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REMAINS OF MOSSES AND FRESHWATER ANIMALS IN SOME HOLOCENE LAKE AND BOG SEDIMENTS FROM GREENLAND

BY

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WITH 8 FIGURES AND 14 TABLES

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Abstract

Core samples of South Greenland lake sediments have been investigated as regards macroscopical remains of mosses and freshwater animals. Besides many widespread species the deeper samples contained species now occurring only in North Greenland, e.g. *Bryum neodamense* ssp. *ovatum* and *Lepidurus arcticus*. During the hypsithermal, *Cristatella mucedo* lived in one of the lakes. The upper samples are poor in species, partly a result of an oligotrophication of the lakes.

From Peary Land, North Greenland, remains from one lake and one bog have been determined. The species found all occur in present day Peary Land.

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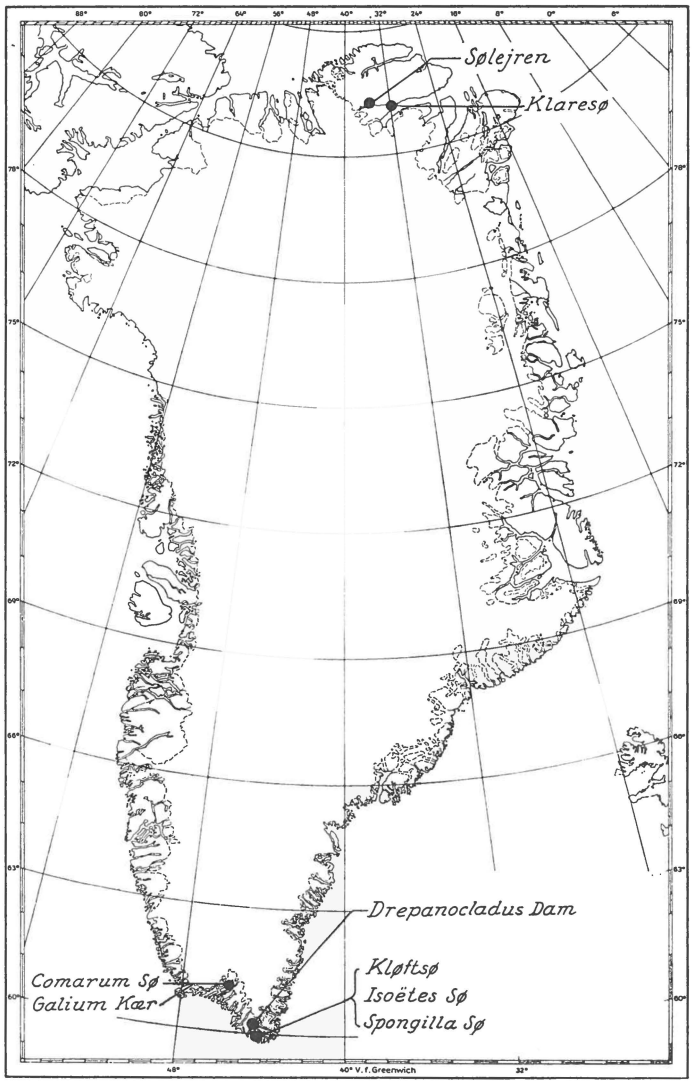


Map indicating the localities mentioned in the text

Introduction

One of the purposes of the Kap Farvel Ekspedition 1970 was to take out cores of lake sediments in order to elucidate the vegetational and climatic development since the last glaciation. Some of the sediments were extremely rich in cladoceran remains, others in mosses, and it seemed tempting to determine the content in selected samples. The obtained results turned out to be so promising that it was decided also to include samples from earlier corings, viz. at Qagssiarssuk, South Greenland, and in Peary Land, North Greenland.

A detailed description of the vegetational history and of the sediments, besides a summary survey of the present vegetation and photoes of the localities, is found in FREDSKILD (1973). However, it seems reasonable to bring af short description of the investigated localities and of their history as judged from the pollen diagrams.

Investigated Localities

Kap Farvel area

Isoëtes Sø (59°58′ N, 44°21′ W) is a tarn, 90×25 m, some sixty m a.s.l. The largest depth of water is 3 m. The vegetation is very poor, consisting of a narrow zone of *Isoëtes setacea* on shallow water, succeeded at a little greater depth by an *I. lacustris* zone. Scattered dwarfed, sterile specimens of *Myriophyllum alterniflorum* were found at ca. 1.5 m's depth. The sediment is (in cm below the lake bottom):

0– 73 cm: Fine detritus gyttja.
73–103 cm: Fine detritus gyttla, often glossy because of a great content of cladocerans.
103–132 cm: Laminated gyttja, rich in mosses.
132–141 cm: Laminated fine detritus gyttja.
>141 cm: Till.

Spongilla Sø (59°58′ N, 44°21′ W) is a shallow lake, 75×45 m, 350 m from Isoëtes Sø, but at an elevation of only 5.5 m. The greatest depth of water is 1.5 m. On shallow water there is a zone of *Isoëtes setacea.* Everywhere on the bottom scattered specimens of *I. lacustris*, *Callitriche hamulata* and sterile *Myriophyllum alterniflorum* grow. *Spongilla* sp. is

rather common, partly as cauliflower-like colonies, partly as a covering on the lower side of the stones at the shore. The sediment is:

0–185 cm: Fine detritus gyttja.
185–194 cm: Laminated fine detritus gyttja.
194–195.5 cm: Clayey gyttja, limnic.
>195.5 cm: Marine clay.

Kløftsø (60°03′ N, 44°14′ W) is situated ca. 15 km farther in the fjord Pamiagdlûp kujatíngua at an elevation of ca. 60 m. It is a 200 m long, 15–35 m wide, shallow lake with a depth of water not exceeding 2 m. *Isoëtes setacea* (presumably also *I. lacustris*) is growing at the beach, otherwise, the lake bottom is completely bare. The sediment is:

0–140 cm: Fine detritus gyttja.
140–161 cm: Fine detritus gyttja, laminated. At 159.5–161 cm some mosses.
161–171 cm: Alternating thin clay gyttja and gyttja layers.
>171 cm: Clay.

Drepanocladus Dam (60°20′ N, 44°16′ W) is a little kettlehole only 12×8 m in a plain between moraines in the Tupaussat valley at the head of the fjord Kangikitsoq. The elevation is ca. 50 m a.s.l. The water in the shallow pond (maximum depth 45 cm) is almost filled with *Hippuris* and *Drepanocladus exannulatus*. A few *Sparganium hyperboreum* was found, and judging from the find of *Isoëtes setacea* spores in a recent gyttja sample this species must also be growing in the pond. The sediment is:

0–119 cm: Detritus gyttja with varying, but often very great content of *Drepanocladus exannulatus*.
119–135 cm: Detritus gyttja with some drift (twigs, fruits of *Sparganium hyperboreum*, etc.).
135–170 cm: Coarse detritus gyttja with drift, sand and clay.
>170 cm: Stones.

The vegetational and climatic history of the Kap Farvel area is best illustrated by fig. 1, showing the development in the three outer coast lakes (Drepanocladus Dam was not formed until ca. 3000 years ago). The vegetation phases a-g refers to the terrestrial vegetation.

During phase a (ca. 9600–9100 B.P.) the bare soil in depressions in the polished gneissic bedrock, left by the melting ice, was invaded by a number of widespread herbs like *Oxyria digyna*, *Koenigia islandica*, *Saxifraga* spp., a.o. Suspended clay in the lakes prevented or highly reduced the biological activity. With the opening of phase b (ca. 9100–8400 B.P.) ericaceous dwarf-shrubs immigrated, but still everything indicates an open vegetation with great snow-patches and moist sandy-

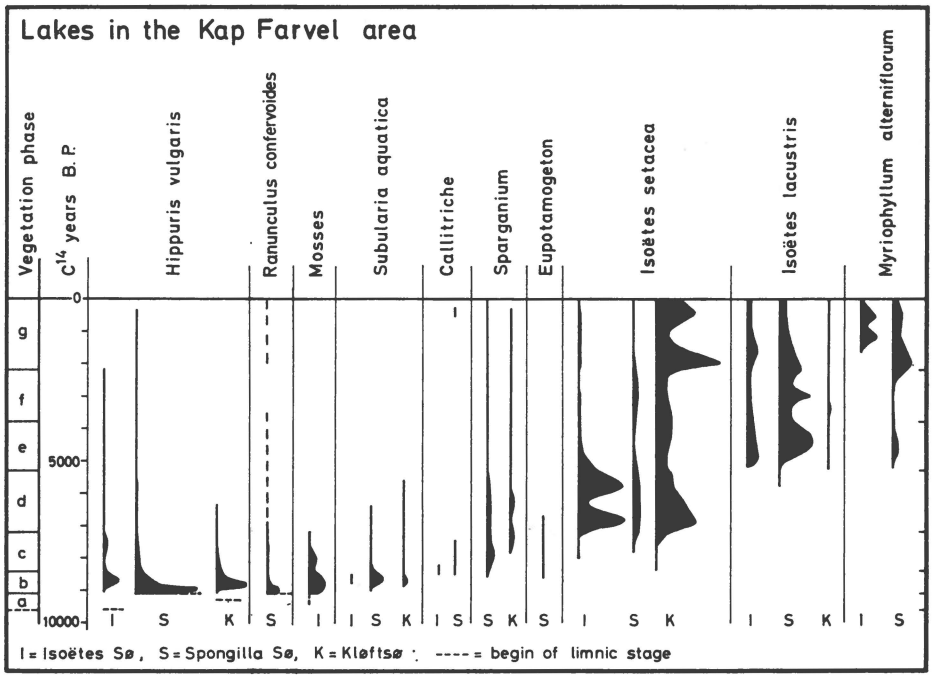


Fig. 1. Summary diagram of the vegetational development of the lakes in the Kap Farvel area. (2 pollen of *Sparganium* were found in phase e in Isoëtes Sø).

clayey soil, and a severe climate. *Hippuris vulgaris*, *Subularia aquatica* and *Pediastrum* spp. flourish in the three lakes, *Ranunculus confervoides* and mosses in two, but rapidly the growth is reduced as a result of too great consumption of nutrients. In the following phase c (ca. 8400–(7500)7200 B.P.) dwarf-shrub heaths rich in *Lycopodiaceae* and *Sedum* with a good snow-cover prevailed. *Callitriche* (presumably *C. hamulata*), *Sparganium* (presumably *S. hyperboreum*) and *Potamogeton* (presumably *P. pusillus*) immigrated at the beginning of the phase. Single *Isoëtes setacea* spores were found. Shortly before 7000 B.P. a climatic amelioration is registered i.a. in the spreading of *Salix* and *Juniperus*. The climate during phase d, which lasts until ca. 5300 B.P. seems to have been almost as warm as today. *Isoëtes setacea* flourished in the lakes, while most other hydrophytes were decimated if not extinct. This is not a result of competition by *Isoëtes*.

