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STUDIES IN THE VEGETATIONAL HISTORY OF GREENLAND

PALAEOBOTANICAL INVESTIGATIONS OF SOME HOLOCENE LAKE AND BOG DEPOSITS

BY

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WITH 32 FIGURES AND 24 TABLES IN THE TEXT,
AND 21 PLATES

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Abstract

The content of pollen in holocene, organic sediments in some Greenland lakes and bogs has been analyzed. The results are presented in relative and absolute diagrams. Furthermore, radiocarbon datings and macrofossil determinations are included in the description of the vegetational history. For the outer coast at Kap Farvel the first vegetation after the deglaciation around or shortly after 10,000 C^{14} years B.P. was an open pioneer vegetation of widely distributed arctic plants. No southern species are proved. Snow-patches seem to have been frequent until ca. 7200 B.P., when *Salix* and *Juniperus* immigrated. A further amelioration is indicated around 5300 B.P. *Betula glandulosa* immigrates ca. 3800 B.P. The hypsithermal falls within 5300–2200 B.P.

In the interior the sedimentation starts later. The vegetation was somewhat different due to the more continental climate, but the trend of the diagrams is parallel. *Salix* immigrates ca. 8000 B.P., *Juniperus* ca. 7000, *Betula glandulosa* between 4500 and 4000, and *B. pubescens* ca. 3600 B.P. The Norse settlement resulted in an opening of the scrubs and an increase in herbs, especially in the introduced strains of *Rumex acetosella*. The abandonment did not result in the extinction of the perennial "Norse plants".

In the beginning the hydrophytes were common in the poor lakes at the outer coast, but oligotrophication soon made them very poor, and most species died out.

At the head of Godthåbsfjord, West Greenland, the vegetational development is parallel and presumably synchronous to that in the interior of South Greenland. In North Greenland the composition of the vegetation seems to have changed little in the past 5000 years, but in a period roughly between 4000–2100 B.P. and again between 1500 and 900 B.P. the climate seems to have been less arid.

Exotic and long distance pollen is important in South Greenland sediments. Most common among the trees are *Alnus*, *Picea* and *Pinus*, but also herbs such as *Ambrosia*, *Artemisia* and *Chenopodiaceae* are frequent. Changes and differences in pollen and matrix sedimentation are discussed. At the outer coast 200–300, at the interior 1700–2700 pollen are sedimentated pr. cm^2/yr. The average gyttja sedimentation is 3.1 cm/100 yr. The content of pollen in 31 recent gyttja samples is discussed.

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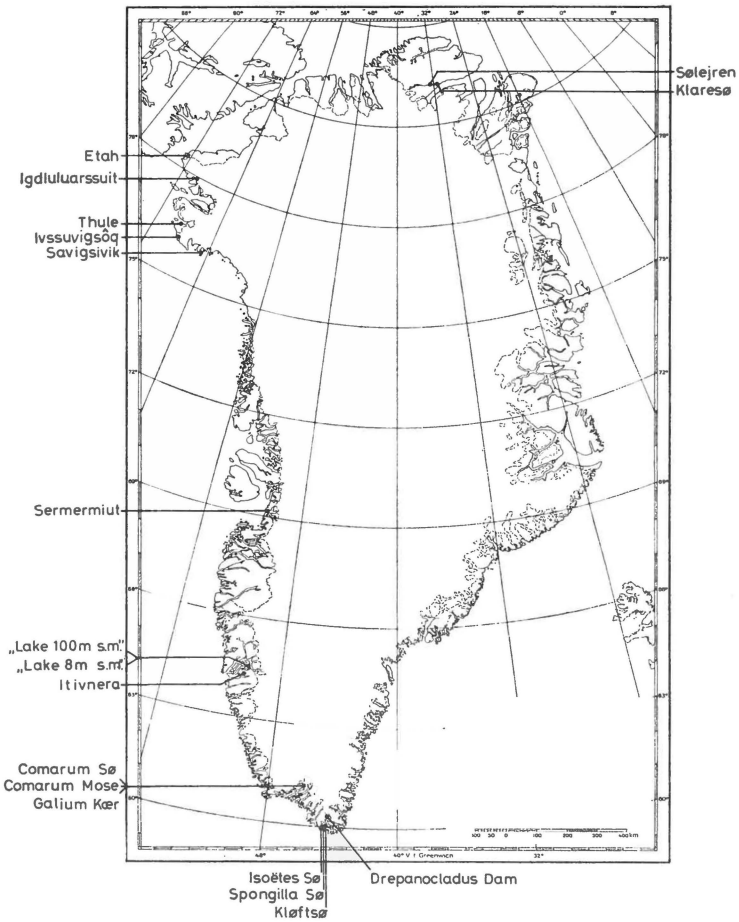
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Map of Greenland showing localities from which pollen diagrams are presented or discussed.

INTRODUCTION

When Johs. Iversen twenty years ago published his important paper on the history of the West Greenland vegetation in the light of pollen analysis only one paper dealing with similar topics in the Arctic part of the New World was found in his references, viz. Wenner's paper on Labrador. Not because of ignorance, but simply because no other work had been published. Due to this, the reconstruction of the vegetational history in this area was based only on the present distribution, combined with an increasing knowledge of the ecological demands. This resulted in often very conflicting views without any possibility for the disputing parties to prove or disprove their theories on a palaeobotanical basis.

In the past decade an increasing number of American and Canadian students have been fascinated by the Arctic and contributed to the elucidation of the problem. But comparing the size of the region with that of Northern Europe where the problems are far from settled, even though they have been tackled for many years, it is obvious that several decades will pass before we have just a rough picture of the immigration routes and of the refugia and their vegetation. I cherish no illusion that the present work has solved all problems. On the contrary, it may create more than it solves. Therefore it is nothing but a piece in a gigantic jigsaw puzzle.

The field work was carried out during six summers' stay in Greenland. Two summers were spent alone (Jakobshavn 1957, Qagssiarssuk 1969), two as a member of archaeological expeditions arranged by the Danish National Museum (Godthåbsfjord 1960, Qagssiarssuk 1962), one as a member of the Second Danish Peary Land Expedition (1963) and one on the Danish Kap Farvel Expedition (1970). I owe my best thanks for good fellowship to the leaders—Jørgen Meldgaard and Knud Krogh, assistant curators of the Danish National Museum, to Count Eigil Knuth, and to Dr. Ulrik Røen of the Zoological Institute of the University of Copenhagen—as well as to my companions, always willing to carry heavy coring equipment in trackless terrain.

The work at the microscope was initiated at the Department of Natural Sciences, the Danish National Museum. I wish to thank the Head of the Department, Dr. J. Troels-Smith, for permission to leave for several

summers' field work and to carry out the laboratory work. I am most grateful to Dr. SVEND JØRGENSEN and Dr. HENRIK TAUBER for numerous valuable and agreeable discussions throughout the years.

In 1969 the Danish National Museum gave me three years' leave of absence to take over a senior research grant at the University of Copenhagen. Thanks to the generosity of the late Dr. JOHS. IVERSEN and his successor, Dr. SV. TH. ANDERSEN, who placed at my disposal laboratory and office facilities, I have spent these three years at the Palaeobotanical Department, Geological Survey of Denmark having only one duty: to work up my Greenland samples.

Throughout the years I have had the good chance to discuss my material with a number of good friends and colleagues in Denmark and abroad, and I ask them to accept my summary thanks without giving a long list of names. Yet I owe special thanks to Mr. NIELS FOGED, Odense, who made diatom analysis on four of the corings (FOGED, 1972). Further to Dr. KJELD HOLMEN, Botanical Museum, and NIELS JACOBSEN, stud. scient., University of Copenhagen, for determination of mosses, to Dr. ULRIK RØEN, University of Copenhagen, for determination of zoological remains, to State Geologist WERNER CHRISTENSEN, Head of the Chemical Department, Geological Survey of Denmark and to Professor MOGENS KØIE, University of Copenhagen, for chemical analyses, and to Mr. HENNER BAHNSON, Department of Sedimentology, Geological Survey of Denmark, for determination of loss on ignition. I gratefully acknowledge the technical assistance of Miss BODIL DYRLUND, Geological Survey of Denmark, who typed the manuscript, and of Miss KIRSTEN ANDERSEN and Mrs. JETTE ØRNBJÆRG JENSEN, who carried out the painstaking work with all the diagrams. Mrs. KARIN FENNOW revised the English language of this paper.

Apart from the support provided by the stipend from the University of Copenhagen, the Danish Natural Science Research Council made possible my trips to Greenland in 1969 and 1970 (grant 511–25/69 and 511–173/69) and also paid for the drawing of the pollen diagrams (511–1078). The Geological Survey of Greenland placed a microscope at my disposal. I am most grateful to these institutions. Without their support this work would not have been possible.

METHODS

Field work

The borings in lakes and ponds were carried out from rafts constructed of wooden poles and empty 200 l petrol drums (fig. 11) or of perforated angle bars with 4 balloons made of heavy nylon (a bigger model of this type is shown in JUST (1970), figs 17–18). This latter type used during the Kap Farvel expedition in 1970 was easy to put together and take apart, and besides it was not too heavy to carry from the ship to lakes some distance from the shore. A canvas boat was used at the head of Godthåbsfjord, and in Peary Land the borings were undertaken from the ice.

The sampler used in most cores was a modified Livingstone sampler which made it possible to take out undisturbed ca. 115 cm long, 3.6 cm wide cores in plexiglass or aluminum tubes. In bogs and in the lakes at Godthåbsfjord a traditional Hiller peat sampler with a 50 cm long chamber was used. In some sediments this equipment works well, while in others contamination cannot be excluded. In the vain hope that contamination by upper layers could be diminished or even avoided, one of the Hiller chambers was equipped with thin, horizontal partition walls every 5 cm. It turned out that if a contamination could be registered in a "normal" Hiller chamber, it was also found in the septated chamber yet usually less contaminated in the deeper of the small sectors. The question of possible contamination will be discussed in the chapters dealing with the localities.

Whenever possible an open profile was dug, but this could only be done in shallow depressions with not too thick peat layers, and, by a stroke of good luck, through the 2 m peat and gyttja layers in the former pond Galium Kær.

In connection with the Livingstone cores and the open profile in Galium Kær clean 1 ml great pollen samples were taken by means of a 10×10 mm square brass tube with piston. The core was split lengthwise and the tube pressed through the gyttja with one of the sides parallel to the sedimentation limits. Thereafter the first part of the little core, which might be contaminated from the inner side of the plexiglass tube, was cut away—the small lumps in fig. 1—and the following 10 mm were cut directly in the pollen glass tube. When the gyttja was rich in mosses,

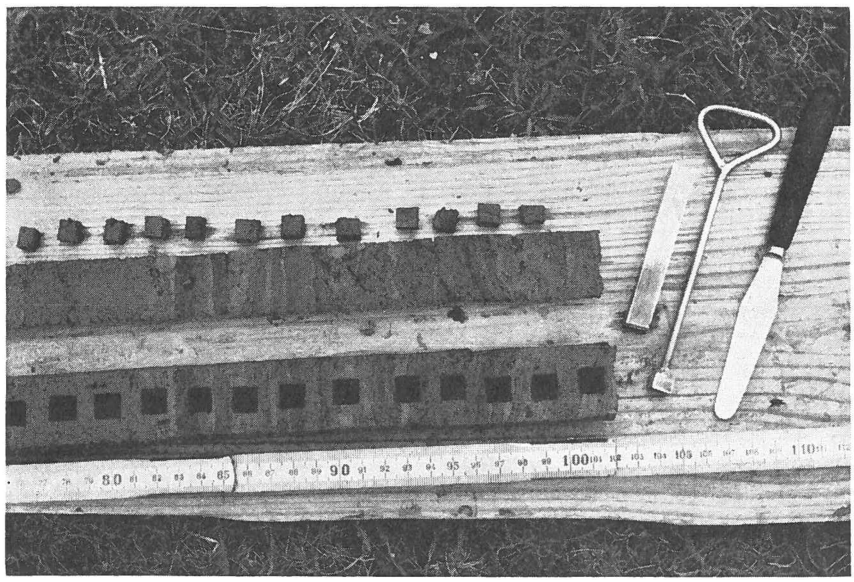


Fig. 1. Comarum Sø, site A. Deeper part of core reaching 502 cm below the water level showing laminated clay and clay gyttja.

or e.g. in the upper 25 cm swamp peat in Galium Kær, the small brass piston sampler did not work, and a Gillette scalpel or a very sharp pocket knife was used. It will be pointed out in the descriptions if this latter method was used to take out the samples, as this method is inaccurate.

In the open profiles 1 cm thick samples 10×10 or 15×15 cm square were taken for radiocarbon dating and macrofossil analysis. When the Livingstone sampler was used it was necessary to accumulate the samples from several cores, and thus a source of error is introduced. In all but one case (Comarum Sø), the whole holocene sequence was covered by taking two overlapping cores. At the bottom of the deeper one a very sharp limit between the late-glacial clay and the gyttja made it simple to arrive at a fixed level for all of the usually 7–10 cores which were used, whereas in the upper one the bottom of the lake indicated the other fixed level as soon as the boring began a few cm above the bottom. As the levels should be synchronous in the 2–3 m^2 of the investigation, this error is believed to be almost negligible. The samples are usually 2 or 3 cm high.

In a few cases it was necessary to use the content of the Hiller chambers for radiocarbon and macrofossil samples. This method should only be used if 1) no other possibility exists and 2) if the upper, usually looser layers are of a deviating colour which make a possible contamination of the deeper layers easy to discover. A comparison between the radiocarbon datings of the two samples taken out from 10 Hiller chambers in

Comarum Mose and corresponding datings based on Livingstone samples in Comarum Sø (pp. 101 and 96) shows the usefulness of this method, whereas a comparison of the two pollen diagrams Galium Kær A and B illustrate the shortcomings of using Hiller borers.

Usually the sediments have been described according to the system proposed by TROELS-SMITH (1955), and the descriptions will be mentioned below. On the other hand, for the sake of economy the signature system of that paper (TROELS-SMITH l. c.) was not used in the sediment columns in the pollen diagrams; only a very simplified system of signatures using the same symbols has replaced it.

In order to get recent pollen spectra a number of methods was used. These will be dealt with in a later chapter and will only be summarized here: In cored lakes the upper one to a few cm thick, watery, still greenish gyttja was fished up. In other lakes or ponds several methods were used, including a casting-net with a glass bottle for limnological sampling. In some cases, a Tauber trap (TAUBER, 1967) was placed on a post or, in the lake Comarum Sø, on a little raft. Finally, a petri-dish with glycerol in weather screens has been used twice (LICHTI-FEDEROVICH & RITCHIE, 1965).

Laboratory work

Macrofossil analysis

The macrofossil and radiocarbon samples were washed through a brass wire sieve with square openings 0.4×0.4 mm. The fine material washed through was sedimentated in big containers and concentrated by decanting. The size of the meshes is too wide to prevent very small seeds and megaspores from running through, and the number of *Juncus* and *Salix* seeds and of *Selaginella* and *Isoëtes* megaspores actually found in the samples must be considered too low. The coarse fractions were examined in small portions in a white plate under a low power stereo microscope and all macrofossils including oribatids, fragments of beetles and other zoological remains were removed and stored.

Pollen analysis

The standard procedure used in preparing of pollen samples is as follows: 1. Boil in 10 % potassium hydroxide on waterbath for 6 min. or longer if necessary. 2. Wash and dehydrate with glacial acetic acid. 3. Treat with 9 parts anhydric acetic acid and 1 part sulphuric acid conc. on waterbath at 100° C for 1 min. 4. Remove sand by decanting. 5. Place overnight in 40 % hydroflouric acid in polyethylene tube. 6. Treat with cold 10 % potassium hydroxide for 10 min. 7. Dehydrate the sample

by washing with pure, waterfree glycerol. 8. Stain with fuchsine and embed in pure glycerol. 9. Seal the coverslip with ercaline.

As all Greenlandic pollen samples contain aeolian silt and therefore have to be treated with hydroflouric acid, the use of polyethylene centrifuge tubes instead of glass tubes is indicative of an improvement of the method.

Most of the pollen samples have been counted "absolutely", and the method described by JØRGENSEN (1967) has been followed with slight modifications.

An attempt was made to count in each sample at least 500 and preferably between 500 and 600 pollen. On the other hand, as all pollen in the slides should be registered when counting absolutely, one has to finish a slide begun with, and therefore the number sometimes becomes too high. In a few cases when only some ten or twenty pollen were missing, to reach the 500 count the missing pollen were counted in another slide, but of course the calculations are only based on the slides counted absolutely.

In some of the diagrams from South Greenland the deepest sample (or samples) was so poor in pollen that fewer pollen were counted, e.g. in sample no. 1 in Isoëtes Sø with a calculated total of 812 pollen in the whole one ml sample. In the Klaresø diagram usually 100–150 pollen were counted. This indeed small number calls for a very cautious use of the results, but in many samples only 6–8 pollen were found per slide (24×24 mm coverslip) and the counting of 500 pollen per sample would at best have been overwhelming, in the worst case simply impossible, because not even 500 pollen could be found in the whole sample.

The results of the absolute pollen countings have been expressed in one of two ways, viz. 1) the pollen concentration expressed as number of pollen per unit weight, or 2) the pollen concentration per unit volume of fresh sediment. In the first case the samples were placed overnight at 105° C and weighed after cooling to room temperature. In the second case the 1 ml samples mentioned above were used.

The sand removed by decanting after the acetolysis was weighed in connection with all abs. counts. It seems a very inaccurate method of examining the content of mineral particles, but an experiment proved the justice of using, with precaution, the results thus obtained. The loss of ignition was kindly measured by Mr. HENNER BAHNSON at the Geol. Survey of Denmark on a series of small samples, usually 2–5 g each, from the open transect in Galium Kær. The results are shown in fig. 16 together with the results obtained by weighing the decanted sand in the two series of pollen samples. As was to be expected, the similarity between the loss of ignition curve is greater with the curve of decanted sand per g dry

sediment than with the curve of decanted sand per ml wet sediment. For further discussion of the curves, see p. 122.

In the same profile all the sand decanted from the pollen samples (Galium Kær B) was cumulated to one sample to get an idea of the size of the grains decanted. The sieving gave the following result: $> 177\mu$ 16 %, 177–125μ 10 %, 125–88μ 16 %, 88–63μ 21 %, $< 63\mu$ 37 %, showing that the decanted material was fine sand and coarse silt.

The pollen slides were counted on different microscopes throughout the years, but whatever microscope was used, a Leitz Apo 100 ×, NA 1.30 or 90 ×, NA 1.32 was mounted in the revolver. Phase contrast equipment with zenon light has always been available.

Chemical analysis

A number of water samples from lakes and ponds has kindly been analyzed at the Chemical Laboratory of the Geological Survey of Denmark. The results of the analyses are given in table 1.

Radiocarbon dating

A number of samples was dated at the Carbon-14 Dating Laboratory of the Danish National Museum and the Geological Survey of Denmark. If nothing is stated, the datings mentioned in the text are uncalibrated.

Identifications

Table 2 gives a summary of the Greenlandic species or genera found during the investigation. By means of asterisks I have tried to evaluate the reliability of the determination. Where no asterisk appears, the identification is uncertain; one asterisk indicates that it is fairly reliable, two that it is completely reliable. In a few cases a question mark (?) has been used in the table to indicate either a questionable occurrence or a less reliable determination in the area in question than otherwise stated. An elaboration of some determinations, as well as information about which species are included in a certain pollen type, appear in the following pages. Macro- and microfossils are treated separately. The latter are divided into two parts, viz. Greenlandic taxa and non-Greenlandic taxa. The nomenclature follows Böcher, Holmen, & Jakobsen (1968).

In addition to the species mentioned in table 2, only a few have been determined in a fossil state in West Greenland: *Carex lachenalii*, *Eriophorum angustifolium*, *Poa glauca*, and *Ranunculus lapponicus* (Fredskild, 1967a).

Table 1. *Chemical analyses of the water of some Greenland lakes.*

	Isoëtes Sø		Spongilla Sø		Kløftsø		Sphagnum Dam		Triangelsø		Drepanocladus Dam		Comarum Sø		Qagssiarssuk, "Vandsøen"		Qagssiarssuk, lake with *Subularia*		Klaresø	
	mg/l	m.eq./l	mg/l	m.eq./l	mg/l	m.eq./l	mg/l	m.eq./l	mg/l	m.eq./l	mg/l	m.eq./l	mg/l	m.eq./l	mg/l	m.eq./l	mg/l	m.eq./l	mg/l	m.eq./l
HCO_3^-	0.7	0.01	6.5	0.11	7.3	0.12	4.3	0.07	10	0.17	3.0	0.05	23	0.38	89	1.46	20	0.32	220	3.60
SO_4^-	3	0.06	4	0.08	3	0.06	< 1		8	0.17	2	0.04	0 or +		0 or +		0 or +		145	3.02
Cl^-	11	0.31	14	0.39	4.2	0.12	6.0	0.17	22	0.62	2.8	0.08	14	0.39	5	0.14	4	0.11	13	0.37
NO_3^-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ca^{++}	1.2	0.06	1.6	0.08	1.8	0.09	1.4	0.07	1.9	0.09	0.99	0.05	3.4	0.17	16	0.80	3.6	0.18	26	1.30
Mg^{++}	0.64	0.05	0.83	0.07	0.75	0.06	0.47	0.04	1.6	0.13	0.36	0.03	2.1	0.17	5.5	0.45	1.7	0.14	67	5.51
Fe^{++}	< 0.05		< 0.05		< 0.05		< 0.05		< 0.05		< 0.05		0.1		< 0.05		< 0.05		< 0.1	
Mn^{++}	0		0		0.01		0		0		0		0.01		< 0.02		< 0.02		< 0.02	
NH_4^+					0	0	0	0	0	0			0	0	< 0.1		< 0.01		0	0
Na^+	5.4	0.23	9.5	0.41	3.0	0.13	3.8	0.16	15	0.65	1.9	0.09	8.70	0.38	7.3	0.32	3.3	0.14	6.5	0.28
K^+	0.80	0.02	0.70	0.02	0.50	0.01	0.20	< 0.01	0.90	0.02	0.40	0.01	0.35	0.01	1.2	0.03	1.0	0.03	2.7	0.28
SiO_2	0.30		1.4		1.1		0.3		1.5		0.3		0		1.9		0.06		12	
pH	6.90		6.70		5.75		5.90		6.40		6.70		6.55		7.35		6.25		7.40	
PO_4^{---}	< 0.02		< 0.02		< 0.02		< 0.02		< 0.02		< 0.02		< 0.02		< 0.02		0.03		< 0.1	
$NaHCO_3$	24	0.28	5.9	0.07							16	0.19	3.4	0.04	18	0.21				
Zn^{++}	0.04		0		0.11		0.01		1.4		0									

Table 2. *Flora list of the fossil Greenlandic taxa.*

** Identification fully reliable * Identification fairly reliable ( ) All remains likely to be long distance transported, or rebedded (Klaresø)		p = pollen or spores f = fruits or seeds v = leaves, bracts etc.	see discussion page	Kap Farvel area	Qagssiarssuk	Head of Godthåbsfjord	Peary Land
Pteridophyta							
Equisetaceae							
Equisetum sp.	**	p		+	+	+	+
— *arvense*	**	v			+		
— *variegatum*	**	v					+
Isoëtaceae							
Isoëtes lacustris	**	p f	27	+			
Isoëtes sectacea ssp. *muric.*	**	p f	27	+	+	+	
Lycopodiaceae							
Diphasium type		p	27	+	+	+	(+)
Huperzia selago	**	p		+	+	+	(+)
Lycopodium dubium	**	p	27	+	+	+	
— *clavatum*	*	p	27		+		
Ophioglossaceae							
Botrychium sp.	**	p		+	+	+	
Polypodiaceae							
Cystopteris fragilis ssp. *fragilis*	**	p		+			
Cystopteris fragilis ssp. *dickieana*	**	p					+
Dryopteris type		p	28	+	+	+	+
Gymnocarpium dryopteris	**	p	28	+	+	+	(+)
Polystichum lonchitis	**	p	28	+	+		
Selaginellaceae							
Selaginella selaginoides	**	p f		+	+	+	
Gymnospermae							
Cupressaceae							
Juniperus communis	**	p v		+	+	+	
Angiospermae							
Betulaceae							
Alnus sp.	**	p		(+)	(+)	+	(+)
Betula sp.	**	p	23	+	+	+	(+)
— *glandulosa*	**	f	20	+	+		
— *nana*	**	f				+	
— *pubescens*	**	f	20	+	+		

(continued)

Table 2 (cont.)

				KF	Q	G	PL
Callitrichaceae							
Callitriche sp.	*	p			+	+	
Campanulaceae							
Campanula sp.	**	p			+	+	+	+
— *gieseckiana* ...	**		f	20		+	
Caryophyllaceae							
Cerastium alpinum/arcticum	**		f			+	
— *cerastoides*	*	p		25	+		
Cerastium-Stellaria type ..		p		25	+	+	+	+
Melandrium sp.....		p				?	
— *apetalum*	**	p	f				+
— *triflorum*.....	**	p					+
Minuartia type		p		25	+	+	+	+
Sagina sp.....	**	p		25	+	+	+	+
Silene acaulis	**		f		+	+		
Silene acaulis type.....		p		25	+	+	+	+
Stellaria humifusa	**	p				+	+	
— *media*.....	**		f			+	+	
Viscaria alpina	**	p	f	25	+	+	+	
Compositae							
Achillea-Tripleurospermum type		p		25		+	
Artemisia sp.....	**	p			+	+	+	
Erigeron type		p		25	+	+	+	+
Liguliflorae	**	p		25	+	+	+	+
Taraxacum sp.	**		f				+	
Convallariaceae							
Streptopus amplexifolius ..	**	p			+			
Cornaceae							
Cornus suecica/canadensis.	**	p			+	+		
Crassulaceae							
Sedum sp.	**	p		25	+	+	+	
Cruciferae							
Capsella bursa-pastoris ...	**		f			+	+	
Draba sp.....	**		f	20				+
— *bellii*	*		f	20				+
Eutrema edwardsii	**	p						+
Rorippa islandica.....	**		f	20		+		
Subularia aquatica.....	**	p	f		+	+	+	
Cyperaceae							
Carex atrata	*		f		+			
— *bigelowii*	*		f	21	+	+		
— *brunnescens*.....	*		f	21	+			
— *brunnescens/canescens*	*		f	21	+		+	

(continued)

Table 2 (cont.)

					KF	Q	G	PL
Carex canescens	**		f		21	+	+	
— *deflexa*	*		f				+	
— *macloviana*.....			f			+		
— *misandra*	**		f					+
— *nigra*.....	**		f		21	+		
— *norvegica*	*		f			+	+	
— *praticola*.....	**		f				+	
— *rariflora*.....	*		f			+		
— *rostrata*	**		f			+		
— *saxatilis*.....	**		f				+	
— *stylosa*	**		f			+		
— *stans*.....	**		f					+
Eleocharis palustris/ uniglumis.....	**		f		21		+	
Empetraceae								
Empetrum nigrum ssp. *hermaphroditum*	**	p	f	v	26	+	+	+	(+)
Ericaceae								
Cassiope type		p			26			+	+
Harrimanella type		p			26	+	+		
— *hypnoides* ..	**			v		+			
Ledum type		p			26	+	+	+	
Loiseleuria procumbens ...	**	p			26	+	+	+	
Phyllodoce coerulea.....	**			v		+			
Phyllodoce-Arctostaphylos type		p			26	+			
Gentianaceae								
Gentiana aurea	**	p					+		
— *nivalis*	**	p				+	+		
Lomatogonium rotatum ...	**	p						+	
Menyanthes trifoliata	**	p		v			+	+	
Gramineae								
Alopecurus alpinus type..		p							+
Alopecurus aequalis	**		f		21		+	+	
Catabrosa aquatica	**		f		21		+		
Elymus sp.	**	p			26	+	+	+	
Phleum commutatum type		p			26	+	+		
Poa sp.....	*		f		21		+		
— *annua*	**		f				+		
Puccinellia sp.....	**		f		21	+	+		
— *langeana*.....	*		f		21	+			
Haloragaceae								
Myriophyllum alterniflorum	**	p	f			+	+	+	
Myriophyllum spicatum ssp. *exalbescens*.....	**	p	f	v			+	+	

(continued)

Table 2 (cont.)

				KF	Q	G	PL
Hippuridaceae							
Hippuris vulgaris	**	p f		+	+	+	
Juncaceae							
Juncus arcticus	*	f			+		
— *biglumis/triglumis*	**	f					+
Luzula sp.	**	f			+	+	
Luzula-Juncus	**	p	27	+	+		+
Labiatae							
Thymus praecox	**	p		+	+	+	
Lentibulariaceae							
Pinguicula vulgaris	**	p		+		+	
Liliaceae							
Tofieldia sp.	**	p		+		+	
Oenotheraceae							
Chamaenerion sp.....	*	p	28	+	+	+	
— *latifolium* ..	*	p	28				+
Epilobium sp.	**	p			+		
Papaveraceae							
Papaver radicatum	**	p f				?	+
Papilionaceae							
Lathyrus japonicus	**	p		?	+		
Plantaginaceae							
Plantago maritima ssp. *borealis*	**	p f		+	+	+	
Plumbaginaceae							
Armeria sp.	**	p		+	+		
Polygonaceae							
Koenigia islandica	**	p		+			+
Oxyria digyna	*	p	28	+	+	+	+
Polygonum aviculare coll. .	**	p f			+	+	
— *viviparum*	**	p		+	+	+	+
Rumex acetosella	**	f			+		
— — */acetosa* ..	*	p	28	+	+	+	
Pomaceae							
Sorbus groenlandicus	**			+			
Portulacaceae							
Montia fontana	**	p f			+	+	
Potamogetonaceae							
Potamogeton alpinus ssp. *tenuifolius*	**	f	22		+		
Potamogeton filiformis	**	p f	22		+	+	
— *gramineus* ...	**	f	22		+		
Potamogeton sect. *Eupotamogeton*	**	p		+	+	+	
Ranunculaceae							
Coptis trifoliata	**	p		+	+		

(continued)

Table 2 (cont.)

					KF	Q	G	PL
Ranunculus sp.	**	p			+	+	+	+
— *acris*	**	f				+		
— *confervoides*	**	f			+	+	+	
— *hyperboreus*	*	f		22		+	+	
— *reptans*	*	f		22		+	+	
— *sulphureus*	**	f						+
Thalictrum alpinum	**	p			+	+	+	
Rosaceae								
Alchemilla sp.		p		29	+	+		
— *alpina*	**	f			+	+		
Comarum palustre	**	f				+		
Dryas type		p			+	+	+	+
Potentilla sp.	**	f				+		+
— *anserina*	**	f				+		
— *crantzii* type		p		29		+	+	
Potentilla-Comarum type		p		29	+	+	+	+
Rubiaceae								
Galium sp.	**	p				+		
Salicaceae								
Salix sp.	**	p	f	v 29	+	+	+	+
— *arctica*	**		f					+
— *herbacea* type		p		29	+	?	?	
Saxifragaceae								
Saxifraga caespitosa type		p		30	+	+		
— *foliolosa* type		p		30	+			
— *nivalis* type		p		30	+	+	+	
— *oppositifolia*	**		f					+
— — type		p		30	+	+	+	+
Scrophulariaceae								
Euphrasia type		p		30	+			
— *frigida*	**		f			+	+	
Pedicularis sp.	**	p					+	
Rhinanthus minor coll.	**		f			+		
Veronica sp.	*	p			+			
— *fruticans*	*	p				+		
Typhaceae								
Sparganium sp.	**	p			+	+	+	
— *hyperboreum*	**		f		+	+	+	
Umbelliferae								
Angelica archangelica	**	p			+	+	+	
Ligusticum type		p		30	+	+	+	
Vacciniaceae								
Oxycoccus palustris ssp. *microphyllus*	**		f		+			
Vaccinium uliginosum	**			v	+	+		

(continued)

Table 2 (cont.)

				KF	Q	G	PL
Vaccinium uliginosum /vitis-idaea	**	f		+	+		
Vaccinium type		p	26	+	+	+	
Violaceae							
Viola palustris	**	f		+	+		
Cenococcum geophilum	**	f		+	+	+	+
Chara sp.	**	f				+	
Nitella flexilis			142			?	
Sphagnum	**	p		+	+	+	(+)
Tilletia sphagni	**	p		+	+		

Macrofossils

Betulaceae

Nutlets and catkin scales of *Betula* are common in the South Greenland samples. In *B. glandulosa* the wings of the nutlets are narrow and the lobes of the scales well separated, while in *B. pubescens* coll. the wings are broader and the basis of the scale lobes more or less overlapping. However, the South Greenland tree birch is supposed to hybridize frequently with *B. glandulosa*, and the reference collections of *B. pubescens* show great variations of the two characters even in collections from a single tree. The fossil material from the coastal area near Kap Farvel was typical of *B. glandulosa*, while both species were represented in the material from the fjord heads.

Campanulaceae

One *Campanula* seed (0.72×0.33 mm) has been determined to *C. gieseckiana*. The length of recent seeds of this species is 0.60–0.80, while in *C. uniflora* 0.85–1.10 mm.

Caryophyllaceae

A photo of *Stellaria media* seeds from Qagssiarssuk is shown in FREDSKILD (1969a).

Cruciferae

A photo of *Capsella* seeds from Qagssiarssuk is given in FREDSKILD (1969b), and of *Rorippa islandica* in FREDSKILD (1969a). *Draba* seeds were common in the samples from Sølejren. The length of the seeds in the reference material varied greatly from collection to collection, only *D. subcapitata* usually having smaller seeds than the other high arctic species. However, *D. bellii* differs from the other species in having a broader, dark,

bead-like ring around the micropyle and generally a greater breadth of the seed. Most fossil seeds showed these characteristics and are thus referred to *D. bellii.*

Cyperaceae

The descriptions and keys in NILSSON & HJELMQVIST (1967) and in BERGGREN (1969) have been very useful. A number of achenes from all the South Greenland localities has been referred to as *C. bigelowii/nigra.* The shape and size of the achenes varies greatly within the reference material, yet the achenes of *C. bigelowii* show a tendency towards a more narrowly elliptic shape and greater epidermis cells than *C. nigra.* A photo of *C.* cf. *bigelowii* from Qagssiarssuk is given in FREDSKILD (1969 a). A complete fruit of *C. nigra* (2.6×1.25 mm) was found in a sample from Spongilla Sø. It is easily distinguished from *C. bigelowii* because of the nerved perigynium. The achenes of *C. brunnescens* and *C. canescens* are very alike, yet they are usually more broadly stipitated and with a thicker wall in the former. Some achenes from Drepanocladus Dam are referred to *C. brunnescens*, some from Eqalugialik to *C. brunnescens/canescens*, while the bulk of achenes of this type has been determined as *C. canescens.* 29 achenes of *Eleocharis palustris* or *E. uniglumis* were found in three samples from Galium Kær. At the base of the best preserved specimen (1.50× 1.25 mm) one bristle, 1.9 mm long, remained, but even in a highly destructed state the achenes are still determinable because of the compact wall and the swollen style-base.

Gramineae

There is a photograph of *Alopecurus aequalis* spikelets from Qagssiarssuk in FREDSKILD (1969b), and of *Catabrosa aquatica* grains from the same locality in FREDSKILD (1969a). The grains of *Puccinellia* can be distinguished from other Greenland genera by having more or less rectangular to square cells of pericarp and a small, rounded hilum some distance from the base, cf. KÖRBER-GROHNE (1964). Three *Puccinellia* grains were found: 1.75×0.65 mm (Comarum Sø), 1.20×0.55 mm (Isoëtes Sø) and ca. 1.4×0.5 mm (Spongilla Sø). According to SØRENSEN (1953), most Greenland species of *Puccinellia* produce grains 1.7–2.1 mm long. The only exceptions are *P. langeana* ssp. *typica* (1.2–1.4 mm), a high arctic species now distributed from West Greenland between $65^1/_2°$ and $70^1/_2°$ N westwards to easternmost Asia, and *P. coarctata*, 1.4–1.6 mm, an amphiatlantic subarctic species. On the basis of their size the two grains from the Kap Farvel area can hardly originate from any other species but *P. langeana*, while the grain from Comarum Sø may originate from more species.

The grains of *Poa* are of the same shape as *Puccinellia* with a small rounded hilum at some distance from the base, but in contrast to *Puccinellia*, the pericarp in *Poa* is without visible cells (except in *P. annua* with rows of hexagonal cells). Some fossil grains have been referred to *Poa* sp. (Comarum Sø).

Potamogetonaceae

Three species of *Potamogeton* have been determined by means of their endocarps: *P. alpinus* ssp. *tenuifolius*, *P. filiformis* and *P. gramineus* (Galium Kær, Comarum Sø and Comarum Mose). The characteristics of the three species usually make a distinction safe (cf. the keys and descriptions in JESSEN (1955) and AALTO (1970). The fourth common species in Greenland, *P. pusillus* ssp. *groenlandicus*, rarely flowers, and it has only been found once with ripe fruits (FREDSKILD, 1961). The size of the endocarps from this collection is 2.6–2.7 × 2.0 mm in KOH treated material, thus differing much from the usually very small endocarps of the *Potamogeton* subsection *Pusilli*. The apex of the lid does reach the base of the beak. The lid is roof-shaped with a hint of a keel. No fossil achenes of this type were found.

Ranunculaceae

The variation in size and shape of achenes of *Ranunculus hyperboreus* and *R. reptans* is so great that a smaller overlapping may occur. Generally, the shape of *R. reptans* is more elongated than in *R. hyperboreus* and the length greater (1.25–1.65 in comparison to 1.00–1.25 mm).

Rosaceae

Within the genus *Potentilla* a number of species including such common ones as e.g. *P. tridentata*, *P. crantzii*, *P. nivea* and *P. chamissonis* have very similar - and very variable - achenes. Fossil achenes of this type have only been referred to as *Potentilla* sp.

Pollen, spores and other microfossils

The following treatment of the determined pollen and spores will be rather summary. Since the pollenmorphological discussions in the Sermermiut paper (FREDSKILD, 1967a) I have concentrated more upon analyzing a number of regional standard pollen diagrams rather than trying to determine almost every pollen grain as to species. There is no doubt that refined methods, including a very rich reference material, will make it possible to go further into the determinations of some pollen referred to as e.g. *Gramineae* sp., *Cyperaceae* sp. On the other hand, it may

well appear that the consequence of a plentiful reference material will be a realization of an untenable distinction between some species if the former distinction has been based on inadequate reference material.

As all the pollen slides are permanent mounts and the position of all rare or doubtful pollen were noted, a revision of some of the pollen was made before the diagrams were drawn and the pollen lists were made. In the following, locality and dating will only be mentioned in connection with some rare pollen. In general, the concept of types follows FREDSKILD (1967a) and further pollen morphological details will only be mentioned if necessary for the determination. For further pollen morphological discussions, often well illustrated by photos, see ANDERSEN (1961), BERGLUND (1966) and FLORIN (1969).

It should be kept in mind that although most of the material published in the present paper was analyzed during the past 3–4 years, part of it was worked out as early as 1960. It is hardly realistic to imagine a completely consistent determination of fossil pollen or a completely unchanged limit between two closely related, possibly overlapping types. Therefore my personal considerations about the reliability of the determinations should be noted. Also, as a consequence of still better reference material and training, more safely determined species will appear in the analyses. The absence of a certain taxon in an earlier diagram therefore does not incontestibly permit the conclusion that it did not appear. It may well be included in another taxon or type.

When on the following pages a species' name is mentioned without any comments, e. g. *Montia fontana*, it means that the pollen found actually originate from *Montia fontana* and no confusion with other pollen is possible. This is the case, too, when the comment is that the determination is fully reliable.

Indigenous taxa

Betulaceae

Betula sp. BERGLUND (1970) gives a summary of the more recent attempts to distinguish between shrub-like and arborescent birches. The diameter of all measurable *Betula* pollen in fossil as well as in some recent samples from South Greenland have been measured. The results are given in plate 1 as silhouettes giving the absolute number of pollen per size class. As the ΣP in most samples is about 500, and as the state of preservation throughout a core usually is rather constant, with a rather constant ratio between measurable and not measurable pollen, a glance at the size and shape of the silhouettes in the figures normally allows for a precise statement of the time of immigration of *Betula* to the surroundings and further what species of *Betula* occurred at a specific time.

Judging from the fossil material the mean size of *B. glandulosa* usually is between 23 and 30μ, while the mean size of *B. pubescens* ranges between 30 and 36μ. This agrees well with the results obtained by other authors, stating the ratio *B. glandulosa : B. pubescens* to be 0.82 (ENEROTH, 1951) and 0.78 (BRYAN, 1954) as well as with my own measurement of reference collections from Greenland giving the ratio 0.84, cf. table 3. The taxonomic position of the South Greenland *B. pubescens* coll. is not quite determined. Hybridization between *B. pubescens* and *B. glandulosa* seems to occur quite often.

Table 3. *Size measurements of recent Betula pollen.*

		MBet.	MCor.	MB:MC	
Betula glandulosa	1	27.22μ	32.28μ	0.843	
	2	24.91μ	30.10μ	0.828	0.835
	3	24.95μ	29.87μ	0.835	
Betula pubescens coll.	4	30.13μ	29.96μ	1.006	
	5	33.10μ	32.70μ	1.013	0.995
	6	36.74μ	37.98μ	0.967	

The collections are: 1. Kuánit, Arsuk, leg. S. LÆGAARD, one specimen. 2. Nunarssuit, leg. S. ØDUM, one spec. 3. Tunugdliarfik, leg. JOHS. GRØNTVED no. 2335, one spec. 4. Kuánit, Arsuk, leg. S. LÆGAARD, one spec. 5. Qagssiarssuk, leg. B. FREDSKILD no. 4525, one spec. 6. Narssarssuaq, leg. B. FREDSKILD no. 4570, several spec. In each sample 100 *Betula* and 100 *Corylus* were measured (δ = 1.67μ).

Most measurements of recent *Betula* were carried out on pollen in the recent gyttja samples (pp. 203–207), two on the content of Tauber traps (p. 207). The results are shown to the right in plate 1. The numbers on the plate refer to the pollen samples as follows: nos 1a and 1b are from fractions of the same sample from the lake in Itivneq, treated and measured in 1960 and 1971 resp., no. 2 = rec. gyttja sample 29, no. 3 = 28, no. 4 = 27, no. 5 = the Tauber trap in Comarum Mose, no. 6 = the Tauber trap in Galium Kær (both the whole season), no. 7 = rec. gyttja sample 26, no. 8 = 25, no. 9 = 24, 10 = 23, 11 = 22, 12 = 21, 13 = 20, 14 = 19, 15 = 18, 16 = 17, 17 = 16, 18 = 15, 19 = 14, 20 = 13, 21 = 12, 22 = 11, 23 = 10, 24 = 9, 25 = 8, 26 = 7, 27 = 6, 28 = 5, 29 = 4, 30 = 3, 31 = 2, no. 32 = rec. gyttja sample 1.

Caryophyllaceae

A tentative key to the pollen of the Greenland *Caryophyllaceae* was given in FREDSKILD (1967a). The treatment of the fossil grains in

that paper showed that when dealing with a sufficiently large fossil material conclusive results can be obtained. In the present paper the *Caryophyllaceae* pollen are too few to allow a statistical treatment of e.g. the pore number, and thus only fewer species or types can be determined.

A characteristic pollen hardly to be confused with any other is found in *Cerastium cerastoides*. The pollen referred to this species have scattered columellae and 12–15(16) large pores. *Viscaria alpina* has grains with columellae which may or may not be arranged in a reticuloid pattern. Only the grains with the reticulum have been distinguished as *Viscaria*, while other *Viscaria* pollen may be included in the *Minuartia* type. Besides some *Viscaria*, this type includes *Minuartia rubella*, *M. rossii*, *Arenaria humifusa*, *A. pseudofrigida*, *Honckenya* and possibly some *Silene acaulis*. Grains of the *Minuartia* type, but with very distinct spines, are separated as *Silene acaulis* type. The reference material at hand is not sufficient to exclude the possibility of a few other pollen included in the *Silene acaulis* type, although the bulk of the pollen referred to as this type is believed to originate from this species. *Sagina* pollen cannot be confused with other pollen, but a determination as to species seems questionable. Many pollen have been referred to as *Cerastium-Stellaria* type, including a number of widespread species such as *Cerastium alpinum*, *C. arcticum* and *Stellaria longipes* s.l.; in addition *S. calycantha*, *C. fontanum* and possibly *Minuartia groenlandica* and *M. stricta* are included in this type. Single badly preserved *Melandrium* sp. pollen from Qagssiarssuk are questionable. Some few grains have been referred to as *Silene-Minuartia* type.

Compositae

Achillea-Tripleurospermum type includes only *Achillea millefolium* and *Tripleurospermum maritimum*, *Erigeron* type includes *Erigeron* and *Gnaphalium*, and *Liguliflorae* includes *Hieracium*, *Taraxacum* and *Leontodon*.

Crassulaceae

It was impossible to distinguish between the species of *Sedum*. In the two diagrams from Galium Kær the lower maximum in the Sedum curve is mainly based on the occurrence of a pollen which in all but one respect is identical with *Sedum*. The exception is that the striation on the tectum was almost or totally invisible. However, as 1) true *Sedum* pollen occurred right to the beginning of the curve, 2) the maximum is synchronous with the maximum in the Comarum Sø 2 km away, and besides, these corresponding *Sedum* maxima occur in all other South Greenland diagrams, 3) the pollen did not resemble any other recent Greenland pollen, and 4) since long distance transport is excluded because of the

amount of pollen found in this very basin and its non-occurrence in other basins, it was decided to include these pollen in the *Sedum* curve.

Ericales (including *Empetraceae*, *Ericaceae* and *Pirolaceae* p.p.)

Well-preserved pollen tetrads of these families may be rather easy to group into a number of types, some of which are represented by only one species or genus. However, the often bad state connected with the unquestionably great variation within the same reference slide or within reference slides of different collections makes the determination a little unsafe. As all badly preserved or atypical ericaceous pollen are included in *Ericales* sp., it must be stated that the different curves such as *Empetrum*, *Vaccinium* type etc. represent minimum values of the species or type in question, and in this context it is also necessary to remember the presumed inconcistency during the years in separating closely related types.

The most common pollen tetrads originate from *Empetrum hermaphroditum*. The *Vaccinium* type includes *V. vitis-idaea*, *V. uliginosum* and *Oxycoccus*. In some samples e.g. from Comarum Mose, this type is very abundant, and significant curves are drawn. In most localities, however, pollen of this type are very sparse, and often the curve has not been drawn. Pollen of *Phyllodoce coerulea*, *Pirola grandiflora*, *P. minor* and *Andromeda polifolia* may be included in *Ericaceae* sp. The possibility of an inclusion in one of the preceding types cannot be totally ruled out. The *Cassiope-Harrimanella* type includes *Cassiope tetragona* and *Harrimanella hypnoides*. In South Greenland diagrams the term *Harrimanella* type is used, in North Greenland diagrams the term *Cassiope* type. The determination is fully reliable. This is the case, too, with typical *Loiseleuria* pollen, whereas less typical tetrads of this species may be included in *Ericales* sp. A few pollen of the *Ledum* type (including *L. palustre* ssp. *decumbens* and *L. groenlandicum*), and of *Rhododendron-Arctostaphylos* type (incl. *Rhododendron lapponicum*, *Arctostaphylos uva-ursi*, *A. alpina*) have been found.

Gramineae

The only fully reliable determination possible within *Gramineae* at the moment is the determination of *Elymus* sp., including *E. arenarius* ssp. *mollis* and possibly the European-Icelandic *E. arenarius* s.str. In the material from North Greenland the *Alopecurus alpinus* type has been separated, but the determination is not fully reliable, being mainly based on the size of the grains, cf. FREDSKILD (1967a). In the same way, *Phleum commutatum* type has been separated in South Greenland material, but further investigations are needed.

Isoëtaceae

As shown by ANDERSEN (1961) the overlapping of the size of the microspores of *Isoëtes setacea* ssp. *muricata* and *I. lacustris* is almost negligible. In one of the fossil samples (Spongilla Sø no. 21) the length of the exine in the first one hundred spores found were measured (δ = 1.67μ). The size varied between 14 and 26δ and grouped in the following classes (beginning with 14δ): 2–4–4–5–2–2–4–5–13–18–23–10–8. Before measuring, all spores 18δ or less were determined as *I. setacea*, while the two 19δ spores were determined as one *I. setacea* and one *I. lacustris*. All spores 20δ or greater were determined as *I. lacustris*. Usually the separation in localities with both species was made without measurements and usually without hesitation.

Juncaceae

Pollen of *Luzula* and/or *Juncus* are frequent in the material. A discussion including photographs of recent and fossil material of the characteristic tetrads appearing like a 4-porate single grain in fossil or acetolyzed state is given in FREDSKILD (1970).

Lycopodiaceae

Undoubtedly the spores referred to as *Lycopodium dubium* all originate from this species, but a few spores may possibly have been included in the following type. The fact is that in reference slides the one end of the variation is made up of spores with so many luminae across the distal surface that, found separately in a fossil slide, they would doubtless be determined as *Diphasium* type. This type includes *D. alpinum* and *D. complanatum*, and possibly single species of *Lycopodium dubium* and *L. clavatum*. The spores of the latter species are characterized by having even more luminae, the muri of which are usually very undulating and provided with knot-like thickenings in the corners. In the samples from the Kap Farvel area, usually very rich in *Diphasium* spores, a few spores were noted as being *Lycopodium clavatum*. As it appeared, however, since this occurrence was related to the maximum in the *Diphasium* curve it is most likely that they represent the one end of the very wide variation. Because of this it was decided to include them in the *Diphasium* curve. Contrary to this, the distinction is retained in the diagrams from Qagssiarssuk area, in which *Diphasium* is very sparse. In the analyses from Comarum Sø 11 *Diphasium* and 2 *Lycopodium clavatum* spores were found. There is every probability that the 2 spores actually originate from *L. clavatum*.

Oenotheraceae

Big (usually 70–110μ wide), single-occurring grains are referred to as *Chamaenerion*, in the diagrams from Peary Land to *C. latifolium*. A few smaller grains united in tetrads originate from *Epilobium* sp. In the rather ample reference material at hand it was found that in a few of the *Epilobium* slides of various species single grains occurred, even if almost all of them were united in tetrads. A possibility that a single-occurring fossil *Epilobium* grain has been included in *Chamaenerion* cannot be excluded, but is hardly likely.

Polygonaceae

As a rule, the distinction between *Oxyria* and *Rumex acetosella/acetosa* is not difficult, but a few intermediate grains have been found. These are referred to as *Oxyria-Rumex* type. The variation and overlapping within *R. acetosella* and *R. acetosa* ssp. *lapponicus* is so great that I did not dare to separate them into two types. Most of the pollen have very long colpes and undoubtedly originate from *R. acetosella*, but a few pollen with short colpes characteristic of *R. acetosa* occur.

Polypodiaceae

The *Dryopteris* type includes all *Polypodiaceae* spores with a smooth surface and without a perine, the sculpture of which in some cases permits a closer determination. In a few fossil spores of *Cystopteris* the perine remained, and the very characteristic spiny resp. rugulate perine made a determination as to *C. fragilis* ssp. *fragilis* (Isoëtes Sø) resp. ssp. *dickieana* (Peary Land) safe. The perine of *Polystichum lonchitis* has a characteristic appearance, being more or less recticulate, with the corners of the reticulum drawn out like spines. This fact was not realized until during the analyzing of the Spongilla Sø samples, and thus *Polystichum* only appears in the latest analyzed diagrams (Spongilla Sø, Kløftsø and Drepanocladus Dam). I am perfectly sure that one or a few spores occurred in the material from the Qagssiarssuk area. The spores of *Gymnocarpium dryopteris* are characterized by a more or less reniform shape and a rounded-verrucate surface pattern. Spores with a similar surface pattern occur now and then in other reference slides of *Polypodiaceae* and in fossil samples, but then in connection with a completely straight proximal seam. The *Gymnocarpium* curves do not include spores with a straight seam.

Ranunculaceae

Generally, the sculpture on the exine of *Ranunculus confervoides* is finer than in other representatives of this genus, of which especially *R. lapponicus*, *R. sulphureus* and *R. acris* are coarse. However, the variation

is very great and in an area like South Greenland where many species occur, I have found it safer to include all the pollen in *Ranunculus* sp., the more so as the macrofossil analyses have provided a much safer basis to illustrate the occurrence of the species. In the Sølejren diagram I have found it justifiable to separate a *R. sulphureus* type, as there is a great difference in morphology between the two possible species, *R. sulphureus* and *R. hyperboreus*.

Rosaceae

The pollen production of *Alchemilla* is very sparse and irregular. It can be mentioned that 4 collections of *A. alpina* were completely without pollen. When *Alchemilla* pollen are found in reference material they are big, with a very thick exine and a very thick tectum; they are often more or less abnormal. With hesitation, a few pollen have been referred to *Alchemilla* sp. They may be abnormal pollen of *Potentilla crantzii* or *P. tridentata*, both of which have pollen with a much thicker exine, especially with a thick tectum, and pollen larger than the common *Potentilla-Comarum* type. Pollen of the former type are included in *Potentilla crantzii* type, while pollen of *Potentilla egedii*, *P. pulchella*, *P. hookeriana*, *P. nivea*, *P. hyparctica*, *P. anserina*, *Comarum palustre* and *Sibbaldia procumbens* are grouped in *Potentilla-Comarum* type. Reference material of a few, rare species has not been available. Pollen of *Dryas* type is very variable and none of the few finds can be considered fully reliable.

Salicaceae

The possibility of determining *Salix* pollen as to species is a very delicate problem. Fægri (1953) distinguishes with reservation between a number of types, while Fægri & Iversen (1964) separate between *S. herbacea* and three further types of which only one, the *S. glauca* type, is of interest in this connection. Berglund (1966, p. 43) writes "However, in fossil material it is difficult to distinguish different pollen types". Florin (1969) describes a *Salix herbacea* type. The pollen depicted as an illustration of this type (l. c. Pl. XIV, 1–2) may be of *S. herbacea*, but in my opinion it may as well have been taken from one of the Greenlandic *Salix glauca* slides. I have earlier (Fredskild, 1967a) separated the Greenland *Salices* in two types: 1) *S. herbacea* type, including *S. herbacea* and part of the material of *S. arctophila*, and 2) *S. glauca* type, also including besides *S. glauca* the other part of *S. arctophila*, *S. arctica* and *S. uva-ursi*, but stating that "within reference slides of *S. herbacea* a few pollen grains of *S. glauca* type can be found, and vice versa". Since then, further reference material has been studied, including a total of 23 collections, and the problem has been discussed with Svend Funder, M.Sc., who has

carried out detailed studies of the Greenland *Salices* in the scanning microscope. For the time being I feel convinced that pollen of the most extreme *S. herbacea* type, i.e. grains in which the reticulum is more or less reduced to knot-like, rounded, or shortly rugulate, accumulations of columellae, will only be found in *S. herbacea*. In *S. glauca* the variation is so great that within the same reference slide the whole spectrum from quite "normal" *Salix* pollen to pollen fulfilling the requirements of being classified as *S. herbacea* in the key in FÆGRI & IVERSEN (1964) can be found. They describe *S. herbacea* in the following manner: "Sculpturing ± irregular, muri with pronounced knot-like thickenings. Columellae indistinct". In this context it should be mentioned that in some reference slides of *S. herbacea* the columellae are very distinct.

After realizing this discouraging fact, I made a revision of the pollen of the *S. herbacea* type, the position of which was noted in the Isoëtes Sø, Spongilla Sø, and Kløftsø diagrams. It is beyond doubt that *Salix herbacea* occurred, and apparently it immigrated slightly before *S. glauca*, or at least it dominated over *S. glauca* in the first "pollen rain" containing *Salix* pollen. However, I have considered the drawing of a special *S. herbacea* curve in the diagrams unjustifiable, and all *Salix* pollen are thus included in the *Salix* curve.

Saxifragaceae

Four types have been distinguished: 1) *Saxifraga oppositifolia* type (incl. *S. oppositifolia*, *S. tricuspidata*, *S. aizoides* and *S. paniculata*), 2) *Saxifraga caespitosa* type (incl. *S. caespitosa*, *S. cernua*, *S. hirculus*, *S. flagellaris*, *S. rivularis*, *S. hyperborea*. In FREDSKILD (1967 a) this type was termed *S. cernua* type, but it seems more reasonable to name it after the most widespread species, 3) *Saxifraga nivalis* type (incl. *S. nivalis*, *S. tenuis* and *S. hieraciifolia*, and 4) *Saxifraga foliolosa* type (incl. *S. foliolosa* and *S. stellaris*). Pollen of all types have been found.

Scrophulariaceae

The *Euphrasia* type includes pollen of *Bartsia*, *Euphrasia* and *Rhinanthus*.

Umbelliferae

Pollen of *Angelica archangelica* ssp. *norvegica* are very frequent, in many samples making up 2 % of ΣP. The pollen of *Ligusticum scoticum* is of a somewhat deviating type, being shorter, usually with a thicker exine and with a more or less protruding pore surrounded by latitudinal as well as longitudinal costae, making the pore almost square. Some pollen found belong to this type, but as the determination is not fully reliable it is called *Ligusticum* type.

In the tables pollen which are indeterminable because of destruction or being too folded or possibly hidden behind plant detritus have been grouped together as P. indet.

The colonies of *Botryococcus* and *Pediastrum* have been counted in most localities. *Pediastrum* species were not separated until the counting of the Isoëtes Sø diagram, where *P. tetras* was separated. In the Spongilla Sø and Kløftsø diagrams a distinction was made between *P. boryanum*, *P. tetras* and a group consisting of one or either of the species *P. integrum* and *P. muticum*. *P. braunii* was not observed (or realized ?) until the counting of the latest diagram, the Drepanocladus Dam diagram. The determination of the *Pediastrum* species was made by means of pictures and keys in different limnological papers, e.g. BRUNNTHALER (1915).

In the pollen samples the spores of *Sphagnum* and *Tilletia sphagni* were also counted, as were the *Microthyrium*-like fruit-bodies (GODWIN & ANDREW, 1951) and the rhizopod *Assulina*, probably *A. muscorum*. Microscopical fragments of charcoal also were counted.

Non-indigenous taxa

Pollen of non-indigenous taxa are united in the diagrams under the term exotic pollen, but in this term a few indigenous pollen may be included, especially in the Peary Land samples, where pollen of *Alnus*, *Betula* etc. cannot be of local, holocene origin. In this case they may either be contemporaneous with the sample, but then long distance transported, or they may be rebedded from an earlier, more favourable period.

I have not devoted much time to a close determination of the long distance, non-indigenous pollen, and many of them have only been referred to at the type level of determination: *Acer* type, *A. pennsylvanicum/rubrum* type, *A. saccharinum* type, *A. spicatum* type, *Ambrosia*, *Carpinus* type, *Carya*, *Castanea* type, *Chenopodiaceae*, *Corylus* type, *Cupressaceae*, *Fagus*, *Fraxinus*, *Humulus* type, *Juglans*, *Myrica*, *Ostrya*, *Quercus*, *Plantago lanceolata*, *Picea*, *Pinus* (in some diagrams united into *Picea/Pinus*), *Platanus*, *Prunus* type, *Pteridium* type, *Rumex* sp. (non *acetosella/acetosa* type), *Tsuga canadensis* type, *Ulmus*, *Urtica*, *Viburnum* type, *Vitis* and *Taxus* type.

The pollen diagrams

The relative diagrams

In the pollen percentage diagram, the traditional pollen diagram, the percentages are based on a Σ P in principle consisting of all local taxa of higher plants including i.a. ferns, and excluding water plants and exotic taxa. However, when dealing with an area as large as Greenland

it is impossible to be consistent, e.g. in the Peary Land diagrams *Betula*, *Alnus* and *Empetrum* are exotic.

Today the southern limit of continuous *Alnus* is just south of the Arsuk Fjord (distribution map in BÖCHER, 1938), i.e. ca. 150 km west of Qagssiarssuk and ca. 300 km from the Kap Farvel area, but as it could not be excluded that the distribution at some period was more southerly, it was decided to include *Alnus* in Σ P in all the South Greenland diagrams and of course in the diagrams from the Godthåbsfjord area, as *Alnus* grows here. *Artemisia* (distribution map in BÖCHER, 1951) is distributed in West Greenland between 63° and 73°N. This species is considered exotic in all South Greenland diagrams.

The greatest problems are connected with the hydrophytes. The inclusion or exclusion of certain taxa have been discussed in numerous papers, e.g. in FÆGRI & IVERSEN (1964) and will not be repeated here. In illustration of the problems concerning Greenland diagrams, it suffices to mention two examples: In Comarum Sø a zone of *Carex rostrata* is found on shallow water, and on the hills around the lake dry, windswept hilltops are covered with *Kobresia myosuroides*. The pollen of both species are included in *Cyperaceae*. Furthermore, *Ranunculus confervoides* is in bloom in the lake, and *R. acris* is common on the slopes around the lake. Both are included in the *Ranunculus* curve. For this and similar reasons it was decided to exclude from the Σ P as few of the local taxa as possible and preferably only the true water plants: *Callitriche*, *Isoëtes*, *Myriophyllum* and *Potamogeton*. However, as *Hippuris* in parts of some diagrams made up some 70 % of all pollen, this species is generally excluded, and similarily *Sparganium* has been excluded in some of the diagrams. It appears from the diagrams whether a plant is included in ΣP or not.

In addition to the information concerning depths, sediments, pollen zones, and uncalibrated radiocarbon datings, the diagrams are divided into three major parts. The first part gives the silhouettes and curves of local taxa, and all pollen (and spores) depicted are included in Σ P, the number of which is found in the column limiting at the right this part of the diagram. Rare pollen, found in only one or two samples, are mentioned in the text together with the discussion of the diagram in question. The basic principle for the order of the curves in lake diagrams has been to try to give an impression of the immigration of the plants, thus starting from the left with the first immigrants (or survivors). When more taxa immigrated simultaneously, the one with the first (earliest) maximum is placed on the left. The magnification of the abcissa unit in the curves is 5 × that of the unit in the silhouettes.

The second part of the lake diagrams gives information about the development of the vegetation in the lake, including higher plants, as

well as some algae. Usually *Sparganium*, though included in Σ P, is placed in this part. The third part includes *Alnus*, exotic pollen and microscopic charcoal. Curves of *Sphagnum*, *Assulina* etc. may be found here. Σ P is the basis for all calculations, and the size of the abcissa units in parts 2 and 3 is thus very variable.

The order of the curves in diagrams from bogs and very small ponds highly influenced by the very local vegetation is somewhat different, but still it appears from the diagrams which taxa are included in Σ P.

The absolute diagrams

Two different types have been constructed: 1) pollen concentration diagrams, in which the pollen frequency is expressed in number of grains per ml wet sediment or per g dry weight, and, 2) pollen deposition rate diagrams in which the pollen grains accumulated per cm^2 per year is given. Both types are presented as histograms. The first type is represented by only two diagrams, viz. Galium Kær A and Klaresø. This type will be discussed in connection with the two localities. The latter type, which is considered more important and further is represented by five diagrams, will be discussed here.

Several absolute diagrams (in the sense of pollen deposition rate diagrams) have been published recently, e.g. Davis (1969) and Pennington & Bonny (1970), and the advantages of this type as compared to the traditional diagrams are obvious. However, I find it unsatisfactory to present from a certain locality only an absolute diagram, as i.a. the varying abcissa units in this type make it very difficult to survey what grains dominate at a certain level. Furthermore, the rather few datings available in this paper make the absolute diagrams not too exact, and at the present stage I find it the best to bring relative as well as absolute diagrams from the same locality. I believe that the parallel use of the two diagrams and a comparison of the information they provide may help us to arrive at the real purpose of palaeopalynology: a reconstruction of the former vegetation, its environment, and development.

A knowledge of the content of pollen in a given volume of sediment, e.g. in one ml, and of the sedimentation rate is necessary for the construction of an absolute diagram. Older radiocarbon datings must be calibrated because of the changing atmospheric content of C^{14} in the past, and before using the datings as a basis for the calculations of the sedimentation rates, the datings have been calibrated according to the curve presented by Suess (1970). With datings older than the range of the Suess curve two possibilities for calibration exist: 1) The level of the atmospheric C^{14} activity in the interval 6000–7000 B.P. has not been changed further back in time, thus giving a calibration of ca. 800 years to the radiocarbon

datings, or, 2) the deviation in C^{14} gradually diminishes until it reaches the 19th Century level about 9 millennia ago (TAUBER, 1967). For the oldest datings presented here this means that the calibration must be either ca. 800 or ca. 100 years, depending on the calibration chosen. If the difference in the two possible calibrations of the following sample in the core is only, say, 100 years, the matrix between the two dated samples has been sedimentated in either n or n + 700 years. At the present it is not known which calibration is correct, and in those parts of the histograms in which the difference in calibration is great, both possibilities have been taken into consideration before calculation of the pollen deposition rate. The thick bar gives the pollen deposition rate with a slow matrix sedimentation rate, i.e. when the C^{14} curve remains at a constant level, while the thick bar plus the thin continuation gives the pollen deposition rate with a faster sedimentation, i.e. when the C^{14} curve reaches the 19th Century level again. It must be added that prior to its use, the curve in TAUBER (1970, fig. 4) was slightly modified in the way that the peak value in C^{14} was extended app. one thousand years further back in time (TAUBER, personal communication).

In each interval between two radiocarbon datings the average sedimentation rate is used for calculation of the pollen deposition rate. If there is a great change in the sedimentation rate between two intervals, there will be a considerable difference in the deposition rate across the artificial boundary, seen e.g. in the Spongilla Sø diagram, where all but one bar is halved as a result of the average sedimentation rate dropping from 2.86 to 1.02 cm/100 yr. This could have been avoided, if, instead of using the average sedimentation rate, a smooth curve was fitted to points in a diagram in which the calibrated datings were plotted against depth. This might give a curve better reflecting the former conditions. But there is no guarantee that this curve is true, as minor fluctuations (and even major ones, cf. DAVIS, 1969, fig. 3) may be hidden, and with only 5 datings spanning ca. 9000 years a diagram without sudden drops might give the impression of an accuracy which is not relevant. Thus it was decided to bring the diagrams in a form out of which the reader easily is warned against drawing too excessive conclusions from – in this context – minor fluctuations. It may be relevant here to quote DAVIS (1969, p. 409): "Changes by a factor of 5 or more for all except rare pollen types from one level to the next were considered significant indication of changes in the pollen input to the lake, reflecting changes in the pollen productivity of the surrounding vegetation", and, l.c. p. 414: "Future studies will indicate whether this opinion is too conservative or too optimistic".

DAVIS *et al.* (1973) have discussed the basic assumptions in connection with absolute counts and the possibility of interpreting past vegetation from fossil samples. They investigated the influx (= number

of grains/cm²/yr) in the post-settlement period in 29 lakes in Michigan. One of the results obtained is that within wide limits pollen influx is uniform in lake basins. Usually the variance does not exceed a factor 3, but exceptional cases with higher (up to 10 ×) difference have been found. Another result is that variations in the influx in lakes surrounded by similar vegetation are similar in magnitude to variations caused by sedimentological factors and cannot be distinguished from them. The lakes investigated are, however, much larger than those in Greenland, mainly 20–80 hectars with a depth of water mainly 6–20 metres, and therefore more exposed to changing matrix sedimentation.



Fig. 2. Nûa on Tôrnârssuk, perched boulders 25 m a.s.l. August 13, 1970.

INVESTIGATED LOCALITIES

South Greenland

The Kap Farvel area

Remarks on the present vegetation

In connection with the description of the investigated localities some remarks on the local vegetation, i.e. the vegetation within the nearest kilometres of the cored lake, will be given. A brief survey of the present vegetation types in South Greenland is given below.

No description of the present vegetation of the Kap Farvel area has been published to date, but the area from Tasermiut fjord northwestwards to Julianehåb District, especially the area around Tunugdliarfik, has been described several times, especially by HARTZ (1894) and ROSENVINGE (1896). Later, BÖCHER (1954) published a survey of the phytogeographical units in Southwest Greenland. Although this only covered the part of Southwest Greenland northwest of Tunugdliarfik, the descriptions are valid for the corresponding units in the southernmost part. DEVOLD & SCHOLANDER (1933) treat the flora of the southeast coast between 60°30′ and 64°30′ N and give a summary of the vegetation types. Finally, a number of Danish botanists dealt with the flora and vegetation of Greenland in "Danmarks Natur" (NØRREVANG *et al.*, 1971).

The vegetational belts in South and West Greenland do not follow the latitude, but run almost parallel to the coast, a response to the great

difference in climate between the, in short, cool, cloudy, often foggy outer coast with high humidity and abundant precipitation, to the warmer, often sunny, more arid inland. Almost the same mean temperature in the warmest month is found at the head of the fjords from Kap Farvel to the Disko Bugt area and corresponding conditions are found at the coast stations, cf. table 56 in PUTNINS (1971). The main climatic difference is based on the longer vegetation period in the south and the lower precipitation during the vegetation period towards north.

The overall dominating vegetation type at the outer coast is the dwarf-shrub heath characterized by ericaceous plants, mainly *Empetrum hermaphroditum*. On the outer skerries almost pure *Empetrum* heaths with mosses, e.g. *Rhacomitrium lanuginosum*, and lichens occur, but usually *Vaccinium uliginosum* ssp. *microphyllum* is a not incidental component of the vegetation a little farther in the fjords. Other plants common to the *Empetrum* heath are *Carex stylosa*, *C. bigelowii* and *Luzula confusa*. The snow-cover of the *Empetrum* heaths is constant to less constant and of moderate thickness (JAKOBSEN, 1971). Dwarf-shrub heaths are frequent in places where the snow-cover is constant; they are dominated by *Betula glandulosa*, but there is a mosaic of ericaceous plants, mainly *Empetrum* and *Vaccinium uliginosum*. With an even better and more constant snow-cover, and growing on an acid, during summer never dried out soil, *Phyllodoce* heaths are found, often rich in *Diphasium alpinum*. Grasses usually play an unimportant role in the dwarf-shrub heath and one of the most important species, *Festuca vivipara*, will not be registered in the pollen spectra. *Salix glauca* occurs in varying quantities in the dwarf-shrub heath, and may dominate on protected slopes.

Nardus heaths are common in the Kap Farvel area. They are usually very poor in species. Another boreal-oceanic species, *Juncus squarrosus*, also occurs in the moister parts of these heaths. *Loiseleuria* heaths are found on windblown places where the snow-cover is unstable. The snow-patch vegetation is widespread, dominated by *Salix herbacea* and accompanied by i.a. *Harrimanella hypnoides*, *Carex bigelowii*, *Sibbaldia procumbens*, *Huperzia selago* and *Diphasium alpinum*.

In lakes and ponds the higher vegetation is extremely poor. (Lakes and ponds are permanent freshwater localities, where a lake never freezes solid, but a pond may freeze right to the bottom. These terms are used regardless of size, according to RØEN (1962). Only one species, *Isoëtes setacea* ssp. *muricata* can be found in almost every body of water, which is illustrated by the fact that it occurred in 15 of the 20 lakes and ponds from the outer coast and outer parts of the fjords in which the present pollen spectrum was analyzed. *I. lacustris* was found in 4 of them. Of the flowering plants *Hippuris* and *Sparganium hyperboreum* are the most frequent, and besides this *Myriophyllum alterniflorum* occur now and then. In the Kap Farvel area *Menyanthes trifoliata* and *Potamo-*

geton pusillus ssp. *groenlandicus* were seen in one locality only during the 1970 field work. In small ponds *Callitriche hamulata* occur now and then. But very often the bottom is completely bare of vegetation. *Subularia aquatica* and *Ranunculus confervoides* are rare.

At a greater distance from the outer coast the character of the vegetation gradually changes. Dwarf-shrub heaths still dominate, but *Salix glauca* becomes more dominating and together with *Betula glandulosa* characterizes the vegetation. Towards the head of the fjords the brownish-green colour of the *Empetrum-Betula glandulosa*-dominated heaths is replaced by the bluish-green colour of the still higher scrubs of *Salix glauca.*

Finally, at the very head of the fjords the South Greenland "forest" is found, usually not climbing more than 100 m up the valley sides. The dominant species are *Betula pubescens* s.l., which can reach a height of 5–7 m, but is smaller, as a rule, and *Salix glauca*, 3–4 m high, at the most. Both plants are typical shrubs, having descendent stems with numerous upright branches. Wherever the possibilities for *B. pubescens* are not at their optimum, the growth becomes smaller and the habitus very much resembles that of *B. glandulosa* with which it has to compete. Scattered in the often very dense and entangled *Betula-Salix* scrubs are *Sorbus decora*, and the ground vegetation is characterized by certain boreal forest species which reach their northern limit in these "forests": *Poa nemoralis*, *Anthoxanthum odoratum* ssp. *alpinum*, a number of ferns such as *Dryopteris felix-mas*, *D. dilatata*, *Polystichum lonchitis*, *Phegopteris connectilis*, *Gymnocarpium dryopteris*, and tall herbs such as *Streptopus amplexifolius*, *Angelica archangelica* and *Chamaenerion angustifolium.*

Juniperus can be found at the outer coast where it occurs as a single stunted specimen, but its highest frequence and best development is seen in the inland, where it is found on rather dry ground with a thin and not too stable snow-cover. All specimens found have a *nana* growth.

In the Kap Farvel area small *Nardus* heaths occur even at the head of the fjords, an indication of the boreal-oceanic conditions that prevail even there. But at corresponding places in the Julianehåb district more subarctic continental conditions prevail and grass heaths occur in places exposed to winds; these heaths are dominated by *Kobresia myosuroides*, *Agrostis canina* ssp. *montana*, *Deschampsia flexuosa* var. *montana* and a number of small herbs such as *Thalictrum alpinum*, *Euphrasia frigida*, *Thymus drucei*, *Cerastium alpinum.* Almost everywhere small specimens of *Salix glauca* can be found.

The vegetation in the lakes and ponds is richer in the inland. *Potamogeton alpinus* ssp. *tenuifolius* and *P. gramineus* are frequent, and *P. pusillus* ssp. *groenlandicus* is not infrequent. *Hippuris* and *Myriophyllum alterniflorum* are common, while *M. spicatum* ssp. *exalbescens* is rarely

found. *Sparganium hyperboreum* is very common, while *S. angustifolium* is rare. In many small waters *Alopecurus aequalis* floats on the water. *Ranunculus confervoides* and *Isoëtes setacea* are common. *I. lacustris* has only been found in the Kap Farvel area.

Remarks on the climate

As mentioned above, the vegetation reflects the great differences in climatic conditions along the fjords. "If, in any latitude of West-Greenland, you move a score of miles eastwards, you will find a larger difference in the climate than in going hundreds of miles northwards or southwards" (O. BENDIXEN, here quoted from PORSILD, 1935). At Prins Christian Sund at the outer coast northeast of Kap Farvel the mean summer temperature (June-August) is 6.3° C for the years 1961–65, while at Narssarssuaq at the head of Tunugdliarfik it is 9.9° C (LYSGAARD, 1969). Correspondingly, the precipitation is very high at the coast and low inland. PUTNIN's paper (1971), which is referred to above, gives a good survey of the climate of Greenland.

Remarks on the geology

The bedrock of the Julianehåb district mainly consists of granites and also of gneiss and metamorphosed sediments and volcanics. In the northwestern part there are younger sandstones and intrusions of alkaline rocks. In the Kap Farvel area rapakivi granites are very common, cfr. ALLART, BRIDGWATER & HENRIKSEN (1969).

Very little has been published concerning, in particular, the quaternary geology of the Kap Farvel area. BØGVAD (1940) mentions some shorelines observed on his sailing route from Frederiksdal through Torssukátak-Ilua-Prins Christians Sund. Most of them had an estimated height of 5–10 m. None was observed at a higher level. Nothing has been mentioned about the upper marine limit. At four localities I have measured by means of a hand level the height of the lowest lying perched boulders. At Nûa on Tôrnârssuk (59°54′N, 44°22′W) the perched boulders shown on fig. 2 (p. 36) were found at the 25 m level on the bedrock directly exposed to the North Atlantic, at a distance of max. 100 m. The marine limit may well be some metres lower, as no suitable places were found until we reached a much lower level which was free of perched boulders. On the opposite side of the fjord Pamiagdlûp kujatíngua the coast of the island Pamiagdluk was searched for signs of the marine limit at two places. Near Spongilla Sø (59°58′N, 44°21′W), isolated ca. 9300 years ago, cf. p. 54, and with a threshold at 5.5 m, consistently over a distance of ca. 1 km abundant perched boulders were found down to a level of 30 m. Suitable places at lower levels were numerous, but completely polished. Farther north on the east coast of Pamiagdluk at 60°05′N, 44°15′W corresponding obser-

vations were made, showing a lot of perched boulders from the 27 m level upwards. West of Itivdleq (59°55'N, 43°45'W) at the north coast of Eggers Ø the corresponding level was ca. 20 m. Because of haste, the estimated accuracy in this case is only 1 m. All levellings were made from the *Fucus* line. At the third, well-protected locality mentioned above, it was noted that the level of the high water line was 1.5 m above the *Fucus* line. No measurements of the recent subsidence of the land has been made.

Many observations concerning the holocene geology of the Julianehåb district have been published. VOGT (1933) has summarized the earlier observations, and later WEIDICK (1963) published his observations from many localities. 5 years later WEIDICK (1968) relates these observations to the stages of the main deglaciation of West Greenland, and in WEIDICK (1972a) a survey of the glacial stages of the whole Greenland finally is given. Concerning Julianehåb District WEIDICK (1968) describes two stages: Tunugdliarfik stage with moraines formed contemporarily with a marine level 10–15 m above the present one, and Narssarssuaq stage formed at a marine level close to the present one, yet Norse ruins situated on and between the deposits prove that the stage was earlier than the Norse period. The deposits of both stages are found in the innermost part of the fjords. At what time the deglaciation of the outer coast of the Julianehåb District occurred cannot be stated, as no deposits from an equivalent to the "Nunataq Zone" (WEIDICK, 1968) have yet been found. Most obviously the deglaciation occurred 10–11,000 years ago, as the oldest datings of basal gyttja in lakes at the outer coast north as well as south of the area are between 10,000 and 9500 (9580 ± 210 B.P. (K–988) and 9840 ± 170 (K–1149), both from Frederikshåb District, [KELLY *in* TAUBER, 1968], and 9440 ± 100 (K–1803), Isoëtes Sø, cf. p. 44).

Isoëtes Sø

Present vegetation

The southern end of Pamiagdluk island is a polished lowland as seen in the oblique photograph (fig. 3) with heights exceptionally exceeding 150 m, contrasting sharply with the 1000–1300 m high ridges of Tôrnârssuk (in front of the photo) and on the western side of Pamiagdluk. The part of the lowland with the two investigated lakes is limited by the outer part of the inlet Tasiussaq and the big, oblong lake south of it. Limited time only permitted a summary survey. Bedrock covered only by lichens makes up a not unessential part of the landscape, but the major area is covered by *Empetrum* heaths of different types: *Empetrum*-lichens, *Empetrum*-mosses (especially *Rhacomitrium lanuginosum*), *Empetrum-Vaccinium uliginosum*. In some of the dwarf-shrub heaths *Salix glauca* and *Betula glandulosa* are fairly common. The two most



Fig. 3. Oblique aerial photo of the southern part of Pamiagdluk looking west-northwest. I = Isoëtes Sø, S = Spongilla Sø. Reproduced with the permission (A. 789/72) of the Geodetic Institute, Copenhagen.

important grasses are *Festuca vivipara* and *Deschampsia alpina*, none of which is registered in the pollen spectra because of vivipari. Small patches of *Nardus stricta* grass heaths are found on well-protected shelves. *Salix herbacea-Harrimanella* snow-patches are small and less important, as are fen and bog vegetation. There is no shore vegetation around lakes and ponds; presumably ice erosion is responsible for this. On the area covered by cormophytes a very rough estimate of the ratio between dwarf-shrubs and herbs is 85–90: 15–10. Within the dwarf-shrubs an even rougher estimate between *Empetrum: Salix: Betula: Vaccinium uliginosum* is 10:2:2:1. In this scale *Juniperus* might be 0.2.

Isoëtes Sø (59°58′N, 44°21′W) is a tarn, 90 × 25 m (fig. 4, fig. 30.9) at an elevation of 60–65 m (altimeter measurement). In the eastern end it is wider, with a shallow part almost blocked by a lengthwise ridge. From this shallow part the tarn is drained by water seeping on the bedrock

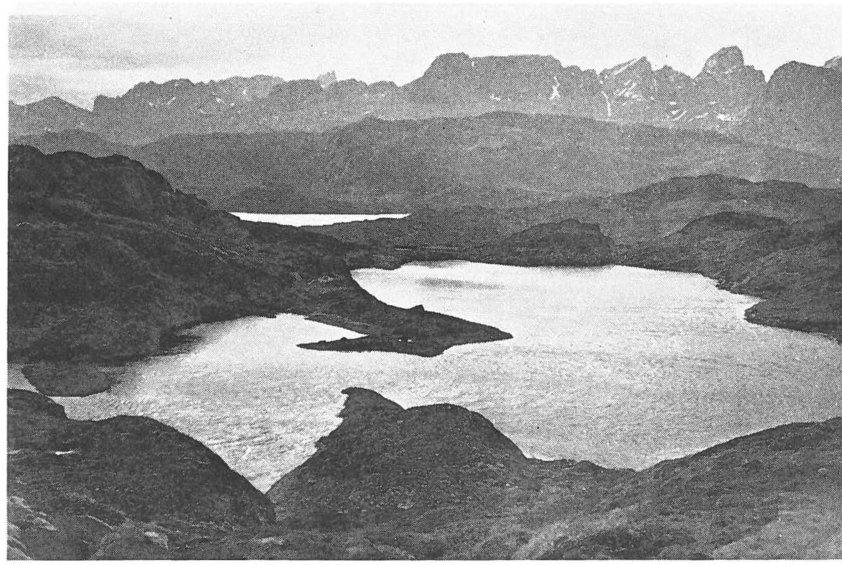


Fig. 4. Isoëtes Sø, looking westwards. July 19, 1970.

through and beneath the vegetation mat. The lake is only supplied by water by means of rain and meltwater from the snow. The eastern part of the main basin is shallow, and partly without organic sediment. The greatest water depth, 2.95–3.00 m, was found in the west end. The vegetation in the tarn is very poor, consisting of a narrow zone of *Isoëtes setacea*, succeeded at a little greater depth by a zone dominated by *I. lacustris* but possibly still with some *I. setacea*. In still deeper water there is a zone of scattered, dwarfed specimens of *Myriophyllum alterniflorum*, only 15–20 cm high. In this zone, at a depth of ca. 1.5 m, no specimen reached the surface, nor did any specimen flower, not even as late as 23 August. Apart from the *Myriophyllum* zone, no plants could be seen in the crystalline water.

