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A POSTGLACIAL POLLEN DIAGRAM FROM ANGMAGSSALIK, EAST GREENLAND

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H. BICK

WITH 3 FIGURES AND 1 PLATE

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Abstract

A pollenanalytic study of a mire at Angmagssalik, East Greenland 65°36′N–37°39′W) has been made in connection with a vegetation research of this area by F. J. A. Daniëls (in prep.) and J. G. De Molenaar (1974, 1976).

Six pollen assemblage zones have been described. In the lowermost zone of the diagram we visualise a local vegetation complex of *Salix* scrub and *Carex bigelowii* grass heaths on fluviatile or colluvial sand deposits. This was probably followed by more chionophytic vegetations (heaths and showbed with *Koenigia*). At ca. 6000 B.P. (radiocarbon date) peat growth started: the pollen assemblage and the lithology reveal a *Carex-Eriophorum* mire vegetation with a.o. *Comarum palustre* and *Sphagnum*, *Drepanocladus* and *Calliergon* spp. After a second extensive zone with willow scrub and grass heaths again a mire vegetation developed, probably in rather recent time.

The diagram offers some evidence for climatic fluctuations, recognised elsewhere in the arctic. During the so called "climatic optimum" (ca. 6000–2200 B.P.) the climate of East Greenland, like that of North Greenland, was presumably more oceanic (with peat growth) than in earlier and later periods. This is in contrast to the conditions in South and West Greenland. The width of the drift ice belt along the East Greenland coast is probably a very important factor for the climate of the coastal area.

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Fig. 1. General map of Greenland.

1. Introduction

The present paper is a pollen analytic study of a core from a mire at Angmagssalik, East Greenland (fig. 1), connected with a phytosociological study of the area by DANIËLS (in preparation) and DE MOLENAAR (1974; 1976).

The purpose of this study is to gain insight in the vegetation succession leading to the present distribution of plant communities and to trace the origin of vegetation types delimited by DANIËLS and DE MOLENAAR.

The mire was cored by DANIËLS and DE MOLENAAR, summer 1968.

2. Location of the core

The coring site (marked A in fig. 2, X in fig. 3) is situated in a strip of lowland between the bay Kong Oscars Havn and a 150 m high ridge. It is just behind, in fact almost inside the Angmagssalik settlement, at a height of about 10 meters above sea-level (65°36′N–37°39′W).

3. Recent vegetation

The vegetation of the coring site is a flat *Carex rariflora-Sphagnum* mire (*Sphagnum riparium-Carex rariflora* sociation DE MOLENAAR 1976), very poor in species.

The mire is surrounded by hills and rocks, covered by heaths, fell-fields and snowbeds where the settlement of Angmagssalik did not yet penetrate. Similar vegetation types are also present on the north-eastern slopes of the ridge above mentioned, along with local snowbeds and moss fens along brooklets. On the southern slopes of this ridge, called Elvbakker, niveo-aeolic sand deposits are covered by *Salix glauca* scrub, alternating with *Carex bigelowii* grass heaths on deeper soil (fig. 2).

Further information about the present vegetation of the area can be found in KRUUSE, 1912; BÖCHER, 1933; DANIËLS, 1969; DE MOLENAAR, 1974, 1976.

