Papers

A STUDY OF LATE-QUATERNARY PLANT-BEARING BEDS IN NORTH-CENTRAL BAFFIN ISLAND, CANADA

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ABSTRACT. Buried plant-bearing beds along Isortoq River at the northern end of Barnes Ice Cap on Baffin Island have been dated at more than 38,830 and 40,000 years B.P. A palynological and palaeobotanical study has indicated the presence of species (e.g. dwarf birch) which now occur several hundred kilometres south of this locality. Because of the inferred climatic conditions, more favourable than the present, an interglacial age (Sangamon) is assigned to the Isortoq plant bearing beds. Folding of the Isortoq beds by overriding ice and the orientation of the overturned folds indicate accumulation of the initial ice cap east of this locality.

RÉSUMÉ. *Étude des dépôts végétaux fini-quaternaires dans le centre-nord de l'île de Baffin, Canada.* On a daté à plus de 38,830 et 40,000 ans av. p. respectivement des horizons végétaux enfouis le long de la rivière Isortoq, à l'extrémité nord de la calotte de Barnes, sur l'île de Baffin. Des études palynologique et paléobotanique indiquent la présence d'espèces (comme le bouleau nain) qui se retrouvent aujourd'hui à plusieurs centaines de kilomètres au sud de cette localité. En déduisant des conditions climatiques plus favorables qu'à présent, on assigne à ces horizons un âge interglaciaire (Sangamon). Le plissement des horizons par de la glace de recouvrement et l'orientation de ces plis indiquent que l'accumulation d'une calotte initiale s'est produite à l'est de la localité.

АБСТРАКТ. ИССЛЕДОВАНИЕ ПОЗДНЕ-ЧЕТВЕРТИЧНЫХ ФЛОРИСТИЧЕСКИХ ПЛАСТОВ В СЕВЕРО-ЦЕНТРАЛЬНОЙ ЧАСТИ ЗЕМЛИ БАФФИНА. Погребенные флористические пласты вдоль реки Исорток, у северного конца ледника Барнес на Земле Баффина были датированы свыше 38.830 и 40.000 лет тому назад. Палинологическое и палеоботаническое исследование показало наличие видов (напр., карликовая береза), которые теперь растут несколько сот километров южнее этой местности. Ввиду означенных климатических условий, более благоприятных, чем современные, межледниковый период (Сангамон) установлен для флористических пластов Исортока. Складчатость пластов, проходящая через лед, и ориентация опрокинутых складок свидетельствуют об аккумуляции первичного покровного ледника на востоке от этой местности.

Introduction

THE PLANT-BEARING BEDS that are the subject of this study were discovered and first sampled along the lower Isortoq River by Andrews in 1962 during geomorphological reconnaissance of north-central Baffin Island. In 1963, as a part of the Geographical Branch Baffin Island Project, Andrews and Webber made further studies of the Isortoq site and also discovered similar beds exposed at Flitaway Lake near the northern end of the Barnes Ice Cap (Fig. 1). Additional investigations by Webber in 1964 concentrated on the palaeobotanical aspects and the recent botany of the area. Palynological studies of the samples from the plant-bearing deposits have been carried out by Terasmae.

Geomorphological studies of the region by Ives and Andrews (1963), Andrews (1963), Ives (1964), Sim (1964), and Andrews and Webber (1964)

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indicate that the Isortoq beds are of Quaternary age and older than the last regional glaciation. Further research, including palaeoclimatology, botany and sedimentology, has been aimed at establishing the nature of the depositional environment and the more exact stratigraphic position of the beds within the Quaternary sequence.

Physiography and Glacial History

The following brief account of the physiography of north-central Baffin Island is based on reports by Dunbar and Greenaway (1956), Ives and Andrews (1963), Ives (1964) and Sim (1964). The western coastal lowland, which slopes gently towards Foxe Basin, is characterized by low irregular hills separated by incised valleys. The interior of the island consists of an extensive plateau, the surface of which is at an average elevation of 550 msm (metres *supra mare*) but which rises northeastward from 240 m. to 760 m. Massive rounded hills rise 90 to 150 m. above this plateau surface and so reach elevations of more than 790 m. The valleys are generally very broad and open with relief commonly less than 90 m., though in the main valleys such as Isortoq and King the relief increases to 300 m. The Barnes Ice Cap (Fig. 1) lies on this plateau west of the regional divide and rises some 610 m. above the surrounding upland surface. It dams portions of preglacial, southwestward flowing drainage systems to form large lakes such as Conn Lake and Bieler Lake.

The interior plateau is bordered on the northeast by a rim of high (up to 1,680 m.), rugged mountains which are cut by northeast-trending fiords. Numerous valley and cirque glaciers occur in these mountains, as well as thin summit ice caps, and the slopes into the fiords are steep. These mountains are bordered by a narrow, broken strip of lowland facing Baffin Bay.

Aerial photo-interpretation, supported by ground studies, has indicated the following history of deglaciation for north-central Baffin Island (Ives and Andrews 1963). During the maximum of the last glaciation a centre of ice accumulation existed over Foxe Basin and ice flowed northeastward across Baffin Island. Some mountain nunataks existed in the high northeastern rim of the island. Outlet glaciers filled the fiords and probably formed an ice-shelf extending into Baffin Bay and Davis Strait. It is possible that some parts of the coastal lowland were not covered by glacier ice, partly because of the lowered sea-level at the maximum of the last glaciation. Ives and Andrews (1963) postulated that the local glacierization in the northeastern high mountains of Baffin Island at that time was probably not more extensive than at present.

During deglaciation, in late-Wisconsin time, the centre of ice dispersal shifted northeastward from Foxe Basin to lie over Baffin Island. Further northeastward retreat of the ice margin was followed by marine inundation of Foxe Basin and the western coast of Baffin Island. The position of the shoreline was controlled by the eustatic rise of sea-level and crustal uplift owing to diminishing ice load. Along the Baffin Bay coast the outlet glaciers retreated and a zone of recessional moraines was formed (the Cockburn moraines) at the heads of the fiords and on the adjacent plateau surface to the southwest. At this time the divide of the elongated ice cap on Baffin Island was to the southwest of the regional watershed and ice-dammed lakes developed along its margin. Recently an age of 8,000-9,000 years B.P. was given to the Cockburn moraines (Falconer, Andrews and Ives 1965), although a date of ± 8,300 B.P. is more likely.