At ca. 5300 B.P. a climatic change is registered, i.a. by the contemporaneous immigration of *Isoëtes lacustris*, which today is found only in the Kap Farvel area. The climate during phase e (ca. 5300–3800 B.P.) and the following phase f (ca. 3800–2200 B.P.) most likely was the warmest, least oceanic in the whole sequence. Around 3800 B.P. *Betula glandulosa* spreads, but it is not clear whether this late immigration

is caused by climatic or dispersal factors. Ca. 2200 B.P. a deterioration is evinced by the decrease in *Juniperus*. In the outer coast area the present day's dwarf-shrub heaths dominated by *Empetrum*, *Betula glandulosa* and *Salix glauca*, rich in mosses take over the dominance, while at the head of the fjord *Betula pubescens* is reduced in favour of an increased growth of *B. glandulosa*.

It should be added that besides the impoverishment of the lakes as evinced by the decimation and, often, extinction of the hydrophytes, the water, poor in puffer, became more acid as a result of humus formation under the surrounding vegetation. Diatom analyses (FOGED, 1972) in the Spongilla Sø core has shown this to happen at the transition between phases c and d.

Qagssiarssuk

At the head of Tunugdliarfik fjord the relative luxuriant *Betula pubescens-Salix glauca* shrubs, often 3–4 m high, bear witness of the favourable, rather continental climate. Two localities have been investigated at the settlement Qagssiarssuk.

Comarum Sø (61°08′ N, 45°32′ W) was originally, i.e. after the deglaciation prior to 8500 B.P., a 180×60 m lake. When the basin was filled up with gyttja, a swamp and bog vegetation spread, and today the water surface is only 90×40 m. The elevation is ca. 125 m a.s.l. The depth of water does not exceed 0.9 m. Floating leaves of *Sparganium hyperboreum* cover most of the water surface. A few *Potamogeton alpinus* and presumably also *Isoëtes setacea* are growing in the lake, which is surrounded by a belt of *Menyanthes trifoliata* and *Carex rostrata*, and with scattered *Ranunculus confervoides*. The following profile was found:

0–246 cm: Fine detritus gyttja.
246–257 cm: Rather coarse, slightly sandy gyttja with many cladocerans.
257–298 cm: *Characé* gyttja.
298–342.5 cm: Stratified detritus gyttja with *Chara*. Rich in cladocerans in the upper part of the layer, a few mosses in the lower part.
342.5–359 cm: Clay with very thin clay gyttja layers.
>359 cm: Sandy clay.

Galium Kær (61°10′ N, 43°31′ W) ca. 65 m a.s.l. is a little marsh, 40×30 m wide. Until a drainage a few decades ago it was a pond. An open transect showed the following sequence (cm below the surface):

0– 25 cm: Swamp peat, with some gyttja in the deeper part.
25– 75 cm: Detritus gyttja with a touch of swamp peat. Numerous *Hippuris* fruits.

75– 98 cm: Fine detritus gyttja with many *Hippuris*.
98–105 cm: Sandy gyttja.
105–155 cm: Slightly sandy-clayey detritus gyttja with drift, i.a. many seeds of *Potamogeton* and *Ranunculus confervoides*.
155–196 cm: Clayey gyttja with *Potamogeton* fruits.
>196 cm: Till.

The sedimentation in Galium Kær did not start until ca. 7000 B.P.

The development of the terrestrial vegetation since deglaciation runs through phases corresponding to those registered at Kap Farvel, but obviously marked by the more continental conditions prevailing in the interior. Although the ice disappeared about one millennium later than at the outer coast, those phase-borders which seem to reflect an amelioration are seen at an earlier date in the interior. A pioneer vegetation dominated by *Oxyria*, *Plantago maritima* and other herbs immigrate around 8700, but very soon *Empetrum* immigrated, and ca. 8000 *Salix* spread. *Juniperus* immigrated ca. 6900 B.P. Low, open xerophytic heaths prevailed in the following millennia. Ca. 4500 B.P. *Betula glandulosa* spread. The temperature was still increasing and reached values higher than today-in the following phase, the *Betula pubescens-B. glandulosa-Salix* phase (ca. 3600–1900 B.P.). Like at Kap Farvel the deterioration (here 2-3 centuries later) is marked by a decrease in *Juniperus* and change in the ratio *Betula pubescens: B. glandulosa* in favour of the latter. The Norse landnam A.D. 987 highly influenced the 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 favorable 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.

The succession is parallel in the two lakes, though with a displacement in time at the beginning. The first stage includes totally submerged plants (*Potamogeton filiformis*, *Chara*, *Subularia*, *Callitriche*, *Isoëtes setacea*, *Myriophyllum spicatum*, *M. alterniflorum*). Next comes a floating leaved macrophytic stage (*Potamogeton alpinus*, *P. gramineus*) with *Ranunculus confervoides*, succeeded by a *Hippuris* stage. Species like *Sparganium hyperboreum*, *Menyanthes* and *Carex rostrata* marks the final shallow water stage, which in Galium Kær and part of the Comarum Sø is succeeded by a swamp vegetation with i.a. *Comarum palustre*.

Peary Land

Klaresø (82°10′ N, 30°34′ W) is a ca. 275×100 m lake, 45 m a.s.l. south of Jørgen Brønlund Fjord. The major part of the lake is shallow, but a minor, 3.3–3.6 m deep basin was cored. *Calliergon trifarium* (Web. & Mohr) Kindb. and *Nostoc commune* are frequent on the bottom, *Ranunculus confervoides* is very rare on shallow water.
The sediment is:

0– 22 cm: Lake marl with a few fragments of *Calliergon trifarium.*
22– 56 cm: Lime gyttja, rich in *Calliergon.*
56– 92 cm: Lime gyttja, gelatinous.
92–102 cm: Clay gyttja rich in lime.
>102 cm: Marine clay with *Astarte borealis.*

Contrary to the South Greenland lakes Klaresø is rich in i.a. bicarbonate (220 mg/l). The datings have been calibrated for hardwater effect but are fairly uncertain. Only minor changes in the composition of the terrestrial vegetation is registered in the pollen diagram, but it seems as if the surroundings were covered by a relatively dense vegetation in a presumably warmer and moister period ca. 4000–3300 B.P. during which period the *Calliergon*-rich layer was sedimentated. About 2.5 millennia ago a deterioration changed the conditions to those prevailing in the present day high arctic desert.

Sølejren (82°13′ N, 32°40′ W). A hummocky area ca. 90 m a.s.l. at the eastern end of Nedre Midsommersø is covered by a moss-rich vegetation in which *Carex stans* and *Salix arctica* dominate. 30 cm of alternating moss and swamp peat layers are found beneath the present vegetation. Sedimentation started ca. 1500 years ago.

Methods

The macrofossil samples, usually covering 3–5 cm of the cores, and with a volume of 0.2–0.3 l, have been washed through a sieve with square openings 0.4 mm. In some samples the total content of remains was taken out, in other, richer samples only a minor part. Single analyses are carried out on remains found in the 1 ml. pollen samples. Some of the samples were after the sieving used as radiocarbon samples. Generally, the datings must not be taken too literally, as many are interpolated datings. Chemical analyses of the waters are found in Fredskild (1973, table 1).

It must be admitted that the inconsistency in the size of and in the distance between the samples in connection with the too scanty material

makes the conclusions to be drawn rather restricted. However, both the zoological remains as well as the mosses seem to support the two theories put forward above: 1. The deglaciation in South Greenland was followed by a climatic regime comparable with that of far higher latitudes today, succeeded by a hypsithermal during which the climate was more favourable than today, and, 2. Especially in the slowly weathering gneissic area at Kap Farvel the lakes in the first phases harboured a comparatively rich fauna and flora but rapidly the oligotrophication reduced the number of species as well as of specimen.

THE MOSSES

Methods

The material consists chiefly of smaller stems (up to 1 cm) with leaves, but also of leaf fragments. It has been kept in 70 % alcohol with a little glycerine added. HOYER's Solution (ANDERSON, 1954), has been used for embedding.

Experience showed that the slides have to lie for some time, as they are at the beginning somewhat opaque as a result of fluidblending and shrinking phenomena. Similar conditions were also found in the corresponding slides of recent plants; heating of the slides accelerates clearing.

The figures in the tables show the approximate number of remains of the species. In those instances where a "cf." is inserted, the materials condition was such, that an exact determination was not possible.

In the tables, C–14 dated samples are marked with a ± value. The slides are kept at the Botanical Museum (C) of Copenhagen, together with the rest of the material.

Kap Farvel area

Isoëtes Sø

The sample from the lower layer was small but quite well preserved. The species-composition in this sample differs from the others.

It is characteristic of the lower samples, that they have a composition, which today, is found on open soil, often near water. Thus, genera like *Bryum* and *Philonotis* are found in these samples.

Drepanocladus exannulatus is only found in the samples, until and including, the one from 6950 B.P. In the latter is also the only find of *Calliergon sarmentosum* from Isoëtes Sø.

Noteworthy is the presence of *Antitrichia curtipendula* in the sample dated 3730 B.P.

Spongilla Sø

As in Isoëtes Sø, the lower sample was small, but quite well preserved and contained many species.

Drepanocladus exannulatus is found throughout the whole series, and becomes absolutely dominant (long waterforms) in the upper samples (more than 1000 large fragments per sample). *Calliergon sarmentosum* was not found in samples later than 8720 B.P.