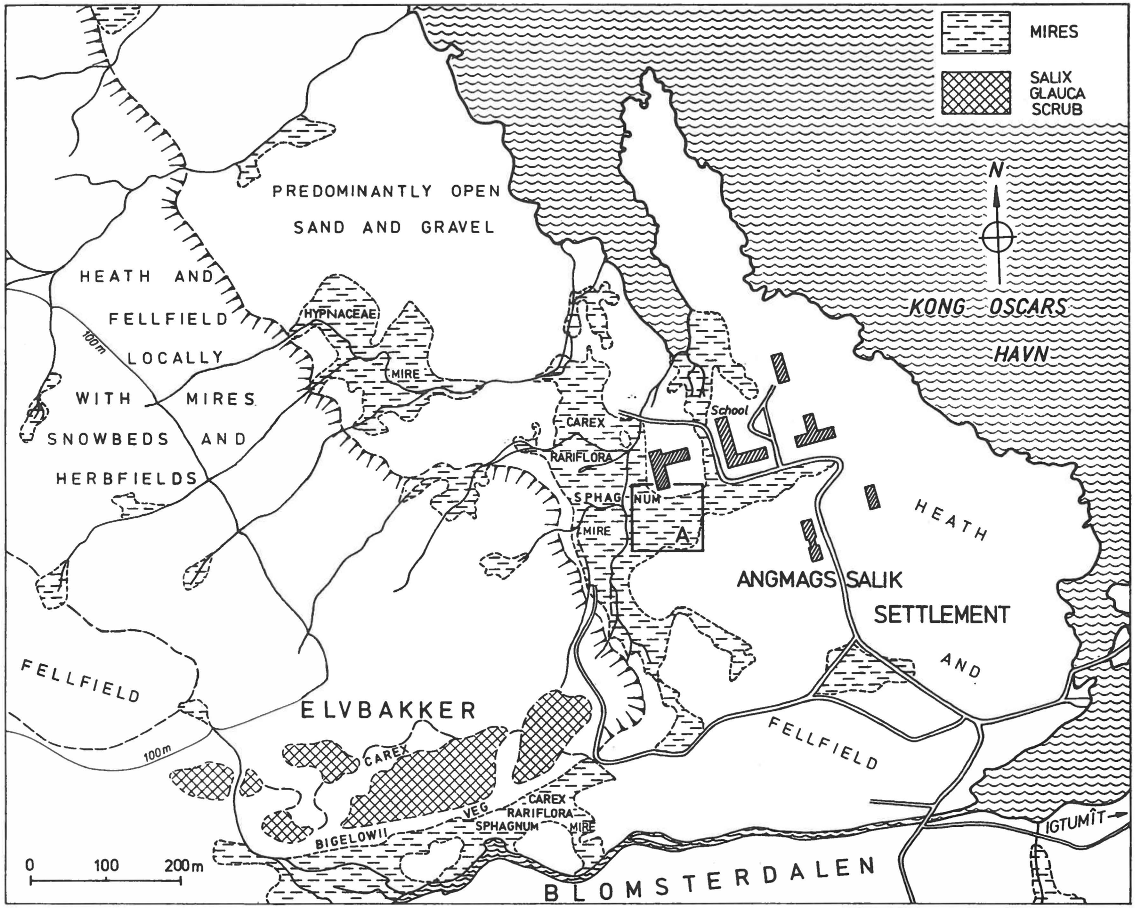

Fig. 2. Area around the Angmagssalik settlement. A: location of core.

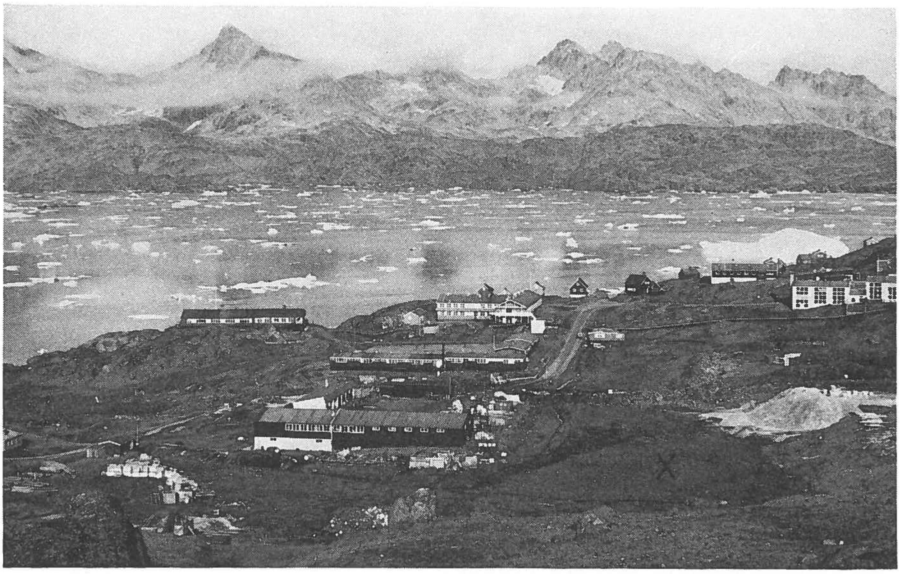

Fig. 3. View on part of the Angmagssalik settlement in NE direction. X: location of core. In the background Kong Oscars Havn and the Kingigtorssuaq mountain ridge.

4. Methods

4 a. Field methods

A 2 m long core was obtained by means of a Dachnowski peat sampler of 6 cm diameter (effective lenght 40 cm). At the base of this core, at 2 m depth, a compact sand layer prevented to sample deposits at greater depths.

A second core, therefore, was taken with a Dachnowski peat sampler of only 2 cm diameter (effective lenght 20 cm). With this core a depth of 3.20 m was reached. At this depth still no bedrock was present.

4 b. Laboratory methods

Pollen analysis of the upper two meters of the core was carried out on material from the core of 6 cm diameter; that of deposits between 2 and 3.20 m on material from the 2 cm diameter core.

