2. Investigations of the Senonian of the Kristianstad District, S. Sweden

I.

On a Cretaceous Pollen and Spore Bearing Clay Deposit of Scania

A preliminary report

By

Nils-Erik Ross

Page

1. Introduction

As a link in Dr. I. HESSLAND's investigations of the Cretaceous in the Kristianstad district the author began to study the microflora of some Scanian clays. This is a preliminary account on the rich pollen and spore flora of a Cretaceous clay from Åsen. Later on the microflora of an Eocene clay from Åhus will be treated.

The author is greatly indebted to Dr. G. ERDTMAN and Dr. O. SELLING for valuable advice in palynological questions, and to Dr. I. HESSLAND who kindly suggested this study.

2. Pollen and spore bearing sediment

The pollen and spore bearing sediment is situated in the Näsum parish on both sides of the NE. bay of Lake Ivösjön. This sediment has long been known for its rich content of fossil tree logs. Earlier, GRÖNWALL (1914) and LUNDEGREN (1931, 1934) have given accounts of this deposit.

At Axeltorp at the E. side of the bay the clays have earlier been dug out at a brickyard but this is now laid down and the sections have been covered with vegetation. At Åsen at the W. side of the bay opposite Axeltorp there are now two large sections in the clay pits of Iföverken and Höganäs-Billesholm, Ltd., which are situated near the shore a few hundred meters from one another. There unclean kaolin clays are exploited. The samples analyzed have been taken from the Ivö pit at Åsen.

The sediment of Åsen is not consolidated. It is composed of stiff kaolin clays horizontally penetrated by stratified, sandy beds. The thickness of the layers exposed is 12 m — the Quaternary deposits not included. The usual colour of the clays is light yellow to nearly black at levels rich in carbon. Threads of roots bore through all the sediment except the sandy beds, which hold the fossil wood. The logs always lie horizontally and are more or less fragmentary and thus they must be allochthonous. Around the wood the sediment is rich in pyrite. Together with the economically worthless sand the tree logs are heaved down on the shore where a lot of the black, charred wood has been accumulated. When exposed to air the logs get dry and rapidly crack. By drenching in glycerine it has, however, been possible to preserve some wood fragments so that slides could be made. Unfortunately, the fine-structures observed in these slides are not so well preserved that they permit a reliable specific determination but both the macro- and microhabitus indicate that they are conifers.

LUNDEGREN (1931) considers the Cretaceous sediment at Åsen to be fluviatile because of the irregular stratification of the sandy beds. In a slide, derived from a sandy clay of Åsen, the author also observed a beautiful microstratification. On the photograph of the slide (Pl. III) the distances between the dark, very fine-grained layers are about 1 mm.

The river which brought forth the material may have drained the deeply weathered upland Archaean district in the north. LUNDEGREN states that the sandy beds may have been deposited when the river flooded. At the same time the drift-wood from the northern forests went ashore.

With the exception of a few *Hystrix* specimens no marine macro- or microfossils have been found in the Åsen sediment. According to an analysis by Mr. Å. BERG the sediment is also devoid of diatoms.

According to LUNDEGREN, borings have shown that the clays of Åsen rest upon green kaolin situated at about the level of the lake surface. At Axeltorp this kaolin begins at a higher level and is there exposed at the old brickyard. Immediately above this kaolin there is found a layer of clayey gravel a few dm thick containing big, angular quartz-pieces. According to the same author borings of 40 m through the kaolin at Axeltorp were made without attaining its floor. The green kaolin is considered to lie in situ and to be a transformation product of the local gneiss (GRÖNWALL 1914).

In the kaolin pit at the N. point of Ivö (Blaksudden) HENNIG (1910) found a layer of sand and dark brown clay containing fossil wood. This sediment appears to correspond to the plant bearing deposits of Åsen and

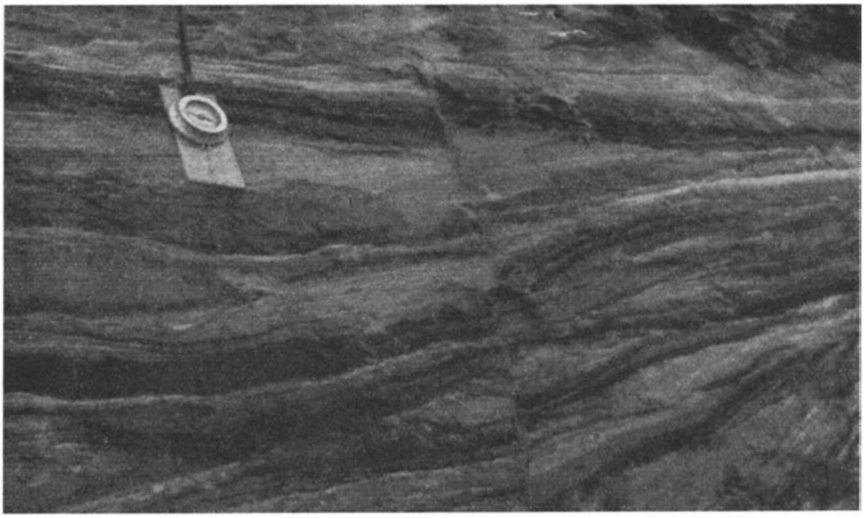


Fig. 1. Stratified, sandy bed of the Cretaceous of Åsen. In this bed a lot of fossil tree logs are embedded.

Axeltorp. It is situated on the kaolin layer and beneath the Cretaceous limestone. According to an analysis by HALLE (recorded in HENNIG's paper) the Blaksudden clay contained spores of *Pteridophytes* and pollen of at least two dicotyledonous species. LUNDEGREN (1934) could not find this clay and considered it to have been dug away. Last summer the author, however, observed the plant bearing clay in the NE. part of the pit at Blaksudden.

Though no invertebrate fossils have been found in the sediment of Åsen it has been considered to be referable to the Cretaceous. The high percentage of pollen grains in the Åsen sediment, reported in the present paper, indicates that the clays must be younger than the Lower Cretaceous because angiospermous plants were common only after that time. On the other hand there are among these pollen grains some ancient types which, in Germany, occur in Upper Cretaceous and Palaeocene strata but not in younger ones. No exact correlations, however, can be drawn on the basis of pollen types for the reason that there are no Cretaceous pollen grains dated to stages with which to correlate.

The stratal position of the plant bearing clay at Blaksudden indicates, however, that it belongs to the basal layer of the Cretaceous of the district. According to LUNDEGREN the lowest part of the limestone at Ivö is referable to the earliest part of the Mammilatus period (Lower Campanian). In a later paper, HÄGG (1943) recorded one specimen of *Scaphites binodosus* from Ivö which may indicate that the Binodosus Zone (Upper Santonian) is also represented. The minimum age of the subjacent plant bearing deposits of the Ivö district (Åsen included) should, therefore, be Upper Santonian or Lower Campanian.

In the deep boring at Åhus HESSLAND (1949) observed carbonaceous clays in the lower part of the Åhus formation. These clays also contain pollen and spores but they are very scanty and badly preserved as is often the case in marine sediments. The basal part of the Åhus Sandstone is Santonian (according to HESSLAND).

