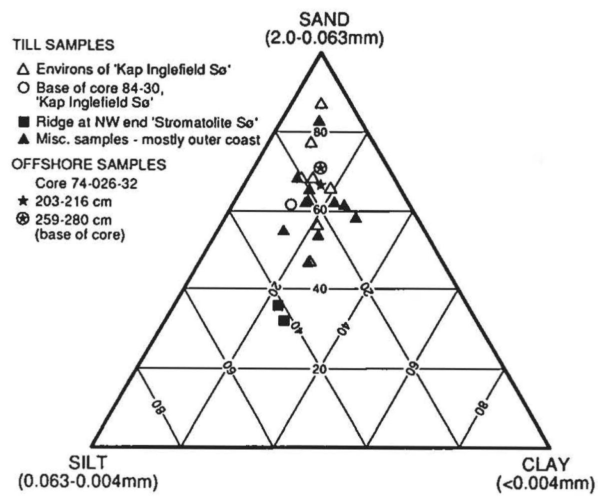

Fig. 17. Triangular diagram showing sand: silt: clay ratios for till samples collected in southern Inglefield Land, including the basal sediment in Core 84–30 from 'Kap Inglefield Sø' as well as from Core HU-74–026-32, southeastern Kane Basin (cf. Fig. 1).

plotted in Fig. 17. The material from Unit 1 (~200 to 250 cm depth in the core), the unit from which the samples subjected to grain size analysis were taken, has been characterized by Marentette (1988, p. 21) as "...unfossiliferous, poorly sorted, pebbly sand. The pebbles in Unit 1 are commonly striated." The material in this unit, in terms of grain size distribution, carbonate content (17–18%) and the lack of fossils, corresponds most closely to Greenland Till (Till 2) as defined by Kravitz (1982). Station 32 is located close to the southern boundary of the area sampled and mapped by Kravitz, but the surface sediment nearby is dominated by "water-transported sediment"; *i.e.*, the "mud with minor pebbles and sand" of Marentette's (1988, pp. 29, 39) Unit 3. Thus the core from this site appears to represent a succession from till, through ice-rafted sediments (from which foraminifera were extracted for dating = Unit 2) to water-laid sediments. It seems reasonable to correlate this till with the single till overlying striated bedrock along that part of the coast of Inglefield Land covered by the present report.

Radiocarbon dating

WESTON BLAKE JR.

The age of the basal 4 cm of organic material in the 1980 core from 'Kap Inglefield Sø' is 7210 ± 130 years (GSC-3732; Table 7). This material occurred at a depth of 45 to 49 cm. In addition to this date three other conventional age determinations were carried out on increments extracted from higher in the core. The basal date, as well as two of the other dates, help to define the age of the pollen zone boundaries (cf. Plate II). In each case an increment of 4 to 6 cm was used, a size necessitated because the organic carbon content of most of the core above 46 cm depth was only 10% to 11%, as determined on a LECO IR12 Carbon Determinator (Table 6). Between 50 cm and the base of the core at 106.5 cm, the organic carbon content was less than 1%. All samples for dating, both by conventional means (proportional counter) and AMS, were extracted from 'windows' cut in the plastic core tubes; *i.e.*, the cores were not extruded. Within each 'window' the outermost 2 to 5 mm of core material was scraped off with a stainless steel spatula. This was done to eliminate the possibility that material (especially mosses) dragged down during the coring procedure could become incorporated in any sample used for dating.

With regard to the calculation of sedimentation rates, discussed below, it should be emphasized that the ^{14}C dates reported in Table 7 and plotted in the chapter on pollen analysis (Fig. 18) are conventional (uncalibrated) dates, as reported by the laboratories. However, the sedimentation rates shown in the same figure, are calculated from calibrated dates, using calibration tables in Clark (1975). R. P. Beukens (personal communication, February 1991) has devised a calibration program based on data in six of the papers in Radiocarbon, vol 28,2B (1986) (as well as other data), and has calibrated each of the five dates from 'Kap Inglefield Sø'. The cal BC ages have been converted to cal BP by following Stuiver & Pearson (1986), where cal BP = 1949 + cal BC. (cf. also Stuiver & Reimer 1986). The results demonstrate that the use of calibrated dates is not simple. The most extreme case is that for the uppermost sample in Core 80–18, 4170 ± 150 years (GSC-3857). For this radiocarbon date there are five different intersections with the dendro calibration curve (100% probability) at ages ranging from 2872 to 2703 cal BC. At the 68% confidence interval, all five solutions fall in the range of 2919 to 2573 cal BC (4868 to 4522 cal BP). In the case of the date on the basal organic sediment, 7210 ± 130 years (GSC-3732), two solutions at the 68% confidence interval fall in the range of 6172 to 5967 cal BC (8121 to 7916 cal BP). Because each of the dated samples from Core 80–18 represents at least a 4 cm sediment increment (6 cm in one case), *i.e.*, sediment deposited over a significant period of time (the total organic sequence is only 49 cm), further discussion of calibrated dates does not seem warranted, although the ranges are given in Table 7. Furthermore, there is also the danger that such dates on bulk sediment samples err on the old side (any increment potentially may contain carbon that is older than it should be for the level at which it occurs – *i.e.*, from the washing in of older detritus, etc.). At best dates on this type of material represent mean values.

One age determination via accelerator mass spectrometry (AMS) was carried out on the Core 84–30, to determine more precisely the time at which the spectacular decrease in *Scenedesmus* occurred, concurrently with an equally spectacular increase in *Pediastrum*. In this case, seventeen 2 mm-thick increments were examined by B. Fredskild, between the sediment surface (0.0 to 0.2 cm, after removal of 3 cm of watery slurry in the field) and the 7.6 cm-level, in order to determine exactly where the change in dominant species of alga occurred. A 2 mm-thick slice at 4.4 to 4.6 cm depth, weighing only 261 mg, was sufficient for an age determination using the AMS technique, and the result was 4050 ± 110 years (TO-329; Table 7). For this age there is one intersection with the dendro calibration curve (100% probability) at an age of 2583 cal BC (4532 cal BP). At the 68% confidence interval the range is 2701 to 2466 cal BC (4650 to 4415 cal BP). If all solutions with a probability of greater than 50% are included, the range of possible calibrated ages is even greater.

Apart from the dates on the cores from 'Kap Inglefield Sø', only a few other radiocarbon age determinations were available from Inglefield Land prior to 1980: 1) Four on marine bivalves, plus one on organic detritus in deltaic sediments, from Rensselaer Bugt to Dallas Bugt, and all of Holocene age (Nichols 1969); 2) three from the Rensselaer Bugt hinterland on organic

Table 5. D/L ratios for aspartic acid on selected shell samples, North-West Greenland and east-central Ellesmere Island.

Locality	Field sample no.	Elev. m	Species [1]	Sample weight g subm.	No. of valves / fragments subm.	Lab. no.[2]	D/L ratio, aspartic acid[3]	Reservoir corrected ^{14}C age, on associated shells[4]	Lab. no.	Species
GREENLAND										
'Kap Inglefield Sø'[5]	84–170	160	*Hiatella arctica*	0.7	1	UA-3107	0.225			
	84–170	160	*Hiatella arctica*	0.6	1	UA-3114	0.216			
'Peninsula Sø'[5]	84–181	130	*Hiatella arctica*	0.6	1	UA-3108	0.173			
Refuge Harbour	84–99	13	*Hiatella arctica*	0.5	1	UA-3113	0.064	6480 ± 70	GSC-3883	*Balanus balanus*
Carey Øer	76–102	20	*Hiatella arctica*	11.6	8	UA-1401	0.091	7900 ± 70	GSC-2372	*Hiatella arctica*
(Isbjørneø)	76–50	2–3	*Mya truncata*	7.0	4	UA-1703	0.179	38 300 ± 1100	GSC-2367	*Chlamys islandica*
	76–50	2–3	*Mya truncata*	11.0	3	UA-1399	0.201			
	76–52	2–3	*Hiatella arctica*	11.9	3	UA-1400	0.226			
Saunders Ø	74–04[6]	< 2	*Mya truncata*	16.5	2	UA-1394	0.026			
	74–06[7]	13.0	*Mya truncata*	6.4	6	UA-1701	0.065	8030 ± 80	GSC-2079	*Mya truncata*[7]
	74–19	16.5	*Mya truncata*	7.0	1	UA-1702	0.185	>30 000	GSC-2747	*Mya truncata*
	74–20[8]	2–3	*Mya truncata*	13.1	16	UA-1398	0.292			
ELLESMERE ISLAND										
SW Buchanan Bay	81–94	50	*Hiatella arctica*	10.3	8	UA-1396	0.119	7000 ± 70	GSC-3288	*Mya truncata*
Leffert Glacier[5]	81–205	165–180	*Mya truncata*	11.5	5	UA-1402	0.117	2880 ± 70	GSC-3793	*Mya truncata*
Cape Herschel[5]	81–197	230	*Hiatella arctica*	10.0	33	UA-1408	0.215	28 900 ± 240[9]	TO-1268	*Mya truncata*
	83–346	230	*Hiatella arctica*	1.2	1	UA-3112	0.214			
Cadogan Inlet	86–107	115	*Hiatella arctica*	1.8	1	UA-3109	0.200	{ 31 600 ± 1120	GSC-4310	*Hiatella arctica*
	86–107	115	*Mya truncata*	1.7	1	UA-3115	0.184	{ 38 540 ± 460[9]	TO-969	*Chlamys islandica*

[1] Pelecypod and cirriped species determined by W. Blake, Jr.
[2] Laboratory designations: UA = Dept. of Geology, University of Alberta, GSC = Geological Survey of Canada, TO = IsoTrace Laboratory, University of Toronto.
[3] Amino acid ratios based on two runs for all samples in the first two batches, three runs for the second two batches. Some of the variation in ratios may be caused by the fact that the identical part of the shell was not used in each case.
[4] See footnotes to Tables 7 and 8.
[5] Shells from surface till samples. All other shells were collected from sections at the coast or, for 81–94, 84–99 and 86–107, along a stream cuts.
[6] Sample collected along the present-day beach.
[7] Sejrup (1990) reported alle: Ile ratios (for the total acid hydrolysate) of 0.013 and 0.014 for *Mya truncata* shells from a nearby section on Saunders Ø; *M. truncata* and *Hiatella arctica* shells from the same collection were dated at 8200 ± 85 BP (K-4780; Mörner and Funder 1990).
[8] An unidentified whale bone (mandible?) from a sand unit overlying the till from which the shells used for UA-1398 were derived had a ^{14}C age of >39 000 years (GSC-2257; Blake 1987a).
[9] Recalculated ages corrected for a total system background of 0.077 ± 0.005 pMC. All Iso Trace results have been corrected for natural and sputtering fractionation to a base of $\delta^{13}C$ = -25‰. Then a reservoir correction of 410 years has been applied (personal communication from R.P. Beukens, July 1991).

matter in soils, two of late Holocene age and one of late Pleistocene age (Tedrow 1970; Blake 1974); and 3) six from a peat monolith on the north side of Foulke Fjord, the lowermost dated horizon of which was less than 2000 years old (Malaurie et al. 1972; Delibrias et al. 1972). New age determinations on Holocene marine shells which are pertinent to the present investigation are listed in Table 8 and discussed below.

