2

# A MESOZOIC FOSSIL FLORA FROM ARCTIC ELLESMERE ISLAND

# A MESOZOIC FOSSIL FLORA FROM ARCTIC ELLESMERE ISLAND

BY

PAMELA GWYNETH DAVIES, B.Sc.

A THESIS

Submitted to the Faculty of Graduate Studies in Partial Fulfillment of the Requirements for the Degree Master of Science.

McMaster University

October 1965

MASTER OF SCIENCE (1965) McMASTER UNIVERSITY

Hamilton, Ontario.

TITLE: A Mesozoic Fossil Flora from Arctic Ellesmere Island

AUTHOR: Pamela Gwyneth Davies, B.Sc. (University of Wales)

SUPERVISOR: Professor N. W. Radforth

NUMBER OF PAGES:

SCOPE AND CONTENTS:

Macrofossils from a Mesozoic fossil flora from Ellesmere Island, North West Territories are described and their affinities discussed. Several rarely occurring genera and species are discussed in detail. The deposit in which they occur is dated using the known ranges of identified macrofossils and miospores, and the results compared with those of other workers. The described flora is compared with floras of similar age in other parts of the world.

## ACKNOWLEDGEMENTS

I would like to thank Dr. N. W. Radforth for providing the previously undescribed material, and for his interest and encouragement during the course of this study.

I would also like to thank Dr. G. Norris for assistance with the miospore analysis and for advice on many points, Dr. G. Westermann for advice on photographic techniques, and the whole of the Biology Department, particularly Mr. Alan Radford and Mr. Wayne Brideaux, for their help and friendship during the past two years.

The award of a research scholarship by the Department of Biology, McMaster University, is gratefully acknowledged.

TABLE OF CONTENTS

# LIST OF ILLUSTRATIONS AND TEXT FIGURES

INTRODUCTION

Much of the Arctic at the present time is barren of plant life or is frozen for much of the year. Evidence of arctic fossil floras ranging from Devonian to Tertiary in age shows, however, that these conditions only became widespread in this region during Pleistocene times. Many of the genera and species found in late Cretaceous and Tertiary floras have a warm-temperate or tropical distribution at the present time. Palaeomagnetic and palaeoclimatic evidence indicates that the position of the poles relative to the land masses has changed through geologic time (Jacobs, Russell, and Wilson, 1959, p.141). A number of theories, for example, Continental Drift (Du Toit, 1937) have been postulated to account for this.

Arctic palaeobotany presents great problems of collection and geological correlation. Palaeobotanists themselves have collected only in parts of Greenland (Heer, 1868; 1880; 1883), (Seward, 1924; 1926), (Harris, 1932-1935); Alaska, (Heer, 1871), (Hollick, 1930; 1936); Spitsbergen (Heer, 1877), (Nathorst, 1894, 1897); and Ellesmere Island (Radforth, Andrews, and Phillips, 1963). Floras from other areas have been investigated briefly by passing exploration parties whose collections were often small because of the cost and difficulties of transport. Floras from geologically little known areas are difficult to date.

Greenland, palaeobotanically the most fully investigated region of the Artic, has a number of fossil floras ranging from Devonian to Tertiary in age. On the west coast is found the controversial Kome flora of Lower Cretaceous age containing possible early angiosperms. The age of the strata containing the Kome flora has been recently worked out by Koch (1964). On the east coast of Greenland is found the Rhaeto-Liassic flora of Scoresby Sound which has been described in great detail by Harris (1926-1937). It shows similarities with Rhaeto-Liassic floras from Germany and Sweden (Harris, 1931).

In recent Arctic studies emphasis is being placed on palynology (Manum, 1954; McGregor, 1961) because of the stratigraphic significance of miospores and their widespread occurrence in strata otherwise barren of fossils.

## The Objectives of the Present Investigation

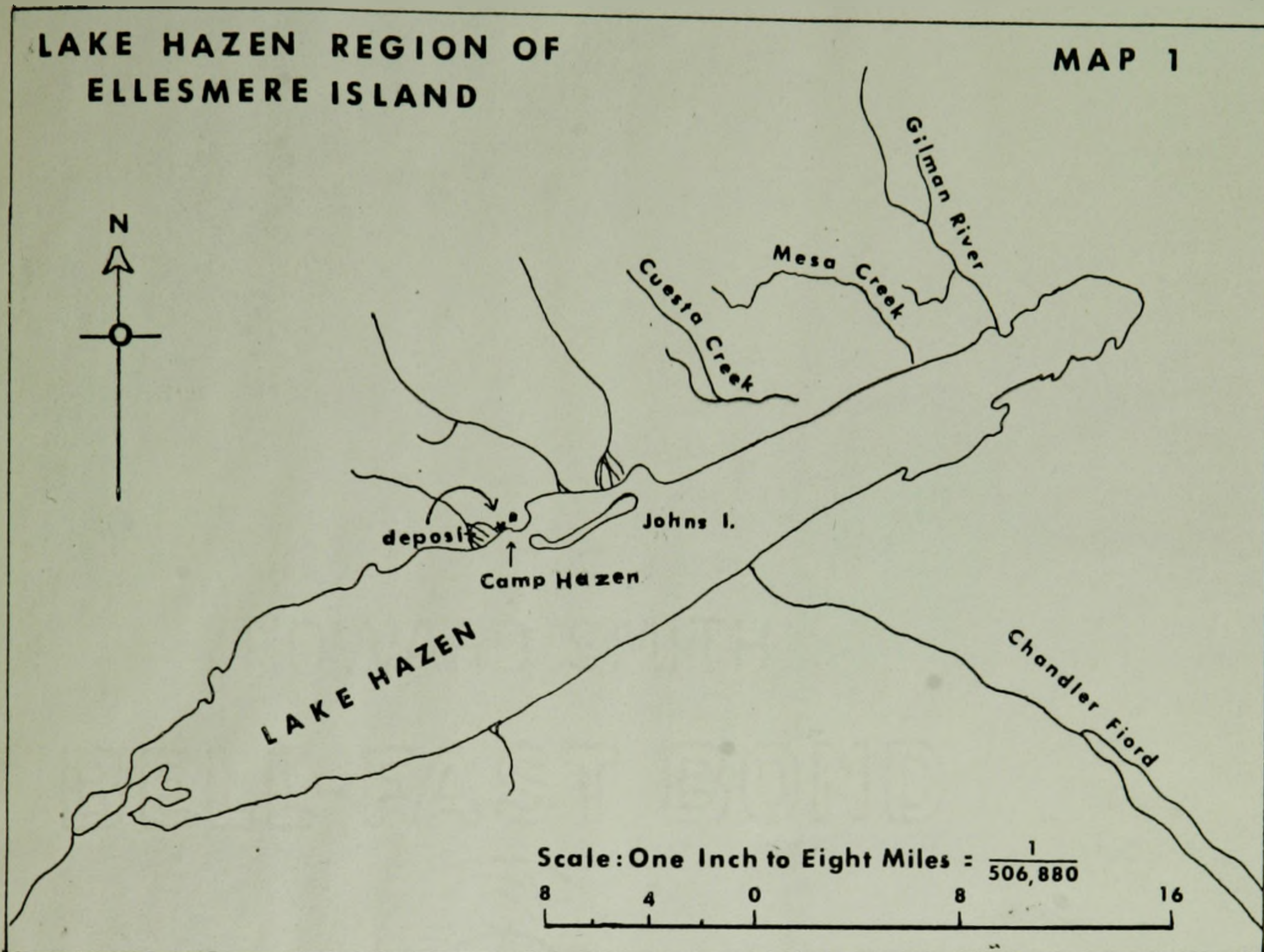
The fossil plant material examined in this thesis came from a previously unexamined deposit of probable Mesozoic age from Ellesmere Island in the Canadian Arctic.

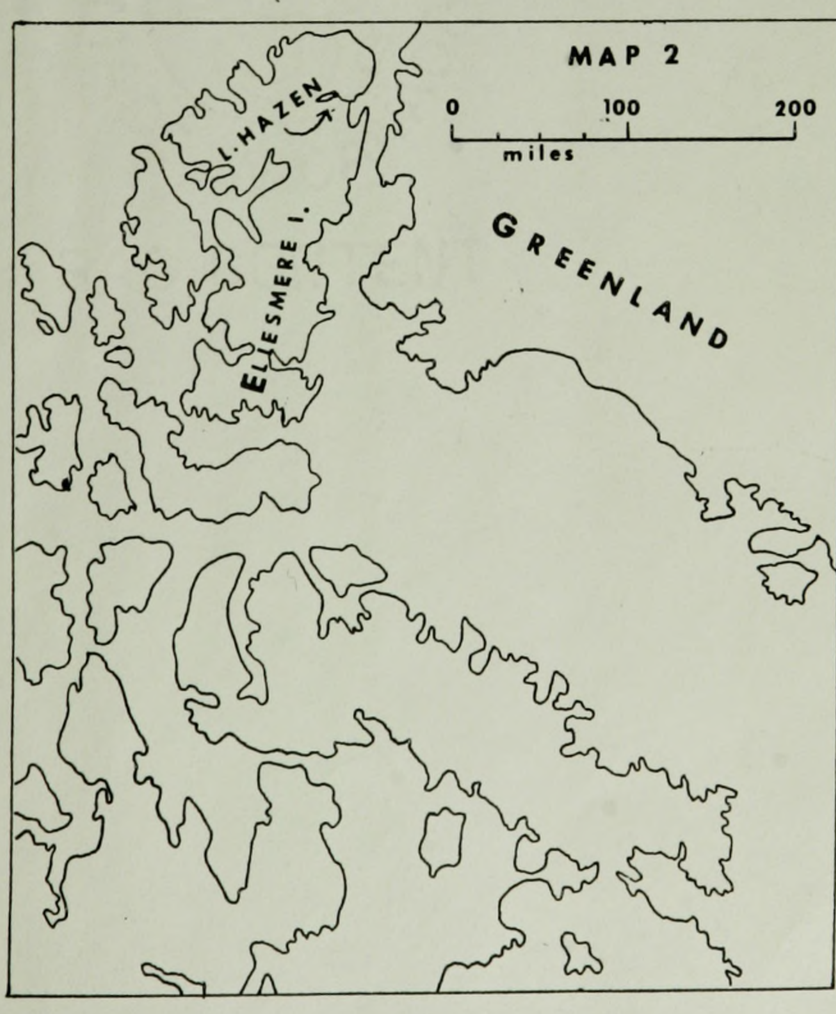
In this investigation there were three main aims:

1. A description of the specimens, their identification wherever possible, and a discussion of the taxonomic significance and relation hips of each.
2. The dating of the deposit using the stratigraphic ranges of the plant macrofossils and miospores obtained from

the rock matrix, and the comparison of these results with those obtained from this area by other workers.

3. The comparison of the flora with other floras of a similar geological age.


LAKE HAZEN REGION OF
ELLESMERE ISLAND
MAP 1
N
Gilman River
Mesa Creek
Cuesta Creek
Johns I.
deposit
Camp Hazen
LAKE HAZEN
Chandler Fiord
Scale: One Inch to Eight Miles : 1/506,880
8
4
0
8
16


MAP 2
0
100
200
miles
L. HAZEN
ELLESMERE I.
GREENLAND

# CHAPTER I

# GEOGRAPHICAL AND GEOLOGICAL INFORMATION

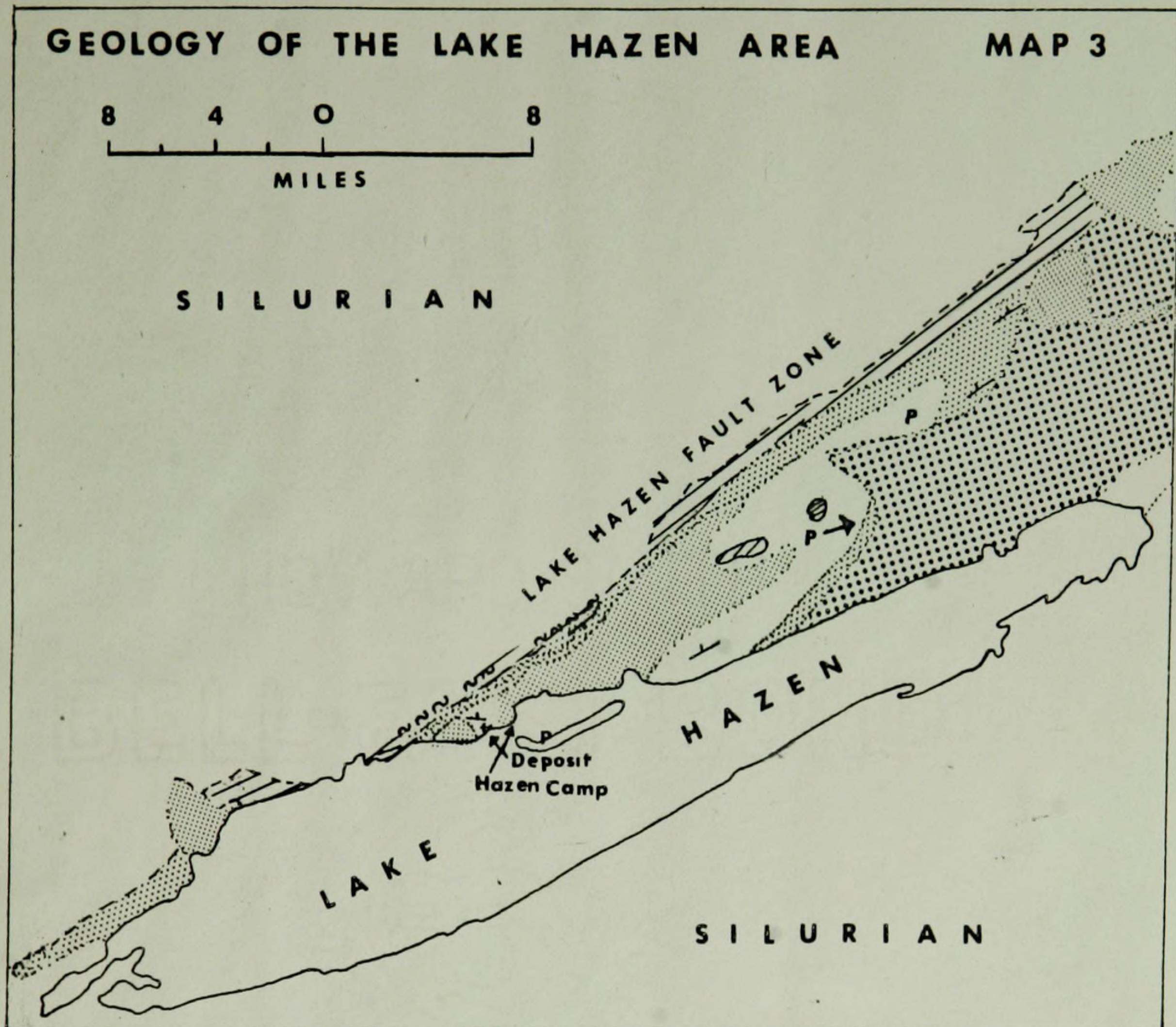
## Collecting Details

The material examined in this thesis was collected by Dr. N. W. Radforth, Dr. H. N. Andrews, and Dr. T. Phillips during a field trip to the Lake Hazen area of northeastern Ellesmere Island, District of Franklin, N.W.T. (see map). The material was collected at a single outcrop on the north shore of Lake Hazen, ¼ of a mile south of the Defence Research Board Camp Hazen (81°49' N: 71°18' W). The deposit outcropped at the waterlevel. All samples were sent back to McMaster University for examination.

## History of Exploration

Christie (1964) has summarised the history of exploration of Ellesmere Island. The northern part was first visited between 1875 and 1876 by a Royal Navy Expedition. Some geological investigation was carried out and the first geological map of the region was published in 1878 by Fielder and De Rance.

In 1882 a United States expedition led by Lieutenant Greely discovered Lake Hazen while carrying out scientific work connected with the International Polar Year. Greely named the lake after General Hazen, then commanding a similar expedition in Alaska. Northern Ellesmere Island has been visited subsequently by a number of scientific expeditions.




LEGEND

Glacial Till

Tertiary

Uppermost Jurassic or Lower Cretaceous; Sandstone, Shale

Triassic; Sandstone, Shale, Coal

Carboniferous, Permian; Limestone, Sandstone, and Conglomerate

Fault, Assumed

P Geological Survey Microfossil Locality

In 1950 a meteorological station was established at Alert on the northeastern coast and this has been used as a base for several recent surveys.

The Geological Survey of Canada began geological reconnaissance work of northern Ellesmere Island in 1950. Reconnaissance was intensified during the Defence Research Board "Operation Hazen" study of the Lake Hazen area, part of the Canadian International Geophysical Year programme, and it is still continuing.

Radforth, Andrews and Phillips used the weather station at Alert as a main base. The camps set up by the Defence Research Board at Lake Hazen and the Gilman River during "Operation Hazen" served as secondary bases.

## Geology of the Area

Lake Hazen lies on a plateau separating two mountain ranges formed of predominately Palaeozoic strata. A major fault zone roughly delimits the plateau from the mountains to the north.

Sedimentary rocks of Permo-Carboniferous to Genozoic age outcrop along the north shore of Lake Hazen. Their structure is difficult to determine because strata of different ages have similar lithologies, varying from sandstone to impure limestone and shale. Outcrops are poor and good index fossils are infrequent. Christie (1964, p.41) comments: "Fossils from these beds have been assigned with varying degrees of certainty to the Permian, Triassic, Jurassic and Cenozoic."

Permo-Carboniferous beds outcrop along the front rangesof the mountains and the fault line to the northwest. Mesozoic beds outcrop to the southeast and Cenozoic beds to the north and northeast of the eastern end of Lake Hazen. Basalt and diabase dykes of probable Cretaceous age cut the Jura-Cretaceous and older strata.

The deposit sampled by Radforth (not visited by the Geological Survey of Canada field parties) outcrops in strata inferred by Christie (1964) to be of Upper Jurassic or Lower Cretaceous age. The ages of the strata were determined by spore analyses of samples from three localities extending over an area of about sixteen miles. (McGregor in Christie, 1964). Sampling points are located at John's Island, two miles to the southeast of the Lake Hazen deposit, and Mesa Creek and Gilman River, sixteen and nineteen miles, respectively, to the northeast (see map). Much of the bedrock geology of the area around Lake Hazen is obscured by glacial till.

The structure of the area is complex and incompletely known. Christie (1964) considers that the beds lie in an open syncline, with a southwest-trending axis north of and nearly parallel with Lake Hazen. The south limb of the syncline dips northwest about twenty to thirty degrees; the north limb is truncated by the Lake Hazen fault zone.