The high carbonaceous percentage and the wood fragments of many of the basal clays in the Cretaceous of the Kristianstad district may originate from the vegetation which was destroyed during the Senonian transgression.

Pollen grains and spores have been observed at many levels of the clays of Åsen. The preliminary results now presented are, however, almost exclusively based upon material from a stiff, greyish-yellow kaolin clay 7.5 m below the soil surface (level 11). This clay appears to be rich in well preserved pollen grains; in fact, the stage of preservation is here nearly as good as that of Quaternary pollen grains. Another still richer level with types varying in part from the preceding ones is a very carbonaceous, nearly black clay 3.5 m below the soil surface.

The good preservation of the spores and pollen at level 11 is probably due to the high percentage of kaolin in the clays — this very fine-grained, soft sediment having protected the grains from corrosion and from the agencies of the atmosphere. Thanks to this fortunate condition the palynological material may only be slightly affected by two types of defects which are common among fossil spores and pollen: the appearance of new structures in the exine because of disintegration of the grain (cf. KIRCHHEIMER 1931) which renders a description of the specimen rather unreliable and, also, the selective destruction of the grains which favours resistant types. In this case the composition of the original pollen flora is not shown.

3. On previous investigations of pre-Quaternary pollen grains and spores

As early as 1867 SCHENK, in his classical description of the Rhaetic of Franconia, pictured spores, and since then palaeobotanists have often completed their descriptions of fossil plants by picturing corresponding spores or pollen grains. In this way a number of Palaeozoic and Mesozoic spores and also some pollen have been known. An analysis almost exclusively dealing with spores in a pre-Quaternary Swedish sediment was made by NATHORST (1908) who investigated a plant-bearing clay of the Lias of Scania. Among the Liassic spores he also found air-sacs bearing pollen grains of coniferous type.

After the Quaternary pollen analysis had been elaborated the investigations soon were extended to pre-Quaternary deposits. German students of Tertiary brown-coal were pioneers because this is rich in well preserved pollen and spores. From the Tertiary we know about 200 types of pollen

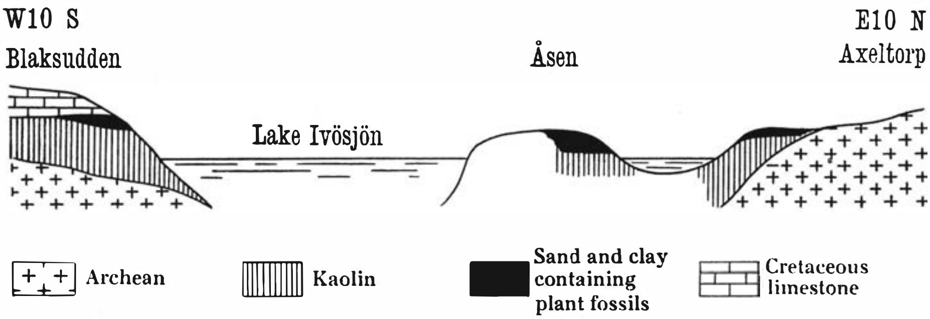


Fig. 2. Schematic section through the N. part of Lake Ivösjön.

and spores. Many of them have been identified. The pollen analysts also have given us a rough idea of the appearance and frequency of these forms from the Palaeocene up to the Quaternary.

Palynological record of Cretaceous strata is very scanty and consists only of a few preliminary notices besides some isolated descriptions of pollen and spores in various palaeobotanical treatises. KIRCHHEIMER (1932) described six pollen types from the Upper Cretaceous dysodil of South Africa. He only estimates those specimens to belong to gymnospermous and angiospermous plants stating that "the exact botanical identification of the pollen and consequently of their plant-species is, for the time being, impossible".

In his comprehensive paper on Mesozoic pollen and spores THIERGART (1949) also deals with some Upper Cretaceous specimens of Germany. (These specimens may originally have been recorded in a paper by the same author of 1942 — not available in Sweden.) The few German pollen and spores do not correspond to the Scanian ones except some *Eucalyptus*-like pollen grains which, according to the present paper, may originate from some extinct plants (cf. p. 36).

R. POTONIÉ, THIERGART, and other brown-coal specialists who introduced the Tertiary pollen analysis in Germany used the palynological material for stratigraphical purpose and they did not investigate thoroughly the botanical relations of their spores and pollen. They based the systematization of the grains on mere morphological characters. Only when an obvious similarity to a recent form was apparent was this fact noted by combining the name of the recent genus with the artificial one e.g. *Alni-pollenites verus* (R. POT.).

The importance of fossil spores, with regard to botanical and plant-ecological aspects, depends on the possibility of their identification. Concerning Tertiary pollen, KIRCHHEIMER, RUDOLPH, WODEHOUSE, and also THIERGART have shown that it is often possible to identify the specimens, at least to the genus, by comparing them with recent forms. Spores and pollen in pre-Tertiary formations, may, however, be more difficult to identify, as the number of extinct plants increases. Among the Upper Cretaceous pollen grains of Åsen no form has yet been possible to identify even though the affinities of some spores seem to be clear. This fact may be a manifestation of the greater conservatism of pteridophytes compared with angiosperms and gymnosperms.

Another obstacle in the identification of pre-Quaternary spores and pollen is the fact that the recent tropic and subtropic vegetation is incompletely known in palynological respect (where the relatives of Lower Tertiary and Cretaceous plants occur in large extent). Further investigations on spores of Australia and New Zealand, for example, may also increase our knowledge about old fossil spores in Europe.

As it is usually impossible to identify fossil spores and pollen as to species, it also is difficult to decide whether a form represents one or more species. ERDTMAN (1947), therefore, has proposed the term sporomorpha to be used instead of pollen or spore "species". Thus, a certain sporomorpha can have been produced by more than one plant species but one single species also can produce several different sporomorphae.

In the paper cited above, ERDTMAN proposed a morphologically based classification for fossil sporomorphae which seems to be more simple, and better corresponds to our knowledge of pollen morphology, than the earlier systems of POTONIÉ and others. In the classification of unidentified sporomorphae I have followed ERDTMAN's system but those names created on a mere morphological basis I only regard as working-names to be used until a closer connection with the natural system is achieved. The names which I consider to be of more permanent value are characterized by *n. spm.* (new sporomorpha). When obvious similarity with a recent sporomorpha occurs the name of the fossil sporomorpha has been formed by adding the ending *-idites* to the name of the genus or species (cf. also COOKSON 1947).

In the description, ERDTMAN's terms of 1943 (somewhat modified and completed by himself in later papers) have been used. The length of the polar and equatorial axes have been stated in the succession now mentioned. On the plates the specimens reproduced, with a few exceptions, are magnified 820 times.

All samples analyzed have been boiled in hydrofluoric acid and then acetolyzed (cf. ERDTMAN 1943, p. 32).

4. Sporomorphae

Trilete spores (*Trilites*).

Lycopodium cerniidites n. spm. Pl. 1, figs. 1—2.

Tetrahedral, trilete, 14 × 27 (10—19 × 24—29) μ. The outline in polar view nearly rounded. Exine light brown, max. 5 μ thick, distinctly two-stratified with a peculiar sculpture of arched crests (cf *Lyc. cernuum, nutans* and *inundatum*). The faceted proximal wall not sculptured. The læsuræ of the tetrad scar do not reach the angles.

