

Palynological zonation and stratigraphy of the Jurassic section in the Gassum No. 1-borehole, Denmark.

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Abstract

The Jurassic section of the Danish onshore borehole Gassum No. 1 has been investigated palynologically. 126 palynomorph-taxa have been recognized, consisting mainly of microspores and gymnosperm pollen. The palynomorphs are treated morphosystematically. 71 samples were prepared and the relative abundances determined in 32 representative samples. 5 spore-pollen zones, A to E, have been defined based on the stratigraphical ranges and abundances of specific taxa.

Correlating with data from Northwest Europe allows the zones to be dated as follows: Zone A: Late Rhaetian, Zone B: Hettangian, Zone C: Early Sinemurian to ?Pliensbachian/Toarcian, Zone D: Kimmeridgian/Early Volgian, Zone E: Middle Volgian. The relative abundances of the main morphological groups of palynomorphs have been calculated and their stratigraphical variations correlated with previously proposed Early Jurassic sea-level changes.

Introduction

The Gassum No. 1-borehole was one of the first deep borings to be drilled in the Danish area and is one of the most intensively investigated Danish on-shore boreholes. It was drilled by the Danish American Prospecting Company (DAPCo) from March 1948 to March 1951, terminating in Upper Permian strata at 3404 m below rotary table. The boring is situated on the flank of a deep-seated salt dome, the elevation of which was responsible for the present 5° dip of the strata.

The Mesozoic sequence was cored at close, regular intervals and these cores have formed the basis for several palaeontological and lithological studies. Preliminary lithological descriptions of the core-material were carried out at the well-site and a bio-stratigraphic subdivision of the Mesozoic sediments was established on the basis of macrofossils, particularly ammonites (Frebald 1948, unpubl., Norwood, Nørvang & von Elm 1951, unpubl., Gregersen & Sorgenfrei 1951). A more detailed lithological study and a chronostratigraphic

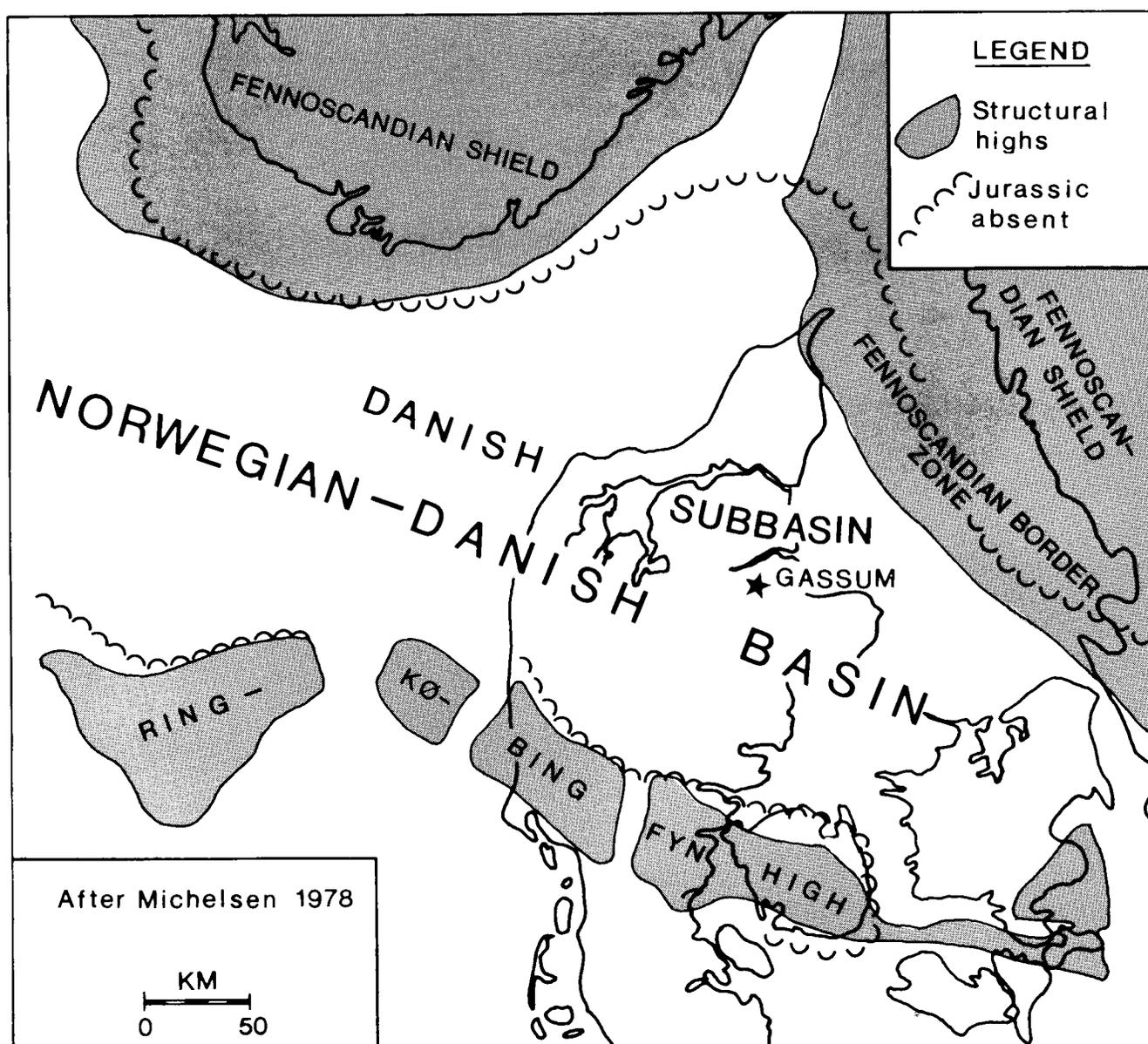


Figure 1. The main structural elements in the Danish area in the Jurassic Period and the location of the Gassum No. 1-borehole.

subdivision was presented by Sorgenfrei & Buch (1964). Larsen (1966) proposed a lithostratigraphic subdivision of the Jurassic sequence in the Danish Sub-basin based partly on the core-material from the Gassum borehole. Biostratigraphical and palaeoecological studies of the core-material include investigations of Early Jurassic foraminiferal faunas (Nørvang 1957), Early Jurassic ostracod assemblages (Michelsen 1973, 1975), Triassic palynomorphs (Bertelsen 1978, Vasard Nielsen in prep.), and variations in the Early Jurassic bivalve fauna (Pedersen 1986).

The general objective of the present investigation has been to establish a biozonation of the Jurassic sequence from the Gassum No. 1-borehole, based on palynomorphs, and to correlate the sequence with palynologically investigated strata from north-western Europe.

Geological setting

The Gassum No. 1-borehole is situated in the central part of the Danish Subbasin (fig. 1). This subbasin comprises the eastern part of the larger Norwegian-Danish Basin and persisted as a major area of subsidence from the Late Permian to the Late Cretaceous. It is separated from the North-German Basin to the south by the Ringkøbing-Fyn High and bounded to the north and east by the Fennoscandian Border Zone. The majority of the sediments deposited in the Danish Subbasin during the Triassic and Jurassic consist of clastic material (sand, silt and clay). Sediments were transported into the basin from the Fennoscandian Shield in the north and east with the result that the coarser clastics were deposited nearest the Fennoscandian Border Zone (Michelsen & Bertelsen 1979).

The Fennoscandian Border Zone was tectonically activated during the Rhaetian (the "early Kimmerian phase"), and a renewed period of subsidence of the Danish Subbasin started. This local tectonism, combined with an eustatic sea-level rise, resulted in the deposition of a thick, deltaic to shallow marine sequence, known as the Gassum Formation (Bertelsen 1978, Ziegler 1982). During continued subsidence of the basin in the Early Jurassic a thick sequence of dark marine claystones was deposited, defined as the Fjerritslev Formation (Michelsen 1978). By the end of the Early Jurassic, and in the Middle Jurassic, the Ringkøbing-Fyn High was uplifted as a result of the "Mid-Kimmerian tectonic phase" (Ziegler 1982). As a consequence, Upper Triassic to lower Upper Jurassic strata were eroded and are generally absent in large areas on the Ringkøbing-Fyn High and along its margins (Michelsen 1978, Michelsen & Bertelsen 1979). During this time-interval the fluvial and deltaic sediments that comprise the Haldager Formation (Michelsen 1978) were deposited in the northern part of the basin. In the

late Middle Jurassic and early Late Jurassic a second phase of subsidence was initiated which resulted in deposition of the marine claystones that comprise the Børglum Member (lower part of the Bream Formation) (Michelsen 1978). Brief uplift occurred at the Jurassic-Cretaceous transition and the reduced water-depth resulted in deposition of the more coarse-grained Fredrikshavn Member (upper part of the Bream Formation) (Michelsen 1978). Subsidence then occurred throughout the Cretaceous, eventually including the Ringkøbing-Fyn High (Michelsen & Bertelsen 1979).

In the Gassum No. 1-borehole the Gassum Formation is represented by 131 m of sediments, mainly limnic sandstones. The Mid-Kimmerian tectonic phase, combined with local salt-movements, has resulted in a hiatus comprising the uppermost Early Jurassic to the lowermost Late Jurassic (Norwood et al. 1951, unpubl., Sorgenfrei & Buch 1964, Larsen 1966). Thus the 314 m of dark grey marine claystones, referred to the Fjerritslev Formation, are erosively overlain by sediments referred to the Bream Formation.

Lithology and lithostratigraphy

The lithology and general stratigraphy of the Gassum No. 1-borehole presented by Sorgenfrei & Buch

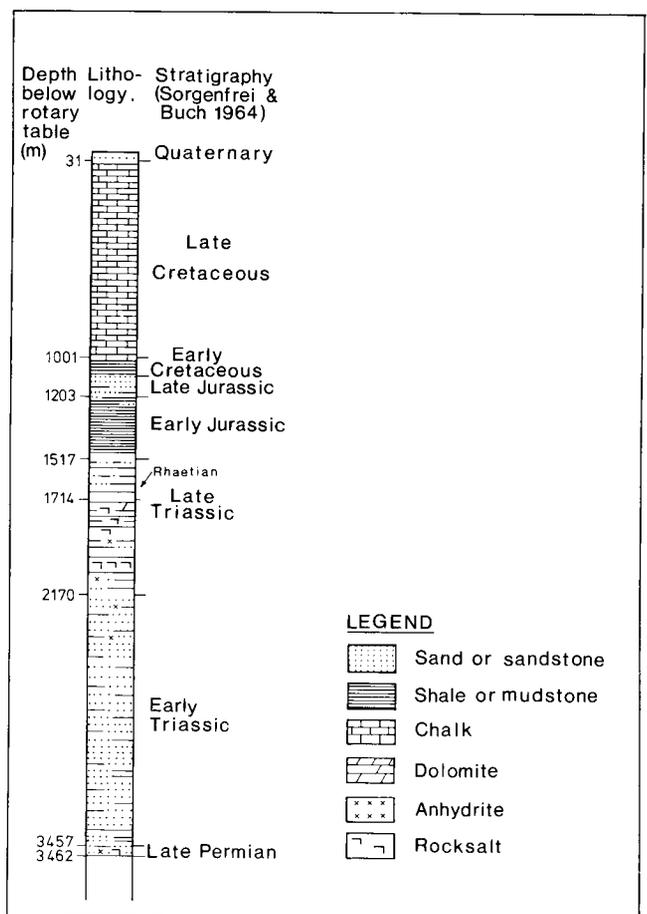


Figure 2. The entire sedimentary sequence of the Gassum No. 1-borehole.

(1964), is shown in figure 2. The more detailed subdivision of the Jurassic sequence, shown in figure 3, is based partly on the subdivision by Sorgenfrei & Buch (1964) and partly on the work by Michelsen (1975) (see discussion on p. 8).

The oldest sediments recorded in the Gassum No. 1 - borehole are of Late Permian age (Norwood et al. 1951, unpubl., Sorgenfrei & Buch 1964) and consist of about 5 m of sandstone and silty clay with anhydrite and rocksalt. The Permian sequence is overlain by about 1900 m of Triassic strata comprising varicoloured shales, claystones and sandstones. While most of the Triassic sediments are red and green in colour, the uppermost 200 m (from a depth about 1714 m), referred to the Rhaetian (Sorgenfrei & Buch 1964), are generally dark coloured. The Gassum Formation (established by Larsen (1966) and emended by Bertelsen (1978)), extends from 1648 to 1517 m and comprises limnic, fine- to medium grained, light grey sandstones with subordinate coal lenses and bands of marine, dark grey to black shale. Marine shales gradually become dominant towards the top of the formation and the marine, dark grey, rather uniform shale which dominates the interval from 1517 to 1203 m, is included in

the Fjerritslev Formation (proposed by Larsen (1966), emended by Michelsen (1978)). This part of the section is erosively overlain by the Bream Formation (Deegan & Scull (1977), emended by Michelsen (1978)), which shows a gradual upward increase in sandy material. In the basal part it is dominated by dark grey, sandy shales, with bands of light grey and greenish-grey sandstones, while from 1152 to 1078 m it consists predominantly of greenish-grey sand with a high mica content, intercalated with bands of greyish-green shaly siltstone. The core from 1193 to 1189 m has a very different appearance, comprising a hard, greenish grey claystone with shining, conchoidal fractures. Irregular patches of deep red and purple colours may indicate a weathering horizon (Norwood et al. 1951, unpubl. Larsen 1966). Above the Bream Formation are 1060 m of Cretaceous shales, limestones and chalk, ultimately capped by about 25 m of Pleistocene deposits.

Bio- and chronostratigraphy

The stratigraphical conclusions derived from the present investigation are presented in figure 9.

The chronostratigraphic subdivision presented by Sorgenfrei & Buch (1964) (see fig. 2, 3 and 9) is based on several palaeontological, geophysical, and lithological studies. Among the most important are Frebold's (1948, unpubl.) macrofossil-analyses (particularly of the ammonite-assemblage), the "Final Report on Gassum No. 1" (Norwood et al. 1951, unpubl.) which is a summary of all recorded well-data, and analyses of foraminifera (Nørvang 1957). Nørvang's correlation of the Early Jurassic foraminiferal fauna with English and German faunas resulted in a chronostratigraphic subdivision that supported and improved Frebold's (1948, unpubl.) proposals.

The Middle and Upper Rhaetic (*sensu germanico*) applied to the Gassum borehole by Sorgenfrei & Buch (1964) correspond to the Rhaetian adopted in the present work, while the Lower Rhaetic (*sensu germanico*) corresponds to the Late Norian (Lund 1977, Pedersen & Lund 1980).

Some more recent biostratigraphic studies have also been carried out. Michelsen (1973) demonstrated some regional differences in the depositional environment of the lowermost Jurassic in Gassum No. 1- and four other boreholes. This was based on variations in the ostracod and holothurian faunas, combined with lithological information from Larsen (1966). Subsequently, Michelsen (1975) presented a biozonation and a chronostratigraphic subdivision of the Lower Jurassic sequence in the Gassum borehole (see fig. 9). The investigations were based on stratigraphic variations in the ostracod fauna, correlated to ostracod-zonated, ammonite-dated sequences in North Germany. Finally, a palynological range-chart for the Upper Triassic and low-

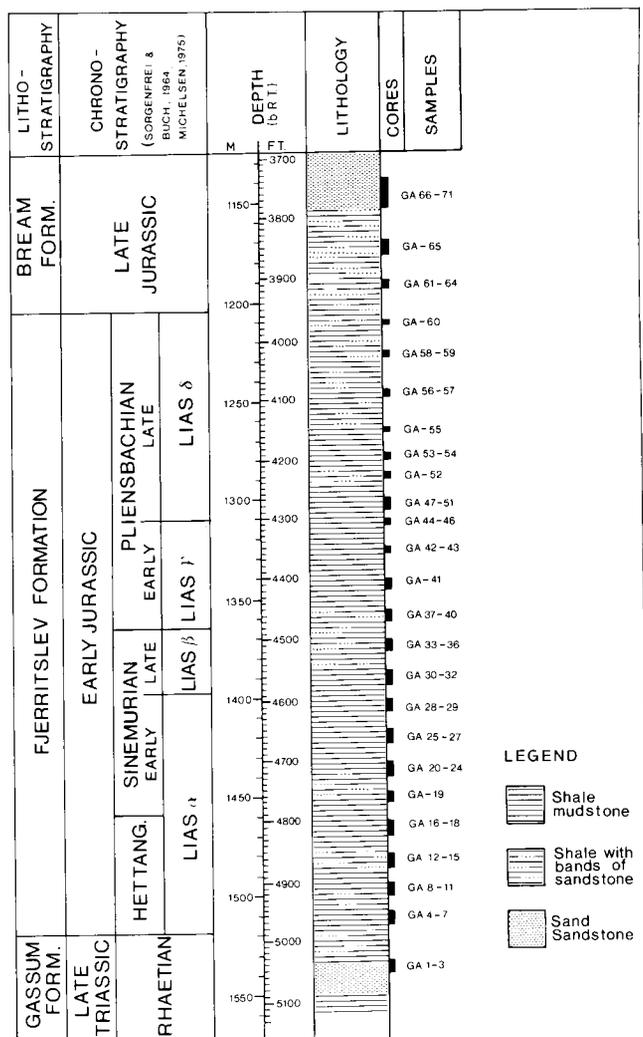


Figure 3. The Jurassic sequence of the Gassum No. 1-borehole, with the cored interval and distribution of samples.

ermost Jurassic section in the Gassum No. 1-borehole has been published by Bertelsen (1978, fig. 3). The illustrated distribution of some selected miospore taxa indicate a Rhaetian age for the Vinding- and almost all the Gassum Formation, while the miospore assemblage in the topmost part of the Gassum Formation is interpreted as transitional Rhaetian-Hettangian.

Position of chronostratigraphical boundaries

According to Frebold (1948, unpubl.), the Triassic-Jurassic boundary is located in the interval 1534–1515 m on the basis of invertebrate macrofossils, and this is supported by Bertelsen's (1978) palynological study. Norwood et al. (1951, unpubl.) placed the boundary at 1517 m, based on a general increase in hardness of strata below this level, and this location for the boundary is followed here (in accordance with Sorgenfrei & Buch (1964) and Michelsen (1975).

Based on ostracods the Hettangian-Early Sinemurian boundary was placed between 1463 m and 1454 m (Michelsen 1975).

The positions of the Early-Late Sinemurian, the Sinemurian-Pliensbachian, and the Early-Late Pliensbachian boundaries proposed by Michelsen (1975) diverge from those given by Sorgenfrei & Buch (1964) (see fig. 9). The disagreement concerning the Early-Late Sinemurian boundary is due to the lack of index-

macrofossils at this level that weakens the early analysis by Frebold (1948, unpubl.) (used by Sorgenfrei & Buch, 1964). The position of the boundary between 1402 m and 1393 m as proposed by Michelsen, is therefore the most reliable and is adopted here (fig. 3). The Sinemurian-Pliensbachian boundary was placed at 1366 m by Sorgenfrei & Buch (1964) and between 1341 m and 1328 m by Michelsen (1975). Michelsen does not discuss the disagreement. The position given by Sorgenfrei & Buch (1964) is adopted here. Finally the different evaluations of the macrofossil-rich interval covering the Early-Late Pliensbachian boundary may be due to the poor ostracod fauna at this level (Michelsen 1975). The position of the boundary at 1310 m given by Sorgenfrei & Buch (1964) is therefore adopted here.

As mentioned earlier, sediments from the late Early Jurassic to the early Late Jurassic are absent in the Gassum No. 1-borehole, partly reflecting uplift of the Ringkøbing-Fyn High-area, and partly because of local salt-movements (Norwood et al. 1951, unpubl., Sorgenfrei & Buch 1964, Larsen 1966).

The Jurassic-Cretaceous boundary is located in the unfossiliferous interval from 1144 to 1089 m, since the underlying deposits are referred to the Late Jurassic, and the overlying sequence to the Early Cretaceous (Norwood et al. 1951, unpubl., Sorgenfrei & Buch 1964).

Materials and methods

Sampling

The material used in this investigation are core-samples from the Gassum No. 1-borehole made available by the Geological Survey of Denmark. In total 71 samples, numbered GA-1 to GA-71, were taken at different intervals through the latest Rhaetian and the Jurassic section. The cored intervals and the stratigraphic positions of the samples are shown in figure 3.

Palynological preparation

About 4 g of crushed material from each of the 71 samples were processed using the procedure normally followed at the Section of Palynology, Geological Institute, University of Aarhus. The samples were treated in 10% HCl for 20 min. to 24 hours to dissolve the calcium carbonate; after centrifugation the HCl was removed. Then 40% HF was added to dissolve siliceous minerals, and the samples were placed in a waterbath at 100°C for 2 hours. The samples were then centrifuged and the HF removed. The HF-treatment was repeated and finally the samples were again treated with 10% HCl and placed in a waterbath at 100°C for 20–30 min. After final centrifugation and removal of the HCl the samples were washed with distilled H₂O and sieved through a 10 µm filter. The filtered residues were examined in order to decide further treatment. This treatment consisted of combinations of the following procedures:

- a) Heavy-liquid separation, using ZnCl (s.g. 1, 9), to remove insoluble mineral particles from the organic fraction.
- b) Peptisator plus ultrasound-treatment on samples with flocculating organic and clayey material to disperse the residue into single grains.
- c) KOH (5%) to bleach dark, carbonized palynomorphs.
- d) HNO₃ (conc.) to dissolve pyrite, which was frequently precipitated inside the palynomorphs, especially in the sacci of saccate pollen.
- e) Extra 10 µm-sieving with distilled water always followed treatment with KOH and ZnCl₂ to remove traces of chemicals remaining in the residue.

Two to four glycerine-slides for transmitted-light microscopy were prepared from each sample.

Microscopical examination

At least one slide from each sample was thoroughly examined using a Leitz Wetzlar light-microscope. Slides from 32 samples, regularly distributed throughout the studied section, were chosen for counting. The counting, carried out at a magnification of x400, continued until at least 250 spores and pollen were identified from each sample (independent of the number of aquatic palynomorphs). All palynomorphs encountered were recorded whether or not they were immediately identifiable.

Palynomorph recovery

126 different palynomorph taxa, including 55 spore species, 40 pollen species, 21 dinoflagellate-cyst species, and 10 other aquatic types, were identified. All species or types encountered are presented in the systematic section. In the range-chart the palynomorphs are listed according to their stratigraphic range in the present study and their percentage distributions in the counted samples are indicated. Each species/type in the range-chart is identified by a number which is also used in the text. "Various dinoflagellate-cysts" (number 107 in the range-chart) includes all the dinoflagellate-cyst species mentioned in figure 7. They are not included in

the systematic section but their references are shown in figure 7. Further taxonomic information can be obtained from Lentin & Williams (1985).

Five spore-pollen zones (A to E) have been proposed on the basis of the stratigraphic ranges and abundances of the palynomorphs (see p. 29). The relative abundances of the main morphological groups of palynomorphs have been calculated (fig. 10) and their stratigraphic variations correlated with previously proposed sea-level changes (Hallam 1978, 1981) (see p. 38).

Systematic section

The following taxa of palynomorphs have been recorded in the studied section of the Gassum No. 1-borehole. The range-chart number for each taxa is indicated together with a reference to illustrations.

The morphosystematic classification system used for the Anteturma Sporites is that proposed by Dettmann (1963) which is a revision of that proposed by Potonié & Kremp (1954, 1955, 1956a, 1956b; Potonié 1956, 1958, 1960). For Anteturma Pollenites the corresponding morphosystematic classification system, proposed by Potonié & Kremp (1954) is used. Taxonomic references to genera and higher taxa are not included. The descriptive terms used in this paper are defined by Tschudy (1969) and Grebe (1971).

The orientation of the grains when measuring their size is in accordance with Schulz (1967, text fig. 1). The size-measurements include sculptural-elements and is stated as follows.: a (b) c (n=d), where a is the minimum size, b the mean-size and c the maximum size measured and d is the number of measurements. Accurate size-measurements of bisaccate pollen are difficult to obtain because of the indistinct delimitations between the corpus and the roots of the sacchi and because of variable orientation of the grains. Because of this, the number of indicated size-measures for each bisaccate pollenspecies is variable. The term "sulcus" is used here to describe the distal area between the sacchi-roots.

Beyond the species names accepted in the present study, the synonym lists only show synonyms used in the most important references.

Spores and pollen

Anteturma *Sporites* H. Potonié 1893
Turma *Triletes* (Reinsch 1881) Dettmann 1963
Subturma *Azonotriletes* (Luber 1937) Dettmann 1963
Infraturma *Laevigati* (Bennie & Kidston 1886) R. Potonié 1956

Genus *Deltoidospora* Miner 1935 emend. Danzé-Corsin & Laveine 1963

This genus includes laevigate, trilete spores with a triangular to subcircular amb, the trilete-mark is distinct with long sutures often bordered by folds and/or a proximal-kyrtome (a thickening of the exine in the contact-area, parallel to the trilete-mark).

Deltoidospora toralis (Leschik) Lund

Pl. 1, figs. 1 & 2

Range-chart number: 27

1955: *Laevigatisporites toralis* – Leschik, p. 12; pl. 1, figs. 1, 2.

1958: *Concavisporites toralis* (Leschik 1955) – Nilsson, p. 34; pl. 1, figs. 12, 13.

1977: *Deltoidospora auritora* (Reinhardt 1961) – Lund, p. 50; pl. 1, fig. 5.

1977: *Deltoidospora toralis* (Leschik 1955) – Lund, p. 49; pl. 1, figs. 2, 3.

Equatorial diameter: 26 (37) 46 μm (n=20).

This species is characterized by having a proximal-kyrtome of variable form, and a thin, laevigate exine, often infolded between equator and the kyrtome. According to Lund (1977) *D. auritora* differs from *D. toralis* in having a proximal-kyrtome which continues around the angles. In the present study a great variation of *Deltoidospora*-types and contact-area thickenings was recorded, including forms intermediate between *D. auritora* and *D. toralis*. *D. auritora* is therefore treated as a synonym of *D. toralis*.

Deltoidospora minor (Couper) Pocock

Pl. 1, fig. 4

Range-chart number: 60

1953: *Cyathidites minor* – Couper, p. 28; pl. 2, fig. 13

1970: *Deltoidospora minor* (Couper 1953) – Pocock, p. 28; pl. 5, fig. 3.

Equatorial diameter: 26 (32) 40 μm (n=10)

D. minor differs from *D. toralis* in the absence of a proximal-kyrtome.

Deltoidospora crassexina (Nilsson) Lund

Pl. 1, fig. 3

Range-chart number: 15

1958: *Concavisporites crassexinus* – Nilsson, p. 35; pl. 1, fig. 11.

1977: *Deltoidospora crassexina* (Nilsson 1958) – Lund, p. 51; pl. 1, fig. 4; pl. 12, fig. 8.

Equatorial diameter: 31 (34) 40 μm (n=10).

This species is characterized by having a proximal-kyrtome and in addition three semidistal, interradian exine-thickenings.

Genus *Cibotiumspora* Chang 1965

Cibotiumspora juriensis (Balme) Filatoff

Pl. 1, fig. 6

Range-chart number: 19

1957: *Concavisporites juriensis* – Balme, p. 20; pl. 2, figs. 30, 31
1975: *Cibotiumspora juriensis* (Balme 1957) – Filatoff, p. 61; pl. 10, figs. 8–13.

Equatorial diameter: 25 (30) 36 μm (n=8)..

A proximal-kyrtome is present in many specimens. The exine is laevigate and 1–2 μm thick. On the distal surface there is a fold across the angular part of the spore-outline perpendicular to the rays of the trilete-mark. The folds occur on at least one, but generally on all three of the angles.

C. juriensis may be poorly developed spores of the *Deltoidospora*-type. The only differences is the distal (secondary?) folds and the smaller size.

Genus *Intrapunctisporis* Krutzsch 1959

This genus differs from *Deltoidospora* in having a scabrate sculpture on the inside of the exine.

Intrapunctisporis toralis (Leschik) Lund

Pl. 1, fig. 5

Range-chart number: 23

1955: *Punctatisporites toralis* – Leschik, p. 19; pl. 2, fig. 11
1977: *Intrapunctisporis toralis* (Leschik 1955) – Lund, p. 51; pl. 1, fig. 8.

Equatorial diameter: 40 (44) 50 μm (n=10).

The proximal-kyrtome is often weakly developed.

Genus *Punctatisporites* Ibrahim 1933 emend. Potonié & Kremp 1954

The proposal of Kedves & Simoncsics (1964) to use *Punctatisporites* also on Mesozoic material is followed here.

Punctatisporites globosus (Leschik) Lund

Pl. 1, fig. 7

Range-chart number: 13

1955: *Laevigatisporites globosus* – Leschik, p. 11; pl. 1, fig. 5
1958: *Todisporites minor* – Couper, p. 135; pl. 16, figs. 9, 10
1977: *Punctatisporites globosus* (Leschik 1955) – Lund, p. 52; pl. 1, fig. 11.

Equatorial diameter: 40 (45) 50 μm (n=12).

The exine is thin (about 1 μm), laevigate or scabrate, often secondarily folded.

P. globosus and *P. major* are separated only by a bimodal size frequency curve, with a spore-diameter of 52 μm as the size limit (see Couper (1958, p. 134–135; text fig. 8)).

Punctatisporites major (Couper) Kedves & Simoncsics

Pl. 1, fig. 8

Range-chart number: 33

1958: *Todisporites major* – Couper, p. 134; pl. 16, figs. 6–8
1964: *Punctatisporites major* (Couper 1958) – Kedves & Simoncsics, p. 13; pl. 3, figs. 1, 2.

Equatorial diameter: 55 (58) 75 μm (n=10).

Genus *Retusotriletes* Naumova 1953

This genus differs from *Punctatisporites* in having a perfect curvature.

Retusotriletes mesozoicus Klaus

Pl. 1, fig. 9

Range-chart number: 4

1960: *Retusotriletes mesozoicus* – Klaus, p. 120; pl. 28, fig. 6.

