Fossil floras of Greenland

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Introduction

Fossil plants ranging in age from Precambrian to Lower Tertiary are known from many parts of Greenland (fig. 418). The various floras indicate climatic conditions quite unlike those experienced in Greenland at the present day and this, in conjunction with the inaccessibility of the region, probably explains the particular interest expressed in them.

The first descriptions of fossil floras from Greenland were given by the Swiss palaeobotanist Oswald Heer in a series of papers published between 1868 and 1883. Heer described large Cretaceous and Tertiary floras from West Greenland which he later brought together in his classic *Flora Fossilis Groenlandica* (a part of *Flora Fossilis Arctica*).

In the later revision of the West Greenland Cretaceous–Tertiary floras by A. C. Seward the importance of the early records of angiospermous leaves was recognised with the initiation of Seward's theory concerning a supposed Arctic origin of this group of plants (Seward, 1924).

The Scoresby Sund flora from the Rhaetic–Liassic sediments of East Greenland was discovered and described by Hartz (1893). This flora has come to be considered as one of the best known Mesozoic floras due to the extensive studies of T. M. Harris between 1926 and 1937. More than 200 species are recorded by Harris indicating a period in Greenland's history much warmer than the present.

The Carboniferous and Devonian floras of North and East Greenland are smaller and less well preserved than their Mesozoic and Tertiary counterparts. They were nearly all discovered at a later date and have not yet been so fully investigated.

Precambrian fossils described from South-West and

Fig. 417. *Vallenia erlingi* Pedersen from the Precambrian metasedimentary succession at Midternæs, South-West Greenland. × 100.

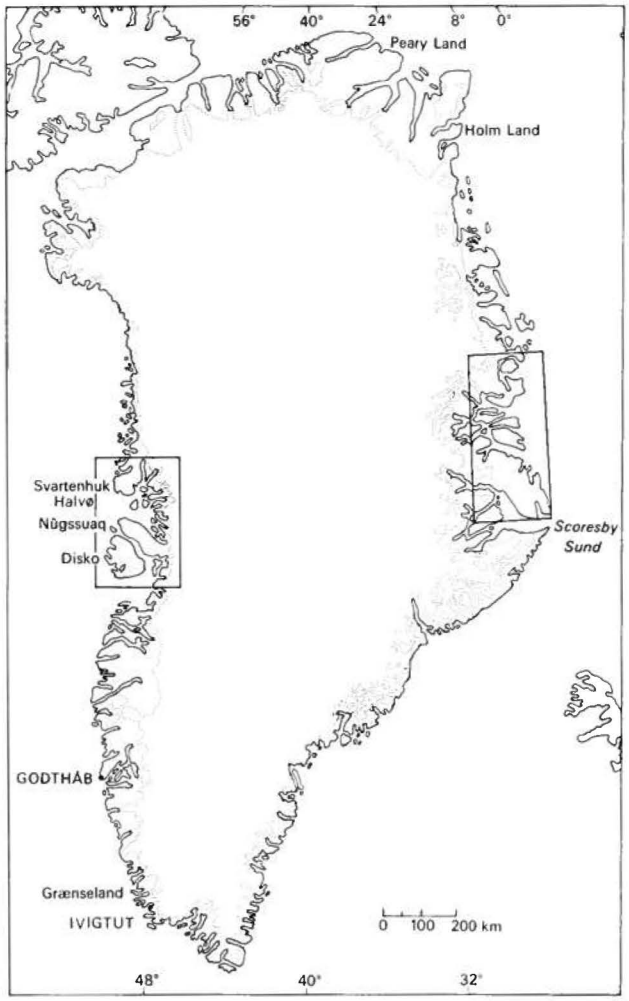


Fig. 418. Index map to the main fossil plant localities in Greenland indicating the positions of fig. 423 on the east coast, and fig. 430 on the west coast.

North-East Greenland seem to represent the oldest of Greenland's fossil floras.

Precambrian

Chemo-fossils and fossils which seem to represent primitive plants have been described from supracrustal rocks of early Proterozoic age from South-West Greenland (Bondesen *et al.*, 1967). Most of the material comes from Grænseland, north-west of Ivigtut (fig. 418), from a thick, low-grade metamorphic succession of the Ketilidian fold belt nearly 2000 m.y. old. The fossils are globular microfossils of different types (fig. 420) together with the larger *Vallenia erlingi* Pedersen (figs 417, 419). Organic compounds extracted from the fossil-bearing rocks indicate that the organisms could photosynthesise (Pedersen & Lam, 1968, 1970; Lam &

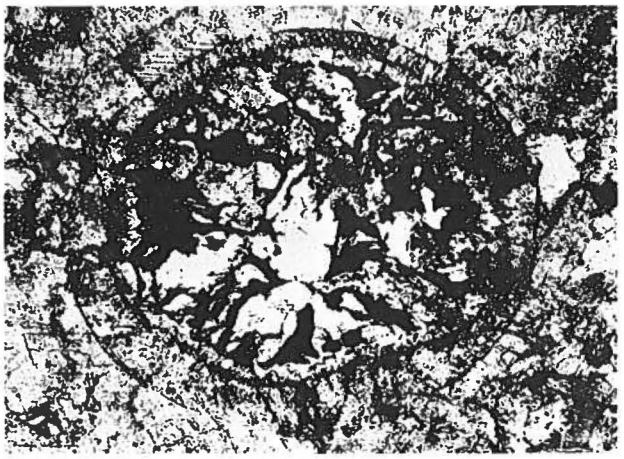


Fig. 419. *Vallenia erlingi* Pedersen from the Ketilidian succession in Grænseland, South-West Greenland. × 50.

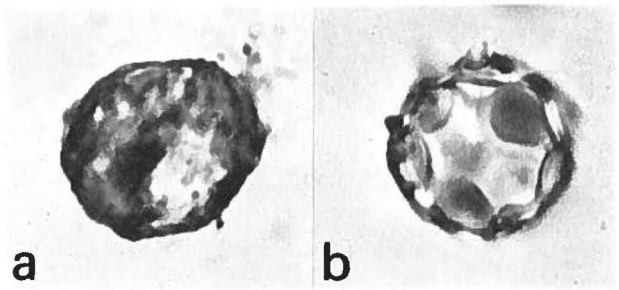
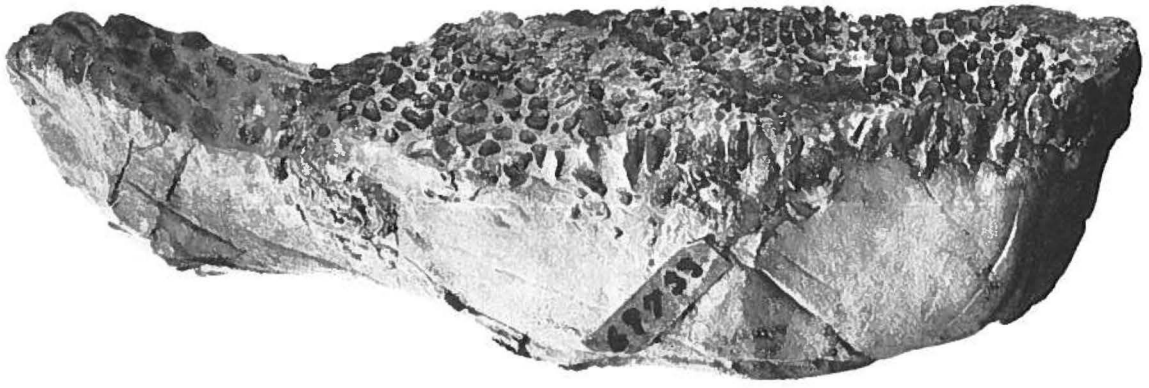


Fig. 420. Microspheres from the Ketilidian succession in Grænseland, South-West Greenland. × 1500.

Fig. 421. Stromatolites from the Ketilidian Lower Zigzagland Formation, Grænseland, South-West Greenland.



Pedersen, 1968, 1972). The largest quantities of organic compounds (Table 28) were obtained from a graphitised coal horizon about one metre thick which seems to represent a considerable accumulation of organic material. The organic compounds extracted from the graphitic material are of a more complex nature than those in other associated rock types.

Stromatolites have also been found in the Grænseland series both from the Grænsesø Formation and from near the base of the Ketilidian succession. They are tube-formed types of a size up to about 1 cm across (fig. 421).

Thread and globular formed microfossils (fig. 422) have been described by K. R. Pedersen (1970) from the youngest Precambrian (? Eocambrian or ? lowermost Cambrian) in southern Peary Land (Portfjeld Formation). Stromatolites have been reported from the same series by Troelsen (1949).

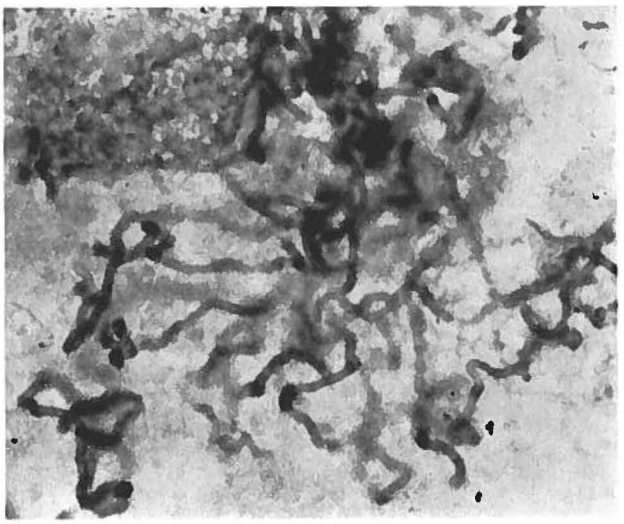


Fig. 422. Microfossils from the youngest Precambrian (Portfjeld Formation) of Peary Land, North Greenland. × 500.