The name alludes to the close resemblance to the recent spore of the tropical *Lycopodium cernuum*. The *Lyc. cernuum* spore is, however, a little greater than the fossil form. SELLING, who studied Hawaiian spores of *Lyc. cernuum* (1946 p. 17), states the dimensions to 19 × 31 μ. The same author also calls attention to the great similarity between the *L. cernuum* spore and a spore from the Oligocene of Germany (THIERGART 1940, Taf. VI, fig. 30).

Gleicheniidites senonicus n. spm. Pl. 1, fig. 3.

Under this name a sporomorpha here is described that probably has been produced by several genera most of which may have belonged to *Gleicheniaceae* — one of the best known Cretaceous fern families. The investigated material is not yet sufficiently great to permit a further division of this type.

Tetrahedral, trilete. 12 measured spores show that at least two size groups are present: 16 × 26 (13—19 × 24—29) μ and 17 × 37 (15—19 × 34—39) μ. In polar view triangular with more or less rounded angles and usually somewhat concave sides. The proximal wall flattened. Exine yellow to light brown, 1.5—2 μ thick and usually devoid of sculpture (on a few spores a faint reticulum was observed). The læsuræ of the tetrad scar always reach the angles.

In shape and size this sporomorpha coincides very well with recent *Gleichenia* spores, especially *Hicriopteris (Gleichenia) glauca* COPEL. According to SELLING (1946, p. 33) the spores of *Hicr. glauca* measures 22 × 30 μ and *Gl. linearis* 27 × 38 μ. The polar axes of the *Gleichenia* spores are longer than those of *Gleicheniidites* but this may depend on a secondary shrivelling of the latter. SELLING states that the *Gleichenia* spores are different from all other spores in the rich Hawaiian flora but "the task of recognizing different species in the fossil finds is at present very hazardous" (1946, p. 35).

It must, however, be pointed out that smooth spores of similar habitus occur in other recent and fossil fern families e.g. the Cretaceous *Tempskya* (ANDREWS and KERN 1947). The spores of the latter are, however, too big to be considered here.

THIERGART has reproduced several smooth, trilete spores from the browncoal of Germany. Judging from his photographs a specimen from the Eocene — the Lower Miocene (*Sporites Neddeni* f. *antiquior* THIERG., THIERGART 1940 p. 25 Taf. IV, fig. 2) resembles the sporomorpha here described very closely. Its equatorial diameter measures about 32 μ. THIERGART states that this form does not occur in sediments younger than Upper Oligocene. It may be pointed out that the palaeobotanists have shown that *Gleichenia* ferns disappeared from Europe in the Oligocene. (GARDNER and ETTINGSHAUSEN 1879.)

"*Microlepiidites psilatus*." Pl. I, fig. 13.

Tetrahedral, trilete 31 μ (1 ex.). In polar view triangular with broad, rounded angles. Exine about 2 μ thick, light brown with a very faint reticulum. The læsuræ do not reach the angles and are surrounded with crests.

SELLING has pictured a Hawaiian spore of *Microlepia setosa* that, judging from the photograph, seems to resemble this form rather well though the Hawaiian spores are somewhat bigger (36 × 44 μ) and devoid of sculpture. According to the author the *Microlepia* spore is "distinct from other Hawaiian types".

"*Anemiidites echinatus*." Pl. I, figs. 17—18.

Tetrahedral, trilete, 18 × 28 μ (1 ex.). In shape and size like *Gleicheniidites* but the brown exine is furnished with spines about 2 μ long. REED (1947) has pictured some *Anemia* spores with similar spiniferous exines (e.g. *A. radicans, A. mandioccana* and *A. underwoodiana*). But these are all bigger than the Cretaceous specimen.

No records of similar, pre-Quaternary spores have been observed.

Cibotiidites zonatus n. spm. Pl. I, figs. 15—16.

Tetrahedral, trilete, 26 × 48 μ (1 ex.). In polar view triangular. Exine dark brown, 4—5 μ thick provided with thickenings in the equator and parallel with this one. The læsuræ are surrounded with crests and reach the angles. The pictured specimen is somewhat cracked.

As the name points out this sporomorpha is compared with *Cibotium* spores. Of investigated recent species, the spore of *Cib. chamissoi* shows the best resemblance but it is bigger than the *Cibotiidites*; SELLING (1946, p. 40) measured 175 Hawaiian *Cib. Chamissoi* spores to 42 × 64 μ.

"*Trilites psilatus*." Pl. I, fig. 12.

Under this name until further notice a trilete, *Sphagnum* like sporomorpha is described.

Tetrahedral, trilete, 12 × 30 μ. Exine smooth, 3—4 μ thick. The læsuræ do not reach the angles.

This type is rather common at Åsen. Because of its indifferent appearance a deciphering is difficult.

"*Trilites scrobiculatus*." Pl. I, figs. 5—7.

Tetrahedral, trilete, 27 × 40 (20—36 × 31—48) μ (9 ex.). In polar view triangular with rounded, against the proximal pole somewhat bowed angles.

The distal wall arched and the proximal wall sharply faceted. Exine yellow—light brown, about 2.5 μ thick. Most characteristic for this type is the distinct sculpture with small rounded pits. The læsuræ usually reach the angles.

At level 11 this sporomorpha is rather common. I have found no descriptions of recent or fossil spores of this type.

"Trilites cristatus." Pl. I, figs. 10—11.

Tetrahedral, trilete, 31 × 38 μ (1 ex.) Habitus similar to that of "*Tril. scrobiculatus*" but the sculpture consists of thin angle-bent crests. The sculpture dissappears towards the tetrad scar. The latter does not reach the periphery. No records of recent or fossil spore of this type have been observed.

Monolete spores (*Monolites*).

Polypodiidites senonicus n. spm. Pl. I, figs. 8—9.

Bilateral, monolete, 18 × 43 μ. Exine brown, about 2 μ thick, covered by large warts shrinking towards the scar. The furrows surrounding the projections form a rather regular reticulum in the same way as is shown by the excellent photograph of the Hawaiian *Polypodium pellucidum*-spore in SELLING's treatise (1946 pl. 7, fig. 158). Beside this spore the *P. vulgare*-spore can be stated. Both these recent *Polypodium* spores are, however, bigger than the Cretaceous one.

THIERGART (1940) has pictured many *Polypodium* spores from the Tertiary of Germany but it is difficult to draw parallels between these ones and the Cretaceous sporomorpha only judging from his photographs. *Polypodium* like spores with rough sculpture THIERGART comprehends under the name of *Sporites favus* POT. to which group also the *Polypodiidites senonicus* could be referred.

Pollen grains with two air-sacs (*Disaccites*).

Pinus.

According to RUDOLPH's investigation (1935) the pollen of Pinus can be divided into two morphological groups: the *silvestris-type* with its air-sacs more or less spherical and standing out from the body and the *haploxylon-type* with its air-sacs half spherical in polar view and running over to the body without angles. The two *Pinus*-sporomorphae found at Åsen represent these two morphological types.

The silvestris-type: Pl. II, figs. 36—38.

Monosulcoid, the body 26 × 43 μ, total length 67 μ. The exine of the proximal cap is dark brown and rather thick (about 5 μ) with a peculiar, rumpled sculpture (fig. 38). The dominating sculpture-elements of the transparent bladders are branching crests.