# CHAPTER II

## MATERIALS AND METHODS

### MATERIALS

The plant remains were found in black, fissile shale with a dull gleam, which splintered readily into fine lamellae. Fragments of carbonaceous plant material, compressed and very fragile, were abundant throughout the rock. Some rock surfaces had oxidized to a mottled grey color. Highly weathered specimens showed oxidized layers throughout the rock. Much of the weathered rock was yellow on the surface, probably due to secondary deposition of sulfur from percolating water (Dr. V. Gwinn, pers.comm.).

Plant macrofossils were found in both compression and impression form. Eight species were reported by the collectors (Radforth 1963, unpublished, p.21). During transport and subsequent handling, the fragile shale split frequently along planes of weakness, revealing many other specimens.

### METHODS

1. Several methods were used to remove a specimen from its rock matrix and render it translucent, in order to examine it by transmitted light.

   (a) Transfer Method (modified after Lang 1926, in Andrews, 1961, p.470). After cleaning the surface, the plant compression and the adjacent rock matrix were flooded with amyl acetate to prevent air bubble formation and coated with two layers of a peel solution of cellulose acetate in amyl acetate. When this was dry, as much rock material as possible was split away from the back of the compression.

This step is followed in the transfer method by soaking the specimem in technical grade (40 to 50%) hydrofluoric acid to remove silica and silicates. This material, however, macerated very slowly in hydrofluoric acid. The process was speeded up by soaking the sample in dilute hydrochloric acid for half an hour before maceration.

The mechanism of this reaction is not clear, since there was little effervescence (the usual sign of the presence of carbonates) when the material was in hydrochloric acid.

During maceration the loosened rock was frequently scraped off the back of the transfer to facilitate solution. When all the rock matrix had been dissolved away (two or three days) the specimen was washed thoroughly by indirect application of distilled water.

The material made poor transfers because portions of the sample frequently dissolved away from the transfer during treatment in hydrofluoric acid, particularly if this was prolonged to remove sediment that remained in the contours of the specimen. If the specimen showed signs of dissolving away from the transfer while in hydrofluoric acid, the transfer was removed from the acid, washed carefully with distilled water and the remaining loosely consolidated sediment dissected away using a tungsten ire needle sharpened in molten sodium nitrite. This differential distruction of specimens is possibly determined by the amount of carbonaceous material contained in the specimen, or the oily content of the shale.

Any remaining, partially dissolved, minerals were removed with 10% potassium hydroxide leaving the cellulose acetate transfer free and the carbonaceous remains exposed. The transfer was washed in distilled water prior to mounting in corn syrup (Radforth, 1938, p. 386). Corn syrup was preferred to mounting media like canada balsam, because it is miscible with water, and therefore transfers can be mounted straight from distilled water and removed from the mounting medium at will. The underside of a specimen transferred in this manner often reveals small, morphological details, for example epidermal hairs, which have been destroyed on the unprotected surface during exposure.

(b) Pull Technique

This is an adaptation of the transfer method. The dried peel is carefully stripped off the compression. It is possible, using this technique, to remove the cuticular impression of a leaf. The remainder of the specimen can be used in a transfer preparation.

(c) Cuticular Analysis

Cellulose acetate transfers containing fragments for cuticle analysis, or small pieces of compression lifted off a rock surface with a dissecting needle, were placed in concavity slides containing Schulze's solution (concentrated nitric acid with a few dissolved crystals of potassium chlorate). The cellulose acetate was removed by the Schulze's solution and the black carbonaceous fragments were oxidized to a light brown color in about one hour. The process was observed with a microscope and when the specimens were sufficiently oxidized, they were washed thoroughly with distilled water. Corn syrup was used for temporary mounts and glycerine jelly for permanent mounts.

2. MIOSPORE ANALYSIS (Radforth, McGregor, 1954: Norris, pers.comm.).

The rock matrix was investigated for miospores, which are present in many sediments, particularly shales, (Andrews 1961, p. 477). The material did not macerate easily, and the method below was developed after several preliminary surveys.

Rock samples were crushed to pass through a 1 mm. sieve. The crushed sample was treated with a 50% solution of orthophosphoric acid for one hour (Staplin, et. al, 1960, p.329). Rock pre-treated in this manner broke down more readily in hydrofluoric acid and gave a fine-textured residue. The reasons for this are not known. Orthophosphoric acid is generally used to remove carbonates (Staplin, et al, ibid.).

After transfer to polythene centrifuge tubes, the sediment was treated with cold hydrofluoric acid for forty-eight hours. The samples were then washed with distilled water and centrifuged at least three times. By-product after hydrofluoric acid was removed by repeatedly washing the residue in warm 10-25% hydrochloric acid until no gelatinous by-product remained, the residue was looser in texture, and the hydrochloric acid no longer turned yellow. The residue was then washed with distilled water.

The residue was oxidized using "dry" Schulze's solution (crystalline potassium chlorate and residue in equal amounts to which an equal amount of concentrated nitric acid is added). Optimum time for this treatment was ascertained by periodic inspection of samples under a microscope; ten minutes was usually sufficient.

The samples were washed in distilled water to dissolve any remaining potassium chlorate and 10 ml of ammonium hydroxide were added to each sample. The mixture turned brown immediately and the ammonium hydroxide was centrifuged off. This step was necessary to remove unwanted flocculent organic debris. It also served to lighten the color of some spores. Prolonged alkali treatment destroyed all organic material including spores, cuticle, etc..

The samples were washed with distilled water until the supernatant liquid remained clear. They were then stained in a 1% solution of safranin alcohol which emphasised morphological features, washed and mounted in glycerine jelly.

3. PHOTOGRAPHY

The black carbonaceous plant fragments showed up clearly on the light, weathered rock surfaces with deposited sulfur, but the low relief and lack of contrast in the unweathered rock specimens made photography difficult. A number of different methods, including infra-red photography and photography of specimens immersed in xylol, were unsuccessful in revealing detail of specimens.

Fossils were finally prepared for photography in one of the following ways:

(a) A specimen was immersed for a few seconds in a dilute solution of nitric acid saturated with chromic anhydride (Funkhouser and Evitt, 1959, p.371). This oxidized the surrounding rock to a light brown color which contrasted with the black, carbonaceous specimen. This method was used only for specimens being transferred, since the prolonged washing necessary to remove the anhydride solution might have caused damage to fragile specimens.

(b) The specimen to be photographed was coated lightly with magnesium oxide by passing it over a piece of burning magnesium ribbon. The magnesium oxide coating was easily removed by gentle washing in distilled water.

Specimens prepared in both ways and specimens on weathered surfaces were photographed using a Zeiss Stereomicroscope II, an Olympus PM-6 camera and a Kodak High Contrast Copy film (ASA 16). The film was developed in AGFA Rodinol and printed on Leonar Leigrano Type I paper.

## CHAPTER III

## TAXONOMY

Andrews (1961, p.21) considers that "a classification should enable us to keep some order among the approximately one-third of a million species of living plants, and, ideally it should iddicate natural relationships."

Living plants can be classified using morphological, anatomical, genetical and biochemical characters of the whole plant. The classification of fossil plants, however, must often be based on the external morphology of isolated plant fragments. Such fragments are classified in "organ genera" e.g. the leaf genus Nilssonia. An organ genus is defined by the 1961 International Committee on Botanical Nomenclature (Article 3, note I) as a genus assignable to a family.

Unrelated groups may have superficially similar organs. Recent investigation of many organ genera, for example the leafy twig Walchia (Florin 1944, fide Andrews 1961, p.322) using cuticle analysis, has shown that several plant groups may be represented. Morphologically similar specimens whose natural affinities are unknown are therefore placed in "form genera" defined by the 1961 International Committee on Botanical Nomenclature as a genus unassignable to a family, which may be referrable to a taxon of a higher group.

The fragmentary nature of the fossil record means that the relationships of many fossil groups to one another and to extant species are uncertain or obscure. Many extant groups however, for example, the conifers and the cycads, can be traced back in the fossil record as independant lines as far as the Paleozoic, although their ultimate ancestry is speculative. For this reason the author has followed Andrews (1961) in the use of Bold's classification (Bold, 1957). This although primarily a classification of living plants, emphasises the great differences between plant groups such as the conifers and cycads, formerly regarded as subclasses of the Spermatophyta (Tippo, 1942 *fide* Bold 1957, Table I) by elevating each group to the rank of a division.

Division PTEROPHYTA

Order FILICALES

Family DIPTERIDACEAE

Genus CLATHROPTERIS Brongniart

CLATHROPTERIS MENISCOIDES Brongniart

Pl. 1, fig. 1.

1825 Clathropteris meniscoides Brongniart (fide: Seward, 1910, p.386) Rhaetic, Scania

1882 Clathropteris platyphylla Zeiller, p.299; pl.XII, fig.5. Lower Jurassic, Tongking.

1906 Clathropteris meniscoides Brongniart (fide: Seward, 1910, p.387) Rhaetic, Scania

1931 Clathropteris meniscoides Brongn., in: Harris, p.88; pl.XV, figs.1-9, pl.XVI, figs. 9,10, pl.XVIII, figs. 3,5,12.

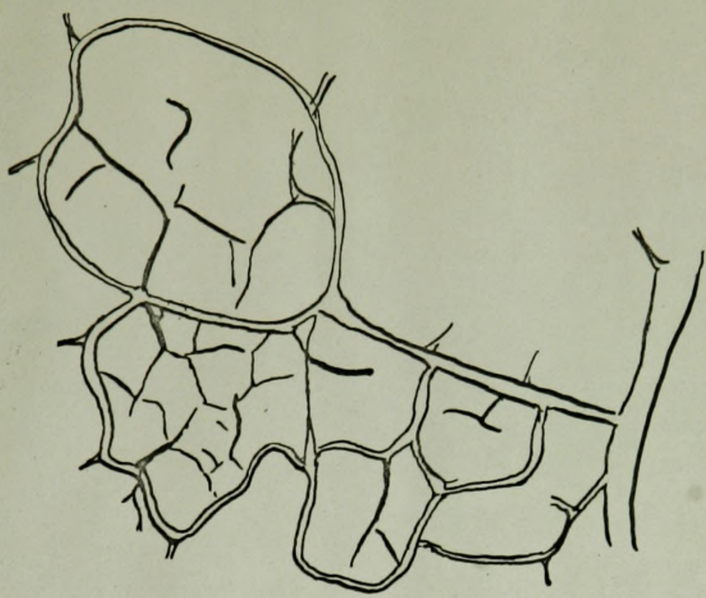
1958 Clathropteris meniscoides Brongniart in: Kräusel, p.75; pl.4, fig.9, pl.5, fig.20, 21. (With complete synonomy). Jurassic, Bamberg.

Description: Thick, weathered leaf impression 6 mm. by 8 mm. which has a strong, irregular main vein, 0.25 mm. across, and polygonal venation. Lateral veins are given off at an angle of forty-five degress or more, and divide repeatedly to give a system of large, irregular polygons or rectangles, divided into smaller polygons (See Text-fig.1)

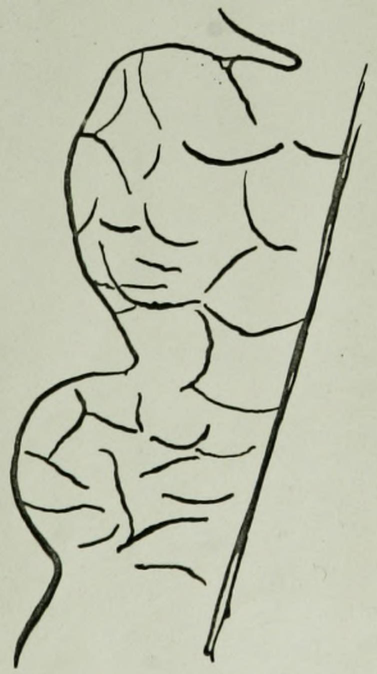
200u to the left of the midrib, is a small, round, raised structure, 400u in diameter, probably a fruiting body, situated between the lateral veins.

Traces of a venation pattern similar to that described above found on the rock surface surrounding the specimen, giveno indication of the size or shape of this leaf.

1 CLATHROPTERIS MENISCOIDES X 40



2. THAUMATOPTERIS SCHENKI X 25



Discussion: The genus Clathropteris was founded by Brongniart for Rhaetic specimens from Scania. He described two species: C. platyphylla; and C. Meniscoides later united into C. meniscoides by Brongniart. The specimen described agrees with the type specimen in the wide angle at which the lateral veins leave the midrib and the characteristic reticulum composed of rectangular and polgonal meshes.

A second specimen, very weathered (not figured) shows traces of the characteristic venation and numerous, small fruiting bodies over the surface of the leaf.

Distribution: Clathropteris has a worldwide distribution and ranges from the Upper Triassic to the Lower Jurassic (Seward, 1910). Seward (1910, p. 387) considers that Clathropteris has affinities with Dictyophyllum and the modern fern Dipteris, on the basis of venation and sporangial characteristics.

Yabe (in Harris 1931, p.139) suggests that identifications should be based on the entire frond. He considers that a number of species are included in Clathropteris meniscoides at present.

Genus THAUMATOPTERIS Goppert

THAUMATOPTERIS SCHENKI Nathorst

Pl. 1, fig. 2.

1875 (?) Anomozamites cretaceus Heer, p.72; fig. XXIII. Cretaceous, Arctic.

1878 Thaumatopteris schenki Nathorst, p.46; pl.2, fig.1. Rhaetic, Germany.

1931 Thaumatopteris schenki Nath., in: Harris, p.93; pl.XVII, figs.6-8, pl. XVIII, figs.1,2.

1958 Thaumatopteris schenki Nathorst in: Kräusel, p.76; pl.5, figs. 22-27. (With complete synonomy). Jurassic, Germany.

Description: Impression of a thick, sterile leaf about 16 mm. long which is broken at both tip and base. Enough of the tip remains to suggest the shape of the whole leaf. The leaf tapers gently towards the apex from a basal width of 4 mm. A strong, deeply dissected midrib, 0.25 mm. wide, running the length of the leaf is present. The margin of the leaf is deeply lobed near the base. Lobes are approximately 1.75 mm. wide, rounded, and penetrate halfway towards the midrib, the lobation becoming shallower apically, and disappearing near the apex. Each lobe is incurled slightly and shows a characteristic venation:- three or four slender lateral veins per lobe are given off the midrib at right angles. These divide and anastomose to form a series of rounded or elongated polygons (see Text-fig. 2).

Discussion: Kräusel (1958, pl.5, fig.24) figures a portion of a pinna of Thaumatopteris schenki. The deep lobing near the base dies out suddenly about halfway along the margin. The specimen measures 18 mm. in length and is 4 mm. wide, at the base, with rounded lobes similar in shape and size to those of the specimen described above. The characteristic reticulate venation is also present. Other specimens figured by

Kräusel (1958, figs. 23, 25, 26 and 27) show pinnae with the marginal lobing extending to the apex. The longitudinal extent of the lobe, therefore, appears to be variable.

Anamozamites cretaceus Heer is based on a single specimen possessing, "small subpinnatifid leaves, rounded lobes and forked veins" (Heer, 1875, p.72). His illustrated specimen is similar in size and venation to the specimen described. The name Anomozamites was first used by Schimper in 1872 (Seward 1910, Vol.III, p.549) for Bennettitalean fronds "with a more or less entire or irregularly pinnatisect lamina which bears a close resemblance to Nilssonia" (Seward, ibid.). Seward (1917) noted that Zeiller considered Anamozamites to be a subgenus of Pterophyllum. Although some species of Pterophyllum show lobation which becomes increasingly shallow apically, they do not show frequently forking or reticulate venation but have simple veins running parallel across the lobe or leaflet. Seward (1921) re-examined Heer's specimen and concluded that it was "unidentifiable".

Thaumatopteris, a genus founded by Goëppert for a form from the Rhaetic of Germany, closely resembles Dictyophyllum in frond shape and venation. Seward (in: Seward and Dale, 1901) considers that the two genera are synonymous).

Distribution: Thaumatopteris schenki Nathorst is found in the European and Greenland Lower Jurassic (Harris 1946, p.35). Seward (1910) noted that this species compares closely with Dictyophyllum fuchsi Zeiller from the Rhaetic of Tongking.

Genus GOEPPERTELLA Oishi and Yamasita

GOEPPERTELLA MICROLOBUS (Schenk) Oishi and Yamasita.

Pl. 1, fig. 3.

Synonomy:

1867 Woodwardites microlobus Schenk, fide: Harris, 1946,p.25

1882 Woodwardites microlobus Schenk, in: Zeiller, p.308; pl. 12, figs. 3,4. Rhaetic, Lower Jurassic, Tonkin.

1892 Woodwardites microlobus Schenk, in: Raciborski, fide Harris, 1946, p.25. Lower Jurassic, Poland.

1903 Woodwardites microlobus Schenk, in: Zeiller, p.91; pl.17, figs. 1,2,2a only. Rhaetic, Lower Jurassic, Tonkin.

1913 Woodwardites microlubus Schenk, in: Anteve, p.14; pl.1, figs. 5,6,6a. Lower Jurassic, Sweden.

1936 Goeppertella microlobus, Schenk Oishi and Yamasita, p.146

1946 Goeppertella microlobus Schenk, Oishi and Yamasita, in: Harris, p.23-25. Lower Jurassic, Greenland.

Description: Fragment of the middle of a pinna, 20 mm. long and 6 mm. in width, which is composed of alternately arranged pinnules with pointed apices, given off the rachis at an agle of 45 degrees, at approximately 2 mm. intervals. The well defined rachis is 1 mm. wide and consists of 2 longitudinal rows of alternately arranged, columnar segments approximately 2 mm. long and slightly constricted at their centres. Each segment ends opposite the midvein of a pinnule. The pinnules are approximately 3 mm. long and consist of two rows of alternately arranged, oval projections, approximately 1 mm. long and 0.5 mm wide at the bases of the pinnules, diminishing in size towards the apices. The projections are sterile and seem to be caused by bulging of the lamina between a deeply depressed vein system. There are up to six projections per pinnule and each pinnule is surrounded by a thick, flat, continuous lamina.

Discussion: In size and appearance and in the distinctive venation the specimen is identical with Goeppertella microlobus (Schenk) Oishi and Yamasita (in: Harris, 1946). The species was attributed to Woodwardites because of its resemblance to the recent genus Woodwardia. Oishi and Yamasita (1936) suggested that the genus should be renamed Goeppertella to avoid confusion with Tertiary representatives of the genus Woodwardia. This is contrary to Article 62 of the International Code of Botanical Nomenclature which states that "a legitimate name or epithet must not be rejected merely because it is inappropriate or disagreeable, or because another is preferable or better known, or because it has lost its original meaning." Nevertheless, Harris (1946) supports the use of the name Goeppertella since Woodwardites Schenk is a junior homonym.

Goeppertella is considered to belong to the Dipteridaceae on the basis of the venation of the sterile pinnae (Harris ibid. p.25). The primary venation is dichotomous; the smaller veins form a reticulum. (Bower, 1926, p.311).

