

Dinoflagellate stratigraphy of the uppermost Danian to Ypresian in the Viborg 1 borehole, central Jylland, Denmark

BY
CLAUS HEILMANN-CLAUSEN



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with 15 plates and 1 range chart

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Claus Heilmann-Clausen, Geological Institute,
Århus University, DK-8000 Århus, Denmark.

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Abstract

Dinoflagellate cysts in the uppermost Danian to Lower Eocene section in the cored Viborg 1 borehole are described. The stratigraphical distribution of the dinoflagellates is shown; eight informal dinoflagellate zones are suggested. The dinoflagellate assemblages in sed-

iments from various Danish localities are correlated with the Viborg 1 cores. A correlation with assemblages from other European Paleocene – Lower Eocene deposits is proposed. Two new species are described, and two new combinations are proposed.

Introduction

The purpose of the present study is to describe the dinoflagellate cysts and their distribution in the Upper Danian to Lower Eocene section of the Viborg 1 borehole and to establish a biostratigraphical zonation which permits correlation with Paleocene – Lower Eocene deposits from other parts of the North Sea Basin.

The Viborg 1 cored borehole was drilled in 1939 near the town Viborg, central Jylland (fig. 1). The boring is situated in the middle part of the Danish–Norwegian Basin and contains a relatively thick and varied sequence of marine sediments. It was chosen for the present study because of an almost complete recovery of cores and because outcrops and other borings indicate that the Viborg 1 boring is the stratigraphically most complete section available of the Upper Paleocene in Denmark. The lithological units in the section are widely distributed in Denmark and at least some of them are also recognized in the North Sea.

The section was described originally by Flagler (1940) and later also by Dinesen, Michelsen & Lieberkind (1977). Thiede, Nielsen & Perch-Nielsen (1980) and Heilmann-Clausen, Nielsen & Gersner (1985) described the upper part of the section.

A comprehensive biostratigraphical investigation of the Upper Paleocene – Lower Eocene in Denmark has not been published. Most of the deposits are essentially non-calcareous and calcareous microfossils are sparse or absent. Dinoflagellates, however, are usually well preserved. They have been described from several Paleocene and Eocene deposits in Denmark by Morgenroth (1968), Hansen (1977, 1979a, b, c, 1980), Heilmann-Clausen (1980, 1982) and Thomsen & Heilmann-Clausen (1985).

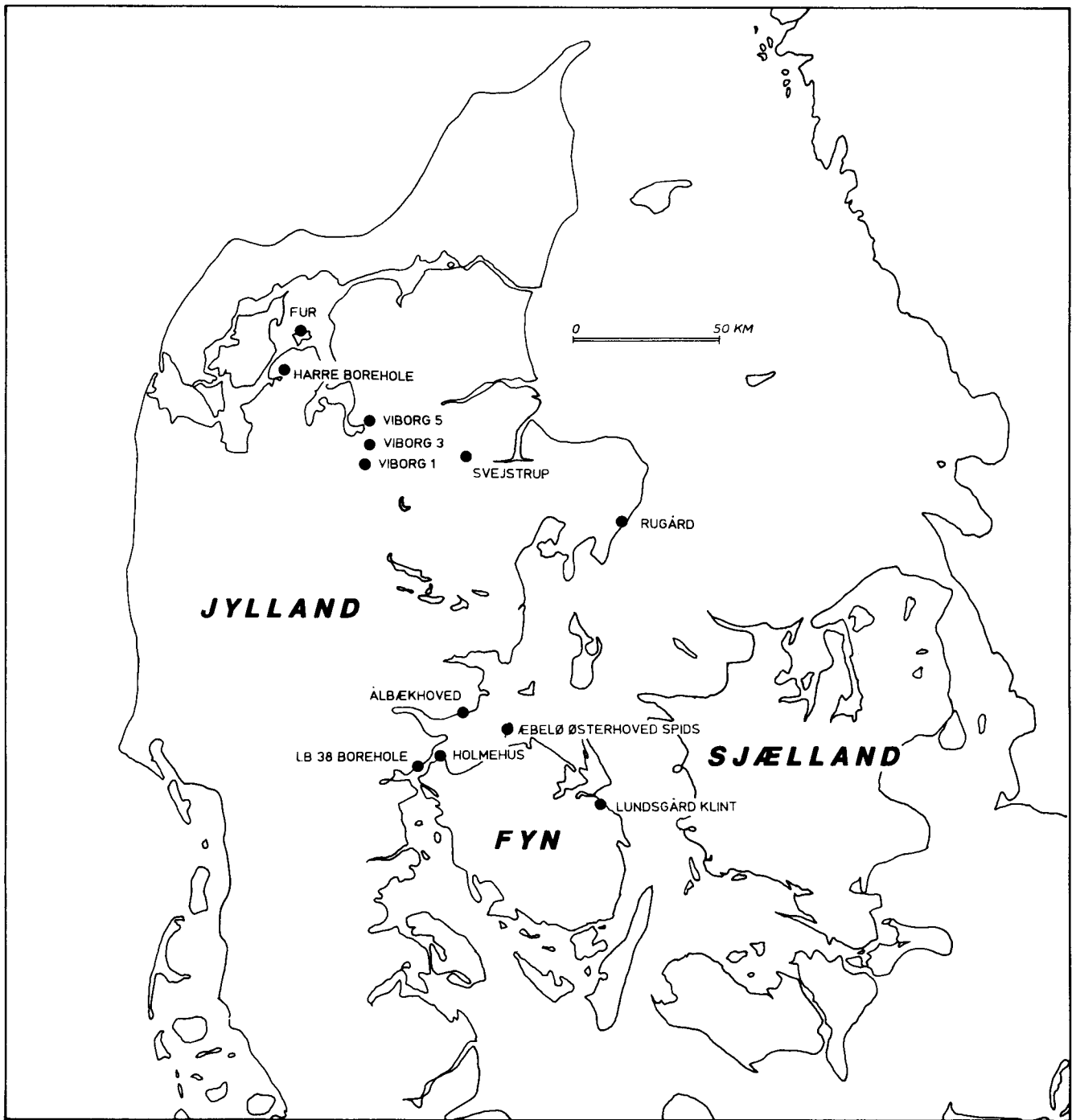


Fig. 1. Locality map.