Equatorial diameter: 33 (42) 50 μm (n=8).

Genus *Calamospora* Schopf, Wilson & Bentall 1944

This genus differs from *Punctatisporites* and *Retusotriletes* in having a very small trilete-mark and a very thin exine.

Calamospora tener Leschik emend. Mädlar

Pl. 1, fig. 10

Range-chart number: 29

1955: *Laevigatisporites tener* – Leschik, p. 13; pl. 1, fig. 20
1964b: *Calamospora tener* Leschik 1955 emend. Mädlar, p. 92; pl. 8, fig. 2.

Equatorial diameter: 26 (35) 50 μm (n=10).

The trilete mark is often indistinct because of secondary folding. The exine is laevigate and only about 0.5 μm thick.

Calamospora sp.

Pl. 1, fig. 11

Range-chart number: 24

Equatorial diameter: 26 (37) 46 μm (n=4).

Identical with *C. tener* apart from a thicker exine (about 1 μm), resulting in less tendency to folding.

Genus *Stereisporites* Pflug 1953

Stereisporites is used here as proposed by Krutzsch (1963) to encompass small, “spagnoide” microspores, unsculptured or with a sculptured distal exine and/or polar thickenings. Cingulate microspores comparable to *Stereisporites* are included in *Infraturma Cingulati*.

Stereisporites stereoides (Potonié & Venitz) Pflug

Pl. 1, fig. 12

Range-chart number: 16

1934: *Laevigatisporites stereoides* – Potonié & Venitz, p. 11; pl. 1, figs. 4, 5

1953: *Stereisporites stereoides* (Potonié & Venitz 1934) – Pflug, in Thomson & Pflug (1953), p. 53; pl. 1, figs. 64–73.

Equatorial diameter: 17 (22) 24 µm (n=10).

The exine is 1.5–2.0 µm thick and laevigate.

Stereisporites antiquasporites (Wilson & Webster) Dettmann

Pl. 1, fig. 13

Range-chart number: 44

1946: *Sphagnum antiquasporites* – Wilson & Webster, p. 273; fig. 2

1963: *Stereisporites antiquasporites* (Wilson & Webster 1946) – Dettmann, p. 25; pl. 1, figs. 20, 21.

Equatorial diameter: 20 (23) 26 µm (n=6).

The exine is laevigate, about 2 µm thick and with a circular thickening at the distal pole, 6–8 µm in diameter. In addition there are some weakly developed radial thickenings in the equatorial region.

Stereisporites punctus (Klaus) Krutzsch

Pl. 2, fig. 1

Range-chart number: 47

1960: *Distalanulisporites punctus* – Klaus, p. 133; pl. 28, fig. 8

1963: *Stereisporites (Distalanulisporites) punctus* (Klaus 1960) – Krutzsch, p. 19.

Equatorial diameter: 23 (25) 28 µm (n=11).

The exine is 1.0–1.5 µm thick, unsculptured, but with a distinct ring-formed thickening of the exine around the distal pole, often in combination with some indistinct, radiating grooves.

Stereisporites cicatricosus (Rogalska) Schulz

Pl. 2, fig. 2

Range-chart number: 42

1954: *Sporites cicatricosus* – Rogalska, p. 44; pl. 12, fig. 11.

1967: *Stereisporites (Rogalskaisporites) cicatricosus* (Rogalska 1954) – Schulz, p. 557; pl. 1, figs. 8, 9.

Equatorial diameter: 20 (26) 34 µm (n=12).

The exine is 1.0–1.5 µm thick, proximally unsculptured, distally with distinct radiating grooves near the equator. A weak ring-thickening and/or a circular area with thickened exine is often present at the distal pole.

Stereisporites cf. seebergensis Schulz

Pl. 2, fig. 4

Range-chart number: 80

Description: Trilete spore with subtriangular amb, convex sides and rounded angles. The trilete-mark is in-

distinct and the sutures extend for ½ to ⅔ of the spore-radius. A distinct perfect curvature is present. The exine is 1.0–1.5 µm thick, laevigate at the proximal surface and with a delicate foveo-reticulate sculpturing at the distal surface.

Equatorial diameter: 23 (29) 33 µm (n=3).

Remarks: This species differs from *S. cf. hauterivensis* in having a thinner exine and a more delicate sculpture. It differs from the spores of *S. seebergensis*, originally described by Schulz (in Döring et al. (1966)), in having a more distinct sculpture (slightly higher sculptured elements)).

Stereisporites cf. hauterivensis Döring

Pl. 2, fig. 3

Range-chart number: 18

Description: Trilete spore with subtriangular amb, convex sides, rounded angles and a slightly undulating edge. The trilete-mark has a narrow but distinct labrum, the sutures extend for ½ to ⅔ of the spore-radius. The exine is about 2 µm thick, laevigate at the proximal surface, foveo-reticulate at the distal surface. Equatorial diameter: 23 (25) 26 µm (n=5).

Remarks: These specimens differ from the spores of *S. hauterivensis*, originally described by Döring (1966) (in Döring, Krutzsch, Schulz & Timmermann (1966)), in having a very narrow labrum.

Infraturma *Apiculati* (Bennie & Kidston 1886) R. Potonié 1956

Genus *Trachysporites* Nilsson 1958

This genus includes trilete, triangular to subcircular spores with an irregular, mixed sculpturing. *Trachysporites* differs from *Conbaculatisporites* in having lower sculptural elements and from *Baculatisporites* in having a more triangular amb.

Trachysporites fuscus Nilsson

Pl. 2, fig. 5

Range-chart number: 14

1958: *Trachysporites fuscus* – Nilsson, p. 38; pl. 2, fig. 1

Equatorial diameter: 30 (40) 46 µm (n=12).

The exine is 1.5–2.0 µm thick, sculptured with densely arranged granulae, about 1 µm high, slightly elongated and irregularly orientated, partly fused to an irregular reticulum.

Trachysporites asper Nilsson

Pl. 2, fig. 6

Range-chart number: 21

1958: *Trachysporites asper* – Nilsson, p. 39; pl. 2, fig. 3

Equatorial diameter: 32 (40) 43 μm (n=10).
The exine is about 1 μm thick, sculptured with dispersed micro-coni (< 1 μm), connected at basis, forming an irregular micro-reticulum.

Trachysporites cf. *sparsus* (Bharadwaj & Singh) Lund
Pl. 2, fig. 7
Range-chart number: 12

Description: Trilete spore with triangular to subtriangular amb and rounded angles. The trilete-mark has a faintly developed labrum, the sutures are straight and extend for $\frac{1}{2}$ of the spore-radius. The exine is 1.5–2.0 μm thick, sculptured with irregularly dispersed granulae, partly connected, forming an irregular reticulum. Equatorial diameter: 33 (43) 52 μm (n=12).

Remarks: The specimens recorded in the present study differs from *Lunzisorites sparsus* Bharadwaj & Singh (1964), in having an exine sculptured with granulae and verrucae, otherwise the exine is laevigate. Nevertheless, the specimens compare very well with the illustration of *Lunzisorites sparsus* Bharadwaj & Singh (1964) and also with the specimens of *Trachysporites* cf. *sparsus* recorded by Lund (1977). Lund erects the new combination *Trachysporites sparsus*.

Genus *Conbaculatisporites* Klaus 1960

According to the generic diagnosis *Conbaculatisporites* includes subtriangular spores with a sculpture consisting exclusively of baculae. However, many authors also include species with a mixed sculpture, consisting of baculae, spinae, and conii, in this genera (Lund 1977, Schuurman 1977, Pedersen & Lund 1980, Hoelstad 1985). This approach is followed here.

Conbaculatisporites mesozoicus Klaus
Pl. 2, fig. 8
Range-chart number: 11

1960: *Conbaculatisporites mesozoicus* – Klaus, p. 126; pl. 29, fig. 15

Equatorial diameter: 36 (44) 60 μm (n=10).
The exine is thin (about 1 μm) and sculptured with conii, spinae, and baculae. The sculptural-elements are up to 3 μm high, connected at basis, forming a low, indistinct reticulum. The sculpturing is highest and most dense at the angles. *C. mesozoicus* differs from *C. spinosus* in having a relatively shorter polar-axis and a larger size.

Conbaculatisporites spinosus (Mädler) Lund
Pl. 2, fig. 9
Range-chart number: 28

1964a: *Anemioidites spinosus* – Mädler, p. 180; pl. 2, fig. 11

1977 : *Conbaculatisporites spinosus* (Mädler 1964a) – Lund, p. 56; pl. 2, figs. 11a, b

Equatorial diameter: 23 (30) 36 μm (n=12).

Genus *Baculatisporites* Thomson & Pflug 1953 emend. Krutzsch 1967

This genus includes trilete spores with a circular to subcircular amb. The exine-ornamentation consists of more or less pointed baculae or granulae. The sculptural-elements are more or less densely spaced, and also the size of the elements are variable.

Baculatisporites wellmanii (Couper) Krutzsch
Pl. 2, fig. 11
Range-chart number: 25

1953: *Osmundacidites wellmanii* – Couper, p. 20; pl. 1, fig. 5

1959: *Baculatisporites wellmanii* (Couper 1953) – Krutzsch, p. 142

Equatorial diameter: 33 (43) 50 μm (n=11).

The exine is about 1 μm thick, ornamented with densely spaced baculae, about 1 μm high. The sculpturing is reduced around the trilete-mark. *B. wellmanii* differs from *B. comaumensis* in having lower, more fused, and more densely spaced sculptural elements.

Baculatisporites comaumensis (Cookson) Potonié
Pl. 2, fig. 12
Range-chart number: 26

1953: *Triletes comaumensis* – Cookson, p. 470; pl. 2, figs. 27, 28

1956: *Baculatisporites (Triletes) comaumensis* (Cookson 1953) – Potonié, p. 33

Equatorial diameter: 35 (44) 55 μm (n=10).

The exine is about 1 μm thick, sculptured with regularly spaced baculae, 1.5–2.0 μm high.

Baculatisporites oppressus (Leschik) Lund
Pl. 2, fig. 10
Range-chart number: 5

1955: *Cyclogranisporites oppressus* – Leschik, p. 17; pl. 1, fig. 23

1977: *Baculatisporites oppressus* (Leschik 1955) – Lund, p. 57; pl. 2, fig. 15a, b

Equatorial diameter: 30 (34) 38 μm (n=11).

This species differs from the other *Baculatisporites*-species in having a mixed sculpturing, consisting of microbaculae, -granulae, and -conii, a smaller size, a more triangular amb, and in having exine-folds bordering the trilete-mark. The specimens recorded in the present study shows a remarkably large size compared to the size of 20 μm stated by Leschik (1955).

Genus *Apiculatisporis* Potonié & Kremp 1956

Apiculatisporis ovalis (Nilsson) Norris
Pl. 3, fig. 1
Range-chart number: 22

1958: *Acanthotriletes ovalis* – Nilsson, p. 40; pl. 2, figs.8, 9
1965: *Apiculatisporis ovalis* (Nilsson 1958) – Norris, p. 245; figs.2b, 18, 22, 23

Equatorial diameter: 30 (37) 50 μm (n=10).

Spore with sub-circular to oval amb. The exine is 0.5–1.0 μm thick, sculptured with irregularly spaced coni and spinae, a few baculae can be present. The sculptural elements are 0.5–1.5 μm high. *A. ovalis* could be confused with *Baculatisporites comaumensis* but differs by the dominance of coni and spinae instead of baculae.

Genus *Anapiculatisporites* Potonié & Kremp 1954

Anapiculatisporites telephorus (Pautsch) Klaus

Pl. 3, fig. 3

Range-chart number: 8

1958: *Sporites telephorus* – Pautsch, p. 323; pl. 1, fig. 12
1960: *Anapiculatisporites telephorus* (Pautsch 1958) – Klaus, p. 124; pl. 29, fig. 17

Equatorial diameter: 33 (40) 50 μm (n=8).

The exine is about 1 μm thick, laevigate to punctate in the contact-area, distally and equatorially sculptured with regularly spaced spinae and coni 1–2 μm high. There are 25–35 spinae/coni around the equator. *A. telephorus* differs from *A. spiniger* in having lower sculptural-elements with a broader base.

Anapiculatisporites spiniger (Leschik) Reinhardt

pl. 3, fig. 2

Range-chart number: 2

1955: *Apiculatisporites spiniger* – Leschik, p. 18; pl. 2, figs.6, 7
1961: *Anapiculatisporites spiniger* (Leschik 1955) – Reinhardt, p. 707; pl. 1, fig. 8

Equatorial diameter: 30 (35) 40 μm (n=4).

Spore with subtriangular to circular amb. The exine is 1.0–1.5 μm thick, punctate in the contact area but equatorially and distally the exine is sculptured with spinae, 2–3 μm high. There are 40–45 spinae around the equator.

Genus *Acanthotriletes* Naumova 1937 emend. Potonié & Kremp 1954

Acanthotriletes varius Nilsson

Pl. 3, fig. 4

Range-chart number: 1

1958: *Acanthotriletes varius* – Nilsson, p. 42; pl. 2, fig. 10

Equatorial diameter: 30 (35) 40 μm (n=6).

This species is characterized by a triangular amb with concave sides and an exine, about 2 μm thick, sculp-

tured with spinae of variable height, up to 2 μm . There are about 30 spinae around the equator.

Genus *Manumia* Pocock 1970

Manumia variverrucata Couper emend. Hoelstad

Pl. 3, fig. 10

Range-chart number: 85

1958: *Concavisporites variverrucatus* – Couper, p. 142; pl. 22, figs. 4,5
1985: *Manumia variverrucata* (Couper 1958) – Hoelstad, p. 123; pl. 2, figs.15–17

The exine is 1.5 μm thick, distally and proximally sculptured with dispersed, irregularly spaced verrucae. The equatorial diameter of the illustrated specimen is 30 μm . This specimen was the only one recorded.

Genus *Uvaesporites* Döring 1965

Uvaesporites argenteaeformis (Bolchovitina) Schulz

Pl. 3, figs. 5, 6

Range-chart number: 39

Iraquispora laevigata (Mädler) Lund

Pl. 3, fig. 7

Range-chart number: 35

1964a: *Kyrtomisporites laevigatus* – Mädler, p. 188; pl. 3, fig. 4
1977 : *Iraquispora laevigata* (Mädler 1964a) – Lund, p. 59; pl. 3, fig. 12

This species is characterized by a large, distinct trilete-mark, bordered by a conspicuous proximal-kyrtome which radially reaches out beyond the rest of the spore. The exine is 3–5 μm thick and sculptured with large, irregularly spaced verrucae, not higher than 1 μm , resulting in an undulating edge. The equatorial diameter of the illustrated specimen is 56 μm . This specimen was the only one recorded.

Genus *Uvaesporites* Döring 1965

Uvaesporites argenteaeformis (Bolchovitina) Schulz

Pl. 3, figs. 5, 6

Range-chart number: 39

1953: *Stenozonotriletes argenteaeformis* – Bolchovitina, p. 51; pl. 7, fig. 9
1961: *Triletes reissingeri* – Reinhardt, p. 707; pl. 2, figs.1, 2
1967: *Uvaesporites argenteaeformis* (Bolchovitina 1953) – Schulz, p. 560; pl. 2, figs.10, 11; pl. 23, fig. 2
1977: *Uvaesporites reissingeri* (Reinhardt 1961) – Lund, p. 60; pl. 3, fig. 14

Equatorial diameter: 38 (44) 50 μm (n=3).

U. argenteaeformis is readily recognized by a dense sculpturing of large verrucae (diameter 2–10 μm , 2–8 μm high) on the equatorial and distal face. In the contact-area the exine is laevigate.

Infraturma *Murornati* Potonié & Kremp 1954

Genus *Lycopodiumsporites* Thiergart 1938 ex. Delcourt & Sprumont 1955

Remarks: This genus includes trilete spores with subtriangular to subcircular amb, a reticulate sculpture on the distal and equatorial surface and often also in the contact-area. The genus *Lycopodiumsporites* is of questionable validity (Döring, Krutzsch, Mai & Schulz, 1963, Dettmann 1963, Tralau 1968), but is widely used. The genus *Retitriletes* (Hammen 1956 ex. Pierce 1961) emend. Döring et al. (1963) is here regarded as a junior synonym of *Lycopodiumsporites*.

Lycopodiumsporites semimuris Danzé-Corsin & Laveine

Pl. 3, figs. 8 & 9

Range-chart number: 73

1963: *Lycopodiumsporites semimuris* – Danzé-Corsin & Laveine, p. 79; pl. 6, figs. 15a, b, 16a, b, 17a, b, c

Equatorial diameter: 28 (33) 40 μm (n=10).

L. semimuris differs from the other species referred to *Lycopodiumsporites* in having a reduced reticulum.

Lycopodiumsporites austroclavatidites (Cookson) Potonié

Pl. 3, fig. 11

Range-chart number: 71

1953: *Lycopodium austroclavatidites* – Cookson, p. 269; pl. 2, fig. 35

1956: *Lycopodiumsporites* (al. *Lycopodium*) *austroclavatidites* (Cookson 1953) – Potonié, p. 46

1963: *Retitriletes austroclavatidites* (Cookson 1953) – Döring, Krutzsch, Mai & Schulz, in Krutzsch (1963, lief. II), p. 16

Equatorial diameter: 26 (35) 46 μm (n=10).

The exine is about 1 μm thick, distally and equatorially sculptured with a conspicuous reticulum, 3–5 μm high. The diameter of the luminae is 4–6 μm , 5–7 luminae per spore-diameter. In the contact-area the exine is sculptured with an indistinct reticulum with a lumen-diameter of 6–10 μm . *L. austroclavatidites* differs from *L. clavatoides* in having more luminae with a smaller diameter.

Lycopodiumsporites clavatoides (Couper) pro parte emend. Tralau

Pl. 3, fig. 12

Range-chart number: 79

1958: *Lycopodiumsporites clavatoides* – Couper, p. 132; pl. 15, figs. 10–13

1963: *Retitriletes clavatoides* (Couper 1958) – Döring, Krutzsch, Mai & Schulz, in Krutzsch (1963, lief. II), p. 16

1968: *Lycopodiumsporites clavatoides* (Couper 1958) pro parte emend. – Tralau, p. 49; pl. 1, figs. 3–5

Equatorial diameter: 34 (38) 42 μm (n=5).

The exine is about 1 μm thick, laevigate in the contact-area but equatorially and distally the exine is sculptured with a conspicuous reticulum, 3–4 μm high. The diameter of the luminae is 6–14 μm and there are 3–5 luminae per spore-diameter.

Genus *Contignisporites* Dettmann 1963

Contignisporites problematicus (Couper) Döring

Pl. 4, figs. 1–3

Range-chart number: 3

1958: *Cingulatisporites problematicus* – Couper, p. 146; pl. 24, figs. 11–13

1965: *Contignisporites problematicus* (Couper 1958) – Döring, p. 51; pl. 18, figs. 6–8

Equatorial diameter: 33 (46) 60 μm (n=12).

Proximally the spore is unsculptured. At the equator there is a “cingulum-like” thickening of the exine, consisting of fused verrucae and distally the exine is sculptured with randomly orientated rugulae and/or elongated verrucae, 3–7 μm wide.

Genus *Lycopodiacidites* Couper 1953

Lycopodiacidites rugulatus (Couper) Schulz

Pl. 4, fig. 12

Range-chart number: 43

1958: *Perotriletes rugulatus* – Couper, p. 147; pl. 25, figs. 7, 8

1967: *Lycopodiacidites rugulatus* (Couper 1958) – Schulz, p. 573; pl. 7, figs. 15, 16

Equatorial diameter: 63 (70) 76 μm (n=3).

The exine is about 2 μm thick, sculptured with partly fused rugulae, 3–5 μm wide, 1–2 μm high, forming an incomplete zigzag-pattern. The sculpturing is less distinct on the proximal side of the spore.

Cf. *Lycopodiacidites*

Pl. 4, fig. 10

Range-chart number: 61

Description: Trilete spore with subtriangular amb, convex sides, and rounded angles. The trilete-mark is simple; the sutures extend for $\frac{3}{4}$ of the spore-radius. The exine is laevigate in the contact-area, but distally and equatorially it is sculptured with distinct rugulae, 2–3 μm wide, 1–2 μm high, forming an incomplete zigzag-pattern. The equatorial diameter of the illustrated specimen is 32 μm .

Remarks: Only two specimens of this type were recorded. Based on form and sculpturing the spores are referred to the genus *Lycopodiacidites*, but they are unusually small compared to the species normally referred to this genus.

Genus *Staplinisporites* Pocock 1962

Staplinisporites telatus (Balme) Döring

Pl. 4, figs. 4 & 5

Range-chart number: 89

1957: *Microreticulatisporites telatus* – Balme, p. 25; pl. 4, figs. 52, 53
1965: *Staplinisporites telatus* (Balme 1957) – Döring, p. 45; pl. 15, figs. 6–8

Equatorial diameter: 40 (43) 46 µm (n=5).

On the proximal surface the exine is laevigate. On the distal surface the sculpture includes a polar, punctate, circular thickening, a semidistal, concentric, sinuous ridge and, in addition, some weak, radially disposed elevations.

Genus *Cicatricosisporites* Potonié & Gelletich 1933

Cicatricosisporites sp.

Pl. 4, fig. 6

Range-chart number: 74

Description: Trilete spore with subtriangular amb, straight or slightly convex sides, and pointed to rounded angles. The trilete-mark is indistinct, the sutures are straight and extend to the equator. The exine is thin, laevigate in the contact-area, but distally and equatorially sculptured with three sets of parallel muri, each set starting at the proximal side, close to one of the angles, spreading out on the distal side running parallel to the interradial edge, converging and ending up at the next angle. The individual muri are slightly sinuous and about 2 µm wide. The equatorial diameter of the illustrated specimen is 50 µm.

Remarks: Only two specimens were recorded.

Infraturma *Auriculati* (Schopf 1938) Dettmann 1963

Genus *Triancoraesporites* Schulz 1962

Triancoraesporites ancorae (Reinhardt) Schulz

Pl. 4, fig. 11

Range-chart number: 10

1962: *Waltzisporea ancorae* – Reinhardt, p. 705; pl. 1, fig. 14
1967: *Triancoraesporites ancorae* (Reinhardt 1962) – Schulz, p. 580; pl. 11, figs. 4, 5

Equatorial diameter: 31 (32) 33 µm (n=4).

This species is characterized by a triangular amb with distinctly concave sides and truncate to rounded, “anchor-shaped”, angles. The exine is laevigate, about 1 µm thick and often slightly thickened in the contact-area and at the angles.

Genus *Trilobosporites* Pant 1954 ex. Potonié 1956

Trilobosporites sp.

Pl. 5, fig. 3

Range-chart number: 93

Description: Trilete spore with triangular amb, straight to slightly concave sides, and rounded angles. The trilete-mark is distinct with labrum, the sutures extend for $\frac{3}{4}$ of the spore-radius. The exine is, proximally as well as distally, sculptured with low, weakly-developed verrucae, up to 5 µm in diameter. The exine is characteristically thickened at the angles, 7–10 µm thick, while the interradial exine is 3–5 µm. The equatorial diameter of the illustrated specimen is 62 µm.

Remarks: This specimen was the only one recorded.

Genus *Platyptera* Naumova 1934 ex. Naumova 1938

Platyptera trilingua (Horst) Schulz

Pl. 4, fig. 9

Range-chart number: 81

1943: *Triletes (Zonale) trilinguis* – Horst, figs. 55, 56
1967: *Platyptera trilingua* (Horst 1943) – Schulz, p. 579; pl. 11, figs. 1, 2

This species is characterized by having a distinct, radial exine-thickening in a 4–7 µm wide zone, lobed at the edge. The rest of the exine is laevigate, 2 µm thick. The equatorial diameter of the illustrated specimen is 37 µm. This specimen was the only one recorded.

Infraturma *Tricrassati* Dettmann 1963

Genus *Gleicheniidites* Ross 1949

Gleicheniidites senonicus Ross

Pl. 5, fig. 4

Range-chart number: 90

1949: *Gleicheniidites senonicus* – Ross, p. 31; pl. 1, fig 3, 4

Equatorial diameter: 23 (29) 38 µm (n=10).

The exine is laevigate, about 1 µm thick in the radial regions and 2–4 µm thick in the interradial parts.

Gleicheniidites conspiciendus (Bolkhovitina) Krutzsch

Pl. 5, fig. 5

Range-chart number: 88

1953: *Gleichenia conspicienda* – Bolkhovitina, p. 45; pl. 8, figs. 4, 5
1959: *Gleicheniidites (Peregrinisporis) conspiciendus* (Bolkhovitina 1953) – Krutzsch, p. 114

Equatorial diameter: 26 (29) 30 µm (n=3).

This species differs from *G. senonicus* in having a scabrate to finely intrapunctate sculpture. The exine is about 1 µm thick in the radial regions, interradially thickened to 2–4 µm.

Genus *Zebrasporites* Klaus 1960 emend. Schulz 1967

Zebrasporites interscriptus (Thiergart) Klaus

Pl. 4, figs. 7 & 8

Range-chart number: 67

1949: *Sporites interscriptus* – Thiergart, pl. 2, fig. 9
1960: *Zebrasporites* (al. *Sporites*) *interscriptus* (Thiergart 1949) – Klaus, p. 139

This species is readily recognized by the three-lobed zona and the striated appearance. The equatorial diameter of the illustrated specimen is 30 μm . This specimen was the only one recorded.

Infraturma *Cingulati* Potonié & Klaus 1954

Genus *Lycospora* Schopf, Wilson & Bentall 1944 emend. Potonié & Kremp 1954

Lycospora salebrosacea (Maljavkina) Schulz

Pl. 5, fig. 8

Range-chart number: 84

1949: *Volucellina salebrosacea* – Maljavkina, p. 65; pl. 13, fig. 14
1967: *Lycospora salebrosacea* (Maljavkina 1949) – Schulz, p. 584; pl. 13, figs. 8–10

Equatorial diameter: 30 (32) 33 μm (n=3).
The cingulum is 3–5 μm wide. The exine is laevigate on the proximal surface and punctate to scabrate on the distal surface.

Genus *Densosporites* Berry 1937 emend. Potonié & Kremp 1954

Densosporites fissus (Reinhardt) Schulz

Pl. 5, fig. 1

Range-chart number: 45

1964: *Densoisporites fissus* – Reinhardt, p. 54; pl. 2, figs. 1–3
1967: *Densosporites fissus* (Reinhardt 1964) – Schulz, p. 582; pl. 12, figs. 5, 6

Equatorial diameter: 36 (41) 46 μm (n=7).
The cingulum is 8–12 μm wide and the outer edge is often slightly sinuous. The exine is laevigate to finely intrareticulate.

Genus *Densoisporites* Weyland & Krieger 1953

Densoisporites microrugulatus Brenner

Pl. 5, fig. 6

1963: *Densoisporites microrugulatus* – Brenner, p. 61; pl. 15, fig. 6; pl. 16, fig. 1

The cingulum is 8–12 μm wide, overlapping the inner body in a 3 μm wide zone. The outer edge of the cingulum is irregularly sinuous. The exine of the body is thin, with an irregular sculpture of densely spaced microrugulae. The exine of the cingulum shows a reticulate sculpturing, often continued on the proximal, radial part of the body, outside the contact-area. The equatorial diameter of the illustrated specimen is 71 μm .

As the only recorded specimen of this type was found in one of the samples not counted (GA-66), it is not mentioned in the range-chart.

Genus *Cingutriteles* Pierce 1961

Cingutriteles infrapunctus (Schulz) Morbey

Pl. 5, fig. 2

Range-chart number: 38

1970: *Stereisporites* (*Cingutriteles*) *infrapunctus* – Schulz, p. 688; pl. 130, figs. 22, 23; pl. 131, fig. 1
1975: *Cingutriteles infrapunctus* (Schulz 1970) – Morbey pl. 9, fig. 4

Equatorial diameter: 24 (25) 26 μm (n=2).

The width of the cingulum is about 1/3 of the spore-radius. The exine is intrapunctate overall, and in addition there is an indistinct, proximal polar-thickening. This species is, in accordance with Morbey (1975), referred to the genus *Cingutriteles* in preference to *Stereisporites*, with the intention of following the morphosystematic system. Morbey (1975) does not mention his proposal in the text, but uses the new combination in the “Explanation of Plates” (p. 72; pl. 9, fig. 4). See also remarks to the genus *Stereisporites*.

Genus *Cingulizonates* Dybova & Jachowicz 1957

Cingulizonates rhaeticus (Reinhardt) Schulz

Pl. 5, fig. 9

Range-chart number: 36

1961: *Aequitriradites?* *rhaeticus* – Reinhardt, p. 709; pl. 2, fig. 3
1967: *Cingulizonates rhaeticus* (Reinhardt 1961) – Schulz, p. 584; pl. 13, figs. 6, 7

This species has a body encircled by a 6–10 μm wide cingulum, which towards the equator passes into a 5–8 μm wide zona. The delimitation between the body and the cingulum is sharp, while the transition from the cingulum to the zona is gradual. The outer edge of the zona is sinuous. The proximal exine of the body has a laevigate to scabrate surface. The distal surface of the body and all of the cingulum is sculptured with some indistinct, irregularly spaced grooves. The zona, consisting of ectexine, is transparent, with irregularly spaced, radiating lists of thickened ectexine, and with a slightly thickened outer edge. The equatorial diameter of the illustrated specimen is 55 μm . This specimen was the only one recorded.

Genus *Limbosporites* Nilsson 1958

Limbosporites lundbladii Nilsson

Pl. 5, fig. 7

Range-chart number: 34

1958: *Limbosporites lundbladii* – Nilsson, p. 47; pl. 3, fig. 7

Equatorial diameter: 40 (44) 46 μm (n=3).

This species is characterized by a distinct foveolate sculpturing on the distal surface of the body, and by a zona with radiating ridges of thickened exine.