Distribution: Goeppertella microlobus is found only in Rhaetic and Lower Jurassic strata. In southeast Asia it occurs in Rhaetic and Lower Jurassic; in Europe and Greenland it occurs only in the Lower Jurassic (Lias).

GOEPPERTELLA CF. G. MICROLOBUS (Schenk), Oishi and Yamasita

Pl.1, figs. 4,5,6.

Description: Fertile pinnule fragments which are almost identical with Goeppertella microlobus, but lack the thick, flat lamina surrounding the pinnules. Transfer preparations were made of two specimens. One protruberance contained 6 to 8 sporangia arranged in a circle, without a central receptacle, and surrounded by a single ring of elongated cells, probably the remains of an indusium. One sorus was macerated revealing a few spores, one of which is figured (pl.1, fig.5). It compares with Dictyophyllites harrissii, the spore of the dipteroid fern Dictyophyllum (Potonie 1960 p.29, pl.1, fig.4). There were few spores found in association with the sorus, and it is possible that they are contaminants. A small number of spores per sorus is however, characteristic of the Dipteridaceae.

The reverse of the leaf transfer shows a primary venation like that of Goeppertella microlobus (figured in Harris, 1946, p.21): strong lateral veins leave the main vein of each pinnule nearly at right angles, dichotomising at an angle less than 120 degrees, halfway across the lamina. The ultimate venation is not preserved.

Discussion: Zeiller (1903, pl.17, figs.3,3a,3b) figured fertile leaves of 'Woodwardites microlobus' The sori were numerous, scattered over the surface of the leaf and consisted of at least 6 sporangia surrounding a central receptacle. Zeiller's fertile specimens, however, differ from the sterile, type species: the pinnules in figs. 3, 3a, 3b, are shorter and broader than the sterile pinnules and do not show the characteristic, raised or hollowed lamina. The faint venation of these specimens compares with that of _Thaumatopteris schenki_, another dipterid fern. (see earlier work).

If _Goeppertella microlobus_ does belong to the Dipteridaceae, as its venation suggest, it seems probable that the narrow pinnules would bear linearly arranged sori, as seen in the specimens described in this thesis. The fertile and sterile specimens figured by Zeiller do not seem to have been found in organic connection. Possibly the fertile specimens belong to another species of _Goeppertella_ or even to another fern genus.

The Diperidaceae are considered by Bower (1926) to be allied to the Matoniaceae, although the fossil evidence for this is slight. (Harris, 1931). The family reached its maximum development in the Rhaetic and Lower Jurassic.

Family MATONIACEAE

Genus PHLEBOPTERIS (Brongn.)

Hirmer and Hoerhammer.

PHLEBOPTERIS ANGUSTILOBA (Presl.)

Pl.1, fig. 7,8.

Selected Synonomy:

1838 Gutbiera angustiloba Presl. in Sternberg, p.116; pl.33,fig.13.

1891 Laccopteris angustiloba Raciborski, p.15; pl.2, figs.6-9, pl.3, figs.1-3. Rhaetic, Poland.

1914 Gutbiera angustileba Presl in Moller and Halle, p.8, pl.1, figs.1-6. Rhaetic, S.E. Scania.

1919 Gutbiera angustiloba Presl in Antevs, p.16; pl.1, figs.7-9 Liassic, Scania.

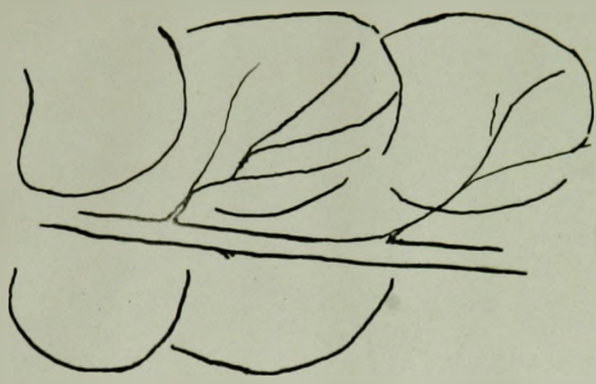
1931 Laccopteris angustiloba (Presl) Raciborski in: Harris, p.74 pl.14, figs.6-17. Rhaetic, Greenland.

1936 Phlebopteris angustiloba (Presl) Hirmer and Hoerhammer, p.14.

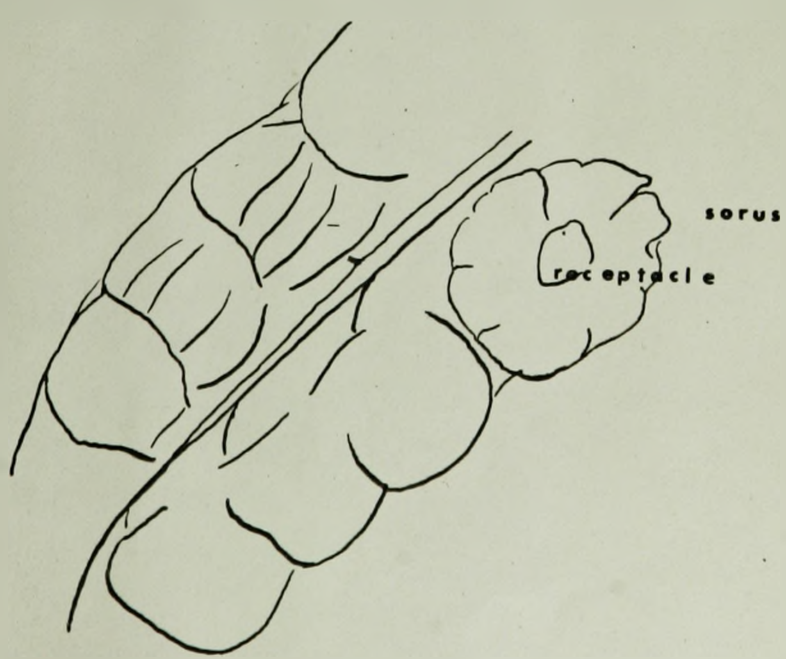
Description: Detached fertile portion of a pinna, 34 mm. long, which tapers from an incomplete base at least 10 mm. wide to an apex 3 mm. wide. Alternately arranged pinnules are inserted at between sixty and eighty degrees to the rachis. Pinnules on the left hand side are inserted at a greater angle than those on the right, due probably to folding during preservation.

The rachis is 0.33 mm. wide, and deeply grooved. Each pinnule consists of approximately seven pairs of rounded sori, flattened at points of contact, on either side of a narrow, deeply depressed, corded midvein. Sporangia are not borne directly on the midvein. Their position in an uncompressed state must have been on the lamina of the leaf (not preserved) very close to the midvein as indicated by traces

3. PHLEBOPTERIS ANGUSTILOBA ×40



4. P. cf. MUENSTERI ×40



of lateral veins from the midvein between the sori. A fine venation over the surface of the sorus is present in several of the better preserved sori (Text-fig.3).

The sori vary in diameter from 1 mm. at the base of each pinnule to 0.5 mm. at the apex. The size of sori is unchanged towards the frond apex.

Sori are longitudinally striated. In a specimen with larger sori, probably belonging to the same species (pl.1, fig.8), these striations are curved and deepened to give six to eight flattened segments per sorus. No receptacle may be seen. Single pinnules comparing closely with those of the figured specimens are common.

Discussion: The figured specimen compares closely with pinnule fragments of Gutbiera angustiloba Presl (in Moller and Halle 1913, pl.1; figs. 1-6) in external appearance, size of sori and venation. The small depressions seen in some of the sori (Moller and Halle, 1913, pl.1; figs. 4 and 5), are not seen in the specimen described above. This may be a characteristic of a mature sorus.

Harris (1931) considers that the species angustiloba (Presl) Raciborski, is better combined with Laccopteris than Gutbiera. Hirmer and Hoerhammer (1936) re-examined the genus Laccopteris and have concluded that it is synonymous with Phlebopteris (Brongniart), which has priority.

All available references to this species are given in Jongmans and Dijkstra (1960), principally under the headings Gutbiera angustiloba Presl, and Laccopteris angustiloba (Presl) Raciborski.

Distribution: Phlebopteris angustiloba has a wide distribution in Rhaetic and Lower Jurassic strata. In Europe and Greenland it is found in the Lower Jurassic and in Southeast Asia in the Rhaetic and Lower Jurassic.

# PHLEBOPTERIS ? MUENSTERI (Schenk) Hirmer and Hoerhammer

Pl. I, fig.2.

Selected Synonomy:

1867 Laccopteris muensteri Schenk, (fide, Sweard 1910, p.357)

1931 Laccopteris brauni Goeppert, in: Harris, p.70; pl.XIV, figs.1,2.

1936 Phlebopteris muensteri (Schenk) Hirmer and Hoerhammer, p.16 pl.III, IV. (Complete synonomy).

1937 Phlebopteris muensteri (Schenk) Hirmer and Hoerhammer, in Harris, p.20.

Description: Fragment of a fertile pinna 5 mm. long and 7 mm. wide, which bears four pinnules. The rachis is 0.5 mm. wide, striated and sunk beneath the level of the sporangia. The pinnules are given off the rachis alternately at an angle of almost 90 degrees, curving upwards at the tips. Each pinnule consists of two rows of sori arranged alternately on either side of a raised, corded midrib. The pinnules are in-complete but there are at least nine sori in each row. The pinnules are approximately 2mm. wide at the base tapering to a width of 0.75 mm. at the tip due to decreasing soral size. Basal sori are approximately 0.5 mm. in diameter, flattened at points of contact. One sorus (see text fig. 4) has a central receptacle surrounded by an indeterminable number of sporangia. In places lateral veins pass from the midvein between or under the sori. On the lowest pinnule one sorus has been broken away revealing anastomoses between the veins.

Discussion: The specimen compares with *Phlebopteris muensteri* in appearance but has smaller sori. *Phlebopteris muensteri* has a maximum of 13 sporangia, with nearly entire transverse annuli, per sorus (Hirmer and Hoerhammer 1936, p.17). The number of sporangia in the sorus and the type of annulus cannot be determined in the described specimen because of poor preservation.

Harris (1931) considered that *Laccopteris muensteri* was synonymous with *Laccopteris brauni*. Later work (Hirmer and Hoerhammer 1936) showed that the species brauni Goeppert and muensteri Schenk were separable. Hirmer and Hoerhammer recombined them with *Phlebopteris* since they consider that the genera *Phlebopteris* and *Laccopteris* are synonymous.

Distribution: *Phlebopteris muensteri* is found in Lower Jurassic strata in Greenland, Europe and probably southeast Asia (Harris 1937, p. 20).

PHLEBOPTERIS SP. A

Pl.1, fig.10.

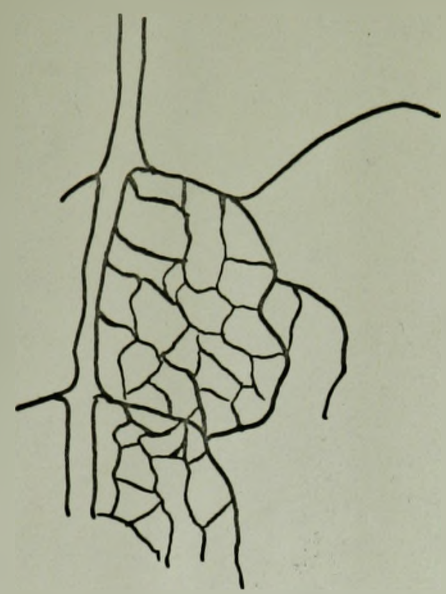
Description: Single thick, almost complete leaf impression which is ovate-elongate, 11 mm. long, rounded at the base and tapers to a blunt apex 1.5 mm. wide. A sinuous, thin, but well-defined midvein is present. Well-defined lateral veins are given off both alternately and oppositely at angles of approximately 80 degrees. About 1.5 mm. from the midvein, the lateral veins dicotomise, each equal dichotomy dividing once more near the margin. The lateral veins anastomose occasionally. Two shallow depressions are present on one side of the lamina parallel with the midvein, which may be sites of sori.

Discussion: Phlebopteris (Brongn.) emend. Hirmer and Hoerhammer (1936, p.14), has the following characters: a pedate frond with linear ultimate segments; secondary dichotomous venation; circular sori, forming a single row on either side of the midrib, and 6-13 sporangia with almost entire, transverse annuli, per sorus. The specimen in Pl.1, fig.10 agrees in definition of venation and possibly the position of the sori. In venation, it compares closely with specimens figured by Moller and Halle (1914, pl.3, fig.14). The ovate-elongate shape of the leaf compares more closely, however, with suborbicular species of Hausmannia (Seward, 1910, p.390), a dipteroid fern with similar venation but no anastomoses, or with Cladophlebis arctica Heer (in Seward, 1927, pl.8, fig.61A). Cladophlebis is a genus of uncertain affinities. It has linear or falcate ultimate segments attached to the pinnae by the entire base, and forked lateral veins given off at an acute angle.

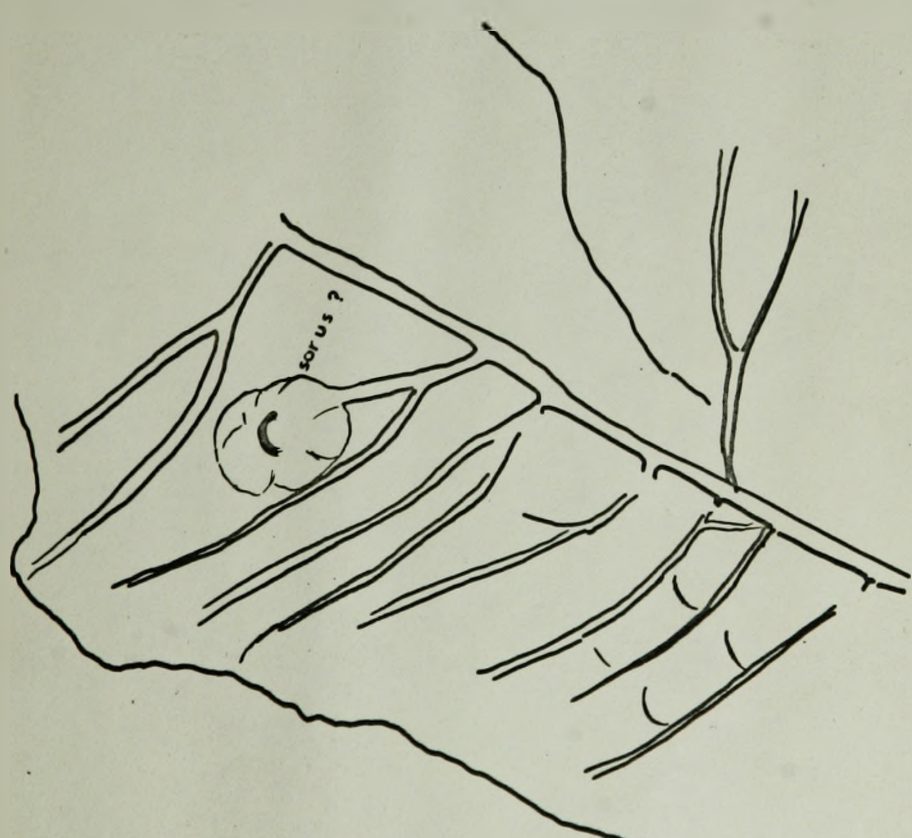
Despite its close resemblance to Cladophlebis arctica Heer in size, shape and venation, the described specimens have not been assigned to that genus and species: the rounded base suggests that the leaf was not attached by the entire base; and the veins are not given off at an acute angle. The specimen compares closely with Phlebopteris in venation, and in the position of the sori.

Several poorly preserved elongate-lanceolate fragments were examined but not figured. They show traces of typical Phlebopteris

5. PHLEBOPTERIS ? SP. B X 25



6. AXIS A. X40



venation. One shows two rows of depressions on either side of the midrib, marking the position of sori.

Distribution: Phlebopteris is found in strata of Rhaetic to Cretaceous age in Europe, Greenland, Russia, South Africa, China and North and South America. A few Asian species are found in strata older than the Rhaetic but still of Triassic age.

PHLEBOPTERIS SP.B

Pl.1, fig.9

Description: Impression of a small, single, ovate-elongate leaf, incompletely preserved, which is 9 mm. long, 4 mm. wide near the pointed tip, with a distinct, raised midvein and reticulate venation. Slender lateral veins are given off alternately at an angle of approximately sixty degrees (Text fig.5). Halfway across the lamina the veins dichotomise at an angle of 120 degrees. Each dichotomous branch is confluent with the vein adjacent to it before a second dichotomy. The area between the distal ends of the veins is filled with a network of anastomosing and dividing ultimate veins. The leaf is sterile.

Discussion: A similar type of venation occurs in a sterile specimen of Laccopteris (phlebopteris) rigida (Heer) Seward (1927, p.82, text-figure). The lateral veins of this specimen, however, dichotomise near the midvein at an angle of greater than 120 degrees and the reticulum is coarser.

Genus MATONIDIUM Schenk

MATONIDIUM CF. M. GOEPPERTI (Ettingshausen)

Pl. 2, fig. 3.

Selected Synonomy:

1852 Matonidium goepperti (Ettingshausen) ?, p.16; pl.V
fide: Seward, 1910, p.362). Jurassic, Europe.

Description: Single poorly preserved specimen consisting of two fertile pinnules, set 6 mm. apart, on an axis 16 mm. in length. The pinnules are both on the right of the axis 4 mm. long, 3 mm. wide at the base, 2 mm. wide at the tip, and semicircular in shape. Each pinnule contains six rounded sori in 2 rows, flattened at points of contact. The top of one sorus (not figured) is removed, revealing at least five sporangia arranged in a ring. It cannot be determined whether or not the sporangia are syangial.

Discussion: In size and appearance the specimen agrees with Matonidium goepperti (Ettingshausen) ? . Ettinghausen's samples, however, have between fifteen and twenty sporangia per sorus.

Distribution: The genus Matonidium is prominent in European floras of Jurassic age (Seward, 1910, p. 361). M. Goepperti, however, is first found in Lower Cretaceous rocks.

Harris (1931a p.70) considers that the only characters separating Laccopteris (Phlebopteris) from Matonia and Matonidium are the presence of a complete annulus, and sori without an indusium, in the latter genera.

PTEROPHYTA INCERTAE AFFINATIS

AXIS A

Plate 2, fig.1

Description: Axis fragment, 9 mm. long, 1.5 mm. wide, bearing opposite or subopposite leaflets which are given off at an angle of approximately 80°, at 4 mm. intervals. Apices of leaflets are obscured. Each leaflet is linear-ovate, at least 5 mm. long and 3 mm. wide, decurrent on the axis, and shows a pronounced venation. (Text-fig.6). Main vein 0.5 mm. wide; lateral veins are given off from the main vein at an acute angle, dichotomising at least once. Several of the leaves bear rounded bodies in a line parallel to the axis, which may be sori or sporangia (Text-fig.6).

The venation of the pinna is similar to the venation of the lamina fragments attached to the branches of Axis B, described below.