Materials and methods

Samples

49 core samples have been palynologically processed. The samples were made available for the present study by the Geological Survey of Denmark. They were selected from the collection of type samples from Viborg 1, stored at the Geological Survey, and the numbers used in this study refer to the sample numbers in the Survey collection. The stratigraphical position of the samples is shown in the range chart.

Palynological preparation

Half of the samples were processed at the Paleoecology Department at Aarhus University, while the other half were processed at the Geological Survey of Denmark.

The samples were processed using normal palynological techniques at both laboratories: twenty to forty grammes of the samples were broken into nut-sized fragments and placed in polypropylene centrifuge-bottles. Dilute hydrochloric acid was added until no further effervescence was observed after stirring, ensuring dissolution of calcium carbonate. The samples were then centrifuged and washed one or several times with water to remove the dissolved calcium carbonate. To remove siliceous matter 40% hydrofluoric acid was added to the samples, which were placed in a water-bath. In order to secure complete reaction, the samples were left in hydrofluoric acid for at least one week. The samples were then centrifuged and the liquid removed. To remove less soluble fluoro-silicate compounds, the samples were boiled for 30 minutes with 5 N hydrochloric acid. After cooling and centrifuging, the liquid was poured off. Gel-like fluoro-compounds sometimes survived the boiling, in which case boiling with fresh hydrochloric acid was repeated up to two times to remove all fluoro-compounds. The samples were then washed three times with water. All samples were filtered on nylon filters with a mesh size of 10 μm . For some levels notably rich in spores and pollen subsamples were filtered on 20 μm filter in order to concentrate the dinoflagellates in the residues. The filtered residues were examined, and when significant amounts of pyrite or other insoluble mineral particles were present, heavy-liquid separation was carried out using zinc-chloride in dilute hydrochloric acid with a specific gravity of 2.0. The filtered residues were finally dehydrated and transferred into silicon oil (Wacker AK 2000). Slides for light microscopy were prepared and sealed

with nail varnish. It should be noted that no oxidation step is involved in this preparation, since experience has shown that oxidation can selectively destroy dinoflagellates.

Some samples were chosen for determination of the number of dinoflagellates per gram sediment. Two preparation techniques were used: one method, described by Stockmarr (1971), involves the addition of a known number of *Lycopodium* spores to the samples and counting both the *Lycopodium* and the dinoflagellates. In this study tablets with a known number of spores per tablet, ($\bar{X} = 10,850$ and with a standard deviation, $s = 200$) were used. Another method, described in detail by Jørgensen (1967) depends on a quantitative transport of the original sample through all preparation steps. The final residue in silicon oil, as well as the fraction of this residue present in one slide, is weighed on a precision weight, and the slide is counted completely. The latter method was used only when no heavy-liquid separation was carried out, since part of the organic fraction may be lost in this step. In some cases both techniques were used on the same samples (i.e. samples with *Lycopodium* tablets were processed, following Jørgensen's method) in order to test the reliability of the results. The two methods gave fairly similar results, so they both probably give acceptable estimates of the true number of dinoflagellates per gram sediment.

The preparations for absolute countings of dinoflagellates were mainly filtered on 20 μm mesh. By comparison with subsamples filtered on 10 μm mesh, the 20 μm filtered samples were found to be underrepresented with small species like *Membranosphaera* sp. B and *Microdinium* cf. *ornatum*. The absolute numbers are therefore too low in those 20 μm samples that are rich in small species. However, the absolute numbers vary with a factor of more than 100 in the section, and the error introduced by the 20 μm filtration is therefore negligible.

Microscopy and microphotography

A Leitz Orthoplan microscope equipped with an Orthomat-w camera was used for the analysis and photography. The slides were examined at magnifications of $\times 100$, $\times 250$ and $\times 400$. In each sample one or two slides (containing 500–10,000 dinoflagellates) were completely examined. Relative counts were run in

preparations filtered on 10 μm mesh to ensure a correct representation of small-sized species.

Microphotography was carried out using plain trans-

mitted light at a magnification of $\times 1000$, except for large species which were photographed at $\times 400$. Agfapan 100 ASA films were used.

Lithostratigraphy

The present account of the lithology in Viborg 1 is based on my own observations and comparison with samples from other Danish localities. The original core descriptions, Flagler's (1940) report, and a review of the Paleogene deposits in western Denmark by Dinesen et al. (1977) have also been considered. The formal lithostratigraphy follows Dinesen et al. (1977) and Heilmann-Clausen et al. (1985).

The section (fig. 2) includes a sequence of lithological units which represent different marine environments. The units are, in ascending order:

Danian Limestone, uppermost part (2 m)

This is a hard, whitish grey, sandy calcisiltite, consisting mainly of shell fragments, pelagic foraminifera and recrystallized calcite. Flint is present in bands and as irregular shaped nodules.

Kerteminde Marl (34 m)

Only the upper 11 m were cored. This is a grey, silty marl. Washed residues include calcareous and arenaceous foraminifera, shell fragments and minor amounts of sponge spicules and pyrite (Flagler 1940). The boundary between the Danian Limestone and the Kerteminde Marl is cored in the nearby Viborg 5 borehole. Here a less than one meter thick, glauconitic layer occurs at the base of the Kerteminde Marl. This lithological development resembles the outcrop of the Danian/Selandian unconformity at Svejstrup (Thomsen & Heilmann-Clausen 1985) except for the apparent absence of a basal conglomerate in the Viborg area.