Table 28. Organic compounds from Precambrian rocks of Greenland

		Ketilidian of Grænseland*							Nagssugtoqidian†
		Dolomite, grey	Graphitised coal	Graphitised coal	Graphitised coal	Dolomite with *Vallenia*	Dolomite with *Vallenia*	Dolomite, black	Graphite, Agto
Extracted material mg per kg		16	48	42		15		17	22
Carbon content ∓		n	l	l	l	s	s	n	l
alkanes	normal alkanes C_{11}–C_{20}		x	x	x	x		x	
	normal alkanes C_{10}–C_{32}						x		
	normal alkanes C_{14}–C_{18}								x
	branched alkanes (including iso- and anteisoalkanes)	x	x	x	x	x	x	x	x
	alkyl cycloalkanes	x	x	x	x	x	x	x	x
	monoterpene hydrocarbons								
aromatic hydrocarbons	alkyl benzenes	x	x	x	x		x	x	x
	alkyl naphthalenes	x	x	x	x		x	x	x
	alkyl phenanthrenes	x	x	x	x		x	x	x
monoterpenoids	monoterpenoids (oxygen containing compounds)	x	x	x	x				
fatty acids	fatty acids or methyl esters of fatty acids		x	x	x	tr	x		x
	unsaturated fatty acids		x	x	x				x

* greenschist facies
† amphibolite facies
tr trace

∓ Carbon content: n no visible grains
s small grains
l large amounts

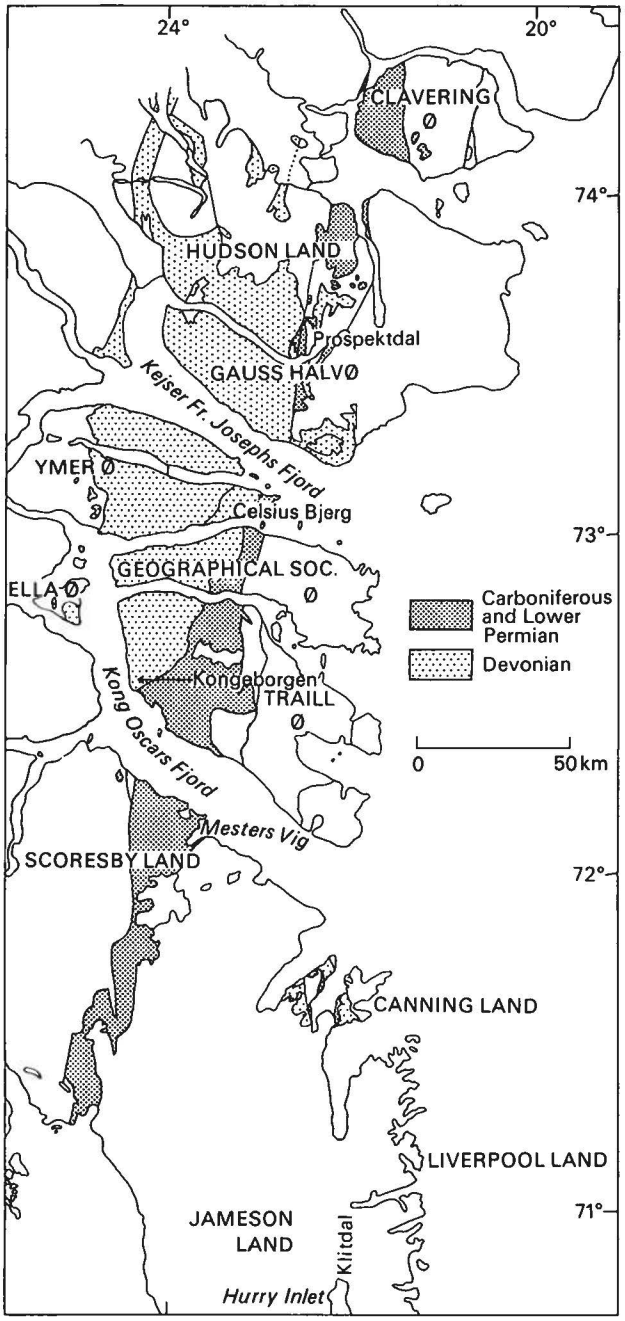


Fig. 423. Geological sketch map of central East Greenland with fossil plant localities mentioned in the text.

Devonian

Fragments of fossil plants have been reported from the continental deposits of Devonian age (fig. 423) in central East Greenland (Kulling, 1929; Säve-Söderbergh, 1937; Bütler, 1961a, b). All the finds are poorly preserved, indistinct impressions without carbonaceous material and closer determination has not been possible. Halle (1931) mentions finds of *Psilophyton* from Ymer Ø which have been found in association with fossil vertebrates referable to the youngest Devonian (*Remigolepis* series) (Table 29). It is suggested that one of the impressions may represent *Archaeopteris*. Säve-Söderbergh (1937) mentions *Thursophyton* and *Psilophyton* from Canning Land dated as Middle Devonian on vertebrate remains. Allen (1972) has described the occurrence of Middle and Upper Devonian megaspores on Ella Ø and Ymer Ø. He noted that the average size of the megaspores from each of the two horizons is comparable to that of material described from equivalent horizons outside Greenland, and that there is a gradual increase in the size of the megaspores during the Devonian and a development against seed megaspores.

Carboniferous

Carboniferous plant fossils of slightly differing age have been found at many localities in East Greenland between Jameson Land and Holm Land (about 81° N), a distance of 1000 km (figs 418, 423).

The East Greenland Carboniferous floras occur in a nearly 6000 m thick succession consisting predominantly of coarse, clastic, continental sediments with numerous conglomerate horizons and thin shale layers. In the upper part of the succession limestone, calcareous shale and fine-grained sandstone are interbedded (Witzig, 1951). The preservation of the fossil plants is rather poor owing to the coarseness of the sediments and there is evidence of strong abrasion during deposition. Major accumulations of plant material are not generally known and coal seams appear to be only present in Holm Land.

The Carboniferous floras of East Greenland are poor. Sphenophytes (horsetails) dominate, with several species of *Asterocalamites* and *Calamites*. Lycophytes (club mosses) are also common and include a few species of *Lepidodendron, Lepidophyllum* and *Stigmaria*. Leaf species such as *Sphenopteris, Rhodea* and *Telangium,* representing seed ferns and ferns, are not common and no reproductive structures have been described. Gymnosperms are represented by leaves of *Cordaites* and *Lebachia* from the upper part of the series.

The oldest and most northerly Carboniferous flora is from Holm Land (fig. 450) from where Nathorst (1911) described:

Lepidodendron spetsbergense Nathorst
Lepidophyllum cf. *L. lanceolatum* Lindley & Hutton
Stigmaria ficoides Brongniart
Asterocalamites scrobiculatus (Schlotheim) Zeiller
Sphenophyllum tenerrimum Ettingshausen var. *elongatum* White
Telangium (Calymmatotheca) bifidum (Lindley & Hutton) Benson

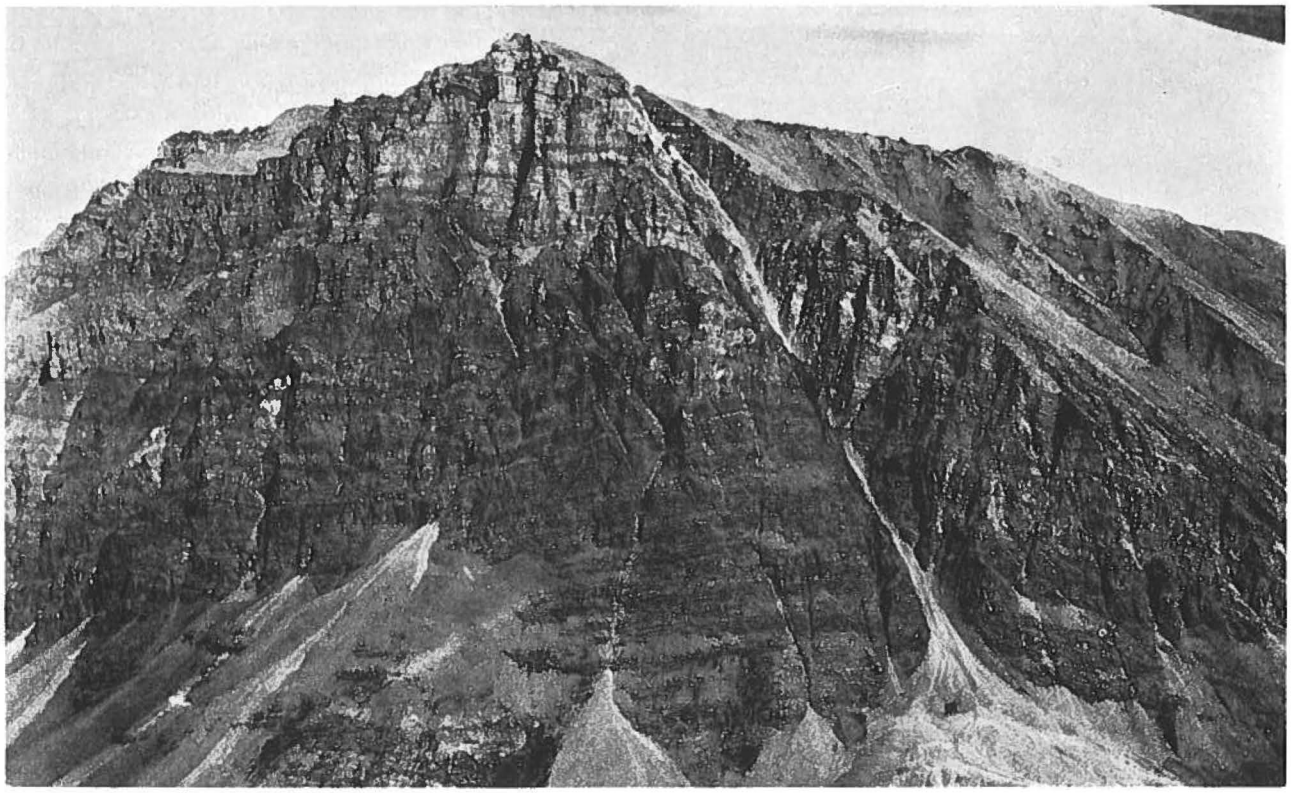


Fig. 424. Carboniferous limnic sediments south of Kongeborgen, Traill Ø, East Greenland. Photo: Bente Soltau Bang.