Discussion: The possible fruiting bodies on the leaf laminae suggest filicean affinities and therefore the axis has been included in the Pterophyta.

AXIS B

Plate 2, fig.2

Description: Weathered fragment of a finely striated, carbonaceous axis, 15 mm long and 1.25 mm. wide. Two pairs of alternate or subopposite lateral branchlets are given off at an angle of approximately 80° at 4 mm. intervals. There are traces of lamina with wide lateral veins on either side of the branches. In the axis of one branch is a fragment of an unattached leaf with similar venation. It is not possible to determine whether each branch bore one leaf or several.

Discussion: Axis B. is similar in size and appearance to Axis A. and may be a poorly preserved specimen of the same type.

Division ARTHROPHYTA

Order EQUISETALES

Family EQUISETACEAE

Genus EQUISETITES Sternberg.

EQUISETITES SP.

Pl. 2, fig. 4.

Description: Poorly preserved impression of a tip of a leaf or leaf sheath which is 5 mm. long, 12 mm. wide, tapering slightly inwards from the distal margin. The margin is divided into five lobes of varying size. The divisions are probably shallow compared to the size of the leaf, extending about 4 mm. into the blade. There are numerous fine longitudinal striations on the lamina.

Discussion: Some of the Triassic and Mesozoic species of Equisetites had leaf sheaths comparable to those of the fragmentary specimen described above (Andrews, 1961, p.274).

Distribution: Equisetites is common in early Mesozoic floras.

Division CYCADOPHYTA

Order CYCADALES

Family CYCADACEAE

Genus NILSSONIA Brongniart.

NILSSONIA PTEROPHYLLOIDES Nathorst

Pl. 2, figs. 6,7,8.

Selected Synonomy:

1878 Nilssonia pterophylloides Nathorst, p.11 (fide: Ward, 1917 p.572). Rhaetic, Scania.

1878 Nilsonia pterophylloides Nathorst, in: (Heer, p.98; pl.11 Jurassic, Spitsbergen.

1905 Nilsonia pterophylloides Nathorst in: Ward, pp. 96-97; pl. XVIII. Jurassic, Oregon, United States.

Description: Fragment of a thick, lanceolate leaflet, 16 mm. long and 3 mm. wide which tapers slighly, with the tapered portion truncated or damaged. Seven longitudinal grooves are present, with a single, unbranched vein lying on the lamina between each pair. A pointed leaf apex with similar venation is illustrated in Pl. 2, fig. 6. Fragments of both impressions and compressions of these leaflets are common in the flora. Their insertion on the midrib is never seen.

Discussion: In venation, possession of grooves, and shape, this specimen compares with isolated leaflets of the species described by Heer (1878, p.98; pl.II) and Ward (1905, p.96; pl.XVIII). The specimens described by Ward are at least 5 mm. wide at the base and up to 65 mm. long. The largest specimen in the material under investigation is 3 mm. wide: beacause a leaf base is never seen, it is inferred that the fragments described are medial or apical segments of the leaves.

Distribution: Nilssonia pterophylloides Nathorst is found in many Rhaetic and Jurassic floras of the Northern hemisphere.

NILSSONIA PARVULA

(Heer) Fontaine

Pl. 2, fig. 5.

1876 Taeniopteris parvula Heer, p.98; pl.xxi, figs. 5,5b. Jurassic, Siberia.

1905 Nilssonia parvula (Heer) Fontaine in: Ward, 1905, p. 92 pl.XVII, figs.1-7. Jurassic, Douglas Co., Oregon.

Description: Part of a lanceolate leaflet compression, which is 4.5 mm. wide and 40 mm. in length. Both tip and base are missing. A corded vein, 1.5 mm. wide, from which numerous, fine, lateral veins are given off at right angles, is present in the center of the lamina. Distally the veins curve (rarely forking) to meet the thickened margin of the lamina. A number of similar specimens have been found.

Discussion: The venation and shape of the leaf are characteristic of the Bennettitalean frond Taeniopteris as well as Nilssonia. Taeniopteris, however, has a well defined midrib on both surfaces of the leaf and unforked lateral veins. The central raised "cord" and the rarely forked veins are characteristic of Nilssonia (Berry, 1911b, p.625). In this genus the lamina is attached to the upper surface of the leaf. On the upper surface the midrib position is occupied by a raised "cord".

In size and external appearance, the specimen illustrated agrees with specimens of Nilsonia parvula (Heer) Fontaine, illustrated by Heer (1876) and Ward (1905). Heer (1876) identified a single specimen from the Jurassic of Siberia. His circumscription was emended by Fontaine who examined plentiful material from the Jurassic of Oregon showing undoubted characteristics of Nilssonia (Fontaine in: Ward, 1905, p.92).

Throughout his paper Ward (1905) refers to 'Nilsonia'. The genus was originally named after the Swedish naturalist Nilsson (Seward, 1917, p.566) and the correct spelling is Nilssonia.

Distribution: Nilssonia parvula (Heer) Fontaine is found in the Jurassic of Siberia and North America.

NILSSONIA ? sp.

Pl. 2, fig. 8.

Description: Compressed, isolated, circular seed, 4 mm. in diameter, which is borne on a curved sporophyll, 3 mm. long, 2 mm. in width. The seed is made up of two concentric rings of cells around a thickened, central area. The cells of the outer ring have thickened margins.

Discussion: This specimen resembles seeds of Nilssonia incisoserrata Harris (1932, p.53; pl.5, fig.11) from Rhaetic and Jurassic strata of Greenland. The specimens figured by Harris show the concentric rings of cells and the curved sporophyll, but are 10-12 mm. in diameter and have characteristic round thickenings formed by resin cells.

Distribution: Nilssonia is a widely ranging genus found in Rhaetic to Lower Cretaceous strata throughout the northern hemisphere. (Seward, 1917, p.566a).

Order BENNETTITALES

Genus ZAMITES Brongniart

ZAMITES SP. A

Pl. 2, fig. 11.

Description: Impression of a basal leaf fragment which is 3.5 mm wide, lanceolate and basally rounded. Eleven prominent ridged veins are present parallel to the margins of the leaf. At the base of the leaf, the lamina is slightly thickened.

Discussion: Heer (1883, p.38) defines Zamites Brongniart in the following way: "pinnae lanceolate, base rounded, nerves numerous, parallel." This specimen conforms closely with Heer's circumscription.

Halle (1913, p.55 - fide Seward, vol.III, p.531) revises the description of Zamites and includes in the genus "fronds with a contracted and always symmetrical base." He mentions as diagnostic the presence of a basal callosity. The characteristics of the specimen agree with this more restricted definition.

Distribution: Zamites ranges from the Rhaetic to the Lower Cretaceous (Seward, Vol. III, p.532).

WILLIAMSONIA Carruthers

WILLIAMSONIA SP. A

pl. 2, figs. 7a.

Description: Fragmented bennettitatlean-like 'flower' with a compressed elliptical receptacle which is basally pointed and expanded distally. The receptacle is 3.5 mm. in length and 3 mm. across at the distal distal end, from one side of which radiate the impressions of three overlapping, ovate bracts. Those on the right hand side of the specimen are not preserved. The bracts are 2.5 to 4 mm. in their medial portions, showing numerous, raised, discontinuous, longitudinal striations of varying sizes. Two rounded, longitudinally striated lobes, 1 mm. in length, 1 mm. wide basally, with pointed, thickened tips are present at the distal end of the cup. Only one specimen was found.

Discussion: The cup-shaped base, opening into expanded lobes, is typical of Williamsonia Carruthers (Andrews, 1961, p.306). The 'flowers' of Williamsonia, however, are generally much larger. Poor preservation made it impossible to determine whether this specimen was monosporangiate or bisporangiate.

Distribution: Williamsonia has a wide geographical distribution throughout strata of Jurassic and Lower Cretaceous age.

WILLIAMSONIA ? SP.

Pl. 2, fig. 10.

Description: Elongate sheath, 3 mm. long, 5 mm. in basal width, which expands to a distal width of 2 mm.; the distal end is incomplete. The sheath encloses an expanded, irregularly bifurcate, ovate bract, 2.3 mm. at the medial portion, convex, probably from compression; longitudinal veins radiate from the base to the margins; a prominent longitudinal vein runs from the bifurcation to the sheath. The blade is thick and probably was fleshy.

Discussion: A similar specimen is figured by Fontaine in: Ward 1905, pl.XXIX, fig 11, without the elongate sheath but showing an irregular mark on the blade which probably indicated the limit of a former sheath, ending approximately a third of the distance from the basal end. Fontain (Ward, 1905, p.119) considers that the structure is probably the "bract of the involucre of some form of Williamsonia". Fontaine's specimen (pl.XXIX, fig.11) shows nervation radiating to the margins. This condition is also shown by the specimen described above but the veins do not dichotomize near the margins as in Fontain's larger specimen. The specimen (pl.2,fig.10) compares in size with the Williamsonia 'flower' (pl.2, fig. 7a).

Division GINKGOPHYTA

Order GINKGOALES

Genus LEPTOSTROBUS (Heer) Harris

LEPTOSTROBUS SP.

Pl. 2, fig. 13.

Description: Elongated, compressed, cylindrical cone, 22 mm. long and 6 mm. wide, which consists of at least twelve loosely imbricated bracts, approximately 2.5 mm. long, with narrow bases and expanded, thickened, lobed margins approximately 3 mm. in width. The bracts are given off the axis at an angle of approximately 45°, and have at least three lobes. Bracts at the base of the cone are broken. No visible pollen sacs or ovules are seen on the scales.

Discussion: The specimen agrees with the description of the genus Leptostrobus Heer (in Heer 1876, p.72) from the Jurassic of Siberia. Heer regarded Leptostrobus as a seed-bearing conifer cone allied to Voltzia. Harris (1935, p.136) emended Heer's description and showed that the lobed bracts are stalked, open cups arranged in a loose spiral and pointing forward and outward. Each cup is divided at the apex into five or six rounded lobes; the base of the cone is covered with semicircular scales. Harris refers Leptostrobus to the Ginkgoales because the cuticle of the axis of Leptostrobus longus Harris from the Lias of Greenland is almost identical with that of Czekanowskia hartzi, a ginkgophyte leaf found in association with that species. Harris suggests that the cups are either seed-bearing cupules which have lost their seeds or pollen-bearing structures made up of a large ring of pollen sacs dehiscing on their inner side. Harris found large amounts of pollen grains of two types within the 'cups' of Leptostrobus longus.

The figured specimen is not referable to Leptostrobus longus Harris, which has larger sporophylls arranged at wider intervals on the axis. Ginkgophyte leaves have not been found in the material, although there are a number of seed bearing complexes referred to the Ginkoales.

Distribution: Leptostrobus is found in Jurassic strata in the northern hemisphere.

Genus STENORACHIS Saports

STENORACHIS DUBIUS Antevs

Plate 2, fig. 9.

1919 Stenorachis dubius Antevs. Lias, Sweden.

Description: Two ovoid, "nutlike" bodies which are borne in a single cupule, and are unequal in size; one is 1.75 mm. in length and width; the other 2.75 mm. in length and width. The wedge-shaped cupule 3 mm. wide and 3 mm. constricts into an axis 1 mm. wide. The cupule dichotomizes unequally at its apex, with the greater division on the side of the larger ovule. The ovules are longitudinally striated and the cupule surface is irregularly striated.

Discussion: The genus Stenorachis includes specimens consisting of a central axis bearing lateral appendages, sometimes split into two divergent arms, each of which bears an oval, longitudinally striated body (Seward, 1919, p.56)

The specimen described resembles Stenorachis dubius, a cupulate ovule-bearing structure from the basal Jurassic (Lias) of Sweden, in external appearance, but is smaller in size, the ovules of S. dubius Antevs being about 4 mm. long.

The cupule and ovoid ovules are characteristic of the Ginkgoales.

Distribution: Stenorachis dubius is found in Lower Jurassic strata of Sweden and Greenland (Harris, 1946).

STENORACHIS ? SP.

Plate 2, fig. 12.

Description: Striated axis 10 mm. long which dichotomizes unequally at least twice and bears paired, ovoid, "nutlike" bodies, probably ovules, at the apices of the ultimate dichotomies. The two ovules are unequal in size, 2 to 2.5 mm. long and 1.5 to 1.75 mm. wide, and are partially enclosed in a cupule 2.5 mm. in width; this cupule partially obscures the remainder of the ovules, of which six are visible. The ovules are compressed, with longitudinal striations radiating from the pointed apices. The cupule is slightly and unequally divided at the apex.

Discussion: This structure resembles a truss of ovules of the recent genus Gingko. A similar truss is described by Newberry (1895) from the Amboy Clays under the generic name Tricarpellites. It consists of a group of "nutlike", irregular, ovoid fruits, enclosed in a longitudinally striated husk or shell with a sharp apex and rounded base, usually in groups of three or eight at the apex of a stem (Newberry, 1895). These fruits, although similar to the described specimen in size and appearance, seem to be borne singly on the axes and do not have cupules. The cupule-ovule "complex" of the described specimen compares closely with the cupule and ovules of Stenorachis dubius (Pl. 2, fig. 9). The ovules of Stenorachis? sp. A, however, are elongate with more slender cupules. The two, therefore, are probably not conspecific but do belong to the same genus, Stenorachis.

Distribution: Stenorachis is found in strata of Rhaetic and Jurassic age in Scania, Belgium, Afghanistan and possibly Siberia (Seward, 1919, p.57).

Division CONIFEROPHYTA

Order CONIFERALES

Family ABIETACEAE.

Genus ABIETITES Goeppert

ABIETITES ? SP.

Plate 3, fig. 5.

Description: Basal fragment of a coniferous cone which bears both ovuliferous scales and bract scales. The cone scales, which are probably woody in life, are massive, imbricated, thickened and expanded distally; with crenulate margins and striae radiating from the distal margins. Scales increase in width from 5 mm. at the base to 8 mm. at the top of the fragment. The length of the scales varies from 3 to 4 mm. No axis is visible; the cone appears to have been sessile. On either side of the specimen, there are broken, elongate, lanceolate bract scales approximately 1.5 mm. wide. No ovules are found.

Discussion: Large, elongate bract scales and persistent ovuliferous scales are shown in several recent genera of the Abietaceae (e.g. Abies and Psuedotusga: Seward, 1919, p.155). This specimen has been tentatively included, therefore, in the genus Abietites (Seward, ibid, p.369). The massive scales are comparable with those of Pityostrobus Nathorst, a genus also referred to the Abietaceae.

Distribution: Seward considers that the Abietaceae are not commonly represented until the Upper Jurassic (Seward, ibid, p. 369), becoming well established by the Lower Cretaceous. Seeds, and pollen grains with bladders like those of modern genera, however, have been found in the Late Triassic and Early Jurassic strata (Delevoryas, 1962).

Genus PINUS Linneaus

"PINUS" NORDENSKIOLDI Heer

Pl. 3, fig. 4.

Selected Synonomy:

1876 *Pinus nordenskioldi* Heer, p. 45; pl.ix, Jurassic, Spitsbergen

1905 *Pinus nordenskioldi* Heer, *in*: Ward, p.131; pl.xxxv, figs. 1-6, Jurassic, Oregon.

Description: Three, thick, isolated leaf compressions, each approximately 6 mm. long, 1.5 mm. wide at the base, which tapers to an acuminate tip. Each leaf has a strong, median vein with faint longitudinal veins on either side of it.

Discussion: The characters described are those of *Pinus nordenskioldi* Heer (1876, p.45). These are unspecific, external characters only, however, and therefore the species should not be referred with certainty to the extant genus *Pinus*.

Distribution: *Pinus nordenskioldi* is found in Jurassic strata of the northern hemisphere (Beauverie, 1933).

Genus PITYOLEPIS Nathorst

PITYOLEPIS sp.

Pl. 3, fig. 2.

Description: Impression of a pair of curved, fused bracts 4 mm. long and approximately 1.5 mm. wide, with narrowed bases which expand into free, irregularly lobed, thickened tips. There is one deep seed impression per bract, 1.75 mm. in width, 1.mm long, which is lobed, suggesting that two seeds were originally present.

Discussion: The presence of two seeds per scale is characteristic of the Abietaceae although two seeds per scale are also occasionally found in the Araucariaceae. (Seward, 1919, p.369). Curved bract scales with an irregularly lobed, thickened distal margin and basally positioned ovules are seen in representatives of the recent genus Pinus. (Foster and Gifford 1959, p. 392) Nathorst (in Seward 1919, p.371) proposed the name Pityolepis for cone scales with Abietaceous characters.

Family ABIETACEAE (Provisional assignment)

Genus PITYOSTROBUS Nathorst

PITYOSTROBUS sp.

Pl. 3, fig. 1.

Description: Weathered, cylindrical cone impression, 5 cm. long and 2 cm. wide, which is borne on a stout stalk 1.5 mm. long and 1mm. wide, covered with small, spirally arranged, imbricate, pointed scales.

The cone consists of numerous, thin, rectangular cone scales, probably leathery in life. Each scale is approximately 3.5 mm. long, 3 mm. in width at the base diminishing in size towards the apex of the cone. No seed impressions were found. Elongate bract scales approximately 6 mm. long, with lobed, thickened apices occur between the cone scales.

Discussion: The described specimen resembles the modern genus Larix (Abietaceae) in shape and size of the female cone, in the appearance of the bract and cone scales and in the presence of an axis covered with small scales. (Seward p.157). The genus name Pityostrobus has been used by Nathorst (in Seward 1919, p.371) for cones showing Abietaceous affinities. This name, although not in accordance with modern taxonomic usage, has been used since the specimen cannot be identified more specifically. The position and number of the ovules is not known, therefore the specimen is only provisionally assigned to the Abietaceae.

Family ARAUCARIACEAE

Genus ELATIDES Heer

ELATIDES BRANDTIANA Heer

Selected Synonomy:

1876 Elatides brandtiana Heer, p. 77-79; pl. XLV.
Jurassic, Siberia.

Description: Elongate, cylindrical impression of a male cone which is 3.3 cm. long, 8 mm. in width. The cone is made up of numerous, flat, ovate-elongate, strongly striated scales, approximately 3 mm. long, 2 mm. in width, with acuminate apices and narrow bases. The edges of the bracts are slightly irregular.

Discussion: Heer (1876) proposed the name *Elatides brandtiana* for cylindrical strobili, 3 to 3.5 cm. long, bearing leathery, rhomboido-elliptical scales with acuminate apices and striated microsporophylls. Seward (1919, p.270) considers that the genus probably belongs to the Araucarineae.

Distribution: *Elatides* is characteristic of Rhaetic, Jurassic and Lower Cretaceous floras (Seward, *ibid*.).

Genus PAGIOPHYLLUM Heer

PAGIOPHYLLUM sp.

Pl. 3, fig. 9.