Unnamed unit (27 m)

Dark grey, silty clay with silicified layers. It is distinguished from the Kerteminde Marl mainly in being non-calcareous or only slightly calcareous. According to Flagler (1940), residues from this and the two overlying units include foraminifera (chiefly arenaceous types), sponge spicules (locally very abundant), pyrite and occasionally other minerals. The lower boundary is gradual and no break in sedimentation is indicated. The unit makes up the lower part of the "grey slightly

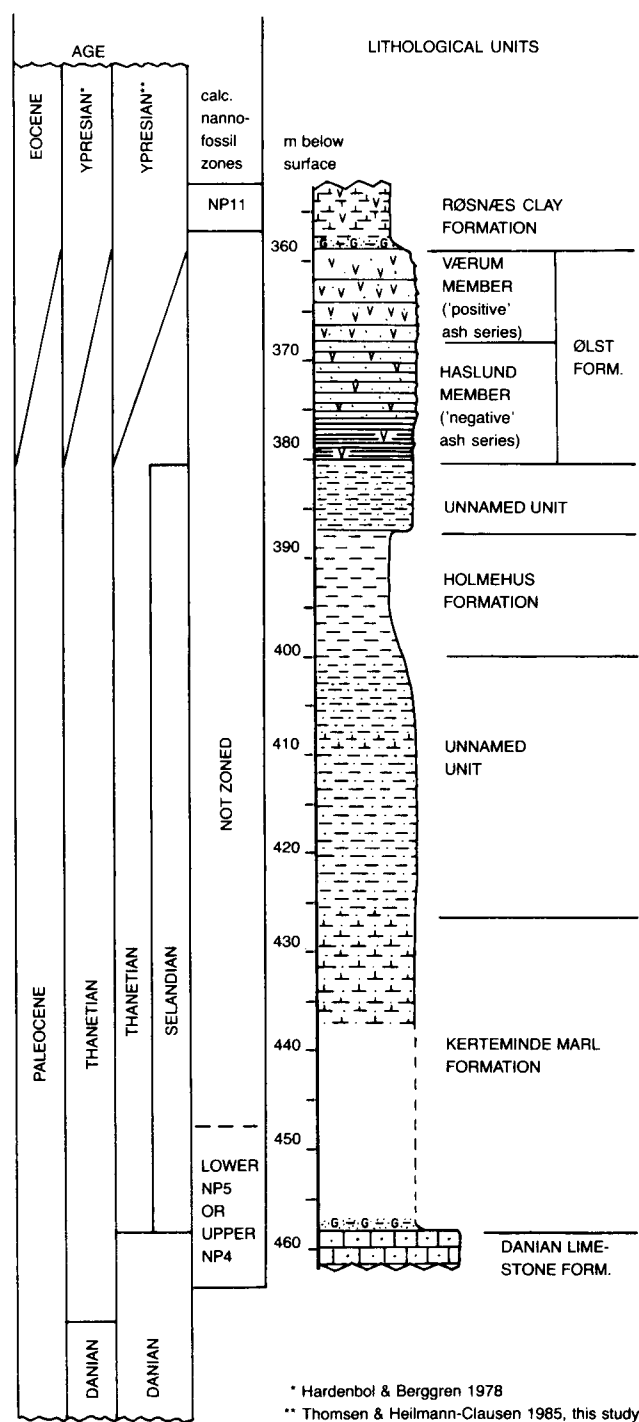


Fig. 2. Viborg 1 borehole, the Danian to Ypresian section. Volcanic ash layers are shown as "v" and presumed glauconitic-rich horizons as "G" in the lithological column. For the position of palynological samples, see the range chart.

calcareous clay” of Dinesen et al. (1977) and older literature. There is a gradual transition to the overlying unit.

Holmehus Formation (12 m)

A sequence of green and brownish, fine-grained, non-calcareous clay beds. The amount of organic carbon is very small. The unit is locally rich in sponge spicules, and burrows (*Chondrites* and cf. *Zoophycos*) are present.

Unnamed unit (6 m)

Dark grey, silty clay, similar to the unit below the Holmehus Formation. It is rich in sponge spicules and contains some foraminifera. Apart from Viborg 1, this unit has previously been known only from the nearby Viborg 3 borehole (Flagler 1940). Recently, a very similar unit has been identified in the same litho- and biostratigraphical position as in Viborg 1, in a boring from the Store Bælt area. The unit is missing, however, at several other localities in the Danish-Norwegian Basin (Heilmann-Clausen et al. 1985). The lateral distribution therefore is restricted, possibly patchy.

Ølst Formation (22 m)

This unit consists of non-calcareous shale and clay, which are delicately laminated in the lower part. Dia-

tomaceous clay layers are included in the upper part. The whole sequence is barren of benthonic fossils. Volcanic ash layers are present throughout the unit, but are especially frequent in the upper part. Identification of the ash layers in the cores (Andersen 1940) permits a correlation with the sequence of ash layers known from outcrops in Denmark – the “negative and positive series” of Bøggild (1918) and Andersen (1937). The lower part probably contains a small number of ash layers older than those known from outcrops, while the upper part is closely comparable to the “positive series”. The boundary between the Ølst Formation and the poorly bedded unit below is sharp and probably marks an unconformity.

Røsnæs Clay Formation (8 m)

This interval comprises bright red, fine-grained, mainly calcareous clay with thin green argillized ash layers. It includes a fairly rich foraminiferal fauna, chiefly calcareous, which is locally dominated by planktonic species (Flagler 1940, Dinesen 1972). It also carries a rich calcareous nannofossil assemblage (Thiede et al. 1980). The amount of organic matter is very small. The lower boundary is sharp and marks a hiatus or a condensed sequence. (Only the lower 5 m are included in the present study).

Depositional environments

The Danian Limestone was deposited in a marine environment with well circulated waters and with only minor terrestrial influence. The Danian Limestone includes a sequence of facies showing gradually shallower water depths, starting with depths below the photic zone in the Lower Danian, and ending with shallow water calcarenites in the Upper Danian (Hansen 1977).

The marked change to clay-dominated shelf deposition which follows the Danian Limestone, is apparently associated with Laramide tectonism leading to uplift of some of the surrounding land areas and eustatic sea level fall (Hansen 1980, Ziegler 1982). The sequence of units from the Kerteminde Marl to the Holmehus Formation probably reflects a gradual increase in water depth from initial values probably around 35–65 m (Larsen & Jørgensen 1977) to much deeper water during deposition of the Holmehus Formation. The bottom water was moderately to well oxidized. The fine grain-size of the sediment in the Holmehus Formation and the small amount of organic matter point to a very slow sedimentation rate during deposition of this formation.