Genus *Heliosporites* Schulz 1962

Heliosporites altmarkensis Schulz

Pl. 6, figs. 1, 2

Range-chart number: 41

1962: *Heliosporites altmarkensis* – Schulz, p. 311; pl. 1, fig. 9; pl. 2, figs. 10, 11

Equatorial diameter: 44 (50) 56 μm (n=3).

This species has a very conspicuous sculpture, distally and on the zona, consisting of 3–12 μm high spines of variable form. The spores are often recorded in tetrads.

Turma *Monoletes* Ibrahim 1933

Subturma *Azonomoletes* Lubert 1955

Genus *Laevigatosporites* Ibrahim 1933

Laevigatosporites sp.

Pl. 6, fig. 3

Range-chart number: 40

Description: Monolete spore with an elliptical to circular amb. In longitudinal, equatorial view, the distal profile is convex, while the proximal profile is concave, giving the spore a “bean-shaped” appearance. The monolete-mark is distinct, simple, and extends for about $\frac{1}{2}$ of the spore-length. The exine is laevigate to scabrate and about 1 μm thick. Spore-length: 26 (35) 46 μm , width: 20 (27) 35 μm (n=3).

Genus *Marattisporites* Couper 1958

Marattisporites scabratus Couper

Pl. 6, fig. 4

Range-chart number: 52

1958: *Marattisporites scabratus* – Couper, p. 133; pl. 15, figs. 20–23

Spore-length: 20 (25) 31 μm , width: 16 (20) 25 μm .

The exine is about 1 μm thick, scabrate to granulate, with sparsely spaced granules.

Subturma *Zonomoletes* Lubert 1935

Genus *Aratrisporites* Leschik 1955 emend. Playford & Dettmann, 1965

Aratrisporites minimus Schulz

Pl. 6, fig. 5

Range-chart number: 66

1967: *Aratrisporites minimus* – Schulz, p. 592; pl. 16, figs. 7–9

Spore-length: 23 (31) 36 μm , width: 16 (25) 28 μm .

This species is characterized by having a 2–5 μm wide “pseudozona” (not distinctly separated from the inner body) at the equator. The monolete-mark is distinct, set off by sinuous elevated lips of exine and extending almost the length of the spore. The exine of the body and zona, are finely punctate to granulate.

Anteturma *Pollenites* Potonié 1931

Turma *Saccites* Erdtman 1947

Subturma *Polysaccites* Cookson 1947

Trisaccate, undet.

Pl. 6, fig. 6

Range-chart number: 82

Description: Trisaccate pollen. In polar view the corpus is circular, the sacci are relatively small, attached to the corpus semi-distally. The exine of the corpus is granulate, while the sacci have a thin, intrareticulate exine. The corpus-width of the illustrated specimen is about 40 μm . The length of the sacci are 25–30 μm , the width 10–15 μm and the height about 15 μm .

Remarks: Only one specimen was recorded. It was in a bad state of preservation, with a corroded surface.

Subturma *Monosaccites* Potonié & Kremp 1954

Monosaccate, undet.

Pl. 6, fig. 7

Range-chart number: 6

Description: Monosaccate pollen with a slightly elliptical to circular amb. There is an indistinct delimitation between the corpus and the surrounding saccus. Often the saccus is most wide in two opposite areas, giving the grain an elliptical amb. The exine on the corpus as well as on the saccus is irregularly reticulate.

Pollen-length: 91 (94) 96 μm ; width: 72 (73) 73 μm (n=3)

Remarks: Very few monosaccate pollen are described from the Jurassic Period. The specimens recorded in the present study could be reworked from older sediments, as the state of preservation is rather bad. Nevertheless, they do have a resemblance to the Early Jurassic cf. *Walchia* sp. Reissinger 1950 (pl. 17, fig. 22), apart from a more distinct delimitation between the corpus and the saccus of the latter.

Subturma *Disaccites* Cookson 1947

Genus *Vitreisporites* Leschik 1955

Vitreisporites pallidus (Reissinger) Nilsson

Pl. 6, figs. 8 & 9

Range-chart number: 50

1950: *Pityosporites pallidus* – Reissinger, p. 109; pl. 15, figs. 1-5
1958: *Vitreisporites pallidus* (Reissinger 1950) – Nilsson, p. 78; pl. 7, figs. 12-14

Pollen length: 14 (18) 21 μm , width: 26 (31) 37 μm (n=11).

Bisaccate (rarely trisaccate) pollen with an elliptical outline and a characteristically small size. The corpus exine is about 0.5 μm thick, scabrate to finely intrareticulate. The exine on the sacchi is about 0.5 μm thick and intrareticulate with luminae about 1 μm in diameter. There is a weak tendency for the luminae to be radially arranged, especially near the roots of the sacchi.

Genus *Pinuspollenites* Raatz 1937 ex. Potonié 1958

Pinuspollenites minimus (Couper) Kemp

Pl. 7, figs. 1 & 2

Range-chart number: 64

1958: *Abietinaepollenites minimus* – Couper, p. 153; pl. 28, figs. 14, 15
1967: *Pityosporites scaurus* (Nilsson 1958) – Schulz, p. 595; pl. 17, figs. 12, 13
1970: *Pinuspollenites minimus* (Couper 1958) – Kemp, p. 116; pl. 24, figs. 1-6

Corpus-length: 26–46 μm , width: 28–50 μm

Sacchi-length: 28–45 μm , width: 22–30 μm

Total length: 36 (41) 50 μm , width: 50 (57) 66 μm (n=10).

The corpus is relatively large, broadly elliptical to circular in polar view. The sacchi are hemispherical and attached to the corpus distally. The corpus-exine is 1–2 μm thick and scabrate to finely intrareticulate. The exine of the sacchi is reticulate, the luminae are 3–5 μm in diameter. *P. minimus* differs from *P. pinoides* in having sacchi distinctly smaller than the corpus and in having a larger total size.

Pinuspollenites pinoides (Nilsson) Lund

Pl. 7, fig. 3

Range-chart number: 63

1958: *Sulcatisorites pinoides* – Nilsson, p. 86; pl. 8, figs. 6, 7
1977: *Pinuspollenites pinoides* (Nilsson 1958) – Lund, p. 76; pl. 9, fig. 7

Corpus-length: 25–32 μm , width: 28–33 μm , height: about 26 μm .

Sacchi-length: 20–25 μm , width: 23–26 μm , height: about 25 μm .

Total length: 26 (33) 43 μm , width: 40 (47) 56 μm (n=10).

The sacchi are more than hemispherical, nearly as large as the corpus, and attached distally. The corpus-exine is 2 μm thick and has a dense sculpture of low, partly

fused, verrucae. The exine of the sacchi is intrareticulate with luminae 1–2 μm in diameter.

Genus *Podocarpidites* Cookson 1947 emend. Potonié 1958

Podocarpidites cf. *biformis* Rouse

Pl. 8, fig. 6

Range-chart number: 7

Description: Bisaccate pollen with a relatively small corpus, circular when seen in polar view. The sacchi are large, kidney-shaped and attached to the corpus distally. The sulcus is about 7 μm wide. The corpus-exine of the sacchi has a less dense intrareticulate structure with a tendency towards a radiating arrangement of the luminae.

Corpus-length: 23–30 μm , width: 25–30 μm

Sacchi-length: 35–39 μm , width: 26–28 μm

Total length: 35 (39) 44 μm , width: 62 (63) 65 μm (n=3).

Remarks: The recorded specimen differs from the pollen of *P. biformis*, originally described by Rouse (1957), in having a more delicate sculpturing and a smaller size (total width of *P. biformis* was stated as 75–90 μm).

Genus *Protopinus* Bolkhovitina 1956

Protopinus cf. *scanicus* Nilsson

Pl. 7, fig. 8

Range-chart number: 9

Description: Bisaccate pollen with a broad, elliptical outline. The corpus is broad elliptical in polar view, with the shortest axis parallel to the longest axis of the grain. The sacchi are attached distally to equatorially; the delimitation between the corpus and the sacchi is indistinct. The sacchi are connected to each other by some 2–8 μm wide, equatorial ridges of thickened exine. The sulcus is 10–18 μm wide. The corpus-exine is 1–2 μm thick, finely intrareticulate, with a lumen-diameter of 0.5–1.0 μm . The exine of the sacchi has a less dense intrareticulate structure, with a lumen-diameter of 2–4 μm .

Pollen-length: 56 (57) 59 μm , width: 86 (91) 95 μm (n=3).

Remarks: The specimens recorded in the present study, referred to *Protopinus* cf. *scanicus*, are rather small compared to the pollen of *P. scanicus* originally described by Nilsson (1958), where the total width was stated as 100–116 μm .

Genus *Alisporites* Daugherty 1941

Alisporites robustus Nilsson

Pl. 8, fig. 2

Range-chart number: 20

1958: *Alisporites robustus* – Nilsson, p. 82; pl. 8, figs.2, 3

Corpus-length: 40–72 μm , width: 33–56 μm .

Sacci-length: 40–73 μm , width: 36–53 μm .

Total length: 40 (60) 72 μm , width: 66 (81) 92 μm (n=10).

Seen in polar view the corpus is broadly elliptical with the shortest axis parallel to the longest axis of the grain. The sacci are hemispherical, approximately of the same size as the corpus, and attached to the corpus semi-distally to equatorially. The roots of the sacci are indistinct. The corpus-exine is finely intrareticulate with a lumen-diameter about 1 μm . The exine of the sacci has an irregular, intrareticulate structure with a lumen-diameter of about 4 μm , and with a tendency towards a radiating arrangement of the luminae (most distinct near the roots of the sacci).

Alisporites radialis (Leschik) Lund

Pl. 8, fig. 1

Range-chart number: 31

1955: *Cunaetisporites radialis* – Leschik, p. 66; pl. 10, fig. 6

1977: *Alisporites radialis* (Leschik 1955) – Lund, p. 75; pl. 9, figs. 3, 4

Corpus-length: 50–72 μm , width: 28–52 μm .

Sacci-length: 53–76 μm , width: 26–48 μm .

Total length: 53 (61) 71 μm , width: 63 (72) 85 μm (n=10).

A. radialis is very similar to *A. robustus* but differs in having sacci larger than the corpus and distinct sacci-roots.

Alisporites thomasii (Couper) Nilsson

Pl. 8, fig. 3

Range-chart number: 78

1958: *Pteruchipollenites thomasii* – Couper, p. 150; pl. 26, figs.10–12

1958: *Alisporites thomasii* (Couper 1958) – Nilsson, p. 83; pl. 8, fig. 1

Corpus-length: 32–47 μm . Total length: 33 (42) 51 μm , width: 50 (61) 76 μm (n=7).

The corpus-exine is thin, finely intrareticulate to punctate. The exine of the sacci has a finely intrareticulate structure with a lumen-diameter about 2 μm and a tendency towards a radiating pattern. *A. thomasii* differs from *A. robustus* and *A. radialis* in having a smaller size, an approximately circular and relatively larger corpus (compared to the sacci), and a thinner, finely sculptured, exine.

Alisporites grandis (Cookson) Dettmann

Pl. 8, fig. 5

Range-chart number: 17

1953: *Disaccites grandis* – Cookson, p. 471. pl. 2, fig. 41

1963: *Alisporites grandis* (Cookson 1953) – Dettmann, p. 102; pl. 25, figs.1-4

Corpus-length: 50–88 μm , width: 51–70 μm .

Sacci-length: 51–88 μm , width: 33–65 μm .

Total length: 50 (73) 88 μm , width: 102 (117) 155 μm (n=7).

The corpus-exine is about 1.5 μm thick, with a finely intrareticulate structure. The exine of the sacci is 1–2 μm thick and has a less dense intrareticulate structure. This species differs from the other species referred to the genus *Alisporites* in having a larger size.

Alisporites microsaccus (Couper) Pocock

Pl. 8, fig. 4

Range-chart number: 76

1958: *Pteruchipollenites microsaccus* – Couper, p. 151; pl. 26, fig. 13

1962: *Alisporites* cf. *A. microsaccus* (Couper 1958) – Pocock, p. 61; pl. 9, figs.138, 139

Corpus-length: 46–95 μm , width: 36–63 μm .

Sacci-length: 46–95 μm , width: 18–45 μm .

Total length: 46 (74) 92 μm , width: 43 (62) 86 μm (n=6).

The corpus-exine is scabrate, while the exine of the sacci has a finely reticulate structure. This species differs from the other species of the genus *Alisporites* in having an elliptical outline with the shortest axis in the width of the grain, and in having relatively small sacci attached to the corpus distally. The specimens recorded are rather large compared to the size-range given by Couper (1958), but corresponds with the size-range given by Pocock (1962).

Genus *Quadraeculina* Maljavkina 1949

Quadraeculina anellaeformis Maljavkina

Pl. 7, fig. 7

Range-chart number: 48

1949: *Quadraeculina anellaeformis* – Maljavkina, p. 110; pl. 39, fig. 3

Pollen-length: 43 (57) 73 μm , width: 33 (47) 60 μm (n=10).

These pollen have a characteristically quadrangular to rectangular outline with rounded angles. The reduced sacci are attached distally and tend to coalesce at their ends, so that in some specimens they appear to encircle the corpus. Between the sacci is a distinct and wide rectangular sulcus. Equatorially, immediately above and parallel to the sacci, there are another two longitudinal areas with thin exine. The exine of the corpus, as well as of the sacci, is intrareticulate; the lumen-diameter is 1–2 μm on the saccus, less on the corpus.

Genus *Schismatosporites* Nilsson 1958

Schismatosporites ovalis Nilsson

Pl. 7, fig. 6

Range-chart number: 65

1958: *Schismatosporites ovalis* – Nilsson, p. 87; pl. 8, fig. 9

Pollen-length: 47 (60) 80 μm , width: 77 (90) 99 μm (n=6).

Equatorially, at the delimitation between the corpus and the sacci, is a small elevation. The exine of the corpus is finely intrareticulate, the sacci-exine is less dense intrareticulate with a lumen-diameter of 2 μm .

Genus *Umbrosaccus* Mädlar 1964

Umbrosaccus keuperianus Mädlar

Pl. 7, fig. 4

Range-chart number: 70

1964b: *Umbrosaccus keuperianus* – Mädlar, p. 118; pl. 11, figs.5, 8

Corpus-length: 32–43 μm , width: 31–57 μm .

Sacci-length: 45–56 μm , width: 26–46 μm .

Total length: 44 (50) 56 μm , width: 76 (82) 92 μm (n=5).

The corpus is circular to rhomboid when seen in polar view. The relatively large sacci are more than hemispherical, attached to the corpus equatorially, nearly encircling the corpus. The corpus-exine is intrapunctate to -scabrate, the exine of the sacci is intrareticulate with a tendency towards a radiating arrangement of the luminae.

Cf. *Umbrosaccus*

Pl. 7, fig. 5

Range-chart number: 37

Description: Bisaccate pollen with relatively large, more than hemispherical sacci and a small, circular to rhomboid corpus (when seen in polar view). The sulcus is only about 3 μm wide. The corpus-exine is relatively thick and intrapunctate. The exine of the sacci is intrareticulate with a lumen-diameter up to 5 μm . The corpus-length is about 65 μm for the illustrated specimen, the width about 55 μm . The sacci-length is 95 μm , the width about 70 μm . The total length is 95 μm , the width 140 μm .

Remarks: Only one specimen was recorded. It is comparable to the genus *Umbrosaccus* in all characters except for the large size.

Turma *Aletes* Ibrahim 1933

Subturma *Azonaletes* (Luber 1935) Potonié & Kremp 1954

Genus *Araucariacites* Cookson 1947 ex Couper 1953

Araucariacites australis Cookson 1947

Pl. 9, fig. 1

Range-chart number: 57

1949: *Granulonapites* (*Araucariacites*) *australis* – Cookson, p. 130; pl. 13, figs. 1–4

Diameter: 46 (69) 99 μm (n=10).

Spherical, though often secondarily folded. The exine is thin with a scabrate to finely granulate sculpturing.

Genus *Perinopollenites* Couper 1958

The genus *Perinopollenites* includes more or less spherical, alete pollen with an exine which is completely separated into a body of endexine enclosed by a very thin, membraneous exine.

Perinopollenites elatoides Couper

Pl. 9, fig. 2

Range-chart number: 54

1958: *Perinopollenites elatoides* – Couper, p. 152; pl. 27, figs. 9–11

Total diameter: 26 (32) 37 μm (n=10).

The size of the body in relation to the total size is very variable.

Genus *Cupressacites* (Bolkhovitina 1956) Krutzsch 1971

Cupressacites sp.

Pl. 9, fig. 3

Range-chart number: 51

Description: Spherical, though often secondarily folded. The exine is very thin (0.5–1.0 μm), transparent, and laevigate. Diameter: 31 (39) 50 μm (n=11).

Genus *Cerebropollenites* Nilsson 1958

Cerebropollenites macroverrucosus (Thiergart) Schulz

Pl. 9, figs.4 & 5

Range-chart number: 72

1949: *Pollenites macroverrucosus* – Thiergart, p. 17; pl. 2, fig. 19

1967: *Cerebropollenites macroverrucosus* (Thiergart 1949) – Schulz, p. 603; pl. 21, figs. 4–6

Equatorial diameter: 41 (48) 56 μm (n=12).

Alete pollen with a more or less circular outline. The exine is sculptured with densely arranged, hollow, and often elongated verrucae, 4–6 μm in diameter. In a circular area (16–20 μm in diameter) the exine is thin and the sculpture reduced. This species differs from *C. thiergartii* in having larger, non-solid, and un-fused sculptural elements.

Cerebropollenites thiergartii Schulz

Pl. 9, fig. 7

Range-chart number: 62

1967: *Cerebropollenites thiergartii* – Schulz, p. 603; pl. 21, figs. 7, 8

Equatorial diameter: 46 (52) 62 µm (n=10).

The exine is sculptured with small, solid verrucae or granulae, 1–4 µm in diameter, and partly fused at the base.

Genus *Spheripollenites* Couper 1958

Couper described this genus as “probably monoporate”. In the present study no convincing pores were observed, thus the genus is here referred to Turma Aletes.

Spheripollenites psilatus Couper

Pl. 9, fig. 9

Range-chart number: 69

1958: *Spheripollenites psilatus* – Couper, p. 159; pl. 31, figs. 4–8

Diameter: 17 (24) 30 µm (n=12).

Spherical, though frequently secondarily folded. The exine is 1.0–1.5 µm thick and laevigate.

Spheripollenites subgranulatus Couper

Pl. 9, fig. 8

Range-chart number: 83

1958: *Spheripollenites subgranulatus* – Couper, p. 158; pl. 31, figs. 9–11.

Diameter: 18 (23) 29 µm (n=12).

Similar to *S. psilatus* apart from a finely granulate sculpturing. According to Schulz (1967) this species often occurs in clusters. This tendency was not observed in the present study.

Genus *Exesipollenites* Balme 1957

Exesipollenites tumulus Balme

Pl. 9, fig. 6

Range-chart number: 68

1957: *Exesipollenites tumulus* – Balme, p. 39; pl. 11, figs. 123–125

Equatorial diameter: 23 (28) 33 µm (n=10).

The exine is laevigate to scabrate and about 2 µm thick. In a circular or triangular area the exine is thickened and in the middle of the thickened area is a circular depression, 4–7 µm in diameter, of thinner exine.

Subturma *Zonaletes* Lubert 1935 emend. Potonié 1958

Genus *Callialasporites* Dev 1961

The genus *Callialasporites* comprises alete pollen with a lensoid shape and a circular, convex triangular or trilobate outline. The exine is differentiated into two layers. The ektexine forms a zona, and on the rest of the surface the exine-layers are partly fused, often resulting in variable patterns of folding.

Callialasporites microvelatus Schulz

Pl. 10, fig. 1

Range-chart number: 86

1966: *Callialasporites microvelatus* – Schulz, p. 136; pl. 7, figs. 1, 2

The outline is circular. The ektexine forms a narrow zona, 3–5 µm wide. On the rest of the surface the two exine layers are partly fused. The body is circular with a diameter of about 7/8 of the total grain-diameter. The endexine is about 2 µm thick, intrareticulate to finely intragranulate. The ektexine is transparent, about 1 µm thick, and finely intragranulate. Both the endexine and the ektexine are unfolded. The equatorial diameter of the illustrated specimen is 58 µm. This species differs from the other species referred to *Callialasporites* in having an endexine that is thicker than the ektexine, a very narrow zona, and an absence of primary folds. Only one specimen was recorded.

Callialasporites trilobatus (Balme) Dev

Pl. 10, fig. 2

Range-chart number: 94

1957: *Zonalapollenites trilobatus* – Balme, p. 33; pl. 8, figs. 91, 92

1961: *Callialasporites trilobatus* (Balme 1957) – Dev, p. 48; pl. 4, figs. 28, 29

The outline is triangular with convex sides. The body is rounded triangular, the diameter is $\frac{2}{3}$ to $\frac{3}{4}$ of the total diameter. The endexine is 1–2 µm thick, scabrate to finely intragranulate. The ektexine is finely granulate. The ektexine forms a trilobate zona and on the rest of the surface it is partly fused with the endexine resulting in both randomly orientated and radiating folds. The equatorial diameter of the illustrated specimen is 54 µm. Only one specimen was recorded. *C. trilobatus* differs from the other species referred to *Callialasporites* in having a trilobate zona.

Callialasporites segmentatus (Balme) Srivastava

Pl. 10, fig. 3

Range-chart number: 87

1957: *Zonalapollenites segmentatus* – Balme, p. 33; pl. 9, figs. 93, 94
1963: *Callialasporites segmentatus* (Balme 1957) – Srivastava, p. 1323

Equatorial diameter: 54 (56) 58 µm (n=4).

The outline is circular. The endexine is 1–2 µm thick, finely punctate, and forms a circular body with a diameter about $\frac{7}{8}$ of the total diameter. The ektexine is about

1 μm thick, and laevigate to finely punctate. The ektexine is partly fused with the endexine, resulting in small, randomly orientated folds all over the grain. This species differs from the other species referred to *Callialasporites* in having a relatively larger body and a conspicuous randomly orientated folding.

Turma *Plicates* (Naumova 1939) Potonié 1960
Subturma *Monocolpates* Iversen & Troels-Smith 1950

Genus *Chasmatosporites* Nilsson 1958 emend. Pocock & Jansonius 1969

Chasmatosporites apertus (Rogalska) Nilsson
Pl. 10, figs. 7 & 8
Range-chart number: 55

1954: *Pollenites apertus* – Rogalska, p. 45; pl. 12, figs. 13–15
1958: *Chasmatosporites apertus* (Rogalska 1954) – Nilsson, p. 56; pl. 4, figs. 5, 6

Equatorial diameter: 30 (34) 46 μm (n=11).
The outline is circular. The colpus is wide open, elliptical to circular; the colpus length is about $\frac{2}{3}$ of the total diameter. The exine is 2–4 μm thick, tectate with an indistinct intrareticulate sculpturing. This species differs from *C. hians* in having a smaller size, from *C. elegans* in having a more circular outline, and from both in having a very thick exine.

Chasmatosporites elegans Nilsson
Pl. 10, figs. 5 & 6
Range-chart number: 56

1958: *Chasmatosporites elegans* – Nilsson, p. 58; pl. 4, figs. 11, 12

Total length: 35 (44) 50 μm , width: 30 (37) 46 μm (n=10).

The outline is elliptical. The colpus is more or less wide open, elliptical to triangular. The exine is 0.5–1.0 μm thick, tectate with a regular micro-intrareticulum. This species differs from *C. hians* in having a smaller size, an elliptical outline, a thinner exine and a regular micro-intrareticulum.

Chasmatosporites hians Nilsson
Pl. 10, fig. 4
Range-chart number: 59

1958: *Chasmatosporites hians* – Nilsson, p. 55; pl. 4, figs. 3, 4

Total length: 46 (57) 73 μm , width: 37 (45) 51 μm (n=11).

The outline is circular to elliptical. The colpus is circular to elliptical, wide open, and extends for about $\frac{2}{3}$ of the total diameter. The exine is 1–2 μm thick, tectate with a distinct, irregular, nearly vermiculate micro-intrareticulum.

Genus *Ricciisporites* Lundblad 1954 emend. Lundblad 1959

Ricciisporites tuberculatus Lundblad
Pl. 11, fig. 1
Range-chart number: 46

1954: *Ricciisporites tuberculatus* – Lundblad, p. 401; pl. 4, figs. 8, 9

Length of single grain: 66 (68) 72 μm , width: 54 (59) 65 μm .

Length of tetrad: 70 (91) 115 μm , width: 61 (72) 83 μm (n=11).

This species usually occurs in tetrads. The single pollen-grain has an elliptical outline. The distal colpus is elongate, narrow in the middle and extends almost the entire length of the grain. The exine is 1.5–2.0 μm thick and sculptured with densely spaced clavae, baculae, and verrucae. The sculptural elements vary in size and shape from specimen to specimen. Some grains appear laevigate, others have very large clavae up to 8 μm high, 16 μm wide.

Genus *Monosulcites* Cookson 1947 ex. Couper 1953

Monosulcites minimus Cookson
Pl. 10, fig. 9
Range-chart number: 53

1947: *Monosulcites minimus* – Cookson, p. 135; pl. 15, figs. 47–50

Total length: 30 (36) 39 μm , width: 20 (23) 27 μm (n=12).

The outline is elliptical with rounded or slightly pointed ends. The colpus extends the entire length of the grain. The exine is laevigate, about 1 μm thick. Cookson (1947) erected *M. minimus* encompassing tertiary specimens. Couper (1958) stated that specimens recorded from Jurassic and Cretaceous strata in New Zealand and Britain appeared indistinguishable from Cookson's specimens, and thus referred the Mesozoic specimens to *M. minimus*, which is followed here.

Monosulcites punctatus Orłowska-Zwolinska
Pl. 10, fig. 10
Range-chart number: 58

1966: *Monosulcites punctatus* – Orłowska-Zwolinska, p. 1015; pl. 9, fig. 46

Total length: 43 (59) 73 μm , width: 26 (33) 40 μm (n=8).

The outline is elongated, elliptical with pointed ends ("spindle-shaped"). The colpus is narrow and extends the entire length of the grain. The exine is 0.5–1.0 μm thick and has a finely intrapunctate structure. This species differs from *Chasmatosporites elegans* in having

a more elongated amb, pointed ends, and a thinner exine.

Monosulcites cf. *punctatus* Orłowska-Zwolińska

Pl. 11, fig. 3

Range-chart number: 49

Description: The recorded specimens are identical with *Monosulcites punctatus* erected by Orłowska-Zwolińska 1966, except for having layers of thin exine that form longitudinal folds.

Total length: 50 (56) 66 μm , width: 20 (24) 27 μm (n=8).

Remarks: The specimens recorded compare very well with the specimens illustrated by Lund (1977).

Genus *Clavatipollenites* Couper 1958

Clavatipollenites hughesii Couper

Pl. 11, fig. 2

Range-chart number: 77

1958: *Clavatipollenites hughesii* – Couper, p. 159; pl. 31, figs. 19–22

Total length: 23 (28) 33 μm , width: 23 (26) 28 μm (n=8).

C. hughesii includes small monocolpate pollen with an elliptical to circular outline. The exine is 1.0–1.5 μm thick, tectate, with a laevigate surface.

Subturma *Praecolpates* Potonié & Kremp 1954

Genus *Eucommiidites* Erdtman 1948 emend. Hughes 1961

Erdtman (1948) and Couper (1958) described the genus *Eucommiidites* as tricolpate. Hughes (1961) interpreted the two narrow “side-colpi” as one ring-furrow which is more or less reduced near the ends of the grain. Hughes therefore referred this genus to Subturma *Praecolpates*, which is followed here.

Eucommiidites minor Groot & Penny

Pl. 11, fig. 5

Range-chart number: 75

1960: *Eucommiidites minor* – Groot & Penny, p. 234; pl. 2, fig. 14

Total length: 22 (27) 30 μm , width: 20 (21) 24 μm (n=5).

The outline is circular to elliptical. Distally there is a distinct colpus, that is narrow in the middle, expands at the ends, and extends almost the entire length of the grain. On the proximal side is a ring-furrow which is more or less reduced near the ends of the grain, giving the appearance of two “side-colpi”. The exine is laevigate and about 2 μm thick. Groot & Penny (1960) described this species as “Tricolpate (?)”.

Eucommiidites troedssonii Erdtman

Pl. 11, fig. 4

Range-chart number: 32

1948: *Eucommiidites troedssonii* – Erdtman, p. 267; figs. 5–10, 13–15

Total length: 33 (36) 38 μm , width: 23 (24) 27 μm (n=5). The exine is about 1 μm thick, laevigate to intrapunctate. *E. troedssonii* is similar to *E. minor* apart from the larger size and thinner exine.

Turma *Poroses* (Naumova 1939) Potonié 1960

Subturma *Monoporines* Naumova 1939

Genus *Corollina* Maljavkina 1949 emend. Cornet & Traverse 1975

1949: *Corollina* Maljavkina

1949: *Circulina* Maljavkina

1953: *Classopollis* Pflug

1958: *Classopollis* Pflug emend. Couper

1960: *Corollina* Maljavkina emend. Klaus

1968: *Circulina* Maljavkina emend. Klaus

1961: *Classopollis* Pflug emend. Pocock & Jansonius

1969: *Classopollis* Pflug emend. Reyre

1975: *Corollina* Maljavkina emend. Cornet & Traverse

1976: *Classopollis* Pflug emend. Srivastava

This long list of synonyms reflects both the deep disagreement concerning the first legitimate name for this genus and the gradually improved interpretation of the morphological characters, that has resulted in several emended diagnoses of the genus. The genus-name *Corollina* Maljavkina 1949 was correctly established, even though the descriptions of both the genus and the belonging species were very weak and thus difficult to use. Cornet & Traverse (1975) discuss the establishment of the younger generic-names and conclude that *Circulina* Maljavkina 1949 and *Corollina* Maljavkina 1949 should be combined into a single genus, named *Corollina*, with *Classopollis* as a junior synonym. They proposed a new genus-description based on a neo-type, as Maljavkina’s genotype (*Corollina compacta*) is not preserved. In addition there is still doubt about whether the distal “pseudopore” is a real pore (functioning as a germinal opening), and thus whether the genus should be referred to Turma *Poroses*, Subturma *Monoporines*. However, there is no better alternative in the systematic system used here.