Date TO-770, 7590 ± 120 years, is an AMS age determination on benthic foraminifera from a piston core collected on *C. S. S. Hudson* Cruise 74–026 in 377 m of water at 78°39.9'N, 72°07.5'W (Fig. 2), approximately 14 km north of Kap Inglefield. A 3 cm-thick increment of the core, at 179 to 182 cm depth and in the middle of a poorly sorted unit of pebbly sand and mud, was used for dating. The underlying unit is made up of a poorly sorted sand, containing striated pebbles, and it is devoid of fossils (Marentette 1988). Although, as indicated earlier, the precise origin of the basal material is uncertain, a correlation with Kravitz's (1982) Greenland Till seems likely. The dated horizon provides a minimum age for the onset of marine sedimentation at this locality, and it corresponds quite closely to the age of the highest dated sample from the raised beaches near 'Kap Inglefield Sø' (TO-923, discussed below).

An age determination of 6480 ± 70 years (GSC-3883) shows that sedimentation in the huge delta northeast of Refuge Harbour (Fig. 3; Plate I) continued well into Holocene time, presumably because meltwater continued to flow into the canyon system from the landward side long after the 'Smith Sound Ice Stream' had receded from the coast. The date was carried out on intact barnacles (*Balanus balanus*) on cobbles and boulders in sand and gravel foreset beds some 13 m a.s.l. (altimeter determination) and several tens of metres north of the delta front (the surface of the delta in the vicinity of the collection site is at 85 m).

At the eastern end of the valley east of 'Kap Inglefield Sø', and north of 'Stromatolite Sø', an area of raised beaches has been dissected by the combined outlet stream which derives from the two lakes (Plate I; Fig. 3). This is the same flight of beaches shown in an aerial view by Nichols (1969, Fig. 7). Marine shell fragments were extremely scarce in the coarse sand and gravel deposits at the stream-cut exposure examined, which was close to the upper limit of beaches. However, a single fragment of *Mya truncata*, at an elevation of approximately 80 m, was found to be 7780 ± 70 years old (TO-923). This fragment was collected one metre below the surface of the beaches and approximately 3 m below the highest visible beaches at 83 m a.s.l. (altimeter determinations). The limit of Holocene marine submergence may be somewhat higher, however, as the highest beaches were overrun by solifluction lobes. Nichols (1969) recorded the highest beaches here of any site in Inglefield Land; his value of 285 feet corresponds to 87 m. The 4 m discrepancy between his result and the one reported here may be because the determinations were made at different sites along the beaches or because a different point was selected for sea level (my determinations are based on the surface of the ice foot, which corresponds, approximately, to high tide level). Some 12 km farther south, along the coast between Refuge Harbour and Kap Hatherton, photogrammetric measurements of beach elevations gave values of close to 90 m above the ocean surface (Plate I and Fig. 3). Unfortunately, no age determinations for the marine limit are available for this area.

Table 6. Carbon content in Core 80–18 from 'Kap Inglefield Sø'.

Sample Depth (cm)	Untreated sample = total C(%)[1]	Treated sample = organic C(%)[1]	Inorganic carbon
2–3	6.3	5.7	0.6
5–6	11.4	10.7	0.7
10–11	11.5	10.1	1.4
15–16	11.1	10.2	0.9
20–21	7.2	7.2	0.0
25–26	10.6	10.6	0.0
30–31	11.4	10.5	0.9
35–36	9.2	7.6	1.6
40–41	11.1	11.1	0.0
45–46	12.1	11.3	0.8
48–49[2]	6.2	6.2	0.0
50–51	1.1	0.3	0.8
52–53	1.2	0.1	1.1
55–56	1.3	0.3	1.0
60–61	1.7	0.2	1.6
65–66	1.6	0.1	1.5
70–71	1.5	<1	1.5
75–76	1.6	<1	1.6
80–81	1.8	<1	1.8
85–86	1.3	<1	1.2
90–91	1.2	<1	1.2
95–96	1.6	0.3	1.3
100–101	1.2	<1	1.1
106–106.5	1.2	0.2	1.0
below 106.5[3]	1.6	0.1	1.5

[1]All determinations represent at least two runs for total C (dried sample) and two runs for organic C (sample treated with concentrated HCl and then dried on a hotplate at ~110°C for approximately 90 minutes) on a LECO IR12 Carbon Determinator.
[2]Base of the organic sequence is at 49 cm.
[3]This material, which extended approximately 5 cm beyond the end of the coring tube, was bagged separately.

Based on the single age determination from the beaches north of 'Stromatolite Sø', there appears to have been a similar amount of rebound here as at Cape Herschel, on the west side of Smith Sound, in the same amount of time (Blake, in press). On the north side of Cape Herschel two samples of shells in silt from 82.0 m (as determined by instrumental leveling) gave 8190 ± 110 years (GSC-2913; *Macoma calcarea*) and 8150 ± 80 years (GSC-3089; both in Blake 1987a), but they relate to a sea level at approximately 87.5 to 90.0 m. Also, at a second site a single *Hiatella arctica* valve in a beach remnant at 87.5 m (Holocene marine limit at 90 m, as determined by instrumental leveling), gave 7990 ± 70 years BP (TO-965). Finally, on nearby Brevoort Island (off the east coast of Pim Island, cf. Fig. 2), the locality on the west side of Smith Sound which is closest to Inglefield Land, *H. arctica* shells at 82 m gave 8060 ± 70 years BP (GSC-3286; Blake 1987a), and a single fragment of the same species from a beach at approximately 89 m (both elevations determined by altimeter) gave 8080 ± 70 years BP (TO-966).

Surprisingly enough, at the time of writing there are no radiocarbon dates older than 8000 years on Holocene materials for the whole of Inglefield Land, although Fredskild (1985b) reported a date of 8620 ± 125 years BP (K-3504) for shells at 43 m at Qeqertat, 170 km to the southeast, near the head of Inglefield Bredning (cf. also Kelly 1985). His sample was composed of approximately equal parts of *Hiatella arctica* and *Mya truncata*, and Weidick (1978a, 1978b) reported two similar ages on these species from nearby Olrik Fjord (Fig. 3). In this connection it should be remembered that a reservoir correction for the apparent age of sea water must be applied to ^{14}C age determinations on shells, in order that they may be compared directly with the ages of terrestrial samples. The Copenhagen and GSC laboratories both use a $\delta^{13}C$ base of 0‰ for calculating the ages of marine shells, as did the IsoTrace Laboratory (Toronto) at the time that the determinations reported here were made. Thus the dates from the three laboratories are directly comparable, and they have a built-in reservoir correction of 410 years. Following Mörner and Funder (1990), who state that dates from the Thule area which have been normalized to a $\delta^{13}C$ base of 0‰ should not be further corrected, no additional corrections have been made. However, the validity of their hypothesis for the waters along the eastern side of Smith Sound and Kane Basin needs to be tested. For Inglefield Land, therefore, the need is to date pelecypods or other invertebrates collected alive prior to 1950, as has been done for samples dredged in 1898 on the opposite side of Smith Sound.

The highest shell sample collected by Nichols (1969), at approximately 49 m at the head of Dallas Bugt, northern Inglefield Land (Fig. 1), gave an age of 5900 ± 150 years BP (L-1091B). This date provided an important point for Weidick's (1976b) isobase map, and the age is comparable to two determinations on marine

Table 7. Radiocarbon age determinations, 'Kap Inglefield Sø'

Sample No.	Depth cm	Sample weight g	Laboratory no.[2,3]	$\delta^{13}C$ (‰)	Age, years BP[4,5]	
					Conventional	Calibrated range[7]
84-BS-30	4.4–4.6[1]	0.261 (dry)	TO-329	-	4050 ± 110[6]	4650 – 4415
Core 1						
BS-80–18	3–7	70.0 (wet)	GSC-3857	−25.9	4170 ± 150	4868 – 4522
Core 1						
	17–21	65.0 (wet)	GSC-3821	−24.2	4980 ± 120	5775 – 5633
	30–36	85.0 (wet)	GSC-3820	−23.0	6020 ± 110	7017 – 6738
	45–49	62.3 (wet)	GSC-3732	−27.2	7210 ± 130	8121 – 7916

[1]This depth was measured from the sediment surface when the core was opened in the laboratory. Approximately 3 cm of slurry at the sediment/water interface was scooped off into a vial in the field.
[2]Laboratory designations: TO = IsoTrace Laboratory, University of Toronto; GSC = Geological Survey of Canada.
[3]NaOH leach omitted from the pretreatment of all four GSC determinations.
[4]At IsoTrace all quoted errors are 68.3% confidence limits (1σ). Preparation of the machine-ready sample causes the fractionation of the sample material to vary systematically from the top to the bottom of the target. The computer analysis program uses the $^{13}C/^{12}C$ ratio obtained during the measurement, which is the product of this fraction and the natural fractionation of the sample, to correct the $^{14}C/^{12}C$ ratio approximately. While this procedure yields a highly reliable result for the $^{14}C/^{12}C$ ratio, at no time during the measurement is a value of the natural fractionation alone obtained (see IsoTrace Laboratory, 1984 Annual Report, 84.12.31, Chapter II.2, p. 31–64, Radiocarbon Analysis, by R.P. Beukens).
[5]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 (BP) 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 P. Fritz and R.J. Drimmie.
[6]At IsoTrace each target is given seven to eight runs, and each run takes 18 to 22 minutes. For TO-329 two targets were counted.
[7]Details of the calculation of calibrated ages (cal BP) are given in the text. The ranges listed are for the 68% confidence interval, based on R.P. Beukens' IsoTrace Radiocarbon Calibration Reports (for cal BC ages).

Table 8. New radiocarbon age determinations on Holocene marine fauna, southern Inglefield Land and adjacent Kane Basin.