Major stagnation in the basin circulation set in during deposition of the Ølst Formation and its allied deposits throughout the North Sea. The lower part of the Ølst Formation was deposited in a basin with anoxic bottom waters (Bonde 1966, Knox & Harland 1979, Pedersen 1981). The sea floor was below wave base and the salinity was probably reduced during the most stagnant period (Knox, Morton & Harland 1981), at least in the surface waters. A moderate increase in circulation apparently took place in the upper part of the unit, as shown in the equivalent Fur Formation of NW Jylland (Pedersen 1981).

The oceanographic setting changed dramatically once again after sedimentation of the Ølst Formation. The Røsnæs Clay Formation was deposited in a basin with waters of normal salinity and with good circulation which carried oxygen to the bottom waters. The environment was of oceanic character and only pelagic clay was deposited. The fossils (including the common *Zoophycos* and *Chondrites* trace fossils known from the outcrops) are evidence of a persisting benthonic fauna and a particularly rich planktonic life.

Firm correlation to the internationally used stages has only been established for the Danian Limestone and the Røsnæs Clay Formation, based on calcareous nannofossil zonation (fig. 2). The main part of the section can at present only be correlated tentatively.

According to Thomsen & Heilmann-Clausen (1985), the Danian Limestone in Viborg 1 is of late NP4 or early NP5 age. They assigned the same age to the lowermost Kerteminde Marl at localities in central Jylland. Other basal Selandian deposits have previously been referred to the NP5 Zone by Perch-Nielsen (1979). The hiatus between the Danian Limestone and the Kerteminde Marl therefore only represents a very short period in Viborg 1.

The calcareous beds of the Røsnæs Clay Formation in Viborg 1 (and at several other localities) are referred to the NP11 and NP12 Zones by Perch-Nielsen (summarized in Thiede et al. 1980). The samples of this formation for the present study are of NP11 age (fig. 2).

The position of stage boundaries

Following Thomsen & Heilmann-Clausen (1985) the Danian Stage is taken to include the complete Danian Limestone Formation (Danskekalken), as initiated in the lower boundary type-section at Stevns and underlying the Kerteminde Marl and its lateral equivalents. Consequently, the Danian/Thanetian boundary is placed near the NP4/NP5 boundary. It should be noted that this definition differs from current usage – Hardenbol & Berggren (1978), for example place the boundary near the NP3/NP4 boundary (cf. fig. 2).

The Selandian Stage (fig. 2) is frequently referred to in Danish publications, but this stage has not gained international acceptance. It was established by Rosenkrantz (1924) and redescribed by Perch-Nielsen & Hansen (1981). In Rosenkrantz' (1924) scheme the Se-

landian comprises the deposits above the Danian Limestone and beneath the layers with volcanic ash, i.e. the Ølst Formation. The position of the Selandian Stage in the Viborg 1 section is therefore well defined.

The Paleocene/Eocene boundary

The Paleocene/Eocene boundary is currently equated with the NP9/NP10 boundary (e.g. Hardenbol & Berggren 1978) and is therefore clearly located beneath the calcareous beds of the Røsnæs Clay Formation. Since calcareous nannofossils are absent in the critical units near the boundary (not only in Denmark, but in the whole North Sea Basin) the precise position of the boundary is uncertain.

A preliminary correlation of volcanic ash layers (Knox 1984) indicates that the boundary is probably close to the base of the Ølst Formation. Knox correlates the ash sequence of the Ølst Formation with a sequence of ash layers in DSDP Hole 550 in the North Atlantic, SW of Ireland. The ashes at this site falls entirely in the NP10 Zone, i.e. in the Eocene.

This is contrary to a recent proposal that the Paleocene/Eocene boundary is above the Ølst Formation (Heilmann-Clausen 1982), based on the finding of the *Wetzelilla astra* dinoflagellate Zone (which was assumed to equate lower NP10 Zone) in the basal Røsnæs Clay Formation. However, Morton, Backman & Harland (1983) cast doubt on the precise position of the *W. astra* Zone relative to the NP9/NP10 boundary.

Despite the fact that dinoflagellate zonation is quite detailed and works well in the Upper Paleocene – Lower Eocene North Sea deposits, it appears most sound therefore not to indicate the Paleocene/Eocene boundary by means of dinoflagellates until more conclusive evidence is available.

Systematic paleontology

The 77 taxa included in the present study are listed alphabetically below. They are illustrated in plates 1–15 and their occurrence is shown in the range chart. Forms which are commented on in the systematic section are indicated with an asterix. Figures in brackets refer to the position in the range chart. The archaeopyle terminology follows Bujak & Davies (1983).

Type depository: The type material (marked with MGUH-numbers) is lodged in the type collection of the Geological Museum, Øster Voldgade 5–7, DK-1350, Copenhagen, Denmark.