Corollina torosus (Reissinger) Klaus emend. Cornet & Traverse

Pl. 11, figs. 6–8

Range-chart number: 30

1950: *Pollenites torosus* – Reissinger, p. 115; pl. 14, fig. 20

1958: *Classopollis torosus* (Reissinger 1950) – Couper, p. 156; pl. 28, figs. 2–7

1960: *Corollina* (al. *Pollenites*) *torosus* (Reissinger 1950) – Klaus, p. 168

1975: *Corollina torosus* (Reissinger 1950) – Klaus 1960 emend. Cornet & Traverse, p. 17; pl. 5, figs. 2–9, 14

Equatorial diameter: 23 (29) 33 μm (n=20).
Monoporate (?), more or less spherical pollen, frequently occurring in tetrads. At the proximal pole is a tetrad-scar that appears as a small triangular area of thin exine or as a small trilete-mark. At the equator is a 5–13 μm wide band of thickened exine. The band is composed of columellae, fused to form 6–10 parallel endexinal ribs. Semidistally, parallel to the equator, is a ring of thin exine, a ring-furrow, and at the distal pole is an, often indistinct, “pseudopore“, 4–9 μm in diameter. The exine is tectate, 1–3 μm thick with a homogeneous, laevigate to scabrate outer layer covering the total surface, and an inner, structured layer of varying thickness and structure. This innerlayer is thin at the proximal tetrad-scar, at the semidistal ring-furrow, and at the distal “pseudo-pore“, while it is thickened at the equatorial band.

Corollina sp. 1

Pl. 11, fig. 9

Range-chart number: 91

Description: Monoporate (?), more or less spherical pollen (not seen in tetrads). At the proximal pole is a tetrad-scar, appearing as a small, triangular area of thin exine. At the equator is a band of thickened exine. The band is composed of columellae, fused to 6–8 endexinal ribs. Semidistally, parallel to the equator, is a ring of thin exine, a ring-furrow, and at the distal pole is an, often indistinct, “pseudo-pore“. The exine is 1.5–2.0 μm thick, tectate, and with small, hair-like micro-echinae on the surface (< 1 μm high).

Equatorial diameter: 30 (31) 34 μm (n=10).

Remarks: This species deviates from *Classopollis echinatus* Burger 1965, in being somewhat larger (*C. echinatus* is 24–26 μm in diameter) and in having more endexinal ribs (*C. echinatus* has 3–5). *Classopollis hammenii* Burger 1965 also has fewer endexinal ribs while *Classopollis rarus* Reyre 1970 has a denser sculpturing than the recorded specimens. *Corollina* sp. 2 of Lund & Pedersen (1985) compare rather well with the specimens recorded in the present study, except for a larger size (about 40 μm in diameter).

Corollina sp. 2

Pl. 11, fig. 10

Range-chart number: 92

Description: Monoporate (?), more or less spherical pollen (not seen in tetrads). At the proximal pole is a tetrad-scar, appearing as a small, triangular area of thin exine. At the equator is a band of thickened exine that appears as a rather homogenous cingulum. Semidistally, parallel to the equator, is a ring of thin exine, a ring-furrow, and at the distal pole is an indistinct “pseudo-pore“. The grains are very dark so the exine-

structure is indistinct. The surface is sculptured with hair-like micro-echinae (< 1 μm high).

Equatorial diameter: 22 (24) 26 μm (n=4).

Aquatic palynomorphs

Dinoflagellata

In the range-chart the occurrences of the Rhaetian-Early Jurassic dinoflagellate-cyst species *Dapcodinium priscum*, *Liasidium variabile* and *Nannoceratopsis gracilis* are shown. All other recorded dinoflagellate-cysts are grouped into “various dinoflagellate-cysts” (no. 107 in the range-chart). The dinoflagellate-cyst species recorded from zone D and E are shown in figure 7 together with their references. See Lentin & Williams (1985) for further information concerning these species.

Division *Pyrrhophyta* Pascher 1914

Class *Dinophyceae* Fritsch 1929

Order *Dinophysiales* Lindemann 1928

Genus *Nannoceratopsis* Deflandre 1938 emend. Piel & Evitt 1980

Nannoceratopsis gracilis Alberti emend. Evitt

Pl. 13, fig. 5

Range-chart number: 105

1961: *Nannoceratopsis gracilis* – Alberti, p. 30; pl. 7, figs. 16, 17

1962: *Nannoceratopsis gracilis* (Alberti 1961) – Evitt, p. 1129–1130

Order *Peridinales* Haeckel 1894

Genus *Dapcodinium* Evitt 1961 emend. Dörhöfer & Davies 1980

Dapcodinium priscum Evitt

Pl. 13, fig. 7

Range-chart number: 96

1961: *Dapcodinium priscum* – Evitt, p. 996–1001; pl. 119, figs. 1–14, text-figs.1–20

The Gassum No. 1-borehole is the type-locality for this species. Evitt (1961) recorded *D. priscum* from the Gassum No. 1-borehole, in the core 1440 m – 1434 m (Early Sinemurian (Michelsen 1975)). In the present study this species was recorded from sample GA-3 (1534 m) to GA-26 (1420 m) (latest Rhaetian to Early Sinemurian (Sorgenfrei & Buch 1964, Michelsen 1975)).

Genus *Liasidium* Drugg 1978

Liasidium variabile Drugg

Pl. 13, fig. 6

Range-chart number: 104

1978: *Liasidium variabile* – Drugg, p. 69; pl. 4, fig. 10, pl. 5, figs. 1–9

In the rich material of this species the epicyst is usually conical in outline, but “shoulders” are present in some of the specimens. A reduced second antapical horn is developed on some specimens, but in most cases only one antapical horn is present. The specimen illustrated by Woollam & Riding (1983) is very similar to the present material. Forms informally assigned as “*Liassogonyaulax complexa*” by Morbey (1978) are also closely similar.

Acritarcha

The specimens referred to Group Cryptarcha and Group Acritarcha have not been defined to a lower taxa than Subgroup, though eventually to genus-level.

Group *Cryptarcha* Diver & Peat 1979

Subgroup *Sphaeromorphitae* Downie, Evitt & Sarjeant 1963

Genus *Halosphaeropsis* Mädler 1963

Pl. 12, fig. 2

Genus *Leiosphaeridia* Eisenack 1958

Pl. 12, fig. 1

The two genera *Halosphaeropsis* and *Leiosphaeridia* are united in the range-chart as Sphaeromorphitae, no. 97.

Group *Acritarcha* (Evitt 1963) Diver & Peat 1979

Subgroup *Acanthomorphitae* Downie, Evitt & Sarjeant 1963

Genus *Micrhystridium* Deflandre 1937 emend. Sarjeant 1967

Examples:

Type 1) Pl. 12, fig. 4

Type 2) Pl. 12, fig. 5

Type 3) Pl. 12, fig. 6

Type 4) Pl. 12, fig. 8

Type 5) Pl. 12, fig. 9

All specimens referred to the genus *Micrhystridium* are united in the range-chart as Acanthomorphitae, nr. 95.

Subgroup *Polygonomorphitae* Downie, Evitt & Sarjeant 1963

Genus *Veryhachium* Deunff 1958 emend. Downie & Sarjeant 1963

Pl. 12, fig. 3

The genus *Veryhachium* constitutes the Subgroup Polygonomorphitae, nr. 98 in the range-chart.

Subgroup *Herkomorphitae* Downie, Evitt & Sarjeant 1963

This acritarch-subgroup is not illustrated at the plates because of their poor state of preservation.

Range-chart number: 102

Subgroup *Netromorphitae* Downie, Evitt & Sarjeant 1963

Remarks: This acritarch-subgroup is not illustrated at the plates because of their poor state of preservation.

Range-chart number: 100

Subgroup *Pteromorphitae* Downie, Evitt & Sarjeant 1963

Genus *Pterospermopsis* Wetzel 1952

Pl. 13, fig. 2

Range-chart number: 103

The fossil genus *Pterospermopsis* resembles the living genus *Pterosperma*, referred to division Chlorophyta (the green algae) (Tappan 1980, p. 808).

Tasmanitids

Division *Chlorophyta* Pascher 1914

Class *Chlorophyceae* Kützing 1843

Family *Tasmanaceae* Sommer 1956

Genus *Tasmanites* Newton 1875

Examples:

Type 1) Pl. 13, fig. 1

Type 2) Pl. 13, fig. 3

Type 3) Pl. 13, fig. 4

All specimens referred to the genus *Tasmanites* are united in the range-chart as *Tasmanites* sp., no. 99. Because of the taxonomic problems in the Tasmanitids, all specimens recorded in the present study have been included in the genus *Tasmanites*.

Botryococcales

Division *Chlorophyta* Pascher 1914

Class *Chlorophyceae* Kützing 1843

Family *Botryococcaceae* Wille 1909

Genus *Botryococcus* Kützing 1849

Pl. 13, fig. 8

Range-chart number: 101

Botryococcus is a limnic-brackish, planktonic, colonial green algae. It ranges from Precambrian to present, known under different names, among those *Gloecapsomorpha*, *Elaeophyton*, *Epopalaia* and *Reinschia*. The genus *Botryococcus* has earlier been referred to Division Cyanophyta (the blue-green algae) and to Division Xanthophyta (the yellow-green algae) (Tappan 1980).

Foraminiferal test-linings

Pl. 12, fig. 7

Range-chart number: 106

The recorded foraminiferal test-linings consist of a chitinous, acid-resistant layer, originally covering the innerside of the foraminiferal test. The calcareous parts of the test have been dissolved.

Palynostratigraphy

Definition of zones

Based on the stratigraphic range and the abundance of the miospores (microspores and pollen), the studied section has been divided into five biozones, A to E (see the range chart and figure 5 and 9). The zonation is partly based on the appearance of stratigraphically important taxa, and partly on variations in the relative abundances of specific taxa or morphological groups (figure 10). The zones are discussed below, and their vertical ranges in the Gassum No. 1-borehole are stated, together with the sample numbers.

Zone A

(GA-1 to GA-3) (1538 m to 1533 m).

No definite base of this zone was recognized in the present study. It was not even possible to define the base of zone A with the help of the zonation defined in earlier studies, as the Rhaetian microspores that define the zonal-boundaries were not recorded.

In general, the trilete spores show an overwhelming dominance (78–87% of all miospores, see fig. 10), among which the genera *Deltoidospora* and *Baculatisporites* constitute the major part. Among the mainly Rhaetian types recorded are *Cingulizonates rhaeticus*, *Ricciisporites tuberculatus*, *Limbosporites lundbladii*, *Triancoraesporites ancorae*, and *Densosporites fissus*. None of the Rhaetian key-species (e.g. *Rhaetipollis germanicus*, *Ovalipollis ovalis* and *Granuloperculati-pollis rudis*) were observed. Among the mainly Early Jurassic forms the species *Perinopollenites elatoides*, *Quadraeculina anellaeformis* and the genus *Chasmatosporites* were recorded. *Pinuspollenites minimus* was not recorded and the relative abundance of *Corollina torosus* did not reach beyond 3%. The aquatic palynomorphs, totally dominated by acritarchs, comprise a very small part of all palynomorphs in this zone.

The considerable dissimilarity of the palynomorph-assemblages in samples GA-1 and GA-3 (see the range-chart) should not be interpreted as a sudden change in the flora, but is probably a result of a change in the sedimentary environment. Sample GA-1 is from a thin, shaly interval in the sandstone covering the interval 1550 to 1535 m while sample GA-3 is from the uppermost Rhaetian marine, dark grey shale which continues into the Lower Jurassic Fjerritslev Formation.

Zone B

(GA-4 to GA-18) (1515 m to 1463 m).

The base of this zone is defined partly by the appearance of abundant *Pinuspollenites minimus* and partly by a conspicuous increase in the relative abundance of *Corollina torosus*. The trilete spores constitute only 20–50% of the miospores in this zone. The saccate pollen dominate in the lower part of the zone and occur frequently in the upper part. Aperturate and alete pollen are also common. The zone is dominated by the miospore species *Corollina torosus*, *Pinuspollenites minimus*, *Deltoidospora toralis*, *Perinopollenites elatoides* and *Calamospora tener*. The species *Quadraeculina anellaeformis*, *Cupressacites* sp., *Vitreisporites pallidus*, *Marattisporites scabratus*, *Cerebropollenites thiergartii*, *Monosulcites minimus* and *Aratrisporites minimus* occur frequently. Of the mainly Rhaetic forms mentioned from Zone A, only *Densosporites fissus* was recorded (sporadically) from Zone B. A marked increase in abundance of aquatic palynomorphs (20–40% of all palynomorphs), totally dominated by acritarchs, is seen in the lower part of the zone.

Zone C

(GA-19 to GA-60) (1454 m to 1209 m).

The base of this zone is defined as the level where *Cerebropollenites macroverrucosus* appears together with *Lycopodiumsporites semimuris*. *Lycopodiumsporites clavatooides* appears higher in the zone. The upper limit of this zone coincides with a hiatus. In general there are relatively few trilete spores (about 10% of the miospores). The zone is dominated by saccate, alete, and aperturate pollen. In Zone C, as in Zone B, the dominating miospore species are *Corollina torosus*, *Pinuspollenites elatoides* and *Calamospora tener*; *Deltoidospora toralis* is less abundant. In the upper part of the zone *Spheripollenites psilatus* occurs frequently. The relative abundance of aquatic palynomorphs ranges from 5 to 35% of all palynomorphs. Among those the acritarchs dominate totally. In the uppermost part of the zone the dinoflagellate-cysts show a rise in relative abundance and the Botryococcales also become more abundant.

Zone D

(GA-65) (1177 m to 1170 m).

This zone is restricted downwards by the hiatus. Six new species are present: *Callialasporites microvelatus*, *Callialasporites segmentatus*, *Gleicheniidites conspicendus*, *Gleicheniidites senonicus*, *Staplinisporites telatus* and *Manumia variverrucata*. The zone is dominated by alete pollen (50% of all miospores), especially by the species *Perinopollenites elatoides* and *Spheripollenites psilatus*. *Deltoidospora toralis* and *Monosulcites minimus* are also relatively abundant while *Corollina torosus* and *Pinuspollenites minimus* show much lower relative abundances than in the preceding zones. The aquatic palynomorphs, still dominated by acritarchs, constitute only about 13% of all palynomorphs. The dinoflagellate-cysts show an increase in diversity and the Botryococcales occur frequently.

Zone E

(GA-66 to GA-71) (1153 m to 1139 m).

The base of this zone is defined as the level where the echinate *Corollina*-types (*Corollina* sp. 1 and *Corollina*

sp. 2) appear. No definite upper boundary of this zone was recognized in the present study but could possibly be placed where the genus *Cicatricosisporites* becomes common. The aperturate and alete pollen dominate among the miospores. The dominant miospore species comprise *Corollina torosus*, *Perinopollenites elatoides*, *Pinuspollenites minimus* and *Corollina* sp. 1. There are about 30% aquatic palynomorphs, among which the

Figure 4. Location of palynological investigations used for correlation:

- 1) The Gassum No. 1-borehole (this study)
- 2) The Hobro No. 1-borehole (Bertelsen 1974)
- 3) Scania (several localities); the Rødby No. 1-borehole, Denmark; the Massbull No. 1-borehole, northwestern Germany; the Eitzendorf No. 8-borehole, northwestern Germany, south of Massbull (Lund 1977)
- 4) German Democratic Republic (Schulz 1967)
- 5) Middle- and southern England (Orbell 1973)
- 6) Northeastern France and Luxemburg (Schuurman 1977)
- 7) Jameson Land, East Greenland (Lund & Pedersen 1985)
- 8) England and Scotland (Couper 1958)
- 9) Eastern Netherlands (Burger 1966).

The coastlines in the Early Jurassic are shown as dotted lines; arrows indicate the main directions of material transport from the land areas into the depositional basins (from Ziegler 1982).



dinoflagellate-cysts are totally dominating. There are relatively few acritarchs while foraminiferal test-linings occur frequently.

Age of the zones

Figure 4 shows the location of the eight previously published palynological investigations used for the correlation and dating of Zones A to E. Figure 5 presents the resulting biostratigraphic zonation of the relevant stratigraphic section from six of these investigations. Neither Couper (1958) nor Burger (1966) are mentioned in figure 5. Couper (1958) does not present a palynological zonation of the investigated strata, while Burger's (1966) investigation probably does not overlap this study stratigraphically. Figure 6 shows the stratigraphic range, according to the literature, of some of the stratigraphically most important miospores recorded in the present study.

Zone A

A Late Rhaetic age can reliably be assigned to this zone. The microflora, composed of both Rhaetic and Early Jurassic forms, corresponds very well with the "Oberrät microflora" defined by Schulz (1967) (= Zone 3 in figure 5). The "Oberrät microflora" is

characterized by the common occurrence of, among others, *Limbosporites lundbladii*, *Densosporites fissus*, *Cingulizonates rhaeticus*, *Heliosporites altmarkensis*, *Lycopodiacidites rugulatus*, *Ricciisporites tuberculatus*, *Quadraeculina anellaeformis*, and species referred to the genus *Chasmatosporites*.

The microflora defining Zone A shows only a slight similarity to the Early and Middle Rhaetic microfloras presented by Orbell (1973) (the *Rhaetipollis* Zone), Bertelsen (1974) (Unit A and B), and by Schuurman (1977) (Phase 3). The microflora of Zone A comprises none of the key-species *Rhaetipollis germanicus*, *Ovalipollis ovalis*, *Ovalipollis pseudoalatus*, and *Granuloperculatipollis rudis*, and only shows a sparse occurrence of *Ricciisporites tuberculatus*.

The "Upper Rhaetic" (sensu germanico) microflora of the *Ricciisporites-Polyodiisporites* Zone proposed by Lund (1977) does not correspond to Zone A, being defined by the common occurrence of the species

Figure 5. Correlation of spore-pollen zones in northwestern Europe. Solid lines: confidently dated zone-boundaries. Dashed lines: less confidently dated zone-boundaries.

U.Z.w.C.m.: "Unnamed Zone with *Cerebropollenites macroverrucosus*"

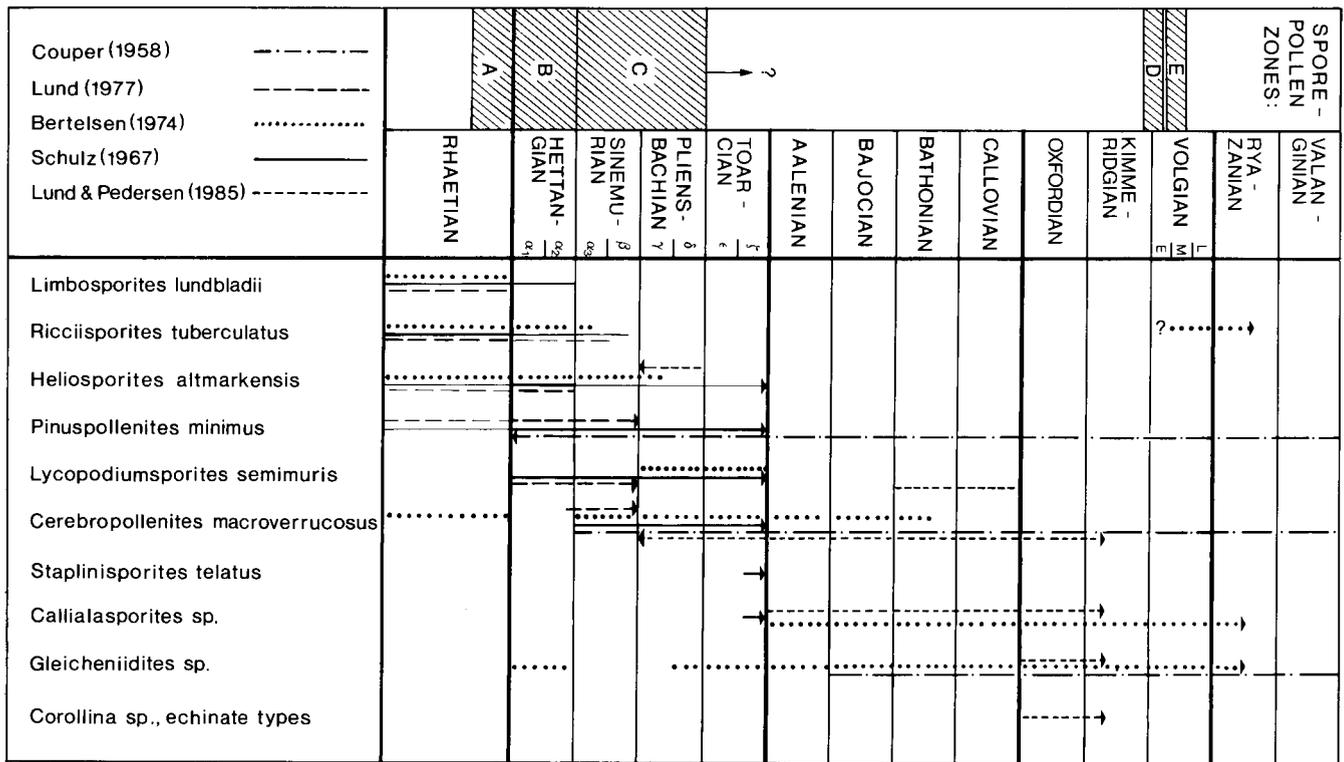
P.T.Z.: The *Pinuspollenites-Trachysporites* Zone

R.P.Z.: The *Ricciisporites-Polyodiisporites* Zone

H.Z.: The *Heliosporites* Zone

R.Z.: The *Rhaetipollis* Zone.

CHRONO-STRATIGRAPHY	This study	Bertelsen (1974)	Lund (1977)	Schulz (1967)	Orbell (1973)	Schuurman (1977)	Lund & Pedersen (1985)
RYAZANIAN							
VOLGIAN	E D	E					
KIMMERIDGIAN							
OXFORDIAN							D
CALLOVIAN							
BATHONIAN		D					C ₃
BAJOCIAN							C ₂
AALENIAN							C ₁ (C)
TOARCIAN				7			B
PLIENS-BACHIAN		C ₄ C ₃	U.Z.w. C.m.	6			A
SINEMURIAN	C	C ₂		5		5	
HETTANGIAN	B	C ₁	P.T.Z.	4			
RHAETIAN	A	B	R.P.Z.	3	H.Z. R.Z.	4 3	



Polypodiisporites polymicroforatus (= *Convolutispora microrugulatus*) and of the genus *Semiretisporis*.

A rise in abundances of *Deltoidospora* and *Baculatisporites*, probably corresponding to the high relative abundances of the two genera in Zone A, was observed in the Rødby No. 1-borehole in an interval referred to "topmost Upper Rhaetic?" (Lund 1977). The mixed Rhaetic-Early Jurassic microflora recorded from this interval corresponds generally with the microflora in Zone A.

Based on comparisons with previously defined microflora-zones, Zone A is confidently considered to be younger than Middle Rhaetic and also younger than Lund's (1977) "Upper Rhaetic" (sensu germanico) *Ricciisporites-Polypodiisporites* Zone. At the same time the microflora of Zone A lacks the most important characteristics of Hettangian microfloras (see discussion of Zone B below).

Zone B

A Hettangian age can confidently be applied to this zone. An abrupt rise in the relative abundance of *Pinuspollenites minimus*, which defines the base of this zone, is observed at the Rhaetic-Hettangian boundary by both Schulz (1967) and Lund (1977).

The Hettangian microflora presented by Schulz (1967) (= Zone 4 in fig. 5) corresponds generally to the microflora of Zone B. Also Lund's (1977) *Pinuspollenites-Trachysporites* Zone, assigned a Hettangian age, corresponds to Zone B, being characterized by the common occurrence of the genera *Conbaculatisporites*,

Figure 6. Stratigraphic ranges, according to the literature, of the stratigraphically important spore-pollen species recorded in the present study. The arrows show limits of the specific investigation and thus do not indicate the first- or last appearance of the species.

Trachysporites and *Uvaesporites*, with Rhaetic forms like *Limbosporites lundbladii* and *Densosporites fissus* being absent or occurring sporadically.

In addition, the microflora of the C₁-subzone defined by Bertelsen (1974) and assigned a Hettangian-Early Sinemurian age, corresponds very well to Zone B as defined in the present study. Bertelsen's Subzone C₁ is dominated by the species *Perinopollenites elatoides*, *Corollina torosus*, and by specimens referred to the genus *Deltoidospora*. *Ricciisporites tuberculatus* occurs sporadically but many other Rhaetic forms have disappeared. *Cerebropollenites thiergartii* appears within Subzone C₁ of Bertelsen.

The upper boundary of Zone B is defined by the appearance of *Cerebropollenites macroverrucosus* at the Hettangian-Sinemurian boundary (see discussion of Zone C below).

Zone C

The base of this zone can confidently be assigned to the Hettangian-Sinemurian boundary. The age of the upper boundary (at the start of the hiatus) is more uncertain, but is probably close to the Pliensbachian-Toarcian boundary.

The species *Cerebropollenites macroverrucosus*, defining the base of Zone C has, according to Schulz (1967), its first occurrence at the Hettangian-Sinemurian boundary in East Germany. According to Lund (1977) it appears in the uppermost Hettangian to the lowermost Sinemurian in the Rødby No. 1-borehole, the Fitzendorf No. 8-borehole, and in Scania. The appearance of this species defines the base of Lund's (1977) "Unnamed Zone with *Cerebropollenites macroverrucosus*". Apart from this species his zone is characterized by the common occurrence of specimens referred to the genus *Lycopodiumsporites* (including *Lycopodiumsporites semimuris*) and corresponds generally to Zone C. Phase 5 of Schuurman (1977) corresponds very well to Zone C, being characterized by the dominance of specimens referred to the genus *Corollina* and smooth, trilete spores together with *Heliosporites reissingeri*, *Lycopodiumsporites semimuris*, *Stereisporites cicatricosus*, *Cerebropollenites macroverrucosus*, and *Zbrasporites interscriptus*. This phase is assigned a Hettangian to Early Pliensbachian age.

The total dominance of *Ricciisporites tuberculatus* in sample GA-53 seems strange. In NW-Europe *R. tuberculatus* ranges from Norian to Sinemurian with its acme in the Rhaetian (Schulz 1967, Lund 1977, Pedersen & Lund 1980). In the present study this species was only recorded in two samples, in GA-3 (1536 m b.r.t.) and in GA-53 (1277 m b.r.t.). According to Sorgenfrei & Buch (1964) the level 1536 m b.r.t. belongs to uppermost Rhaetian, while the level 1277 m b.r.t. is referred to Late Pliensbachian. In GA-53 *R. tuberculatus* constitutes about 35% of the recorded spores and pollen and is clearly the dominant palynomorph. As the species was not recorded in the interval between these two levels and as it normally does not occur above Sinemurian, the pollen-grains in GA-53 are presumed to have been reworked from older sediments.

None of the genera *Callialasporites*, *Gleichenioidites*, *Staplinisporites* and *Manumia*, which have their first appearance in the uppermost Early Jurassic and Middle Jurassic, were recorded in Zone C.

A sudden dominance of *Nannoceratopsis gracilis* was recorded in sample GA-60 (only a few specimens had been recorded from samples below). This sudden dominance may indicate an age near the Pliensbachian-Toarcian boundary (Morbey 1978).

Zone D

This zone, comprising only one sample, cannot, on the basis of miospores alone, be assigned an age more accurate than between Late Toarcian and Kimmeridgian.

The stratigraphically most important miospore taxa recorded in this zone are *Callialasporites*, *Gleichenioidites*, *Staplinisporites telatus*, and *Manumia variverrucata*.

The genus *Callialasporites* appears in Late Toarcian in East Germany (Schulz 1967). In the Hobro No. 1-borehole it was recorded from the Middle Jurassic (Bertelsen 1974) and in Jameson Land, East Greenland, it was recorded from the Bajocian (Lund & Pedersen 1985).

The genus *Gleichenioidites* was recorded from the Bajocian in Great Britain (Couper 1958), the Hettangian-Sinemurian in the Hobro No. 1-borehole (Bertelsen 1974), and the Oxfordian in Jameson Land, East Greenland (Lund & Pedersen 1985).

The zone D defined by Lund & Pedersen (1985) and assigned an Oxfordian-Kimmeridgian age, is characterized by the appearance of the genus *Gleichenioidites*, especially the species *Gleichenioidites conspicendus*, which is also recorded from the Zone D of the present study.

The species *Staplinisporites telatus* was recorded from Late Toarcian in East Germany (Schulz 1967). The genus *Manumia* was recorded from Toarcian in Jameson Land, East Greenland (Lund & Pedersen 1985), and the species *Manumia variverrucata* has its first occurrence in Early Toarcian in DDR and the eastern Netherlands (Schulz 1967, Hergren & de Boer 1974).

No echinate *Corollina*-types were recorded from Zone D (see discussion of Zone E below).

Zone E

This zone can be assigned an age from Oxfordian to the latest Jurassic. A more accurate dating is not possible on the basis of miospores alone.

The base of Zone E is defined as the level where echinate *Corollina*-types appear. Those are recorded from the Oxfordian in Jameson Land, East Greenland (Lund & Pedersen 1985) and from the uppermost Late Jurassic ("higher Upper Malm") in the eastern Netherlands (Burger 1966).

In the Hobro No. 1-borehole and in the eastern Netherlands specimens referred to the genus *Cicatricosisporites* were recorded in large numbers from the uppermost Late Jurassic (Burger 1966, Bertelsen 1974). A single specimen referred to this genus was recorded from sample GA-71, the topmost sample of Zone E.