Sample no. and coordinates	Depth below sediment surface m	Sample weight g	Depth/ elevation m	Laboratory no.[1],[2]	$\delta^{13}C$ (‰)	Reservoir corrected age[3],[4]	Dated species
HU74–026–32–3 78°39.9'N, 72°07.5'W	1.79-1.82	0.190	-377	TO-770	-	7590±120	*Islandiella norcrossi*[5] *Cassidulina reniforme*[5]
84-BS-99 78°27.2'N, 72°37.5'W	~69	47.0	13	GSC-3883	+0.9	6480±70	*Balanus balanus*[6]
84-BS-122 78°31.0'N, 72°17.0'W	1	0.328	80	TO-923	-	7780±70	*Mya truncata*[6]

[1]Laboratory designations as in Table 7.
[2]Because of the small size, no preleach was carried out on TO-770, whereas TO-923 received a preleach of 40 to 50% (personal communications from R. P. Beukens, 1987 and 1988).
[3]The results for TO-770 and −923 are each the average of two machine-ready targets measured on different occasions. They have been corrected for natural, preparation and sputtering fractionation to a base of δ^{13} = 0 ‰, equivalent to a reservoir correction of 410 years. The ages are quoted in uncalibrated radiocarbon years using the Libby ^{14}C meanlife of 8033 years. The errors represent 68.3% confidence limits.
[4]See footnotes 4 and 5 to Table 7. Like IsoTrace, GSC age determination on marine shells are normalized to a base of $\delta^{13}C$ = 0‰. Following Mörner and Funder (1990), who suggest that ^{14}C ages from the Thule area which have been normalized to 0 ‰ should not be further corrected, no additional corrections have been made.
[5]The two most abundant species of benthic foraminifera in Zone 3, from the upper part of Unit 2 (Marentette 1988).
[6]Pelecypods and cirripeds identified by W. Blake, Jr. The *Mya truncata* fragment was aragonitic, the *Balanus* shells were calcitic. The intact and abundant barnacles used for GSC-3883 were found in association with a few thin valves of *Mya truncata, Hiatella arctica, Macoma calcarea,* and *Clinocardium ciliatum. Macoma calcarea* also has been reported by Nichols (1969) from Holocene deposits in Rensselaer Bugt, but neither *M. calcarea* nor *Clinocardium ciliatum* have been found in Holocene deposits in eastern North Greenland (Bennike et al. 1986; Bennike 1987).

shells collected by N. Henriksen and J.S. Peel at similar elevations in southern Washington Land; 6400 ± 100 years BP (GSC-2370) for *Mya truncata* at 55 m in a valley east of Benton Bugt and 5980 ± 70 years BP (GSC-2334) for *Hiatella arctica* at approximately 46 m at the head of the inner eastern branch of Cass Fjord (Weidick 1977; Blake 1987a; cf. Fig. 1). In all likelihood by 8000 years ago the 'Smith Sound Ice Stream' had receded well to the north of Kap Inglefield. In fact, to judge by the available radiocarbon age determinations on marine pelecypod shells (cf. Weidick 1977, Blake 1987a), by 6500 radiocarbon years ago the ice front on the Greenland side was probably close to, or behind, the position now occupied by Humboldt Gletscher.

Pollen analytical investigations

BENT FREDSKILD

Methods

The pollen samples were transferred from Core 80–18 to plastic boxes containing approximately 6 ml. As the compression of the sediment in these boxes may differ slightly from that of the original setting, calculations based on the subsample volume, usually ¼ to ⅓ of the box content, are subject to some uncertainty.

The upper 50 cm of slightly organic sediment (samples 10 to 21) were treated as follows: The samples were boiled in 10% KOH, inspected under low power microscope to count and remove macrofossils, acetolysed, sand was decanted and weighed, treated with 40% HF for between 4 and 16 hours, washed in KOH, washed in glycerol and stained. The residue as well as the aliquot used for each slide were weighed. The total amount of pollen was counted by inspecting the total cover slip area of the analysed slides, which allowed for the calculation of number per ml wet sediment. The deeper, minerogenic samples (1 to 9) were treated with cold or 100°C HF prior to the procedure described above. Decanted sand was not weighed, as part of it was dissolved by the first HF treatment.

In addition to pollen and spores, certain green algae and the labiae of Chironomidae were counted in the slides. Not shown in the diagram (Plate II) are: *Erigeron* type – one pollen in samples 3 and 16, *Luzula/Juncus* in sample 4, *Melandrium* in 6, *Pedicularis* in 20, *Polygonum viviparum* in 17 and 20, *Taraxacum* type two in 11, *Sphagnum* in 19 (two spores) and 21, "*Hystrix*" in sample 3 (three specimens). Macrofossils counted were ephippiae of *Daphnia pulex*, head capsules of Chironomidae, *Nostoc commune* spherules and *Cenococcum geophilum* schleroties; their numbers are shown in the pollen diagram (Plate II). A fragment of a Tricoptera larval house was found in sample 10 and a mandible of *Lepidurus arcticus* occurred in sample 15. Moss fragments were seen in each of the samples between 10 and 21. In the diagram, percentages are based on the sum of pollen and spores of local taxa, including indeterminable pollen, but excluding exotics. The fuchsin staining of the pollen makes a distinction possible, with reasonable certainty, between contemporary and rebedded pollen, the former having a violet tinge. The pollen samples usually comprise a 1 cm-thick increment from the core. The exceptions are samples 1 (105.5 to 106 cm) and 21 (0 to 3 cm, marked in the diagram (Plate II) at a depth of 1.5 cm).

Zonation of the diagram

A. *Poaceae* zone with pioneer plants (106 to 61 cm)

Virtually all pollen in this zone are flattened and often broken, with signs of mechanical damage. There is no evidence of corrosion from chemical or biological processes. Presumably this is a result of the pollen washing into the lake in rapidly-flowing meltwater streams carrying a significant load of mud and sand, and if there was a semi-permanent ice cover on the lake, no pollen would fall directly onto the coring site. Generally, all thin-walled pollen such as Cyperaceae, Poaceae, *Papaver*, *Oxyria*, *Saxifraga oppositifolia* type, and *Minuartia/Silene* are contemporary, *Salix* and *Cassiope* are mainly contemporary, all exotic pollen and spores and Ericales (apart from *Cassiope*) are rebedded. As the curve of pollen, indeterminable because of being too corroded or folded, parallels the curve of rebedded exotics, the major part of the indeterminable pollen are considered to be rebedded. This is confirmed by their colour and their "old" appearance.

A short time after deglaciation some dwarf-shrubs – *Salix arctica, Cassiope* and *Dryas* – were growing around the lake, but grasses and pioneer herbs, typical of fell-fields, dominated. These plants, e.g. *Saxifraga oppositifolia*, *S. tricuspidata* (incl. in *S. oppositifolia* type), *S. nivalis, S. tenuis* and *S. hieraciifolia* (*S. nivalis* type), *Erigeron* spp., *Oxyria digyna* and *Papaver radicatum* have a wide ecological and geographical tolerance but are restricted to open soil, in many places unstable, or rocks. The increase in Poaceae may indicate the formation of fen-like communities at the lake shore and along inlets or outlets, but unfortunately only one of the grasses can be determined by means of pollen: *Alopecurus alpinus*, single grains of which have been found scattered throughout the diagram. It prefers moist ground. Spores of *Cystopteris fragilis* ssp. *dickieana*, still with the delicate perine surrounding the *Dryopteris*-type spore, were found in samples 4 and 5. It is most unlikely that such spores are derived from older sediments. The maximum in *Dryopteris* type in the upper part of zone A and in zone B may well be caused by the presence of this species, growing in crevices in rocks and on scree slopes. Only two more ferns grow in Inglefield Land today: *Woodsia glabella* and *Dryopteris fragrans*.

The lake water was rich in suspended clay, which prevented algae and animals from living in deeper water, apart from the fact that the pelagic region of the lake was presumably permanently ice-covered. Only in a narrow zone along the shore was there a slight production of benthic green algae (*Pediastrum, Botryococcus*), enabling some Chironomidae to live on the bottom. There are no indications of pelagic organisms.

B. *Salix arctica* – Polypodiaceae zone (61 to 49 cm)

Salix arctica is expanding at the expense of Poaceae, but still the fell-field plants are common. Like other Pteridophyte spores the *Dryopteris*-type spores, being very resistant to corrosion, are often found in till and other rebedded materials, but since the *Dryopteris* peak in zone B is coincident with a decrease in definitely rebedded pollen and spores, it is concluded that the major part of the *Dryopteris*-type spores are contemporary. Today the ferns of Inglefield Land are all rock- and scree plants. The sudden occurrence of *Microthyrium* and *Cenococcum*, both tiny, soil-living fungi, requires an explanation. Conditions in the lake seem unchanged.

C. *Salix arctica* zone (49 to 32 cm)

Salix arctica, totally dominating the pollen spectra of this zone, has a very wide ecological tolerance, ranging from hummocky fens to dry ridges. The range of *Salix arctica* extends from individuals occurring under long-lingering snow-patches, well beyond the tolerance of *Cassiope*, to dry heaths with a snow-cover too short and too unpredictable for *Cassiope*. Thus, the scarcity or even absence of *Cassiope* pollen in the four samples (2, 0, 0 and 1, respectively) only indicates that there were few habitats suitable for this plant, not whether there was too much or too little snow in general. The few *Dryas* pollen in the lower three samples (1, 1 and 0, respectively) suggest that the former explanation is correct. The tip of a *Salix arctica* bud scale was found at 31 to 35 cm depth (between samples 13 and 14), and an unmistakable *Salix herbacea* pollen (Fredskild 1973, Funder 1978) was found in sample 12. The northernmost known present occurrence of this species is at Siorapaluk (77°48′N), some 90 km to the south-southeast.

The marked change in physical conditions around the lake at the time of the zone border B-C is reflected clearly within the lake. Quieter water, with less suspended clay, allows development of a relatively rich assemblage of life forms, with a high primary production of microscopic algae and *Nostoc*, feeding Chironomidae, Cladocera and Tricoptera. Among algae, *Cosmarium* spp. exceed 22 000/ml in sample 10, in which Dr. Kuno Thomasson, Uppsala, has determined the following species: *Cosmarium subspeciosum* Nordst., *C. quasillus* Lund., *C. granatum* Bréb. and *C. pseudonitidulum* Nordst. According to him they are all cosmopolitan, benthic species, giving little ecological information. *Nostoc* is benthic too, and *Botryococcus braunii* and *Pediastrum boryanum* (var. *longicorne* Reinsch, according to K.T.) cover a very wide spectrum. They thrive well in the benthos. All species of *Scenedesmus* are four-cellular, some of them with a parachute device; they are euplanktonic or tychoplanktonic; that is, they spend all or part of their lives as pelagic organisms. The fact that not a single specimen is found in sample 10 is taken as an indication that a permanent ice-cover persisted on the lake at the beginning of this zone. If so, then the sudden occurrence of *Scenedesmus* in the following sample shows the opening of a major part of the lake during summer. *Nostoc commune*, which is found all over Greenland today on the bottom of more productive lakes and ponds, is frequent throughout the zone; cf. also Croasdale (1973) for information on the widespread occurrence of *Nostoc* on Ellesmere Island. A fragment of a larval house of a Tricoptera, presumably *Apatania zonella*, is found in sample 10.

D. Cyperaceae zone with *Dryas, Oxyria* and *Salix* (32 to 5 cm)

At the opening of this zone a drastic decrease in *Salix arctica* percentages is caused in the first place by an increase in *Dryas*, which prefers dry sites with thin or unstable snow-cover, and in Cyperaceae. One *Dryas integrifolia* leaf was found in each of samples 16 and 17. Without macrofossils allowing a species determination, the Cyperaceae increase is difficult to explain as no less than 10 species, ranging from *Eriophorum* spp. and *Carex stans* in fen-like communities to *Kobresia myosuroides* and *Carex nardina* on dry ground, even on windswept ridges, have been found in Inglefield Land today (Bay 1983). *Cassiope* peaks at 10% in sample 16. *Oxyria* and, from the middle of the zone, *Saxifraga oppositifolia* type, gradually increase, whereas *Dryas* after a 17% maximum in sample 15, in which a leaf of *Dryas* also was found, decreases towards the zone border. This may suggest the start of a retrogression, with fell-fields covering greater areas. Two *Salix herbacea* pollen occur in sample 18, indicating temperatures still higher than at present.