The samples for pollen analysis were subjected to standard preparation methods: boiling with 10 % KOH for one minute, sieving through a screen (meshes 250 μ), treatment with cold HF during 22 hours (most of the samples are sandy) and acetolysis at 98°C for 5 minutes. Unstained material was mounted in silicone oil CS. 2000.

Whole slides were counted to avoid statistically inaccurate results due to uneven distribution of pollen under the cover slip.

5. Lithology

Part of the material of the core was suspended in water in order to identify remains of moss leaves, rootlets, etc.

The gross lithology is as follows:

0– 6 cm	Light-brown *Sphagnum*-peat.
6– 8 cm	Black-brown humiferous sandy layer with many woody twigs and roots.
8– 19 cm	Horizontally layered humiferous fluviatile sand with wood remains.
19– 30 cm	Humiferous fluviatile sand with layers disturbed by cryoturbation; *Carex*-rootlets and some wood and bark remains.
30– 31 cm	Light-brown *Sphagnum-Carex*-peat.
31– 59 cm	Humiferous sand, horizontally layered, with wood and bark remains; at 36 cm *Carex*-rootlets.
59– 60 cm	Dark-brown *Carex*-peat.
60– 70 cm	Humiferous sand with wood remains.
70– 76 cm	Light-brown *Calliergon* cf. *sarmentosum**)-*Sphagnum*-peat.
76– 81 cm	Dark-brown *Sphagnum-Carex*-peat.
81– 90 cm	As 60–70 cm.
90– 98 cm	Light-brown *Sphagnum-Hypnaceae*-peat (with twigs and leaves of *Calliergon* cf. *sarmentosum* and *Drepanocladus* sp.); some *Carex*-rootlets.
98–105 cm	Dark-brown *Carex*-peat.
105–110 cm	As 90–98 cm.
110–114 cm	Dark-brown sandy *Carex*-peat.
114–120 cm	Light-brown *Calliergon* cf. *sarmentosum-Carex*-peat.
120–126 cm	Humiferous sand with rootlets indet.
126–134 cm	Dark-brown *Carex*-peat.
134–137 cm	Light-brown *Sphagnum-Calliergon* cf. *sarmentosum*-peat.
137–146 cm	Dark-brown *Carex*-peat with some *Eriophorum* sheaths and *Sphagnum*-twigs.
at 146 cm	Thin oblique sand layer.
146–156 cm	Dark-brown peat with twigs and leaves of *Sphagnum* and *Calliergon* cf. *sarmentosum*, *Carex*-rootlets and some *Eriophorum* sheaths.
156–160 cm	Black-brown peat with many old stems and leaves of *Calliergon stramineum*, *Eriophorum* sheaths and *Carex*-rootlets.

*) The only common large *Calliergon* species besides *C. stramineum* in the Angmagssalik district is *C. sarmentosum*.

160–194 cm Dark-brown *Carex-Eriophorum*-peat with sand layers at 175, 181 and 184 cm; some branches and leaves of *Sphagnum* and *Calliergon* cf. *sarmentosum.*

194–235 cm Humiferous fluviatile sand with some *Carex*-rootlets; still more humiferous layers are present around 200 cm.

235–245 cm Light-brown peat-like sandy layer with many branches and leaves of *Drepanocladus* cf. *uncinatus;* some leaves of *Calliergon* and *Sphagnum.*

245–320 cm Clayey humiferous fluviatile sand, rich in biotite, layered, with some *Carex*-rootlets and some wood remains.

6. Pollen diagram

Relative as well as concentration pollen values are presented (plate 1). In the percentage curves two curves for each type are used: one (black silhouettes) that shows the values on the abscissa at the base of the diagram and a 5 times exaggerated curve showing the minor values more clearly.

The concentration curves show the amount of pollen grains per 0.2 mg weight of the fresh sediment. These values were determined by addition of a known volume of a standard *Eucalyptus* pollen suspension (Benninghoff, 1962; Matthews, 1969). Curves for the total concentration values and for the dominant pollen types (*Salix* and *Cyperaceae*) are shown behind the percentage curves.

For calculation of the percentages and concentration values and drawing of the diagram the X-8 computer of the State University of Utrecht was used (Voorrips, 1973).

6 a. Pollen sum

The number of species that mires and upland vegetation in arctic regions have in common is very large. This prevents a separation of the pollen of local mire vegetation from that of the vegetation on the surrounding upland solely on the basis of species composition. Moreover, the lithology of the core includes sandy deposits as well as peat layers. It is therefore difficult to exclude local pollen types from the pollen sum, as can be done in many pollen diagrams from temperate regions.

