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PALAEOBOTANICAL INVESTIGATIONS INTO SOME CORMOPHYTIC MACROFOSSILS FROM THE NEOGENE TERTIARY LIGNITES OF CENTRAL JUTLAND

PART I:

INTRODUCTION AND *PTERIDOPHYTES*

BY

FR. J. MATHIESEN

København 1965
Kommissionær: Ejnar Munksgaard

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Synopsis

The discovery of a fossiliferous layer of Neogene-Tertiary age, rich in plant remains, at Moselund (Denmark, Central Jutland) in the year 1916 gave rise to intensified geological investigations of the Danish lignite beds, made accessible during the great brown-coal mining campaign in the years 1917–20. The quarrying favoured an inspection of the layers of clayey soil (hardened "Gyttja"), which, accompanying the coal, according to previous experiences was to be regarded as one of the main localities for determinable plant remains of this geological period.

Besides the find at Moselund, the investigations at Silkeborg Vesterskov and the Fasterholt quarries proved particularly successful; the fossils procured: leaves, twigs, cones, and seeds were in part so well preserved as to make an anatomical study possible; animal remains were scarce.

Gymnospermous wood was very common in the coal layers, sometimes remains of the trees were found on the stumps.

This memoir, the first of the series of papers giving the results of our investigations, contains – besides a geological survey – a systematic account of the ferns and fern allies discovered. An anatomical study of a *Salvinia* from Moselund has yielded details for a closer comparison with the recent species.

The floristic character of the fossils, found in the layers at Moselund, Silkeborg Vesterskov, Fasterholt, and Salten, points towards an "Aquitanian" age, approaching the biological aspect of the lignitic floras of the Upper Oligocene and Lower Miocene from Eastern Central Europe (Hungary, Austria, Bohemia, Switzerland, Germany and Poland) and also exhibiting relations to the flora of the lignites of Bovey-Tracey (Kent).

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BIANCO LUNOS BOGTRYKKERI A/S

Preface

The main material on which this paper is based was procured during the lignite mining campaign in the years 1917–1920 by J. P. J. Ravn, Keeper of the palaeontological Department of the Mineralogical and Geological Museum of the University, V. Milthers, State Geologist, Thorkil Bjerring Pedersen, M. Sc. (all deceased), and the author. It is deposited in the collections of the University and of Danmarks Geologiske Undersøgelse (D.G.U.) and has liberally been placed at my disposal. In the following years supplementary material has become available through excavations made by Professor A. Mentz (†) and Preparator K. Skou (1924 and 1937, respectively). All the material at hand was collected in Jutland, partly from the Tertiary clay (hardened "gyttja") at Moselund and partly from layers of an identical nature accompanying coal-producing layers in Silkeborg Vesterskov and the quarries at Fasterholt (Skibild), and also, though to a somewhat lesser degree, from the coal itself in the quarries west of the Silkeborg-Herning area, mainly near Troldhede, from the Torvig quarry as well as from the state quarry in this locality. The majority of the samples of fossil wood suitable for anatomical investigation, originate from the last-named quarries.

From our Palaeogene Tertiary (the Diatomite on the islands of Mors and Fur in the Limfjord, as well as from the lower Oligocene) no finds of fossil higher plants, save for some pollen, have been described since the publication of N. Hartz 1909.

The material from the coal layers and accompanying clay is, even if the geological age in some details is still open to discussion, to be referred to the Neogene Tertiary. The floras from the Silkeborg-Herning area are of a rather uniform type, and will be dealt with in the present paper as a palaeontological unit. Previous to the floristical account is given, as a general introduction, a description of the stratigraphy of the fossiliferous layers investigated, with details of the profiles as they appeared in 1920.

The number of the determinable specimens of the Tertiary flora of Denmark has grown considerably as a result of our collections. Besides such ubiquitous types as *Taxodium*, *Glyptostrobus* and *Sequoia*, to mention a few Gymnosperms, we have succeeded in demonstrating the presence of many types (Gymnosperms as well as Ferns and Angiosperms) of a more restricted vertical distribution. In the last section of this paper the age of the floras will be discussed, mainly by comparison with some Neogene Tertiary floras from Europe which through the presence of animal remains

in the plant bearing layer, or—more commonly—by the character of the bordering strata, have been dated rather exactly.

In recent years Mr. P. Ingwersen from the staff of D.G.U. has started an investigation of the pollen types occurring in the lignite. The first very promising results of this work agree with my determinations of macrofossils from the brown-coal "gyttja", but have also shown the existence of types not present in my material.

I started upon these researches, which I regarded as an extension of my former studies in the systematic anatomy of higher plants, mainly because of the interest the late Lecturer in Palaeontology at the University, J.P.J. Ravn, and the Director of Danmarks Geologiske Undersøgelse at that time, Dr. V. Madsen, took in the question of our Tertiary floras. The state of preservation of the material was an invitation to extend the research on anatomical details, in order to supplement determinations based on macroscopic inspection. This method is now in common use and quite indispensable, especially regarding the leaves of Dicotyledons.

In 1921 the Royal Danish Academy of Sciences and Letters proposed as a subject for a prize dissertation: "An investigation of the fossils of higher plants occurring in the Danish Tertiary strata". This gave me the opportunity of preparing a provisional account of my studies, which the Academy considered worthy of the prize. The final publication had to be postponed until now, owing to the pressure of my duties whilst at the Royal School of Pharmacy, Copenhagen. This paper contains the information given in my prize dissertation, but is completed by the results obtained by studying the new supplies of material, and in a good many cases extended by inspection of the literature of recent years.

In the Dansk Geologisk Forening and the Dansk Botanisk Forening I had the opportunity of giving a general review of my studies during the spring session of 1922.

As for the work in the field, Professor A. Mentz and the State Geologists V. Milthers and Dr. V. Nordmann showed the kindest interest, and the local knowledge of Mr. Milthers, in particular, proved invaluable. Mr. K. Skou has been good enough to hand his collections from the Moselund locality over to me for investigation. The Chief Inspector of the Silkeborg forest district, Mr. N. Bojesen, as well as the District Superintendent at the State Railways, Mr. M. J. C. T. Lysholm, Skanderborg, showed their interest in my work by arranging for assistance with excavating. I have very pleasant memories of my stay in the friendly home of Mr. P. C. Christensen, Engesvang, during the work at Moselund. Finally the Carlsberg Foundation awarded me a grant for the completion of this paper.

Danmarks Geologiske Undersøgelse has permitted the completion of field work, and I have had en opportunity of discussing stratigraphical details with the former Director, Dr. H. Ødum, as well as with the staff of D.G.U. This institution has also borne the expense of a rather deep boring at Moselund. Professor A. Rosenkrantz has in many questions of a general geological nature rendered me a most valuable help.

The Botanical Museum and Botanical Garden of the University as well as the Forest Department and the Arboreta of the Royal Veterinary and Agricultural School,

Copenhagen, has kindly placed material for comparison at my disposal. I am indebted to the Royal Society for Gardening for material of roots and knees of Taxodium. The readiness of our University Libraries in procuring papers not at hand here, e.g. from Kgl. Vetenskaps Acad. in Stockholm, has in many ways been extremely useful. The Mineralogical and Geological Museum as well as the Royal School of Pharmacy, Copenhagen, have kindly placed working facilities at my disposal.

My thanks are due to all these institutions and their staffs for their efforts in making it possible to finish this memoir—a work not without some difficulties, mainly those of procuring material for comparison. Works on these subjects are, after the publications of N. Hartz, rather scarce in our literature.

In rendering my thanks for all the courtesy received and keeping the deceased colleagues in a grateful memory, I would also express the hope that the results of my studies may not prove unworthy of our united efforts, as I, at an advanced age, offer these notes for the kind review of the public.

Dr. B.T. Walton has been good enough to revise my translation into English. My thanks are also due to Mr. P. Ingwersen from the staff of D.G.U. for his kind help in reading a proof.

Introduction

Description of the localities investigated

I. The fossiliferous stratum at Moselund railway station

In the summer of 1916 Thorkil Bjerring Pedersen, M. Sc., discovered a layer of yellowish clayey soil in the gravel pit belonging to the State Railways near the station of Moselund on the Silkeborg-Herning line. This soil proved rich in imprints of leaves and various other parts of plants. At a meeting of the Dansk Geologisk Forening the following winter the Keeper of the palaeontological Department of the University Museum, J. P. J. Ravn, gave an account of the find and exhibited a number of the fossils, the nature of which proved that they belonged to a flora of a Neogene Tertiary character.

Tertiary strata containing such an abundance of well preserved vegetable remains had hitherto been unknown in this country and so the find claimed the greatest interest. In the summer of 1917 an excursion was therefore arranged to the place in question by Mr. J. P. J. Ravn and the present writer in order to make a closer investigation of the locality and, if possible, to collect some more material.

The locality discovered by Mr. Thorkil Bjerring Pedersen is marked + in the map Fig. 1.

At a distance of 10 m from a steep slope about 2 m high that bounds the gravel pit to the south-east, a ochreous layer of the fossiliferous clayey soil came to the surface. This layer extended below the slope. The covering layer had been stripped off and the gravel digging stopped on reaching the clay. By digging a ditch at right angles from the edge of the clay towards the slope it was found that the line of demarcation at this point presumably must be the natural one, the layer tapering very much towards the edge, whereas, only one metre further in, it attained a thickness of about 1 m and retained this thickness for the following 10 m. It was bedded on medium—grained, ochreous sand.

We were told by Mr. Lysholm, the District Superintendent of the line at that time, that extensive amounts of clay of a similar kind had been found close to the railway during the building of the line. The rising ground to the north-east of the gravel pit in question and consequently on the other side of the present railway line was cleared away during the building, its gravel furnishing good material for the construction of the railway track. The stripping of this low hill was continued until

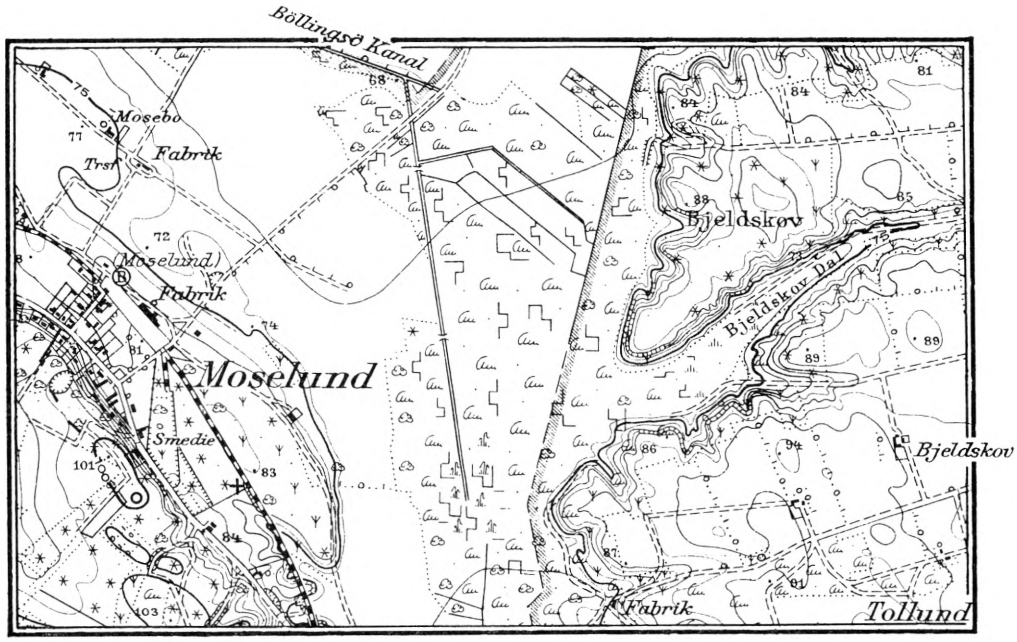

Fig. 1. Part of the topographical map M 2409, Kragelund, (Copyright Dansk Geodætisk Institut) including the area at Moselund. Scale 1:20 000. Altitudes in metres.

a level had been reached at which outcrops of the clay mentioned above—which was useless for building purposes—occurred in several places.

North-east of the line, on the almost level site of the formerly rising ground, a small plantation was laid out the circumference of which roughly indicates that of the hill (Fig. 2. A magnified copy of part of an older edition of the map Fig. 1). Where the clay approached the surface, foliiferous trees were planted (alder and ash), but where the substratum of gravel and sand reached some depth, Conifers (Mountain Pine and Silver Fir) were preferred. Three groups of foliiferous trees are indicated on the map Fig. 2. A fourth is not noted in this figure, although, in 1917, it was by far the most important in the plantation. It began just opposite the high south-eastern rim of the present gravel pit and extended towards the south-east for a distance of about 50 m and with a similar width (compare Fig. 2). The recording of the site of the last mentioned area is of importance, as the best preserved fossils of our material originate from this place.