Description of the sediments

The first number given below refers to the number shown in the pollen diagram. After this there follow the depths in cm below the bottom of the lake, the verbal description, and the formula according to TROELS-SMITH (1955). Generally, the colour of the organic layers is brown, often bright-brown, but rapidly darkening by light and air to dark-olive or almost black. If nothing is stated about the sharpness of the boundary between the layers, the lim.sup. of the layer is 1 in the Troels-Smith scale, i.e. the boundary area is within 2 and 10 mm wide. The bulk of mosses has been determined by N. JACOBSEN as *Drepanocladus exannulatus*.

17. 0–10 cm: Rather loose, watery, fine detritus gyttja with a touch of fine sand. Ld^1 4, Ga + +. The pollen sample no. 39 could not be taken with the 1 ml piston corer, and the accuracy in taking nos 38 and 37 is not so high as in the deeper samples.
16. 10–32 cm: Fine detritus gyttja, with a touch of sand and single, very small stones. Ld^1 4, Ga + +.
15. 32–73 cm: Fine detritus gyttja. Ld^1 4, Ga +. Lim. sup. 0–1.
14. 73–76 cm: Rather fine detritus gyttja, glossy because of content of cladoceran remains. Ld^1 3.5, Dg 0.5, Ga +.
13. 76–82 cm: Fine detritus gyttja, like layer 15.
12. 82–95 cm: Detritus gyttja, very glossy because of great content of cladoceran remains. Ld^1 3, Dg 1, Ga +.
11. 95–103 cm: Fine detritus gyttja. Ld^1 4, Ga +.
10. 103–105 cm: Detritus gyttja, with mosses. Colour darker. Ld^1 3, Tb^1 1, Ga +.
9. 105–108 cm: Fine detritus gyttja. Ld^1 4, Ga +.
8. 108–116.5 cm: Moss-rich gyttja. Ld^1 2, Tb^1 2, Ga +. Sample no. 6 cut by scalpel.
7. 116.5–119.5 cm: Fine detritus gyttja. Ld^1 4, Ga +.
6. 119.5–132 cm: Moss with gyttja. Ld^1 1.5, Tb^1 2.5, Ga +. Samples nos 4 and 3 cut by scalpel.
5. 132–137 cm: Finely laminated, fine detritus gyttja, slightly clayey. In some of the cores a few mosses were found. Ld^1 4, Ga + +, (Ag + As) + +, Lim. sup. 2.
4. 137–139 cm: Very finely laminated, sandy-clayey fine detritus gyttja. The colours of the almost paper-thin layers varying in brown and olive tones. Ld^1 3, Ga 0.5, (Ag + As) 0.5.
3. 139–140 cm: Clay with sand, grey. Ga 1, (Ag + As) 3. Lim. sup. 3.
2. 140–141 cm: Clay-gyttja. Ld^1 1, Ga 1, (Ag + As) 2. Lim. sup. 2.
1. 141–142 cm: Bluish clay with sharp sand and small stones. Lim. sup. 3.

Macrofossils

8 cores were taken from the lake bottom to a depth of 55–60 cm and cut into 3 cm thick slices, while 10 cores ranging from ca. 50 cm to the till (layer 1) were cut into 2 cm slices. By comparing the deeper cores it turned out that the deliminations of the moss layers were not consistent. The upper finds of mosses in the gyttja varied between 103 and 91 cm. But in the deepest layers the following sequence was found in all cores: Till, clayey with sand and stones, followed by 7 (6.5–8) cm laminated gyttja (in some of the cores some of the thin layers contained mosses), and then came the moss gyttjas.

The content of botanical macrofossils found in the radiocarbon samples and in some supplementary samples is shown in table 4.

Table 4. *Isoëtes Sø, macrofossils.*

cm below lake bottom	vol., ml.	*Carex bigelowii/ nigra*	*Empetrum*, fruits	*Empetrum*, leaves	*Puccinellia* cf. *langeana*	*Salix*, fragments of leaves
23–26	240		2	2		
41–44	240	2	5	4		
59–61	200		2	2		
79–81	200	1	1	10		
99–101	200	3	26	8		2
119–121	200	1		23		
123–125	200		4	32		
137–139	200	3			1	

Datings

5 samples have been dated: 137–139 cm: 9440 ± 140 B.P. (K–1803), 123–125 cm: 8700 ± 110 (K–1953), 99–101 cm: 6950 ± 130 (K–1804), 41–44 cm: 3730 ± 100 (K–1805) and 23–26 cm: 3140 ± 100 B.P. (K–1806). Concerning the reliability of the latter dating, see the discussion below.

Pollen zones

Two diagrams have been constructed, viz. a relative diagram and a pollen deposition rate diagram (Plates 2–3). The following pollen and spores not shown in the diagrams were found: *Armeria* in sample no. 3: 1 pollen grain, *Callitriche* 5:2, *Cerastium cerastoides* 3:4, *Cerastium-Stellaria* type 3:5, 7:1, 15:1, 19:1, 33:2, 36:1, *Chamaenerion* 39:1, *Cruciferae* 3:1, 4:1, 9:1, *Cystopteris fragilis* ssp. *fragilis* 26:1, *Dryas* type 4:1, 5:1, *Equisetum* 5:1, 7:1, 10:1, *Euphrasia* type 26:1, *Oxyria-Rumex acetosella* type 33:1, 34:1, 36:1, *Ranunculus* 17:1, *Selaginella* 12:1, *Silene-Minuartia* type 7:1, 23:1, 29:1, *Sparganium* 18:1, 19:1, *Subularia* 4:1, *Thymus* 27:1, 33:2, P. indet. 2:10, 3:3, 4:5, 5:11, 6:2, 9:1, 11:3, 12:1, 13:2, 15:1, 16:2, 17:1, 19:1, 21:1, 22:3, 23:3, 24:1, 25:1, 26:1, 28:2, 29:1, 31:1, 34:2, 35:1, 38:1, 39:1.

Pollen zone A: *Sagina-Oxyria-Koenigia* zone (samples 1–2)

The local pollen originate from small herbs such as *Oxyria*, *Saxifraga oppositifolia* type, *S. caespitosa* type, *Sagina*, *Koenigia*, *Erigeron* type, *Silene* type and *Luzula-Juncus*. Furthermore, some of the *Gramineae* are considered local. *Cyperaceae* pollen are very scarce. In the relative diagram exotic pollen, *Alnus* and charcoal are very important. *Pediastrum*

is frequent in the lake. A later investigation showed that this high frequency is caused almost exclusively by *P. boryanum*; only a small percent of *P. braunii* type was observed. No *P. tetras*, which was the only species separated during the counting, was found.

The zone boundary A-B is defined where the ericaceous dwarf-shrubs emerge.

Pollen zone B: *Oxyria-Sagina-Loiseleuria* zone (samples 3–4)

In this zone *Oxyria* attains its maximum. *Empetrum*, *Loiseleuria*, *Vaccinium* and *Harrimanella* immigrate. Spores of the *Dryopteris* type make up ca. 10 %. *Armeria*, *Cerastium cerastoides* and *Subularia* are found only in this zone. Pollen of the *Dryas* type is only found in samples 4 and 5. *Hippuris* and *Botryococcus* grow in the lake and *Pediastrum* attains its maximum (120,000/ml).

The zone boundary B-C is defined at the sudden occurrence of *Sedum* and *Lycopodium dubium.*

Pollen zone C: *Sedum-Lycopodium dubium-Dryopteris* zone (samples 5–8)

Cyperaceae, *Sedum*, *Dryopteris* type, *Empetrum* and *Lycopodium dubium* dominate the spectra of this zone. *Oxyria* is still frequent, but less important and decreasing throughout the zone. *Sagina* disappear. *Huperzia* and *Diphasium* increase, and *Liguliflorae*, *Potentilla-Comarum* type, *Saxifraga nivalis* type, *Angelica* and other plants have their first occurrence. *Hippuris* still grows in the lake (pollen in three out of four samples), and single spores of *Isoëtes* were found in three samples. *Pediastrum tetras* replaced *P. boryanum* (and others).

The zone boundary C-D is placed at the immigration of *Salix* and *Juniperus.*

Pollen zone D: *Salix-Juniperus-Gramineae* zone (samples 9–17)

From the opening of this zone a number of the plants characterizing zones A and B disappear or at least become severely decimated: *Koenigia*, *Oxyria*, *Sedum*, *Luzula-Juncus*, *Harrimanella*, *Loiseleuria.* On the other hand, besides *Salix* and *Juniperus*, *Thalictrum alpinum* and *Coptis trifoliata* emerge. Apart from the strange, marked, but shortlived maximum of *Gramineae* at the beginning of the zone, most of the curves are fairly smooth, yet the *Empetrum* curve throughout the zone shows an increasing tendency, which in the relative diagram must of course be compensated for by slightly decreasing curves in other species. However, in the pollen concentration diagram the concentration of all other pollen but *Empetrum* seems constant. *Alnus* has an extended maximum.

Isoëtes setacea dominates in the lake, which otherwise is very poor in *Pediastrum* and rather poor in *Botryococcus.* In each of the samples 11 and 16 one *Isoëtes* spore has been referred to as *I. lacustris.*

The zone boundary D-E is mainly based on the shift in the micro- and macrophyte vegetation in the lake.

Pollen zone E: *Empetrum-Salix* zone (samples 18–25)

Pediastrum (excl. *P. tetras*) which was not found at all in the three uppermost samples in zone D suddenly re-occur, *Botryococcus* increases and rapidly reaches its second maximum. At the same time *Isoëtes setacea* drops and from the next sample (19) *I. lacustris* spreads in the lake, from now on dominating over *I. setacea*. *Sparganium* has been found only twice in the whole diagram, viz. in samples 18 and 19.

Empetrum dominates the terrestrial pollen together with *Salix*, *Gramineae*, *Cyperaceae* and *Diphasium* type. *Salix* and especially *Empetrum* attain higher frequencies than in the preceeding zone. Towards the end of the zone most curves decrease while *Empetrum* reaches its maximum. The only three *Campanula* pollen found in the diagram occur in samples 22, 23 and 25.

The zone boundary E-F is placed at the sudden rise in the *Betula* curve.

Pollen zone F: *Betula glandulosa-Empetrum* zone (samples 26–30)

At the zone boundary *Betula* increase threefold in the relative diagram. Judging from the pollen concentration diagram (FREDSKILD, 1972), *Salix*, *Cyperaceae*, and *Diphasium* type suffers a little, while *Empetrum*, *Juniperus* and *Gramineae* remain almost unchanged.

In the lake *Pediastrum* and the two *Isoëtes* species keep constant values, only *Botryococcus* decreases.

The zone boundary F-G is placed at the abrupt fall in the *Betula* curve.

Pollen zone G: *Empetrum-Betula glandulosa* zone (samples 31–39)

Across the boundary *Betula* drops from 36 to 12 % or, in terms of pollen per ml, from 17,400 to 4060 – the same values as in pollen zones C-D. In sample 32 *Betula* increases to 19 %, and in 33 to 27 %. *Harrimanella* pollen not found since sample 14 occurs in 31 and 32 with 2 resp. 1 grain. *Diphasium* and *Huperzia* show a slight maximum in 31, and in 31 and 32 *Alnus* attains its greatest values since the maximum in zone D.

During the rest of the zone most curves are fairly constant, with *Betula* on an essentially lower level than in zone E. *Juniperus* decreases and in the three uppermost samples attains its lowest values since the immigration. *Luzula-Juncus* type occurs in most samples. *Vaccinium* type has a slight maximum, and *Sedum* seems more abundant than in the preceeding zones. *Rumex acetosella/acetosa* type has been found in three samples (29,33,37).

In the lake *Pediastrum* (excl. *P. tetras*) and *Botryococcus* increase. The latest find of *Hippuris*, which was not observed in the lake today, is in sample 32. *Isoëtes lacustris* dominates over *I. setacea*. The latest immigrant to the lake is *Myriophyllum alterniflorum*, which first emerges in sample 34.

Discussion

The depression in the bedrock in which Isoëtes Sø later was formed may well have been filled with dead ice and till after the retreat of the continous ice cover. This delayed the formation of the tarn for some time. The dating of the clayey gyttja layer (4) is the oldest known so far from South Greenland (9440 ± 100 B.P.), and the traces of the first vegetation thus are of great importance. In the very first pollen sample, taken in layer 4, only few pollen of supposedly local origin were found: *Gramineae*, *Cyperaceae*, *Sagina*, *Saxifraga oppositifolia* type and *Erigeron* type. In the radiocarbon sample 2 achenes of *Carex bigelowii/nigra*, most resembling the reference material of *C. bigelowii*, and one seed of *Puccinellia*, presumably *P. langeana*, were found. Which other species of grasses and sedges were found cannot be stated. The *Sagina* pollen resembles those of *S. saginoides*, but the determination is not safe. Pollen of *Saxifraga oppositifolia* type is found in 4 species. Pollen of *Erigeron* type also occur in *Gnaphalium*, represented by the two species *G. supinum* and *G. norvegicum*. The pollen of *Juncus-Luzula* and the spores of *Dryopteris* type may represent too many species to permit including them in the discussion.

The anemophilous *Oxyria* is not registered in sample 1 and can hardly have been common, whereas *Koenigia*, *Silene acaulis* type (most likely *S. acaulis* itself) and *Saxifraga caespitosa* type (including 6 species), seemingly new to sample 2, may well have occurred from the very beginning. This is the case, too, with *Armeria*, *Cerastium cerastoides* and *Luzula-Juncus*, occurring for the first time in sample 3. The pollen of *Alnus*, *Betula* and possibly the single grains of *Salix* (cf. p. 83) are considered long distance. The spores of *Diphasium* type may be of local origin, whereas the *Gymnocarpium* spores (cf. the Kløftsø diagram) are considered as originating from a more or less distant source.

Physiognomically the picture of a rôche moutonneé landscape with only small patches of soil is outlined. This soil is rapidly occupied by a number of widespread arctic plants, well adapted to the most extreme environments, cf. the discussion in Savile (1972). Whether these plants are spread to the virgin soil around Isoëtes Sø from a distance of 5, 10 or 500 km is of lesser importance in the discussion as they are supposed to have found their way easily to any refugium that was ice-free at any time during the 70,000 years of the last glaciation.

Most of these proved or possible species are characteristic of wet, sandy-clayey soil (*Sagina saginoides*, *S. caespitosa*, *S. intermedia*, *Koenigia*, *Saxifraga hirculus*, *S. cernua*, *S. rivularis*, *S. hyperborea*, *S. flagellaris*), of snow-patches (*Cerastium cerastoides*, *Erigeron humilis*, *Gnaphalium supinum*), of fell-fields (*Saxifraga oppositifolia*, *S. caespitosa*, *Erigeron eriocephalus*, *Silene acaulis*, *Armeria scabra*), of rocks (*Saxifraga tricuspidata*, *S. aizoides*, *S. paniculata*, *Erigeron compositus*), of beaches (*Puccinellia*) or being rather ubiquitous (*Oxyria*, *Carex bigelowii*). Most of these species are distributed all over Greenland. Some are exclusively northerly or with a tendency to being alpine towards south. The northern limit, if existing, is to be found around 70°–72°N.

A few of the theoretically possible species are today found only in South Greenland (*Armeria maritima*, *Sagina procumbens* and the possibly introduced *S. nodosa*), or are characteristic of willow scrubs and tall herb communities (*Gnaphalium norvegicum*, *Erigeron alpiniformis*), but in my opinion it would seem rather far-fetched to select just these species as the source of the pollen rain. In any case, it can be stated that no conclusive proofs at all of southerly plants, and not even of plants characteristic of heaths are found in the first samples.

The only other diagram extending backwards in time to the period prior to the immigration of ericaceous plants, is from Kløftsø (p. 62). In this diagram pollen zone A, comprising samples 1 and 2, is almost identical with zone A in Isoëtes Sø. By extrapolation of the datings Kløftsø-sample 1 is dated to app. 9300, sample 2 app. 9000 and sample 3 (with *Empetrum* etc.) app. 8700. The corresponding samples in Isoëtes Sø are in the same way dated to app. 9500, 9300 and between 9100 and 8900 B.P. By means of the first samples in Kløftsø the picture of the pioneer vegetation is completed with the find of pollen of *Saxifraga nivalis* type (including the widespread species *S. nivalis* and *S. tenuis* besides the northern *S. hieraciifolius*), of *Huperzia* and of *Minuartia* type.

In the Kløftsø diagram we may have the first hint of a southern species in sample 2, viz. two spores of *Botrychium*. As it is found in most samples in the diagram, including samples 2 through 10, it must be considered an early immigrant. No spores at all are found in Isoëtes Sø, whereas it is found scattered in Spongilla Sø with sample 5 as the earliest find. IVERSEN (1952–53) considers *Botrychium lunaria* an early immigrant because of its occurrence from the very first sample in the diagram from "Lake 100 m". It must be mentioned, however, that although *B. lunaria* is common in South Greenland today, it can be found northwards to app. 73° N. Other species of *Botrychium* are more southerly in the Greenland distribution, but it is not possible by means of the spore morphology to determine which species occur in the fossil samples.

In both lakes *Hippuris* is the first hydrophyte registered in sample 3 in Isoëtes Sø, and in sample 2 in Kløftsø. It is distributed all over Greenland, but is rare in the northernmost part. Of the registered algae *Pediastrum* (excl. *P. tetras*) are common (ca. 300/cm²/yr), but compared to other lakes, e.g. the deepest samples in Spongilla Sø with 48,300/cm²/yr, the production is very small. No doubt mosses and lichens immediately found their way to the bare soil, but we have no possibilities of tracing this in the samples.

After some (four?) centuries, around 9100 B.P. the ericaceous plants immigrate: *Empetrum*, *Loiseleuria*, *Harrimanella*, *Vaccinium*. What species of *Vaccinium* (including *Oxycoccus*) occurred cannot be stated, but most likely this was either *V. uliginosum* or *V. vitis-idaea*. *Empetrum* dominates the pollen spectra, but it must be kept in mind that this species is anemophilous contrary to *Ericaceae*, *Vacciniaceae* and *Pyrolaceae*. Because of this, the ratio in plant cover between the species cannot be stated, but compared with the recent pollen spectra it seems as if *Empetrum* was not so dominating, whereas *Loiseleuria* and *Harrimanella* played a bigger role. This indicates that the succession from the bare soil with an open pioneer vegetation to the closed dwarf-shrub heath was an extended process lasting app. two millennia until the immigration of *Salix* around 7000 B.P. *Harrimanella* snow-patches have been rather frequent.

In most respects – apart from the ericaceous pollen – the spectra in samples 3 and 4 resemble those of the first two samples. A marked shift can be seen in the sediment at the zone boundary. The spreading of *Drepanocladus exannulatus* may well be related to the lower content of silt and clay in layer 6. The great content of suspended clay prevents mosses from growing at a water depth of more than four metres. *Hippuris* attains its highest frequency in this and the following zone.

With the opening of zone C a change in the vegetation is indicated dated by interpolation at app. 8400 B.P. Most conspicuous is the spreading of *Sedum* and *Lycopodium*, and the increasing importance of *Dryopteris* type, *Luzula-Juncus*, *Diphasium* type and *Cyperaceae*. Add to this the few but significant grains of *Liguliflorae* and *Angelica*. Three species of *Sedum* can be taken into consideration: *S. rosea*, growing in rock crevices, gravel, talus slopes, heaths and herb slopes, *S. annuun*, characteristic of sunny cliffs, stony places and open herb slopes, and *S. villosum*, preferring damp, southward facing rocks and moist clay between boulders and along streams. Unfortunately it is not possible to say what species is responsible, but all species indicate a still rather open soil. JOHANSEN (1968) in a diagram from the Faroe Islands covering the late Preboreal and early Boreal time shows "amazingly high percentages for *Sedum*" in the beginning of the diagram, often between 25 and 30 %. In the Faroes only *S. rosea* and *S. villosum* occur today.

Huperzia, *Lycopodium dubium* and *Diphasium alpinum* (which must be considered much more likely than the rare *D. complanatum*, today restricted to the continental interior part) are all characteristic of heaths with a long snow-cover. Spores of the *Dryopteris* type occur in zone C with abs. frequencies 20–30 times as high as at present. This could be caused by a vigorous growth of the species from rocky crevices, etc. (*Woodsia*, *Cystopteris*, *Phegopteris*), but a more likely source seems *Athyrium distentifolium*. This species is common in the area today in snow-patches and in damp places, often growing with *Phyllodoce*, *Harrimanella*, *Huperzia*, *Diphasium alpinum*, *Sibbaldia*, and *Cerastium alpinum*. Besides a single occurrence in Arsuk Fjord, Southwest Greenland, the present distribution of *Athyrium* ranges from the Kap Farvel area to 64° on the east coast. The tall *Dryopteris* species (*D. filix-mas* and *D. dilatata*) from scrubs and luxuriant scree-slopes do not seem likely. The *Luzula-Juncus* maximum, the abundant *Cyperaceae* and the scattered *Liguliflorae* give no hint as to the vegetation type because there are too many possibilities.

Angelica, occurring in samples 6 and 7, seems to be the first proof of a climatic amelioration. It should be mentioned that *Angelica* occurs at an earlier stage in Kløftsø and especially in Spongilla Sø. It has a present distribution ranging from Disko at almost 70° N on the west coast around Kap Farvel to the Angmagssalik area at 66°–67° N on the east coast (BÖCHER, 1938, fig. 81). Outside Greenland the distribution includes Iceland, Scandinavia, middle and eastern Europe between the Polar Sea, the Urals and the Carpathians (HULTÉN, 1958, map 82). In Europe a littoral type has taxonomic ranks ranging from variety to species according to different taxonomists. In northern Scandinavia and Russia the coastal and the inland forms are so closely related that a distinction often is impossible. However, only ssp. *norvegica* has been described from Greenland.

Angelica most often occurs in willow scrubs and in damp, luxuriant herb-slopes, but it is also frequent in springs, between stones in brooks, in ravines and along the shores. It can be found high up in the inland, and, strangely enough, the highest records are from the northernmost finds: Kvandalen behind Ujaragsugssuk on Disko on the west coast, ca. 69°47′ N, at an elevation of 550 m (PORSILD, 1920), and close to its northern limit on the east coast: Qáqarssuaq, 66°06′ N at Angmagssalik. At an elevation of 500–600 m KRUUSE (1912) describes herb-slopes with *Angelica*, and even gives a photo of a 1 m high specimen from 630 m a.s.l. (l.c. p. 128). *Angelica* demands a constant, but early melting snow-cover, and an abundant water supply in the growing season. But what climatic factors limit its vertical and latitudional distribution is not clear. Possibly the length of the growing season plays a decisive role. Sea currents carrying

ice floes with embedded drift material (including fruits), washed out by rivers and brooks in Scandinavia must be responsible for the early immigration to South Greenland and to the head of Godthåbsfjord, from where IVERSEN (1952–53) mentions it as an early immigrant, occurring in zone Ib. Its pollen have not so far been found in samples prior to the immigration of ericaceous plants, but it must be admitted that the analyzed material is very small.

Thalictrum alpinum is first found in sample 7, and from now on it occurs regularly during the remaining part of the diagram. Its distribution ranges northwards to 71° N on the west and almost 74° N on the east coast. It has a rather wide ecological spectrum.

In the lake *Pediastrum tetras* takes over the dominance, seemingly at the expense of *P. boryanum* and possibly other species. *Hippuris* is found in the three out of four samples, as is the next immigrated species among the higher plants: *Isoëtes setacea* ssp. *muricata*. This American subspecies is found on the west coast of Greenland from 69° N to the Kap Farvel (BÖCHER, 1963, fig. 47). To this map there should be added numerous dots from the head of Godthåbsfjord, where I noted it from almost every body of water in 1960. Towards its northern limit it is found only in the continental interior. Most likely the distribution towards the north is restricted by the number of days with water temperature exceeding a certain limit, or by some other more complicated relation between temperature and time.The scattered spores in the zone C samples seem to indicate that temperature conditions were just fulfilled, but no more than this.

With the opening of zone D app. 7000 B.P. a number of marked changes in the composition of the vegetation is registered. *Gramineae* increase by a factor 4, absolutely as well as relatively. This may indicate the immigration of a new species (*Nardus*?). The marked maximum app. 6800–6700 B.P. may well be contemporaneous with an almost as pronounced maximum dated at app. 6600–6300 in Spongilla Sø and a smaller max. in Kløftsø app. 6500–6300 B.P. The most important immigrants are *Salix* (incl. *S. glauca* and beyond doubt some *S. herbacea*) and *Juniperus*. *S. herbacea* is distributed northwards to 77°–78° on both coasts, and *S. glauca* has a similar distribution. The latter species is one of the commonest plants in Greenland. The best developed specimens, up to 6 m high, are found in the continental parts of South and West Greenland, but can be found in a wide spectrum of communities ranging from fellfields to bogs. The major occurrence, however, is seen in the dwarf-shrub heaths.

Juniperus is widely distributed northwards to 69° on the west and 67° on the east coast, preferring dry rocks, heaths and open scrubs. In the Isoëtes Sø diagram the immigration of *Salix* and *Juniperus* is registered in the same sample, whereas in the diagrams from Spongilla Sø and Kløftsø

(and from Qagssiarssuk and Godthåbsfjord) there is a time lag of several centuries to almost a millennium. Presumably the conditions around Isoëtes Sø were more unfavourable to *Salix* growth and ΣP too small to register scattered *Salix* specimens in earlier samples (cf. discussion p. 83).

Coptis trifoliata emerge along with *Salix*. The present distribution includes South Greenland northwards to 68° on the west and 67° on the east coast. It grows between moss in willow copses, in herb-fields, in *Phyllodoce* heaths and *Salix herbacea* snow-beds. The demands of this North American forest plant seem to be a good snow protection of not too long a duration combined with an acid-neutral, humus-rich soil.

Suffering in the competition with the grasses, with *Salix*, *Juniperus* and *Coptis* are the pioneer and open soil plants: *Oxyria*, *Koenigia*, *Sedum*. The decrease in *Dryopteris* type is difficult to understand. During the first part of zone D the plant cover seems to be stabilized with a ground cover of mosses leaving little bare soil.

At the zone border C–D the aquatic mosses disappeared. Instead of this the sediments in zone D (layers 11–14) bear witness to a very rich life of cladoceras. *Isoëtes setacea* attains its maximum in zone D along with a dramatic reduction in *Pediastrum*. A few *Hippuris* must still have been growing.

Around 5400 the sediment changes to a fine detritus gyttja with fewer cladoceras. *Pediastrum* and *Botryococcus* make up a greater part of the sediment. *Isoëtes setacea* decreases and is partly replaced by *I. lacustris*. In the terrestrial vegetation only minor changes are registered. The most important change is that the amount of *Empetrum* pollen is doubled.

In the whole diagram *Euphrasia* is found only in sample 26, *Thymus* in 27 and 33, and *Campanula* in 22, 23 and 25. This might be an indication of a warmer/drier period just prior to the immigration of *Betula glandulosa* around 3800 B.P. This South Greenland species is distributed northwards to app. 62° on both coasts. North of this the eastern species *B. nana* replaces it. *B. glandulosa* is common in dwarf-shrub heaths with a medium snow-cover and often on a humus-rich soil. The maximum growth is attained in the interior, where it can form up to 1 m high scrubs. Judging from the diagram, the spreading of *Betula* was at the expense of *Cyperaceae*, *Diphasium* and *Empetrum*.

One might argue that with a yearly input of ca. 50 pollen/cm^2 *Betula* had been growing in the vicinity at an earlier stage. The question of long distance pollen will be discussed later (p. 200), and here attention should only be called to the facts that size measurements show that great-leaved *Betula* is as common in the preceeding zones as small-leaved ones and that *Alnus*, which evidently never grew on the southern end of Pamiagdluk, is as common as *Betula* in zone E and almost twice as common in

zone D. *Picea* and *Pinus* are found in the same zones with 21 and 15 pollen/cm²/yr on the average (table 16).

At the zone border F–G a number of strange alterations occur, and the circumstances around the sedimentation of pollen samples 31 and 32, as well as of the upper radiocarbon dating should be discussed more closely:

In many respects the two pollen samples 31 and 32 call attention to much older samples: 1) *Betula* drops relatively, as well as in terms of pollen/ml to the same level as before its immigration to the area, 2) a glance at the *Betula* size measurements (plate 1) shows that while all samples since the immigration and up to the present gyttja clearly indicate a local growth of *B. glandulosa*, these two samples show the same trend as early samples indicating long distance transported pollen of several species, 3) these two samples are the only ones containing *Harrimanella* pollen in the wide span of time from the sedimentation of sample 14 up till today, 4) *Alnus* attains its greatest values since the maximum in zone C. None of these peculiarities, 1) to 4), is seen in the diagram from the lake Spongilla Sø, only 350 m away. Furthermore, 5) if the upper radiocarbon dating was correct, the average sedimentation rate in zone F would be 0.72 cm/100 yr, the slowest rate found in the present investigation, even slower than the slowest phase in the high arctic lake Klaresø (cf. p. 181). This, per se, is no proof, but, 6) the number/ml of exotic pollen is on the average 1.5× higher in zone E than in zone F. With a fairly constant influx of exotic pollen over not too long a period this would indicate a 1.5× higher sedimentation rate in zone F, whereas this rate should be ca. 3× slower in F (0.72/2.38) if based on these datings, or, a sudden drop by a factor 5 in the influx of exotic pollen across the zone boundary.

These indices, along with additional indications from the diagrams not mentioned here, seem to justify the explanation that the layer ca. 23–27 cm below the lake bottom has been contaminated with some older material. As no higher content of *Oxyria* and *Sedum* was observed in samples 31 and 32 it seems most reasonable to assume that a contamination with zone C material took place. If the dating is ca. 1000 yr too old, which for several reasons is a likely assumption, and the samples were contaminated only with zone C material, some 4000 years older, this would, according to the curves presented by Olsson (1972), indicate a contamination of ca. 30 %. This is not enough to explain the strange *Betula* frequencies and measurements, and the most likely explanation thus is that the layer consists of mixed material from the beginning of zone C and up to the time of sedimentation of the critical layer. The most likely explanation of this would be erosion of older sediments in the shallower part of the basin by the winter ice caused either by a

lowering of the water table in the lake or by a thicker ice cover as a result of more severe winter cold, cf. the discussion of bottom ice in arctic lakes in NICHOLS (1967a). Considering the topography and the climate, the latter explanation is by far the most likely. Because of this, samples 31 and 32, as well as the upper dating, are left out of account, and the sedimentation rate of the upper 41 cm of the diagram has been based on the dating of the samples 41–44 cm below the lake bottom. The dating of the zone border F–G will be around 2400 B.P.

In zone G most indices suggest an enlargement of the *Empetrum* heaths: increasing trends in *Empetrum*, *Ericales*, *Vaccinium* type, *Diphasium*, *Cyperaceae* (*Carex stylosa*?), and *Luzula-Juncus* (*Luzula confusa*?). *Betula glandulosa* is somewhat reduced as is *Juniperus*. This points to more oceanic conditions in zone G. Sample 39–the present gyttja–with 62 % *Betula* must be considered abnormal, presumably contaminated by macroscopically added pollen.

Only minor changes took place in the lake during the past five millennia, the most conspicuous being the gradual disappearance of *Hippuris* and the no doubt accidentally late immigration of *Myriophyllum alterniflorum.*

Spongilla Sø

Present vegetation

The vegetation of the surroundings has already been described in connection with Isoëtes Sø, situated at a distance of 350 m. Spongilla Sø (59°58′N, 44°21′W, fig. 5, fig. 30. 10) is a shallow lake, 75×45 m, at an elevation of 5.5 m above the *Fucus* line. The water supply comes from a valley with some marsh vegetation and a number of small ponds in the bottom, and with some snow-patch vegetation on the north-east exposed slope. The overflow water from Isoëtes Sø, lying almost on the watershed, runs through this valley, through Spongilla Sø and farther out in the fjord.

The greatest water depth is 1.5 m. At the coring site the depth is 1.22–1.25 m. On the shallow water at the edge of the lake there is a zone of *Isoëtes setacea.* Everywhere on the lake bottom scattered specimens of *I. lacustris*, *Myriophyllum alterniflorum* and *Callitriche hamulata* grow, but the main part of the lake bottom is completely free of vegetation. Like in Isoëtes Sø the specimens of *Myriophyllum* are only 20–30 cm high and do not reach the surface. Scattered cauliflower-like colonies of *Spongilla* sp. were found all over the lake. In the stony zone at the edge *Spongilla* was found on the lower part of the stones. In Greenland it has only been found in this lake and in a lake 100 m from Comarum Mose (cf. p. 205).

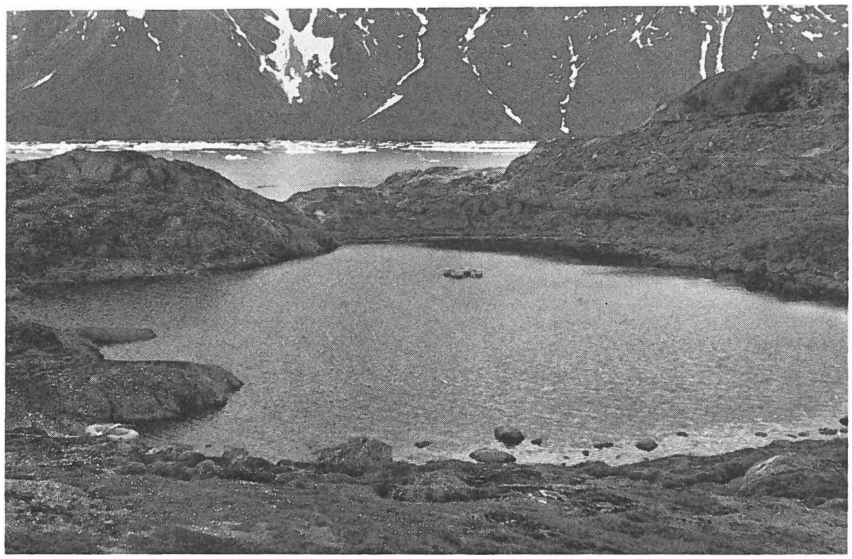


Fig. 5. Spongilla Sø, looking eastwards. July 17, 1970.

Description of the sediments

8. 0– 14.5 cm: Fine detritus gyttja, loose, watery. Colour greyish-olive-brown. Ld^1 4, Ga +.

7. 14.5– 45 cm: Fine detritus gyttja with some few rootlets (look like *Myriophyllum* rootlets). The structure loose, watery. Brown. Ld^1 4, Th^1 +, Ga +.

6. 45 – 68 cm: Fine detritus gyttja, felted by *Drepanocladus exannulatus* (N. Jacobsen det.) and rootlets. Brown. Ld^1 3.5, Th^1 0.5, Tb^1 ++, Ga +. In some cases it was difficult to take very accurate 1 ml pollen samples.

5. 68 –185 cm: Fine detritus gyttja. In the deeper part stratified with rather thick, not sharply defined layers. In the upper part no stratification could be seen. Single rootlets. Olive-brown. Ld^1 4, Th^1 (+), Ga +.

4. 185 –194 cm: Fine detritus gyttja, stratified. The layers often only a few mm thick. Colours varying, often in brownish to bright-brownish tones. Ld^1 4, Ga ++.

3. 194 –195.5 cm: Clayey gyttja, sharply delimited, greyish. The diatom analysis (Foged, 1972), as well as the extremely high content of *Pediastrum* proves the limnic origin of this layer. Ld^1 3.5, (Ga + Ag + As) 0.5, Lim. sup. 3.

2. 195.5–196 cm: Clay with sand and small stones, grey. Lim. sup. 3.
1. 196 –240+ cm: Marine clay with sand, small stones and gyttja. Greyish brown, darkening rapidly to dark grey. Lim. sup. 3.

Macrofossils

6 cores from the lake bottom and to a depth of 110 cm, and 6 cores covering the 100–234 cm layer were taken. They were cut into 5 cm slices and accumulated as radiocarbon and macrofossil samples. The content of macrofossils found in the radiocarbon samples is shown in table 5.

Table 5. *Spongilla Sø, macrofossils.*

cm below lake bottom, samples á 300 ml.	*Alchemilla alpina*	*Betula glandulosa*, fruits	*Betula glandulosa*, scales	*Betula glandulosa*, leaves	*Carex atrata*	*Carex bigelowii/nigra*	*Carex nigra*	*Carex stylosa*	*Empetrum*, fruitstones	*Empetrum*, leaves	*Hippuris*	*Isoëtes lacustris*	*Phyllodoce*, leaves	*Puccinellia* cf. *langeana*	*Ranunculus confervoides*	*Salix*, leaves	*Salix*, twigs	*Subularia*	*Vaccinium vitis-idaea/uliginosum*
33–38								1	1	23		1				1			
73–78	1	1	1	1	2	1			19	56		94	1			20			1
116–121							1		22	3	1				3	3	1		
146–151	1					5			7	10	12				2				1
191–196						11			40	30	28			1	14			4	

Furthermore, one achene of *Ranunculus confervoides* was found in pollen sample no. 2, and six *Empetrum* fruitstones were found in no. 15.

Datings

5 samples have been dated: 191–196 cm: 9210 ± 140 B.P. (K-1872) 146–151 cm: 8720 ± 140 (K-1873), 116–121 cm: 7670 ± 130 (K-1874), 73–78 cm: 3500 ± 100 (K-1875), and 33–38 cm: 2110 ± 100 B.P. (K-1876).

Pollen zones

Two pollen diagrams have been constructed, viz. a relative diagram and a pollen deposition rate diagram (plates 4–5). The following pollen and spores not shown in the diagrams were found: *Alchemilla* in sample

30: 1 grain, *Campanula* 36:1, *Coptis* 23:1, *Dryas* type 9:1, *Elymus* 15:1, 27:1, *Erigeron* type 10:1, 14:1, 29:1, 36:1, *Euphrasia* type 8:1, ?*Ligusticum* 11:1, *Lathyrus* 32:1, *Liguliflorae* 6:1, 9:3, 28:1, *Pinguicula*, one grain in a sample, only surveyed, at a depth of 108 cm, *Plantago maritima* 12:1, 15:1, 26:1, 29:1, *Polygonum viviparum* 32:1, 34:1, *Polystichum* 30:1, *Rhododendron-Arctostaphylos* type 12:1, *Saxifraga nivalis* 7:1, 20:2, *S. oppositifolia* type 9:1, 35:1, *Selaginella* 22:1, *Streptopus* 29:1, *Thymus* 24:1, *Viscaria* 9:1, P. indet. 3:2, 5:1, 19:2, 31:1, 32:1, 33:1. By accident the *Sphagnum* curve was not drawn in the diagrams. Spores were found in the following samples (if nothing is mentioned only one spore): 2, 3(3), 6, 7, 9, 11, 12, 13, 14, 15(2), 16, 20, 21(3), 22(3), 23(4), 24, 25, 26, 27(3), 28(3), 29(5), 30(3), 31(2), 32(2), 34(3), 35(4), 36(4).

Pollen zone A: *Oxyria-Sagina-Ericales* zone (samples 1–6)

In this zone *Oxyria*, *Koenigia*, *Cerastium cerastoides*, *Sagina*, *Subularia*, *Ranunculus*, *Loiseleuria* and *Vaccinium* type attain their highest frequencies. Furthermore, the zone is characterized by *Empetrum* and *Cyperaceae*, each making up ca. 15 %, the latter increasing towards the end of the zone. *Angelica* occur almost from the beginning of the zone. The sediment is poor in pollen, and ΣP consequently varies between 200 and 234 in samples 2–6. In sample 1 it is only 49, partly because the sample was extremely rich in *Pediastrum* (ca. 600,000 ml), resulting in a rapid sedimentation and some slides paved with *Pediastrum*, difficult to count and poor in pollen. In addition, *Hystrix* was common, blown in from the sea or even washed in by extreme high water in the first years after the isolation of the lake. In the C^{14} sample 191–196 cm i.a. 11 fruits of *Carex bigelowii/nigra* and one of *Puccinellia* cf. *langeana* were found.

Hippuris, *Callitriche* and *Ranunculus confervoides* (proved by macrofossils) flowered in the lake. *Hippuris* attains its maximum in this zone, as do *Pediastrum boryanum* and *P. integrum/muticum* type. *Botryococcus* is common, too. In this context the *Subularia* maximum must be recalled.

The zone boundary A–B is placed at the increase in *Cyperaceae* and in ΣP/cm^2/yr and the contemporary decrease in a number of very small herbs.

Pollen zone B: *Oxyria-Cyperaceae* zone (samples 7–9)

This zone is characterized by extremely high values of *Cyperaceae*. *Oxyria* and *Empetrum* still play a not unimportant role in the spectra (cf. the absolute diagram), but most other plants characterizing zone A decrease. *Harrimanella* attains its maximum. The sedimentation of sand/cm^2/yr decreases.

Hippuris is still in vigorous flower in the lake, and *Sparganium* and *Eupotamogeton* emerge. The decreasing trend of the *Pediastrum* curves is continuous, whereas *Botryococcus* reaches a first maximum in the absolute diagram.

The zone boundary B–C is placed at the sharp increase in *Sedum*.

Pollen zone C: *Sedum-Lycopodiaceae* zone (samples 10–14)

The opening of this zone is characterized by the marked increase in *Sedum*, making up 20–26 % of ΣP in the first samples. In addition, *Lycopodium dubium* and *Huperzia* attain their maximum. In all or most samples herbs such as *Oxyria*, *Koenigia*, *Luzula-Juncus*, *Subularia*, *Botrychium* occur in but small quantities. *Cyperaceae* are frequent. Only one grain of *Loiseleuria* has been found (sample 11). In the relative diagram the minimum of *Empetrum* extends throughout the zone.

Hippuris, as well as *Pediastrum* and *Botryococcus* decrease in the lake. *Sparganium* attains its maximum, and in the middle of the zone *Isoëtes setacea* emerge. As in the preceeding zone only one grain of *Eupotamogeton* is found.

The zone boundary C–D is placed at the immigration of *Salix*.

Pollen zone D: *Salix-Gramineae* zone (samples 15–20)

Besides the appearance of *Salix* and later the scattered *Juniperus*, the zone is characterized by the decrease in a number of herbs including *Cyperaceae*, *Sedum* and *Lycopodiaceae* as the most important. *Harrimanella* still occur, as do *Angelica* and *Botrychium*. *Gymnocarpium*, not found since zone A, now occur regularly although in small quantities. *Gramineae* have a shortlived but significant maximum. *Alnus* attains its extended maximum.

In the lake the slightly decreasing tendency of *Hippuris* and *Sparganium* continues. *Isoëtes setacea* is common throughout the zone. Two *Eupotamogeton* pollen were found (samples 16 and 17).

The zone boundary D–E is defined by a number of changes in the micro- and macrophyte vegetation in the lake and the increase in *Empetrum*.

Pollen zone E: *Salix-Juniperus-Empetrum* zone (samples 21–23)

In this zone *Juniperus* attains its maximum. *Empetrum* and *Betula* increase, *Cyperaceae*, *Dryopteris*, *Botrychium* and *Angelica* decrease. *Sphagnum*, only found in 12 out of the first 20 samples, occur from now in each sample, usually with more than one spore. In the lake *Isoëtes lacustris* dominate. *Myriophyllum alterniflorum* and *Pediastrum tetras* immigrate, while *Sparganium* almost disappear, but can still be found now and then in the rest of the diagram.

The zone boundary E–F is placed between the two samples showing the greatest increase in *Betula* pollen.

Pollen zone F: *Betula-Empetrum* zone (samples 24–29)

This zone is characterized by the dominance of *Betula* and *Empetrum*, making up together 61–70 % of ΣP. *Salix* and *Gramineae* keep their level, as does *Juniperus*, at least in the first half of the zone. Some species, common in the preceding zones as well as in the following, are extremely rare (*Botrychium*) or missing (*Vaccinium* type, *Minuartia* type and *Ranunculus*). Also, a number of species or genera which were frequent earlier now almost disappear from the pollen samples; these include, e.g. *Harrimanella*, *Angelica*, *Oxyria*, *Potentilla*, *Sedum*, *Chamaenerion* and *Koenigia*. On the other hand, *Thalictrum* and *Plantago maritima* seem most frequent in zone E, and the single find of *Thymus* is from this zone, too, (sample 24).

In the lake *Hippuris* and *Myriophyllum* attain low values only, and no *Ranunculus confervoides* achenes were found in the 73–78 and 33–38 cm samples. Among the *Chlorophyceae Pediastrum* is sparse, while *Botryococcus* is very abundant. *Isoëtes lacustris* is by far the most common of the two *Isoëtes* species.

The zone boundary F–G is placed at the fall in the *Juniperus* and *Betula* curves.

Pollen zone G: *Empetrum-Betula* zone (samples 30–36)

Across the boundary *Juniperus* decreases from an average percentage of 1.85 in zone F to 0.29 in zone G, or in terms of number/cm²/yr, from 3.7 to 0.5. *Betula* has a short minimum (samples 30 and 31). After this it increases again but never attains the same level as in zone F. *Empetrum* dominates the spectra with frequencies ranging between 42 and 51 %.

In the lake *Hippuris* becomes more rare. No pollen was found in the upper sample, and no living specimen was observed in the lake. *Myriophyllum* and both *Isoëtes* species show a decreasing tendency. *Botryococcus* is common, *Pediastrum* rare.

Diatom analyses

Foged (1972) has made diatom analyses of 25 samples from the cores. All but one sample – the sample from layer 3, taken from the pollen sample no. 1 in the diagram – were taken from every second of the 300 ml radiocarbon/macrofossil samples. Nos 1–5 are from layer 1, no. 5a from layer 3, and nos 6–24 from the gyttja layers 4–8. In the marine facies only marine and brackish water forms occur, apart from single shells of freshwater diatoms such as *Eunotia pectinalis* var. *ventralis* and *Frustulia rhomboides* var. *saxonica*, washed out in the then existing fjord.

On the contrary, no marine forms were found in the limnic facies. In the 1.5 cm thick clayey gyttja (layer 3) 9 freshwater species are found together with 6 haline species. With respect to the freshwater species one is acidophilous, five are indifferent and three are alkaliphilous. According to this the pH-tendency of the environment was alkaline.

From the composition of the diatom spectra in the analyses 6–24 it appears very clearly that the reaction of the environment during the limnic stage was acid. The older samples 6–12 seem to have been deposited in an environment with a somewhat less acid tendency than the younger. The transition to the more acid environment is rather gradual. The older samples are sedimentated during pollen zones A–C. Sample 12 originates from 126–131 cm below the lake bottom, sample 13 – the radiocarbon sample – from 116–121 cm. The chemical composition of the very soft water of Spongilla Sø is shown in table 1.

Discussion

The isolation of Spongilla Sø app. 9200 B.P. happened after the immigration of *Ericales*, but compared to later periods the dwarf-shrub heaths did not quite cover the whole surface. A number of species has been discussed in the preceding chapter, but a few should be added. *Cerastium cerastoides*, common in zone A, is found northwards to 72°–73° but with a much higher frequency on the more oceanic east coast. It is characteristic of moist, late snow-patches and mossy communities along brooks. The occurrence in manured soil at bird cliffs and around settlements shows its tolerance to edaphic conditions, provided that the moisture demand is fulfilled. *Subularia*, rare in the area today, is found scattered northwards to 69° on the west and 66° on the east coast. *Ranunculus confervoides*, the achenes of which are common in the deepest samples, is found all over Greenland, although it is rare in the northernmost part.

Chamaenerion pollen, found in samples 3, 4 and 5 and scattered later in the diagram, most likely originate from *C. latifolium*, which is found in stony riverbeds, on shingle and in ravines all over Greenland. The other representative of the genus, *C. angustifolium*, distributed south of 70° on the west and 67° on the east coast, does not produce ripe seeds in Greenland today. Its rather wide distribution is ascribed to a former, more favourable period during which ripe seeds were produced (BÖCHER, 1938). The early occurrence (sample 4) of *Angelica* has been mentioned above.

As in zone B in Isoëtes Sø the most prominent vegetation types must have been late snow-patches and moist areas in which *Empetrum-Vaccinium* heaths were not able to thrive. 5% *Koenigia*, 5% *Subularia*, 3% *Sagina* and 2% *Cerastium cerastoides* pollen speak for themselves.

What species of *Cyperaceae* is responsible for the maximum (up to 59%) characterizing zone B cannot be stated. The increasing frequency of *Harrimanella*, reaching its maximum in sample 9, might indicate one of the snow-patch species: *Carex bigelowii*, *C. lachenalii* or *C. scirpoidea*. *C. bigelowii* is by far the most likely, and fruits of this species (or of *C. nigra*) are found in the macrofossil samples. Taking into consideration the topography around Spongilla Sø marshy communities – usually rich in *Cyperaceae* – of any importance can be excluded.

The zone border A–B is by interpolation dated at app. 8900 B.P. The zone border B–C is radiocarbon dated at 8720 ± 140, in accordance with the interpolated dating (8400) for the corresponding zone border in Isoëtes Sø. In the radiocarbon sample one fruit of *Alchemilla alpina* was found. This plant, characteristic i.a. of a transition zone between late snow-beds and the surrounding snow-protected heaths, is common in South and East Greenland northwards to 69°. In West Greenland, where the northern limit is 67°, it is not so common and prefers the outer coast.

Pediastrum, which composed a considerable part of the sediment in the lake, decreases gradually as *Hippuris* and *Ranunculus confervoides* also do. Pollen of *Callitriche* (*C. hamulata* still grows in the lake) have been found in three samples (4, 10, 35) throughout the diagram, while the four grains of *Potamogeton* sect. *Eupotamogeton* all are from deeper samples (7, 12, 16, 17). It is worth mentioning that during the 1970 field season only one species of *Potamogeton* (*P. pusillus* ssp. *groenlandicus*) was found, and in only one locality, viz. a pond one km to the south of Spongilla Sø. Unfortunately, no macrofossils were found. *Sparganium*, presumably *S. hyperboreum*, immigrates in the middle of zone B, attains its maximum in zone C and then subsides, attaining only very low values in the remaining part of the diagram.

The *Sedum* zone (C) in Spongilla Sø is almost identical with the C zone in Isoëtes Sø. The immigration of *Salix* is dated by the sample 116–121 cm at 7670 ± 130 B.P. One *Salix* pollen was found in sample 14 (120 cm), five in sample 15 (117 cm). Based on the pollen morphology it is beyond doubt that *S. herbacea* occurred at the beginning, but *S. glauca* also was found from the very beginning of zone D, as proved by the find of leaves in the radiocarbon sample. Safely determined *Juniperus* pollen were found from sample 17 (110 cm) onwards, dated at app. 6800. It should be mentioned, however, that in each of the samples 8, 13 and 14 one *Juniperus*-like spore was found. These were not indisputable *Juniperus* spores and may as well originate from another *Cupressaceae* or even something else. Around 6600 B.P. a shortlived but marked maximum in *Gramineae* can be seen, as discussed under Isoëtes Sø.

Throughout the first two millennia the formation of humus under the heath and snow-bed vegetation must have caused a gradual change

from neutral-slightly acid to more acid conditions in the lake. The fact that FOGED (1972) places the boundary between samples 12 (126–131 cm) and 13 (116–121 cm) might indicate a causal relation. A likely explanation is that the greater cover of *Empetrum-Salix* heaths enhances formation of acid humus.

With pollen sample 21 (92 cm) a number of changes in the vegetation of the lake is registered: *Isoëtes lacustris*, of which single spores were found in the three preceding samples, occur in great quantities contemporaneous with the immigration of *Myriophyllum alterniflorum* and *Pediastrum tetras*, and the decimation in *Sparganium*. The zone boundary D–E defined by these events is dated at app. 5400 B.P., in accordance with the corresponding boundary in Isoëtes Sø. But contrary to the Isoëtes Sø diagram the *Betula* immigration is not sharply defined in the relative diagram from Spongilla Sø. However, the number of *Betula* pollen/ml, and the size measurements (plate 1) show that the border is best placed between samples 23 (80 cm) and 24 (74 cm), dated at app. 3700 B.P. In the latter radiocarbon sample a number of species is proved by macrofossils: *Alchemilla alpina*, *Phyllodoce*, and the South and Southeast Greenland species *Carex atrata*.

Throughout zone F most curves remain fairly unchanged, indicating stable conditions during the one and a half millennia until the zone border F–G, which is dated at 2110 ± 100 B.P. The most important changes across the zone border are the increase in *Empetrum* at the expense of *Juniperus* and *Betula*. This seems to indicate more humid conditions in zone G.

Kløftsø

The two to three km wide lowland on the south end of Pamiagdluk continues all the way up the east side of the island. Some 15 km farther in the fjord Pamiagdlûp kujatíngua some small but several km long rift valleys run parallel to the coast. In one of these a number of connected lakes are drained through a brooklet to the fjord. The cored lake Kløftsø (60°03′N, 44°14′W, fig. 6, fig. 30. 11) is 200 m long but mostly only 15–20 m wide. In the southern end the width is expanded to 35 m. The coring took place in the middle of this basin. The elevation is ca. 60 m a.s.l. (altimeter measurement). Run-off water from the surrounding slopes supply the lake, illustrated by the fact that a heavy rain during an afternoon and evening raised the water level in the lake by 15 cm. The precipitation in the same period was measured at ca. 30 mm. The maximum depth of water in the lake is 2 m.

Present vegetation

The overall dominating vegetation around the lake is *Empetrum* heaths, partly with mosses and lichens, partly with an abundant mixture

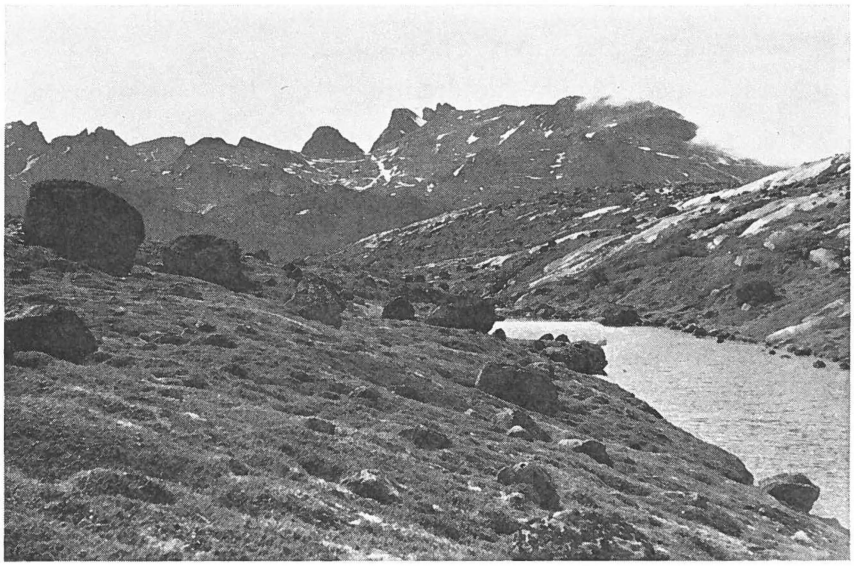


Fig. 6. Kløftsø, looking southwards. Tôrnârssuk in the background. August 3, 1970.

of *Betula glandulosa*. *Vaccinium uliginosum* is found scattered in the heath. *Salix glauca* is rare in the surroundings. In the lake a narrow zone of *Isoëtes setacea* was found at the edge, otherwise the lake bottom was completely plain and bare. As single spores of *I. lacustris* were found in the samples almost to the present one, a scattered growth of this species in the *Isoëtes* zone cannot be precluded.

Description of the sediments

8. 0 –140 cm below the lake bottom: Fine detritus gyttja. Scattered throughout the layer single grains of coarse sand, leaves or fruit stones of *Empetrum*, fragments of twigs etc. were observed, otherwise the structure is very fine-grained. The colour is bright olive-brown but darkens rapidly to dark olive. Ld^1 4, Dg +, Ga +, Gs +.

7. 140 –157 cm: Fine detritus gyttja, stratified. The colour of the often very thin layers varies in brown tones, but also black, grey or café au lait colours were seen. Ld^1 4, Ga +.

6. 157 –159.5 cm: Fine detritus gyttja, slightly sandy. Colour greyish-olive. Ld^1 4, Ga ++, (Ag + As) +. Lim. sup. 2.

5. 159.5–161 cm: Fine detritus gyttja, finely stratified, with some moss. Colour olive. Ld^1 4, Tb^1 ++, Ga ++, (Ag + As) +. Lim. sup. 2.

4. 161 –163 cm: Clayey fine detritus gyttja. Greyish. Ld[1] 3, Ga ++, (Ag + As) 1. Lim. sup. 2.

3. 163 –167 cm: Clayey fine detritus gyttja. Café au lait coloured. Ld[1] 3, Ga ++, (Ag + As) 1. Lim. sup. 2.

2. 167 –171 cm: Stratified layer with alternating, very thin clay and gyttja layers. The deepest gyttja layer is found between 170.5 and 171 cm.

1. 171 –179.5 cm: Clay, sticky, presumably water-sedimentated, with single sand grains. Bluish grey.

Macrofossils

8 cores from the lake bottom to a depth of 0.7–0.9 m, and 7 cores ending in the clay, were cut into 3 cm slices and accumulated as radiocarbon and macrofossil samples. The content of macrofossils in the 5 samples used afterwards for radiocarbon dating is shown in the table 6.

Table 6. *Kløftsø, macrofossils.*

vol., ml	cm below lake bottom	*Alchemilla alpina*	*Betula glandulosa*, fruits	*Betula glandulosa*, scales	*Carex bigelowii/nigra*	*Carex canescens*	*Carex stylosa*	*Empetrum*, fruitstones	*Empetrum*, leaves	*Harrimanella*, leaves	*Juniperus*, leaves	*Oxycoccus*	*Phyllodoce*, leaves	*Salix*, leaves	*Salix*, twigs	*Silene acaulis*	*Vaccinium uliginosum*, leaves	*Vaccinium uliginos./vitis-idaea*
240	35–38	1	13	9	1		2	70	>100		4	1					2	
240	62–65		16	11			4	62	>100	1	2	3						
210	95–98							15	>100							1	1	
210	110–113	1			1			8	>100					5	2			1
210	128–131				1			23	>100		1		1		2		1	
210	140–143				3			60	>100					3	3		1	
210	149–152	1			5	1		32	>100									
140	158–160				1	2		20	>100									

In addition, *Betula glandulosa* fruits and/or scales were found in pollen samples nos 31 and 34, and *Empetrum* fruitstones and/or leaves were found in sample nos 8, 19, 23, 24, 25, 31, and 32.

Datings

5 samples have been dated: 35–38 cm: 3210 ± 100 B.P. (K-1899), 62–65 cm: 3980 ± 100 (K-1898), 95–98 cm: 4870 ± 110 (K-1897), 128–131 cm: 6590 ± 120 (K-1896), and 158–160 cm: 8620 ± 140 (K-1808).

Pollen zones

2 diagrams have been constructed, viz. a relative diagram and a pollen deposition rate diagram (plates 6–7). The following pollen and spores not shown in the diagrams were found: *Cerastium-Stellaria* type, sample 10: 1 grain, 38:1, *Cornus* 38:1, *Cruciferae* 2:1, *Dryas* type 32:1, *Euphrasia* type 2:11, *Gentiana nivalis* 13:1, 27:1, *Rumex acetosella/acetosa* 48:1, *Oxyria-Rumex* type 42:1, 44:1, 45:1, *Plantago maritima* 11:1, *Potentilla-Comarum* type 18:1, 27:1, 35:1, 46:1, *Ranunculus* 24:1, *Selaginella* 48:1, *Tofieldia* 20:1, *Veronica* 39:1, P. indet. 2:2, 4:2, 6:2, 10:2, 11:3 12:1, 13:1, 17:1, 18:4, 19:1, 22:2, 23:2, 25:1, 26:1, 30:1, 33:1, 34:2,' 35:1, 40:2, 41:6, 45:1. *Microthyrium* type 22:1.

Pollen zone A: *Oxyria-Koenigia-Sagina* zone (pollen sample nos 1–2)

In these two samples *Oxyria* makes up 75 and 76% of ΣP, and *Koenigia* 3.8 and 4.5%. Pollen of *Gramineae*, *Sagina*, *Saxifraga oppositifolia* type, *S. nivalis* type, and spores of *Dryopteris* type are characteristic. The find of 11 pollen of *Euphrasia* type in sample 2 should be mentioned. No pollen of this type was found in other samples in this diagram. Contamination during the taking of the 1 ml sample seems the most likely explanation. *Pediastrum boryanum* is very common in the lake. Sample 2 contains a single grain of *Hippuris*. The zone boundary A–B is defined where *Ericales* emerge.

Pollen zone B: *Oxyria-Harrimanella-Loiseleuria* zone (samples 3–5)

Oxyria is still important, but otherwise the zone is characterized by *Ericales*. In sample 3 *Empetrum* dominates, while in the following samples *Harrimanella* and *Loiseleuria* are the most conspicuous. The occurrence of *Koenigia*, *Sagina*, *Cerastium cerastoides*, *Chamaenerion*, *Botrychium* and *Huperzia* is worth mentioning. The latter two emerged already in sample 2. In this zone *Cyperaceae* increase from 1 to 32% while *Gramineae* make up less than 5%.

Subularia and especially *Hippuris* are common in this zone. Among the *Chlorophyceae*, *Pediastrum boryanum* attains its highest frequency (295 colonies/cm²/yr) in sample 3, decreasing to less than 1/10 in sample 6. *Pediastrum integrum/muticum* has a shortlived maximum. *Botryococcus* is rare.

The zone boundary B–C is defined at the emergence of *Sedum* and the increase in the curve of *Diphasium* type.

Zone C: *Sedum-Diphasium-Cyperaceae* zone (samples 6–9)

With the opening of this zone the number of *Oxyria* and other plants – *Koenigia*, *Sagina* etc. – characteristic of zone A and B is reduced to a minimum. *Cyperaceae*, *Diphasium* type, *Dryopteris* type, *Lycopodium dubium* and *Sedum* dominate together with *Ericales*, among which *Empetrum* attains its minimum in this zone. *Harrimanella* and especially *Loiseleuria* are reduced. *Huperzia* and *Luzula-Juncus* attain their maximum. In the lake *Isoëtes setacea*, of which a few microspores were found in sample 6, suddenly becomes very important along with the emergence of *Sparganium*. *Hippuris* and *Pediastrum* almost disappear.

The zone boundary C–D is defined at the increase in *Salix*.

Zone D: *Salix-Empetrum-Gramineae* zone (samples 10–18)

Shortly after the spreading of *Salix*, *Juniperus* also emerges and rapidly attains its maximum (5.8 % in sample 15). The dominating pollen in the zone are *Empetrum*, *Gramineae* with a generally increasing trend, and *Cyperaceae* with a decreasing tendency. *Alnus* shows an extended maximum. *Lycopodium dubium*, *Huperzia* and *Gymnocarpium* also play a role. *Coptis* emerges.

Only one grain of *Hippuris* was found in the lake (sample 12). *Subularia* was proved in two samples, *Sparganium* in all but one. In most samples no *Pediastrum* was found at all, and *Botryococcus* still occur in very low frequencies. The absolute counts show that *Isoëtes setacea* attains almost constant values from samples 8 to 30.

The zone boundary D–E is placed at the 101 cm level where a number of minor alterations in the curves are registered.

Zone E: *Juniperus-Salix-Empetrum* zone (samples 19–27)

Empetrum, *Gramineae*, *Cyperaceae*, *Diphasium*, *Juniperus* and *Salix* dominate the zone with slightly oscillating curves. But in some of the rarer pollen types a change can be seen at the boundary of the zone. Most conspicuous is the decline in *Alnus* and *Lycopodium dubium*. Some plants, the occurrence of which subsided during zone D now disappear totally in the diagram (*Koenigia*, *Saxifraga nivalis* type, *Cerastium cerastoides*, *Subularia*) or become very reduced in number (*Sedum*, *Sparganium*). *Botryococcus* becomes more common in the lake, and although *Isoëtes lacustris* emerges, it never becomes common here.

The zone boundary E–F is defined at the sudden rise in *Betula*.

Zone F: *Betula-Empetrum-Gramineae* zone (samples 28–34)

In this zone *Betula* makes up app. 30 % of ΣP, in the first half slightly more, in the second half slightly less. *Gramineae* and *Empetrum* are the two other main components, the first increasing, the latter decreasing

throughout the zone. Apart from the increase in *Betula* by a factor 5, the most conspicuous trend in the curves in this zone is the abrupt decrease in *Cyperaceae* and the not so sharply defined but still incontestable decrease in *Juniperus*. The frequency of *Diphasium* and *Gymnocarpium* is lower than in zone E. No changes in the lake vegetation between the zones can be seen.

The zone boundary F–G is defined at a second increase in the *Betula* curve along with a decrease in *Gramineae* and a number of alterations in the composition of the flora in the lake.

Zone G: *Betula-Empetrum-Gramineae* zone (samples 35–48)

With the opening of this zone the *Gramineae* maximum, characterizing the latter half of zone F, is brought to an end. *Betula*, on the other hand, increases from below 30 to more than 40 %. This level remains in the first part of the zone and is succeeded by a gradual decrease. *Salix* and *Juniperus* decrease. One grain of *Rumex acetosella/acetosa* was found in sample 48, the recent gyttja. In addition, 3 grains which were either *Rumex* or *Oxyria* were found in this zone. The content of sand in the samples is greater than in the preceeding zone when expressed in mg/ml, but when calculated as mg/cm²/yr remains almost constant.

Pediastrum boryanum, which was almost extinct since zone B, has a second growth in the lake at the same time as *P. tetras*, which did not occur in the lake before. *P. integrum/muticum*, which had not occurred since zone B, was found in two samples. *Isoëtes setacea* attains its maximum in the beginning of the zone and then like all *Pediastrum* species decreases to a minimum in samples 39 to 41.

Discussion

The composition of the vegetation in pollen zone A, completely dominated by *Oxyria*, *Koenigia* etc. was mentioned under Isoëtes Sø. With less than 200 colonies/cm²/yr *Pediastrum boryanum* is a negligible part of the firmly laminated clay gyttja. The start of the sedimentation is dated by extrapolation to app. 9400 B.P. or possibly a little later, as the deepest 10 cm with a rather large content of silt-clay, supposedly were sedimentated at a higher rate than the following. The zone boundary A–B is dated at app. 8900 B.P. This boundary marks the immigration of Ericales, with the anemophilous *Empetrum* dominant in the pollen spectra, but presumably with *Loiseleuria* and *Harrimanella* being more important in the vegetation cover. The vegetation seems to be almost identical to that around Isoëtes Sø and especially Spongilla Sø. *Hippuris* is common in the lake. In the radiocarbon sample 158–160 cm one fruit of *Carex bigelowii/nigra* and two of *C. canescens* were found. The latter, widely-distributed, circumpolar plant must be charac-

terized as being temperate-subarctic. Its northernmost occurrence (apart from Scandinavia) is at 69°–70° on the west coast of Greenland. On the east coast its northern limit lies between 63° and 64°. It grows in springs, around lakes and ponds and in marsh and bog communities.

App. 8200 B.P. *Sedum* is spreading, with *Huperzia*, *Lycopodium dubium* and *Dryopteris* type being co-dominants at the expense of *Oxyria* and the other pioneer plants. *Gymnocarpium* must be considered more or less local, too, but as in the Isoëtes Sø diagram it remains an open question whether the single spores in samples 1, 2 and 3 are due to long distance transport. In the Spongilla Sø diagram *Gymnocarpium* seems to be local from the very beginning. It grows in sheltered spots, in willow scrubs, in *Empetrum-Vaccinium* heaths and in rock crevices ranging northwards to 69° on the west and 67° on the east coast. *Isoëtes setacea* is common in the lake; *Sparganium* is rarer. Almost no *Chlorophyceae* occur.

It is difficult to determine diagramatically the precise date when the *Salix* immigrated; this is illustrated in the best way by giving the number of grains counted in the samples 1 through 11: 1,2,2,0,0,1,0,1,1, 6,12. In all samples ΣP ranges between 500 and 607. Sample 8 (143 cm) is dated at app. 7500 B.P. The zone boundary has been placed between samples 9 (140 cm) and 10 (137 cm), app. 7200 B.P. It seems reasonable that the climatic demands of *Salix* were fulfilled maybe half a millennium earlier at Kløftsø than at the area at Spongilla Sø and Isoëtes Sø. Fragments of leaves and twigs of *Salix glauca* type were actually found in the 140–143 cm sample. This might seem a proof of an earlier immigration of *Salix* than indicated by the zone boundary, but may as well indicate that the accuracy in taking samples from a number of cores may be defective. This was especially the case with the cores from Kløftsø, as the cohesion in the clay underlying the gyttja was large enough to draw out the clay again from many of the tubes. Therefore the cores were arranged according to the upper limit of the stratified gyttja (layer 7) before cutting into slices. It was observed that the thickness of this layer varied between 14.5 and 18 cm. As on the whole the 140 cm thick gyttja layer (8) was completely uniform, it was impossible to control the samples.

Juniperus pollen do not occur until sample no. 13 at 123 cm's depth, although a leaf was found in the radiocarbon sample from 128–131 cm.

The zone boundary D–E is dated at app. 5100 B.P. *Empetrum*, *Huperzia* and *Lycopodium dubium* decrease while *Gramineae* increase. The extended *Alnus* maximum, covering most of zone D, is brought to an end. In the lake *Isoëtes lacustris* immigrate, and *Botryococcus* becomes more common, yet very sparse as compared with other diagrams.

The determination of the zone boundary E–F, defined by the immigration of *Betula glandulosa*, creates no problems. In sample 27 (67 cm)

Betula amounts to 6.1 %, in sample 28, 4 cm higher up in the profile, 33 %. The dating of the radiocarbon sample 62–65 cm gives the age (3980 ± 100 B.P.) of the *Betula* invasion, which clearly marked the composition of the vegetation. *Cyperaceae* suffered much, *Empetrum* and *Juniperus* to a lesser extent. Towards the end of the zone *Gramineae* attain their maximum at the expense of *Betula* and *Empetrum*. The nature of this event is not clear. Nor is the explanation around the changes at the zone boundary F–G. *Betula* has a second increase contemporaneous with a decrease in *Gramineae*. Apart from this no marked changes can be seen in the terrestrial flora. But in the lake *Pediastrum boryanum*, having been almost extinct since zones A and B, again is rather common, and *P. tetras* immigrates. The relative frequency of *Isoëtes setacea* increases by a factor 4.

Throughout zones E and F the average sedimentation rate is 2.64 cm/100 yr, decreasing by a factor 2.5 to 1.06 cm/100 yr in zone G. The abrupt fall across the boundary in ΣP/cm²/yr does not, of course, reflect true conditions in the sense that the vegetation cover and/or flowering was drastically reduced. Apart from the in this context unimportant fluctuations, the pollen spectra are almost unchanged, showing no signs of a catastrophe. But even considering the great uncertainties connected with the radiocarbon sampling and dating, it is beyond doubt that the matrix sedimentation rate was lowered. The average ΣP/ml in zone E, F and G is fairly constant: 29,600, 31,900 and 26,700 resp.

Changes in pollen accumulation without contemporaneous changes in the pollen spectra have been discussed i.a. by Davis *et al.* (1973), and M. B. Davis explains in her paper (1969) that this is a result of a changing water circulation pattern, decreasing sedimentation of pollen quite naturally connected with decreasing sedimentation of matrix.

Sphagnum Dam

A pond, Sphagnum Dam (60°05′N, 44°16′W), is situated on the northeast side of Pamiagdluk at an elevation of ca. 68 m (altimeter measurement), (fig. 7, fig. 30.14). The shape is irregularly triangular, with app. 60 m long sides. Along the northwest and southwest sides the bottom is stony, without vegetation, possibly because these sides are exposed to wave action by the foehns coming from northeast. Along the east side a 20 m wide swamp has filled in the pond. *Eriophorum angustifolium* and *Carex nigra* totally dominate the swamp, while *Scirpus caespitosus* is only found scattered. The surroundings are lichen-rich *Empetrum-Nardus* heaths with frequent *Betula glandulosa* and scattered *Salix glauca* and *Vaccinium uliginosum*. The depth of the water does not exceed 55 cm. Almost the whole bottom is covered with *Sphagnum lind-*

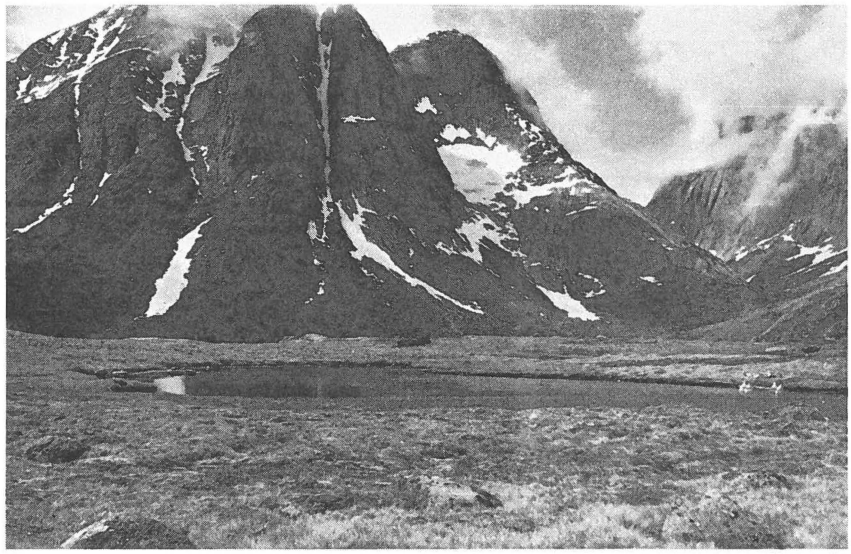


Fig. 7. Sphagnum Dam, looking south-westwards. Naujarssuit in the background. July 15, 1970.

bergii (N. JACOBSEN det.). *Isoëtes setacea* and *Sparganium hyperboreum* grow in the pond.

The pond was cored, but a pollen diagram has not yet been worked out. Most Hiller cores were stopped by stones or gravel ca. 1.1 m below the bottom, but in one case penetrated ca. 20 cm further down in bluish-grey clay with coarse sand. An average profile looks like this:

0– 64 cm:	Different gyttja layers in varying brown tones. Now and then with some moss.
64– 69 cm:	Grey clay gyttja.
69– 85 cm:	Dark-brown, slightly clayey gyttja.
85– 90 cm:	Grey-brown clay gyttja.
90– 94 cm:	Brownish clay gyttja with *Hippuris* fruits.
94–110 cm:	Grey sandy-stony clay, upwards with gyttja.
110– ? cm:	Stone and gravel with bluish clay.

Besides a recent gyttja sample (p. 204), a sample from the 90–94 cm layer has been analyzed. The spectrum indicates that this sample was sedimentated in the phase b, the *Oxyria-Loiseleuria* phase, dated at app. 91–8400 B.P. (cf. p. 82). The following pollen and spores were found: *Betula* 1.9 %, *Alnus* 0.38, *Empetrum* 8.1, *Ericales* 1.5, *Harrimanella* 1.7, *Loiseleuria* 0.94, *Cyperaceae* 55, *Chamaenerion* 0.75, *Gramineae* 10, *Koenigia* 0.94, *Liguliflorae* 0.38, *Minuartia* type 0.56, *Oxyria* 3.2, *Silene acaulis* type 0.56, *Subularia* 13, *Botrychium* 0.19, *Dryopteris*

type 0.19, *Eupotamogeton* 0.19, *Hippuris* 28, *Isoëtes setacea* 1.7, *Sparganium* 2.1, *Botryococcus* 39, *Pediastrum boryanum* 212, *Chenopodiaceae* 0.19, *Myrica* 0.19, *Pinus* 0.47, *Picea* 0.19, *Sphagnum* 0.19, charcoal 0.56, P. indet. 0.19, ΣP 530.

The rather few *Oxyria* and the dominating *Cyperaceae* indicate a dating of the beginning sedimentation to the latter part of the phase. But this single observation does not allow any conclusion to be drawn about the speed of the ice recession along the east coast of Pamiagdluk, cf. the different dating of the bottom layer in Galium Kær and the nearby Comarum Sø (pp. 114 and 96).

Triangelsø

On the northern side of Eggers Ø, ca. 1 km west of the former settlement Itivdleq, the lake Triangelsø (59°54′N, 43°44′W, fig. 30.8) is situated at a distance of ca. 300 m from the sea, at an elevation of ca. 22 m a.s.l. (altimeter measurement). Its area is app. 40×40×35 m, the greatest depth of water is slightly more than three metres. Triangelsø is one of a series of small lakes connected with a little brook passing down to the Ikeq.

Parallel to the coast there is a ca. 300 m wide belt of ablation barrens, dominated by *Silene acaulis*, *Juncus triglumis*, *Loiseleuria*, and *Saxifraga oppositifolia*. On places protected against the strong easterlies small *Empetrum* heaths, some *Juniperus*, *Salix glauca*, *Vaccinium uliginosum* and *Lathyrus* can be found, e.g. on the 1–5 m wide slopes around Triangelsø. *Betula glandulosa* is very scarse and only one single specimen of *B. pubescens* was observed on a 3 km long stretch. A rough estimation of the ratio *Empetrum*:*Salix*:*Betula*:*Vaccinium*:*Juniperus* is 10:2:2:1:$^1/_2$. Dwarf-shrubs grow on ca. 2/3 of the area covered by vegetation, herbs, mainly grasses on 1/3 of this area.

There is a narrow belt of *Isoëtes setacea* and *I. lacustris*, as well as single, very small specimens of *Sparganium hyperboreum* in the lake.

Thirteen cores were taken at a water depth of 311 cm; an average profile looks as follows:

0– 8 cm: Watery gyttja with coarse sand and small stones.

8– 51 cm: Gyttja, yellow-olive, rapid darkening. Coarse sand and small stones. *Empetrum* leaves, twigs etc.

51– 54 cm: Bright yellow gyttja, with clay and abundant macrospores of *Isoëtes*.

54– 61 cm: Darker gyttja with coarse sand and small stones.

61– 68 cm: Like the layer 51–54 cm.

68–103 cm: Gyttja, downwards more clayey, with coarse sand and small stones concentrated in layers.

103–110 cm: Bright-grey clay with some gyttja and with coarse sand and small stones. The cohesion in this layer was so considerable that it was possible to obtain some material in but one of the 13 cores. Otherwise the vacuum in the Livingstone core was broken, and the core was torn above the clay.

The position of the two *Isoëtes* gyttja layers was not quite the same in all the cores. The upper border of the upper one varied between 47 and 58 cm. In some of the cores only one of the layers was observed.

Besides the recent gyttja sample (table 22), a sample from 102 cm, i.e. from just above the clay, was analyzed, and the following were found: *Betula* 4.1 %, *Juniperus* 1.0, *Salix* 2.2, *Alnus* 5.5, *Empetrum* 13, *Ericales* 2.4, *Harrimanella* 0.17, *Loiseleuria* 0.68, *Vaccinium* 0.17, *Cyperaceae* 31, *Gramineae* 23, *Minuartia* type 1.0, *Saxifraga nivalis* type 0.17, *Saxifraga oppositifolia* type 0.17, *Silene acaulis* type 0.17, *Botrychium* 0.51, *Diphasium* type 12, *Lycopodium dubium* 1.2, *Huperzia* 1.5, *Isoëtes setacea* 8.9, *Artemisia* 0.34, *Chenopodiaceae* 0.17, *Quercus* 0.68, *Picea* 0.60, *Pinus* 0.68, *Pinus/Picea* 0.09, charcoal 3.8, *Botryococcus* 4.9, *Pediastrum boryanum* 3.8, P. indet. 0.17, ΣP 585, 29,410/ml.

The spectrum indicates a start of the sedimentation sometime during phase d, the *Salix-Gramineae* phase, but a closer dating within this phase, which covers ca. two millennia, cannot be given. With the equipment at hand it was not possible to penetrate the clay, and thus it cannot be determined whether the clay only was of smaller, vertical extension, covering older organic sediments.

Drepanocladus Dam

The continuation of Kangikitsoq fjord consists of the U-shaped Tupaussat valley, which stretches northwest at a length of 10 km. Some lakes, the largest of them 3 km long, occur in the valley; its major part is, however, composed of a mixture of moraines, fragments of outwash plains, occasional kettleholes, erosion cones, etc. A foaming river and glacial streams from a number of hanging glacier lobes and snow-beds transverse it on both sides of the valley (fig. 8). The crests on both sides of the valley are 1000 to 1500 m high; their peaks are more than 2000 m high.

An outwash plain, 1.5 km from the head of the fjord, some 200 m long and at its broadest 50 m wide, was pockmarked with numerous very small kettleholes. The biggest of these (60°20′N, 44°16′W, fig. 9, fig. 30.22) is filled with a little pond with a water table only 12×8 m. The elevation is estimated at 40–50 m a.s.l.

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Fig. 8. Tupaussat, looking southwards. July 23, 1970.

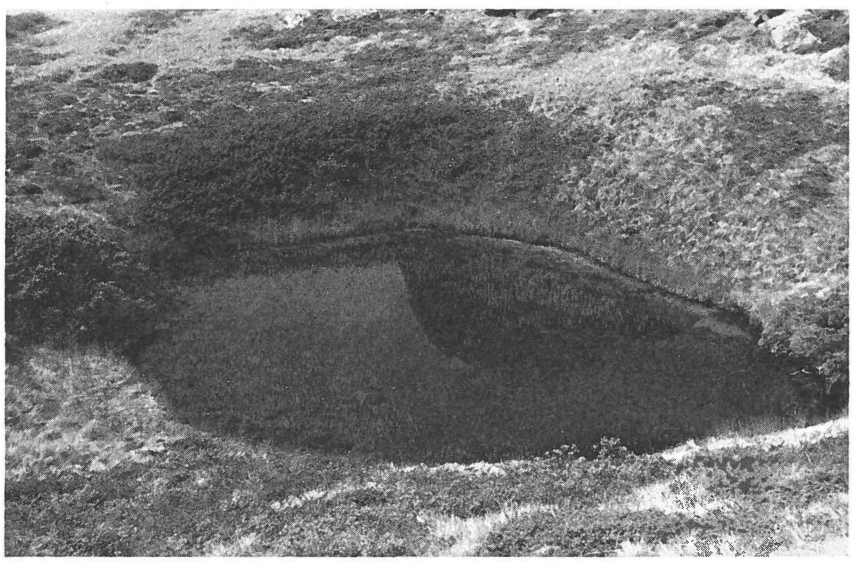


Fig. 9. Drepanocladus Dam. July 12, 1970.