Included in the pollen sum thus are almost all the pollen types, except a few *(Pinus, Picea, Fagus, Ulmus, Alnus)* from trees that never occurred in the Angmagssalik district (long distance transport), a type of doubtful origin *(Typha latifolia)*, and the indeterminable pollen grains.

6 b. Zonation and arrangement of pollen types

Six pollen assemblage zones have been established, informally called ANG-A through ANG-F. They will be defined and discussed below.

The pollen types have been arranged in stratigraphic groups: curves with maxima in the early zones in the core were placed first, those that show maxima in later zones subsequently later in the diagram. Some of the groups however were also established on an ecologic basis.

The pollen groups are numbered 1 through 11.

6 b. 1. Definition of the pollen groups

A. Groups of types included in the pollen sum

group 1: *Salix*, *Cyperaceae:* dominant types, stratigraphically significant, but not restricted to one or more zones.

group 2: *Angelica*, *Selaginella selaginoides*, *Lycopodium selago:* low percentages, almost restricted to the zones ANG-A through ANG-C.

group 3: *Campanula*, *Chamaenerion*, *Compositae tubuliflorae:* types with maxima in zone ANG-A.

groups 4 and 5: types, nearly restricted to zone ANG-B. For ecologic reasons (see pag. 14) divided into:

group 4: *Lycopodium annotinum*, *L. alpinum*, *Dryopteris* type: spores from species of chionophilous heaths and herbfields.

group 5: *Koenigia islandica* and *Cerastium cerastioides.*

group 6: *Gramineae*, *Saxifraga nivalis* type, *Minuartia* type, *Oxyria digyna*, *Thalictrum alpinum*, *Ericaceae*, *Empetrum*, *Compositae liguliflorae*, *Phyllodoce:* curves very similar in shape, with highest values in the three lower zones, especially in zone ANG-B. Within this group an ecologic subdivision is possible: *Thalictrum* up to and including *Phyllodoce* are species which occur mostly in heath vegetations; the other pollen types are from species preferring open ground.

group 7: *Dryas* type, *Cruciferae*, *Juniperus*, *Betula:* low percentages, occurring in all zones, but with highest values in the upper part of the diagram (zones ANG-C through ANG-F).

group 8a: *Potentilla-Comarum* type: most abundant in zones ANG-C and ANG-D.

group 8b: *Polygonum viviparum:* maximum in zone ANG-E.

group 9: Stratigraphically insignificant types, mostly occurring in a few samples. Within this group a certain stratigraphic arrangement has been made.

B. Groups of types not included in the pollen sum

group 10: *Pinus*, *Picea*, *Fagus*, *Ulmus*, *Alnus:* tree pollen types, transported over long distance. A curve showing the sum of the percentages of these types (total long distance curve) has been added.

group 11: *Typha latifolia:* pollen of doubtful origin.

6 b. 2. Comments on some pollen types

Salix: includes *S. glauca* type and *S. herbacea* type (Faegri & Iversen, 1964). Fredskild (1967a) separates the two types; however, he notes that a small amount of *S. glauca* type pollen is produced by *S. herbacea*, and conversely a small amount of *S. herbacea* type pollen is produced by *S. glauca*.

According to Fredskild (1973, p. 29) extreme *S. herbacea* type pollen is produced by *S. herbacea* only, but *S. glauca* produces both types and a range of intermediate forms.

In this paper therefore no separate curves for the two types have been drawn. Moreover, in this particular case it was very difficult to keep these types apart because of poorly preserved material.

Saxifraga nivalis type: includes *S. nivalis*, *S. tenuis* and *S. stellaris*.

Minuartia type (=*Lychnis* type according to Faegri & Iversen, 1964): includes *Minuartia biflora*, *M. rubella*, *Silene acaulis* and *Viscaria alpina.*

Ericaceae: includes *Vaccinium uliginosum*, *Loiseleuria procumbens*, *Harrimanella hypnoides* and *Cassiope tetragona.*

It was difficult to separate these species because of poor preservation of pollen. This pollen type may therefore also include a few poorly preserved *Empetrum* grains: the *Empetrum* curve thus represents only minimum values.

Potentilla-Comarum type: includes at least *Potentilla crantzii*, *P. tridentata*, *P. nivea*, *Comarum palustre* and *Sibbaldia procumbens.*

Again poor preservation made it difficult to distinguish the *Potentilla* species from one another. See also Fredskild, 1973, p. 29.

Saxifraga oppositifolia type: includes *S. oppositifolia*, *S. aizoides* and *S. aizoon.*

Saxifraga caespitosa type (=*S. hirculus* type according to FAEGRI & IVERSEN, 1964): includes *S. caespitosa*, *S. cernua*, *S. hyperborea* and *S. rivularis*.