In the autumn of the same year (1917) the locality was again visited by Mr. J. P. J. Ravn, this time accompanied by Mr. V. Milthers. Prior to their visit the Danmarks Geologiske Undersøgelse had caused diggings to be made in the layer. Amongst others, at the suggestion of Mr. V. Milthers, two excavations, each 1.1 m wide, had been sunk in the midst of the largest group of the foliiferous trees. One excavation was dug 20 m north-east to the railway line, the other further in (10 m) to the north-east of the first one. Both excavations were carried through the clay which was over-

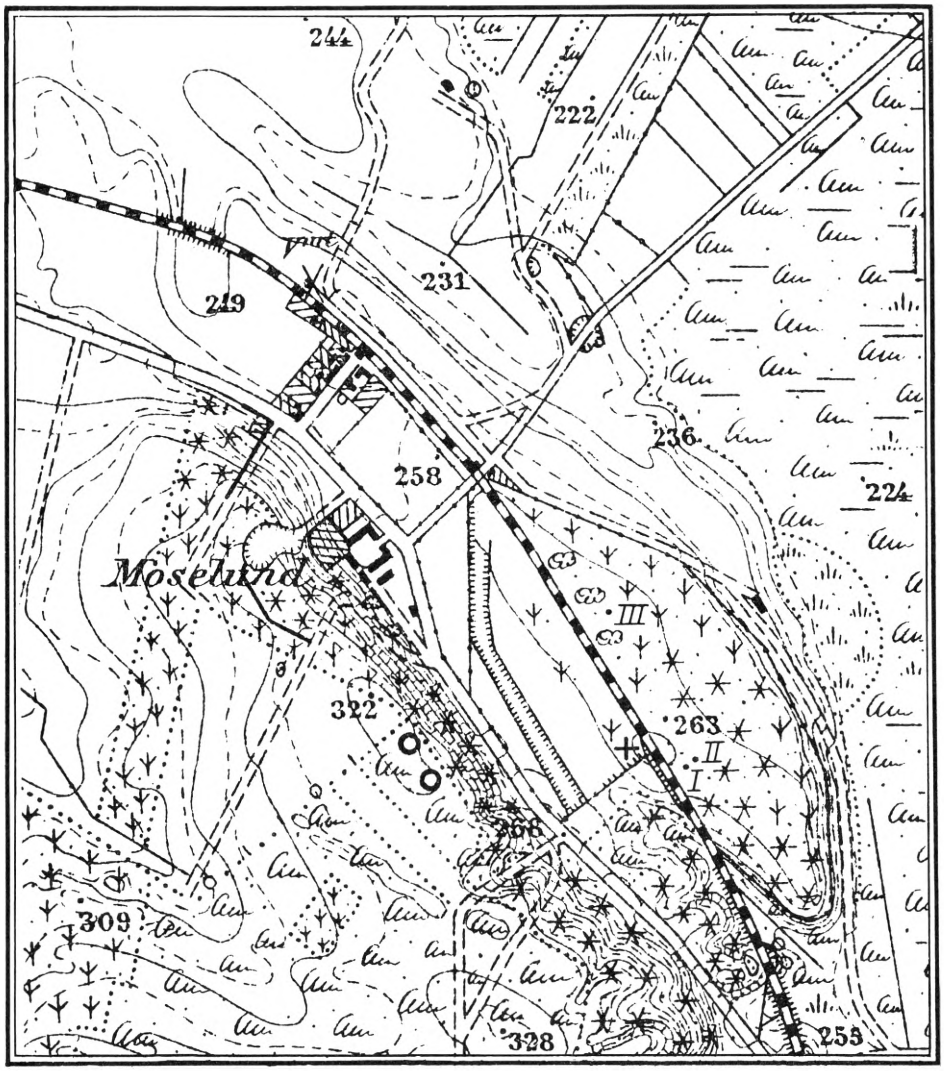

Fig. 2. Part of the map Fig. 1. Scale 1:10 000. The + in the eastern corner of the gravel pit marks the protruding margin of the fossiliferous layer, discovered 1917 by Th. Bjerring Pedersen. I, II and III indicate the situation of the wells east of the railway line. Altitudes given in Danish feet (one foot = about 31.4 cm).

lain by about 75 cm of gravel. The first excavation was 2.5 m, the other 3.8 m deep. The layer of clay thus increases considerably in thickness towards the north-east. In both excavations it was bedded on the coarse, ochreous sand, familiar from the excavation in the gravel pit. The situation of the excavations is marked on the map Fig. 2 (I and II); they are to be found near the highest point of the plantation area (83 m in Fig. 1; 263 feet in Fig. 2. One Danish foot is equivalent to 0.314 m).

In the excavation no. I the whole of the clay from top to bottom was of an

ochreous yellow colour, but considerably darker than the clay of the gravel pit. In excavation no. II on the other hand, with the exception of the first 50 cm at the top, the clay was pitch-black as long as it was damp; on drying it turned from a lighter to a darker grey. It was of a far harder and firmer consistence and, as it was transversed by cracks at right angles to the direction of the layer, it proved rather easy to excavate the material in large unbroken pieces, which could be split up very regularly, almost like schist.

The clay brought up from the excavations proved rich in fossils (twigs, leaves, cones and seeds) evenly distributed troughout the layer, but while the ochreous clay of excavation no. I mainly offered imprints of the various plant remains, the black clay of excavation no. II yielded fossils far better preserved; the vegetable substance being only slightly carbonised. The transition from the brownish clay at the top, to the underlaying black clay of excavation no. II, took place by imperceptible degrees and, altogether, the brown and yellow clay is to be regarded as transformation products of the black, due to oxidizing and decomposing agencies.

Some packing cases containing blocks of clay from excavation no. II were, by the care of Mr. Milthers, sent to the museum and a number of excellent fossils was in this way obtained.

In 1919, owing to a grant-in-aid from the Mineralogical and Geological Museum of the University, I was able to spend a fortnight at Moselund. Excavation no. I was found dry, excavation no. II was unfortunately filled with water up to the height of about 1 m. After it had been emptied the water poured in again so briskly that in a quarter of an hour it was too full of water to work in. Through the obliging assistance of Mr. Lysholm the necessary help was, however, obtained, and some cubic metres of the black clay were brought up for examination. From excavation no. I a similar quantity was secured. The material was split up in as thin and regular layers as possible. After drying in the air for a few days, it split very easily and presented in many cases rather perfect, even cleavage surfaces.

The number of species represented in the flora was considerably increased by this inspection, and as the result of this and former investigations abundant material was obtained.

The black clay was in some places, notably in the lower parts of this layer, rich in mica scales. Here and there the cleavage surfaces were quite covered with mica intermixed with vegetable detritus.

What makes the black clay from excavation no. II of special interest is the fact that the tissue of the plant remains, though carbonized, is on the whole well preserved. In several instances it has been possible to obtain anatomical preparations of epidermis, even of the leaves of foliiferous trees, and in one instance also transverse sections. Cones, seeds and twigs were obtained perfectly fitted for anatomical investigation.

Regarding remains of animals I have only found a wing of a dragon-fly, determined by the late Dr. K. Henriksen as belonging to a hitherto unknown species:

Oplonaeschna staurophlebioides (A new Tertiary Dragon Fly *O. st.* n. sp. from Denmark. Medd. fra Dansk Geologisk Forening. Bd. 6. Nr. 9. 1922).

To preserve the excavations for future investigation frames of boards were placed round them at their top edges to prevent loose gravel, overlying the clay, from sliding down and filling them. They were also covered with sleepers.

Little is known about the horizontal extension of the clay outside the plantation as it was not at that time possible to make borings. According to Mr. Lysholm's statement it must be assumed to extend over a larger part of the area along the railway and it is certain that the clay in the gravel pit and that of the excavations forms a continuous layer. The clay increases in thickness towards the north-east, and I came across it again on digging through the gravel about 20 m to the north-east from excavation no. II. Also a third excavation (III), dug by Mr. K. Skou (1937) about 200 m to the north-west of excavation no. I and II, showed the same thickness of the fossiliferous layer as was found in those excavations. Therefore it is to be supposed, that the area covered by the plantation alone is so considerable as to render it improbable that the clay could represent a loose flake carried by the ice from its original bed. It must be assumed to have been originally deposited in its present place.

A statement made by the foreman of the line at the Moselund station would seem to indicate that the clay in question has a still greater extension. An old workman, who was employed in the diggings for the foundation of the water-tower at the station, thought that he recognized in the hard black clay from excavation no. II the "coaly-looking" clay that he remembered coming across on that occasion.

Investigations of the ground sloping towards Bølling bog and on the steep slopes on the opposite side of the bog at Bjeldskov did not give any results.

As regards the nature of the clay it seems beyond doubt that it was deposited as a mud ("gyttja") on the bottom of a freshwater lake and later became hardened and shale-like. It looks exactly like layers found both in this country and elsewhere associated with lignite, either interspersed between coal producing layers or forming the base of the series (Hartz 1909, p. 71). As mentioned above, gravel overlies the clay, and it is thus impossible to determine how much has disappeared by erosion. Most probably the clay once formed part of a bottom layer in a basin of lignite, and the less resistant, overlying coal succumbed to erosion.

A boring reaching a depth of about 45 m was sunk in 1960 by Danmarks Geologiske Undersøgelse, mainly in the hope of finding layers of marine origin below the clay. Such layers were not found; the underlying stratum proved to consist of yellowish, medium-grained sand, alternating with thin layers of coal, containing fossil wood. The sand is of the same nature as that directly underlying the clay in the excavations in the plantation.

II. The fossiliferous layers of the lignite series

In 1917–1918, when the exploitation of our brown-coals was extended to a hitherto unknown degree owing to the shortage of fuel caused by the war, the possibility

of finding determinable macrofossils greatly increased. With this object in view and at the request of Danmarks Geologiske Undersøgelse I spent about three weeks in the mining district in Jutland in the summer of 1919.

According to experience gained elsewhere it could not be expected to find well preserved plant remains, with the exception of fossil wood, in the coal itself, whereas such remains are frequent in the associated layers of clay and sand. Other Things being equal, the fossils in question are of course the better preserved the finer the material of the surrounding matrix. As pointed out by HARTZ 1909, the comparatively few macrofossils of plants known at that time from our Neogene Tertiary are mainly found in such layers, and it would be, as a first step, convenient to look for the existence of the fine, dense and shale-like clay (hardened "gyttja") in the sections presented in the quarries. Therefore I visited all the localities where lignite had been quarried to any considerable extent during the previous years.

The places were examined in the following order:

1. The district of Troldhede with the large State quarry and the Torvig quarry at Vorgod Å; The Sk(j)ærbæk quarry; the quarry at Torsk(j)eld Bjerg and the quarry at Pøl Mose on the south side of Vonds Å.

2. The district of Fasterholt with the State quarry at Skibildgård (indicated as the State quarry, Fasterholt, in the description of the fossils); the private quarries a little further west near the briquette factory; the three small private quarries to the east of Skibild at Holtum Å, named "Nissen Jøkers quarry", "Harildgårds quarry", both south of the river, and "Skibild eastern quarry" north of the Holtum Å (Fig. 3).

3. The more remote localities at Sandfeldgård, well known from Hartz's description.

4. The district in the neighbourhood of Silkeborg; viz. the quarries at Gammel Ry and those in Silkeborg Sønder- and Vesterskov. Finally some days were spent in investigation of the localities at Bryrup, where brown-coal had been quarried at Vorret and Lystrupsminde. Also an excursion was made to the Salten profile.

As a result of this reconnaissance I decided that work had to be concentrated on the State quarry at Fasterholt and the locality in Silkeborg Vesterskov, these being the only places where clay contained macrofossils of plants in the desirable state of preservation. It was further ascertained that the State quarry and the Torvig quarry at Troldhede deserved attention owing to the admirably well preserved fossil wood occurring there.

Of the time remaining at my disposal I spent another ten days in the State quarry at Fasterholt, five days in the locality in Silkeborg Vesterskov and two days at Troldhede. The results of these investigations may be considered satisfactory as more well preserved specimens of leaves, twigs, cones and seeds were collected and my collections of fossil wood were considerably augmented.

In 1920 I again made an excursion to the mining district, my chief object being to continue the examination of the locality in Silkeborg Vesterskov. I could now put

Fig. 3. Part of the topographical map M 2707, Brande, (Copyright Dansk Geodætisk Institut) showing the position of the quarries at Skibild and along the Holtum Å, marked ⊗ and ×. Scale 1:20 000. Altitudes given in Danish feet (one foot = about 31.4 cm).

in twelve days at the place, and owing to the kind assistance of Mr. N. Bojesen, the Chief Inspector of the Silkeborg forest district, in obtaining the necessary help with excavation, I obtained a very satisfactory result.

When the work in this place was finished, I made short visits to Fasterholt and Troldhede. In the former locality work in the State quarry had been stopped, and further investigation was consequently not possible. From the quarries at Troldhede a number of fine specimens of wood were again obtained.

Stratigraphical details of the localities visited are given in the following notes.

A. Silkeborg Vesterskov and the other finds in the neighbourhood of Silkeborg.

In the steep slope bordering on the north the bogland which, under the name of Jensk(j)ær, forms a continuation of the Thorsø depression to the west, is situated the

lignite layer first known from C. Ring's excavation in 1861 (HARTZ 1909, p. 22—in the map l.c. fig. 10, p. 51 marked +).

During the Great War 1914–1918 attempts were made to utilize the coal. The gravel and sandy micaceous clay overlying the producing layer were removed and shot down the slope, thus uncovering the lignite for exploitation. When mining stopped in 1918 a semicircular incision with a diameter of about 30 m had been produced; the bottom of which was level and almost horizontal. At the back Ring's old adit could be seen. Its supporting props had almost rotted away, but the ceiling and walls of the gallery had apparently not suffered much, thanks to the considerable stiffness of the strata. A spring had made its way out through the passage.

At the back and on the right hand side of the excavation the overlying moraine gravel had already fallen in to a great extent and quite hidden the lignite layer. However, towards the edge on the left hand side, where the slope was more gradual, and where some beech stumps with their long horizontally extending roots had formed a protecting cover, a profile could be dug out showing a layer of coal about 70 cm thick in which flattened trunks of fossil wood were preserved. Under the coal bed appeared a layer of almost 1 m thickness of a fine and stiff clay, pitch-black in its humid condition and chocolate-brown after drying. The clay was riddled with cracks across the horizontal direction of the layer and for that reason was easily broken out in blocks. The top part of it proved extremely hard, the middle part was softer and richer in mica with coarse mica scales on the cleavage surfaces, whilst the lowest part was of a nature similar to that of the top. The clay was resting on micaceous sand. It abounded in plant remains (leaves, twigs, cones and seeds) for the most part well preserved. Unfortunately it does not split up so regularly in the direction of the layer as does that from Moselund, and consequently it was difficult to extract the larger leaves without damaging them. Some of the cleavage surfaces prove to be almost covered with twigs of *Taxodium*. On fractures at right angles to the layer yellow retinite stripes frequently appear. They indicate the presence of *Taxodium* cone scales; the fossil *Taxodium*, like the recent one, encloses resiniferous cysts in the scales. Fruit stones of *Nyssa* and seeds of *Taxodium* are frequent; also some curious fossils, referred to the larval tubes of a *Phryganida* species, could be demonstrated. The clay abounded in pyrite, and in some cases small branches of Gymnosperms were found completely replaced by this mineral.

Next to that at Moselund the clay in Silkeborg Vesterskov, owing to its abundance in fossils and its accessibility, is at present the most important place known for the study of our Neogene Tertiary flora.

The layers on the south side of Jensk(j)ær (in the map on pag. 51 of N. HARTZ' paper also marked by a +), in the Gjedsø Skov and at Gjedsø Savmølle, were not accessible during my stay. Most probably they are to be considered as having been formed in connection with those in Silkeborg Vesterskov in order afterwards to be separated from them by the excavation of the depression of Jensk(j)ær, formed during the Ice Age.

Among the other lignite occurrences in the neighbourhood of Silkeborg, Ring's second locality in Silkeborg Sønderskov at Slåen Sø, might be expected to yield some interesting fossils. Here N. Hartz found a cone referred to *Pinus Laricio Thomasiana* O. Heer and seeds of *Hydrocharis tertiaria* N. Hartz, in a bed of clay under the coal. An excavation, made shortly before my visit to the place, was found to be filled almost entirely with gravel, and without greater means than were at my disposal it would be useless to begin investigations here. However, as the layer in Sønderskov could evidently yield other kinds of fossils than those from Vesterskov, it would be highly desirable if it could be subjected to a closer examination in the future.