Among recent Pinus-species RUDOLPH found the silvestris-type chiefly limited to the subgenus *Diploxylon*. These recent grains are generally somewhat bigger than the Cretaceous specimen. (The length of acetolyzed grains of *P. silvestris* usually exceeds 70 μ). THIERGART (1940) has pictured Tertiary specimens ranging within 60—85 μ.

The haploxylon-type: Pl. II, figs. 39—40.

Monosulcoid, the body 20 × 35 μ. Total length 40 μ. The sculpture of the bladders is a coarse reticulum that runs over the body with diminishing meshes. The brown exine is rather thin.

In his description of Liassic spores and pollen cited above NATHORST has pictured some coniferous pollen-grains whose bladders all have the same contour as those of the haploxylon-type.

In the Tertiary grains of *haploxylon*-type are common but disappear in the Upper Pliocene according to THIERGART. (1940, p. 33). Among recent species RUDOLPH (1935) found *haploxylon* characters only by the pollen of *Pinus peuce*.

Monosulcate pollen grains (*Monosulcites*).

"*Monosulcites reticulatus*" Pl. II, fig. 33.

Monosulcate, spheroidal, 25 μ in diameter. Exine about 5 μ thick with a faint reticulum.

It may have been produced by some monocotyledonous plant.

Triorate pollen grains (*Triorites*).

"*Triorites vestibulus.*" Pl. II, figs. 26—28.

Triorate, prolate, 17 × 19 μ (5 ex.). Exine light yellow and transparent, devoid of sculpture. The vestibules inside the ora are limited by an inner exine layer. One specimen with four apertures was observed (fig. 26).

The principal construction details of this sporomorpha appear to be the same as in *Betula* and *Alnus*.

Tricolporate pollen grains (*Tricolporites*).

"*Tricolporites psilatus.*" Pl. III, fig. 46.

Under this name small, tricolporate and smooth pollen are summed up.

Tricolporate, prolate, 10 × 15 (9—12 × 12—17) μ (8 ex.). Rounded poles, colpae always well marked. Exine transparent, yellow and devoid of sculpture.

Pollen of this type is found e.g. in *Rubiaceae*, *Celastraceae*, *Gesneriaceae* (cf. SELLING 1947) and are according to SELLING sometimes difficult to keep apart. The specimens of level 11 are rather uniform in regard to shape and size. It may, however, be difficult to refer them to a special family.

THIERGART (1940) has described similar smooth, tricolporate forms from the Tertiary which he considers to be *Castanea* pollen. They measure 9—15 μ and are common in the whole Tertiary with a maximum in the Lower Tertiary.

"*Tricolporites pilatus*." Pl. II, figs. 19—21.

Tricolporate, suboblate, 19 × 25 μ (2 ex.). Ora not distinct, colpae long and rather broad. Sexine distinctly pilate, about 4 μ thick. Nexine about 2 μ thick.

Though this pollen is very well preserved and can be studied in detail an identification is not easy because there are many families that produce similar pollen. The *Ligustrum vulgare* pollen show rather close similarity (cf. ERDTMAN 1943, p. 114) and also the pollen of some *Kadua* species (SELLING 1947, p. 300).

POTONIÉ has pictured a similar type from the Tertiary of Germany (1931, Taf. I, Fig. 26).

"*Tricolporites reticulatus*." Pl. II, figs. 22—23.

Tricolporate, prolate, 16 × 13 μ. To shape and size similar to the "*Tric. psilatus*" but the exine is furnished with a rough reticulum.

Judging from the photograph this sporomorpha coincides rather well with a Miocene pollen (*Poll. confinis* R. POT., THIERGART 1940, Taf. III, Fig. 30). According to THIERGART (p. 46) "ähnliche Formen finden sich bei Salicaceen, Oleaceen und Caprifoliaceen."

Tricolporites protrudens-type. Pl. II, fig. 25, Pl. III, fig. 42.

Tricolporate, peroblate, 12 × 29 μ. Exine pitted, 3—4 μ thick. This sporomorpha appears to be closely related to *Tricolporites protrudens* ERDTMAN described below. ERDTMAN's specimen has been found in a Quaternary clay of Scania and may originate from some Cretaceous clay which has been eroded during the Quaternary glaciation.

Tricolpate pollen grains (*Tricolpites*).

"*Tricolpites aspidatus*"-types.

Under this name the author until further notice describes some pollen grains with very thick exines and big intumescences around the apertures. The external shape coincides sometimes with that of *Tricolporites protrudens* ERDTM. but the similarity does not include the sporoderm stratigraphy.

f. *tricirculatus*. Pl. II, fig. 35.

Peroblate, 10 × 25 μ. The big aperture intumescences are dark brown and somewhat bent against one pole. Exine yellow and transparent, 1—1,5 μ thick with a very faint sculpture.

According to verbal information from DR. J. IVERSEN similar types have been observed as "secondary pollen" in Quaternary deposits of Denmark.

Another pollen of this morphological group (Pl. II, fig. 29) observed in the Åsen sediment corresponds very well in shape and size with some Palaeocene specimens of *Poll. Pompeckij* R. POT. (e.g. THIERGART 1940 Taf. XII, Fig. 19—20).

In a later paper THIERGART (1945) referred some of his *Poll. Pompeckij* specimens to the genus *Symplocos*. The sporomorpha here described, however, appears to be quite different from the hitherto described pollen of that genus.

f. *triangulatus*. Pl. III, fig. 41.

Oblate spheroidal — suboblate, 15 × 18 (10—18 × 15—22) μ. Exine dark yellow, 2—3 μ thick, usually smooth but sometimes reticulate. Colpae (or ora) rectangular, about 5 μ long.

In the Upper Cretaceous and the Palaeocene of Germany THIERGART (1940, Taf. XII, Fig. 21, 23—26, 1949, Taf. IV/V, Fig. 59—60, 66—68) observed pollen grains of the same type as the sporomorpha here described. These grains he names "*Eucalyptus*-ähnlicher Typ".

Though the present sporomorpha shows a rough similarity to *Eucalyptus* pollen it cannot be referred to this genus because it is devoid of a morphological feature characterizing certain myrtaceous pollen grains e.g. *Eucalyptus* and *Metrosideros,* viz. the furrows crossing over each aperture. In polar view these furrows are seen as three arches connecting the apertures (cf. e.g. ERDTMAN 1943, p. 108 and SELLING 1947, p. 161). Only one of THIERGART's *Eucalyptus*-like pollen (1940, Taf. XII, Fig. 26) is equipped with distinct arches. (The details of the apertures is not shown because the specimens are pictured in polar view.) It is, therefore, open to question whether the other of THIERGART's *Eucalyptus*-like pollen grains really can be compared with this genus or not.

The aspidate sporomorphae described above do not appear to show close affinity to any known modern pollen grain. For the present, therefore, we must refer them to some extinct plant family or genus.

Their thick exines render them rather resistant against corrosion which may explain their occurrence as secondary pollen in Quaternary deposits.

"*Tricolpites peroblatus*." Pl. II, fig. 31.

Tricolpate, peroblate, 7 × 21 μ (4 ex.). Exine rather thin with a rough sculpture.