Present vegetation

The south and southwest exposed lower parts of the valley sides and moraine slopes are covered with an, in Greenland scales, luxuriant *Betula pubescens-Salix glauca* scrub, up to 2 m high. The undergrowth and the vegetation in small openings is rich in species of tall herbs such as *Streptopus amplexifolius*, *Chamaenerion angustifolium*, *Angelica archangelica*,

and of ferns such as *Athyrium distentifolium*, *Phegopteris connectilis*, *Gymnocarpium dryopteris*, *Dryopteris filix-mas*, *D. dilatata*, *Polystichum lonchitis*. Furthermore, grasses like *Poa nemoralis*, *Deschampsia flexuosa*, *Phleum commutatum* and *Anthoxanthum odoratum* ssp. *alpinum* and herbs such as *Taraxacum* sp., *Alchemilla glomerulans*, *Sedum rosea*, *Veronica wormskjoldii* and *Gnaphalium norvegicum*. The bottom of the valley and the drier parts of the moraines are covered with extensive *Betula glandulosa* scrubs with *Salix glauca* as subdominant, and with *Juniperus*, *Vaccinium uliginosum* and scattered *Empetrum*. Small patches of *Nardus* grass-heaths are seen, especially on the plains with the cored pond. Solitary *Sorbus groenlandica* occur in the scrubs and between the boulders. *Ledum groenlandicum* also occurs. *Diphasium complanatum*, otherwise rare in the Kap Farvel area, was found here.

The vegetation around Drepanocladus Dam (fig. 9) is dominated by *Betula glandulosa* and *Nardus*. Some *Salix glauca* can also be found at both ends of the pond. Between the *Betula* shrubs and the pond on the distant side herbs such as *Viola palustris*, *Taraxacum* sp., *Angelica*, *Coptis*, *Phleum commutatum*, *Stellaria calycantha*. Around the pond there is a narrow zone of *Sphagnum girgensohnii* (K. HOLMEN det.) with *Juncus filiformis*, *Carex nigra*, *Calamagrostis langsdorfii*. In the pond numerous *Hippuris* and a few *Sparganium hyperboreum* occur. The find of some few spores of *Isoëtes setacea* in the present gyttja sample (table 22) indicates a scattered growth of this species. The water is almost filled with giant specimens of *Drepanocladus exannulatus*.

Borings

The borings with the Livingstone sampler were connected with certain difficulties, partly because of too shallow water (45 cm). Also, after two cores down to 85 cm and one from 84 to 147 cm below the bottom were taken, the sampler broke down. After this 12 cores were taken with the Hiller corer which before the opening in the sediment was pressed down as far as possible. Evidently, the coring was stopped each time by a stony pavement beginning from 147 to 170 cm below the bottom. The deepest 10 cm of the Hiller corer is made up of the "worm", and thus samples could only be taken to a depth of 160 cm. It could be observed, however, that the sediment continued unchanged right down to the stones.

Because of the very well consolidated sediments and the marked differences above and below the 119 cm boundary, I did not hesitate to use the Hiller cores for radiocarbon datings. When a part of the content of the chamber had been contaminated by younger (= above the 119 cm limit) sediment, it was very easy to observe.

Description of the sediments

5. 0– 15 cm below the bottom: Fine detritus gyttja with few mosses and a touch of sand. The colour rather bright, greyish-brown. Ld^1 4, Tb^1 ++, Gs +, Ga +.

4. 15–119 cm: Detritus gyttja with changing content of *Drepanocladus exannulatus* (N. JACOBSEN det.). In certain layers the mosses seemed to make up 3/4 or even more of the volume, but a later inspection in the laboratory proved this to be an optical illusion. The layers 15–31 cm, 59–92.5, 97–109.5, 111–113.5 and 115.5–119 were very rich in mosses. Colour brown. The accuracy of the 1 ml samples is not too great. Average formula Ld^1 2, Tb^1 2.

3. 119–ca. 135 cm: Detritus gyttja with some drift. Colour brown. Fruits of *Sparganium hyperboreum*, twigs, insect fragments etc. Ld^1 4, Dl +, Dg +, (Ga + Gs) ++. Lim. sup. 2.

2. ca. 135–160(170) cm: Coarse detritus gyttja with drift, sand and clay. Greyish-brown. Fruits of *Sparganium hyperboreum*, *Hippuris*, many twigs, etc. Increasing minerogenic content downwards. Ld^1 3.5, Dl ++, Dg +, (Ga + Gs) 0.5, (Ag + As) ++.

1. 160(170)– ? cm: Stones.

Table 7. *Drepanocladus Dam, macrofossils.*

cm below lake bottom	*Alchemilla alpina*	*Betula*, fruits	*Betula*, scales	*Carex bigelowii/nigra*	*Carex brunnescens*	*Carex brunn./canescens*	*Carex norvegica*	*Cenococcum*	*Empetrum*, fruits	*Empetrum*, leaves	*Juniperus*, leaves	*Hippuris*	*Salix*, leaves	*Sparganium hyperboreum*	*Viola palustris*
115–20		14	9	8		5			7	5				37	1
120–25		24	11			9		1	1	1			1	78	4
150–55	2	21	34	9	20		1	12	5		6	2		2	10
155–60	1	9	5	2	1	4		2	1			2			6

Macrofossils

The content of macrofossils in 4 samples, two of which were afterwards used for radiocarbon dating, are shown in table 7. The precise volume of the samples cannot be stated.

In the field and during preparation of the pollen samples, fruits and seeds of *Sparganium hyperboreum* were found at the following depths: 146, 142, 136, 134, 131, 130, 110, 80, 30 cm, of *Viola palustris* at 147, 142, 30, of *Empetrum* at 114 and of *Carex bigelowii/nigra* at 113 cm.

Datings

2 samples have been dated: 150–155 cm below the bottom: 2990 ± 100 B.P. (K-1807) and 115–120 cm: 2240 ± 100 B.P. (K-1933).

Pollen zones

Only one diagram, viz. a relative diagram (plate 8) has been made. The main reason why no pollen deposition rate diagram or at least a pollen concentration diagram has been drawn is the exorbitant number of pollen in the deeper samples, with 1,771,000/ml in sample 3. This means that with the number of pollen counted in this sample one single pollen grain corresponds to a total of 2830/ml, while in the upper 10 samples the average content/ml is 44,000, with one grain corresponding to 82/ml. Samples 1 and 2 were taken from a Hiller core, while the rest of the samples were taken from two Livingstone cores.

The following finds are not shown in the diagram: *Callitriche* in pollen sample 31: 1 grain, *Elymus* 6:1, *Epilobium* 29:1, *Equisetum* 3:1, 31:1, *Erigeron* 16:1, 34:1, 40:1, *Euphrasia* type 7:1, 14:1, 23:1, 39:1, *Harrimanella* type 32:1, *Phleum commutatum* type 31:1, 36:1, *Plantago maritima* 33:1, 38:1, *Polygonum viviparum* 3:1, 6:1, 14:1, *Ranunculus* 35:1, *Sagina* 38:1, *Saxifraga nivalis* type 10:1, 38:1, *S. oppositifolia* type 9:1, 25:1, *S. foliolosa* type 33:1, *Selaginella* 35:1, *Thymus* 3:1, 33:1, *Vaccinium* type 3:1, *Veronica* 2:1, P. indet. 1:6, 2:9, 3:9, 4:7, 5:8, 6:4, 7:1, 8:4, 9:8, 10:1, 14:3, 16:2, 20:1, 21:1, 32:1, *Pediastrum integrum/muticum* 36:2, *Assulina* 18:1, 28:1, 39:1, *Tilletia* 31:1.

Pollen zone A: *Betula pubescens-Juniperus* zone (samples 1–8)

Betula pollen dominates this zone. Size measurements (plate 1.4) show that by far most of the *Betula* pollen originate from *B. pubescens*. Other dominants of the pollen spectra are found within *Gramineae*, *Diphasium* and *Dryopteris*, whereas *Cyperaceae* are not so dominating. In this zone *Juniperus* exceeds 1 % in most samples. *Ericales* + *Empetrum* are extraordinarily rare, usually making up 1 %, as compared to the outer coast diagrams. The curve of sand runs almost parallel to that of the ΣP/ml. In the "lake" very little vegetation is registered in the

deeper samples, only a few pollen and fruits of *Hippuris* were found. In the later part of the zone *Pediastrum boryanum*, *Botryococcus* and *Sparganium* emerge.

The zone boundary A–B is defined where a number of concurrent changes occur around the 122 cm level.

Pollen zone B: *Betula glandulosa-Sorbus* zone (samples 9–27)

From the zone boundary onwards the ΣP/ml remains more or less constant, oscillating mostly between 40,000 and 85,000. The character of the sediment changes from a gyttja with a rather large content of minerogenous particles and twigs etc. to a gyttja with a considerable content of mosses. The composition of the *Betula* pollen rain changes towards a distinct dominance of *Betula glandulosa*. *Juniperus* decreases by a factor 4 (1.25 % on the average in zone A as against 0.31 % in zone B) while *Salix* becomes more common yet still making up only 5–8 %. The oldest find of *Sorbus groenlandica* is in sample 10. Once emerged, it is found in all but two samples in zone B. Among herbs and ferns only minor alterations can be seen. The most conspicuous is the constant, but of course sparse, occurrence of pollen of *Chamaenerion*. In zone A only one grain of this genus was found.

In the pond the zone is opened with maxima in the occurrence of *Sparganium* and *Botryococcus*. Later in the zone these two, together with *Pediastrum boryanum*, have two simultaneous maxima. The number of *Hippuris* pollen is very varying, ranging from 0 to 13 %. Towards the end of the zone *Pediastrum braunii* and *P. tetras* emerge.

The zone boundary B–C is defined at the sudden increase in charcoal.

Pollen zone C: *Betula glandulosa-Salix-Rumex* zone (samples 28–34)

Most conspicuous is the maximum in microscopical charcoal in the first half of the zone. Among the shrubs *Sorbus* is decimated. *Betula* shows a decreasing tendency, reaching a minimum in samples 33 and 34. During the zone *Salix* increases from 8 to 22 %. *Cyperaceae*, *Gramineae* and *Chamaenerion* decrease. In the middle of the zone *Rumex acetosella/acetosa* emerge.

Hippuris and *Sparganium* flourish in the pond. *Botryococcus*, *Pediastrum braunii* and *P. tetras* decrease, while the number of *P. boryanum* is very varying. *Sphagnum* attains its maximum.

The zone boundary C–D is defined at the increase in *Betula* and the decrease in *Rumex* and *Diphasium* between samples 34 and 35.

Pollen zone D: *Betula glandulosa-Salix* zone (samples 35–40)

Betula remains at the 25 % level throughout the zone, *Salix* attains its maximum in the beginning. *Gramineae* increase, while *Rumex*, *Polypo-*

diaceae and *Lycopodiaceae* decrease. Apart from the present gyttja (sample 40) the frequency of charcoal keeps a level much lower than in zone C, yet still higher than in zones A and B. The content of sand increases.

In the pond *Hippuris* and *Sparganium* are more frequent than in zone C, and the *Chlorophyceae* also are important. *Isoëtes setacea*, of which a single spore was found in zone B, are found in 4 samples in this zone.

Discussion

The very high content of pollen in the first samples might be caused by an extremely slow sedimentation rate, increasing through zone A. This, however, is contradicted by the radiocarbon datings. The almost parallel curves of ΣP/ml and mg sand/ml indicate that outwash from the slopes surrounding the kettlehole must be responsible. The same phenomenon is seen in the deepest samples in another little (former) pond, Galium Kær (p. 115). There the number exceeded one million/ml in the deepest four samples. In Galium Kær eight samples have been dated, showing that the sedimentation rate in the deepest layer (with the great content of sand and pollen) was almost the most rapid throughout the whole profile (5 cm/100 yr). Presumably this also was the case in Drepanocladus Dam. One further argument against a slow sedimentation rate can be found in the very low frequencies of exotic pollen in the deeper part of the diagram. The total absence of *Chlorophyceae* in the first five samples (2 *Botryococcus* were actually found as early as in sample 4) indicates so much suspended clay that assimilation of these algae was prevented. On the other hand, this could not prevent the emergent hydrophytes *Sparganium hyperboreum* and *Hippuris* from invading the pond very rapidly after its forming, cf. table 7.

The sedimentation of gyttja directly upon the till must have been initiated shortly earlier, perhaps one or two centuries. Furthermore, the melting of such a small amount of ice responsible for the formation of a kettlehole of this size can hardly have taken much time. The withdrawal of the ice is thus estimated to have happened some time between 3000 and 3500 B.P. At what time the ice lobes grew and filled in the Tupaussat valley cannot be stated. It can only be presumed that this advance was hardly serious enough to eradicate the *Betula pubescens* scrubs from this valley-fjord system, as the *B. pubescens* scrubs immediately after the retreat of the ice could cover the fresh moraines. If the immigration of *B. pubescens* to this part of Greenland was contemporaneous with the immigration to the Tunugdliarfik area, the advance happened after 4000 B.P. It is hardly realistic to imagine that the Tupaussat valley had not been free of ice earlier in the holocene.

On the other hand, it can be maintained that nothing in the present investigation supports the theory put forward by BÖCHER (1956). According to this, some of the valleys in this interior part of the Kap Farvel area, i. a. Qínguadalen 10 km to the southwest of Tupaussat, was free of ice during the Wisconsin, and even warmth-demanding species such as *Betula pubescens* might have wintered here.

The very few *Ericales* in the pollen diagram have been mentioned above, but the find of macrofossils of *Empetrum* indicates that some specimens grew on the surrounding moraine slopes, which otherwise must have been covered with *B. pubescens* scrubs with, presumably on the drier parts, some *B. glandulosa* and *Juniperus*. *Salix* plays a very small role in zone A. In the *Betula* scrubs *Alchemilla alpina*, *Angelica*, *Carex brunnescens*, *Coptis*, *Taraxacum* and ferns (? *Dryopteris filix*-mas, ? *D. dilatata*, ? *Athyrium distentifolium*) grew in the more protected parts, while *Campanula*, ? *Minuartia rubella*, *Polygonum viviparum*, *Thalictrum*, *Thymus* and evt. *Potentilla tridentata* (no *Comarum* seeds were found) preferred slightly drier communities, e. g. a *Betula glandulosa* scrub with scattered *Juniperus*. *Viola palustris* grew in moss carpets at the shore together with *Carex* ? *nigra*.

After some centuries the vegetation on the slopes around the pond almost entirely covers the ground, and only aeolian minerogenic particles are sedimentated in the pond, thus allowing the algae and the water mosses to thrive. Simultaneously with this shift in the sediment the changes described above at the zone boundary A–B occur. Conditions must have been more unfavourable to *Juniperus* and *Betula pubescens*. A climatic change may be responsible, but with a basin so small as the one we are dealing with (9×12 m) it seems dangerous to draw too far-reaching conclusions based on pollen of plants which may have been growing like *Salix glauca* today, i. e. with flowering branches hanging over the water table. On the contrary, *Juniperus* can hardly ever have been a component of the shore vegetation proper, and the decrease may be a response to a climatic change. In this context it must be kept in mind that in all other diagrams from South Greenland a decrease in *Juniperus* takes place around 2 millennia ago. The radiocarbon sample just above the zone border has been dated at 2240 ± 100 B.P.

Sorbus pollen have not been found in zone A, but when recalling the fact that *Sparganium* fruits were found as low as the very bottom of the core while the first pollen of this species was found in sample 6, it can hardly be postulated that *Sorbus* did not immigrate until zone B.

Shortly after the zone boundary A–B the plant communities established around the little pond seem to be almost in equilibrium. Judging from the present pollen spectrum, the plain with the small kettleholes must have been covered with grasses (*Nardus*?). *Polystichum* and *Chamaenerion*

should be noted as new plants in zone B. It is not possible by means of the pollen morphology to distinguish between *Chamaenerion latifolium* and *C. angustifolium*, but the latter seems most likely in this closed community.

The drastic increase in the number of microscopic charcoal at the opening of zone C calls for an explanation of a special kind. As forest fires caused by lightning are out of the question, man must be responsible. A large Norse farm was situated near the coast, at a distance of about 1200 m; apparently this maximum of charcoal can be connected with the clearing by fire of the often impenetrable South Greenland scrubs. The use of fire in the landnam phase has been proved at several localities, e.g. in the Godthåbsfjord area (IVERSEN, 1934 and 1952–53). The need for timber and fuel no doubt caused cutting of the *Betula* and *Sorbus* in the valley. The openings in the scrubs around our pond seem to have been occupied by *Salix* with a *Diphasium* ? *alpinum* undergrowth. An increase in the *Gramineae* was to be expected, but sheep grazing may have reduced the blooming of the *Nardus* and other grasses.

A moist, narrow zone of *Sphagnum*, *Viola palustris*, ? *Juncus filiformis*, *Saxifraga* ? *stellaris* and *Carex spp.* was found around the pond.

Nothing is known of the dating of the Norse farm, but a dating at some time during the 11th Century is hardly wrong. After some time the Norse settlers disappeared. Presumably this appears in the diagram at the C–D boundary where there is an increase of *Betula*, *Salix*, and *Juniperus*, and a decrease of *Rumex* and charcoal. Still more charcoal than normally expected was found in samples 35–39 and especially in 40. A peninsula next to the outlet of the river is filled with evidences of human activity in the past (and present), and no doubt this ideal trout fishing locality has been visited by Eskimoes ever since the Norse period. Their numerous camp-fires, now and then spreading to the surrounding vegetation may well be responsible for the unexpectedly high frequency of microscopic charcoal in our pond. The effectivity of a ground fire in this area was demonstrated shortly before the visits there in July 1970. Several acres of land were completely black and scorched, only some charred trunks in the former scrub remained. This big fire which must have taken place in the preceding year, was traced in the present gyttja in Drepanocladus Dam by the marked increase in sample 40, which of course covers not only 1970 but also some of the preceding years.

Summary of the vegetational and climatic history of the Kap Farvel area

The terrestrial vegetation

The plant successions described in the four localities exhibit so many common features that a general survey can be given. Considering the uncertainty in the radiocarbon datings and, especially the sampling method, the dating of marked changes in the diagrams often agree surprisingly well. The datings mentioned in the following pages must not be taken too literally; they are the result of weighing of the available datings, inter- and extrapolation, changes in sedimentation rate etc. The vegetational history will be divided into seven phases. The distribution and ecology of a number of species has been discussed in connection with the treatment of the pollen zones of the single localities and will not be repeated in this survey.

a. *Oxyria-Koenigia* phase (ca. 9600–9100 B.P.)

When the ice receded the fresh soil found in depressions and sheltered places between the polished rocks and boulders was invaded by a number of pioneer plants. In the pollen spectra there are found *Oxyria*, *Sagina*, *Saxifraga caespitosa* type, *S. nivalis* type, *S. oppositifolia* type, *Koenigia*, *Erigeron* type, *Silene* type, *Dryopteris* type, *Cruciferae*, *Cyperaceae*, *Gramineae*, *Huperzia*, *Botrychium*, *Diphasium* type and *Gymnocarpium*. The local pollen production was very low, and exotic pollen therefore was important. Some of the pollen (*Cyperaceae*, *Gramineae*) and spores (*Dryopteris* type, *Gymnocarpium*) may partly or totally originate from distant sources. But the small herbs must have been growing on the spot. Seeds of *Carex bigelowii* (rather than *C. nigra*) and of *Puccinellia* cf. *langeana* have been found. Since no indices at all of southern, more warmth-demanding plants have been found, the climate supposedly was severe. It must be recalled that during this phase an ice cover greater than the European ice sheet during the maximum glaciation covered North America. This inevitably must have had a cooling effect on the climate in South and West Greenland.

The major part of the vegetation cover supposedly was snow-patches, and the numerous and detailed descriptions of the vegetation types in Southwest and South Greenland (Böcher, 1954, 1963) can be consulted regarding description of communities dominated by the above-mentioned species. It can be mentioned that *Koenigia* is an EG-species (= ecogeographical) of "The *Deschampsia alpina-Carex rufina* Type (Sub- and low arctic oceanic marsh, snow-patches and related wet-soil vegetation)", belonging to "The *Deschampsia alpina-Gnaphalium supinum-*

Cassiope hypnoides Complex (Oceanic snow-patch (or snow-bed) vegetation and related vegetations on wet soil)" (BÖCHER, 1954, pp. 126, 108). *Oxyria* is most common in different types belonging to this complex, but also occurs in "The *Saxifraga foliolosa-Timmia austriaca* Type (Arctic continental snow-patch vegetation rich in mosses)", which belongs to "The *Saxifraga foliolosa-Ranunculus sulphureus* Complex (Arctic continental snow-patch vegetation and related marsh vegetation on wet soil)", (BÖCHER, 1954, pp. 178, 176).

b. *Oxyria-Loiseleuria* phase (ca. 9100–8400 B.P.)

After half a millennium a number of ericaceous dwarf-shrubs immigrated: *Loiseleuria*, *Harrimanella*, *Empetrum*, *Vaccinium*. *Phyllodoce* supposedly is an early immigrant, too, but as it cannot be determined with certainty by means of pollen, its existence was not proved until the find of a leaf in a later period. During this phase the following species (genera, types) immigrate or at least appear in the pollen analyses: *Armeria*, *Cerastium-Stellaria* type, *Cerastium cerastoides*, *Dryas* type, *Luzula-Juncus*, *Subularia*, *Angelica*, *Chamaenerion*, *Liguliflorae*, *Minuartia* type, *Sedum*, *Equisetum*, *Sphagnum*. Two pollen grains of the anemophilous *Thalictrum* (ΣP: 3135) may be of distant origin. Seeds of *Carex bigelowii/nigra*, *C. canescens* and of *Puccinellia* cf. *langeana* have been found. One seed of *Alchemilla alpina* was found in the radiocarbon sample dating the upper phase border in Spongilla Sø.

Still everything indicates an open vegetation with great snow-patches and moist sandy-clayey spots. In this connection the most important species is *Cerastium cerastoides*. This is an EG species of "The *Cerastium-cerastioides-Veronica alpina* Type (Low arctic oceanic herb snow-patch vegetation)" (BÖCHER, 1954, p. 110), belonging to "The *Deschampsia alpina-Gnaphalium-Cassiope hypnoides* Complex". *Alchemilla alpina* is an EG species of "The *Alchemilla vulgaris-Phleum commutatum* Type (Sub-low arctic oceanic, mesophytic, medium chionophilous herb vegetation)", belonging to "The *Alchemilla-Phyllodoce-Scirpus austriacus* Complex" (BÖCHER, 1954, pp. 76, 53). *Harrimanella* is an EG species of "The *Salix herbacea-Cassiope hypnoides* Type (Low arctic oceanic dwarf-shrub snow-patch vegetation)" (BÖCHER, 1954, p. 117), belonging to "The *Deschampsia alpina-Gnaphalium supinum-Cassiope hypnoides* Complex".

c. *Sedum-Lycopodiaceae* phase (ca. 8400–(7500)7200 B.P.)

The pollen spectra in this phase are dominated by *Sedum*, *Cyperaceae*, *Dryopteris*-type, *Diphasium* type, *Huperzia*, *Lycopodium dubium* and *Ericales*, yet with rather few *Empetrum*. New to this phase are *Potentilla-Comarum* type, *Viscaria*, *Plantago maritima*. *Thalictrum* may be local.

Still the vegetation was characterized by moist conditions and a good snow-cover, but dwarf-shrub vegetation occupied a greater part of the surface. E.g. *Diphasium alpinum* (the only reasonable explanation of the many spores of *Diphasium* type) is an EG species of "The *Phyllodoce coerulea-Lycopodium alpinum* Type (Sub-low arctic oceanic, medium chionophilous dwarf-shrub vegetation rich in mesophytes and mosses; soil acid, very rich in humus)", belonging to "The *Alchemilla-Phyllodoce-Scirpus austriacus* Complex" (Böcher, 1954, p. 94). *Huperzia* is a habitat species of "The *Saxifraga foliolosa-Ranunculus sulphureus* Complex". *Angelica* has been discussed above (p. 50). It can be mentioned that this species occurs in most of the types belonging to "The *Alchemilla-Phyllodoce-Scirpus austriacus* Complex". It is assumed that most of the *Sedum* pollen originate from *S. rosea.*

d. *Salix-Gramineae* phase (ca. (7500)7200–5300 B.P.)

New to this phase are *Coptis*, *Elymus* and *Gentiana nivalis*, besides *Salix* (*glauca* and *herbacea*) and *Juniperus*. *Salix* pollen have been found earlier, in the Isoëtes Sø diagram in 5 out of 8 samples ($\Sigma P = 2854$), in Spongilla Sø in 2 out of 14 samples ($\Sigma P = 5359$), and in Kløftsø in 6 out of 9 samples ($\Sigma P = 4851$). It should be mentioned that all the early *Salix* pollen are of typically *S. glauca* types. The first typical *S. herbacea* pollen is found at the beginning of this phase. The question now arises: Does the early *Salix* (*glauca*) pollen bear witness to an early immigration?

In favour of this explanation: It seems difficult to understand that a plant producing enormous amounts of seeds well-suited for long distance dispersal should need more than two millennia to reach South Greenland whether from west (Labrador?) or east (Iceland). If an early immigration is assumed and the early pollen grains originate from scattered specimens we need an explanation of the late expansion. A tentative explanation might be that the climate, especially the oceanity with a long and extensive snow-cover, prevented the spreading from the few and favoured habitats on ridges having a southern exposure. Not until the climatic amelioration about 7500–7200 B.P. environmental changes made spreading possible. This seems to be supported by the fact that most of the plants found during phase a–c are characteristic of snow-patches and wet-soil communities which do not normally include *Salix glauca* in their vegetation cover. Furthermore, *Salix* is entomophilous with sticky pollen. Therefore, although it is a big pollen producer with exposed stamens, it must only exceptionally be capable of long distance transport.

Against the assumption of an early immigration are: *Angelica* is registered as early as around 9000 B.P. and attains its maximum in Spongilla Sø in the following half millennium with absolute values approaching 10/cm²/yr. If *Salix* was growing nearby it is hard to imagine

that it was not able to take over some of the not too extreme snow-patch habitats such as *Angelica* did (unless all the *Angelica* grew among boulders at the edge of the melt water brooks). And, besides, if *Salix* immigrated early, the greatest chance of establishing a more or less vigorous growth was to be found in the more continental parts of the fjords. In Comarum Sø at the head of Tunugdliarfik (p. 97) the continuous *Salix* curve, starting abruptly with the highest frequencies (20–24 %) and almost the highest absolute values (150–200/cm²/yr) attained in the whole diagram, begins around 8000 B.P., more than half a millennium earlier than at the outer coast at Kap Farvel.

If the *Salix* pollen in the phase a–c samples is of long distance origin, a constant ratio *Salix:* exotic in the different lakes (incl. Comarum Sø) could be expected. Table 7 gives the number of *Salix*, *Betula*, *Alnus* (both of which are of long distance origin in this part of the diagram) and exotic pollen. However, the statistical material (especially as regards Comarum Sø) hardly allows any definite conclusion to be drawn about possible early *Salix* in the Kap Farvel area.

Table 8. *Number of pollen of Salix, Betula, Alnus and exotic pollen in the early phases in four South Greenland pollen diagrams.*

	sample no.	Σ *Salix*	% *Salix*	Σ *Betula*	% *Betula*	Σ *Alnus*	% *Alnus*	Σ exotic	% exotic	*Bet., Aln.* + exotic	Σ P
Isoëtes Sø . .	1–8	9	1.3 %	249	37 %	173	26 %	251	37 %	673	2858
Spongilla Sø	1–14	4	0.7 %	237	43 %	124	23 %	187	34 %	548	5359
Kløftsø	1–9	8	1.8 %	226	51 %	115	26 %	102½	23 %	443½	4851
Comarum Sø	1–5	0	0 %	32	51 %	20	32 %	10½	17 %	62½	1848

At the moment it seems best to use the term emerged instead of immigrated, stating: *Salix glauca* s.l. emerged rather late, around 7500–7200 B.P., in the Kap Farvel outer coast area, presumably in response to a climatic amelioration (cf. the immigration of *Isoëtes setacea*, p. 90).

The absolute counts show that shortly after its immigration *Salix* was as common as it is today. Most of the pioneer plants have disappeared, and a common vegetation type must have been dwarf-shrub heaths consisting of *Salix*, *Empetrum* (still not as important as today), with *Diphasium*, *Huperzia*, *Lycopodium dubium*, *Thalictrum* and *Coptis*. This latter species is an EG species of "The *Alchemilla-Phyllodoce-Scirpus austriacus* Complex" (BÖCHER, 1954, p. 67) and especially frequent in "The *Phyllodoce coerulea-Lycopodium alpinum* Type" of this complex. The immigration, or at least the rise, in *Juniperus*, came some centuries later

than *Salix*. It must be concluded that the opening of this phase marked a climatic amelioration, and during this and the following phase summer conditions may have been as warm as today, if not even more so. The snow-cover must have been constant, but the summer climate may well have been rather dry, favouring a more vigorous growth (judging from the abs. counts) than today. Heaths, rich in lichens and grasses (*Nardus*?), and with some *Juniperus* and *Gentiana nivalis* may have covered the ridges.

e. *Salix-Juniperus-Empetrum* phase (ca. 5300–3800 B.P.)

The most significant changes in the diagrams around 5300 B.P. are registered in the lake vegetation, i.a. in the contemporaneous immigration of *Isoëtes lacustris*, but minor changes also occur in the terrestrial vegetation. In the two diagrams nearest to the outer coast a marked increase in *Empetrum* sets in, whereas in Kløftsø *Gramineae* increases. New to this phase are *Campanula*, *Selaginella* and *Tofieldia*.

The fact that contemporaneous changes in all three lakes are registered calls for a common, climatic cause, the nature of which is not quite clear. Judging from the present distribution (HULTÉN, 1958, map 247) it seems obvious to connect the immigration of *Isoëtes lacustris* with an increasing summer temperature. Most likely the climate in this phase was the warmest, least oceanic in the whole sequence.

f. *Betula-Empetrum* phase (ca. 3800–2200 B.P.)

Again we are faced with one of the most puzzling questions: Why did *Betula glandulosa* not immigrate earlier to the Kap Farvel area? Was it only a question of failing dispersal or had the environment been unfavourable in the preceding phases? Judging from the present distribution and ecology of this plant it is hard to believe that it could not have grown on Pamiagdluk at an earlier stage. At the head of Tunugdliarfik *B. glandulosa* immigrated ca. 4500 B.P. (cf. p. 120), *B. pubescens* some few centuries later.

In the Scoresby Sund area 70°–72°N on the east coast of Greenland *Betula nana* already immigrated around 8000 B.P. (FUNDER, 1971). Around 1000 years later it spread to the head of Godthåbsfjord, which today marks its southern limit. In Greenland this species decidedly is a more continental species than *B. glandulosa*, and this may explain that not even during phases d and e was *B. nana* able to thrive in South Greenland. At least it seems less reasonable that it could spread across Denmark Strait and later cross the Inland ice, but could not spread to South and Southwest Greenland.

The distance across Davis Strait is much longer than across Denmark Strait and this may be the reason for the late immigration of *B. glandulosa*. On the other hand, it immigrated at the head of Tunugdliarfik

just as *Salix* did half a millennium earlier. This can be fortuitous, but may also mean that the environment was favourable for its growth at a later stage at Kap Farvel. The increase in *Betula* pollen in both areas is more gradual than e.g. the abrupt increase in *Salix* in Comarum Sø or the similar increase of *Betula nana* in "Lake 100 m" (Godthåbsfjord, p.140). These latter trends can be interpreted as indications of favourable environmental conditions even for some time prior to the immigration of the two species. But the more gradual increase in *B. glandulosa* may have been caused by the fact that all potential habitats were already inhabited by dwarf-shrub heaths. *Betula* therefore had to compete with and displace other plants. Until more radiocarbon dated diagrams from the area of *B. glandulosa* in Greenland are at hand it seems impossible to understand fully the history of this plant in Greenland.

New to this phase are *Euphrasia* type, *Rumex acetosella/acetosa*, *Streptopus*, *Cystopteris fragilis* and *Thymus* (occurring in two diagrams) as well as *Carex atrata*, *C. stylosa* and *Oxycoccus*, the latter three found as macrofossils. Extensive dwarf-shrub heaths must have covered Pamiagdluk during this phase. The effect upon the vegetation of the spreading of *B. glandulosa* tends to hide the effect of any contemporaneous climatic changes. Such changes can, however, only have been of minor importance, for an almost unchanged, rather warm/dry climate is mainly indicated.

The only inland diagram from the Kap Farvel area, Drepanocladus Dam, starts in this zone. *Betula pubescens* dominates the vegetation, which also includes *B. glandulosa*, *Salix*, *Juniperus* etc. The total amount of ericaceous pollen makes up only ca. 1 %.

g. *Empetrum-Betula glandulosa* phase (ca. 2200–0 B.P.)

Empetrum and *Betula* dominate the pollen spectra. In Isoëtes Sø and Spongilla Sø *Juniperus* show an abrupt decline across the boundary, and a number of species, rare or even absent during the preceding phase (or phases) re-occur, i.a. *Vaccinium*, *Luzula-Juncus*, *Saxifraga oppositifolia* type, *Saxifraga nivalis* type, *Botrychium*, *Minuartia* type. In Kløftsø the decline in *Juniperus* is more even, but in Drepanocladus Dam it is very marked. No doubt these changes, especially the *Juniperus* decline, were caused by a climatic deterioration towards more humid conditions, and gradually the vegetation was changed to the present one.

The effect of the Norse settlers is only registered in the diagram from the inland.

The lacustrine vegetation

The history of the higher vegetation in the lakes is best illustrated by fig. 10. From this it appears that *Hippuris* immigrates soon after the

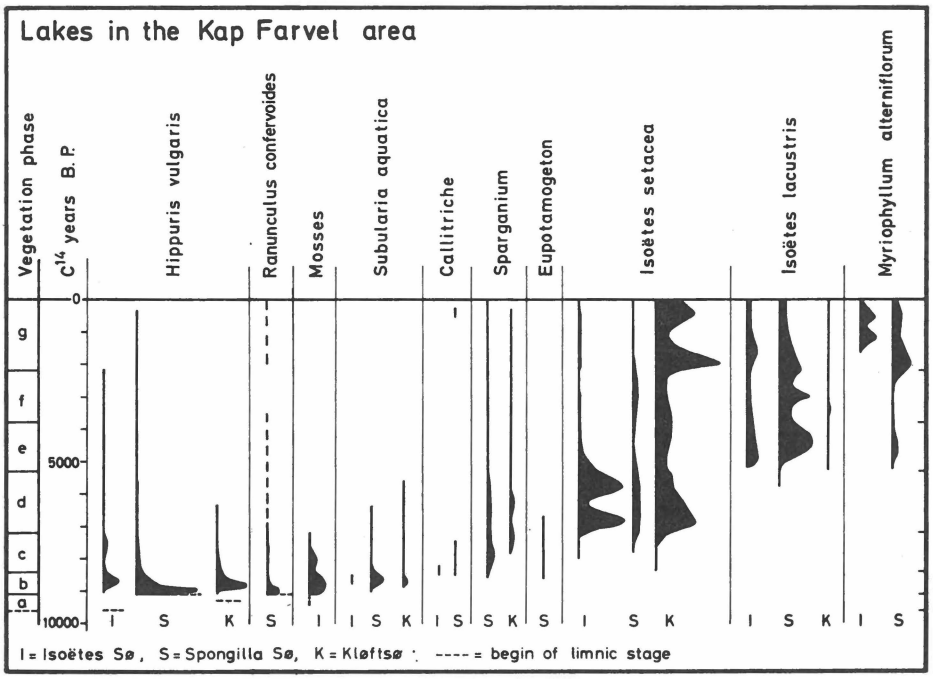


Fig. 10. Summary diagram of the vegetational development of the lakes in the Kap Farvel area. (2 pollen of *Sparganium* were found in phase e in Isoëtes Sø).

formation of the three lakes on Pamiagdluk. Shortly thereafter *Subularia* also occurs in these lakes, *Callitriche* (presumably *C. hamulata*) and *Sparganium* (presumably *S. hyperboreum*) in two, and *Ranunculus confervoides* and *Eupotamogeton* in one. *Isoëtes setacea* immigrates slightly later, at the beginning of phase c. To this should be added the statement of the single analysis of the oldest sample in Sphagnum Dam (p. 70), farther north on Pamiagdluk. The spectrum dates this sample to phase b, presumably the later part. *Hippuris* attains 28 %, *Subularia* 13, *Sparganium* 2.1, *Isoëtes setacea* 1.7 and *Eupotamogeton* 0.2 %. The flourishing immediately after arrival is common to all plants; this is soon followed by a decrease, and in most cases, sooner or later, by extinction. *Isoëtes setacea* survives in all of four lakes. In three of these the present growth (and spore frequency) is very restricted. *Isoëtes lacustris* is a late immigrant with a contemporaneous emergence about 5000 B.P. Its curves oscillate without any parallel trend, apart from a slightly decreasing tendency in the uppermost samples. *Myriophyllum alterniflorum* is also a late (Spongilla Sø) or even very late (Isoëtes Sø) immigrant.

A summary of the vegetation in the Greenland lakes, as described by Böcher (1954) and of the ecological demands of the species recorded

in the Kap Farvel corings, will precede the following discussion. BÖCHER (l. c.) describes three types:

"The *Potamogeton tenuifolius-Myriophyllum exalbescens* Type (Subarctic-temperate, mesotrophic vegetation of hydrophytes, some of which have floating leaves; isoetids generally absent)". EG species are *Myriophyllum spicatum* ssp. *exalbescens*, *Potamogeton alpinus* ssp. *tenuifolius*, *P. gramineus*, *P. pusillus* ssp. *groenlandicus* and *Ranunculus confervoides*. *R. reptans*, *R. hyperboreus*, *Sparganium hyperboreum*, *Hippuris*, *Menyanthes* are frequent, *Comarum* rare. pH moderately acid to neutral.

"The *Potamogeton filiformis* Type (Subarctic-temperate mesotrophic vegetation of hydrophytes; nymphaeids and isoetids absent)". EG species are *Potamogeton filiformis* and *Chara fragilis*. *Hippuris* is frequent, *Myriophyllum spicatum* and *Ranunculus confervoides* rare. pH above 7.5.

"The *Myriophyllum alterniflorum-Subularia* Type (Subarctic-temperate, meso-oligotrophic vegetation of hydrophytes, as a rule without floating leaves; isoetids frequently present)". EG species are the two *Isoëtes*, *Myriophyllum alterniflorum* and *Subularia*. Lakes of this type are dominant in the Kap Farvel area today. They are moderately acid and very poor in nutrients, cf. table 1.

Hippuris vulgaris, found all over Greenland today although rare in the north seems to be a rather ubiquitous species. "From fresh water a number of statements are known from oligotrophic and eutrophic localities, while unambiguous records from acidotrophic waters do not seem to be available" (OLSEN, 1950, p. 348). *Subularia* has a very disjunct distribution in Greenland ranging northwards to 69° on the west and 64° on the east coast. In the Kap Farvel area it was only found once, in a lake 0.5 km west of Triangelsø on Eggers Ø, growing together with i.a. *Juncus subtilis* and *Myriophyllum alterniflorum*. It is characteristic of oligotrophic, slightly acid to neutral waters with a clear affinity to *Isoëtes*. In Scandinavia it is calciphobe (SAMUELSON, 1934). *Ranunculus confervoides* is distributed all over Greenland but rare towards the north. It is an EG species of the *Potamogeton tenuifolius-Myriophyllum exalbescens* type, but may occur in alkaline lakes, too, e.g. in Klaresø, Peary Land (FREDSKILD, 1966), with 220 mg HCO_3/l, and in Scandinavia its main distribution is in the area of "kalkreichen Gebirgen" (SAMUELSON l. c.). It is very rare in the Kap Farvel area, and in Herb. Cop. only a few collections are found in spite of several years' intensive botanical investigations (Itivdleq, Ivssortussut, Máukarneq, Frederiksdal and some collections from Qinguadalen in Tasermiut). The species of *Callitriche* could not be determined by means of pollen morphology, but *C. hamulata*, common in the area today, seems most likely. It is a South Greenland species, ranging northwards to 69° on the west, 63° on the east coast. The fossil pollen of *Sparganium* likewise could not be determined as to species,

but *S. hyperboreum*, common in the area today and found as fruits in Drepanocladus Dam is by far the most likely. It is rather common on the west coast northwards to 70°. From the east coast only one uncertain record is at hand (DEVOLD & SCHOLANDER, 1933). It is found in oligo- and mesotrophic waters. *Eupotamogeton* pollen cannot be determined as to species. It was mentioned above that only one occurrence of *Eupotamogeton* (*P. pusillus* ssp. *groenlandicus*) was seen in the Kap Farvel area.

Both *Isoëtes* species are characteristic of oligotrophic waters (SPENCE, 1964; SAMUELSON, 1934), usually more or less acid, although occurrences in alkaline waters have been registered (IVERSEN, 1929). *I. lacustris* is only known from the Kap Farvel area, where it is common, whereas *I. setacea* is found as far north as 69° on the west coast. It is not known from East Greenland. The Greenland distribution of the two species reflects well the total distribution, *I. setacea* being found farther north than *I. lacustris* (HULTÉN, 1958). In this connection SPENCE (l.c., p. 326) should be quoted: "*Spongilla lacustris*, the fresh water sponge, is often conspicuous and has a presence of 70 per cent in this society. Amongst these societies it is, moreover, almost exclusive to *Isoëtes*."

Myriophyllum alterniflorum is distributed in South and West Greenland northwards to Godthåbsfjord. As mentioned above, it occurs in meso- and oligotrophic water.

The early flourishing and later extinction of a number of species calls for an explanation. The most obvious is the following: Pamiagdluk consists of granites and the surroundings of the lakes are mainly polished bedrock. But after the retreat of the ice there was some till around the lakes and at their bottom, and as soon as the water was free of clay the plants were able to flourish, utilizing the relatively rich water. After a short period, however, most of the nutrients were used up. The supply in the run-off water from the surroundings was diminished, partly because of leaching, partly because the nutrients were used by the terrestrial plants and to a certain degree bound in the slowly decomposed litter. Furthermore, according to the diatom analyses, as a result of the humus formation the acidity of the water increased.

In Spongilla Sø the initial growth of *Hippuris* must have been very vigorous, but this could hardly prevent a growth of *Subularia* and other plants and at least in the two other lakes competition from *Hippuris* was not severe. The slightly later emergence of *Subularia* may well have been climatically conditioned. Here the following remark should be inserted: Generally it must be taken for granted that from the beginning of the history of a lake propagules of at least the more common species of hydrophytes will be brought in rather frequently. It cannot be accepted that e.g. *Isoëtes* macrospores of both species were not presented to the

lakes at an earlier stage of their history than shown by the silhouettes in fig. 10.

During phase b all but the two most southern species immigrated to one or more of the lakes. *Isoëtes setacea* was sparse throughout phase c. This could hardly be because of competition with respect to the light, for *Hippuris* had for a long time had a very reduced growth (or at least flowering), and *Sparganium* never seems to have been frequent. Nor could it be because of the oligotrophication of the water, as *Isoëtes* actually prefers oligotrophic waters, and the only possible explanation seems to be that climatic conditions were just at the border of tolerance of this species during phase c.

The opening of phase d indicates an amelioration, which is reflected in the flourishing of *Isoëtes setacea.* This boundary in the terrestrial vegetation characterized by the emergence of *Salix* is the most important since the deglaciation. It is also reflected in the zoological finds in the radiocarbon samples and in some supplementary macrofossil samples (RØEN & FREDSKILD, in prep.). The most important indices of cold environments prior to the boundary are: *Lepidurus arcticus* (*Euphyllopoda*) is found in samples from Isoëtes Sø (phase b, late, and c), from Spongilla Sø (phase b, late), and from Comarum Sø in samples older than the *Salix* emergence. The species is very common on the northern parts of the west and east coast south of 79° N. Its southern limit is at 66°–67° N (RØEN, 1962, fig. 40). *Eurycercus glacialis*, at present common south of 72° N does not immigrate until after the phase c-d boundary but afterwards becomes very common in the three lakes.

Daphnia pulex is very common in the older samples in Isoëtes Sø and Spongilla Sø. It is found all over Greenland but is extinct in Isoëtes Sø and rare in Spongilla Sø. It is uncommon in the Kap Farvel area today. This no doubt is caused by the oligotrophication of the lakes. *Chironomids* are only found above the boundary in the three lakes.

The emergence of *Salix* and the flourishing of *Isoëtes setacea* is closely connected elsewhere; i.e. not only in the Kap Farvel area. In Comarum Sø neither *Salix* nor *Isoëtes* was found in samples 1–5. In sample 6, six cm higher than sample 5, 126 (155) *Salix* pollen and 516 (635) *Isoëtes* spores/cm²/yr were found. Furthermore, in some cores from the Frederikshåb district taken by MICHAEL KELLY, the unpublished diagrams exhibit an "explosive emergence of *Isoëtes setacea* contemporary with the immigration of *Salix*" (FUNDER, 1971, translated from Danish). The underlying amelioration, presumably connected with the disintegration of the Laurentide Ice in North America between 8000 and 6500 B.P. (BRYSON *et al.*, 1969) was first registered at the head of the fjords, later at the outer coast. The oligotrophication of the waters in the area of archaean rocks may well have been accelerated by the increasing temperature.

At the transition between phase d and e a further amelioration made possible the immigration of *Isoëtes lacustris* in the three lakes. The late immigration of *Myriophyllum alterniflorum* is not easy to understand. From now on only oscillations are registered in the curves of the hydrophytes, apart from the very late immigration of *Myriophyllum alterniflorum* in Isoëtes Sø. As an indication of the further impoverishment of the lakes it can be mentioned that in two of the three lakes neither chironomids nor *Eurycercus* were found in the upper samples.

Generally *Pediastrum*, like the hydrophytes, has a period of flourishing just after its emergence and then decreases to very low values. The curves of *Botryococcus* are irregular and difficult to explain.

Before leaving the discussion of the history of the lakes I should like once more to call attention to the fossil occurrences of *Subularia* compared with the present situation. In all, 13 recent finds are known, most (11) from South Greenland, but two as far north as 69° on the west and 64° on the east coast. In the Kap Farvel area 4 of the cores cover the whole sequence since deglaciation. *Subularia* was found in early samples in the 4 lakes, but does not grow in any of them today, and was only found once during the field season. Two corings at the head of Tunugdliarfik go far back in time. *Subularia* is found in three samples in the one basin (Comarum Mose and Comarum Sø), partly older, partly slightly younger than the *Salix* boundary. In Godthåbsfjord Iversen (1952–53) (cf. also p. 139 in the present paper) has a find of *Subularia* pollen, too.

In all, we know of six localities where *Subularia* grew. Taking into consideration the very little palaeobotanical material at hand it is not unreasonable to assume that this plant was very common in the first period after deglaciation. Its rather disjunct distribution (which was formerly believed indicative of its being a glacial survivor, cf. Böcher, 1956) is simply considered as relict from the wide "late-glacial" distribution.

The head of Tunugdliarfik

Comarum Sø and Comarum Mose

Ca. two km southwest of Qagssiarssuk, close to the head of Tunugdliarfik, a N–S orientated ca. 180 m long, 40–60 m wide depression is filled in with a bog, Comarum Mose (fig. 30.27). In the south end there is a small lake, ca. 90 × 40 m, Comarum Sø, (61°08′ N, 45°32′ W). The elevation is estimated at ca. 125 m a.s.l.

The vegetation in the area west of Qagssiarssuk is dominated by extensive *Salix glauca* copses in depressions where the snow-cover protects not only against desiccation during winter but also against the thousands of sheep belonging to farmers in Qagssiarssuk and on isolated farms. *Betula pubescens* does not reach the same size as on the protected screes

on the opposite side of the fjord, but it is very common, although not as common as *B. glandulosa*, which covers large areas. On more exposed habitats *Kobresia* heaths are found close to the fjord. Farther away grass-herb heaths are found, but still with dwarfish *Salix glauca* and *Betula glandulosa*.

On the slopes surrounding the bog the following vegetation was seen: On the slope southeast of the bog snow-patches, often with a drift of snow until late June, are dominated by *Rumex acetosa* ssp. *lapponicus*, *Alchemilla alpina*, *Achillea millefolium*, usually sterile, and with *Taraxacum* and *Phleum commutatum*. South and east of the lake the slope is covered by a willow scrub with *Ranunculus acris*, *Anthoxanthum*, *Luzula multiflora*, *Potentilla crantzii*. On the ridge west of the bog, dry, windblown areas with outcrops of the bedrock are covered by open dwarf-shrub heaths with *Salix*, *Potentilla tridentata*, *Agrostis canina* ssp. *montana*, *Trisetum*, *Campanula gieseckiana*, *Poa pratensis*, *Luzula spicata*, *Festuca rubra*, *Deschampsia flexuosa*, *Thalictrum*, *Juncus trifidus*, *Hieracium alpinum*. Both species of *Betula* occur, but *B. glandulosa* is the most common.

In the moist rim around the lake mosses, incl. *Mnium cinclidioides*, *Calliergon sarmentosum*, *Aulacomnium palustre* and *Sphagnum fimbriatum*, (K. HOLMEN det.) dominate. In this carpet *Agrostis scabra*, *Epilobium palustre*, *Comarum*, *Carex rariflora* and *C. canescens* are common, *Montia* and *Galium brandegei* scattered. The major part of this bog is covered by *Calamagrostis langsdorfii*, *C. neglecta*, *Carex rostrata* and *C. canescens*. Further, *C. rariflora*, *C. nigra*, *Eriophorum angustifolium*, *Viola palustris* and others can be found. *Salix arctophila* is common.

Almost the whole surface of the lake is covered by the floating leaves of *Sparganium hyperboreum*. At the edge it is replaced by a zone of fertile *Menyanthes*, which is in turn replaced by a belt of *Carex rostrata* with single *Ranunculus confervoides*. A few specimens of *Potamogeton alpinus* were seen to the southeast corner. The find of spores of *Isoëtes setacea* right in the recent gyttja sample indicates an overlooked occurrence of this species. The water depth over the greater part of the lake is 75–85 cm.

In the north end, the lake is drained by a "channel", easily seen on fig. 11. Open water cannot be seen in the channel, on exception only where there is a seepage of water. A few *Hippuris* were found here.

In the lake two corings with the Livingstone sampler were undertaken in the 1969 field season (A and B in fig. 12), besides seven Hiller corings (C, D and F–K) along a line through the bog. This line included a point (E) cored by the Hiller sampler in 1962. On the sketch map (fig. 12) the position of the two Tauber traps in 1969 also is noted.

A survey of the sediments in the cores is shown in fig. 13. Presumably the bedrock, which was found at points I and K, is covered by some



Fig. 11. Comarum Sø with the raft and part of Comarum Mose looking westwards. In the background "vandsøen", the lake supplying Qagssiarssuk with water. July 15, 1969.

stony till (F and H). This, in turn, is covered by finely laminated, lilac clay, in places more than 1.5 m thick (E). The colour originates from the very loose Precambrian lava exposed on the slopes southeast of the lake.

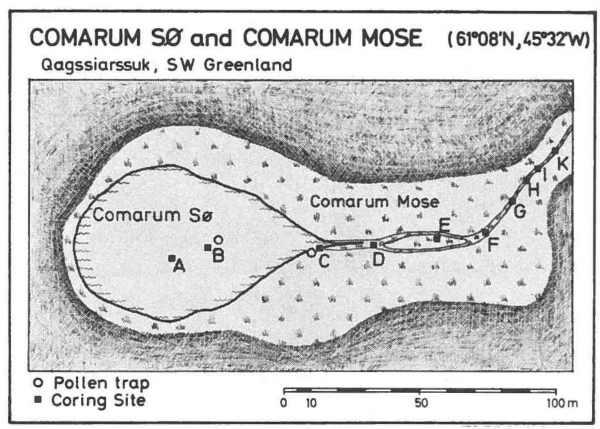


Fig. 12. Comarum Sø and Comarum Mose, sketch map.

West of the lake the bedrock is partly gneissic. Several up to five m thick gyttja layers cover the clay. When the basin was almost filled in, the formation of swamp peat and moss peat started, and at a certain time the outlet was blocked. This made the drainage so ineffective that the bog

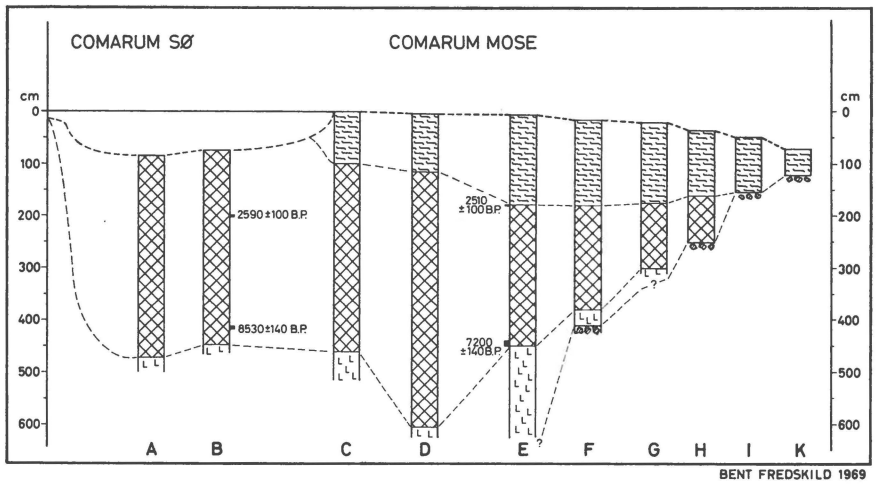


Fig. 13. Comarum Sø and Comarum Mose, longitudinal section.

continued growing. The water level of the lake is now 70 cm above the surface of the peat at the threshold.

Unfortunately, only two of the cores, from B (in the following termed Comarum Sø, or the lake diagram) and E (Comarum Mose, or the bog diagram) have been worked up, and it cannot be determined whether the underside of the peat marks an almost synchronous layer or whether the area of the lake is still shrinking. Judging from the transect, the latter seems the most likely.

Comarum Sø

Description of the sediments

Coring spot B, depth of water 80 cm. 1 ml samples.

9. 0–173 cm: below the lake bottom: Fine detritus gyttja. The colour brown, darkens somewhat towards olive. Scattered seeds, fruits and twigs. In all the cores used for radiocarbon samples twigs and small fragments of wood were observed at a depth of 80–85 cm. The upper 20 cm were loose and watery; therefore it was difficult to obtain 1 ml samples. Sample 39 originates from the uppermost cm at site A. Ld^1 4, Dg + +, Ga +, (Ag + As) +.

8. 173–246 cm: Fine detritus gyttja, with fine rootlets. Brown, darkens to darker olive than layer 9. Structure elastic, like stiff jelly. Throughout the layer short, vertical, delicate rootlets (*Potamogeton* ?). Scattered seeds, etc. Ld^1 4, Dg + +, Ga +, (Ag + As) +.

7. 246–257 cm: Slightly sandy, rather coarse gyttja. The structure rather heterogenous because of sand and coarse sand being found in small aggregates. Many cladoceras and other coarse particles, possible fragments of *Chara*. Fine rootlets, such as in layer 8. Ld^1 3, Dg 1, Ga + +, Gs +, (Ag + As) +.

6. 257–298 cm: *Characé* gyttja. Rather bright brown, darkens to olive. Structure solid, elastic, gelatinous, slightly felted by straw-coloured fragments of characeous plants, besides single, white, fine rootlets. Spores of *Chara*. At 272–273.5 a bright yellow-brown layer (Lim. 2–3) with a considerable content of *Chara* spores. Ld^1 3, Dh 0.5, Dg 0.5, Ga + +, Gs +, (Ag + As) +.

5. 298–326.5 cm: Stratified detritus gyttja with *Chara*. Rather dark brown, darkens to dark-olive. Large content of cladoceras etc. in addition to some fragments and spores of *Chara*. Slightly elastic, solid jelly. Ld^1 3, Dg 1, Dh + +, Ga + +, (Ag + As) +.

4. 326.5–327 cm: Sharply delimited (Lim. 3) bright, clayey-sandy layer. This layer was found in all cores from sites A and B and was used to correlate the cores before slicing them for radiocarbon and macrofossil samples.

3. 327–342.5 cm: Finely stratified gyttja. The layers often less than 1 mm thick. Some layers with great content of clay, others more sandy, most of them rather pure gyttja with many cladoceras, *Chara* spores, now and then with a single fragment of a moss. The colour varies from dark-brown to bright-olive with single, coarse, lilac sand grains. Ld^1 3, Dg 0.5, Dh +, Ga + +, Gs +, (Ag + As) 0.5. The boundary between layers 2 and 3 has erroneously been placed at 338.5 cm instead of at 342.5 cm in the diagram, plate 10.

2. 342.5–359 cm: Clay with very thin, clay gyttja layers.

1. 359–366.5 cm: Sandy clay, colour lilac.

Macrofossils

Ten cores starting from a depth of ca. 50 cm below the lake bottom and ranging to a depth of ca. 165 cm, another ten cores from 154 to ca. 265, and seven cores from 240, one from 250 and two from 260 cm, all ten ending well down in layer 2 or 1, were cut into two cm slices and accumulated for radiocarbon and macrofossil samples.

Table 9. *Comarum Sø, macrofossils.*

200 ml samples cm below lake bottom	*Carex canescens*	*Carex macloviana/canescens*	*Carex norvegica*	*Carex rariflora*	*Carex rostrata*	*Cenococcum*	*Chara*	*Empetrum*	*Hippuris*	*Isoëtes setacea*	*Menyanthes*	*Montia*	*Myriophyllum alterniflorum*	*Myriophyllum spicatum*	*Plantago maritima*	*Poa*	*Potamogeton alpinus*	*Potamogeton gramineus*	*Potamogeton filiformis*	*Potentilla*	*Puccinellia*	*Ranunculus confervoides*	*Selaginella selaginoides*	*Silene acaulis*	*Sparganium hyperboreum*	*Viola palustris*
50–52	3				20						1	2					1					40			25	
88–90					9																					
108–10	1				12				7													15				
126–28	1				20				41													8				
166–68					16				5				3				6	1				15			1	
176–78					8				21								5					11			4	1
190–92	1				2			5	16	1							2	1				10				1
204–06								1	24					1			3	24				45				1
246–48	8				1			1	2		1		4				2	38				31	2			
284–86			1			>100							3	2			1	11	1			1				
318–20		1				100													1			1		1		
338–40			4			>100	8									2			1			3				
340–42						75	8															2				
342–44						>100	10									1			2	2		3				
344–46						>100	3								1	1			6		1	8				

The content of macrofossils found in the samples, afterwards used for dating, as well as in some supplementary macrofossil samples, are shown in table 9.

The following macrofossils were found during the field work or during preparation of the pollen samples: *Carex bigelowii/nigra* 280 cm, *C. rostrata* 157, *Chara* 353–348–344–342–330–324–318–306–294–288–282–270, *Hippuris* 300–218–206–205–204–201–200–198–190–187–178–176–168–166–139–133–112–48, *Menyanthes* 153–28, *Myriophyllum spicatum* (a bract) 273, *Potamogeton alpinus* 238–194–189–163–30, *Potamogeton filiformis* 259, *P. gramineus* 250–248–246–236–219–194, *Ranunculus confervoides* 253–242–206–180–176–139–102–22, *Sparganium hyperboreum* 150–63–29.

Datings

Five samples have been dated: 126–128 cm below the lake bottom: 2590 ± 100 (K–1748), 204–206 cm: 4150 ± 100 (K–1747), 284–286 cm: 6890 ± 120 (K–1746), 318–320 cm: 7940 ± 130 (K–1745) and 338–342 cm: 8530 ± 140 B.P. (K–1744).

Pollen zones

Two diagrams have been constructed: a relative and an absolute (= a pollen deposition rate) diagram (plate 9–10). A number of minor components are included in the absolute, but not in the relative diagram. The following pollen and spores, not shown in any of the diagrams, were found: *Achillea-Tripleurospermum* sample 39: 1 grain, *Epilobium* one grain in 17 and 23, *Erigeron* one in 3 and 14, as well as one in a sample older than sample 1, cf. zone A, *Galium* one grain in 8, 23, 34, *Gentiana aurea* 35: 1, *Gentiana* 12: 1, *Lycopodium clavatum* 8:1, 22:1, *Oxyria-Rumex* type 4:2, 7:1, 9:1, *Phleum type* 34:1, *Polygonum viviparum* 17:1, 19:1, 23:2, 29:2, 36:1, *Pyrola* type 32:1, *Sagina* 5:1, *Saxifraga nivalis* type 3:7, cf. *Stellaria humifusa* 7:1, *Subularia* 9:1, *Tilletia*, one spore in 20, 32, 35, P. indet. 2:2, 3:1, 4:1, 5:1, 6:1, 11:1, 15:3, 18:1, 20:1, 21:1, 23:2, 26:2, 27:1, 29:2, 32:1, 33:1, 34:1, 38:1.

Pollen zone A: *Cyperaceae-Gramineae-Plantago maritima* zone (pollen samples 1–5)

The deepest sample in this herb zone is very poor in pollen, and only 112 pollen were counted. The spectrum, including 20 % *Plantago maritima*, 11 % *Chamaenerion*, 10 % *Silene-Minuartia* type and 3.6 % *Oxyria* deviates so much from the following that it might justify a separation of a *Chamaenerion-Plantago* zone. In a slide from a sample 2.5 cm deeper than sample 1, four pollen were found (2 *Gramineae*, 1 *Chamaenerion* and 1 *Erigeron* type), corresponding to less than 500 pollen per ml. Furthermore, 25 *Chara* spores, 269 *Botryococcus* and 15 *Pediastrum* occurred. But generally the zone is characterized by *Cyperaceae*, which attain their highest relative frequencies in this zone, and by *Gramineae*. Four fruits of *Carex norvegica* as well as one fruit, resembling *C. macloviana*, were found. In this zone *Plantago maritima*, *Oxyria*, *Chamaenerion*, *Silene-Minuartia* type, *Saxifraga oppositifolia* type, *Empetrum* and *Elymus* attain their highest abs. values, *Sedum* and *Dryopteris* type the highest relative, while pollen of *Dryas* type have only been found here. Towards the end of the zone *Thalictrum* emerge.

In the lake *Potamogeton filiformis*, *Chara*, *Menyanthes* and *Sparganium* occur from the beginning, later accompanied by some *Eupotamogeton*. Achenes of *Ranunculus confervoides* were found. 100–200 mg coarse silt and sand was sedimentated per cm^2 per year. It should be mentioned that no *Chlorophyceae* were counted in this diagram. The zone boundary A–B is defined at the immigration of *Salix*.

Pollen zone B: *Salix-Gramineae* zone (samples 6–8)

No *Salix* pollen were found in zone A, but as early as sample 6 *Salix* attains the same absolute values as today. Relatively, it attains its maxi-

mum in zone B, exceeding 20 % in two of the samples. The increasing tendency in *Gramineae* continues throughout the zone, and at the zone boundary B–C, *Gramineae* reach their relative maximum. *Thalictrum* also reaches its highest frequencies in this zone. The increasing importance of the mentioned plants seems to be at the expense of the many zone A herbs, all of which only attain very low frequencies or even disappear. New to the zone are *Diphasium* type, *Galium* and *Huperzia*.

Isoëtes setacea dominates in the lake; in common with *Myriophyllum spicatum*, which also immigrates at the opening of this zone, it reaches the highest frequencies. *Potamogeton filiformis* and *Eupotamogeton* continues almost unchanged, while *Chara* oospores are fewer than in zone A. *Hippuris* occurs in two samples. Only a small amount of silt is sedimentated. The zone boundary B–C is defined at the immigration of *Juniperus*.

Pollen zone C: *Juniperus-Gramineae* zone (samples 9–16)

At the beginning of the zone *Juniperus* attains its highest frequencies. Shortly afterward *Selaginella* emerges and rapidly reaches its maximum. Apart from *Plantago maritima* and *Oxyria*, which almost disappear, most of the plants from zone B continue with almost unchanged frequencies. *Campanula* emerges in this zone, and *Gymnocarpium*, which only occurs in two of the older samples, attains constant but low values. *Alnus* reaches its maximum in this zone. The first fruit of *Carex rostrata* is found.

Isoëtes decreases in the beginning of the zone, and until zone G commences only a few spores occur. *Chara* oospores and pollen of *Potamogeton filiformis* are abundant in samples 9–11 and then disappear. *Eupotamogeton*, mainly *P. gramineus*, are the dominating macrophytes. *Myriophyllum alterniflorum* emerges and is at a maximum in the beginning. *Hippuris* pollen was not found, but 2 fruits occurred in the 246–248 cm sample (table 9). Achenes of *Ranunculus confervoides* indicate that part of the *Ranunculus* curve must be ascribed to this species. *Subularia* was found in sample 9.

The zone boundary C–D is defined at the increase in *Betula*.

Pollen zone D: *Juniperus-Gramineae-Betula glandulosa* zone (samples 17–21)

The size measurements of the *Betula* pollen (plate 1.5) show that in the preceding zones many species of *Betula* were included in the pollen rain, but from sample 16 the many small grains indicate the dominance of *B. glandulosa*. Because of the limited material at hand it is difficult to define precisely the increase in *Betula*, illustrated by its percentages in samples 15–19: 2.3, 2.5, 4.1, 5.6 and 8.3 %.

Sedum, almost absent since zone A, re-occurs, and attains its highest frequencies in this zone. *Cymnocarpium* is twice as common as in zone C.

Towards the end *Juniperus* decreases and *Cyperaceae* increases, but apart from this most frequencies are fairly constant. *Epilobium*, *Polygonum viviparum* and *Tilletia* are new to the zone. Seeds of *Viola palustris* were found in the 3 macrofossil samples in this zone. None was found outside the zone.

Hippuris and *Menyanthes* spread in the lake along with a decimation in *Eupotamogeton*. The youngest fruit of *P. gramineus* is found at the zone border D–E, while *P. alpinus* continues up to the present day. The zone boundary D–E is defined at the second increase in *Betula*.

Pollen zone E: *Betula pubescens-Salix-Cyperaceae* zone (samples 22–27)

The second increase in *Betula* no doubt is caused by the immigration of *B. pubescens* as demonstrated by the size measurements. *Salix* increases too, as do *Cyperaceae*, attaining their highest frequencies in the middle of the zone. Judging from the macrofossils *Carex rostrata* is the main supplier of local *Cyperaceae* pollen. The *Angelica* curve is somewhat oscillating in the whole diagram, but generally it has its highest frequencies in zones D, E and F. *Sedum* is constant, at much lower values than during the preceeding zones. *Gramineae* decreases to a minimum of 12 % in sample 25. Absolutely speaking, this also, apart from the very poor sample 1, marks the minimum of the whole diagram. *Montia* is new to the zone.

Menyanthes dominates in the lake, whereas most other macrophytes are rare. *Hippuris* dropped at the boundary D–E. Both species of *Myriophyllum* disappear during the zone.

The zone boundary E–F is placed at the decrease in *Juniperus* and the increase in *Gymnocarpium* and *Sphagnum*.

Pollen zone F: *Betula-Salix-Gymnocarpium* zone (samples 28–31)

This zone is dominated by *Betula*, *Salix* and *Gymnocarpium*. *Angelica* has a second maximum, and *Chamaenerion*, not seen in the preceeding 17 samples, now occur in three out of four samples. *Gramineae* and *Cyperaceae*, like most other plants, are fairly constant.

The macrophytic vegetation in the lake seems even poorer than in zone E; only single *Eupotamogeton*, *Hippuris*, *Menyanthes* and *Sparganium* occur.

The zone boundary F–G is defined at the emergence of *Rumex acetosella/acetosa* and the increase in *Sparganium* and *Isoëtes*.

Pollen zone G: *Rumex-Sphagnum* zone (samples 32–39)

In the terrestrial flora the emergence of *Rumex acetosella/acetosa* is the most conspicuous alteration across the boundary, but minor changes are seen too, e.g. the *Vaccinium* pollen in samples 32 and 33, the decrease

in *Salix*, *Angelica*, *Sedum*, and the increase in *Sphagnum* and *Ranunculaceae*. New to the zone are *Achillea-Tripleurospermum*, *Gentiana aurea*, *Phleum commutatum* type and *Pyrola* type.

The sudden increase of *Sparganium* and the re-occurence of *Isoëtes setacea* in the lake are the most striking changes. *Hippuris* disappear, while single *Eupotamogeton* grains can be found up to the recent gyttja.

Comarum Mose

Description of the sediments

In 1962 a Hiller boring was undertaken in the bog at E (fig. 12). This spot is the highest point in the bog, and only here a few specimens of *Salix glauca* grew. The following profile was found:

6. 0–151 cm below the surface: Moss peat with swamp peat. Yellow-brown, darkens to brown. Very felted. Now and then with some gyttja-like substances. Downwards with increasing amount of swamp peat. Tb^2 3, Th^2 1, Dl +, (Ag + As) +.

5. 151–166 cm: Swamp peat. Yellow-brown, darkens slowly. Very felted. Many *Carex* fruits. Th^2 4, Tb^2 ++, Ld^2 +, (Ag + As) +.

4. 166–199 cm: Coarse detritus gyttja with a touch of swamp peat. Brown with a reddish tone, darkens to dark olive-grey. The deepest lump of swamp peat was a 1–2 cm thick layer at 197 cm. Ld^2 3, Dg 1, Dh +, Dl +, Th^2 ++, (Ag + As) +.

3. 199–445 cm: Fine detritus gyttja. Slightly reddish yellow-brown, darkens to olive. The upper 10–20 cm slightly coarser, with a hint of swamp peat now and then (Ld^1 3.5, Dg 0.5, Th^1 (+), (Ag + As) +). Downwards with increasing content of clay. Scattered fruits of *Hippuris* and *Potamogeton*. Ld^1 4, Dg +, Ga +, (Ag + As) ++.

2. 445–464 cm: Stratified clay gyttja. Thin layers of clay gyttja alternate with almost pure clay. The colour varies from grey over yellow to olive. Lim. sup. 3.

1. 464–480 cm: Stratified clay. Most layers lilac, with thin, greyish layers alternating. By continued coring it was observed that the clay continued with increasing content of sand to at least 600 cm. Lim. sup. 3.

Macrofossils

Nine cores from 410–460 cm were taken, and two radiocarbon samples were carefully taken, viz. 435–440 cm and 440–445 cm. Be-

cause of the limited content of organic material, it was necessary to use both of them together.

Furthermore, nine cores from 150–200 cm were taken, and a sample covering the upper five cm of the gyttja was taken.

A macrofossil sample consisting of layer 5 was taken, but only a small fraction was analyzed. In this sample the following macrofossils were found: *Betula pubescens* 1, *Carex canescens* 11, *C. rostrata* 46, *Comarum palustre* 7, *Montia* 5, and *Salix* one twig. Furthermore, the following species were found during preparation and field work: *Carex canescens* at 45 cm, *C. rariflora* 125 cm, *C. rostrata* 201, 165, 127, *Chara* 448, 443, 425, 405, 386, 363, *Empetrum* 448, 443, *Equisetum arvense* (rhizomes) 85, *Juniperus* (leaf) 165, *Salix* (twig) 65, *Potamogeton alpinus* 368, 284, *P. gramineus* 332, *Ranunculus confervoides* 245 cm.

The boundary between layers 5 and 4 usually was found at 170 cm, ranging between 165–170 cm. As a result, the radiocarbon sample is given as 170–175 cm (Tauber, 1966). But as it actually consists of the upper five cm of layer 4, it is placed at 166–171 cm in the diagram.

Datings

Two samples have been dated: 170–175 cm: 2510 ± 100 (K–803) and 435–445 cm: 7200 ± 140 B.P. (K–804), both published in Tauber (1966).

Pollen zones

One diagram is presented; this is a relative diagram (plate 11). The following pollen and spores are not shown in the diagram: *Callitriche* 1:1, 3:1, *Chamaenerion* 8:1, *Coptis* 7:1, *Dryas* type 5:1, 14:1, *Epilobium* 17:1, *Ericales* 1:1, 2:1, 6:2, 9:2, 11:1, 14:1, 32:1, *Erigeron* type 5:1, 10:1, 11:3, *Gentiana nivalis* 7:1, *Gentianaceae* 8:1, 32:1, *Lomatogonium* 5:1, *Sagina* 5:1, 7:2, *Subularia* 2:1, *Tilletia* 18:3, 19:5, 20:8, 21:18, 30:1, 31:5, 32:2, P. indet. 2:1, 5:2, 8:1, 9:3, 10:1, 11:3, 12:1, 13:1, 19:1, 20:2, 21:4, 23:1, 24:2, 26:3, 28:1, 32:2. A pollen sample from 473 cm was extremely poor in pollen. A count of eight slides gave the following result: *Betula* pollen 4, *Alnus* 3, *Oxyria* 6, *Cyperaceae* 2, *Gramineae* 1, *Dryopteris* type 1, *Dryas* type 1, *Subularia* 1, *Potamogeton filiformis* 26, *Pinus* 0.5, *Quercus* 1, *Pediastrum* cc, *Botryococcus* c. The latter sample is not included in the diagram.

Pollen zone A: *Salix-Gramineae-Cyperaceae* zone (sample 1)

In general, the description of zone B in Comarum Sø fits in. The zone boundary A–B is placed at the increase in *Juniperus* and the emergence of *Isoëtes setacea.*

Pollen zone B: *Juniperus-Gramineae* zone (samples 2–8)

With but one exception the description of zone C in the lake diagram is usable. This exception is the displacement in the *Isoëtes* maximum, which here is found well within the zone, while in the lake diagram it is found in the preceeding zone. This might indicate that the zone boundary A–B should be placed just below sample 3 instead of below sample 2. The two *Juniperus* pollen in sample 2 might be the result of contamination in the Hiller core from above.

Pollen zone C: *Juniperus-Gramineae-Betula glandulosa* zone (samples 9–11)

Generally speaking, the description of the corresponding zone (D) in the lake diagram fits in. The zone boundary C–D is placed at the sharp increase in *Cyperaceae*, the second increase in *Betula* and the decrease in *Gramineae*.

Pollen zone D: *Cyperaceae-Betula-Menyanthes* zone (samples 12–15)

At the lower zone boundary *Sparganium* and *Ranunculus* attain their maximum. The only achene of *Ranunculus confervoides* in the diagram is found here. The *Menyanthes* maximum then follows. *Cyperaceae* steadily increase throughout the zone, reaching 65 % at the upper zone boundary. Most other curves decrease; only *Betula* (both species), *Salix*, *Angelica* and *Lycopodium dubium* show increasing tendencies.

As in the lake diagram, *Hippuris* attains its maximum at the lower zone boundary. *Isoëtes* and *Myriophyllum spicatum* disappear, and *Eupotamogeton* is reduced to very low frequencies.

The zone boundary D–E is defined at the increase in *Potentilla-Comarum* type and the decrease in *Menyanthes*.

Pollen zone E: *Cyperaceae-Comarum* zone (samples 16–19)

The opening of the zone shows a most marked minimum in *Gramineae*: 1.2 %, contemporary with a 75 % maximum in *Cyperaceae*. Shortly after, *Potentilla-Comarum* type makes up 20 %. *Montia* is not uncommon in this first half of the zone. The second half is characterized by pollen of *Vaccinium* type, and slightly later *Sphagnum* occurs in large quantities. *Ranunculus*, *Sparganium*, *Eupotamogeton* and *Hippuris* are absent, and *Menyanthes* very rare.

The zone boundary E–F is defined at the increase in *Betula* and the decrease in *Cyperaceae* and *Vaccinium* type.

Pollen zone F: *Rumex acetosella/acetosa* zone (samples 20–33)

The trend of the curves in this zone is very confusing, but in brief the succession is as follows: Two shortlived but very marked maxima in *Betula glandulosa* (31 % and 58 % *Betula* in samples 20 and 21, 41 %

in 25) are separated by a maximum in *Cyperaceae*, *Cruciferae*, *Galium* and *Montia*. The second *Betula* maximum is contemporary with a maximum in the *Vaccinium* type. The *Potentilla-Comarum* type and *Cyperaceae*, and later on, *Sphagnum*, thereupon increase. *Gramineae* dominate in sample 32 (82 %), whereas *Cyperaceae* (28 %) and *Rumex acetosella/acetosa* (5.5 %) are most conspicuous in the uppermost sample (33). The *Salix* curve is very irregular, but as a rule *Salix* attains high frequencies.

Discussion

It is impossible to state precisely when the gyttja began to sedimentate in the Comarum Sø—Comarum Mose basin. The possibility of a lacuna between the clay and the gyttja in the lake diagram cannot be excluded, as a lacuna evidently exists at the corresponding place in the core from the bog. At site B the oldest dating, based on the 4 deepest cm of layer 3, is 8530 ± 140 B.P. Sedimentation of the underlying clay with thin bands of gyttja could scarcely have been a matter of many centuries. Provided that no lacuna occurred, the transition from a sterile lake to a lake in which smaller amounts of suspended clay permitted biological activity took place between 9000 and 8500 B.P., presumably closer to the latter date.

The oldest vegetation around the basin was a pioneer vegetation of herbs, as indicated by sample 1 and the even older sample in the lake diagram, and by the 473 cm sample in the bog diagram. *Oxyria*, *Plantago maritima*, *Chamaenerion* (presumably *latifolium*), *Gramineae* (incl. *Puccinellia* and *Poa*) and *Silene-Minuartia* type were the dominants. Also, *Erigeron* type (*Gnaphalium* or *Erigeron*?), *Dryas* type, *Cyperaceae*, *Saxifraga oppositifolia* type, *Dryopteris* type and *Botrychium* occurred. *Empetrum* pollen is not found in the oldest sample in the bog diagram, but judging from the fairly large amount of fruits found in the samples from 338 to 346 cm, and from the 2 % *Empetrum* pollen in sample 1 (348 cm) in the lake diagram, it must have settled around the basin rather rapidly. The loose, clayey lava soil on the east side of the lake must have been very unstable, and the almost pure clay layers interrupting the gyttja formation indicate landslides and severe erosion. Today *Minuartia rubella* is common on open, dry places on this soil on exposed places between the lake and the fjord, and this species may well have been a member of the pioneer vegetation. A seed of *Silene acaulis* in the 318–320 cm sample shows the rather early occurrence of this species. It is probable that *Empetrum* grew west of the lake on the gneissic bedrock.

Most of the mentioned species are found (or in the case of types represented by found species) all over Greenland, or at least distributed very far north. *Plantago maritima* is distributed northwards to 71° on the west, 66° on the east coast. It is mostly found near the sea but may

well occur on rocks and clayey flats inland, e.g. the *Plantago-Puccinellia deschampsioides* soc. at the head of Søndre Strømfjord (BÖCHER, 1954, p. 259). The find of a *Plantago* seed in the 344–346 cm sample proves that it must have been found on the surrounding slopes. Exclusive character plants of snow-patches are not found in the first samples, and compared with the outer coast diagrams the climatic conditions must have been more continental. Yet the ample *Empetrum* pollen and fruits are indicative of somewhat more humid conditions than at present. (Within the nearest km of Comarum Sø I have only succeeded in finding 4 tiny specimens of *Empetrum*).

Potamogeton filiformis and *Chara* were very common in the lake; *Ranunculus confervoides* also occurred. *Botryococcus* and *Pediastrum* flourished right from the beginning. As a result of the lava soil the water must have had a neutral-alkaline reaction. It should be stated that no chalk was found in the sediment, and therefore the radiocarbon datings should be fully reliable. *Potamogeton filiformis*, the character plant of one of the three lake types described in BÖCHER (1954), is distributed northwards to 71° on the west, 74°30′ on the east coast. It is most common in alkaline waters, often rich in lime, but it may also occur in mesotrophic waters. It is common today in "vandsøen" at Qagssiarssuk and its tributaries, 500 m away, growing together with *P. gramineus*, *Myriophyllum spicatum*, *M. alterniflorum* and *Ranunculus confervoides*. In this lake *Chara fragilis* (kindly determined by HELLE NIELSEN, Botanical Institute, University of Copenhagen) and *Isoëtes setacea* (!) are growing. An analysis of the water is found in table 1.

It has not been possible to determine the *Chara* oospores as to species, but *C. fragilis* seems the most reasonable. This species has been found, too, by A. E. PORSILD in a lake at the head of Søndre Strømfjord (BÖCHER, 1954, p. 299). IVERSEN (1929) mentions this species as the only *Chara* not exclusively found in alkaline waters, and describes that even in a lake very poor in lime this plant is encrusted by chalk. In this (Danish) lake it grows together with i.a. *Myriophyllum alterniflorum*, *Potamogeton gramineus* and *Isoëtes lacustris* (!).

Subularia, discussed in connection with the Kap Farvel lakes, occurs right from the beginning.

After this short initial vegetational stage a larger part of the surrounding slopes was covered by a still open vegetation around 8500 B.P. *Cyperaceae* and *Gramineae* dominate together with *Plantago*, *Oxyria*, *Silene-Minuartia* type and *Empetrum*, but *Elymus*, *Sedum* (?*rosea*), *Angelica*, *Vaccinium* type, *Equisetum*, and later in this zone, *Thalictrum*, *Liguliflorae*, *Cerastium-Stellaria* type, *Ledum* type, *Euphrasia* type, *Lomatogonium rotatum*, and *Juncus-Luzula* enter the vegetation. Seven grains of *Saxifraga nivalis* type were found in sample 3. *Elymus arenarius*

ssp. *mollis* is common on the west coast northwards to ca. 71°, while on the east coast it only reaches 63°30′ N. *Lomatogonium* is distributed on the west coast between 60° and 69° N. It is rather common in the interior parts of the fjords and only very few finds are reported from the outer coast. IVERSEN (1952–53) mentions this species as an early immigrant in Godthåbsfjord (sample 5 in "Lake 100 m", cf. p. 139).

Sparganium, *Menyanthes*, *Callitriche*, and *Eupotamogeton* occur in the lake, but *Chara*, *Ranunculus confervoides* and *Potamogeton filiformis* are still common there. The distribution of *Menyanthes* is almost identical to that of *Lomatogonium* (BÖCHER, 1952, fig. 17). The occurrence of these two species, which do not occur north of the 69° on both coasts today, from the middle of zone A, as well as the absence of snow-patch plants, are indicative of rather continental climatic conditions. On the other hand, the finds in layers 2 and 3 of *Lepidurus arcticus* (RØEN & FREDSKILD, in prep.), which is not found south of the 67° on both coasts today, prove that the climate was cold.