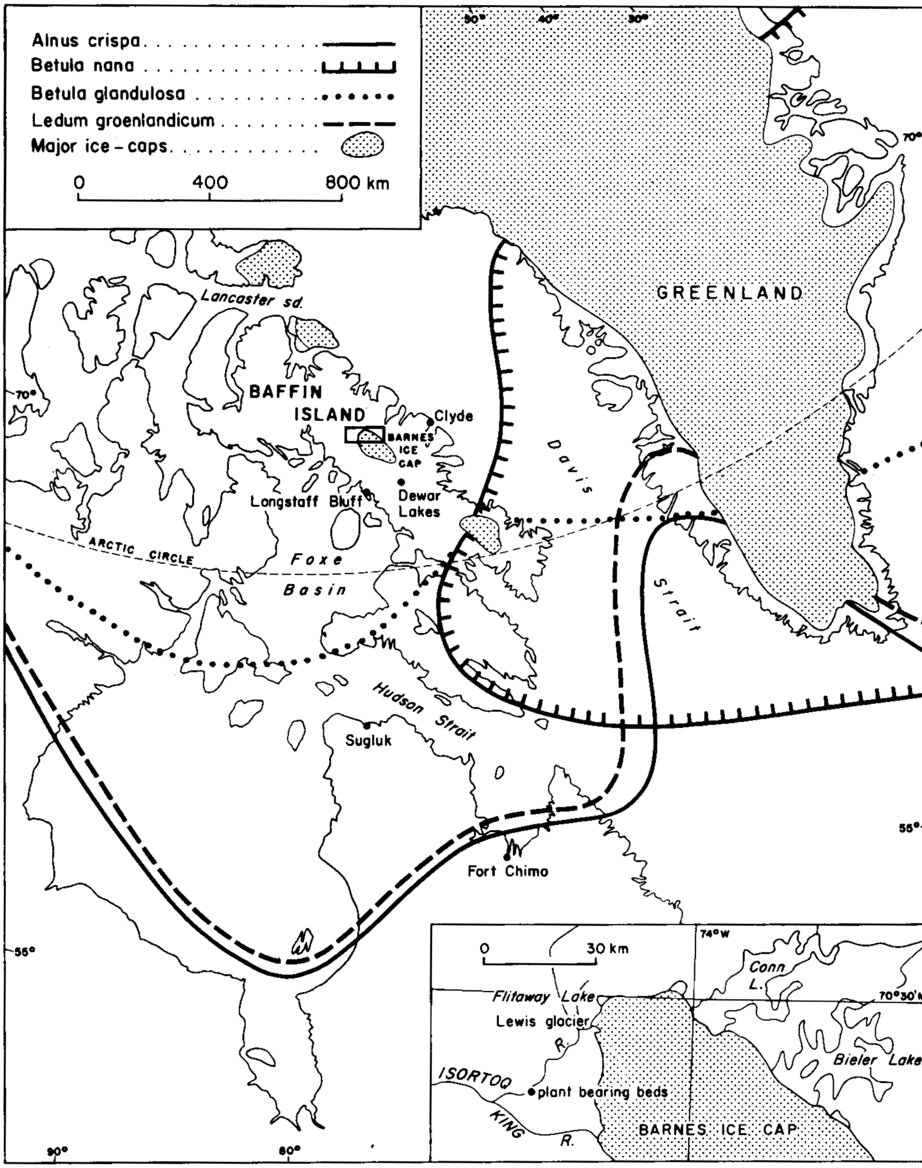

Fig. 1. Map of the eastern Nearctic, showing present distribution of four vascular plant species. *Alnus crispa, Betula nana, B. glandulosa* and *Ledum groenlandicum*. The inset map shows locations of fossil sites. Small rectangle indicates the location of the inset map.

Ives and Andrews (1963, p. 37) suggested that the present Barnes Ice Cap may be a relic of the last glaciation (Wisconsin). On the other hand, the small plateaux ice caps had a reduced areal extent in postglacial times. Ives (1962) postulated that about 70 per cent of the interior uplands of the region was covered by permanent snow and ice within the last two or three centuries. This estimate was based on aerial photo-interpretation of the extent of light-toned areas with only scattered lichen cover, believed to indicate former occurrence of permanent snow and ice cover (Beschel 1961).

The foregoing summary suggests that a study of the area immediately adjacent to the Barnes Ice Cap might yield valuable information on postglacial palaeo-ecology and palaeoclimatology.

Present Vegetation and Climate

The Canadian Arctic area lies north of the tree-line, which approximately follows the 10°C. July isotherm, and consists of two principal phytogeographic regions, the Arctic Archipelago and the continental Northwest Territories and Ungava (Fig. 2). These are distinguished climatically by the 7°C. July isotherm which roughly corresponds with the northern limit of the mainland (Fig. 3). Baffin Island, which belongs in the Arctic Archipelago, is separated as a biogeographical unit from the remainder of the Arctic by Lancaster Sound to the north; Fury and Hecla Strait and Foxe Basin to the west; and Hudson Strait to the south. These significant features and the high mountains that extend along the entire northeast coast of the island were pointed out by Porsild (1964).

The island can be subdivided into three major districts as shown in Fig. 2. These regions have been called *northern*, *central* and *southern* Baffin Island by Polunin (1948). Although the boundaries between them are arbitrary, Polunin believed that they represented fairly natural and different phytogeographic subdivisions (Polunin 1948, pp. 61 and 131). The Isortoq plant bearing beds occur in the northern part of *central* Baffin Island.

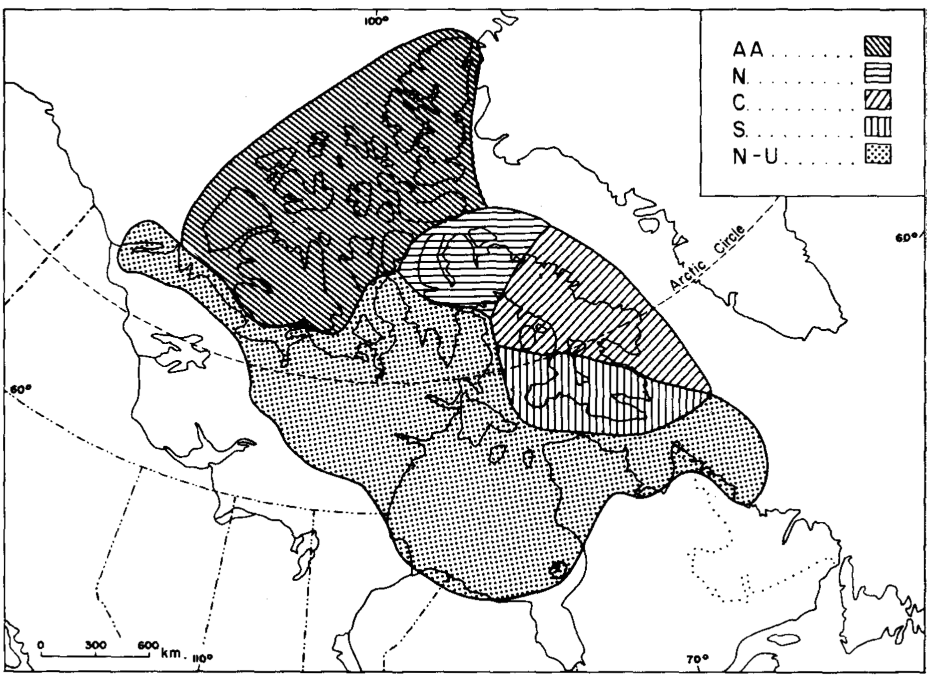

Fig. 2. Phytogeographic regions of the Canadian Arctic (after Porsild 1955). AA — Arctic Archipelago; N-U — continental N.W.T. and Ungava. N — Northern, C — Central and S — Southern are the major subdivisions of Baffin Island (after Polunin 1940).

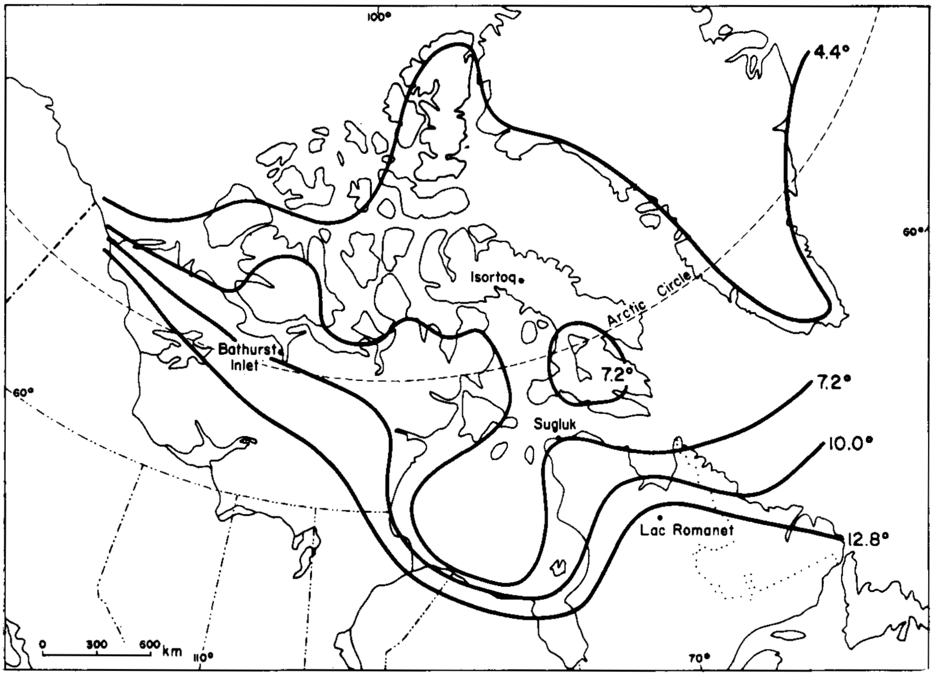

Fig. 3. Mean July daily isotherms (4.4, 7.2, 10.0, and 12.8°C.) of northern Canada and Greenland (after Boughner and Thomas 1960; Critchfield 1960).