In Ry Sønderskov, to the west of Gammel Ry, on the outskirts of the forest south of Knasbjerg, lignite had been quarried to some slight extent in 1917. In 1919 the quarry had almost entirely fallen in, and only from the bottom of a small pool in the middle of it it was possible to obtain samples of coal. They proved to be of a rather peculiar nature, differing from those in the other quarries by their large content of coarse mineral constituents (sand, mica) and by the much less advanced transformation of the plant remains inclosed. On cleavage surfaces were found cones of *Glyptostrobus*, seeds of *Sequoia* and twigs of *Taxodium*.

In the profile at Salten (Hartz 1909, p. 49, figs. 8 and 9) unmethodical digging and subsequent landslips had made the lignite bed inaccessible. In the layer of clay overlying the coal N. Hartz found badly preserved parts of leaves of Dicotyledones and pinnulae of a Fern, determined as *Pteris parschlugiana* Unger, seeds of *Sequoia* and some carpoliths, together with abundant fossil wood. The only result of my visit here was some samples of fossil wood that lay scattered about. One of the samples proved to be of some interest representing the type of fossil wood designated as *Taxoxylon*.

In the valley of the Lystrup Å at Lystrupsminde brown-coal was extensively quarried during 1917–1918. The producing bed was found on the eastern side of the valley about half way up the steep slope which bounds the river there. Work was stopped in 1919, and the sides had already been greatly affected by slips. The coal layer was about 1 m thick, it was bedded between layers of mica-containing clay and sand, but no macrofossils, except fossil wood, were preserved in such a state that further work was likely to be of any use.

Some of the samples of fossil wood showed anatomical details fairly well and yielded material of much interest.

B. The State quarries at Fasterholt (Skibild) and the other lignite localities in the district of Brande.

About 1.4 km south of Fasterholt station, where a road from Vester Harild to Skibild cuts the railway line from Herning to Brande, and from there southward

to Skibildgård (fig. 3), the State began very extensive quarrying in 1917. The ground in this area very much favoured the exploitation of the coal beds, as only comparatively thin layers of gravel were superposed and drainage conditions were favourable, since the ground sloped towards the Holtum Å. Furthermore the beds had considerable horizontal extent.

Two quarries were made, one on either side of, and close to, the railway line. In 1919 the work had resulted in the excavation of a pit east of the line about 200 m in length, 100 m wide and extending to the south almost as far as Skibildgård.

Work in the eastern quarry had been stopped the previous year and its sides had caved in. In the quarry on the western side of the railway some work was still carried on in 1919. The excavation had there attained a length to the south of about 300 m, its breadth varied somewhat (50–100 m), the depth in the eastern half was about 6 m, in the western part only about 4 m.

In the last-mentioned quarry the whole of the western side appeared as an almost clean-cut profile; the two coal beds in the cut running almost parallel and horizontal. Measurements near the middle of the pit showed a sequence of strata as follows:

Gravel the lower 10 cm of which were mixed with particles of coal	95 cm
Uppermost coal bed, free from fossil wood, of which the upper 60 cm were of a loose, earthy consistence, designated as A-coals	145 cm
Fine, sharp quartz-sand, with brown stripes of coal	7 cm
Clay the lower 20 cm of which were fossiliferous	48 cm
Fine, sharp quartz-sand	15 cm
Lowermost coal bed, rich in fossil wood, designated as B-coals	80 cm
	390 cm

The bottom of the quarry in this place consisted of a layer of fine, mica-containing quartz-sand.

During the first period of quarrying an underlying layer of coal about 1.5 m in thickness was also exploited; this was designated as C-coals. As the digging proceeded from east to west, this layer was abandoned, and consequently the bottom of the western part of the quarry was higher by the amount of the thickness of the C-coals. At the time of my visit the bottom layer exhibited a profile in a north–south direction almost in the middle of the quarry. This showed that the C-coals were almost of the same vertical extent throughout the area.

The C-coals consisted partly of a substance closely corresponding to the "Brunkul-Gytje fra Sandfeldgård" described and figured by Hartz 1909, p. 72. fig. 11. On the surface of the flakes there was a thin covering of fine, white micaceous sand and an irregular network of finer and coarser dark lines, no doubt due to cracks in the mass, filled with humus and without direct connection with organisms. The C-coals did not contain enough organic material to be profitable for fuel. The plant remains in them were only present as detritus. The C-coal layer was bedded on very

fine, sharp, mica-containing sand, which presumably constitutes a deposit of some considerable vertical extent, as a boring with a drill 3 m in length did not reach the bottom of it.

The layers between the A- and B-coals varied slightly in individual thickness in different places of the cut, but their total magnitude was very nearly the same everywhere.

At the south end of the profile the Tertiary deposits had been worn away by erosion almost down to the B-coals. The layer of A-coal disappeared suddenly, the underlying clay had resisted erosion better and formed a southward pointed wedge. As the thickness of the gravel layer increased in the same ratio as the underlying Tertiary decreased, the surface remained almost parallel with the bottom of the pit.

The upper 20 cm of the clay above the B-coals consisted of a more or less fine debris, whilst the lower 28 cm cohered in blocks of various sizes, the clay being divided by cracks (as was also the clay at Moselund and Silkeborg Vesterskov). On the surface of the cracks it was black, whereas the interior of the blocks was of a dark chocolate brown. On drying the clay assumed a lighter or darker grey colour and split readily, though somewhat irregularly, in the horizontal direction of the layer. It contained some mica and abundant pyrits. In the lower part a good many fossils were found but the dicotyledonous leaves were mainly met with in fragments or as imprints.

As already mentioned the B-coals abounded in fossil wood. No stumps of trees could be demonstrated, and, so I was told, none had been found there. The trunks were always pressed flat and the early formed parts of the growth rings (the "spring-wood"), consisting of large and relatively thin-walled elements, folded and destroyed. A determination was consequently difficult, but most of the fossil wood is probably to be referred to *Taxodioxylon*. The trunks were often of considerable dimensions. According to the report of the foreman of the quarry a specimen had been dug up, shortly before my arrival in 1919, that measured 10 m in length and 2 m at its broadest part (i.e. measured along the greater axis of the strongly elliptical transverse section) which may correspond to a thickness of the trunk in an unaltered state of about 1.5 m.

In the private quarry somewhat further to the west (in the map fig. 3 marked ⊗) were also found two coal layers, the lower one with, the top one without fossil wood. They were separated by layers of quartz sand and clay and the entire sequence was of a magnitude similar to that in the State quarry. A certain hesitation on the part of the managers prevented more accurate examination. The clay contained plant remains in the same state of preservation as those found in the State quarry and belonging to the same species.

During my stay only very little of the fossiliferous layer of the private quarry was brought up, the work there consisting mainly in removing the cover of gravel and the upper coal layer over a rather extensive area, in order to lay open the layer of B-coals and thus to procure suitable material for the production of briquettes.

The three smaller quarries along the Holtum Å valley (marked × in the map fig. 3) were abandoned and for the most part already filled by landslips. Yet in the eastenmost quarry, on the south side of the river ("Nissen Jökers Brud") one wall remained almost intact. The profile showed the following sequence of strata:

Gravel	350 cm
Fine, sharp quartz sand	10 cm
Cracked clay of the same nature as the lower part of the clay at Fasterholt	35 cm
Coals without fossil wood. — As the water stood high in the bottom of the quarry, the actual thickness of this layer has remained unknown. Presumably it has a thickness of about	100 cm
	(495 cm)

In "Skibild østre Brud" in the bluff north of the river the northern wall showed the following sequence:

Gravel	200 cm
Fine and firm clay. About 1 m at the top of a light brown colour, the lower part black	225 cm
Coarse ochreous sand	60 cm
Earthy coal	50 cm
Mica-containing black clay	45 cm
Coal with fossil wood	50 cm
	630 cm

The coal was bedded on mica-containing clay and sand. In the ochreous sand above the upper coal layer were found a couple of flint boulders. None of the clay in these two quarries yielded determinable plant remains.

At Sandfeldgård lignite had been quarried in several places in the bank of the Skjern Å. Hartz 1909, p. 32 gives a map of the district. The coal beds were, as appears from the borings of 1906, of a rather considerable extension.—They are now completely exhausted. According to the profiles measured and the report on the 30 borings, the sequence of the layers was, at least where the series was more completely developed, very much like that found at Fasterholt. Two producing coal beds, separated by a layer of clay, with a layer of sandy coal at the bottom, correspond to the A-, B- and C-coal layers at the locality formerly mentioned. The largest quarry was found a little to the north-west of the most easterly of the three places marked with a × in the map cited. Work had been stopped in 1919 and water stood high in the pit, so that the bed of "gyttja" below the coal with its interesting matting of tiny roots (l.c. Fig. 3 and p. 72) was inaccessible. In the coal bed N. Hartz found the stump of a tree in a very perfect state of preservation.

C. Brown-coal quarries in the Troldhede district.

Whereas at Fasterholt and Sandfeldgård the coal beds as a whole were lying rather near the surface, in the localities around Troldhede station they were covered by layers of gravel of a considerable thickness, which made their exploitation difficult, the mechanical facilities at that time not being so highly developed as subsequently.

In the State quarry the bottom lay much lower than the adjacent river Vorgod Å. This necessitated constant pumping to keep the pit free from water. At the time of my visit 1919 the work there, as well as in the Torvig quarry, had been stopped temporarily. The State quarry appeared in the landscape as a lake surrounded by sand slopes. The Torvig quarry too was for the most part under water, so stratigraphical details were not available.

The coals in these places were rich in fossil wood. On the slopes of both quarries I found numerous pieces scattered on the sand, partly in a very perfect state of preservation. I was told by Mr. V. Milthers, that stumps, standing on the root in these coal beds, were very commonly found, sometimes attaining such a height, that their tops rose above the level of the coal into the overlying layer of gravel.

The wood in such stumps was nearly always well preserved, the pressure perpendicular to the length of the trunk, so destructive to the more thin-walled springwood elements of the growth rings, having been avoided.

An examination of the coal heaps near the branch line from the quarries to Troldhede station on the Herning–Skjern railway line also furnished several good specimens of fossil wood.

On my second visit in 1920 the work in the Torvig quarry had been resumed. I then had an opportunity of seeing 8 basal parts of trees, about 3 m in height and 1–1.5 m in diameter, on the stump. The distance between them was varying from 5 to 8 m. The roots proper had quite disappeared, no doubt the rule in such cases, but the huge root bases indicated that the trees had grown on the same level and consequently belonged to a group of the same geological age. Lignite was also found below the stumps.

Five samples were taken from each of two of the stumps, viz. one from the root base, and one each from the centre and circumference of the trunk at two different heights. The object was to find possible variations in anatomical details of the wood in the various parts; such variations were found to be very slight. The wood of all the stumps examined could be referred to *Cupressionoxylon sequoianum*, so that the group of trees was most probably composed of individuals of a *Sequoia*. For anatomical details of the fossil wood from Troldhede and elsewhere reference should be made to the systematical description of the flora. All the samples of wood gathered in our Neogene Tertiary originate from Gymnosperms.

The other, rather small quarries in this district (Sk(j)ærbæk, Føvdals Mose south of Bjørslev (Thorsk(j)eld Bjerg), Brunshøj- and Pøl Mose showed nothing of

much interest. The coals in the two last-named quarries are rich in fossil wood, but it was always so much decayed and compressed that a closer examination of it was useless. In the coals from Brunshøj were found remains of small globular cones peculiar on account of yellow stripes of retinite, which the cone scales had left in the matrix.

From the above it will appear that it is by no means a hopeless undertaking to look for beds containing well-preserved and consequently determinable macrofossils of plants in our deposits of lignite. As already pointed out by HARTZ 1909 attention should especially be directed towards the accompanying beds of fine clay (hardened mud, "gyttja"), but the fossil wood bedded in the coals themselves should not be neglected. Groups of trees on the stump are particularly important finds, partly because their wood is generally in such perfect state of preservation and partly also because collective occurrences of them—similar to the stump layers in our bogs—would help in the understanding of the character of Tertiary forests.

The systematic description of determinable macrofossils from our Neogene Tertiary now follows. The first section which describes the Pteridophytes, will terminate this part of the paper. The second will be devoted to the Gymnosperms, enclosing the fossil wood, and the third and last part is planned to embrace the angiospermous remains, to be followed by a discussion of the geological age of the fossiliferous layers.

Most of the fossils described have been dealt with in a good many previous publications and their names are consequently cited in numerous papers. A reference to the first adequate diagnosis only is given, together with references to papers of more recent date.

It will be readily understood that in an exposition like this it has not always been possible to distinguish between that which has already been stated in the literature and hitherto unknown facts. Where information of some importance especially concerning details of structure was at hand, references are included in the text.

In many cases, particularly where only an imprint of the fossil in the matrix was available, a photographical reproduction proved unsatisfactory so it was necessary to have recourse to drawings. These were all executed by means of a camera lucida; the real size of the object will be evident from the information given in the text accompanying each figure.

The Flora of the fossileferous layers from Moselund and the lignite series

I. *Pteridophyta*

Osmunda lignitum (*Pecopteris lignitum* C. Giebel) D. Stur.

An extensive list of the literature dealing with this characteristic Fern, together with a specification of synonyms, is given by P. FRIEDRICH 1883, p. 41.

From the layer of clay at Moselund we have numerous fragments of pinnules of *O. lignitum*, partly with well preserved leaf substance. A number of the finest specimens are shown in fig. 4, A–G, magnified twice.

O. lignitum is a rather variable type, mostly known from isolated pinnules. GIEBEL 1857, p. 303 has, out of 5 fragments, founded no less than 4 species: *Pecopteris leucopetrae, lignitum, angusta* and *crassinervis*, mainly to be distinguished by the shape of the marginal incisions and the somewhat different ramification of the tertiary veinules. The accompanying figures are not convincing and according to the more recent investigators HEER (1862, p. 1047. *Pecopteris lignitum*), as well as GARDNER and ETTINGSHAUSEN (1879–1886, p. 49 and 66) the species of C. GIEBEL are regarded as mere varieties. By the last-named authors the species, as already proposed by STUR 1870, is correctly referred to the recent genus *Osmunda*.

In the memoir of GARDNER and ETTINGSHAUSEN (vol. I, p. 50) the following, very extensive diagnosis of the pinnules is given: Osmunda fronde pinnata, pinnis elongato-linearibus, subcoriaceis, apice valde attenuatis et acuminatis, basi breviter petiolatis, margine profunde incisio-serratis rarius remote denticulatis vel basi undulatis; nervatione Pecopteridis verae, nervo primario basi valido prominente, subrecto, apicem versus attenuato, indiviso; nervis secundariis numerosis, angulis acutis egredientibus, plus minusve flexuosis sub apicibus loborum plerumque furcatis; nervis tertiariis inferioribus furcatis sub angulis minus acutis orientibus, rarius elongatis convergenti-arcuatis, sinum attingentibus; nervis tertiariis superioribus sub angulis acutissimis orientibus, saepe simplicibus subcurvatis flexuosisve — —.