The absence of *Salix* in zone A can hardly be climatically caused. This is evinced, too, by the explosive spreading of *Salix* when it immigrates around 8000 B.P. The decimation in pioneer plants must be ascribed to competition from *Salix*, but the maximum in *Thalictrum* and the still rather many *Plantago maritima*, *Oxyria*, *Elymus* and *Botrychium* indicate that *Salix* grew as a dwarf-shrub rather than as a tall shrub. Towards the end of the zone *Salix* decreases while *Gramineae* attain their maximum. *Gymnocarpium*, only seen in sample 3, now begins to grow constantly.

Isoëtes setacea immigrates to the lake and immediately becomes very common. The decrease in *Chara* oospores may well be a result of competition, as the later decrease in *Isoëtes* conforms to an increase in *Chara* (the lake diagram samples 7–11). *Myriophyllum spicatum*, occurring scattered from South Greenland to Ikerasak (70°30′ N) immigrates and attains its maximum in this zone. A few *Hippuris* grew in the lake, but conditions were not favourable enough to permit a dominance of the macrophyte vegetation. On the contrary, after this short emergence it disappeared again (or at least it is not registered in any of the samples in the following zone in either of the diagrams).

Around 7000–6900 B.P. *Juniperus* immigrated, and like *Salix*, its appearance was dramatic, indicating that environmental conditions were fully favourable, and presumably had been so for some time. Within 6 cm, corresponding to app. 200 years, the number of pollen per cm^2 per year increased from 5.5 to 310. The minimum in *Salix* must be related to competition from *Juniperus*. During the first part of this zone, most of the pioneer plants disappear or become very rare. Around 6300 B.P. the extremely great production of *Juniperus* pollen is over. At the same time *Selaginella* emerges. This species is distributed south of 65° on the

west, 64° on the east coast. It is common in South Greenland today, especially in the interior parts, yet strangely enough it has not yet been found in the continental parts of Godthåbsfjord, but only near Godthåb proper.

Eupotamogeton flourish in the lake, seemingly at the expense of *Isoëtes* and *Myriophyllum spicatum*, which are severely decimated, and *Chara*, which disappear. Judging from the macrofossils, this maximum in *Eupotamogeton* is mainly caused by *P. gramineus*. Only a few *P. alpinus* occurred. The present distribution of the two species is almost identical from South Greenland to the polar circle on the west coast (BÖCHER, 1952, fig. 22). Their ecological requirements also seem to be rather similar, being mesotrophic-eutrophic, and they often grow together. Like *P. pusillus* ssp. *groenlandicus*, *Myriophyllum spicatum* and *Ranunculus confervoides* both are EG species of the *Potamogeton tenuifolius-Myriophyllum exalbescens* Type (BÖCHER, 1954).

Myriophyllum alterniflorum, distributed from South Greenland to Godthåbsfjord, immigrates and attains its maximum in the beginning of the zone at a time when the *Potamogeton* curve has not reached the maximum. *Ranunculus confervoides* and *Sparganium* are rather frequent in the later half of the zone, but as mentioned above, no *Hippuris* was found during the whole zone.

In the two millennia from around 6300 to 4300 B.P. the conditions around and in the lake must have been very stable. The small and gradual alterations in the curves might reflect fluctuations in competition as well as in climate. Contrary to the explosive spreading of *Salix* and *Juniperus* the spreading of *Betula glandulosa* between 4400 and 4000 B.P. is very gradual. This could be caused by an inability to compete with the established communities, mainly grass and dwarf-shrub heaths. But as no ericaceous dwarf-shrub heaths existed, and the only important dwarf-shrub, *Salix glauca*, increases parallel to *Betula glandulosa*, it merely can be taken as an indication of a climatic change.

At the opening of the zone the content of sand has a marked maximum. This might be caused 1) by drier conditions with more open soil on exposed sites and sedimentation of aeolian sand, or 2) by greater precipitation and washing out of sand. In case 1) the maximum in *Sedum* pollen could be caused by spreading of *S. annuum*, but this would undoubtedly be accompanied by species such as *Minuartia rubella*, which actually disappear in the diagram. The increase in *Salix* and *Angelica* indicates more humid conditions, as does the fact that the three macrofossil samples from zone D contain seeds of *Viola palustris* which is distributed northwards to 63° on the west, 66° on the east coast. They are not found outside this zone. *Gymnocarpium* is more common than in the preceding zones.

Hippuris became dominant in the lake. *Menyanthes* had occurred for 4000 years, then suddenly became common, indicating that a belt was established all around the lake on shallow water. This is hardly a question of competition with *Potamogeton*, but indicates, instead, an increasing temperature.

The description of the vegetational changes has been based on both diagrams, but from the end of the *Betula glandulosa* zone the bog diagram is too local in character, and the following description is mainly based on the lake diagram. Around 3400 B.P. *Betula pubescens* immigrates, and rapidly becomes the most common of the birches. Parallel to this there is an increasing amount of *Salix* and a decreasing amount of herbs, i.a. *Sedum*. The number of *Juniperus* pollen drops to almost one-third, most likely a result of competition in connection with a change to warmer, but more humid conditions. This made it possible for *Betula pubescens* to occupy large areas at the same time as the area with *Juniperus* became restricted.

Apart from *Menyanthes* and, to a lesser extent, *Sparganium* and *Ranunculus confervoides*, the hydrophytes decimate or even disappear (both *Myriophyllum* species, and, judging from the macrofossils, *Potamogeton gramineus*). The first chance of determining *Sparganium* arises: 4 fruits of *S. hyperboreum* in the 176–178 cm sample (ca. 3600 B.P.). This sample, however, contained more exciting macrofossils: statoblasts of the bryozoan *Cristatella mucedo* (Røen & Fredskild, in prep.). This southern species has not yet been found living in Greenland, and its occurrence (and later extinction) can only be taken as a proof of this zone's being the warmest. Many statoblasts were found in the 166–168 cm sample. Still, in the 126–128 cm sample (dated at app. 2600 B.P.) a few statoblasts occur, while in the following sample (108–110 cm) dated at app. 2100 B.P., none was found. Likewise, the 190–192 cm sample, dated at app. 3900 B.P., was without *Cristatella*.

Around 1900 B.P. the decrease in *Juniperus* is ascribed to a climatic deterioration. This also is reflected in the gradual shifting of the dominance from *Betula pubescens* to *B. glandulosa*, as indicated by size measurements (plate 1). Furthermore, the oceanic *Gymnocarpium* becomes very common. This species is an EG species of "The *Streptopus-Lastraea dryopteris* Type (Subarctic sylvicolous-oceanic and hygrophilous fern- and high-growing herb-vegetation)", belonging to "The *Alchemilla-Phyllodoce-Scirpus austriacus* Complex" (Böcher, 1954, p. 65). *Chamaenerion* pollen, not seen for a very long time, now occur again, but while the early pollen grains were ascribed to *C. latifolium*, it seems much more reasonable to ascribe these zone F pollen to *C. angustifolium*, which mainly occurs in vegetational types belonging to the complex just mentioned. The now constantly occurring *Empetrum* pollen also is indicative of more

oceanic conditions, whereas the increasing *Sphagnum* curve can scarcely be accepted as a proof of this theory. It merely reflects the growth of the bog.

Of all the zones, this seems the poorest as far as the macrophytes are concerned. The macrofossil sample 88–90 cm contained nothing but 9 fruits of *Carex rostrata*. Even *Menyanthes* shows low frequencies in the diagrams.

The Norse settlement in A.D. 985 is reflected in the curves, first and foremost in the occurrence of *Rumex acetosella/acetosa*, but also by increasing amounts of charcoal. Otherwise, the development of the local hydrosere tends to conceal the more regional changes. It seems impossible to find an explanation of the sudden re-growth of *Isoëtes* in the lake contemporaneous with the Norse landnam.

The later part of the hydroseral sequence is well-illustrated by the bog diagram. The *Hippuris-Ranunculus* (*?confervoides*)-*Sparganium* maximum is succeeded by increasing amounts of *Cyperaceae*, presumably mainly *Carex rostrata*, and *Menyanthes*, growing in shallow water. By app. 2500 B.P. the boring site is overgrown, and the last pollen of *Potamogeton* and *Hippuris* is seen contemporaneously with the decline in *Menyanthes* and *Sparganium*. The influence of *Cyperaceae* – mainly *Carex rostrata* and *C. canescens* – culminates in the thin swamp peat layer (5). The following decrease is compensated for by an increase in *Comarum* and *Montia*.

The next stage is characterized by *Sphagnum* and *Vaccinium* type. Unfortunately no seeds were found, but immediately seen the combination *Oxycoccus-Sphagnum* seems much more likely than *Vaccinium uliginosum-Sphagnum*. However, BÖCHER (1954, p. 102) gives a very interesting description of a *Vaccinium uliginosum-Betula glandulosa* soc. rich in *Sphagnum*. It was found at Narssarssuaq (7 km east of Qagssiarssuk), and on the very tussocky ground with the said species as dominants, and *Salix arctophila* almost as common, species such as *Empetrum*, *Tofieldia pusilla*, *Pedicularis flammea*, *Carex rariflora*, *C. scirpoides*, *Equisetum arvense* and *E. variegatum* occur. *Sphagnum acutifolium* dominates together with *Aulacomnium palustre* and *Brachythecium* sp.; *Hylocomium schreberi* and *Paludella squarrosa* also are found. As the following step in the succession in Comarum Mose indicates even more arid conditions, viz. a *Betula glandulosa* soc. (plate 1.6), it seems reasonable to assume that the *Sphagnum-Vaccinium* stage reflected a vegetation like the one described.

The *Betula* maximum (samples 20 and 21) was followed by a brief stage (samples 22–24), in which *Galium*, *Montia*, *Polygonum viviparum*, *Cruciferae* (most pollen resembled *Cardamine pratensis*, but the determination is not fully reliable) and, especially, *Cyperaceae* were important.



Fig. 14. Galium Kær, looking south-westwards. The filled-up hole is seen as the dark area in the center of the fen. August 3, 1969.

This may indicate slightly moister conditions. A new *Betula* maximum (sample 25) is paralleled by a *Vaccinium* maximum. The following *Comarum* maximum is indicative of moister conditions. Towards the end of the hydrosere *Gramineae* (presumably *Calamagrostis langsdorfii*, *C. neglecta* and *Agrostis scabra*) become more important (82 % in sample 32). No sample from the upper 20 cm is at hand.

The first *Rumex* pollen are found in the first *Betula glandulosa* maximum, but this maximum could hardly have been a result of human influence, especially as it represents a stage in a natural succession. Most likely, the climatic amelioration reflected in this succession was connected with the immigration of Norse farmers to Iceland and, about a century later, to South Greenland.

Galium Kær

Present vegetation

400 m from Tunugdliarfik, at an elevation of ca. 65 m (altimeter measurement), Galium Kær is located in the northern outskirts of the Qagssiarssuk settlement (61°10′N, 43°31′W). As seen on the photo (fig. 14) and on fig. 15, G, it is situated in a cirque-like depression in the bedrock, surrounded on the three sides by gentle slopes. On the south side it is bounded by a ridge, only a few m wide. The top of the ridge is about 1 m higher than the surface of the marsh. A narrow drainage channel through this ridge will be discussed below. The transition between the horizontal marsh and the surrounding slopes is marked by a 0.5



Fig. 15. Qagssiarssuk, vertical aerial photo. A = transect ERA, B = transect QD, C = transect LM, G = Galium Kær. Reproduced with the permission (A. 789/72) of the Geodetic Institute, Copenhagen.

– 2 m wide "shelf", raised 20–25 cm above the surface of the marsh, showing the collapse as a result of the drainage.

The marsh covers an area of ca. 40 × 30 m. The dominating plants are *Carex canescens*, *C. nigra*, *Agrostis scabra* and *Eriophorum scheuchzeri*, and *Galium brandegei* is common. These plants grow in a carpet of mosses, dominated by *Drepanocladus exannulatus*. Scattered specimens of *Viola plaustris*, *Montia*, *Epilobium palustre* and *Juncus filiformis* can be seen. On the lower part of the slopes low *Salix glauca* copses with an undergrowth of grasses, i.a. *Anthoxanthum*, dominate. In the northeast corner this is replaced by an *Alchemilla alpina* snow-patch with *Anthoxanthum* and *Vaccinium uliginosum*. Ten gnawed-off specimens of *Betula pubescens* grow at the edge of the snow-patch; otherwise, no *Betula* occurs in the vicinity of Galium Kær.

On the drier part of the slopes and on the ridges, open lichen-rich *Potentilla tridentata*-grass heaths cover the surface. Among the grasses, *Trisetum*, *Agrostis canina* ssp. *montana* and *Deschampsia flexuosa* dominate. *Thymus*, *Viscaria alpina*, *Euphrasia*, *Cerastium alpina*, *Draba incana*, *Rumex acetosella*, *Viola canina*, *Campanula gieseckiana*, *Achillea* (sterile), *Polygonum viviparum*, *Ranunculus acris* and, especially in the ravines and on recently uncovered soil, *Sedum annuum* are common.

Galium Kær was cored by means of a Hiller equipment in the beginning of July 1962. At that time the marsh was covered by shallow water. It appeared later that this caused some contamination of the deeper, more solid layers, as the surface water mixed with the upper, watery gyttja had run into the chamber before it was opened.

Besides the relative diagram, a pollen concentration diagram (pollen per g dry sediment) was made: Galium Kær A. The results obtained tempted me to return to Qagssiarssuk in order to get an uncontaminated Livingstone core. This would also make possible the construction of a pollen deposition rate diagram.

Galium Kær was revisited in 1969, but because of a winter with only light snowfall, the marsh was completely dried out. The sediments turned out to be so solid that the Livingstone core could only be pressed through the upper half metre. A hole was dug right down to the stony till underlying the gyttja at a depth of two m. In the wall two series of 1 ml samples were taken with the square 1 × 1 cm piston sampler described above. The distance between the samples was one cm. In addition, a series of radiocarbon and a series of macrofossil samples were taken, each 15 × 15 cm square, 1 cm thick. The analyzed series of pollen samples were taken at the edge of the radiocarbon samples. The stony pavement on top of the till caused some complications when the deepest samples were taken. Pollen samples 1 (197.5 cm), 2 (195.5), 3 (192), 4 (188), 6 (184) and 8 (180) were taken in a short series between two stones, 20 cm from the main series, which was ended at a depth of 185.5 cm by one of the stones. The deepest samples in the main series are 5 (185 cm), 7 (181) and 9 (175). The same stone prevented taking the deepest radiocarbon samples. The uppermost seven dated samples originate from the same vertical column, whereas the deepest, termed 196–197 cm in the diagram, was taken as the deepest cm of gyttja at some distance from the column.

Description of the sediments

Galium Kær B

A detailed description of the layers in the open profile will be given below, followed by a summary description of the layers found during the 1962 coring. Now and then in the whole excavation (175 × 80 cm) stones up to head-size could be found in the gyttja. Evidently these

originated from the slope north of the marsh which, during winter, slid on snowdrifts out in the then extant lake.

9. 0– 3 cm below the surface: Moss peat and the recent moss carpet.

8. 3–13 cm: Swamp peat. Bright-brown to yellow-brown. Heavily felted. The 1 ml samples were cut out by a sharp knife. Single *Hippuris* and *Sparganium hyperboreum* fruits were observed. Water could be pressed out. Th^2 4, Dh +.

7. 13–25.5 cm: Swamp peat with gyttja. Brown, felted, like layer 8, very elastic. The samples cut out. Water could be pressed out. Many fruits of *Hippuris*. Ld^2 1, Th^2 3, Dh +.

6. 25.5–75.5 cm: Detritus gyttja with a touch of swamp peat. Dark-brown with reddish tone, darkens rapidly to dark grey-brown. Rather watery and loose, yet slightly felted by fossil rootlets. Decreasing content of swamp peat downwards. The upper cm of the layer usually considerably darker. Numerous *Hippuris* fruits. Ld^2 3, Th^2 0.5, Dg 0.5, Dh + +, Ga + +, (Ag + As) +.

5. 75.5–98.5 cm: Fine detritus gyttja. Bright-brown with olive tone. Dry, easily split up horizontally, and also vertically, yet not as marked as layer 3. Many *Hippuris* fruits, single *Ranunculus confervoides*. Ld^1 3.5, Dg 0.5, Dh +, Ga + +, (Ag + As) +.

4. 98.5–105.5 cm: Sandy gyttja. Bright grey-brown, darkens slightly. Dry, crumbling, partly because of the content of sand. Small stones and coarse sand not rare. A few fruits of *Potamogeton* and *Myriophyllum spicatum*, some twigs. Ld^1 2.5, Dg 0.5, Dh + +, Dl +, Gg +, Gs + +, Ga 1, (Ag + As) + +, lim. sup. 2.

3. 105.5–155.5 cm: Slightly sandy-clayey detritus gyttja with drift. Brown, rapidly darkening to greyish-brown. Dry, split up in vertical, ca. 1 cm^2 wide, hexagonal pillars. Many fruits of *Potamogeton*, besides achenes of *Ranunculus confervoides*, leaves of *Juniperus* and *Salix*, twigs, tricoptér larval cases, etc. Ld^1 3, Dg 1, Dh + +, Dl +, Ga + +, Gs +, (Ag + As) + +, lim. sup. 2.

2. 155.5–196.5 cm: Clayey gyttja. Brown, rapidly darkening. Dry, solid. Slightly stratified. At 172–173.5 and 175–177 cm

two darker layers. *Potamogeton* fruits right down to the surface of the till. Ld^1 3, Dg 0.5, Dh +, Ga + +, Gs +, (Ag + As) 0.5.

1. 196.5–>250 cm: Till. At the upper limit a rather dense pavement of up to 0.5 m, but usually hand-size stones with hard clay in between. Downwards almost free of stones but more sandy. Dry, crumbling. Lim. sup. 3.

Galium Kær A

6. 0– 9 cm: Swamp peat.
5. 9–20 cm: Watery gyttja, brown, slightly felted. Ld^2 3, Dg 0.5, Dh 0.5, Ga + +, (Ag + As) + +. Some *Hippuris* fruits.
4. 20–71 cm: Gyttja, like layer 5, but darker and not so watery. Many *Hippuris* fruits.
3. 71–92 cm: Fine detritus gyttja. Slightly greyish-brown. Some *Hippuris* fruits. Ld^2 4, Dg +, Dh +, Ga +, (Ag + As) + +.
2. 92–199 cm: Clayey gyttja. Greyish-brown, rapidly darkening to grey with olive tone. *Hippuris* fruits only in the upper part, many *Potamogeton*. Ld^2 3, Ga + +, (Ag + As) 1.
1. 199–230 cm: Sandy clay, bluish-grey.

Macrofossils

In the radiocarbon samples in Galium Kær B the following seeds, fruits etc. were found (table 10, next page).

In addition, during the work in the field, or in the laboratory with Galium Kær B samples, the following were observed: *Carex bigelowii/nigra* 5 cm, 3 cm, *C. canescens* 5 cm, *Hippuris* 91, 85, 79, 73, 67, 61, 55, 49, 43, 37, 35, 33, 31, 29, 27, 25, 23, 21, 19, 11, 9, *Potamogeton alpinus* 181, 180, 175, 169, 151, 127, 115, 109, 91, *P. gramineus*, 145, 115, *Ranunculus confervoides* 197.5, 195.5, 184, 181, 169, 157, 151, 133, 121, 115, 109, 103, 97, 79, 49, *R. hyperboreus* 163, 109, 33, 31, 29, *R. reptans* 17, *Ranunculus* sp. 103, 23, 13, 7, *Sparganium hyperboreum* 17 cm.

In connection with Galium Kær A the following were found: *Hippuris* 162.5 cm, 127.5 cm, 96.5, 91.5, 86.5, 81.5, 76.5, 71.5, 67, 66.5, 62, 57, 52, 47.5, 47, 42.5, 42, 40, 37.5, 37, 35, 32.5, 30, 27.5, *Isoëtes setacea* 177.5, 165, 142.5, 135, 86.5, *Potamogeton alpinus* 202.5, 195, 192.5, 190, 185, 170, 162.5, 150, 142.5, 135, 122.5, 111.5, *P. gramineus* 142.5, 122.5, 71.5, *Potentilla* 30, *Ranunculus confervoides* 205, 200, 197.5, 195, 192.5, 190, 187.5, 177.5, 170, 165, 157.5, 150, 142.5, 135, 127.5, 122.5, 111.5,

Table 10. *Galium Kær B, macrofossils.*

volume, cm³	cm below surface	*Alopecurus aequalis*	*Betula*, scales	*Betula*, fruits	*Campanula gieseckiana*	*Carex bigelowii/nigra*	*Carex canescens*	*Carex norvegica*	*Cenococcum*	*Cerastium alpinum/arcticum*	*Chara*	*Eleocharis palustris* s.l.	*Empetrum*	*Euphrasia*	*Hippuris*	*Juncus arcticus*	*Juniperus*, leaves	*Myriophyllum spicatum*	*Potamogeton alpinus*	*Potamogeton gramineus*	*Potentilla*	*Ranunculus confervoides*	*Ranunculus hyperboreus*	*Ranunculus reptans*	*Rumex acetosella*	*Sparganium hyperboreum*	*Charcoal*
225	18–19		1			3			1					1	547	1					1	2	6	8	1	4	
225	32–33			1		1		1	1						1247						6	11		41		9	
225	68–69	1	4	10	1	13	1	3		1			1		629		8		4	13		78	1	3			1
225	101–02	1		3		10		7					2		5		38	5	7	167		1000	5			1	
225	119–20					4	1								2		14	31	131	7		375	2				
225	160–61					1			1		3	3					3	30	36	5		62	4				
225	186–87	1				4						20					5		230		1	66	6			6	
< 225	195–96											6							20			9				4	

106.5, 101.5, 96.5, 91.5, 81.5, 71.5, 42.5, *R. hyperboreus* 47, 42.5, 40, 37.5, 30, 27.5, 25, *R. reptans* 40, 35, *Salix* (twig) 187.5 cm.

Datings

Eight samples in B have been dated: 18–19 cm: 560 ± 100 B.P. (K-1648), 32–33 cm: 1160 ± 100 (K-1647), 68–69 cm: 2420 ± 100 (K-1646), 101–102 cm: 4390 ± 110 (K-1645), 119–120 cm: 5350 ± 120 (K-1644), 160–161 cm: 6080 ± 120 (K-1643), 186–187 cm: 6800 ± 110 (K-1642), the average of two datings: 6830 ± 130 and 6780 ± 130, and finally, 196–197 cm: 7000 ± 130 B.P. (K-1641).

Pollen zones

A total of four diagrams will be shown: From Galium Kær A a relative and a pollen concentration diagram (plates 12–13), and from Galium Kær B a relative and a pollen deposition rate diagram (plates 14–15). Only a part of the samples in Galium Kær A was counted absolutely.

Besides the pollen shown in the diagram, the following were found: Galium Kær A: *Alchemilla*, sample 40: one grain, *Coptis* 34:1, *Epilobium* 1:1, *Galium* 43:1, *Gentiana nivalis* 19:1, 38:1, *Huperzia* one spore in 3, 9, 12, 17, 22, 25, *Ligusticum* type one grain in 17, 23, 24, 31, 34, 41, 42, *Montia* 4:2, *Saxifraga cernua* type 9:1, 17:1, *Veronica fruticans* 38:1, *Viscaria* 9:1, 18:1, 29:1, 42:1, P. indet. 1:8, 2:4, 3:11, 4:4, 5:6, 6:7,

7:8, 8:7, 9:11, 10:7, 11:6, 12:5, 13:11, 14:8, 15:3, 16:3, 17:1, 18:2, 20:2, 22:2, 23:1, 24:7, 25:1, 26:11, 29:1, 30:2, 31:2, 32:2, 33:1, 34:2, 36:4, 37:1, 38:2, 39:3, 40:2, 41:1, 42:2, 43:2, *Sphagnum*, one spore in 17, 18, 20, 23, 35, 37, 43, two in 40.

And in Galium Kær B these were found: *Alchemilla* 8:1, *Armeria* 45:1, *Caryophyllaceae* 46:1, *Cornus suecica* 27:1, 37:1, *Dryas* type 2:1, *Gentiana nivalis* 23:1, *Huperzia* 12:2, 15:1, *Ligusticum* type 28:1, 29:1, 42:1, 46:1, *Melandrium* type 2:1, 3:1, *Minuartia* type 2:1, 3:1, *Phleum commutatum* type 35:1, 37:1, 39:1, 41:1, *Saxifraga cernua* type 43:1, P. indet. 1:1, 2:9, 3:1, 4:2, 5:4, 6:2, 7:3, 8:7, 9:5, 10:3, 11:8, 12:3, 13:4, 14:3, 15:3, 16:3, 17:6, 18:5, 20:1, 21:2, 22:1, 25:1, 26:2, 28:3, 29:4, 30:1, 33:4, 34:2, 35:3, 36:6, 37:5, 38:8, 39:22, 40:6, 41:4, 42:4, 43:1, 44:3, 45:2, 46:2, 48:1, 49:1, *Sphagnum* 14:1, 41:1, 45:1.

Pollen zone A: *Cyperaceae-Gramineae-Salix* zone (B, samples 1–4)

85–90 % of all the pollen originate from *Cyperaceae* and *Gramineae*, and *Salix* and *Dryopteris* type each amount to 3 %. Quite a long list of herbs share the remainder. Besides those shown in the diagram, pollen of *Dryas* in sample 2 and of *Melandrium* type (cf. p. 118) and *Minuartia* type in samples 2 and 3 should be mentioned. Macrofossils of *Eleocharis palustris* indicate that part of the *Cyperaceae* pollen may originate from this plant.

In the lake few *Eupotamogeton* (fruits of *P. alpinus* found right to the till), *Callitriche*, *Sparganium hyperboreum* and *Ranunculus confervoides* were growing, and only a few *Pediastrum* occurred. The zone boundary A-B is defined at the immigration of *Juniperus*. The sandy sediment is extremely rich in pollen: more than 1.1 million/ml in samples 2–4.

Pollen zone B: *Gramineae-Dryopteris-Juniperus* zone (A, samples 1–14, B, samples 5–15)

As defined, this zone is characterized by *Juniperus*, but the main dominants are *Gramineae*, amounting to 40–45 %. *Cyperaceae* decrease throughout the zone, while *Salix* and *Dryopteris* type are fairly constant. *Sagina*, *Silene acaulis* type, *Sedum*, *Thalictrum* and *Botrychium* attain their maxima in this zone. *Lomatogonium rotatum* occurs in 11 samples; outside this zone it is only found in 4 samples, all in zone F. *Huperzia* is found in 4 samples; outside the zone only in zone C (3 samples) and D (1 sample). In addition, a number of herbs has almost the same occurrence in the diagrams: *Chamaenerion*, *Plantago maritima*, *Thymus*.

Eupotamogeton, *Isoëtes* and *Pediastrum* flourish in the lake. *Myriophyllum spicatum*, and, towards the end of the zone, *M. alterniflorum* are sparse. *Sparganium* disappears rather early in the zone. *Ranunculus*

confervoides and *R. hyperboreus* make up a part of the *Ranunculus* curve. A few *Chara* occurred.

The zone boundary B-C is defined at a number of contemporaneous alterations in the curves.

Pollen zone C: *Juniperus-Gramineae* zone (A, samples 15–19, B, samples 16–20)

At the opening of this zone a number of plants disappear for a long time (*Chamaenerion*, *Thymus*) or decrease markedly (*Cyperaceae*, *Silene acaulis* type, *Thalictrum*, *Plantago maritima*, *Sedum*) while *Gymnocarpium* and *Juniperus* increase throughout the zone. The decrease in *Gramineae* is not parallel in the two diagrams: In A the decreasing trend starts at the end of zone B, while in diagram B it starts at the beginning of zone C. Apart from this, and from the evident cases of contamination in some of the A samples, the curves are surprisingly similar in the two diagrams. Examples of the contamination are seen e.g. in the parallel maxima in *Betula*, *Gymnocarpium* and *Hippuris* in A samples 9–11, and later in samples 14–17. These samples are from the upper part of two Hiller chambers.

In the lake *Eupotamogeton*, mainly *P. alpinus*, *Myriophyllum spicatum* and *Isoëtes* reach their maximum, as does *Ranunculus confervoides*, judging from the number of achenes found. At the opening of the zone *Sparganium* re-emerged, and some few *Menyanthes* pollen, not earlier noted, are found.

The zone boundary C-D is defined at the increase in *Betula*.

Pollen zone D: *Juniperus-Betula* zone (A, samples 20–27, B, samples 21–25)

The size measurements (plate 1.7–8), especially in the not compromised B samples, clearly demonstrate that *Betula glandulosa* was the only species in the first two samples, but already in the third sample *B. pubescens* was an important supplier. The increase in *Gymnocarpium*, begun at the opening of zone C, continues, now paralleled by *Angelica*. During the zone *Betula* increases from 2 to 25 %, or, in absolute terms, from less than 100 to 1000/cm²/yr. *Salix* increases slightly. At the same time *Juniperus* decreases from 6–700 to ca. 100/cm²/yr. Most other curves are fairly constant. *Gramineae* attain their minimum.

Considerable changes take place in the lake. *Myriophyllum spicatum* disappears in the beginning of the zone, and *Eupotamogeton*, *Isoëtes* and *Pediastrum* decrease during the zone to very low frequencies. *Potamogeton gramineus* dominates over *P. alpinus*. The *Ranunculus* curve also decreases. *Hippuris* emerges at the opening of the zone and increases to high values (note the difference in scale between *Hippuris* and the other macrophytes). Single *Hippuris* fruits were already found in the 119–120

cm sample in the middle of zone C and in a surveyed, but not counted macrofossil sample at 107–108 cm. In another surveyed sample at 113–114 cm no *Hippuris* fruits occurred.

The zone boundary D-E is placed where the increase in *Betula*, *Gymnocarpium*, and *Salix* ends.

Pollen zone E: *Betula-Salix-Gymnocarpium* zone (A, samples 28–36, B, samples 26–33)

This zone is characterized by almost constant frequencies. *Betula*, *Gramineae*, *Gymnocarpium*, and *Salix* dominate. *Angelica* shows optimal values. In the second half of the zone *Juniperus* attains its minimum since the immigration. A number of herbs standing their ground since the beginning of zone A or B now disappear: *Sagina*, *Selaginella*, *Saxifraga nivalis* type, *S. oppositifolia* type, *Erigeron* type, while others' frequencies become very low. A pronounced maximum of charcoal can be seen in the first half of this zone. *Coptis* and *Cornus suecica* are new.

Hippuris is the paramount dominant in the lake, overshadowing all other hydrophytes, among which *Isoëtes* disappears.

The zone boundary E-F is placed at the emergence of *Rumex acetosella/acetosa.*

Pollen zone F: *Rumex-Gramineae*-herb zone (A, samples 37–43, B, sample 34–41)

Apart from the emergence and rapid increase in *Rumex acetosella/acetosa*, the zone is characterized by the re-occurrence or re-flourishing of numerous herbs from the first zones: *Sagina*, *Erigeron* type, *Silene acaulis* type, *Plantago maritima*, *Liguliflorae*, *Sedum*, *Thymus*, *Saxifraga oppositifolia* type, *Thalictrum. Campanula* attains its maximum in this zone. *Polygonum aviculare*, *Achillea/Tripleurospermum* and *Phleum commutatum* are new types. *Betula*, *Gymnocarpium*, *Gramineae* and *Angelica* oscillate, but on the whole decrease throughout the zone. *Betula* size measurements show a decreasing amount of *B. pubescens.* Charcoal has a second maximum, starting with the opening of the zone.

In the lake *Hippuris* increases, as does *Sparganium. Menyanthes*, not seen since the single finds at the end of zone C, now becomes common. *Botryococcus* flourishes. The *Ranunculus* curve increases, partly caused by *R. reptans.*

The zone boundary F-G is placed at the increase of *Juniperus* and *Salix.*

Pollen zone G: *Juniperus-Salix*-herb zone (B, samples 42–49)

The uppermost two samples, with 82 and 90 % *Cyperaceae* pollen, are left out of consideration, as they evidently are completely stamped by

the vegetation on the spot. Relatively speaking, *Salix* attains its maximum in this zone. *Juniperus* is as important as in the late zone D. Furthermore, *Angelica*, *Sedum* and *Campanula* show increasing tendencies. Most herbs, including *Rumex* and *Achillea/Tripleurospermum*, continue unchanged, only *Gramineae* decrease. According to the B diagram, *Lathyrus* occurs for the first time, but in the A diagram (with Σ P twice as great as in B) three grains were found in zone E, two in zone F. The charcoal curve oscillates.

Hippuris, *Sparganium* and *Botryococcus* attain their maximum; *Menyanthes* still grows in the lake. *Pediastrum* has a small maximum. The youngest *Potamogeton* pollen is found in sample 44.

Discussion

In the protected little depression in which Galium Kær later was formed, a till-covered dead ice could persist for quite a long period. In any case, the gyttja sedimentation began in the only 2 km distant Comarum Sø around 8700 B.P., but the first cm of gyttja in Galium Kær was first formed at 7000 ± 130 B.P. It seems obvious to connect this with the climatic amelioration between 8000 and 7000 B.P.

When the history of Galium Kær started, the vegetation cover on the surrounding slopes was rather open, as indicated by the large amount of sand and clay washed out in the basin. In samples B 2–5 Σ P/ml exceeds 1 million. With the calculated sedimentation rate this should correspond to a yearly input of between 30,000 and 60,000 cm², a completely unrealistic assumption under natural conditions. As discussed under Drepanocladus Dam, the pollen must have been washed out together with the minerogenic matter. The ΣP/ml curve decreases almost to the upper boundary of the clayey gyttja (layer 2).

The first samples originate from the end of the *Salix-Gramineae* zone of Comarum Sø, but in Galium Kær a growth of *Eleocharis palustris/uniglumis* and presumably other *Cyperaceae* characterize the spectra. *Eleocharis palustris* has only been found twice in Greenland, viz. at Kiagtût at Narssarssuaq and at Igaliko, both close to the head of Tunugdliarfik, and *E. uniglumis* has only been found at Igaliko. Both species are circumpolar boreal plants which occur far north in Labrador, in Iceland, and in the most of Scandinavia. The possible introduction by the Norsemen of *E. uniglumis* to Greenland has been discussed by PORSILD (1932). Almost as important in zone A as *Cyperaceae* are *Gramineae*, while *Salix* does not exceed 5 %. Unfortunately, the two grains referred to as *Melandrium* type in samples B 2 and 3 were too badly preserved to make the determination fully reliable. With the present distribution in Greenland of this genus (not south of 66° on the west, 68° on the east coast), a proof of an early occurrence in South Greenland would have been most valuable.

Potamogeton alpinus, *Sparganium hyperboreum*, *Callitriche* and *Ranunculus confervoides* grew in the lake, although the rather opaque, clayey water must have reduced their growth and may have prevented the growth of Isoëtids.

After two centuries, around 6800 B.P., *Juniperus* immigrates. Judging from the relative diagram it does not reach its maximum (29 %) until sample 19, dated at app. 5100 B.P., but this is partly caused by the very high frequencies of *Gramineae* and *Cyperaceae*. The absolute diagram can, with caution, be used in discussing samples 9–12, and from sample 13 onwards the disturbing outwashed pollen are negligible. According to this, *Juniperus* gradually increases from the immigration until sample 12 (ca. 6000 B.P.) and then keeps almost constant until sample 23 (ca. 3500 B.P.). Unfortunately, however, the different bases of calculation on either side of the radiocarbon samples 119–120 cm, connected with the decrease in sedimentation rate by a factor 3.4, tend to blur the picture. Of course, the sedimentation rate did not drop suddenly, but gradually, and therefore the length of the bars in the absolute diagram close to the 119–120 cm dividing line should not be compared. Weighing all the indices, including an unpublished diagram of ΣP/ml, the following can be said: Soon after the immigration *Juniperus* reaches a certain level, which is kept almost unchanged or with a slightly increasing tendency until a marked increase occurs between samples 18 and 19, around 5400–5300 B.P. The considerable frequency is kept through the following 5–6 samples and is then succeeded by a decrease.

The great frequency of a number of herbs, of which *Sagina*, *Silene acaulis* type, *Sedum* (*annuum* ?), *Thalictrum* and *Botrychium* attain their maximum in zone B, is indicative of open and dry conditions on the surrounding slopes. *Lomatogonium* has its greatest frequency in this zone. *Salix* is rather common, although not as common as today, but no doubt a low *Salix* scrub was found at the foot of the ravine north of the lake.

In the lake all the hydrophytes flourish, with *Potamogeton alpinus* and *Isoëtes setacea* the most important. *Myriophyllum spicatum*, *Ranunculus hyperboreus* and *Potamogeton gramineus* immigrate. Usually grass fruits are not preserved, but the few *Alopecurus aequalis* fruits found in the profile, incl. 1 fruit in the 186–187 cm sample, may indicate that this species was an important supplier of the *Gramineae* pollen. It is rather common in the area at present, growing at the edge of small lakes and ponds, often floating like a carpet. In West Greenland it goes northwards to 70°, while on the east coast it only has an isolated occurrence at Angmagssalik. Besides *Eleocharis*, *Carex bigelowii/nigra* were important suppliers of the *Cyperaceae* pollen. 3 oospores of *Chara* sp. in the 160–161 cm sample shows a brief occurrence of presumably *C. fragilis* in the lake.

FOGED (1972) has determined the content of diatoms in 51 samples in Galium Kær. The results clearly show that the water was slightly alkaline during pollen zone A–C. An analysis of the till in the bottom of the B profile gave: 0.1 % of CO_2, 0.2 % of $CaCO_3$ (Geol. Surv. of Denmark).

Around 5600, many of the herbs characterizing the preceeding zone disappear or at least decrease markedly. *Gymnocarpium* increases by a factor 4. Some 2–300 years later the marked increase in *Juniperus* occurs, in the relative diagram by a factor 3. Considering the wide spectrum of vegetation types in which *Gymnocarpium* can be found, it seems difficult to explain the change in vegetation cover across the zone B–C boundary in terms of plant communities; only the diminishing influence of open soil plants indicates more closed, presumably lichen-rich heaths with abundant *Juniperus*. *Empetrum* attains its maximum in this zone and must have grown close to the lake. The missing fruits in the macrofossil sample from this zone must be accidental, as compared to the find of fruits in two later samples with much lower abs. frequencies of *Empetrum* pollen.

In the lake most hydrophytes attain their maximum in this zone. In the 119–120 cm sample 2 fruits of *Hippuris* were found, but in the pollen diagram B this plant does not occur until the beginning of the next zone.

Around 4500 B.P. *Betula glandulosa* immigrates. The increase is rather gradual although the time of immigration is not so difficult to determine as in Comarum Sø. The increase in *Gymnocarpium* continues through the beginning of the zone, parallelled by *Angelica* but opposed by a slight decrease in *Juniperus*. No doubt *Betula glandulosa* was able to displace *Juniperus* on more protected spots.

Around 3600 B.P. *Betula pubescens* immigrates. *Salix* and *Angelica* increase too, while most other plants, especially *Juniperus* suffer. By the end of this zone, around 2900 B.P., the increase in *Betula* ends, and most open soil or low heath plants are extinct or reduced in the vegetation around Galium Kær.

The succession in the lake exhibits interesting features. The maximum in most hydrophytes occurs between 110 and 125 cm, in layer 3. Across the zone boundary C–D, which coincides with the boundary between the gyttja layer (3) and the sandy gyttja (4) at 105.5 cm, especially *Potamogeton* drops, and at the upper boundary of layer 4 *Myriophyllum spicatum* disappear. The sandy layer is well-reflected in the marked increase in the residue of ignition and in the curve of mg sand/ml (fig. 16). The greater content of sand may be a result of a greater snowfall during winter and greater erosion of meltwater on the surrounding slopes.

It is difficult to say what caused the decrease of the hydrophytes, but presumably the use of nutrients was greater than the supply, and an

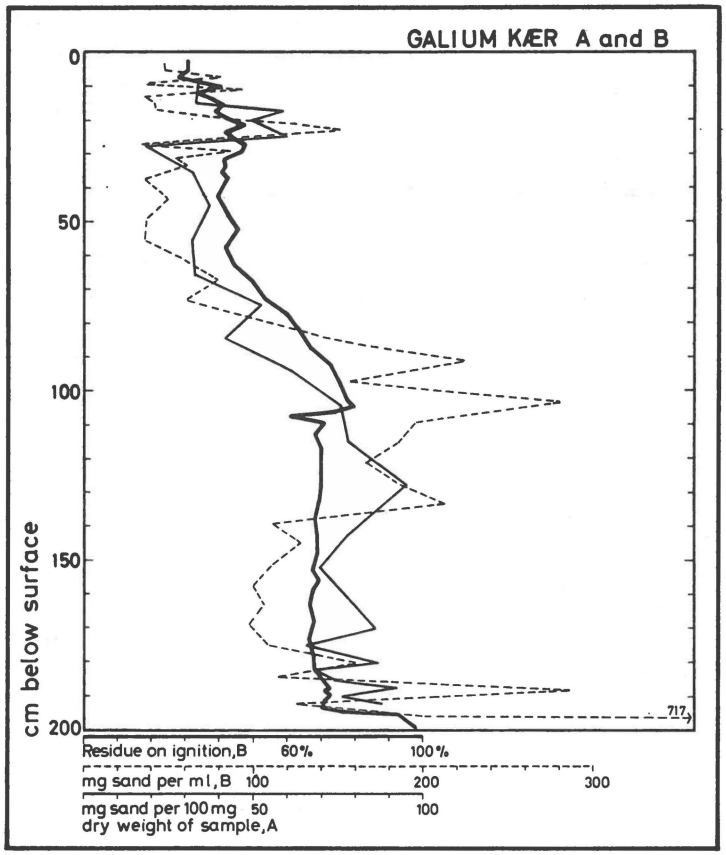


Fig. 16. Galium Kær A and B. Curves showing the content of minerogenic content versus depth.

oligotrophication was the result, though not as pronounced as in the Kap Farvel lakes. It should be mentioned that the slopes around Galium Kær are built up of crystalline rocks, not, as around Comarum Sø, partly of sedimentary rocks with lava.

Across the boundary between layers 4 and 5 a marked change in the chemical composition of the water is demonstrated by the diatoms. In brief, the alkalibiontic species disappear and the alkaliphilous are reduced, and Foged (1972) characterizes the change as a shift from a slightly alkaline to a slightly acid water. In sample B 22, just above the boundary, the *Hippuris* curve starts. As indicated by the fruits in the 119–120 cm sample, this species had been growing in the lake for some time, but without the possibility of asserting itself.

The immigration of *Betula glandulosa* seems to be connected with a climatic change, but a direct climatic cause of the changing pH in the lake is difficult to see. The most likely explanation seems to be the follow-

ing: The formation of *Betula* scrubs on the slopes caused the formation of an acid humus layer, partly because the litter of Betula is acid, partly because the greater shadow, even under *B. glandulosa* than under *Juniperus*, permitted the formation of a moss carpet. Water seeping through this layer to the lake, presumably poor in puffer, caused the slight, but to the alkalibiontic diatoms disastrous change in pH.

The more closed vegetation cover is also indicated by the marked decrease in the three curves in fig. 16. Furthermore, the fact that the curve of mg sand/100 mg dry weight in the deepest metre of the profile lies above, in the upper metre below the curve of residue on ignition, shows that the minerogenic fraction changed from consisting mainly of washed-out sand to a more fine-grained composition, consisting mainly of aeolian clay.

The opening of zone E around 2900 B.P. marks the beginning of a long period with stable conditions. The vegetation is characterized by *Betula-Salix* scrubs with *Angelica*, *Gymnocarpium*, *Lycopodium dubium* and presumably a dense moss carpet, but still with some *Juniperus*, *Campanula*, *Empetrum* etc. on the drier habitats. In the middle of the zone, between samples B 29 and 30, dated at app. 1900 B.P., *Juniperus* decreases, and a tendency of a displacement in the ratio *Betula glandulosa*: *B. pubescens* in favour of the former is seen in the pollen size diagrams (plate 1. 7–8).

A marked maximum in charcoal in samples B 26 and 27 (ca. 2700–2300 B.P.) must be ascribed to palaeo-Eskimo activity. Several indices of their settling at the coast at Qagssiarssuk and farther in the fjord Tunugdliarfik have been found. If the maximum was caused by e. g. Canadian forest fires, which often are traced in Greenland pollen diagrams, the same maximum should be much more pronounced in the Comarum Sø diagram, as this is more regional than the Galium Kær diagram. This, however, is not the case.

Hippuris dominates completely in the lake. *Myriophyllum alterniflorum* and *Isoëtes* disappear, and *Potamogeton*, now mainly *P. gramineus*, and *Ranunculus confervoides*, are very reduced. *Ranunculus reptans* emerges.

The Norse landnam app. A.D. 985 evidently takes place between samples B 33 and 34. This date, given at the 34 cm level, is used in calculating the sedimentation rates and the absolute counts, not the radiocarbon dating of the 32–33 cm sample (1160 ± 100 B.P.). The influence of man, sheep and cattle on the vegetation is drastic. The birches, mainly *Betula pubescens*, were cut down (cf. the evidences in the size measurements, samples B 34–41) and used for timber and fuel. The rather low frequency of charcoal seems to prove that they did not use fire when they cleared the copses, cf. the discussion under Drepanocladus Dam and in IVERSEN (1934 and 1952–53).

The broken vegetation cover permitted a number of species to spread again, e.g. *Silene acaulis* type, *Plantago maritima*, *Liguliflorae*, *Sedum*, *Thymus*, *Saxifraga oppositifolia* type, *Thalictrum*, *Botrychium*, *Lomatogonium*, *Campanula*. And finally the Norsemen introduced a number of weeds, first and foremost *Rumex acetosella*, but also *R. acetosa* ssp. *lapponicus*. In addition, *Achillea millefolium*, *Polygonum aviculare*, and, possibly hidden in the *Liguliflorae* curve, *Leontodon autumnalis* were introduced. The "Norse plants" will be discussed a little later.

In the lake a number of acidophilous diatoms emerge along with the landnam, and the content of sand increases. *Hippuris* increases again, and the sediment contains more than 5 fruits/ml. *Ranunculus confervoides* decreases, and in spite of the many fruits of *R. hyperboreus*, the increase in the *Ranunculus* curve supposedly also indicates a growth of *R. acris*. *Sparganium hyperboreum* and *Menyanthes* also become common. *Botryococcus*, which has only attained very low values hitherto, now flourishes.

By the time of the landnam the greater part of the basin was filled in. The maximum depth of water at the place of the profile, provided that no natural drainage channel was found in the ridge to the south, was 120 cm. The succession shown in the diagram might be quite natural. But the fact that just in the first sample after the landnam *Sparganium* spreads rapidly and *Ranunculus hyperboreus* and *Menyanthes* become common, calls for circumspection. It seems likely that the Norsemen made, or deepened, an already existing drainage channel in order to irrigate the slopes beneath the escarpment. In this connection it should be mentioned that all over Brattahlid (Qagssiarssuk), Erik den Røde's (Eirik the Red's) domicile and one of the most important Norse settlements, systems of irrigation ditches can be seen (fig. 6 in FREDSKILD, 1969b). And later, the present farmers of Qagssiarssuk, had the same idea. LARS MOTZFELDT of Qagssiarssuk told me in 1969 that about 30 years earlier he and some other men made a drainage channel in order to carry the water off from the pond (Galium Kær) and irrigate the slope. In this work they used no explosives, only levers. But he did not remember whether they deepened an existing channel or made a new one. The effect upon the vegetation downslope of the irrigation is very distinct.

The increase in *Juniperus*, *Salix* and *Angelica* between samples B 41 and 42 is interpreted as the consequence of the stopping of sheep grazing at the end of the Norse period. The dating of the 18–19 cm sample (560 ± 100 B.P.) seems to confirm the assumption. Contrary to e.g. Scandinavia, where *Juniperus* is favoured by sheep grazing, the hungry Greenland sheep eat everything edible during winter, even withered Christmas trees (*Picea abies*)! As *Juniperus* usually grows on places with

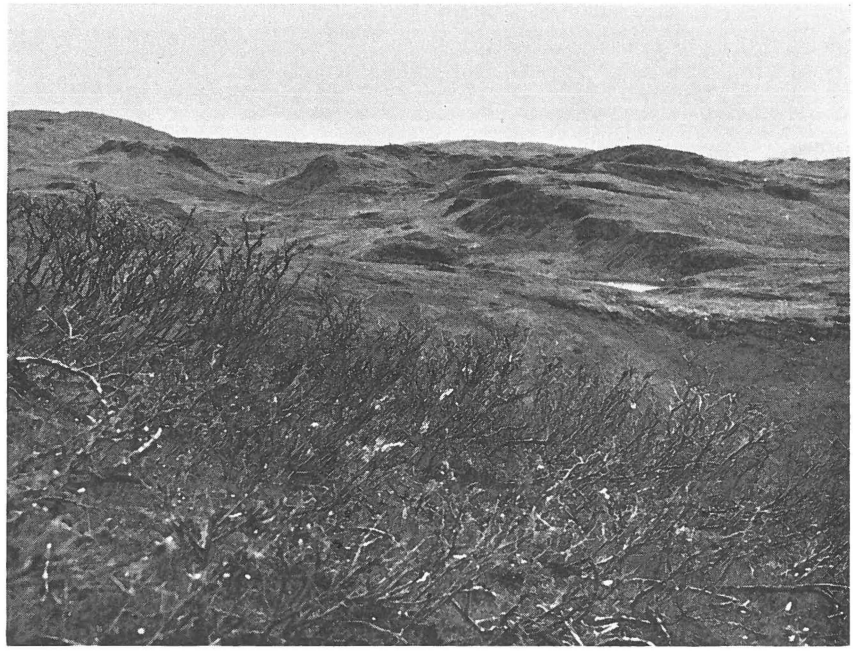


Fig. 17. *Salix glauca* scrub west of Qagssiarssuk, almost defoliated as a result of sheep grazing. July 5, 1970.

only a slight snow-cover, it is especially exposed to the attack of sheep. Many *Salix* scrubs suffer the same fate (fig. 17).

It is most remarkable that the antropochores as well as the apophytes continue right up to the present swamp peat almost unchanged. The effect of some 400 years' culture must have been so strong that even about 500 following years could not erase their traces. The neo-Eskimo settlement at the fjord after the disappearance of the Norsemen may have had some slight influence as a result of collecting of shrubs for fuel, but inland (Comarum Sø) this could not cause the continued growth of the perennial antropochores.

The quite recent drainage is believed to be responsible for the transition from swamp peat (layer 8) to moss peat (9).

Macrofossils from Norse culture layers

During the 1962 field season some transects were dug through moist depressions between the Norse ruins of Brattahlid.

Transect ERA

The first transect, fig. 18, is from a slightly sloping, very moist area, only 5 m wide, between two brooklets. It is situated between the great

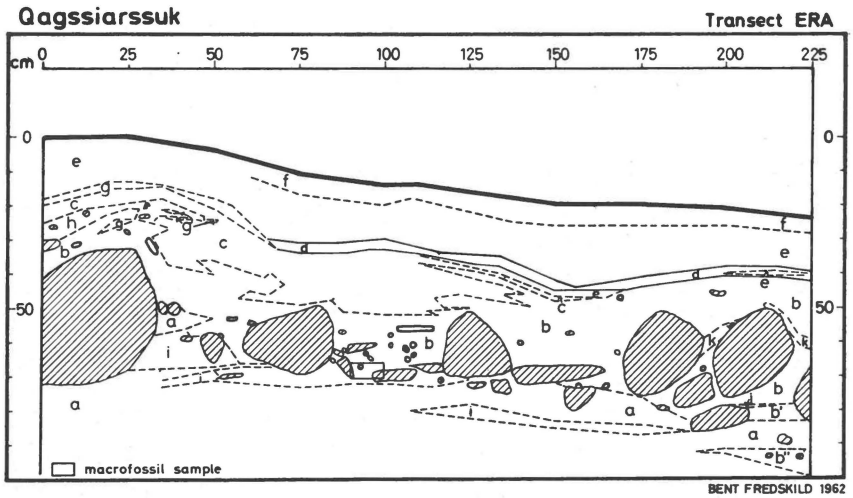


Fig. 18. Qagssiarssuk, transect ERA.

hall (ruin no. 2, cf. NØRLUND & STENBERGER, 1934) and the coast, marked A on fig. 15. The present vegetation is dominated by *Carex nigra* and *Poa pratensis* with many *Potentilla egedii*. *Polygonum viviparum* and *Carex glareosa* grow on the hummocks. *Triglochin palustre*, *Montia* and *Cardamine pratensis* grow along the brooklets.

The following layers were separated:

i. Sand with humus. Evidently this layer is mixed as a result of solifluction between layers b and a.
h. Swamp peat with charcoal. Brown to black, heterogenous, rich in charcoal. Th^3 4, Tb ?, Ga ++.
g. Sandy swamp peat. Greyish-brown. Th^3 3, Ga 1.
f. Swamp peat. Yellow brown. Th^2 4, Ga +, (Ag + As) +.
e. Humified swamp peat. Dark brown, darkens to black-brown. Heterogenous with scattered spots of sand, charcoal and other cultural traces. Distinct smell of H_2S. Th^3 4, Ga ++.
d. Slightly clayey sand. Greyish. Small pieces of charcoal, especially at the boundaries. Ga 3, (Ag + As) 1, Gs ++.
c. Moss peat. Yellow-brown, darkens to brown. The uppermost cm slightly darker. Seeds of *Montia*. This layer was still sterile in regard to cultural traces. Tb^2 4, Ga (+), (Ag + As) +.
b. Moss peat (culture layer). The colour, spotted reddish or yellowish-brown, darkens immediately to dark-brown. Heterogenous. Many wooden chips, especially at the lower boundary. In addition, charcoal, twigs, bones, worked antlers, a fragment of a stave, etc. Tb^3 4, Ga ++, (Ag + As) ++. b' is like b, but more sandy (Ga 0.5), b'' is even more sandy (Ga 1).

a. Clayey sand with gravel and stones. Yellow-grey. Smell of H_2S. Due to solifluction some schlieren of the culture layer is seen (b′, b″ and i). Gg 1, Gs 1, Ga 1, (Ag + As) 1.

In the greater part of the walls the sterile c-layer sealed the Norse layer. The cultural traces in the younger layers no doubt originate from the later Eskimo settlement, the ruins of which are found only 20–25 m away.

A macrofossil sample, marked on fig. 18, has been analyzed. The volume was of the order of 100 ml. The following seeds and fruits were found: *Alchemilla alpina* 1, *Alopecurus aequalis* 363, *Betula* 3, *Capsella bursa-pastoris* 4, *Carex bigelowii/nigra* 10, *Carex canescens* 1, *Carex* sp. 12, *Catabrosa aquatica* 124, *Cenococcum geophilum* 73, *Corylus* 1 (!), *Empetrum* 11, *Juniperus* (leaves) 16, *Montia* 279, *Polygonum boreale* 27, *Rorippa islandica* 1, *Stellaria media* 111. The average length of the *Polygonum* fruits is 2.83 mm, ranging between 2.5 and 3.3 mm (+ one, 3.7 mm long). The size of the *Stellaria* seeds is 1.35 mm (1.1–1.7 mm).

Transect QD

The marshy area between some raised beaches, seen as the dark area on the lower left in fig. 15, is artificially drained by a ditch. Along this a transect, marked B in fig. 15, was cleaned (fig. 19). The present vegetation is totally dominated by *Carex nigra*. In addition *C. rariflora*, *Cardamine pratensis* and *Poa pratensis* grow here.

The following layers were described:

a. Swamp peat, dark-brown. Th^3 4, Ga (+), (Ag + As) ++.
b. Swamp peat, bright-brown. Some fragments of twigs. Th^2 4, Dl +, (Ag + As) ++.
c. Swamp peat, dark-brown, darkens immediately to black-brown. Th^3 4, Tb ?, (Ag + As) ++. In part of the wall the lower part of this layer was a bright-brown swamp peat like layer b.
d. Moss peat. Bright-brown to yellow-brown. Tb^2 3, Th^2 1, Ga ++, Gs (+), (Ag + As) ++.
e. Moss peat with cultural traces, i.a. wooden chips. Dark, brownish-grey. Tb^3 4, Gg +, Gs +, Ga +, (Ag + As) ++.
f. Moss peat. Yellow-brown. Tb^2 4, (Ag + As) ++.
g. Culture layer. Dark-grey to black, heterogenous. Many wooden chips and much charcoal. In addition, steatite sherds and a wooden stave. The deepest ca. 4 cm of the layer could be separated through a transitional layer as a more sandy "Schwemm-detritus". Sh 3,Tb^1 1, Gs +, Ga ++, (Ag + As) ++.
h. Stones, sand and clay.

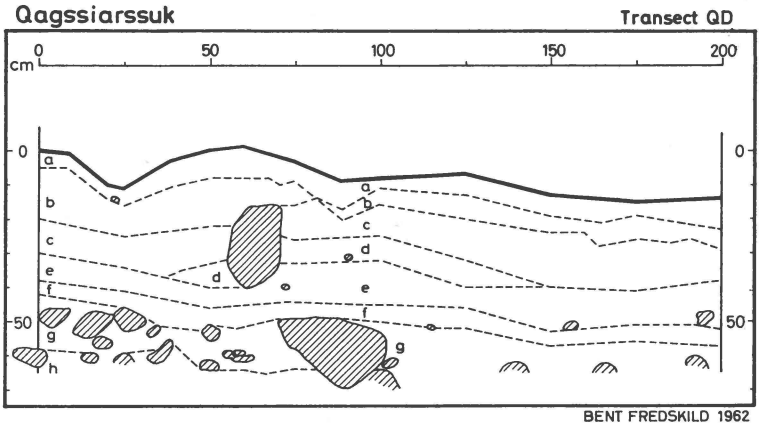


Fig. 19. Qagssiarssuk, transect QD.

A pillar 20 cm in front of the transect was cut into 2 cm thick slices. One of these, from the middle of the culture layer (g) was analyzed, and the following seeds and fruits were found (volume ca. 265 ml): *Betula* 6, *Capsella* 27, *Carex bigelowii/nigra* 10, *C. canescens* 1, *Carex* sp. 2, *Catabrosa* 21, *Cerastium alpinum/arcticum* 1, *Cenococcum* 170, *Empetrum* 1, *Euphrasia* 1, *Montia* 45, *Poa annua* 1, *Polygonum boreale* 23, *Potentilla anserina* 5, *Ranunculus acris* 3, *Rumex acetosella* 12, *Rhinanthus* 1, *Salix*, one seed, several leaves, *Selaginella* 72, *Stellaria media* 38, *Vaccinium vitis-idaea/uliginosum* 1, *V. uliginosum*, several leaves, *Viscaria alpina* 1. In a smaller sample from layer e there were found: *Carex bigelowii/nigra* 3, *C. atrata* 1, *Carex* sp. 1, *Montia* 142, *Polygonum boreale* 29, *Stellaria media* 16.

Transect LM

In the bottom of a former meltwater valley (C in fig. 15) a moist carpet of *Carex nigra* and *Poa pratensis*, with some *Ranunculus acris*, *Equisetum arvense* and *Polygonum viviparum* covers half a metre of peat. The following layers were separated (fig. 20):

g. The present vegetation mat.
f. Swamp peat with recent cultural traces. Yellow-brown. Th^1 4, Ga +.
e. Swamp peat, very dark-brown. Th^3 4, Ga +.
d. Swamp peat, dark-brown. Th^3, Ga +.
c. Swamp peat, bright-brown. Th^2 4, Ga +, charcoal.
b. Sandy humus layer, greyish, with many cultural traces (chips, charcoal and twigs). Th^2 ++, Sh 3, Ga 1.
a. Clay with stones.

In the upper 200 ml-sample there were found: *Alchemilla alpina* 35, *Carex*, mainly *C. bigelowii/nigra* 36, *Cenococcum* 1, *Empetrum* 4. In the

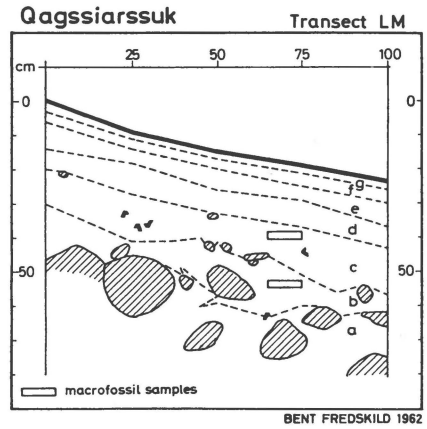


Fig. 20. Qagssiarssuk, transect LM.

lower sample (200 ml) there were found: *Cenococcum* 6, *Montia* 2, *Polygonum boreale* 1, *Rorippa islandica* 3, *Selaginella* 70.

Narssaq

A sample from the culture layer in a Norse ruin (no. 17a) in the outskirts of Narssaq was surveyed. *Stellaria media* is very common. Furthermore, *Polygonum aviculare*, *Montia*, *Luzula*, *Viola*, *Alchemilla alpina*, *Empetrum*, *Selaginella*, *Carex* spp. and others were found.

Several other transects were dug in Brattahlid, and still the sequence in sediments was the same: Upon the underground of sand and stone a Norse culture layer usually with many of or even a pavement of chips at the bottom. The culture layer is sealed upwards by often thick swamp and moss peat layers of varying degrees of humification. Traces of the recent or sub-recent Eskimo culture can be found in the upper layer.

No doubt the manured soil in the culture layers caused a vigorous growth of a number of apophytes and anthropochores as demonstrated by the content of macrofossils. When the Norse influence ended it was to be expected that the peat formation would stop quite soon and the shrubs would cover the areas. But this did not happen. On the contrary, thick layers of moss and swamp peat often developed. The most likely explanation is that during the following centuries the climate was wetter. This is confirmed by the Comarum Mose profile, in which the second *Betula glandulosa* stage in the later part of the Norse period was succeeded by moister *Comarum* and *Cyperaceae* stages.

Norse plants

The discussion concerning which species were introduced by the Norsemen was started by ROSENVINGE (1896). Several later papers have

dealt with this topic. The most detailed are PORSILD (1932) and PEDERSEN (1972). Because of the very up-to-date and thorough treatment in the latter, only a few species will be mentioned.

Rumex acetosella s. l.

In Greenland this plant includes two ecologically very different strains. The indigenous strain is distributed in West Greenland south of ca. 71°, occurring in dry rocky crevices, in lichen heaths, on dunes and similar places. Towards the south it is difficult to distinguish this decidedly not hemerophilous plant from those specimens of the other strain, growing on similar biotopes. In East Greenland, besides isolated occurrences at Tingmiarmiut and in the Angmagssalik region, it is widely distributed towards the northeast between 70° and 75°. The other strain is hemerophilous and no doubt introduced. It has been found as far north as Disko (PORSILD, 1920).

During the whole field season NIELS JACOBSEN of the Institute of Systematic Botany, the University of Copenhagen, and I searched for *Rumex acetosella* and *R. acetosa* in the Kap Farvel area. We found only the following: On Pamiagdluk at the former settlement Anordliuitsoq *R. acetosella* grew partly on the collapsed walls, partly – and then much poorer specimens – in crevices on outcrops of bedrock between the ruins. At the former settlement Pamiagdluk, at the southern end of Pamiagdluk, *R. acetosa* grew vigorously on the collapsed walls and within the nearest metres. At Tupaussat both species grew on the peninsula west of the outlet at places highly influenced by former (Norse) and recent cultures, cf. p. 80. Finally, *R. acetosella* was found (N. J.) on a slope ca. 150 m a.s.l. on the east side of Tupaussat valley.

In the Qagssiarssuk area *R. acetosella* grows in a number of habitats varying from culture soil to dry slopes, rocks, and heaths.

The anemophilous *R. acetosella* is a prolific pollen producer. In the 4 diagrams from Kap Farvel only 2 grains were found prior to the Norse landnam, both in the diagram from Isoëtes Sø, which exhibit the highest frequency of long distance pollen (e. g. in the same period in this diagram 55 *Ambrosia* pollen were sedimentated). In the uncontaminated diagrams from Qagssiarssuk not a single *Rumex* pollen, neither *acetosella* nor *acetosa*, was found prior to the landnam. But after this, it constitutes up to 5 % of ΣP.

Until further investigations are at hand, it seems justifiable to postulate that *Rumex acetosella* was introduced at least to the parts of South Greenland that have been investigated palaeobotanically.

Rumex acetosa s. l.

Rumex acetosa ssp. *acetosa* has been found a few times (PEDERSEN, 1972) in connection with habitation. Ssp. *lapponicus* is distributed on the

west coast between 60° and 62°. According to ROSENVINGE it "is principally to be met with on manured spots near present and former habitation" (quoted after PORSILD, 1932), but it can also be found north of the area of the "Eastern settlement". Around Qagssiarssuk it occurs rather commonly, especially in low, open, snow-protected willow scrubs in a completely naturalized state.

The distinction between the pollen of *R. acetosa* and *R. acetosella* is difficult to make because of considerable morphological overlapping; both are included in the same curve in the diagrams. It is my impression that the latter species is by far the most frequent in the pollen spectra. Whether *R. acetosa* was spread to the occurrences outside the Norse area directly from Iceland or Scandinavia by natural ways or whether it spread via the Norse areas is uncertain, but with the same reservation as above, *R. acetosa* ssp. *lapponicus* seems to have been introduced by the Norsemen.

Elymus arenarius s. l.

The tetraploid *Elymus arenarius* ssp. *mollis* (2n = 28) is widely distributed in Greenland. In the Kap Farvel area it was observed that a deviating *Elymus* grew only directly upon or very close to ruins, while ssp. *mollis* grew along the shore, independent of cultural influences. The same form is very common in Qagssiarssuk and was also found on a stone fence at the harbour in Julianehåb. PEDERSEN (1972) has a morphological description of this form, referring it to *E. arenarius* s.str. This seemed supported by an (erroneous) report of 2n = 56, which, however, is due to an unfortunate mistake on my part. 2n = 56 has not so far been reported from Greenland, whereas the collection from Julianehåb was counted at 2n = 42 by K. RAHN, Botanical Museum, University of Copenhagen. Furthermore, N. JACOBSEN counted 2n = 42 in collections from i.a. Qagssiarssuk, Anordliuitsoq and Tupaussat. BOWDEN (1957) mentions three North American lower taxa, possibly hybrids, with this number.

Achillea millefolium s. l.

The pollen of *Achillea-Tripleurospermum* type found from the landnam onwards are ascribed to *Achillea*, as this species is very common in the area today, whereas *Tripleurospermum* is tied to recent culture soil in Qagssiarssuk proper. All the way between Qagssiarssuk and Tasiussaq at Nordre Sermilik fully naturalized *Achillea* covers great areas on grassy slopes close to Norse ruins. No doubt they are favoured by the present sheep grazing, but the growth was registered (ROSENVINGE, 1896, p. 181) prior to the establishment of Qagssiarssuk in 1924.

Besides the palynological evidences of plants introduced by the Norsemen, we have in the culture layers seeds and fruits of *Stellaria*

media, *Capsella*, *Poa annua*, *Polygonum boreale*, *Potentilla anserina*, *Rumex acetosella* and *Ranunculus acris*. The latter is indigenous in Greenland, but introduced strains supposedly also occur.

Summary of the vegetational and climatic history of Qagssiarssuk

The direction of glacier movement at Qagssiarssuk in the last phase of glaciation was across the fjord Tunugdliarfik from Kiagtût sermiat towards Tasiussaq at Nordre Sermilik, but nothing is known about the time of deglaciation (Weidick, 1963). The thick laminated clays in the bottom of the Comarum Mose basin must have been deposited by the water from melting ice on the surrounding hilly landscape or very shortly thereafter, before the vegetation could cover and bind the soil. The dating of the basal gyttja dates the change from clay to gyttja to 8700–8500 B.P. and thereby gives a minimum dating for the last connection with the ice lobes across the fjord, and at the same time for the formation of the system of beach ridges at an elevation of ca. 37 m, seen on fig. 15 (top left). These seem to mark the upper marine limit.

The terrestrial vegetation

a. *Cyperaceae-Plantago maritima-Empetrum* phase (ca. 8700–8000 B.P.)

A pioneer vegetation dominated by *Chamaenerion*, *Silene acaulis*, *Minuartia rubella*, *Plantago maritima*, and with i.a. *Oxyria*, *Empetrum*, *Saxifraga nivalis* or *tenuis*, *Elymus*, *Poa*, *Puccinellia*, *Dryas*, *Angelica* and *Carex norvegica* covered the soil when the ice receded. Compared to the outer coast, the conditions must have been more continental. No decidedly southern plants were found, and there are several indices of climatic conditions as those found today between 67° and 69° on the west coast. All the species found (incl. the entomostrac *Lepidurus arcticus*) occur (and the genera found are represented) in the present flora e.g. around Sydostbugten at 68°30′N.

b. *Salix-Thalictrum* phase (ca. 8000–6900 B.P.)

Salix immigrates around 8000 B.P. and immediately spreads, attaining the same absolute values as today. Its immigration therefore seems to have been delayed due to lack of dispersal.

c. *Juniperus-Gramineae* phase (ca. 6900–4500 B.P.)

Juniperus immigrates around 6900 B.P. A century or two earlier *Eleocharis palustris* s.l. was already growing vigorously around Galium Kær. This and other evidence, i.a. the occurrence of *Selaginella*, which

emerges around 6700 B.P., indicate favourable climatic conditions not much different from those of today. An equilibrium came about in the vegetation during a half-millennium. In the following period the still large quantities of herb pollen seem to indicate that low, open, xerophytic heath types dominated. Around Comarum Sø stable conditions are reflected in the pollen curves during the next two millennia, while at Galium Kær a vegetational change was recorded at 5500–5300 B.P. Many of the low herbs disappeared or became decimated, and *Juniperus* increased, attaining frequencies (29 %), only found in late-glacial sediments e.g. PENNINGTON & BONNY (1970) and BERGLUND (1966).

d. *Juniperus-Betula glandulosa* phase (ca. 4500–3600 B.P.)

The two shrubs had to compete, which might explain the more even increase in the *Betula glandulosa* curve, but whether the late immigration was a question of climate or dispersal remains open. There are several indices of increasing temperature and drier conditions through this phase. Possibly this trend was already registered in the *Juniperus* increase around 5300 B.P.

e. *Betula pubescens-B. glandulosa-Salix* phase (ca. 3600–1900 B.P.)

By the opening of this phase, the climatic amelioration must have reached its maximum. Whether this maximum was reached during the preceding phase cannot be said, as the argument is mainly based on organisms whose immigration could have been delayed because of less effective dispersal. Everything considered, conditions in phase d were warm and dry, in the beginning of phase e maybe even warmer, but not so dry. *Salix-Betula pubescens* scrubs with an undergrowth of *Angelica*, *Gymnocarpium*, grasses etc. must have covered protected valleys and slopes, while on the more exposed areas *B. glandulosa*, *Juniperus* and *Salix* were forming low (dwarf-)shrubby heaths. Towards the end of the zone *B. pubescens* seems to decrease, while *B. glandulosa* increases.

f. *Betula glandulosa-Salix* phase (ca. 1900–1000 B.P.)

The deterioration begun towards the end of phase e also manifests itself in the decrease in *Juniperus*, most marked around 1900 B.P. *B. glandulosa-Salix* heaths must have covered wide areas. The drier conditions on Comarum Mose, where *B. glandulosa* was able to grow directly on the bog, are interpreted as indicating lower precipitation (or greater evaporation), although it may be argued that it simply was a final stage in the hydrosere.

g. *Rumex acetosella* phase (ca. 1000–0 B.P.)

The influence of the Norse landnam on the vegetation was so radical that the influence of any climatic changes are easily hidden, at least in

the lake diagram. The transects and the Comarum Mose diagram seem to indicate 1) that the Norsemen had to cut away dense scrub over greater parts of Brattahlid (just like at the settling in 1924; verbal information by JEHU DAVIDSEN of Qagssiarssuk, who joined the recent landnam-people from the first day), 2) that some time after the landnam there was a moister period, again succeeded by a drier period, 3) that their disappearance was succeeded by a moist period, and, 4) that the perennial anthropochores and apophytes were able to stand their ground until the present landnam.

The lacustrine vegetation

In the Kap Farvel lakes climatic changes and oligotrophication were the overall dominating factors behind the succession of the hydrophytes. At Qagssiarssuk the climate presumably was favourable enough to permit any of the plants that were found, to grow in the lakes right from the beginning, possibly with the most southern of the species, *Myriophyllum alterniflorum*, as an exception. During the major part of the development the water was richer in nutrients, and still Comarum Sø is more nutritious than the Kap Farvel lakes. Physical competition in connection with a rapidly lowering depth of water allowing reedswamp plants to settle has played a decisive role in the greater part of the history of the lakes.

Up to around 3500 B.P. there is a striking parallelism between the succession in the two lakes, although at the beginning with a displacement in time (fig. 21). First there is a stage with totally submerged plants (*Potamogeton filiformis*, *Chara*, *Subularia*, *Callitriche*, *Isoëtes setacea*, *Myriophyllum spicatum*, *Myriophyllum alterniflorum*). This is succeeded by a stage of floating-leaved macrophytes (*Potamogeton alpinus*, *P. gramineus*; reverse order in Galium Kær) with *Ranunculus confervoides*, having no floating leaves. The succession in Comarum Mose then is: 1) *Hippuris-Sparganium hyperboreum*, 2) *Carex rostrata-Menyanthes*, 3) *Comarum-Cyperaceae* fen. In Comarum Sø 1) the *Menyanthes-Hippuris* stage is succeeded by 2) the *Carex rostrata-Menyanthes* stage. This stage, now and then with some *Hippuris*, is very drawn out as a result of the formation of a swamp which blocked the drainage system and caused a more or less constant water depth in the remaining lake. No doubt an oligotrophication sets in during this period, as the supply of melting water was filtered through the surrounding fen and swamp. Between 1500 and 1000 B.P. an increase in *Ranunculus confervoides* and later *Sparganium* and *Menyanthes* sets in. At the same time a drying up of the fen is registered. Both events start before the Norse landnam and must be ascribed to drier climatic conditions, and, as a result, a lower depth of

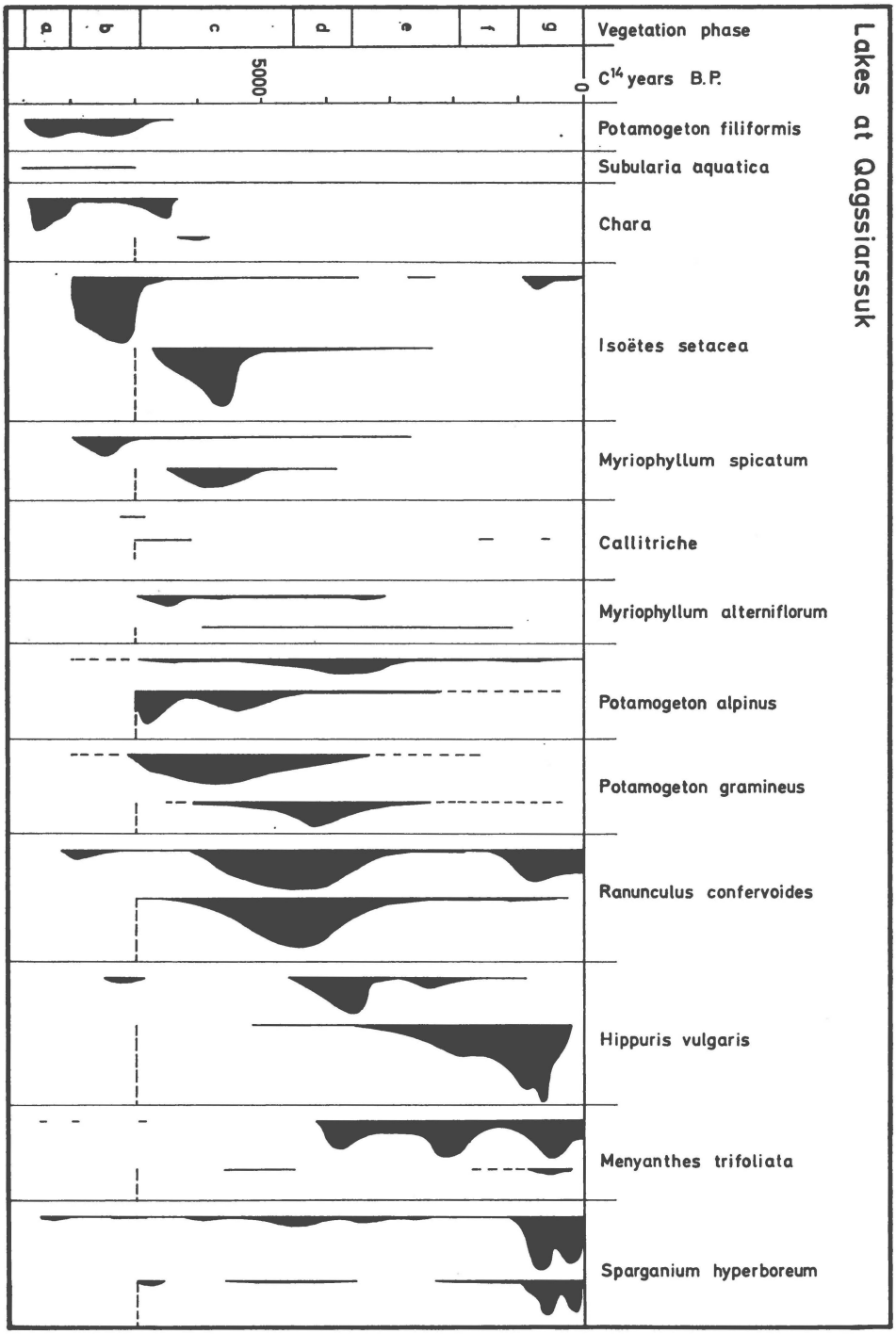


Fig. 21. Summary diagram of the vegetational development of Comarum Sø and Galium Kær. The silhouettes delimited downwards by a dashed line show conditions in Galium Kær.

water in the lake. The flourishing of *Isoëtes* contemporaneously with the Norse period is difficult to explain.

In Galium Kær the floating-leaf stage is succeeded by a *Hippuris* stage. This might be a quite natural succession, but since 1) *Hippuris* did not increase until both *Potamogeton* and *Ranunculus confervoides* were very reduced, 2) a change from slightly alkaline to slightly acid water is indicated by diatoms contemporaneous with the *Hippuris* increase, and, 3) this occurs along with the immigration of *Betula*, these events seem connected. The next stage in the filling in of the pond is a *Hippuris-Sparganium-Menyanthes* stage. This might be quite natural, eventually accelerated by the drier climate shortly before 1000 B.P., but the fact that the increase is completely coincident with the landnam may indicate that the lowering of the water was artificial. In any case, the final step to the *Carex nigra-Carex canescens* stage is artificial.

West Greenland

The Godthåbsfjord area

Remarks on the present vegetation

The vegetation in the different climatic regions of Godthåbsfjord has been treated by TRAPNELL (1933). PORSILD (1935) gives a short description of the vegetation at some localities, visited on an excursion, and BÖCHER (1959) gives a flora list from three localities, visited by A. HEMMINGSEN. As an introduction to his palynological paper IVERSEN (1952–53) gives a general survey; in another paper he deals with the vegetation in a valley in the most continental part of the fjord (IVERSEN, 1954b).

TRAPNELL (l.c.) divides the vegetation into the following types: 1) Open vegetation predominantly herbaceous, with species like *Papaver radicatum*, *Luzula confusa*, *Oxyria*, *Saxifraga* spp. This type is polar, or maritime high arctic, or high montane. 2) Open mat vegetation with various dwarf-shrubs, such as *Dryas*, *Cassiope*, *Rhododendron lapponicum*, with very various, scattered herbs. This type has a high arctic and continental montane distribution. 3) Moss mat dominated by *Rhacomitrium hypnoides* or *Dicranum* spp. Dominating dwarf-shrubs are *Empetrum* or *Salix herbacea*, and often *Vaccinium uliginosum*. *Carex* spp. and grasses such as *Deschampsia flexuosa*, *Festuca vivipara*, *Agrostis borealis* and *Trisetum spicatum* are plentiful. Maritime arctic or low montane in cloudy regions. 4) Lichen mat. *Cladonia mitis*, *C. alpestris* and *Stereocaulon paschale* dominating together with *Polytrichum juniperinum*. *Betula nana* and *Vaccinium uliginosum* are the chief dwarf-shrubs, while *Empetrum* is sparse. *Ledum palustre* ssp. *decumbens* is common. Herbs are sparse except for a few xerophytic *Carex* or *Luzula*, as well as *Hierochloë alpina*. Continental low arctic, or low montane in sunny regions. 5) Heath mat vegetation of *Ledum groenlandicum*, *Betula* or *Vaccinium uliginosum*, with scattered *Salix glauca* and herbs. Moss undergrowth. Occurs only in more favoured places. Subcontinental low arctic.

Palynological investigations are only at hand from the interior part of the fjords. In this area variants of type 4 are the overall dominating vegetation. *Betula nana* is the most common dwarf-shrub. In favourable places and along brooks and in rivulets tall copses of *Salix glauca* are common, along with a few *Alnus crispa*. Otherwise, *S. glauca* is common

as a dwarf-shrub in the *Betula nana* heaths. Ericaceous plants are widespread, with *Vaccinium uliginosum* and *Empetrum* the most common, especially in the montane zone, while *Ledum decumbens* is common on less favoured places. *Juniperus* is restricted to dry, southerly slopes. The vegetation in lakes and ponds is fairly rich, and the following species are frequent in Itivneq and along the lower part of the Kapisilik river: *Isoëtes setacea*, *Ranunculus confervoides*, *Myriophyllum alterniflorum*, *Hippuris*, *Potamogeton filiformis*, *P. pusillus* ssp. *groenlandicus*, *P. gramineus*, *P. alpinus*, and *Sparganium hyperboreum*. The following were found only once or twice: *Callitriche intermedia*, *C. palustris*, *Montia*, *Menyanthes*, *Myriophyllum spicatum*, *Limosella*, *Juncus subtilis*, *Eleocharis acicularis*, *Sparganium angustifolium*, and *Nitella flexilis*.