Although a variety of factors, such as geographic setting, nature of the soils, and presence of migration barriers, might be used to assess the vegetation of a region, the number of vascular plant species and the climate are considered to be the simplest and most useful parameters for the present study (Table 1). The numbers of species in Table 1 have been obtained from Polunin (1948) and Porsild (1955) and the figures rounded to the next even ten because commonly species lists may be increased by further collections and by more critical taxonomic evaluation. The weather data have been interpolated from climatic maps and tables (Boughner and Thomas 1960; and Thomas 1960; and Cook and Mackay 1963). The length of growing season is expressed as the number of days when

Table 1. The number of species and some climatic parameters of selected areas within the Canadian Arctic.

PHYTOGEOGRAPHICAL REGION	NUMBER OF VASCULAR PLANT SPECIES	MEAN JULY TEMPERATURE (°C.)	MEAN ANNUAL TEMPERATURE (°C.)	NUMBER OF DAYS WITH MEAN TEMP. >0°C.	TOTAL ANNUAL PRECIPITATION (cm.)
Arctic Archipelago	330+	5.0 to 7.2	−17.8 to −9.4	80 to 135	13 to 38
Baffin Island:	240+				
northern (Pond Inlet)	150+	5.6	−13.9	90	18
central (Longstaff Bluff)	170+	6.2	−12.8	95	22
southern (Lake Harbour)	210+	7.2	− 7.8	135	38
Central N.W.T. and Ungava	650+	7.2 to 10.0	−12.3 to −7.7	110 to 155	13 to 51

mean daily temperature is above freezing, but it is known that in the Arctic many species are able to grow at temperatures which fluctuate around freezing (Sørensen 1941, p. 264) and that mean ground temperatures may be higher than the mean air temperatures that are measured at most weather stations (Powell 1961).

As expected, there is a southward gradient of increasing temperature, precipitation, length of growing season, and number of species. From north to southern Baffin Island there is an increase of 1.7°C. in the mean July temperature, 5.5°C. in the annual temperature, and an increase of about 60 species of plants.

At the moment there are no adequate climatic data available for the immediate Barnes Ice Cap area. The three nearest records for central Baffin Island (Fig. 1) are from Clyde (3 msm), Dewar Lakes (146 msm) and Longstaff Bluff (12.8 msm). A summary of the monthly precipitation and temperatures at these stations for 1961-1963 is given in Table 2. Three-year records may not be representative but they demonstrate the annual weather pattern for the region. Most of the precipitation occurs during the summer, and mainly on the west coast. Dewar Lakes has slightly higher July temperatures than the coastal stations. The data for interior central Baffin seem to be supported by data collected during the summers of 1963 and 1964 near the ice cap. The Lewis Valley at 230 msm has had mean July temperatures of 6.9°C. and 6.2°C. for these two years. Both are higher than those for the corresponding years at the other stations. The Lewis Valley is sheltered and the climate is much milder than at nearby Flitaway Lake (300 m. higher in elevation) which regularly has summer temperatures 3.9—5.5°C. lower than the Lewis Valley, and also receives slightly more rainfall. The marginal character for plant growth of this area is demonstrated by a delay in the flowering of many species compared with the more clement Lewis Valley (Webber 1964). It is important to note that rather large yearly climatic variations have occurred at the different stations. For example, the mean daily temperature for 1950 at Clyde was —20.1°C., and —32.6°C. in 1953. Precipitation at Clyde between 1949 and 1952 ranged from 31.8 to 44.0 cm., whereas in the following years (1953-1957) it was about 11.4 cm. with a low of 7.4 cm. in 1958.

The writers suggest that the climatic extremes occurring infrequently, rather than the average conditions, effectively limit the distribution of species. The meteorological data need to be more complete before reliable statements can be made but they indicate that the current poverty of the flora and vegetation in the Barnes Ice Cap region, as discussed by Webber (1964), is probably related more to the newness of this landscape surface than to the harsh climate or limited available habitats. The climate-vegetation relationships are complex and depend not so much on any single climatic factor, but rather on the combined effect of several.

The number of species around the northwestern margin of the ice cap is 84, but on the west coast it is 142. The difference is due only in part to fewer available habitats, for even if seashore species are excluded, the drop is still 45 species. Further comparison of the interior flora around the Barnes Ice Cap with that of the west coast can be made by considering the ratio of low to high arctic circumpolar species. Porsild (1955) lists for the Archipelago 33 high arctic species from a list of 143 circumpolar Canadian species, of which 68 are low arctic. For the circumpolar species in the Archipelago the ratio is 1:2 (low:high); for west coast stations of Baffin Island (Isortoq Fiord and Longstaff

Table 2. Meteorological data for 3 stations in Central Baffin Island. Data are monthly means for the three years 1961-1963.

	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	MEAN	TOTAL
Clyde 3 msm														
lat. 70°27′N. long. 68°33′W.														
Min. (°C.)	−31.3	−32.6	−32.8	−22.6	−13.8	−2.00	0.9	1.3	−3.7	−10.6	−21.3	−27.1	−16.3	
Max. (°C.)	−22.4	−24.4	−23.3	−11.2	− 4.4	4.6	9.4	7.5	1.6	− 4.4	−13.7	−16.9	− 8.3	
Mean (°C.)	−26.9	−28.5	−28.1	−16.8	− 9.17	1.3	5.1	4.4	−1.1	− 7.5	−18.1	−22.8	−12.3	
Precipitation (cm.)	1.32	0.05	0.15	0.41	1.55	0.41	2.18	3.56	5.74	2.29	1.65	1.02	—	20.33
Longstaff Bluff 12.8 msm														
lat. 68°18′N. long. 75°18′W.														
Min. (°C.)	−32.1	−33.3	−30.5	−19.5	−12.9	−1.2	4.4	2.3	−4.2	−13.2	−21.3	−26.7	−15.7	
Max. (°C.)	−24.4	−26.3	−25.0	−12.8	− 7.1	4.5	7.61	7.8	−0.1	− 7.4	−14.4	−19.3	− 9.7	
Mean (°C.)	−28.3	−29.8	−27.8	−19.4	−10.0	1.7	6.0	5.0	−2.1	−10.3	−17.9	−23.0	−12.7	
Precipitation (cm.)	0.28	0.33	0.79	0.36	1.68	0.89	5.23	4.76	4.04	1.88	0.58	0.56		21.38
Dewar Lakes 146 msm														
lat. 68°31′N. long. 71°10′W.														
Min. (°C.)	−31.5	−31.4	−29.5	−19.2	−14.3	−2.8	3.4	0.7	−6.8	−14.8	−20.7	−25.3	−16.1	
Max. (°C.)	−24.1	−24.9	−23.3	−12.7	− 8.6	2.78	10.5	6.1	−2.8	− 8.4	−14.3	−18.5	− 9.9	
Mean (°C.)	−27.8	−28.2	−26.4	−15.9	−11.4	−0.11	6.9	3.4	−4,8	−11.7	−17.5	−21.9	−12.9	
Precipitation (cm.)	0.64	0.20	0.33	0.84	2.13	0.76	2.24	4.98	3.46	1.49	1.09	0.66		18.82

Bluff) it is 1:1; and for interior sites (Lewis Glacier and Isortoq Valley) it is 1:2. Thus on Baffin Island there are proportionally more high arctic circumpolar species in the flora of the interior than at the west coast.

At the Isortoq beds locality, 16 km. from the ice cap, the vegetation is noticeably richer than at Lewis Glacier and Flitaway Lake. Several species, that are rare around the ice-cap margin, become common in the vegetation of the Isortoq beds where *Hierochloe alpina, Silene acaulis, Pyrola grandiflora, Vaccinium uliginosum,* and *Taraxacum arctogenum* are the most prominent. Although the vegetation is richer at that site than at the ice cap, it is still sparse and confined largely to valley bottoms, terraces, or hollows where there has been an accumulation of fine-grained deposits. Hill summits and sides that are covered with sand and coarse gravel have few vascular plants, and only in wet sites is there ever a complete cover of vegetation. Commonly the vascular plant cover is below 15 per cent and even the moss and lichen cover rarely exceeds 50 per cent of the total area. There is no noticeable accumulation of organic matter of plant detritus even in marshy or alluvial habitats.

The general aspect of the more common vegetation types in the upper Isortoq River valley area is shown in Figs. 4 and 5.