To this diagnosis may be added that the tertiary venation shows catadromy, i.e. the first tertiary vein proceeds from the outward side of the secondary. As can be seen from our figures, the starting point of the lowermost tertiary veinule has often been so much displaced in the proximal direction that it in fact issues from the primary vein of the pinnule. GARDNER and ETTINGSHAUSEN's figures show similar peculiarities as is also the case with those of HEER.

As already mentioned STUR (1870) was the first to refer the species to the recent genus *Osmunda*. He compared it with the recent *O. Presliana* J. Sm. (= *O. banksiaefolia* (Presl). Kuhn). GARDNER and ETTINGSHAUSEN mention *O. javanica* Blume as the closest allied, now extant type. Yet the three still existing species of the first section of the genus *Osmunda* are closely related; HOOKER and BAKER even class them in the same species (Synopsis Filicum. 1874) and consequently retain the oldest specific name *O. javanica* Blume, while *O. Vachelli* and *O. Presliana* are noted as synonyms. L. DIELS in ENGLER und PRANTL 1902, p. 378 characterizes the genus *Osmunda*. Sect. I. Plenasium as follows: Bl. einfach gefiedert. Fiedern I höchstens gelappt. Aderung nach V. Pecopteridis. — *O. javanica* Blume is described as a large, rather robust Fern. The sterile pinnules are from 2–2.5 cm broad, linear-lanceolate, petiolate, the margin entire, crenate, serrate or slightly lobed, vide J. MILDE (1868, p. 21 — and Pl. VI, figs. 1–20). *O. Presliana* J. Sm. = *O. banksiaefolia* (Presl) Kuhn (CHRISTENSEN: Index Filicum I, p. 4. 1906) and *O. Vachelli* Hooker are smaller, the pinnules of the last-

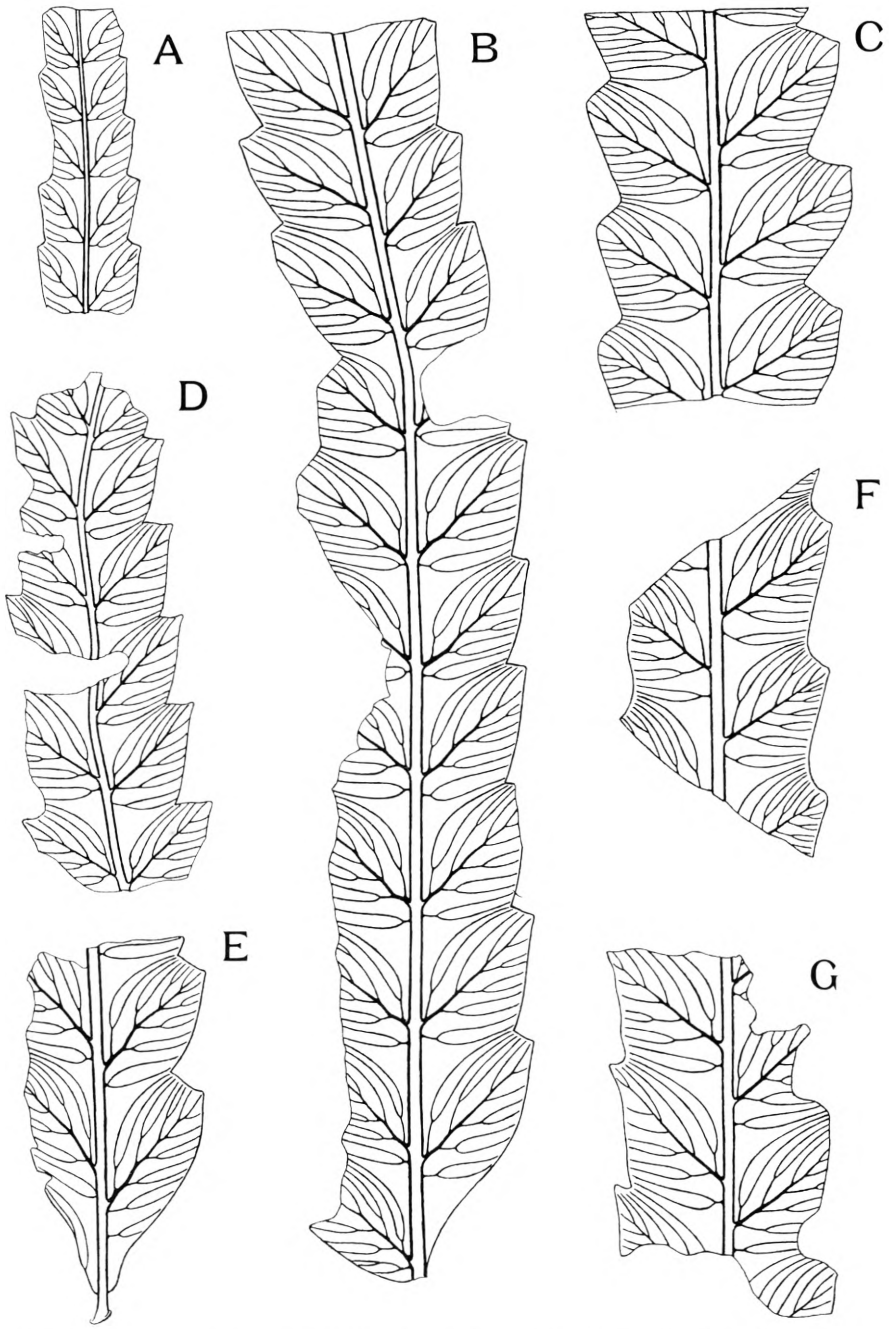

Fig. 4. *Osmunda lignitum* (Giebel) D. Stur. Fragments of pinnules (Moselund) (× 2).

named, a native of South China, are only 5–6 mm broad with entire margin. *O. banksiaefolia* is noted from China, South-east Asia, Ceylon, Malaysia, the Philippine Islands and spreads northward to Japan and Kamchatka. The secondary veins of the pinnules of *O. banksiaefolia* issue at more acute angles than is the case with the two other species and the margin is always serrulate to serrulate-lobate. The displacement of the lowermost tertiary veinule in the proximal direction of the primary vein, and so apparently issuing from this, proved to be a very common feature in material at hand from the Philippine Islands. So a very close agreement between *O. lignitum* and the recent *O. banksiaefolia* is beyond doubt. At least it is certain that a species of an *Osmunda* belonging to the section given, whose habitat is now exclusively limited to the Far East, was widespread in Europe in the Tertiary. It probably formed an important part of the vegetation here, as in the floras where it occurs its remains are often to be found in considerable numbers.

Stur (1870, p. 9) has described and figured an *Osmunda* of a related type, but differing in certain details which may be of some systematic value and so possiby should allow the constitution of a distinct species, i. e. the author's *Osmunda Grutschreiberi*. Stur has figured a very beautiful specimen in which some pinnules are found in connection with rachis. The pinnules are sessile and at the outer side of the base widened into a lobe. The type has only been found at Möttnig (Carinthia, the Sotzka-Series) and its specific value is doubted by Gardner and Ettingshausen.

When the leaves wither, the pinnules in the *Osmunda* genus separate from the rachis by a special detachment layer, leaving a regular scar. Fig. 4 E shows the basal part of a pinnule of *O. lignitum*. Judging from the shape of the end of the petiole it is evident that it has separated from the rachis in a similar way.

In the fossil the leaf substance must have been of the same firm, almost coriaceous consistence as is found in the recent *O. banksiaefolia*. The carbonized crust, into which it has been transformed, is unfortunately very brittle and inclined to crumble and scale off. By clearing with a diluted solution of sodium hypochlorite fairly good preparations of the leaf substance could be obtained; fig. 5, A and B, is drawn from such. A shows a portion of the epidermis of the upper side of a pinnule, B a portion of the under side, the latter exhibiting two stomata, while an oval aperture indicates the place of a third one, the guard cells here being dissolved. Stomata are only found on the underside; they are level with the surface.

For comparison the corresponding parts of epidermis of *O. banksiaefolia* are reproduced at the same magnification (fig. 5, C and D). As might be expected, the fossil also in this respect closely agrees with the recent species. The slighter thickness of the epidermal walls of the fossil may very well be due to a waste of substance caused by the maceration and clearing. Fig. 5 E shows a transverse section of the epidermis from the underside of a pinnule of *O. banksiaefolia*. The stomata appear to be of an uncomplicated type. The thin ridges terminating the guard cells at the aperture have disappeared in the preparation of the fossil, so that the unnaturally large apertures in the stomata figured (fig. 5 B) are not an original feature.

Fertile pinnules are not yet observed.

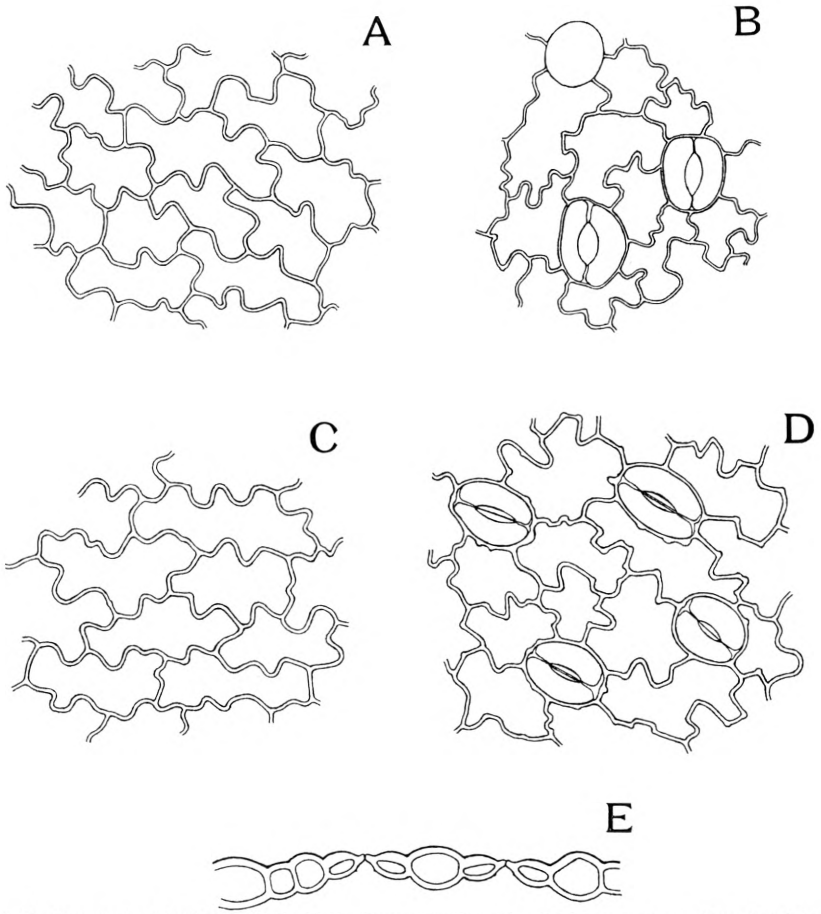

Fig. 5. A and B, *Osmunda lignitum* (Giebel) D. Stur. Epidermis of the upper- and underside of a pinnule. (Moselund). C–E, *Osmunda banksiaefolia* Presl (recent). C and D, epidermis of the upper- and underside of a pinnule, E, transverse section of epidermis (A–E × 300).

Finds of *O. lignitum* (Giebel) D. Stur are noted e.g. from the following localities:

Bournemouth (England) ..... Eocene.
Bovey Tracey (England) ..... (Upper) Oligocene.
Manosque (Switzerland) ..... Aquitanian (Lower Miocene).
Sotzka (Styria) ..... Aquitanian.
Zsilthal (Hungary) ..... Aquitanian.
Münzenberg, Stedten, Segengottesschacht, Runthal b. Weissenfels ..... (Thuringia, Germany) ..... Oligocene-Miocene.

Osmunda Heerii Gaudin

In the clay from the State quarry at Fasterholt was found an almost complete pinnule of a species of an *Osmunda* belonging to the section II. Eu-Osmunda Presl.

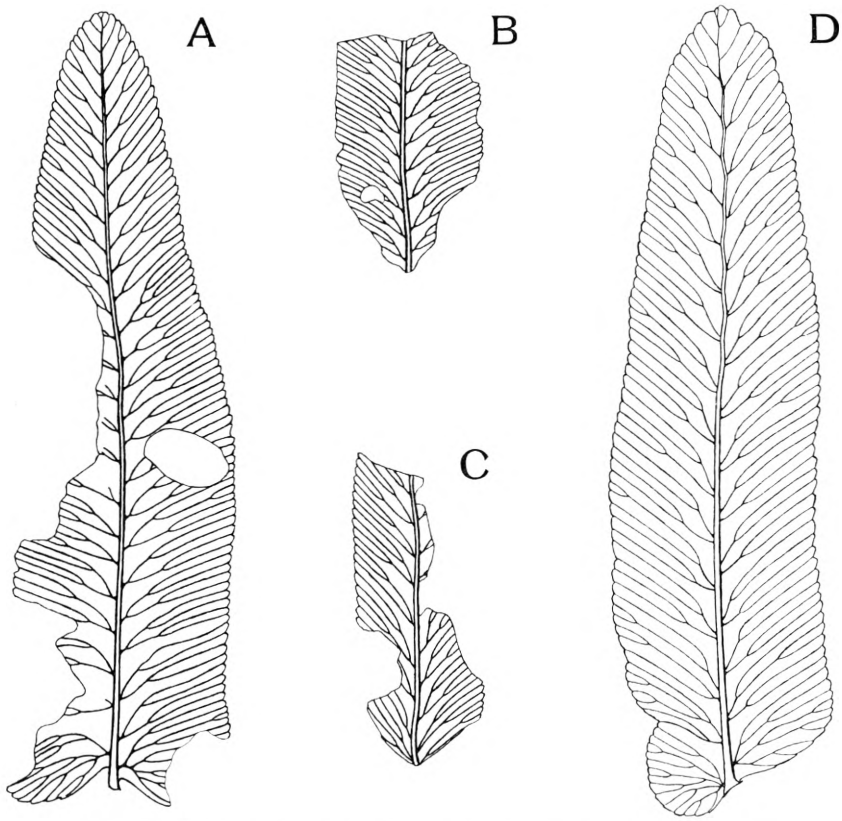

Fig. 6. A–C, *Osmunda Heerii* Gaudin. Pinnule and some fragments of pinnules (Fasterholt). D, pinnule of the recent *O. regalis* L. (A–D × 2).