Description: Weathered axis 17 mm. long, 9.5 mm. wide, with crowded spirally arranged linear leaves which are given off the axis at an angle less than 45 degrees. The leaves, approximately 7 mm. long, are curved, pointed and have a distinct dorsal keel. The leaves transgressing planes of foliation of the rock have been broken off or crushed against the other leaves. Cuticle analysis gave no information on the cuticle or stomata because the cells were damaged by heavy mineralisation.

Discussion: *Pagiophyllum* is a form genus instituted for fossil leaves with araucarian affinities (Seward, 1919, p.275).

Distribution: The genus occurs widely in strata of Jurassic, Cretaceous and Tertiary ages in the northern and southern regions and in both polar areas (Plumstead 1962).

Family TAXODIACEAE

Genus TAXODITES Unger

Taxodites ? sp.

Pl. 3, fig. 8.

Description: Weathered, globose cone which is 8.5 mm. in diameter and 14 mm. long, and has a narrow, naked stalk. The cone consists of few, imbricate, spirally or possibly decussately arranged, stalked ovuliferous scales, varying in shape from wedgeshaped with a rounded apex to irregularly heart-shaped. They are approximately 6 mm. long. Each heartshaped scale has a blade approximately 2 mm. in width, which varies in length from 2 to 3 mm. The central scales are united in pairs by a bract with a slender stalk which expands to a width of 2.5 mm. and then tapers to a point 2 mm. from the distal ends of the ovuliferous scales. This bract is formed from two bracts fused at the midline. The bracts have fine longitudinal striations, and each ovuliferous scale has coarser striations radiating to the margin from the base. No seeds were found.

Poor preservation makes it impossible to see whether all the scales are united in pairs by bracts and whether the paired scales are fused.

Discussion: The described specimen has been provisionally included in the Taxodiaceae because it has taxodiaceous characters: the cones are globose, thecone scales spirally or decussately arranged, and partially consolidated with the bracts. (Florin 1951, p. 350, Dallimore and Jackson 1954).

The specimen has been assigned to the genus Taxodites because of a superficial resemblance to the cone Taxodites europaeus (Seward, 1919, p. 329). This cone is globose, with 18-20 semicircular scales each subtended by a stalked bract. The ovuliferous scales, however, have deeply divided margins and are not in pairs.

Distribution: Taxodites europaeus is found in Cretaceous and Tertiary strata (Seward 1919, p. 329). The Taxodiaceae, however, extend back into the Jurassic or possibly earlier (Delevoryas 1961, p.163) although Taxodites is not usually found before the Cretaceous (Seward, 1919, p.328).

TAXODITES ? sp.

Plate 3, fig. 6.

Description: Paired cone scales which are very similar to those of the above specimen. They show that the paired ovuliferous scales are fused to each other and to the bract scale.

A number of these paired scales are found in the deposit.

Many species of the Taxodiaceae have deciduous scales, therefore complete taxodiaceous cones are rare in the fossil record (Chaney, 1950, p. 172). This could account for the lack of fertile taxodiaceous material in rocks older than Cretaceous in age.

Genus SEQUOIA Endlicher

SEQUOIA sp.

Pl. 3, fig. 3.

Description: Upper portion of a poorly preserved, cylindrical cone, 19 mm. long and 12 mm. wide, which has a stout axis and a rounded apex. It consists of numerous peltate or wedgeshaped scales. The majority of scales are peltate with thickened apices. Both types have a deep median sulcus. No seeds were found.

Discussion: The specimen described resembles a specimen of *Sequoia reichenbachi* (Gein.) Heer, from the Upper Cretaceous of Greenland (Heer, 1868, p.77; pl.xii). This species, however, has been emended by Berry (1911, p. 243) and the described specimen does not agree with his more specific definition.

Cylindrical cone shape and peltate or wedgeshaped scales with transverse depressions are characteristic of the genus *Sequoia* (Harlow and Harrer, 1941, p.188).

Distribution: *Sequoia* first becomes common during the Cretaceous (Harlow and Harrer 1941, p. 186). Cones similar to those of the modern *Sequoia* however, are known from the Jurassic (Delevoryas 1961, p.163).

CONIFERALES INCERTAE AFFINATIS

PODOZAMITES Braun

PODOZAMITES LANCEOLATUS var. LATIFOLIUS (F.Braun), Heer

Pl. 4, fig. 3.

Selected synonomy:

1840 *Zamites latifolius* Fr Br. non (Brongn.) *in*: Presl, p.100.

1847 *Zamites distans latifolius* Fr. Br. p.85

1870 Podozamites lanceolatus latifolius (Fr.Br.) Heer, p.109 pl. XXVI, figs. 5,6,8B,8c. Jurassic, Siberia.

1905 Podozamites lanceolatus latifolius (Fr. Br.) Heer, in: Ward, p.112, pl. XXV, figs. 5-7. Jurassic of Oregon, North America.

Descriptions: Stem fragment, 1.5 mm. wide, 8 mm. long, rounded and slightly compressed, with pronounced longitudinal grooves. One leaf, with a decurrent base, is given off the stem at an angle of approximately 45 degrees, and is folded and pressed against the stem. The leaf is ovate, folded in two, with a folded width of 4 mm. and therefore an expanded width of at least 7 mm., and it tapers towards the apex (not present). At least 8 longitudinal grooves are present, with slender longitudinal unbranched veins lying between them. The leaf lamina is thick, and was probably fleshy in life. Leaf margins are entire. To the right of the stem previously described lies a leaf impression fragment, 6 mm. wide with similar venation but with a linear shape.

Discussion: The leaf attached to the stem described above compares closely in shape and venation, but not in size, with specimens of Podozamites lanceolatus latifolius figured by Heer (1876, pl. XXVI, figs. 5,6,8b,8c), and Ward (1905, pl. XXV, figs. 5-7). Specimens figured by Ward may reach half an inch in length. The described specimen could either be a small representative of this species or possible a difference Podozamites species.

Podozamites, once regarded as a pinnate leaf, is now considered to be a leafy stem as a result of Nathorst's discovery that the leaves of certain species are attached spirally (Harris 1935).

Harris (*ibid.*) considers that *Podozamites* is an artificial group containing many species which are not easily distinguished. *Podozamites* species have very fragile cuticles. Those examined have been of generalised gymosperm type, more comparable with cuticles of conifers than with those of cycads.

Distribution: *Podozamites lanceolatus latifolius* is found in Jurassic strata of Europe, Siberia and North America.

PODOZAMITES sp.

Pl. 4, fig. 1.

Description: Rounded, compressed stem, 2 mm. wide, with longitudinal striations which is associated with two stalked leaves. The insertion of the leaves is not seen; however, both leaves lie at an angle of approximately 75 degrees towards the stem. The leaves are ovate-lanceolate, at least 4.5 mm. wide near the base, tapering sharply towards the apex, which is not present. The leaf lamina is thick and was probably fleshy in life. Parallel veins approximately 10 in number, slender but distinct, lie between longitudinal grooves (resin ducts, Harris 1935). Both ducts and veins converge towards the apex.

Discussion: The specimen shows venation and shape similar to *Podozamites*, but is smaller than the majority of species of this genus.

Leaf fragments of similar size and appearance are common throughout the material.

genus SWEDENBORGIA Nathorst

SWEDENBORGIA ? sp.

Pl. 3, fig. 10.

Description: Partial compression of two triangular overlapping sporophylls borne on a massive, grooved axis 4 mm. long, 2 mm. wide at the base, which expands to a width of 3 mm. at its apex. Each sporophyll is approximately 4 mm. long, 2 mm. wide at the base and .5 mm. wide at the pointed apex, and has a vertical inner edge and a curved outer edge, narrowing to the apex. A number of anastomosing veins radiate to the curved margin. The lamina between the veins is frequently drawn into folds. The lamina of the foremost sporophyll either overlaps the lamina of the second sporophyll or is continuous with the axis. The relationship is not clear because the axis has been damaged at this point.

At the base of the curved edge of each bract there is a small, curved spur which may have contained an ovule.

Discussion: Similar bracts with spurs containing ovules, are seen in *Swedenborgia* (Nathorst *in*: Harris 1935, p.107). This form is characterised by slender axes dividing apically into 5 approximately equal, spurred lobes. In species figured by Harris (*ibid* pl.18, figs. 8 and 10 - 22; pl.19, figs. 5-8, 10-14, 17 and 20-22) the bract scales are slender and five or more in number. In the specimen described, there are only two bracts, which are not slender and are borne on a stout axis. The specimen has been tentatively included in the genus *Swedenborgia* on the basis of the spurs.

Swedenborgia is considered to resemble the recent cupress-aceous genus Cryptomeria. (Harris, ibid, p.108). The main difference between the two genera is that the cone scale of Cryptomeria is more solid and its parts more intimately fused.

Distribution: Swedenborgia is found in Rhaetic and Lower Jurassic strata of Greenland and Europe.

genus SCHIZOLEPIS Braun

SCHIZOLEPIS CYLINDRICA Nathorst

Pl. 4, fig. 6.

Synonomy:

1879 Schizolepis cylindrica Nath. p. 39; pl.2, figs. 1,2
Upper Jurassic, Spitsbergen

Description: Impression of a pair of stalked cone scales. One scale is 3.5 mm. long, 2 mm. wide, the other is 3 mm. long, 2 mm. wide. Both are spatulate in shape, narrowing basally into fused stalks, 2 mm. long, 1 mm. in width. The scales are longitudinally striated, the striations coverging at the junction of the scales and and the stalks. The scales are free for two-thirds of their length but overlap or fuse near the junction with the stalks. At the base of each scale, above the stalk, there is an impression of a single, oval seed, 1.5 mm. wide, 1 mm. long.

Discussion: These isolated, paired scales are similar to the paired cone scales from a cone of Schizolepis cylindrica (Nathorst 1879, pl.2, fig.2). The described specimen is smaller than Nathorst's specimen.

Distribution: Schizolepis cylindrica is found in Upper Jurassic strata of Spitsbergen (Nathorst ibid).

SCHIZOLEPIS cf. S. RETROFLEXA Nathorst

Pl. 4, fig. 2.

1879 Schizolepis ? retroflexa Nathorst, p.60, pl.3, figs.11 and 12. Upper Jurassic, Spitsbergen.

Description: Impression of an elongate, cylindrical strobilus, 32 mm. long, 3 mm. wide at the base and expanding distally to a width of 9 mm. at the apex. It consists of at least 9 loosely imbricated, fused, ovate bracts with free spatulate apices. The bracts are fused in pairs or threes and vary in size from 3 mm. long, 1.5 mm. wide, to 4 mm. long and 2 mm. wide. The fused bracts are borne on single, elongated narrow stalks, which expand distally into small collars 1 mm. wide, on which the bracts are borne. The basal bracts are folded and pressed against the axis, the distal bracts expanded. All bracts are radially striated. A single, winged seed is borne on the adaxial surface, of the fused bracts.

Discussion: The figured specimen compares with Schisolepis ? retroflexa (Nathorst, 1879, pl.3, figs. 31). The figured specimen is much smaller, however and has a greater number of fused bracts, more closely packed on the axis.

Florin (1951) noted that Schizolepis is a seed scale complex, formed by three partially fused steril scales and three megasporophylls. He shows that the megasporophylls are fused to the ovuliferous scales as in later conifers.

Seward (1919, p.440) considers that Schizolepis is possibly allied to the Abietineae. amd draws attention to a similarity between the scales of Schizolepis and the reflexed cone scales of Picea brewiana.

Distribution: Schizolepis ? retroflexa is found in Upper Jurassic strata of Spitsbergen only. Schizolepis, however, is a genus with a predominately Upper Triassic to Lower Jurassic range, a few species rarely occuring in the Middle and Upper Jurassic (Seward ibid, p. 442; Florin, 1951, p.345).

Cone A

Pl. 4, fig. 4.

Description: Entire, cylindrical, cone compression, 23 mm. long, 8 mm. wide which consists of a number of loosely imbricate scales pressed to the axis. Scales at the distal end of the cone are ovate-elongate and possibly sterile. Scales in the centre of the cone are wedge-shaped and 3 mm. long. They appear to be fused in pairs, the distal ends free, rounded and approximately 1.5 mm. wide. The impressions of the adaxial surface of two pairs of bracts occupy the centre of the cone. No seed impressions are present; instead two elongate saclike impressions, 1.5 mm. long, 0.25 mm. wide, probably the marks of pollen sacs, are present on each scale beneath the free, distal apices.

Discussion: The fertile cone scales of the described specimen resemble those of Schizolepis brauni from the Rhaetic of Germany, which is characterised by deeply split cone scales. No pollen sacs have been discovered in species of Schizolepis (Seward, 1919, p.441). The described specimen also resembles the extant genus Pinus in the number and appearance of pollen sacs. Fused microsporophylls, are not present in this genus (Bold 1957, p. 493).

PLANTAE INCERTAE SEDIS

Genus CARPOLITHUS Harris

CARPOLITHUS sp.

Pl. 4, fig. 5

Description: Impression of a compressed oval, seedlike body, whose axis is 11.5 mm. in length and circumference 9 mm. Part of the seed has a smooth, thin integument; the remainder is divided into two irregular, elongated regions by a raised median ridge.

Discussion: Harris (1935) defines the genus Carpolithus as a more or less oval seed of unknown structure. In this group he includes "uncutinised seeds, isolated 'stones' of seeds and possibly bodies which are not seeds at all." (Harris, 1935, p.120).

# CHAPTER IV

## MIOSPORES

Miospores from the rock matrix surrounding the Ellesmere Island macrofossils were used for dating the deposit. Most identifications are tentative, being based on a few specimens, or in some cases only on one.

The miospores were classified following the system used by Wall (1965). Different systems of classification and nomenclature were employed by several of the authors mentioned below, but detailed taxonomic discussion is beyond the scope of this chapter.

The miospore names used are those of the original author in most cases. Synonomy and validity of each species is not considered in this chapter. Almost certainly, however, many species mentioned here may ultimately prove to be synonymous with others.

Principal works on Triassic and Jurassic spores used here are: Nilsson (1958), Couper (1958), Klaus (1960), McGregor (1965), Wall (1965). A list of leading Lower Jurassic palynological references is given in Wall (1965).

The botanical affinities of the miospores are not considered. (Potonie 1962 gives a complete summary of the known affinities of spores.) No description or photographs are given, the reader being referred, in all cases, to the original definitions.

### TRILETE SPORES

#### Genus CYATHIDITES Couper

##### CYATHIDITES AUSTRALIS Couper

Selected Synonomy:

1953 Cyathidites australis Couper, p. 27; pl. 2, fig. 11. Jurassic and Lower Cretaceous of England and New Zealand.

1965 Cyathidites australis Couper, in: McGregor, pl. 11, fig. 6; pl IV, fig. 1; pl. V, figs. 1, 2; pl. VIII, figs. 3,4. Upper Triassic, Jurassic and Cretaceous of Arctic Canada, including Ellesmere Island.

CYATHIDITES MINOR Couper

1953 Cyathidites minor Couper, p.28; pl. 2, fig. 13, fide Couper 1958, p. 139. Jurassic and Lower Cretaceous of New Zealand, England.

1965 Cyathidites minor Couper, in: McGregor, pl. VII, figs. 3, 4. Lower Cretaceous of Artic Canada.

Genus LIEIOTRILETES (Naum.) Pot. and Kr.

LEIOTRILETES MEDIUS Nilsson

1958 Leiotriletes medius Nilsson, p.31; pl. 1, figs. 2-4. Lower Jurassic of Sweden.

Genus CONCAVISPORITES (Pflug) Delcourt and Spruemont

CONCAVISPORITES TORALIS (Leschik) Nilsson

Selected Synonomy:

1955 Laevigatisporites toralis Leschik, p. 12; pl. 1, fig. 9. Triassic of Switzerland. fide Nilsson, 1958 p. 110.

1958 Concavisporites toralis (Leschik) Nilsson, p. 110; pl. 1, figs 12-13. Rhaetic and Lower Jurassic of Sweden.

Genus ACANTHOTRILETES (Naum.) Pot. and Kr.

? ACANTHOTRILETES OVALIS Nilsson

1958 Acanthotriletes ovalis Nilsson, p. 40; pl. 2, figs 8-9 Lower Jurassic of Sweden.

Genus LYCOPODIUMSPORITES Thierg: ex. Delcourt and Sprumont

LYCOPODIUMSPORITES AUSTROCLAVATIDITES (Cookson) Potonie

Selected Synonomy:

1957 Lycopodiumsporites austroclavatidites (Cookson) Potonie: Delcourt and Sprumont; pl. 3, fig. 27. fide Dettmann, 1963.

1963 Lycopodiumsporites austroclavatidites (Cookson) Potonie, in: Dettmann, p.44; pl. VI, figs. 18-21 (Complete synonomy.) Widely distributed in the Jurassic and Cretaceous.

1965 Lycopodiumsporites austroclavatidites (Cookson) Potonie, in McGregor, pl. III, figs. 47, 48, pl. IV, figs 13, 14. Triassic and Lower Jurassic of Ellesmere Island.

LYCOPODIUMSPORITES sp.

Genus DICTYOPHYLLITIES Couper

DICTYOPHYLLITES HARRISII Couper

1958 Dictyophyllites harrisii Couper, p. 140; pl. 21. figs. 5-6 Jurassic, England.

Genus LYCOPODIACIDITES Couper

LYCOPODIACIDITES sp.

MONOLETE SPORES

Genus MARATTISPORITES Couper

MARATTISPORITES SCABRATUS Couper

Selected Synonomy:

1958 Marattisporites scabratus Couper, p. 133; pl. 15, figs. 20-23 Jurassic and Lower Cretaceous of England.

1958 Marattisporites scabratus Couper, in: Nilsson, p. 50; pl. 3, figs 4-6. Lower Jurassic (Thaumatopteris zone) of Sweden.

1965 Marattisporites scabratus Couper, in: McGregor, pl. III, fig. 1. Upper Trias of Arctic Canada.

Genus CHASMATOSPORITES Nilsson

CHASMATOSPORITES HIANS Nilsson

1958 Chasmatosporites hians Nilsson, p. 55; pl. 4, figs. 3-4. Rhaetic and Lower Jurassic of Sweden.

CHASMATOSPORITES APERTUS (Rogalska) Nilsson

Selected Synonomy:

1954 Pollenites apertus Rogalska, p. 45; pl. 12, figs. 13, 15. fide Nilsson 1958, p. 56. Lower Jurassic of Poland.

1958 Chasmatosporites apertus (Rogalska) Nilsson, pl. 4, figs. 5-6. Lower Jurassic (Thaumatopteris zone) of Sweden.

CHASMATOSPORITES MINOR Nilsson

1958 Chasmatosporites minor Nilsson, p. 58; pl. 4, fig. 10. Lower Jurassic (Thaumatopteris zone) of Sweden.

CHASMATOSPORITES ELEGANS Nilsson

1958 Chasmatosporites elegans Nilsson, p. 58; pl. 4, figs. 11-12. Lower Jurassic (Thaumatopteris zone) of Sweden.

Genus LAEVIGATOSPORITES Ibr.