Description of Localities

ISORTOQ RIVER. On the basis of lichenometrical studies Andrews and Webber (1964) have estimated that the site of the Isortoq plant-bearing beds was deglacierized during the last 1,000 to 2,000 years. Major moraines mark the ice margin

Fig. 4. *Poa glauca* steppe which occurs on fine textured soils between cross valley moraines at the confluence of the Isortoq and Striding rivers. *Poa glauca* is the dominant species of this vegetation type; only a few other species occur here. They are *Salix arctica, Saxifraga caespitosa, Cerastium alpinum, Stellaria laxmanni* and *Draba glabella*.

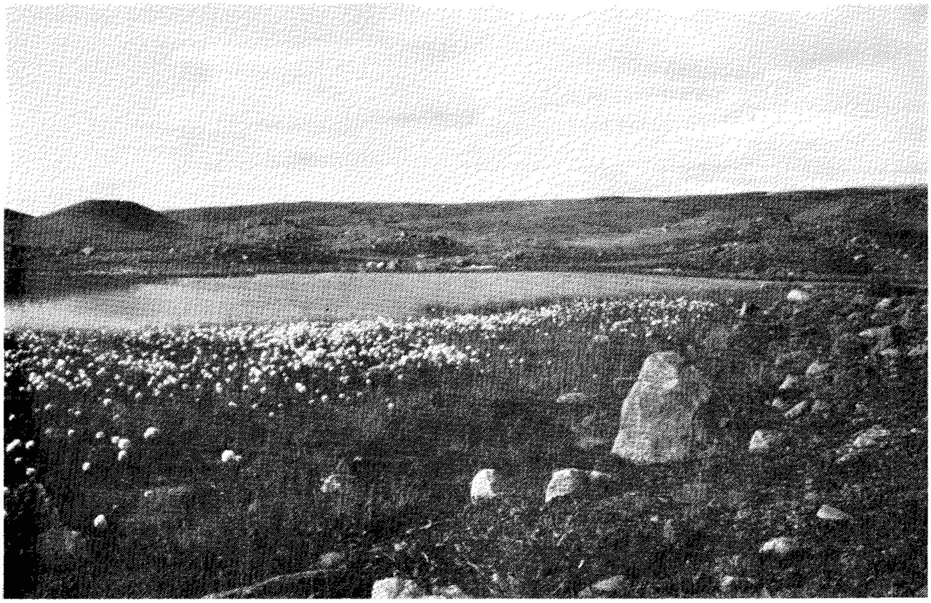

Fig. 5. *Eriophorum scheuchzeri* marsh around the margin of a small pond. The most frequent plants with *Eriophorum* are *Carex stans, Alopecurus alpinus* and thick mats of the mosses *Campylium stellatum* and *Aulacomnium turgidum.*

of the *King* phase (Andrews 1965) and are located at the junction of the Isortoq and King rivers (Fig. 1). These moraines are associated with an outwash and river terrace level now 30 m. above present river level. Following the *King* phase, the Isortoq lobe retreated upvalley, and a series of lower terraces was formed. The Isortoq plant-bearing beds were eroded and truncated by an outwash deposit, constructed by frontal meltwaters from the glacier, and now lying 4.6 m. above the present river level. Subsequent downcutting has exposed the beds along the river in a more or less continuous section of about 240 m. (Fig. 6). The main body of the beds has been folded, probably attributable to overriding by ice, and the orientation of the folds suggests a movement of ice from east to west (downvalley). The folds are truncated at the top (Fig. 7) and are overlain unconformably by a thinner unit of horizontally stratified alluvium containing a large proportion of plant material. The occurrence of boulders, and lenses of sand and gravel along this contact are considered to indicate the presence of a former till unit. The plant-bearing beds extend beneath the river level for an unknown depth, and drilling through the frozen sediments has not been possible. The deposit is composed of interbedded sand, silt, gravel, and plant detritus; the last occurs in layers as much as one inch thick. The predominantly organic layers are darker in colour and contain more leaves and compressed woody stems near the river level than higher up in the sequence where they are composed of smaller plant fragments and moss remains. A study by Andrews of the inorganic portion of these sediments has indicated an alluvial or glaciofluvial origin. He concluded that the sand and silt were not sufficiently well sorted to indicate aeolian deposition. The character of the beds indicates deposition under a general aggrading fluvial cycle.

The upper unit of horizontally stratified sediments is composed of alluvial deposits, derived in part by erosion and redeposition from the underlying folded sediments.

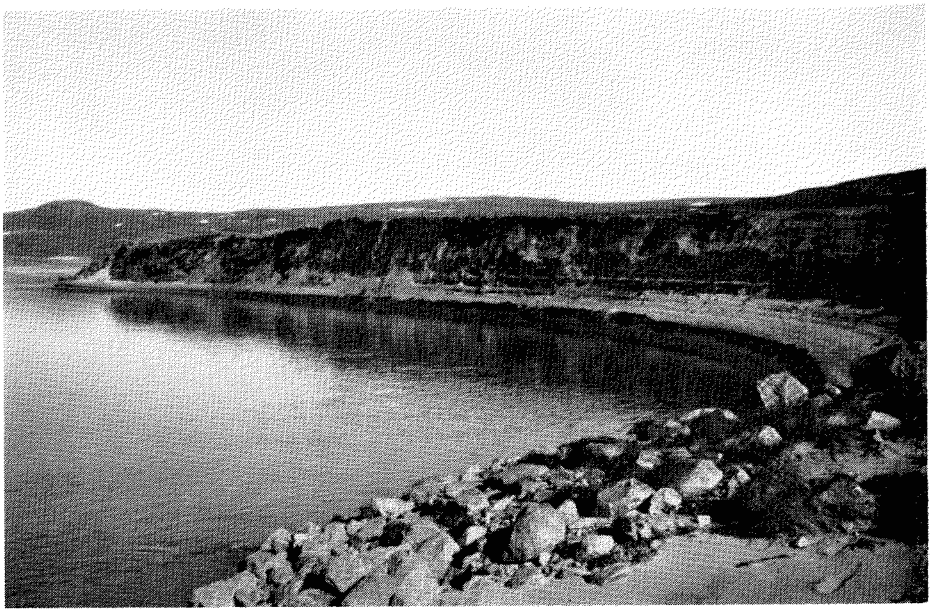

Fig. 6. The Isortoq exposure from the west. The Isortoq River is in the foreground.

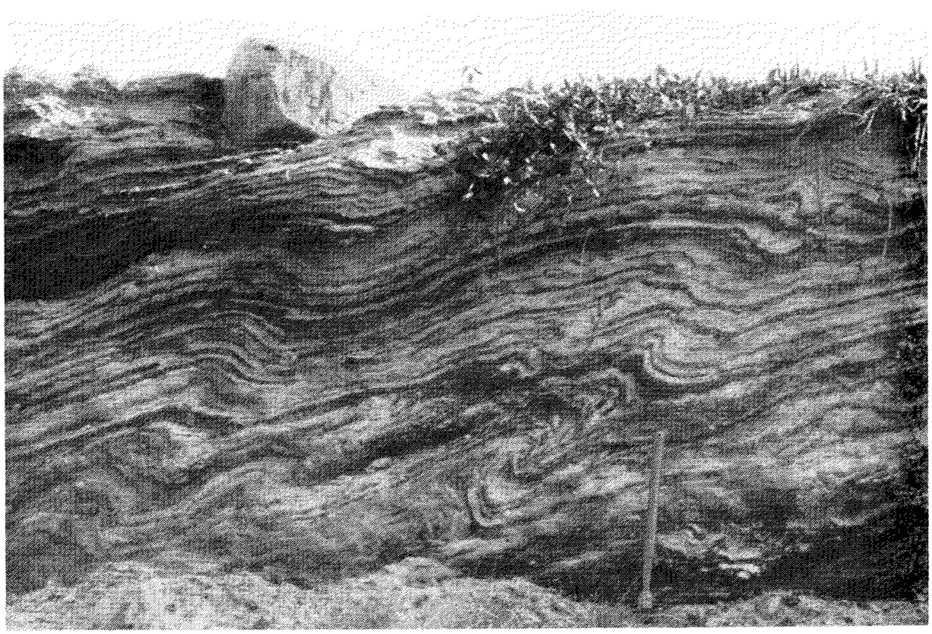

Fig. 7. Folded beds of the Isortoq deposit; the dark layers contain plant detritus.