Age of the zones D and E based on dinoflagellate-cysts

In addition to the spores and pollen, the samples from the zones D and E contain a diverse and well-preserved dinoflagellate-cyst assemblage. The recorded dinoflagellate-cysts permit a more detailed stratigraphical correlation of the two zones. Identification and correla-

SPORE / POLLEN ZONES	D	E		
SAMPLE NUMBERS (GA-)	65	67	69	71
<i>Hystrichogonyaulax cladophora</i> (Deflandre 1938) Stover & Evitt 1978	?			
<i>Gonyaulacysta jurassica</i> (Deflandre 1938) Sarjeant 1982	X	X		
<i>Occisucysta balia</i> Gitzme 1970	X	X		
<i>Mendicodinium groenlandicum</i> (Pacock & Sarjeant 1972) Davey 1979	X	X		
<i>Senoniasphaera jurassica</i> (Gitzme & Sarjeant 1972) Lentin & Williams 1981	X	X		
<i>Sirmiodinium grossii</i> (Albert 1961) Warren 1973	X	X		
<i>Tubotuberella apateia</i> (Cookson & Eisenack 1960) Sarjeant 1982	X	X		
<i>Hystrichogonyaulax pennata</i> (Riley in Fischer & Riley 1980) Lentin & Williams 1981	X	X		
<i>Egmontodinium expiratum</i> Davey 1982	X	X	X	X
<i>Kleithrasphaeridium porosispinum</i> Davey 1982	X	X	X	X
<i>Ctenidodinium panneum</i> (Norris 1965) Lentin & Williams 1973	X	X	X	X
<i>Systematophora</i> sp. 1 sensu Davey 1982	X	X	X	X
<i>Glossodinium dimorphum</i> Ioannides et al. 1977	X	X	X	X
<i>Dichadogonyaulax culmula</i> (Norris 1965) Loeblich & Loeblich 1968	X	X	X	X
<i>Egmontodinium torynum</i> (Cookson & Eisenack 1960) Davey 1979	X	X	X	X
<i>Dingodinium tuberosum</i> (Gitzme 1970) Fischer & Riley 1980	X	X	X	X
<i>Cannosphaeropsis thula</i> Davey 1982	X	X	X	X
<i>Gochtheadinia mutabilis</i> (Riley in Fischer & Riley 1980) Davey 1982	X	X	X	X

• Incomplete specimen
 •• Single specimen with processes shorter than normal

Figure 7. Dinoflagellate-cyst species recorded from the four top-most samples counted (in the spore-pollen zones D and E). The specimens were identified by C. Heilmann-Clausen, Geological Institute, University of Aarhus.

tion of the dinoflagellate-cysts was carried out by Claus Heilmann-Clausen, Geological Institute, University of Aarhus. The recorded dinoflagellate-cysts species are shown in figure 7; figure 8 shows the stratigraphically most important ones and their ranges according to the literature.

Zone D

A Kimmeridgian – Early Volgian age can be confidently assigned on the presence of *Gonyaulacysta jurassica*, *Occisucysta balia* and *Senoniasphaera jurassica*. The presence of a doubtful *Hystrichogonyaulax cladophora* and the absence of *Ctenidodinium panneum* suggests a Kimmeridgian (pre-Volgian) age.

Zone E

A Middle Volgian age, no younger than the *Anguiformis* ammonite Zone, can be reliably applied, but the exact age within the Middle Volgian is uncertain. The presence of *Egmontodinium expiratum* in sample GA-67 points to an age for this sample no older than the *Kerberus* ammonite Zone. On the other hand, *Senoniasphaera jurassica* in samples GA-67 and GA-69 is not considered to range above the *Albani* ammonite Zone.

The presence of *Dichadogonyaulax culmula* (frequent) and *Glossodinium dimorphum* in sample GA-71 is a reliable indication of an age no younger than the *Anguiformis* ammonite Zone. The absence of *Senoniasphaera jurassica* and presence of *Cannosphaeropsis thula* (frequent) probably indicates an age within the *Kerberus*-*Anguiformis* ammonite Zones.

	OXFORDIAN	KIMMERIDGIAN	VOLGIAN			RAZANIAN	CHRONO STRATI-GRAPHY	BOREAL AMMONITE ZONES
			early	middle	late			
			Baylei Cymodose Mutabilis Eudoxus Autissiodorensis Elegans Scitulus Wheatleyensis Hudlestoni Pectinatus Pallasoides Rotunda Albani Fittoni Kerberus Anguiformis Oppressus Primitivus Preplicomphalus Lamplughii Runctoni					
x Woollam & Riding (1983)								
O Davey (1982)								
Δ Fischer & Riley (1980)								
□ Riding (1984)								
••••• rare or uncertain								
H. CLADOPHORA (x)								
G. JURASSICA (□)								
G. DIMORPHUM (x)								
O. BALIA (□)								
S. JURASSICA (x)								
C. PANNEUM (□)								
G. MUTABILIS (OΔ)								
K. POROSISPINUM (O)								
H. PENNATA (Δ)								
C. THULA (O)								
D. CULMULA (□)								
E. EXPIRATUM (□)								

Figure 8. Ranges, according to the literature, of the stratigraphically most important dinoflagellate-cysts species recorded from the four top-most samples counted (in the spore-pollen zones D and E) in the present study. The references from which the stated ranges have been obtained are indicated.

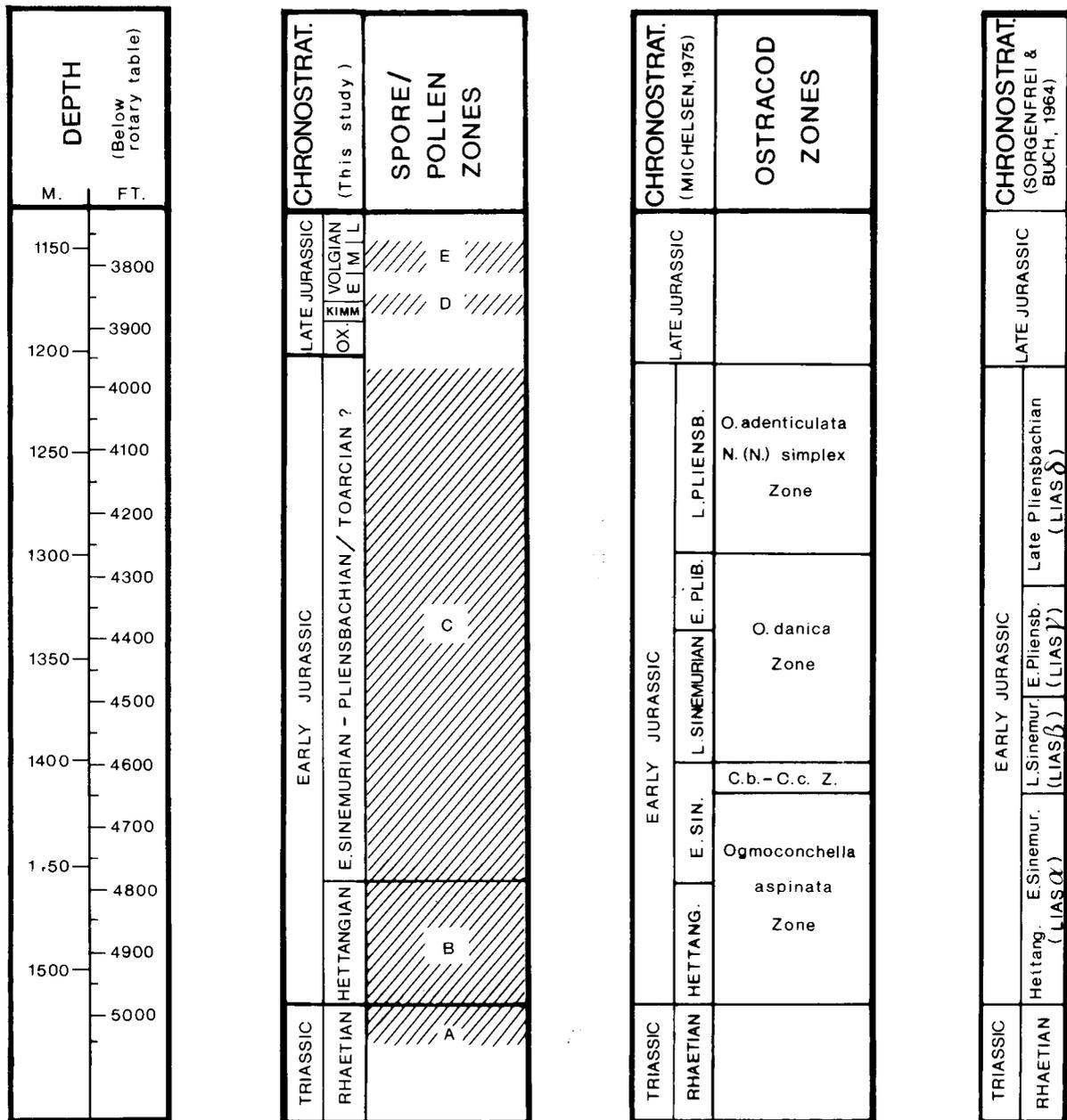


Figure 9. Correlation of biozonations and chronostratigraphy of the Lower Jurassic section in the Gassum No. 1-borehole. C.b.-C.c.Z.: *C. betzi* - *C. crassireticulata* Zone.

Stratigraphical conclusion

Correlation with previous palynological investigations in Northwest Europe allows the five zones, A to E, of the present study, to be dated as follows:

- | | |
|---|--|
| Zone E:
(GA-66 to GA-71)
(1153 m to 1139 m) | Middle Volgian |
| Zone D:
(GA-65)
(1177 m to 1170 m) | Kimmeridgian - Early Volgian |
| Zone C:
(GA-19 to GA-60)
(1454 m to 1209 m) | Early Sinemurian to
?Pliensbachian/Toarcian |

- | | |
|--|---------------|
| Zone B:
(GA-4 to GA-18)
(1515 m to 1463 m) | Hettangian |
| Zone A:
(GA-1 to GA-3)
(1538 m to 1533 m) | Late Rhaetian |

This stratigraphical conclusion corresponds well with the bio- and chronostratigraphical subdivisions of the Gassum borehole by Sorngrenfrei & Buch (1964) and Michelsen (1975) (see fig. 9).

Palaeoenvironment

The recording of frequent marine palynomorphs in all counted samples reveals that the depositional environment was marine throughout the studied section in the Gassum No. 1-borehole.

Further information concerning the depositional environment can be obtained by dividing the palynomorphs into specific groups and study variations in the relative abundances of these groups. This has been done by Pedersen & Lund (1980, figs. 11 and 12) and Lund & Pedersen (1985, fig. 7). They divided the terrestrial palynomorphs (the miospores) into five main morphological groups: trilete spores, monolete spores, saccate pollen, alete pollen, and aperturate pollen. The relative occurrence of these groups through the studied section was used to interpret the palaeoenvironment. According to Lund & Pedersen (1985) the group of trilete spores comprises relatively heavy, mainly water-transported palynomorphs. The frequency of this group is therefore possibly inversely proportional to the distance from rivermouths and shorelines. Conversely, a relative maximum of saccate pollen indicates a greater distance from the shore.

A corresponding grouping of the palynomorphs recorded in the present study is shown in figure 10. The first part of the figure (part I) shows the relationship between the terrestrial palynomorphs (the miospores and *Botryococcales*) and the marine palynomorphs. These variations are presumed to be related to changes in sea-level (see also p. 38). Part II of the figure shows the relative mutual abundance of the five main morphological groups of terrestrial palynomorphs, and part III shows the relative mutual abundance of the five aquatic groups: Dinoflagellate-cysts, Acritarchs, Tasmanitids, Botryococcales and Foraminiferal test-linings.

Botryococcus is a freshwater to brackish colonial algae. Thus a large relative abundance of these indicates an influence of fresh to brackish water. The remaining four groups together constitute the marine palynomorphs (see part I, fig. 10).

In general the variation in the relative abundance of marine palynomorphs in relation to the terrestrial palynomorphs, and the relative abundance of saccate pollen, correspond very well. As expected, the curve showing the relative abundance of trilete spores shows a reverse tendency. Thus a coincident minimum of trilete spores and a maximum of saccate pollen and marine palynomorphs indicate a fully marine environ-

ment, while the opposite pattern indicates a more marginal, fluviially-influenced depositional environment.

Based on these assumptions the maximum marine conditions occurred in the following intervals: 1) uppermost Rhaetian to lowermost Hettangian, 2) Lower Sinemurian, 3) 1402 m to 1341 m (Upper Sinemurian according to Sorgenfrei & Buch, 1964), 4) 1341 m to 1280 m (Lower to Upper Pliensbachian according to Sorgenfrei & Buch, 1964) (see also p. 38).

The sudden maximum of dinoflagellate-cysts in sample GA-36 at 1372 m is due to the abundance of only one species *Liasidium variable* and not a normal, diverse marine assemblage. This maxima probably indicates a restricted environment, inducing a bloom of *L. variable*, rather than a fully marine environment.

Two remarkable maxima occur in sample GA-53: one in the aperturate pollen due to the sudden abundance of *Ricciisporites tuberculatus*, and one shown by the Botryococcales. Marine palynomorphs are less abundant at this level. The sudden appearance of abun-

Figure 10. The relative abundances of the main morphological groups.

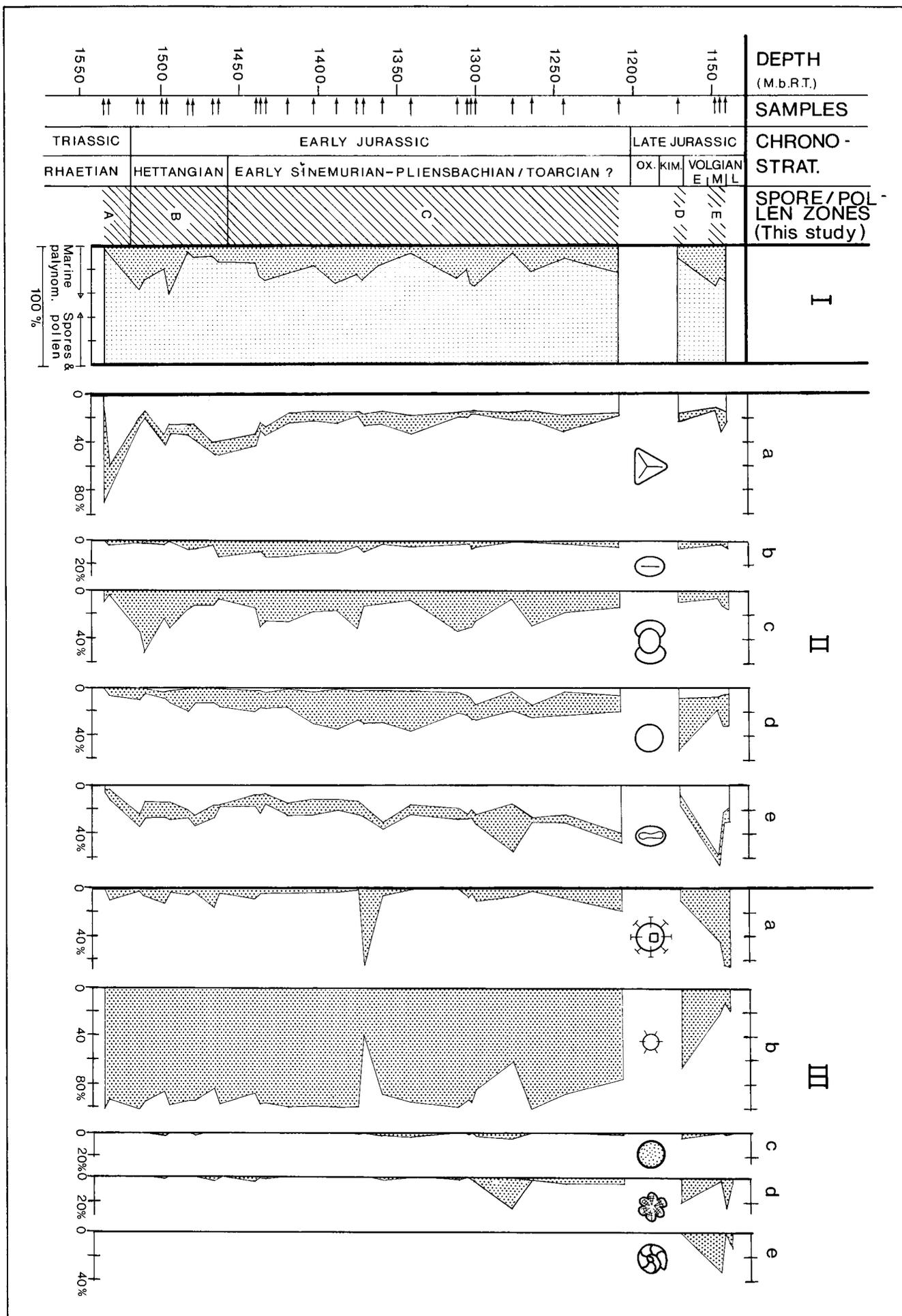
Part I: The relationship between terrestrial and marine palynomorphs. The limnic algae-genus *Botryococcus* is included in the terrestrial palynomorphs together with the spores and pollen. The four remaining groups of aquatic palynomorphs together constitute the marine palynomorphs (100% = all recorded palynomorphs).

Part II: Distribution of the five main morphological groups of spores and pollen (100% = total of spores + pollen):

- The trilete spores. The innermost curve indicates laevigate (unsculptured) trilete spores while the outermost curve indicates the sculptured trilete spores
- The monolete spores
- The saccate pollen
- The alete pollen. The innermost curve shows the genus *Spheripollenites*
- The aperturate pollen (monocolpate, praecolpate and monoporate). The innermost curve shows the genus *Corollina*.

Part III: Distribution of aquatic palynomorphs, divided into the following groups (100% = total of aquatic palynomorphs):

- The dinoflagellate-cysts
- The acritarchs
- The tasmanitids
- The botryococcales
- The foraminiferal test-linings.



dant *R. tuberculatus* possibly indicates a short-spanned regressive phase resulting in erosion and reworking of older sediments (see p. 33). The coincident increased recovery of Botryococcales also points towards a regressive phase with greater influence from fluvial systems.

A remarkable maximum of the genus *Spheripollenites* was recorded by Lund & Pedersen (1985) in Jameson Land, East Greenland, in their assemblage B, referred to Early Toarcian. A contemporary maximum of *Spheripollenites* was observed by Morbey (1978) in northwestern Europe and was supposed to be climatically controlled. The recorded maximum coincided with a maximum of *Corollina* and a minimum of bisaccate pollen. In the present study *Spheripollenites* has low occurrence up to about 1310 m where there is a rise in the relative abundance from about 1 to about 14%; above this level the abundance varies between 1% and 13%. The increase in *Spheripollenites* is contemporary with a weak, gradual rise in the abundance of *Corollina* (fig. 10, part II, e), and a weak fall in the abundance of saccate pollen. According to Sorgenfrei & Buch (1964) the level where these tendencies start should be of Late Pliensbachian age. This agrees generally with the observations of Morbey (1978) and Lund & Pedersen (1985).

Eustatic sea-level changes reflected in the distribution of palynomorphs

The Early Jurassic Transgression recognized in northwestern Europe consisted of successive phases of sea-level rises interrupted by minor shallowing events (Hallam 1978, 1981; Vail & Todd 1981). According to Hallam (1981) the most important of these transgression phases, recognized through sedimentological and palaeontological investigations, occurred in the following periods: earliest Hettangian, Early Sinemurian, Late Sinemurian to Early Pliensbachian, Late Pliensbachian, and Early Toarcian (see figure 11).

Subsidence in the Danish Subbasin during the Early Jurassic was probably fault-controlled, but it is still possible to recognize the five regional, eustatic phases of sea-level rise in the sedimentary sequences along the margin of the Danish Subbasin, and as weaker lithological changes in the central parts of the basin (Bertelsen 1978, Michelsen 1978, Pedersen 1986). In addition to the five regional phases, there is evidence for Mid- to Late Sinemurian deepening events in the Danish Subbasin (Pedersen 1986).

As the phases of transgression are lithologically recognizable they must also be expected to have influenced the distribution of micro- and macrofossils. According to Hallam (1976) the initial phases of smaller transgressions favour development of anoxic conditions

and thus influence the composition of the bivalve fauna.

Pedersen (1986), who studied the bivalve fauna in the Lower Jurassic section of the Gassum No. 1-borehole, divided the fauna into five feeding groups and compared their mutual variations with the phases of sea-level rise. She concluded that the phases of sea-level rise in the earliest Hettangian, the Early Sinemurian and the Late Pliensbachian had no significant effect on the composition of the bivalve fauna, while the Late Sinemurian – Early Pliensbachian deepening event was clearly reflected by a distinct change in the faunal composition, probably caused by a decrease in the oxygen-content of the bottom-water. A further drop in the oxygen-content at the Early Toarcian deepening event probably caused the disappearance of bivalves in the uppermost core of Late Pliensbachian age.

The relationship between marine and terrestrial palynomorphs in the present study is shown in figure 10, part I. The same curve is shown in figure 11 where it is vertically compressed to allow correlation with Hallam's (1981) curve of eustatic sea-level changes in the Early Jurassic. His five major phases of sea-level rise are marked by an asterisk.

Comparison of the two curves in figure 11 shows:

The basal Hettangian phase of sea-level rise coincides with a distinct maximum of marine palynomorphs.

The phase of sea-level rise in Early Sinemurian also coincides with a maximum of marine palynomorphs, although it is not as distinct as the preceding one.

A third maximum of marine palynomorphs occurs in the middle of Sinemurian. This maximum does not correlate with any of Hallam's phases of sea-level rise, but supports evidence for Mid- to Late Sinemurian deepening events in the Danish Basin presented by Pedersen (1986, fig. 7).

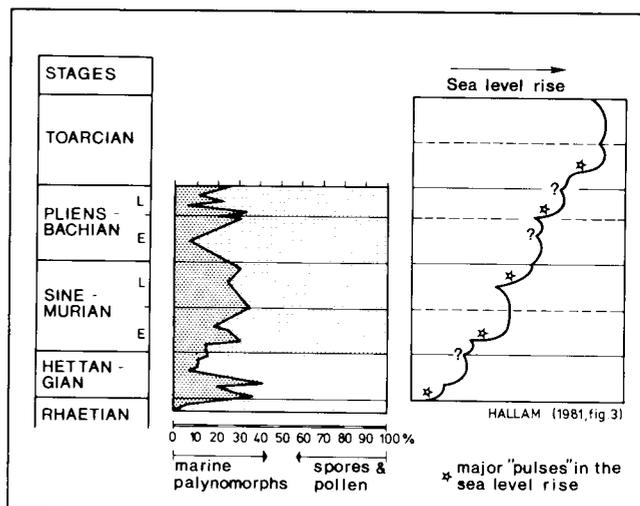


Figure 11. The relationship between marine- and terrestrial palynomorphs, correlated with Hallam's (1981) curve of Early Jurassic eustatic sea-level changes.

The Late Sinemurian to Early Pliensbachian phase of sea-level rise is contemporary with a maximum of marine palynomorphs, although it is partly masked by the maximum in the middle of the Sinemurian.

Finally, the Late Pliensbachian phase of sea-level rise coincides with a distinct maximum of marine palynomorphs. There is a weak tendency towards a rise in the marine palynomorphs in the samples just below the hiatus, which could reflect initiation of the Early Toarcian rise in sea-level.

It seems that the levels showing maximal relative abundances of marine palynomorphs correlate rather well with the phases of sea-level rise presented by Hallam (1981) and sedimentologically recorded in the Danish Subbasin. Nevertheless, these results have to be used with some reservation as the lack of an ammonite-zonation of the Gassum No. 1-borehole prevents detailed stratigraphical correlation.

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Plates

The number of the sample from which the illustrated specimen was recorded is given in the figure text.

The slides containing the illustrated specimens, together with a list of stage coordinates for the Leitz Wetzlar microscope used, are available from the Geological Institute, University of Aarhus, Denmark.

PLATE 1

Magnifications: x1000

- Fig. 1. *Deltoidospora toralis* (Leschik) Lund. Sample GA-7.
- Fig. 2. *Deltoidospora toralis* (Leschik) Lund. Sample GA-7.
- Fig. 3. *Deltoidospora crassexina* (Nilsson) Lund. Sample GA-22.
- Fig. 4. *Deltoidospora minor* (Couper) Pocock. Sample GA-38.
- Fig. 5. *Intrapunctisporis toralis* (Leschik) Lund. Sample GA-4.
- Fig. 6. *Cibotiumspora juriensis* (Balme) Filatoff. Sample GA-11.
- Fig. 7. *Punctatisporites globosus* (Leschik) Lund. Sample GA-2.
- Fig. 8. *Punctatisporites major* (Couper) Kedves & Simoncsics. Sample GA-2.
- Fig. 9. *Retusotriletes mesozoicus* Klaus. Sample GA-2.
- Fig. 10. *Calamospora tener* (Leschik) Mädlar. Sample GA-8.
- Fig. 11. *Calamospora* sp. Sample GA-16.
- Fig. 12. *Stereisporites stereoides* (Potonié & Venitz) Pflug. Sample GA-11.
- Fig. 13. *Stereisporites antiquasporites* (Wilson & Webster) Dettmann. Sample GA-41.

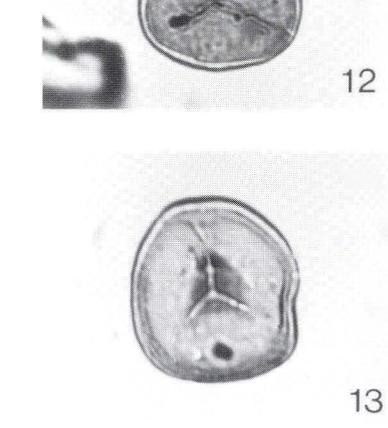
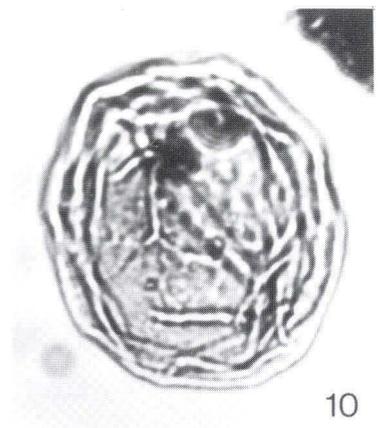
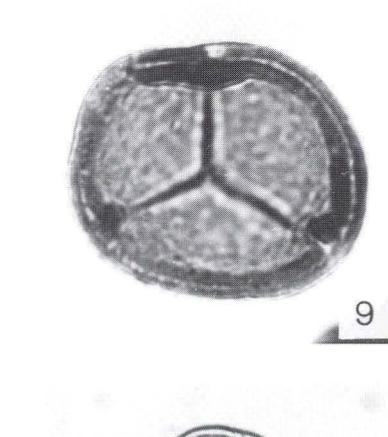
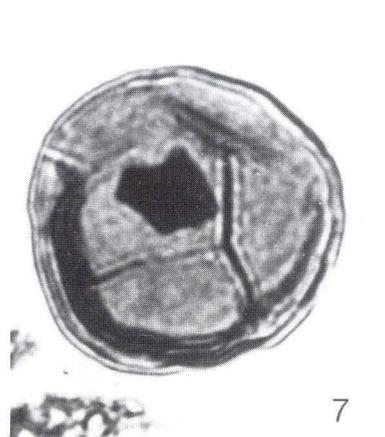
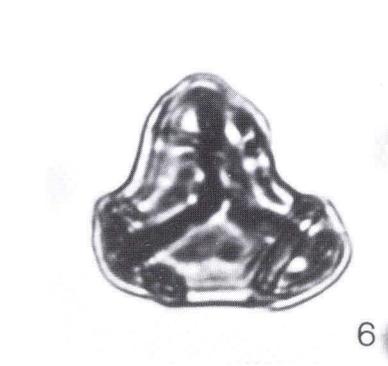
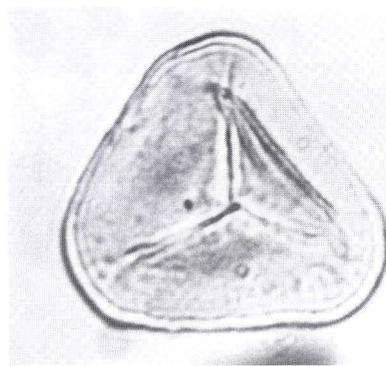
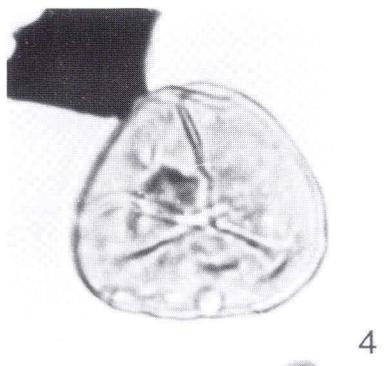
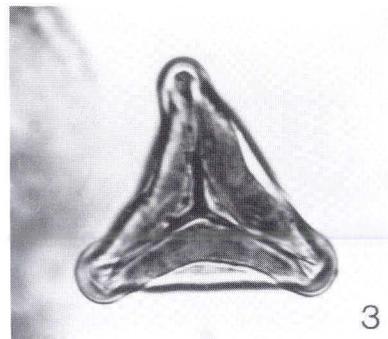
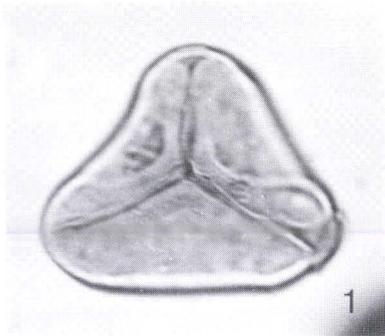


PLATE 2

Magnifications: x1000

- Fig. 1. *Stereisporites punctus* (Klaus) Krutzsch. Sample GA-34.
- Fig. 2. *Stereisporites cicatricosus* (Rogalska) Schulz. Sample GA-39.
- Fig. 3. *Stereisporites* cf. *hauterivensis* Döring. Sample GA-69.
- Fig. 4. *Stereisporites* cf. *seebergensis* Schulz. Sample GA-44.
- Fig. 5. *Trachysporites fuscus* Nilsson. Sample GA-15.
- Fig. 6. *Trachysporites asper* Nilsson. Sample GA-24.
- Fig. 7. *Trachysporites* cf. *sparsus* (Bharadwaj & Singh) Lund. Sample GA-2.
- Fig. 8. *Conbaculatisporites mesozoicus* Klaus. Sample GA-1.
- Fig. 9. *Conbaculatisporites spinosus* (Mädler) Lund. Sample GA-38.
- Fig. 10. *Baculatisporites oppressus* (Leschik) Lund. Sample GA-1.
- Fig. 11. *Baculatisporites wellmanii* (Couper) Krutzsch. Sample GA-29.
- Fig. 12. *Baculatisporites comaumensis* (Cookson) Potonié. Sample GA-5.