A Dinantian age was assigned to the deposits on the basis of the first three species. The flora differs from the Dinantian flora of Spitsbergen in that it contains *Asterocalamites* while *Sublepidodendron,* found in Spitsbergen, is not present. The limnic plant-bearing layers consist of alternating shale and sandstone. Several coal seams up to 1 m thick are reported from the series which is overlain by marine Upper Carboniferous and Lower Permian deposits (Nielsen, 1941).

A slightly younger flora has been found in the lower part of the Carboniferous in Prospektdal on Hudson Land from where Halle (1931, 1953) described:

Lepidophyllum sp.
Stigmaria ficoides Brongniart
Asterocalamites sp.
Telangium bifidum (Lindley & Hutton) Benson
Adiantites cf. *A. bellidulus* Heer
Sphenopteris fragilis Schlotheim
Diplotmema (Sphenopteris) adiantoides Schlotheim
Rhodea stachia Stur

On the basis of a smaller species list Halle (1931) referred the flora to the Dinantian, but after examination of later collections, when the last three species were added, Halle (1953) changed the age to Lower Namurian (Namurian A?). Examination of the spore content also suggests a Namurian age (Bütler, 1961 b).

From Kongeborgen on the south-west coast of Traill Ø (fig. 424) fossil plants have been described by Halle (1931) and Witzig (1951). The following species were obtained from different levels in a 1100 m high profile (Witzig, 1951):

Lepidodendron cf. *L. obovatum* Zeiller
Lepidodendron cf. *L. ophiurus* Brongniart
Stigmaria rugulosa Gothan
Calamites suckowii Brongniart (fig. 425b)
Calamites haueri Stur
Calamites undulatus Sternberg
Alethopteris lonchitica Brongniart

Lepidodendron is common in the lower horizons often as *Knorria* while *Calamites* is present throughout. Witzig (1951) states that the flora from Kongeborgen is essentially of Namurian character, but in the higher part of the series types are found which have their main development in the Westphalian.

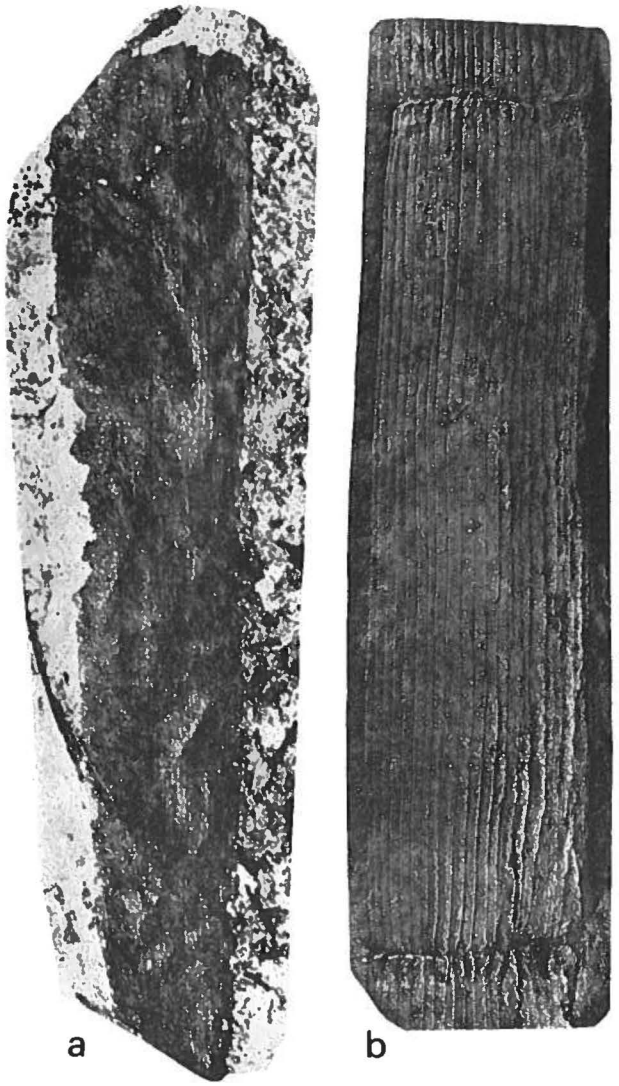


Fig. 425. a. *Cordaites* sp., Traill Ø, East Greenland. × 1/3. b. *Calamites suckowii* Brongniart, Kongeborgen, East Greenland × 3/4. From Witzig (1951).

From the northern part of Scoresby Land, in the area around Mesters Vig, an Upper Carboniferous to Lower Permian flora is described by Witzig (1951, 1954). The following species are recorded from the Blyklippen Member (*c.* 1000 m thick), from the lower part of the Mesters Vig Formation:

Lepidodendron cf. *L. aculeatum* Sternberg (fig. 426)
Calamites cf. *C. undulatus* Sternberg
Calamites cf. *C. cisti* Brongniart
Calamites carinatus Sternberg

Witzig considers this flora to be mainly Westphalian.

The Blyklippen Member is overlain by the Profilbjerg Member (*Lebachia* series of Witzig) about 1300 m thick (fig. 453). From this series Halle (1953) and Witzig (1954) identified:

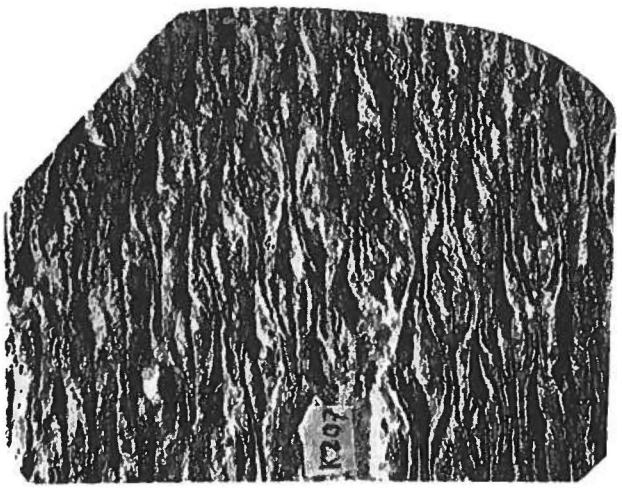
Calamites gigas Brongniart
Calamites cf. *C. undulatus* Sternberg
Cordaites sp. (fig. 425a)
Lebachia (Walchia) parvifolia Florin

The first and the two last of these species range from the uppermost Carboniferous to Lower Permian and, as exclusively Permian species are absent, the series is referred to the Permo-Carboniferous (Halle, 1953; Witzig, 1951). Witzig (1954) remarks that *Lepidodendron* seems to be absent from the uppermost flora.

Lower Permian spores and pollen have been identified from the upper part of the Profilbjerg Member in southern Scoresby Land (Kempter, 1961).

Examination of the Carboniferous floras of the different areas in East Greenland shows that the oldest Carboniferous flora is from Holm Land in North-East Greenland while younger Carboniferous floras are found to the south. Throughout the Carboniferous there appears to have been a steady development of the flora and no abrupt 'florensprung' are demonstrated. The floras are of limited size, fragmentary and comparatively badly preserved and it is not possible to obtain reliable climatic information from the fossil plants. Stems with diameters up to about 30 cm (A. Rosenkrantz, personal communication) and pieces about 1 m long are found. The piece of wood figured by Kempter (1961, p. 53) seems to show annual rings, though these have not been specifically reported. Kempter (1961, p. 70) states that a warm humid climate with dry seasons is the most probable, to judge from the plant material and sedimentary conditions.

Fig. 426. *Lepidodendron* sp., Scoresby Land, East Greenland. From Witzig (1951). × 1.



Rhaetic–Liassic

The plant-bearing sedimentary series on the west side of Hurry Inlet, Scoresby Sund in East Greenland, was first mentioned by William Scoresby junior, and an account of the presence of coal was referred to the Carboniferous by Jameson (1823). Later it was thought that the coal was of Tertiary age (Heer, 1868) but this was corrected when Rhaetic fossil plants were found in the sediments by N. Hartz (1896).