In the lake the production of *Botryococcus, Pediastrum* and especially of *Scenedesmus* increases towards the end of the zone, judging from the content/ml. However, this conclusion implies a constant sedimentation rate, which seems likely but cannot be proved (Fig. 18). The sudden peak of washed-in sand at the 20 to 21 cm

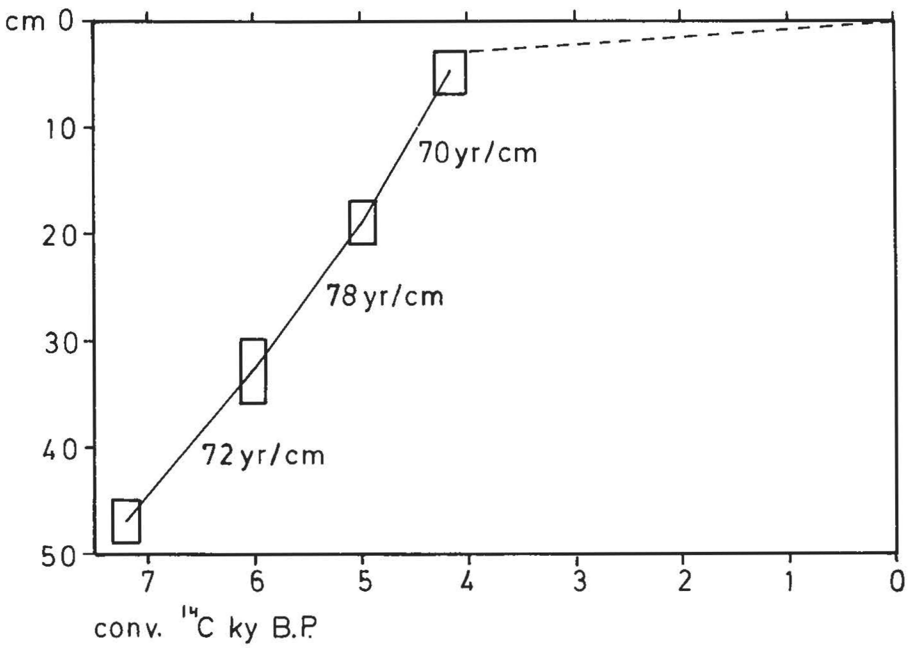

Fig. 18. Radiocarbon age versus depth in 'Kap Inglefield Sø'. Ages are given as uncalibrated dates with two standard deviations; sedimentation rates are calculated from calibrated dates (Clark, 1975).

level indicates unstable surroundings or the deposition locally of minerogenic matter released from a melting ice-floe. In the same sample the content of *Cosmarium* is 17 800/ml against less than 50, if any, in all other samples apart from no. 10. K. Thomasson has determined *Cosmarium galeritum* Nordst. and *C. formosulum* Hoff., two benthic cosmopolitans of little recognized indicator value, like those in sample 10, but the sudden flourishing of *Cosmarium* remains unexplained. *Nostoc* is less frequent, presumably an indication of a slight oligotrophication which may also be reflected in the increase in *Pediastrum integrum/muticum*, usually peaking after *P. boryanum* in Holocene sediments in Greenland (Fredskild 1983a). *Daphnia* and Chironomidae are frequent throughout. *Lepidurus arcticus*, identified in sample 15, also lived in the lake, which was not ice-covered during summers, although minor ice-floes may have been present.

E. *Saxifraga oppositifolia – Papaver* zone (5 to 0 cm)

The ubiquitous and widespread *Saxifraga oppositifolia* – the only likely explanation to the peak (25 and 32%, respectively) of *S. oppositifolia* type pollen – dominates the spectra in the only two samples from this zone. *Papaver radicatum* reaches percentages previously not encountered in Greenland lake sediments (4 and 7%, respectively). Other *Saxifraga* species emerge, and everything considered, fell-fields dominate the surroundings, with dwarf-shrubs present only on small, protected sites. The most drastic change, however, is registered in the life in the lake: not a single *Scenedesmus* was seen in the slides, no *Nostoc* colonies were found, and the number of Chironomidae is reduced. On the contrary, the content of *Pediastrum*, mainly *P. integrum/muticum*, suddenly increases dramatically, peaking at 251 000/ml in sample 20.

Discussion

Generally, the West Greenland lakes pass through a number of stages during the Holocene, starting with an eutrophic stage characterized by macrophytes which require a rich supply of nutrients, like *Myriophyllum spicatum, Potamogeton filiformis* and Characeae, as well as by a high production of phytoplankton. Eventually, oligotrophication sets in, depending on the supply of nutrients from the catchment area, and the above-mentioned species are replaced by, e.g., *Isoëtes* and *Myriophyllum alterniflorum*. The production of phytoplankton, partly with other contributing species, decreases also. A corresponding development is registered in the zoological remains (Fredskild 1983a). In Table 9 the average production of *Pediastrum* and of *Botryococcus braunii*, expressed as number of coenobia sedimented per cm^2/yr, is given for the lower, highly productive zone(s) and for the recent zone of six West Greenland lakes. Four lakes are from the low arctic Godthåbsfjord (64° to 65°N) (Fredskild 1983b): Johs. Iversen Sø in the continental interior, Karra halfway out the fjord, Terte and Sardloq near the outer coast (cf. Fig. 1). The high arctic lakes are represented by Langesø, situated on Tugtuligssuaq peninsula, Melville Bugt (75°22'N) and the isle of Qeqertat at the head of Inglefield Bredning

(77°30′N) (Fredskild 1985a, 1985b). Langesø shows the same paleolimnological development as the four low arctic ones, whereas the lake on Qeqertat shows an increasing production of *Pediastrum* as a result of the washing-in, during the younger part of its history, of nutrient-rich material from raised marine beds around the lake.

Table 9. Average accumulation rates (fossils/cm^2/year) of *Pediastrum* coenobia (all species) and *Botryococcus braunii* in older (lower sample numbers) and (sub-)recent pollen zones.

	Qeqer-tat	Lan-gesø	Sar-dloq	Terte	Karra	Johs. Iversen Sø
Samples	1–4	1–5	1–7	1–10	1–3	2–6
Pediastrum	108	2028	4275	8628	883	22702
Botryococcus	83	148	916	392	1081	8672
Samples no.	25–34	22–25	27–41	30–34	24–30	32–40
Pediastrum	241	0.03	62	27	43	1229
Botryococcus	13	3	120	121	486	868

Table 10. Yearly sediment accumulation rates per cm^2 in 'Kap Inglefield Sø'.

Sample No.	*B*	*P*	*S*
19	22	29	130
18	26	105	155
17	29	29	56
16	9	3	12
15	8	7	18
14	22	19	59
13	1	15	5
12	6	180	49
11	3	20	22
10	4	24	0

B = *Botryococcus*
P = *Pediastrum*
S = *Scenedesmus*

The average sedimentation of *Pediastrum* in samples 10 to 19 in 'Kap Inglefield Sø' is 43/cm^2/yr, ranging from 3 to 180 (Table 10), a production of the same order as in the most recent, oligotrophic stages of three of the Godthåbsfjord lakes. Corresponding numbers for *Botryococcus* are 13 (0.7 to 36) and for *Scenedesmus* 51 (0 to 155). With a constant sedimentation rate throughout the organic sediment, the sedimentation of *Pediastrum* would increase from 29, 105 and 29 in samples 17 to 19, respectively, to 3400 in sample 20. This number is three times as high as in Johs. Iversen Sø, a lake which is still mesotrophic and which is situated in the part of Greenland with the highest July mean temperature. A more likely explanation, therefore, would be to assume a drastic decrease in matrix sedimentation rate at the transition D-E. This might be caused by a permanent ice-cover on the lake apart from a narrow littoral zone, allowing for the production of some benthic *Pediastrum* but excluding any pelagic organisms like *Scenedesmus*, and also reducing animal life such as Chironomidae. A similar Late Holocene development has been described in 'Rock Basin Lake' in innermost Baird Inlet on the opposite side of Smith Sound (Smol 1983, Hyvärinen 1985).

At first impression the four ^{14}C dates on the organic sediment (Fig. 18) might lead to the conclusion that some sediment has been removed at the coring site, assuming that the dating of the sample at 3 to 7 cm depth is correct. There is no reason to doubt the validity of the date, as neither this sample nor the ones from lower in the core contain "old" carbon (lime or coal, and there is no evidence that significant amounts of older Holocene humus have washed in). Sediment-focussing (Davis & Ford 1982) of course cannot be ruled out, but as no eroding stream flows through the lake, and as the theory of a permanent ice-cover is strongly supported by the paleolimnology, this is accepted as the explanation for the drop in sedimentation rate. Other high arctic lakes exhibit extremely slow sedimentation rates, especially in the recent past. In "Rock Basin Lake" the mean of the upper 30 to 35 cm is 1 cm in approximately 230 years, the mean rate of a 6430 year-old core from "Sommersø" at Station Nord, eastern North Greenland (81°36′N) is 1 cm in 189 years (Funder and Abrahamsen 1988), and in Klaresø, central Peary Land (82°10′N) the date of a gyttja sample at 3 to 6 cm depth, unfortunately carbonate-rich, is 2610 ± 120 BP (K-885, Fredskild 1973; 1969).

The exact date of the climatic change causing the permanent ice-cover on 'Kap Inglefield Sø' would, under ordinary circumstances, be difficult to determine with precision, as 4170 ± 150 BP is the age of a 4 cm-thick increment. This sediment has been deposited over three centuries if the matrix sedimentation rate, being fairly constant in zones B-D (1 cm in approximately 74 yr), was the same to the top of the uppermost increment. This seems likely, because if the ^{14}C sample contained more than a few per cent of the slowly sedimented zone E material, a significantly younger age for the sample at 3 to 7 cm would have resulted. It is therefore concluded that the break in the curve is close to the 3 cm level, *i.e.*, it occurred close to 4000 radiocarbon years BP (see discussion below).

In summing up the climatic evidence of the pollen-analytical investigation, it can be stated that the change from minerogenic to organic sediment took place at approximately 7500 radiocarbon years BP. This date need not be the dating of any climatic change, but perhaps only reflects a quite local stage in the deglaciation of the area. Summer melting of the ice on the lake started between sample 10 and 11, *i.e.*, at approximately 7250 BP. By 6700 BP the presence of a *Salix herbacea* pollen grain indicates warmer summers than today. Around 5900 BP an increase in contemporary long distance pollen indicates that southerly winds penetrated that far north. This is a little later than at Melville Bugt and Inglefield Bredning, where this event is

Table 11. Content of pollen, algae and other constituents in the upper samples of Core 84-30 from 'Kap Inglefield Sø' and (below) in the recent gyttja of Core 84-46 from 'Stromatolite Sø'.