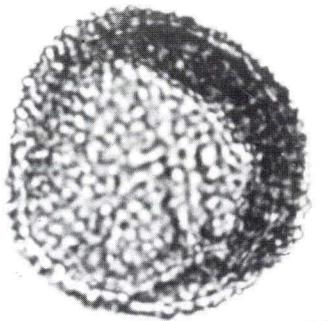
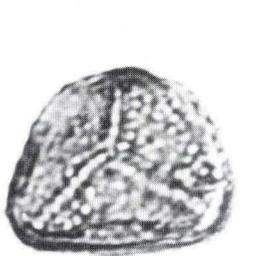
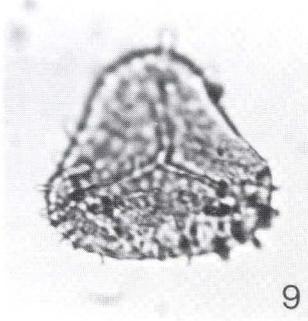
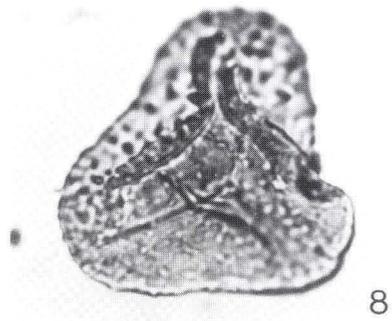
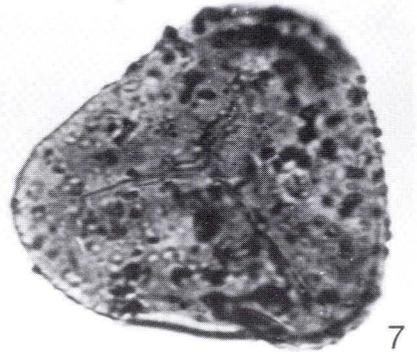
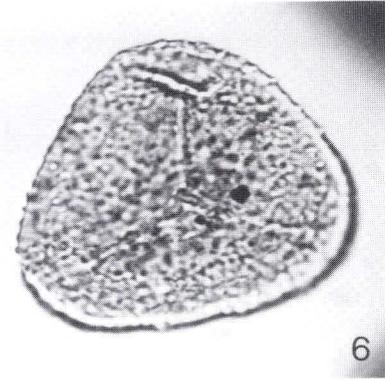
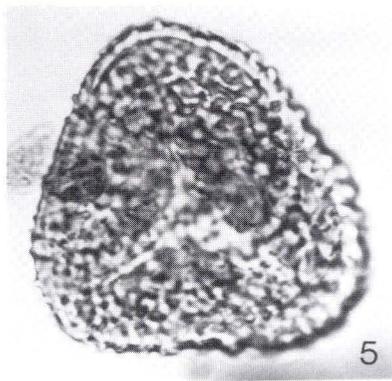
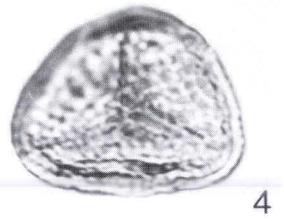
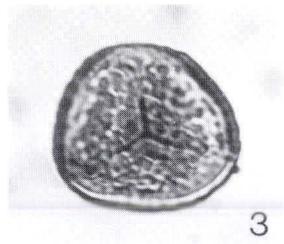
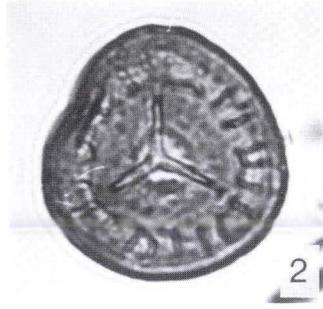
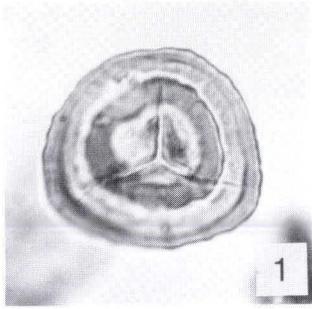


PLATE 3

Magnifications: x1000

- Fig. 1. *Apiculatisporis ovalis* (Nilsson) Norris. Sample GA-1.
- Fig. 2. *Anapiculatisporites spiniger* (Leschik) Reinhardt. Sample GA-15.
- Fig. 3. *Anapiculatisporites telephorus* (Pautsch) Klaus. Sample GA-1.
- Fig. 4. *Acanthotriletes varius* Nilsson. Sample GA-1.
- Fig. 5. *Uvaesporites argenteaeformis* (Bolkhovitina) Schulz. Tetrad. Sample GA-24.
- Fig. 6. *Uvaesporites argenteaeformis* (Bolkhovitina) Schulz. Sample GA-50.
- Fig. 7. *Iraquispora laevigata* (Mädler) Lund. Sample GA-3.
- Fig. 8. *Lycopodiumsporites semimuris* Danzé-Corsin & Laveine. Distal side (high focus). Sample GA-7.
- Fig. 9. Same specimen as fig. 8. Proximal side (low focus).
- Fig. 10. *Manumia variverrucata* Couper emend. Hoelstad. Sample GA-65.
- Fig. 11. *Lycopodiumsporites austroclavatidites* (Cookson) Potonié. Sample GA-38.
- Fig. 12. *Lycopodiumsporites clavatooides* (Couper) Tralau. Sample GA-33.

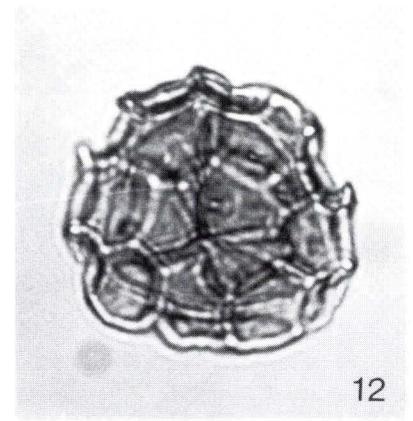
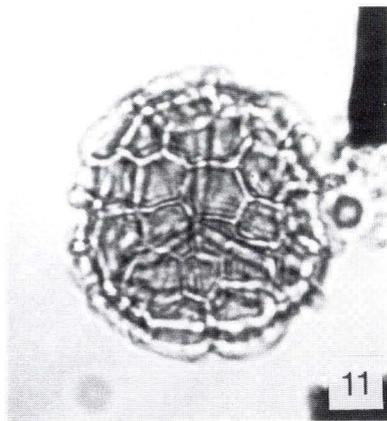
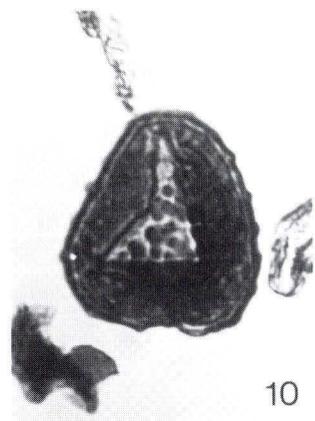
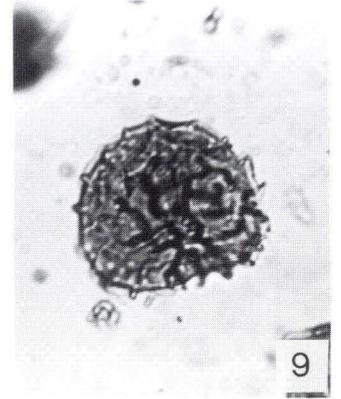
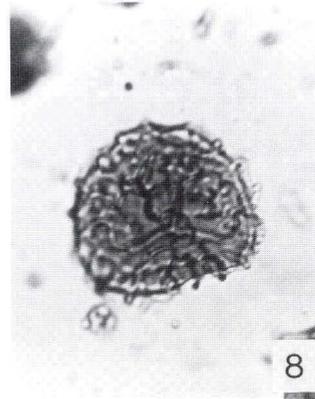
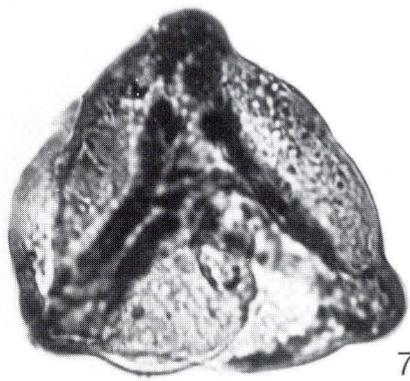
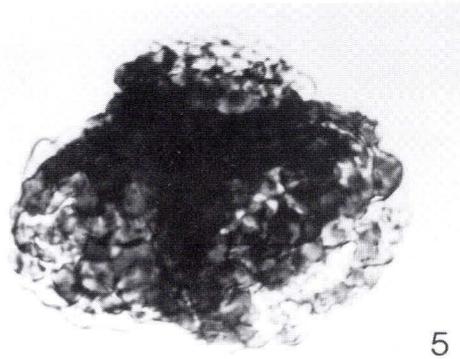
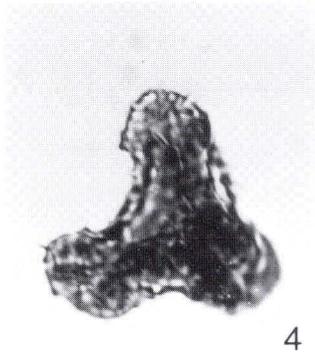
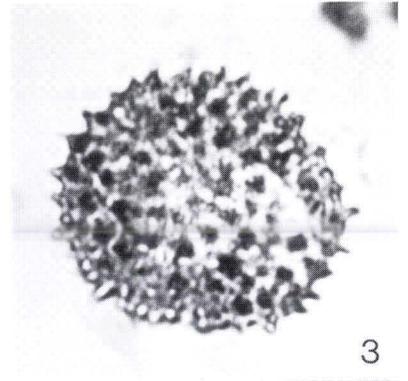
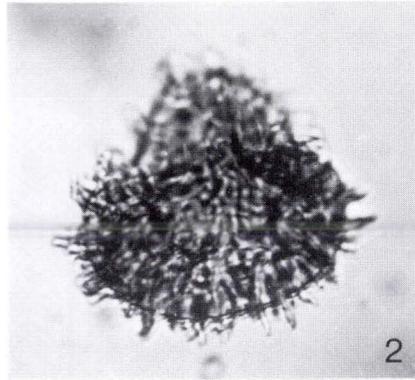
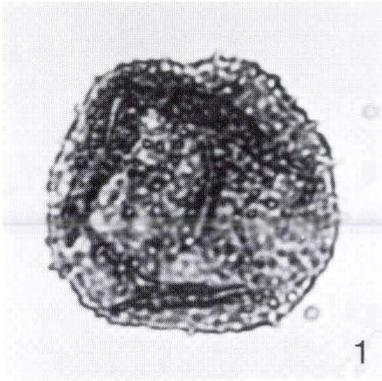


PLATE 4

Magnifications: x1000

- Fig. 1. *Contignisporites problematicus* (Couper) Döring. Proximal side (high focus). Sample GA-2.
- Fig. 2. Same specimen as fig. 1. Distal side (low focus).
- Fig. 3. *Contignisporites problematicus* (Couper) Döring. Sample GA-1.
- Fig. 4. *Staplinisporites telatus* (Balme) Döring. Proximal side (high focus). Sample GA-65.
- Fig. 5. Same specimen as fig. 4. Distal side (low focus).
- Fig. 6. *Cicatricosisporites* sp. Sample GA-71.
- Fig. 7. *Zebrasporites interscriptus* (Thiergart) Klaus. Proximal side (high focus). Sample GA-7.
- Fig. 8. Same specimen as fig. 7. Distal side (low focus).
- Fig. 9. *Platyptera trilingua* (Horst) Schulz. Sample GA-47.
- Fig. 10. Cf. *Lycopodiacidites*. Sample GA-34.
- Fig. 11. *Triancoraesporites ancorae* (Reinhardt) Schulz. Sample GA-1.
- Fig. 12. *Lycopodiacidites rugulatus* (Couper) Schulz. Sample GA-33.

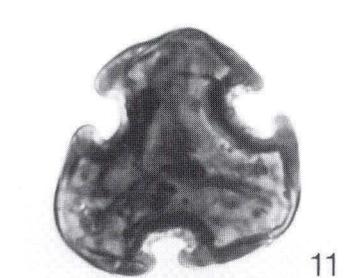
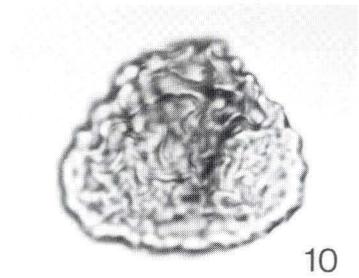
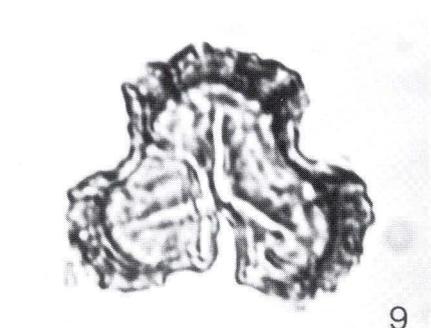
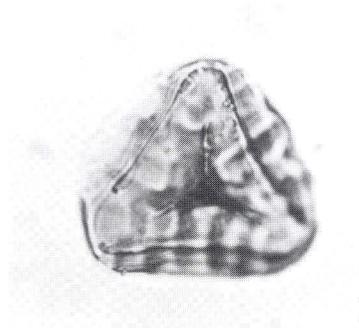
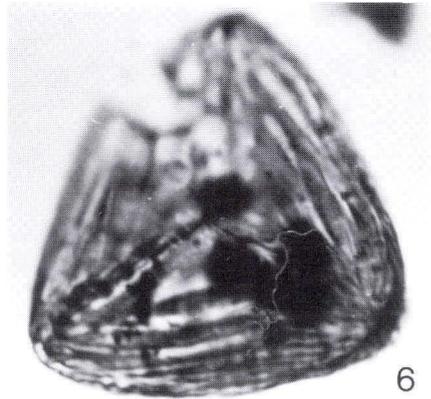
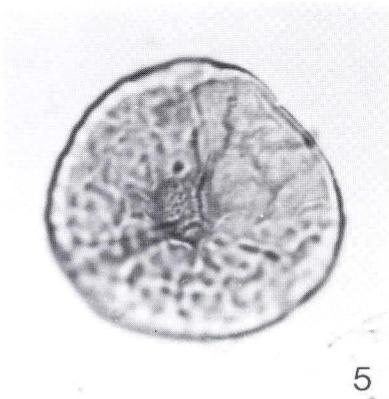
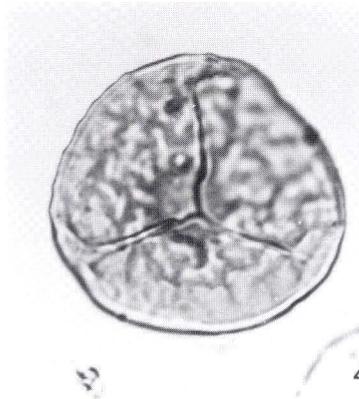
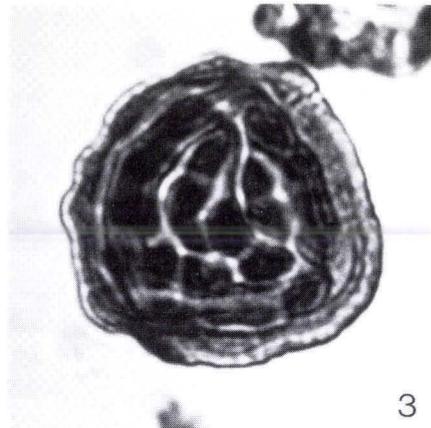
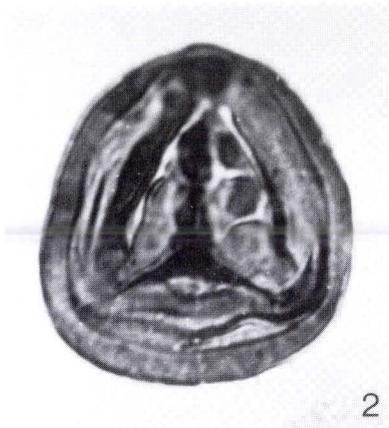
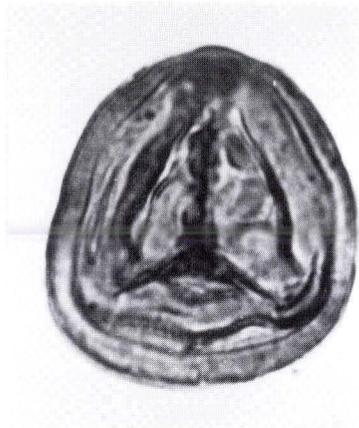


PLATE 5

Magnifications: x1000

- Fig. 1. *Densosporites fissus* (Reinhardt) Schulz. Sample GA-4.
- Fig. 2. *Cingurilettes infrapunctus* (Schulz) Morbey. Sample GA-42.
- Fig. 3. *Trilobosporites* sp. Sample GA-70.
- Fig. 4. *Gleicheniidites senonicus* Ross. Sample GA-69.
- Fig. 5. *Gleicheniidites conspiciendus* (Bolkhovitina) Krutzsch. Sample GA-69.
- Fig. 6. *Densoisporites microrugulatus* Brenner. Sample GA-66.
- Fig. 7. *Limboisporites lundbladii* Nilsson. Sample GA-3.
- Fig. 8. *Lycospora salebrosacea* (Maljavkina) Schulz. Sample GA-57.
- Fig. 9. *Cingulizonates rhaeticus* (Reinhardt) Schulz. Sample GA-3.

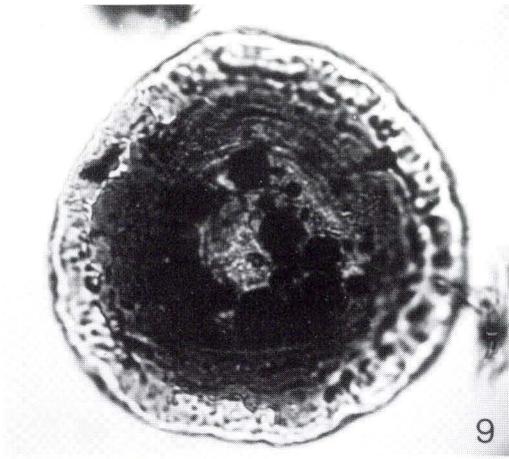
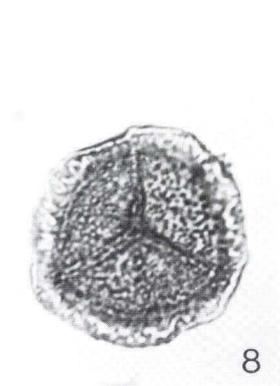
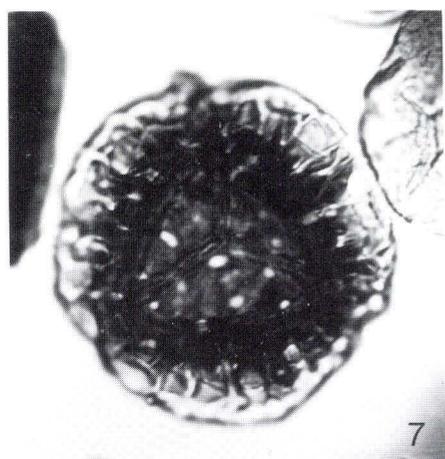
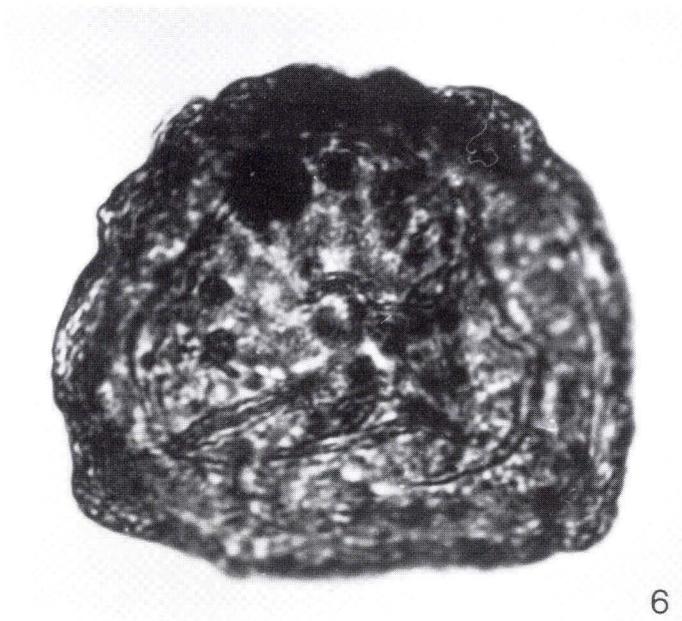
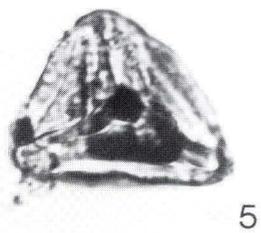
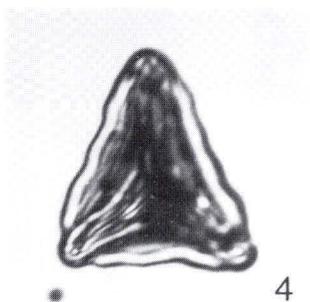
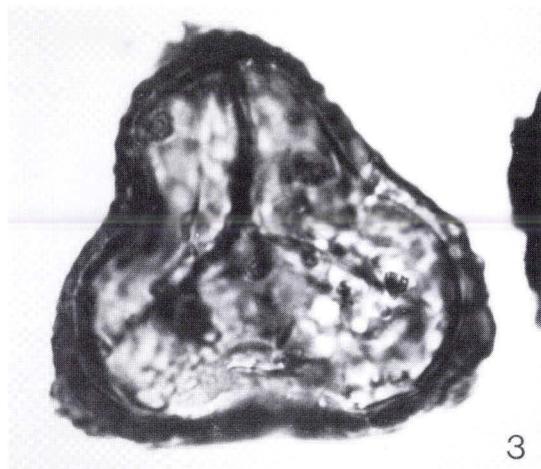
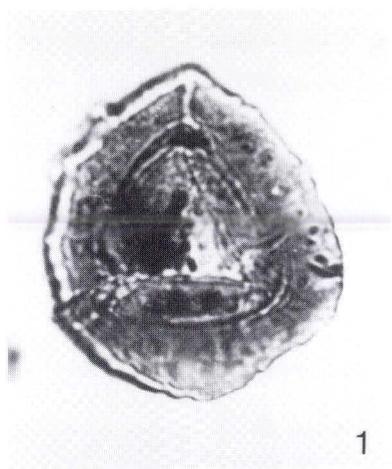


PLATE 6

Magnifications: x1000

- Fig. 1. *Heliosporites altmarkensis* Schulz. Sample GA-16.
- Fig. 2. *Heliosporites altmarkensis* Schulz. Tetrad. Sample GA-12.
- Fig. 3. *Laevigatosporites* sp. Sample GA-24.
- Fig. 4. *Marattisporites scabratus* Couper. Sample GA-23.
- Fig. 5. *Aratrisporites minimus* Schulz. Sample GA-4.
- Fig. 6. Trisaccate, undet. Sample GA-49.
- Fig. 7. Monosaccate, undet. Sample GA-1.
- Fig. 8. *Vitreisporites pallidus* (Reissinger) Nilsson. Sample GA-46.
- Fig. 9. *Vitreisporites pallidus* (Reissinger) Nilsson. Trisaccate specimen. Sample GA-7.

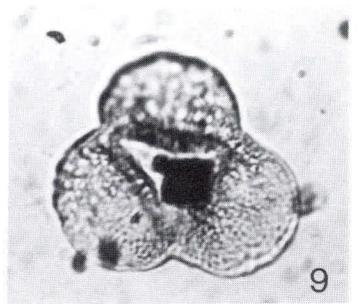
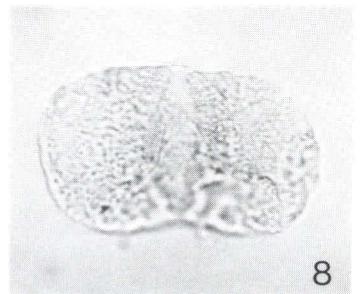
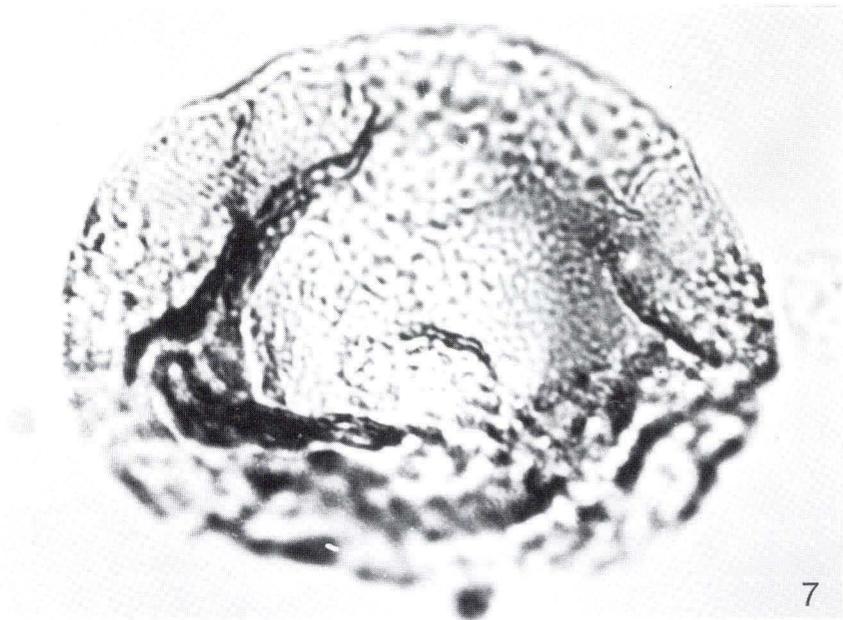
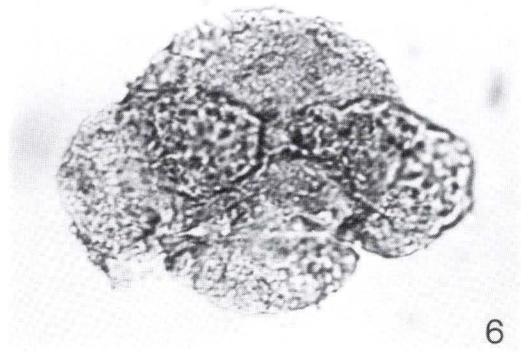
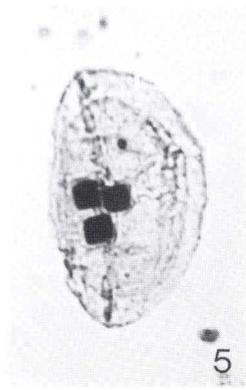
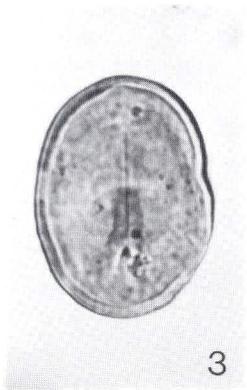
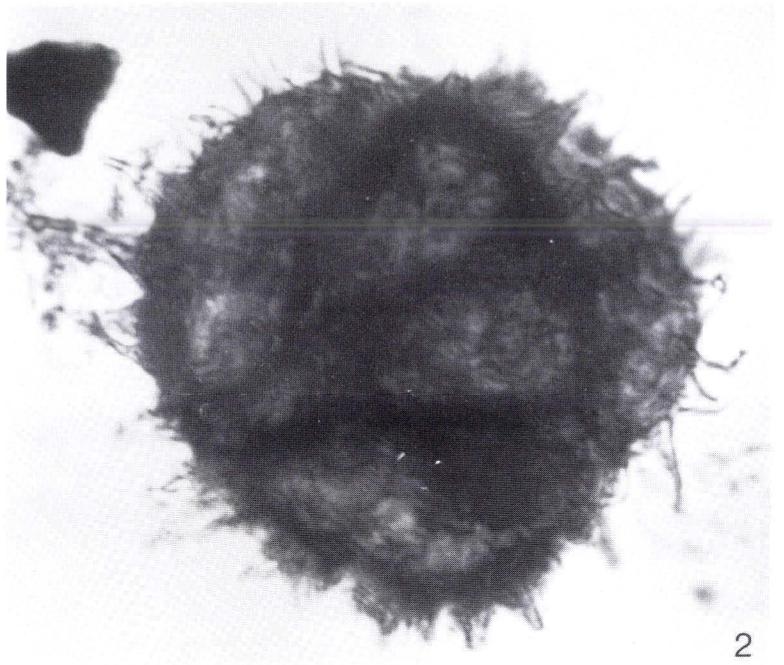
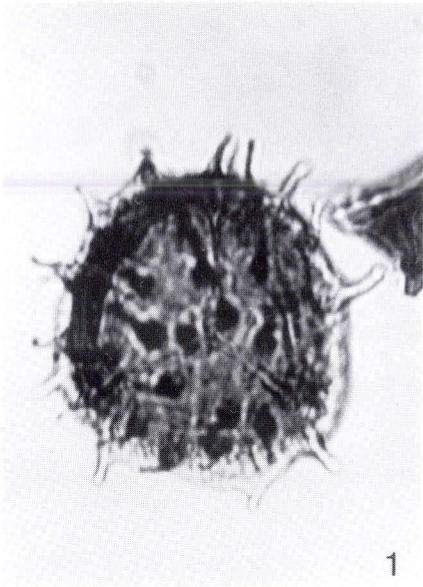


PLATE 7

Magnifications: x1000 except for fig. 5, which is x500.