LAEVIGATOSPORITES sp.

MONOSULCATE SPORES

Genus ENTYLISSA (Naumova) Pot. and Kremp.

ENTYLISSA TECTA Nilsson

Selected Synonomy:

1958 Entylissa tecta Nilsson, p. 62; pl. 5, fig. 13.

Lower Jurassic of Sweden.

Genus MONOSULCITES Cookson ex Couper

MONOSULCITIES sp.

"TRICOLPATE" SPORES

Genus EUCOMMIIDITES Erdtm. emend. Couper

EUCOMMIIDITES TROEDSSONII Erdtm.

Selected Synonomy:

1948 Tricolpites (Eucommiidites) troedssonii Erdtm., p. 267-269 figs 5-10, 13-15. fide Nilsson 1958, p. 64. Rhaetic and Lower Jurassic of Poland, Germany.

1958 Eucommiidites troedssonii Erdtm., in: Couper, p. 160-65, pl. 31, figs. 23-27. Middle and Upper Jurassic and Lower Cretaceous of England.

1958 Eucommiidites troedssonii Erdtm. in: Nilsson, p. 64; pl. 5 figs 17-19 Lower Jurassic (Thaumatopteris zone) of Sweden.

1965 Ecommiidites troedssonii Erdtm., in: McGregor, pl. III, fig. 8; pl. IV, fig. 29. Rhaetic and Lower Jurassic of Ellesmere Island.

This species is not truely tricolpate but rather monosulcate with a ring furrow, as discussed by Hughes (1961).

INAPERTURATE SPORES

Genus INAPERTUROPOLLENITES Thompson and Pflug, emend. Nilsson.

INAPERTUROPOLLENITES ORBICULTATUS Nilsson

Selected Synonomy:

1958 Inaperturopollenites orbiculatus Nilsson, p. 68; pl. 6, figs 2-4 Rhaetic and Lower Jurassic (Thaumatopteris zone) of Sweden, Lower Jurassic of Germany.

SACCATE POLLEN GRAINS

Genus CEREBROPOLLENITES Nilsson

CEREBROPOLLENITES MESOZOICUS (Couper) Nilsson

Selected Synonomy:

1958 Tsugaepollenites mesozoicus Couper, p. 155, fig. 1, pl. 30, figs 8-10. Jurassic and Lower Cretaceous of England.

1958 Cerebropollenites mesozoicus (Couper) Nilsson, p. 72; pl. 6, figs. 10-12. Lower Jurassic (Thaumatopteris zone) of Sweden, Lower Jurassic of Poland.

Genus VITREISPORITES Leschik

VITREISPORITES PALLIDUS (Reissinger) Nilsson

Selected Synonomy:

1950 Pityopollenites pallidus Reissinger, p. 109; pl. 15, figs 1-5 fide: Nilsson 1958, p. 78. Lower Jurassic of Germany.

1958 Caytonipollenites pallidus (Reissinger) Couper, p. 150; pl. 26, fig. 7, 8. Jurassic and Lower Cretaceous of England.

1958 Vitreisporites pallidus (Reissinger) Nilsson, p. 78, pl. 7, figs 12-14. Lower Jurassic (Thaumatopteris zone) of Sweden.

1965 Vitreisporites pallidus (Reissinger) Nilsson, in: McGregor, pl. III, figs. 13, 15; pl. IV, fig. 33, pl. VII, fig. 38. Upper Trias, Lower Jurassic and Lower Cretaceous of Northern Artic Canada.

Genus ALISPORITES Daugherty emend. Nilsson

ALISPORITES ROBUSTUS Nilsson

1958 Alisporites robustus Nilsson p. 82; pl. 8, figs. 2-3. Lower Jurassic (Thaumatopteris zone) of Sweden.

Genus SULCATISPORITES Leschik

SULCATISPORITES PINOIDES Nilsson

1958 Sulcatisporites pinoides Nilsson, p. 86, pl. 8, figs 6-7. Lower Jurassic (Thaumatopteris zone) of Sweden.

Genus PODOCARPIDITES Cookson ex Couper

PODOCARPIDITES cf. P. ELLIPTICUS Cookson

Selected Synonomy:

1963 Podocarpidites cf. P. ellipticus Cookson, in: Dettmann, p. 103, pl. XXV, figs. 8-12 Jurassic and Cretaceous of Australia.

1965 Podocarpidites cf. P. Ellipticus Cookson, pl. IV, figs. 34,35, 41. Lower Jurassic, Ellesmere Island.

Genus CEDRIPIDITES Wodehouse

CEDRIPIDITES cf. C. CRETACEOUS Pocock

Selected Synonomy:

Cedripidites cretaceous Pocok, p. 63, pl. 10, figs 149-150. Jurassic and Cretaceous of Canada.

SPORAE INCERTAE

Genus CIRCULINA Maljawkina

CIRCULINA ? MEYERIANA Klaus

1960 Circulina meyeriana Klaus, p. 165, pl. 36, fig. 57. Upper Trias of Austria.

# DISCUSSION

Fossil plants have long been used as collateral to date sediments, although there are objections to their use without due regard to differential migration of floras. The theory of multiple genesis of floras is not widely accepted today; species are now thought to have arisen in one place and migrated outwards. Species, therefore, could not have reached all areas of the world at the same time, nor would they necessarily have died out simultaneously. In some areas relict assemblages are found persisting long after the assemblage has perished throughout the rest of the world, (Darrah, 1960, p.254).

The use of miospores for dating has more recently become widespread. Miospores are present in many types of sediments, often including those otherwise unfossiliferous. They occur in great numbers and there are many short ranging forms. It is possible, however, that a miospore assemblage from a single deposit could reflect a relict flora, and therefore a number of analyses should be made, over a wide area.

Accurate age determinations should be based on all available stratigraphic, lithological and fossil information.

TABLE I. STRATIGRAPHIC RANGES OF MACROFOSSILS

| Name | Range | | | | | Distribution |
|---|---|---|---|---|---|---|
| | Upper Trias | Jurassic Lower | Jurassic Middle | Jurassic Upper | Lower Cret. | |
| Clathropteris meniscoides | x | x | | | | Worldwide |
| Thaumatopteris schenki | | x | | | | Europe, Greenland |
| Goeppertella microlobus | x | x | | | | Europe, S.E.Asia, Greenland |
| Phlebopteris angustiloba | | x | | | | Europe, Greenland |
| Phlebopteris muensteri ? | x | x | | | | Europe, S.E.Asia, Greenland |
| Phlebopteris sp. | x | x | x | x | x | Worldwide |
| Matonidium cf. M.goepperti | | | | x | x | Europe |
| Equisitites sp. | x | x | x | x | x | Worldwide |
| Nilssonia pterophylloides | x | x | x | | | Scania, Japan, N.America |
| Nilssonia parvula | | x | x | ? | | N.America, Siberia |
| Nilssonia sp. | x | x | x | x | x | Worldwide |
| Zamites sp. | x | x | x | x | x | Worldwide |
| Williamsonia sp. | | x | x | x | x | Worldwide |
| Stenorachis spp. | x | x | x | x | x | N. hemisphere |
| Stenorachis dubius | | x | | | | Sweden |
| Leptostrobus sp. | | x | x | x | | N. hemisphere |
| Pinus nordenskioldi | | x | x | x | | Spitsbergen, N.America |
| Abietites?sp. | ? | ? | ? | x | x | N. hemisphere |
| Pityolepis sp. | ? | ? | x | x | x | N. hemisphere |
| Pityostrobus sp. | ? | ? | ? | x | x | N. hemisphere |
| Taxodites?sp. | | | | | x | Worldwide |
| Sequoia sp. | | ? | x | x | x | N. hemisphere, N.America |
| Elatides brandtiana | | x | x | x | x | Siberia, Arctic |
| Pagiophyllum sp. | x | x | x | x | x | N.hemisphere |
| Swedenborgia sp. | x | x | | | | Greenland, Europe |
| Schizolepis cylindrica | | | | x | | Spitsbergen |
| Schizolepis cf. S? retroflexa | | | | x | | Spitsbergen |
| Schizolepis sp. | x | x | x | x | | Europe, Asia, N.America |
| Podozamites lanceolatus var. latifolius | | x | x | x | | Europe, Siberia, N.America |
| Podozamites sp. | x | x | x | x | ? | Worldwide |
| Carpolithus sp. | not known | | | | | |

TABLE II. STRATIGRAPHIC RANGES OF MICROSPORES

| Name | Range | | | | | Distribution |
|---|---|---|---|---|---|---|
| | Upper Trias | Jurassic Lower | Jurassic Middle | Jurassic Upper | Lower Cret. | |
| Cyathidites minor | | x | x | x | x | England, Arctic, Antarctic |
| Cyathidites australis | x | x | x | x | x | Worldwide |
| Concavisporites toralis | x | x | | | | Sweden |
| Dictyophyllites harrisii | | x | x | x | | England |
| Leiotriletes medius | | x | | | | Sweden |
| ? Acanthotriletes ovalis | | x | | | | Sweden, Antarctic |
| Lycopodiacidites sp. | | | | | | |
| Lycopodiumsporites austro-clavatidites | | x | x | x | x | Worldwide |
| Microreticulatisporites sp. | | | | | | |
| Laevigatosporites sp. | | No stratigraphic significance | | | | |
| Marattisporites scabratus | x | x | x | x | x | Sweden, England Arctic, Antarctic |
| Chasmatosporites minor | x | x | | | | Sweden, Poland |
| Chasmatosporites elegans | | x | | | | Sweden |
| Chasmatosporites hians | x | x | | | | Sweden |
| Chasmatosporites apertus | | x | | | | Sweden |
| Alisporites robustus | | x | | | | Sweden |
| Vitreisporites pallidus | x | x | x | x | x | Arctic, Australia, Sweden |
| Sulcatisporites pinoides | | x | | | | Sweden |
| Cedripites cf. canadensis | | x | x | x | x | Canada |
| Podocarpidites cf. ellipticus | | x | x | x | x | Arctic, Sweden, Australia |
| Inaperturopollinites orbiculatus | x | x | | | | Sweden, Poland, Germany |
| Monosulcites sp. | | | | | | |
| Entylissa tecta | | x | | | | Sweden |
| Eucommiidites troedssoni | x | x | x | x | x | Arctic, Sweden, England |
| Cerebropollenites mesozoicus | | x | x | x | x | Sweden, Poland, England. |
| Circulina ? meyeriana | x | | | | | Austria |
| ? Botryococcus colony | | | | | | |

## Age Estimation of the Deposit

Tables I and II show the known ranges of the macrofossils and miospores found in the deposit. The greatest concentration of species occurs in the Lower Jurassic, a number of miospore species occurring solely at this level. Harris (1937) considers that the macrofossil species Thaumatopteris schenki and Phlebopteris muensteri also occur uniquely to this horizon. The rare species Goeppertella microlobus occurs in the Arctic and Europe only in the Lower Jurassic, although it is also found in Rhaetic-Lower Jurassic strata of Southeast Asia (Zeiller 1903).

There are a number of discordant ranges in Table I: an attempt is made to explain these in the following paragraphs. The identification of Matonidium cf. M. goepperti is for comparison only, the specimen differing significantly from the type specimen. It is possible that the specimen described is an earlier, morphologically similar representative of the genus.

Schizolepis cylindrica and Schizolepis cf. S.? retroflexa have been reported previously but only from the Upper Jurassic of Spitsbergen (Nathorst, 1897). The genus Schizolepis has a mainly Rhaetic-Lower Jurassic distribution, with a few species rarely occurring in Middle and Upper Jurassic strata (Seward, 1919). Further investigation of the two Ellesmere Island Schizolepis species is needed in order to decide whether they are sp. nov. or whether the ranges of Nathorst's species should be extended into the Lower Jurassic.

Taxodiaceous remains have been found throughout the Jurassic and possibly even earlier, (Delevoryas 1962, p.163). Although Taxodites, a form genus for leaves and cones, which compares with the extant genera Taxodium and Glyptostrobus, is first reported from the Lower Cretaceous (Seward, 1919, p.328), the specimen from Ellesmere Island, (pl.3, fig.8) has been included in this genus because of its superficicial resemblance to Taxodium.

The genera Abietites, Pityolepis and Pityostrobus, like Taxodites, are not commonly found before the Upper Jurassic, and only become widespread in the Lower Cretaceous. Winged pollen grains and isolated seed scales comparable to those of extant members of the Abietaceae however, have been found from the Rhaetic onwards, (Cooper, 1958; Delevoryas, 1962). Abietites, Pityolepis and Pityostrobus are subgenera proposed by Nathorst for cones and cone scales showing affinities with modern abietaceous genera, e.g. Pinus, Abies and Larix (Nathorst in Seward, 1919, p.371). Although the use of these subgenera does not conform with the rules of modern botanical nomenclature, (see section on Taxonomy), the author has found them convenient in identifying specimens with apparent abietaceous features, which have not been found in the literature.

The frequent occurrence, in a deposit of Lower Jurassic age, of cones and cone scales with abietaceous characters is unusual since these are rarely found in deposits below the Upper Jurassic. There are three possible explanations:

1. The deposit contains a 'mixed' flora of different ages,
2. The flora is of Lower Jurassic age, and contains a large abietaceous element,
3. The specimens considered here to belong to this family belong to other groups.

The deposit does not contain a 'mixed' flora, since both apparently older and younger elements are frequently found in the same sample. There are no signs of reworking, for example, rounding of specimens, presence of phosphate nodules (Jones 1956, p.262). It is reasonable to expect that, in a reworked deposit the older element would be in a poorer state of preservation than the younger. In the Ellesmere Island deposit the reverse is found, the supposed 'younger' element is in a poorer state of preservation than the Rhaetic-Lower Jurassic index species. Possibly the cones and cone scales forming the 'younger' element (Abietites, Pityolepis, Pityostrobus and Taxodites) were broken and decayed before preservation, since many extant conifers retain their cones for several years after the seeds are shed. Preliminary miospore analysis gives no indication of floras of different ages.

Few abietaceous grains are found in the deposit. This might only mean that the deposit was laid down at a time of year when pollen was not being shed. There is frequently a differential deposition of waterborne material (Moseley in Andrews 1961, p. 191) which could also explain the lack of abietaceous pollen grains: the pollen grains, lighter and smaller than the cones bearing them, would be waterborne for longer distances and therefore be deposited elsewhere. McGregor (1965, pl.IV) has found a number of pollen grains e.g. Pinuspollenites Vancampoi with characters similar to those of abietaceous pollen grains (Potonie 1958, p.62) in the Lower Jurassic of west Ellesmere Island. It has recently been shown that fossil cones, outwardly similar to modern genera, are not always related. For example, the cone Pararaucaria from the Cerro Cuadrado of Patagonia, is similar in external appearance to the modern genera Picea and Larix (Abietaceae). Its internal characters, however, are araucarian, and it contains scales with both one and two seeds within the same cone (Wieland 1930). Further work on the coniferous element of the Ellesmere Island flora is needed to clarify these points.

The presence of cones and cone scales with abietaceous characteristics in this deposit, and the discovery of apparent abietaceous pollen in the Lower Jurassic of west Ellesmere Island, suggests that the Abietaceae did occur in the Lower Jurassic in this area. Further work on this area may provide much valuable information on early representatives of the Abietaceae.

## Stratigraphical and Structural Correlations.

The area in which the described deposit is located is inferred to be Upper Jurassic or Lower Cretaceous. (Christie 1964). This dating is based on miospore analysis of deposits to the south and northeast (McGregor in Christie ibid. p.51); McGregor considers that an Upper Jurassic age is the more probable of the two, because certain typical Cretaceous genera are absent.

Age determination of the Lake Hazen deposit, using the ranges of both macrofossils and miospores, does not agree with the above result. A Lower Jurassic age for this deposit, however, does support Christie's hypothesis of a syncline in the Mesozoic rocks, its axis north of, and nearly parallel with the southeast axis of Lake Hazen. (Christie ibid. p.48. See also the section on Geology in this thesis). Evidence is given by beds of progressively younger age outcropping to the north: Upper Jurassic on Johns Island, (Geological Survey of Canada sampling point), Lower Jurassic at Camp Hazen two miles to the Northeast, and Triassic, probably conformable with this, to the northeast and northwest (see map II). Areas to the west and east of the deposit are obscured by glacial till. Little is known about the stratigraphy of the beds making up the deposit, and therefore no further deductions about the structure of the area can be made. Further work is to be done in this area in the summer of 1965 (Christie pers. comm.).

## Comparison with Floras of Similar Age

The Ellesmere Island flora has a number of species in common with Lower Jurassic floras from Greenland (Harris 1937, 1946), southeast Sweden (Moller and Halle 1913; Nilsson 1958) and Germany (Gothan in Harris 1937). A few species are found in common with Lower Jurassic floras of France, Poland and southeast Asia, including Japan (Harris ibid.).

The rich fossil flora of Scoresby Sound, east Greenland (Harris 1931-2, 1935, 1937) can be divided into two zones; the *Lepidopteris* zone of Rhaetic age, and the *Thaumatopteris* zone of Jurassic age. The flora contains 26 common species, only occuring in Lower Jurassic strata (Harris 1937). Of these, *Thaumatopteris schenki*, and possibly *Phlebopteris muensteri* are also found in the Ellesmere Island deposit. *Phlebopteris angustiloba*, a Lower Jurassic fern, occurring rarely in the Greenland flora, is common in the Ellesmere Island flora. Specimens of *Podozamites*, *Nilssonia*, *Swedenborgia* and *Leptostrobus*, which either cannot be identified to specific level or which are too widely ranging to be of stratigraphic value, are found in both deposits. *Clathropteris meniscoides*, also found in the Ellesmere Island flora, ranges throughout the *Lepidopteris* and *Thaumatopteris* zones.

Another '*Thaumatopteris*' flora from east Greenland, (Harris 1946) contains *Thaumatopteris schenki*, *Phlebopteris muensteri*, *Goeppertella microlobus*, *Stenorachis dubius* and a number of unidentified *Podozamites* and *Equisitites* species, also found in the Ellesmere Island flora.

It is possible that the Greenland and Ellesmere Island floras have more species in common. Many of the Greenland species, however, were identified using the form of an entire leaf or frond, details rarely available in the fragmented Ellesmere Island material.

Harris (1937, p.76 *et.seq.*), has shown that the *Lepidopteris* and *Thaumatopteris* zones also occur in Rhaetic and Lower Jurassic floras of many other parts of the world. He found representatives of the

*Thaumatopteris* flora in southeast Sweden, southwest Germany, France, Bornholm and Poland, and in areas across Europe and Asia to Japan. *Phlebopteris muensteri*, *Phlebopteris angustiloba*, *Thaumatopteris schenki* and *Clathropteris meniscoides* are common to the Ellesmere Island flora and the Lower Jurassic flora of Germany. A few of the Swedish Lower Jurassic floras contain, in addition, *Goeppertella microlobus*, a common constituent of the Ellesmere Island flora.