- Achilleodinium biformoides* (Eisenack) Eaton 1976 – (69) Pl. 9, figs. 5–7
Achomosphaera crassipellis (Deflandre & Cookson) Stover & Evitt 1978 – (49) Pl. 7, figs. 15, 16
Adnatosphaeridium robustum (Morgenroth) De Coninck 1975b – (58) Pl. 13, figs. 1–3
Adnatosphaeridium cf. *vittatum* Williams & Downie 1966c – (67) Pl. 13, figs. 4, 5
Alisocysta circumtabulata (Drugg) Stover & Evitt 1978 – (9) Pl. 11, figs. 28–31
**Alisocysta margarita* (Harland) Harland 1979a – (48) Pl. 11, figs. 7, 12–17, 22
**Alisocysta reticulata* Damassa 1979b – Pl. 11, fig. 23
**Alisocysta* sp. 1 – (47) Pl. 11, figs. 18–21, 24–26
**Alisocysta* sp. 2 – (57) Pl. 11, figs. 1–6, 8–11
**Alterbia circula* sp. nov. – (4) Pl. 1, figs. 1–8
**Apectodinium augustum* (Harland) Lentin & Williams 1981 – (61) Pl. 5, figs. 6, 7
**Apectodinium homomorphum* (Deflandre & Cookson) Lentin & Williams 1977b – (59) Pl. 5, figs. 8–10
**Apectodinium hyperacanthum* (Cookson & Eisenack) Lentin & Williams 1977b – (65) Pl. 6, fig. 8
**Apectodinium paniculatum* (Costa & Downie) Lentin & Williams 1977b – (62) Pl. 6, fig. 7
**Apectodinium parvum* (Alberti) Lentin & Williams 1977b – (63) Pl. 5, fig. 11
**Apectodinium quinquelatum* (Williams & Downie) Costa & Downie 1979 – (60) Pl. 5, figs. 14–17
**Apectodinium sumissum* (Harland) Lentin & Williams 1981 – (64) Pl. 5, figs. 12–13
**Areoligera coronata* sensu lato – (35) Pl. 14, figs. 2, 3
**Areoligera senonensis* sensu lato – (36) Pl. 14, figs. 4–7
**Caligodinium aceras* (Manum & Cookson) Lentin & Williams 1973 – (30) Pl. 15, figs. 18–21
Ceratiopsis depressa (Morgenroth) Lentin & Williams 1977b – (41) Pl. 2, figs. 8–10.

- Ceratiopsis diebelii* (Alberti) Vozzhennikova 1967 – (12) Pl. 2, figs. 11, 15
**Ceratiopsis medcalfii* (Stover 1974) comb. nov. – (51) Pl. 3, figs. 4–6
**Ceratiopsis speciosa* subsp. *glabra* (Gocht) Lentin & Williams 1977b – (53) Pl. 3, figs. 7–10
**Ceratiopsis speciosa* subsp. *speciosa* (Alberti) Lentin & Williams 1977b – (15) Pl. 2, figs. 12, 16
**Ceratiopsis striata* (Drugg) Lentin & Williams 1977b – (16) Pl. 2, figs. 13, 14, 17, 18
Cladopyxidium saeptum (Morgenroth) Stover & Evitt 1978 – (18) Pl. 12, figs. 5–12
Conneximura fimbriata (Morgenroth) May 1980 – (22) Pl. 15, figs. 13–17
**Cyclapophysis monmouthensis* Benson 1976 – (5) Pl. 9, figs. 12, 13
Danea californica (Drugg) Stover & Evitt 1978 – (6) Pl. 9, figs. 10, 11
Deflandrea denticulata Alberti 1959b – (50) Pl. 3, figs. 1–3
**Deflandrea oebisfeldensis* Alberti 1959b – (52) Pl. 4, figs. 1–6
**Deflandrea phosphoritica* Eisenack 1938 – (70) Pl. 4, figs. 7–9
**Dinogymnium sibiricum* (Vozzhennikova) Lentin & Williams 1973 – (23) Pl. 15, figs. 5, 6
**Diphyes colligerum* (Deflandre & Cookson) Cookson 1965a – (40) Pl. 12, figs. 31–35
**Dracodinium condylos* (Williams & Downie) Costa & Downie 1979 – (71) Pl. 6, fig. 11
**Dracodinium varielongitudum* (Williams & Downie) Costa & Downie 1979 – (72) Pl. 6, figs. 9, 10
Eatonicysta ursulae (Morgenroth) Stover & Evitt 1978 – (73) Pl. 8, fig. 6
Fibradinium annetorpense Morgenroth 1968 – (13) Pl. 12, figs. 13–18
Florentinia ferox (Deflandre) Duxbury 1980 – (34) Pl. 9, figs. 1–4
**Fromea ? laevigata* (Drugg) Stover & Evitt 1978 – (19) Pl. 15, figs. 1–4
Glaphyrocysta divaricata (Williams & Downie) Stover & Evitt 1978 – (38) Pl. 13, figs. 9–11
Glaphyrocysta ordinata (Williams & Downie) Stover & Evitt 1978 – (37) Pl. 13, figs. 6–8
Glaphyrocysta pastielsii (Deflandre & Cookson) Stover & Evitt 1978 – (39) Pl. 13, figs. 12–14
Gonyaulacysta wetzelii (Lejeune-Carpentier) Sarjeant 1969 – (7) Pl. 9, figs. 8, 9