Plant-bearing strata of Rhaetic–Liassic age are known from Jameson Land and Traill Ø. The best localities occur along Hurry Inlet and Klitdal (fig. 423, 427) and it was from here that the well-known 'Scoresby Sund flora' described by Harris (1926, 1931, 1932a, b, 1935, 1937, 1946) was collected. The plant-bearing beds are found in the limnic Kap Stewart Formation, which is about 150 m thick (see Birkelund & Perch-Nielsen, this volume). The lower part of the formation (about 85 m) consists of current-bedded sandstones and from here only a single plant bed is known (Surlyk *et al.*, 1971). The upper part of the formation (about 90 m) differs from the lower part in containing more fine-grained sediments and many beds yield fossil plants in great abundance. From these, Harris (op. cit.) has described almost 200 species of fossil plants. Preservation is good and the cuticle is often well-preserved. Two distinct floral zones are recognised, the *Lepidopteris* and *Thaumatopteris* zones, with only a few species common to both. Each flora consists of about 100 species in which gymnosperms (Cycadophytes, Ginkgophytes and conifers) are dominant, while ferns are also common.

The entire 'Scoresby Sund flora' consists, according to Harris (op. cit.), of the following important genera (figs. 428, 429).

Bryophytes. Finds of four species of the liverwort genus *Hepaticites* are remarkable because normally such fragile plants are not preserved.

Sphenophytes. The horsetails are represented by the genera *Equisetites* (4 species), *Neocalamites* and *Lobatannularia.* In certain layers these are present in large numbers and reach sizes of one to two metres.

Lycophytes. Club mosses do not seem to have grown on the site of deposition as they are represented mainly by isolated megaspores (14 species including *Lycostrobus scotti* and species of *'Triletes')* and small stem fragments.

Filicophytes. The ferns are often represented by large fossil leaves of many genera and species. The family Osmundaceae is represented by numerous

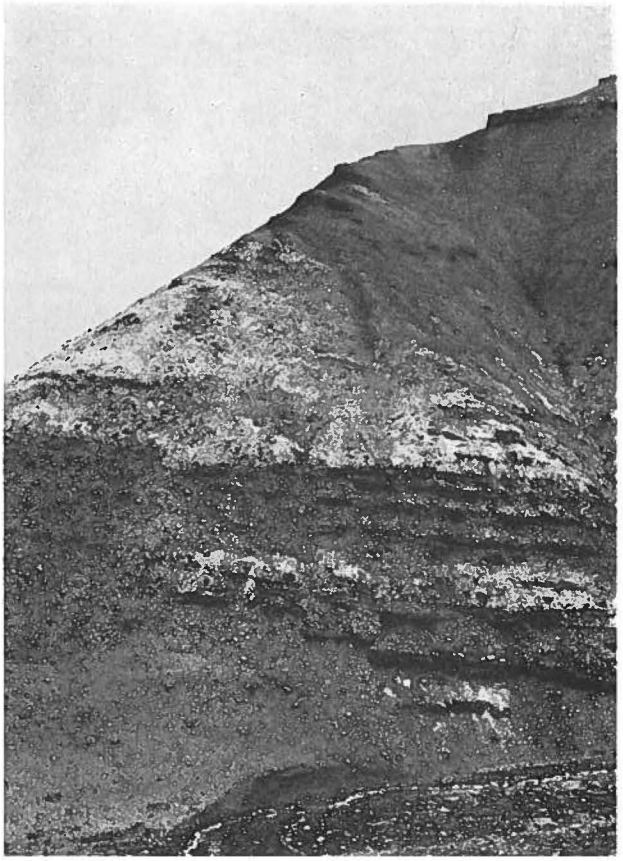


Fig. 427. Rhaetic–Liassic sediments at the plant locality Astartekløft, Jameson Land, East Greenland.

leaves of the genera *Todites* (5 species), *Cladophlebis* (3 species) and *Osmundopsis.* The Marattiaceae (*Rhinipteris* and *Marattiopsis*) and the Gleicheniaceae (*Gleichenites*) are poorly represented. The Matoniaceae (*Phlebopteris* 3 species) and the Dipteridaceae (*Dictyophyllum* 3 species, *Clathropteris, Thaumatopteris* 2 species and *Hausmannia*) are very common and stratigraphically very important, with the exception of *Hausmannia.*

Pteridosperms. Seed ferns are richly represented. Leaves of *Lepidopteris* are especially common, while the reproductive organs referred to it by Harris, *Peltaspermum* and *Antevsia,* are rare. *Ptilozamites nilssoni* Nathorst is common, and it is to this species that Harris considered the microsporangiate organ *Hydropterangium marsilioides* to belong. The characteristic pteridosperm genus *Stenopteris* (2 species) is also common. The seed genus *Caytonia,* the related microsporangiate organ *Caytonanthus* (3 species) and the leaves *Sagenopteris* (3 species) are found only at a few localities, but the discoveries have been important in the interpretation of these organs and recognition of their common origin.

Cycadophytes. Cycadophytes are present with many representatives of the Bennettitales and Cycadales.

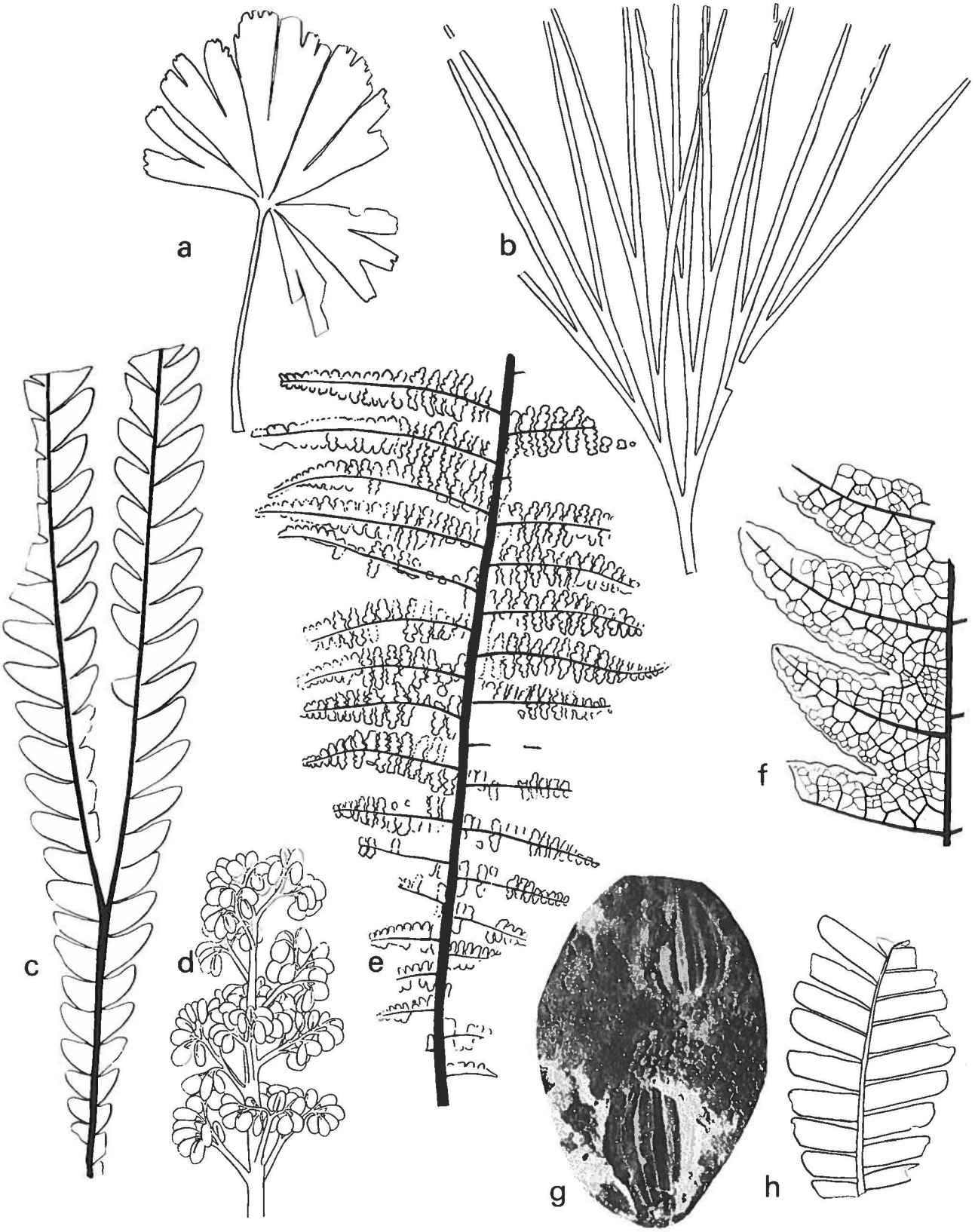


Fig. 428. Representatives of the 'Scoresby Sund flora' of Rhaetic–Liassic age from Jameson Land, East Greenland. a. *Ginkgoites acosmia* Harris; b. *Sphenobaiera spectabilis* (Nathorst) Florin; c. *Ptilozamites nilssoni* Nathorst and d. its microsporangiate organ *Hydropterangium marsilioides* Halle (× 3/2); *Todites princeps* (Presl) Gothan; f. *Dictyophyllum nilssoni* (Brongniart) Goeppert; g. the reproductive organ *Vardekloeftia sulcata* Harris (× 3) referred to h. *Pterophyllum kochi* Harris. All × 4/5 except where stated otherwise. From Harris (1926, 1931, 1932a, b, 1935).