Table 1. *Isoëtes Sø*

cm below lake bottom	137–139 (9440 ± 140)	130,5	123–125 (8700 ± 110)	112	99–101 (6950 ± 130)	79–81	41–44 (3730 ± 100)
Vol., ml	200	1	200	1	200	200	240
Ptilidium ciliare						1	
Antitrichia curtipendula							1
Bryum sp.	1		1				
Calliergon sarmentosum					5		
Drepanocladus exannulatus	> 100	> 100	> 100	> 25	> 100		
Drepanocladus uncinatus					15		
Kiaeria blyttii							2
Philonotis cf. *fontana*	2						
Pogonatum capillare			4				
Polytrichum alpinum	7					2	
Polytrichum juni./pilif.	4		1		1	1	1
Racomitrium canescens	2						
Racomitrium lanuginosum				1	7	3	15
Racomitrium sudeticum						3	
Musci spp. indet.	1	2					

Table 2. *Spongilla Sø*

cm below lake bottom (samples à 300 ml)	191–196 (9210 ± 140)	146–151 (8720 ± 140)	116–121 (7670 ± 130)	73–78 (3500 ± 100)	33–38 (2110 ± 100)
Sphagnum girgensohnii		1		20	
Bryum cf. *neodamense* ssp. *ovatum*	10	2			
Bryum cf. *pseudotriquetrum*	2				
Calliergon sarmentosum	20	15			
Calliergon stramineum	1				
Dicranum scoparium			1		
Drepanocladus exannulatus	20	15	5	> 1000	> 1000
Drepanocladus uncinatus				5	
Mniobryum wahlenbergii	5				
Philonotis cf. *fontana*	2		1		
Pohlia sp.				1	
Pogonatum capillare			2		
Polytrichum alpinum	15	5	3	2	
Polytrichum juni./pilif.		1	1		
Racomitrium lanuginosum	3		> 15	2	1
Racomitrium sudeticum			3		
Musci spp. indet.		3		1	

Table 3. *Kløftsø*

cm below lake bottom	169	158–160 (8620 ± 140)	149–152	140–143	128–131 (6590 ± 120)	110–113	95–98 (4870 ± 110)	79	62–65 (3980 ± 100)	35–38 (3210 ± 100)
Vol., ml	1	140	210	210	210	210	210	1	240	240
Barbilophozia hatcheri			1							
Ptilidium ciliare				1		1				
Sphagnum compactum					10	7	6			
Sphagnum girgensohnii					6					
Andreaea alpestris			5	5	7	3	6		5	1
Calliergon sarmentosum		> 15	5		1					
Dicranum scoparium						1	3	1	1	1
Distichium sp.						1				
Drepanocladus exannulatus		1	5							
Grimmia cf. *torquata*					1		3		2	
Hylocomium spendens							1		1	
Isopterygium pulchellum					1					
Kiaeria blyttii		1	3	3	3	3			2	
Kiaeria glacialis									1	
Philonotis fontana	3		1							
Pohlia spp.					1		1		1	1
Pogonatum urnigerum					1					
Polytrichum alpinum		5		5						
Polytrichum juni./pilif.				3	15		1		5	3
Polytrichum norvegicum			2							
Racomitrium lanuginosum		10	> 25	> 25	> 15	5	10		5	15
Racomitrium sudeticum		5								
Tortella tortuosa		1								
Muscii spp. indet.				1		1	1		1	1

Noteworthy is the presence of *Mniobryum wahlenbergii* and *Bryum* cf. *neodamense* ssp. *ovatum* in the lower sample.

Kløftsø

Of the lakes investigated this is the one with most species, thus *Hepaticae*, *Sphagna* and a species of *Andreaea* were found.

Considering the situation of the lake, it is the ideal place for accumulation of mosses, as there are slopes on both sides of the lake with a characteristic low heath-vegetation, and ice-polished rocks where the water runs down. It is here on these open surfaces, that *Andreaea alpestris* and *Kiaeria blyttii* are found in large mats. On drier places *Racomitrium lanuginosum* is populous.

As in the previous lakes *Calliergon sarmentosum* is only found in the lower samples. *Drepanocladus exannulatus* is only found in the lower

Table 4. *Drepanocladus Dam*

cm below lake bottom	165–170	155–160	150–155 (2990±100)
Drepanocladus exannulatus	>100	>100	>100
Pleurozium schreberi	1		
Racomitrium lanuginosum	10	1	
Polytrichum sp.	1		

samples, same as in Isoëtes Sø. These two species are probably the only ones whose disappearance indicates that they have become extinct around this lake.

It is to be noticed that a change of species composition takes place through the series, but a clearly defined pattern cannot be shown.

Drepanocladus Dam

Drepanocladus exannulatus dominates the three samples from this locality, often in well preserved fragments. The only find of *Pleurozium* is from this locality.

Species from Kap Farvel area

Barbilophozia hatcheri (Evans) Loeske, has been found in one sample from Kløftsø. It is common over most of Greenland till over 70° N lat. It occurs in moist heath-vegetation, often together with *Sphagnum.*

Ptilidium ciliare (L.) Nees, was found as well preserved fragments in three different samples. It has a wide distribution in Greenland, where it occurs in dry and moist heaths.

Sphagnum compactum Lam. & Cand., was found in three samples from Kløftsø. The fragments were branch-leaves more or less puttied together, so they looked like branches. This species is common in the Kap Farvel area and is found everywhere in the more moist parts of the *Empetrum* and *Betula* heaths. According to Lange (1952), it is found along the West Coast up to 69° N lat., and Lewinsky (1971), reports it from ca. 63° N lat. on the East Coast.

Sphagnum cf. *girgensohnii* Russ., occurs in three samples from Spongilla Sø and Kløftsø. The material consists entirely of detached stem- and branch leaves. This causes some doubt as to the identification of the material, as *S. girgensohnii* in such cases can be difficult to separate

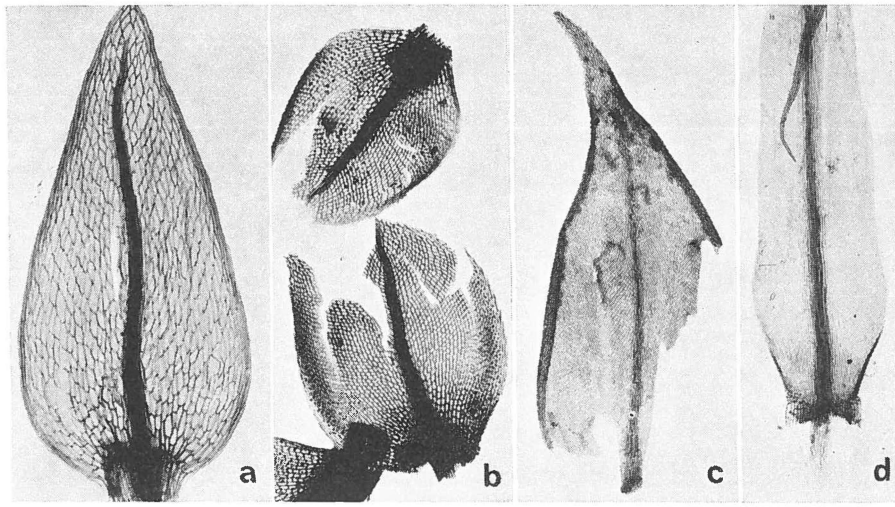


Fig. 2. a) *Mniobryum wahlenbergii*, b) *Bryum neodamense* ssp. *ovatum*, c) *Antitrichia curtipendula*, d) *Drepanocladus exannulatus* from Spongilla Sø. ca. × 30.

from *S. fimbriatum* WILS. Both species are found in the Kap Farvel area, and have a wide distribution in Greenland (LANGE, 1952).

Andreaea alpestris (THED.) B.S.G. Some samples from Kløftsø contained very well preserved shoots. This species was, in addition to the Kløftsø locality, collected at several localities in the Kap Farvel area in 1970. It is common in South Greenland, but decreases towards the north. It grows in much damper places than *A. rupestris*, and forms large black-brown mats on sloping rock-surfaces (mostly gneiss), with percolating water.

Antitrichia curtipendula (HEDW.) BRID. (fig. 2 c). Only a leaf fragment from Isoëtes Sø (3730 B.P.). This species was collected twice in the Kap Farvel area in 1970, one 300 m NW of Isoëtes Sø on a north-exposed slope, growing in a thick moss carpet among *Hylocomium splendens* and *Pleurozium schreberi*. *Antitrichia* is only known from Southern Greenland.

Bryum cf. *neodamense* ITZIGS. ssp. *ovatum* (C. JENS.) KINDB. (fig. 2 b). This species was found in the lower samples from Spongilla Sø. Here were several well preserved shoots, with the characteristic, almost round, hollow leaves. The same species was found in the samples from Peary Land, where it occurred together with *Calliergon giganteum* and *Drepanocladus brevifolius*. The plants from Spongilla Sø differ from the Peary Land material, in having more acuminate leaves with an almost

excurrent nerve, and a denser aerolation. The identification of a sterile *Bryum* is always a problem, but the present material is like other Greenlandic material with more acuminate leaves. This species grows on calcareous soil, usually in rich fens (MÅRTENSSON, 1956; HOLMEN, 1960). It is found in Northern Greenland, and has not been found south of 69° N lat.

Bryum cf. *pseudotriquetrum* (HEDW.) GAERTN., MEYER & SCHREB. A few stems were found in the lower sample from Spongilla Sø. This species is common in the subarctic region, but was only collected once in the Kap Farvel area in 1970, growing together with *Mniobryum.*

Calliergon sarmentosum (WAHLENB.) KINDB. Only found in samples from the three outer-coastal lakes. The remains are well preserved and often about 1–2 cm, and are of the typical terrestrial form. It can be assumed, that these plants grew along the lakeshore associated with *Drepanocladus exannulatus;* and judging from its occurrence today, it has probably been dominant. MÅRTENSSON (1956:276), mentions that *C. sarmentosum* in Northern Sweden, often grows together with *Drepanocladus purpurescens*, which is also often the case in South Greenland. In the Kap Farvel area it occurred on not too poor soils, with percolating or running water. Today it is not found in the immediate neighbourhood of the lakes investigated, but has been found several places in the area.

Calliergon stramineum (BRID.) KINDB. Single shoots were found in the lower samples from Spongilla Sø. This species is common in the Kap Farvel area, and was collected on most of the localities visited, where it's associates are different species of *Sphagnum.*

Dicarnum scoparium HEDW., occurs as single leaves in several samples. It is common in this area.

Distichium sp. Only a single, badly preserved shoot, was found in Kløftsø. Another, slightly better shoot, was found in a sample from Comarum Sø. It probably belongs to *D. capillaceum* (HEDW.) B.S.G. *D. capillaceum* was collected at several localities in the Kap Farvel area in 1970, where it grew on vertical rock-surfaces as well as in bogs among other mosses.

Drepanocladus exannulatus (B.S.G.) WARNST. s.l. (fig. 2 d). This species dominated the samples from the Kap Farvel lakes, some samples contained nothing but this species. Some specimens were badly preserved, e.g. in the lower sample from Isoëtes Sø, where all leaves were detached from the stems. This species has, to some extent, the same occurrence in the

samples as *Calliergon sarmentosum*, as it was found in great numbers in the lower samples, and then disappears. However, the upper samples from Spongilla Sø, contained more than 1000 stems! In the Kap Farvel area this species is mainly represented by the form called *D. purpurescens* (SCHIMP.) LOESKE. In this area are also found plants which represent the main form. The material in the samples are often long slender aquatic plants, the well developed specimens having large angular cells, therefore much of the material can be referred to *D. purpurescens*. This species was collected several times in the Kap Farvel area in 1970, and usually had the characteristic red colour. It occurs in tufts along streams, often together with *Calliergon sarmentosum*. BÖCHER (1963:244), mentions a "*Deschampsia alpina* sociation rich in mosses", in which among others *Polytrichum alpinum*, *Drepanocladus uncinatus*, *D. purpurescens*, *Kiaeria glacialis*, *Calliergon sarmentosum* and *C. stramineum* occur, an association that resembles that of the samples.

Drepanocladus uncinatus (HEDW.) WARNST., was found in several of the samples, but was usually not well preserved. In 1970, this species was collected at all localities visited in the Kap Farvel area.