- Fig. 1. *Pinuspollenites minimus* (Couper) Kemp. Sample GA-4.
- Fig. 2. *Pinuspollenites minimus* (Couper) Kemp. Sample GA-11.
- Fig. 3. *Pinuspollenites pinoides* (Nilsson) Lund. Sample GA-16.
- Fig. 4. *Umbrosaccus keuperianus* Mädlér. Sample GA-49.
- Fig. 5. Cf. *Umbrosaccus*. NOTICE: Magnification x500. Sample GA-39.
- Fig. 6. *Schismatosporites ovalis* Nilsson. Sample GA-4.
- Fig. 7. *Quadraeculina anellaeformis* Maljavkina. Sample GA-15.
- Fig. 8. *Protopinus* cf. *scanicus* Nilsson. Sample GA-33.

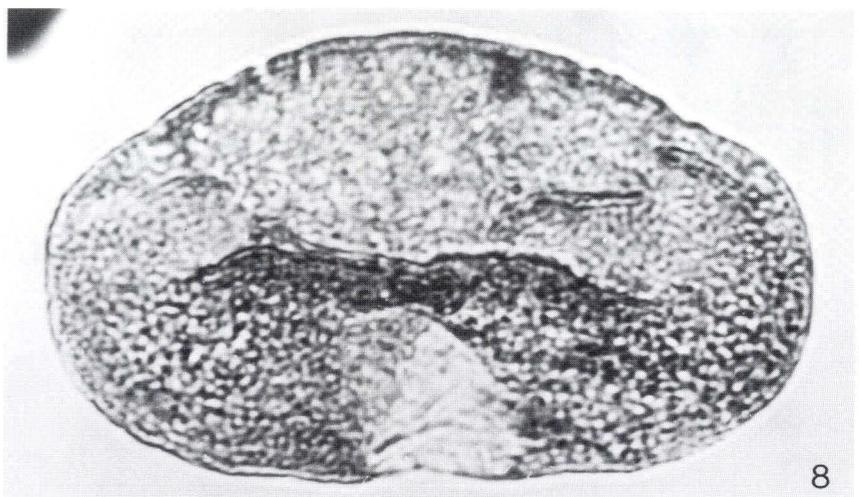
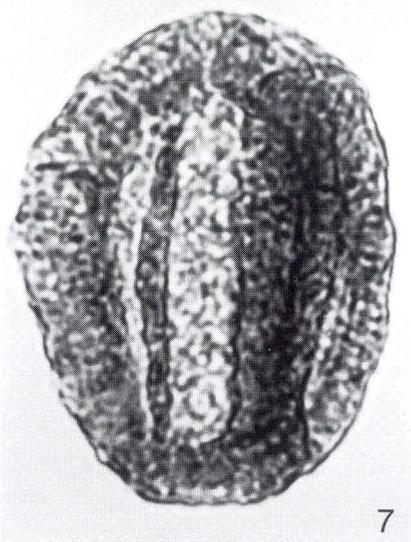
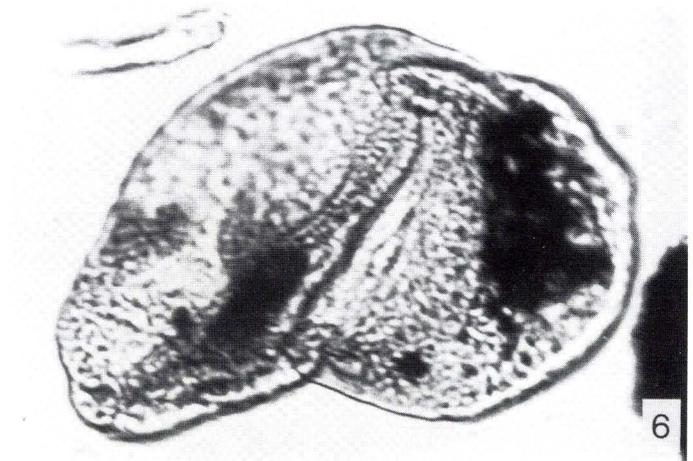
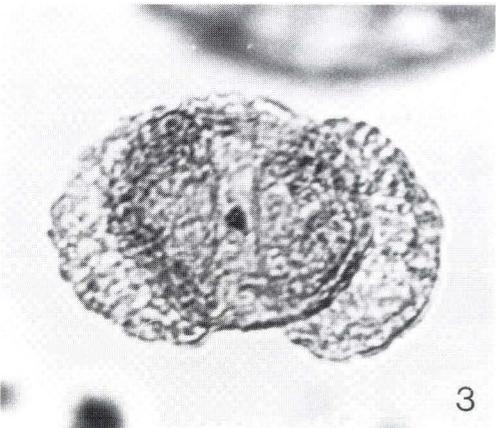
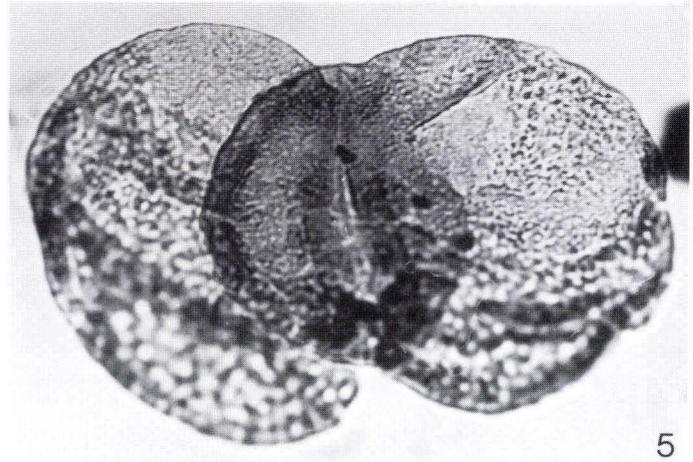
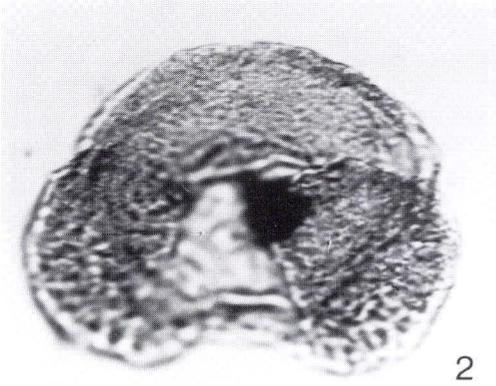
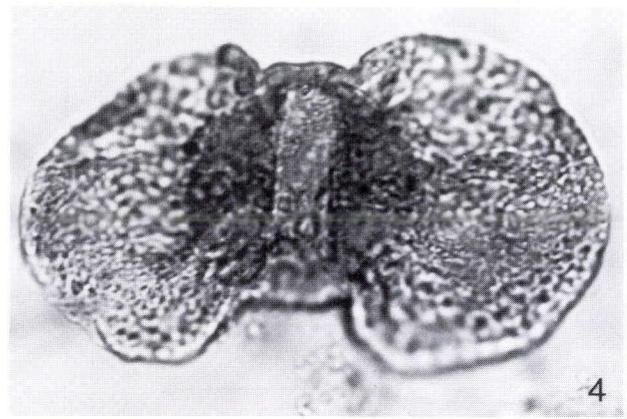
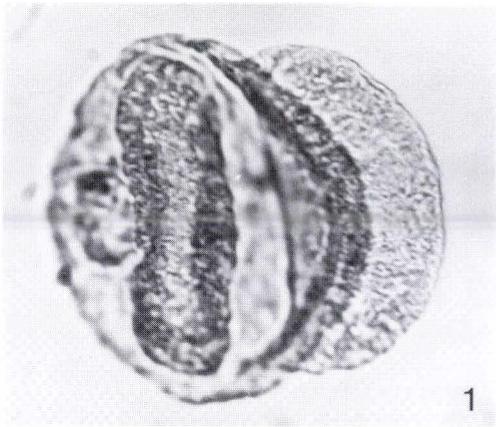


PLATE 8

Magnifications: x1000 except for fig. 5, which is x500.

- Fig. 1. *Alisporites radialis* (Leschik) Lund. Sample GA-2.
- Fig. 2. *Alisporites robustus* Nilsson. Sample GA-24.
- Fig. 3. *Alisporites thomasi* (Couper) Nilsson. Sample GA-29.
- Fig. 4. *Alisporites microsaccus* (Couper) Pocock. Sample GA-33.
- Fig. 5. *Alisporites grandis* (Cookson) Dettmann. NOTICE: Magnification x500. Sample GA-38.
- Fig. 6. *Podocarpidites* cf. *biformis* Rouse. Sample GA-20.

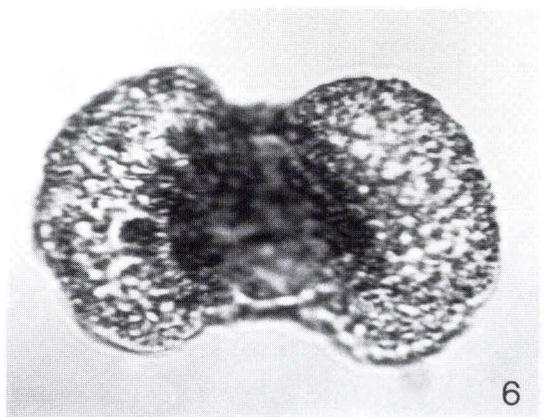
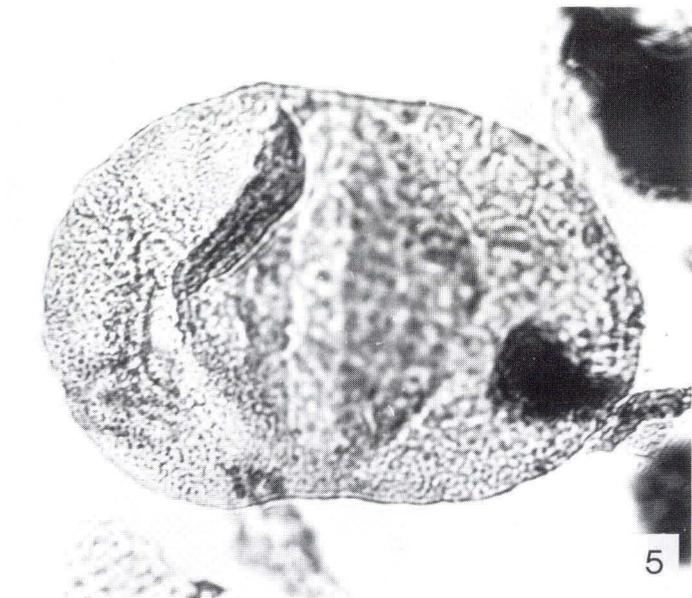
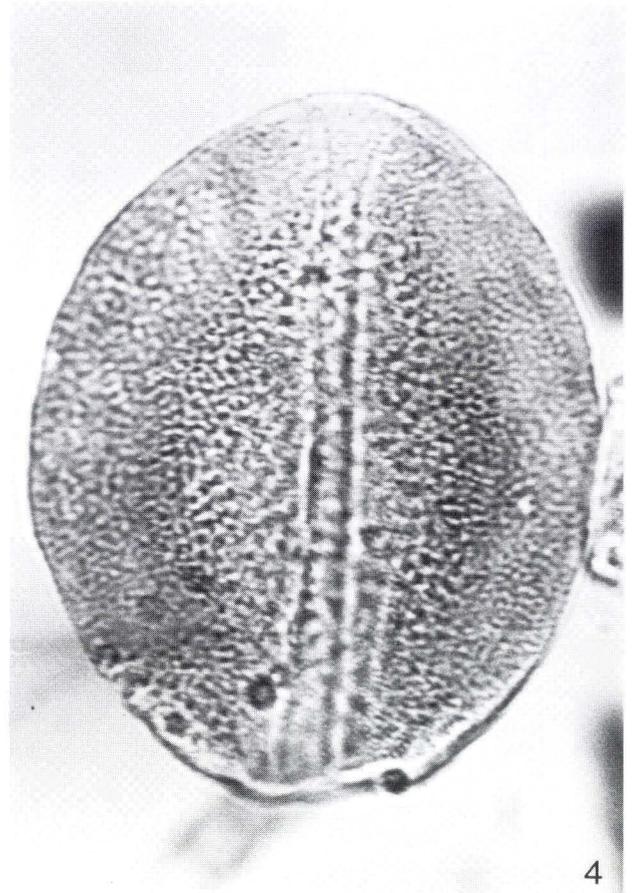
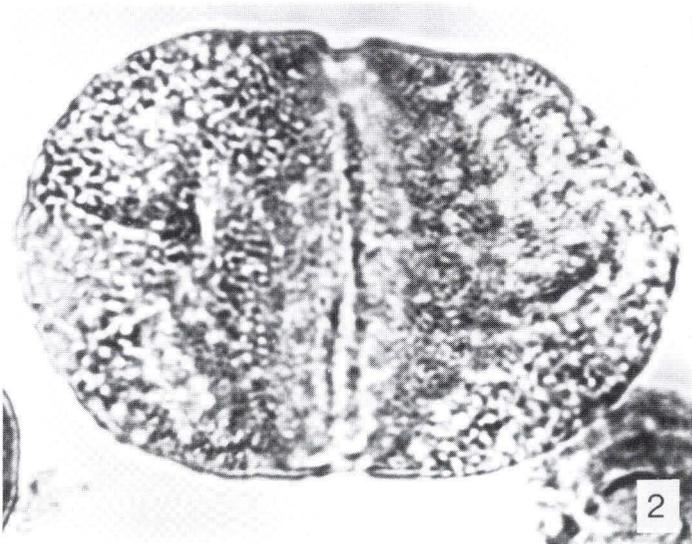
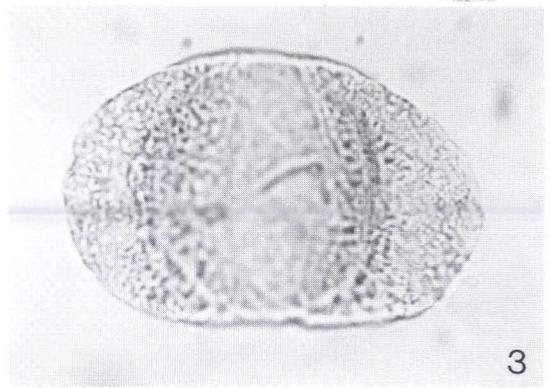
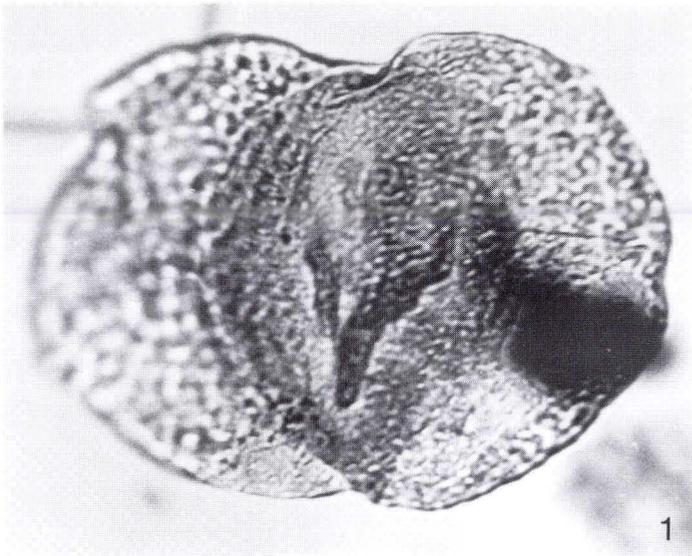


PLATE 9

Magnifications: x1000

- Fig. 1. *Araucariacites australis*. Sample GA-4.
- Fig. 2. *Perinopollenites elatoides* Couper. Sample GA-40.
- Fig. 3. *Cupressacites* sp. Sample GA-40.
- Fig. 4. *Cerebropollenites macroverrucosus* (Thiergart) Schulz. Sample GA-21.
- Fig. 5. *Cerebropollenites macroverrucosus* (Thiergart) Schulz. Sample GA-48.
- Fig. 6. *Exesipollenites tumulus* Balme. Sample GA-67.
- Fig. 7. *Cerebropollenites thiergartii* Schulz. Sample GA-56.
- Fig. 8. *Spheripollenites subgranulatus* Couper. Sample GA-55.
- Fig. 9. *Spheripollenites psilatus* Couper. Sample GA-29.

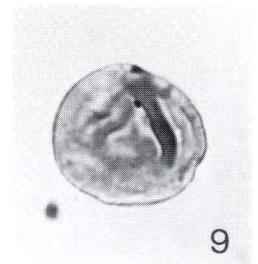
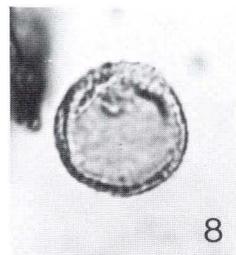
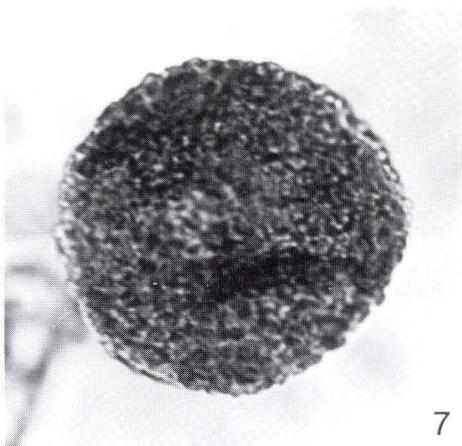
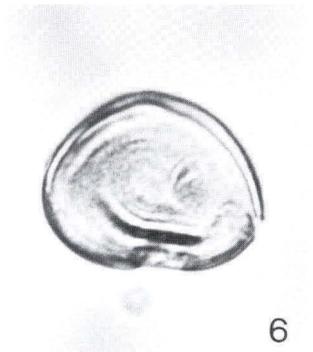
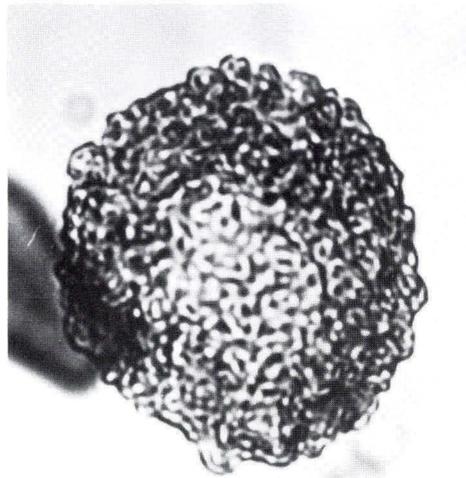
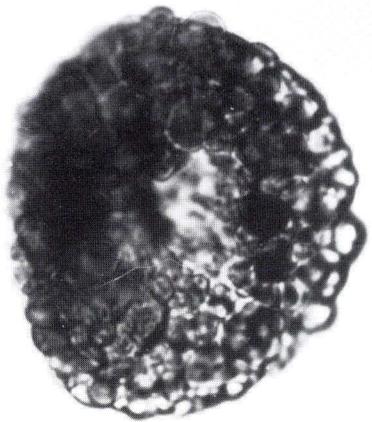
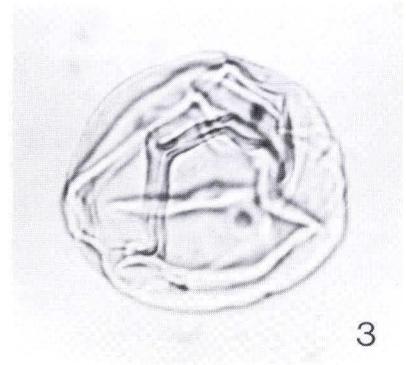
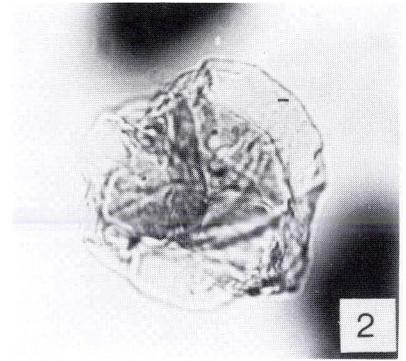


PLATE 10

Magnifications: x1000

- Fig. 1. *Callialasporites microvelatus* Schulz. Sample GA-59.
- Fig. 2. *Callialasporites trilobatus* (Balme) Dev. Sample GA-71.
- Fig. 3. *Callialasporites segmentatus* (Balme) Srivastava. Sample GA-65.
- Fig. 4. *Chasmatosporites hians* Nilsson. Sample GA-60.
- Fig. 5. *Chasmatosporites elegans* Nilsson. Sample GA-36.
- Fig. 6. *Chasmatosporites elegans* Nilsson. Sample GA-39.
- Fig. 7. *Chasmatosporites apertus* (Rogalska) Nilsson. Sample GA-8.
- Fig. 8. *Chasmatosporites apertus* (Rogalska) Nilsson. Sample GA-20.
- Fig. 9. *Monosulcites minimus* Cookson. Sample GA-8.
- Fig. 10. *Monosulcites punctatus* Orłowska-Zwolińska. Sample GA-34.

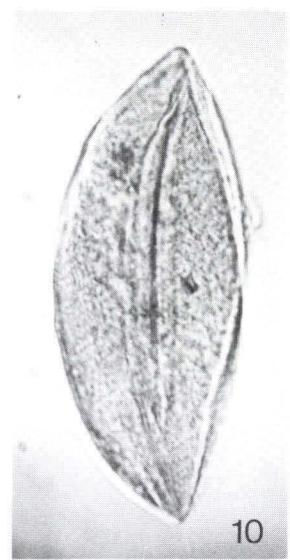
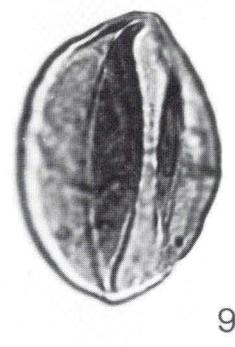
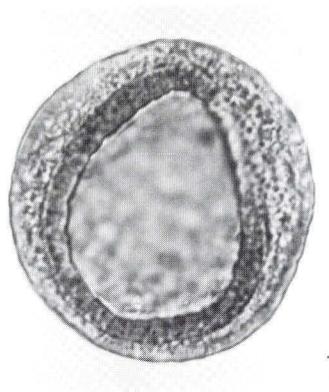
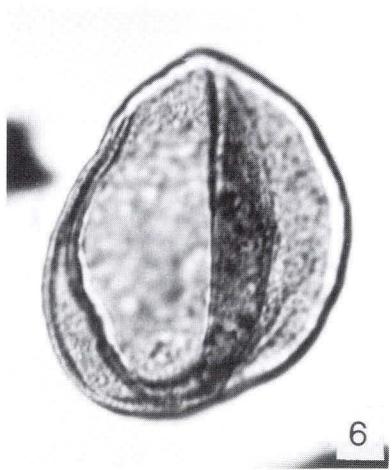
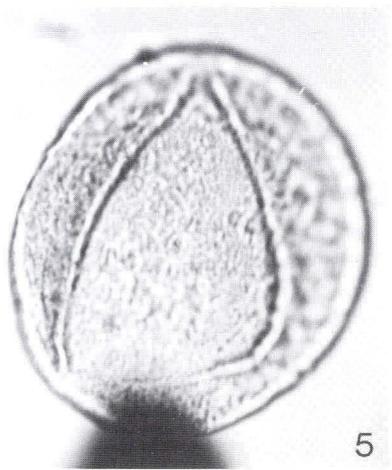
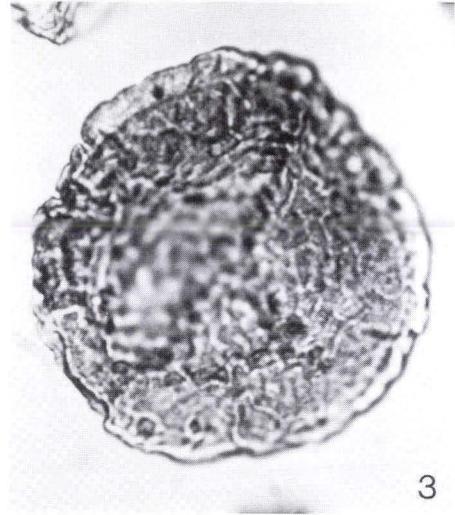
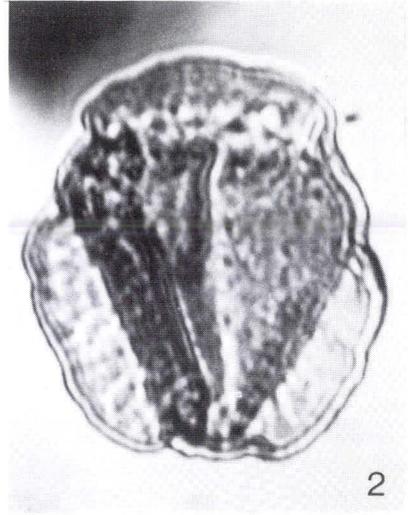
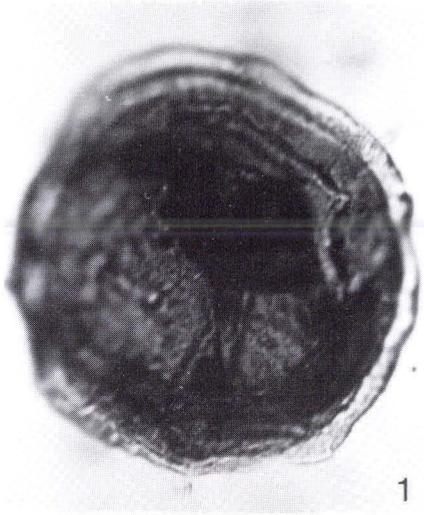


PLATE 11

Magnifications: x1000

- Fig. 1. *Ricciisporites tuberculatus* Lundblad. Tetrad. Sample GA-53.
- Fig. 2. *Clavatipollenites hughesii* Couper. Sample GA-26.
- Fig. 3. *Monosulcites* cf. *punctatus* Orłowska-Zwolinska. Sample GA-28.
- Fig. 4. *Eucommiidites troedssonii* Erdtman. Sample GA-40.
- Fig. 5. *Eucommiidites minor* Groot & Penny. Sample GA-30.
- Fig. 6. *Corollina torosus* (Reissinger) Klaus emend. Cornet & Traverse. Tetrad. Sample GA-4.
- Fig. 7. *Corollina torosus* (Reissinger) Klaus emend. Cornet & Traverse. Sample GA-20.
- Fig. 8. *Corollina torosus* (Reissinger) Klaus emend. Cornet & Traverse. Sample GA-34.
- Fig. 9. *Corollina* sp. 1. Sample GA-67.
- Fig. 10. *Corollina* sp. 2. Sample GA-67.