Depth, cm	*Pediastrum*		*Botryococcus*		*Scenedesmus*		*Salix arctica*	*Saxifraga oppositifolia*	*Oxyria digyna*	Cyperaceae	*Dryas integrifolia*	Poaceae	*Papaver radicatum*	*Draba* type	*Cassiope tetragona*	*Pinus*	*Alopeurus alpinus* type	*Huperzia selago*	*Dryopteris* type	*Cerastium/Stellaria*	*Ranunculus*	*Erigeron*	*Alnus*	Chironominae, labiae	Wood fragments	Charcoal
	n	%	n	%	n	%																				
'Kap Inglefield Sø'[1]																										
0.0–0.2 total sample							7	10	9	1	2	2	1							1	1	1	1	2	7	2
0.0–0.2	441	99	5	1.1	1	0.2						2	1											0.5		
0.4–0.7	338	96	14	4.0			1	3										1	1					1		
0.9–1.1	226	98	5	1.8	1	0.4	1	1	1								1								4	
1.4–1.6	469	99	3	0.6																					1	1
1.9–2.1	1599	99	20	1.2			2			1		1	1			1									5	
2.4–2.6	471	99	4	0.8	1	0.2	1	1								1								0.5		1
2.9–3.1	274	93	13	4.4	8	2.7																		1		
3.4–3.6	690	99	7	1.0	1	0.1	2																			
3.9–4.1	617	96	16	2.5	10	1.6						2												1		
4.4–4.6[2]	229	95	11	4.5	2	0.8	2		1				2													
4.7–4.8	114	41	33	12	131	47																		10		
4.9–5.1	26	56	6	13	13	28				1		1												5	1	
5.4–5.6	116	62	26	14	44	24	3		2	1					1									1	3	
5.9–6.1	73	37	20	10	107	53	1																	2	4	
6.4–6.6	92	55	26	16	49	29	3			2				1										0.5	1	
6.9–7.1	83	47	16	9.0	79	44	1	1	2	2	1		1											0.5	6	
7.4–7.6	39	65	8	13	13	22	2	2	4															3	1	
'Stromatolite Sø'																										
0.3							30	41	8	11	2	5	5		1	1	1		2		1		3	5.5	4	4

[1]This depth was measured from the sediment surface when the core was opened in the laboratory. Approximately 3 cm of slurry at the sediment/water interface was scooped off into a vial in the field.

[2]Horizon which shows the spectacular rise in *Pediastrum* and the fall in *Scenedesmus*. An AMS ^{14}C date of 4050 ± 110 yr. BP (TO-329) was obtained on this 2 mm-thick slice of sediment.

dated at 6500 to 6000 BP (Fredskild 1984). By 4500 BP two *Salix herbacea* pollen indicate favourable summers, but the beginning of a retrogression is corroborated by the onset of permanently ice-covered conditions at approximately 4000 BP.

The average pollen influx of samples 11 to 19 is 8/cm²/yr (10 if the somewhat odd sample 10 is included). The influx, or rather the annual deposition in the middle of the lake, ice-covered all the year round, amounts to approximately 0.2 during zone E. By way of comparison, Langesø in Melville Bugt has a hypsithermal influx of 20 to 30, decreasing to 5 to 7 in the recent samples, in Qeqertat the decrease is from 7 to 1 (Fredskild 1985a), in 'Rock Basin Lake' the Hypsithermal influx is closer to 5 than to 15, decreasing to approximately 1 in the recent pollen zone (Hyvärinen 1985), and in "Sommersø" it ranges between 2 and 12 in the warmer *Salix arctica* zone, decreasing to approximately 2 in the recent, colder Polar desert zone (Funder and Abrahamsen 1988).

In order to confirm the marked sediment change at zone border D-E in the 1980 Core 80–18, a series of small samples from the upper part of Core 84–30 was investigated, all except one representing only two millimetre-thick increments. Every sample consisted of dried-out, more or less sandy clay-gyttja, and apart from the 0.0 to 0.2 cm increment, the weight ranged between 17 and 28 mg. These increments were treated like the pollen samples, but only two or three slides could be made of each sample. As a result of the drying-out of this highly minerogenic sediment, most of the algae, pollen, etc., were crushed and crumbled, and the counting of coenobia, consequently is subject to some uncertainty. As the number of pollen was too small to

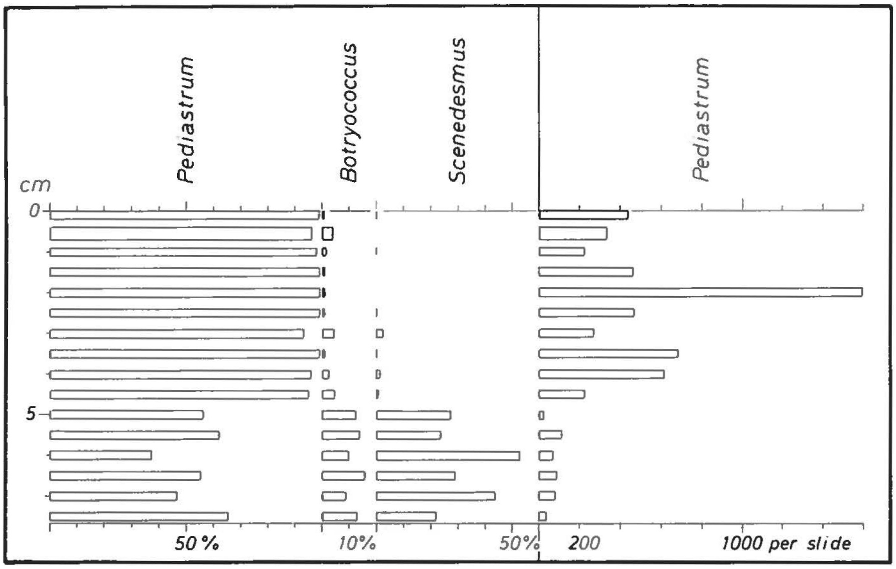

Fig. 19. Percentages of certain algae and number of *Pediastrum* per slide in a series of samples at the top of Core 84–30 from 'Kap Inglefield Sø'.

allow for a normal pollen analysis (Table 11), the investigation was focussed on the number and percentages of *Pediastrum, Botryococcus* and *Scenedesmus*, the total of which was counted in every second traverse (50% of the cover slip area) on one of the slides. Even considering the uncertainty owing to varying size of samples, the number of slides and the crushed coenobia, the number of *Pediastrum* shows a marked increase between the 4.7 to 4.8 cm and the 4.4 to 4.6 cm samples. Even more marked is the change at the same level in the ratio *Pediastrum: Botryococcus: Scenedesmus* (Fig. 19). *Scenedesmus*, in the deeper samples ranging from 22 to 53% of the sum of the three genera, almost disappears. It is missing in three of the upper ten samples and is represented by only one specimen in four others (Table 11). The decrease in percentages of *Botryococcus* is partly caused by the increase in absolute numbers of *Pediastrum*. Thus, the average number of *Botryococcus* per slide only decreases from 17 in the deeper samples to 10 in the upper. As in the pollen diagram the number of labiae of Chironominae is small in the samples rich in *Pediastrum*.

The investigation of Core 84–30 has confirmed, that around 4000 BP there was a sudden increase in the number of *Pediastrum*, close to the present mud/water interface (4.7 to 4.6 cm depth in the core), and that this change coincided with the near disappearance of *Scenedesmus*. This event was not caused by a change in the extremely local conditions at the first coring site, where it happened just below the 3 cm level, judging from the radiocarbon age determination.

The 0.0 to 0.2 cm sample from Core 84–30 weighed 147 mg, of which 71 mg were left after decanting, following the acetolysis. Every traverse was counted, in the four slides made, in order to obtain a recent pollen spectrum. The result is given in the top line in Table 11, whereas for comparison with the other samples the next line shows the number in every second traverse in the first slide. The spectrum, dominated by *Saxifraga oppositifolia, Oxyria* and *Salix arctica*, closely matches the pollen zone E spectra in the diagram.

As recent pollen spectra from high arctic lakes are rare, the spectrum of the 0 to 3 cm sample from Core 84–46 in nearby "Stromatolite Sø" is included (Table 11, below). Further, the following were found: *Salix herbacea* type, 1 pollen; Cruciferae, 1; *Potentilla*, 1; *Taraxacum*, 1; *Betula*, 2; "Coryloid", 2; *Sphagnum*, 1 spore and *Filinia* (a Rotatorie), 1. The span of time represented by this sample is unknown.

Fossil bryophytes

JAN A. JANSSENS

All samples between 5 to 49 cm depth in Core 80–18 from 'Kap Inglefield Sø' contained numerous fragments of either *Limprichtia revolvens* or *Calliergon giganteum*. Both species are common minerotrophic rich-fen species with a widespread boreal and arctic range in the northern hemisphere (Janssens 1983, Karczmarz 1971). In the general region under investigation *Limprichtia revolvens* has been found in a core from southern Bache Peninsula, Ellesmere Island (Blake 1987a). One sample at 35 to 36 cm depth in Core 80–18 also contained a few fragments of *Drepanocladus brevifolius*. This species has a circumpolar arctic distribution (Janssens 1983). It grows in rich fens and shallow pools and has been recorded, for instance, in a core from 'Moraine Pond' near 'Rock Basin Lake', south of Baird Inlet on the opposite side of Smith Sound (Blake 1981a, 1987a).

Table 12 summarizes means and ranges for three water-chemistry variables frequently measured in association with populations of these bryophytes. The statistics are based on the entire North American database, including values associated with populations from Alaska, northern Ontario, Minnesota, Maine, and the Maritime Provinces of Canada. Bog/fen differentiation and classification are discussed in Gorham and Janssens (in press).

Terrestrial wetland communities were present surrounding the lake during the *Salix arctica* zone (49 to 32 cm) and Cyperaceae zone (32 to 5 cm). No bryophytes were deposited or were growing in the lake during periods of permanent ice cover.

Table 12. Statistics for minerotrophic variables associated with North American populations of *Limprichtia revolvens* and *Calliergon giganteum*.

	MIN	AVG	MAX	STD	N
Limprichtia revolvens					
pH	4.60	6.55	7.57	0.62	65
Ca^{++}	1.2	48	102	31	43
K_{corr}	16.5	157	560	118	28
Calliergon giganteum					
pH	4.82	6.60	7.98	0.68	95
Ca^{++}	3.0	30	102	25	52
K_{corr}	22.5	143	560	114	29

N.B.: MIN = minimum, AVG = arithmetic average, MAX = maximum, STD = standard deviation, N = number of populations with associated water chemistry, Ca^{++} = calcium cation concentration in ppm, K_{corr} = conductivity in µS/cm at 25°C, corrected for H^+ contribution.