Grimmia sp. was found in samples from Kløftsø, as small and badly preserved specimens, which resemble recent material of *G. torquata* GREV., collected at several places in the neighbourhood. An exact determination was not possible.

Hylocomium splendens (HEDW.) B.S.G., was found twice in samples from Kløftsø. Although in small fragments, they were easily recognisable. The species was collected at several localities in the Kap Farvel area in 1970, on moss covered slopes.

Isopterygium pulchellum (HEDW.) JAEG. Only one small fragment was found in Kløftsø. This species was found once in 1970 in the Kap Farvel area.

Kiaeria blyttii (B.S.G.) BROTH., was found several times in the samples from Kløftsø, and in one sample from Isoëtes Sø. The pieces were small and consisted mainly of stems with a few leaves. The identification has been difficult, and it is possible that some of the other fragments in the samples belong to another species. In 1970, *K. blyttii* was collected several times in the Kap Farvel area. Often occurs in mats in moist boggy places.

Kiaeria glacialis (BERGGR.) HAG., was a poorly preserved fragment from Kløftsø. It occurs on moist soil and often in snow-patches. Rather common in the southern part of Greenland, but becomes rare further north (HOLMEN, 1971).

Mniobryum wahlenbergii (Web. & Mohr) Jenn. (fig. 2 a). Several small stems were found in the lower layer in Spongilla Sø. They were quite well preserved and very characteristic. *Mniobryum* is common in the sub-arctic regions, but was only collected once in the Kap Farvel area in 1970, where it grew in a transitional poor fen along a small brook.

Philonotis cf. *fontana* (Hedw.) Brid., was found in one sample from Kløftsø, and in two samples from Spongilla Sø. Although well preserved the shoots were difficult to identify; provisionally referred to *P. fontana.* In 1970, in South Greenland, a few collections of four species of *Philonotis* were made. All of them were collected along brooks, where they grew in large mats. One could assume that *P. tomentella* Mol. should occur in the lower samples, but the leaves of the plants concerned were shortly acuminate as in *P. fontana.*

Pleurozium schreberi (Brid.) Mitt., was found only once in a sample from Drepanocladus Dam. Today it is quite common on the heaths in the Kap Farvel area.

Pogonatum capillare (Michx.) Brid., was found as detached leaves in samples from Isoëtes Sø and Spongilla Sø. In 1970, *P. capillare* was collected a few times in the Kap Farvel area, but in all cases, some distance from the two lakes.

Pogonatum urnigerum (Hedw.) P. Beauv. Only one leaf was found in a sample from Kløftsø. In 1970, this species was only collected once in the Kap Farvel area, growing on open soil.

Polytrichum alpinum Hedw., was found in several samples from the three outer-coastal lakes; as detached leaves, and once as a whole shoot. In 1970, *P. alpinum* was found at several localities in the Kap Farvel area, and also near the lakes, where it grew on open soil. It is a tolerant species, which is found on heaths and snow-beds, open unstable soils and also on calcareous soil.

Polytrichum juniperinum Hedw., or *P. piliferum* Hedw. Unfortunately the material made it impossible to seperate these two species. Both are common in Southern Greenland.

Polytrichum norvegicum Hedw. One leaf was found in Kløftsø. In 1970, this species was found once in a snow-bed north of Prins Christians Sund. It is rather specific for poor snow beds.

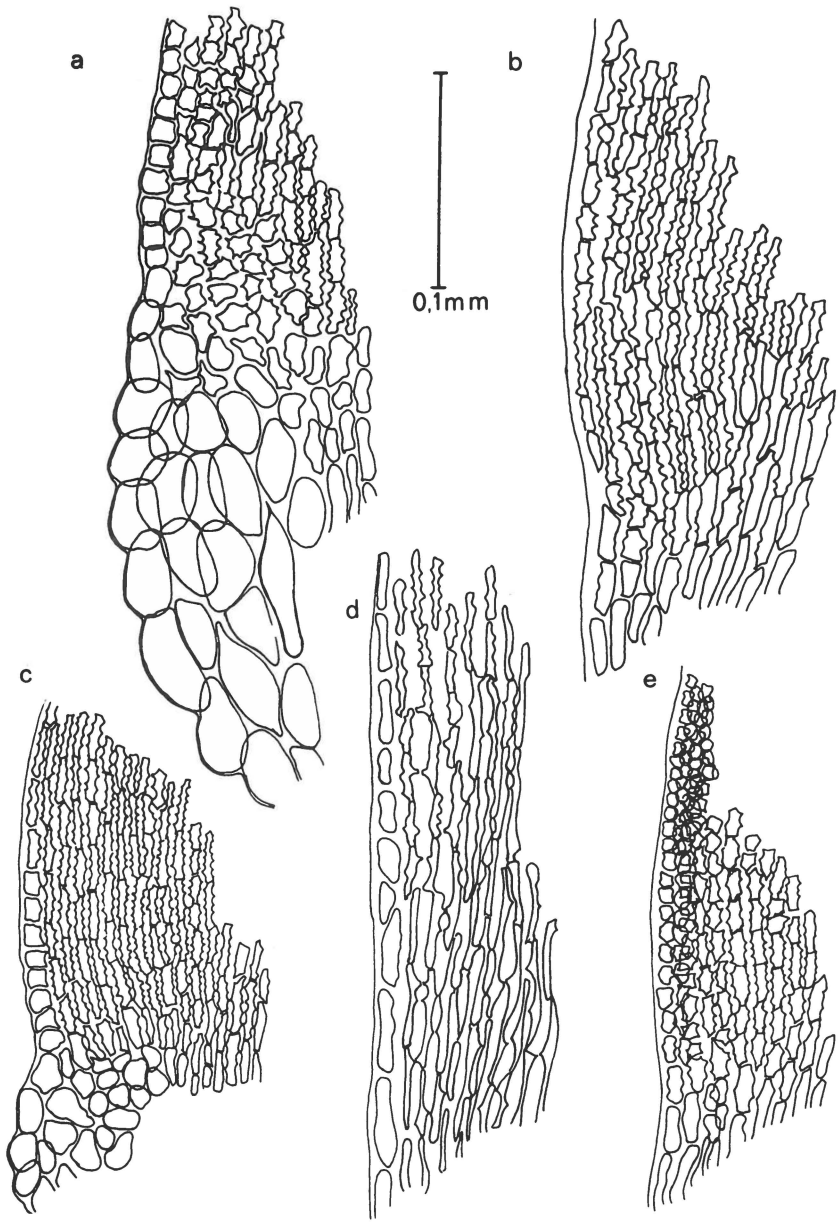


Fig. 3. Angular cells of a) *Racomitrium canescens* (HEDW.) BRID. var. *ericoides* (HEDW.) HAMP. (NJ 9376). b) *R. microcarpon* (HEDW.) BRID. (NJ 4083. c) *R. fasciculare* (HEDW.) BRID. (NJ 3070). d) *R. lanuginosum* (HEDW.) BRID. (NJ 2962). e) *R. sudeticum* (FUNCK.) B.S.G. (NJ 2974).

Racomitrium. The remains of *Racomitrium* species often lack leaf points, a feature most useful for the identification. *R. canescens* and *R. sudeticum* however, had at times a few leaf points. A more careful study, including a comparison of the angular cells and the cells in the lower half of the leaf, has given valuable characteristics for separating the species. Leaves from stem apices show a different cell structure, as they are not completely differentiated; the cells here are more swollen and thin-walled. An exact determination of this kind of material can be almost impossible. Fig. 3 shows angular cells from some species of *Racomitrium*, drawn after recent material from South Greenland.

Racomitrium canescens (HEDW.) BRID. One shoot, rather well preserved, was found in the lower sample from Isoëtes Sø. In 1970, the species was collected at several localities in the Kap Farvel area, where it grew on open, newly established ground, often in heaths. Most of the collections are represented by the var. *ericoides* (HEDW.) HAMP.

Racomitrium lanuginosum (HEDW.) BRID., was found in most of the samples from the Kap Farvel lakes. The shoots were well preserved, except for the hyaline hairpoint. *R. lanuginosum* is probably the most common moss in the Kap Farvel area, also with a wide distribution on Greenland. It is the main component of the *Racomitrium* heaths, and is a very important element in the *Empetrum* and *Betula* heaths.

Racomitrium sudeticum (FUNCK) B.S.G., shoots occur in several samples from the outer-coastal lakes, but never in large numbers. The fragments resemble small tousled pieces of *R. lanuginosum*, single leaves might have been overlooked in other samples. In 1970, the species was found in several places in the Kap Farvel area, where it grew in snow-beds and on periodically wet surfaces on poor soil. BÖCHER (1963:192), mentions a *Salix herbacea* snow-bed sociation with *R. sudeticum.*

Tortella tortuosa (HEDW.) LIMPR. One shoot was found in a sample from Kløftsø. It was with some hesitation, that this fragment was referred to *T. tortuosa*, as the border between the hyaline basis and the rest of the leaf was rather indistinct, as well as the hyaline cells being very wide. The reason might be that the shoot was not yet fully grown. *T. tortuosa* was in 1970 found near Kløftsø, growing on a vertical rock wall with a little percolating water.

Discussion

Regarding the origin, the material can roughly be divided into two groups.

1. Plants that have been growing in the lakes or nearby e.g. *Drepanocladus exannulatus* and *Calliergon sarmentosum.*

2. Plants that have been transported longer distances e.g. *Tortella tortuosa* and *Racomitrium lanuginosum.*

The first group is mostly well preserved, while the remains from the other group can be difficult to determine. DICKSON (1973:68), mentions that liverworts are usually poorly represented in Pleistocene deposits, which was also the case here. The material of *Sphagnum* is likewise scarce compared to the massive occurrence of the genus in the Kap Farvel area today.

Calliergon sarmentosum is found in the lower samples from the three outer-coastal lakes; the uppermost find is from Kløftsø (6590 B.P.), where a single shoot was found.

Drepanocladus exannulatus has a similar occurrence in Isoëtes Sø and Kløftsø. In Spongilla Sø, however, it occurs in all the samples, and in the two later samples there are more than 1000 stems in each. The immense increase of *D. exannulatus* in these samples, might be owing to the fact that the nutrion contents in the lake was so great that it resulted in a high plancton production. Therefore, not until later, when the water gradually became clearer, was *D. exannulatus* able to thrive in the lake itself. Today the species is not to be found in the lake.