FLITAWAY LAKE. This lake is dammed at the northern end of the Barnes Ice Cap, and the exposure of plant-bearing beds was found on a hillside some 30 m. above the 1961 level of the lake, and about 1 mile from the margin of the ice cap. This site was uncovered by the retreating ice margin about 100 years ago (Andrews and Webber 1964). The plant-bearing beds are capping a small hillock about 6 m. in diameter and 3 m. in height. This hillock has a solid ice core of unknown size which is overlain by sandy glacial till. The plant-bearing unit of stratified sand and plant detritus overlies the till. The inorganic material is comparable to that in the Isortoq exposure. The beds dip downward on all sides of the ice dome. It is assumed that the top of the plant bearing unit is truncated and forms an erosional surface, which was horizontal before the formation of the ground-ice core. Because of its present location perched on the side of a hill, it is suggested that this deposit is an erosional remnant of a formerly more extensive unit, or it may have been transported to its present site as a glacial float.

LEWIS GLACIER. Along the northern margin of Lewis Glacier (Fig. 1), several pieces of willow (*Salix*) wood were found embedded in a moraine, which was exposed sometime after 1948 by the retreating glacier margin, as indicated by air photographs taken that year. A piece of this wood was dated by the radiocarbon method, at >35,000 years (I-1240).

Palynological and Palaeobotanical Studies

A vertical series of samples for plant microfossil studies was collected from the Isortoq River exposure. In addition, several spot samples from various parts of the section were collected. Only one representative sample from the Flitaway Lake exposure was examined for plant microfossils. Palaeobotanical studies were made both in the field and later in the laboratory on large samples collected specially for this purpose. Numerous samples, spaced across the stratigraphic units were collected for radiocarbon dating. Only one sample (I-1233) was considered to have contamination by modern carbon. The other samples were all taken from a fresh vertical cut-bank face which had no plants growing on it.

In the laboratory, all samples were disaggregated by boiling them in dilute (10 per cent) potassium hydroxide. The sample was then put through a screen to remove the coarse fraction. Hydrofluoric acid was used on the fine fraction to remove some of the inorganic material, and the residue was treated with the acetolysis method.

At least 150 pollen grains and spores were counted in each preparation, and the counts were about 200 for each sample from the folded Isortoq beds because of greater pollen abundance in those deposits.

The fossil pollen of spruce, pine, birch, alder, and willow was classified under the heading of arboreal pollen in the diagrams for expediency in comparison of the Isortoq diagram with those from adjacent regions. Although some palynologists prefer to express the percentage of individual pollen and spore types based on the total count comprising the assemblage, the present authors prefer to subdivide each of the total assemblages into three major groups: the arboreal pollen, the non-arboreal pollen, and spores.

The scale of percentage in the pollen diagrams (i.e. the width of the vertical columns) has been expanded or compressed for certain pollen or spore types, to show a legible graph for very low percentages or to keep the size of the pollen diagram as a whole within reproducible limits. A vertical dashed line in some columns has been used to show legibly both the low and high percentages of this pollen type and to keep the total width of the column manageable for drawing the diagram.

Results of the palynological studies of the Isortoq River beds have been compiled in a pollen diagram (Fig. 8). This pollen sequence is truncated both

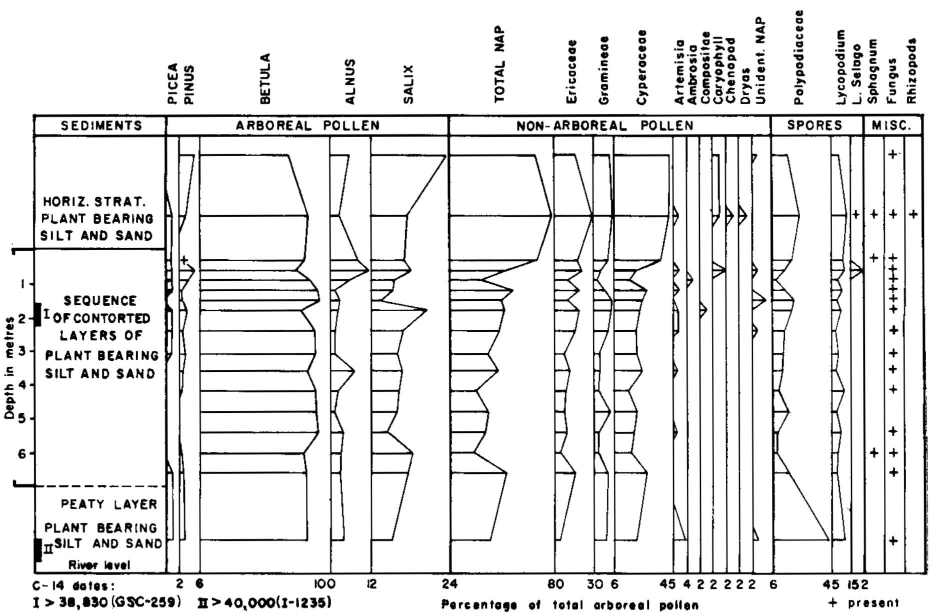

Fig. 8. Pollen diagram of plant bearing beds, Isortoq River exposure, Baffin Island, N.W.T.

at the base and top. It is difficult to determine on the basis of one diagram only whether certain minor changes in the pollen frequencies in the middle part of the diagram reflect regional or merely local changes in vegetation. However, the higher percentages of willow and nonarboreal pollen at the base and top of the diagram are of importance. The predominance of birch (*Betula*) pollen and the consistent presence of alder (*Alnus*) pollen throughout the diagram are significant features. Based on a comparison with available reference material the birch pollen appears to be that of dwarf species.

The occurrence of small numbers of spruce (*Picea*) and pine (*Pinus*) pollen are attributed to long distance wind transport.

The composition of a plant microfossil assemblage from the Flitaway Lake deposit is shown below.

Arboreal pollen	No. counted	Per cent
Pinus banksiana	2	1.5
Betula	105	78.0
Alnus	6	4.5
Salix	21	16.0
	134	100.0

NONARBOREAL POLLEN	NO. COUNTED	PER CENT
Ericaceae	26	19.0
Cyperaceae	23	17.0
Gramineae	1	0.7
Artemisia	1	0.7
SPORES	NO. COUNTED	PER CENT
Polypodiaceae	12	9.0
Lycopodium (not *L. selago*)	10	7.5
Fungus	present	

This assemblage is very similar to those from the Isortoq River exposure and suggests correlation of these two deposits.

A sample of fine material derived from the ice core of a moraine 48 km. to the south of this area and close to the ice cap margin was obtained by G. Østrem and was analysed for spores and pollen by Professor G. Erdtman. It contained the following assemblage:

	NO. OF MICROFOSSILS COUNTED
Pinus	3
Betula	76
Salix	2
Artemisia	1
Ledum (or *Empetrum*)	3
Other nonarboreal pollen	4
Monolete fern spores	24

This assemblage is similar to those of the basal part of the Isortoq River sequence and indicates that buried plant-bearing beds might be more common in north-central Baffin Island than so far determined.

The following list of macrofossils was identified by Webber from the Isortoq River and the Flitaway Lake deposits (fossils representing three of the species are shown in Fig. 9):

	ISORTOQ RIVER		FLITAWAY LAKE
	UPPER UNIT	FOLDED BEDS	
Betula scales	+	+	+
Salix herbacea leaves	+	+	+
Salix leaves	—	+	+
Salix capsules	—	+	+
Ledum groenlandicum leaves and pedicels	+	+	+
Ledum decumbens leaves	—	+	+
Vaccinium uliginosum leaves	—	+	+
Cassiope tetragona leaves and fruits	+	—	—
Carex leaves	+	+	+
Carex fruits	+	+	+
Sphagnum fragments	+	+	—
Polytrichum fragments	+	+	+
Drepanocladus fragments	+	+	+
Other Bryophyte fragments	+	+	+

(+ = present)

To obtain reference data on the present pollen deposition in north-central Baffin Island, several short cores of lake bottom sediment were collected in 1964