- Hafniasphaera septata* (Cookson & Eisenack) Hansen 1977 – (24) Pl. 7, figs. 10, 11, 14
- Hystrichokolpoma cinctum* Klumpp 1953 – (74) Pl. 10, figs. 1–3
- Hystrichosphaeridium tubiferum* (Ehrenberg) Deflandre 1937b – (29) Pl. 10, figs. 8–11
- **Hystrichosphaeridium* sp. 1 – (45) Pl. 11, figs. 27, 32, 33
- **Hystrichosphaeridium* ? *palmatum* (White ex Bronn) Downie & Sarjeant 1965 – (11) Pl. 10, figs. 20, 21
- **Hystrichostrogylon coninckii* Heilmann-Clausen 1985 – (8) Pl. 7, figs. 5–8
- **Impagidinium* sp. 1 – (43) Pl. 12, figs. 25–30
- Impletosphaeridium severinii* (Cookson & Cranwell) Liengjarern et al. 1980 – (56) Pl. 14, figs. 8–12
- **Incertae sedis* 1 – (17) Pl. 15, figs. 7–10
- **Isabelidinium* ? *viborgense* sp. nov. – (44) Pl. 1, figs. 21–25
- Kallosphaeridium brevibarbatum* De Coninck 1969 – (68) Pl. 15, figs. 11, 12
- Lingulodinium machaerophorum* (Deflandre & Cookson) Wall 1967 – (55) Pl. 15, figs. 24, 25
- **Melitasphaeridium pseudorecurvatum* (Morgenroth) Bujak 1980 – (25) Pl. 10, figs. 12–16
- **Melitasphaeridium* ? sp. 1 – (46) Pl. 10, figs. 17–19
- **Membranosphaera* sp. B De Coninck 1975a – (31) Pl. 12, figs. 22–24
- **Microdinium* cf. *ornatum* Cookson & Eisenack 1960a – (32) Pl. 12, figs. 19–21
- **Muratodinium fimbriatum* (Cookson & Eisenack) Drugg 1970b – (66) Pl. 8, figs. 7, 8
- Oligosphaeridium complex* (White) Davey & Williams 1966b – (28) Pl. 10, figs. 4–7
- **Palaeocystodinium australinum* (Cookson) Lentin & Williams 1976 – (14) Pl. 6, figs. 4, 5
- **Palaeocystodinium lidiae* (Gorka) Davey 1969b – (26) Pl. 6, figs. 1–3
- Palaeoperidinium pyrophorum* (Ehrenberg) Sarjeant 1967b – (20) Pl. 7, figs. 1–3
- Palaeotetradinium minusculum* (Alberti) Stover & Evitt 1978 – (27) Pl. 5, figs. 1–5
- Palambages morulosa* O. Wetzel 1961 – (33) Pl. 15, figs. 22, 23
- **Phthanoperidinium crenulatum* (De Coninck) Lentin & Williams 1977b – (54) Pl. 2, figs. 1–7
- **Spinidinium* cf. *clavum* Harland 1973 – (3) Pl. 1, figs. 16–20
- **Spinidinium densispinatum* Stanley 1965 – (2) Pl. 1, figs. 9–12
- **Spinidinium echinoideum* (Cookson & Eisenack) Lentin & Williams 1976 – (1) Pl. 1, figs. 13–15
- Tanyosphaeridium xanthiopyxides* (O. Wetzel) Stover & Evitt 1978 – (21) Pl. 12, figs. 1–4
- Thalassiphora delicata* Williams & Downie 1966c – (42) Pl. 8, figs. 3–5
- **Thalassiphora inflata* Heilmann-Clausen 1985 – (10) Pl. 7, figs. 4, 9, 12, 13
- Thalassiphora pelagica* (Eisenack) Eisenack & Gocht 1960 – (75) Pl. 8, figs. 1, 2
- Wetzeliiella meckelfeldensis* Gocht 1969 – (76) Pl. 6, fig. 6

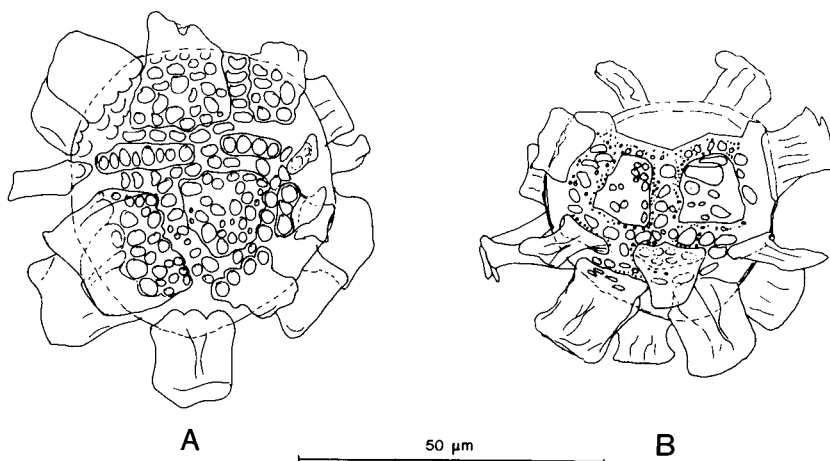
Taxa of dinoflagellates and acritarchs which have been seen in one or several of the samples which are not treated in this study include: *Achomosphaera* spp., *Apteodinium* sp., *Comasphaeridium cometes*, *Cordosphaeridium* spp., *Dinopterygium* cf. *cladoides*, *Fibrocysta* spp., *Hafniasphaera cryptovesiculata*, *Impagidinium* sp., *Micrhystridium* sp., *Millioudodinium* cf. *giuseppei*, *Nematosphaeropsis* cf. *philippotii*, *Operculodinium* cf. *centrocarpum*, *Paralecaniella indentata*, *Phthanoperidinium* sp., *Polysphaeridium zoharyi*, *Rottnestia borussica*, *Senegalinium* ? *dilwynense*, *Spiniferites* spp., *Trigonopyxidia ginella*, *Veryhachium* sp.

Class Dinophyceae Fritsch 1929

Order Peridiniales Haeckel 1894

Genus *Alisocysta* Stover & Evitt 1978

Fig. 3. A: *Alisocysta reticulata*, a specimen from the Danian Limestone in Vejrum-4 well, Denmark (sample V26-1, slide B1 J28/1). B: *Alisocysta* sp. 1 from the Holmehus Formation in the LB 38 borehole (sample chc 320). Same specimen also shown in pl. 11, figs. 18, 19. Camera lucida drawings. The sculptures of the cyst walls are shown only over parts of the surfaces.



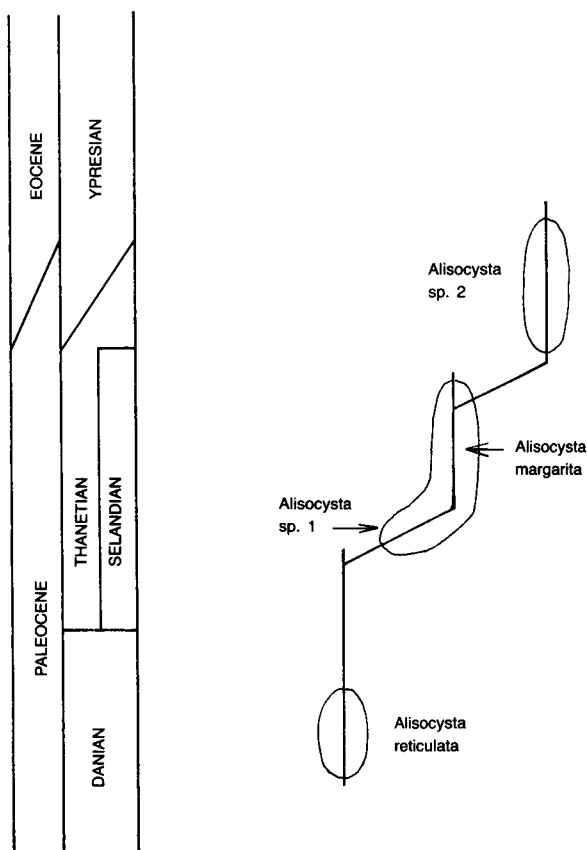


Fig. 4. A possible phylogeny of species of *Alisocysta* discussed in the text.