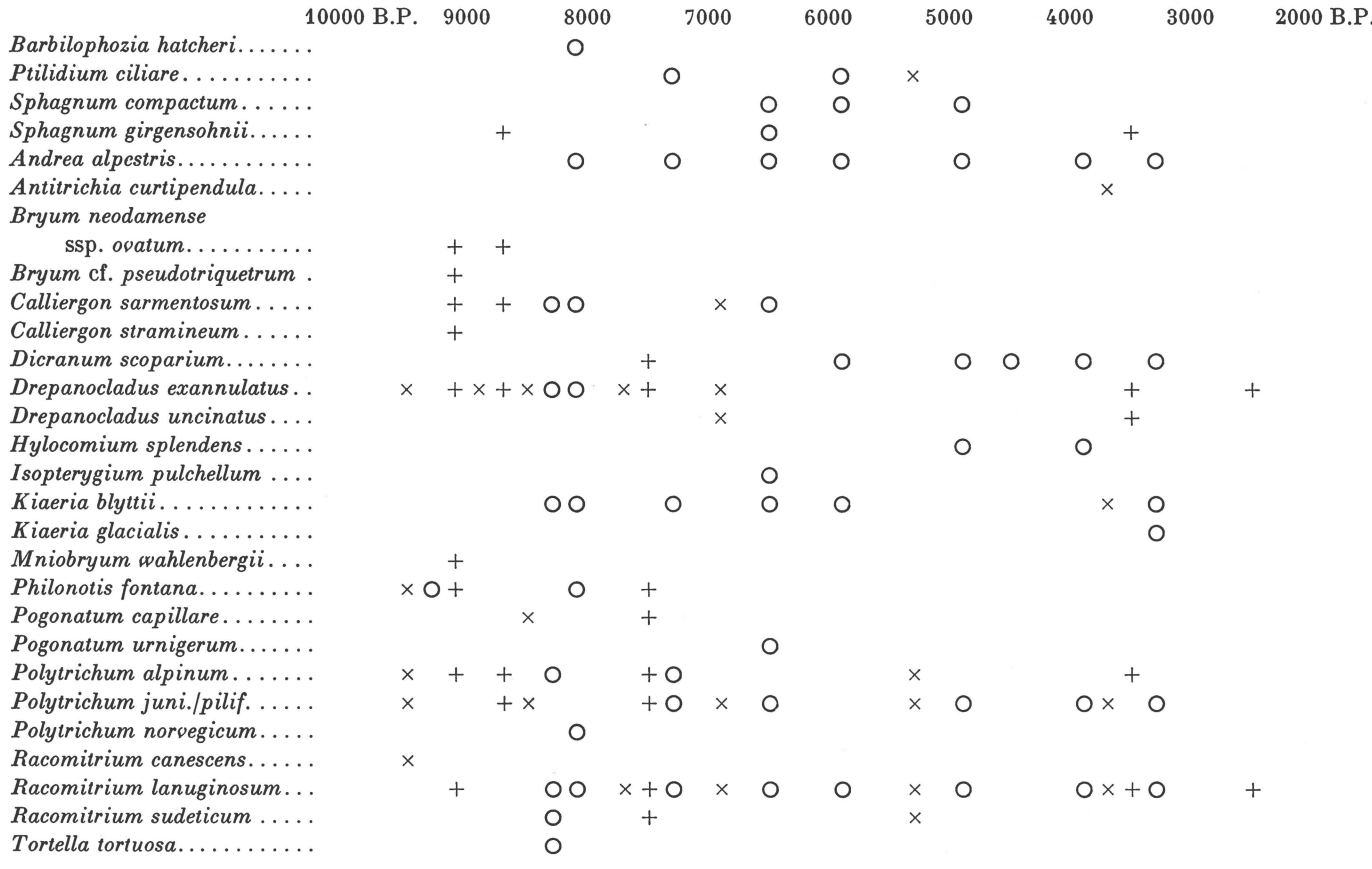
As a reason for the disappearance of some of the higher plants from the lakes around 7000 B.P., FREDSKILD (1973:89), suggests an oligotrophiation in connection with an amelioration. As for the mosses, one must confine in saying, that a change takes place in vegetation phase d (table 5), and that there is no inconsistency with this interpretation.

An interesting occurrence in the samples is *Mniobryum wahlenbergii.* It cannot grow at Spongilla Sø today, the soil is much too poor. One can assume that *Mniobryum* has been growing along the streamlet, running in the little valley from NW. The melting ice has left some moraine deposits that have been able to supply some nutrition to the soil, and the excess water. In 1970, *Mniobryum* was collected in a transitional poor fen (see p. 20) at Tupaussat, at the head of Kangikitsoq Fjord.

According to BÖCHER (1954:86), *Mniobryum* is an EG-species (Ecogeographical guiding species (B. 1954:10)), or at least an important Hb-species (Habitat-species = Ecological differential-species) belonging to "The *Epilobium hornemannii-Saxifraga stellaris Type*". HESSELBO (1918:550–552) describes the same community from Iceland, and NORDHAGEN (1943:420), describes "*Mniobryo-Epilobion hornemannii*" from Norway.

Another noteworthy find in the lower samples from Spongilla Sø is *Bryum* cf. *neodamense* ssp. *ovatum*, which today has not been found south of 69° N. lat. in Greenland, signifying that it has not been found

Table 5. *Summary diagram of the mosses in the Kap Farvel area*



× = Isoëtes Sø
\+ = Spongilla Sø
○ = Kløftsø

in that part of Greenland which mainly consists of acid gnejsic rocks. As this species is a typical rich fen moss, it is possible that the moraine deposits, left by the ice, formed the basis for its occurrence.

The occurrence of *Antitrichia curtipendula* in Isoëtes Sø in the sample from 3730 B.P. is of interest. Only two thirds of a leaf was found, and its occurrence at the beginning of the warmest period in South Greenland should be met with certain reservations. It is a boreal species, which is known from the western part of North America, Asia, Europe, Iceland (STÖRMER, 1969), Greenland and Patagonia. DICKSON (1973:120), mentions it from several English interglacial deposits. In Greenland today, it occurs in protected places with open vegetation.

Qagssiarssuk

Table 6. *Comarum Sø*

cm below lake bottom samples of 200 ml	318–320 (7940±130)	246–248	166–168	126–128 (2590±100)	88–90	50–52
Calliergon stramineum		×				
Distichium cf. *capillaceum*	×					
Helodium blandowii		×			×	×
Pseudobryum cinclidioides				×		
Paludella squarrosa		×				×
Musci spp. indet.	×	×	×		×	×

Species from Qagssiarssuk

Calliergon stramineum (BRID.) KINDB. A single well preserved shoot was found.

Distichium cf. *capillaceum* (HEDW.) B.S.G. The find was a single shoot, consisting of a few leaves on the piece of a stem.

Helodium blandowii (WEB. & MOHR) WARNST., occurs in three of the samples, and quite well preserved in one. Today it occurs in fens together with *Paludella.*

Pseudobryum cinclidioides (HUEB.) KOP. A single well preserved shoot was found. Distribution map is found in HOLMEN & *al.* (1974).

Paludella squarrosa (HEDW.) BRID., was found two places in this series; in the upper sample it was well preserved. Distribution map is found in

HOLMEN & *al.* (1974). The last three mentioned mosses were all found in the three transitional poor fens that were visited in 1970.

The moss fragments from this lake are few in numbers, and usually badly preserved. The determinations, in several cases, are based on very small fragments e.g. *Helodium* and *Paludella.*

All the samples contained remains of unidentified hypnoid mosses. The latter, in connection with the rather large samples, may indicate that there has been vegetation along the lake which has retained material, or that the material has been transported some distance. Unfortunately, Comarum Sø was not visited in 1970. A recent moss sample brought back by FREDSKILD, and determined by K. HOLMEN somewhat different from the core samples, as it contained *Pseudobryum cinclidioides* (HUEB.) KOP., *Calliergon sarmentosum* (WAHLENB.) KINDB., *Aulacomnium palustre* (HEDW.) SCHWAEGR. and *Sphagnum fimbriatum* WILS.

In 1970, in a fen located ca. 200 m SE of Comarum Sø, was found a species composition corresponding to the one found in the core samples. This fen was characteristic by existing seeping water, which apparently is a feature not found in Comarum Sø today. Similar fens were seen at Tupaussat, and at the waterfall at Amitsuarssuk at the head of one of the arms of Lichtenau Fjord. The mosses from Comarum Sø belong to a completely different association than the associations found in the Kap Farvel lakes, as they were mosses from a transitional poor fen, or the so called *Paludella* fen. This type of fen has been treated by several authors, ALBERTSON (1949), DU RIETZ (1949), HOLMEN (1971), MENTZ (1912) and WITTING (1949).

Peary Land

Sølejren

The vegetation and the higher plants have been treated by HOLMEN (1957), and FREDSKILD (1966). A survey of the moss associations is given by HOLMEN (1955), while the individual species and examples of their associates are to be found in HOLMEN (1960).

The samples 10–11.5 cm and 18–19.5 cm, are from a different monolit than the others.

Several C-14 datings have been made (FREDSKILD, 1973:185). The oldest is from 23.5–28 cm under the bog surface, and dates 1520 ± 100 B.P.

Table 7. *Sølejren*

cm below the surface	23,5–28	18–19,5	14–16	10–12	10–11,5
Bryum neodamense ssp. *ovatum*		×			
Calliergon giganteum	×	×	×	×	×
Catoscopium nigritum		×			
Drepanocladus brevifolius	×	×	×	×	×
Drepanucladus revolvens		×			
Meesia trifaria			×		×
Philonotis tomentella					×
Musci sp. indet.				×	×

Species from Peary Land

Bryum neodamense ITZIGS. ssp. *ovatum* (C. JENS.) KINDB., was represented in the samples by a few stems. It is a common calciphile species found in meadows, and is in Greenland only known north of 69° N lat. In Scandinavia it occurs in rich fens in the subalpine belt (MÅRTENSSON, 1956), together with e.g. *Catoscopium nigritum*, *Drepanocladus revolvens* and *Meesia trifaria.*

In the lower sample from Spongilla Sø is a find which is referred to this species.

Calliergon giganteum (SCHIMP.) KINDB., was numerous, and in all samples well preserved. In Peary Land it is common along streams and on wet soil. HOLMEN (1955), describes a "*Calliergon giganteum* community" in wet *Eriophorum scheuchzeri* marshes, where *Bryum neodamense* ssp. *ovatum* also occurs. Also *Calliergon giganteum* is mentioned as an associate in the "*Drepanocladus brevifolius* community", together with *D. revolvens. C. giganteum* is widely distributed in the northern part of Greenland.

Catoscopium nigritum (HEDW.) BRID. A few stems were found in the samples. HOLMEN (1960), reports this calcicole species as rather rare in Peary Land, where it occurs in wet meadows and fens, together with e.g. *Philonotis tomentella* and *Drepanocladus brevifolius. Catoscopium* in Greenland only grows on calcareous soil, which in general is north of 70° N lat. Distribution map is found in HOLMEN & *al.* (1974).