Bennettitalean leaves are the most common fossils in some beds. The genera *Anomozamites* (5 species), *Pterophyllum* (10 species) and *Nilssoniopteris* (3 species) are especially abundant. Reproductive organs of the Bennettitales are infrequent, but well-preserved specimens of *Wielandiella, Bennettistemon* (3 species), *Bennetticarpus* (3 species) and *Vardekloeftia* (2 species) are known.

Harris considered *Anomozamites minor* Nathorst to be one of the most useful zone fossils of the limnic Rhaetic. Branched stems with leaves of this species and the reproductive organ *Wielandiella angustifolia* Nathorst are found in association. *Pterophyllum schenki* Zeiller probably belongs to the reproductive organ *Bennetticarpus exiguus* Harris, while *Bennettistemon bursigerum* Harris is perhaps the related microsporophyll. *Pterophyllum kochi* Harris has been referred to the same plant as the reproductive organ *Vardekloeftia sulcata* Harris.

Cycadales are represented with leaves of the genera *Ctenis* (3 species), *Pseudoctenis* (2 species), *Doratophyllum, Taeniopteris* and *Nilssonia* (6 species). Harris refers the reproductive organ *Beania kochi* Harris to the same plant as *Nilssonia incisocerrata* Harris.

Ginkgophytes. Leaves of ginkgophytes are numerous in many plant beds. Representatives include the genera *Ginkgoites* (5 species), *Sphenobaiera* (4 species) and *Baiera,* besides *Czekanowskia* (2 species) and *Hartzia* with very narrow leaf lobes. The male reproductive structure *Leptostrobus longus* Harris is referred to *Czekanowskia hartzi* Harris and the fruit *Staphidiophora secunda* Harris is referred to *Hartzia tenuis* Harris.

Coniferophytes. Conifers are represented partly by finds of leaves and partly by reproductive organs. Types are found with single veined leaves, *Stachyotaxus* (2 species), *Elatocladus* and *Storgaardia* (17 species), or broad leaves with several veins, *Podozamites* (7 species). The latter is very commonly found. Reproductive organs, probably belonging to *Podozamites,* are *Cycadocarpidium* (2 species) and *Swedenborgia* (3 species).

Genera which could not originally be classified systematically, include *Scoresbya,* which is now referred to the ferns, and *Furcula,* with dicotyledon cuticle type and venation but with a leaf form which is pteridosperm-like.

The lower *Lepidopteris* zone, occurs in about 30 m of strata. The flora is uniform throughout and the following species are common and restricted to this zone:

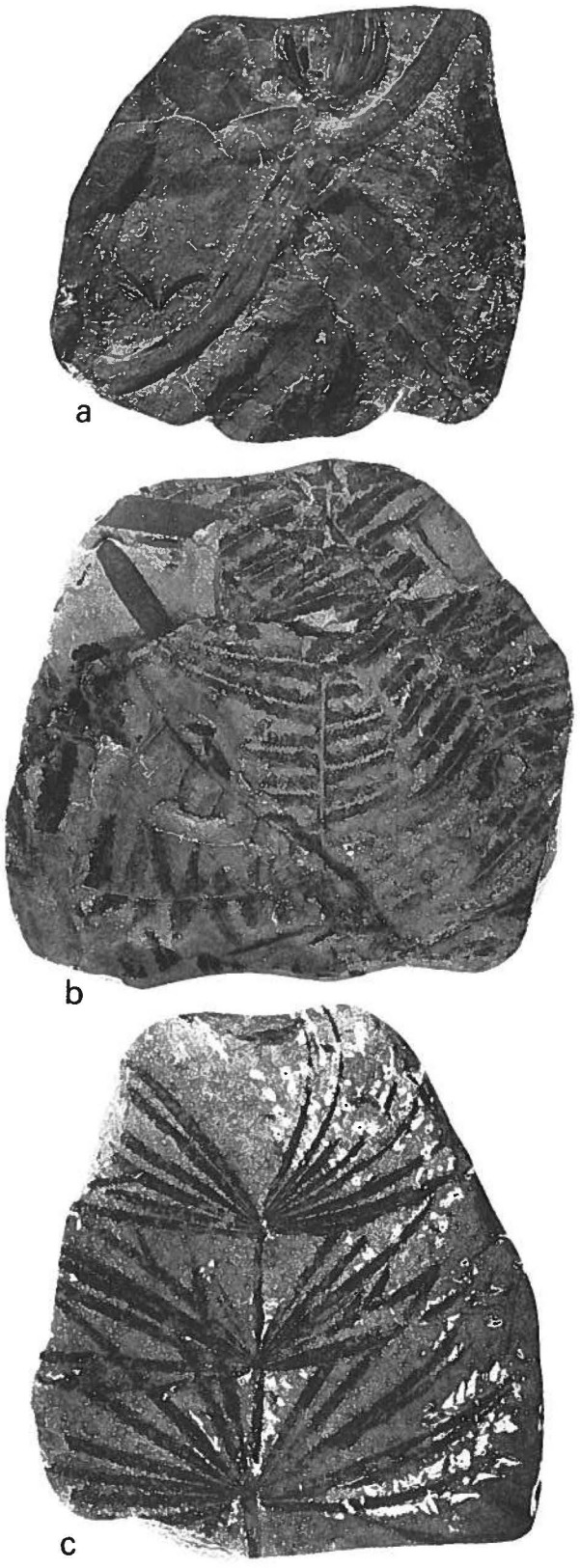


Fig. 429. Representatives of the 'Scoresby Sund flora' continued. a. *Wielandiella angustifolia* Nathorst with leaves of *Anomozamites minor* Nathorst; b. *Thaumatopteris schenki* Nathorst; c. *Lobatannularia carcinoides* (Harris). All × 3/5. From Harris (1931, 1932b).

Neocalamites hoerensis (Schimper) Halle
Equisetites grosphodon Harris
Dictyophyllum exile (Brauns) Nathorst
Lepidopteris ottonis (Goeppert) Schimper
Ptilozamites nilssoni Nathorst
Anomozamites minor Nathorst
Pterophyllum ptilum Harris
Pterophyllum pinnattifidum Harris
Vardekloeftia sulcata Harris
Baiera minuta Nathorst
Stachyotaxus elegans Nathorst

About ten additional species continue up into the upper, *Thaumatopteris,* zone. The most important of these are:

Equisetites muensteri Sternberg
Equisetites laevis Halle
Clathropteris meniscoides Brongniart
Pseudoctenis spectabilis Harris

The transition region between the two zones is about 5 m thick and lacks characteristic species (Harris, 1937). Besides the few common species the last representatives of the *Lepidopteris* zone and the first representatives of the *Thaumatopteris* zone are found.

The *Thaumatopteris* zone is represented by about 60 m of strata. The flora is not as uniform as in the zone below, since some new species appear in the upper layers. In addition to the few species common with the lower zone, the *Thaumatopteris* zone has the following common forms:

Equisetites sarrani (Zeiller) Harris
Todites princeps (Presl) Gothan
Dictyophyllum nilssoni (Brongniart) Goeppert
Thaumatopteris brauniana Popp
Thaumatopteris schenki Nathorst
Phlebopteris muensteri (Schenk) Hirmer & Hoerhammer
Sagenopteris nilssoniana (Brongniart) Ward
Stenopteris dinosaurensis Harris
Pterophyllum subaequale Hartz
Ginkgoites hermelini (Hartz) Harris
Sphenobaiera spectabilis (Nathorst) Florin
Czekanowskia nathorsti Harris

Genera which are only found in the upper part of the *Thaumatopteris* zone are:

Lobatannularia carcinoides Harris
Gleichenites nitida Harris
Ctenis stewartiana Harris
Czekanowskia hartzi Harris

The plant beds are found at all levels in the upper part of the Kap Stewart Formation. The greater part of the formation consists of grey and yellow sandstone and arkose with the finer grained sediments of the plant beds forming only a small part of the whole succession. The number of plant beds varies considerably from section to section (Harris, 1937). Many of the beds consist of several horizons with different floras alternating with layers without fossils. Harris (1937) distinguishes two types of plant beds. One type consists of fine-grained, well-stratified sediments with large, well-preserved leaves and often with a few species represented in abundance. This type may be interpreted as deposited in quieter water with rich representation of the vegetation which grew nearby (autochthonous plant beds). The other type consists of coarser sediments and contains fragments of plants (leaves and wood) which are often very worn and of small size. Many species are represented in these layers. This type of plant bed represents stream deposition where the plant material has been brought together from a large area (allochthonous plant beds). Both types vary strongly in horizontal extent from a few to several hundred metres. The beds are often lens-shaped and up to 1 m thick. Occasionally, root horizons and upright stems (often horsetails) are found associated with the autochthonous plant beds.

Coal seams of varying thickness occur in the Kap Stewart Formation in connection with the plant beds. The seams are often only a few centimetres thick, but there are beds which locally may be up to about 50 cm thick. Impressions of stems more than half a metre in diameter are present. Organo-chemical examination of one of the coal seams has shown the presence of compounds which characterise conifers and fungi. The latter are supposed to have taken part in the decomposition of plants (K. R. Pedersen & Lam, 1975).

The plants from the Kap Stewart Formation generally show that there have been good conditions for growth and a rather warm climate. The horsetails reach a considerable size and the ferns have large and often rather thin leaves. The leaves of the gymnospermous plants range from types with a thick cuticle to forms with a thin cuticle, but mainly the latter (Harris, 1937). Moderate annual growth rings (1–3 mm across) are present in the gymnospermous tree stems from which it is concluded that a favourable growing season existed with some difference between the seasons.