No similar fossil or recent pollen was observed in the literature.

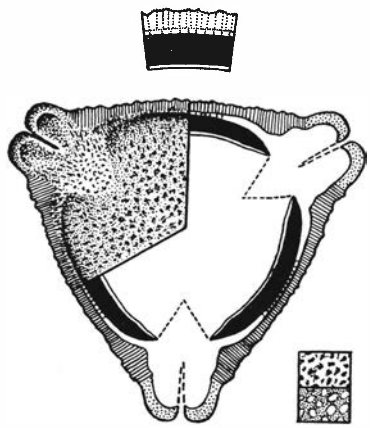


Fig. 3. *Tricolporites protrudens*. Pollen grain, polar view (surface view and optical section combined). 1050×. Upper detail figure: sclerine stratification, 2100×. Lower detail figure: sexine details from above at high and low adjustment of the microscope (G. ERDTMAN).

Tricolporites protrudens n. sporomorpha.[1]

Pollen grains tricolporate, of medium size, equatorial diameter about 40 μ [= 5 μ (sclerine thickness) + 25 μ (diameter of intranexinous lumen) + 10 μ (height of sexinous aspidoid angles)], flattened (probably suboblate or oblate), triangular with slightly convex sides and protruding rounded angles. For other details, see fig. 3. Type specimen in slide No. 1, sporomorph slide collection, Palynological Laboratory, Stockholm. This slide contains material from a Late Glacial clay sample from Scania entered as No. 1549 in the collections of the Geological Survey of Sweden.

The pollen grains in *Betulaceae*, *Casuarinaceae*, *Myricaceae* (with the exception of *Didymeles*, a genus *incertae sedis* which must be referred to another family), and certain *Rosaceae* (*Lyonothamnus* and other genera), etc. are more or less similar to *Tricolporites protrudens* as far as sporoderm stratigraphy is concerned. There is also some resemblance — more or less superficial — between *T. protrudens* and the pollen grains in certain genera of *Valerianaceae* (*Triplostegia*), *Oenotheraceae*, *Haloragidaceae*, *Araliaceae* (*Acanthopanax*), *Calyceraceae* (*Nastanthus*), *Caprifoliaceae* (*Abelia* sect. *Zabelia*) etc.

5. Conclusion

The number of sporomorphae from the sediments of Åsen which have hitherto been identified is too small to be indicative of the Upper Cretaceous vegetation of the district in any higher degree. But even at this early stage in the investigation the material presents some interesting information about the fossil flora.

The Cretaceous flora of Sweden is very little known. S. NILSSON de-

[1] Courteously contributed by Dr. G. ERDTMAN.

scribed long ago a few dubious dicotyledonous fossils [*Acerites*, *Alnites*, *Cycadites* (*Dewalquea*), *Salicites*] from the Upper Cretaceous of Scania. Of greater importance is the occurrence of fossil wood in the Ryedal Sandstone which appears as boulders at Nya Ryedal E. of Åsen. It is probably equivalent to the Åsen sediments. According to CONWENTZ (1891) the dominating wood in the sandstone originates from a "two-needled" pine — *Pinus Nathorsti* CONW. which is closely related to the amber pines and the recent *Pinus silvestris*. Whether any of the *Pinus* pollen from Åsen has come from Nathorst pines is, of course, impossible to decide. The sporomorpha which would be included in such a comparison would be that of *Pinus silvestris*-type.

Fortunately, the Cretaceous flora is rather well known outside Scandinavia. From the classic East Greenland localities of Cretaceous plants O. HEER distinguished no less than 300 species distributed among 60 families, most of which HEER referred to the Upper Cretaceous (Cenomanian and Senonian). In these later investigations a flora was described which was very different from the recent one at these latitudes. Besides the angiosperms, the sudden rise of which indicates the beginning of the modern flora, there are a number of gymnosperms and pteridophytes of Jurassic character. Also more modern gymnosperms such as *Pinus*, *Araucaria* and *Sequoia* are known. Another famous region with Cretaceous plants is Bohemia where the Cretaceous flora is referable to the Cenomanian and the Lower Senonian, according to the invertebrates. The plant association of this flora and also of early Tertiary ones was quite different from that of the modern North European flora. Side by side flourished East-Asiatic, Australian and North American elements.

Among the Upper Cretaceous families, *Gleichenia* is perhaps the most characteristic, and, in the present discussion, the most interesting. In the Cretaceous of Greenland, HEER has distinguished no less than 18 *Gleichenia* species, ten of them belonging to the Lower Cretaceous. They disappear from the Arctic and Europe in the Eocene. According to COPELAND (1947), the modern *Gleicheniae* are "a most natural family, of some 130 known species, tropical and southern with two species reaching Japan". The family is old, dating back to the Trias and perhaps also occurs in the Carboniferous.

Certain recent *Gleicheniae* are known as bad weeds which rapidly colonize clearings and burn-beaten lands, surpressing other plants with their thick leafage. GARDNER and ETTINGHAUSEN (1879) have described fossil mass-appearance of *Gleicheniae* from the Eocene of Britain. The fern fossils are abundant there in a very thin layer. The subjacent layer is densely penetrated by the fern roots. The aforementioned authors are of the opinion that the *Gleicheniae* grew "in a wet, clayey hollow".

Of 327 pollen and spores counted from level 11 at Åsen no less than 40 % pertain to *Gleicheniidites*. Modern *Gleicheniae* are known to be rich

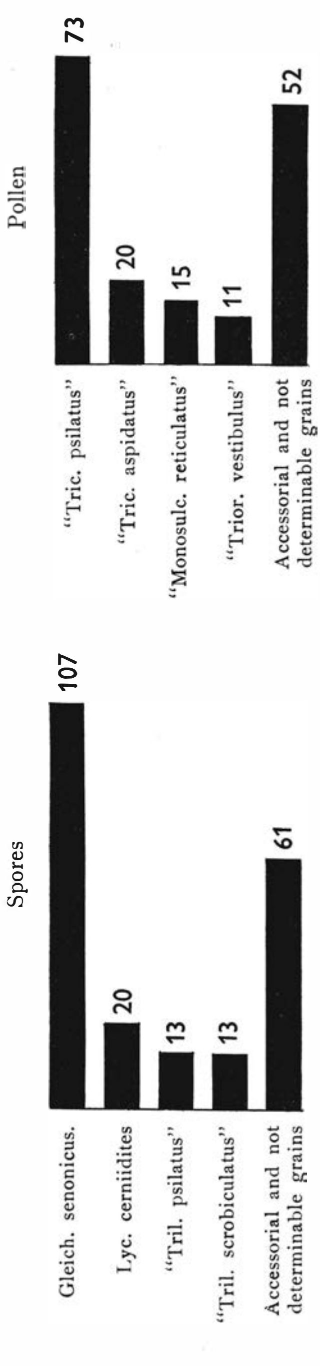


Fig. 4. The absolute number of counted sporomorphae at level 11, Åsen.

spore producers and for this reason they may be somewhat overrepresented in a pollen spectrum. The dominance of the Åsen species suggested as referable to *Gleichenia* is, however, so great that this fern must have been a very important component of the flora — even if the pollen spectrum does not exactly reflect its occurrence. (It is scarcely probable that a selective destruction would have favoured the small, thin-membraned *Gleicheniidites* spores.) Further, both recent and fossil *Gleicheniae* are herbaceous plants which is why the high frequency of *Gleicheniidites* may indicate a local *Gleichenia*-vegetation, the long-distance dissemination being of less importance for herbaceous plants.