Alisocysta margarita (Harland) Harland 1979a
Pl. 11, figs. 7, 12–17, 22

Remarks. The present specimens are similar to the type material and display the same great variability in height of the penitabular crests, varying from low ridges to high membraneous processes.

Alisocysta reticulata Damassa 1979b
Pl. 11, fig. 23; text-fig. 3

Remarks. *A. reticulata* is not present in Viborg 1, but occurs in the Danian in the Vejrum 4 boring. It is included in this study since it closely resembles *Alisocysta* sp. 1. *A. reticulata* is coarsely reticulate, and the luminae of the reticulum tend to be exclusively of large size, and are markedly deeper than in *Alisocysta* sp. 1 (fig. 3). This development of the reticulum clearly separates *A. reticulata* from *Alisocysta* sp. 1.

The morphological similarities and stratigraphical relationships of the two species suggest that *A. reticulata* is ancestral to *Alisocysta* sp. 1. A phylogenetic model is shown in fig. 4.

Alisocysta sp. 1
Pl. 11, figs. 18–21, 24–26; text-fig. 3

1980: *Hystrichokolpoma* aff. *mentitum* McLean 1974 – Heilmann-Clausen, p. 49, figs. 2–4, 6

Remarks. *Alisocysta* sp. 1 is differentiated from *A. margarita* by its distinct surface sculpture (fig. 3) which is a reticulum composed of both large and small luminae. In *A. margarita* the wall surface is smooth to microreticulate, with random wall-thickenings mainly inside the penitabular membranes. Transitional forms between *Alisocysta* sp. 1 and *A. margarita* have been observed.

Alisocysta sp. 2
Pl. 11, figs. 1–6, 8–11

1968: *Schematophora* ? sp. – De Coninck, p. 47; pl. 2, figs. 18, 19
1975b cf. *Eisenackia* sp. A – De Coninck, p. 95; pl. 17, figs. 8–10

Description. The cysts are thin-walled and colourless. The wall is only faintly and indistinctly sculptured. The penitabular septa are very delicate and almost invisible. The septa often seem to split into separate threads.

Remarks. *Alisocysta* sp. 2 only differs from *A. margarita* in the reduced sculpture and more delicate periphragm and endophragm. It appears later than *A. margarita* and may therefore be phylogenetically derived from *A. margarita* (fig. 4). The specimens described from the basal Ypresian in Belgium (De Coninck 1968, 1975b) fall within the stratigraphical range of the species in Viborg 1.

Genus *Alterbia* Lentin & Williams 1976

Alterbia circula sp. nov.
Pl. 1, figs. 1–8; text-fig. 5

Diagnosis. A species of *Alterbia* Lentin & Williams 1976, with the following specific characters: The cyst is circumcavate. The smooth pericyst has convex lateral margins of the epicyst. The right antapical horn is reduced, but not completely absent. The peri-archaeopyle is intercalary, or an intercalary-precingular combination type. The shape of paraplate 2a is steno to isodeltaform to thetaform. The endocyst is almost circular in ambitus and shows a faint paratabulation mid-dorsally. The endo-archaeopyle is intercalary. The endophragm is thicker than the periphragm.

Description. A circumcavate peridiniacean cyst.
Pericyst:

The pericyst is smooth-walled, and the outline is peridinioid. The epicyst has convex lateral margins, “shoulders”, and an apical horn of moderate length with a truncated apex. The left antapical horn is longer than the right one which may be almost absent.

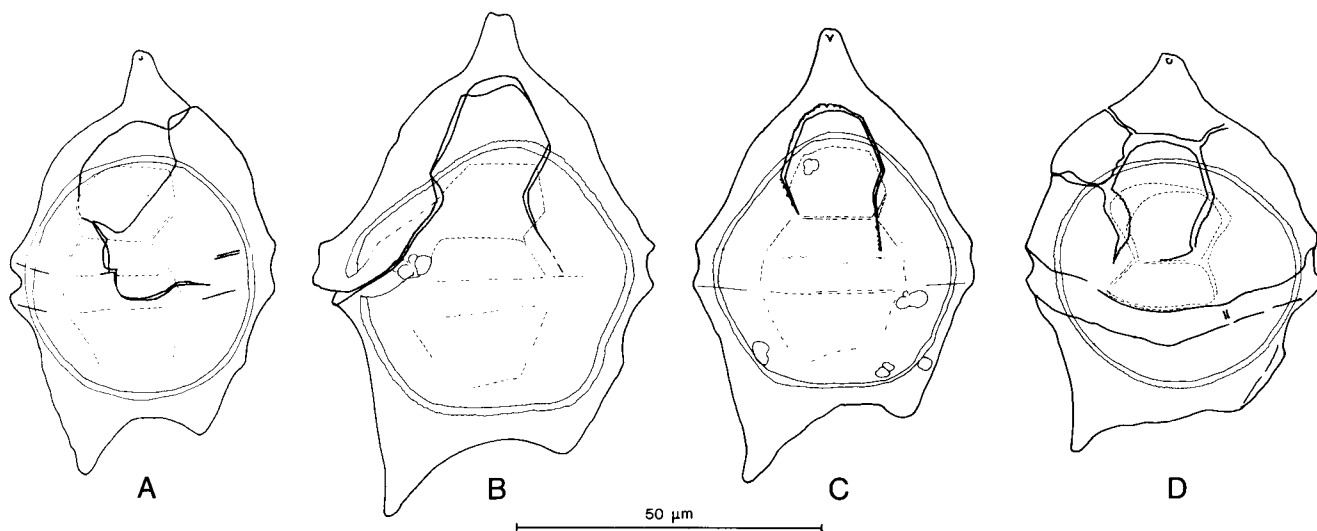


Fig. 5. *Alterbia circula* sp. nov. All from sample 228, camera lucida drawings. A: same specimen as pl. 1, fig. 6. B: same as pl. 1, fig. 7. C: holotype (also pl. 1, figs. 1, 2). D: same as pl. 1, figs. 3, 4. Faint paratabulation of central body is shown with dotted lines.