Harris (1937) refers the *Lepidopteris* flora to the Rhaetic and the *Thaumatopteris* flora to the basal Liassic on the basis of agreement with fossil floras in southern Sweden and southern Germany.

Cretaceous–Tertiary

Fossil plants of Cretaceous and Lower Tertiary age have long been known from many localities on Nûgssuaq, Disko and Svartenhuk Halvø in western Greenland (fig. 430). These fossils were first described by Oswald Heer in a series of classic papers between 1868 and 1883 (Heer, 1868, 1874a, b, 1880, 1882 and 1883a, b) which aroused considerable interest in the floras because of their northern derivation (69° to 72°N) and composition. Heer divided the western Greenland floras into three Cretaceous floras (Kome, Atane and Pautut) and a Tertiary flora (of which the Upper Atanikerdluk, Ifsorisok and Hareøen floras are the most important). Nathorst (1890, 1907) later described leaves and fruits of *Artocarpus* (breadfruit) and *Pseudocyas,* referred to the Bennettitales by means of cuticular analysis. The floras were later re-examined by A. C. Seward (Seward, 1924, 1926; Seward & Conway, 1935, 1939) who subsequently propounded the theory that the angiosperms had developed in these northern areas and from here had migrated southwards. The Tertiary floras have since been described by B. E. Koch (Koch, 1959, 1963, 1964, 1972a, b), but the older floras have not been re-investigated.

The floras occur in a succession of about 1500 m of mainly continental shale and sandstone. There are marine intercalations associated with the younger floras and these allow a more precise determination of age.

Fig. 430. Geological sketch map of central West Greenland with fossil plant localities mentioned in the text.

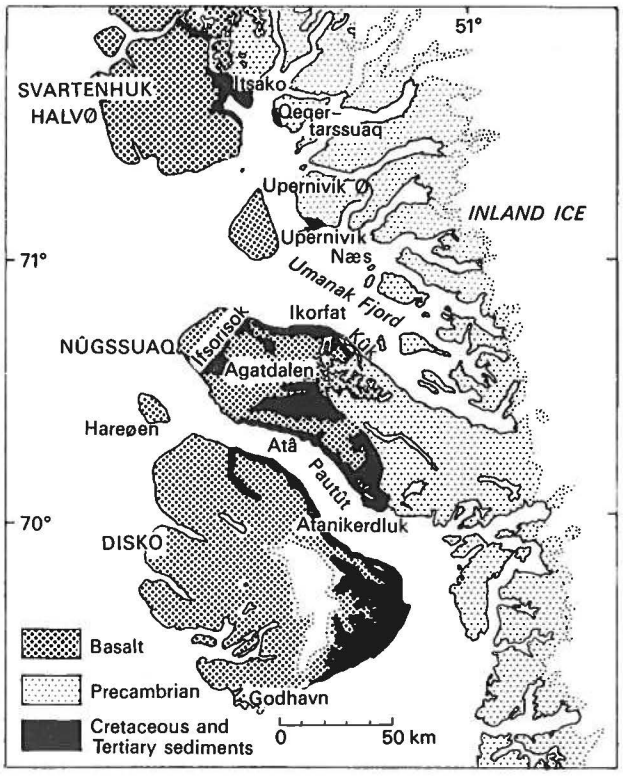


Fig. 431. Profile in the Kome Formation at Ikorfat, north coast of Nûgssuaq, West Greenland.

Cretaceous floras

Kome flora

This flora, which is the oldest from western Greenland, occurs in a lithologically variable sedimentary series (Kome Formation) of dark shale and sandstone with coal seams up to 1 m thick. Localities yielding the Kome flora are known on the north coast of Nûgssuaq from Kûk to Ikorfat (fig. 431) and from Itsako on Svartenhuk Halvø (see Henderson *et al.*, this volume).

The Kome flora consists of ferns, Cycadophytes, Ginkgophytes and conifers. A few discoveries of angiospermous leaves have also been reported.

Heer's description of the Kome flora (op. cit.) includes 88 species, whereas Seward (1926), after revision and new collections, described 28 species from localities which are now considered as certain Kome localities. Preservation is excellent and Seward was able to examine the structure of the cuticle in some of the material.

The following genera are represented:

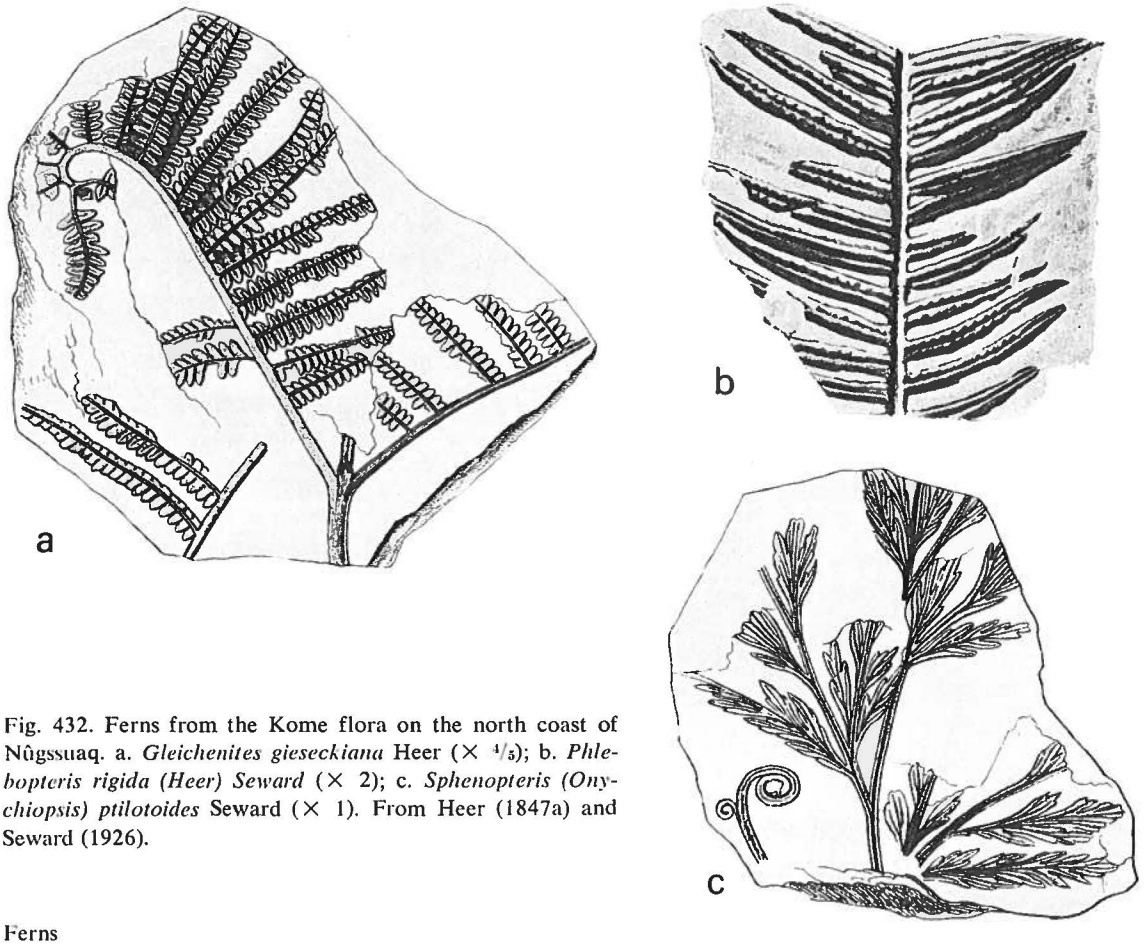


Fig. 432. Ferns from the Kome flora on the north coast of Nûgssuaq. a. *Gleichenites gieseckiana* Heer (× 4/5); b. *Phlebopteris rigida (Heer) Seward* (× 2); c. *Sphenopteris (Onychiopsis) ptilotoides* Seward (× 1). From Heer (1847a) and Seward (1926).

Ferns

Gleichenites (4 species)
Laccopteris (= *Phlebopteris*)
Hausmannia
Sphenopteris (*Onychiopsis*) (3 species)
Cladophlebis (2 species)

Cycadophytes

Pterophyllum
Ptilophyllum
Otozamites
Taeniopteris

Ginkgophytes

Ginkgoites
Baiera

Conifers

Sciadopitytes (3 species)
Pagiophyllum
Elatocladus (2 species)
Dammarites
Cyparissidium
Pityophyllum

The records of angiosperms by Heer and Seward are either doubtful, owing to the preservation, or are based upon material from localities which do not belong to the Kome Formation (Koch, 1964). Undoubted angiospermous pollen has not been found in the Kome sediments, but a new discovery of angiospermous leaves has been reported (Pedersen, 1968).

Fern leaves are the dominant element of the Kome flora, especially *Gleichenites* (fig. 432). Cycadophyte and Ginkgophyte leaves may also be well represented while mass occurrences of *Sciadopitytes* leaves are found at certain horizons which locally form thin coal seams.

The age of the Kome flora, according to Heer (op. cit.), is Lower Cretaceous, and Seward (1926) emphasises the considerable similarity between the Wealden flora and the fossil flora from localities considered to belong to the Kome Formation. A Lower Cretaceous age is also suggested from palynological examination (Pedersen, 1968).

Atane and Pautut floras

The Atane flora is known from the Atane Formation, a 1000–1500 m thick series consisting of sandstone and shale with locally numerous coal seams up to about 1 m thick. Plant-bearing horizons occur at many localities on the southern coast of Nûgssuaq, the east and south-east coasts of Disko and a few localities in Umanak Fjord (fig. 430).