Diatom analyses

JOHN P. SMOL

Preparations for diatom analyses followed standard quantitative procedures (detailed description in Smol 1983), and used evaporation trays similar to those described by Battarbee (1973). An average of 1000 diatom valves, from at least two different slide preparations, were identified and enumerated from each sedimentary level. Following standard protocols, the data are presented using relative frequency (%) diagrams, with the concentration of diatoms also recorded (Fig. 20). We did not attempt to determine accumulation rates (*i.e.* diatom valves/cm²/yr) for the core, although comments are included on the importance of this effect on our interpretations (see below). Chrysophycean stomatocysts were also enumerated; however, cysts were completely absent or were only present at trace levels throughout the core (never more than about 4% of the diatom counts).

Taxonomic references are similar to those listed in Smol (1983). We recognize, however, that the diatom (and other algal) floras from these high arctic lakes are still poorly documented. The purpose of this paper is to outline the overall pattern of diatom succession in this lake, not to provide a detailed taxonomic description of the taxa recorded. Research on the systematics and ecological characterization of the taxa in these high arctic sites continues to be a major research effort in the Queen's University Paleolimnology Laboratory (e.g., Douglas 1989).

One taxonomic note is warranted in this paper. The systematics of *Fragilaria* diatoms continues to be an area of research and some controversy (Williams and Round 1987, Lange-Bertalot 1989). It is evident that the flora is overwhelmingly dominated by small benthic *Fragilaria* spp. The nomenclature used in Patrick and Reimer (1966) has been tentatively retained for these taxa. In particular, however, it was at times difficult to distinguish our two dominant diatoms: *Fragilaria construens* var. *venter* (Ehr.) Grun. and *F. pinnata* Ehr. Transmission electron micrographs of the two major forms are presented here (Fig. 21), although in many specimens the distinction between the two taxa became difficult using the light microscope. Further work on these taxonomic problems is necessary. In any case, our data show that both forms often occur together, although their abundances may indicate subtle environmental changes.

Although diatom valves were well preserved throughout the organic sequence, only 20 diatom taxa were identified. The low species richness is characteristic of algal floras in these extreme environments, although the especially low diversity is striking, even for the high arctic (Smol, 1983). All the diatoms were benthic species, and no euplanktonic forms were recorded. This again is perhaps typical of these environments (Smol 1983) and may at least partially be a result of the extensive ice and snow cover present on these lakes, which precludes the development of open water floras (Smol 1988). The following genera were identified (in several cases only one valve of the genus was recorded in this entire study, further demonstrating the low species diversity in 'Kap Inglefield Sø'): *Achnanthes, Anomoeoneis, Amphora, Caloneis, Cymbella, Eunotia, Fragilaria, Gomphonema, Navicula, Nitzschia, Stauroneis*, and *Cyclotella*. The last-named genus was represented by a few valves of the benthic *C. antiqua*. The lack of plankton is also emphasized by the paucity of chrysophycean stomatocysts and the complete absence of chrysophycean scales.

As with the other paleoindicators, the diatom data are discussed in relation to the pollen zones. The taxa that are dominant in the core (namely *Fragilaria con-*

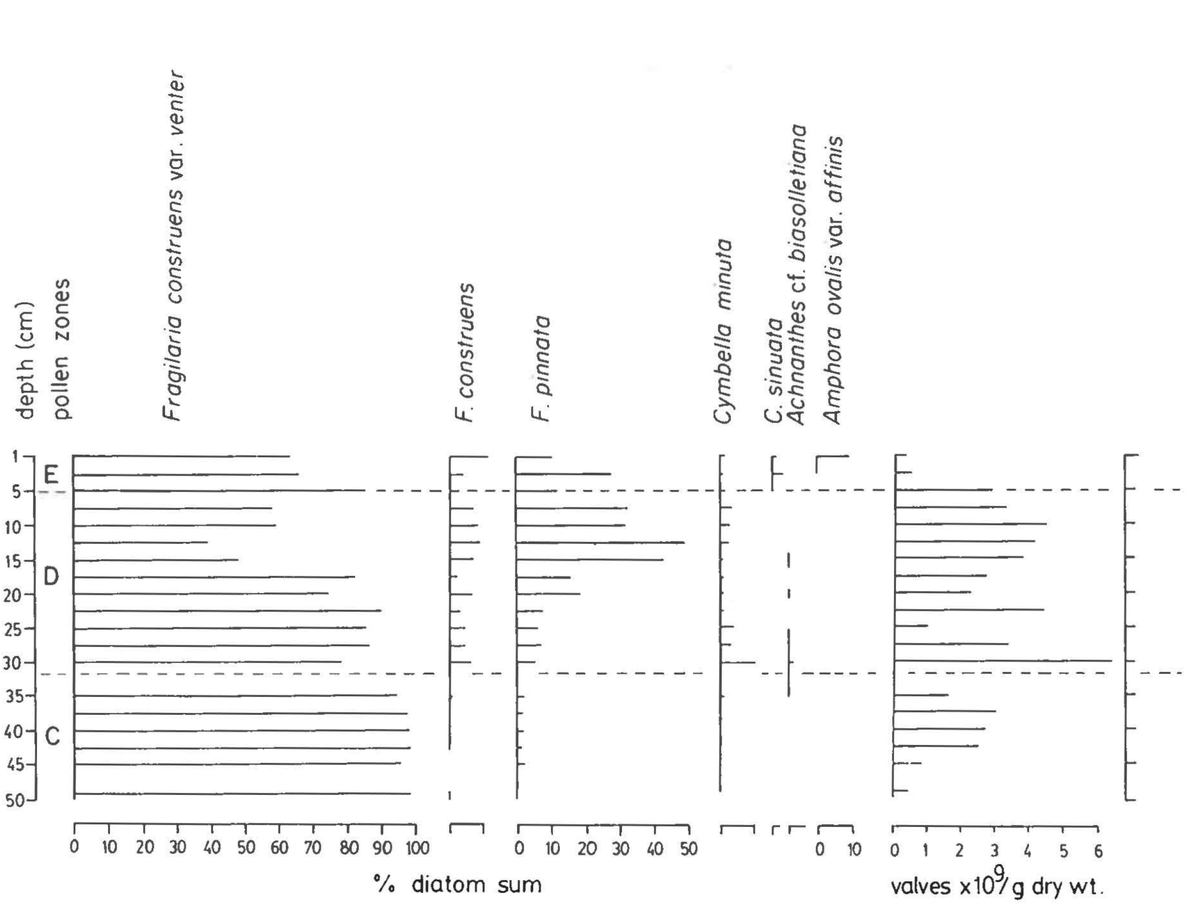

Fig. 20. Relative frequency diagram of the percent distribution of dominant diatoms present in Core 80–18 from 'Kap Inglefield Sø'. *Cymbella sinuata* is synonymous with *Reimeria sinuata*. (see text for additional taxonomic notes). Histograms depicting the concentration of diatom valves are shown to the right. Zones follow the pollen zones (cf. Plate II).

struens (Ehr.) Grun. and the variety *venter, F. pinnata*, and *Cymbella minuta* Hilse *ex* Rabh.) are taxa typical of early postglacial sediments of temperate (Smol 1988) and even some mid-arctic (Lemmen *et al.* 1987) and high arctic (Smol 1983) sites. One can speculate that the extreme climatic conditions that lakes like 'Kap Inglefield Sø' are subjected to have kept these lakes in early successional stages, and in many respects this site might be considered a contemporaneous analog to early postglacial environments that existed in more temperate regions, immediately following deglaciation.

Twenty-five sediment levels were analyzed for diatoms; however, only the top 19 levels (all in the organic sequence) contained appreciable numbers of diatoms. Sediment samples below the 48 to 49 cm level (samples from the clayey, silty and sandy sediments) were almost completely devoid of diatom remains. In most cases, only a single small *Fragilaria* might be recorded after covering many transects of a microscope slide – in some of the lower sedimentary levels, no diatoms were ever recorded. In contrast, diatoms are numerous in every field studied at the 48 to 49 cm level. Our interpretation of these results follows that of the other sections discussed in this paper, namely that the lake was completely or nearly completely frozen over during Pollen Zones A and B, and lake biota could not develop. Implicit in this interpretation is our conclusion that near the 48 to 49 cm level (the start of Pollen Zone C) a major climatic warming occurred that allowed at least the littoral zone of the lake to open up, and benthic diatoms (along with other lake organisms) began to flourish.

Fragilaria construens var. *venter* dominates or co-dominates the entire 'Kap Inglefield Sø' core, but it is especially common during Pollen Zone C, where it represents almost the entire diatom assemblage. During this early successional stage in the lake's development, this taxon was especially competitive. The low numbers of the other diatom taxa are not related to slower colonization rates, as founder populations of the other taxa are also present in the lake at this time, albeit at trace levels.

Coincident with the shift to Pollen Zone D, diatom species composition also changes as the other diatoms in the 'Kap Inglefield Sø' core increase in both relative abundance and in concentration. For example, *F. pinnata* increases in relative frequency throughout most of this zone, and then begins to decline again. Because the

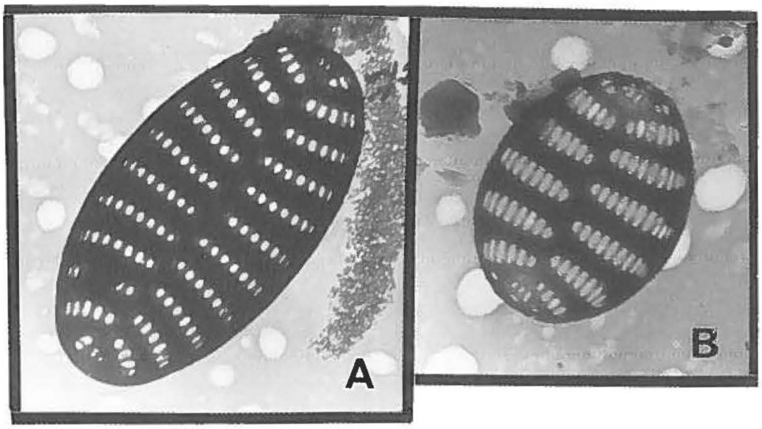

Fig. 21. Transmission electron micrographs of the two dominant *Fragilaria* morphs recorded in the core (see text for additional comments). A is representative of the morph we call *Fragilaria construens* var. *venter*. Most specimens were about 8µm × 4µm. B is representative of the morph we refer to as *F. pinnata*. Its measurements are usually about 6µm × 4µm. As noted in the text, there is considerable variability in these forms.

autecologies of these various taxa are still poorly documented, it is difficult to interpret these successional changes. Apparently the conditions present in the shallow "moat" around the lake allowed these benthic diatoms to survive.

The most striking change in the concentration of diatoms occurs at the boundary to Pollen Zone E. Diatom concentration decreases over an order of magnitude, and remains low for the remainder of the core. Diatom species composition also changes somewhat, with taxa such as *Cymbella sinuata* Greg. (synonymous to *Reimeria sinuata* (Greg.) Kociolek & Stoermer) and *Amphora ovalis* var. *affinis* (Kürz) V.H. *ex* Det. increasing in relative frequency. All these changes are consistent with our interpretation of a marked deterioration in climate, that resulted in more extensive ice-cover conditions.