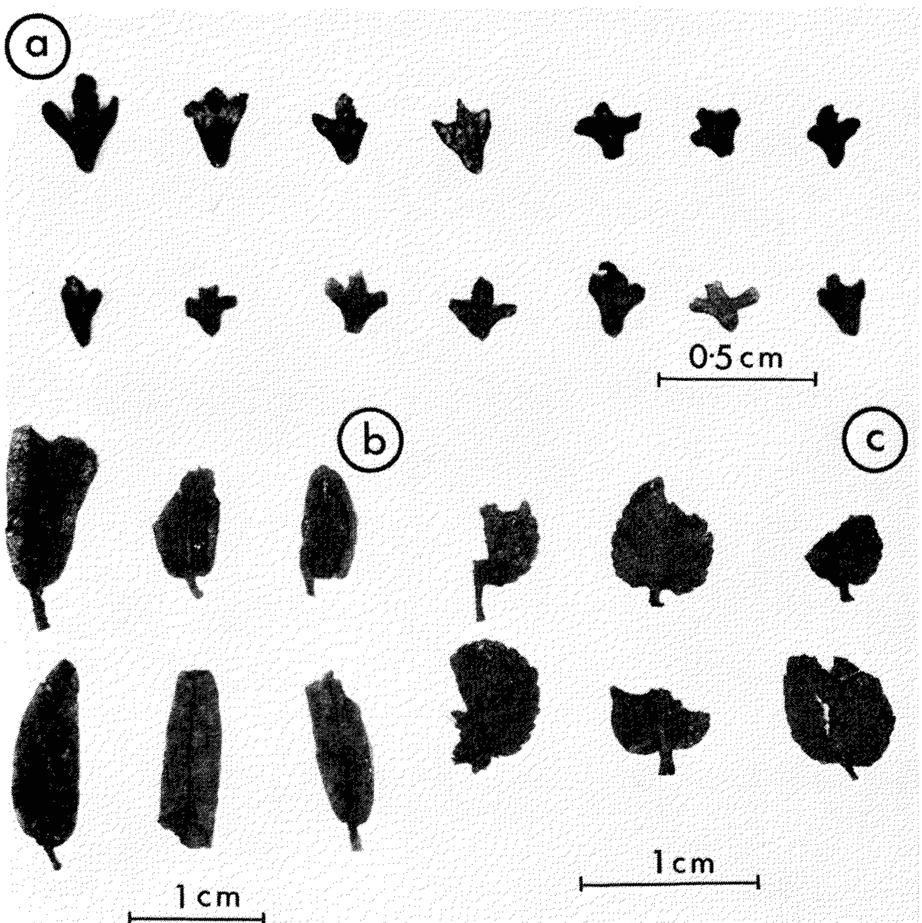

Fig. 9. Macrofossils from the Flitaway Lake deposit; (a) female cone scales of dwarf birch; (b) leaf fragments of *Ledum groenlandicum*; (c) leaf fragments of *Salix herbacea*.

by D. M. Barnett of the Geographical Branch. They were taken with a Phleger corer in a lake near the head of Inugsuin Fiord, east of the southern margin of the Barnes Ice Cap. Pollen frequency in the samples studied was low. The sediment was a silty clay with some fine sand and contained very little plant detritus. The following assemblage was obtained from the surface 10 cm. layer of sediment.

	No. of microfossils counted (4 slides)
Betula	2
Alnus	3
Salix	5
Pinus banksiana	2
Ericaceae	21
Cyperaceae	17

	No. of microfossils counted (4 slides)
Gramineae	13
Caryophyllaceae	1
Nonarboreal pollen (unidentified)	8
Polypodiaceae	3
Lycopodium selago (?)	4
Lycopodium sp.	1
Sphagnum spore	1

A sample of foliose lichens collected by Webber close to the ice cap and analysed for pollen by Professor Erdtman, contained a rather large assemblage of plant microfossils.

	No. of microfossils counted
Salix	33
Pinus	2
Ericaceae	5
Cyperaceae	4
Rosaceae	5
Potentilla sp.	4
Leguminosae	8
Elaeagnaceae	3
Nonarboreal pollen (unidentified)	9
Pteridophyte spores	1

Collections of airborne pollen were made in this area in 1963, but the results have not been compiled yet.

The palynological results presented here have demonstrated that the modern pollen assemblages recovered from surface samples are quite different from those preserved in the Isortoq and Flitaway beds, which contain an abundance of birch pollen. The surface samples contain little birch pollen, but may be rich in willow, grass, sedge, and ericaceous pollen.

Radiocarbon Dating

The dates obtained by the radiocarbon method are given in Table 3. The radiocarbon ages for the Isortoq River (folded unit), Flitaway Lake, and Lewis Glacier plant material all appear to be greater than the range of the dating method.

There is no reason to doubt the accuracy of the date itself of 14,000 years (I-1233) for the horizontally stratified sediments. However, assuming an age of 40,000 years for this unit, a contamination of 20 per cent by modern carbon would be necessary to produce the age of 14,000 years (Olsson and Blake 1961-62). The sample for radiocarbon dating from the horizontally stratified beds was carefully examined and rootlets were removed after inspection under a microscope. The resulting date of 14,000 years is anomalous if compared with others from the site and stands in contrast with the recent date of deglacierization suggested by Andrews and Webber (1964). Furthermore, the postglacial marine transgression along the west coast of the island is dated at about 6,700 years ago (Sim 1964; Ives 1964; Andrews 1965). It is suggested that the plant material in this stratigraphic unit is a mixture of materials derived from the old plant-bearing

Table 3. Radiocarbon dates for plant materials from north-central Baffin Island.

SOURCE OF MATERIAL	AGE IN YEARS B.P.	LABORATORY SAMPLE NUMBER
The Isortoq River Exposure		
1. Upper horizontally stratified beds	14,000 ± 400	I-1233
2. Top of folded beds (*c.* 30 m. east of the pollen profile)	>35,000	I-1234
3. Base of folded beds (*c.* 25 m. west of the pollen profile)	>40,000	I-1235
4. Upper part of the folded sediments:		
Soluble fraction	>36,900	GSC-259
Insoluble fraction	>38,830	GSC-259
5. Folded sediments near river level:		
Soluble fraction	>34,800	GSC-427
Insoluble fraction	>40,000	GSC-427
The Flitaway Lake Deposits		
A representative sample of the plant-bearing beds	>30,000	I-1241
The Lewis Glacier Locality		
Willow wood from moraine near the glacier margin	>35,000	I-1240

beds during the fluvial erosion of the beds at the 4.5 m. terrace level and plant detritus dating from the period of terrace deposition (i.e. 1,000 to 2,000 years ago). The exact age of these sediments remains unknown, but they are post-glacial, and probably date from the episode of high terrace formation about 1,000 to 2,000 years B.P. as estimated by Andrews (1965).

Discussion

The evidence obtained indicates that the lower, folded unit of the Isortoq beds was deposited in an alluvial environment along the former Isortoq River. The subsequent folding of the sediments by the overriding glacier indicates that they were not frozen at that time. Shear faulting rather than the observed folding would be expected if permafrost conditions had prevailed at the time (Mathews and MacKay 1960; Müller 1963). It is interesting to note that these alluvial beds were folded by ice movement from an easterly direction which implies that initial ice accumulation must have occurred east of this site and the glacier later advanced towards Foxe Basin.

Palynology has proved to be useful in the study of past vegetation and climate in obtaining quantitative estimates of plants present. However, disproportional occurrence of pollen, whether it results from differential preservation, production or dispersal, must always be considered carefully before interpretation of pollen diagrams (Terasmae and Mott 1965). When macrofossils are found in the samples used for pollen analysis, added assurance of the local presence of a species is gained. Using the mutually supporting palynological and palaeobotonical data in conjunction with records on the present day distribution of plants, it is possible to infer the climate at the time of deposition of the fossils. However, it is necessary to emphasize that the distribution of plants is not solely dependent on climate, but may be influenced by barriers to migration and edaphic conditions. Some indication of past climate can be obtained by considering the length of growing season and summer temperatures. The importance of these factors in controlling the distribution of plants in northern North America has been discussed by Sjörs (1963).

Present-day distribution of the plant species, found as fossils, may be grouped under three headings: (1) those that grow in the vicinity of the deposits (north-central Baffin Island); (2) those that reach their northern distribution limits in the area and occur only on the most favourable sites; and (3) those species whose present distribution limits now lie far south of north-central Baffin Island.