Drepanocladus brevifolius (LINDB.) WARNST., dominates all the samples. The material was mostly well preserved, but difficult to determine, as the fragments were of all sizes and shapes. HOLMEN (1955), describes the

"*Drepanocladus brevifolius* community" as the most important moss community on moist ground. It occurs in *Carex stans*, *Alopecurus alpinus* and *Eriophorum scheuchzeri* meadows. It can form pure stands, but is often associated with e.g. *Calliergon giganteum* and *Drepanocladus revolvens*. BRASSARD (1971:250), mentions a corresponding "*Drepanocladus brevifolius* community" on Ellesmere Island, which includes almost the same plants as in Peary Land. The distribution of *D. brevifolius* in Greenland is northern.

Drepanocladus revolvens (SW.) WARNST. (incl. *D. intermedius* (LINDB.) WARNST.). The remains in the samples cannot with certainty be referred to one of the two taxa, but mainly they resemble *D. intermedius*. This species occurs in fens and meadows and along streams, where it grows together with e.g. *Meesia* spp., *Bryum* spp. and *Drepanocladus* spp. (HOLMEN, 1960). *D. revolvens* is found over most of Greenland.

Meesia trifaria CRUM, STEERE & ANDERSON (Syn.: *M. tristicha* BRUCH). Of this species, a few well preserved stems were found. In Peary Land it occurs in wet moist mosstundra, together with *Drepanocladus brevifolius* and *D. revolvens*. It is quite rare on Greenland, and is generally found north of the polar circle. A distribution map is found in HOLMEN & *al.* (1974).

Philonotis tomentella MOL., is common in most parts of Peary Land, where it is found in bog and fen vegetation.

The mosses from Sølejren are typical for calcareous soil. *Bryum neodamense* ssp. *ovatum* is the only species also found in the samples from Kap Farvel.

In general, all the mosses found are calciphile, and occur in fens and meadows and in the characteristic mats along brooks. All species are known from Northern Greenland, while *Calliergon giganteum*, *Drepanocladus revolvens* and *Philonotis tomentella* (more common towards the north), are found in the southern part of Greenland, too. Any succession, like the one found in the Kap Farvel lakes, cannot be recognized.

A change in the climatic conditions will only cause a variation in the peat growth (e.g. hiatus), and from the scarse material (and datings), it will not be possible to ascertain changed conditions, within the period in which the peat was formed.

One can conclude that the material could be part of a variation pattern in the *Drepanocladus brevifolius — Calliergon giganteum* communities.

The Zoological remains

Methods

In the tables 8–14 below a survey is given of the distribution of the remains in the localities. In the cases, where only a single figure indicate the depth below bottom (or surface) the remain is found in a pollen-sample (1 ml) or taken out of the core during the first investigation. In all other cases the remains are found from larger volumens of the core. It is however not possible to compare the number of remains directly, as the samples, even from the same core not always could be of the same size.

A relative comparison of the frequency is made by mean of the sample symbols: + (unique to rare) + + (rather frequent) + + + (common).

The datings reterred to in the tables are C-14 years B.P.

Several datings are inter-or extrapolated.

Table 8. *Galium Kær*

Cm below surface	68–69	101–102	119–102	160–161	186–187
Daphnia pulex	+	+	++	+++	++
Simocephalus vetulus	+				
Tricoptera "Limnophilus"	+	+	+		
Chironomidae		++			++
App. year B.P.	2400	4400	5400	6100	6800

Table 9. *Drepanocladus Dani*

Cm below lake bottom	30	54	115–120	120–125	139	140	141	145	150	150–155	155–160	157.5
Daphnia pulex			++	+								
Tricoptera "Limnophilus"			+	+						+	+	
Hydroporus polaris			+	+			+		+			+
Colymbetes dolabratus		+			+	+		+				
Chironomidae	+		++	++								
Hydracnidae			+									
App. year B.P.	600	1100	2200	2400	2700		2800	2900	3000		3100	

Table 10. *Isoëtes Sø*

Cm below lake bottom	23–26	41–44	59–61	79–81	99–101	112	119–121	123–125	137–139
Lepidurus arcticus						++	++	++	
Daphnia pulex					+++		+++	+++	+++
Simocephalus vetulus					+		+	++	
Eurycercus glacialis	+++	++	+++	+++	+++				
Acroperus harpae				++				+++	
Hydroporus polaris		+							
Tricoptera Apatania zonella							+		
Tricoptera "Limnophilus"	+	+	++		+				
Chironomidae			++	++	++			+	
App. year B.P.	3140	3700	4700	5800	7200	7800	8500	8700	9400

Table 11. *Spongilla Sø*

Cm below lake bottom	33–38	73–78	83–88	93–98	103–108	116–121	146–151	191–196
Lepidurus arcticus							+	
Daphnia pulex		++				+++		++
Simocephalus vetulus			+				+	
Eurycercus glacialis		+++	++	+++	++			
Alona affinis		+	+++	+	++			
Alona rustica				+				
Chydorus sphaericus				++				
Hydroporus polaris	+							
Tricoptera "Limnophilus"	+							
Tricopta, Apatania zonella								+
Chironomidae		++	+	+++	++			
Hydracnidae			+					
App. year B.P.	2100	3500	4500	5500	6500	7700	8700	9200

Table 12. *Kløftsø*

Cm below lake bottom	31	35–38	62–65	95–98	110–113	128–31	140–43	149–52	158–60
Simocephalus vetulus							+		
Eurycercus glacialis			+	+		+	+		
Acroperus harpae			+						
Alona affinis				+	+				
Cyprinotus incongruens								+	
Tricoptera "Limnophilus"	+	+	+			+			
Hydroporus polaris					+				+
Chironomidae		+		++	+	+	+	+	
Simulium						+			
App. year B.P.	2500	3200	4000	4900	5700	6600	7400	8000	8600

Table 13. *Comarum Sø*

Cm below lake bottom	50–52	88–90	108–110	126–28	166–68	176–78	190–92	204–06	246–48	284–86	306	318	318–20	340–42	342–44	344–46
Cristatella mucedo				+	+++	++										
Lepidurus arcticus														+	+	
Daphnia pulex	++	++	+	++		++	+	++	+	+			+++	+++	++	+
Simocephalus vetulus							+							+		
Alona affinis						+										
Cyprinotus incongruens													+			
Hydroporus polaris	++			+		+		+		+			++	++		
Colymbetes dolabratus							++									
Chironomidae	+++	++		++			+			++		+	+++	+		++
Ceratopogonidae						+										
Hydracnidae											+	+				
App. year B.P.	800	1700	2100	2600	3400	3600	3900	4200	5600	6900	7500	7900		8600	8700	

Table 14. *Klaresø*

Cm below lake bottom	12–15	24–27	36–39	48–51	72–75	84–87	96–99
Daphnia pulex	++	+++	++	++	+++	+++	+++
Prinocypris glacialis							+
Candona subgibba	++	+					
Tricoptera Apatania zonella			+				
Chironomidae					+		
App. year B.P.	1500	3000	3500	3800	4300	4600	4800

Description of the zoological remains

Bryozoa

Cristatella mucedo CUVIER.

All the remains of this species are statoblastes. Nearly all are more or less broken, but still easy to identify (Fig. 4). The species is only recorded from Comarum Sø. The species was never before found in Greenland, and it is unlikely that it occurs there to-day.

Crustacea

Lepidurus arcticus (PALLAS).

Remains of this species represent mandibles (Fig. 5), abdominal rings, or, rather seldom, fragments of carapaces. Such remains are found in three localities, Spongilla Sø and Isoëtes Sø on Pamiagdluk, and Comarum Sø.

The distribution of the species in Greenland to-day is between 66° and 78° N, on the west as well as on the east coast. In the northernmost and southernmost parts of Greenland the species is never seen.

Daphnia pulex (DE GEER).

Without exception the remains of this species belong to ephipiae and are found in all localities except Kløftsø.

The species is found throughout Greenland except in the southern part of the east coast, from Scoresbysund to Kap Farvel, it is common in the northern part of the range of distribution, but is fairly rare in the southern part.

Of the six lakes investigated, *Daphnia pulex* to-day occurs in Comarum Sø, Spongilla Sø, and Klaresø; in all three localities the species is common.

Simocephalus vetulus (O. F. MÜLLER).

Most of the remains of this species belong to ephipiae, but in one single case (Isoëtes Sø, 123–125) a head carapace was found. The pos-

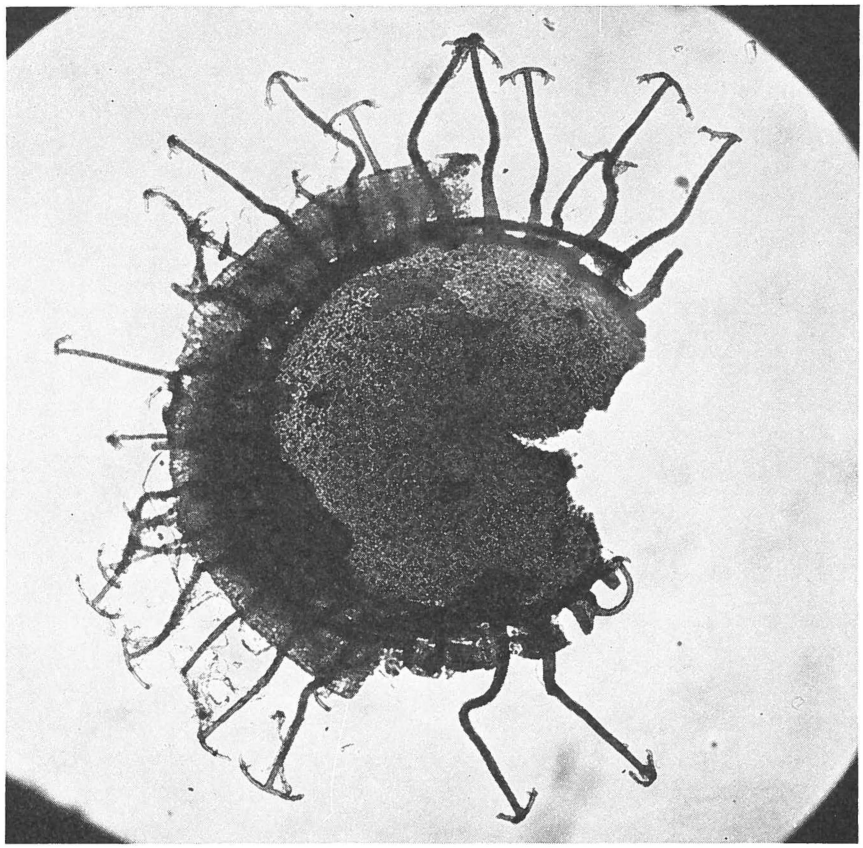


Fig. 4. Statoblast of *Cristatella mucedo*. (Comarum Sø, 176–78 cm below lake bottom).

sibility might exist that ephipiae from the Kap Farvel area belongs to the species *S. serrulatus*, since in 1970 this species was found in two localities there (RØEN, in preparation), but the head shield without doubt belongs to *S. vetulus*.