Remarks on the climate

The highest summer temperatures (means for June-August) in Greenland are recorded at Kapisigdlit at the head of Godthåbsfjord: 9.7° C (Juli 10.9° C). The corresponding mean for Igaliko, close to Qagssiarssuk in Tunugdliarfik is 9.3° C (July 10.3 °). As mentioned earlier, the main difference in climate between the latitudes in South and West Greenland as seen from a vegetational point of view is found in the length of the vegetation period. E.g. the monthly mean temp. for Oct. and April at Igaliko is 1.9° and 1.0° resp., while at Kapisigdlit the corresponding figures are -3.4° and -1.7° C. The differences along a latitude can be illustrated by the three stations at Godthåbsfjord: Godthåb at the outer coast, Qornoq halfway in the fjord, and Kapisigdlit at the head. The mean summer temp. is 6.7°, 8.7° and 9.7° (PUTNINS, 1971). These differences are also evident when the rich precipitation at the outer coast is compared with the lighter one at its head.

The favourable summer climate no doubt is the reason why the only collection of *Potamogeton pusillus* ssp. *groenlandicus* with ripe fruits and the only of flowering *Utricularia* are from this area. The endemic *P. pusillus* ssp. *groenlandicus* is distributed from 60° to 70° N on the west coast. It is common around Disko Bugt, but is also frequent at the head of the great fjords southwards. It has been found with flowers only a few times (FREDSKILD, 1961) and with fruits only in a lake 700 m east of the outlet of the Kapisilik river, where it grew together with *Sparganium hyperboreum*, *Menyanthes*, *Hippuris*, *Potamogeton alpinus* and *Ranunculus hyperboreus*, all fertile. The water was brownish, but the limited amount of chemical information (table 11) does not indicate special chemical properties.

The three rare Greenland species of *Utricularia* (*minor*, *ochroleuca* and *intermedia*), only found a few times in West and South Greenland

(FREDSKILD, 1961), have only been found sterile, except for the coll. of blooming *U. intermedia*, found in Itivneq. Here it grew together with i.a. sterile *U. minor* in a shallow extension of the brooklet, draining the big lake in the middle of the isthmus (see p. 153).

In table 11, the analyses of water from a lake at Ikiniligssuaq (64°23′.5N, 50°21′.5W), northeast of Itivnera, also is included. In this shallow, muddy lake (or pond) 300 × 50 m wide, *Myriophyllum spicatum*, *Eleocharis acicularis*, *Sparganium hyperboreum* and *Comarum palustre* grew.

Finally, the water of the three cored lakes is included. The water samples taken in late July and August were kindly examined at the end of August at the Institute of Botanical Ecology at the University of Copenhagen. The pH measurements were made according to the method described in IVERSEN (1929). The specific conductivity is expressed as $\varkappa_{20} \times 10^6$.

Table 11. *Chemical analyses of the water of some lakes at the head of Godthåbsfjord.*

	pH			conductivity	K m. eqv./l	Na m. eqv./l	Ca + Mg m. eqv./l
	actual	lowest	highest				
"Lake 8 m"	6.40	5.90	7.65	21	0.03	0.05	0.5
Lake in Itivneq	6.55	6.35	8.95	68	0.07	0.22	0.5
Lake at Itivnera	6.40	6.20	8.90	57	0.06	0.16	0.5
Lake with *Potamogeton groenlandic.*	6.45	6.05	8.10	46	0.06	0.19	0.5
Lake at Ikiniligssuaq	6.40	6.20	7.50	42	0.02	0.18	0.6
Brooklet with *Utricularia*	7.15	6.80	9.10	133	0.07	0.31	2.2

Remarks on the geology

The entire area of the fjord is built up of Precambrian rocks, predominantly grey gneisses. These are often covered by till, and e.g. in Itivnera wave cut moraines and raised beaches can be seen. The upper marine limit is ca. 110 m, and based on IVERSENS (1952–53) tentative dating of the vegetational stages in "Lake 100 m", on a dating of the lower 9 cm of gyttja overlying marine clay in "Lake 8 m" (FREDSKILD, 1967a) and on a shell dating (WEIDICK, 1968) from Kapisigdlit, WEIDICK (1972b) has presented an uplift curve for the area around the head of the fjord.

"Lake 100 m s.m."

IVERSEN (1952–53) published the first standard pollen diagram from Greenland. Only some of the curves, however, were given in the diagram,

and furthermore some of the counts were corrected. These corrections were based on vegetation analyses of a transect through the valley (IVERSEN, 1954b). *Betula* and *Alnus* were divided by four, *Juniperus* by two, while *Ericaceae* were doubled. Insofar as it would be highly desirable to be able to draw direct conclusions from the frequency in a pollen spectrum to the area covered by the plant in question on the surrounding area, the method may be used, and for forested areas it has turned out to be a succes, e.g. ANDERSEN (1970). But with the very restricted knowledge of recent pollen sedimentation in arctic areas and the often very strong local winds, the results obtained by this method may be just as wrong (or true) as those deduced from a diagram without corrections. In order better to be able to compare the "Lake 100 m" diagram with the other Greenland diagrams, it has been re-drawn without corrections and with some additional curves included (plate 16). The late Dr. IVERSEN kindly placed all his Greenland material at my disposal, including diaries and the result of the pollen analyses. Dr. HARALD KROG, Geol. Survey of Denmark, who analyzed the half of the diagram, has kindly informed me about details in the pollen determination etc.

Dr. J. TROELS-SMITH, Danish National Museum, who carried out the borings in 1937, has kindly informed me about the position of this and another cored lake. "Lake 100 m" (64°24'N, 50°12'W, fig. 22, C) is a small lake without an inlet, app. 1 km west of Igdlorssuit tasiat. The sediment is a gyttja, except for some cm of bluish clay underlying it. The lowermost analyses are from samples deposited in brackish water, as indicated by the saltwater diatoms and by the ample occurrence of pollen from seashore plants (e.g. *Plantago maritima* and *Stellaria humifusa;* IVERSEN, 1952–53).

The following pollen, not shown in the diagram, have been found: *Campanula*, sample 17: 2 pollen, 21:1, *Cruciferae* 4:1, 8:1, 9:1, *Dryas* 2:1, *Elymus* 6:1, 9:1, *Ligusticum* 8:1, *Lomatogonium* 5:1, *Montia* 3:1, 4:1, ?*Papaver* 5:1, *Pinguicula* 9:1, *Polygonum viviparum* 14:1, *Tubuliflorae* 7:1, 17:1, 18:1, *Umbelliferae* 20:1, 21:1, P. indet. 1:3, 7:1, 8:1, 9:2, 10:1, 11:1, 15:1. Besides *Stellaria humifusa* the *Caryophyllaceae* p.p. curve includes some *Sagina*, especially in the deeper samples, and presumably *Silene* and *Minuartia* types. In the original analyses the *Chamaenerion* curve was termed *Epilobium/Chamaenerion*, but with the abundant occurrence in the oldest samples and IVERSEN's statement that *Chamaenerion latifolium* was demonstrated in the earliest samples, I found it justifiable to exclude *Epilobium* from the head of the curve. Based on the same type of arguments, the curve of pollen in the original counts termed "*Saxifraga*, reticulate" has been termed *Saxifraga nivalis* type. Possibly *Subularia* is included in the *Cruciferae*.

Pollen zones

Pollen zone A: *Empetrum-Gramineae* zone (samples 1–12)

This zone might as well be divided into two zones, 1) an older one, characterized by *Gramineae*, *Chamaenerion*, *Plantago maritima*, *Caryophyllaceae* p.p., *Cerastium-Stellaria* type and with only some scattered *Eupotamogeton* pollen (already from sample 2) as a proof of higher plant growth in the lake, and, 2) a younger one, dominated by *Empetrum* and other *Ericales* and with increasing *Cyperaceae* and decreasing *Gramineae*. All the species (genera, types etc.) mentioned, apart from *Eupotamogeton*, attain their maximum in this zone. This is also true of *Oxyria-Rumex acetosella* type, *Ranunculus*, *Huperzia*, *Saxifraga nivalis*, *Elymus*, *Dryas*, *Lomatogonium*, *Montia*, *Pinguicula*, *Cruciferae*, *Ligusticum* (?) and *Papaver* (?) which are only found in this zone. Towards the end, *Botrychium* attains its maximum, and *Thalictrum* emerges. The scattered *Salix* pollen "consist principally of *Salix herbacea* pollen, which can be distinguished morphologically" (IVERSEN, 1952–53, p. 88).

Hippuris and *Myriophyllum spicatum* flourish vigorously in the lake in the second part of the zone. In particular, *Myriophyllum* must have been extremely common, reaching 553 % in sample 8, which is the oldest sample in which it occurs. *Potamogeton filiformis* and *Sparganium* are sparse. The zone boundary is defined at the immigration of *Salix glauca*.

Pollen zone B: *Salix-Thalictrum-Cyperaceae* zone (samples 13–18)

The *Gramineae* curve is still decreasing, as are most curves of the pioneer plants, and *Empetrum* drops at the opening. *Dryopteris* type, *Equisetum*, *Thalictrum* and *Salix* attain their maximum in this zone, and *Gymnocarpium* and *Diphasium* are more constant than in zone A. *Cyperaceae* are common, and *Sphagnum* has a marked maximum. In samples 1–14 only one pollen of *Artemisia* was found, but from sample 15 onwards it has an almost uninterrupted curve. Towards the end of the zone *Selaginella* emerges.

In the lake *Myriophyllum spicatum* and *Hippuris* decrease, *Potamogeton filiformis* and *Sparganium* are still sparse. Towards the end the *Eupotamogeton* curve becomes continuous. The zone boundary B-C is defined at the immigration of *Betula* and *Juniperus*.

Pollen zone C: *Betula nana-Juniperus* zone (samples 19–23)

The opening is characterized by the most marked increase in any of the Greenland lake diagrams. Between samples 18 and 19 (10 cm apart) *Betula* increases from 3.9 to 53 %. *Juniperus* emerges slightly earlier and rapidly attains its maximum (7.0 % in sample 19). *Salix* almost stands its ground in this zone, *Lycopodium dubium*, *Gymnocarpium* and

Diphasium type even increase, while *Gramineae* and especially *Cyperaceae* pay for this development.

Potamogeton filiformis and *Hippuris* have appeared for the last time in the lake and *Myriophyllum spicatum* attains only low frequencies, while *Eupotamogeton* reaches its maximum in the later part of the zone. *Sparganium* is still sparse. The zone boundary C-D is defined at the increase in *Alnus*.

Pollen zone D: *Alnus-Betula nana* zone (samples 24–28)

The increase in *Alnus* is more gradual than that of *Betula* in the preceeding zone. The increase is compensated for by a decrease in *Juniperus* (4.3 % as an average of zone C, 1.3 % as an average of D) and *Betula*, which gradually decreases from 59 to 38 %.

Myriophyllum spicatum is only found in 3 out of 5 samples in the lake, *Eupotamogeton* in none. But *Myriophyllum alterniflorum* and *Menyanthes* emerge, and have marked maxima in the middle of the zone. The zone boundary D-E is defined at the decrease in *Alnus* and the increase in *Betula*, *Gramineae* and *Empetrum*.

Pollen zone E: *Betula nana-Alnus-Gramineae* zone (samples 29–32)

The decreasing *Alnus* is compensated for by increasing *Betula* and *Gramineae*, and, to a lesser extent, *Empetrum*. Apart from this, most curves stay at the same level. *Myriophyllum spicatum* disappear, and *M. alterniflorum*, *Menyanthes* and *Eupotamogeton* are rare.

Igdlorssuit tasiat

Igdlorssuit tasiat (64°24′ N, 50°10′ W) is one of the lakes connected like a necklace with Kapisilik river. It is 2.3 × 0.8 km wide (fig. 22, B) This lake, mentioned in Iversen (1952–53, p. 93) as "a large lake at an altitude of 50 m above the recent sea level", was cored by J. Troels-Smith in 1937. On map 64 V.2. of the Geodetic Institute, Copenhagen, the height is stated to be 90 m a.s.l. However, Anker Weidick of the Geological Survey of Greenland, Copenhagen, who by means of an altimeter has measured the level of the next lake downstream and that of some raised beaches just north of Igdlorssuit tasiat, confirms that the level of this lake is ca. 50 m in accordance with Iversen's pauline measurements.

At ca. 4 m's depth of water the following profile was cored:

0–223 cm below the lake bottom: Grey-green gyttja.
223–250 cm: Clay gyttja.
250–300 cm: Greyish-blue clay.
300–350 cm: Sandy, greyish-blue clay. At 345 cm a fragment of a *Balanus*.

Table 12. *Igdlorssuit tasiat, content of pollen in four fossil samples.*

Number of pollen and spores counted.

Depth, cm	176	196	216	243	Depth, cm	176	196	216	243
Betula	4	1	1	13	*Saxifraga opposit.* type	1			
Salix	11	19	27	3	cf. *Silene acaulis*				2
Alnus	22	7	8	8	*Thalictrum*	14	2	4	
Cassiope/Loiseleuria			1	1	*Botrychium*		1	1	1
Empetrum	5			5	*Cystopteris*			1	
Ericaceae	1			4	*Diphasium*			1	3
Vaccinium			1		*Dryopteris* type	8	11	7	
Angelica	1				*Equisetum*	1	1	2	2
Artemisia	2	1			*Gymnocarpium*	1	2	2	4
Caryophyllaceae	1			3	*Huperzia*		1		2
Chamaen./Epilobium				1	*Lycopodium dubium*	4	3	2	2
Coptis			1		Σ P	252	133	236	145
Cruciferae	1	2	7						
Cyperaceae	87	53	60	37	*Isoëtes*	60	107		
Elymus				3	*Myriophyllum spicatum*		1		2
Gramineae	73	20	61	41	*Potamogeton*	2	16	2	
Menyanthes		1							
Oxyria	1			4	*Sphagnum*	2	1	1	
Oxyria/Rumex		1	2		*Hystrix*	41	70	7	
Plantago maritima				5	*Corylus*				1
Potentilla	2			1	*Chenopodiaceae*				5
Ranunculus	12	7	45		*Picea*			1.5	1.5
Sagina			1		*Pinus*			0.5	

Not far from this coring site, at a depth of 4.2 m, this profile was cored:

0–217 cm: Gyttja.
217–280 cm: Sand with stones and shell fragments.

From this latter core JOHS. IVERSEN analyzed in 1944–45 a sample from 216 and another from 243 cm. Later, in 1950, H. KROG continued the counting of the 243 cm sample and also analyzed 2 samples from 196 and 176 cm resp. The results are given in table 12. The determination of *Sagina* is based on a drawing in the notes belonging to the 216 cm sample. The notes furthermore stated: "Characé sporer cc". A later addition is: "*Nitella flex.*". This may indicate either that IVERSEN realized that the spores were of *Nitella*, or that he had collected this species in the lake. It grows today in a nearby lake (p. 155). In the notes pertaining to the 243 cm sample KROG wrote that he had found recent contamination (still with plasma) of *Betula*, *Alnus* and *Corylus*, and IVERSEN found recent *Quercus*. Furthermore, IVERSEN wrote that many *Betula* and



Fig. 22. Oblique aerial photo of the Kapisigdlit area, head of Godthåbsfjord looking towards the northeast. A = "Lake 8 m s.m.", B = Igdlorssuit tasiat, C = "Lake 100 m s.m.". Behind the ice-filled fjord Kangersuneq, Nunatarssuaq and Inlandsisen can be seen. Reproduced with the permission (A. 789/72) of the Geodetic Institute, Copenhagen.

Alnus were secondary (brown, destructed), and that the *Picea* was of a Prequaternary type.

According to Iversen (1952–53 p. 93), this lake became isolated in the middle of pollen zone B, but by comparing the spectrum from 216 cm with the "Lake 100 m" diagram it can be seen that it fits in everywhere in the first half of the zone as well. As the 196 and 176 cm samples originate from zone B, too, the 216 cm sample most likely was sedimentated in the very beginning of the zone. However, the sharp transition from a very coarse sediment – sand with stones and shell fragments – to a gyttja indicate a lacuna, and thus the dating of the 216 cm sample only gives a terminus ante quem for the isolation. The lake in Itivneq, 62 m

a.s.l. was isolated around the middle of zone A (p. 154), whereas the lake at Itivnera at 40.5 m was isolated in the first half of zone B (p. 156).

The great amount of *Hystrix* in the 196 and 176 cm samples probably was washed out from marine sediments around the lake and its tributaries.

"Lake 8 m s.m."

IVERSEN (1952–53) also contains a diagram from a lake (64°26′ N, 50°12′ W) 8 m a.s.l. This is the last of the series of lakes through which the Kapisilik river runs (fig. 22, A). By means of a hand level I measured the altitude to 9.5 m above the daily high water mark in 1960, but the tidal variation is extremely high, and IVERSEN made his measurements from the spring tide high water mark.

The present vegetation in the ca. 300 × 100 m wide lake, the depth of which hardly exceeds 4 m, is completely dominated by *Myriophyllum alterniflorum*, which covers almost the entire bottom outside the shelf, but no flowering specimens were seen. On the more shallow water at the eastern end, *Potamogeton alpinus* and *P. pusillus* ssp. *groenlandicus* were growing together with scattered *Isoëtes setacea* and, along the beach, *Menyanthes*. On the shelf, formed by the ice in all Greenland lakes surrounded by loose sediments, numerous *Sparganium angustifolium* grew together with *Hippuris*, *Callitriche*, *Sparganium hyperboreum* and *Potamogeton filiformis*. *Ranunculus confervoides* grew in deeper water at the inlet.

J. TROELS-SMITH cored the lake in 1937. The depth of water at the site was 250 cm, and the following profile was found:

9. 0–ca. 32 cm below the lake bottom: Gyttja.
8. ca. 32–ca. 62 cm: Sandy gyttja.
7. ca. 62–195 cm: Yellow-brown gyttja.
6. at 195 cm: 2 thin, white-grey layers.
5. 195–205 cm: Yellow-brown gyttja.
4. 205–ca. 206 cm: Bluish-grey clay.
3. ca. 206–210 cm: Gyttja with mosses.
2. 210–220 cm: Yellow-brown gyttja.
1. 220–295 cm: Marine clay. Further coring was prevented by stones.

During the field work IVERSEN made microscopical investigations of the sediments, and his diary of June 15, 1937, contains the following interesting information about a first coring in "Lake 8 m" (translated): "The upper 205 cm are green-grey, slightly clayey gyttja, followed by 20 cm sand, finally 10 cm grey clay gyttja. A microscopical analysis showed that the deepest part of the upper gyttja is a freshwater sediment with Desmids, Spongie needles, and, few *Pediastrum* and *Botryococcus*." As

mentioned (p. 54), no living *Spongilla* was found in Greenland until 1969, viz. in Spongilla Sø and in a lake 100 m east of Comarum Sø. Because of the favourable climate at Kapisigdlit, it is probable that it still occurs there today. As all pollen samples from Greenland are treated with hydroflouric acid before investigation, *Spongilla* needles are not found in routine analysis.

"Lake 8 m", core B

I cored the lake twice in 1960, using a Hiller peat borer. At 153 cm depth of water the following were found:

11. 0– 55 cm below the lake bottom: Detritus gyttja. Slightly brownish-olive-grey. Loose, watery, with many rootlets of *Myriophyllum*. Ld^1 2, Dg 1.5, Dh 0.5, Ga ++, (Ag + As) +.
10. 55– 56 cm: Sand, slightly bluish. Ld^1 1, Ga 3, Gs +.
9. 56–300 cm: Fine detritus gyttja. Bright, olive-brown, turning greyish when oxidized. Gelatinous, with only few fine rootlets. Ld^1 3, Dg 1, Dh +, Ga ++, (Ag + As) +. Downwards this gyttja gradually changes to an even finer detritus gyttja, bright olive-grey. Almost without rootlets. Ld^1 3.5, Dg 0.5, Dh +, Ga ++, (Ag + As) ?.
8. 300–301 cm: Sand, bluish. Ga 4, Gs ++.
7. 301–305 cm: Fine detritus gyttja, like the deeper part of layer 9.
6. 305–316 cm: Stratified, clayey gyttja. Olive-grey. At 315.5 cm a 2 mm thick layer of pure clay. Between 315.5 and 314 cm the gyttja is highly clayey. Ld^1 2, Dg 1.5, Dh +, Ga +++, (Ag + As) 0.5.
5. 316–316.5 cm: Sand, bluish. Ga 3.5, Gs 0.5.
4. 316.5–331 cm: Stratified, clayey gyttja. Olive-grey. Plastic. Some of the layers very clayey. Average formula like layer 6.
3. 331–344 cm: Clay gyttja. Olive-grey with bluish tone. Highly plastic. Rather many mosses. Ld^1 2, Dh +, Ga +++, (Ag + As) 2.
2. 344–361 cm: Sand. Slightly greyish-blue. Ld^1 + (contamination ?), Ga 2, Gs 1, (Ag + As) 1.
1. 361–364 cm: Coarse sand and small pebbles.

6 pollen samples from this core, around the transition marine to limnic, have been analyzed, viz. from depths of 289.5, 297, 302, 307, 315.5 and 319 cm.

"Lake 8 m", core C

Because of difficulties in operating coring equipment from a light canvas boat, a somewhat shallower site close to the preceding one was chosen for the taking of radiocarbon samples. At this site the profile around the isolation level looks like this (depth of water ca. 135 cm):

5. 259 –271 cm: Gyttja, olive with brownish tone. Plastic, with some mosses. Ld[1] 3, Dg 0.5, Dh +, Ga ++, (Ag + As) 0.5.
4. 271 –278 cm: Slightly stratified, clayey gyttja. At 278 cm a 2 mm thick layer of bluish, pure clay. Otherwise, like layer 2.
3. 278 –279 cm: Sand. Bluish. Ga 4, Gs +.
2. 279 –296.5 cm: Slightly stratified, clayey gyttja. Olive-brown. Highly plastic. Single mosses. The content of clay very varying from layer to layer. Ld[1] 2, Dg 1, Dh +, Ga ++, Gs +, (Ag + As) 1.
1. 296.5–309 cm: Sand with some clay. Grey, slightly bluish. Ga 3, (Ag + As) 1.

The sand layer (no. 3), varying in thickness from 0.5 to 10 mm, succeeded upwards by a slight indication of a gyttja layer and thereupon by a still 2 mm thicker layer of pure clay, was common to 19 cores. The 15 cm overlying this clay was cut into 3 cm slices, but because of a high inorganic content it was necessary to use the 3 lowermost samples (269–278 cm) to obtain a dating: 4340 ± 120 B.P. (K–802, TAUBER, 1966).

6 pollen samples have been analyzed. The depths are 261.5, 269, 276, 280.5, 287.5 and 296 cm resp.

As very few pollen curves were published in the mentioned paper, I have drawn a new diagram (plate 17), based on IVERSEN's original countings. Part of the samples (nos 1–7, 9–11, 13, 17, 19, 21 and 23) were analyzed at an early stage, presumably in 1945, before the determination of *Juniperus* was a simple routine. The few counts of *Juniperus* in these samples have been omitted, and no curve has been drawn in this part of the diagram. The same is the case with respect to *Hystrix* and charcoal. The curve of *Macrobiotus* has not been drawn because of difficulties in reading the notes, and the reader is referred to the first publication.

Besides the re-drawn diagram the two short diagrams from core B and C are shown on the plate. The following pollen not shown in the diagram were found (the "old" diagram is termed A): *Caryophyllaceae* A1:1 pollen, 3:2, 10:1, 11:1, 16:2, 27:1, *Cruciferae* A9:1, 11:2, 20:1, 25:1, 27:1, 28:1, B1:1, C4:1, 5:1, *Elymus* A4:1, *Erigeron* type/*Tubuliflorae* A5:1, 6:1, 12:1, C5:2, *Euphrasia* type B2:1, C3:1, *Lomatogonium* A4:1, 14:1, *Minuartia* type B2:3, 5:1, C5:1, *Myriophyllum spicatum* C1:1, 6:1,

Oxyria C1:1 (all other pollen included in the *Rumex/Oxyria* curve in B and C were *Rumex acetosella* type), *Polygonum viviparum* A27:1, *Potamogeton filiformis* C1:1, 5:1, *Saxifraga nivalis* B1:1, C4:3, *Scrophulariaceae* A2:1, 27:1, 28:1, *Sedum* A8:1, 26:1, C3:1, 4:1, *Silene acaulis* type B2:1, *Viscaria* type A20:1, "Varia" A1:1, 4:3, 5:2, 7:1, 8:2, 9:1, 10:1, 11:4, 13:4, 14:1, 15:1, 16:2, 17:5, 19:1, 20:1, 21:2, 23:4, 25:1, 26:1, 28:1.

It is difficult to determine in the cores precisely when the last inflow of salt water to the lake occurred, for 1) the rate of emergence was slow at this time, 2) tidal variation and calving icebergs may cause extremely high waves that bring salt water into the lake long after the isolation, 3) older marine sediments along the river and in the lakes may be reworked by the spring flood, contaminating the otherwise pure lacustrine sediment with *Hystrix* and other marine indicators, and 4), vice versa, in the lagoon stage pollen of freshwater plants (*Eupotamogeton*, *Myriophyllum* etc.) is washed out into an environment in which the plants could not live.

In core C layer 1 no doubt is marine. Layer 2 supposedly represents a lagoon stage with alternating limnic and marine sediments. The single mosses may have been washed out by the river or may represent short limnic stages. The nature of the sand layer 3 is not clear. Most likely it represents a marine transgression, but similar layers can be found at later stages, although only erosion caused by the river can explain this (layer B 10). Most likely the thin clayey layers in layer 4 still represent lagoon stages (*Hystrix* 6.3 $^0/_0$ in sample 4, 0.4 $^0/_0$ in sample 5), but with the beginning of the sedimentation of layer 5, the influence of saltwater seems to be over.

The sand layer (5) in core B must be identical with layer C 3, and the lower parts of the diagrams are very much alike. In B, however, the sedimentation of layer 7 is interrupted by a new sand layer (8), which marks a lacuna, presumably only of shorter duration, as the increase in *Alnus* above the lacuna is not finished. In core A the marine sandy clay is overlain by a series of thin gyttja layers interrupted by clay bands (4 and 6). Layer A 4 may well be identical with layers B 5 and C 3.

Pollen zones

The zonation used in the "Lake 100 m" diagram is also used here.

Pollen zone C: *Juniperus-Betula-Lycopodium dubium* zone (samples A 1–5, B 1–4, C 1–6)

Juniperus attains very high values in this zone, up to 19 $^0/_0$. This is only exceeded by some samples in the diagrams from Qagssiarssuk. *Betula* is not as dominating as in "Lake 100 m", whereas *Cyperaceae* and especially *Lycopodium dubium* are frequent. *Plantago maritima* is rather common.

Pollen zone D: *Alnus-Betula* zone (A 6–11, B 5–6)

The increase in *Alnus* from less than 5 % to 35–40 % is compensated by a decrease in most herbs, whereas shrubs and dwarf-shrubs continue unchanged, judging from the core A diagram. Core B shows decreasing *Juniperus* and *Salix*, too, but increasing *Ericales*, mainly *Empetrum*. Absolute counts are necessary to determine whether the decreases are real.

Pollen zone E_1: *Betula-Alnus* zone (A 12–16)

This zone is characterized by the decrease in *Alnus* and the increase in *Ericales*, as well as, later, in *Cyperaceae*. The two samples, in which *Juniperus* has been counted, show very low frequencies. *Isoëtes* attains a maximum in the lake.

Pollen zone E_2: *Betula-Ericales-Lycopodium dubium* zone (A 17–24)

Besides the continued decrease in *Alnus* this zone is characterized by decreasing *Salix*, increasing *Ericales*, *Dryopteris*, *Gymnocarpium*, *Selaginella* and, not least, *Lycopodium dubium*, which attains its maximum in this zone. Furthermore, there are numerous microscopical fragments of charcoal. *Sphagnum* reaches its maximum at the end of this zone.

The ruins of a Norse farm are situated on the slopes going downwards to the lake; IVERSEN (1952–53) explained the decrease in the shrubs as a result of a "forest" clearance. The many charcoal fragments and not least a distinct charcoal layer in small bogs situated directly on the "tun" (the croft at the homestead) indicate that fire was used at the clearance. On the more open soil, heaths and herb communities spread. *Isoëtes* and other hydrophytes almost disappear in the lake, and the sediment becomes more sandy.

Pollen zone E_3: *Betula-Rumex acetosella* zone (A 25–29)

According to IVERSEN (l.c.), the lower boundary of this zone is mainly based on the decrease in charcoal and the return to a gyttja without sand. He writes, further, (l.c. p. 94): "On the withdrawal of the Norsemen the scrub regenerated", but admittedly it is difficult to establish precisely when this happens in the diagram. The *Betula* maximum in sample 22 might as well mark the beginning of the regeneration. Towards the end of the zone *Alnus* increases. *Rumex acetosella* is common, and its curve is interesting, especially when compared with the corresponding curve in the South Greenland diagrams. While the South Greenland strains of *R. acetosella* are highly hemerophilous, and most likely introduced, this is not the case with respect to the native strains in West Greenland (cf. PORSILD, 1932). No increase in *Rumex* is observable in the Norse period at Kapisigdlit; it only increases markedly after the Norsemen's departure from the scene.

Of special interest is the curve of eggs of *Macrobiotus* (a tartigrade), brought in the original publication of the diagram. These animals live in mosscarpets (*Aulacomnium* spp., *Sphagnum* spp). "A similar curve is found in all diagrams, and it indicates that this type of bog did not become common until the Norse colonization had been abandoned. The reason underlying this may be found in climatic changes or some change in conditions of the soil connected with the former culture" (IVERSEN, l.c. p. 92).

The *Hystrix* curve seems parallel to the content of sand in the sediment, whereas the *Isoëtes* curve is opposed to this, and zone E_3 shows a renewed growth of *Isoëtes* and the other hydrophytes in the lake.

Discussion

Provided that most, if not all, pollen of *Oxyria-Rumex acetosella* type originate from *Oxyria*, the pollen zone A ("Lake 100 m") is so identical with zone A in Comarum Sø, situated 370 km to the south, that they might well be from two neighbouring lakes. Were it not for the reverse *Gramineae* and *Cyperaceae* curves and the early occurrence of *Diphasium* and *Huperzia* in "Lake 100", they might as well originate from different borings in the same basin.

IVERSEN (1952–53) has a list of 16 species, supposed survivors of the last glaciation, demonstrated in the oldest samples of his investigation, which must be "Lake 100 m". These species are *Papaver*, *Saxifraga nivalis/stellaris*, *S. oppositifolia/aizoides*, *Oxyria*, *Cerastium alpinum*, *Silene acaulis*, *Minuartia rubella/biflora*, *Huperzia*, *Dryas integrifolia*, *Chamaenerion latifolium*, *Cystopteris fragilis*, *Stellaria humifusa*, *Salix herbacea*, *Empetrum*, *Vaccinium uliginosum* and *Ledum decumbens*. All of these are distributed all over Greenland–or are only missing in the farthest north–and 8 of them can be found at J. A. D. Jensens Nunatakker, which emerge through Indlandsisen, 60 km from its edge, at an elevation of 1250 m. The highest peak is 1500 m a.s.l. Besides, he mentions as early immigrants *Diphasium alpinum*, *Lycopodium dubium*, *Gymnocarpium*, *Botrychium lunaria*, *Atriplex* sp., *Elymus*, *Montia*, *Triglochin*, *Plantago maritima*, *Lomatogonium*, *Rumex acetosella* and *Thalictrum*, and the hydrophytes *Hippuris*, *Myriophyllum spicatum*, *Potamogeton filiformis* and *Eupotamogeton*. *Angelica* is mentioned as having immigrated in his period I b.

In the discussion of his periods, IVERSEN writes (l.c. p. 88): "On the other hand, there is a fairly rich flora of herbaceous plants and dwarf shrubs; of special interest is the presence of a series of thermophilous herbs, e.g. *Atriplex*, the northern limit of which is now in Godthaab Fjord. This shows that the climate was already rather favourable, the temperature being almost at the same level as today."

Recently the *Atriplex* from Greenland has been determined as to species, being *A. longipes* DREJER ssp. *praecox* (HÜLPH.) TURESS., which

is distributed along the coast of the Baltic Sea, Northern Russia, Northern and Western Norway, Iceland and Greenland (PEDERSEN, 1972). In Greenland it has been found at Tasermiut, South Greenland, and at three branches of Ameralik (Præstefjord, Itivdleq and Ameragdla) and at the Kapisigdlit branch of Godthåbsfjord, in all 8 coll. from 5 localities. Theoretically, *Atriplex*, the pollen of which can hardly be distinguished from i.a. *Chenopodium* and *Amaranthus*, might be an early immigrant, but the much greater material of fossil and recent pollen spectra from Greenland at hand today support the much more likely explanation that the grains of *Chenopodiaceae* from "Lake 100 m" (one grain in samples 7, 14, 16, 28) from Igdlorssuit tasiat (5 grains in the 243 cm sample, rich in rebedded and recent pollen), from "Lake 8 m" (one grain in A2, A29, C1 and C4. Three of these samples are rich in marine material, the fourth is subrecent), and from the lake at Itivnera (one in the deepest limnic sample, still with 2.3 % *Hystrix*) are due to either long distance transport or to rebedding. In this context it should be added that in the Comarum Sø diagram 1, in Isoëtes Sø 14, in Spongilla Sø 9 and in Kløftsø 4 fossil *Chenopodiaceae* pollen were found. In the recent gyttja samples (table 22) there was a total of 3 grains, in a Tauber trap placed in Comarum Mose during the summer 1969 1 grain was found (table 23), and at Sermermiut (69°13′ N) 1 grain in a recent moss polster and 2 fossil grains were found (FREDSKILD, 1967a). These facts should convince one about the undue assumption of an early immigration of *Atriplex*.

If we exclude *Atriplex* from the discussion about the climatic conditions in zone A, *Lomatogonium* (one grain in sample 5), just as in Comarum Sø, is the most southern of the early species, with a northern limit today at 69°. The high frequencies of *Ranunculus* pollen in zone A and B presumably are due to a species living in or close to the water, and *R. confervoides* seems the most likely, although *R. reptans* or *R. hyperboreus* cannot be excluded. But even without this knowledge, the considerations concerning zone A conditions in Comarum Sø could be repeated here. Furthermore, in both diagrams *Thalictrum* spreads slightly before *Salix* spreads.

The greatest dissimilarities between the two diagrams are found in the hydrophytes. In "Lake 100 m" the *Myriophyllum spicatum-Hippuris-Potamogeton filiformis* maximum in the second half of zone A, decreasing through zone B, is succeeded by an *Eupotamogeton* maximum in zone D. In Comarum Sø the *Myriophyllum spicatum-Isoëtes-Chara-Potamogeton filiformis* maximum does not reach maximum values until zone B, followed by an *Eupotamogeton-Myriophyllum alterniflorum* maximum, which finally is followed by the *Hippuris* maximum. But comparing Comarum Sø with the Kap Farvel lakes (with e.g. the *Hip-*

puris maximum between 9000 and 8500 B.P.) this dissimilarity is of no importance in the discussion of the age of the sediments.

Everything considered, a contemporaneity between zone A in the two diagrams is likely. The liminic gyttja in "Lake 100 m" overlies only a very thin layer of marine clay, showing that the lake was isolated very shortly after the deglaciation. WEIDICK (1972 b), on the basis on IVERSEN'S considerations about the correlation between the vegetational development in Greenland with that of northern Europe and North America, estimates that the isolation of "Lake 100 m" happened ca. 8500 B.P. This is supported by the dating of the oldest part of zone A in Comarum Sø (8530 ± 140 B.P.), if the contemporaneity is accepted.

The similarities between the two B zones also are considerable. Both are characterized by decreasing amounts of pioneer herbs, most of which still occur, by the spreading of *Salix glauca* slightly after the spreading of *Thalictrum*, and by the drop in *Empetrum* and *Ericales*. We have no possibilities of deciding whether a chronological displacement did or did not occur, but nothing seems to support a displacement of longer duration. *Salix glauca* spread around Comarum Sø app. 8000 B.P. During zone B *Artemisia borealis* spread at the head of Godthåbsfjord. This plant is characteristic of dry, sunny slopes, especially in the continental parts of West Greenland between 63° and 73° N.

The explosive spreading of *Betula nana* at the beginning of zone C shows conditions optimal to the species from the very beginning of the immigration. In East Greenland *B. nana*, coming from the east, immigrated at Hugins Sø on Jameson Land (70°46' N, 24°07' W) ca. 8000 B.P. (FUNDER, 1971). At the same time that it immigrated to Godthåbsfjord, *Juniperus* and *Selaginella* immigrated. In Comarum Sø *Juniperus* immigrated 7000–6900 B.P., and this may also have been true at "Lake 100 m". This gives a displacement in time between East and West Greenland of ca. 1000 years, which might be ascribed to a lack in dispersal across the inland ice. It should be remembered, however, that wind dispersal across ice is the most effective dispersal mechanism in arctic areas, and a single gale might carry seeds at a distance of 2000 km, cf. the discussion in SAVILE (1972). This, and the fact that the uplift of inner West Greenland is approximately 1000 years later relative to that of East Greenland (WEIDICK, 1972b) indicate that lack in dispersal was not alone responsible for the later immigration in West Greenland. Most likely, the influence of the great Canadian ice until the end of the Cochrane-Cockburn re-advance caused a delay in the deglaciation of West Greenland, which in connection with a delay in climatic amelioration caused a delay in the vegetational development as compared with East Greenland.

Igdlorssuit tasiat was isolated in the beginning of zone B. This, and a shell date from Kapisigdlit (7560 ± 150 B.P., alt. 40 ± 5 m, WEIDICK, 1968) do not contradict the assumption of a dating of the zone boundary B–C at between 7000 and 6500 B.P., possibly almost contemporaneous with the *Juniperus* immigration at Qagssiarssuk.

During zone C extensive *Betula nana* heaths rich in *Juniperus*, but with very few *Ericales* must have covered the surroundings. The *Oxyria-Rumex acetosella* curve may well represent a widespread growth of *R. acetosella*. The only two *Campanula* pollen are found in samples 17 and 21. Presumably conditions were dry and almost as warm as today.

The opening of zone D is characterized by three marked increases: *Alnus*, *Myriophyllum alterniflorum* and *Menyanthes*, by the decrease in *Juniperus*, and by a slight increase in *Ericales*. "The fourth period is the warm period in Greenland, at any rate as to the vegetational aspect. The alder, which had hitherto been sparse, now became very abundant. (One might perhaps suggest that the alder now occurred for the first time in Godthaab Fjord. So far this possibility cannot be excluded although the former explanation seems more probable)." (IVERSEN 1952–53, p. 89). In my opinion, the low frequencies of *Alnus* (as an average of zone A, B and C: 1.2, 3.3 and 3.0 % resp.) and the shape of the *Alnus* curve during the 3 zones compared with the South Greenland diagrams with the pronounced *Alnus* maximum roughly between 7000 and 5000 B.P. make it much more reasonable to assume that *Alnus* did not grow earlier in the area, but immigrated to the head of Godthåbsfjord ca. 4000 years ago, cf. the dating in "Lake 8 m".

Alnus is distributed between 60° and 66°, and *Myriophyllum alterniflorum* between 60° and 64° on the west coast (both are totally absent from the east coast). No doubt IVERSEN is right in assuming that this period was the warmest. The decrease in *Juniperus* hardly was caused by *Alnus*, as they prefer different biotopes, and it seems necessary to assume that this warm climate was connected with more humid conditions. At Qagssiarssuk a corresponding trend is registered in the decrease in *Juniperus* contemporaneously with the immigration of *Betula pubescens* app. 3600 B.P.

During zone D in "Lake 100 m", as well as in "Lake 8 m", the flowering of *Myriophyllum alterniflorum* is severely reduced. This can hardly be ascribed to an impoverishment of the water, as the Kapisilik river runs through the lakes; a lowering of the temperature may well be the cause. This, too, must be responsible for the drop in *Alnus*, characterizing the zone boundary D–E. On the assumption of a fairly uniform sedimentation rate from the isolation of "Lake 8 m" up to the Norse landnam, *Myriophyllum* stops flowering between 2800 and 2300 B.P., and the zone boundary can be dated at 1900–1300 B.P. (the distance between the pollen

samples is 20 cm). IVERSEN estimates the zone boundary as being contemporaneous with RY II in North Europe, dated at 1500 B.P. in accordance with what was mentioned above. *Myriophyllum alterniflorum* did flower again in "Lake 8 m" shortly before and again at the end of the Norse period, possibly because of minor climatic improvements. But apart from this, the diagrams from these two lakes give very little information as to the climatic changes in the last millennium. This will be discussed later in connection with some peat profiles.

Lake in Itivneq

On the less than 3 km wide isthmus, Itivneq – between Godthåbsfjord and the Itivdleq branch of Ameralik – I cored a lake in 1960. This rather shallow lake, 400 m long and max. 150 m wide (64°22′ N, 50°23.5′ W, fig. 23, D) is situated at an altitude of 62 m (measured by hand level). The depth of water does not exceed 1.5 m. The present vegetation includes *Ranunculus confervoides*, flowering in spite of being submerged, *Hippuris*, *Potamogeton filiformis*, *P. pusillus* ssp. *groenlandicus*, *P. gramineus*, *P. alpinus*, *Isoëtes setacea*, *Sparganium hyperboreum*, *Menyanthes*, *Ranunculus reptans* and *Montia*. Besides these, up to 30–40 cm (!) colonies of *Nostoc commune*, (kindly determined by TYGE CHRISTENSEN, the Botanical Institute, University of Copenhagen) grew at the bottom of the lake.

The following profile was found at a depth of water of 125 cm:

0– 34 cm below lake bottom: Fine detritus gyttja. Ld^2 3.5, Dg 0.5, Dh +, Ga +, (Ag + As) +.

34– 57 cm: Detritus gyttja. Ld^2 3, Dg 1, Dh +, Lc ?, Ga ++, Gs + (Ag + As) +.

57–128 cm: Detritus gyttja, with slight content of chalk and single shell fragments. $Ld^2$3, Dg 0.5, Dh +, Lc 0.5, Ga ++, (Ag + As) +.

128–140 cm: Chalk gyttja. Ld^1 2, Dg 0.5, Lc 1.5, Ga ++, (Ag + As) +.

140–228 cm: Lake marl, with characeous spores. Ld^1 0.5, (Dg + Dh) 0.5, Lc 3, Ga +.

228–247 cm: Finely stratified chalk gyttja, with characeous spores. Ld^1 1.5, Dg 0.5, Dh ++, Lc 2, Ga +.

247–251 cm: Stratified gyttja, partly chalk gyttja, partly *Cyanophyceae* gyttja. At 249 cm a thin clay layer.

251–262 cm: Stratified clay. Between 251 and 254 cm thin gyttja layers. At 251 cm the uppermost fragment of *Mytilus*.

262–270 cm: Clay, upwards slightly stratified, with fragments of i.a. *Mytilus*.

270–285 cm: Sand, with shell fragments.

285–290 cm: Clay, with shell fragments.



Fig. 23. Oblique aerial photo of the Itivneq area, head of Godthåbsfjord, looking towards the southeast. A = the lake at Itivnera, B = the former ponds, C = Itivnera with the palaeo-Eskimo settlement, D = the lake in Itivneq, E = Eqalugialik. Reproduced with the permission (A. 789/72) of the Geodetic Institute, Copenhagen.

The thin clay layer at 249 cm may well mark the latest transgression. Two pollen samples from 247.5 and 245 cm have been analyzed. Both contained hundreds of *Chara* spores, but were otherwise characterized by being very poor in pollen. Thus, in the deepest sample ΣP in the resulting 9 slides (counted absolutely) is only 162, while 6 slides in the upper sample gave 177. The results are shown in table 13.

The spectra clearly indicate an isolation during pollen zone A, as defined in connection with the "Lake 100 m" diagram. Presumably this happened in the middle of the zone; at least the absence of *Thalictrum* shows that it took place before the immigration of this species, which occurred in the later part of the zone.

According to the uplift curve for Kapisigdlit, 10 km to the northwest, the isolation of this lake occurred slightly after 8000 B.P. (WEIDICK,

Table 13. *Lake in Itivneq and lake at Itivnera, content of pollen in three fossil samples.*

Number of pollen and spores counted

Depth, cm	Itivneq 247.5	Itivneq 245	Itivnera 207.5	Depth, cm	Itivneq 247.5	Itivneq 245	Itivnera 207.5
Betula	8	3	1	*Silene acaulis* type			1
Salix			23	*Thalictrum*			7
Alnus	3	3	27	*Botrychium*	2	7	2
Empetrum	3	3	4	*Cystopteris fragilis* ssp. *fragilis*		8	
Ericaceae	3	2	3	*Diphasium* type	1		5
Koiseleuria	2			*Dryopteris* type	21	30	33
Artemisia		2	1	*Equisetum*	3	1	4
Cerastium/Stellaria		1		*Lycopodium dubium*	2	1	10
Cruciferae	1	1		Σ P	162	177	398
Cyperaceae	26	58	166				
Elymus	1	4		*Sphagnum*			1
Gentiana nivalis			1	*Myriophyllum alternifl.*			1
Gramineae	81	47	91	*Myriophyllum spicatum*	264	900	
Minuartia type	2	4	3	*Botryococcus*	ccc	ccc	r
Oxyria	2	2	8	*Pediastrum*	c	c	r
Oxyria/Rumex			1				
Plantago maritima	1			*Hystrix*	12	15	9
Potentilla			2	*Chenopodiaceae*			1
P. crantzii type			1	*Picea*			0.5
Rumex acetosella			3	*Pinus*			3.5
Ranunculus			1	*Quercus*		1	1

1972b). If, however, the simultaneousness between the pollen zones at Godthåbsfjord and Qagssiarssuk is accepted, this happened some centuries earlier. (*Thalictrum* immigrated at Qagssiarssuk ca. 8300–8200 B.P.).

Lake at Itivnera

500 m east of the reindeer breeding station at Itivnera a circular, 1 km wide lake is situated (64°22′ N, 50°23′ W, fig. 23, A) at an elevation of 40.5 m (hand level). The lake is very deep, at least 25 m. The present vegetation includes *Isoëtes setacea*, *Myriophyllum alterniflorum*, *Callitriche hamulata*, *Eleocharis acicularis*, *Sparganium hyperboreum*, *Hippuris*, *Potamogeton pusillus* ssp. *groenlandicus*, *P. gramineus*, *Ranunculus reptans* and *Nitella flexilis*. This species, new to Greenland, has been determined by Helle Nielsen. Some chemical data appear in table 11. A coring was made at a depth of 2.4 m of water in the southern end of the lake. The following layers were separated:

0– 50 cm below the lake bottom: Coarse detritus gyttja. Ld^2 1, Dg 2, Dh 1, Ga +, (Ag + As) +.

50– 62 cm: Slightly sandy detritus gyttja. Ld^2 1, Dg 1.5, Dh 1.5, Ga + +, (Ag + As) +.

62–125 cm: Coarse detritus gyttja. Ld^2 2, Dh 1, Dg 1, (Ag + As) +.

125–181 cm: Fine detritus gyttja. Ld^1 4, Dg + +, Dh +, Ga +, (Ag + As) +.

181–190.5 cm: Chalk gyttja, like 194–207, but decreasing content of chalk upwards.

190.5–194 cm: Finely stratified *Cyanophyceae* gyttja, with layers of chalk gyttja (ratio app. 2:1).

194–207 cm: Chalk gyttja, towards the boundaries with thin *Cyanophyceae* gyttja layers. Shells of different freshwater snails, spores of *Characeae*. Ld^1 1.5, Dg 0.5, Lc 2, Ga +, (Ag + As) +.

207–209.5 cm: Finely stratified *Cyanophyceae* gyttja with single, paper-thin, chalk gyttja layers. Ld^1 4, Ga +, (Ag + As) +.

209.5–217 cm: Sand, almost free of mollusk fragments.

217–221.5 cm: Sand, with considerable *Mytilus* fragments.

221.5–267.5 cm: Clay, with single fragments of *Mytilus*.

267.5–290 cm: Sandy clay with fragments of *Mytilus*.

An analysis of a pollen sample with a few *Chara* spores from the oldest *Cyanophyceae* gyttja (207.5 cm) gave a spectrum, shown in table 13, which clearly shows that this lake was isolated during pollen zone B. The frequent *Oxyria* and *Dryopteris* are indicative of the first half of the zone, thus presumably between 8000 and 7500 B.P.

Former ponds at Itivnera

On the watershed between Itivnera and the lake just mentioned, two former ponds, 100 m apart, were seen at an elevation of 45 m a.s.l. (fig. 23, B).

In an almost circular, shallow depression (fig. 24), the central part, with a diameter of ca. 30 m, is covered by a vegetation in which low *Salix glauca* grows together with *Agrostis borealis*, *Alopecurus aequalis*, *Campanula rotundifolia*, *Calamagrostis langsdorfii*, *Carex bigelowii* (dominating), *C. norvegica*, *C. saxatilis*, *Draba incana*, *Equisetum arvense*, *Poa pratensis* and *Trisetum*. Around this a ring of *Betula* and *Salix* scrub, a few m wide, delimit the vegetation on a slightly higher ground. Here the soil is stony, and the vegetation only covers half of the surface. Creeping *Betula nana* dominate, but almost every species growing in the vicinity

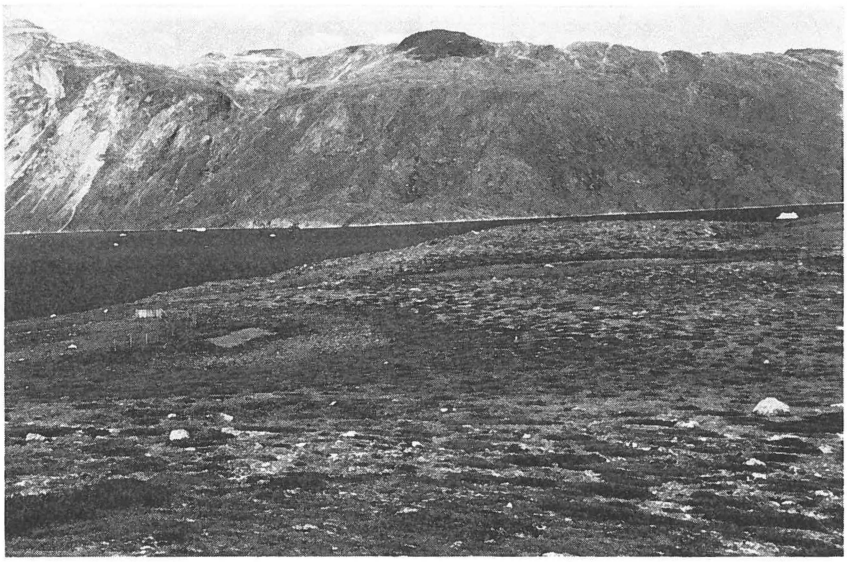


Fig. 24. Itivnera, the two dried-up ponds in shallow depressions in the dry lichen-rich *Betula nana* heath. July 29, 1960.

was found here. These evidently unstable vegetations show that the occupation of the area took place quite recently.

A profile in the deepest part showed the following layers under a 2 cm thick mat covered by *Carex bigelowii*:

0– 8 cm: Slightly peaty, coarse detritus gyttja, with scattered fruits of *Hippuris* and *Ranunculus confervoides.*

8–15 cm: Coarse detritus gyttja, with many fruits of *Hippuris* and *Ranunculus confervoides.*

15–? cm: Sand and clay, with solifluction figures.

Two macrofossil samples (12–14 and 14–16 cm below 0) were surveyed, and the following species were observed: ca. 300 *Hippuris*, ca. 40 *Ranunculus confervoides*, 2 *R. hyperboreus*, 3 *R. reptans*, 1 *Sparganium hyperboreum*, 1 *Alopecurus aequalis*, besides 1 *Empetrum* and 1 distigmate *Carex.* In the description of this site in Fredskild (1972) *Ranunculus confervoides* was erroneously called *Potamogeton.*

In another, slightly smaller depression, where *Carex saxatilis* was the dominating plant and with many *Salix arctophila*, coarse detritus gyttja, ranging in thickness between 8 and 20 cm, overlay sandy gravel. Fruits of *Hippuris* were found up to the surface. Two macrofossil samples, 2–4 and 4–6 cm below the surface, were surveyed, and the following were observed: ca. 100 *Hippuris*, a few *Ranunculus reptans*, *Sparganium hyperboreum*, *Carex saxatilis* and *Cenococcum*, as well as a single *Empetrum* and a *Carex.*

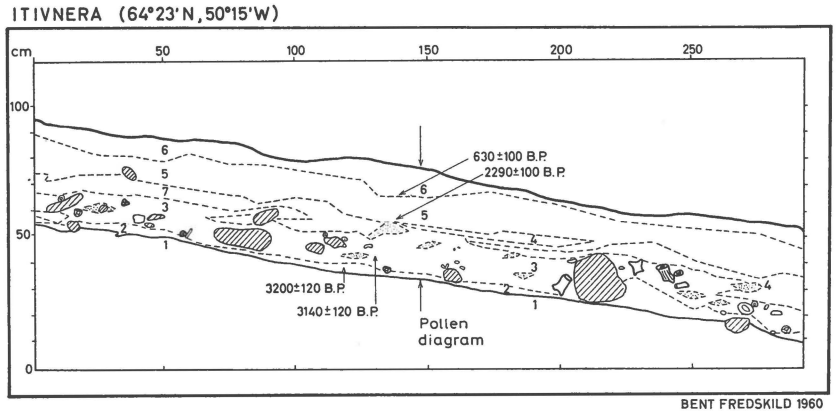


Fig. 25. Itivnera, transect.

Transect at Itivnera

At Itivnera man has been associated with reindeer over a long period of time. Thus, the present reindeer breeding station which was established in 1952, is situated where palaeo-Eskimo reindeer hunters had their settlement three millennia ago. Repeated excavations by the Danish National Museum have exposed an area of app. 2000 square metres, in which there are remnants of 4 or 5 houses (64°23′ N, 50°15′ W, fig. 23 C).

It is situated on the gentle northern slope of sand and gravel formed by the fjord during the upheaval. The present submergence has exposed a profile in the culture layer and subsequent layers. The transect (fig. 25) was dug at a right angle to the coast line. The following layers could be separated at the place from which the pollen diagram originates. It should be mentioned that before the excavation in 1960 started, we had to tear up the dense willow scrub with the thick moss carpet in order to have the sun melt the frozen ground. As a result of this heavy-handed clearance the upper cm's of the sub-recent peat may have been removed.

6. 0–13.5 cm below the actual surface: Moss peat. Bright rust-brown. Heavily felted, partly by recent *Salix* roots and *Equisetum* rhizomes. Tb^2 3.5, Th^2 0.5 (Ag + As) +.

5. 13.5–21.5 cm: Humified peat. Dark-brown to black-brown. Presumably a highly humified peat formed by herbs and dwarf-shrubs. Solifluction visible. (Th^4 + Tl^4) 4, Ga +, (Ag + As) +.

4. 21.5–23.5 cm: Slightly humified peat. Bright-brown with beige tone. Structure leafy. Solifluction visible. The sand mostly concentrated in certain layers. (Th^2 + Tl^2) 4, Ga +, (Ag + As) +.

3. 23.5–40.5 cm: Culture layer. Heterogenous, the colour varying between dark-grey and black. Large content of charcoal, bones, especially of reindeer, antler fragments, stones and other artifacts. The thickness of the layer varying through the transect, partly because of solifluction. Almost pure lenses of sand. Sh 3.5, Ga 0.5.
2. 40.5–44.5 cm: Humified peat. Brown, with a slightly reddish tone. Leafy, with horizontal structures indicating highly humified twigs and/or remnants of grass-sedge tufts. Fruitstones of *Empetrum*. (Th^3 + Tl^3) 4, Ga +, (Ag + As) +.
1. 44.5–64 cm: Coarse sand and gravel. Yellowish, in dry state whiter. Ga 1, Gs 2, Gg 1.

Besides these, one more layer is found on the transect, fig. 25, viz. 7: Highly humified peat. Dark-brown to black. Solifluction stripes visible, often with charcoal. (Th^3 + Tl^3) 4, Ga +, (Ag + As) +.

Macrofossils

No real macrofossil analyses were undertaken from this transect; only the radiocarbon samples were surveyed under microscope and all recent roots were removed before dating. In the samples from layer 2 and from the transition 4–5 numerous *Empetrum* seeds were found, while fewer were observed in the sample from layer 6. Some *Cenococcum geophilum* were found in the sample from layers 4–5.

Datings

4 samples, the position of which are shown in fig. 25, have been dated: Layer 2: 3200 ± 120 B.P. (K-1192), layer 3 (charcoal: 275 pieces of *Betula*, 67 pieces of *Salix;* E. Tellerup det.): 3140 ± 120 B.P. (K-1193), Layer 4–5: 2290 ± 100 B.P. (K-1194) and layer 6, the deepest 2 cm: 630 ± 100 B.P. (K-1195, Tauber, 1968). Furthermore, some *Juniperus* wood from the floor of one of the houses has been dated: 2960 ± 110 B.P. (K-588, Tauber, 1962).

Pollen diagram

A relative pollen diagram is given (plate 18). Some of the samples (2, 4–7, 9, 15) were analyzed in 1960, while the remainder was counted in 1971. The latter were counted absolutely, and at the right in the diagram a histogram shows Σ P/g. Besides the pollen etc. shown in the diagram, the following were found: *Caryophyllaceae* sample 1:1 grain, 2:1,

5:1, 15:2, *Cruciferae* 1:1, 5:1, 9:1, 15:1, *Elymus* 1:1, *Erigeron* 11:1, cf. *Ligusticum* 3:1, *Oxyria* 15:1, *Oxyria/Rumex acetosella* type 13:1, *Plantago maritima* 5:1, 7:1, 11:1, *Polygonum viviparum* 2:1, *Rumex acetosella* type 1:1, 6:1, *Saxifraga nivalis* type 2:2, *Sedum* 5:1, 10:1, *Stellaria humifusa* 3:1, *Thymus* 5:1, cf. *Viscaria* 8:1, *Lycopodium* sp. 5:1, *Selaginella* 2:1, 13:1, P. indet. 1:10, 2:21, 3:22, 4:4, 5:27, 6:5, 7:7, 8:14, 9:20, 10:2, 11:8, 12:4, 13:11, 14:12, 15:6, charcoal (not counted in sample 2, 4, 6, 7 and 15): 1:55, 3:103, 5: numerous, 8:2, 9:3, 10:17, 11:12, 12:1, 13:24, 14:2, *Assulina* 12:1, 14:33, *Microthyrium* type 13:15, 14:17 (15: not counted). The per cent by weight of sand as measured in the 1971 samples: sample 1: >99 %, 3:97, 8:26, 10:33, 11:25, 12:28, 13:32, 14:30 %. The degree of destruction, expressed as the ratio between psilate pollen with signs of destruction against the total of psilate pollen, is in samples 1–15: 72, 20, 76, 12, 45, 25, 25, 86, 67, 74, 76, 65, 52, 34, 20 %.

The changes in the pollen curves are so closely connected with the changes in sediment that the succession may just as well be described layer by layer instead of by pollen zones.

The raised beach (layer 1) must have been covered by a very open vegetation, forming no humus, (content of organic matter less than 1 %). Supposedly there was a heath covered by low *Salix glauca* and rich in *Lycopodium dubium*. The nearby beach is indicated by the pollen of *Elymus*, *Stellaria humifusa* and the not fully reliable grain of *Ligusticum*. Shortly before the Sarqaq people settled, the vegetation changed, and a heath rich in grass with *Ericales*, mainly *Empetrum*, and possibly with scattered *Betula nana* covered the area. This might seem a quite natural succession, as the raised beach was more elevated. But this usually 3–4 cm thick peat layer was found all over the excavation in spite of a difference in height a.s.l. of about 2 m, and it may well be that before 3200 ± 120 B.P. (the dating of this layer) the whole gentle slope was covered by the *Salix-Lycopodium* heath and then at the same time the vegetation changed to the presumably moister humus-forming *Empetrum*-grass heath. This would be a parallel to the estimated conditions at Sermermiut (FREDSKILD, 1967a), but cannot be proved until more datings are at hand. Cultural traces were only as an exception tread down in layer 2, and the material used for dating was free of this.

The vegetational development during the settlement period is completely obscure, and only one sample (6) in the culture layer (3) has been analyzed. Apart from the high *Alnus* frequency, to which any importance scarsely can be attached in connection with the vegetation on the spot, the spectrum resembles those of the preceding samples. Presumably the site was used during a number of years (one or two centuries?). After the Eskimoes left, *Empetrum* again spread over the ruins,

now mainly accompanied by *Betula nana*. The first radiocarbon sample from the deepest part of this layer (4) turned out to be contaminated as a result of solifluction with charcoal from the culture layer, and because of this the next sample, marking the transition to layer 5, was used: 2290 ± 100 B.P.

The vegetation that formed layer 5 was an ericaceous dwarf-shrub heath with decreasing amounts of *Betula nana*. The pollen was badly destructed (78 % as an average of samples 8–10 against 25 % in sample 7). The fact that *Ledum* (presumably *L. palustre* ssp. *decumbens*) seems to dominate over *Empetrum* may partly be caused by a safer determination of *Ledum* pollen than of *Empetrum* pollen in highly destructed samples. *Vaccinium* type pollen have not been separated. *Equisetum* was very common in the plant community, and *Lycopodium dubium* was not infrequent. *Tofieldia* also grew at the spot. The considerable content of pollen and the high destruction, especially in sample 8 (86 %) indicates a slow sedimentation rate, but recalling the solifluction stripes in the transect, too literal conclusions about the vegetational succession in layer 5 should not be drawn.

Böcher (1954, p. 267) gives a thorough description of the vegetation belonging to "The *Ledum decumbens-Betula nana* Type (Low arctic, continental, moist heath and dwarf-shrub bog-vegetation on moderately acid soil)". This parallel to the South Greenland "*Phyllodoce-Lycopodium alpinum* Type" covers vast areas on northern slopes in the interior of West Greenland. The soil mainly consists of raw humus. Permafrost usually is found under these vegetations. The most frequent plants given in the 25 analyses (Böcher l.c., table 36) are: *Ledum palustre*, *Betula nana*, *Vaccinium uliginosum*, *Equisetum arvense*, *Empetrum*, *Stellaria longipes-monantha*, *Calamagrostis lapponica*, *Poa pratensis*. Mosses are very frequent, especially *Aulacomnium turgidum* and *Hylocomium splendens*, as well as the lichen *Peltigera aphthosa*. No doubt the vegetation covering the abandoned Itivnera settlement belonged to this vegetation type.

At a certain time the character of the plant community changed. The degree of destruction decreased, which is also reflected by the lower degree of humification in layer 6, and Σ P/g decreased parallelly, which indicates an increasing sedimentation rate.

To begin with, *Ericales* dominate the dwarf-shrub heath, but soon *Cyperaceae*, *Tofieldia* (presumably *T. pusilla*), *Diphasium*, *Harrimanella* and *Sphagnum* indicate more humid conditions. *Tofieldia pusilla*, growing in damp heaths and mesotrophic bogs, is a widespread species in Greenland, especially towards the south. Everything considered, the succession from a dwarf-shrub heath to a moist, bog-like heath must be climatically caused. No signs of Norse or neo-Eskimo activity were found in the

vicinity. The dating of the 11–13 cm sample (630 ± 100 B.P.) connects this climatic change with the early medieval deterioration.

Quite recently *Salix glauca* and *Gramineae* took over the dominance, but at what time this change occurred cannot be stated. It seems to mark a return to not quite as moist conditions.

Transects in Norse culture layers

Eqalugialik

A transect 30 m from the fjord, 5 m a.s.l., in the croft of a Norse farm at Eqalugialik at the head of Itivdleq (64°21′ N, 50°25′ W, fig. 23 E) showed the following profile:

0– 6 cm: The recent grass mat, formed by a luxuriant, almost 1 m high vegetation of *Calamagrostis langsdorfii* and *Poa pratensis*.

6–11 cm: Moss peat, bright-brown. Tb^2 4, Th^2 + +.

11–15 cm: Highly humified peat, dark grey-brown. Sh 4, Tb^3 +, Ga + +.

15–17 cm: Moss peat, bright-brown. Tb^2 4, Ga (+).

17–19 cm: Dark, humified swamp peat. Th^3 4, Ga +.

19–22 cm: Swamp peat, bright-brown. Very flaky structure. Th^2 4, Tb^2 +, Ga +.

22–28.5 cm: Swamp peat with cultural traces. Brown. Slightly stratified. Charcoal, bark, and twigs. Th^2 4, Ga +.

28.5–30 cm: Sandy layer with charcoal. Grey, with brownish tone. Th^2 0.5, Sh 3, Ga 0.5, Gs +, Gg +.

30–32 cm: Highly humified (?moss-) peat. Dark-brown. Sh 3.5, Tb^2 0.5, Ga + +, Th^2 +.

32–45 cm: Solifluction soil, rich in organic matter. Dark grey-brown. Stones, sand, and organic matter in layers and stripes of varying composition. Sh 3.5, (Ga + Ag + As), 0.5.

Two other transects closer to the fjord showed very similar stratigraphy. One of them will be mentioned briefly:

0–5.5 cm: Swamp peat and recent vegetation mat.

5.5–8 cm: Bright-brown swamp peat.

8–17.5 cm: Greyish-brown swamp peat.

17.5–19 cm: Sandy swamp peat, dark-grey to black-grey, rich in charcoal, chips, etc.

19–27 cm: Swamp peat, brown. Charcoal, chips, pebbles and sand.

27–30 cm: Black-brown humified peat rich in twigs, but without worked wood (presumably a peat formed under a scrub).

30–35 cm: Solifluction soil.

The following succession is common to these 3 transects: 1) Solifluction soil, 2) a highly humified peat, formed by a scrub or another vegetation with only small humus production, 3) a culture layer, 4) a bright-brown, only slightly humified moss or swamp peat, indicating moist conditions, and, 5) different peat layers up to the present surface.

A 200 ml macrofossil sample from the culture layer (24–26 cm below the surface) was analyzed from the last mentioned transect. The following were found: *Betula nana* 15 seeds, *Capsella bursa-pastoris* 26, *Carex canescens/brunnescens* 7, *C. deflexa* 2, *C. praticola* 20, *C. rariflora* 23, *Cenococcum* 6, *Empetrum* 20, *Euphrasia* 17, *Gramineae* >100, *Luzula* 7, *Polygonum boreale* 1, *Potentilla* 23, *Stellaria* 369, *Taraxacum* 1, *Vaccinium vitis-idaea/uliginosum* 1. The weeds demonstrated in the Norse layers at Tunugdliarfik also grew here in the Western Settlement.

Ujaragssuit

The ruins of a Norse farm and church are situated (64°50′N, 50°08′W) at the head of Ujaragssuit pâvat, one of the northern branches of Godthåbsfjord. In 1932 Johs. Iversen made a transect in a 1100–1200 m² wide, shallow bog. He published the results of his investigation, including a pollen diagram, two years later (Iversen, 1934). An abbreviated translation (from the German) of the description of the layers in the transect is given below:

i. 0–8.5 cm below the surface: Slightly sandy, peaty layer more or less humified. Numerous *Calamagrostis* cf. *langsdorfii* rhizomes, 4 seeds of *Montia*. Present vegetation: thick moss carpet with, in particular, *Calamagrostis langsdorfii*.

h. 8.5–12 cm: Fresh *Sphagnum* peat, consisting of one brown and two bright-brown layers. Numerous *Calamagrostis rhizomes*, approx. 50 *Montia* seeds.

g. 12–13.5 cm: Sandy detritus peat. Numerous rhizomes of *Polygonum viviparum* and *Calamagrostis*, 11 *Montia* seeds, 6 seeds of *Luzula*. Especially at the upper boundary numerous pupae of the butterfly *Agrotis oculta*.

f. 13.5–33 cm: Brown, sandy "Schwemmdetritus". Approx. 1300 achenes of *Ranunculus hyperboreus*, 75 *Montia*, 7 *Empetrum*, 7 *Luzula*, 3 *Sibbaldia*, 1 *Angelica*, *Stellaria* and *Carex* seeds and fruits. At 23–24 cm woody chips

and a large amount of charcoal. Scattered charcoal above, none below.

e. 33–48 cm: Dark-brown, soil-like "Schwemmdetritus".

d–a. 48–>81 cm: Alternating gravel and sandy "Schwemmdetritus".

The pollen diagram, re-drawn in FREDSKILD (1972), can be divided into 3 zones. From below they are:

1. *Alnus-Salix* zone (incl. layers a–c). In this zone *Alnus* dominated (65 %, decreasing upwards to 46 %), with *Salix* (17 %, increasing to 26 %) the next important. *Betula* increases from 11 to 17 %. Herbs are very few, and the site must have been covered with or very closely surrounded by a dense *Alnus-Salix glauca* scrub. Most likely this zone represents the late part of zone D in "Lake 100 m".

2. *Alnus-Betula-Salix* zone (layers d–e plus beginning of f). The succession suggested during zone 1 by the reverse trend in the *Alnus* curve on the one side and the *Salix* and *Betula* curves on the other side is accomplished. In this zone *Alnus* makes up ca. 20 %, *Salix* ca. 25, and *Betula* ranges between 30 and 48 %. In addition *Ericales* make up ca. 10 %. Changes in humidity or temperature (or both) may be responsible for the local retreat of *Alnus*. Tentatively the zone boundary 1–2 is paralleled to the zone boundary D–E in "Lake 100 m".

3. *Gramineae*-herb zone (layer f–i). Between 30 and 26.5 cm an abrupt increase in *Gramineae* (from few per cent to 45–70 %) occurs. *Rumex* and "other herbs" become frequent, while shrubs and dwarf-shrubs are decimated. This happens along with the formation of the layer rich in wooden chips and charcoal and marks the Norse "forest clearance". Between layers f and h (no sample from layer g was analyzed) there is a slight decrease in *Rumex*, "other herbs", *Lycopodium* and *Alnus*, and a further increase in *Gramineae*. This is caused by the growth of *Calamagrostis* in the bog after the disappearance of the Norsemen around A.D. 1350 or earlier. A concurrent cause of the leaving of this site may have been one of the disastrous attacks of myriads of larvae of the butterfly *Agrotis* (*Eurois*) *oculta* which were capable of eating every single green leaf (including mosses and lichens) over large areas and thus of preventing the grazing of cattle and gathering of hay for winter food. IVERSEN (1934, p. 356) considers this as a possible main cause of the extermination of the Norsemen of the Western Settlement. An attack would hardly affect all the farms (not a single pupa was found in the transects at Eqalugialik, cf. p. 162, in spite of eager search), and therefore an attack may only have been a contributory cause locally, cf. also the discussion in VIBE (1967, p. 157).

The changes in the local vegetation of the bog from the Norse period to the following period without human influence have been explained by IVERSEN (l.c.) as reflecting a change from a wetter to a drier period, indicated by the change in sediment from "Schwemmdetritus" to a peat without signs of the erosional effect of water. In addition, the numerous seeds of the highly hydrophilous species *Montia* and *Ranunculus hyperboreus* in the Norse layer, in contrast to the *Calamagrostis langsdorfii* and *Polygonum viviparum* growing in the overlaying peat, support the conclusion that (translated) "Shortly before the disappearance of the Norsemen the climate became drier, i.e. more continental. Yet an appreciable change in the summer temperature is unlikely. Unpublished pollen analyses of the upper peat layers of a bog outside the Norse settlement showed neither an *Alnus* decrease – nor an increase – which would otherwise be expected."

However, during the Norse period we must think of the bog as a moist depression in the settlement, especially in the spring. Charcoal, chips, sand, etc. are washed out into the basin from the surrounding slopes which have a soil surface not covered by a closed vegetation. In the bog, perennial plant growth was prevented by the traffic of children and domestic animals, as proved by the extensive growth of the annuals *Montia* and *Ranunculus hyperboreus*. These two species are highly favoured by culture and are very common in moist depressions in the towns today. PORSILD (1932) writes about *Montia*: "Strongly nitrophilous and very commonly to be found amongst mosses in badly polluted pools near Eskimo dwellings", and about *Ranunculus hyperboreus*: "Strongly nitrophilous growing in great abundance in manured pools near the settlements".

As soon as the cultural influences end these two species succumb, and it seems unnecessary to resort to an explanation of a drying-out. On the contrary, the fact that a fresh *Sphagnum* bog covers the surface instead of, for example, a hummocky, mossy *Vaccinium uliginosum-Ledum decumbens* vegetation, could better be accepted in support of the view that the climate grew moister.

Umîviarssuk

IVERSEN (1943) published another profile and pollen diagram from a Norse farmstead, viz. from Umîviarssuk at the head of Ameragdla (64°14′ N, 50°10′ W). Here, too, the culture layer, with several seeds of *Ranunculus hyperboreus* and thousands of seeds of *Montia*, is covered by a bright-brown moss peat. The arguments applying to the preceding locality seem valid.

Summary of the vegetational and climatic history around the head of Godthåbsfjord

Contrary to South Greenland, the development at the head of Godthåbsfjord is inaccurately dated. In fact, only one dated level in one diagram is at hand. But several indices support the assumption of a contemporaneity between Qagssiarssuk and Godthåbsfjord, cf. the discussion on p. 151. The datings with a question mark below are given on the assumption of contemporaneity.

The terrestrial vegetation

a. *Gramineae-Plantago maritima-Empetrum* phase (?8700–8000 B.P.)

A pioneer vegetation was dominated by *Gramineae*, *Cyperaceae*, *Plantago maritima*, *Empetrum*, *Loiseleuria* and other *Ericales*, and with i.a. *Chamaenerion*, *Saxifraga nivalis* or *S. tenuis*, *Sagina* and other *Caryophyllaceae*, *Oxyria* and *Dryas*. Most of the registered plants, especially in the beginning of the phase, are widespread, and *Lomatogonium*, the southernmost example of the species that was found, has its northern limit five latitudes farther north. Supposedly a climate resembling the present one in Disko Bugt prevailed then.

b. *Cyperaceae-Salix-Thalictrum* phase (?8000–7000 B.P.)

In addition to the above-mentioned plants *Pteridophytae* (*Equisetum*, *Botrychium*, *Lycopodium dubium*, *Diphasium*, *Dryopteris* type) are characteristic of this phase, and the pioneer plants are highly decimated. Dry soil plants like *Artemisia*, *Rumex acetosella*, *Gentiana nivalis* and *Campanula* indicate a continental climate. The maximum in *Sphagnum* seems to contradict this, but may be a response to an increasing temperature making possible sporogenesis of *Sphagna* in the moist surroundings of "Lake 100 m".

c. *Betula nana-Juniperus* phase (?7000–ca. 4000 B.P.)

During this phase *Betula nana* dwarf-shrub heaths with *Juniperus* and *Salix glauca*, partly as a component of the heaths, partly as a scrub on favoured places, covered the main part of the area. Climatic conditions supposedly were dry and almost as warm as today.

d. *Betula nana-Alnus crispa* phase (ca. 4000–?1900 B.P.)

Scrubs and dwarf-shrub heaths still dominate, but *Alnus* and *Ericales* seem to have conquered part of the area covered with *Juniperus* and *Betula* during the preceeding zone. This indicates more humid conditions. At the same time the flourishing of *Alnus* seems to indicate a maximum as far as the temperature is concerned.

e. *Betula-Alnus-Ericales-Gramineae* phase (?1900–0 B.P.)

The decrease in *Alnus* and the increase in *Ericales* supposedly is indicative of a deterioration. In diagrams some distance away from Norse farms, the clearance about A.D. 1000 and the following three centuries of sheep and cattle breeding has but a slight influence on the vegetation. Moister conditions are registered as occurring about 650 B.P. in bogs at Norse sites, as well as in a distant one. Presumably, the recent drying-up of some former ponds is a manifestation of the amelioration in the 20th Century.

The lacustrine vegetation

The succession of hydrophytes since deglaciation is known from only one lake, but shorter cores and single analyses from other lakes make it possible to give a very summary survey of the immigration. *Potomogeton filiformis* and *Eupotamogeton* immigrated very early in phase a, and shortly afterwards, *Hippuris* and *Myriophyllum spicatum* had very pronounced maxima. In one of the lakes, isolated during this phase, *Chara* sp. flourished in the alkaline water. The decrease in *Hippuris*, *Myriophyllum spicatum* and *Potamogeton filiformis* during phase b must be ascribed to the oligotrophication which, however, sets in at different times in the different lakes, according to the quality of the surrounding bedrock or moraines. In phase b *Isoëtes setacea* is common, whereas there is only a single grain of *Menyanthes* and *Myriophyllum alterniflorum*. The flourishing of these two species in phase d presumably reflects the highest holocene summer temperatures.

Sermermiut

Before leaving West Greenland, the palaeobotanical investigations at the former Eskimo settlement Sermermiut (69°12′ N, 51°08′ W) at the mouth of Jakobshavns Isfjord will be mentioned briefly. Detailed descriptions are found in Fredskild (1967a) and in an abbreviated form in Fredskild (1967b).

On a raised beach covered with i.a. *Elymus* and *Stellaria humifusa*, the Sarqaq Eskimoes settled around 3360 ± 120 B.P. (K-807). *Alopecurus alpinus*, highly favoured by human activity (= manuring) was the dominating plant during the habitation period. After the abandonment, a short period with an *Empetrum-Ledum decumbens* heath (2740 ± 100 B.P., K-516) was succeeded by the driest plant community represented in the profile: a *Betula nana* heath. Presumably as a result of moister conditions, the area was covered by a *Salix glauca* scrub (2570 ± 110 B.P., K-809), which in turn was replaced by a very wet stage, a *Sphagnum squarrosum* blanket bog with *Montia*, *Ranunculus hyperboreus*, *R. lapponicus*, *Carex*

bigelowii and *C. rariflora* (2350 ± 110 B.P., K-811). When conditions again became too dry, the bog was covered by a heath, dominated by *Empetrum* and *Ledum*, later by *Gramineae* and *Stellaria longipes* s.l. On this heath the Dorset Eskimoes settled 2000–1900 years ago. Sometime after their disappearance the area was again covered by a *Sphagnum* bog resembling the above-mentioned. A dating in the middle of the *Sphagnum* peat is 1540 ± 100 B.P. (K-813). Later a heath covered the area, and then either sedimentation stopped, or the younger peat was removed for fuel or sod by the neo-Eskimoes, who settled at the site some centuries ago.

This profile is too brief to give information about the immigration of the plants, but the two recurrence-surface like stages around 2350 and 1550 B.P. give valuable climatic information.

Potamogeton filiformis and *Myriophyllum spicatum* once grew in a now temporary pond at Sermermiut (FREDSKILD, 1961). This is presumably a parallel to the former ponds at Itivnera (p. 156).

North Greenland

Thule area and Inglefield Land

The vegetation in this part of Greenland has only been treated sporadically; no recent survey exists. A high arctic desert vegetation covers the major part of the area. The soils in Inglefield Land have been treated by TEDROW (1970). The pedological conditions in the different plant communities are treated in this paper.

A few datings based on marine deposits of delta terraces are available. Apparently the deglaciation began ca. 8000 B.P. (MALAURIE, in MALAURIE *et al.*, 1972). In this latter paper HYVÄRINEN and VASARI presented some pollen diagrams of peat deposits. The discussion following these are very summary, and as I do not always agree with the interpretation, the diagrams will be discussed below.

The first of HYVÄRINENS diagrams originates from a bog close to the now abandoned Thule settlement. The peat monolith taken was 82 cm long. A dating of a 63–66 cm sample gave 1350 ± 100 B.P. (GIF-1549, DELIBRIAS, in MALAURIE *et al.*, 1972), but nothing is known about when the peat sedimentation started, and it is unknown whether organic material could be found below 82 cm.

The lower part of the analyzed section (the uppermost 66 cm) consists of a medium humified, sedgy peat, downwards more sandy. The pollen spectra are totally dominated by *Cyperaceae*, making up between 80 and 95 % of ΣP which varies between 100 and 150. The sedimentation rate is fast, 10 cm/100 yr as an average between the 63–66 and the 39–41 cm sample (1120 ± 90 B.P., GIF-1653). Conditions must have been moist to wet, which can also be concluded from the *Koenigia* pollen found in 3 of the samples and in the abundant freshwater diatoms. Around 900 ± 90 B.P. (GIF-1692), the dating of a 32–35 cm sample, the vegetation changed character to a drier grass heath with *Salix*, *Ranunculus*, *Saxifraga* and *Caryophyllaceae* growing in a moss carpet. The sedimentation rate is slower, on the average for the upper 40 cm of the profile 3.6 cm/100 yr. In the uppermost 6 cm *Cyperaceae* are more common (20–30 %), but *Gramineae* still dominate, *Salix* is frequent, and no vegetational (or climatic) change can be deduced from this.

The second diagram originates from a 55 cm peat monolith from Ivssuvigsôq near Kap Dudley Digges, ca. 45 km south of the preceding

locality. The main part of the monolith is made of a dark, medium humified, felted peat overlaying 6–7 cm of bright, only slightly humified peat. With the exception of one sample, all spectra are dominated by *Gramineae*, with *Caryophyllaceae* being the second important pollen type. Few *Salix* grew on the spot in the deeper part, but in the middle, during a short spell in the period between 550 ± 90 B.P. (GIF-1749), the dating of a sample 30–35 cm below the surface, and 150 ± 50 B.P. (GIF-1649), 20–25 cm below the surface, *Salix* dominated. Thereupon it disappeared from the place. The total absence of *Cyperaceae* (single grains were seen in only 3 out of 11 samples) is indicative of a mossy grass-community on rather dry, but presumably manured soil. The description of the *Alopecurus alpinus-Poa arctica* sociation with *Stellaria longipes* upon and between former Eskimo houses at Sermermiut (FREDSKILD, 1961, p. 25) may be recalled, especially as the pollen spectrum from the present moss carpet there (FREDSKILD, 1967 a, table V) very much resembles the spectra from Ivssuvigsôq. This site is "situated near old Eskimo settlements" (HYVÄRINEN l.c.). The sedimentation rate is rapid in the beginning, but at some time between 950 ± 90 B.P. (GIF-1750) and 550 ± 90 B.P. it became slower.

From Savigsivik island in the northern end of Melville Bugt, ca. 100 km to the east of Ivssuvigsôq, HYVÄRINEN tried to analyse a 82 cm thick raw moss peat, which turned out to be extremely poor in pollen. Some datings have been made; the uppermost of them directly below the surface gave 1320 ± 90, whereas a sample at 60 cm gave 1480 ± 90 B.P. The only conclusion that can be made is that about 1300–1500 years ago a very rapid peat formation, caused by manuring either from birds or by some early neo-Eskimos, took place.