The Pautut flora occurs in strata situated along the central part of the southern coast of Nûgssuaq (fig.

433). These strata are similar in lithology to the Atane Formation, consisting of alternating shale, sandstone and coal seams with marine intercalations (Koch, 1964), but have previously been considered to form a distinct formation, the Pautut Formation. However, according to Koch (1964), it is probable that the Pautut Formation forms a part of the same series as the Atane Formation but with marine intercalations.

Heer (op. cit.) describes 117 and 118 species from the Atane and Pautut floras respectively of which only 25 are common to both. Seward (1926) and Seward & Conway (1935) treated the two floras as an entity and reduced the total number of species to 65. After a preliminary examination Koch (1964) concluded that between two-thirds and one-half of the species of the Pautut flora are also found in the Atane flora and that there is a group of endemic species in the Pautut flora. The differences between the two floras could be a result of sorting in connection with the depositional environment.

The Atane and Pautut floras are dominated by angiosperms, especially in terms of the number of specimens. In addition, there are many ferns and conifers, with a few Cycadophytes and Ginkgophytes. The most important genera, represented in the two floras (Seward, 1926; Seward & Conway, 1935) are:

Sphenophytes
- *Equisetites*

Ferns
- *Gleichenites* (3 species)
- *Laccopteris* (= *Phlebopteris*)
- *Hausmannia*
- *Sphenopteris* (*Onychiopsis*) (3 species)
- *Cladophlebis* (2 species)

Cycadophytes (particularly the Bennettitales)
- *Pseudocycas* (3 species)
- *Pterophyllum*
- *Williamsonia*
- *Pseudoctenis*

Ginkgophytes
- *Ginkgoites* (2 species)
- *Baiera*

Conifers
- *Dammarites*
- *Pagiophyllum*
- *Cupressionocladus*
- *Moriconia*
- *Sequoiites*
- *Elatocladus* (4 species)
- *Sciadopitytes*
- *Cyparissidium*

Angiosperms
- *Macclintockia* (2 species)
- *Quercus*

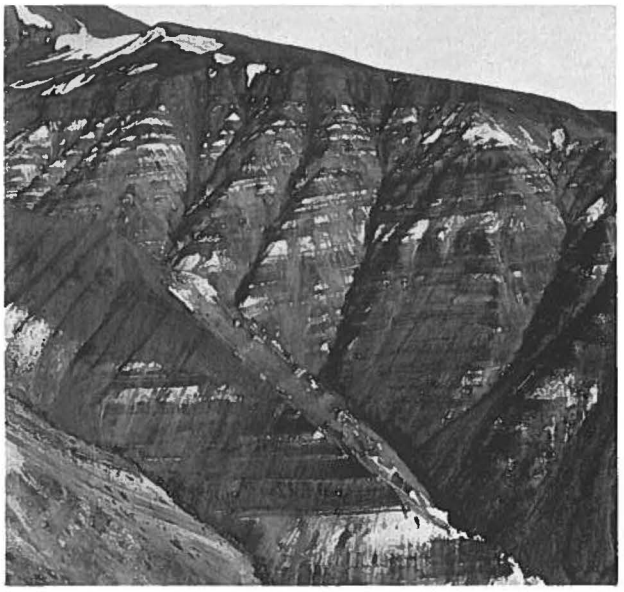


Fig. 433. Profile in the Pautut Formation at Pautût, Nûgssuaq, West Greenland.

- *Artocarpus*
- *Magnoliaephyllum* (3 species)
- *Menispermites* (2 species)
- *Laurophyllum*
- *Myrtophyllum*
- *Cinnamomoides* (2 species)
- *Platanus* (2 species)
- *Platanophyllum* (4 species)
- *Dalbergites* (2 species)
- *Bauchinites*
- *Sapindopsis*
- *Dictylophyllum* (2 species)

The composition of the flora shows a mixture of older Lower Cretaceous species together with well differentiated angiosperm species representative of many families. The most common elements in the Atane and Pautut floras are angiospermous leaves. Certain genera may dominate some horizons, for example *Platanus*-type leaves (fig. 434) are very common in parts of the series, especially in the Pautût area.

Many of the fossil plants from the Atane Formation are well preserved and Seward (1926) has examined cuticles from some of the species. However, much of the fossil material consists of impressions without carbonaceous matter, especially the fossils which originate from the yellow-red burnt shales. The Pautut flora is exclusively preserved as impressions in burnt shales.

The age of the Atane and Pautut floras has always been considered as Upper Cretaceous as there is good agreement between these floras and Upper Cretaceous floras from North America and Europe. Heer mentioned an age between Gault and Senonian with a Cenomanian age being most likely for the

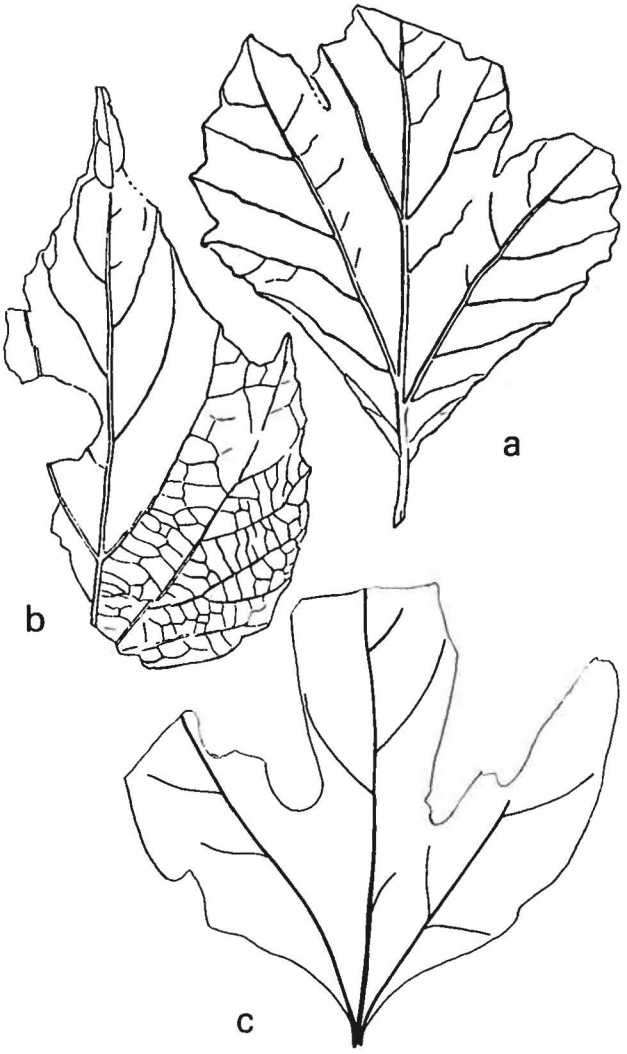


Fig. 434. a. *Platanus latiloba* Newberry; b. *Platanus newberryana* Heer; and c. *Platanophyllum insigne* (Heer) Seward from the Atane and Pautut floras of Nûgssuaq, West Greenland. All × 1. From Seward (1926) and Seward & Conway (1935).

Atane flora, and an Upper Senonian age for the Pautut flora.

Later studies in the area have indicated that the Atane flora is not much older than the Lower Senonian (Rosenkrantz, 1970). The age of the Pautut flora is dated to the transition between the Santonian and the Campanian by means of marine fossils in the same formation.

A flora has been found at Agatdalen in the central part of Nûgssuaq in marine strata of the same age as at Pautût, but it is yet undescribed (Koch, 1964).

Local floras from some localities in the Umanak Fjord area (e. g. Upernivik Næs), which are here included in the Atane flora, possibly represent transitions between the Kome and Atane floras (Koch, 1964; Rosenkrantz, 1970).

Tertiary floras

Tertiary floras from western Greenland may be collected in the same areas as the Cretaceous floras and have sometimes been confused with these in old collections (Koch, 1964).

The Tertiary floras are obtained partly from clay-ironstone horizons in a sandstone series and partly from shales which belong to the Upper Atanikerdluk and Agatdal Formations. These formations unconformably overlie Cretaceous sediments and are themselves overlain by a thick series of plateau basalt (fig. 435).

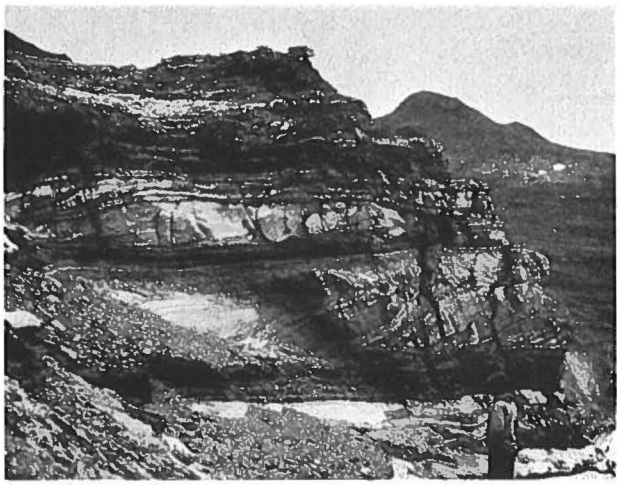
Fossil plants have also been found in the interbasaltic sediments of the Ifsorisok Formation (Koch, 1964).

The Tertiary floras consist principally of angiosperm leaves, together with a few conifers, whereas ferns and Ginkgophytes are less important.