S. vetulus is found all over Greenland south of 73° N, but it is rather rare in the southern and southeastern parts.

Remains are found in all localities except three, viz. Drepanocladus Dam, Kløftsø, and Klaresø.

A few specimens were found in a recent plankton sample from Comarum Sø, but none in the other four localities.

Eurycercus glacialis LILLJEBORG.

Remains of *Eurycercus glacialis*, carapaces and exugii of postabdomen, were found in three localities, Kløftsø, Spongilla Sø, and Isoëtes Sø.

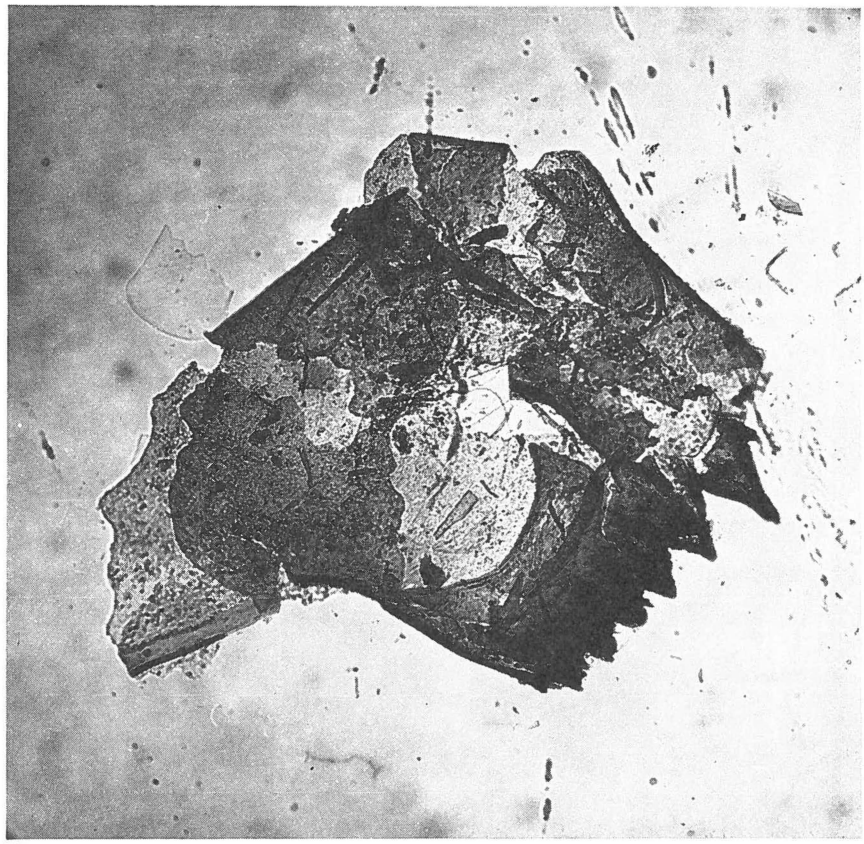


Fig. 5. Mandibel of *Lepidurus arcticus*. (Isoëtes Sø, 119–21 cm below lake bottom).

The species is distributed on the west coast of Greenland, from 72° N to Kap Farvel; it is rare in the northern parts, and common south of 70° N. On the east coast south of 70° N it is found very scattered.

Eurycercus glacialis was rather frequent in the plankton samples from Comarum Sø, Spongilla Sø, and Isoëtes Sø.

Alona affinis (LEYDIG).

Carapaces of this species were found in Spongilla Sø and Kløftsø.

The species is rather common throughout Greenland south of 73° N. In plankton samples the species were found in all southern localities except Drepanocladus Dam.

Alona rustica SCOTT.

A single carapace of this species was found in Spongilla Sø. The species is rare in Greenland, only found in the Kap Farvel area. The species was not found in the lakes investigated.

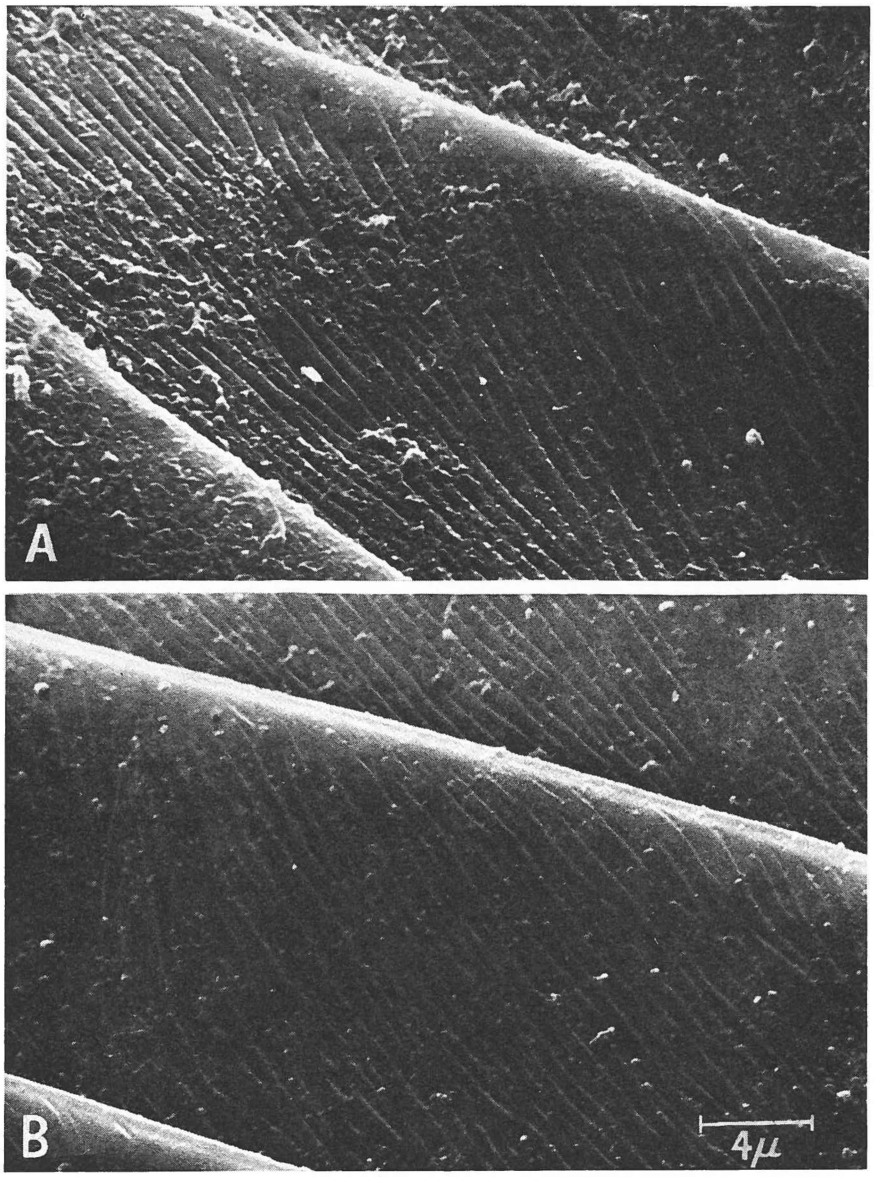


Fig. 6. Scanning fotos of the surface of the carapax of *Acroperus harpae* from Isoëtes Sø. A. Specimen from the core sample, 8700 B.P. B. Recent specimen.

Acroperus harpae (BAIRD).

Most of the remains of this species are intact carapaces, but in some cases only part of body carapaces were left. In the last case the remains were identified by the fine sculpture on the surface, compared to recent specimens from the same locality, by means of scanning microscopy (Fig. 6).

Remains of *Acroperus harpae* are only recorded from two localities: Isoëtes Sø and Kløftsø.

The species is common in West Greenland, south of 75° N, and in East Greenland south of 72° N.

In plankton samples the species were present in all localities except in Drepanocladus Dam and Klaresø.

Chydorus sphaericus (O. F. MÜLLER).

A number of carapaces of this species was found in Spongilla Sø. The species is common all over Greenland.

The species was found in the plankton from all the localities investigated.

Cyprinotus incongruens (RAMDOHR).

Carapaces of this species were found in samples from Comarum Sø and Kløftsø.

The species occurs all over Greenland except in the extreme northern part, but is rather rare.

The species was not found in the plankton samples.

Prionocypris glacialis (G. O. SARS).

In the samples from Klaresø a few shells of this species were found.

In Greenland the species is rather scattered on the West Coast southwards to ca. 61° N. On the North Coast, and in the part of the East Coast north of 70° N it is somewhat more common.

It was rather common in plankton samples from Klaresø, but not in any of the other localities.

Candona subgibba G. O. SARS.

This species has been found in fairly large numbers in samples from Klaresø. In all cases well preserved shells were found. In Greenland the species has only been found in the Thule area and in Peary Land.

Insecta

Colymbetes dolabratus PAYK.

Identifiable remains of *Colymbetes dolabratus* are wings of the 1st pair. Such remains were found only in Comarum Sø and Drepanocladus Dam.

In Greenland the subspecies *C. d. groenlandica* (AUBÉ) is common south of 74° N. It cannot be decided whether the remains found belong to this subspecies, but it is most likely.

Specimens of ssp. *groenlandica* were found in all localities and their surroundings except in Klaresø.

Hydroporus polaris FALL.

The remains of *Hydroporus polaris* consisted of the sternum, head capsula, and wings of the 1st pair.

Remains were found in all localities except Galium Kær and Klaresø.

The species is rather common all over Greenland, and specimens were found in all the localities investigated and in the vicinity.

Tricoptera

The remains of *Tricoptera* always represented larval or pupal houses or parts of these. I am not able to identify all these parts to species or genus. The *Tricoptera* fauna in Greenland is not very well known, and some of the remains do not agree with the known species. Most of the remains consists of about 1 cm long houses of small stones of almost the same width at both ends. These types may belong to the genus *Limnophilus*, and are found in Isoëtes Sø, Spongilla Sø and Kløftsø.

Finally, from Klaresø and the lower deposits in Spongilla Sø, and Isoëtes Sø, a quite different type exists, rather irregular houses, which are broadest in the middle, and tapering at the ends, 1.0-1.5 cm long. This is most likely the larvae or pupae houses of *Apatania zonella* ZETT., a species which today occurs in whole Greenland whereas no other species have been found north of 69° N.

Chironomidae

I have made no attempt to identify the rather large number of head capsulae of *Chironomidae*, found in the samples.

Ceratopogonidae

In one sample, from Comarum Sø, a fragment of an egg mass was found.

Simulium sp.

A few houses of *Simulium* larvae were found in Kløftsø. Species of *Simulium* are today common all over Greenland.

Hydrachnidae

Remains of *Hydrachnidae* were found in samples from Comarum Sø and Drepanocladus Dam. Unfortunately, all remains were indeterminable parts of the exosceleton.

Today *Hydrachnidae* are known from freshwater all over Greenland in seven species, but all species are very rare.