The specimen is shown in Fig. 6A; in B and C are figured fragments of pinnules, probably of the same species. DIELS (ENGLER und PRANTL 1902, p. 380) characterizes the section Eu-Osmunda as follows: Blätter doppelt gefiedert. Aderung nach V. Neuropteridis oder V. Sphenopteridis.—The section comprises three species: *O. lancea* Thunberg, *O. bipinnata* Hooker and *O. regalis* L. In the first species the: Fiedern II (i.e. the pinnules of the second order) schmal-lanzettlich—while the other two species have: Fiedern II länglich oder oval.—*O. bipinnata* is described as having: Fiedern II sitzend—Adern in die Zähnchen auslaufend.—And *O. regalis*: Fiedern II kurz gestielt—Adern in die Buchten der Zähnchen auslaufend—However, it should be noted, in this connection, that according to MILDE (1868, p. 60), a var. *acuminata* of *O. regalis* exists, in which the margin of the pinnules is finely dentate and the veinules run into the denticles. The variety is found "In Wohlau and Bärhaus zugleich mit der Normalform—An ihren Standorten in Wohlau geht sie allmählich in die Stammform über" (l.c.). According to MILDE, *O. regalis* is an extremely variable species.

A close examination of the material at hand, combined with a study of the

figures given by ETTINGSHAUSEN (1865), showed that the pinnules of *O. regalis* are really so well defined, that a determination of them, even in the isolated condition, is possible. On withering the pinnules detach and it is rare to find specimens of the fossil where pinnules and secondary ribs are still connected. HEER (1859, vol. III, Pl. CXLIII, fig. 1) has figured such a one referred to *O. Heerii* Gaudin.

Fig. 6D shows a pinnule of *O. regalis* L., which resembles the pinnules of *O. Heerii*, and like fig. 6A is magnified twice. They agree so well, that the fossil must be assumed to originate from an *Osmunda* species at least closely related to the recent *O. regalis* L., if not identical with it. Several specimens of such pinnules from the European Tertiary have been figured and described.

The species *O. Heerii* was first constituted by GAUDIN et DE LA HARPE (1855, p. 423). It is found in the "Molasse" of Switzerland, and noted l.c. without description or figure. It is described by HEER (1859, vol. III, p. 155) as showing a: Fronde bipinnata, pinnulis sessilibus, alternis, oblongo-lanceolatis, basi rotundatis, plerumque inaequilaterales, apice obtusiusculis, subtilissime crenulatis, nervis secundariis dichotomis. Rivaz bei Lausanne—SCHIMPER (1869, vol. I, p. 678) observes about this species: Ressemble à l'*Osmunda regalis* L., mais les pinnules sont beaucoup plus courtes, en proportion plus larges et moins rétrécies vers le haut.—But as HEER (l.c. p. 156) mentions having seen another specimen from the same locality in which the pinnules were narrower and more elongated, the difference pointed out can hardly be of much significance.

O. schemnitziensis (J. v. PETTKO) has been described and figured by STUR (1867, p. 136, Pl. III, fig. 1–3). The name of J. v. PETTKO, given in brackets, is according to UNGER (1854, p. 137), referring to an admirably preserved rhizome, discovered in the Tertiary "Süsswasserquarze von Ilia" in Hungary and formerly described by v. PETTKO as *Asterochlaena schemnicensis*. UNGER referred it to *Osmunda* (*Osmundites*) and by D. Stur brought in relation to some pinnules found in the same locality. Some rhizones probably appartaining to an Osmunda sp. are figured by *Unger* (Salzhausen, Austria) (1864), and fossils of the same type are also mentioned from Bovey Tracey (Kent, England).—The *Asterochlaena* (*Osmundites*) may, according to the anatomy, which is very exactly figured by UNGER, appertain to an osmundaceous Fern, but it is certainly differing from the extant Osmunda sp. by the development of numerous adventitious roots, very conspicour in the transverse section, and taking their origin as well from the centre as from the outer side of the stele.

About the *O. polybotrya* (Brongniart) Schimper (fertile pinnules), this last author notes (1869, p. 679): Le *Filicites polybotrya* Brongniart a tous les charactères d'un *Osmunda*, et paraît même être assez voisine de l'*Osmunda Heerii*. The specimen is also recorded by SAPORTA (1865, p. 38).

Some intact sterile pinnules of an *Osmunda* are figured Pl. I, fig. 1 in the memoir of GAUDIN and STROZZI (1862, p. 9, Pl. I, figs. 1–4). These fossils agree very well with *O. regalis* and are named *O. Strozzi* by the authors who accompany their description with the following note: Cette espèce ressemble beaucoup à l'*O. regia* L.;

elle paraît en differer par ses pinnules plus larges et toutes dépourvues d'ailerons à la base; ces pinnules sont ègalement plus larges et plus longues que celles de l'*O. Heerii* —Age: Pliocene, Northern Italy.

Some pinnules from the Danian-Paleocene layer of Atanikerdluk (W. Greenland, Nûgssuaq Peninsula) are referred by HEER (1868, p. 88, Pl. I, figs. 6–11, Pl. II, fig. 15b) to *O. Heerii* Gaudin. The determination may be correct.

SAPORTA and MARION (1873, Pl. I, fig. 2) describe a small fragment of a pinnule as *O. eocenica*. The specimen is a rather problematical one, having a finely denticulated margin and showing a venation which is not at all convincing. Age: Eocene.

Whether there is actually any reason to distinguish the European and arctic fossil species (except *O. eocenica*) from each other and from the recent *O. regalis* seems rather doubtful. But bearing in mind the extreme range of variation of *O. regalis*, and as our knowledge of the fossils of this type is almost exclusively based upon isolated pinnules, it is at present hardly possible to solve this question.

That *O. regalis* probably represents a very ancient type is not only apparent from the fossil remains mentioned but also from its remarkable geographical distribution. Quoting L. Diels it is: eine sehr verbreitete Art; in verschiedenen Formen durch die borealen Länder Eurasiens, Indien und Ostasien (besonders in den Gebirgen), das atlantische Nordamerika, die Gebirge der Antillen und Südamerikas bis Uruguay, Ostafrika bis zum Cap, Angola, das madagassische Gebiet. Doch ist das Areal durch weite Lücken stark zerklüftet— —.

Finds of *O. Heerii* Gaudin are registered from the following localities:

Atanikerdluk (W. Greenland) ..... Paleocene.
Rivaz by Lausanne ..... Aquitanian (Lower Miocene).
Wiener and ungarisches Becken ..... Miocene, Pliocene.
Northern Italy ..... Pliocene.

Lygodium Gaudini O. Heer

In the layer of clay at Moselund were found two small fragments of fern leaves, the nearest living analogue of which must be sought for in the recent genus *Lygodium*.

Sterile leaf segments referred to *Lygodium* have previously been detected in Tertiary deposits in Europe and North America. In the Eocene and Lower Oligocene *L. Kaulfussii* Heer is noted from England and Germany. This species is distinguished by its rather large, regularly dissected, palmate segments with rather broad lobes and repeatedly furcated veins. From the "Lower Molasse" of Switzerland, HEER has described and figured four *Lygodium* species: *L. Gaudini*, *L. acutangulum*, *L. Laharpii* and *L. achrostichoides* (1855, pp. 41–43, Pl. XIII, figs. 1–15—1859, p. 155, Pl. CXVII, fig. 25b). *L. Gaudini* is described as having palmate, 3–4 lobed secondary segments

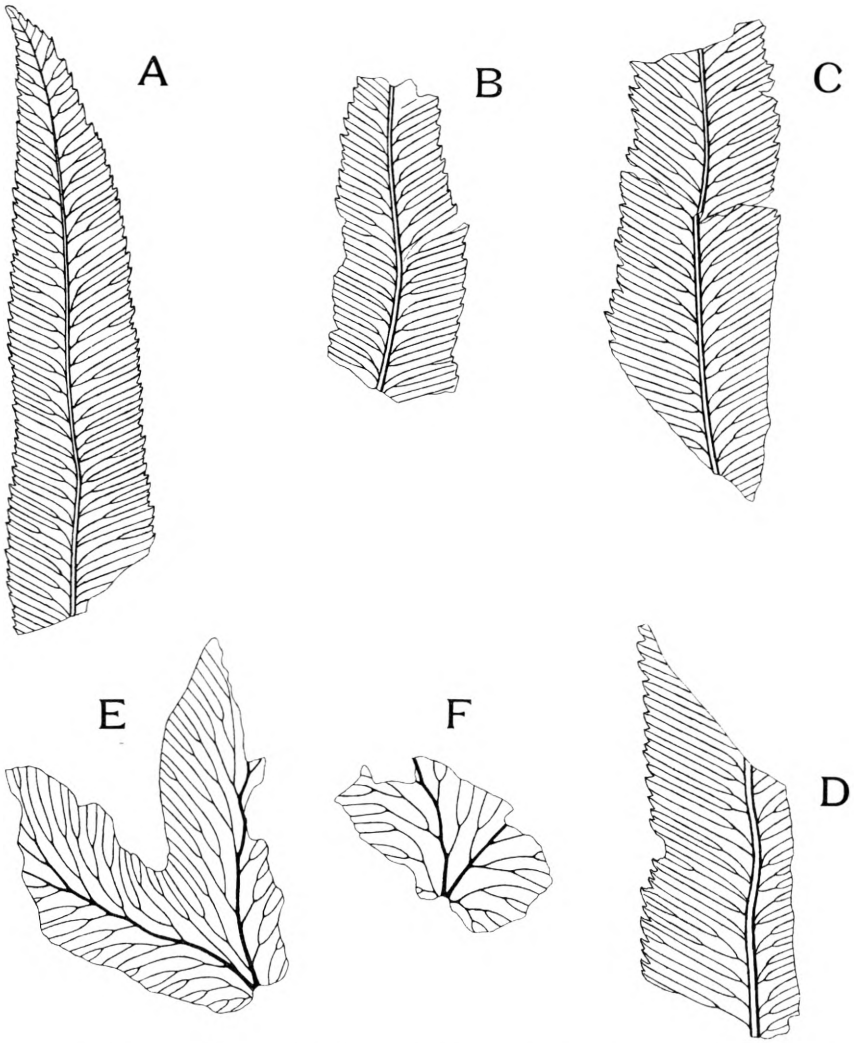

Fig. 7. A–D, *Pteris sp.*, probably *Pt. parschlugiana* Fr. Unger. Fragments of pinnules (Fasterholt). E and F, *Lygodium Gaudini* O. Heer. Fragments of leaf sections (Moselund) (A–F ×2).

of sterile leaves, the lobes of which are 6–8 cm long, 3–6 mm broad, with entire margin. In the figures the venation is only indicated, it appears rather open, as is also the case in the leaves of the three other species. These differ only slightly from *L. Gaudini*, but the figured segments are smaller with partly quite short lobes which are fewer in number.

As for *L. acutangulum*, the specimen figured as Taf. CXVII. Fig. 25 b shows the venation particularly distinct and has thus allowed a correct reproduction of the veinlets. They appear here more close set than in the other figures cited and may represent the typical feature; it agrees closely with our fossils, which also show an

entire margin. The two fragments, reproduced in our fig. 7, E and F, probably represent parts of two-lobed segments.

Gardner and Ettingshausen (1879, p. 48) as well as Friedrich (1883, p. 81) are inclined to unite the four species of Heer under the name of *Lygodium Gaudini*, and so am I. In some recent *Lygodia* a variation of the secondary leaf segments similar to that which has served Heer in establishing his four species, is met with even in the same specimen.

The living *Lygodium* species have creeping rhizomes from which proceed leaves with a slender rachis with apical growth and which finally attains a considerable length. In section I. of the subgenus Palmatae the sterile leaf segments of the second order show a repeatedly dichotomous venation; mostly they are pedate with lobes of various length and width. In subsection I.B (Engler und Prantl 1902, L. Diels p. 366) where the segments are almost sessile, is included *L. circinnatum* (Burm.) Sw., which Heer has regarded as a living analogue of *L. Gaudini*. Its area of distribution is stated to be: Ceylon, Southeast Asia, Southern China, Malaysia and New Guinea. Friedrich (l.c.) gives expression to some hesitation in respect of its correlation with the fossil. A close examination of the very complete collection of *Lygodium* in the Botanical Museum of the University, made it seem probable that a living species completely agreeing with the fossil is not really to be found. *L. circinnatum* may be an allied type, but the range of variation in shape and size of the secondary leaf segments of the type constituting *L. Gaudini* is occasionally to be found also in other species. The segments of *L. cubense*, figured by Ettingshausen (1865, Pl. 169, figs. 2 and 7) are very much like some of the specimens reproduced by Heer.

Lygodium Gaudini Heer has previously been noted from the plant-bearing beds at Rochette (near Lausanne), probably of Aquitanian age.

Goniopteris stiriaca (Fr. Unger) A. Braun

A list comprising the main literature of this fossil up to the year 1887 is given by Staub (1887, p. 232). References to papers of a later date are to be found in the memoir of H. Czeczott (1959, part. 2, p. 15).

In the clay at Moselund fragments of pinnules that are to be referred to this Fern are found, but they are rather rare. Fig. 8, A and B, shows such fragments, magnified twice.

Gardner and Ettingshausen (1879–86, vol. I, p. 39) have given an ample diagnosis of the species as follows: *Goniopteris* fronde pinnata. Pinnis linearibus, prælongis, inferioribus grosse crenatis serratisve, superioribus argute serratis vel serrulatis; nervatione Goniopteridis Aspidii, nervo primario valido prominente, recto, nervis secundariis sub angulo 50–60° orientibus, tenuibus subrectis vel paulo arcuatis, nervis tertiariis in pinnis inferioribus plerumque 6–7, in pinnis superioribus plerumque 4–5, cum vicinis conniventibus, angulis remoto curvatis, subparallelis, angulo acuto egredientibus. Soris rotundatis biseriatis— —.