The Lower Jurassic flora of Poland contains the species *Clathropteris meniscoides*, *Phlebopteris muensteri*, *Phlebopteris angustiloba* and a *Schizolepis* species in common with the Ellesmere Island flora. It also contains an increasing number of cones and cone scales which, Harris considers, indicate a younger age for this flora than that of the Scoresby Sound assemblage. It is possible that the Ellesmere Island flora is also slightly younger than the Scoresby Sound flora. The main difference between the two floras is the increased number of cones and cone scales and the lack of the older *Thinnfeldia* and *Ctenis* leaf series (Harris 1931, p.144) in the Ellesmere Island flora.

In southeast Asia and Japan 'Lepidopteris' zone and 'Thaumatopteris' zone species occur together. The flora of Tonkin (Zeiller, 1882, 1903), is thought to be Rhaetic - Lower Jurassic and contains *Goeppertella microlobus*, *Phlebopteris angustiloba* and *Clathropteris meniscoides* in common with the Ellesmere Island flora.

## Miospore Floras

6 miospore species (see Table II) from the Camp Hazen deposit were found by McGregor (1965) in Arctic Canada including west Ellesmere

Island. All have wide stratigraphic ranges.

15 miospore species (see Table II) from Ellesmere Island are also found in the Lower Jurassic of Sweden (Nilsson, 1958). These are frequently found in Thaumatopteris zone strata. Marattiosporites scabratus and Eucommiidites troedssoni are found in the Jurassic of both England and Sweden (Couper 1958, Nilsson ibid.). Dictyophyllites harrisi, Cyathidites minor, and Cyathidites australis are found in the English Jurassic (Couper ibid.). A number of miospore species from Ellesmere Island are also found in Upper Trias and Lower Jurassic strata of Australia, and northern Antarctica (Dr. G. Norris, pers. com.). Vitreisporites pallidus is found in the Upper Trias and Lower Jurassic of both Antarctica and Australia, and Lycopodiumsporites austroclavatidites and Cyathadities minor are found in the Lower Jurassic of both continents. Marritisporites scarbatus and Acanthotrilietes ovalis are found in the Lower Jurassic of Antarctica, and the spore of Clathropteris meniscoides — Convaricosisporites cameroni (Harris 1931, pl.18, fig.3) is found in the Upper Trias of Antactica and in the Upper Trias and Lower Jurassic of Australia.

Harris (1937, p.97 et seq.), considers that "floras of the 'Thaumatopteris' type are known all round the world, not scattered indiscriminately, but grouped in a belt of the earth's surface which takes an oblique course from Greenland at 70° N, Europe from Sweden to Austria (46°N - 56°N): through Russia and Siberia at about the same latitudes and finally in Japan at about 35°N." He emphasises, however, that much of his extrapolated data about the central European and Asian floras is based on poorly described specimens.

The Ellesmere Island flora, at 84°N also falls in Harris' oblique belt. It is interesting to note the position of this belt on a map showing deduced positions of continents in Jurassic times (e.g. Bain, 1963, p.107, fig. 4), using the theory of Continental Drift. Bain considers that the North pole in Jurassic times was located at N.41°E.178°, and that the Equator passed through present day Central America, south central Europe, Ceylon and Tasmania. The oblique belt containing the lower Jurassic floras described by Harris, and the Ellesmere Island flora fall in a wide belt parallel to and north of this equator. 'Australia' and 'northern Antarctica' also fall in this zone.

Conditions of Deposition

The uniform finegrained texture of the sediments suggests quiet water deposition. The satiny lustre, uniform fine grain size, dark color, oily touch and resistance to maceration in hydrofluoric acid are characteristics of kerogen shales. These are organic shales, often algal in origin, containing 'kerogen', partially or completely macerated organic debris of chiefly plant origin, mixed with inorganic clays, sands and carbonates (Levorsen, 1954). Nilsson (1958) describes a '<u>Botryococus</u>' algal shale from Sweden containing miospore species also found in Ellesmere Island. The Ellesmere Island microflora also contains a *Botryococcus* colony, and is possibly also an algal shale.

The cones are more poorly preserved than the majority of the leaves, suggesting either that they were derived from areas farther away from the deposition site than the leaves, or that they were decayed before preservation (see earlier discussion).

The Rhaetic-Lower Jurassic fern *Goeppertella microlobus* is known only from localities in Sweden, Greenland, Ellesmere Island, Poland and southeast Asia (Tonkon). The lithology of the strata in which it is found in Poland is not known, but in all other localities it is only found in black, organic shales or coals. It seems probable, therefore, although specimens have not been found *in situ*, that it inhabited swamp or bog areas.

## CONCLUSIONS

1. The known ranges of the macrofossil and miospore species described indicate a Lower Jurassic age for the deposit discussed in this thesis. Lithological correlations, however, suggest an Upper Jurassic or Lower Cretaceous age. Dating using fossils is probably more accurate because the lithology of beds from Carboniferous to Jura-Cretaceous age is similar in this area.

2. A number of conifer cones and cone scales with apparent abietaceous characters are found in the deposit, although the Abietaceae are rarely represented in other deposits before the Upper Jurassic. Miospores with abietaceous characters are not found in the deposit, although they are found in Lower Jurassic deposits of west Ellesmere Island. Evidence therefore suggests that early representatives of the Abietaceae, or types ancestral to this family, do occur in the Lower Jurassic of Ellesmere Island.

3. The possible fertile pinna of a rare Lower Jurassic fern - Goeppertella microlobus (Schenk) Oishi and Yamasita is described. It shows a greater similarity to the sterile form of Goeppertella microlobus than the only fertile form found, figured by Zeiller. The validity of Zeiller's identifications cannot be ascertained without recourse to the type specimens because no description of the fossil is given with the plates.

The fern is reported from black, carbonaceous shales or coals only and therefore possibly lived in a swamp habitat.

4. The lack of conifer pollen grains despite the presence of abundant conifer cones suggests that deposition may have been seasonal, possibly due to fluctuating water level. Notes on lithology were not made during collection of the material and therefore the rock cannot be examined for layering or banding that would support this suggestion.

5. A number of species occuring in the deposit are shown by comparative study to be those occuring in Lower Jurassic floras across the world.

6. The deposit occurs at 81°N, one of the most northerly plant fossil localities known. The fossil flora at this latitude falls in a continuation of the oblique belt of Lower Jurassic floras described by Harris. On a map showing postulated positions of the landmasses in Lower Jurassic times, using the theory of Continental drift, this belt occupies an area north of and parallel to the postulated equator. This suggests that a widely distributed flora uniform over great areas, was present at lower latitudes of the northern hemisphere during the Lower Jurassic.

# APPENDIX I

## List of Macrofossils (including specimen numbers)

PTEROPHYTA

FILICALES

Dipteridaceae

| | |
|---|---|
| Clathropteris meniscoides Brongn. | E.J. 1,2 |
| Thaumatopteris schenki Nath. | E.J. 3 |
| Goeppertella microlobus (Schenk) Oishi and Yamasita | E.J. 4 |
| Goeppertella cf. microlobus | E.J. 5, 6 |

Matoniaceae

| | |
|---|---|
| Phlebopteris angustiloba (Presl) Hirmer and Hoerhammer | E.J. 7,8 |
| Phlebopteris ? muensteri (Schenk) Hirmer and Hoerhammer | E.J. 9 |
| Phlebopteris sp. A | E.J. 10 |
| Phlebopteris ? sp. B | E.J. 11 |
| Matonidium cf. goepperti (Ettingshausen) | E.J. 12 |

PTEROPHYTA INCERTAE SEDIS

| | |
|---|---|
| Axis A | E.J. 13 |
| Axis B | E.J. 14 |

ARTHROPHYTA

EQUISITALES

Equistaceae

| | |
|---|---|
| Equisitites sp. | E.J. 15 |

CYCADOPHYTA

CYCADALES

Cycadacea

| | |
|---|---|
| Nilssonia pterophylloides Nath. | E.J. 16 |
| Nilssonia parvula Heer | E.J. 17 |
| Nilssonia sp. | E.J. 18 |
| BENNETTITALES | |
| Williamsonia sp. | E.J. 19 |
| Williamsonia ? sp. | E.J. 20 |
| Zamites sp. | E.J. 21 |
| GINKGOPHYTA | |
| GINKGOALES | |
| Stenorachis dubius ? Antevs | E.J. 22 |
| Stenorachis ? sp. | E.J. 23 |
| Leptostrobus sp. | E.J. 24 |
| CONIFEROPHYTA | |
| CONIFERALES | |
| Abietaceae | |
| Abietites ? sp. | E.J. 25 |
| Pityolepis sp. | E.J. 26 |
| Pityostrobus sp. | E.J. 27 |
| Pinus nordenskioldi Heer | E.J. 28 |
| Taxodiaceae | |
| Taxodites sp. A | E.J. 29 |
| Taxodites sp. B | E.J. 30 |
| Sequoia sp. | E.J. 31 |
| Araucariaceae | |
| Elatides brandtiana Heer | E.J. 32 |
| Pagiophyllum sp. | E.J. 33 |
| Coniferales Incertae Sedis | |

Coniferales Incertae Sedis

| | |
|---|---|
| _Swedenborgia_ ? sp. | E.J. 34 |
| _Schizolepis cylindrica_ Nath. | E.J. 35 |
| _Schizolepis cf. S ? retroflexa_ Nath. | E.J. 36 |
| _Schizolepis_ sp. | E.J. 37 |
| _Podozamites lanceolatus_ var. _latifolius_ (F. Braun) Heer | E.J. 38 |
| _Podozamites_ sp. | E.J. 39 |
| Cone A | E.J. 40 |

PLANTAE INCERTAE SEDIS

| | |
|---|---|
| _Carpolithus_ sp. | E.J. 41 |

All specimens deposited in the McMaster Palaebotanical Collection.

APPENDIX II

Miospores from Hazen flora matrix

Slides labelled P D1 to P D5.

Cyathidites minor Couper

Cyathidites australis

Concavisporites toralis (Leschik) Nilsson

Dictyophyllidites harrisii Couper

Leiotriletes medius Nilsson

? Acanthotriletes ovalis Nilsson

Lycopodiacidites sp.

Lycopodiumsporites austroclavatidites (Cookson) Potonie

Microreticulatisporites sp.

fig. 4 as "cf. Microfoveolatispora directa"

Laevigatosporites sp.

Marattisporites scabratus Couper

Chasmatosporites minor Nilsson

Chasmatosporites elegans Nilsson

Chasmatosporites hians Nilsson

Chasmatosporites apertus (Rogalska) Nilsson

Chasmatosporites sp. A of Nilsson 1958

Alisporites robustus Nilsson

Vitreisporites pallidus (Reissinger) Nilsson

Sulcatisporites pinoides Nilsson

Cedripites cf. canadensis Pocock

Podocarpidites cf. ellipticus Cookson

Inaperturopollenites orbiculatus Nilsson

Monosulcites sp.

*Entylissa tecta* Nilsson

*Eucommiidites troedssoni* Erdtman

*Cerebropollenites mesozoicus* (Couper) Nilsson

? *Botryococcus* colony

*Circulina* ? *Meyeriana* Klaus

## LITERATURE CITED

Andrews, H.N. 1961. Studies in Paleobotany. J. Wiley & Co., New York and London.

Andrews, H.N., N.W. Redforth, and T. Phillips. 1963. Paleobotanical Studies on Ellesmere Island. Am.J.Bot., 50:627

Antevs, E. 1919. Die Liassiche des Horsandsteine. Kgl. Sv. Vet. Akad. Handl., 59: #8.

Bain, G. W. 1963. Climatic Zones Throughout the Ages. Soc.Econ. Paleont. and Mineral. #10. Tulsa.

Berry, E. 1911a. A revision of the Potomac Plants. Proc. U.S. Nat. Mus. 40: 1821

1911b. A revision of the Fossil Plants of the Genera Arostichopteris, Taeniopteris, Nilsonia, and Sapindopsis, from the Potomac Group. Proc. U.S. Nat. Mus. 38: 625

Beauverie, J. 1923. Les Gymnosperms Vivantes et Fossiles. Lyon.

Bold, H. C. 1957. Morphology of Plants. Harper. New York

Bower, F. 1923. The Ferns (Filicales) Vol. II Cambridge.

1926, Vol. III.

Brongniart, A. 1825. Observations sur les Vegetaux. Fossiles Renformes dans les Gres de Hoer en Scanie Ann. Sci. Nat. 4: 417

1828. Essai d'une Flore des Gres bigarre Ann. Sci. Nat. 5: 435

Bucholtz, J.T. 1948. Generic and Subgeneric Distribution of the Coniferales. Bot. Gaz. 110: 80.

Carruthers, W. 1870. On Fossil Cycadean Stems from the Secondary Rocks of Britain. Trans. Linn. Soc. 26: 675.

Chaney, R.W. 1950. A revision of Fossil Sequoia and Taxodium in Western North America based on the Recent Discovery of Metasequoia. Trans. Amer. Phil. Soc. 40: 171.

Christie, R.L. 1964. Geological Reconnaissance of North Eastern Ellesmere Island, District of Franklin. Geol. Surv., Canada, Mem. 331.

Couper, R.A. 1958. British Mesozoic Microspores and Pollen Grains. Palaeont. 103, Abt. B.

Dallimore, W. and A. Jackson. 1954. A Handbook of Coniferae. Arnold Ltd. London.

Delevoryas, T. 1962. Morphology and Evolution of Fossil Plants. New York.

Dettmann, M.E. Upper Mesozoic Microfloras from South Eastern Australia. Proc. Roy. Soc. Victoria 77, pt. 1.

Du Toit, A.L. 1937. Our Wandering Continents. Edinburgh.

Endo, S. and R.W. Chaney, 1951. A record of Sequoia in the Jurassic Rocks of Manchuria. Bot. Gaz. 113: 228.

Ettingshausen, C. von. 1852. Bednindung einiger neuen. Oder nicht genau bekannnten Arten der Lias- und der Oolithflora. Abh. K. k. geol. Reichs. Wein. 1: Abth. 3.

Florin, R. 1951. Evolution in Cordaites and Conifers. Acta Horti Bergiani, 15 (11): 285-388.

1954. The female reproductive organs of conifers and taxads. Biol. Revs. 29: 376-389.

1958. On Jurassic taxads and conifers from north western Europe and eastern Greenland. Acta Horti Bergiani, 17 (10): 259-402.

Foster, A and E.M. Gifford. 1959. Comparative Morphology of Vascular Plants. San Francisco.

Funkhouser, J.W. and W.R. Evitt. 1959. Preparation techniques for acid-insoluble macrofossils. Micropal. 5 (3): 369-375.

Goeppert, H.R. 1841. Die Gattungen der Fossilen Pflanzen. Bonn.

Halle, T.G. 1913. The Mesozoic Floras of Graham Land.

Wiss. Ergeb. Schwed. sudpolar Exped. 1901-03. Bd. 3: Lief. 14, 1.

Harlow, W.M. and E.S. Harrar. 1941. Textbook of Dendrology. New York.

Harris, T.M. 1931a. Rhaetic Floras. Biol. Revs. 6: 133.

1931b-1937. The Fossil Flora of Scoresby Sound, East Greenland. 1-5. Medd. Gronland, 85 (2) P1-105; 85(3), p.1-114; 85(5), 1-133; 112(1), 1-176; 112(2), p.1-114.

1946. Liassic and Rhaetic Plants from East Greenland. Medd. Gronland, 114(9), 1-35.

Hattersley-Smith, G. Ed. Operation Hazen. Narrative and Preliminary Reports, 1957-58. Defence Research Board, Ottawa.

Heer, O. 1868. Flora Fossilis Arctica 1(2). Fossile Flora von Nordgronland 86-129. Zurich.

1871. ---- 2(2). Flora fossilis Alaskana; Kongl. Svensk. Vet. Acad. Handl. 8(4): 1-41.

1875 ----- 3(2). Die Kreideflora der Artischen Zone. Kongl. Svensk. Vet. Acad. Handl. 12 (6): 1-138. (3) Nachtrage zur miocenen Flora Gronlands: 1-29.

1877 ------ 4(1). Beitrage zur fossilen Flora Spitsbergens. Kongl. Svensk. Vet. Akad. Handl. 14(5): 1-141.

1878 ------ 5(1). Die miocene Flora des Grinnell-Landes: 1-38. (2). Beitrage zur fossilen Flora Siberiences und des Amurlandes. Mem. Acad. Sci. St. Petersbourg. 7th ser. 25(6): 1-58.

1880 ----------- 6 (1). Nachtrage zur fossilen Flora Gronlands. Kongl. Svensk. Vet. Acad. Handl. 18(2): 1-17.

1882 ----------- (2). Der ersten Theil der fossilen Flora Gronlands: 1-112.

1883------------ (7). Den zweiter Theil der fossilen Flora Gronlands: 1-275.

Hirmer, M and L. Hoerhammer 1936. Morphologie, Systematik und Geographische Verbreitung der fossilen und rezenten Matoniaceen. Palaeontographica. 81. B: 1-70.

Hollick, A. 1930. The Upper Cretaceous Floras of Alaska. U.S. Geol. Survey Prof. Paper 159: 1-116.

1936. The Tertiary Floras of Alaska. U.S. Geol. Survey Prof. Paper 182: 1-185.

Hughes, N.F. 1961. Further Interpretations of Eucommiidites Erdtm. 1948. Palaeontology, 4(2): 292-9.

Jongmans, W and S.J. Dijkstra 1964 Fossilium Catalogus. II. Plantae. Filicales, Pteridospermae, Cycadales. Parts 40, 41, 42, 43, 44.

Jacobs, J.A, R.D. Russell and J. Tuzo Wilson, Physics and Geology. McGraw-Hill.

Klaus, von W. 1960. Sporen der karnischen Stufe der ostalpinen Trias. Jb. Geol. B.A. 5: 107-183.

Koch, B.E. 1964 Review of fossil floras and nonmarine deposits of West Greenland. Bull. Geol. Soc. Amer. 75 (6): 535-548.

Krausel, R. Die Juraflora von Sassendorf bei Bamberg.

1958. Sporenpflanzen. Senck. leth. 39: 67-103.

1959. Samenpflazen. Senck. leth. 40: 97-136.

Leschik, G. 1955. Die Keuperflora von Neuewelt bei Basel. II Schweiz. Palaeont. Abh. 72. Basel.

Levorsen, A. 1954. Geology of Petroleum. San Francisco.

McGregor, D.C. 1961. Dev nian spores from Melville Island. Palaeontology, 3 (1): 26-44.

1965. Triassic, Jurassic and Lower Cretaceous spores and pollen of Artic Canada. Geol. Surv. Can. 64-55.

Moller, Hj. and T.G. Halle. Fossil floras of South East Scania. Arkiv for Bot., 13 (7): 1-45.