The absence of comparable paleolimnological data from polar environments hampers interpretations of these diatom data. However, one study certainly warrants comparison. Foged (1972) documented the stratigraphic changes in diatom species composition in a core from Klaresø (82°10'N, 30°34"W), Peary Land, North Greenland. Following the lake's isolation from the sea about 5000 years ago, the entire lacustrine sequence is overwhelmingly dominated (*i.e.*, 99% to 100% of valves counted in some sections) by *F. pinnata*. Interestingly, and similar to our study, other benthic taxa (such as species belonging to the genera *Cymbella, Achnanthes*, and *Amphora*) increased in the more recent sediments. The ecological significance of these changes could not be determined, but conceivably they could have been climate-related.

Invertebrate microfossils

MARY M. BOUCHERLE

Twenty sediment levels were selected for detailed animal microfossil analyses. Each sample was dried at 80°C for 24 hours, cooled in a desiccator, and then weighed. Samples were treated with 10% KOH and heated for 20 minutes. The residue was then screened through a 37 µm sieve, washed with distilled water, and preserved in 70% ethanol. All animal remains were enumerated, but only the most numerous skeletal part was used to calculate concentrations. A known volume of material was mounted in Karo medium (Taft 1978).

Core 80–18 from 'Kap Inglefield Sø' contained only a small number and an extremely low diversity of invertebrate remains. Three Cladocera taxa were identified: *Chydorus* cf. *sphaericus* (which dominated all the samples), *Daphnia pulex* (which was found in 13 of the samples) and a *Bosmina* sp. (which occurred in only one sample, and then at trace levels). These Cladocera are common in many high arctic sites. For example, Røen (1981 a, b) has found these taxa at the Camp Hazen area of northern Ellesmere Island, in Greenland at Thule (Dundas) and in Peary Land, and in Svalbard.

Ostracoda remains were rarely encountered, although chironomid head capsules were found in all but one sample. The latter were enumerated, but not identified to the generic level.

Figure 22 illustrates the stratigraphic distribution of invertebrate microfossil concentrations in the core from 'Kap Inglefield Sø'. Note that the scale of the concentrations is not consistent for all animal groups, and that the *Daphnia* and *Bosmina* scale is an order of magnitude lower in concentration than for the *Chydorus* and chironomid profiles. There may appear to be some disagreement between the chironomid profiles noted in these slides, as opposed to the chironomid remains enumerated in the pollen slides. This is because in the mounts prepared for the aquatic invertebrates, only complete, intact head capsules were enumerated, whereas labiae were counted in the pollen preparations.

The most striking feature of the profiles is the low species diversity and the low concentrations of remains. The latter is especially striking when one realizes that these are concentration data, and that if the samples were converted to accumulation rates (*i.e.* number of

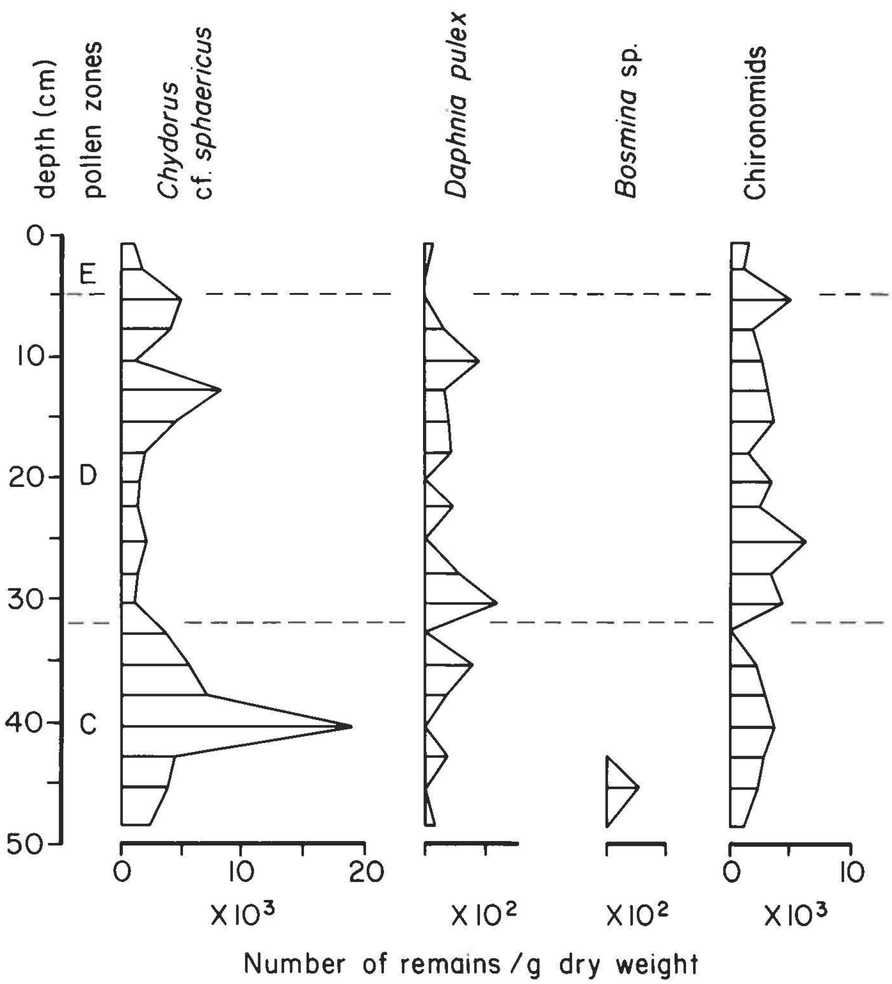

Fig. 22. Concentration profiles of cladoceran microfossils. Note that the scale is different for the various taxa. The concentration of complete, intact chironomid headcapsules is illustrated in the far right panel. Zones follow the pollen zones (cf. Plate II).

remains/cm^2/yr) the numbers would be much lower, considering that the last 7000 years of the lake's history is contained in the top 50 cm of sediment. The low diversity and concentration of invertebrates is perhaps expected, as it reflects the cold and other harsh environmental conditions present at this site (e.g., extensive ice cover, etc). As with many of the other limnological fossils in this core, the overwhelmingly dominant cladoceran fossil, *Chydorus* cf. *sphaericus*, is generally a littoral taxon, and was most competitive in the thawed moat that characterised this lake's littoral zone for much of its development.

Despite the low diversity and concentrations, several stratigraphic changes are evident, and these are discussed within the context of the pollen zones.

No cladoceran fossils were recorded in the sediment from pollen zones E and D. As noted previously, this time period was represented by harsh conditions with perhaps complete (or near complete) ice-cover, with little production occurring in the lake. Not surprisingly, aquatic invertebrates had not colonized the lake to any extent at this time. A marked change occurs in Pollen Zone C, where the highest concentrations of cladoceran remains are recorded, with an especially high peak of *Chydorus* near the middle of the zone. Planktonic taxa, such as *Daphnia pulex* and the *Bosmina* sp. are also present, and these taxa probably reflect the more "open water" conditions perhaps occurring at this time.

Coincident with the onset of Pollen Zone D and the cooler conditions it implies, cladoceran microfossils became less abundant. This trend is especially evident during Pollen Zone E, where invertebrate microfossils are almost absent. Considering that the data are presented as concentrations, and that Zone E represents a relatively short sedimentary sequence but covers a relatively long period of time, these results are especially striking. Had we calculated the accumulation rate of invertebrate fossils, they would be at trace levels. The deterioration of climate during this period, and the consequent changes in ice-cover, had a major impact on the aquatic invertebrates, just as it did on all lake biota recorded in this paper.

Summary discussion

WESTON BLAKE, JR., BENT FREDSKILD & JOHN P. SMOL

Investigations in southwestern Inglefield Land have provided much useful information about the glacial history of this corner of Greenland. The presence of lateral drainage channels on the plateau plus a network of canyons cut by meltwater and modified by ice, the spectacular glacial sculpture along the coast, and the presence of shelly till at inland sites provide convincing evidence that a southward-flowing ice stream formerly filled Smith Sound and the southern part of Kane Basin. Similar sculpture has been described earlier from Pim Island and the adjacent coast of Ellesmere Island, on the opposite side of Smith Sound (Blake 1977, 1981a). As depths in Smith Sound reach over 600 m in places, and the sculptured top of Pim Island is at 550 m, the southward-flowing 'Smith Sound Ice Stream' – which derived from the coalesced Greenland and Innuitian Ice Sheets – must have been close to 1500 m thick in the middle of the channel.

'Kap Inglefield Sø' lies at the head of one of the valleys, in this case one that is oriented parallel to the coast, into which glacier ice pushed from the seaward side. When the ice retreated, the basin now occupied by 'Kap Inglefield Sø' was, for a time, the site of an ice-dammed lake, as indicated by the laminated nature of the minerogenic sediments recovered by coring. This ice-dammed lake may have been held up at its southwestern end by another lobe of ice, which pushed inland through the valley in which 'Peninsula Sø' is now situated.

The age of the basal organic sediments in 'Kap Inglefield Sø' is 7210 ± 130 conventional radiocarbon years or 8121 to 7916 cal BP (GSC-3732). A shell fragment at 80 m a.s.l. in raised beaches along the outlet stream from the lake gave a value of 7780 ± 70 (TO-923). In addition, foraminifera from the base of a core taken in Kane Basin, approximately 14 km north of Kap Inglefield, are 7590 ± 120 years old (TO-770). Both these dates are reservoir corrected but not calibrated. These young ages, the more than 80 m of emergence that has taken place in Holocene time (rebound resulting from the removal of an ice load), the freshness of the glacial sculpture, and the relatively low D/L ratios (= young age) for aspartic acid on *Hiatella arctica* shells in the surface till – all these features suggest that Smith Sound was filled by an ice stream during the last glacial maximum, *i.e.*, during late Wisconsinan time. The presence of this ice excluded the sea, apparently, from the coast of Inglefield Land for much of the first two millenia of Holocene time.

The pollen analytical investigations have allowed the construction of a diagram (Plate II) with five zones: A. Poaceae zone with pioneer plants (106 to 61 cm; represented entirely by minerogenic sediment believed to have been deposited in an ice-dammed lake which existed at the site); B. *Salix arctica* – Polypodiceae zone (61 to 49 cm; *Salix arctica* expanded at the expense of Poaceae); C. *Salix arctica* zone (49 to 32 cm); D. Cyperaceae zone with *Dryas, Oxyria* and *Salix* (32 to 5 cm); and E. *Saxifraga oppositifolia* – *Papaver* zone (5 to 0 cm).

There is remarkably good agreement between changes in the local plant communities, as reflected in the pollen diagram, and changes in the lake biota. Had the zonal boundaries been based on autochthonous (lacustrine) fossils, the same lines would have been drawn as those defined by the pollen spectra. This shows that effects caused by climatic change have overpowered the 'normal' development of lake biota.