VASARI (in MALAURIE *et al.*, 1972) presents two diagrams from the northern part of Thule district. One of them, from Igdluluarssuit in Robertson Fjord, resembles in many respects the above-mentioned diagram from Ivssuvigsôq. *Gramineae* amount to no less than 85 % in any of the samples. *Cerastium-Stellaria* type is the second important component. *Salix* amounts to few percent, and a *Cyperaceae* pollen was found in only one sample (the total ΣP in the 10 samples is 3807). Macrofossil analysis of some of the samples showed dominance of the mosses *Aulacomnium palustre* and *Polytrichum* cf. *hyperboreum*. Most common among the vascular plants were *Luzula confusa* or *L. arctica*, and in addition *Potentilla*, *Cerastium* and *Euphrasia* were found. The monolith is 82 cm deep. In his description of the sites MALAURIE mentions that for operational reasons the greatest depth of the monoliths at two of the bogs was 82 cm and that it could not be precluded that sedimentation started earlier in these sites. Nor could this be precluded at two of the other 5 sites.

A dating of the 4 deepest cm at Igdluluarssuit is 1250 ± 140 B.P. (GIF-573). Only the samples from 55 cm to the present surface have been counted. In this part of the monolith the datings are almost identical; thus, 6 datings of 3 or 6 cm thick samples between 9 and 45 cm inconsistently range between 780 and 580 B.P. Only the upper one, 3–6 cm below the surface, gives a younger date: 90 ± 90 B.P. (GIF-568), but this may partly be caused by recent roots.

VASARI (l.c.) explains this rapid peat growth, formed by a monotonous vegetation, as a result of the manuring effect of birds, but the mossy, rather dry, grass heath vegetation with *Luzula* does not support this assumption. The similarities with the Sermermiut vegetation and pollen spectra mentioned above seems to indicate that about 600–800 years ago there was a Thule-Eskimo settlement here.

The second of VASARI's diagrams, however, does not seem to be influenced by man. It is from Etah in the western end of Inglefield Land. The peat layer had a thickness of 52 cm. It cannot be ruled out that peat growth started before the dating of the basal peat (48–52 cm), the dating of which is 1860 ± 150 B.P. (GIF-576). The deepest pollen sample is from ca. 48 cm. The dating of the 42–45 cm sample is 1480 ± 140 B.P. (GIF-577), that of the 12–15 cm sample 1200 ± 140 B.P. (GIF-575), showing a very fast sedimentation rate, roughly 10 cm/100 yr during the major part of the sedimentation. *Gramineae* dominate (ca. 60 %), *Cassiope tetragona* (ca. 10 % or more in all but one sample) and *Salix* (varying, mostly between 10 and 20 %) are also frequent. In addition, *Cerastium-Stellaria* type, *Potentilla* and *Saxifraga*, mainly *oppositifolia* type, are not infrequent. *Cyperaceae* make up ca. 2 %. Noteworthy are the *Sphagnum* spores in the two deepest samples. Only two species occur so far north, viz. *Sphagnum girgensohnii* (LANGE, 1952) and *S. warnstorfianum*, and only exceptionally *Sphagnum* produce spores in Greenland (K. HOLMEN, verbal information). As long distance *Betula* and *Alnus* only are marked in one sample each (the total Σ P in the 11 samples is 1857), it must be concluded that the *Sphagnum* spores really belong to the vegetation, thus probably indicating a warmer climate. At some time the rapid growth was brought to an end, and more dry conditions must have prevailed, resulting in a heath vegetation dominated by *Gramineae*, *Salix*, *Potentilla*, *Saxifraga* and *Polypodiaceae*. *Woodsia glabella* and *Cystopteris fragilis* ssp. *fragilis* are the only ferns living in that area today; the latter seems the only possibility if a local growth is assumed.

Dating of three subsequent samples, 12–15 cm: 1200 ± 140 B.P., 9–12 cm: 330 ± 90 B.P. (GIF-1748) and 6–9 cm: 175 ± 90 B.P. (GIF-574) do not give any precise dating of the climatic change, which must have caused the peat growth to stop, and must also be responsible for the concurrent change in the vegetation. Most likely this must have been con-

nected with the beginning of one of the cooling and therefore drier fluctuations which sets in around 1100, 1000 and the most severe one 850 B.P. (DANSGAARD *et al.*, 1969).

The effect on vegetation of manuring from Eskimo settlements is so overwhelming that any climatic effect during the same period will be hidden, and because of this only two of the mentioned diagrams can be used in studying the relation between climatic and vegetational changes, viz. the diagrams from Thule and Etah. Common to both is a rapid peat growth formed by *Cyperaceae* (Thule) or a moss-rich grass-*Cassiope* heath (Etah), indicating a good snow cover during winter. This period of a moist and presumably warm climate lasted roughly from before 1350 B.P. to ca. 900 B.P. in one case, from around 1500–1800 (or earlier) to presumably between 1100 and 850 B.P. in the other case. After this the vegetation changed to more dry heaths, a result of drier and colder conditions.

Peary Land

Remarks on the present vegetation

The vegetation and flora of Peary Land has been treated by HOLMEN (1957) and FREDSKILD (1966). The most pronounced high arctic desert is found in "the *Dryas*-areas" found in the interior (HOLMEN l.c.). Here the vegetation is characterized by *Dryas* heaths, *Kobresia myosuroides* vegetation, *Carex stans* meadows, and by rather open communities with *Melandrium triflorum* and *Taraxacum arctogenum*, but areas completely lacking vegetation are the most characteristic. Only 2–3 % of the *Dryas* areas are covered with vegetation, and by far most of this is found along streams, around lakes and on slopes below snow-patches. Ca. $^1/_4$ of the Peary Land flora, which includes 106 species of higher plants, is restricted to these areas, e.g. *Kobresia myosuroides*, *Carex maritima*, *C. nardina*, *Braya purpurascens*, *B. thorild-wulffii*, *Dryas integrifolia*, *Lesquerella arctica*, *Eutrema edwardsii*, *Melandrium triflorum*, *Draba arctogena*. The soil is neutral-alkaline, rich in lime and often with efflorescenses of salts.

The plant communities of "the *Cassiope*-areas" (HOLMEN l.c.) can be found at the outer districts and on protected areas in the interior. Most characteristic are *Cassiope tetragona* heaths. The fell-field vegetation is dominated by *Potentilla hyparctica*, *Poa glauca*, *Trisetum spicatum*, *Luzula confusa*, *Orthotrichum killiasii* and *Cetraria nivalis*. Furthermore, mossy swamps with *Tomenthypnum nitens*, *Meesia triquetra*, *Drepanocladus revolvens* and *Aulacomnium turgidum* are not rare. Around $^1/_6$ of the higher flora is restricted to the *Cassiope* areas, e.g. the species just mentioned, as well as *Silene acaulis*, *Hierochloë alpina* and *Cardamine bellidi-*

folia. In the *Cassiope* heaths the soil may be rather humic, but due to mixing with minerogenic particles the reaction is nowhere acid.

The flora of Peary Land also includes quite a number of widely distributed, ubiquitous plants, such as *Saxifraga oppositifolia*, *Poa abbreviata*, *Polygonum viviparum*, *Oxyria*, *Cerastium alpinum*, *Minuartia rubella*, *Papaver radicatum*, *Alopecurus alpinus*, *Ranunculus sulphureus* and *Salix arctica.*

Remarks on the climate

Holmen (1957) gives a summary of the climatic conditions, which are otherwise described in detail by Fristrup (1952 and 1961). The precipitation, which amounts to about 25 mm per year, if not less, is the most important factor affecting the vegetation. On the higher elevation the precipitation is somewhat greater. The snow falling during the winter season (September to May incl.) is blown together in large snowdrifts on lee slopes, and extensive areas are without the protecting snow-cover during most of the winter. From the middle of June until late August the temperature is positive all day round, and because of the low orbit of the sun the diurnal variation is very small. During a period of ca. 70 days no negative temperature was measured during several years at Jørgen Brønlund Fjord. The mean temperature in July is ca. 6° C, which in fact tells very little about the microclimate in the low vegetation cover. It should be stressed that because of the midnight sun (April 10–Sept. 3 at Jørgen Brønlund Fjord) the vegetation period is rather long. Gales are frequent.

Remarks on the geology

The bedrock in the southern part of Peary Land, e.g. around Jørgen Brønlund Fjord, consists of undisturbed sedimentary rocks of Precambrian to Silurian age, rich in dolomite. The ca. 1000 m high plateaus are intersected by fjords and valleys. In the northern part the Caledonian folding has disturbed and re-worked the bedrock. During the Wisconsin glaciation most, if not all, of Peary Land was covered by local glaciers. Great moraine-like deposits on the low coast land at Herlufsholm Strand and at Kap København on the east coast north of the mouth of Independence Fjord have been assumed to mark the maximum extension of the Wisconsin glaciation, but this has later been doubted i.a. by Kirkeby (1963) and Weidick (verbal information). The "moraines" have been modified by a marine invasion that planed and covered them with a veneer of gravel. They may as well have been formed by shelf ice as by an active glacier (Weidick, verbal information), and submarine terminal moraines may well be found outside the present coast line, eventually destroyed by sea ice and shelf ice.

The deglaciation of Peary Land started before 8000 B.P. (WEIDICK, 1972a), followed by a rapid recession. The upper marine limit is 129 m (DAVIES, 1961). However, some time before 6000 B.P. a re-advance of local valley glaciers occurred, and the moraines on the 65 m plain south of Jørgen Brønlund Fjord were formed (KIRKEBY, 1963). Prior to this re-advance the extensive marine silt-clay beds along the fjord were formed. Datings of paired *Mya truncata* shells *in situ* in the surface of these beds (7290 ± 130 B.P. (K-964) and 7740 ± 130 (K-965), KNUTH, 1964) seem to indicate that the re-advance was a good deal older than ca. 6000 B.P., as the *Mya* most likely are younger than this re-advance. But as they were embedded in sediments rich in carbonate, an exchange of ions between the shells and the clay will cause too old datings, cf. the datings of the sediments from Klaresø. Furthermore, during the summer the environment must have had a considerable supply of meltwater. This must have caused a contamination of the centemporary carbonate with "old" carbonate and therefore gives too old datings.

By far the most precise dating of the deglaciation of the Jørgen Brønlund Fjord area is obtained by the many datings of charred driftwood and local *Salix* found in the hearths of palaeo-Eskimo sites on raised beaches (KNUTH, 1967). The oldest of these datings is 4540 ± 120 B.P. (K-754) made on charred driftwood from the 21 m terrace. By means of these datings an uplift curve is shown in FREDSKILD (1969). The dating 5780 ± 100 B.P. (Y-19) of a piece of driftwood from Jørgen Brøndlund Fjord was not taken into consideration in constructing this curve, as the field altitude is uncertain (E. KNUTH, verbal information). The upper part of the curve doubtless is too steep, and a smoother uplift curve is given in WEIDICK (1972b). However, the re-advance may have postponed the uplift for a period, and there may be a slight bend on the curve between the 60 and 70 m level. WEIDICK (1972b) gives an up-to-date list of all published datings from North Greenland.

Klaresø

Klaresø is situated in a kettlehole in the marine silt-clay beds south of Jørgen Brønlund Fjord at 44.6 m a.s.l. (82°10′ N, 30°34′ W, fig. 26). The size of the lake is app. 275 × 100 m. The greater part is shallow and stony, eroded by the winter ice, the thickness of which was measured at 235 cm at the end of May 1963. In the eastern end a minor basin with a depth of water of 3.3–3.6 m is found. Great snow-patches south and west of the lake supply part of the surroundings with water until they disappear in late July (fig. 27).

The vegetation on the area around Klaresø was mapped in 1963 (fig. 28). The major part of the area, especially on the plateau, is com-

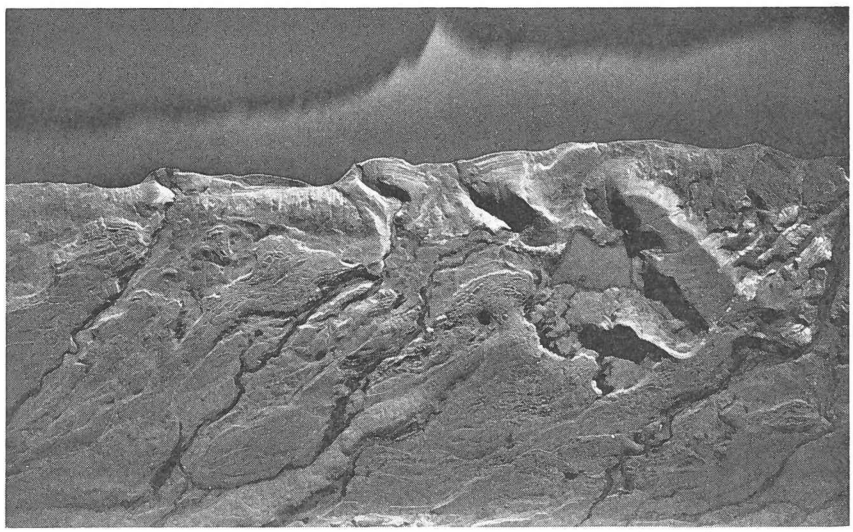


Fig. 26. Peary Land, vertical aerial photo showing landscape south of Jørgen Brønlund Fjord. North upwards. Lersø looks grey due to suspended clay, while Klaresø south of it appears dark because of its clear water. Note the systems of frost cracks and the raised beaches. Ca. 1:30,000. Reproduced with the permission (A. 789/72) of the Geodetic Institute, Copenhagen.



Fig. 27. Klaresø, looking towards the northwest. July 6, 1963.

pletely bare, or with only single specimens of *Puccinellia angustata* with several metres between the tiny individuals. These areas are free of snow long before the vegetation period, and apart from one light drizzle and one light snow-squall, which evaporated almost immediately, there was

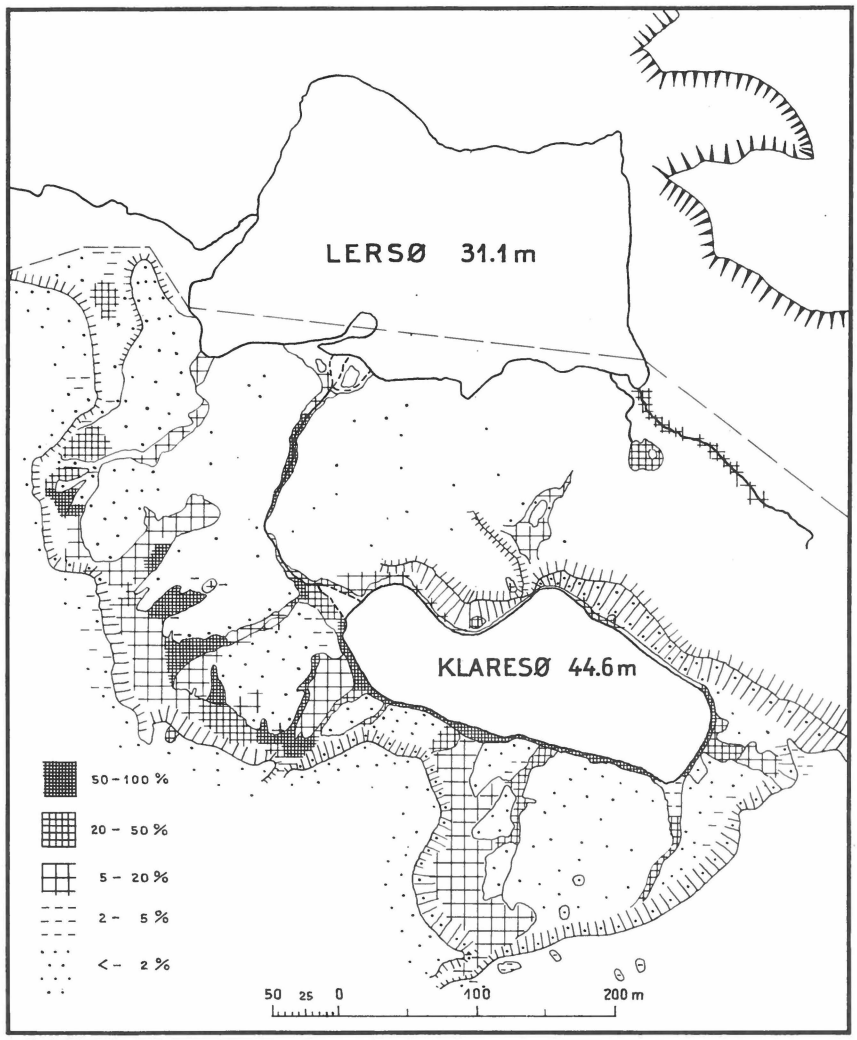


Fig. 28. Sketch map of the surroundings of Klaresø showing the degree of vegetation cover. The dashed line delimits the surveyed area.

no supply of water during the 1963-season. These areas are without signature or with the $< 2\ \%$ signature. Fragments of *Dryas chamissonis-Carex nardina* heaths can be found on slightly protected areas, i.a. in the deep depression in the polygon soil. Narrow belts of *Dryas-Kobresia myosuroides-Salix arctica* heath-like vegetations are frequent at the edge of the moist vegetations described below.

The area marked by the signature for 5–20 % degree of cover is dominated by *Phippsia-Alopecurus alpinus-Juncus biglumis* snow-patches. In addition to the three above-mentioned species, *Carex misandra*,

Colpodium vahlianum, *Draba bellii*, *D. lactea*, *D. oblongata*, *D. subcapitata*, *Luzula arctica*, *Oxyria*, *Saxifraga tenuis* and *Stellaria crassipes* are common. Most *Alopecurus* are sterile. Mosses are frequent.

Areas with a degree of cover between 20 and 50 % are mainly hummocky, with *Salix arctica*, *Alopecurus*, *Carex misandra*, *Phippsia algida* and *Oxyria*. In some "channels" with seeping water until the last snow is melted, the degree of cover is between 50 and 100 %. *Eriophorum triste*, *Juncus biglumis*, *J. triglumis*, *Alopecurus* and *Colpodium* are the most frequent plants. Finally, in a rim of mosses around the lake *Alopecurus* and *Eriophorum triste* are the dominating species, growing together with *Juncus biglumis*, *Arctagrostis*, *Salix*, *Polygonum viviparum*, *Luzula arctica*, *Melandrium apetalum* and *Stellaria crassipes*. *Ranunculus sulphureus*, *Eutrema edwardsii*, *Cardamine bellidifolia* and *Draba lactea* are scattered here.

It has been calculated that only 2.8 % of the mapped area is covered by vegetation. Of the plants that occur here, *Cyperaceae* covers 38 %, *Gramineae* 29, *Dryas* 6.8, *Salix* 6.1, *Oxyria* 2.5, *Saxifraga oppositifolia* 0.4, and other species in all 17 %. This should be compared with the content of pollen in the Tauber trap placed in the <2 % area 50 m west of the lake (table 24), and with the pollen spectrum in the uppermost sample in the diagram.

Pleuropogon sabinei is common in shallow water in the lake; *Calliergon trifarium* is frequent on the bottom close to the beach, now and then together with some tiny specimens of *Ranunculus confervoides* and with many colonies of *Nostoc*. In this zone of the lake icefloes drifting around the lake until mid-July do not erode (fig. 27). Only minor, thin fragments may reach the beach. No vegetation whatsoever was observed in deeper water, i.e. to a depth of slightly more than 2 m, but scattered *Calliergon* were found growing on the bottom of the deep basin.

Description of the sediments

The lake was cored from the ice in the period from late May to mid-June, 1963. Ca. 30 corings were made; with deviations of one or a few cm the stratigraphy still was the same. The following layers were separated in the analyzed core:

5. 0– 22 cm below the lake bottom: Slightly sandy-clayey lake marl. Very dark with olive tone. Exposed to the air, it changes to olive-green with yellow grains of chalk. Loose, gritty. Few fragments of *Calliergon*. Ld^1 1, Tb^1 + +, Lc 2.5, Ga +, (Ag + As) 0.5.

4. 22– 56 cm: Slightly sandy-clayey lime gyttja, rich in *Calliergon*. Colour like 5. Ld^1 1.5, Tb^1 0.5, Lc 1.5, Ga +, (Ag + As) 0.5.

3. 56– 92 cm: Sandy-clayey lime gyttja. Colour dark-olive, brightens to light olive-green with yellow tone. Gelatinous. Ld^1 1.5, Lc 1.5, Ga +, (Ag + As) 1.

2. 92–102 cm: Clay gyttja rich in lime. Dark-olive, brightens to bright olive-grey. Rather loose, falls easily into small lime concretions. Single fragments of mosses in some of the cores. Ld^1 1.5, Lc 1, (Ag + As) 1.5.

1. 102–136 cm: Marine clay. Grey, slightly bluish. A few shells of *Astarte borealis*. (Ag + As) 4, Ga +.

The pollen samples from the gyttja (nos 8–25) all originate from one uninterrupted core, while the samples from the marine clay originate from two other cores.

Macrofossils

Besides the fragments of *Calliergon trifarium* (K. HOLMEN det.) only epphibians of *Daphnia pulex* (U. RØEN det.) were found. They occurred in all the pollen samples from the limnic facies except in nos 17, 24 and 25. The species occur in the lake today (RØEN, 1968).

Datings

11 Livingstone cores covering the whole or most of the gyttja were cut into 3 cm slices and accumulated as radiocarbon samples, 9 of which were dated: 3–6 cm below the lake bottom: 2610 ± 120 B.P. (K-885), 15–21 cm: 4090 ± 140 (K-1425), 27–33 cm: 5180 ± 140 (K-884), 39–45 cm: 5970 ± 120 (K-1424), 51–54 cm: 5870 ± 140 (K-883), 63–66 cm: 6060 ± 130 (K-1422) the average of two datings: 6030 ± 170 and 6080 ± 170, 75–81 cm: 6040 ± 140 (K-882), 90–93 cm: 6780 ± 120 (K-1423), the average of two datings: 6840 ± 150 and 6720 ± 150, and finally 99–102 cm: 6850 ± 140 B.P. (K-868). At the pre-treatment of the samples the material was divided into carbonates and soluble matters, ash, and loss on ignition. The ratio in weight between these fractions is given in the "absolute" pollen diagram.

As a considerable amount of "old" carbonate has been dissolved in the lake all through its history, the organisms forming the gyttja must contain "old" as well as contemporary carbonate, and the datings of the gyttja will be too old. If the datings are plotted against depth (FREDSKILD, 1969, fig. 2) it can be seen that the line fitted to most datings cuts the present lake bottom at an age of ca. 1900 B.P. In the following discussion all the dates have been corrected by this number of years, but it must be admitted that great uncertainties are connected with this, and the dates must not be taken too literally.

Pollen zones

The pollen samples were very poor or extremely poor in pollen. Often the total content of pollen in a slide (coverslip 24 × 24 mm) was 6–15 pollen, and therefore Σ P in the samples ranges between 102 and 187. In particular, the samples from the marine clay and the uppermost gyttja were poor, with a calculated content of 200–850 pollen per g (the deeper samples in Galium Kær contained ca. 1.5 million per g).

Two diagrams are given, viz. a) a relative diagram (plate 19) in which the basic sum includes spermatophytes as well as pteridophytes regardless of the possible rebedded or long distance origin, and, b) an absolute diagram (plate 20) in which the pollen etc. are expressed as number per g dry weight. Besides the pollen and spores shown in the diagrams, the following were found: *Campanula*: in sample 14 one grain, *Caryophyllaceae* 1:1, 5:2, 7:1, *Koenigia* 12:1, *Quercus* 15:1, *Sagina* 7:2, *Silene acaulis* type 21:1 and *Ulmus* 20:1, 21:1

Pollen zone A: *Gramineae-Cyperacea-Oxyria* zone (samples 1–5)

In addition to the plants mentioned, this zone is characterized by exotic pollen: *Alnus*, *Betula*, *Ericales*, *Huperzia* etc., shown to the left in the relative diagram. Some *Salix* also occur. Almost all of the exotic pollen were highly destructed, as were also the pollen grains of *Salix* and part of *Saxifraga oppositifolia*. The zone boundary A-B is defined at the increase in *Saxifraga oppositifolia*.

Pollen zone B: *Saxifraga oppositifolia-Gramineae* zone (samples 6–9)

Oxyria, *Cyperaceae*, *Potentilla* and, in the later part, *Ranunculus*, are common, too, while *Salix* is missing. Exotic pollen, most frequent in the marine samples, are fewer than in zone A. Along with the shift from clay to gyttja, *Pediastrum* and *Botryococcus* become frequent and *Daphnia pulex* occur. At the same time the content of pollen increases. Only exceptionally destructed pollen are found in the gyttja. This is valid for the whole core. The zone boundary B-C is placed at the increase in *Salix*.

Pollen zone C: *Salix-Saxifraga oppositifolia* zone (samples 10–15)

Throughout this zone *Salix* increases, making up a total of 50–60 % of the pollen towards the end. Relatively speaking, this is at the expense of *Saxifraga*, but in the absolute diagram most herbs attain constant frequencies. The increase in ΣP/g is mainly caused by *Salix*. Exotic pollen are few. *Pediastrum* and *Botryococcus* decrease. The zone boundary C-D is placed at the end of the *Salix* increase along with a change in the sediment as reflected in the abrupt increase in *Botryococcus* and the spreading of *Calliergon* on the lake bottom.

Pollen zone D: *Salix* zone (samples 16–22)

In this zone *Salix* makes up 50–60 % of all pollen, and the pollen content in the sediment attains its maximum values, up to 10,000/g. *Botryococcus* is most frequent in samples 16–20, ranging between 27,000 and 40,000/g. In the later part of the zone the total pollen (and *Botryococcus*) decrease, together with a change in sediment, but no change in the composition of the pollen spectra is visible until the last zone boundary is reached. This zone boundary (D-E) is defined at the drop in ΣP/g, at the decrease in *Salix* and the increase in *Cyperaceae* and *Gramineae*.

Pollen zone E: *Gramineae-Salix* zone (samples 23–25)

In this zone *Cyperaceae*, *Gramineae*, *Saxifraga oppositifolia*, *Oxyria* and possibly others are relatively more frequent than in the preceding zone, but the small ΣP does not permit detailed conclusions.

Diatom analyses

FOGED (1972) has analyzed the diatom content in 41 samples from the core, viz. the 21 pollen samples nos 5–25 and in addition 20 intermediate samples. The flora in the 6 samples from the marine clay is characterized by poly- and mesohalobous species. The three most common mesohalobous species are known to occur as littoral forms in the open sea, as well as in lagoons, and FOGED (l.c.) concludes that there was an open connection with the sea until the actual isolation of the basin, and that a proper lagoon stage seems to be out of question.

The freshwater samples between 102 and 30 cm below the lake bottom are all totally dominated by the widespread *Fragillaria pinnata*, which makes up more than 99 % of the valves counted. Only a few other species are represented. Between 30 and 20 cm the flora gradually becomes richer. Thus, in the deepest 5 gyttja samples only 13 species were found, while in the uppermost 5 samples 80 species are recorded. *Fragillaria pinnata* is still dominating, in the upper 18 cm making up 90 % of all valves.

Discussion

The samples from the marine facies are marked by the rebedded pollen and therefore the composition of the contemporary vegetation is not quite clear. As by far most of the *Salix* pollen in samples 1–5 were destructed, it can be concluded that *Salix* did not grow around Klaresø in the first centuries. *Oxyria*, *Gramineae* and *Cyperaceae* dominated, with some *Potentilla* and *Saxifraga oppositifolia* in between. *Saxifraga tricuspidata*, with pollen of the *S. oppositifolia* type, is left out of the discussion, as it has been found only once in Peary Land (FREDSKILD, 1966).

The most marked change in the pollen diagram at the transition from clay to gyttja is the emergence of *Ranunculus*. In this part of Greenland 4 species occur: *R. affinis*, found only twice, viz. in one loc. not far from Klaresø, and south of Nedre Midsommersø, *R. hyperboreus*, not rare in moss cushions between the stones at the shore of lakes (not found at Klaresø), *R. sulphureus*, which is common in moist to rather wet soil, i.a. between the mosses along the beach of Klaresø, and, finally, *R. confervoides*, which has been found three times, i.a. in Klaresø, where today it is very rare (FREDSKILD, 1966). The moss-herb vegetation along the lake was not established until after the isolation, and most likely the increase in *Ranunculus* at the beginning of the limnic facies must be ascribed to a spreading of *R. sulphureus* to the actual beach of the lake.

Salix seems to immigrate between samples 9 and 10, along with a change in the sediment from a more clayey gyttja (41 % of ash in the deepest radiocarbon sample as compared with 31 % as an average of the 3 samples from layer 3). This may be a coincidence, or may be caused by a common climatic change. As *Salix arctica* is one of the commonest plants in North Greenalnd today, growing on almost all substrates and found in almost every plant community, it may well have been a question of dispersal possibilities. Once *Salix* immigrated, it seems to have dominated the vegetation around Klaresø. However, a comparison with the present vegetation around Klaresø (*Salix* covers 6 % of the vegetation-covered area) and the pollen spectrum in the uppermost gyttja sample (39 % *Salix*) and in the Tauber trap placed next to the lake during a whole flowering season (12 *Salix* pollen out of 40 pollen trapped) shows that it is highly over-represented. But during zone D the relative importance of *Salix* must have been greater than today. This zone, too, is characterized by the highest production of *Botryococcus*, of *Calliergon* and ΣP.

If the correction of the datings is a constant value (e.g. 1900 yr), the average sedimentation rate of layers 2–4 is 4.5 cm/100 yr, while in layer 5 it is 0.76 cm/100 yr. This, connected with the much lower ΣP/g in zone E, (6650 as an average of samples 16–20, 590 as an average of samples 23–25) tell, that even considering the great uncertainties in calculating the sedimentation rates and the pollen content, the pollen input to Klaresø seems to have been much greater during zone B-D than during zone E.

In discussing the possible causes of the pronounced decrease in pollen and matrix sedimentation rate, it should be recalled that in some lakes (e.g. Spongilla Sø, Kløftsø and Rogers Lake, cf. DAVIS, 1969) examples are seen on a related drop in rates, presumably a result of changing currents. This, however, mainly seems to occur in big lakes or in lakes with flowing water. Klaresø has no inlet, only in the beginning of summer excess water seeps from the west end down to Lersø and the fjord. Fur-

thermore, if there is any correlation between the sedimentation rates of pollen and matrix, in other words that the major part of both was sedimentated at another place in the basin, the number of pollen per unit matrix would be constant, provided that no major concurrent change in the particle size of the matrix occurred. But all cores from different sites in the lake were equal, and the ratio pollen to matrix drops roughly ten times. Everything considered, the pollen input dropped at the zone boundary D-E.

As illustrated by the vegetation map (fig. 28) and the photo (fig. 27), the vegetation is restricted to areas with seeping water from late snow-patches. In between, the soil is completely bare or with only single specimens mainly of *Puccinellia angustata*. If the higher input of pollen during zone B-D is directly related to an equally higher vegetation cover around the lake, it must be concluded that a greater part of the ground was sufficiently supplied by water during the growing season. Greater snow-patches may give a better supply in and around the drainage "channels", but hardly in the slightly higher areas in between, and furthermore the area in the center of the snow-patches with only poor vegetation (without *Salix*) will be greater. The only possible explanation left seems to be that the whole area was supplied by a not infrequent precipitation during the summer.

Today all the big fjords in Peary Land are frozen all year round, but driftwood on raised beaches even to their heads prove that this was not always so. The oldest dating of driftwood is from the 38 m terrace at Kap Viborg, 4975 ± 150 B.P. (I-312), and from the 27 m terrace at Kap Trend, 4860 ± 150 B.P. (I-306), WEIDICK (1972b). As mentioned above, the oldest datings in Jørgen Brønlund Fjord are 5780 ± 100 B.P., possibly from the 65 m terrace, and 4540 ± 120 B.P. from the 21 m terrace at Deltaterrasserne at the head of the fjord, while the youngest is 2720 ± 110 B.P. (K-934) from the 7 m terrace at Vandfaldnæs in the outer part of the same fjord (KNUTH, 1967). If the 1900 years' correction is accepted, Klaresø was isolated ca. 5000 B.P., *Salix* immigrated a century or two later, the zone boundary C-D (and sediment boundary 3–4) was around 4000, the first drop in ΣP and *Botryococcus* around 3300 and the zone boundary D-E around 2100 B.P.

At present the distance to partly open sea in summer is several hundreds of km. This is partly responsible for the highly continental climate in the interior. But if the great fjord system including Danmark Fjord, Hagen Fjord, and not least the almost 200 km long, 30 km wide Independence Fjord, was open during summer this must greatly have influenced the climate in the interior. Cloudier weather, now and then with some precipitation, is to be expected, and the vegetation was able to cover a greater area. As mentioned above, the oldest sign of a palaeo-

Eskimo habitation is the 4540 ± 120 B.P. dating, but the bulk of datings on Independence-I culture are from the period between 4000 and 3600 B.P. (KNUTH, 1967). Judging from the bones found in the sites, musk-ox was the most important game to these people. Seal-hunting was much less important. No doubt a better vegetation cover is advantageous to the musk-ox, provided that the snow-cover during winter is not too thick to allow grazing (VIBE, 1967). The sedimentation of layer 4 lasted from ca. 4000 to 3300 B.P.

After a time-gap with no habitation, the people of the Independence-II culture settled on the lower, raised beaches between 3300 and 2500 B.P. While no harpoon heads or lance heads of bone were found in the Independence-I ruins, these types of implements for seal-hunting are common in Independence-II ruins, and seal bones also are most common here. This indicates a change in the material culture and, therefore, a change in climate.

A first drop in ΣP/g is found between samples 20 and 21, ca. 3300 B.P., and about the same time the sedimentation rate slows down. A second drop occurs between nos 22 and 23, ca. 2100 B.P. By this time the last palaeo-Eskimo had left Peary Land. The much smaller pollen input during pollen zone E, reflecting a smaller vegetation cover, may have influenced the grazing possibilities of the musk-ox, but it is not possible to weigh the importance of this contra the influence of man's hunting during centuries. According to VIBE (l.c.) man is fateful to musk-ox.

Only three poor pollen samples from the period 2100 B.P. to the present day have been analyzed, and quite naturally nothing can be said about possible climatic and vegetational fluctuations within this period from the Klaresø-diagrams.

Sølejren

At the eastern end of Nedre Midsommersø, in the heart of Peary Land, there is a boggy area roughly 90 m a.s.l. some hundred metres east of Sølejren (82°13′ N, 32°40′ W, fig. 29). The ground is hummocky, with the permafrost beginning at a depth of 13–15 cm (July 22–24). *Carex stans* and *Salix arctica* dominate. Besides these, the following species are found close to the hole that was dug: *Alopecurus alpinus*, *Arctagrostis latifolia*, *Carex misandra*, *Draba lactea*, *Equisetum variegatum*, *Eriophorum scheuchzeri*, *E. triste*, *Eutrema edwardsii*, *Festuca hyperborea*, *Juncus biglumis*, *J. triglumis*, *Luzula arctica*, *Melandrium apetalum*, *Pedicularis hirsuta*, *Polygonum viviparum*, *Stellaria longipes* s.l. *Dryas chamissonis* grows on top of the highest hummock. The degree of cover of phanerogams is 75 %, of mosses almost 100 %.

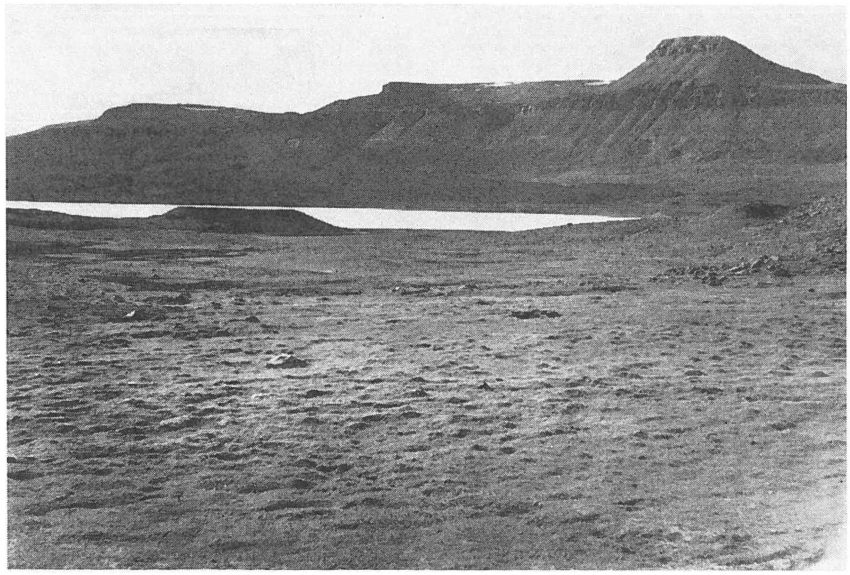


Fig. 29. Peary Land, Sølejren, looking towards the northwest. In the foreground the boggy, slightly hummocky area, with the dug-up peat marking the position of the pollen diagram. Nedre Midsommersø covered with perennial ice. July 24, 1963.

Description of the sediments

A 25–30 cm deep, small hole (ca. 0.8 × 0.6 m) was dug, well down into the sandy subsoil. The surface of the different peat layers was slightly undulating. The following layers could be separated, partly in the field, partly on the peat monoliths brought back to the laboratory. All samples were taken in these monoliths.

8. 0– 5 cm below the surface: Moss peat, bright-brown. Tb^1 4, Th^1 +, Ga + (Ag + As) +.

7. 5– 7 cm: Moss peat, dark-brown. Tb^2 4, Th^2 +, Dl +, Ga + +, (Ag + As) +.

6. 7–10 cm: Swamp peat with some moss peat. Beige-brown. Some small willow twigs. Th^2 3, Tb^2 1, Dh + +, Ga +, (Ag + As) +.

5. 10–11.5 cm: Moss and swamp peat. Dark-brown, rather many willow twigs. Tb^3 2, Th^3 2, Dl + +, Ga + +, (Ag + As) +.

4. 11.5–16.5 cm: Moss peat, clayey-sandy. Greyish-brown. Tb^2 3, Th^2 +, Ga + +, (Ag + As) 1.

3. 16.5–24 cm: Slightly clayey-sandy moss peat with swamp peat. Dark-brown. Content of moss peat decreasing downwards. Tb^2 3, Th^3 1, Ga + +, (Ag + As) +.

2. 24–26 cm: Sandy moss peat with swamp peat. Dark-brown. Single willow twigs. Tb^3 2, Th^3 1, Dl +, Ga 1, (Ag + As) +.

1. 26–30 cm: Sandy swamp peat. Greyish-brown. Single willow twigs. Th^3 2, Tb^2 +, Dl +, Ga 2, (Ag + As) + +.

Macrofossils

The content of macrofossils in the radiocarbon samples and some intermediate macrofossil samples are given in table 14. All samples, except the 18–19.5 cm and the two 10–11.5 cm samples are from the same monolith.

Table 14. *Sølejren, macrofossils.*

cm below surface	x = samples from the same monolith	*Carex misandra*	*Carex stans*	*Cenococcum geophilum*	*Draba bellii*	*Draba* sp.	*Dryas*, leaves	*Equisetum variegatum*, rhizomes	*Juncus biglumis/triglumis*	*Melandrium apetalum*	*Papaver radicatum*	*Potentilla*	*Ranunculus sulphureus*	*Salix*, seed	*Salix*, leaves	*Salix*, twigs	*Saxifraga oppositifolia*
2 – 4	x		1	5		1	1		2	2					6		1
6 – 8	x				4	1	1	+	6						2		
10 –11.5.....		1		2	10				1	4			2			+	
10 –11.5.....			4													+	
10 –12	x		1	3	13				1	10			5			+	
14 –16	x			1	3		2		1		1		1		2		
18 –19.5.....			3													+	
18 –20	x	2	8													+	
22 –23.5.....	x		3				1		6			1		1			
23.5–28	x	1	24	1		2			1			1				+	

Diatom analyses

Foged (1972) has analyzed the diatoms in the 14 pollen samples. Most samples were poor in valves, and in some of them (1, 2, 3, 7, 11, 12) the content was even too small to allow for specific conclusions. On the basis of the content in some other samples (4, 5, 9, 10, 14), it can be stated that during most of the history of the bog the reaction was alkaline. In two samples (6 and 8) the indifferent (circum-neutral) and acidophilous diatoms are considerably predominant with respect to the number of valves, as well as of species. Foged takes this as a proof of some humification of the plant debris during this interval.

Datings

3 levels have been dated: Layer 1 + 2 (sample originates from 23.5–28 cm below the surface): 1520 ± 100 B.P. (K-1524), layer 3 (18–20 cm):

760 ± 100 B.P. (K-1523) and layer 5, from which 3 samples have been dated. From the same monolith as the pollen series and the two above-mentioned datings a dating of a sample, 10–12 cm below the surface exists: 770 ± 100 B.P. (K-1525 B). As this is almost identical with the 18–20 cm dating, 2 additional samples from this layer in two monoliths, 10 cm distant, were dated: 1170 ± 100 B.P. (K-1525 A) and 360 ± 100 B.P. (K-1772).

Pollen zones

The left part of the pollen diagram (plate 21) is a relative one. To the right, the 5 most important pollen types, sand, charcoal, and ΣP are given, expressed in number (or mg) per g dry weight. As the content of sand, which is the most important component of the samples as far as weight is concerned, is not constant throughout the profile, ΣP/g is expressed in two ways in the diagram. The length of the black part of the bar shows the rough ΣP/g, while the total length shows ΣP/g after a calibration for content of sand.

In addition to the pollen and spores shown in the diagram, the following were found: *Caryophyllaceae* sp. samples 9:3, 10:1, *Cassiope* type 8:1, *Chamaenerion* 8:1, *Erigeron* type 8:2, 12:1, *Polygonum viviparum* 11:1, *Saxifraga caespitosa* type 3:1, 4:2, *Saxifraga nivalis* type 3:1, *Silene acaulis* type 5:1, P. indet. 1:2, 2:5, 3:1, 4:5, 6:1, 7:3, 8:5, 9:7, 10:7, 11:3, 14:1. Furthermore, finds of epidermis fragments of *Juncus* seeds are marked.

Pollen zone A: *Eutrema-Cyperaceae-Salix* zone (samples 1–4)

Eutrema edwardsii is the most conspicuous species during this zone, which otherwise is dominated by *Cyperaceae*. *Salix* makes up ca. 10 %. *Pedicularis hirsuta* is found in sample 1. The macrofossils are dominated by *Carex stans*, but *C. misandra*, *Draba* sp., *Juncus biglumis* or *triglumis*, *Potentilla*, *Salix* (twigs and one seed) and *Cenococcum* also occur. The content of sand is decreasing, that of pollen increasing during the zone.

Pollen zone B: *Cyperaceae* zone (samples 5–7)

In this zone *Cyperaceae* are predominant, making up 93–96 % of all pollen. *Carex stans* and *C. misandra* occur in the macrofossil samples. ΣP/g attains the maximum in this zone.

Pollen zone C: *Gramineae-Cyperaceae* zone (samples 8–9)

Cyperaceae are still most important, but *Gramineae* (10 %), *Oxyria* (4–5 %), *Saxifraga oppositifolia* (4 %) and other herbs are rather frequent, too. Part of the *Gramineae* pollen originate from *Alopecurus alpinus*. Charcoal, otherwise only sporadic, is common. The content of pollen is very low. The macrofossils include *Draba bellii*, *Dryas*, *Juncus*, *Papaver radicatum*, *Ranunculus sulphureus* and *Salix*, but no *Cyperaceae*.

Pollen zone D: *Salix-Cyperaceae* zone (samples 10–14)

Generally this zone is dominated by *Cyperaceae* and *Salix*, but the curves are undulating. By the beginning of this zone most of the herbs and charcoal characterizing the preceding zone are considerably decimated. Among the macrofossils *Draba bellii*, *Juncus*, *Melandrium apetalum* and *Salix* are the most important. ΣP/g is three times as great as in zone C.

Discussion

It was not possible to go deeper down in the frozen ground, and it cannot be said whether the sandy swamp peat is underlain by older organic sediments. But what could be observed was a very sandy, slightly humic soil with signs of solifluction. Pollen sample no. 1 and the deepest macrofossil sample may give an idea of the first vegetation on the spot, being a *Carex* stans meadow with scattered *Salix arctica* and *Pedicularis hirsuta.* At a certain time a vegetation dominated by *Cyperaceae* (still mainly *Carex stans*) and *Eutrema edwardsii* spread over the area. *Eutrema* is a high arctic species growing in moist to wet soil, either on sandy soil with *Eriophorum scheuchzeri*, or in mossy communities with *Carex misandra.* In Greenland its southern limit is at Disko on the west coast, Scoresby Sund on the east coast. It is not frequent in Peary Land, but grows in the bog today, as do most of the other plants shown in zone A. Only *Minuartia rubella*, which grows exclusively on dry soil, is not found here, but the few pollen of these plants probably originate in a somewhat distant place. Higher up the peat is mossier; apart from the numerous *Eutrema*, the vegetation must have closely resembled the current one.

The earliest dating is from this zone, but consideration of the inconsistent datings warns against using them. It can only be concluded that the dating can scarcely be too old. On the contrary, contamination with younger roots might tend to make it younger.

After some time the vegetation was totally dominated by mosses and *Cyperaceae*; *Carex stans* was the most important of these. This high arctic species with southern limits in Greenland around 68° on the west coast, 76° on the east coast is one of the most common plants in this part of Peary Land. Holmen (1957) describes two different types of vegetation dominated by this species, viz. 1) "Broad hollows which during the vegetative period are constantly wet. It is here the only species . . . in a dense cover of mosses, of which *Drepanocladus brevifolius* is the most conspicuous", and 2) "In moist, sandy flats along rivers, in deltas and on "islands" formed by anastomozing rivers. Because of the annual accumulation of sand no mosses are found here". The vegetation during zone B must have been very like the first one, and moister conditions than in

zone A seem to have prevailed. The very high $\Sigma P/g$ may be caused either by a great production of the plants growing on the spot or a slow sedimentation rate. The first explanation seems the most likely. Due to some humification, the pH of the substratum changed towards slightly acid.

Pollen zone C covers the period in which the moss peat (layer 4) was sedimentated. If the sedimentation rate was constant, it is seen from the histograms that the supply of pollen of *Gramineae*, *Oxyria* and *Saxifraga oppositifolia* also is constant, and these would merely represent a constant influx from a distant (the surroundings of the bog) source, rather than from plants growing on the spot. But the find of macrofossils of *Papaver radicatum*, *Dryas*, *Cenococcum* and *Draba bellii* indicate that *Cyperaceae* now had to share the place with a number of other plants. Everything considered, conditions must have been drier during this zone than during zone B. The reaction of the substratum has changed to alkaline, presumably a result of the mixing with aeolian (?) clay from the surrounding basic rocks.

The large amount of charcoal in the pollen samples is most conspicuous. Thus, 123 pieces were counted in sample 8. These could hardly originate from e.g. a Canadian forest fire, nor from a palaeo-Eskimo fire. But Eskimoes of a younger culture have been in Peary Land, and on Teltnæs, on the opposite side of the lake, charred *Salix* from a fireplace has been dated at 770 = 100 B.P. (K-1004, KNUTH, 1967). At Sølejren several tent rings younger than the palaeo-Eskimo types (KNUTH, personal information) bear witness of activity close to the bog. It seems reasonable to relate the charcoal maximum with this older part of neo-Eskimo culture.

In fact, very few datings of Thule-Eskimo material are at hand from northernmost Greenland, but it seems obvious to relate the inland activity with hunting of musk-oxen and possibly reindeer in a period with a frozen polar basin, and therefore a continental climate. This period, in which the Teltnæs dating falls (and layer 4 is sedimentated), is followed by a period with so much open water that the Thule-Eskimoes were able to sail by umiak north around Greenland, as proved by the find of the umiak at Herlufholm Strand (460 ± 100 B.P., K-566). Conditions may well have been more humid even in the interior during this spell (layer 5).

Judging from the colour, this moss and swamp peat layer (5) is the most humified layer in the profile and therefore formed under a rather dry vegetation with a slow sedimentation rate. However, two almost identical macrofossil samples are dominated by *Salix*, *Draba bellii*, *Melandrium apetalum* and *Ranunculus sulphureus*, which indicates

a moist community, rich in mosses. A third sample from the same layer only contains fruits of *Carex stans* and willow twigs. The real nature of this layer and its dating is subject to some uncertainty.

During the remainder of zone D *Cyperaceae* and *Salix* are the most prominent pollen producers. The pollen spectra are similar to the present one.

Summary: During zone A the climatic conditions resembled the present. After this there was a moist period (zone B), which in turn was succeeded by a dry period (zone C), presumably in the first half of the last millennium B.P. Finally, present-day conditions have prevailed during the last pollen zone (D).

Summary of the vegetational and climatic changes in North Greenland

In the Klaresø diagram the immigration of *Salix arctica* seems to have been delayed a century or two after the isolation of the lake around 5000 years ago. This may have pedological reasons, as the recently emerged marine beds may have contained too much NaCl to begin with. Apart from this possible exception, none of the diagrams from North Greenland bears witness of a plant immigration conditioned by climatic or dispersal factors. Presumably all present-day high arctic species were adapted to the arctic conditions very long ago, in early Pleistocene. During Wisconsin (and earlier glaciations) the widespread high arctic plants survived in the smaller or bigger not glaciated areas which presumably can be found at any time in high latitudes during glaciations. With the effective dispersal mechanisms, most of these species are able to spread very fast to new habitats, even if examples of slower dispersals also can be found, e.g. *Saxifraga tricuspidata*, cf. discussion in SAVILE (1972).

SAVILE (l.c.) argues that Peary Land was a refugium during Wisconsin, but the high marine limit (129 m) indicates a very heavy glacial load which would hardly allow any great ice free area. Assuming that this limit is of Late Wisconsin age, better possibilities for major refugia may have occurred in the other two areas mentioned by SAVILE, viz. Yukon and Alaska, but it can not be excluded that minor ice free areas were found in Peary Land during the glaciation.

All changes in vegetation registered in the North Greenland diagrams seem to be related to climatic changes. The amelioration opened the fjords between 5000 and 4500 B.P., and around 4000 B.P. it conditioned the relatively vigorous plant growth around Klaresø, and the beginning of the rapid sedimentation. About 3300 B.P. a minor climatic deterioration is indicated. As a result of a severe deterioration the fjords were

closed, and desert-like conditions began about 2100 B.P. Datings of basal (?) peats in Thule area and at Sølejren indicate that this deterioration did not prevail uninterruptedly until the present day. Some time during the first millennium of our era, most likely in the later half, rapid peat growth caused by moisture-conditioned plant communities indicates a greater snow-cover and a more humid summer climate. Later, around 1100–850 B.P., drier heath vegetations show a return to arid conditions.

Former pollen sedimentation

Thanks to its isolated position and its treeless vegetation (apart from tall shrubs of *Betula pubescens*, *Sorbus groenlandica* and *Alnus crispa*), Greenland offers good possibilities of studying the supply of exotic pollen. In the following discussion a distinction will be made between exotic pollen, including only non-Greenland taxa, and long distance pollen, including Greenland taxa not growing precisely in that part of the country from which the samples originate. It seems practical to treat separately the diagrams and the recent samples, though in the discussion of the fossil occurrence of single species their recent occurrence also will be considered.

Exotic and long distance pollen in the diagrams

In North and West Greenland the frequency of exotic and long distance pollen is low. In the limnic facies in Klaresø 8 exotic (5 *Pinus*, 1 *Quercus*, 2 *Ulmus*) and 13 long distance (2 *Alnus*, 6 *Betula*, 1 *Ericales*, 1 *Diphasium*, 1 *Huperzia* and 2 *Sphagnum*) were found. This is 1.0 % of ΣP (2194). In the bog at Sølejren, with a greater local production, the frequency is only 0.06 % of 15,886 (1 *Pinus*, 2 *Alnus*, 5 *Betula*, 1 *Chenopodiaceae*). In the bog profile at Sermerniut 0.04 % exotic (2 *Chenop.*, 3 *Corylus* type, 3.5 *Picea*, 17 *Pinus*, 1 *Ulmus*) and 0.16 % long distance (54 *Alnus*, 1 *Juniperus*, 52 *Artemisia*) out of a total of 65,038 pollen were found. In my analyses from the lakes at the head of Godthåbsfjord the exotic amount to 0.53 % of 7044 (2 *Ambrosia*, 1 *Carya*, 1 *Castanea*, 3 *Chenop.*, 10 *Picea*, 15 *Pinus*, 1.5 *Picea/Pinus*, 4 *Quercus*). In the bog at Itivnera the percentage is 0.37 (1 *Ambrosia*, 1 *Castanea*, 2 *Chenop.*, 7 *Picea*, 20.5 *Pinus*) with ΣP = 8519.

Even in the continental interior of South Greenland the exotic pollen (including *Artemisia*) make up only a small percentage. In the diagrams from Comarum Sø and Galium Kær it most frequently is about 0.5 % and only exceptionally exceeds 1 %, while in a certain period *Alnus*, the most important long distance species, ranges between 1 and 2 % and then decreases to less than 1 %. But in the Kap Farvel area, with its high precipitation the exotic and long distance pollen are much more important. The following table 15 includes all analyses from the corings

in this area mentioned on pp. 40–80. In the diagram from Isoëtes Sø no distinction was made between *Picea* and *Pinus*.

Table 15. *Total number of fossil exotic pollen in the Kap Farvel area.*

Acer rubrum type	2	*Fagus*	11	*Prunus* type	3
Acer saccharinum	1	*Fraxinus*	53	*Quercus*	227
Acer spicatum	2	*Humulus*	1	*Rosaceae*	4
Acer sp.	6	*Myrica*	25	*Rumex*	2
Ambrosia	89	*Ostrya*	3	*Taxus* type	8
Artemisia	198	*Picea*	277.5	*Tilia*	1
Carya	14	*Pinus*	331	*Tsuga*	18
Castanea	20	*Picea/Pinus*	680.5	*Ulmus*	11
Chenopodiaceae	30	*Plantago lanceolata*	2	*Viburnum* type	1
Corylus type	31	*Populus*	6	*Vitis*	1
Cupressaceae	10				

This gives a total of 2069 exotic pollen = 2.3 % of ΣP (88,669). A total of 3378 = 3.8 % *Alnus* was counted in the same samples (*Alnus* is included in ΣP, but exotic pollen are not included). With a material of this size it should be possible to detect any change in the influx of exotic pollen during the holocene.

6 tables (16–21) have been divided according to the pollen zones. For each zone the average n/cm²/yr has been calculated for the most important exotic pollen, *Alnus*, Σ exotic and for ΣP. Furthermore, the % of the taxon in question, based on Σ exotic in the zone in question, as well as the ratio (in %) Σ exotic: ΣP. Finally, it has been calculated how many pollen have been sedimentated per cm² in the whole history of the lake. This is listed as 10^3p. The different species will be treated separately.

Ambrosia

This genera, whose pollen constantly occur in all North American diagrams, also is frequent in the Greenland diagrams. n/cm²/yr ranges between o.1 or less in the inland diagrams to 0.2–0.8 in the coast diagrams. The material at hand is small, and it is not known whether the tendency to a higher frequency in the B-D zones in Isoëtes Sø, Spongilla Sø and Kløftsø is real. If so, it is a parallel to the *Ambrosia* maximum seen in zone C-1 in many American diagrams, whether or not this maximum is caused by long distance transported pollen from the extensive prairie in the Midwest (WRIGHT, 1968) or from decreasing forest density (DAVIS, 1969). E.g. in Rogers Lake, Conn. an *Ambrosia* maximum, reaching values (500–800/cm²/yr) half as great as at present, occur between 8500 and 5000 B.P., and in Manitoba a similar maximum (30–80/cm²/yr) begins at sometime between 11,000 and 8000 B.P. and lasts until ca. 6000 B.P. (RITCHIE, 1969).

Pollen zone	*Ambrosia*		*Artemisia*		*Chenopodiaceae*		*Fraxinus*		*Picea + Pinus*		*Quercus*		Σ exotic			*Alnus*		Σ P	
	n	%	n	%	n	%	n	%	n	%	n	%	10^3	n	% of Σ P	n	%	10^3	n
G.....	0.3	2.0	0.9	7.5	0.3	2.9	0.2	2.0	8.6	71	0.8	6.8	31.6	12	3.7	12	100	849.3	327
F.....	+	0.2	1.1	6.4	0.2	1.1	0.3	1.5	11	68	1.3	7.8	25.6	17	3.9	14	85	662.3	430
E.....	1.1	3.5	2.8	9.0	0.2	0.6	0.2	0.5	21	67	1.7	5.3	54.7	31	5.5	51	165	999.0	569
D.....	1.9	7.5	2.2	8.7	0.3	1.1	1.0	3.9	15	60	2.3	9.0	45.3	26	5.2	80	310	869.8	494
C.....	1.1	6.8	1.1	7.3	0.3	1.7	0.6	4.1	8.1	53	2.8	18	21.4	15	6.4	13	86	333.3	240
	(1.6)		(1.7)		(0.4)		(1.0)		(12)		(4.3)			(23)		(20)			(367)
B.....	0.7	4.4	1.0	6.4	0.1	0.8			5.7	38	5.5	37	6.6	15	9.5	7.2	48	69.7	164
A.....			1.1	9.8					4.9	45	3.6	33	2.5	11	19	3.5	33	13.3	58
A–G.....	0.78	4.1	1.6	8.5	0.24	1.3	0.39	2.1	12	63	1.8	9.7		19	4.9	31	163		384
10^3 p.....	7.7		16.1		2.4		3.9		118.8		18.3		187.8			306.3		3796	

Figures in ( ) denotes n with a fast sedimentation rate (cf. p. 34).
n = average number of pollen sedimentated per cm^2 per year.
10^3 p = number of pollen (in thousands) sedimentated per cm^2 during the whole period.

Table 17. *Spongilla Sø, number and ratio of exotic Pollen, Alnus and Σ P in the zones.*

Pollen zone	*Ambrosia*		*Artemisia*		*Chenopodiaceae*		*Fraxinus*		*Picea*		*Pinus*		*Quercus*		Σ exotic			*Alnus*		Σ P	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%	10^3	n	% of Σ P	n	%	10^3	n
G.....	0.3	7.3	0.3	5.8	+	0.1	0.1	3.0	2.2	47	1.0	21	0.1	1.6	9.6	4.5	2.6	6.2	137	375	177
F.....	+	0.7	0.5	7.9	0.3	4.8	0.2	2.9	3.2	46	1.6	23	0.6	8.2	12.7	6.8	2.9	8.7	126	435	235
E.....			0.3	5.7	0.1	1.2	0.2	3.3	2.7	46	1.5	25	0.2	3.9	9.6	5.7	4.2	6.5	113	228	437
D.....	0.1	3.2	0.4	11	+	1.3	0.2	4.3	0.4	12	2.0	56	0.3	9.6	8.4	3.6	2.4	9.8	274	352	149
C.....	0.6	7.7	0.4	5.1	0.2	3.0	+	0.8	0.5	6.9	3.5	45	1.4	19	7.8	7.7	2.2	9.0	118	357	352
	(0.8)		(0.5)		(0.3)				(0.7)		(4.9)		(2.0)			(11)		(13)			(493)
A+B...	0.5	2.8	1.2	7.2			0.5	3.2	0.8	4.8	5.6	34	4.3	26	8.5	16	4.2	8.6	53	200	384
A–G....	0.2	3.3	0.4	7.1	0.1	1.9	0.2	3.0	1.7	30	1.9	33	0.6	11		5.8	2.9	7.9	136		202
10^3 p...	1.9		4.0		1.1		1.7		16.8		18.5		6.1		56.5			76.5		1947	

Table 18. *Kløftsø, number and ratio of exotic pollen, Alnus and ΣP in the zones.*

Pollen zone	*Ambrosia*		*Artemisia*		*Chenopodiaceae*		*Fraxinus*		*Picea*		*Pinus*		*Quercus*		Σ exotic			*Alnus*		Σ P	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%	10^3	n	% of ΣP	n	%	10^3	n
G.....	0.1	4.1	0.4	15			0.1	2.8	1.5	51	0.5	19			10.0	2.8	0.9	4.9	161	1074	318
F.....	0.1	1.4	0.7	7.6			0.2	2.4	4.0	42	1.9	20	0.7	7.6	9.0	8.5	1.0	17	180	878	930
E.....	0.8	5.1	1.1	7.5			0.3	1.8	4.4	30	5.9	41	0.8	5.2	19.9	15	1.8	25	170	1103	808
D.....	0.3	5.3	1.1	19	0.1	1.7	0.3	4.3	0.5	9.2	1.9	33	0.8	1.3	13.5	5.9	1.4	28	485	963	417
C.....	1.0	6.4	1.0	19	0.1	2.1	0.3	6.4	0.3	5.6	2.3	41	0.4	6.8	4.6	5.2	1.8	8.7	167	257	293
	(0.6)		(1.7)		(0.2)		(0.6)		(0.5)		(3.6)		(0.6)			(9.5)		(15)			(490)
B.....	0.2	7.0	0.6	19			0.5	16	0.1	1.6	1.1	38	0.1	1.9	1.7	3.0	1.4	5.3	191	125	214
	(0.3)		(0.9)				(0.8)		(0.1)		(1.9)		(0.1)			(5.0)		(9.5)			(358)
A.....	0.1	2.9	1.0	23	0.1	2.3			0.1	2.9	2.2	49	0.3	5.7	1.5	4.4	3.0	0.9	21	51	146
	(0.2)		(1.7)		(0.2)				(0.2)		(3.6)		(0.4)			(7.3)		(1.6)			(246)
A–G ...	0.3	4.5	0.8	13	+	0.6	0.2	3.3	1.7	27	2.0	32	0.4	6.5		6.2	1.4	15	237		461
10^3 p ...	2.7		7.9		0.4		2.0		16.4		19.5		3.9		60.2			142.8		4452	

Table 19. *Drepanocladus Dam, number and ratio of exotic pollen, Alnus and ΣP in the zones.*

Pollen zone	*Ambrosia*		*Artemisia*		*Chenopodiaceae*		*Fraxinus*		*Picea*		*Pinus*		Σ exotic			*Alnus*		Σ P	
	n	%	n	%	n	%	n	%	n	%	n	%	10^3	n	% of ΣP	n	%	10^3	n
D.....	0.3	3.2	1.6	20			0.5	6.6	4.9	62	0.6	7.7	3.0	7.8	0.3	13	171	1017	2650
C.....			0.4	2.8			0.1	0.6	5.1	36	5.0	36	7.5	14	0.6	7.1	51	1167	2180
B.....			1.4	16	0.3	3.6	0.7	8.1	3.2	38	0.7	8.2	11.8	8.4	0.2	8.4	100	5024	3550
B–D.....	+	0.4	1.2	12	0.2	1.8	0.5	5.1	3.9	39	1.7	17	22.4	9.6	0.3	8.9	89	7208	3100
A.....									11	56	8.0	44	19.7	19	0.1	8.1	43	14681	14150

Table 20. *Comarum Sø, number and ratio of exotic pollen, Alnus and ΣP in the zones.*

Pollen zone	*Ambrosia*		*Artemisia*		*Chenopodiaceae*		*Fraxinus*		*Picea +Pinus*		*Quercus*		Σ exotic			*Alnus*		Σ P	
	n	%	n	%	n	%	n	%	n	%	n	%	10^3	n	% of Σ P	n	%	10^3	n
G									4.2	97			4.3	4.4	0.3	2.6	61	1683	1710
F			0.2	0.6	0.7	1.8			2.9	79			3.6	3.7	0.3	5.3	142	1418	1475
E			1.2	30	0.1	2.2			2.5	62			7.7	4.0	0.3	6.6	163	2805	1475
D	0.2	2.5	0.2	2.5					5.8	79	0.6	8.4	8.0	7.3	0.5	13	180	1513	1385
C			0.6	8.9					4.6	73	0.1	1.9	16.4	6.3	0.7	16	257	2472	945
B	0.3	6.4	1.2	23					3.6	71			5.0	5.1	0.7	8.5	168	722	745
	(0.4)		(1.5)						(4.5)					(6.3)		(10)			(917)
A	0.5	20	0.4	13			0.2	5.9	1.0	38	0.3	9.1	3.0	2.7	0.7	3.8	141	458	417
	(1.1)		(0.8)				(0.3)		(2.1)		(0.5)			(5.5)		(7.8)			(851)
A–G	0.12	2.3	0.6	12	0.1	1.7	+	0.4	3.8	72	0.1	2.6		5.3	0.4	9.8	186		1210
10^3 p	1.1		5.7		0.8		0.2		34.6		1.3		47.8			89.0		11071	

Table 21. *Galium Kær B, number and ratio of exotic pollen, Alnus and ΣP in the zones.*

Pollen zone	*Ambrosia*		*Artemisia*		*Picea +Pinus*		Σ exotic			*Alnus*		Σ P	
	n	%	n	%	n	%	10^3	n	% of Σ P	n	%	10^3	n
G	0.4	13	0.4	13	2.3	74	1.6	3.1	0.1	6.8	218	1314	2610
F			1.2	22	3.0	53	3.0	5.7	0.1	8.8	155	3297	6140
E			0.1	1.0	4.7	99	9.3	4.7	0.1	5.5	111	9039	4630
D					1.8	100	4.3	1.8	0.1	16	865	6855	2860
C			1.5	8.9	15	86	11.4	17	0.3	41	242	4420	6600
B			1.0	12	4.3	53	9.2	7.9	0.1	62	780	15699	13650
A										43		10161	50800
A–G	+	0.5	0.4	8.0	3.9	80		4.9	0.1	21	428		6400
10^3 p	0.2		3.1		30.9		38.7			165.7		50785	

The recent forest clearance and cultivation is reflected in huge amounts of *Ambrosia* pollen in sub-recent and recent pollen samples all over North America, and even in 18 out of 21 recent samples from Kap Farvel (table 22) *Ambrosia* is found, making up 0.33 % of ΣP on the average. In the samples from the interior South and from West and North Greenland it is like all other exotic less frequent but it was found in even 2 out of 15 samples at Sermermiut. In Arctic Canada it also is a not infrequent component, see e.g. LICHTI-FEDEROVICH & RITCHIE (1968) and NICHOLS (1970). According to RITCHIE & LICHTI-FEDEROVICH (1967) *Ambrosia* makes up 0.1–0.9 % in the dwarf-shrub tundra in Northeast Canada, and in the arctic desert at Resolute 4 %.

Artemisia

This is one of the most important long distance pollen. *Artemisia borealis* grows in West Greenland today, being common in dry soil communities in the interior between 63° and 72°30′ N. No attempt has been made to try to separate the pollen of this species from other species. All finds of *Artemisia* pollen in South Greenland deposits are considered as having originated from abroad, and are therefore included in exotic pollen in the diagrams and tables.

The occurrence is rather constant throughout the pollen zones. It makes up 7–13 % of exotic pollen. The average n/cm²/yr ranges between 0.4 and 1.6. In late-glacial sediments in North America it has an extended maximum, which decreases concurrently with the forestation, but unlike *Ambrosia*, it has no pronounced recent maximum. In the tundra samples it makes up 0–2.1 %, equating 0–3.8/cm²/yr (RITCHIE & LICHTI-FEDEROVICH, 1967). The high frequencies in the Sermermiut samples must be ascribed to more local sources, as the site is within the Greenland range of *Artemisia*. But it was not observed within the nearest few km.

In South Greenland *Artemisia* accounts for 0.13 % of ΣP in the recent samples from the outer coast, half as much in the interior. While in the fossil samples *Artemisia* occurs more than twice as often as *Ambrosia*, the reverse is the case in the recent samples, in accordance with the recent *Ambrosia* maximum in North America.

Chenopodiaceae

It must be admitted that no attempt has been made to determine genera within this family; furthermore *Amaranthaceae* pollen may also be included. The finds are too few to reveal any change during the course of time. The occurrence of early holocene *Chenopodiaceae* pollen in Greenland was discussed on p. 150. The average n/cm²/yr does not exceed 0.2. In the recent samples 3 grains were found in the Kap Farvel area, 1 at Sermermiut.

Fraxinus

Among the deciduous trees *Fraxinus* is the third most important after *Alnus* and *Quercus*. Most grains were tetracolpate, resembling *Fraxinus pennsylvanica* (RICHARD, 1970), but several species doubtless are included. It amounts to 1–5 % of exotic pollen in the Kap Farvel samples, ranging between 0.2 and 0.5/cm²/yr. In the diagrams with most finds there is a tendency towards a greater occurrence in the older zones. *Fraxinus* is of minor importance in most North American diagrams, yet it can occur in great numbers in zones C–1 and C–2, e.g. 500–1000/cm²/yr in Rogers Lake (DAVIS, 1969). In recent samples it was only found once, and in Arctic Canada it is not included in the list in RITCHIE & LICHTI-FEDEROVICH (1967). In the recent samples from eastern and central Canada and adjacent United States (DAVIS, 1967) it was found in 29 out of 94 samples, rarely exceeding some few %.

Picea and *Pinus*

Among exotic pollen, conifers are the most important. Unfortunately a distinction between *Pinus* and *Picea* was not made until the latest diagrams were counted. From these it appears that in the first zones *Pinus* was about 10 times as frequent as *Picea*, while in the most recent zones *Picea* is about twice as frequent as *Pinus*. In Spongilla Sø the decline in *Pinus* can be dated at ca. 3500 B.P., in Kløftsø ca. 3700 B.P. The incline in *Picea* can be dated at 5000 and 4700 B.P.

A *Pinus* maximum is common to all Southeast Canadian and New England diagrams starting at the beginning of zone B, roughly 9000 B.P., lasting shorter (Rogers Lake until ca. 8000 B.P.) or longer, e.g. to the end of zone C–1 around 5500–5000 B.P. (Upper Gillis Lake, N.S.), or even to the end of C–2 around 4500 B.P. (Salmon River Lake, N.S. and Bluff Lake, N.S.; LIVINGSTONE, 1968). In none of the diagrams mentioned, however, has *Picea* played any role since the late glacial, and the sources of the *Picea* pollen must be sought farther north, reflecting the spreading of *Picea* to the vast areas now occupied by forest tundra and northern conifer forests. In this context the dated diagrams from interior Labrador (MORRISON, 1970) are important, showing that between 5500 and 5200 B.P. *Picea* increased from almost zero to 75 %; This high frequency has remained almost unchanged until the present. This should be compared with the results from Kløftsø (table 18), in which *Picea* pollen makes up 1–9 % of the exotic pollen between 9000 and 4700 B.P. and then sharply increases, reaching a maximum in the last pollen zone of 51 %.

Together, *Pinus* and *Picea* make up the greater part of exotic pollen in Greenland, ranging between 56 and 80 % for the whole period in the six lakes counted absolutely. In n/cm²/yr the number varies between 3.6 and 5.6 in the five lakes, reaching 12 in Isoëtes Sø. In the recent samples

Picea makes up 0.56, Pinus 0.27 and not distinguished conifers 0.09 % of ΣP (13,523) in the outer coast samples, less in the interior and farther north.

Quercus

Quercus is the most frequent exotic deciduous tree pollen type. Therefore the greater frequency, absolutely as well as relatively, in the older zones must be significant. In New England *Quercus* is the most important tree pollen since the beginning of zone B. In Nova Scotia *Quercus* reaches a maximum in C–1 and C–2, but is generally much less important in this area, where *Betula* and *Pinus* characterize the spectra.

In the outer coast diagrams from South Greenland n/cm²/yr vary on the average between 0.4 and 1.8 for the whole period. In the diagrams from the interior of South and West Greenland it is rare. No grains were found in Drepanocladus Dam, Comarum Mose, Galium Kær B, Itivnera, Sermermiut, nor in Peary Land. In Galium Kær A six grains, in Comarum Sø three, and in lakes at Godthåbsfjord four grains occurred.

Only four grains have been found in the recent samples from the Kap Farvel area, all in outer coast samples. They were not caught in the traps in Arctic Canada, and were not found in surface samples from Arctic Quebec (BARTLEY, 1967).

Σ exotic

In arctic and late-glacial forestless areas the importance of long distance pollen has long been realized. In high latitudes where pollen-carrying winds blow in from forested areas, the long distance pollen may amount to 70 % (Resolute on Cornwallis Island, RITCHIE & LICHTI-FEDEROVICH, 1967) or even more (Spitsbergen, HYVÄRINEN, 1972). In phases a and b in the Kap Farvel diagrams exotic pollen make up between some few and twenty % of ΣP. *Betula* and *Alnus* should be added to this. Concurrently with increasing local pollen production, the relative importance of exotic and long distance pollen decreases, but the absolute counts demonstrate that generally speaking, the yearly influx remains fairly constant through all the phases. At least, any changes may as well be explained by changing local conditions such as changing matrix (and thereby pollen) sedimentation rates. The differences in the total amount of exotic/cm² (= 10^3p) between nearby lakes will be discussed together with changes in pollen sedimentation.

Alnus

Alnus crispa is distributed in West Greenland from Arsuk Fjord (ca. 61° N, 48° W) to Nordre Strømfjord (ca. 67°25′ N). Outside this main area it has an isolated occurrence at Torssukátak (60°56′ N, 46°48′ W),

and recently it has been observed southeast of Søndre Igaliko at the long lake behind Qordlortorssûp tasia (ca. 60°51–54′ N, 45°06–02′ W; L. KLIIM-NIELSEN, verbal information). Towards the northern limit it shows a decidedly continental distribution, found only at the head of the fjords, but farther south it also prefers the interior. Its ecological demands are discussed in BÖCHER (1949). According to these, it must be characterized as a subcontinental plant with a distribution whose northern limit runs parallel to the summer isotherm. Its southern limit is almost identical with the northern limit of *Betula pubescens*, not due to competition, but apparently to some climatic factors. BÖCHER (l.c.) put forward the theory that the southern limit is historically, not climatically conditioned, but it seems difficult to understand that once *Alnus* had gained its foothold at Nordre Sermilik and even farther east, it did not spread e.g. to the head of Sermilik and Tunugdliarfik. Its dispersal power to an area covered with heaths and willow scrubs was clearly demonstrated by its late holocene spreading from North America to the head of Godthåbsfjord.

Judging from the diagrams from Kap Farvel and Qagssiarssuk it can be maintained that it never grew in any of these areas, even if a glance at e.g. the diagram from Isoëtes Sø with 15 % *Alnus* through a long period might make one assume that this is a local growth.

A common trend in the *Alnus* curves is evident from the tables (16–21) and the diagrams: At a certain period in the middle holocene *Alnus* became very important, exceeding Σ exotic by a factor 2–5. By interpolation of the datings this period began between 7700 and 6900 and lasted until between 5500 and 5100 B.P. During this period pollen assemblages characteristic of zone C–1 were sedimentated in the lakes in Nova Scotia, New England and adjacent parts of USA and Canada. In these *Alnus* usually makes up only 1–20 %, e.g. in GILLIS Lake (LIVINGSTONE & LIVINGSTONE, 1958), Brownington Pond (DAVIS, 1965) and a number of lakes mentioned in WRIGHT (1971). In some lakes, e.g. Silver Lake, N.S. (LIVINGSTONE, 1968) and Rogers Lake, Conn. (DAVIS, 1969) the frequency may reach 10–15 %, but then conifers and *Quercus* are even more frequent.

WENNER (1947) has some holocene samples rich in *Alnus* from Labrador, and the diagrams from interior Labrador (MORRISON, 1970) make it seem reasonable to search for the source of the South Greenland *Alnus* maximum there: After a brief pioneer period (with 25 % long distance *Alnus*) *Alnus*, *Betula* and *Salix* occupied vast areas, and around 5600 B.P. *Alnus* makes up 75 % of all pollen (on the average of 7 diagrams). This maximum is succeeded by a shortlived *Betula* maximum of 50 % around 5300 B.P, which in turn is succeeded by the mentioned *Picea* maximum. During this *Alnus* makes up only 5 %. According to BRYSON *et al.* (1969) the part of Labrador investigated by MORRISON is the last

one to be deglaciated. At Mackenzie River a marked increase in *Alnus* is dated at 5500 B.P. (RITCHIE, 1972).

During the *Alnus* maximum n/cm²/yr varies between 10 and 80 in the Kap Farvel lakes, between 16 and 62 at Qagssiarssuk. In the recent zone the number is between 2.6 and 13, in accordance with the result obtained by the Tauber traps at Qagssiarssuk in 1969 (5.0–5.5, table 23). The importance of *Alnus* as a long distance pollen and a prolific producer has been demonstrated repeatedly, e. g. by LIVINGSTONE (1955), who found 5–10 % *Alnus* pollen 120 km north of the nearest alder bush, by NICHOLS (1970), who found 4–17 % *Alnus* in recent samples at Pelly Lake and 15–20 % throughout the diagram, hundreds of km north of recent *Alnus* growth and by COLINVAUX (in TEDROW, 1972) who found 36 % *Alnus* in a 0–3 inch sample on Prince Patrick Island, Canada, 600–700 miles from the nearest alder shrub. By means of the absolute counts (n/g) and datings, I have calculated n/cm²/yr (provided that 1 cm³ corresponds to 2 g) to be around 20 in the interval 3400–2100 B.P., 40 in the interval 2100–900 B.P. at Pelly Lake. In the recent tundra samples RITCHIE & LICHTI-FEDEROVICH (1967) found 1.5–5.8 % *Alnus* (0.8–26/cm²/yr), and in recent *Sphagnum* and other moss polsters in Northern Ungava, ca. 500 km from *Alnus* scrub, BARTLEY (1967) found 0.2–3.0 %.

In the recent samples from the outer coast at Kap Farvel *Alnus* amounts to 1.52 % on an average of 21 samples, while in the interior the frequency is only about one third (0.51 % on an average of 6 samples). In the recent samples from the head of Godthåbsfjord, where *Alnus* grows today, the percentage varies between 9 and 20. Farther north, at Sermermiut, only 0.05 % *Alnus* pollen was found in the recent samples, 0.08 % in the fossil.

Concerning pollen production and dispersal, *Betula* behave like *Alnus*. Once it is realized that the *Alnus* pollen in the whole holocene in South Greenland and prior to its immigration to West Greenland in the hypsithermal between 5000 and 4000 B.P. are long distance transported, there should be no hesitation to accept that there also has been a constant influx of *Betula* pollen, especially since in many New England and in most Nova Scotia and Quebec diagrams *Betula* accounts for 30–35 % of ΣP during the whole holocene. This means that not until the marked increase in the *Betula* curves *Betula* grew in the area dealt with.

The average recent spectrum of exotic and long distance pollen in the outer coast Kap Farvel samples (table 22) is: *Ambrosia* 21 %, *Artemisia* 8.5, *Castanea* 0.7, *Chenopodiaceae* 2.0, *Fraxinus* 0.7, *Picea* 36, *Pinus* 18, *Picea/Pinus* 5.8, *Quercus* 2.0, *Rumex* (not *acetosella* type) 0.7, *Viburnum* type 0.7, indet. 3.9 % of Σ exotic. Besides, *Alnus* makes up 99 %. Broadly outlined, this spectrum resembles the recent spectra from the Alder zone of Labrador (WENNER, 1947), from northern Quebec

(TERASMAE & MOTT, 1964) and from the area south of James Bay (DAVIS, 1967), but mostly the *Alnus* percentages are too low.

The evidence from the exotic pollen and *Alnus* seems to justify the following tentative interpretation of the changes in influx of exotic pollen to the South Greenland lakes: Between 10,000 and 8000 B.P. the ice covered East Canada down to the Great Lakes. The pollen-carrying winds either crossed this ice shield, bringing i.a. *Artemisia* and *Ambrosia* from the Midwest, or they passed along the shield, picking up pollen from the ice-free areas around Gulf of St. Lawrence. Here *Betula* and *Pinus* dominated the pollen spectra (e.g. Silver Lake, N.S., Folly Bog, N.S., Harriman Lake, P.Q.; LIVINGSTONE, 1968), as they did in South Greenland. Nothing is known about the vegetation in the eastern part of Labrador at this time. Following the rapidly disintegrating Laurentian ice in Central Labrador between 8000 and 5000 B.P. were *Alnus-Betula-Salix* scrubs, which in turn were succeeded by *Picea* forest. Presumably the southerly winds reaching South Greenland now turned more to the southwest and west, bringing first great amounts of *Alnus*, later of *Picea* pollen. The present day rain of exotic and long distance pollen in South Greenland has its main source area in Labrador and adjacent parts of Canada, but of course it is diluted with pollen from a much wider area.

The changes in prevailing winds during spring and summer implied above seem to be supported by the gradual northward dislocation ca. 8500 B.P. of the low pressure centre from the Great Lakes - St. Lawrence region to Baffin Island (LAMB *et al.*, 1966).

Variation and changes in pollen sedimentation

As discussed by DAVIS (1969) the changes in absolute counts in a core are caused either by changes in the composition of the surrounding vegetation or by changes in matrix sedimentation. In the first case, a contemporaneous change in the pollen spectrum is evident, in the second, it is not seen. DAVIS (l.c.) considers changes in pollen deposition by less than a factor five insignificant.

It might be expected that the number of exotic pollen/cm^2/yr is constant within a fairly great area. Judging from the results obtained, however, this does not seem evident. E.g. in Isoëtes Sø and Spongilla Sø two lakes of almost the same size and only 400 m apart, the number of exotic pollen (expressed as 10^3 grains/cm^2) during holocene is 187.8 and 56.5 resp., and of *Alnus* the numbers are 306.3 and 76.5 resp. In this context it is unimportant that the sedimentation period is a few hundred years longer in Isoëtes Sø. In some lakes quite normally a difference by a factor 3 of pollen deposition within the same basin occurs (DAVIS *et al.*, 1973), but this seems to be connected with larger lakes with a bottom

topography causing currents of varying intensity. In small lakes quite another problem seems to be of paramount importance: The ratio between the surface and the part of the bottom where the pollen can be deposited permanently, or, in other words, deep enough to allow for a sedimentation not disturbed by ice. In small lakes and ponds in a polished landscape not only the actual surface of the lake but also of the surrounding slopes, from where the rainwater runs down to the lake, not filtered through a vegetation cover, is of importance. Only a minor part of Isoëtes Sø is sufficiently deep for gyttja to be sedimentated, while in Spongilla Sø gyttja covers almost the whole bottom. With a correction of the stated ratio, 10^3 p as well as n for exotic and *Alnus* are expected to be more similar.

The sedimentation of ΣP/cm²/yr is much greater in the interior. Thus, on the average for the latest pollen zone it amounts to 177, 318 and 327 for the outer coast diagrams, as compared to 1710, 2610 and 2650 for the diagrams from the head of the fjords (tables 16–21). PENNINGTON & BONNY (1970) calculated n to vary between 1000 and 3000 during Allerød in Blelham Bog, England. Yet in the Younger Dryas samples from this locality the number decreases to 500–1000, or almost the same size of order as in today's interior South Greenland fjords. In Rogers Lake, Conn., n is 500–1000 in the willow-herb zone 15,000–12,000 B.P., followed by an increase by a factor 50 (!) between 12,000 and 9000 B.P. as the forest immigrated (DAVIS, 1969).