7. Results and discussion

7 a. Problems in interpretation

1. No surface samples were available: the relationship between present vegetation types and recent pollen assemblages in East Greenland is therefore unknown. Instead references have been made with recent pollen deposition studies elsewhere in arctic regions: Canada (WENNER, 1947; RITCHIE & LICHTI-FEDEROVICH, 1967; LICHTI-FEDEROVICH & RITCHIE, 1968); West Greenland (FREDSKILD, 1967a); South Greenland (FREDSKILD, 1973); Iceland (RYMER, 1972, cited in BIRKS, 1973) and Spitzbergen (SRODON, 1960). BIRKS (1973) summarizes surface sample studies in these regions.
2. This diagram being the first one from East Greenland, no comparison with other diagrams from this region could be made. Comparison with diagrams from other regions in the arctic is difficult because of differences in climate, flora, vegetation and pollen deposition. Canadian pollen assemblages show a much larger amount of arboreal pollen; in Iceland human influence is larger (EINARSSON, 1963). Even in West Greenland and South Greenland the assemblages are quite different from those in the Angmagssalik diagram.

7 b. Zones

7. b. 1. Zone ANG-A

Characterisation of the assemblages

High values of *Salix* (up to 90 %) alternate with maxima in the *Cyperaceae* curve. *Campanula*, *Chamaenerion* and *Compositae tubuliflorae* show striking maxima; values of other types are relatively low. The sediment is a rather homogeneous humiferous clayey sand.

Discussion

The high percentage of *Salix* point to a local vegetation of *Salix glauca:* according to SRODON (1960) *Salix* percentages in surface samples from *S. herbacea* and *S. polaris* vegetations at Spitzbergen never exceed 25 %. FREDSKILD (1967a, 1967b) observes percentages up to 10 % when *S. glauca* is locally absent, up to 22 % at occurrence of scattered shrubs and more then 99 % in dense *S. glauca* scrub.

Also the high values of *Campanula* and *Chamaenerion* in spectrum 3 may very well mean that these plants were locally present. In the Angmagssalik region only a few vegetation types with both a *Campanula* and a *Chamaenerion* species exist today: *Carex bigelowii* grass heaths on niveo-aeolic and fluviatile sand deposits (*Nardo-Caricion bigelowii* NORDH. 1936), a few allied other vegetation types (DE MOLENAAR, 1976) and a willow scrub type *(Polygono-Salicetum glaucae)* (DANIËLS pers. communication). In all these cases the species involved are *Campanula gieseckiana* and *Chamaenerion angustifolium*. *Chamaenerion latifolium* has its optimum in pioneer vegetations on sandy outwash plains, river beds, etc. and never occurs together with *Campanula* (DANIËLS, DE MOLENAAR pers. communication).

The local vegetation during the period of zone ANG-A was therefore presumably *Salix glauca* scrub, temporarily and spatially alternating with *Carex bigelowii* grass heaths, on rather dry fluviatile or colluvial sand deposits as appears from the lithology. Such a vegetation complex can be found at the Elvbakker slope today (fig. 2); it requires a continous but not too long-lasting snow cover.

Compositae tubuliflorae pollen may be attributed to *Gnaphalium* (in this case probably *G. norvegicum*) or *Erigeron* spp., that may occur in willow scrubs.

The diagram offers little evidence for the nature of the surrounding vegetation. Perhaps the presence of the *Dryopteris* type points to rich heaths or herb fields, although *Dryopteris linnaeana* may have been a component of the local willow scrub. Some spores of *D. linnaeana* have been found in the samples, but have not been counted separately.

An alternative explanation for the pollen assemblages of this zone would be to assume an allochthonous origin of the material. Any reconstruction of the vegetation and the origin of the pollen then is of course extremely difficult. The high *Salix* values however may point to a local autochthonous rather than to an allochthonous origin.

7 b. 2. Zone ANG-B

Characterisation of the assemblages

Salix values are much lower than in zone ANG-A (± 25 $^0/_0$) and rather constant. Maxima of types within groups 4 and 5 are present; those within group 6 reach higher percentages than in zone ANG-A. The sediment is less homogeneous than in the preceding zone; humiferous sand layers alternate with a peat-like layer rich in moss remains.

Discussion

The lower percentages of *Salix* may indicate that the *Salix* scrub dissappeared from the site. A striking feature is the presence of *Koenigia* and *Cerastium cerastioides* pollen (group 5); assemblages with these two types have also been found by Fredskild (1973) in the basal zones of several of his diagrams from South Greenland. The percentages of both pollen types also agree with those of Fredskild and point to a local occurrence.