According to the recent and Eocene mass-appearance of *Gleicheniae* it is not surprising to find a similar appearance in the Cretaceous of Scania, especially as macrofossils of this family are very abundant in the Cretaceous of our latitudes.

The sandy layers at Åsen indicate repeated inundations during which the vegetation of the clay banks may have been submerged and then the emerging banks could rapidly be colonized by *Gleicheniae* analogous to the modern invasions of *Gleicheniae* pointed out above.

It would be of some interest to compare the *Gleicheniidites* of Åsen with spores from determined macrofossils of *Gleicheniae* and in this way find a closer conception of the affinity of the Scanian spores. The possibility of such an investigation was supported by NATHORST (1908), stating "dass man von beinahe jedem fossilen Farn, dessen fertile, die Sori tragende Blätter verkohlt sind, Präparate von den Sporen bekommen kann." Prof. HALLE has graciously permitted the author to examine the rich Greenland material of the Palaeobotanical Department of the Swedish State Mus., Stockholm. A rock sample of *Gleichenia Gieseckiana* HEER from the Cretaceous Kome layers of East Greenland was preliminarily investigated. From this sample a few spores were isolated which, in spite of being rather corroded, showed affinity to *Gleicheniidites* (Pl. III, fig. 45).

Lycopodium cerniidites is another spore of high frequency at level 11. The recent *Lycopodium cernuum* is distributed in the tropics. According to SELLING (1943) it is very common in the Hawaiian Islands where it flourishes in open places, and is in ecological respect similar to *Gleichenia linearis* and *emarginata*. Macrofossils of *Lycopodium* from the Upper Cretaceous are missing nearly completely.

Besides the spore now discussed, the "*Trilites scrobiculatus*" and "*Tril. psilatus*" are common. They may have been produced by local herbaceous ferns.

"*Tric. psilatus*" dominates among the pollen types. Another very common sporomorpha is *Monosulcites* — a monocotyledonous type. The remaining pollen grains of common occurrence are not identified.

At level 11 there are also a number of accessorial sporomorphae. The majority of them were only found in a single specimen. These types must have been produced partly by rare plants in the local flora and partly transported there by long distance dissemination. Several factors, however, indicate that the local production was dominant.

Further, the fossil wood in the sediments of Åsen indicates abundant adjacent coniferous forests which may have dispersed rich pollen-rains over the district. The two *Pinus* pollen observed are very poor remains of these pollen grains. Nor have any pollen of *palms*, *ginkgos* or other common trees in the Cretaceous forests been found. Thus much material remains to be investigated before the pollen and spores distributed from the vegetation of adjacent districts may attain such a great quantity that the clays of Åsen can furnish a record on the Upper Cretaceous forest vegetation of N. Scania. Other levels in the Åsen deposits are possibly more suitable in this respect than that now investigated.

*

Pollen floras in the different levels of the Åsen profile are intended as the subject of further study. On the basis of Dr. ERDTMAN's comprehensive collection of recent spores and pollen grains it may be possible to identify further sporomorphae and thus increase the knowledge of the nearly unknown Upper Cretaceous flora of Sweden.

Further investigations also will show the possibility of using the Cretaceous sporomorphae as index fossils for fluviatile deposits.

References

ANDREWS, H., and KERN, E., 1947. The Idaho Tempskyas and associated fossil plants. Ann. Miss. Bot. Gard. 34. St. Louis.

ARNOLD, CH. A., 1947. An introduction to paleobotany. New York and London.

BERRY, E. B., 1916. The Upper Cretaceous floras of the world. Maryl. Geol. Survey, Baltimore.

CONWENTZ, H., 1891. Untersuchungen über fossile Hölzer Schwedens. Sv. Geol. Unders. Ser. C. No 120. Stockholm.

COOKSON, ISABEL, 1947. Plant Microfossils from the Lignites of Kerguelen Archipelago. Mawson, B. A. N. Z. Antarctic Research Exp. 1929—1931, Rep. Ser. A, Vol. II, Part 8. Adelaide.

ERDTMAN, G., 1943. An introduction to pollen analysis. Waltham.

—— 1946. Pollen Morphology and Plant Taxonomy. VI. On pollen and spore formulae. Sv. Bot. Tidskr. 40: 1., Uppsala.

—— 1947. Suggestions for the classification of fossil and recent pollen grains and spores. Ibid. 41: 1.

—— 1948. Did dicotyledonous plants exist in early Jurassic times? Geol. Fören. Förhandl. Bd. 70. Stockholm.

—— 1948. Algunos aspectos de la palinologia. Anal. Inst. Esp. Edaf., 7: 2. Madrid.

GRÖNWALL, K. A., 1915. Nordöstra Skånes kaolin- och kritbildningar. Sv. Geol. Unders. Ser. C. No 261. Stockholm.

HENNIG, A., 1910. Guide pour le Terrain crétacé de la Suède. Geol. Fören. Förhandl. Bd. 32. Stockholm.

HESSLAND, I. Sedimentology and Lithogenesis of the Åhus Formation. Bull. Geol. Inst. Upsala. Vol. XXXIV. Uppsala. *In print.*

HEER, O., 1869. Contributions to the Fossil Flora of N. Greenland. Flora. Foss. Arct. I. Zürich.

—— 1874. Die Kreide-Flora der Arctischen Zone. Ibid. III: 2.

—— 1882. Die fossile Flora der Polarländer. Ibid. VI.

HÄGG, R., 1943. *Scaphites* (*Discoscaphites*) *binodosus* A. Roemer från Blaksudden på Ivö. Geol. Fören. Förhandl. Bd. 65. Stockholm.

KIRCHHEIMER, F., 1931. Zur pollenanalytischen Braunkohlenforschung. Mitt. Braunkohle, Halle.

—— 1932. On pollen from the Upper Cretaceous Dysodil of Banke, Namaqualand (South Africa). Trans. Roy. Soc. S. Afr. Vol. XXI: 1. Cape Town.

LUNDEGREN, A., 1931. De kretaceiska ler- och sandförekomsterna N. om Ivösjön. Geol. Fören. Förhandl. Bd. 52. Stockholm.

—— 1943. Kristianstadsområdets kritbildningar. Ibid. Bd. 55.

NATHORST, A. G., 1908. Paläobotanische Mitteilungen 4—6. Kgl. Sv. Vet. Akad. Handl. Bd. 43: 6. Stockholm.

NILSSON. S., 1824. Sur quelques végétaux terrestres fossils, qui se trouvent dans le grès vert en Scanie. Ibid. Bd. 1.

—— 1827. Petrificata suecana formationis cretaceae. Lund.

POTONIÉ, R., 1931. Zur Mikroskopie der Braunkohlen. Tertiäre Blütenstaubformen I. Mitt. Braunkohle. Halle.

RUDOLPH, K., 1935. Mikrofloristische Untersuchung tertiärer Ablagerung im nördlichen Böhmen. Beih. Bot. Centralbl. Vol. LIV. Abt. B. Dresden.