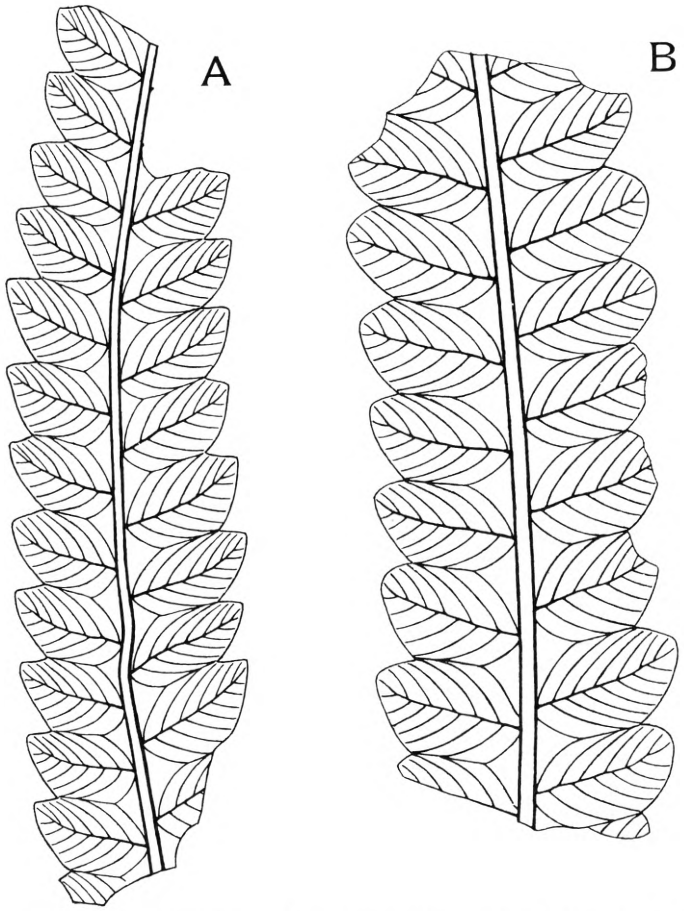

Fig. 8. *Goniopteris stiriaca* (Fr. Unger) Alex. Braun. Fragments of pinnules (Moselund) (× 2).

It is not uncommon to find specimens of this fossil Fern on which pinnules are still in connection with the rachis, thus giving an impression of the very considerable total size of the leaf. Heer has recorded such large fragments (1855, Pl. VIII, figs. 1–2); also other authors e.g. Czeczott (1959, Pl. V, fig. 1) and Dotzler (1937, Pl. I, fig. 1) have had the opportunity of meeting such.

The size of the pinnules may also be considerable. Some dimensions are given by the authors cited. Czeczott notes: 79–110 mm length of pinnules on the right side of a rachis, 51 mm on the left side; width 22–24 and 14 mm (ditto); Dotzler (1937, Pl. II, fig. 1) has figured a pinnule attaining a length of about 200 mm, being about 20 mm broad, but his photo Pl. I, fig. 1 shows pinnules of far more modest dimensions, i.e. 120×10 mm. Czeczott emphasizes the great range of variation as regards the marginal incisions: The lobes – – – – are essentially subcircular but may taper into sharp points directed towards the apex of the segment (ɔ: pinnule). The

apical segments are almost lobeless but bear sharp teeth along the margin (Pl. V, fig. 2–p. 88 in the English translation accompanying the Polish text). Other details concerning the structure of the margin appear from the excellent photos of DOTZLER. In his Pl. I, fig. 2 the pinnules show at their basal part an entire or only slightly crenated border; the characteristic denticulation is first developed some cm.s from the base and fades out again in the apical part, here—as also noted by CZECZOTT—only represented by small teeth. Here and there a rounded lobe is found intermingled between the pointed ones, but the specimens figured in the photos cited clearly belong to the type with serrate or serrulate margin.

As appears from HEER's figures the rounded lobes may prevail in some specimens (1855, Pl. VII and VIII) which is also in accordance with the diagnosis cited and the notes of CZECZOTT. HEER states (l.c. p. 31): Die Zähne – – – bei den meisten Exemplaren sind sie scharf, bei einzelnen (so figs. 4 und 6) sehr scharf, bei anderen dagegen (figs. 3 und 7) stumpf, so dass die Fieder gekerbt wird – – Our material evidently belongs to the last type.

The arrangement of the veins of the secondary and tertiary order agrees with what is demanded in the diagnosis and what also is shown by the figures given by previous authors, so I have no hesitation in referring our fossil to *G. stiriaca*, so common in the Tertiary floras of Europe, especially those of Aquitanian age.

Fertile pinnules of *G. stiriaca* are met with and are figured e.g. by HEER (1859, Pl. CXLIII, figs. 7 and 8). The sori are placed in the middle of the tertiary veins of the pinnule, one sorus on each; consequently the secondary veins have a row of sori on either side. HEER has also succeeded in demonstrating sporangia and a group of these is figured as l.c. fig. 9, magnified about 50 times.

Some allied fossil species, probably of a somewhat doubtful specific rank, have been described and figured by HEER l.c.: *Lastraea* (*Goniopteris*) *helvetica*, *oeningensis* and *dalmatica*. They mainly differ from *G. stiriaca* and from one another by the shape of the marginal incisions, a character which is shown to be very variable (GARDNER and ETTINGSHAUSEN).

This fossil Fern has been referred to various living species. ZINCKEN (1867, p. 53) considers *Lastrae prolifera* Kaulfuss as being a related type and so does KRÄUSEL (*Phegopteris prolifera* Mettenius). According to CHRISTENSEN (1906, p. 300) this species has to be named provisionally *Dryopteris vivipara* (Raddi), and so as to point out that it belongs to the group of *Dryopteris* characterized by "Venatio Goniopteridis", the prefix *Go-* (in brackets) may be added. The genus name *Goniopteris* may be retained provisionally for the fossil.

According to CZECZOTT (l.c.) the material from Turow (Poland) has yielded remains of about 1 cm thick, branched creeping rhizomes, evidently belonging to a Fern, which may be referred to *G. stiriaca*, the only known and very common Fern from this locality. The rhizomes of some *Dryopteris* (*Goniopteris*) species are in fact of this type (ENGLER und PRANTL 1902, L. DIELS p. 178).

Goniopteris stiriaca (Fr. Unger) A. Braun is noted e. g. from the following localities:

Altenrath (Germany) ..... Lower Oligocene.
Zsilthal (Hungary),
Monod, Rivaz, Rochette,
Paudeze, Hohe Rhonen (Switzerland) and
Macedonia (R. Kräusel 1927) ..... Upper Oligocene-Aquitanian.
Eriz, St. Gallen (Switzerland) and
Münzenberg (Germany) ..... Lower Miocene.
Parschlug (Styria),
Rilzing and
Lemnos, Thessalonike ..... Middle Miocene.

A statement of its occurrence in the Lower Pliocene, given by Palibin 1937 (The fossil flora of the Goderzhy summit. Acta Instit. Bot. in Acad. Science Ser. I. Fasc. 4. p. 7–92. Moscow-Leningrad) is regarded by Czeczott as probably being insufficiently supported, the geological age seems doubtful.

Blechnum dentatum (Goeppert) Ettingshausen

This species is first mentioned by Goeppert (1836, pp. 128, 138, 355, Pl. XXI, figs. 7 and 8), under the name of *Aspidites dentatus* then noted by Sternberg (1838, p. 142) as *Taeniopteris dentata*, and finally by Ettingshausen (1854, p. 15, Pl. XIV, fig. 2 and 1867, p. 90, Pl. III, figs. 1, 2 and 4) referred to the genus *Blechnum*.

The clay at Moselund has yielded a considerable number of fragments of pinnules which are to be referred to this interesting and, as it seems, rather rare fossil Fern. In our fig. 9 some of these are reproduced, magnified twice. A–C show fragments of sterile, D and E of fertile pinnules. Both agree very well with the specimens of these types figured by Ettingshausen, and they very probably belong to the same species. The specimen figured by Goeppert only represents a fragment of a sterile pinnule. The fertile pinnules of some *Blechnum* sp. (sectio Eublechnum) are markedly narrower than the sterile ones and sufficiently characterized by the two anastomoses of veinlets, parallel with and near to the midrib, bearing the sporangia and indusium and forming the sori.

Ettingshausen (l. c.) gives the diagnosis as follows: Blechnum fronde pinnata, pennis linearibus vel lineari-lanceolatis, apices versus attenuatis, basi rotundata brevissime petiolatis, margine dentatis, nervatione Taeniopteridis, nervo primario valido, prominente, recto, nervis secundariis angulis acutis vel subacutis egredientibus, creberrimis, tenuissimis, furcatis vel dichotomis, ramis elongatis craspedodromis; soris linearibus continuis, nervo primario utrinque adnatis.

As shown by the figures of Ettingshausen as well as by our reproductions, the veinlets part from the midrib at an acute angle and are very closely set, the space between them rarely surpassing 0.5 mm. The portion of the veinlets between the

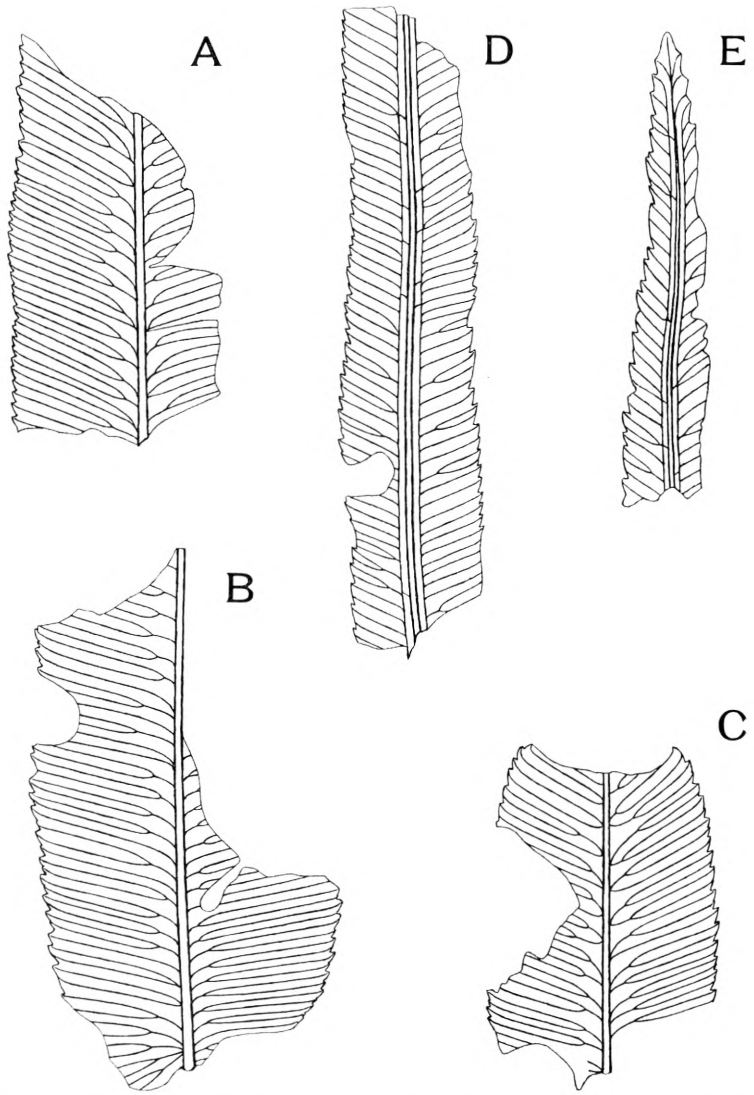

Fig. 9. *Blechnum dentatum* (H. R. Goeppert) C. v. Ettingshausen. A, B and C, fragments of sterile — and D and E, of fertile pinnules (Moselund) (A–E × 2).

sori and the main rib is somewhat difficult to distinguish in the fossil as the leaf substance in this part is a deep black colour. The details figured do, however, conform with what is found in the related living species.

The base of the sterile pinnule shows a slight incision on both sides of the very short stalk, thus being faintly auriculate (Ettingshausen 1867, Pl. III). A complete basal part was not found in our material. Fig. 9B will give an impression of a base conforming to the figures of ETTINGSHAUSEN.

Fertile pinnules of the same shape, denticulation and venation as found in the fossil are met with, as mentioned, in several living species of *Blechnum*. These belong to the section Eublechnum, characterized by L. Diels (1902, p. 246, Engler und Prantl) as follows: Blätter meist nicht oder schwach dimorph, ungeteilt oder einfach gefiedert. Blattstiel gerade, nicht windend. Sori parallel zur Mittelrippe und ihr dicht anliegend; zwischen Sorus und Rand ein breiter Raum – –

Hence *B. dentatum* comes under this section and is to be referred to its group B: Sori nahe der Mittelrippe. The sub-group Ba is characterized by undivided leaves. Bb and Bc both comprise species with sectioned leaves and the living analogue is consequently to be sought for in one of these two sub-groups. A further approximation is not possible as the characters distinguishing Bb and Bc are such as cannot be demonstrated by isolated pinnules.

B. brasiliense Dev. is, among others, regarded as a living analogue, and certainly there is some resemblance between this species and the fossil, but not to such a degree that one would venture to regard them as closely related or even identical. *B. serrulatum* Rech. might also be considered an allied species.

The fact that sterile and fertile pinnules of types agreeing with the corresponding parts of certain *Blechnum* species have been found together in two so widely separated localities as Bohemia and Denmark and of probably almost the same geological age, must strengthen the opinion that they in fact belong to the same species.

Blechnum dentatum (H. R. Goeppert) C. v. Ettingshausen has previously been recorded from Kutterschütz at Teplitz, Priesen and from Bilin, Bohemia, all comprising floras of the Aquitanian type.

Pteris parschlugiana Fr. Unger

A fragment of a pinnule, found at Salten and figured by Hartz (1909, p. 55, Pl. III, fig. 1) has been referred to this Fern. Remains of it are said to be common in the lignite of this locality but are difficult to secure intact because of the nature of the matrix. The l.c. figured specimen is indeed very incomplete, as both apex, base and margin are damaged, and only the midrib and the inner part of the venation passably preserved. The author refers to the figures published by Friedrich (1883, Pl. VIII, IX and XXIX) who also discusses the relationship of this and some other Tertiary *Pteris* spp.

The diagnoses given by Unger (1847, p. 122) and O. Heer (1855, p. 38) are completed by P. Friedrich as follows: Folia pinnata, pinnulae alternae, sessiles, lineari-lanceolatae, basi inaequilaterali rotundatae, argute serrulatae; nervus primarius validus, nervi secundarii angulo acuto egredientibus, semel-bi-vel tri-furcati.