At present *Koenigia islandica* and *Cerastium cerastioides* dominate with *Drepanocladus uncinatus* in a chionophytic vegetation type, intermediate between snowpatch and mire vegetation, that occurs very locally in the Angmagssalik district at present (De Molenaar pers. communication). If this interpretation of the local vegetation is correct, the presence of the peat layer between 245 and 235 cm indicates that this vegetation type may generate peat under favourable conditions, for instance a high summer precipitation.

The *Koenigia-Cerastium* vegetation may alternate with snowpatch vegetation in which *Salix herbacea* dominates; the *Salix* pollen in zone ANG-B could partly have come from *S. herbacea*. However, *S. glauca* still may have been present on the surrounding slopes.

The pollen types of group 4 point to a rich, rather chionophilous heath with *Lycopodium annotinum*, *L. alpinum* and perhaps also *Cystopteris fragilis* in the immediate surroundings. At present such a vegetation covers vast surfaces only in more interior parts of the Angmagssalik region; in the coastal area it is restricted to small, sheltered sites (Daniëls, De Molenaar pers. communication). A part of the fern spores however comes from *Dryopteris linnaeana* (not counted separately) which has its optimum along the margins of *Salix* scrub.

An origin of the pollen of the groups 4 and 5 that is spatially separated is very likely but not the only possibility. The vegetation at the site may also have been of a mosaic character as a result of cryoturbation causing an uneven microtopography. Thus the more mesophytic plants could grow in the lower parts and the heath plants in the higher parts. According to this theory, the *Lycopodium* species may have been growing locally.

The chionophytic vegetation types in and around the site possibly point to a higher winter precipitation and a more continuous snow cover than today in the coastal area, a situation resembling conditions in the interior. Also the change from *Salix* scrub to chionophytic vegetations at the transition ANG-A/ANG-B may have been a result of an increase of winter precipitation and/or a decrease of summer evaporation. The sand layers in zone ANG-B are probably deposited by melt water.

7 b. 3. Zone ANG-C

Characterisation of the assemblage

Salix values are low, *Cyperaceae* values high. First maximum of the *Potentilla-Comarum* type. Other herb pollen percentages are low. The uppermost spectrum (21) differs from the other spectra in that it shows high values of some pollen types of group 6 *(Oxyria digyna, Thalictrum alpinum, Compositae liguliflorae)*. This spectrum also correlates with a special layer (with *Calliergon stramineum*) in the lithology; in the rest of the zone *Cyperaceae* peat prevails.

Discussion

From this zone on a long period of peat growth begins. A radiocarbon date at 185–195 cm is 5905 ± 65 years B.P. It is difficult to assess the cause: it may have been a local event (stagnation of water) as well as a regional one, i.e. a climatic change, for instance an increase of summer precipitation (rain !). A rise of winter precipitation — very high during the preceeding zone — and/or a long duration of snow cover seems unlikely: in the latter case the growing season would be too short for peat growth. Also the strong decrease of the *Lycopodium* and *Dryopteris* percentages may point to a climatic change resulting in the disappearance of the chionophilous heath vegetations in the surroundings.

In the lowermost peat layers *Eriophorum* remains are present together with the alga *Mougeotia* (spectrum 17), perhaps indicating the presence of pools or hollows. This stage may have been followed by a *Carex* (e.g. *C. rariflora*) mire vegetation (*Carex* rootlets are present in the peat). The *Potentilla-Comarum* maximum can be attributed to *Comarum palustre*.

It is difficult to interpret the assemblage of spectrum 21. A wet open *Eriophorum-Carex* vegetation with a (submersed ?) moss layer of *Calliergon stramineum* may have been present. The pollen of *Oxyria*, *Thalictrum*, *Compositae liguliflorae* a.o. may have come from the immediate surroundings.

7 b. 4. Zone ANG-D

Characterisation of the assemblage

Salix values increase, those of the *Cyperaceae* are lower than in zone ANG-C. There is a second large maximum of the *Potentilla-Comarum* type followed by a few smaller ones. The sediment is largely peat with a considerable amount of moss remains, alternating with a few sand layers. The contact with zone ANG-E has been placed where the values of the *Potentilla-Comarum* type decrease clearly and where *Salix* shows a maximum.

Discussion

The succession in the mire vegetation is essentially the same as in the preceeding zone: *Eriophorum* → *Carex spp.* (e.g. *C. rariflora*) →

Carex spp. + *Comarum palustre.* At 126 cm the peat growth is interrupted by a sand layer: here *Salix* shows a temporary maximum, perhaps indicating a local *Salix* scrub. Peat growth starts again above that level, also with *Comarum palustre.*

At spectrum 29 *Salix* shows a maximum once more, here together with a *Carex* peat layer. A *Salix* scrub on peat ("*Salicetum glaucae muscosum*", Böcher, 1933) may have been possible.