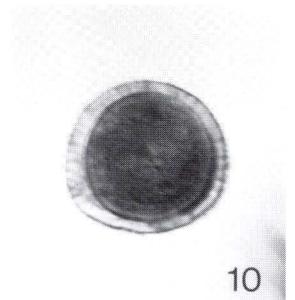
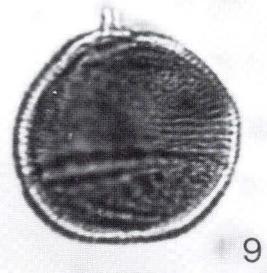
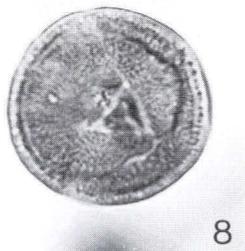
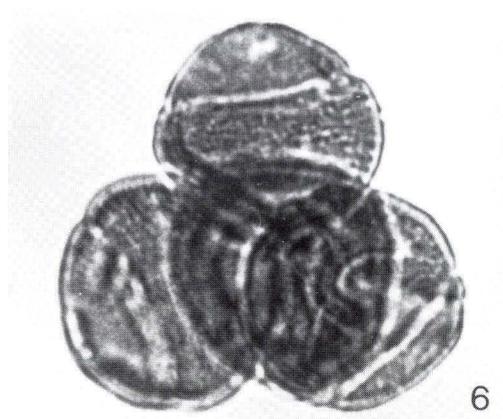
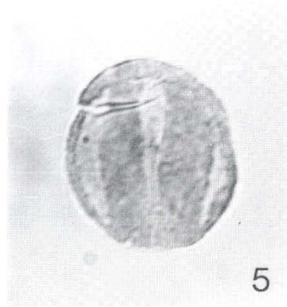
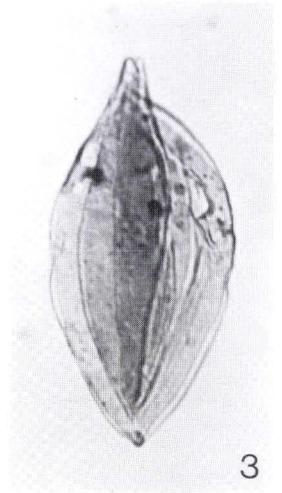
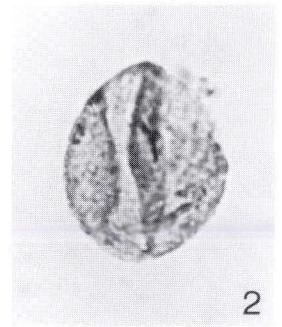
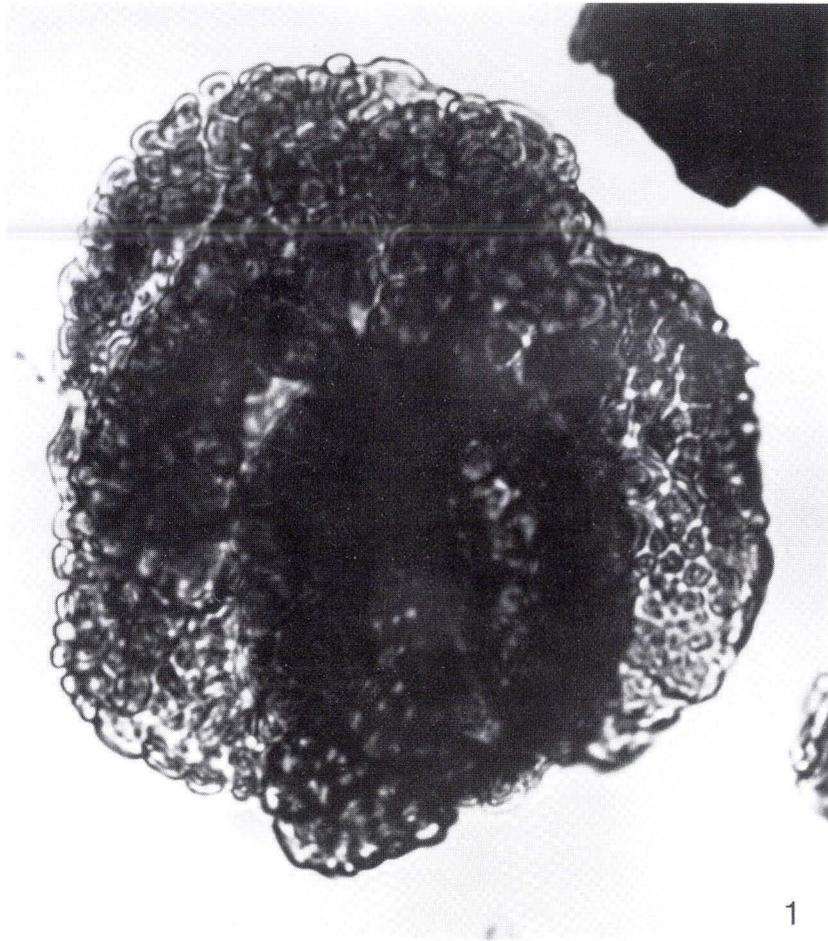


PLATE 12

Magnifications: x1000

- Fig. 1. *Leiosphaeridia* sp. Sample GA-42.
- Fig. 2. *Halosphaeropsis* sp. Sample GA-12.
- Fig. 3. *Veryhachium* sp. Sample GA-16.
- Fig. 4. *Micrhystridium* sp., type 1. Sample GA-36.
- Fig. 5. *Micrhystridium* sp., type 2. Sample GA-32.
- Fig. 6. *Micrhystridium* sp., type 3. Sample GA-17.
- Fig. 7. Foraminiferal test-linings. Sample GA-71.
- Fig. 8. *Micrhystridium* sp., type 4. Sample GA-42.
- Fig. 9. *Micrhystridium* sp., type 5. Sample GA-32.

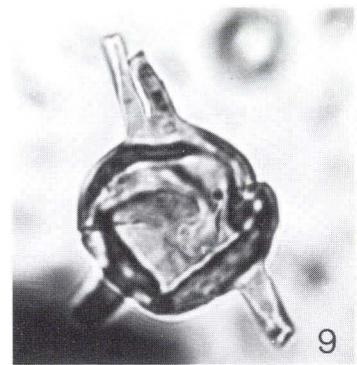
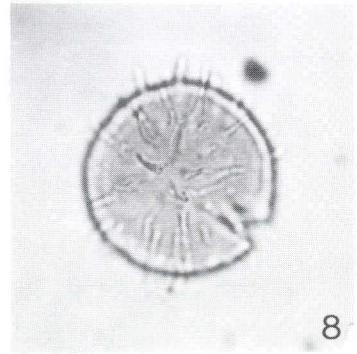
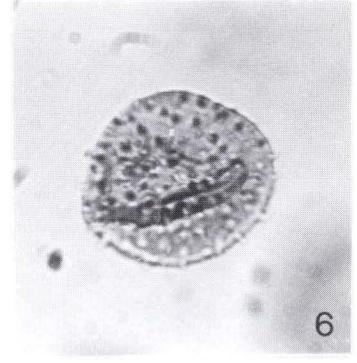
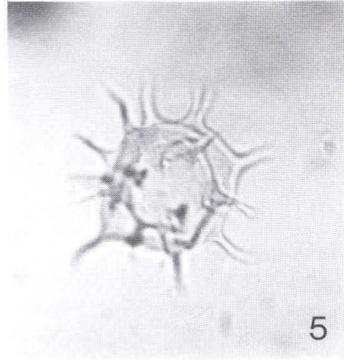
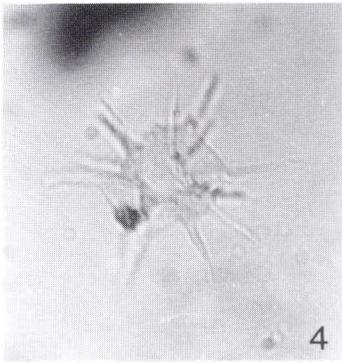
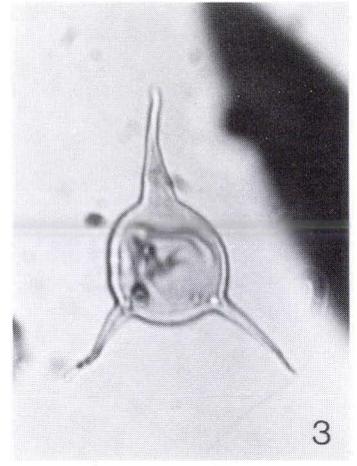
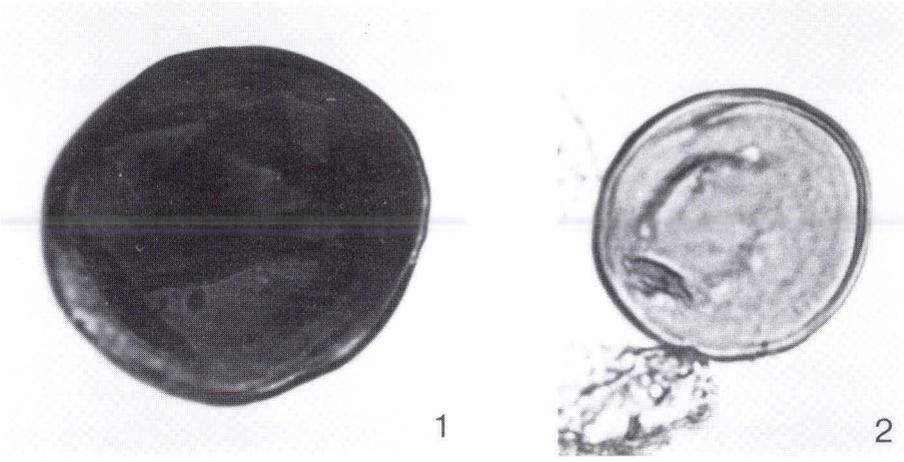
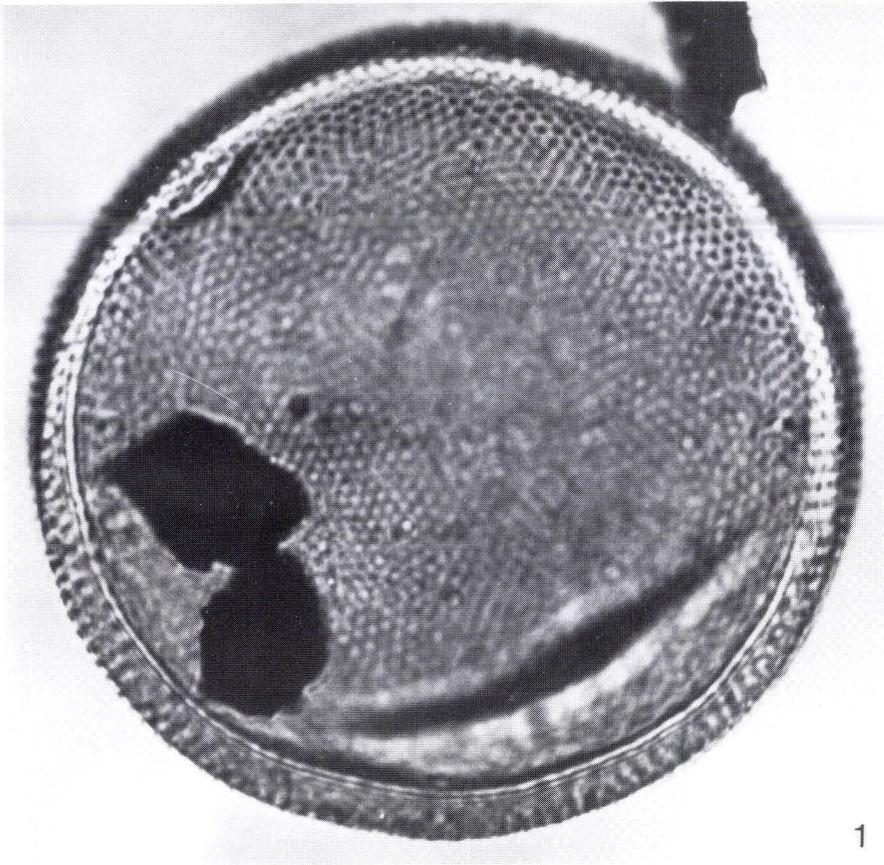


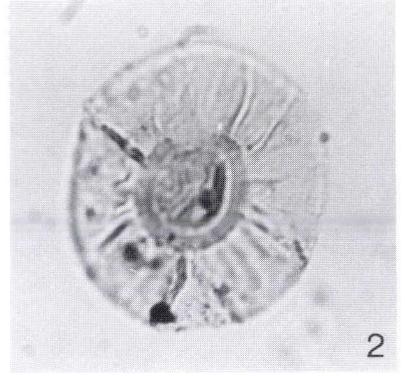
PLATE 13

Magnifications: x1000

- Fig. 1. *Tasmanites* sp., type 1. Sample GA-50.
- Fig. 2. *Pterospermopsis* sp. Sample GA-68.
- Fig. 3. *Tasmanites* sp., type 2. Sample GA-54.
- Fig. 4. *Tasmanites* sp. type 3. Sample GA-36.
- Fig. 5. *Nannoceratopsis gracilis* Alberti. Sample GA-60.
- Fig. 6. *Liasidium variabile* Drugg. Sample GA-36.
- Fig. 7. *Dapcodinium priscum* Evitt. Sample GA-6.
- Fig. 8. *Botryococcus* sp. Sample GA-65.



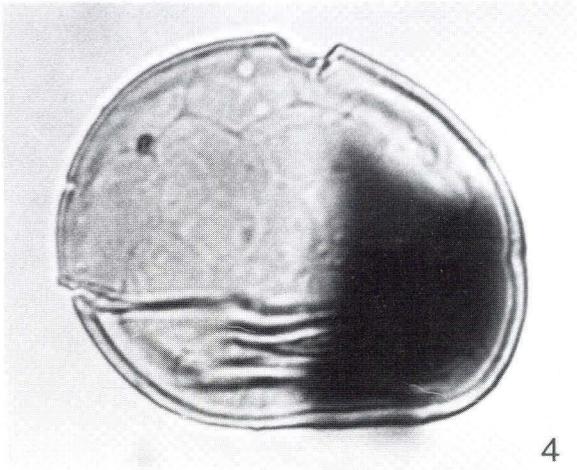
1



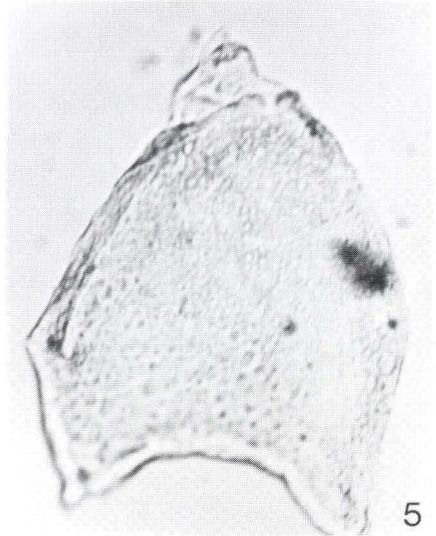
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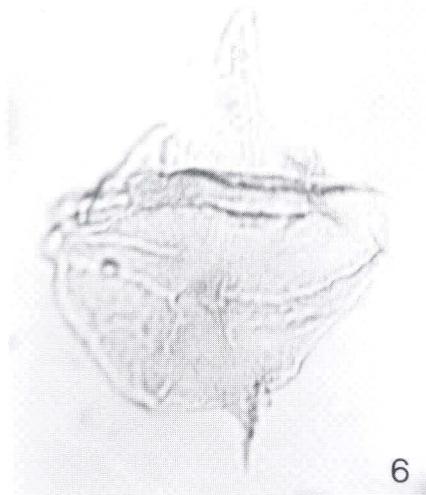
3



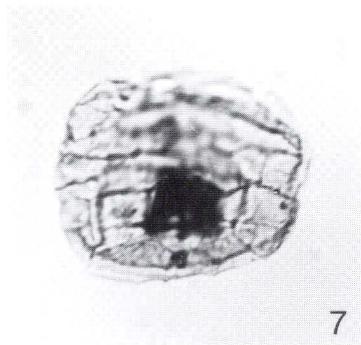
4



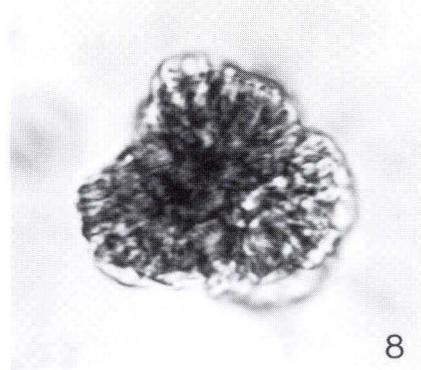
5



6



7

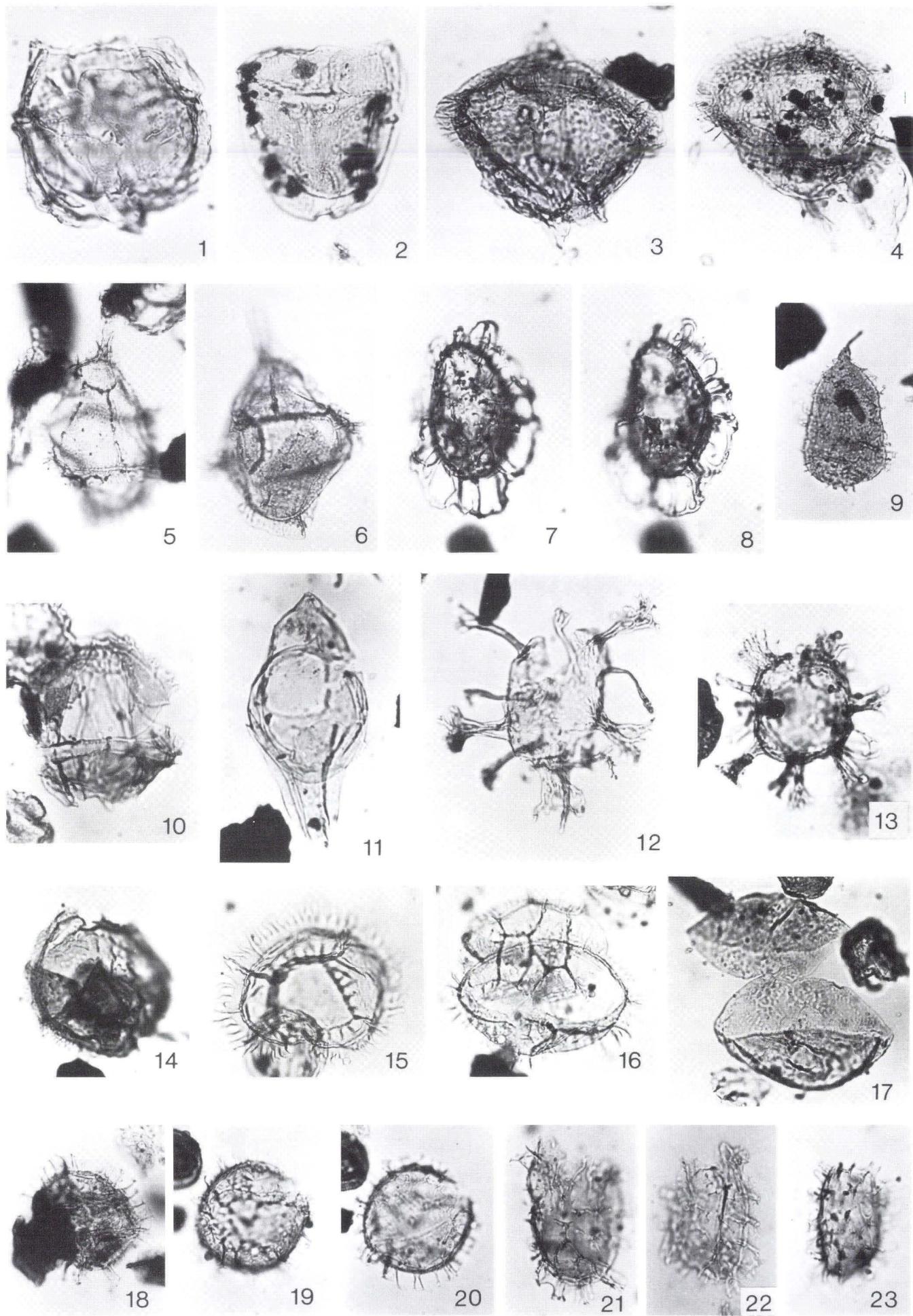


8

PLATE 14

Magnifications: x500

- Fig. 1. *Senoniasphaera jurassica* (Gitmez & Sarjeant) Lentin & Williams. Sample GA-67.
- Fig. 2. *Senoniasphaera jurassica* (Gitmez & Sarjeant) Lentin & Williams. Sample GA-67.
- Fig. 3. *Glossodinium dimorphum* Ioannides et al. Sample GA-71.
- Fig. 4. *Glossodinium dimorphum* Ioannides et al. Sample GA-71.
- Fig. 5. *Hystrichogonyaulax pennata* (Riley) Lentin & Williams. Sample GA-67.
- Fig. 6. *Hystrichogonyaulax pennata* (Riley) Lentin & Williams. Sample GA-69.
- Fig. 7. *Cannosphaeropsis thula* Davey. Sample GA-71.
- Fig. 8. Same specimen as fig. 7, showing dorsal surface with archaeopyle.
- Fig. 9. *Gochteodinia mutabilis* (Riley) Davey. Sample GA-71.
- Fig. 10. *Gonyaulacysta jurassica* (Deflandre) Sarjeant. Sample GA-65.
- Fig. 11. *Tubotuberella apatela* (Cookson & Eisenack) Sarjeant. Sample GA-67.
- Fig. 12. *Kleithriasphaeridium porosispinum* Davey. Sample GA-67.
- Fig. 13. *Kleithriasphaeridium porosispinum* Davey. Sample GA-71.
- Fig. 14. *Occisucysta balia* Gitmez. Sample GA-65.
- Fig. 15. *Ctenidodinium panneum* (Norris) Lentin & Williams. Sample GA-67. Hypocyst.
- Fig. 16. *Ctenidodinium panneum* (Norris) Lentin & Williams. Sample GA-71. Complete specimen.
- Fig. 17. *Mendicodinium groenlandicum* (Pocock & Sarjeant) Davey. Sample GA-65.
- Fig. 18. *Dichadogonyaulax culmula* (Norris) Loeblich & Loeblich. Sample GA-71.
- Fig. 19. *Dichadogonyaulax culmula* (Norris) Loeblich & Loeblich. Sample GA-71.
- Fig. 20. Same specimen as fig. 19.
- Fig. 21. *Egmontodinium expiratum* Davey. Sample GA-71.
- Fig. 22. *Egmontodinium expiratum* Davey. Sample GA-67.
- Fig. 23. *Egmontodinium torynum* (Cookson & Eisenack) Davey. Sample GA-69.



Index of species

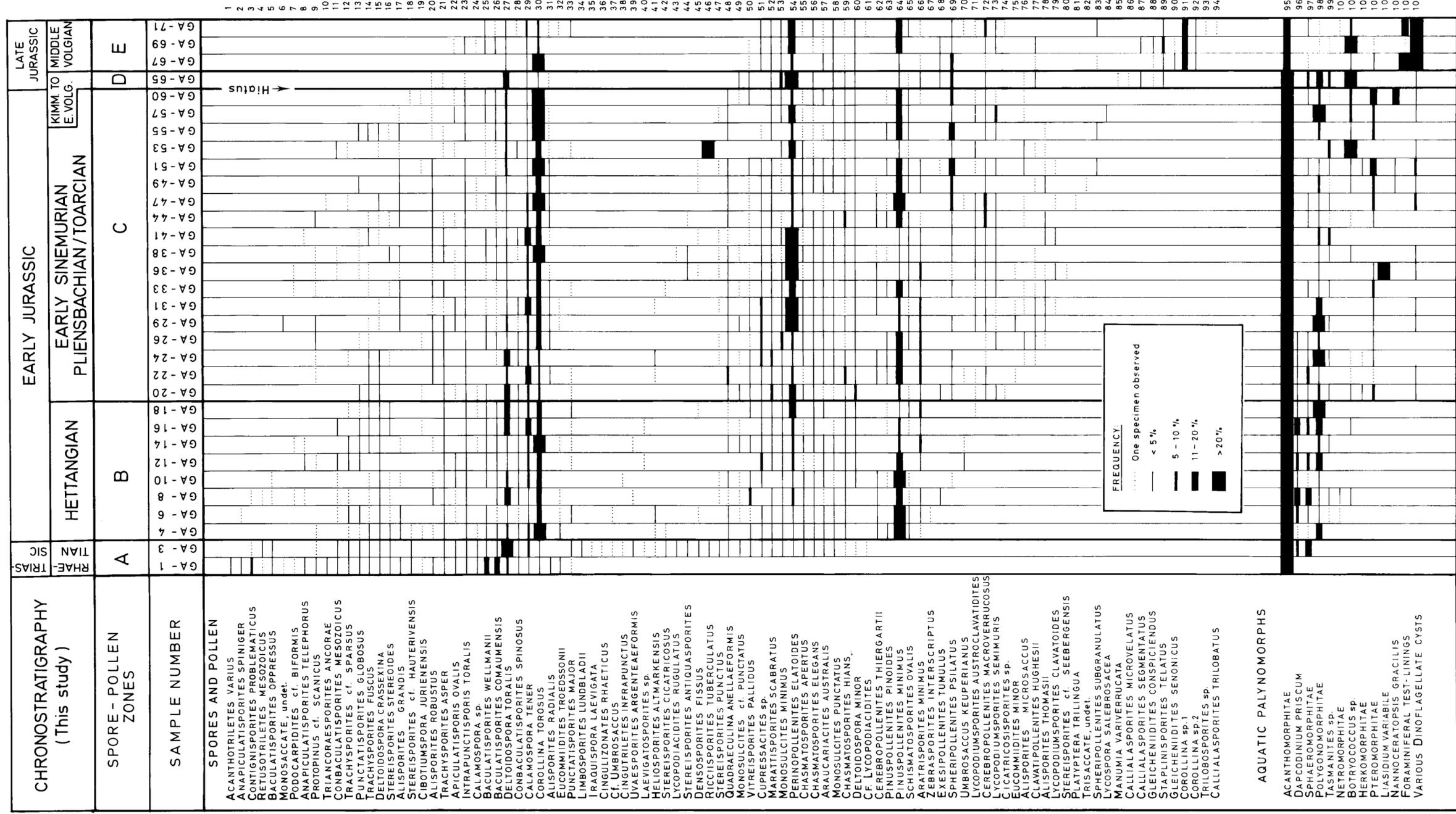
Pollen and spores:

<i>Acanthotriletes varius</i>	p. 15	<i>Intrapunctisporis toralis</i>	p. 12
<i>Alisporites grandis</i>	p. 21	<i>Iraquispora laevigata</i>	p. 15
<i>Alisporites microsaccus</i>	p. 21	<i>Laevigatosporites</i> sp.	p. 19
<i>Alisporites radialis</i>	p. 21	<i>Limbosporites lundbladii</i>	p. 18
<i>Alisporites robustus</i>	p. 21	<i>Lycopodiacidites rugulatus</i>	p. 16
<i>Alisporites thomasii</i>	p. 21	Cf. <i>Lycopodiacidites</i>	p. 16
<i>Anapiculatisporites spiniger</i>	p. 15	<i>Lycopodiumsporites austroclavatidites</i>	p. 16
<i>Anapiculatisporites telephorus</i>	p. 15	<i>Lycopodiumsporites clavatooides</i>	p. 16
<i>Apiculatisporites ovalis</i>	p. 14	<i>Lycopodiumsporites semimuris</i>	p. 16
<i>Aratrisporites minimus</i>	p. 19	<i>Lycospora salebrosacea</i>	p. 18
<i>Araucariacites australis</i>	p. 22	<i>Manumia variverrucata</i>	p. 15
<i>Baculatisporites comaumensis</i>	p. 14	<i>Marattisporites scabratus</i>	p. 19
<i>Baculatisporites oppressus</i>	p. 14	Monosaccate, undet.	p. 19
<i>Baculatisporites wellmanii</i>	p. 14	<i>Monosulcites minimus</i>	p. 24
<i>Calamospora tener</i>	p. 12	<i>Monosulcites punctatus</i>	p. 24
<i>Calamospora</i> sp.	p. 12	<i>Monosulcites</i> cf. <i>punctatus</i>	p. 25
<i>Callialasporites microvelatus</i>	p. 23	<i>Perinopollenites elatoides</i>	p. 22
<i>Callialasporites segmentatus</i>	p. 23	<i>Pinuspollenites minimus</i>	p. 20
<i>Callialasporites trilobatus</i>	p. 23	<i>Pinuspollenites pinoides</i>	p. 20
<i>Cerebropollenites macroverrucosus</i>	p. 22	<i>Platyptera trilingua</i>	p. 17
<i>Cerebropollenites thiergartii</i>	p. 23	<i>Podocarpidites</i> cf. <i>biformis</i>	p. 20
<i>Chasmatosporites apertus</i>	p. 24	<i>Protopinus</i> cf. <i>scanicus</i>	p. 20
<i>Chasmatosporites elegans</i>	p. 24	<i>Punctatisporites globosus</i>	p. 12
<i>Chasmatosporites hians</i>	p. 24	<i>Punctatisporites major</i>	p. 12
<i>Cibotiumspora jurienensis</i>	p. 12	<i>Quadraeculina anellaeformis</i>	p. 21
<i>Cicatricosisporites</i> sp.	p. 17	<i>Retusotriletes mesozoicus</i>	p. 12
<i>Cingulizonata rhaeticus</i>	p. 18	<i>Ricciisporites tuberculatus</i>	p. 24
<i>Cingutriletes infrapunctus</i>	p. 18	<i>Schismatosporites ovalis</i>	p. 22
<i>Clavatipollenites hughesii</i>	p. 25	<i>Spheripollenites psilatus</i>	p. 23
<i>Conbaculatisporites mesozoicus</i>	p. 14	<i>Spheripollenites subgranulatus</i>	p. 23
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<i>Corollina</i> sp. 1	p. 26	<i>Stereisporites</i> cf. <i>hauterivensis</i>	p. 13
<i>Corollina</i> sp. 2	p. 26	<i>Stereisporites punctus</i>	p. 13
<i>Cupressacites</i> sp.	p. 22	<i>Stereisporites</i> cf. <i>seebergensis</i>	p. 13
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<i>Eucommiidites minor</i>	p. 25	<i>Trilobosporites</i> sp.	p. 17
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<i>Gleicheniidites conspicendus</i>	p. 17	Cf. <i>Umbrosaccus</i>	p. 22
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<i>Heliosporites altmarkensis</i>	p. 19	<i>Vitreisporites pallidus</i>	p. 20
		<i>Zebrasporites interscriptus</i>	p. 17

Aquatic palynomorphs:

The page-number stated for most of the dinoflagellate-cyst species, refer to fig. 7., where these species are listed, together with their references and their stratigraphic ranges in the present study. These species are not included in the systematic section.

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<i>Dapcodinium priscum</i>	p. 26
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<i>Dingodinium tuberosum</i>	p. 34
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<i>Hystrichogonyaulax pennata</i>	p. 34
<i>Kleithriasphaeridium porosispinum</i>	p. 34
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<i>Leiosphaeridia</i> sp.	p. 27
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<i>Tasmanites</i> sp.	p. 27
<i>Tubotuberella apatela</i>	p. 34
<i>Veryhachium</i> sp.	p. 27



Karen Dybkjær, 1988: Palynological zonation and stratigraphy of the Jurassic section in the Gassum No. 1-borehole, Denmark. Danm. geol. Unders., Ser. A, 21.

Frequencies of spore- and pollen species are calculated as percentages of total spores and pollen; frequencies of aquatic palynomorphs as percentages of total aquatic palynomorphs.

This paper presents a palynological zonation and stratigraphy of the Jurassic section of the Danish onshore borehole Gassum No. 1. The palynomorphs are treated morphosystematically and comments are added to most of the species. Interpretations of the depositional environment are made, especially concerning sea-level changes.