Friedrich is inclined to regard *Pt. parschlugiana* as closely related to the Eocene *Pt. Prestwichii* Gardner and Ettingshausen (1879, p. 53, Pl. X, fig. 8), but the diagnosis of the last-named species maintains that its pinnules have an entire margin

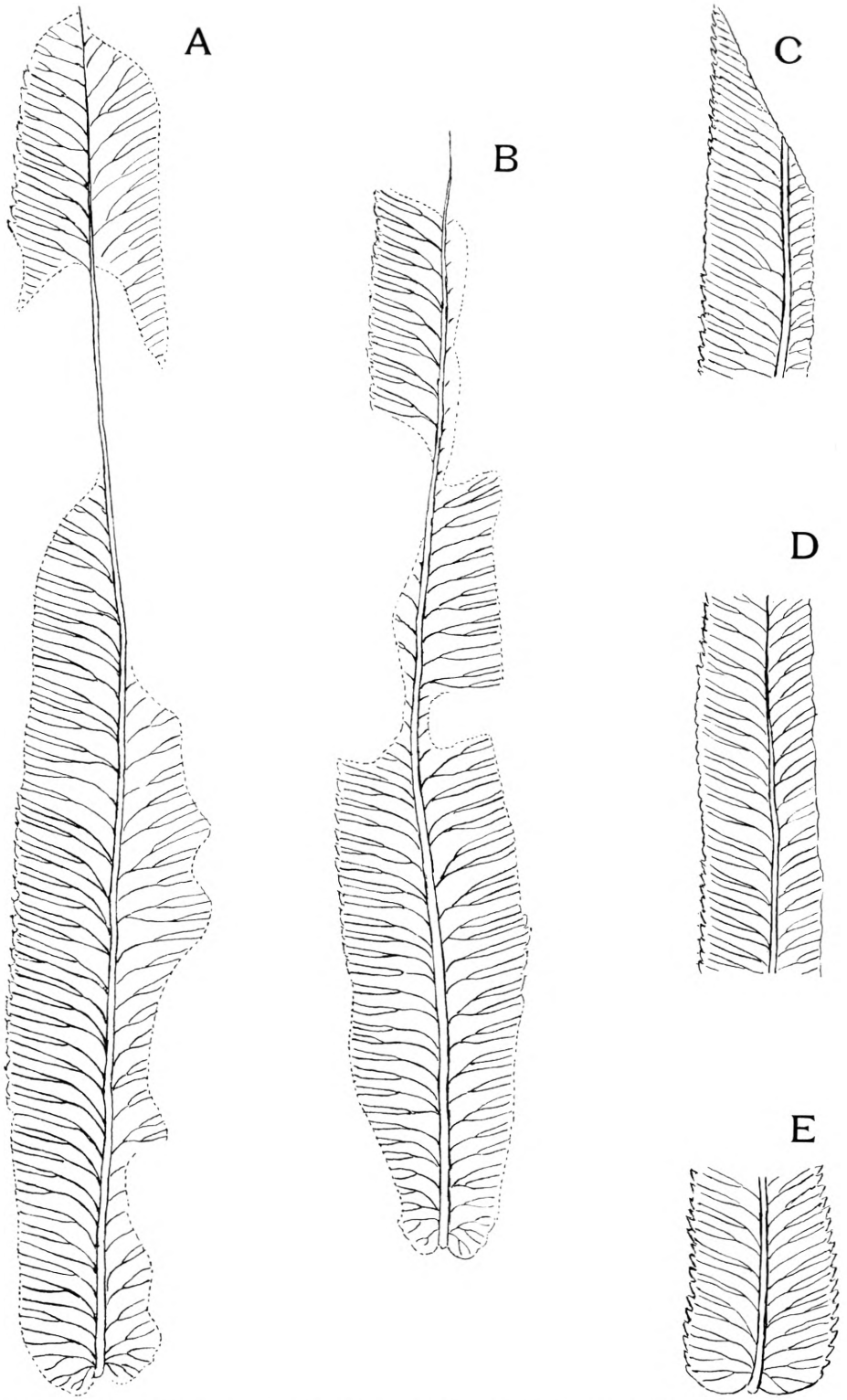

Fig. 10. A–C, *Pteris parschlugiana* Fr. Unger. Fragments of pinnules; C shows a part of the margin which probably had carried a sorus (Moselund) (× 2). D–E, *Pteris longifolia* L. (recent). Parts of pinnules. In D the margin has partly been sorus-carrying. E, base of a pinnule (× 2).

(margine integerrimis), this being the only real difference between the two species in question. FRIEDRICH has somewhat bridged over the gap by altering the diagnosis of *Pt. Prestwichii* from "margine integerrimis" to "pinnae integerrimis vel crenulate", but a marked point of distinction is at any rate obvious from this term and the note "argute serrulatae", used to characterize the nature of the margin of the pinnules in *Pt. parschlugiana*. Also O. HEER (l.c.) attributes to *Pt. parschlugiana* the character "margine argute serratis". He further adds the rather important information: Fieder am Grunde zugerundet, auf einer Seite etwas breiter – deutlich und scharf, aber sehr fein sägezähnig, nach vorn stehen die Zähne gedrängter –. The statements of FRIEDRICH agree very well with these details.

The specific rank of *Pt. pennaeformis* O. Heer and *Pt. Gaudini* O. HEER is rather doubtful according to the last cited author. The base of the pinnules is not preserved, though in the former species it was probably tapering. The venation is chiefly of the same nature as in *Pt. parschlugiana*, but the veinules are probably more densely set.

On the whole I should be inclined to refer our material to the species described by UNGER, which is a rather widespread type. Pinnules and fragments are common in the clay at Moselund, and some fragments, probably to be referred to the same species, are also found in the State quarry at Fasterholt. Figures 7, A–D, and 10, A–C, show specimens of this fossil; those from Fasterholt are distinguished by having a somewhat more markedly serrulate margin and more close set veinules than those from Moselund, but probably do not surpass the range of variation characteristic of the species. The rounded basal lobes are evident in the specimens from Moselund shown in Fig. 10, A and B. Towards the apex of the pinnules the denticulation grows more marked.

These fossils are very much like the pinnules of some still living *Pteris* species of the section I. Eupteris § 1. Simplicinnatae (L. DIELS). O. HEER states *Pt. longifolia* L. as an allied species, and indeed the morphological parallelism between *Pt. parschlugiana* and its probably most nearly related living analogon is very striking. (ETTINGSHAUSEN 1865, Pl. 52, fig. 15 and Pl. 54, fig. 1, etc.) A serious disadvantage to the determination of the generic relation has hitherto been the lack of demonstration of the linear marginal sori so characteristic in *Pteris*. The sporangia and indusium in the fossils might be destroyed by crumbling away, but their place should always be recognizable by the line of marginal anastomosing veinlets on which the sori develop and by the absence of a marked denticulation of the part of the margin outside the sorus. In some extant species the whole margin is bordered by sori, but often—as just in *Pt. longifolia*—the sorus line might be interrupted by parts of the margin showing the normal denticulation and the usual ending of the veinlets in the denticles. Fig. 10 D shows such a part of the margin from a pinnule of *Pt. longifolia* (the sorus itself has been removed) and Fig. 10 C a corresponding part from the fossil; the similarity of the two parts figured is evident. Fig. 10 C is drawn from a specimen from Moselund, with the leaf substance partly preserved. In the imprints these details are often somewhat obscure, but in many cases at least traceable.

As for anatomical details only the structure of the mesophyll could be demonstrated. The uppermost layer consists of small, cohesive elements, the lowest of a lacunous tissue, details which are not very characteristic, but which at any rate agree very well with the mesophyll of *Pteris longifolia*.

Pteris longifolia L. is a tropical and subtropical cosmopolite with a very broad range of variation; the apex of the pinnules is mostly tapering, but may exceptionally end bluntly.

Pteris parschlugiana Unger has been recorded from the following localities:

Bornstedt (Saxony) ..... Lower Oligocene.
Monod, Rochelle, Paudeze (Switzerland) ..... Aquitanian.
Parschlug, Leoben (Styria) ..... Middle Miocene.

Salvinia Bjerringii n. sp.

An extensive list of the literature dealing with the morphology, development, systematics, geographical and geological distribution of the known living and fossil *Salvinia* species, is to be found in the papers of Florin (1919 and 1940). The references here given to the papers of Hollick (1894), Herzog (1934) and Kopp (1936) are of special importance regarding the comparison of the living *Salvinia* species with the fossils.

In the clay at Moselund the floating leaves of a *Salvinia*, are found rather commonly both as fossils, in which the leaf substance is admirably preserved, and as imprints only. The former occur mainly in the black parts of the layer.

A selection of such leaves is shown in fig. 11, A–D, reproduced double life size; all these figures show the upper side of leaf. Though some of the specimens are somewhat damaged, the figures will give an impression of the range of variation with regard to shape and size. The outline is from oval-cordate to ovoid-cordate, the apex obtuse or slightly incised, and the deep incision at the base is often disguised as the two lobes are partly overlapping. In short and relatively broad leaves the outline can consequently become almost circular. Fig. 11 D shows a leaf of an exceptionally large size.

The point where the lamina has been connected with the stalk can be traced in fig. 11, E and F, as the secondary basal veins radiate out from there. In cases where the underside of the leaf presents itself by turning upward (in the imprint fig. 11 H) the scar left by the disintegration of the lamina is very conspicuous. From the base to about the middle of the leaf the midrib on the underside is rather thick and somewhat protruding, but towards the apex, it passes rather suddenly into a slender and low part. A longitudinal marking, not unlike a scar, is often found on the relief of the thickened part. The real length of the stalk could not be ascertained. It is most probably connected with the lamina at an angle of about 120° and thus inclined to be broken off by the horizontal splitting of the matrix. In a few cases the length could be estimated at about 1 cm, for a *Salvinia* consequently rather long.

As is well known, the leaves of *Salvinia* are arranged in whorls of three, each

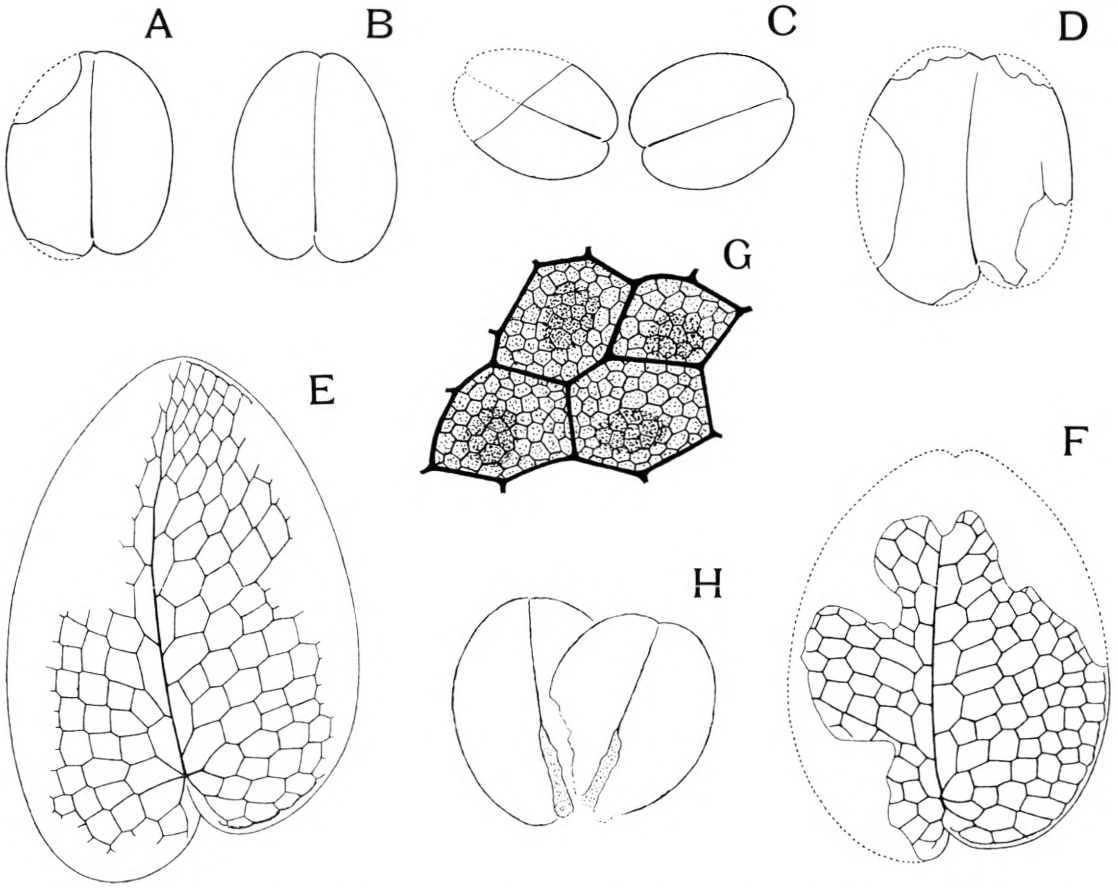

Fig. 11. *Salvinia Bjerringii* n. sp. A–D, outlines of floating leaves, upper side, and H of under side (× 2). E and F, outlines and venation of floating leaves (× 4). G, some intervenia with air chambers of the middle layer of äërenchyma, as seen from below, and showing the extension of some black spots of the upper side of mesophyll (All from Moselund) (× 20).

whorl consisting of two dorsal floating leaves and a ventral one, submerged and split up in numerous hairlike laciniae. Submerged leaves were not found in the material at hand, but in the figures of FLORIN (1919) leaves of this type are also reproduced (*S. formosa* from the Tertiary of Japan). In several instances the dorsal leaves, as shown in our figures, were found connected in pairs, undoubtedly representing the two floating leaves of the same whorl.

In the outline-figures A–D only the midrib of the leaf is shown in. E and F show details of the venation. The meshes of the network, formed by the anastomoses of the veinlets, are rather regular, exhibiting a system of five- to six-sided polygons, the size of which only slightly diminishes from midrib to margin. The type of venation corresponds to what is known from the fossil species *S. formosa* O. Heer and *S. Mildeana* Goeppert; see R. FLORIN (1940).

A character of some importance according to KOPP (1936, p. 19), but rather difficult to ascertain in the fossils, is the pattern formed by the last ramification of the veins. KOPP (l. c.) distinguishes two types in the living species of *Salvinia*: I. Die Seitennerven I. Ordnung werden nach dem Blattrande zu in fortschreitendem Masse vermehrt durch gleichlaufende, jedesmal kürzere Seitennerven höherer Ordnungen, die von den Anastomosenwinkeln entspringen. Die Maschen des Gesamtnetzes werden dadurch nach der Peripherie des Blattes zu kleiner und zahlreicher (wiederholt trichotom-anastomosierend). II. Die Maschen bilden ein annähernd gleichmässiges Netzwerk (gleichmässiger Netztypus) – – The latter group only includes two living species: *S. nigropunctata* A. Braun and *S. oblongifolia* Martius. The two Tertiary *Salvinia* species mentioned above, as well as our fossil, are evidently to be referred to the last group. In the species belonging to the former group, including the rest of the living *Salviniae*, the last ramifications end freely just inside the margin of the leaf. In *S. nigropunctata* A. Braun (= *S. nymphellula* Desveaux) and *S. oblongifolia* Martius they form connecting arches, in *S. nigropunctata* (as shown in the figures Pl. IV. 1 and 2 by KOPP) at least in the apex and at the base of the leaf. Such anastomoses could be demonstrated in our fossils, though of course only where the margin was left intact and the outline of the peripheral meshes could be distinguished (fig. 11, E and F). This is often better to ascertain in the imprints than in cases where the leaf substance is preserved.