7 b. 5. Zone ANG-E

Characterisation of the assemblage

Salix reaches high values again; the values of most of the other types are quite low. In spectrum 40 *Polygonum viviparum* has a remarkable high percentage. In the lowermost part of the zone moss peat still prevails. It is followed by finely stratified sand deposits interrupted by thin peat layers.

Discussion

At the beginning of this zone *Salix* values decrease, perhaps indicating that the local *Salix* scrub is replaced by an open mire vegetation. On the sand layers deposited after this period again a *Salix* scrub develops, perhaps like in zone ANG-A alternating with *Carex bigelowii* grass heaths. However, pollen of *Chamaenerion*, considered to come from *C. angustifolium* (see discussion of zone ANG-A, page 13), is absent here, in contrast to zone ANG-A. The plant may have been present but like recently, hardly have produced flowers. The high percentage of *Polygonum viviparum* in spectrum 40 is certainly due to local occurrence; this species may indicate a relatively dry substrate.

It is striking that in the thin peat layers at 60 and 30 cm. *Salix* (although generally high) shows minimum values. These periods of peat growth might have been too short to wipe out *Salix* completely. Between 8 and 6 cm there is a dark humiferous layer, rich in woody twigs and roots, probably from *Salix glauca.*

When peat growth has started again, the *Salix* values are still very high (spectrum 42). It seems that *Salix* scrub was paludified by expansive *Sphagnum* growth caused by a change of edaphic and/or climatic conditions.

7 b. 6. Zone ANG-F

Characterisation of the assemblage

The uppermost spectrum is so different from the preceding ones, that a separate zone has been established. It shows a very low *Salix* percentage, a maximum of the *Potentilla-Comarum* type and maxima of some types within groups 6 and 9.

Discussion

The *Salix* scrub of the preceding zone is followed by an open *Sphagnum* mire with *Cyperaceae* and *Comarum palustre*, comparable with the present vegetation in which, however, *Comarum* is absent. There is probably a fair amount of pollen transported from the surroundings (*Oxyria*, *Gramineae*, etc.).

The *Ranunculus* maximum can be attributed to human influence. In the settlement at present *R. hyperboreus* occurs in eutrophicated pools (De Molenaar pers. communication). The first colonisation by the Danish and the foundation of Angmagssalik took place in 1894 A.D.: the uppermost spectrum may very well date from after that time.

This view is supported by the occurrence of a *Plantago major* pollen grain in this spectrum. This species is absent from East Greenland today but it has been imported during colonisation and has lived here for a short time (Kruuse, 1906).

The Eskimoes live in the Angmagssalik district since around 600 B.P., i.e. in an older settlement called Igtumît (= Igdlumiut), 1 km east of Angmagssalik at the entrance of Kong Oscars Havn. The present pollen diagram does not show any trace of the existence of that settlement. The influence of these people on the vegetation may have been neglible on account of their small population.

7 c. Remarks on separate pollen curves

Selaginella selaginoides, *Lycopodium selago*, *Chamaenerion*, *Compositae liguliflorae*

Pollen types, almost exclusively restricted to the basal three zones. They originate from species that have their optimum in rich heaths, willow scrubs or herb vegetations, best developed at sheltered sites at least at some distance from the coast. (Böcher, 1933, 1938; De Molenaar, 1976). *Chamaenerion angustifolium* still occurs in the coastal area today but is practically sterile (De Molenaar, pers. communication). In the Kap Farvel coastal area (South Greenland) *Angelica* and *Chamaenerion* are also restricted to the lowermost zones of pollen diagrams (Fredskild, 1973: Spongilla Sø f.e.). Fredskild also mentions the sterility of *Chamaenerion angustifolium* in recent time in this area.

These features may point to a more continental climate, at least during the period represented by zones ANG-A and ANG-B.

Juniperus, *Betula*

Some of the *Betula* pollen may originate from *B. nana*, but pollen of other *Betula* species may have been transported over long distance. The values of *Juniperus* and *Betula* are very low, indicating that these species were always rare and occurred far from the coring site, like today.

Long distance transport of arboreal pollen (group 10)

The total percentage of long distance pollen is 0.04 % (compare with 0.1 % for Jakobshavn, West Greenland (Fredskild, 1967a, 1967b).

The source area is probably mainly Labrador because of the prevailing air currents (Hastings, 1960). *Alnus viridis* also occurs in West-Greenland.