Heer (op. cit.) described 275 species from Tertiary horizons, with Atanikerdluk (Upper Atanikerdluk A and B floras) as the most important locality. At some localities material from Tertiary strata was described by Seward & Conway (1939) together with Cretaceous fossil plants. A recent revision of material from some of the localities has been made in connection with the investigation of the Tertiary flora from marine horizons (Agatdal Formation, Sonja Member) in central Nûgssuaq (Koch, 1959, 1964, 1972a, b). From this new flora (the Agatdal flora) Koch (1964, 1972a, b) describes the following species of leaves and two species of fruits:

Cladophlebis groenlandica (Heer) Bell
Hemitelites torelli Heer
Ginkgo adiantoides (Unger) Shaparenko
Metasequoia occidentalis (Newberry) Chaney
? Populus sp.

Fig. 435. Profile in Upper Atanikerdluk Formation, Atanikerdluk, Nûgssuaq, West Greenland.



Dryophyllum cf. *D. subfalcatum* Lesquereux
Quercophyllum groenlandicus (Heer) Koch
Q. furcinervis americana (Rossmässler) Knowlton
Cupuliferites angmartusuticus Koch
Juglandiphyllum denticulatum (Heer) Koch
? Liriodendron sp.
Cercidiphyllum arcticum (Heer) Brown
Corylopsiphyllum groenlandicum Koch
Platanus cf. *P. aceroides* Goeppert
Lauraceaephyllum stenolobatus Koch
? Vitis olriki Heer
? Amicia
? Rhododendron sp.
Dicotylophyllum bellum (Heer) Seward & Conway
D. eridani (Unger) Koch
D. scottii (Heer) Koch
D. steenstrupianum (Heer) Seward & Conway
Macclintockia kanei (Heer) Seward & Conway
M. lyalli Heer
M. dentata Heer
Nordenskiöldia borealis Heer
Credneria spectabilis (Heer) Koch
Rosenkrantzia picrodendroides Koch (fruit)
Coryphoides poulseni Koch (fruit)

Fig. 436. *Rosenkrantzia picrodendroides* Koch from the Agatdal flora of Nûgssuaq, West Greenland. From B. E. Koch (1972a). × 3.

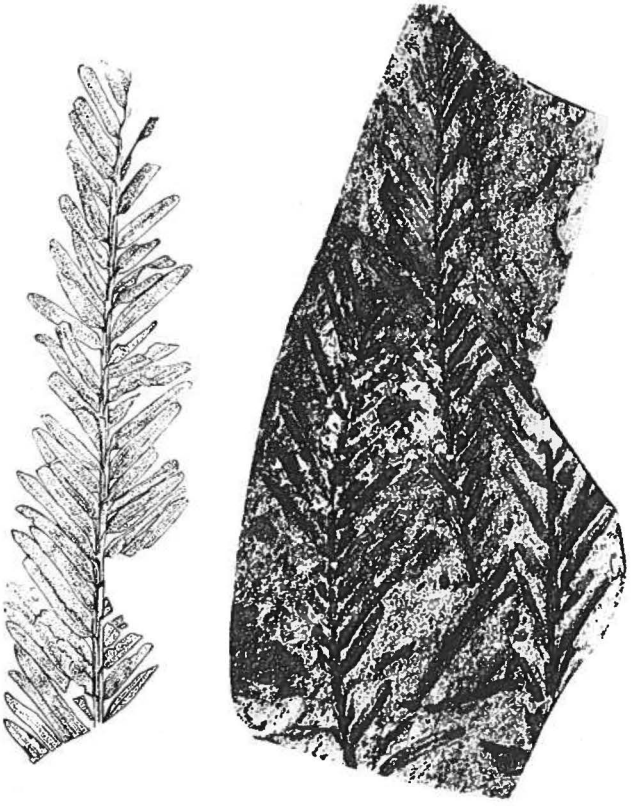
Rosenkrantzia picrodendroides (fig. 436) and *Coryphoides poulseni* are structurally preserved fruits which are placed intermediate between the Cupuliferae and Juglandales, and in the Palmae, respectively.

There is a close relationship between the Agatdal flora and Heer's floras from Atanikerdluk. In the Agatdal flora (and Upper Atanikerdluk A flora) the species *Metasequoia occidentalis, Cercidiphyllum arcticum, Macclintockia kanei, M. lyalli* and *Dicotylophyllum bellum* are very common and the first four mentioned may be dominant in some layers (figs 437, 438). Their relative abundance varies between the different localities. The flora includes genera with relatives in the Cretaceous (e. g. *Credneria*) and genera which have living representatives at other latitudes. Angiosperms are dominant and the flora, on the evidence of its composition, may be considered a representative of the 'Arcto-Tertiary Flora' (Engler, 1882).

On the basis of analysis of the leaf morphology, especially the proportion between species with entire and non-entire leaves, and the percentage of leaves with dripping points in the Agatdal flora, Koch (1963) concludes that the prevailing climatic conditions were temperate with a tendency towards warm temperate. An analysis of the climatic demands of the closest living relatives of some of the fossils gave the same result.

Well-preserved fossil wood, still with adhering bark, is described from marine strata of the Kangilia and Agatdal Formations on the north coast of

Fig. 437. *Metasequoia occidentalis* (Newberry) Chaney from the Agatdal flora of Nûgssuaq, West Greenland. From B. E. Koch (1963). × $^{2}/_{3}$ and $^{3}/_{2}$.



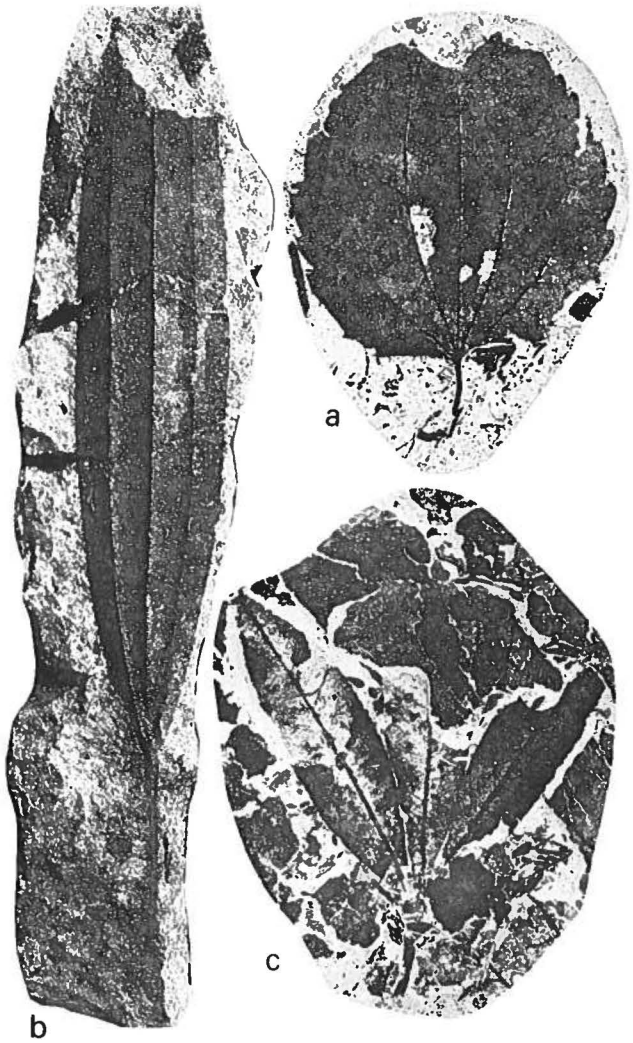


Fig. 438. Representatives of the Agatdal flora of Nûgssuaq, West Greenland. a. *Cercidiphyllum arcticum* (Heer) Brown (× 2/3); b. *Macclintockia kanei* (Heer) Seward & Conway (× 1/2). c. *Dicotylophyllum bellum* (Heer) Seward & Conway (× 3/4). From B. E. Koch (1963).

Nûgssuaq by Mathiesen (1961) as *Cedroxylon saviarqatense* and *Aphoioxylon groenlandicum*.

The floras from the interbasaltic sediments are the youngest fossil floras in western Greenland. These are found in western Nûgssuaq and on Hareøen and show a very limited number of species. The fossil plants are preserved in tuff layers which are referred to the Ifsorisok Formation. The flora was described by Heer and has never been revised, but Koch (1963) mentions six species which are also found in the Agatdal flora:

Ginkgo adiantoides (Unger) Shaparenko
Metasequoia occidentalis (Newberry) Chaney
Quercophyllum groenlandicus (Heer) Koch
Cercidiphyllum arcticum (Heer) Brown
Platanus cf. *P. aceroides* Goeppert
Credneria spectabilis (Heer) Koch

The Tertiary plant fossils are mainly preserved as impressions in clay-ironstone (without the original plant material) and as impressions in shale where some carbonaceous substance may be preserved; cuticle has not been described. Fossils found as petrifactions, viz. fruits and wood, may be extremely well preserved.

The age of the Greenland Tertiary floras was considered by Heer (op. cit.) to be Upper Miocene but the association of marine fossils of Upper Danian age with the Agatdal flora dates the Upper Atanikerdluk flora from the limnic deposits as Upper Danian (Lower Paleocene) (Koch, 1963; Rosenkrantz, 1970). The fossil plants from the interbasaltic Ifsorisok Formation are supposed to be pre-Miocene (Koch, 1964) while the presence of *Cercidiphyllum arcticum* var. *richardsoni* seems to suggest an age not younger than the Upper Eocene (Seward & Edwards, 1941).

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