The following species are found living today in the middle Isortoq Valley: *Drepanocladus* species, *Polytrichum*, *Lycopodium selago*, *Dryas integrifolia*, *Vaccinium uliginosum*, *Cassiope tetragona* and several species of *Carex* and *Salix*, including *Salix herbacea*. The presence of *Cassiope tetragona*, a widely distributed arctic species in the fossil flora, indicates that the mean July temperature was probably not warmer than 10°C., as this isotherm coincides with its present southern limit. Occasional spores of *Lycopodium selago* were found in the deposits but another *Lycopodium* species (of the *L. annotinum* type) was much more common. Although *L. annotinum* may be present in the modern flora, only *L. selago* was collected.

Sphagnum, ferns (Polypodiaceae) and *Ledum decumbens* are restricted to the west coast of Baffin Island. *Ledum decumbens* is at its northern limit and the collections from Isortoq Fiord are the northernmost for Baffin Island (Webber 1964). *Sphagnum* and *Ledum* were found as macrofossils, and indicate that the climate must have been at least as favourable at the time of deposition as at present. It is not certain that ferns were present locally because no macrofossils were found and because their spores disperse efficiently.

Fig. 1 shows the distributions of 4 southern species. These limits have been derived from several sources, the main ones being Polunin 1940 and 1948; Porsild 1964; Raup 1947; Böcher *et al.* 1957. *Ledum groenlandicum* and dwarf birch are common macrofossils in both deposits. Their present distributions are restricted to southern Baffin Island. *Alnus* pollen is plentiful in the Isortoq beds, but no macrofossils have been found. The large quantities of pollen and its occurrence as aggregates suggest that the species was probably present in the immediate area. The northernmost alder species is *Alnus crispa* and the pollen has been assigned to it.

The specific identification of *Betula* pollen is difficult. The pollen (Terasmae 1951; Godwin 1956; Leopold 1956) and scales indicate a dwarf species. Hultén (1958) stated that no two authors agree on the taxonomy of northern *Betula* species and he refrains from drawing a distribution map of Amphi-Atlantic *Betula nana* L. ssp. *nana*. Polunin (1940), Porsild (1964), Böcher *et al.* (1957) and Swarzenbach (MS) list only two dwarf birches for Baffin Island and Greenland; *Betula nana* L. ssp. *nana* and B. *glandulosa* Michx. In Greenland *B. glandulosa* is restricted to the south. Böcher (1954) refers *B. glandulosa* to *B. glandulosa* var. *rotundifolia* (Spach) Regel. which he equates with *B. exilis* Sukatchev or *B. nana* L. ssp *exilis* (Sukatchev) Hultén. Hultén (1958) does not equate *B. nana* ssp. *exilis* with *Betula glandulosa* and he makes two species of them. He notes that these latter two species are commonly grouped as *Betula glandulosa* and that intermediate forms close to *B. nana* ssp. *exilis* are called *B. glandulosa* var. *rotundifolia*. For Baffin Island Hultén recognizes two dwarf birches, that is the two subspecies of *B. nana*, but for Greenland he lists in addition to these *B. glandulosa sensu stricto*. It is doubtful if the true *B. glandulosa* of the boreal forest or shrub zones of the subarctic is present today on Baffin Island. *B. nana* ssp. *nana* does not reach the mainland of Canada. In Labrador and Ungava in addition to *B. glandulosa* and *B. nana* ssp. *exilis*, *B. pumila* L. further adds to the confusion. The limits of *Betula glandulosa sensu lato* and *B. nana* in Fig. 1 follow Porsild (1964) and the determinations of our fossil material must stand as dwarf birch in the widest sense. In eastern Canada dwarf birches reach latitude

65°N. and even further north around the Penny Ice Cap of Baffin Island (Swarzenbach, F.H.; *in* Baird 1953). It is conceivable that *B. nana* ssp. *nana* could grow in north-central Baffin Island. Its absence might be owing to the barrier created by the eastern mountains. The apparent absence of *B. glandulosa sensu stricto* and the rarity of *B. nana* ssp. *exilis* in Baffin Island may be related to the greater continentality of Baffin (Cook and Mackay 1963) compared with Greenland. Böcher (1954) says that the latter two species are restricted to the oceanic southern areas of Greenland.

In discussing palaeoclimates the distribution in Greenland of *Ledum, Alnus,* and *Betula* cannot be ignored. Plant refugia and the humidity in the southern part of the island create a unique phytogeographical situation and several species including *Ledum groenlandicum* and *Alnus crispa* which are restricted to the tree-line in Canada go further north than the 10°C. July isotherm in Greenland.

The low value of *Pinus* and *Picea* pollen in the interglacial beds clearly indicates that the tree-line did not reach north-central Baffin Island at the time of deposition of the folded Isortoq beds. The interglacial climate of the Barnes Ice Cap region was probably similar to that of southern Baffin Island today.

A further improvement of the palaeoclimatic interpretation has been attempted on the basis of comparison of the Isortoq pollen diagram with those of postglacial deposits from the Ungava region of northern Quebec and the Bathurst Inlet area of the northern mainland coast, just south of Victoria Island (Figs. 10, 11, and 12). Although none of these pollen profiles, as a whole, is identical with

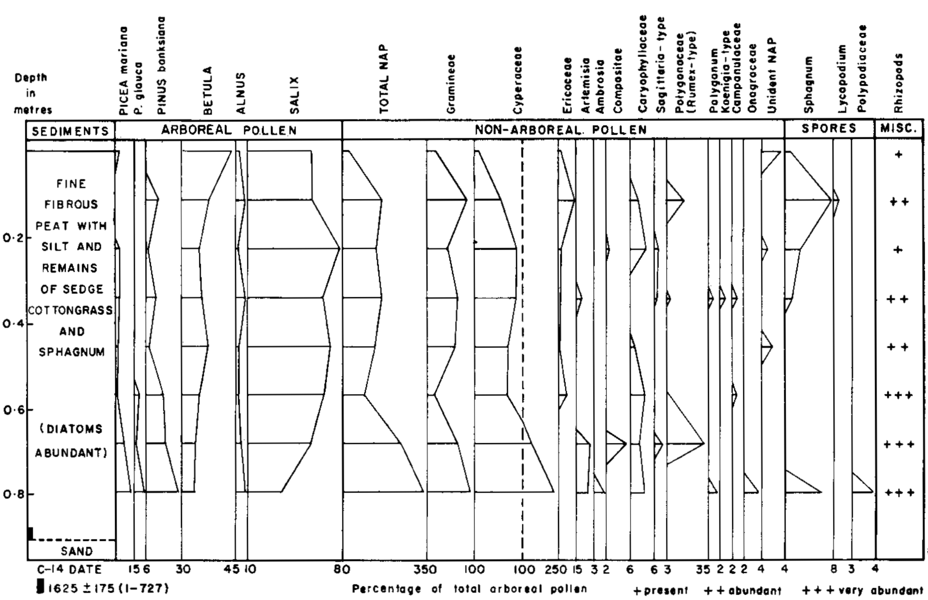

Fig. 10. Pollen diagram of surface peat, Vaccinium Valley, Sugluk Inlet, Ungava Peninsula, Quebec.

the Isortoq profile, there are certain diagnostic features which are helpful in palaeoecological correlation and interpretation of the Isortoq plant fossil assemblages. During most of the interval represented by the Isortoq folded sediments, the environmental conditions seem to have been similar to those in the present Bathurst Inlet area as indicated by the top part of the Bathurst diagram (Fig. 12). The greatest difference lies in the generally higher percentages of *Salix* in the Isortoq profile. Wenner (1947, p. 248) reports that high (4 per cent) values of *Salix* are good indications of tundra. This statement is supported by the abundance of willow pollen in the Sugluk profile and the present pollen spectrum from the lichen thalli in Baffin Island. However, the Isortoq profile shows an