Typha latifolia

At present *T. latifolia* is absent from Greenland and Iceland and has so far not been recorded in pollen spectra of these countries. Contamination from more temperate regions is possible but not likely because the samples were prepared outside the flowering period of *Typha.*

7 d. Remarks on concentration values

Only one radiocarbon date is available: estimates of the accumulation rates of the various sediment types are therefore impossible, and interpretation of the concentration values in terms of pollen deposition in time must be necessarily inconclusive.

Three abrupt changes in the concentration values are present. One of these correlates with the sand-peat contact at the transition ANG-B/ANG-C. However, the abrupt fall of concentration values at the transition ANG-A/ANG-B is not reflected in the lithology of the core: perhaps there is a gap in the record. A similar feature is present at the transition ANG-C/ANG-D, where the aberrant spectrum 21 is found. Perhaps peat accumulation slowed down at this contact.

7 e. Climatic fluctuations

A *climatic optimum* in Greenland and surrounding arctic areas has been recorded by several authors: zone IV of the lake deposits at Godthaab, West Greenland (Iversen, 1954); Jakobshavn, West Greenland (Fredskild, 1967a, 1967b, 1972, 1973); North Greenland (Fredskild, 1969, 1972, 1973); South Greenland (Fredskild, 1972, 1973) and Iceland (Einarsson, 1963; Vasari, 1972).

In the Kap Farvel region (South Greenland) this phase starts around 7000 B.P. and reaches its maximum between 5300 and 3800 B.P. In West Greenland the maximum lies between 4000 and 3200 B.P. (Fredskild, 1967a, 1967b, 1973). In North Greenland the climatic optimum begins some time before 6000 B.P. with the retreat of the fjord glaciers; from 5900 B.P. driftwood is present in the fjords of Peary Land witnessing that the fjords must have been free of ice at least during summer (Fredskild, 1969, 1973). Radiocarbon dates of driftwood in the fjords of Northern Ellesmere Island (Canada) are between 6300 and

3000 B.P., thus also not much before 6000 B.P. (Crary, 1960; Blake, 1972).

The climatic deterioration after the "warm period" begins in the Kap Farvel region around 2200 B.P. (Fredskild, 1973); at Jakobshavn, West Greenland around 2400 B.P. (Fredskild, 1967a, 1967b). In Peary Land, North Greenland the fjords are closed by ice again shortly after 2700 B.P.; from 2100 B.P. up to now an arctic desert climate prevails here.

During the time of general deterioration of the climate some smaller oscillations occur. The most important one in South Greenland is between 1000 and 800 B.P. (Fredskild, 1973), in which the amount of pack ice in front of the coast was small (Vibe, 1967). During this "warm" oscillation the Norsemen settled in Greenland around 1000 B.P.

The various regions of Greenland show different climatic regimes in the past:

In West and South Greenland the climatic optimum is characterised by a relatively warm and dry, more or less continental climate unfavourable for peat growth. Later, during the climatic deterioration conditions became colder and moister.

In contrast, the conditions in North Greenland during the climatic optimum were more oceanic than at present, the fjords being free of ice.

According to our data, the climatic regime in East Greenland may have been relatively similar to that of North Greenland. If

1) the start of peat growth at the transition ANG-B/ANG-C at 5900 B.P. corresponds with the beginning of the climatic optimum, and

2) the sand deposits in zone ANG-E represent the colder time after that period, then the conditions during the climatic optimum must have been oceanic. The climatic fluctuations in the Angmagssalik region thus are rather similar to those in North Greenland.

These facts may be explained by fluctuations of the width of the pack and drift ice belt along the East Greenland coast: when this belt is wide, the climate will be more continental than when little or no ice is present. The drift ice is carried down by the cold East Greenland Current from the north. During the climatic optimum the amount of ice may have been small: the fjords of North Greenland were open in that period. During the climatic deterioration the width of the ice belt presumably increased, resulting in more continental conditions in the Angmagssalik region.

According to the drift ice curve of Koch (1945), showing the amount of ice north of Iceland from 850 B.P. up to the present, there was little ice during the warm oscillation of 1000–800 B.P. After that period the amount of ice increased up to ca. 100 B.P. (1860 A.D.), with an interruption between 600 and 400 B.P. From 1860 A.D. to present there is a strong decrease of the amount of ice.

During the period 1000–800 B.P. the climate in the Angmagssalik region could have been oceanic and favourable for peat growth. However, there is no evidence in the lithology: only two thin peat layers at 60 and 30 cm are present. Only the uppermost peat layer (6–0 cm) may correspond with the oceanic period after 1860 A.D.

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Plate 1. Pollen diagram.
Symbols of lithology according to Faegri & Iversen (1964).