SELLING, O. H., 1946. Studies in Hawaiian Pollen Statistics. Part I. The spores of the Hawaiian pteridophytes. Bernice Bishop Mus. Spec. Publ. 37. Honolulu.

—— 1947. Studies in Hawaiian Pollen Statistics. Part II. The pollens of the Hawaiian phanerogams. Ibid. 38.

THIERGART, F., 1940. Die Micropaläontologie als Pollenanalyse im Dienst der Braunkohlenforschung. Stuttgart.

—— 1942. Dikotylenpollen des ausgehenden Mesozoikums und ihre systematische Stellung. Jahrb. Reichst. Bodenforsch. (1941). Bd. 62.

—— 1945. Leitpollen der untermiozänen und oberpliozänen Braunkohle und ihre systematische Stellung. Zeitschr. Deutsch. Geol. Ges. Bd. 97.

—— 1949. Der stratigraphische Wert mesozoischer Pollen und Sporen. Palaeontographica. LXXXIX: B.

VELENOVSKÝ, J., and VINIKLÀŘ, L., 1926—27. Flora Cretacea Bohemiae I—II. Prag.

WODEHOUSE, R., 1932. Tertiary pollen I. Pollen from the living representatives of the Green River flora. Bull. Torr. Bot. Club. vol. 59. New York.

—— 1933. Tertiary pollen II. The oil shales of the Green River formation. Ibid. vol. 60.

Explanation of Plates

When nothing is stated the magnification is 820 ×. All the specimens and negatives are kept in the Paleont. Inst., Univ. of Uppsala. The photographs are taken by Mr. N. HJORT and the author.

Plate I. Spores.

Figs. 1—2. *Lycopodium cerniidites* n. spm. Fig. 1: Polar view, 2: Equatorial view.

Fig. 3. *Gleicheniidites senonicus* n. spm. Polar view.

Fig. 4. *Gleichenia gigantea* WALL. (*Hicriopteris glauca* COPEL.) — Mont Khasia, coll. THOMSON. Polar view (recent spore!).

Figs. 5—7. "*Trilites scrobiculatus*". Fig. 5: Polar view, 6: Surface view, 7: Equatorial view.

Figs. 8—9. *Polypodiidites senonicus* n. spm. Fig. 8: Proximal view, 9: Lateral view.

Figs. 10—11. "*Trilites cristatus*". Fig. 10: Polar view, 11: Equatorial view.

Fig. 12. "*Trilites psilatus.*" Polar view.

Fig. 13. "*Microlepiidites psilatus.*" Polar view.

Fig. 14. Sporomorpha not yet described. Polar view.

Figs. 15—16. *Cibotiidites zonatus* n. spm. Polar view. Fig. 15: Distal wall, 16: Proximal wall.

Figs. 17—18. "*Anemiidites echinatus.*" Fig. 17: Polar view, 18: Equatorial view.

Plate II. Pollen Grains.

Figs. 19—21. "*Tricolporites pilatus.*" Fig. 19: Equatorial view, 20: Polar view, 21: Surface view.

Figs. 22—23. "*Tricolporites reticulatus.*" Equatorial view.

Fig. 24. Cf. *Tricolporites protrudens*-type. Polar view.

Fig. 25. *Tricolporites protrudens*-type. Polar view.

Figs. 26—28. "*Triorites vestibulus.*" Fig. 26: Tetraorate specimen, polar view, 27: (triorate sp.), 28: polar view.

Figs. 29 and 35. "*Tricolpites aspidatus* f. *tricirculoides.*" Polar views.

Figs. 30, 32 and 34. Sporomorphae not yet closely studied. Polar views.

Fig. 31. "*Tricolpites suboblatus.*" Polar view.

Fig. 33. "*Monosulcites reticulatus.*" Equatorial view.

Figs. 36—38. *Pinus silvestris*-type. Fig. 36: Lateral view, 37: Proximal view, 38: Detail of the proximal wall — about 1700 ×.

Figs. 39—40. *Pinus haploxylon*-type. Fig. 39: Lateral view, 40: Distal view.

Plate III. Various.

Fig. 41. "*Tricolpites aspidatus* f. *triangulatus.*" Polar view. 1700 ×.

Fig. 42. *Tricolporites protrudens*-type. Polar view. (The same as fig. 25.) 1700 ×.

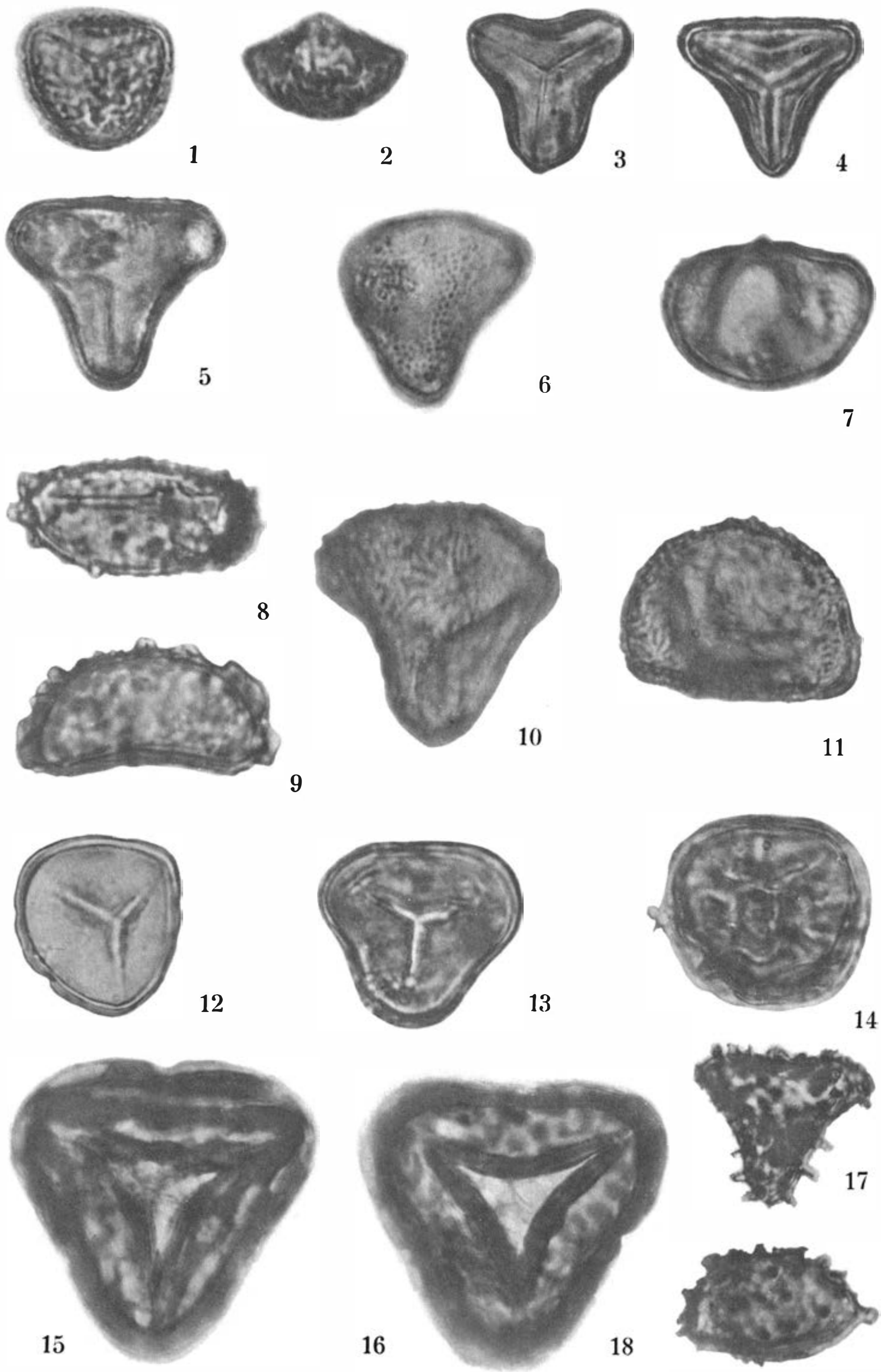
Fig. 43. Cf. "*Tric. asp.* f. *triangulatus.*" Polar view.