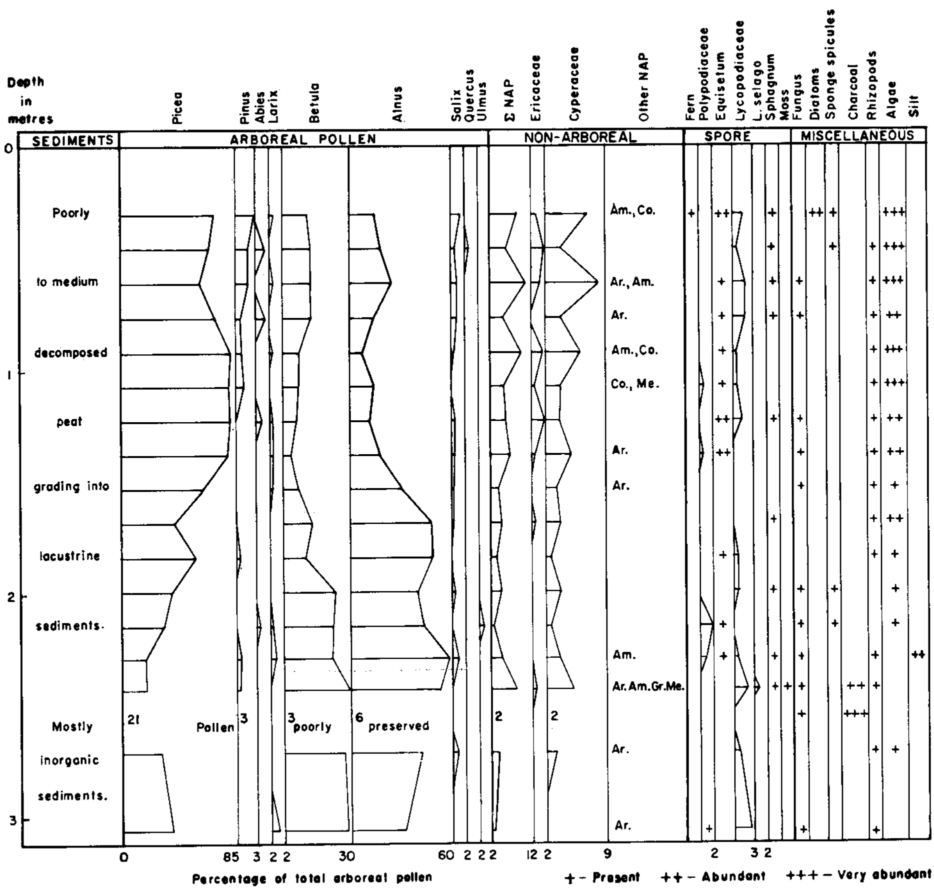

Fig. 11. Pollen diagram of lake and peat deposits, Lac Romanet area, Northern Quebec. Abbreviations: Am., *Ambrosia*; Ar., *Artemisia*; Co., Compositae; Gr., Gramineae; Me., *Menyanthes*.

abundance of birch pollen thoughout and the best correlation is with the late postglacial sediments at Bathurst Inlet, about 320 km. north of the tree-line. *Betula glandulosa* grows at Bathurst Inlet today.

Only the earliest postglacial pollen assemblages from the Lac Romanet area (Fig. 11) near Cambrian Lake, which lies within the limits of the northern Boreal Forest region 160 km. south of Fort Chimo, Quebec, bear any resemblance to the Isortoq assemblages. This evidence supports the assumption that the climate during deposition of the folded Isortoq beds was not similar to that prevailing now at or just within the northern tree-line. Unfortunately, there are no pollen diagrams from southern Baffin Island available for comparison.

Palaeoecological interpretation of the upper horizontally stratified unit of the Isortoq River exposure presents certain difficulties. The pollen diagram from the Sugluk Inlet area (Fig. 10), particularly the middle and upper part, is in many respects similar to the horizontally stratified sediments. It is possible that birch pollen, being more resistant than some other types of pollen, is over-represented

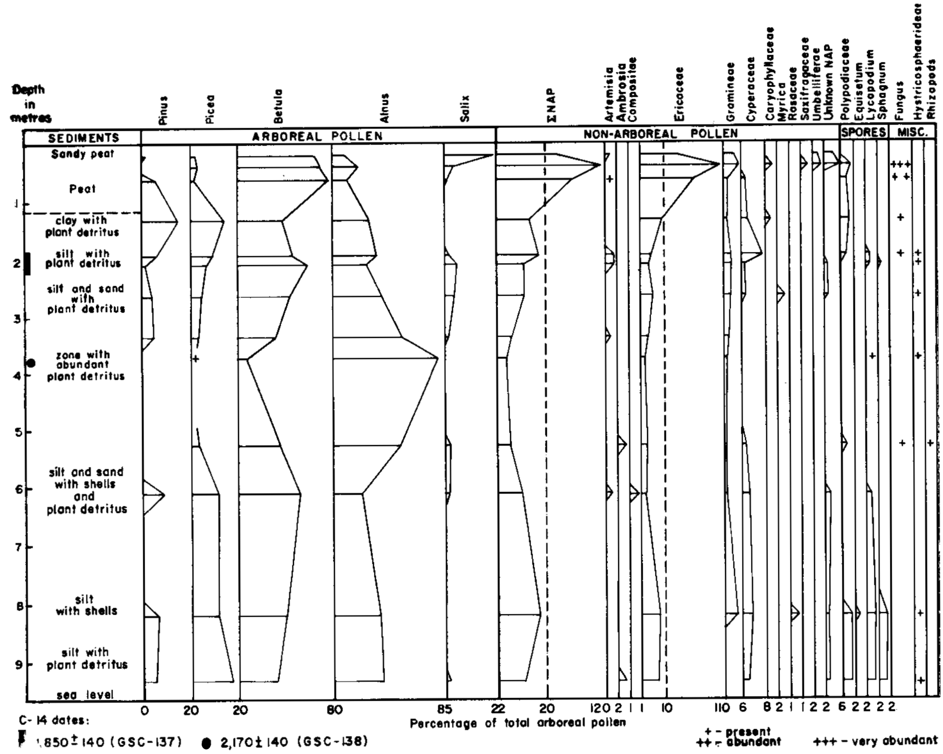

Fig. 12. Pollen diagram of postglacial deposits from head of Gordon Bay, Bathurst Inlet, Northwest Territories.

in the upper unit owing to redeposition from the underlying folded unit. The horizontal layers contain predominantly small plant fragments and the fossil *Betula* cone-scales may be redeposited, too. In the Sugluk area, and generally in Ungava north of latitude 60°, the vegetation is rich only in sheltered habitats; ridges and exposed slopes and hills are rather barren (Polunin 1948). Interior north-central Baffin Island may have resembled this region during the deposition of the horizontally stratified sediments. However, the established redeposition does not permit a more accurate estimate of the climate of this episode and it may have been similar to that of the present day.

The following interpretation is suggested for the Isortoq River and Flitaway Lake plant-bearing beds. The main part of the deposits accumulated during an interglacial interval dated at more than 40,000 years B.P. This statement concurs with similar findings from elsewhere in Canada where the climate of interglacial intervals is inferred to have been warmer than the present (Terasmae 1960).

The probable palaeoclimatic conditions during deposition of the interglacial Isortoq beds can be suggested on the basis of results of the palynological and palaeobotanical studies made, when compared with existing geobotanical and climatic conditions and modern ranges of the indicator (or prominent) species found in the fossil assemblages. July temperatures were probably between 7 and 10°C., that is, about 1 to 4°C. higher than the present. Total precipitation may have been 38 cm. a year which would represent an increase of 12.7 cm., and the growing season may have been 20-25 days longer, that is, a total length of about 120 days.

The vegetation was probably similar to that of southern Baffin Island today, or the Bathurst Inlet area on the mainland of Arctic Canada. Luxuriant shrubby vegetation was probably restricted to sheltered valley bottoms; the hill summits and uplands of north-central Baffin Island were probably almost barren.

The main unit of the plant bearing Isortoq beds was folded by overriding ice and the lack of shear faults within this unit suggests the absence of permafrost in the area at the end of the interglacial interval. Ice movement was from east to west suggesting an accumulation to the east of the site with subsequent advancement towards Foxe Basin. It is probable that there was no former Barnes Ice Cap during the proposed interglacial interval.

The discovery of three separate occurrences of plant-bearing beds, dated as older than the range of the radiocarbon method, and the presence of corresponding pollen assemblages in ice-cored moraines indicate that this stratigraphic unit of Late-Quaternary age may extend beneath the present Barnes Ice Cap along former river valleys, and that the buried plant-bearing beds might prove to be more common in north-central Baffin Island than determined to date.

The upper horizontally stratified unit of the Isortoq beds is probably postglacial in age, but the inferred redeposition from the underlying sediments makes dating of the unit difficult. Redeposition also complicates the interpretation of palaeoclimatic conditions during that episode and it is suggested that the climate may have been as favourable as that of present north-central Baffin Island.

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