Nathorst, A.G. 1878-1886. Om Floran i Skanes Kolforande Bildningar. I. Floran vid Bjuf. sver. geol. Unters. ser. C, Nos. 27, 33, 85.

1894. Zur palaozoischen Flora der artischen Zone. K. Svensk. Vet. Akad. Handl., 26 (4).

1897. Zur mesozoischen Flora Spitsbergens. K. Svensk. Vet. Acad. Handl., 30 (1).

1907. Palaobotanische Mitteilungen. I. Pseudocycas, eine neue Cycadophytengattung aus den Cenomanian Kreideablagerungen Gronlands. K. Svensk. Vet. Akad. Handl. 42 (5).

Newberry, J.S. 1895. Flora of the Amboy Clays. U.S. Geol. Surv. 26.

Nilsson, T. 1958. Uber das vorkommen eines Mesozoischen Sapropelgesteins in Schonen. Lunds Universitets Arsskrift, 54 (10): 1-111.

Oishi and K. Yamasita. 1936. On the fossil Dipteridaceae. Journ. Faculty Sci. Hokkaido Imper. Univ. ser. IV, vol. III, No. 2: 135-184.

Plumstead, E.P. 1962, Fossil Floras of Antarctica. Trans. Antarct. Exp. 1955-1958. Sci. Rep.s 9: 1-154.

Pocock, A. 1962. Microfloral Analysis and Age Determination of Strata at the Jurassic-Cretaceous Boundary in the western Canada plains. Palaeontographica, III, B: 1-95.

Potonie, R. Synopsis der Gattungen der Sporae dispersae. Beih, Geol.Jb,

1956. Vol.I Beih Geol.Jb. 23: 1-103

1958. Vol.II Beih. Geol. Jb. 31: 1-114

1960. Vol.III. Beih.Geol. Jb. 39: 1-189.

1962. Synopsis der Sporae in situ. Beih.Geol.Jb. 52: 1-240

Raciborski, M. 1892. Flora retycka polnecnego stoku gor Swietokryzyskich, Mater. pryzyr. Akad. Umiej. w Krakowie.P.15

Radforth, N.W. 1938. An analysis and Comparison of the Structural features of Dactylotheca plumosa Artis sp. and Senftenbergia ophiodermatica Goppert sp. Trans. Roy. Soc. Edin. 59, pt. 2 (14): 385-396.

1963. Diary of the Expedition to northeastern Ellesmere Island. Unpublished. In the Biology Dept., McMaster University, Hamilton, Ontario.

and D.C. McGregor. 1954. Some plant microfossils important to pre-Carboniferous stratigraphy and contributing to our knowledge of early floras. Can, Journ.Bot., 32: 601-621.

Schenk, A 1867. Die fossile Flora der Grenzschichten des Keupers und Lias Frankens. Weisbaden.

Schenk, E. T. and J. McMasters. 1948. Procedure in Taxonomy. London.

Seward, A. C. Fossil Plants. London

1910. Vol. II Pteridophyta.

1917. Vol.III Pteridospermae, Cycadofilicales, Cordaitales, Cycadophyta.

1919. Vol.III. Ginkgoales, coniferales, Gnetales.

1924 Notes sur la Flora Cretacique du Gronland. Societe Geologique du Belgique. 50 Anniversaire. livre Jubilaire, 1874-1924.

1926 The Cretaceous Plant-bearing Rocks of western Greenland. Phil. Trans.Roy.Soc. Lond. 215, B.

Staplin, F. L. 1960. Palynological Treatments for Sediments. Micropal. 6(3): 329-331.

Sterberg, K. Graf. 1883. Versuch einer geognostich-botanischen Darstellung der Flora der Vorwelt, 2, 7-8: 115.

Wall, D. 1965. Microplankton, pollen and spores from the Lower Jurassic in Britain. Micropal. 11 (2): 151-190.

Ward, L. F. 1906. Status of the Mesozoic Floras of the United States. U.S. Geol. Survey. Monographs. Vol.48.

Weiland, G.R. 1930. The Conifer Inflorescence. Science 72.

Zeiller, M. R. 1882. Examin de la flore fossile des couches de charbon du Tongking. Ann.d.Mines 8: 298-349.

1903. Flore fossile des Gites de Charbon du Tonkin. Paris.

PLATE 1

Unless otherwise stated all specimens are X4.

Fig. 1 Clathropteris meiscoides Brongniart. Fragment of a fertile pinna. Page 16.

Fig. 22 Thaumatopteris schenki Nathorst. Sterile pinnule. Page 19.

Fig. 3. Goeppertella microlobus (Schenk) Oishi and Yamasita. Sterile pinna. Page 21.

Fig. 4-6 Goeppertella cf. microlobus. Page 23.

4. Fertile pinna.

5. Spore dissected from a sorus of the specimen in Fig. 4, x 750.

6. Sorus from Fig. 4. x 40.

Fig. 7,8 Phlebopteris angustiloba (Presl) Hirmer and Hoerhammer. Fertile pinnae Page 25.

Fig. 9. Phlebopteris ? sp. B. Sterile leaf. Page 32.

Fig. 10. Phlebopteris sp. A. Fertile leaf. Page 29.

Fig. 11. Phlebopteris of muensteri (Schenk) Hirmer and Hoerhammer. Fertile pinna. Page 28.

# PLATE 1

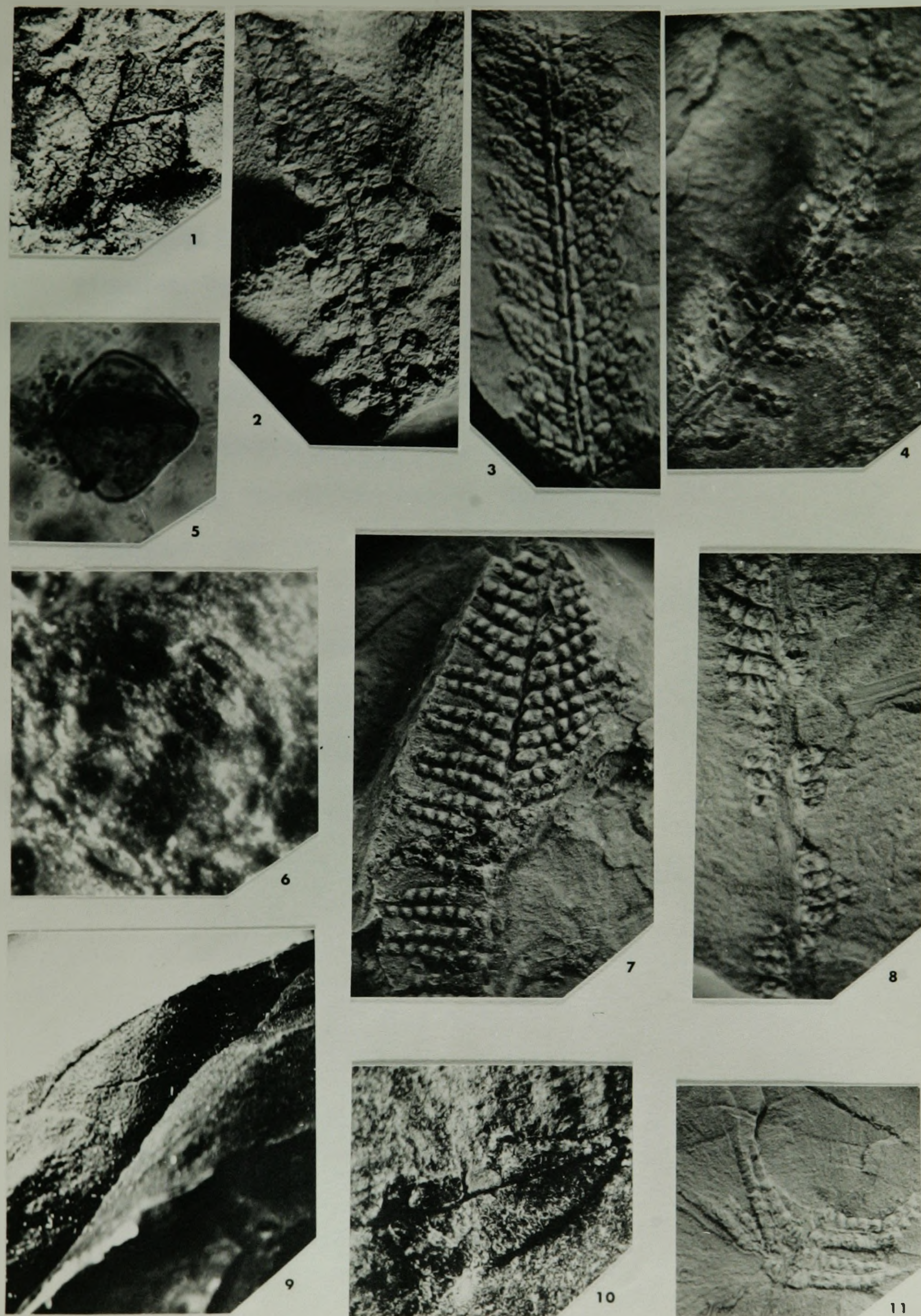


PLATE 2

Fig. 1. Axis A. Fertile pinna. Page 34.

Fig. 2. Axis B. Page 34.

Fig. 3. Matonidium cf. goepperti (Ettingshausen). Fertile pinnules. Page 33.

Fig. 4. Equisitites sp. Fragment of a sheath. Page 35.

Fig. 5. Nilssonia parvula Heer. Middle portion of a leaf. Page 37.

Fig. 6,7B Nilssonia pterophylloides. Page 36

Fig. 7A Williamsonia sp. Inflorescence. Page 40

Fig. 8. Nilssonia ? sp. Seed. Page 38

Fig. 9. Stenorachis dubius. ? Antevs. Page 43

Fig. 10. Williamsonia ? sp. Involucre bract. Page 40

Fig. 11. Zamites sp. Basal portion of a leaf. Page 39

Fig. 12. Stenorachis? sp. Page 44

Fig. 13. Leptostrobus sp. Cone. Page 42

**PLATE 2**

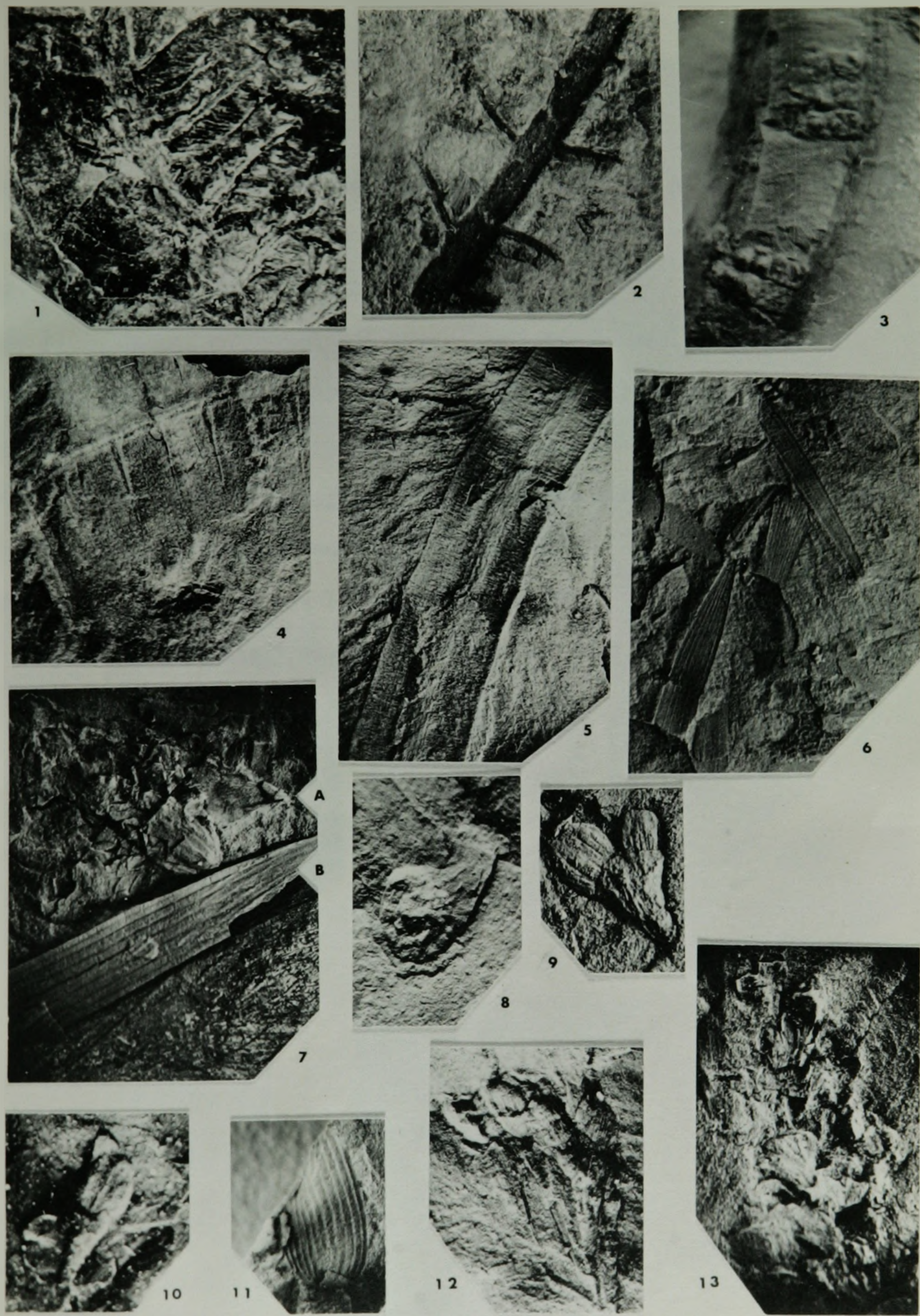


PLATE 3

Fig. 1. Pityostrobus sp. Middle portion of a female cone. Page 48.

Fig. 2. Pityolepis sp. Cone scales. Page 48.

Fig. 3. Sequoia sp. Female cone. Page 52

Fig. 4. "Pinus" nordenskioldi Heer. Isolated leaves. Page 47

Fig. 5. Abietites sp. Basal fragment of a female cone. Page 46.

Fig. 6. Taxodites sp. Cone scales. Page 52

Fig. 7. Elatides brandtiana. Heer. Cone with microsporophylls. Page 49.

Fig. 8. Taxodites sp. Female cone. Page 51

Fig. 9. Pagiophyllum sp. Leaf axis. Page 50

Fig. 10. Swedenborgia ? sp. Megasporophyll. Page 56.

PLATE 3

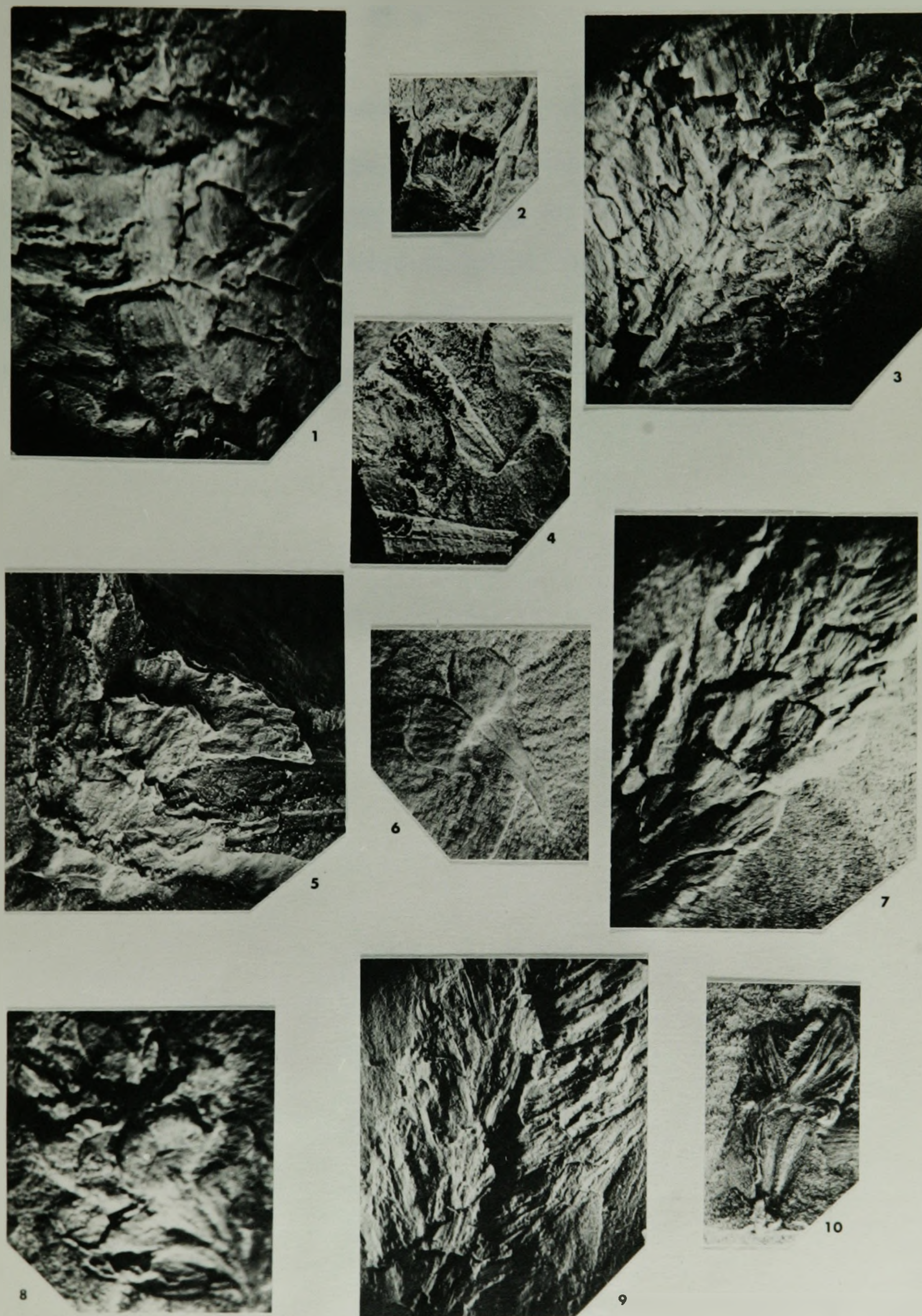


PLATE 4

Fig. 1. *Podozamites* sp. Fragments of leaves and an axis. Page 55

Fig. 2. *Schizolepis* *cf. S.* *retroflexa* Nathorst. Cone. Page 58

Fig. 3. *Podozamites* *lanceolatus* *latifolius* (F. Braun) Heer. Page53

Fig. 4. Cone A. Cone with microsporophylls. Page 59

Fig. 5. *Carpolithus* sp. Seed. Page 60

Fig. 6. *Schizolepis* *cylindrica* Nathorst. Cone scales. Page57

**PLATE 4**