Discussion of the zoological remains

Occurrence of the zoological remains listed according to age:

	Southern area	Peary Land
1. *Daphnia pulex*	9400 to present	4800 to present
2. *Tricoptera Apatania zonella*	9200 to present	3500 to present
3. *Lepidurus arcticus*	8700 to 7800	
4. *Simocephalus vetulus*	8700 to present	
5. *Acroperus harpae*	8700 to present	
6. *Chironomidae*	8700 to present	4300 to present
7. *Hydroporus polaris*	8600 to present	present
8. *Cyprinotus incongruens*	8000 to present	
9. *Hydrachnidae*	7900 to present	present
10. *Eurycercus glacialis*	7400 to present	
11. *Tricoptera "Limnophilus"*	7000 to present	
12. *Simulium* sp.	6600 to present	present
13. *Alona affinis*	6500 to present	
14. *Alona rustica*	5500 to present	
15. *Chydorus sphaericus*	5500 to present	present
16. *Prionocypris glacialis*		4800 to present
17. *Colymbetes dolobratus*	3900 to present	
18. *Ceratopogonidae*	3600 to present	
19. *Cristatella mucedo*	3600 to 2600	
20. *Candona subgibba*		3000 to present

It has universally been anticipated that even if a species is absent at some depths, but present in the area today, this does not imply that it has disappeared and re-immigrated into the area as a whole, but possibly in the single locality, whereas a total disappearance of the species in the profile, which also has not been found recent in the area, must mean that it is actually extinct there.

In the core samples in South Greenland *Daphnia pulex* is obviously the first species which occurs after the localities have been established as freshwater localities, immediately followed by *Tricoptera* of the *Apatania zonella* type. This is distinctly seen in Isoëtes Sø and Spongilla Sø, and in some degree, in Comarum Sø, where it occurs together with *Chironomidae*, while, for some reason, the species has hardly been able to establish a population in Kløftsø. This demonstration of *Daphnia pulex* in the oldest deposits in South Greenland seems to show that the present author (RØEN, 1962, p. 217) has misinterpreted the distribution of the species and thereby referred it to the northwestern fauna element, an element which most probably immigrated fairly late to Greenland from North America via the North-Canadian islands. According to the present information, the species should rather be referred to the fauna element

which is distributed all over Greenland, and probably survived the last great glaciation, in nunatak areas in or near Greenland, and thus was able, immediately, to invade the freshwater localities, provided that life conditions were favourable. That the species today is comparatively rare in Southwest Greenland (30 % of the investigated localities (RØEN, 1962)), rare in the Kap Farvel area (4 % of the investigated localities (RØEN, in preparation)) and has not been recorded from East Greenland south of Scoresbysund, in this case might be due to the fact that the ecological conditions of the species, in the area from Kap Farvel to Scoresbysund, today are inferior to those prevailing earlier.

This seemed to be confirmed by the fact that while the species occurred subfossil in three of the four investigated cored lakes in the Kap Farvel area, it was only present in five plankton samples out of the 130 investigated localities in the area (RØEN, in preparation).

The next group, which in the sample occurs almost simultaneously in period, comprises the following species: *Lepidurus arcticus*, *Simocephalus vetulus*, *Acroperus harpae*, *Chironomidae* and *Hydroporus polaris*. It is a very heterogeneous group. As a matter of fact, it consists of three groups. One group comprises two predatory animals, *L. arcticus* and *H. polaris*. It applies to both these species that in order to be able to colonize a locality, well established prey animals must be present, as far as *Lepidurus* is concerned, probably here *Daphnia pulex;* today both occur very far to the north, since *H. polaris* has been found in Peary Land, while *L. arcticus* has its northern limit at ca. 78° N in Greenland, and in Ellesmere Island at any rate reaches as far as 82° N. While the former of these species is still common in South Greenland, *Lepidurus arcticus* has however disappeared, its southern limit is now in West Greenland at ca. 67° N.

The other group comprises *S. vetulus* and *A. harpae*. Both these species are southern species in Greenland, having their northern limit at ca. 74° N, and their occurrence in the localities may be associated with the change reflected by the fact that *Pediastrum* sp. decrease. The occurrence of the last type: *Chironomidae* is more difficult to explain. The *Chironomidae* today are found throughout Greenland, in all freshwater types, and possibly it is only accidental that remains have not been found in deeper layers.

About 8000 B.P. two species occur, which apparently have different causes of invasion, viz. the ostracod *Cyprinotus incongruens* and *Hydrachnidae*. It seems most probale that these species — as regards period — belong together with the five above mentioned species, and only by accident, were found in a younger deposit. This is supported by the fact that *C. incongruens* extends almost as far north in Greenland today as does *L. arcticus*, and that *Hydracarina* has been found throughout Greenland, although in smaller numbers.

That *Eurycercus*, on the other hand, invades the localities about 7400 B.P., the first record of the species, is rather certain. It is true that the species was not common when it was first recorded from Kløftsø, and it never became abundant in this locality, whereas its occurrence in Spongilla Sø, as well as in Isoëtes Sø, in the first sample after 7400 B.P. is surprisingly numerous. Just at that time a change of the climate takes place in the area (cp. p. 7), and this is reflected in the fauna which at that time, both in Spongilla Sø and in Isoëtes Sø, changes its character, among other things, *Daphnia pulex* disappears, which indicates a beginning oligotrophiation.

It is probable that the types "*Limnophilus*", *Alona affinis* and *Simulium* sp. immigrate almost simultaneously with *Eurycercus glacialis*. It is true that the earlier finds of these species are later (400–900 years) than the earliest *Eurycercus glacialis*, but in Spongilla Sø and Isoëtes Sø respectively, "*Limnophilus*" and *Alona affinis* occur simultaneously with the earlier *Eurycercus* finds. The find of *Simulium* is so isolated that no conclusions can be drawn from it.

Alona rustica and *Chydorus sphaericus* are probably not together in the same invasion group, even if they occur simultaneously. The occurrence of the species in Greenland today hardly indicates that the species immigrated so late; it is rather accidental that it was not found in deeper layers or more abundantly at all. On the other hand, there is every indication that *Alona rustica* is a rather late invader. As already stated (p. 7), a pronounced amelioration of the climate occurs around 5300 B.P. At this time there is an invesion of a number of plants which today occur only in the Kap Farvel area. *Alona rustica* is just an example of a species which today has only been found in the Kap Farvel area, the only one found in the core samples, but a number of other species has the same distribution, e.g. *Simocephalus serrulatus*, *Ceriodaphnia setosa* and *Cyclops viridis* (RØEN, in preparation). In Greenland it is thus a pronounced southern fauna element. The find of *A. rustica* may well date the earliest invasion of this element.

Finally, there are three types, which have their first occurrence about 3900–3600 B.P. These are *Colymbetes dolabratus*, *Ceratopogonidae*, and *Cristatella mucedo*. This period coincides with the beginning of phase f (p. 7), and at any rate the occurrence of *Cristatella* indicates that climatic optimal conditions are responsible, since this species which is not at all known from Greenland today just remains during this phase.

If there might be a climatic factor which conditions the presence of *Cristatella* just in this period, it is more doubtful, why the two other types do not occur until this time, since the present distribution in Greenland indicates an earlier invasion. Two factors may play a rôle, either that not climate but dispersal conditions are responsible for the

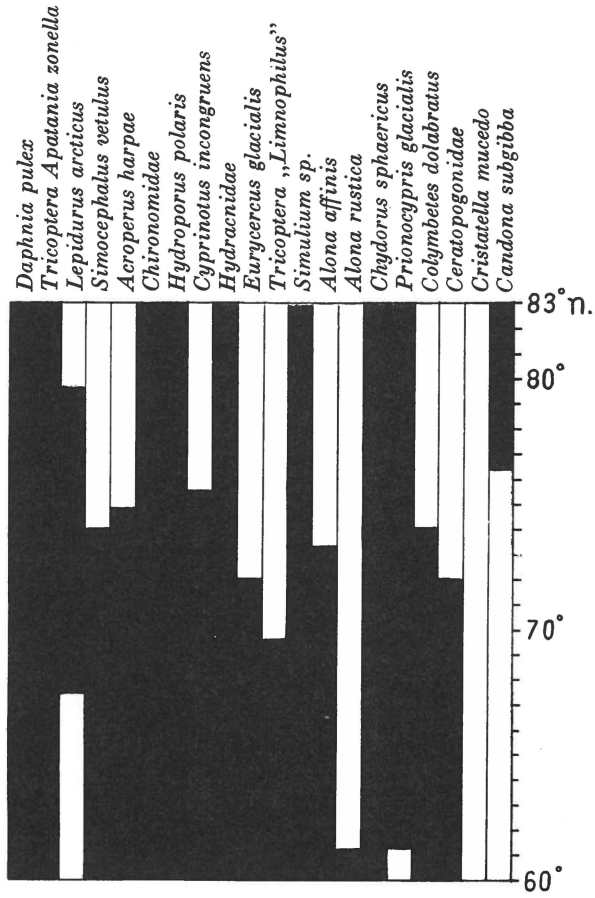


Fig. 7. Explanation se text p. 42.

fact that they do not occur until now, or partly sheer accidents in the find series. As far as *Ceratopogonidae* are concerned, the latter is the more probable cause, since the only existing find is not indicative.

The series from Klaresø in Peary Land is much more perspicuous, partly because the range of time is shorter than most of the series from South Greenland, partly because numbers of species as well as of individuals are small. The tendency however is clear. The only species found in the whole sampling series is *Daphnia pulex*. This might indicate that in this locality no principal change of the ecological conditions in the lake has occurred, in contrast to what happened in South Greenland, from the formation of the lake, up to the present time.

The find in the lower deposits of *Prionocypris glacialis* merely shows — what is also evident from its distribution today — that it invaded Greenland at an early date.

The two rather accidental finds of *Chironomidae* and *Apatania zonella* respectively, also do not give any new information of the invasion of the species.

On the other hand, the find of *Candona subgibba* in the two upper samples is interesting. First this species occurs in a period, in which the remaining deposits of the locality show that conditions in Peary Land undergo a change which leads to its present state (p. 10), secondly, the late occurrence of the species agrees well with the very limited distribution of the species in Greenland (RØEN, 1962, p. 209). This coincidence supports the view that this species, at a late time, invaded Greenland from the North-Canadian islands.

In Fig. 7 is given a survey of the present distribution in Greenland of the forms found, the species being arranged according to their earliest occurrence in all the localities investigated. Even if there is no quite clear conformity between the present distribution of the species and their "arrival", there is still a tendency showing that the earlier the species were found, the more extensive is their present distribution. This is especially evident for the species identified with certainty, while the higher taxa do not fit in with this picture, which could not be expected, because a group of species will always have a greater dispersion than a single species. More detailed investigations of new core sample series in other places in Greenland may probably add to our knowledge, and thus contribute to the understanding of the zoogeography of the freshwater fauna in Greenland.

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