In the tundra phase in Lake Joncas bog, Quebec, RICHARD (1971) calculated n to be app. 300, and in the following *Betula glandulosa* phase app. 1000. And in the tundra zone, with spruce at lower elevations, in Buckle's Bog, Md. (DAVIS *et al.*, 1973), n varies between 1000 and 2000. The results from Greenland thus confirm the statement by CRAIG (1972) of a pollen influx of about 1000/cm²/yr in full-glacial and late-glacial herb-dominated environments, and by DAVIS *et al.* (l.c.), that the fossil influx in tundra regions ranges between 500 and 2000.

A greater deposition of exotic pollen might be assumed for the outer coast areas due to the higher precipitation, but the material is too scant to confirm this.

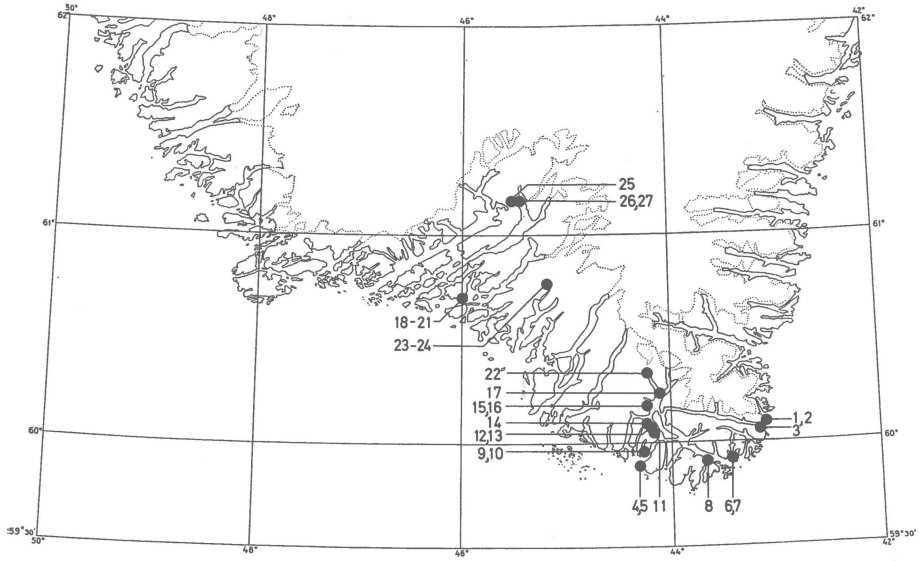


Fig. 30. Map of South Greenland showing the position of recent gyttja samples.

Recent pollen sedimentation

Recent gyttja samples

Recent gyttja samples were taken from a number of lakes and ponds in South Greenland in 1970, (fig. 30) as well as from the cored lakes at the head of Godthåbsfjord in 1960. Brief descriptions of the localities will be given below:

1. Nunato (60°05′.4 N, 43°05′.6 W). A pond 12×8 m, with *Isoëtes setacea*, *Eriophorum* and mosses. Depth of water 35 cm. Vegetation within the nearest 50 m: 60 % *Empetrum*, 25–30 % herbs (many *Nardus*). *Salix glauca*, *Juniperus* and *Vaccinium uliginosum*. *Betula glandulosa* grows in the environs. Sample taken by U. RØEN (loc. U.R. 654).
2. Nunato (60°05′.6 N, 43°05′.9 W). A pond 9×9 m, without hydrophytes. Depth of water 25 cm. Surrounded by *Salix herbacea* snow-patches and marshes. Taken by U. RØEN (loc. U.R. 655).
3. Prins Christians Sund (60°02′.2 N, 43°11′.0 W). Rounded pond, 15 m in diameter. No hydrophytes. Within the nearest 100 m: 60 % *Empetrum*, a few specimens of *Salix glauca*, *Vaccinium uliginosum*, *Betula glandulosa*, but no *Juniperus*. *Nardus* dominating among the herbs. Taken by U. RØEN (loc. U.R. 658).

4–5. Tôrnârssuk (59°54′ N, 44°23′ W). On the southwest corner a one km long, 140 m high, barren peninsula juts into the North Atlantic. The vegetation is totally dominated by *Empetrum* heaths, rich in

mosses and lichens. *Salix* and expecially *Vaccinium uliginosum* are rare. A total of max. 10 small specimens of *Juniperus* and one poor *Betula glandulosa* were observed during two days. Herbs constitute 10–15 % of the vegetation cover. *Carex stylosa*, *C. bigelowii* and *Festuca vivipara* dominate. *Nardus* only occurs on some small shelves having a southern exposure. Slopes with a northern exposure are covered with snow-patches rich in mosses. Sample no. 4 is from a 5×8 m pond with *Hippuris* and *Isoëtes setacea*. Depth of water 20 cm. No. 5 is from a pond, 10×20 m, with *Isoëtes setacea*.

6–7. Qernertoq (59°54′.5 N, 43°30′ W). The southern, low part of the 9×2 km peninsula which stretches out into Ikeq is covered by ericaceous dwarf-shrub heaths, with *Empetrum* dominating. Sample 6 is from a quite deep lake, 25×60 m, ca. 100 m a.s.l. An estimated ratio *Empetrum: Betula glandulosa: Vaccinium uliginosum: Salix glauca* in the environs is 10:2:2:1, and the ratio dwarf-shrubs: herbs is 9:1. There is a single specimen of *Juniperus*. Loc. 7 is a circular lake, 40 m in diameter. Sourroundings dominated by barren rocks, *Empetrum* heaths, and more *Nardus* heaths than around the preceding lake.

8. Eggers Ø, Triangelsø, see p. 71.

9. Pamiagdluk, Isoëtes Sø, see p. 41.

10. Pamiagdluk, Spongilla Sø, see p. 54.

11. Pamiagdluk, Kløftsø, see p. 62.

12. Pamiagdluk, Naujarssuit, 20×25 m pond, ca. 400 m a.s.l. on the east slope (60°03′.5 N, 44°17′ W). Depth of water does not exceed 1 m. Surrounded by bare rocks and snow-patches with *Sibbaldia*, *Harrimanella*, *Diphasium alpinum*, *Athyrium*, *Oxyria*, *Phyllodoce* and *Taraxacum*.

13. Pamiagdluk, Anordliuitsoq, 60°05′N , 44°16′ W. The big lake, ca. 1 km in diameter. The sample was taken at 1.5–2 m depth of water. Dwarf-shrub heaths cover ca. 80 % of this part of the island, dominated by a great variety of *Empetrum* heaths. Estimated ratio *Empetrum: Betula glandulosa: Vaccinium uliginosum: Salix glauca* = 10:3–4:2:0.5. *Juniperus* rare. A few tiny specimens of *Betula pubescens* were observed once on a favoured spot. *Nardus* and other grasses make up 15 %, *Cyperaceae* plus various herbs 5 %.

14. Pamiagdluk, Sphagnum Dam, see p. 69.

15–16. Ivssortussut, 60°11′.5 N, 44°16′ W. A small, low, peninsula stretching out into Ilua mainly consists of bare rocks with poor fragments of *Empetrum* heaths. In a pond 10×15 m with *Callitriche* and *Isoëtes setacea*, 2 samples were taken at each end with an interval of two weeks.

17. Nûk, 60°14′ N, 44°10′ W is another peninsula in Ilua with an abandoned settlement. *Empetrum* heaths dominate the vegetation. A sample was taken in a 5×18 m pool in the polished bedrock.

18–21. Julianehåb (60°43′ N, 46°03′ W). Dwarf-shrub heaths with *Empetrum* the dominant, and *Salix glauca* as the subdominant, cover the greater part of the area. Here and there *Betula glandulosa* and *Vaccinium uliginosum* are common, while only a few single *Juniperus* were seen. 4 recent gyttja samples were taken: no. 18 in a pond north of the town, 25×20 m wide, with *Isoëtes setacea* and *Sparganium hyperboreum*. No. 19 is from a 50×50 m pond north of the town, with *Isoëtes setacea* and *Sparganium hyperboreum*; no. 20 is from a 10×20 m pond northeast of the town, 100 m a.s.l., with the same two species, and no. 21 is from a 200×75 m lake at Munkebugt west of the town. *Hippuris* and submersed *Ranunculus reptans* were observed.

22. Tupaussat, Drepanocladus Dam, see p. 72.

23–24. Amitsuarssuk, 60°46′ N, 45°13′ W. The head of the fjord is famous for its up to 6 m high birch forest. In a lake ca. 150 m a.s.l., above the greatest waterfall in Greenland, N. Jacobsen took a sample (no. 23). It was not possible to take a gyttja sample from the bottom of the big lake, almost 1 km long, between the waterfall and the fjord, but a sample of the clayey coating on the stones at the water's edge was scraped away (no. 24). This sample had a very strange pollen spectrum.

25. The isthmus between Tunugdliarfik and Nordre Sermilik, 3 km west of Qagssiarssuk (61°09′ N, 45°33′ W). A lake 100×40 m close to the watershed is surrounded by marshes. *Salix glauca* dominates among the dwarf-shrubs, whereas within the nearest 100 m *Betula* is rare. But in the area as a whole, *B. glandulosa* is very common. No hydrophytes were observed in the beginning of July.

26. Qagssiarssuk. Ca. 100 m east of Comarum Sø (see p. 91), a 120×80 m lake is situated ca. 150 m a.s.l. The vegetation in and at the lake is rich, including *Potamogeton alpinus*, *Sparganium angustifolium*, *S. hyperboreum*. Partly submerged, partly growing on the gravelly beach above the water table in the late summer, are *Subularia*, *Ranunculus reptans* and *Isoëtes setacea*. On the latter place they are accompanied by *Limosella* and *Callitriche verna* and slightly drier, *Rorippa islandica*. In this lake I found in 1969 some mucous, intense green coatings on the underside of stones. Based on my description, U. Røen presumed this to be *Spongilla* sp., new to Greenland, and on a visit in 1970 this was confirmed. An analysis of the water is seen in table 1.

27. Qagssiarssuk, Comarum Sø, see p. 91.
28. Godthåbsfjord, lake at Itivnera, see p. 155.
29. Godthåbsfjord, "Lake 8 m", see p. 144.
30. Godthåbsfjord, lake in Itivneq (p. 153). Two samples–a and b–from different depths in the middle of the lake were analyzed.
31. Godthåbsfjord, "Lake 100 m", see p. 138. The sample has been analyzed by JOHS. IVERSEN.

The result of the analyses appears in table 22 (inside the backcover) The localities are broadly arranged according to their "oceanity". A calculation of the average spectrum of what have been called the outer coast samples follows locality 21. Six samples from the interior of South Greenland and an average then follow. Finally, the table shows the spectra from 5 lakes at the head of Godthåbsfjord. In these samples *Artemisia* is included in ΣP. The two samples 30a and 30b were taken on the same day, not far apart. Both analyses are given, but in calculating the average from the 5 lakes they are treated as one sample, no. 30.

The material from the interior is inadequate, but even so, the table shows some characteristic features. The difference in ericaceous pollen, mainly *Empetrum*, is most conspicuous: 21 % at the outer coast as compared to 1.7 % in the interior South and 6.2 % at Godthåbsfjord. *Empetrum* attains its maximum (42 and 48 %) at Nûa on Tôrnârssuk (loc. 4 and 5) where the pools are not surrounded by a marsh, as is the case in loc. 1–3. Apart from loc. 2, *Empetrum* always exceeds 7 % at the outer coast, but never exceeds 2.2 in the interior, where *Empetrum* is missing in 3 out of 6 samples. Characteristic of the outer coast spectra also are: higher frequencies of *Alnus* (1.5 against 0.5 %), of exotic (1.5–0.4 %) and *Cyperaceae* (24–15 %). Also, *Coptis* (5 localities) and *Oxyria* (6 loc.) as well as some rare pollen types have only been found at the outer coast, but the material is not sufficient to confirm the assumption that these also are characteristic.

In the spectra from the interior, *Gramineae* may be more common (16 as compared to 11 %), but most characteristic is a number of herbs: *Angelica* (0.40–0.01 %), *Liguliflorae* (0.28–0.01%), *Ranunculus* (3.5–0.08 %), *Rumex acetosella/acetosa* (1.8–0.05 %) and *Thalictrum* (3.1–0.19 %), as well as the Pteridophytes: *Dryopteris* type (6.5–1.1 %), *Gymnocarpium* (5.2–0.59 %) and possibly *Botrychium* (0.29–0.11 %). Among the shrubs *Betula pubescens* is characteristic, and *Salix glauca* (9.4–5.5 %) and *Juniperus* (0.75–0.28 %) also seem to be more common in the inland spectra.

The samples from Godthåbsfjord are characterized by *Betula* (42 %), *Alnus* (13 %, growing in the area), *Juniperus* (1.2 %), *Ledum* and other *Ericales*, and *Lycopodium*. There are few *Gramineae* (4.1 %).

Absurdities caused by macroscopic contamination are seen in the spectra, e.g. 62 % *Betula* in Isoëtes Sø and 70 % *Pteridophytes* at loc. 24, but everything considered, the spectra reflect the dominating vegetation types in the area, and with reasonable certainty it is possible to infer from a spectrum to the surrounding vegetation. These spectra have been used in interpreting the diagrams, but without absolute counts the basis would have been very uncertain. I need only emphasize one point: *Alnus* attains 5.8 % in one of the pools at Tôrnârssuk, at least 100 km from the nearest isolated alder shrub (and 250 km from denser growth) in Greenland and 1000 km from Labrador. In "Lake 8 m", with alder scrubs growing in the same valley, *Alnus* amounts to 9.1 %.

Pollen traps

Qagssiarssuk

During the summer of 1969 three Tauber traps (TAUBER, 1967) were placed at Qagssiarssuk. Mr. VIGGO ASMUSSEN kindly placed the two of them on 1.8 m posts in the middle of Galium Kær and in Comarum Mose at site C on May 10, long before the first flowering of local plants, but, it must be admitted, not before flowering of *Alnus*, *Betula* and others in certain areas of North America. Ca. one cm of glycerol was put into the traps to prevent desiccation. On July 1st a third trap was placed on a little raft in Comarum Sø, anchored a few metres from site B. During the summer the traps were emptied on July 1, July 23 (not Galium Kær), August 3 and September 21. On July 4 the post in Galium Kær was overturned, and the middle period therefore only included July 5–August 3.

On my arrival on June 25 every *Betula* had ceased flowering in that part of the fjord. At Comarum Sø and Mose the most important phenological observations are: July 1: *Menyanthes* beginning to flower. Among *Cyperaceae* only single specimens of *Carex nigra* flowered, and there were no grasses in bloom. *Salix* flowered. July 10: *Sparganium* flowers. July 23: *Carex rostrata* still flowers, while *C. nigra* and *Salix* have ceased. *Comarum* flowers, but the three most important grasses in the bog, *Calamagrostis langsdorfii*, *C. neglecta* and *Agrostis scabra*, have not started. July 30: *Calamagrostis* still not flowering. August 3: *Calamagrostis* and *Agrostis* beginning to flower. In Galium Kær, *Carex canescens* and *C. nigra* are flowering on July 5 (but not on June 30), as is *Salix glauca* on the slope north of the marsh.

In table 23 the results are given for the single periods in the three traps, expressed as n/cm². Furthermore, the n/cm² and the percentage composition is shown for Comarum Mose and Galium Kær throughout

Table 23. *Content of pollen in Tauber traps, Qagssiarssuk 1969.*

Tauber traps at Qagssiarssuk, 1969	Galium Kær					Comarum Mose						Comarum Sø		
	May 10–July 1	July 5–Aug. 3	Aug. 3–Sept. 21	May 10–Sept. 21	% of local pollen types	May 10–July 1	July 1–July 23	July 23–Aug. 3	Aug. 3–Sept. 21	May 10–Sept. 21	% of local pollen types	July 1–July 23	July 23–Aug. 3	Aug. 3–Sept. 21
	n	n	n	n	%	n	n	n	n	n	%	n	n	n
Alnus	3.9	0.2	1.4	5.5	1.6	4.8	0.1	0.1		5.0	1.2	0.2	0.3	0.1
Betula	38.0	1.1	2.8	41.9	12	34.8	1.3	12.9	3.2	39.3	9.7	0.5	1.6	5.0
Juniperus	4.5	4.6	2.1	11.2	3.2	2.1	6.2	1.5	4.2	14.0	3.5	3.7	2.4	0.7
Salix	29.2	9.1	26.1	64.4	18	83.6	19.5	7.8	18.2	129.1	32	19.1	14.8	9.8
Empetrum	0.6			0.6	0.17									
Ericales	0.3			0.3	0.09	0.3	0.2			0.5	0.12		0.1	0.3
Vaccinium type			5.3	5.3	1.5			0.1	0.5	0.6	0.15			
Achillea type		2.0	3.2	5.2	1.5			0.4	9.3*	0.4	0.10		0.3	1.0
Alchemilla		0.2		0.2	0.06			0.1	0.5	0.6	0.15			
Angelica			0.4	0.4	0.11			0.3	0.5	0.8	0.20			
Campanula	0.3	5.9	28.2*	6.2	1.8			5.0	72.3*	5.0	1.2		0.9	1.0
Cerastium-Stellaria		0.9	0 4	1.3	0.37			0.1	1.9	2.0	0.49		0.9	
Cruciferae	0.3	0.6		0.9	0.26				0.9	0.9	0.22	0.1	0.4	
Cyperaceae	22.1	9.1	2.1	33.3	9.5	7.4	5.2	1.6	2.3	16.5	4.1	5.5	10.1	99.7
Elymus	0.3			0.3	0.09				0.5	0.5	0.12			0.3
Erigeron type								0.1		0.1	0.02			
Euphrasia type		0.4	0.4	0.8	0.23	0.6		0.1	0.9	1.6	0.40		0.1	
Gramineae	5.4	18.6	42.3	66.3	19	3.9	4.4	8.0	66.7	83.0	21	4.1	15.4	36.0
Juncus-Luzula		0.2		0.2	0.06	0.3	0.1			0.4	0.10	0.1	0.3	
Liguliflorae	0.6	5.2	15.5	5.8	1.7	1.8		6.1		7.9	2.0	0.1	5.1	2.3
Minuartia type		0.2		0.2	0.06									
Plantago maritima	0.6	0.7	0.7	2.0	0.57		0.1	0.1		0.2	0.05	0.1	0.7	0.3
Polygonum aviculare		0.2		0.2	0.06			0.1	0.5	0.6	0.15	0.1	0.1	
Polygonum viviparum													0.7	

Saxifraga oppositifolia type	1.0			1.0	0.28	1.5	0.1			1.6	0.40				
Sedum			1.1	1.1	0.31	0.3		0.1		0.4	0.10	0.1			
Silene acaulis type													0.4	0.3	
Thalictrum	15.2	1.3	3.2	19.7	5.6	8.3	2.0	0.1	0.9	11.3	2.8	1.5	1.3	1.3	
Thymus		2.6*	1.4	1.4	0.40			0.1		0.1	0.02		0.1		
Viola canina type	0.2			0.2	0.06										
Viscaria type			0.4	0.4	0.12										
Botrychium			0.4	0.4	0.12			0.1		0.1	0.02	0.1			
Cystopteris			1.8	1.8	0.52										
Diphasium type									0.5	0.5	0.10				
Dryopteris type	1.0	0.4	9.5	10.9	3.1	0.3	0.3	1.6	5.6	7.8	1.9		1.3	1.3	
Gymnocarpium		1.1	0.4	1.5	0.43	0.3			2.3	2.6	0.64		1.4		
Lycopodium dubium			0.4	0.4	0.09										
Eupotamogeton		0.7		0.7	0.20								0.1	0.3	
Hippuris		3.2	0.7	3.9	1.1										
Menyanthes												8.3	0.3	2.7	
Myriophyllum alterniflorum									0.5	0.5	0.12			2.0	
Sparganium									0.5	0.5	0.12	0.1	0.1	0.7	
P. indet		0.6	1.5	2.1	0.60			0.1		0.1	0.02	0.1	0.1	0.3	
Σ local pollen types	158	97	174	348		152	46	65	234	403		46	89	174	
Σ P	496	521	491	1508		510	368	488	504	1870					
Ambrosia			1.1	1.1	0.31										
Artemisia	0.6		0.4	1.0	0.28		0.1	0.1		0.2	0.04			0.3	
Chenopodiaceae									0.5	0.5	0.12				
Corylus													0.1		
Picea/Pinus	0.3	0.4	0.4	1.1	0.31		0.1			0.1	0.02	0.1		0.7	
Sambucus								0.1		0.1	0.02				
Urtica							0.1			0.1	0.02				
Ulmus									0.5	0.5	0.12				
Sphagnum			0.4	0.4	0.12				0.5	0.5	0.12				
Botryococcus		0.6		0.6	0.17	0.3	0.1			0.4	0.10		0.1	2.3	
Pediastrum		10.2		10.2	2.9			0.1	0.5	0.6	0.15	0.9	4.4	11.1	
Charcoal	24.0	5.2	>1.1	>30.3	>8.6	31.2	5.9	20.8		57.9	14	7.9	7.8	5.9	

the season. Before calculation of the percentages a few pollen were omitted. In some cases the considerable amount of entomophilous pollen found in the sample evidently stems from drowned insects: *Achillea* (omitted from one sample), *Campanula* (two samples) *Liguliflorae* (one sample), *Ranunculus* (one sample) and *Thymus* (one sample). In all cases an asterisk in the table indicates the number omitted. No doubt other similar cases occur, but they are of minor importance. In addition, in the sample in Comarum Mose, July 23–August 3 the *Betula* pollen were very different from the other pollen in the sample: almost all were very crumbled and more or less destructed. The number 12.9/cm² is unreasonably high in comparison to 1.6 for the same period in Comarum Sø. The most reliable explanation is that one of the foehns coming at intervals from the inland ice must have blown some partly decayed fragment of a catkin to the trap.

When comparing the recent spectra mutually, or with the recent gyttja sample from Comarum Sø (table 22, no. 27), a few dissimilarities are conspicuous. *Salix* is very high (32 %) in Comarum Mose, presumably caused by a contamination by insects in the first period, in which it makes up 55 % (as compared to 23 % *Betula*, which flowers in this period). In Comarum Mose with the trap 1.8 m above the ground, *Cyperaceae* make up 4.1 % as compared to 21 % *Gramineae*, whereas in the recent gyttja in the lake the percentages are 19 and 24 % resp., indicating a less effective dispersal of *Cyperaceae* pollen. More similar cases could be mentioned, but taking into consideration that the traps only have been placed for one flowering season, the spectra agree well.

One additional circumstance should be pointed out, i.e. the pollen of the hydrophytes. In two of the periods *Hippuris* pollen (1.1 % for the whole season !) were found in Galium Kær, which, as mentioned above, is a marsh completely without hydrophytes. Ca. 100 m to the northeast of Galium Kær, at a slightly higher elevation, a 50×30 m pond is completely filled in with *Hippuris*, which doubtless is its source. Another case of wind dispersal of *Hippuris* pollen can be seen in the gyttja sample (table 22, no. 5) from Tôrnârssuk. 0.4 % *Hippuris* was found in a pond without this epceies, but this pond is surrounded by other ponds in which it grows. In Galium Kær *Eupotamogeton*, *Botryococcus* and *Pediastrum* also were found. And pollen of *Myriophyllum alterniflorum* were found in Comarum Mose as well as in Comarum Sø. It does not grow in the lake, but is very common in the lake "vandsøen" at a distance of ca. 250 m. Not only in the trap on the lake, but also in the trap in the bog, a few colonies of *Botryococcus* and *Pediastrum* occurred.

These observations indicate that even though their stamens only are exposed a few cm above the water table, *Potamogeton* and *Myriophyllum* have a very effective dispersal, and that a single pollen in a

diagram does not always indicate that the plant grows in the lake in question. Furthermore, single colonies of *Botryococcus* and *Pediastrum* can be found almost everywhere.

During the whole season 348.3 pollen/cm² were deposited in Galium Kær, 403.1/cm² in Comarum Mose. This is roughly one-third to one-fourth of the average number sedimentated in Comarum Sø during the last two millennia. This tells nothing about the efficiency of the trap per se, but only that under the local topographic and climatic conditions the efficiency as compared with that of the lake is one-third to one-fourth.

North Greenland

Ca. 50 m west of Klaresø Eigil Knuth kindly placed a Tauber trap on a ca. 1 m high post on May 31, 1968, before the start of the flowering season. It was removed on Aug. 19. As was to be expected, the content of pollen was very low: in 84.2 % of the glycerol 75 pollen were found. 24 of these are considered local, 17 (*Cyperaceae*, *Gramineae* and *Dryopteris* type) are probably of local origin, too, but as anemophilous plants a single pollen or spore may be long distance transported, and 24 are either long distance or contamination (*Fagus*, *Trifolium pratense*, *Secale* and several others may originate from an earlier use of the trap in Denmark). The results are given in table 24. The spectrum is amazingly similar to that of the recent pollen zone as far as the most common plants are concerned. Ca. 2.1 local pollen/cm² was sedimentated in the period. With an estimated specific gravity of 1.5 of the sandy-clayey lake marl in layer 5 in Klaresø, the pollen sedimentation in the last two millenia is ca. 6/cm²/yr (with a specific gravity of 2: ca. 8/cm²/yr), or almost the same ratio between the efficiency of the trap and of the lake as observed at Comarum Sø.

In almost the same period (May 26–Aug. 19) a 63.2 cm² petri-dish in a plywood board (Lichti-Federovich & Ritchie, 1965) was placed in the weather screen at Brønlundhus at the beach of Jørgen Brønlund Fjord, ca. 2 km northeast of Klaresø, and at Station Nord (81°36′ N, 17° W), close to the northeasternmost point of Greenland. The latter trap worked in the period May 29–Aug. 24. In the petri-dish at Brønlundhus a considerable content of silt-clay (ca. 4 cm³) was found, but the content of pollen was very low. In 93.1 % of the glycerol 60 pollen, or 1.0/cm²/season of supposedly local pollen were found (table 24). *Gramineae* and *Cyperaceae* dominate the spectrum (53 pollen), whereas *Salix* is rare, and *Saxifraga* absent.

The petri-dish at Station Nord contained only a small amount of silt-clay as a result of the much lower wind velocities. Some dust-like fragments of scaled-off painting from the screen could not be removed.

Table 24. *Content of pollen in Tauber traps and Petri-dishes, North Greenland 1968.*

Pollen traps, North Greenland.	Klaresø	Brønlundhus	Station Nord		Klaresø	Brønlundhus	Station Nord
Cerastium-Stellaria	1		1	*Betula*			47
Cruciferae			2	*Chenopodiaceae*			7
Cyperaceae	4	15	9	*Corylus*			1
Dryas	1	1	1	*Fagus*	7		1
Dryopteris type	1	1		*Fraxinus*			2
Gramineae	12	38	7	cf. *Filipendula*	1		
Liguliflorae		2	1	cf. *Humulus*	1		
Melandrium triflorum	1			*Lycopodium*	1	1	1
Minuartia type	1	1	1	*Picea/Pinus*	4	1	3
Oxyria			37	*Quercus*	1		1
Papaver	1		9	*Rumex acetosella* type			1
Potentilla	1			*Secale*	1		
Ranunculus		1		*Sphagnum*	1		
Salix	12	1	24	*Trifolium pratense*	1		
Saxifraga nivalis type	1			*Ulmus*			6
Saxifraga oppositifolia type	5		7	P. indet			4
Tubuliflorae			2	Σ non local taxa	24	2	80
Σ local taxa	41	60	101	*Botryococcus*		2	
Alnus	4		4	*Pediastrum*		5	
Artemisia	2		2				

This turned out to contaminate the sample severely, and a later analyses of some more painting, kindly scraped off from the same screen by the Head of the station, Mr. VIGAND OLSEN, proved that it must have been painted at a more southerly latitude and exposed to the wind during drying. In 87.3 % of the material 101 supposedly local pollen (= 1.8/cm²/season) were found. The spectrum with dominating *Oxyria* and *Salix* and frequent *Papaver*, *Saxifraga oppositifolia*, *Cyperaceae* and *Gramineae* differs from those at Jørgen Brønlund Fjord, but is in accordance with the local vegetation. Only the high *Salix* frequency looks somewhat strange, but some of the *Salix* pollen may originate from the painting-dust, although *Salix* pollen were not actually found in the analyzed slides (*Betula* 12, *Cruciferae* 1, *Corylus* 1, *Dryopteris* type 1, *Gramineae* 1, *Pinus* 0.5, *Ulmus* 1, unknown 1).

One more investigation of the recent pollen deposition has been carried out by DYAKOWSKA (1947). On a sea-voyage to Greenland petri-

dishes with glycerol-soaked filter paper were exposed at 24 hour intervals. A total of 127 pollen was counted in the samples, starting with Copenhagen and ending at Egedesminde, at almost 69° N in West Greenland. On the route from Kap Farvel to Egedesminde 2 *Pinus*, 1 *Abies*, 3 *Picea*, 1 *Betula*, 1 *Alnus*, 1 *Fraxinus*, 3 *Lycopodium clavatum*, 1 *Athyrium*, 2 *Dryopteris*, 5 *Gramineae*, 2 *Chenopodiaceae*, 10 *Compositae* and 9 Varia were trapped.

Matrix sedimentation rates

In northern temperate regions holocene gyttja beds of 5–10 metres are common, and a thickness of as much as 37.5 m has been recorded in Denmark (Stockmarr, personal communication). In England Walker (1970) has calculated the sedimentation rates for different sediment types during holocene. For 18 nekron muds, commonly accumulated in deep water lacking macrophytes, the average rate is 7.3 cm/100 yr; for 50 fine detritus muds, commonly accumulated beneath water in which floating-leaved and submerged macrophytes grow, the average rate is 5.0 cm/100 yr, and for 26 coarse detritus muds, commonly accummulated in shallow water, the average is 6.6 cm/100 yr. In temperate North American lakes the sedimentation rates resemble the British ones. In Wreck Cove, N.S. (Livingstone & Estes, 1967) 310 cm gyttja have been sedimentated in 9000 years (3.6 cm/100 yr), in Silver Lake, N.S. 465 cm gyttja in 9700 years (4.4, 4.0 and 5.5 cm/100 yr in different periods), in Salmon River Lake, N.S. (Livingstone, 1968) 375 cm in 9900 years (2.9 and 5.0 cm/100 yr), in Gillis Lake, N.S. (Livingstone & Livingstone, 1958), 440 cm in 10,300 years (4.3 cm/100 yr) and in Rogers Lake, Conn. (Davis, 1969) 11.5 m have been sedimentated in 14,300 years, with rates varying between 3 and 12/cm/100 yr. In Linsley Pond, Conn., 13 m cover the Late- and Post-Glacial (Livingstone, 1957).

But in arctic environments the sedimentation rate of essentially organic sediments is usually low, as a result of low temperatures, short seasons and deficiency in nutrients, mainly phosphorus and nitrogen. Of 33 calculated sedimentation rates, shown in fig. 31, 2 are below 1 cm/100 yr, 11 between 1 and 2, 6 between 2 and 3, 6 between 3 and 4, 4 between 5 and 6, 3 between 6 and 7, and 1 is between 9 and 10. On the average, the rate is 3.1 cm/100 yr, half the rate in the British Isles. In Godthåbsfjord 370 cm gyttja were sedimentated in ca. 8500 years (4.4 cm/100 yr) in "Lake 100 m", 251 cm in ca. 8200 years (3.1 cm/100 yr) in the lake in Itivneq, 217 cm in ca. 8000 years (2.7 cm/100 yr) in Igdlorssuit tasiat, and 210 cm in ca. 7800 years (2.7 cm/100 yr) in the lake at Itivnera.

This is in accordance with the rates obtained by Rampton (1971) from Antifreeze Pond, Yukon. Since 10,000 B.P., 207 cm of gyttja have been sedimentated at rates varying between 1.4 and 2.5 cm/100 yr. And

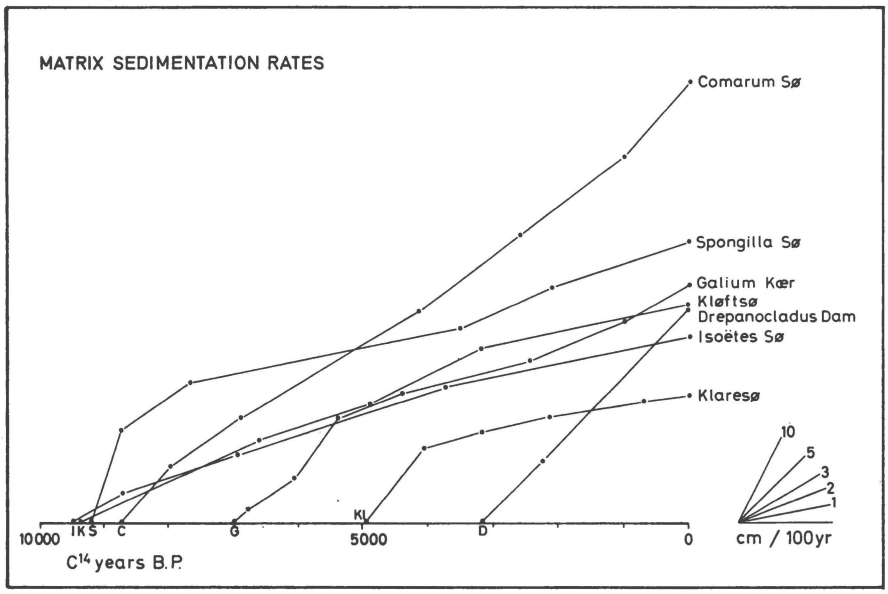


Fig. 31. Matrix sedimentation rates versus age for 7 Greenland lakes.

RITCHIE (1969) found the rates for fine gyttja in Riding Mountain, Manitoba, varying between 3.5 and 3.7. In the Allerød period, with climatic conditions comparable with today's low arctic South Greenland, 30–40 cm organic mud (3–4 cm/100 yr) were sedimentated in Blelham Bog, England (PENNINGTON & BONNY, 1970), and in Allerød b + c 20 cm (roughly 2.5 cm/100 yr) were sedimentated at Torreberga, Sweden (DIGERFELDT, 1970).

In fig. 31 the sedimentation rates in different periods in the dated lakes are shown. The slope of the curves indicates the rate. In some cases (Isoëtes Sø, Kløftsø, Drepanocladus Dam and Comarum Sø) the sedimentation rate is almost constant throughout the history of the lake, while in other cases (Spongilla Sø, Galium Kær, Klaresø) the initial rate is high, and then after about one and a half millennia decreases and remains almost constant, eventually with a slightly increasing tendency towards the end.

Among the lakes with a constant rate, two have been very poor throughout their existence, and the total sediment depths are very small (1.39 m in Isoëtes Sø, 1.71 in Kløftsø). Today they are almost without hydrophytes, and as seen in table 1, the water is very poor. The two other lakes with a constant ratio have, however, been relatively rich throughout the period, and the rates are almost like those in most British post-glacial lakes. 3.43 m of gyttja are found in Comarum, Sø and in Drepanocladus Dam 1.70 m were sedimentated during 3000 years. Both lakes have a

fairly rich hydrophytic vegetation today. Judging from the results obtained by the chemical analyses (table 1) none of the measured nutrients can explain this difference in vegetation between the two outer coast lakes and the two lakes from the interior. But the differences must be ascribed to the surroundings, rather than to the climate. The outer coast lakes are found in depressions in polished igneous bedrocks, whereas the lakes in the interior are surrounded by moraines or very loose sedimentary bedrocks. No doubt the latter lakes receive a constant supply of one or more micro-nutrients.

The shape of the Spongilla Sø curve appears reverse sigmoid. The high rate in the first period is not due to a greater sedimentation of clay, nor is it caused by better climatic conditions in this period, cf. Isoëtes Sø and Kløftsø with constant rates. It must be ascribed to a greater supply of nutrients by the brooklet running through it. After a period with a very low sedimentation rate, an increase is seen about 3500 B.P. Whether this is climatically significant or not cannot be stated. The fact that the sedimentation rate in the period ca. 7700 to 3500 B.P. is the lowest seen in the South Greenland lakes, viz. 1.02 cm/100 yr, makes it likely that the rate was decreased by currents at the coring spot.

In Galium Kær the initial rate is almost as high as in Spongilla Sø and in Comarum Sø, but unlike Comarum Sø, which is surrounded by easily weathered bedrock, the supply of nutrients decreases in Galium Kær, and the rate is of the same order of magnitude as in the outer coast lakes. In Klaresø the high rate in the beginning may be caused by nutrient supplies from the moraines at Okseslette, brought down by meltwater streams in early summer and possibly by torrents during summer. A raised assimilation by plancton and mosses in the lake will increase the amount of precipitated carbonates, which makes up a great part of the sediment.

The material supplied from low-arctic and sub-arctic Greenland is limited, indeed; yet it seems sufficient to indicate that 1) the average sedimentation rates are lesser than in temperate regions, presumably a result of low temperature and a short season, 2) deficiency in nutrients is the paramount limiting factor completely concealing any climatic influence in space (outer coast contra interior) and in time, and 3) no indication of a sigmoid increase in the organic content, characteristic of many temperate lakes, has been found. This is in accordance with the opinions of Livingstone (Livingstone *et al.*, 1958), who found that this often drastic increase is the result of the change from arctic to temperate conditions.

CONCLUDING REMARKS ON THE HOLOCENE VEGETATIONAL AND CLIMATIC CHANGES IN GREENLAND

Even if it is not the main subject of this paper to discuss survival, it seems inevitable prior to the summary of the holocene vegetational and climatic history to try to form an impression of which plants might have survived. There is reason to suppose that even under the extreme cold Late-Wisconsin glaciation, nunataks in the coastal mountains in several parts of Greenland penetrated the ice cap. Possibly some lowland areas in North Greenland also were ice-free, making a parallel to the present-day oasis in Antarctica. Whether these areas were free of snow and ice every summer, or whether perennial snowdrifts or stationary ice caps periodically covered the ground, cf. the conditions in Queen Elizabeth Islands (SAVILE, 1961), cannot be determined.

ANDREWS & IVES (1972) present indications of ice recession and argue that considerable stretches of the outer coast and fjords of eastern Baffin Island were not covered by glacial ice in the Late Wisconsin. TEDROW (1970) gives a dating (20,800 ± 2900 B.P., I–2322) of a buried soil in a glacio-fluvial terrace in Inglefield Land, Northwest Greenland. The pollen spectrum is strange, and as the dating was done on a soil with an organic content of only 1.6 %, this sample must be ruled out as a proof of an unglaciated area during Late Wisconsin. With some reservations FUNDER (1972) put forward the theory based on shell datings that part of the lowland on southern and western Jameson Land, East Greenland, was ice-free under Late Wisconsin.

But even if some of the geological evidences of ice-free areas may still be open to discussion, this is of minor importance insofar as the tabula rasa theory hardly can be valid for the whole Greenland-North America area. The Wisconsin glaciation was not one uninterrupted glaciation covering the whole area with a heavy ice blanket. Interstadials, changing centers of glaciation etc. altered the conditions through space and time, and with the effective dispersal of many arctic plants these were able to settle as soon as an ice-free ground was exposed, provided that physical conditions permitted this. This brings up to the most

important question: Which species were able to stand the harsh conditions on the refugia?

Unfortunately the δO^{18} curves from the Camp Century ice core cannot be converted into a temperature curve (DANSGAARD *et al.*, 1971), but a number of other estimates about the extent of the Wisconsin temperature depressions are available. EMILIANI (1971) concludes on the basis of micropaleontological evidences from deep sea cores that glacial surface temperatures were at least 8° C lower than today in the Carribean and at least 5° C lower in the equatorial Atlantic. FARRAND (1971) compiles evidence from many fields and concludes that the mean temperature was lowered by some 5° to 7° C in the eastern Mediterranean area. GROSS (1958) estimates the July temperature in Germany during the "Hauptwürm", ca. 20,000 B.P., to be 5° C as compared to 19° C today. ANDERSEN (1961) argues that the summer temperature decreased by at least 10° C in Denmark, and CONOLLY (in CONOLLY & DAHL, 1970) arrive at the conclusion that the Weichselian was at least 5° C colder than at present in East Anglia, England.

At higher latitudes the cooling was greater, and DANSGAARD & TAUBER (1969) estimated that the annual mean temperature in North Greenland in the period 25,000–20,000 B.P. was at least 13° C lower than today. It is impossible to say how much this would result in a lower summer temperature. But with a normal lapse rate in the atmosphere of 0.65° C/100 m a lowering of say 5° C would cause a depression of vegetation belts on the mountains of ca. 750 m. 106 species of flowering plants are known from the flora of Peary Land (HOLMEN, 1957; FREDSKILD, 1966, + a recent find of *Saxifraga hieraciifolia*). 42 of these have only been found below 200 m (among these only one – *Puccinellia andersonii* – is bound to the seashore), one species (*Saxifraga tricuspidata*) was found only once at an elevation of 350 m; 35 have their upper limit around 500 m, two (*Cassiope* and *Pedicularis hirsuta*) at around 700 m, while 26 ascends to higher elevations, not rarely to 1000–1100 m. Any Wisconsin refugium in Peary Land may well have harboured only these latter 26 species: *Alopecurus alpinus*, *Phippsia algida*, *Poa abbreviata*, *P. arctica*, *P. glauca*, *Luzula arctica*, *L. confusa*, *Cerastium alpinum/arcticum*, *Minuartia rubella*, *Stellaria longipes* s.l., *Braya thorildwulffii*, *Cardamine bellidifolia*, *Draba arctogena*, *D. bellii*, *D. oblongata*, *D. subcapitata*, *Papaver radicatum*, *Dryas chamissonis*, *Potentilla hyparctica*, *P. pulchella*, *Saxifraga caespitosa*, *S. cernua*, *S. flagellaris*, *S. hyperborea*, *S. oppositifolia*, *S. tenuis*.

Unquestionably, the present distribution of plants may often give a clue as to their history, but the environmental conditions in the possible refugia, vital to the plants, should not be forgotten in the discussion. A plant can only be included in the group of survivors if it by experience

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or experiment has proved able to grow and reproduce under similar conditions. In this context the pioneer vegetation of zone A in Isoëtes Sø and Kløftsø should be recalled. Every species proved there grows in Peary Land today, and apart from *Sagina*, every genus or type proved is represented in the Peary Land flora.

SCHWARZENBACH (1951), working on the nunataks at the head of Kejser Franz Joseph Fjord between 72° and 74° N on the east coast, and IVERSEN (1952–53), dealing with Godthåbsfjord, have based their estimates of which species could survive on the same principles.

Before summarizing the vegetational and especially the climatic holocene history and comparing it with contemporary events in North America, I must interpose the remark that I am fully aware of the scanty material as compared to the size of Greenland, and coming investigations may well modify the scheme in several important respects. I am also quite aware of the danger of drawing too far-reaching conclusions from the find of a plant remain. When a palaeobotanist is lucky, he is able to determine it as to species, but it is impossible to determine which ecotype, race, variety or any other lower taxonomic rank the find represents. A great difference in respect to ecological demands may be found on this level. I need only refer to the investigation of *Betula nana* by CONOLLY & DAHL (1970). This species is very sensitive to summer maximum temperature, and with the present oceanic climate in Scotland, it does not occur in areas with a "maximum summit temperature" higher than 22° C. In the more continental southern Scandinavia the limiting temperature is 30° C! In order to minimize these fallacies, references have usually only been made to Greenland vegetations and not to the environments of the species in question in e.g. Europe.

Pre-Hypsithermal

By 11,000 B.P. the recession of the West Greenland ice had commenced, but the oldest gyttja samples investigated so far originate from ca. 9600 B.P. (Isoëtes Sø). During the intervening period, with increasing temperatures and still greater ice-free areas, the possible survivors were able to spread along the coast, but plants from abroad could also immigrate. This indicates that not even all species in the very poor pioneer vegetation in the oldest samples are not necessarily survivors, but far more investigations are necessary to elucidate this problem.

The effeciency in winter dispersal in arctic areas has been referred to above (SAVILE, 1972), but the importance of dispersal by birds should not be underestimated, as illustrated by a recent investigation by FRIDRIKSSON & SIGURDSSON (1968). Out of 32 snow buntings caught on Surtsey off Southwest Iceland in the spring of 1967, 10 individuals had seeds in their gizzards. The following seeds were found: *Polygonum*

persicaria 1, *Carex nigra* 1, *Empetrum* 70, *Spergularia* 3, *Medicago sativa* 6, *Scirpus* 2, *Andromeda polifolia* 1, unidentified 3. The minerals and rock-types plus the seeds of *Andromeda* and *Medicago* prove that they had last fed in Scotland. Some seeds were tested as to their viability, and three germinated, two of which had matured, viz. *Polygonum persicaria* and *Carex nigra*. For further discussion about post-glacial dispersal see DANIELSEN (1970).

In the first half-millennium the main vegetation type in the Kap Farvel area was snow-patches with widespread arctic plants. Then a number of ericaceous shrubs immigrated, but still snow-patches and open vegetation seem to dominate. The recession of the ice sheet was 2–5 km/100 yr (WEIDICK, 1972a), and by ca. 8500 the margin was roughly at the present position in South and West Greenland. In Comarum Sø at the head of Tunugdliarfik, and in "Lake 100 m" at the head of Godthåbsfjord the sedimentation started 8700–8500 B.P. The pioneer vegetation quite naturally indicates more continental conditions, but still no thermophilous plants have been proved. Everything is indicative of a displacement of summer temperature as compared to that of today, of 6–9 latitudes.

In North America the Laurentian Ice still covered a vast area (BRYSON *et al.*, 1969), but west of it the tundra (12,900–11,600 B.P.) had been replaced by an open spruce-tundra (11,600–8500 B.P., RITCHIE, 1972). By 9000 B.P. nearly all the inter-island channels of the Canadian archipelago north and west of Baffin Island were open to driftwood (BLAKE, 1972). Between 8200 and 8000 the Cochrane re-advance could be traced all along the edge of the Laurentian Ice, and in Alaska an early holocene, warm interval is ended by an advance of Brooks Range glaciers around 8200 (ANDREWS & IVES, 1972; TEDROW, 1972). In West Greenland this is paralleled by the Fjord stage re-advance (WEIDICK, 1968). This short spell does not seem to be registered in the pollen diagrams.

Hypsithermal

In Europe the hypsithermal began ca. 8500 B.P., but in Canada and South and West Greenland it was not initiated until much later. At Kap Farvel, cool, moist conditions prevailed until ca. 7200 B.P. But around 7000 B.P. the spreading of *Juniperus* and *Selaginella*, the occurrence of *Eleocharis*, and other evidences mark the beginning of a period with conditions as warm/dry as today, if not even more so. Within half a millennium or so an equilibrium in vegetation, lasting until ca. 5300 B.P. in South Greenland, was established.

The duration of the climatic optimum in North America differs somewhat, partly dependent on the evidences used for its interpretation, but in general the authors agree. Thus, ANDREWS & IVES (1972) tentatively

place the optimum between 6000 and 4800 B.P. on Baffin Island, the latter dating being of a marked re-advance. BLAKE (1972) finds that by far the most of the datings on driftwood in the Canadian archipelago belong between 6500 to 4500 B.P. Even the fjords on northern Ellesmere Island, now concealed behind the 10–20 km wide Ward Hunt Ice shelf were open, as shown by datings of driftwood ranging from 6300 to 3000 B.P. (CRARY, 1960; BLAKE, 1972). In the Mackenzie Region the spruce forest spreads northwards in the period 8500–4000 B.P. (RITCHIE, 1972), and RITCHIE & HARE (1971) have outlined the climatic implications: The mean daily temperatures for the warmest months were about 5° C higher than at present, and the growing season about 30 days longer. This would require a northward displacement of the median July position of the Arctic Front about 350 km north of its present position. The oldest dating in the diagram from Colville Lake, Mackenzie Terr., confirms this by showing that already by 6000 B.P. the spruce forest was north of its present limit (NICHOLS, 1972).

Minor fluctuations are registered during the climatic optimum. Thus, at Kap Farvel a change occuring about 5300 B.P. can be seen; the following period, up to 3800 B.P., apparently was the warmest one, with the least oceanic climate. At 3800 B.P. *Betula glandulosa* immigrate, but as it is not clear whether this late immigration has dispersal or climatic reasons, any contemporary climatic change remains uncertain. It can only be said that in the following millennium the climate was still rather warm and dry. At Qagssiarssuk a change to more dry conditions is indicated around 5500–5300 B.P. These remain unchanged up to 3600 B.P., when *Betula pubescens* immigrate ca. 800 years after *B. glandulosa*. In the beginning of the following period the climate may have been even warmer, but not so dry. At Godthåbsfjord the climate ca. 7000–4000 B.P., judging from the extensive *Betula nana-Juniperus* heaths, was dry, with temperatures almost like the present ones. At 4000 B.P. *Alnus* immigrates, and the temperature in the coming 800 years presumably reaches the maximum, yet like at Qagssiarssuk more humid conditions seem to have been connected with this late climatic optimum.

In North Greenland the optimum began some time before 6000 B.P. with the recession of fjord glaciers, and driftwood from ca. 5900 B.P. proves that the fjords became open. The delay in *Salix arctica* emergence in the Klaresø diagram may have been caused by local pedological factors. Apart from this, only minor differences in the ratios between the species (but considerable differences in pollen input) separate the oldest samples from the present ones. The climatic optimum seems to occur between 4000 and 3300 B.P.

The re-advance in the Holsteinsborg-Sukkertoppen area around 6000 B.P. (WEIDICK, 1972a) has not been traced in the pollen diagrams.

In Canada, NICHOLS (1972) mentions a shortlived deterioration around 4800 B.P. at Ennadai Lake, Keewatin, and at 5100 B.P. at Lynn Lake, Manitoba, but around 4500 B.P. these were ended. The following millennium saw a northward movement of the forest up to 250 km north of the present tree line, indicating a summer temperature probably 3° C above the present one.

Opinions differ in regard to the part of the hypsithermal in which the real climatic optimum was reached, presumably because the difference was small and to a great extent dependent on local conditions. Judging from most Greenland diagrams, the latter part was the warmest.

In Canada the people of the Arctic Small Tool Tradition expanded rapidly from Alaska all the way to Peary Land within a few centuries around 4200–4000 B.P., but how this is connected with migrations of game–reindeer and musk-oxen–and thereby climatic changes has not yet been established (MCGHEE, 1972). In the Canadian archipelago the number of driftwood datings decrease after 4500 B.P., whereas in Peary Land most datings are from the period 4000–3600 B.P. (KNUTH, 1967), in accordance with HEGG (1963), who suggests that the climate on Axel Heiberg Island was more favourable to the vegetation in the period ca. 4000–3000 B.P. Between 3500 and 3100 B.P. the palaeo-Eskimoes are forced southwards in response to a cooler climatic regime of a few centuries' duration. At Godthåbsfjord a change to more humid conditions is indicated in the beginning peat growth at Itivnera 3200 B.P. But between 2800 and 2500 B.P. a northward expansion again occurs, this time by Dorset and Independence II people; a warmer climate is responsible for this (MCGHEE, 1972).

In South and Southwest Greenland a number of plant species is usually restricted to higher elevations and north slopes, while the same species farther north are common in the lowland. Examples include: *Woodsia glabella*, *Ranunculus pygmaeus*, *Potentilla nivea*, *Papaver radicatum*, *Draba lactea*, *D. arctica* ssp. *groenlandica*, *Cardamine bellidifolia*, *Campanula uniflora*, *Erigeron eriocephalus*, *E. humilis*, *Juncus biglumis* and *Phippsia algida* (BÖCHER *et al.*, 1968). Plants with this type of distribution may well be considered relicts from a more common occurrence in the local late-glacial epoch (BÖCHER, in litt.), as may *Subularia aquatica*. But no doubt the Greenland flora also includes relicts from the climatic optimum. It has been mentioned that *Chamaenerion angustifolium* is sterile today, and BÖCHER (1938) supposes that it spread by seeds in a more favourable period. *Potamogeton pusillus* ssp. *groenlandicus*, with a single exception found only sterile, maintains its place in the lakes and ponds, but the turions, by which it survives, are hardly effective as a dispersal agency. It seems very likely that it was fertile during the climatic optimum and spread vigorously at that time (PORSILD, 1946).

Post-Hypsithermal

In the Kap Farvel area the deterioration begins 2200 B.P. In the outer coast it is initiated by an abrupt *Juniperus* decline, and *Empetrum* heaths dominate totally in the coming period. In the interior, both at Kap Farvel and at Qagssiarssuk, the *Juniperus* decline (2200–1900 B.P.) is contemporary with a decrease in *Betula pubescens* and an increase in *B. glandulosa*. In Godthåbsfjord, *Alnus* decreases and *Ericaceae* increase at a time tentatively dated at 1900 B.P. At Sermermiut the *Sphagnum* bog spread over the dwarf-shrub heath around 2400 B.P., indicating moister conditions. In Peary Land the fjords were closed by ice sometime after 2700 B.P., and about 2100 B.P. the vegetation aquired the desert nature which characterizes it at present.

In northern Ellesmere Island the shelf ice began to develop at some time after 3000 B.P. (CRARY, 1960). In Keewatin the spruce forest began to retreat 2600 B.P. (NICHOLS, 1967b). In northern Labrador the deterioration started 2800 B.P. (BARTLEY & MATTHEWS, 1969); at Mackenzie River delta it seems to begin as early as about 4000 B.P. (RITCHIE, 1972).

The deterioration did not continue uninterruptedly, however; all diagrams from peat profiles from Greenland and Canada evince a later amelioration. In southern latitudes it is usually reflected in a cessation of peat growth due to warmer/drier summers, e.g. Comarum Mose, contrary to the northern latitudes, where peat growth is possible under moister conditions. In Northwest Greenland this period lasts from sometime between 1800 and 1350 up to 900 B.P., and in Peary Land this period took place within the interval 1500–500 B.P.

In Keewatin the southward extension of the tundra reached a maximum ca. 2100 B.P., followed by an amelioration which reached a maximum of summer warmth ca. 1000 B.P., when the northern forest limit advanced northwards. Very shortly after that date there was a sharp return to cold, dry summers, and the forest retreated south once more (NICHOLS, 1970). In northern Labrador the period 1600–700 B.P. was mild (BARTLEY & MATTHEWS, 1969).

The archaeological evidences (MCGHEE, 1972) indicate unfavourable, cool conditions in the period 2500–1900 B.P., followed by three centuries with a warmer climate, which may have caused the rapid spread of the Dorset people. After some centuries almost devoid of dated finds, the Thule Eskimoes spread out along the coasts, hunting baleen whale, a result of the smaller amount of pack ice (VIBE, 1967). The greatest expansion took place 1000–800 B.P. Ca. 1000 B.P. the Norsemen settled in Greenland.

In bogs in South and West Greenland cool, moist conditions and in bogs in North Greenland cool, dry conditions began between 700–500

B.P. Re-advances of local Greenland glaciers began around 450 B.P., attaining their maximum 350 and 200 B.P. (WEIDICK, 1972a).

The amelioration in the first half of the 20th century, reflected in glacier recessions, is only registered in the present investigation by the drying out of ponds at Godthåbsfjord and at Sermermint.

SEIDENFADEN & SØRENSEN (1937) discussed the history of the Greenland flora and divided it into 6 groups (l.c. pp. 181–202): 1) "The relatively recent immigrants", usually characterized by an oblique distribution without isolated occurrences outside their main area. 2) "The immigrants of the post-glacial heat period", a large group which includes ca. 30 % of the East Greenland flora. A closed southern area and isolated occurrences farther north are common. The northern finds often originate from favourable places in the interior, frequently, as well, on basaltic or calcareous soil. 3) "The boreal steppe plants", restricted to the most continental areas in East and West Greenland. According to the authors, these plants have had a large, continuous area of distribution during a warmer continental period. 4) "The arctic desert plants", a small group of plants with a northern distribution, but with some isolated occurrences in more southerly, dry, fjord localities, relicts from a period with a more continental climate. 5) "The ancient cold plants" comprise very early immigrants into Greenland. Towards the north, they are distinguished by a continuous distribution, while to the south they only have isolated occurrences, as a rule only on the highest summits. The authors regard the latter as relicts from a colder period in Greenland, but do not distinguish between survivors and early Post-Wisconsin immigrants. 6) "The ubiquists", widely distributed in different habitats and including many circum-greenlandic species.

The present investigation, however restricted it may be, seems to some degree to support the above division insofar as groups 2, 5, and 6 are concerned. Whether the oblique distribution characterizing group 1 is due to historical or climatological-pedological factors cannot be proved until far more dated diagrams are at hand. This will also be necessary to evaluate groups 3 and 4.

I am convinced that palaeobotanical methods–in the widest sense–are the best to elucidate the history of the Greenland flora and vegetation. Palynology–in spite of its limitations–is the most important tool, and I do not at all agree with COLINVAUX (1967, p. 208) who writes: ". . . . in the arctic, pollen analysis is a rather blunt instrument". It is my vain hope that the present work has proved that the instrument is viable.

DANSK RESUMÉ

Afhandlingen behandler undersøgelserne af det sediment, der er blevet aflejret siden sidste istid i en del grønlandske søer og tørvemoser, og de slutninger m.h.t. udviklingen af vegetation og klima, der kan drages.

Indledningsvis beskrives de anvendte metoder (pp. 9–13), dels i felten, dels i laboratoriet. De vigtigste feltmetoder har været boring med et Livingstone-bor i søernes bund. Herved kan tages uforstyrrede, godt een m lange kerner, der tillader udtagelsen af 1 ml pollenprøver (fig. 1). Hvor det har været muligt, er der blevet gravet åbne profiler i moser. Ved behandlingen af pollenprøverne er der anvendt en metode, der gør det muligt at beregne det totale indhold af pollen i ml-prøverne.

I kapitlet Identifications (pp. 13–31) bringes en oversigt over pollen m. m. af de påviste arter og slægter (tabel 2), og en del bestemmelser kommenteres. I de tilfælde, hvor flere arter eller slægter er hinanden så lig, at en sikker adskillelse ikke kan foretages, er i diagrammer og tabeller anvendt ordet type. I dette kapitel kan ses, hvilke taxa en type omfatter.

Pollen-diagrams (pp. 31–35). To forskellige typer bliver præsenteret. I det relative diagram (silhuet-diagram) er de forskellige slags pollen afbildet i $^0/_0$'er af en sum, hvori indgår samtlige pollen (incl. bregnesporer) med undtagelse af de exotiske og pollen fra egentlige vandplanter. De absolutte diagrammer er histogrammer, hvor længden af søjlen oftest er et udtryk for antallet af pollen, sedimenteret pr. cm^2 søbund pr. år. For at udregne dette tælles det totale indhold i en kendt fraktion af 1 ml-prøven. Derefter beregnes indholdet i hele denne prøve, og endelig beregnes ved hjælp af C^{14} dateringer, hvor mange år det har taget at sedimentere 1 cm gytje. I to af de absolutte diagrammer (Galium Kær A og Klaresø) afbildes indholdet af pollen pr. g tør vægt.

I yderkystområdet vest for Kap Farvel er 3 søer blevet undersøgt. I Isoëtes Sø begynder udviklingen efter isens afsmeltning ca. 9600 B.P., og i Kløftsø, ca. 15 km længere inde, ca. 9300 B.P. Spongilla Sø, kun 5,5 m o.h., bliver isoleret ca. 9200 B.P. Tilsammen giver diagrammerne og dateringerne følgende billede af vegetationens og klimaets udvikling (summary p. 81–90): I begyndelsen findes en spredt pioner-vegetation af vidt udbredte arktiske planter som *Saxifraga oppositifolia* type, *S. nivalis*

type, *S. caespitosa* type, *Erigeron* type, *Carex* (formentlig *C. bigelowii*) og andre *Cyperaceae*, *Poa*, *Puccinellia* (bl.a. vistnok *P. langeana*) og andre *Gramineae*, *Armeria*, *Koenigia*, *Cerastium cerastoides*, *Oxyria*, *Silene acaulis*, *Minuartia* type, *Huperzia* og *Sagina*. Det er altså planter, der kan træffes næsten overalt på Grønland eller i hvert fald langt mod nord. De af planterne, der er karakteristiske for specielle plantesamfund, vidner om, at der har været udbredte snelejer og fugtig, sandet-leret bund, og altså et koldt og vel også nedbørsrigt klima.

Først efter nogle hundrede år, ca. 9100 B.P., indfinder de første dværgbuske sig: *Loiseleuria*, *Harrimanella*, *Vaccinium* (velsagtens *V. uliginosum*) og *Empetrum*. Sidtsnævnte, der i dag er den almindeligste plante i området, spiller i begyndelsen en underordnet rolle. Omkring 8400 B.P. ændres vegetationens sammensætning med en spredning af *Sedum* og *Lycopodium dubium* og en stigning i *Dryopteris*-, *Luzula-Juncus*-, *Diphasium*- og *Cyperaceae*-kurverne, men stadig er snelejer og heder med langt snedække fremherskende.

Omkring 7200 B.P. registreres en række ændringer, der tyder på en forbedring af klimaet, idet *Salix* (både *S. herbacea* og især *S. glauca*) og *Juniperus* indvandrer, samtidig med at en lang række af pioner-planterne decimeres eller helt forsvinder. Enkelte *Salix* har måske vokset i omegnen på et tidligere tidspunkt. Klimaet i de næste 2 årtusinder må have været omtrent så varmt som i dag og formentlig mere tørt.

Omkring 5300 B.P. tyder en række indicier på, at den kommende periode, specielt tiden umiddelbart før indvandringen af *Betula glandulosa* omkring 3800 B.P., var endnu varmere. Om den sene indvandring af *Betula* skyldes klimatiske eller indvandrings-historiske årsager kan ikke afgøres. Det eneste indlandsdiagram fra Kap Farvel området – Drepanocladus Dam (plate 8) – går kun tilbage til ca. 3000 B.P. På det tidspunkt er *Betula pubescens* almindelig omkring dette lille dødishul.

Ca. 2200 B.P. konstateres en markant ændring i alle diagrammer: Mængden af *Juniperus* pollen falder kraftigt ligesom også *Betula pubescens* reduceres i indlandsdiagrammet. Samtidig breder *Betula glandulosa* og *Empetrum* sig og dominerer spektrene i den sidste fase. Det må tages som et udtryk for en forværring af klimaet til det køligere og fugtigere.

Yderkystens søer er i dag meget næringsfattige (table 1), og – bortset fra spredt forekomst af *Isoëtes setacea* og *I. lacustris* – hyppigt uden højere plantevækst. Men straks efter søernes dannelse indvandrede *Hippuris*, og kort tid efter også *Subularia* til de tre søer (og til Sphagnum Dam, p. 69), mens *Callitriche*, *Sparganium*, *Ranunculus confervoides* og *Eupotamogeton* optrådte i en eller flere af søerne. De havde en kortvarig opblomstring (fig. 10), fulgt af en decimering, og i løbet af kortere eller længere tid forsvandt de fleste på grund af søernes oligotrofiering. I to af

søerne levede i den første tid den arktiske damrokke (*Lepidurus arcticus*), der i dag ikke træffes syd for 67° N.

Ligesom på landjorden sker en ændring i søernes vegetation omkring 7200 B.P.: *Isoëtes setacea*, der har forekommet sparsomt i slutningen af den foregående periode, breder sig eksplosivt. Og lige så markant er den samtidige spredning af *I. lacustris* i de 3 søer ved begyndelsen af den varmeste periode ca. 5300 B.P. *Myriophyllum alterniflorum* indvandrer samtidig i en af søerne, endnu senere i en anden.

Ved Qagssiarssuk inderst i fjorden Tunugdliarfik er foretaget undersøgelser i 2 bassiner: Comarum Sø og Mose samt Galium Kær (p. 91–124). Comarum Sø (fig. 11–13) var i begyndelsen af dens historie kort før 8500 B.P. betydeligt større. Omgivelserne var delvis dækket af en pioner-vegetation bestående hovedsagelig af urter: *Oxyria*, *Plantago maritima*, *Chamaenerion* (velsagtens *latifolium*), *Puccinellia*, *Poa*, *Elymus* og andre *Gramineae*, *Silene acaulis*, *Minuartia* (velsagtens *rubella*), *Erigeron* type, *Cyperaceae*, *Saxifraga oppositifolia* type, *S. nivalis* type med flere. Empetrum indvandrede på et tidligt tidspunkt. Karakteristisk er – ligesom i Kap Farvel diagrammerne – at ingen sydlige arter er påvist, kun vidtudbredte, ofte circum-grønlandske arter. Dog vidner vegetationen omkring Comarum Sø om mere kontinentale forhold. Også her findes *Lepidurus arcticus* i de ældste prøver. *Chara*, *Potamogeton filiformis* og – i mindre grad – *Ranunculus confervoides* og *Subularia* var almindelige fra begyndelsen. Den rigere hydrophyt-vegetation, der kendetegner søen helt til i dag, skyldes de omgivende skråninger af letforvitrende sedimentære bjergarter, tildels bestående af prækambrisk lava.

Ca. 8000 B.P. indvandrer *Salix glauca* og breder sig eksplosivt, tildels på bekostning af pioner-planterne. Og i søen breder *Isoëtes setacea* og *Myriophyllum spicatum* sig. Omkring 7000 B.P. indvandrer *Juniperus*, og også den breder sig eksplosivt, mens pioner-planterne forsvinder. I søen dominerer *Potamogeton gramineus*, men også *P. alpinus* og *Myriophyllum alterniflorum* forekommer. Efter nogle årtusinder synes der at være indtrådt en balance, og i perioden 6300–4300 B.P. er der kun tale om små svingninger i kurverne, både for land- og vandplanter.

Mellem 4400 og 4000 B.P. indvandrer *Betula glandulosa* samtidig med en klimaændring, muligvis til det fugtigere. Ca. 3400 B.P. indvandrer *Betula pubescens*, og den følgende periode er formentlig den varmeste, underbygget af, at der i prøver fra tidsrummet 3600–2600 B.P. er påvist statoblaster af ferskvands-bryozoen *Cristatella mucedo*, som ikke kendes levende fra Grønland.

Søen blev langsomt opfyldt, og en sumpvegetation af *Menyanthes* og *Carex rostrata* bredte sig som en forløber for en fugtig mose-vegetation over store dele af bassinet, samtidig med at afløbet blev blokeret, så søens vandspejl steg. Diagrammet fra mosen (plate 11), der hidtil har

været ganske lig diagrammet fra søen (plate 9), viser, at ca. 2500B.P. nåede sumpen midten af bassinet.

Omkring 1900 B.P. registreres en klimaforværring, dels i den faldende *Juniperus* kurve, dels i den forskydning i forholdet *Betula pubescens: B. glandulosa* til fordel for den sidste (plate 1). Det efterhånden brede bælte af mose hindrer næringsrigt vand i at komme ud til søen, og m.h.t. vandplanter er perioden meget fattig.

Nogle århundreder senere begynder en mere tør (og vel varmere) periode, og *Betula glandulosa* breder sig over den i dag meget våde mose. Samtidig hermed indtræffer nordboernes landnam, der radikalt ændrer egnens vegetation, især som følge af fåregræsning. Mest markant er kurven for *Rumex acetosella/acetosa:* Før landnam'et er ikke fundet eet eneste pollen, men efter udgør de ofte 3–5 % af ΣP. Bemærkelsesværdigt er det, at afslutningen af nordbobebyggelsen står så svagt markeret i diagrammerne. *Rumex*-kurven fortsætter uændret til i dag.

Fra Galium Kær (fig. 14) i udkanten af Qagssiarssuk, nordboernes Brattahlid, foreligger dels 2 diagrammer fra en boring (plate 12 og 13), dels 2 diagrammer fra et åbent profil (plate 14 og 15). Sedimentationen begyndte så sent som ca. 7000 B.P., og i begyndelsen skyllede enorme mængder pollen ud i den lille sø, således at der er over en million pollen pr. ml, svarende til en årlig pollen influx på 30.000–60.000/cm^2. Noget tilsvarende var fundet i det endnu mindre dødishul Drepanocladus Dam. I de nederste prøver er fundet velbevarede frugter af den i dag meget sjældne *Eleocharis palustris* s.l., hvilket vidner om, at allerede dengang var klimaet nogenlunde som i dag.

Helt op til nordbotiden er udviklingen i store træk identisk med den fra Comarum Sø beskrevne. Dog må det nævnes, at ca. 5300 B.P. vidner en kraftig stigning i *Juniperus* om ændrede konkurrencebetingelser. Og samtidig med indvandringen af *Betula glandulosa* ca. 4500 B.P. sker der en drastisk ændring i vandplanterne, idet *Potamogeton*, *Isoëtes setacea* og begge *Myriophyllum* arter decimeres eller helt forsvinder, mens *Hippuris* næsten må have opfyldt hele søen. Samtidig stiger antallet af acidophile diatomeer, de alkaliphile reduceres og de alkalibiontiske forsvinder. Det skyldes velsagtens, at der under birkekrattet på de omgivende skråninger dannes sur humus, således at det vand, der siver ud til søen, er surt.

Formentlig gennembrød nordboerne (ligesom de lokale fåreholdere for 30–40 år siden) den lave, smalle ryg, der afgrænser søen mod skråningen ned til Brattahlid for at overrisle denne, og derved sænkedes vandstanden. I hvert fald breder *Sparganium*, *Ranunculus hyperboreus* og *Menyanthes* sig umiddelbart efter landnam'et. Rydningen af krat og den intensive afgræsning bevirkede, at udover de indslæbte ukrudtsplanter (*Rumex acetosella/acetosa*, *Achillea*, *Polygonum aviculare* s.l.) stiger også frekvensen af en lang række arter, der kræver åben bund, og hvoraf en

del havde været almindelige i egnen i den lokale sen-glacialtid: *Plantago maritima*, *Silene*-type, *Liguliflorae*, *Campanula*, *Sedum* og *Thymus*. Ved afslutningen af nordbo-perioden breder *Juniperus* og *Salix* sig noget, men ukrudsplanterne holder sig til i dag.

I de sumpede arealer mellem nordboruinerne er en del tørveprofiler undersøgt, (pp. 124–128). Fælles for disse er følgende: Nederst den hævede, sandet-grusede strandterrasse. Direkte herpå en mængde huggespåner og andre kulturspor fra nordbotid. Derover et kulturlag, der øverst ofte består af en frisk mos- eller sumptørv. Derefter skiftende, mere eller mindre destruerede tørv. Det tyder på, at sidst i nordbotiden kom en fugtig og kølig periode, hvilket også bekræftes af diagrammet fra Comarum Mose. I nordbolagene er fundet frø og frugter af *Polygonum boreale*, *Stellaria media*, *Capsella*, *Potentilla anserina*, *Poa annua*, *Rumex acetosella* og *Ranunculus acris*. De sydgrønlandske, stærkt hemerophile *Rumex acetosella*-bestande formodes at være indslæbt, og måske er *Ranunculus acris* også tildels indslæbt.

Fra bunden af Godthåbsfjord foreligger 3 diagrammer (plate 16–18). En del af kurverne fra den første lokalitet, "Lake 100 m s.m.", har tidligere været publiceret af JOHS. IVERSEN i 1952–53. Formentlig omkring 8500 B.P. blev denne sø isoleret fra fjorden. I de første zoner er udviklingen så lig den fra Comarum Sø beskrevne, at var det ikke for et forskelligt forløb af samlekurverne for *Gramineae* og *Cyperaceae*, kunne de to diagrammer stamme fra samme bassin. Og selv om afstanden er 370 km, tyder alt på, at der er tale om en synkron udvikling. Ved begyndelsen af den lokale pollen-zone C, mellem 7000 og 6500 B.P., indvandrer *Juniperus* og *Betula nana*. Sidstnævnte stiger øjeblikkelig til over 50 %, og udstrakte *Betula nana* heder med spredte *Juniperus* (men med meget få *Ericales*) har dækket landet i de følgende årtusinder.

"Lake 8 m s.m." blev isoleret i slutningen af denne zone. Plate 17 viser dels det omtegnede og udvidede diagram fra IVERSEN (1952–53), dels to mindre diagrammer fra nye boringer. De blev lavet for at sikre en datering af den vigtige zonegrænse C–D, karakteriseret ved indvandringen af *Alnus crispa*, formentlig samtidig med begyndelsen af den klimatisk mest gunstige periode. C^{14} dateringen viser, at dette skete ca. 4000 B.P. Efter et par tusind års forløb vidner faldet i *Alnus* i diagrammerne fra begge søer og den samtidige stigning i *Ericales*, *Betula* og *Gramineae* om køligere klima. Nordboernes bosættelse i Vesterbygden, bl. a. på skråningen ned mod "Lake 8 m", karakteriseres ved en nedgang i pollen af buske og tilsvarende stigning i urter, men så drastisk som omkring Qagssiarssuk er virkningen ikke. Afslutningen af bosættelsen er vagt defineret.

Ved Itivnera er et profil gennem en palaeo-eskimobebyggelse opmålt (fig. 25), og et pollen-diagram udarbejdet (plate 18). Ca. 3200 B.P.

bredte sig—formentlig som følge af en klimaændring—en græsrig hede med *Empetrum* over den hævede strandterrasse, hvis grus ellers havde været dækket af en ganske åben vegetation, under hvilken der ikke blev dannet humus. Omkring 100 år senere bosatte Sarqaq-eskimoer sig her og aflejrede et tykt kulturlag. Efter deres forsvinden bredte en *Empetrum-Betula nana* hede sig over de sammenstyrtede husrester, og senere blev det en *Ledum-Empetrum* hede med *Equisetum* og *Lycopodium dubium.* Tørven og pollenet er stærkt humificeret. Men for ca. 600 år siden ændrede vegetationen karakter, og der bredte sig en fugtig, tildels mose-agtig vegetation med *Cyperaceae*, *Tofieldia*, *Diphasium*, *Harrimanella* og *Sphagnum.*

Ved Eqalugialik er undersøgt nogle profiler i et nordbo-tun (p. 162), og sekvensen grus-nordbolag-lidet humificeret tørv er parallel med tilsvarende profiler i Qagssiarssuk. Tolkningen af profilerne gennem nordbolag ved Ujaragssuit og Umîviarssuk (IVERSEN, 1934) er taget op til fornyet bedømmelse. Begge profiler peger mod fugtigere forhold ved afslutningen af nordboperioden. Ved Itivnera er et par damme, hvori tidligere voksede *Hippuris*, *Ranunculus hyperboreus*, *R. reptans* og *Sparganium hyperboreum* (p. 156) formentlig udtørrede som følge af klimaforbedringen i dette århundrede.

Fra Nordgrønland diskuteres 5 profiler fra Thule området og Inglefield Land, publiceret i 1972 af HYVÄRINEN og VASARI. Fælles for de to pollen-diagrammer, der ikke er påvirket af eskimobebyggelse, er afspejlingen af en klimaændring for omkring 1500 år siden (dateringen ret usikker). I det ene tilfælde bredte en fugtig *Cyperaceae* mose med *Koenigia* sig over området. Omkring 900 B.P. skiftede vegetationen karakter til en mere tør græshede med *Salix* og urter som følge af en forværring af klimaet i retning af det højarktiske ørkenklima, der hersker i dag. I det andet tilfælde starter tørvedannelsen for ca. 1800 år siden. Der er tale om en fugtig vegetation med *Gramineae*, *Cyperaceae* og *Salix.* På et senere tidspunkt standser den hurtige tørvedannelse, og vegetationen ændrer karakter.

Fra Klaresø, Peary Land, (fig. 27), foreligger 2 diagrammer (plate 19 og 20). Nederst findes marint ler med en mængde sekundært pollen. For ca. 5000 år siden isoleredes søen. *Salix arctica* synes ikke at have groet omkring søen i de første par århundreder, men om dette skyldes edafiske eller indvandrings-historiske forhold kan ikke afgøres. Ellers er der kun mindre forskelle i det relative diagram. Men den yppige vækst af *Calliergon trifarium* og det langt større pollenindhold (30–70× så stor pollen influx pr. cm^2 pr. år) vidner om varmere og fugtigere forhold i tidsrummet ca. 4000–2100 B.P. Dette må ses i forbindelse med de mere eller mindre isfri fjorde og det tildels åbne pol-bassin, der sendte en strøm af drivtømmer ind på de nu hævede strandterrasser. Fra omkring 2100 B.P. har der været en arktisk ørken omkring Klaresø.

Fra det centrale Peary Land er et profil fra en mose ved Sølejren undersøgt. Tørvedannelsen begynder sandsynligvis omkring 1500 B.P. I begyndelsen fandtes en *Carex stans* eng med spredte *Salix arctica* og *Pedicularis hirsuta*. Den afløstes af en *Carex stans-Eutrema* vegetation og derefter af en fugtigere, mosrig *Carex stans* vegetation. I en senere, mere tør periode breder *Dryas*, *Draba bellii*, *Juncus*, *Papaver radicatum*, *Ranunculus sulphureus*, *Alopecurus alpinus* og *Salix* sig, men *Cyperaceae* er dog stadig almindelige. I denne zone vidner store mængder trækulstøv om en nærliggende eskimobebyggelse, og sandsynligvis daterer denne sig fra 800–700 B.P. I den øverste zone dominerer *Salix* og *Cyperaceae*. C^{14} dateringerne er desværre noget suspekte, men det er ikke urimeligt at formode, at den fugtige zone er synkron med den tilsvarende fra Thule-Inglefield Land.

Fjerntransporteret pollen spiller en stor rolle i de sydgrønlandske diagrammer fra yderkysten, specielt tidligt i de relative diagrammer. Blandt urterne er *Ambrosia* (0,2–0,8 pollen/cm²/år), *Artemisia* (0,4–1,6) og *Chenopodiaceae* (< 0,2) de hyppigste. Blandt de løvfældende træer er *Alnus*, der i de relative diagrammer kan få op på 10–20 % i perioden 6000–5000 B.P., den vigtigste, og i absolutte tal varierer *Alnus* mellem 10 og 80/cm²/år under *Alnus*-maximet. Også *Betula* pollen med flere arter involveret er hyppige længe før indvandringen til området. *Quercus* er især almindelig i de ældre dele af diagrammerne (0,4–1,8), mens *Fraxinus* er sjældnere (0,2–0,5). Nåletræerne er rigt repræsenterede. I begyndelsen dominerer *Pinus* med en faktor 10 over *Picea*. Omkring 5000 B.P. stiger *Picea*, og omkring 3600 B.P. falder *Pinus*. I dag er der dobbelt så mange *Picea* som *Pinus* pollen i prøverne.

Takket være de fjerntransporterede pollen kan man ved at sammenligne med nordamerikanske diagrammer vise, at i begyndelsen kom de fremherskende vinde til Sydgrønland fra området syd for de store søer og fra New England. Efterhånden som den laurentiske is smeltede af, blev lavtryksbanerne og de fremherskende vinde forskudt mod nord, og Quebec, det sydlige Labrador og senere det centrale Labrador blev efterhånden de områder, hvorfra hovedparten af det fjerntransporterede pollen stammer.

Den gennemsnitlige og totale pollen influx for forskellige søer og de holocene ændringer bliver diskuteret (pp. 191–202). For den sidste pollenzone er tallene ved yderkysten med den sparsomme, hedeagtige vegetation 177–327, mens tilsvarende for de frodigere indre egne er 1710–2650/cm²/år. Dette svarer til senglaciale aflejringer i England, New England og Quebec. Det var ventet, at den totale mængde fjerntransporteret pollen pr. cm² i samme tidsrum var lige stort i nærliggende søer som f. eks. Isoëtes Sø og Spongilla Sø. Når dette ikke er tilfældet, må det især skyldes, at forholdet mellem søernes overflade og den del af søbunden, hvor vinterisen tillader en uforstyrret sedimentation, ikke er ens fra sø til sø.

For at give en bedre tolkning af fossile pollen spektre er der analyseret en række recente gytjeprøver, især fra Sydgrønland (fig. 30 og table 22). Som venteligt er der store forskelle mellem spektrene fra yderkysten og de indre fjordområder. Som gennemsnit af 21 yderkystprøver udgør *Empetrum* 21 % af ΣP mod 1,7 % inderst i fjordene (6 prøver). For *Cyperaceae* er tallene 24 mod 15 %, for *Alnus* 1,5 mod 0,5 % og for exotiske 1,5 mod 0,4 %. Omvendt dominerer i de kontinentale egne *Gramineae* (16 mod 11 %) og en række urter, men også *Juniperus* (0,75 mod 0,28 %) og *Salix* (9,4 mod 5,5 %) spiller en større rolle i spektrene.

Ved Qagssiarssuk var i sommeren 1969 opstillet 3 pollenfælder (Tauber traps). De 2–i Comarum Mose og Galium Kær–dækker hele blomstringsperioden, mens den tredie–på en flåde i Comarum Sø–blev opstillet 1. juli. Fælderne blev tømt 3–4 gange i sommerens løb og analyseret separat (table 23), således at der er mulighed for at kombinere indholdet med fænologiske iagttagelser. Størrelsesordenen af fanget pollen er 400/cm². Bemærkelsesværdigt er fundet af enkelte pollenkorn af *Hippuris*, *Eupotamogeton* og *Myriophyllum* i fælderne, selv om de nærmeste individer af disse vandplanter ofte er flere hundrede m væk i andre søer eller damme.

I Nordgrønland stod i 1968 en Tauber trap ved Klaresø og en petri-skål med glycerin i termometerburet ved Brønlundhus og Station Nord. Det meget sparsomme indhold (1–2 pollen/cm²) er analyseret (table 24).

Den gennemsnitlige sedimentationshastighed af gytje er angivet i de absolutte diagrammer. I fig. 31 er værdierne afbildet som funktion af alderen. En trediedel af de beregnede hastigheder er mellem 1 og 2 cm gytje pr. 100 år, og kun i 4 af 33 perioder er der sedimenteret mere end 6 cm gytje pr. 100 år. Som gennemsnit for alle er tallet 3,1 cm/100 år. Disse tal bliver sammenlignet med andre publicerede resultater. I nogle søer er der en større sedimentation i de ældste perioder, men p.g.a. oligotrofieringen falder søernes produktivitet. I den fattigste sø–Isoëtes Sø–er kun afsat 1,39 m gytje på ca. 9600 år.

Til sidst gives (pp. 216–223) nogle afsluttende bemærkninger om den holocene vegetations- og klimaudvikling i de undersøgte dele af Grønland, og sammenligninger drages med tilsvarende undersøgelser, især i Canada, og med de vidnesbyrd om klimaændringer, der kan hentes fra boringer i dybhavssedimenter og i Grønlands indlandsis. Problemet om "overvintring" af planter på nunatakker og højarktiske lavlands-refugier omtales. Med udsagnene om temperatursænkningerne under sidste istid in mente må det fastslås, at kun de mest hårdføre arter har været i stand til at overleve.