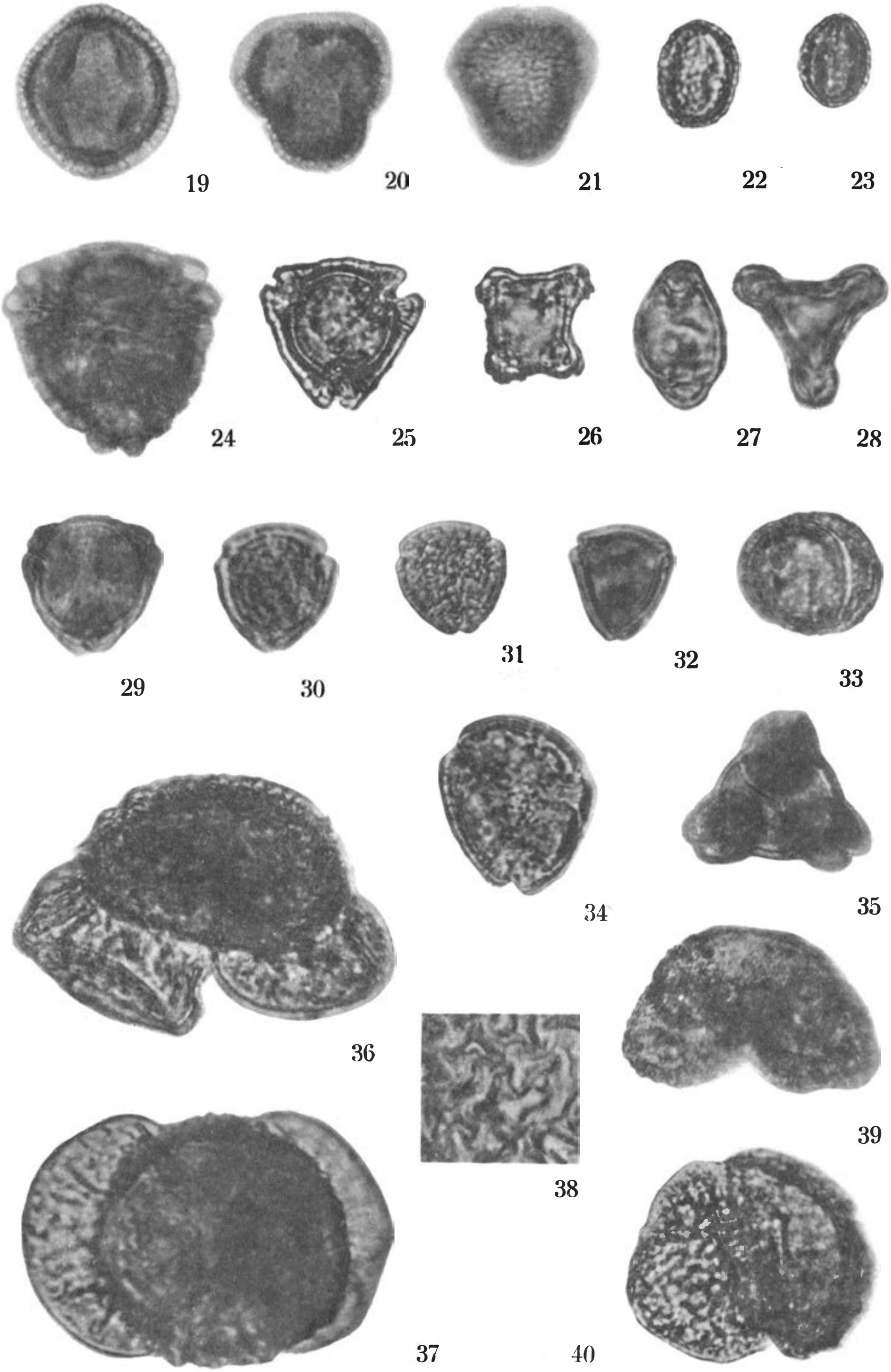
Fig. 44. *Lycopodium cernuum* L. — Cuba, coll. EKMAN. Polar view. (recent spore!) Cf. fig. 1.

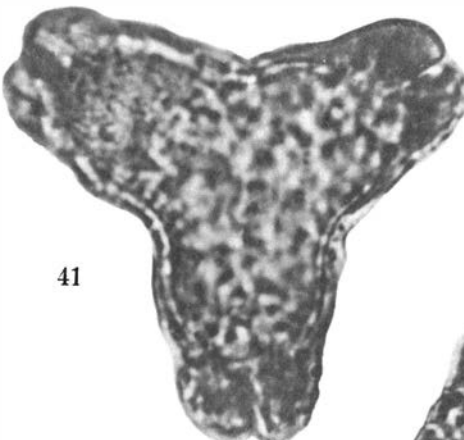
Fig. 45. Spore derived from a sample of *Gleichenia Gieseckiana* HEER from the Cretaceous strata of Kook, E. Greenland. Polar view.

Fig. 46. "*Tricolporites psilatus.*" Polar view. 1700 ×.

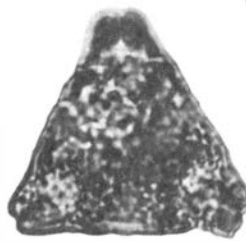
The lowest photograph shows the microstratification of a clayey, not consolidated sediment from the Cretaceous of Åsen. The distances between the dark layers are about 1 mm. The black particles are wood fragments of different sizes; the light, angular minerals are quartz-pieces. 72 ×. The slide was made by Mr. G. ANDERSSON.

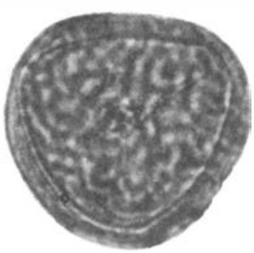

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
18
17

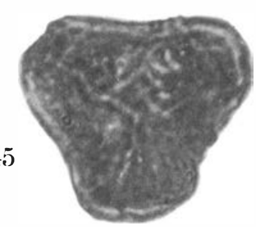

19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40

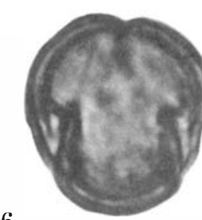

41


42


43


44


45


46