In the papers of earlier authors the venation of the *Salvinia* leaf is generally reproduced in a very diagrammatic way, though UNGER has given a fairly accurate representation of it as to *S. Mildeana* in his Sylloge Plantarum fossilium (Part I, 1861, Pl. I, fig. 10). According to the venation the *Salvinia* species of KOPP's group II, as well as the two fossil species mentioned above and also the *Salvinia* from Moselund, have the lamina divided into a number of polygonal fields corresponding to the meshes of the veins. These fields consequently show a rather regular arrangement in series, in the lower half of the leaf almost transverse or slightly ascending, with a decidedly apically directed curve towards the upper part and a somewhat fan-shaped pattern in the basal lobes. In our fossil the middle part of the upper side of the field often shows a darker patch, slightly projecting as a low papilla' and, corresponding to this, an the under side a more or less deep depression. The nature of this last feature is not immediately obvious; as far as I know no recent *Salvinia* show anything similar, and it is probably caused by the shrinking of the underside mesophyll under decay and fossilization. According to the facts mentioned the extant *S. nigropunctata*, a West African species, might be a related type and consequently deserves special attention. This view is further strenghtened by the study of the anatomy of the two species. As a preliminary guide the figures of HERZOG and KOPP have served; from the Collections of the Musée d'histoire Naturelle, Brussels, and of Riksmuseet, Stockholm, material of *S. nigropunctata* for comparison has kindly been placed at my disposal.

Anatomy

The anatomy of the *Salvinia* leaf offers some very peculiar details, which from an early time attracted the attention of botanists. The results of these studies are reviewed in the papers of HERZOG and KOPP, and used recently by FLORIN for palaeobotanical purposes. In our material a good many details are preserved, which can be fairly well demonstrated in reflected light under a low-power objective. If the leaf substance is moistened with xylene or cedar oil the structure becomes more apparent. However, even for these objects I have found it most convenient to reproduce the details by drawings.

On the upper side of the floating leaf the form and size of the epidermal cells are traceable where the side walls locally are left intact; the outer walls seem most often to have vanished; where they are preserved, as is mainly the case in the parts covering the veins, they appear flat or slightly convex; real papillae could not be demonstrated. Fig. 12A shows a group of epidermal elements; lateral walls straight and thin, the size of the cells is varying from 50–80 μ. The three small elliptical gaps probably represent places of stomata; here, as in the whole genus *Salvinia*, quite small (14–16 μ); the guard cells are dissolved. The mesophyll is in the intervenia developed as a three-storied aërenchyma, the intercellular spaces (air chambers) of the middle and undermost layer forming penta- to hexagonal polygons, while the smaller ones of the uppermost layer are more rounded in outline. The shape and relative size of the air chambers are exhibited in fig. 12C; the polygons of the undermost layer measure 120–180 μ in diameter, of the middle layer 80–100 μ and of the uppermost only 30–50 μ. The separating borders are in fact one cell-layer thick, but in the lamellae of the middle and undermost layer of aërenchyma details are not discernible in the fossil. However, those of the uppermost layer are partly better preserved. As can be seen from fig. 12, D and E, the undermost part of their sideward borders, as well as the lamella separating the uppermost layer of aërenchyma from the middle one, is formed by quite small cells, 4–6 μ in diameter. In the uppermost parts of the borders these elements are far less distinct, the lumina being filled with a dark material and also the walls are dark coloured, so that details were not discernible; they are consequently in the figures shown in unbroken lines.

The black spot in the centre of the intervenia is mainly caused by the dark substance here filling the tissue to a higher degree than elsewhere in the leaf. Here and there, especially in the vicinity of the veins, smaller groups of such dark coloured cells also can be found.

In several recent *Salvinia* spp. (e.g. *S. natans* and *auriculata*) the conductive tissue of the veins on the upper side of the floating leaf is accompanied by cells markedly smaller than the surrounding elements each containing a globular or ellipsoidal concretion of silica, with a finely warted surface (Fig. 12F). In *S. nigropunctata* such idioblasts are lacking, but a quite small, stellate concretion of silica is to be found at the top of the greatly protruding papilla of every epidermal cell.

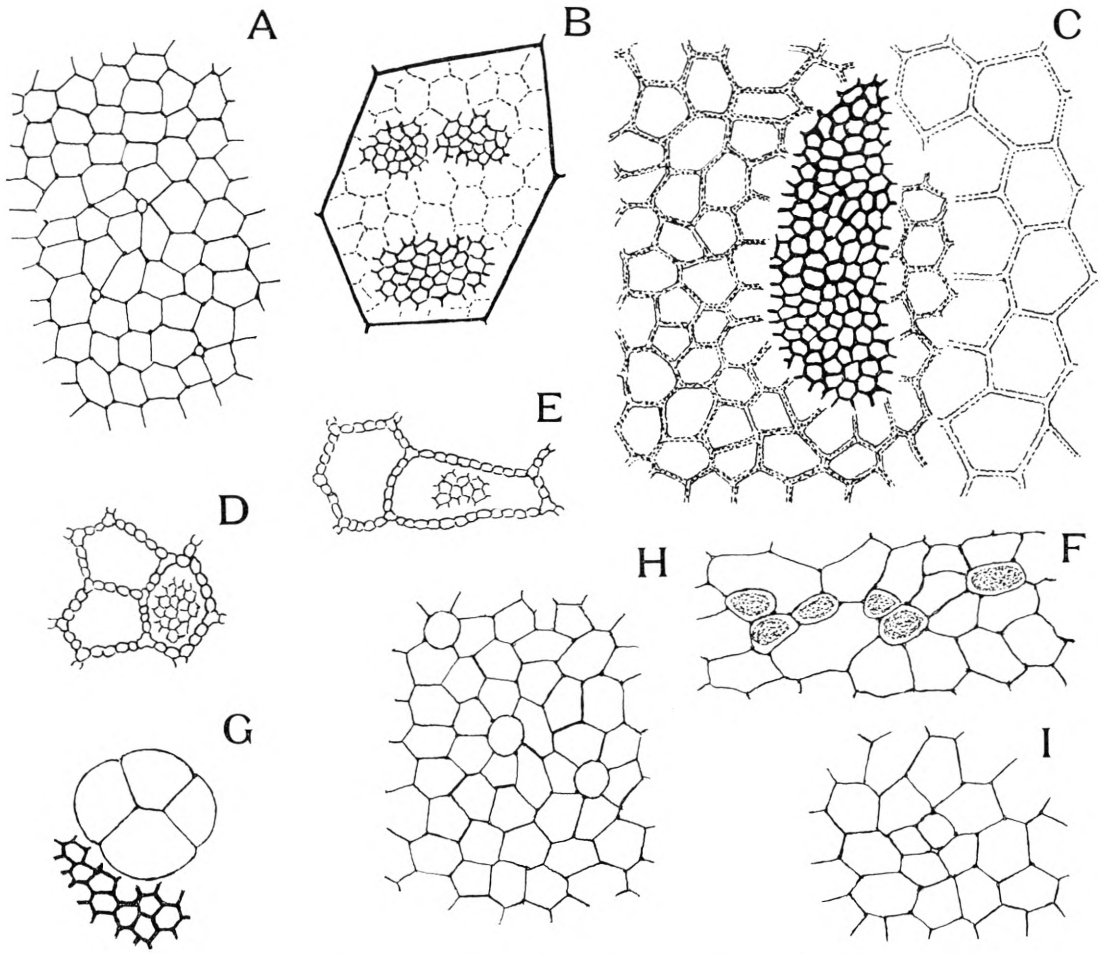

Fig. 12. A–E, *Salvinia Bjerringii* n. sp. A, epidermis from the upper side of floating leaves (× 100). B, intervenium with outline of air chambers from upper and middle layer of aërenchyma (× 50). C, outline of air chambers from upper, middle and lower layer of aërenchyma (× 100). D and E, airchambers from the uppermost layer of aërenchyma, showing the cellular texture of side walls and some cells from the bottom of the intercellular space (× 400). F, recent *Salvinia auriculata*. Part of tissue bordering on a vein from the upper side of a floating leaf showing idioblasts containing silica concretions (× 400). G–I, *Salvinia Bjerringii* n. sp. G, elements of epidermis from the bottom of an underside depression of a leaf, probably indicating the four cells which have carried a "Sockelbüschel" (× 100). H, part of epidermis from upper side; three circular cells probably indicating the bases of "Papillenhaare" (× 100). I, upperside epidermis from the central part of an intervenium; the four stellately arranged cells in the centre might have carried the four branches of a "Sockelbüschel" (× 100).

These features have not previously been recorded. As in our fossil the outer walls of epidermal tissue has almost totally vanished, I had no opportunity of demonstrating the detail last mentioned. The silica concretions would certainly have been dissolved, but the type of the epidermal elements in question should be recognizable.

The epidermis of the underside of the floating leaf had in all specimens been

totally dissolved, so that details such as hair-covering, the occurrence of "hydropotes", etc., were not demonstrable.

As the type of hair-covering, especially that of the upper surface, is to be regarded as being of systematic value, some efforts were made to clear up this feature. Unfortunately this was not thoroughly successful, as the epidermis, as mentioned, is only preserved in small patches and furthermore the outer wall of the elements is mostly dissolved, so that the bases of the trichomes consequently may have disappeared. On the top of the somewhat projecting dark spot in the centre of the intervenia, where bases of larger trichomes pre-eminently might be sought for, in the epidermis in some cases a regular star-shaped group of four cells could be traced. According to their size and outline these groups might be regarded as the place where a four-branched tuft of trichomes, forming what KOPP has termed a "Sockelbüschel", had emerged (fig. 12 I). Particularly at the bottom of the shallow pits of the imprints (underside of the floating leaf turning upward) which correspond to the somewhat elevated central parts of the intervenia, several epidermal elements are often preserved. Such groups of four, not unlike a clover-leaf with four leaflets, probably representing the base of a "Sockelbüschel" seen from below (Fig. 12 G).

Fig. 12 H show some cells of the common epidermal type surrounding some circular elements, evidently belonging to the same layer. Such cells are not uncommon, their distribution is somewhat irregular but, as far as could be ascertained, mainly occurring in small groups near the veins. Their nature is uncertain, most probably they represent the bases of what KOPP termed "Papillenhaare".

The presence of a "keel", i.e. an on the underside of the floating leaf from the proximal part of the midrib protruding part of tissue connected with the petiole, is not clearly demonstrable from the material at hand, but some facts might be regarded as hints indicating the existence of such a formation. The scar on the underside of the thickened proximal part of the midrib (fig. 11 H), in connection with the relatively long petiole, in a single case found adjoining with remains of tissue which could be referred to a keel, would perhaps point in this direction. As the hypothetic keel would be oriented vertically towards the layers of matrix, it is not likely to be found in situ, and its presence is not noted in any of the fossil species formerly described.

Of fossil *Salvinia* spp. only the *S. formosa* O. Heer, *S. Mildeana* Fr. Goeppert and *S. macrophylla* Kirchheimer have been studied in such detail that a comparison is of any use for stating the specific value of our fossil.

According to the photos of FLORIN (1940) *S. formosa* and *S. Mildeana* exhibit, as mentioned, the type of venation agreeing with the *Salvinia* from Moselund, the veinlets forming meshes of approximately the same type and—as far as could be ascertained— anastomosing by marginal arches. *S. Mildeana* is l.c. described as having: zwischen den Sekundärnerven befindlichen Doppelreihen seichter Vertiefungen, die von Haargebilden hervorgerufen sind – – The photo Pl. III, Fig. 3 shows this character very distinctly. *S. macrophylla*, which according to CZECZOTT (1959) might be identical with *S. Reussii* Ettingshausen, shows, in the photos of FLORIN, the resistant

basal parts of large "Sockelhaare" (KOPP). The markedly protruding papillae on the upper surface of the leaf in the photos of CZECZOTT may be of the same origin. As a closer relative perhaps *S. formosa* may be considered. However, the floating leaves here are much larger than is commonly the case in our specimens and also of a somewhat other shape, i.e. more oblong in outline. As for the number of layers of air chambers in the mesophyll, none of the figures cited offer the details necessary for exact comparison.

O. HEER has noted *S. Mildeana* in his memoir: Miocene baltische Flora (1869) and has figured two leaves which are referred to this species (Pl. III, figs. 1 and 2). One agrees in outline and size with the main type in our material and also here represents the most common form. The other, of a rarer occurrence, conforms with our leaf pictured as fig. 11 D. These two leaves may belong to the same species, as this is the case according to anatomical details with all the leaves figured by me. The floating leaves of the same *Salvinia* sp. may, as shown by experiment (KOPP), vary greatly in size and also somewhat in outline according to the nature of environment. The intensity of insolation and abundance or shortage of nutrients in particular play a decisive role. The same types of floating leaves, occurring associated both at Rixhöft in Samland and at Moselund, might suggest that the specimens are identical, in which case the determination of HEER is not correct. Furthermore HEER (l.c. p. 17) notes: In jeder Zelle die so entsteht (i.e. in the meshes of veinlets), bemerkt man einen schwarzen Flecken—which is in accordance with our specimens.

An absolute identity with any of the fossil species considered cannot be demonstrated and it is consequently necessary to constitute the *Salvinia* from Moselund as a new systematic unit: *Salvinia Bjerringii*—the specific name commemorating the discoverer of the fossil flora of this locality.

As for still existing species of *Salvinia* an uppermost third layer of small air chambers is only recorded in the West African *S. nigropunctata* Alex Braun. The structure of the mesophyll agrees in the main with that found in our fossil; however, the rings of small, closely set cells forming the undermost part of the top layer of the aërenchyma are in *S. nigropunctata* crowned by vertically extended, almost palisade-like elements, which cannot be demonstrated in the fossil; the structure of this part must consequently remain obscure, as transverse sections were not available. A marked difference is to be found in the size and structure of the epidermal cells of the upper side of the floating leaves; the elements are in *S. nigropunctata* much smaller than in our fossil (only 30–40 μ in diameter) and, as mentioned, each protruding as a marked papilla. The keel is developed as a 1–2 mm thick, semicircular lamina, built up of exceedingly thin-walled cells and protruding as a continuation of the underside layer of aërenchyma, consequently with very large air chambers. On the upper side of the floating leaves of *S. nigropunctata* are found "Sockelbüschel", one or two in each intervenium, "Papillenhaare" and "Thurmhaare" (KOPP), the last type not beeing demonstrable in the fossil the reasons advanced.

Considering the limited amount of fossiliferous material examined, the Pterido-

phyte flora of Moselund is to be regarded as astonishingly rich, both concerning the number of species and the abundance of specimens. The locality of Fasterholt has yielded two species, of which *Osmunda Heerii* is only found here. It may be added that at Moselund also some isolated leaf-sheets of an *Equisetum* are found, not unlike the specimen figured by ETTINGSHAUSEN (1867, Pl. II, fig. 15), and that Ferns and Fern Allies were lacking in the fossiliferous layer at Silkeborg Vesterskov.

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