SUMMARY

This paper is concerned with the investigations of some Greenlandic sediments which were deposited after the last glaciation. The development of the vegetation and the climate is discussed on the basis of these investigations.

The methods used are described on pp. 9–13. A Livingstone corer yielding slightly more than 1 m long cores was used in the field. Whenever possible, open profiles were dug.

Table 2 (p. 15) gives a survey of the indigenous species and genera determined. Discussions of the determination of macrofossils (mainly seeds and fruits) and microfossils (pollen and spores) appear on pp. 20–31. When a closer determination was impossible, the suffix type has been used. The content of species or genera included in each type is contained in this chapter.

Two types of pollen diagrams are included. Relative diagrams appear as silhouette diagrams, whereas absolute diagrams are histograms. The length of the bar usually denotes the number of pollen deposited pr. cm^2 pr. year on the lake bottom. This was calculated by counting the number of pollen in an aliquot of the 1 ml sample. The matrix sedimentation rate, which is necessary for calculation, was determined by C^{14} datings. In two absolute diagrams (Galium Kær A and Klaresø), the length of the bar denotes the content of pollen pr. g dry weight. The basic sum includes all pollen (including ferns, etc.), but excludes pollen of exotic plants and hydrophytes.

Three lakes were investigated in the outer coast area west of Kap Farvel. The history of Isoëtes Sø (pp. 40–54) starts with the melting of the ice, ca. 9600 B.P. Spongilla Sø (pp. 54–62), 400 m distant, was isolated ca. 9200 B.P. Kløftsø, 15 km farther in the fjord, began depositing gyttja ca. 9300 B.P. To begin with, there was an open pioneer vegetation of widely distributed arctic plants, which included plants such as *Saxifraga oppositifolia* type, *S. nivalis* type, *S. caespitosa* type, *Erigeron* type, *Carex* (presumably *C. bigelowii*), and other *Cyperaceae*, *Poa*, *Puccinellia* (i.a. *P. langeana*), as well as other *Gramineae*, *Armeria*, *Koenigia*, *Oxyria*, *Cerastium cerastoides*, *Silene acaulis*, *Minuartia* type, *Huperzia*, and *Sagina*. Almost all of these plants grow all over Greenland. Those species, which

are characteristic of any type of vegetation, indicate that there were snow-patches and moist sandy soil; a cold, humid climate presumably prevailed.

The first dwarf-shrubs immigrate a few centuries later, ca. 9100 B.P.: *Loiseleuria*, *Harrimanella*, *Vaccinium* (presumably *V. uliginosum*) and *Empetrum*. The latter, which is the most common plant at present, is of minor importance in comparison to the other *Ericales*. About 8400 B.P. *Sedum* and *Lycopodium* spread, and the curves of *Dropteris* type, *Luzula/Juncus*, *Diphasium* type, and *Cyperaceae* increase. But snow-patches and heaths with a lengthy snow-cover still dominate.

A number of changes indicative of an amelioration are registered ca. 7200 B.P. *Salix* (*S. herbacea*, as well as *S. glauca*) and *Juniperus* immigrate along with the decrease or even the extinction of many pioneer plants. A few *Salix* may have grown in the area prior to this time. In the two following millenia the climate supposedly was as warm, and presumably drier than it is today.

Several minor changes which took place ca. 5300 B.P. indicate that the temperature rose until *Betula glandulosa* immigrated ca. 3800 B.P. It cannot be determined whether climatic or dispersal factors were responsible for this late immigration. The only diagram from the inland behind Kap Farvel, Drepanocladus Dam (plate 8) starts very late, ca. 3000 B.P. At this time *Betula pubescens* is common around this small kettlehole, but has never grown at the outer coast.

A marked change indicating a climatic deterioration appears in all diagrams ca. 2200 B.P. *Juniperus* is greatly decimated; at the same time *Betula glandulosa* and *Empetrum* increase. In the inland diagram *Betula pubescens* decreases.

The lakes at the outer coast are highly oligotrophic (table 1, p. 14). Apart from a scattered occurrence of *Isoëtes setacea* and *I. lacustris*, they often lack higher vegetation. Immediately after the ice retreated, however, *Hippuris*, and soon afterwards, *Subularia* immigrated to the three lakes (and to Sphagnum Dam, p. 69), whereas *Callitriche*, *Sparganium*, *Ranunculus confervoides* and *Eupotamogeton* grew in one or more of the lakes. After flowering briefly (fig. 10), growth was reduced, and as a result of oligotrophication, most species became extinct. *Lepidurus arcticus* (*Entomostraca*) lived in two of the lakes. Today it does not occur south of 67° N.

The change that took place ca. 7200 is also registered in the lakes; *Isoëtes setacea*, which had a scattered occurrence in the preceding centuries, spreads explosively. Similarily, the warmest period is characterized by the spreading of *Isoëtes lacustris* ca. 5300 B.P.

Two basins were investigated at Qagssiarssuk at the head of Tunugdliarfik: Comarum Sø (partly surrounded by Comarum Mose) and Galium

Kær. Comarum Sø was much larger when it was formed, shortly before 8500 B.P. (figs 11–13, pp. 93–94). A pioneer vegetation, mainly consisting of herbs, grew in the surroundings: *Oxyria*, *Plantago maritima*, *Chamaenerion* (presumably *C. latifolium*), *Puccinellia*, *Poa*, *Elymus*, and other *Gramineae*, *Silene acaulis*, *Minuartia* type (presumably *M. rubella*), *Erigeron* type, *Cyperaceae*, *Saxifraga oppositifolia* type, *S. nivalis* type, etc. *Empetrum* immigrated early. In common with the Kap Farvel diagrams, only widespread, often circum-Greenland species, but no decidely southern plants have been determined. Yet the vegetation indicates more continental conditions. *Lepidurus arcticus* occurs in some of the earliest samples. *Chara*, *Potamogeton filiformis* and, to a lesser extent, *Ranunculus confervoides* and *Subularia* were common to begin with. Even at present the rich hydrophyte vegetation in the lake is caused by the surrounding sedimentary bedrock, which is partly composed of Precambrian lava.

Salix glauca immigrates ca. 8000 B.P. It spreads explosively, partly at the expense of the pioneer plants. *Isoëtes setacea* and *Myriophyllum spicatum* invade the lake. *Juniperus* immigrates ca. 7000 B.P., and immediately covers wide areas. This happens along with the extinction of the pioneer plants. *Potamogeton gramineus* dominates in the lake. *P. alpinus* and *Myriophyllum* also occur. After a few centuries an equilibrium is reached, and in the period 6300–4300 B.P. only minor oscillations appear in the diagram.

Betula glandulosa immigrates between 4400 and 4000 B.P., along with a climatic change, possibly due to more humid conditions. *Betula pubescens* immigrates ca. 3400 B.P. The following period supposedly is the warmest one; this theory is supported by the occurrence of the freshwater-living *Cristatella mucedo* (*Bryozoa*) in the period 3600–2600 B.P. This southern species does not occur in Greenland today.

The lake was partly filled in, and a *Menyanthes-Carex rostrata* swamp spread, followed by a moist bog vegetation. This blocked the water outlet, with the result that the water level rose in the remaining lake. The diagram from the bog (plate 11), which up to then was identical with the lake diagram (plate 9), shows that ca. 2500 B.P. the swamp covered the northern half of the basin.

A climatic deterioration is indicated ca. 1900 B.P. by the decreasing *Juniperus* and the shift in the ratio *Betula pubescens: B. glandulosa* in favour of the latter (plate 1). In consideration of the hydrophytes, the period is very poor, presumably because the surrounding bog prevents a supply of washed-out nutrients from the surroundings.

A drier (and warmer?) period sets in a few centuries later, and *Betula glandulosa* grows in the bog that today is very wet. This happens along with the Norse landnam ca. 985 A.D. The vegetation is radically changed as a result of sheep grazing. For example, not a single pollen of *Rumex*

acetosella/acetosa was found prior to the landnam. Afterwards it often makes up 3–5 % of ΣP. The *Rumex* curve continues almost unchanged to the present day, and only minor alterations indicate the disappearance of the Norsemen.

Two diagrams from a coring (plates 12–13) and two from an open profile (plates 14–15) are shown from Galium Kær (fig. 14, pp. 109–124) in Qagssiarssuk, South Greenland (Brattahlid of the Norsemen). The sedimentation began as late as ca. 7000 B.P. In the first centuries enormous quantities of pollen were washed out in the lake (more than 1 million/ml, equalling 30,000–60,000/cm²/yr. This phenomenon had also been observed in the small kettlehole Drepanocladus Dam. Fruits of the very rare *Eleocharis palustris* s.l. were found in even the deepest samples, which indicates climatic conditions almost like those prevailing today.

The outline of the vegetational development at Galium Kær up to the Norse period is identical with that in Comarum Sø. Yet it should be mentioned that a marked increase in *Juniperus* ca. 5300 B.P. indicates changed conditions. And along with the immigration of *Betula glandulosa* ca. 4500 B.P., a drastic change in the hydrophyte vegetation is registered. Two species of *Potamogeton* and of *Myriophyllum*, as well as *Isoëtes setacea*, are highly decimated or even become extinct, whereas *Hippuris* seems to have filled in almost the whole shallow basin. The alkalibiontic diatoms disappear, the alkaliphilous decrease, and the acidophilous increase. This is explained as a result of the formation of humus under the birch-scrub, causing an acid water supply to the lake.

Presumably, the Norsemen broke a channel through the low narrow ridge damming the lake, in order to irrigate the slope (as the farmers did 30–40 years ago). The water level fell, and *Sparganium*, *Ranunculus hyperboreus* and *Menyanthes* spread immediately after the landnam. Apart from the introduced weeds (*Rumex acetosella/acetosa*, *Achillea*, *Polygonum aviculare* s.l.), the clearance of scrubs and intensive sheep grazing caused an increase in open soil plants. A number of these had been pioneer plants in the local late-glacial: *Plantago maritima*, *Silene* type, *Liguliflorae*, *Campanula*, *Sedum*, and *Thymus*. An increase in *Salix* and *Juniperus* is an indication of the Norsemen's disappearance; perennial weeds do not disappear, however.

Some open profiles among the Norse ruins have been investigated. A common profile looks as follows: There are wooden chips and other cultural traces directly on the raised beach. A fresh moss or swamp peat ends the culture layer followed by more or less humified peat. This is indicative of a humid and cool period in the centuries around the disappearance of the Norsemen, as the diagram from Comarum Mose shows. Seeds and fruits of *Polygonum boreale*, *Stellaria media*, *Capsella bursa pastoris*, *Potentilla anserina*, *Poa annua*, *Rumex acetosella*, and

Ranunculus acris are found in the culture layers. The highly hemerophilous South Greenland strains of *Rumex acetosella* supposedly are introduced. This may also be true with respect to *Ranunculus acris*.

Three diagrams (plates 16–18) are given from the head of Godthåbsfjord, West Greenland. Part of the curves from "Lake 100 m s.m." (pp. 138–141) were published by JOHS. IVERSEN (1952–53). This lake was isolated ca. 8500 B.P. The oldest zones are almost identical with those described from Comarum Sø. In spite of a distance of 370 km a synchronous history is estimated. *Juniperus* and *Betula nana* immigrate at the opening of zone C between 7000 and 6500 B.P. The latter increases to more than 50 % of ΣP. Extended *Betula nana* heaths with scattered *Juniperus*, but with very few *Ericales*, covered the surroundings in the coming millenia.

"Lake 8 m s.m." was isolated towards the end of this zone (pp. 144–153). Plate 17 gives the re-drawn diagram from IVERSEN (1952–53), as well as some new brief diagrams around the zone border C-D, defined by the immigration of *Alnus crispa*. According to the C^{14} dating, this happens ca. 4000 B.P. Two millennia later a decrease in *Alnus* and an increase in *Ericales*, *Betula nana*, and *Gramineae* indicate a deterioration in both lakes. A decrease in the shrubs indicates the Norse landnam, but this influence is not as marked as in Qagssiarssuk. The Norsemen's disappearance is only vaguely indicated.

A profile through the palaeo-Eskimo settlement Itivnera was investigated (fig. 25, pp. 158–162). A pollen diagram (plate 18) is given. Presumably, a rich grass heath with *Empetrum* spread over the raised beach. The Sarqaq Eskimos settled a century later, leaving a thick culture layer. An *Empetrum*-heath spread over the collapsed ruins; later, this was succeeded by a *Ledum-Empetrum* heath with *Equisetum* and *Lycopodium dubium*. The peat and pollen from these layers are highly destructed. The vegetation changed ca. 600 B.P. to a moist, almost bog-like vegetation with *Cyperaceae*, *Tofieldia*, *Diphasium*, *Harrimanella*, and *Sphagnum*.

Some profiles in a Norse croft at Eqalugialik show a sequence (p. 162) parallel to corresponding profiles at Qagssiarssuk. The interpretation of the climatic history of the Norse layers at Ujaragssuit and Umîviarssuk (IVERSEN, 1934) has been revised. Both profiles indicate humid conditions towards the end of the settlement period. Some former ponds at Itivnera (p. 156) with i.a. *Hippuris* and *Sparganium hyperboreum* dried out, presumably as a result of the amelioration in the 20th Century.

Five profiles from the Thule area and Inglefield Land, North Greenland, published by VASARI and HYVÄRINEN in 1972, have been discussed. The reflection of a climatic change to more humid conditions about one and a half millennia ago is common to the only two diagrams which are not influenced by human activity. Later on, about 900 B.P., or slightly

later, conditions change to the continental climate prevailing on today's high arctic desert (pp. 169–172).

Two diagrams (plates 19–20) are given from Klaresø, Peary Land, North Greenland (fig. 27). The lake was isolated ca. 5000 years ago. Presumably, *Salix arctica* did not grow around the lake in the first centuries, but this may be a result of edaphic conditions. Apart from this, only minor alterations appear in the relative diagram. But the vigorous growth of *Calliergon trifarium* and other mosses in the lake, as well as the much greater content of pollen than at present (pollen influx/cm²/yr 30–70 times greater) indicates that conditions were more humid in the period 4000–2100 B.P. This is ascribed to the effect on the local climate of the open fjords, as indicated by the masses of driftwood on the raised beaches. Today's high arctic desert around Klaresø was formed about 2100 B.P.

A profile in a bog at Sølejren was investigated (pp. 183–189). Peat formation began ca. 1500 B.P. under a *Carex stans*-meadow with scattered *Salix arctica* and *Pedicularis hirsuta*. This was succeeded by a *Carex stans-Eutrema* vegetation, which was followed, in turn, by a moister, richly mossy *Carex stans* vegetation. In a later and drier period *Dryas*, *Draba bellii*, *Juncus*, *Papaver radicatum*, *Ranunculus sulphureus*, *Alopecurus alpinus* and *Salix* spread over the area; yet *Cyperaceae* still are important. A large amount of microscopic charcoal indicates the existence of a 700–800 year old neighbouring Eskimo camp. The upper zone is dominated by *Salix* and *Cyperaceae*. The C^{14} datings are problematical, but presumably the moist period is synchronous with the corresponding period in the Thule-Inglefield Land area.

Long distance transported pollen (pp. 191–201) is very important in the diagrams from the outer coast in South Greenland, especially in the earlier parts of the relative diagrams. *Ambrosia* (0.2–0.8 pollen/cm²/yr), *Artemisia* (0.4–1.6), and *Chenopodiaceae* (< 0.2) are most common among herbs. *Alnus*, which in relative diagrams may amount to 10–20 % (only long distance) is most important among deciduous trees in the period 6000–5000 B.P. In absolute counts it varies between 10 and 80/cm²/yr during the *Alnus* maximum. It has never grown in South Greenland. *Betula*, including several species, is very common long before the immigration of *Betula glandulosa*. *Quercus* is most frequent in earlier zones (0.4–1.8), whereas *Fraxinus* is rarer (0.2–0.5). Conifers are very common. In the earlier zones *Pinus* dominates over *Picea* by a factor 10. *Pinus* decreases ca. 3600 B.P., whereas *Picea* increases ca. 5000 B.P. In today's pollen influx *Picea* is twice as common as *Pinus*.

A comparison of the changing spectra of long distance pollen with contemporary North American diagrams indicates that prevailing winds reaching South Greenland during the earliest zones came from the area south of the Great Lakes and from New England. Later, concurrently

with the disintegration of the Laurentide ice, the winds shifted northwards, and Quebec, southern Labrador, and, between 6000 and 5000 B.P., central Labrador, became the main source areas of long distance pollen.

The average and total pollen influx in different lakes, as well as the alterations in influx during holocene, are discussed. At the outer coast, which is covered by dwarf-shrub heaths between outcrops of bedrock, the number varies between 177 and 327/cm²/yr, whereas in the interior, where the vegetation is more luxuriant, the numbers are 1710–2650. This corresponds to late-glacial conditions in England, New England, and Quebec. Great differences appear between the outer coast and the interior. As an average of 21 outer coast samples *Empetrum* makes up 21 % of ΣP. In the 6 samples from the interior it only amounts to 1.7 %. The corresponding numbers for *Cyperaceae* are 24 and 15 %, for *Alnus* 1.5 and 0.5 %, and for exotic 1.5 and 0.4 %. *Gramineae* dominate in the interior (16 as against 11 %), as do a number of other herbs, *Juniperus* (0.75 and 0.28 %) and *Salix* (9.4 and 5.5 %).

Three Tauber traps, two of which covered the whole flowering season, were placed at Qagssiarssuk in 1969. Their contents are given in table 23. About 400 pollen/cm² were trapped. The finds of single pollen of *Hippuris*, *Eupotamogeton*, and *Myriophyllum* is remarkable, as the nearest specimens of these hydrophytes usually are several hundreds of metres distant. Three pollen traps were placed in North Greenland in 1968. Very few (1–2/cm²) pollen were trapped (table 24).

The average matrix sedimentation rates appear in the absolute diagrams. The rates as a function of the age are shown in fig. 31. One-third of the calculated rates varies between 1 and 2 cm/100 yr, and in only 4 out of 33 periods the rate exceeds 6 cm/100 yr. The average of all periods is 3.1 cm/100 yr. The initial rate is greater in some of the lakes, but drops later as a result of oligotrophication. In the poorest lake, Isoëtes Sø, only 1.39 m of gyttja has been deposited during the past 9600 years.

Finally, some concluding remarks (pp. 216–223) are made about the holocene development of the vegetation and the climate in the investigated areas of Greenland, and these investigations have been compared with corresponding investigations, especially in Canada. Furthermore, the climatic changes deduced from deep sea cores and from the Camp Century ice core have been included in the discussion. The problem concerning the survival of plants on nunataks and high arctic ice-free lowland refugia is discussed. Keeping in mind the temperature depression during the last glaciation, it seems justifiable to postulate that only the most hardy plants could survive, the more so as the pollen analyses of the earliest samples seem to confirm this.

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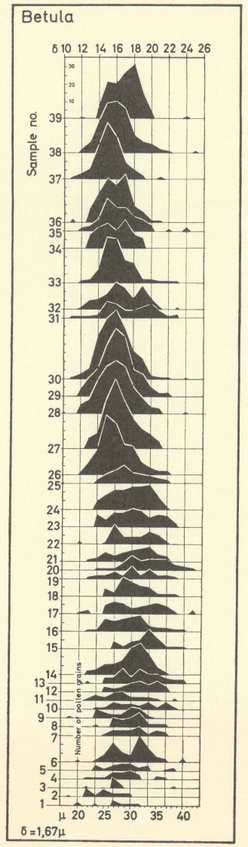
PLATES

Plate 1. Size measurements of *Betula* pollen.
Plate 2. Isoëtes Sø, relative pollen diagram.
Plate 3. Isoëtes Sø, absolute pollen diagram.
Plate 4. Spongilla Sø, relative pollen diagram.
Plate 5. Spongilla Sø, absolute pollen diagram.
Plate 6. Kløftsø, relative pollen diagram.
Plate 7. Kløftsø, absolute pollen diagram.
Plate 8. Drepanocladus Dam, relative pollen diagram.
Plate 9. Comarum Sø, relative pollen diagram.
Plate 10. Comarum Sø, absolute pollen diagram.
Plate 11. Comarum Mose, relative pollen diagram.
Plate 12. Galium Kær A, relative pollen diagram.
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Plate 15. Galium Kær B, absolute pollen diagram.
Plate 16. "Lake 100 m s.m.", relative pollen diagram.
Plate 17. "Lake 8 m s.m.", relative pollen diagram.
Plate 18. Itivnera, relative pollen diagram.
Plate 19. Klaresø, relative pollen diagram.
Plate 20. Klaresø, absolute pollen diagram.
Plate 21. Sølejren, relative and absolute pollen diagram.

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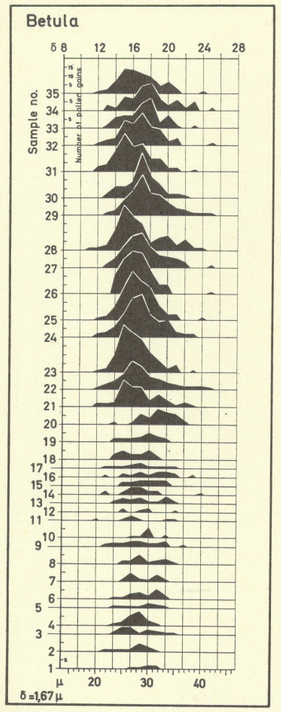
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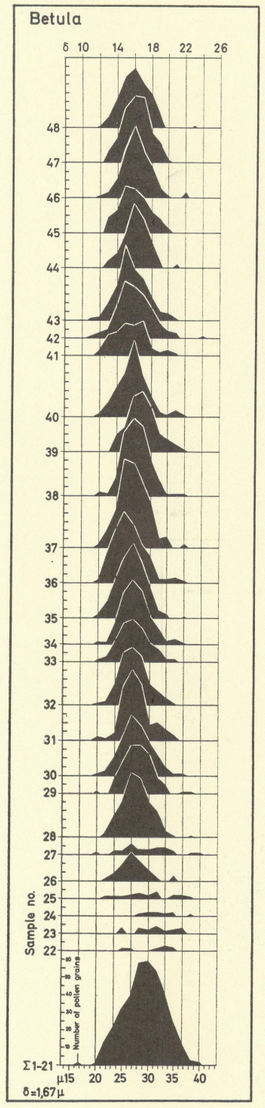
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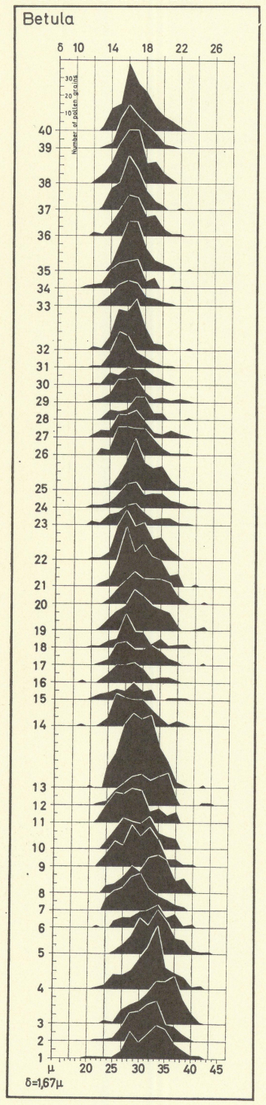
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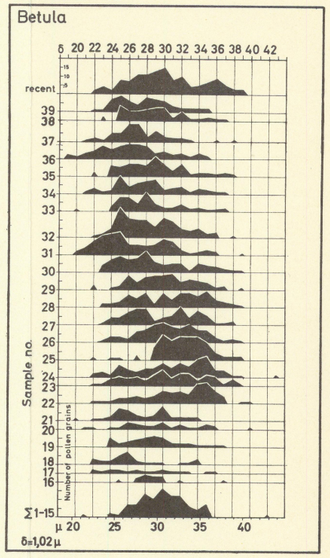
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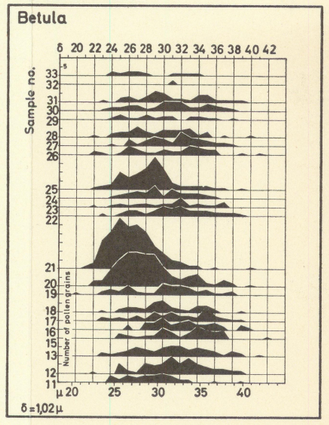
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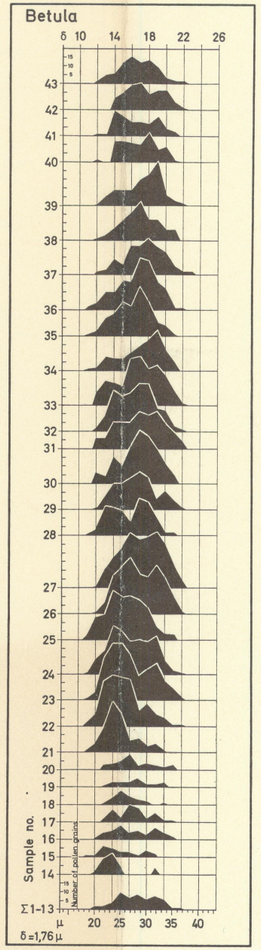
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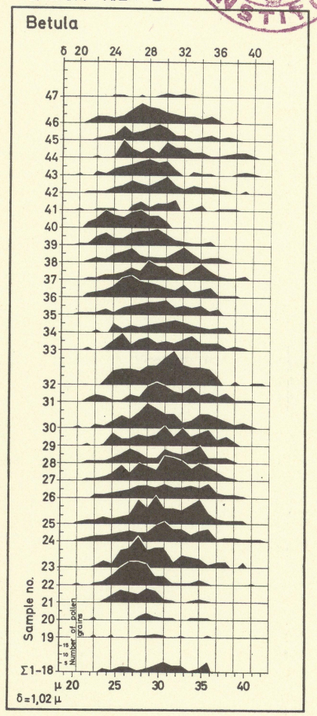
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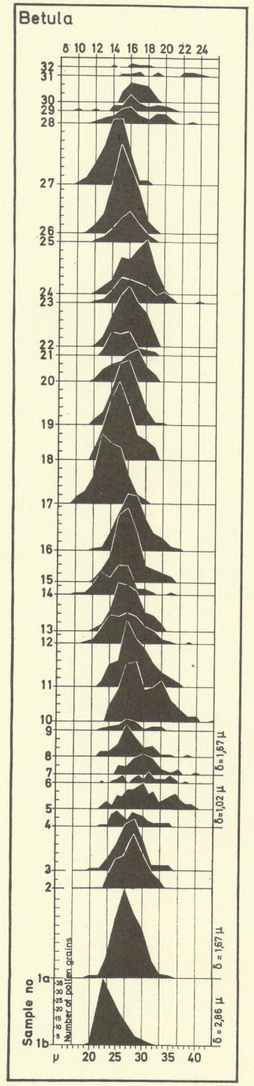
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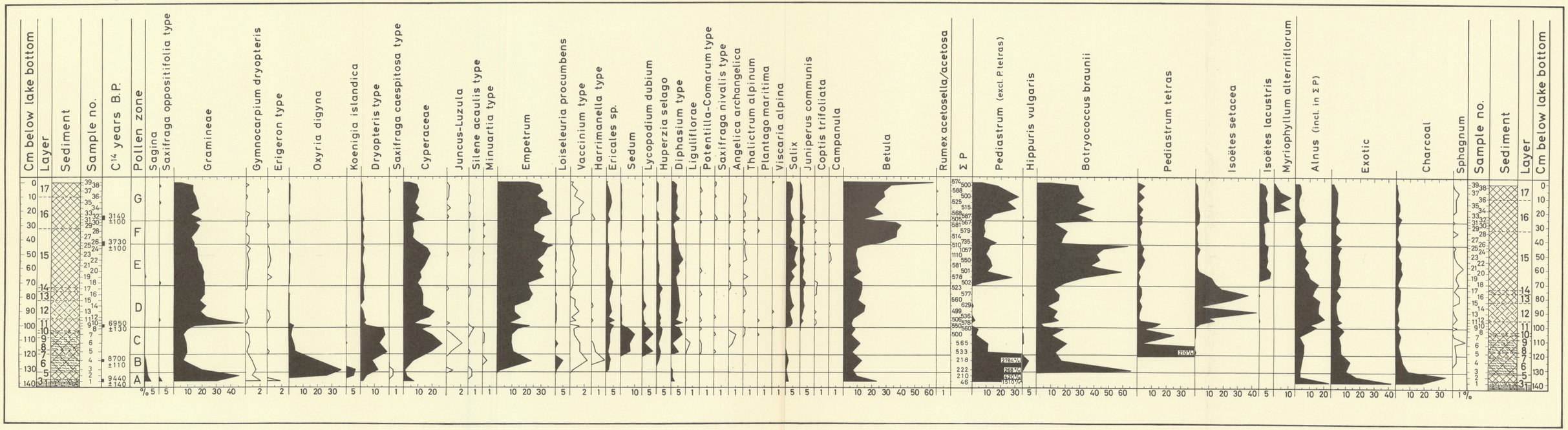
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ISOËTES SØ (59°58'N, 44°21'W)

Pamiagdluk, S. Greenland

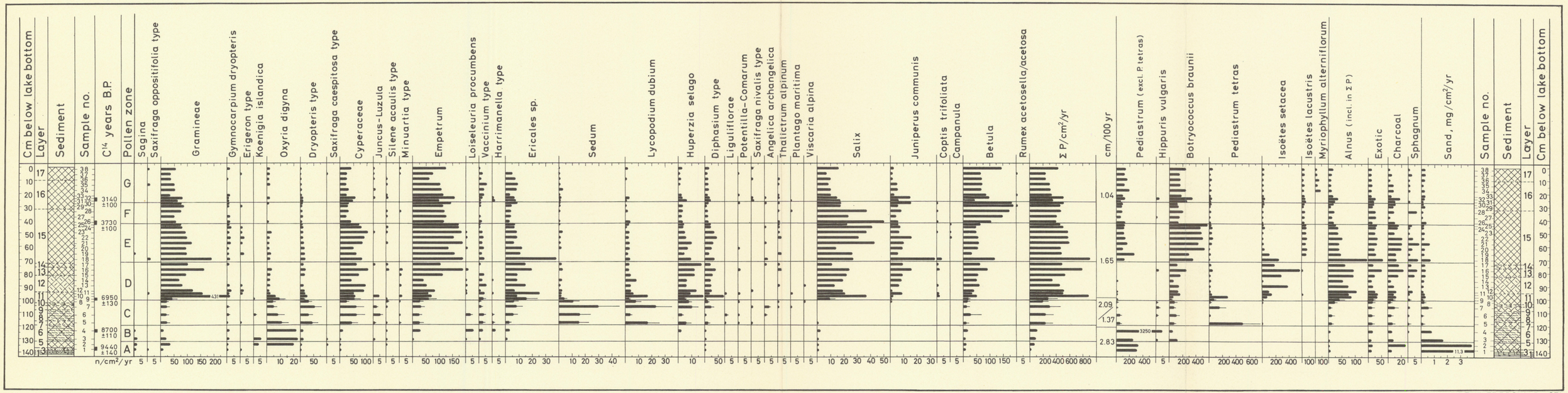


BENT FREDSKILD 1971

Universitetets Geografiske Institut

ISOËTES SØ (59°58'N, 44°21'W)

Pamiagdluk, S. Greenland

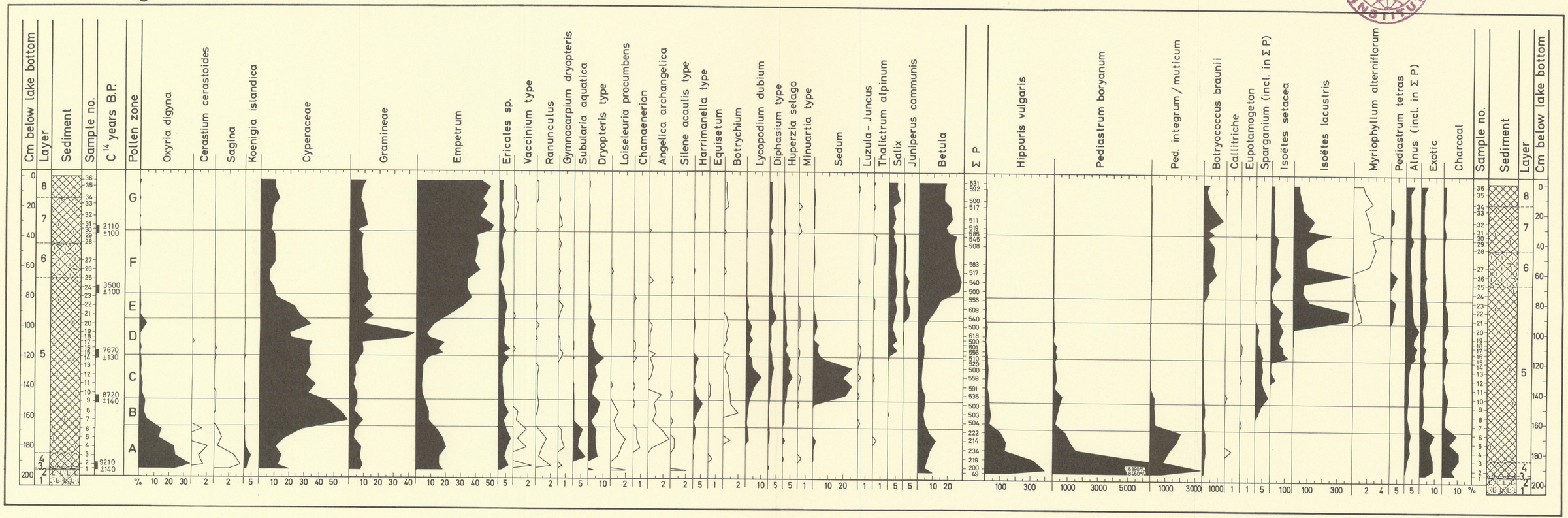


BENT FREDSKILD 1971

Universitetets Geografiske Institut

SPONGILLA SØ (59° 58' N, 44° 21' W)

Pamiagdluk, S. Greenland

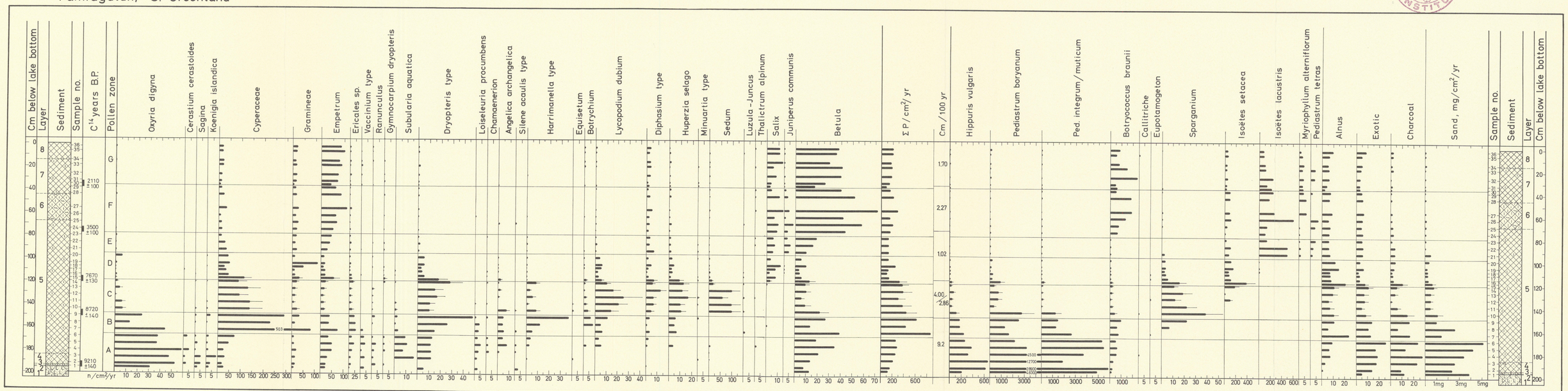


BENT FREDSKILD 1971

Universitetets Geografiske Institut

SPONGILLA SØ (59° 58' N, 44° 21' W)

Pamiagdluk, S. Greenland

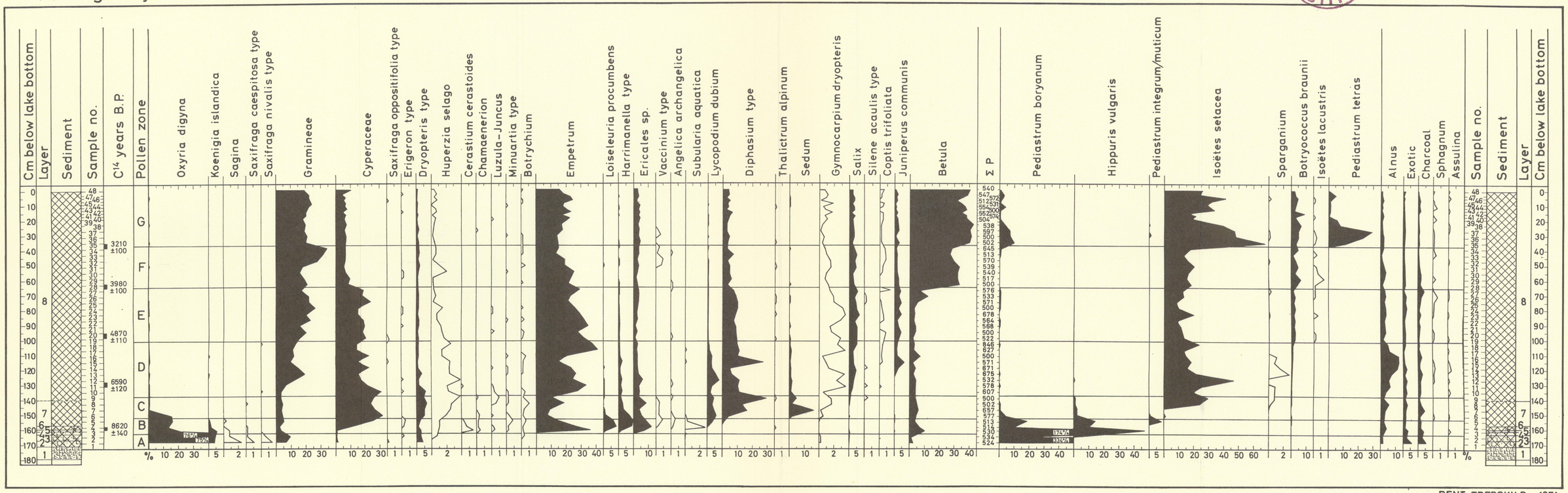


BENT FREDSKILD 1971

Universitetets Geografiske Institut

KLØFTSØ (60°03'N, 44°14'W)

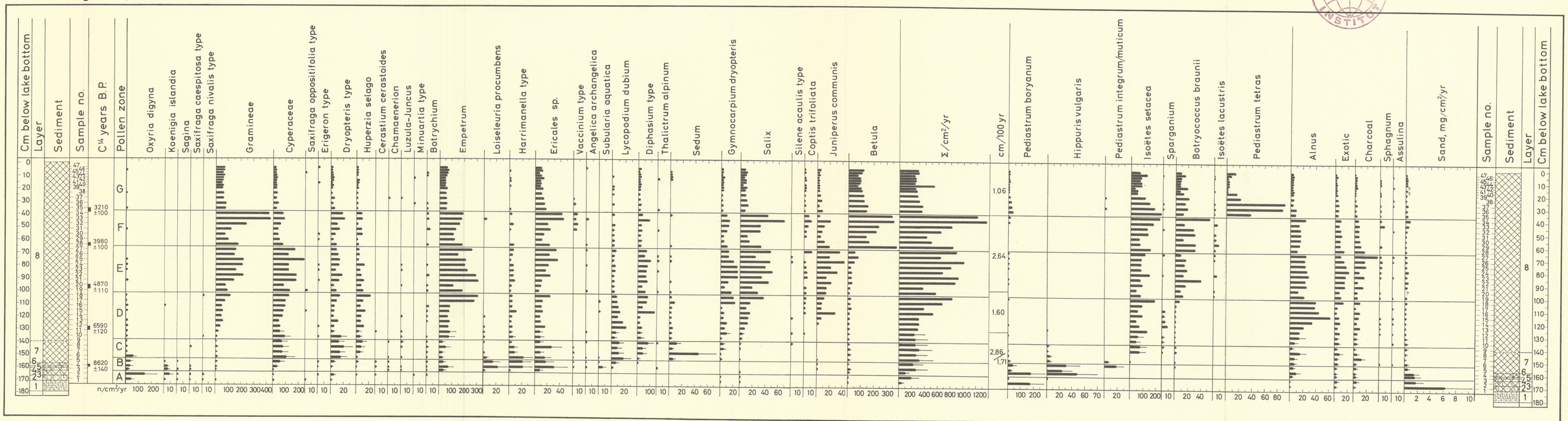
Pamiagdluk, S.Greenland



BENT FREDSKILD 1971

KLØFTSØ (60°03'N, 44°14'W)

Pamiagdluk, S. Greenland



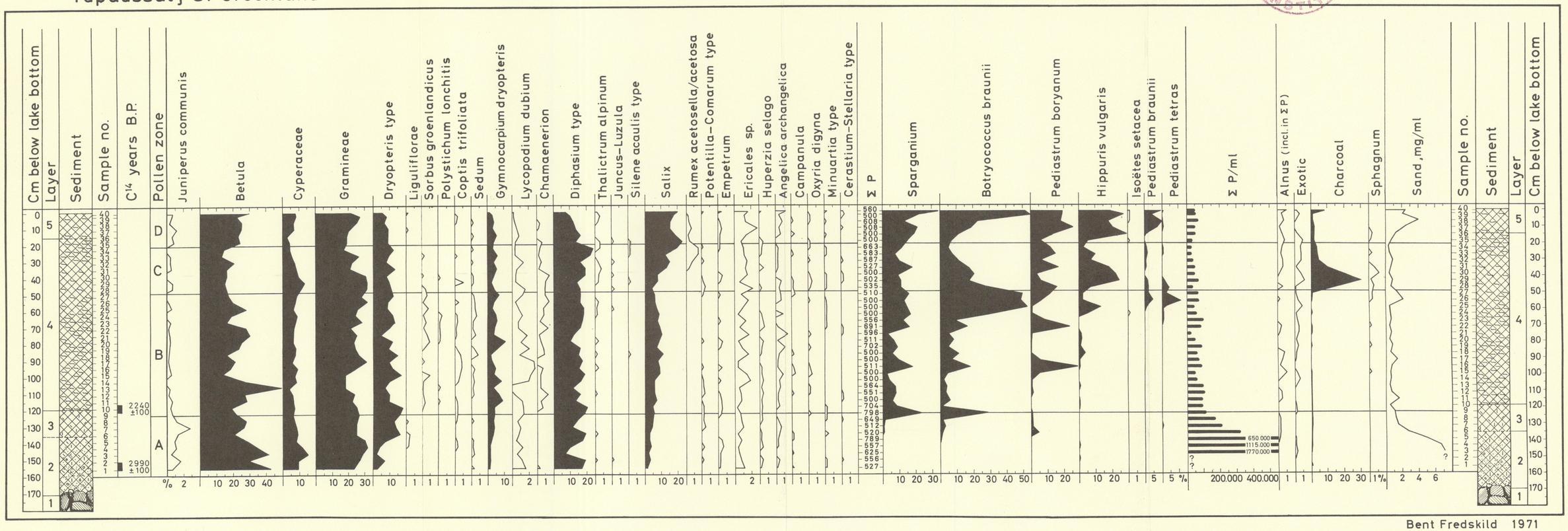
BENT FREDSKILD 1971

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DREPANOCLADUS DAM (60°20'N, 44°16'W)

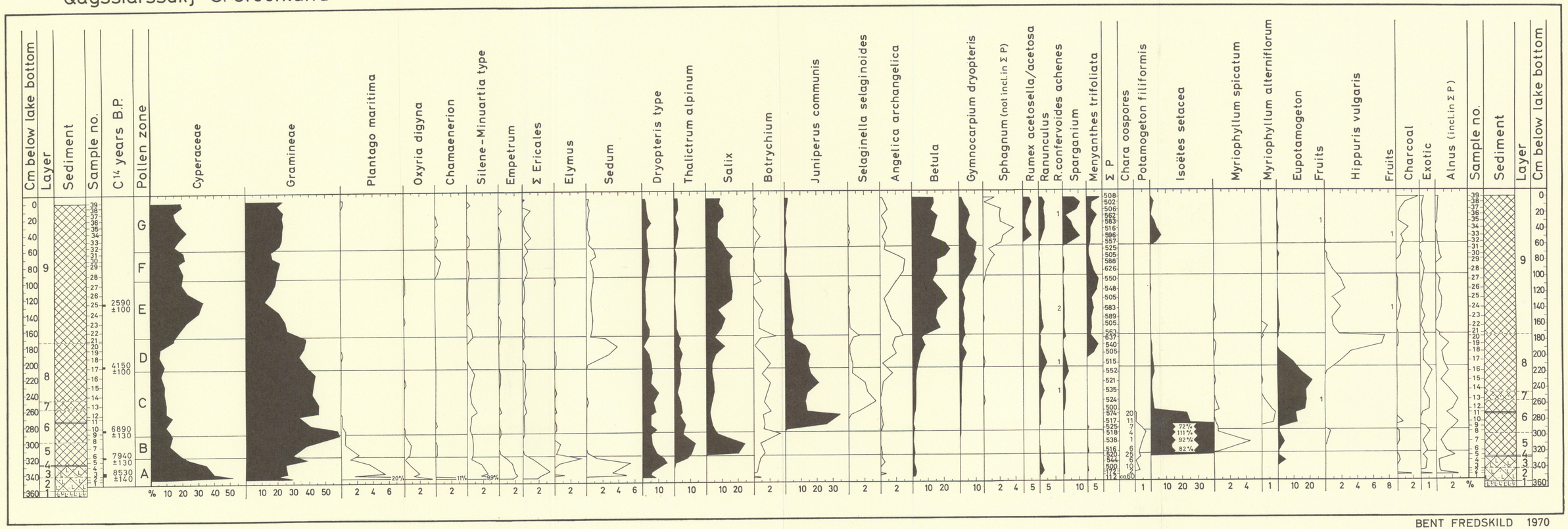
Tupaussat, S. Greenland



Bent Fredskild 1971

COMARUM SØ (61°08'N, 45°32'W)

Qagssiarssuk, S. Greenland

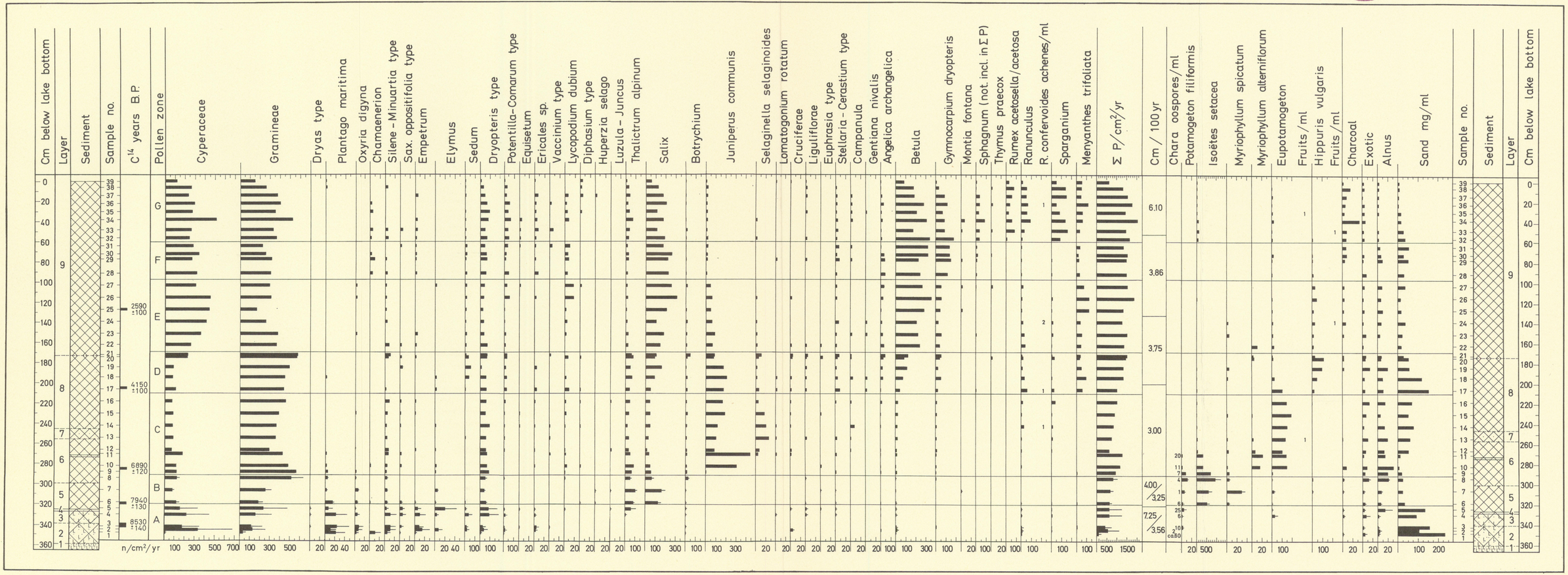


BENT FREDSKILD 1970

Universitetets Geografiske Institut

COMARUM SØ (61° 08' N, 45° 32' W)

Qagssiarssuk, S. Greenland

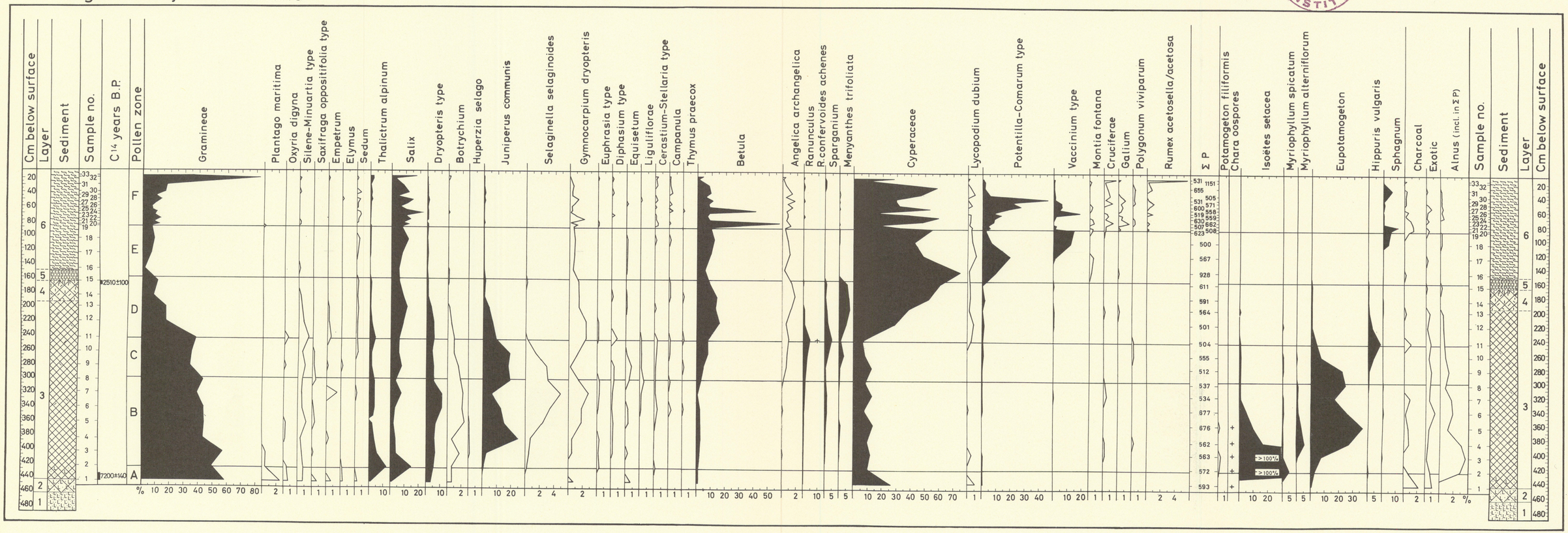


BENT FREDSKILD 1970

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COMARUM MOSE (61° 08'N, 45° 32'W)

Qagssiarssuk, S. Greenland

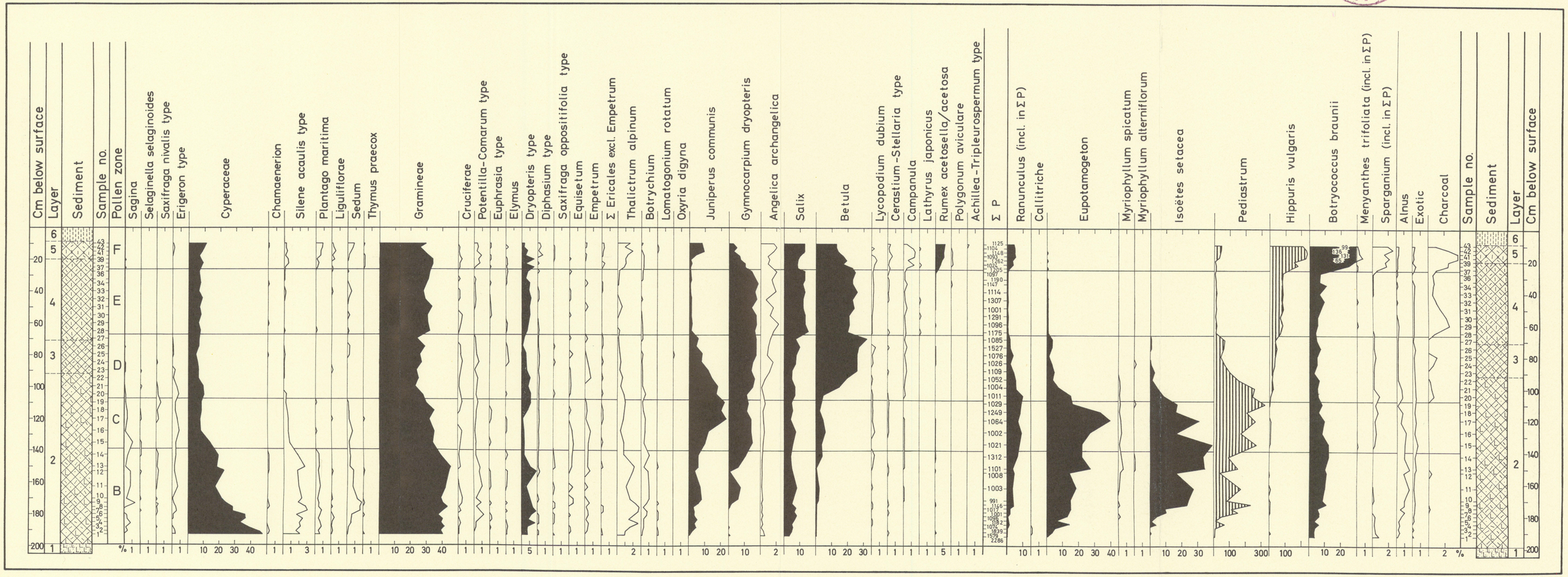


BENT FREDSKILD 1962–70

Universitetets Geografiske Institut

GALIUM KÆR A (61° 10' N, 45° 31' W)

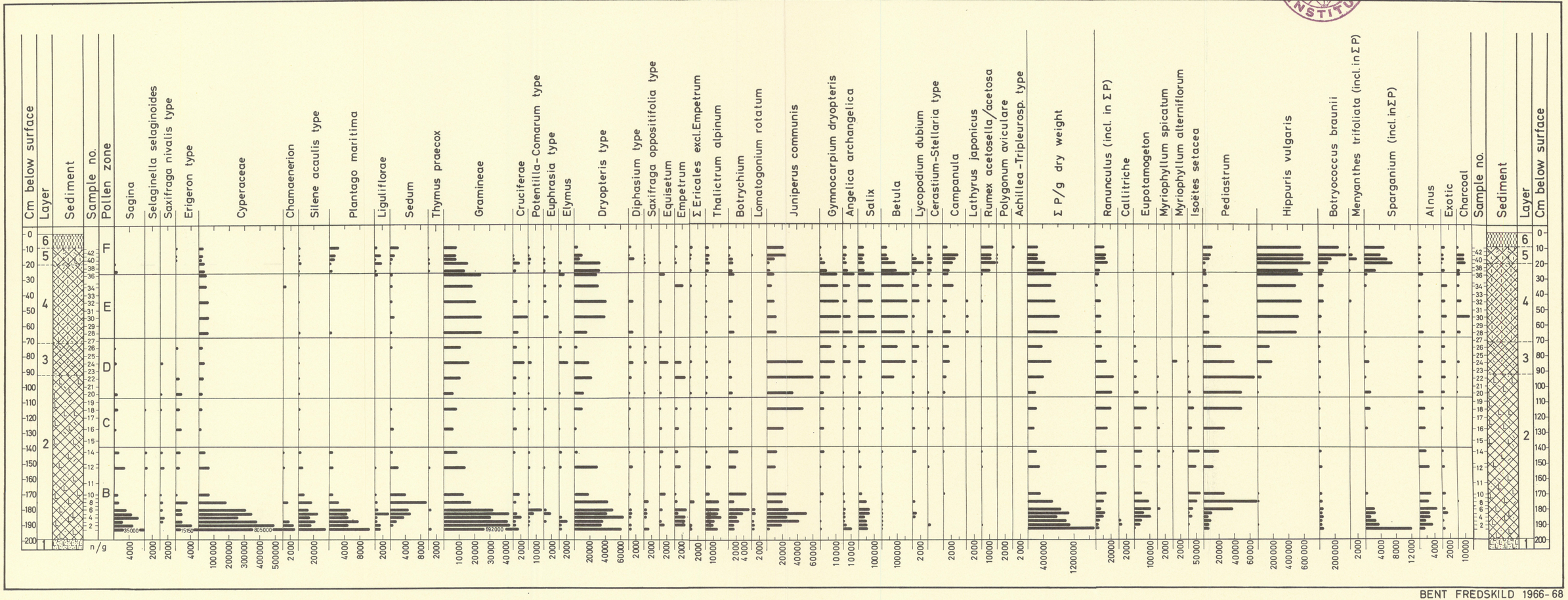
Qagssiarssuk, S. Greenland



BENT FREDSKILD 1966-68

GALIUM KÆR A (61° 10' N, 45° 31' W)

Qagssiarssuk, S. Greenland

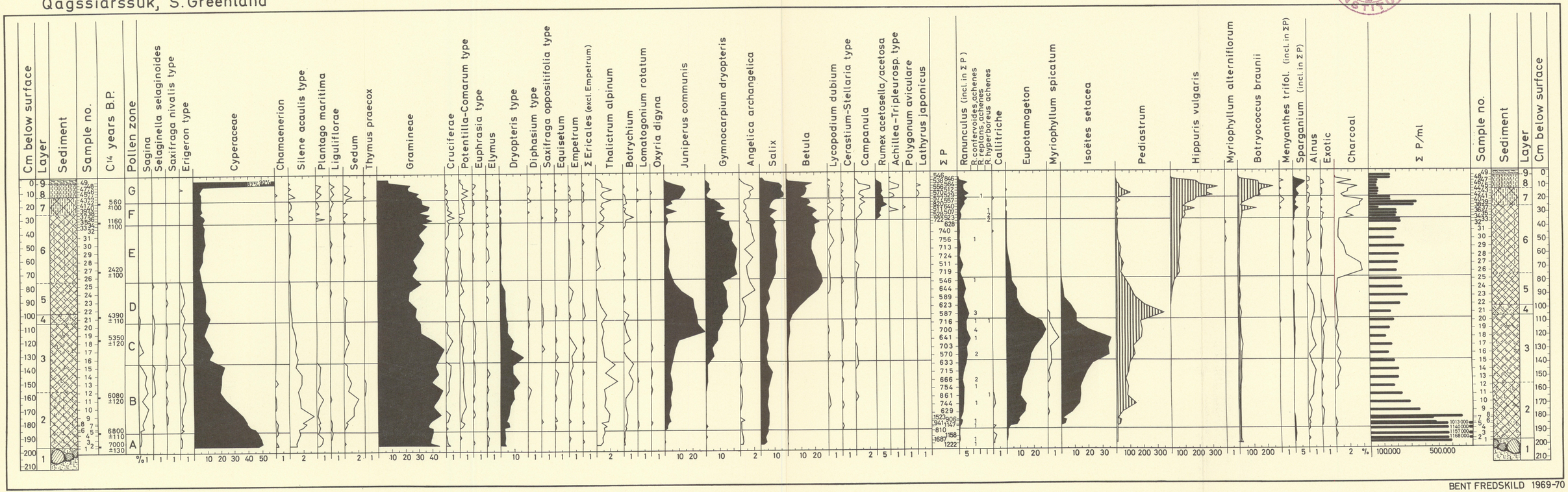


UNIVERSITETETS GEOGRAFISKE INSTITUT

Universitetets Geografiske Institut

GALIUM KÆR B (61°10'N, 45°31'W)

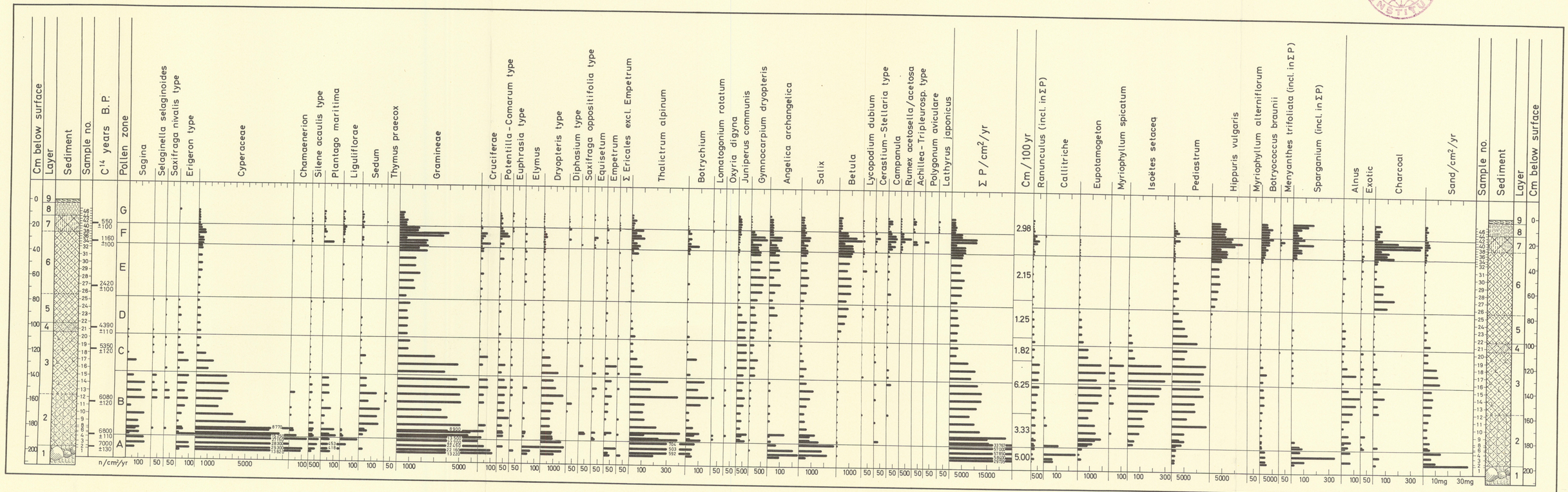
Qagssiarssuk, S. Greenland



BENT FREDSKILD 1969-70

GALIUM KÆR B (61° 10' N, 45° 31' W)

Qagssiarssuk, S. Greenland

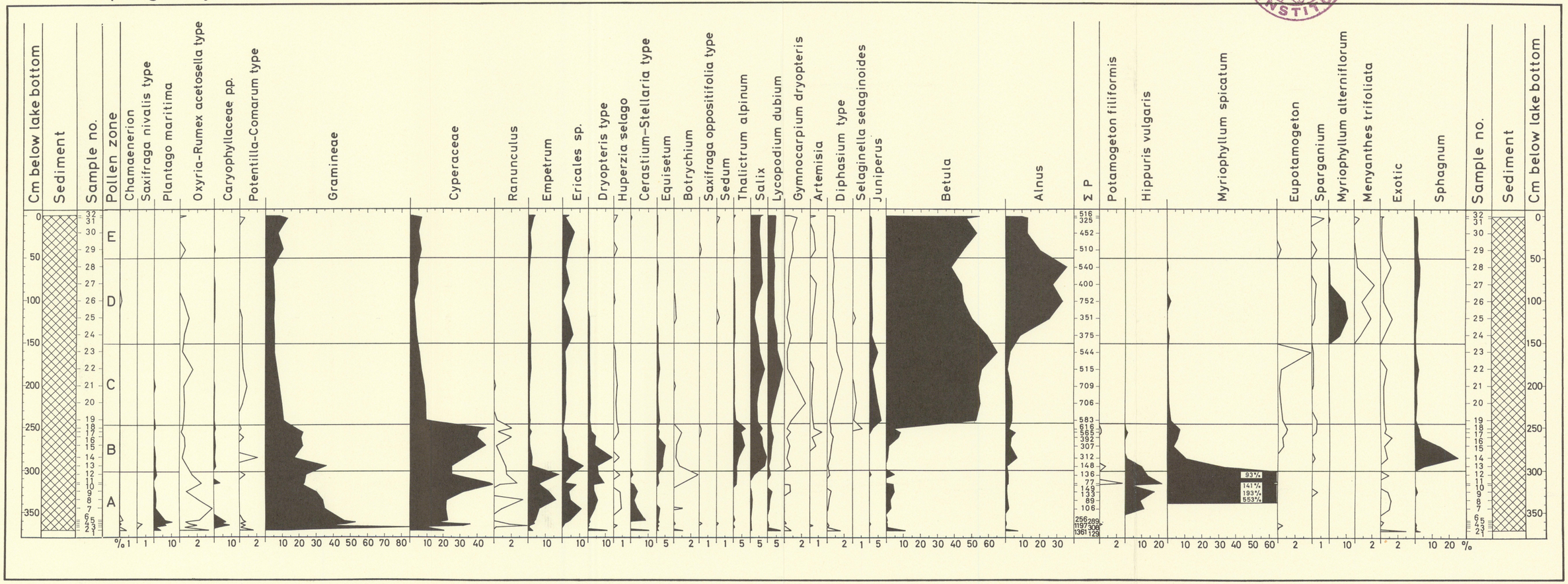


BENT FREDSKILD 1969-70

Universitetets Geografiske Institut

"LAKE 100m s.m." (64°24'N, 50°12'W)

Kapisigdlit, W. Greenland

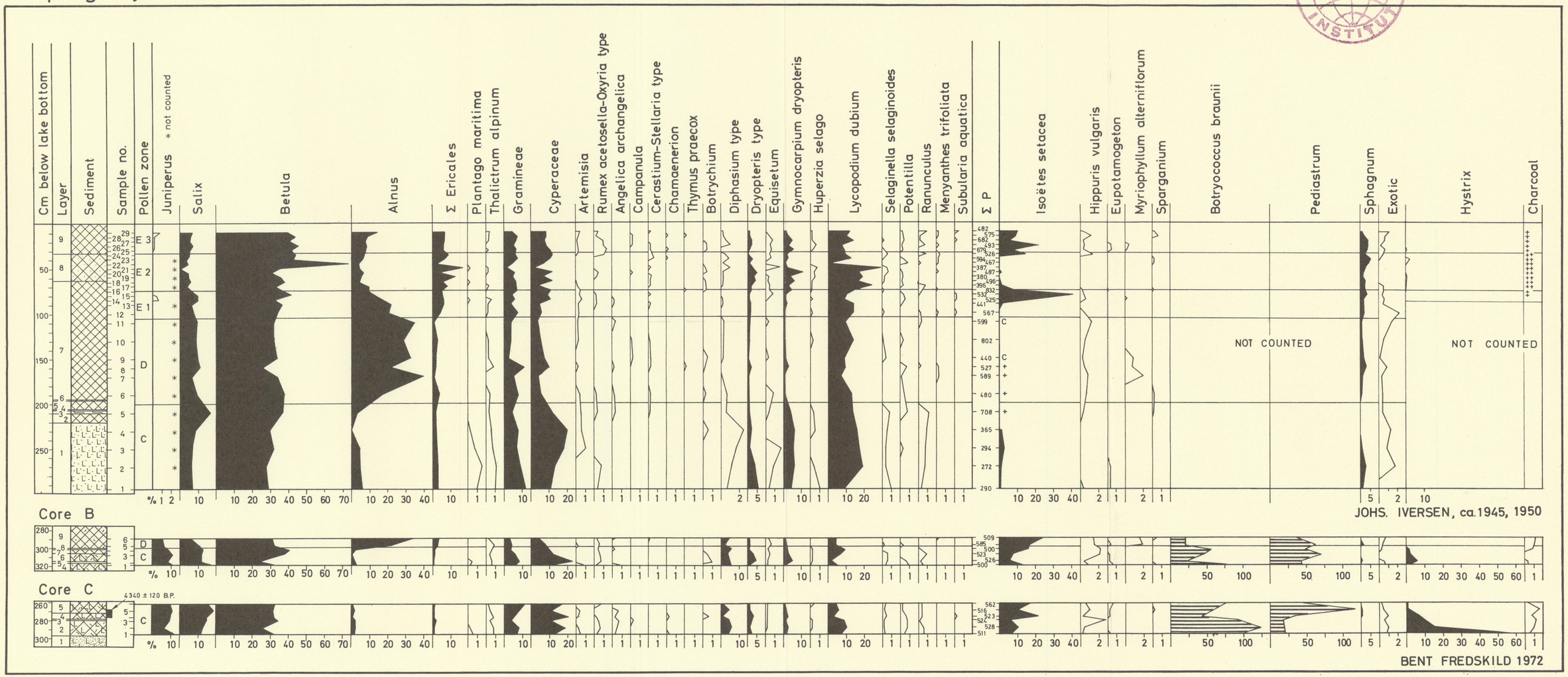


JOHS. IVERSEN and H. KROG 1950

UNIVERSITETETS GEOGRAFISKE INSTITUT

"LAKE 8 m s.m." (64° 26' N, 50° 12' W)

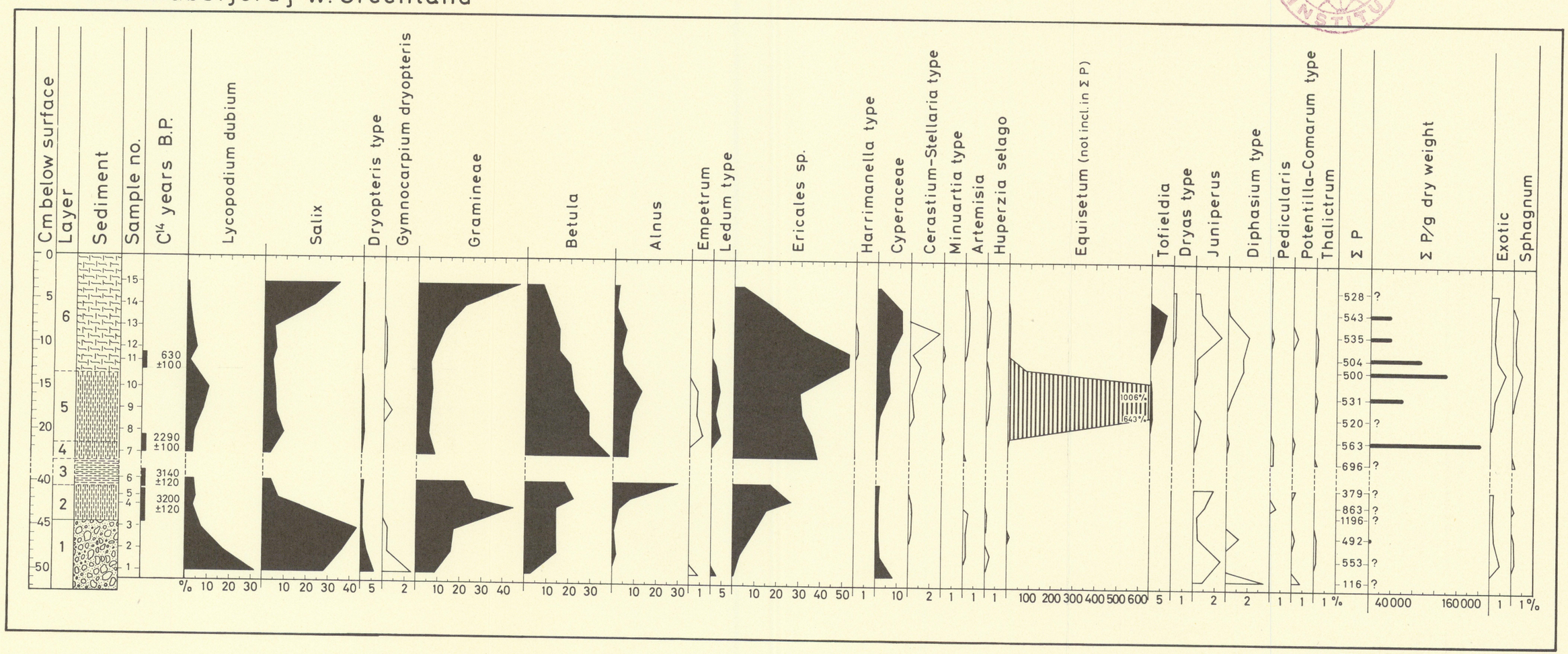
Kapisigdlit, W. Greenland



UNIVERSITETETS GEOGRAFISKE INSTITUT

ITIVNERA (64°23'N, 50°15'W)

Godthåbsfjord, W. Greenland



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KLARESØ (82°10'N, 30°34'W)

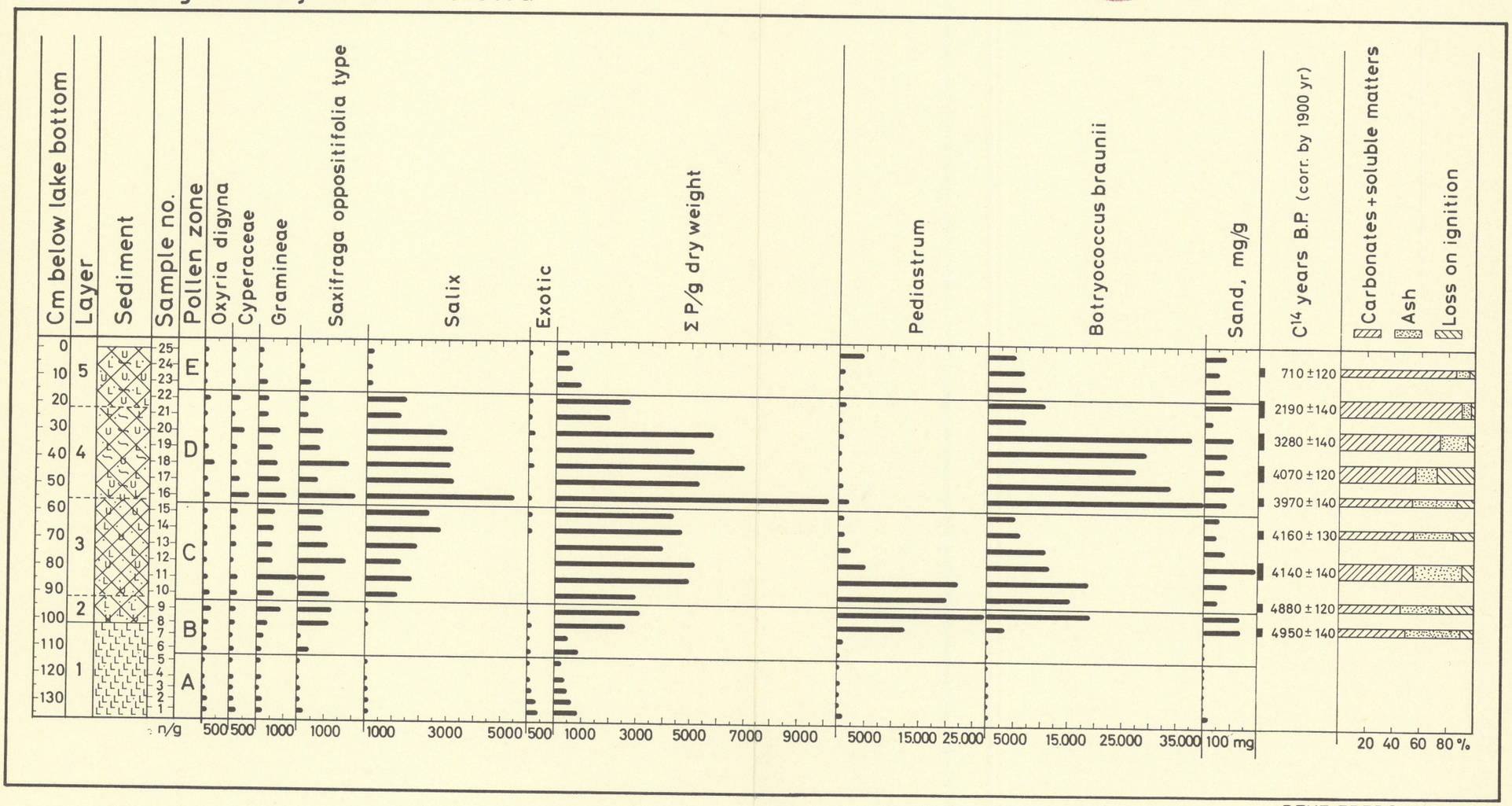
Peary Land, N. Greenland

BENT FREDSKILD 1968

Universitetets Geografiske Institut

KLARESØ (82°10'N, 30°34'W)

Peary Land, N. Greenland

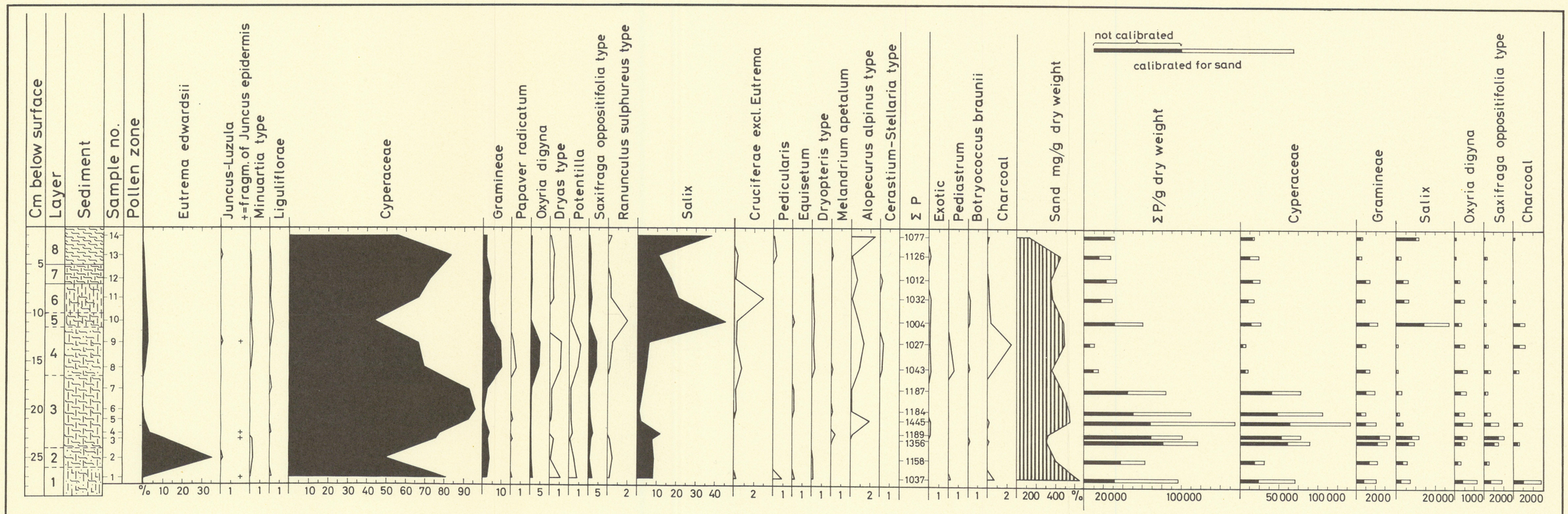


BENT FREDSKILD 1968

UNIVERSITETETS GEOGRAFISKE INSTITUT

SØLEJREN (82°13'N, 32°40'W)

Peary Land, N. Greenland



BENT FREDSKILD 1969

Table 22. *Content of pollen in recent gyttja samples.*

| Locality no. | *Alnus* | *Betula* | *Juniperus communis* | *Salix* | *Empetrum* | *Ericales* sp. | *Harrimanella* type | *Ledum* type | *Loiseleuria procumbens* | *Rhododendron* type | *Vaccinium* type | Σ *Ericales* | *Achillea-Tripleur.* type | *Alchemilla* | *Angelica archangelica* | *Campanula* | *Cerastium cerastioides* | *Cerastium-Stellaria* type | *Chamaenerion* | *Copris trifolata* | *Cruciferae* | *Cyperaceae* | *Erigeron* type | *Euphrasia* type | *Gentiana nivalis* | *Gramineae* | *Juncus-Luzula* | *Koenigia islandica* | *Lathyrus japonicus* | *Ligusticum* | *Lomatogonium rotatum* | *Menyanthes trifoliata* | *Mousstria* type | *Oxyria digyna* | *Pedicularis* | *Pilosum commutatum* type | *Plantago maritima* | *Polygonum viviparum* | *Potentilla-Comarum* type | *Potentilla crantzii* type | *Ranunculus* | *Rumex acetosella/acetosa* | *Sagina* | *Saxifraga nivalis* type | *Saxifraga oppositifolia* type | *Sedum* | *Silene acaulis* type | *Thalictrum alpinum* | *Thamus graeca* | *Trifolium* | *Tubuliflorae* | *Viscaria alpina* | P. indet. | *Botrychium* | *Diphasium* type | *Dryopteris* type | *Equisetum* | *Gymnocarpium dryopteris* | *Huperzia selago* | *Lycopodium dubium* | *Polypodium boreale* | *Selaginella selaginoides* | Σ P | *Equisetumspoten* | *Hyparis vulgaris* | *Isoëtes setacea* | *Isoëtes lacustris* | *Myriophyllum alterniflorum* | *Sparganium* | *Ambrosia* | *Artemisia* | *Castanea* | *Chenopodiaceae* | *Fraxinus* | *Picea* | *Pinus* | *Picea/Pinus* | *Quercus* | *Rumex*, not acet. type | *Viburnum* type | Ekolit indet. | Σ exotic | *Charcoal* | *Sphagnum* | *Tillaria cylnyri* | *Azolla* | *Microthyrium* type |
|---|---|---