Although pollen analyses carried out on the sediments of High Arctic lakes have yielded important paleoclimatic data (e.g., Fredskild 1969, 1973, 1983a, 1985b; Hyvärinen 1970, 1985; Funder & Abrahamsen 1988), the work is never easy and as noted by Smol (1988, p. 837), referring to Hyvärinen (1985), "palynological studies from this extreme environment have limitations. For example, pollen production is very low, pollen dispersal is ineffective, and the likelihood of contamination of recent sediments with reworked, older pollen grains is much higher than in other environments". Because sufficient pollen were extracted to construct a diagram, however, 'Kap Inglefield Sø' has proved to be a good reference site.

In general, overall species diversity is extremely low, hence the value of an integrated approach, using as many indicators as possible, is clearly desirable and is demonstrated in this paper. Despite the low diversity, the excellent preservation of chlorophycean (green algae, such as *Cosmarium, Scenedesmus, Botryococcus*, and *Pediastrum*) and cyanobacterial (blue-green algae, such as *Nostoc*) fossils in the sediments of 'Kap Inglefield Sø' allows us to reconstruct a more complete assemblage of past lake communities, and hence to increase our confidence in the paleoecological interpretations. The excellent preservation is presumably a reflection of the low temperatures and the low amounts of light under the cover of ice and snow.

The results from this investigation also suggest that sedimentation rates, as well as the accumulation of lake biota remains, can provide important climatic proxy data (Smol *et al.* 1991). Sedimentation rates are intimately associated with ice cover in these latitudes. This relationship is clearly indicated by the marked decrease in the sedimentation rate in 'Kap Inglefield Sø' approximately 4000 conventional radiocarbon years ago (4650 to 4415 cal BP), an event which is paralleled by the equally marked decrease in *Scenedesmus* and concomitant increase in *Pediastrum* (cf. Table 11, Figs. 13 & 14) as a result of the development of a nearly permanent ice cover on the lake. At the same time the top of Core 80–18, at 2 to 3 cm depth, is characterized by both a decrease in organic carbon content (the lowest carbon content throughout the entire organic sequence) and an increase in the presence of minerogenic detritus in the form of sand and pebbles.

This apparently widespread High Arctic phenomenon of a decrease in sedimentation rates in late Holocene time was recorded for Klaresø, Peary Land, more than 20 years ago by Fredskild (1969). More recently, the climatic deterioration following the relative warmth of the Hypsithermal Interval has been documented at a increasing number of localities. For instance, it is reflected in both the assemblage of diatoms (Smol 1983, 1988) and the pollen record (Hyvärinen 1985) at 'Rock Basin Lake', Baird Inlet, on the opposite side of Smith Sound, by the development of permanent bottom ice in a high level lake on the west side of the Prince of Wales Icefield (Blake 1989a), by the cessation of peat growth at a plateau site on the Carey Øer, just over 200 km to the south (Brassard & Blake 1978), and by the disappearance of *Salix arctica* at Sommersø, eastern North Greenland (Funder & Abrahamsen 1988). From the lake on Qeqertat, 170 km southeast of 'Kap Inglefield Sø', Foged's examination of the diatoms (reported in Fredskild 1985b, p. 16) showed that "Roughly 4000 BP, at the 60 cm level, a drastic change is recorded in the diatoms: alkaliphilous diatoms increase three fold at the expense of the indifferent and the few acidophilous species...". For the Beaufort Lakes, in northern Ellesmere Island, Retelle *et al.* (1989) stated that contamination by old carbon was a factor, although they acknowledged that the decreased sedimentation rate recorded in two of the lakes might be, in part, the result of late Holocene climatic cooling. Here again, the development of a more permanent ice cover may have played a role.

The response of glaciers was somewhat slower, and the precise timing of the readvance(s) is less well known (Blake 1981b, 1989b). However, the dating carried out so far at a number of moraines along the Ellesmere Island coast shows that the fronts of all tidewater glaciers were behind their present positions during the Hypsithermal Interval, just as the lakes were characterized by much more open water during this period (Blake 1989a).

Much work remains to be done. Additional lakes in Inglefield Land need to be examined and cored, both to determine the age of the basal organic sediments over a wider area and to see if more than one organic sequence is present in any of the lakes. In interpreting the changes in biota we are hampered by our relatively poor understanding of the autecology and systematics of the organisms that live in these High Arctic lakes, although research along these lines is in progress. We also know little about the taphonomy and transport of fossils in such lakes. For instance, with incomplete mixing, in part because of the ice cover, what sort of transport of littoral fossils takes place? How representative of the lake is the deeper area where a core has been taken (sounding traverses to determine the bathymetry are usually not possible because of the ice cover)? More work is needed along all these lines.

Nonetheless, based on our integrated approach, we believe that we have provided a reliable interpretation of the postglacial ontogeny of 'Kap Inglefield Sø'. This lake should serve as an important reference site for future paleoecological comparisons in this climatically sensitive region.

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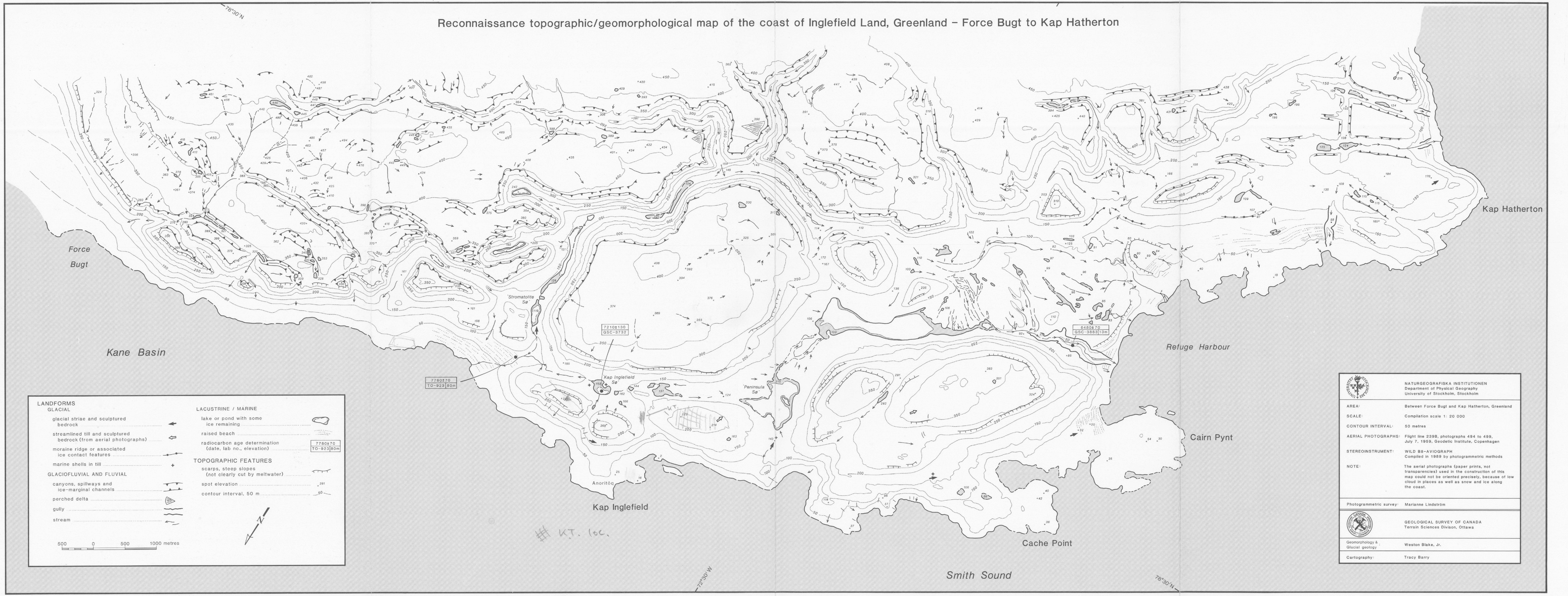
Plate I. Reconnaissance topographic/geomorphological map of the coast of Inglefield Land, Greenland – Force Bugt to Kap Hatherton.



KAP INGLEFIELD SØ 78°32'N 72°21'W

INGLEFIELD LAND, NW GREENLAND

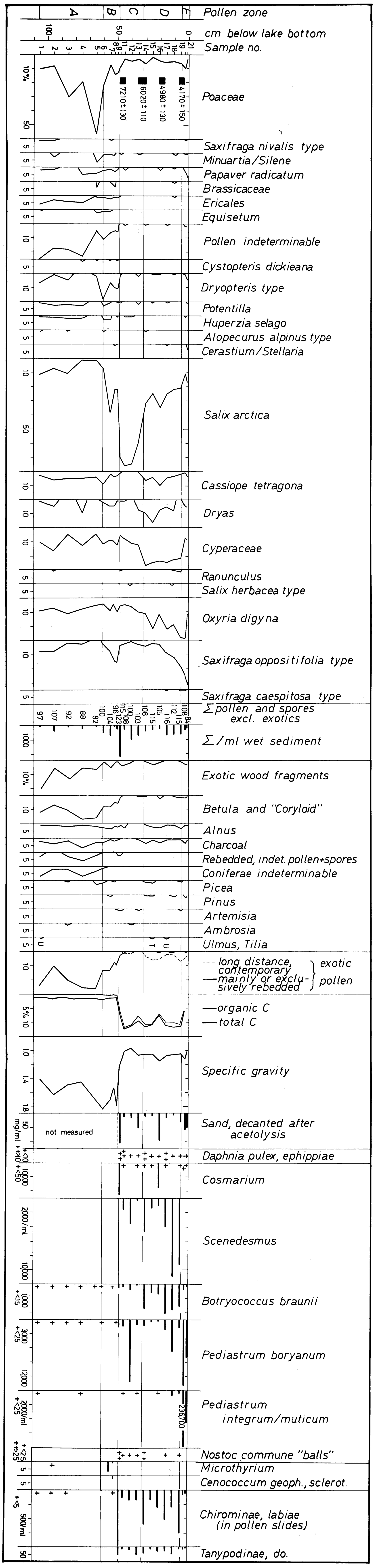


Plate II. Diagram of pollen, algae and other components in the 1980 core from 'Kap Inglefield Sø'. Radiocarbon dates are in uncalibrated ¹⁴C years before 1950.

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Two copies of the manuscript, each complete with illustrations, tables, captions, etc. should be sent to the Secretary, Kommissionen for videnskabelige Undersøgelser i Grønland. Manuscripts will be forwarded to referees for evaluation. Authors will be notified as quickly as possible about acceptance, rejection, or desired alterations. The final decision on these matter rests with the editor.

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Place names. – All Greenland place names used in the text and in illustrations must be names authorised by The Greenlandic Language Committee. Authors are advised to submit sketch-maps with all required names to the Secretary for checking before the manuscript is submitted. Names of Greenland localities outside the area with which the paper is concerned should be accompanied by coordinates (longitude and latitude).

Title. – Titles should be as short as possible, with emphasis on words useful for indexing and information retrieval.

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