The paracingulum is clearly marked laterally by indentations of the periphragm, but otherwise is not expressed, or is only indicated by faint parasutural lines. The parasulcus is only indicated as an indentation of the ventral surface of the hypocyst. The peri-archaeopyle is intercalary, or is an intercalary-precingular combination type. The variation of the archaeopyle includes the types Ia(2a) (fig. 5C, D), I(2a) (fig. 5A) and $\overline{\text{IPa}}(2a, 4'')$ (fig. 5B). The shape of plate 2a is steno to iso – deltaform to thetaform.

Endocyst:

The endocyst is thick-walled (about 1 µm) and finely granular, occasionally bearing a few large verrucae. The outline in dorsoventral view is almost perfectly circular to sub-pentagonal. A paratabulation is expressed mid-dorsally as a hexa I(2a) archaeopyle, and additionally as fine parasutural lines showing the paraplates 4'', 3c and 3''', or parts of these paraplates (fig. 5).

Dimensions

Pericyst, length, max., (mean), min.: 83, (73), 66 µm, width: 53, (46), 41 µm.

Endocyst, length: 46, (42), 37 µm, width: 45, (40), 35 µm.

(10 specimens measured). Holotype: pericyst length 75 µm, width 46 µm; endocyst length 43 µm, width 40 µm.

Holotype. Fig. 5C; pl. 1, figs. 1, 2; slide Viborg 1-AD 228-10, coordinates L 46, MGUH-16829. Type locality and type stratum: Viborg 1, Danian Limestone, sample 228, Danian (Lower Paleocene).

Remarks. *A. circula* bears some resemblance to, and may be a descendant of, *Alterbia acutula* (Wilson) Lentin & Williams 1976. *A. acutula* is widely distributed in Upper Cretaceous deposits. *A. circula* differs from *A.*

acutula in the almost circular, partially tabulated endocyst, in having “shoulders” and a shorter apical horn. The right antapical horn is better developed in *A. circula* and the shape of the second intercalary paraplate tends to be more thetaform, whereas it is distinctly deltaform in *A. acutula*.

Occurrence. Danian Limestone in Viborg 1, rare (re-worked?) in Selandian dark grey clay in Viborg 1.

Genus *Apectodinium* (Costa & Downie) Lentin & Williams 1977b

The *Apectodinium homomorphum* plexus sensu Harland 1979c

Pl. 5, figs. 6–17; pl. 6, figs. 7, 8

Remarks. The genus *Apectodinium* is extremely well represented in the lower part of the Ølst Formation where it usually dominates in the dinoflagellate assemblages. Several species of *Apectodinium* occur. They are known from other parts of the North Sea Basin to intergrade in morphology with time and at the population level (Harland 1979c). Harland therefore proposed to use the plexus-concept for species of *Apectodinium*, i.e. a concept of an apparent network of species in a phylogenetic lineage.

A similar intergradation in morphology of the individual species has been found in the present investigation. Nevertheless, morphologically well separated end-members of the plexus are represented in the samples, especially by the species *A. homomorphum*, *A. quinquelatum*, *A. augustum* and *A. parvum*. These exhibit different stratigraphical ranges, and are therefore shown separately in the range chart. *A. homomorphum* appears earlier than the other species and is infrequently, but consistently, present in the unit below the Ølst Formation. The appearance of the *Apectodinium*



Fig. 6. *Caligodinium aceras*. Camera lucida drawings. A: specimen from sample 207 (also pl. 15, fig. 18) showing two or three partially attached opercular plates. B: specimen from sample 179 (same as pl. 15, fig. 21) showing three opercular plates. C: specimen from the Kerteminde Marl at Svejstrup, sample SV-11 (same as Thomsen & Heilmann-Clausen 1985, pl. 4, fig. 8), showing accessory archaeopyle sutures, suggesting the presence of at least eight paraplates bordering on the archaeopyle.

plexus, however, is abrupt, and takes place just above the base of the anoxic, lower part of the Ølst Formation. At previously examined localities in Denmark the *Apectodinium* plexus is intimately associated with this anoxic episode.

Genus *Areoligera* Lejeune-Carpentier 1938 emend. Williams & Downie 1966

The *Areoligera senonensis* complex sensu Eaton 1976 Pl. 14, figs. 2–7

Remarks. Varieties of *Areoligera* with processes on paraplate 6', but otherwise similar to *A. senonensis* and *A. coronata* were described from the English Eocene by Williams & Downie (1966) and Eaton (1976), as *A. cf. senonensis* and *A. cf. coronata* respectively.

In the present study such varieties were frequently encountered, together with typical forms. All transitions seem to exist between forms devoid of processes and forms with well developed processes on this paraplate; they have therefore been grouped in the range chart as *A. senonensis* sensu lato and as *A. coronata* sensu lato.

A. senonensis and *A. coronata* are separated on the morphology of the process complexes. A gradual transition between the two morphologies is observed in the present study, as is the case in the English Eocene material (Eaton 1976).

Genus *Caligodinium* Drugg 1970

Caligodinium aceras (Manum & Cookson) Lentin & Williams 1973

Pl. 15, figs. 18–21; text-fig. 6

1964: *Kalyptea aceras* – Manum & Cookson, p. 27, 28; pl. 6, figs. 9–11

1970: *Caligodinium amiculum* – Drugg, p. 815, figs. 8A, B, 9A–E

1973: *Caligodinium aceras* (Manum & Cookson) – Lentin & Williams, p. 21

1974: *Pareodinia aceras* (Manum & Cookson) – Davey & Verdier, p. 645

1975: *Caligodinium aceras* (Manum & Cookson) Lentin & Williams 1973 – Lentin & Williams, p. 2148

1985: *Caligodinium amiculum* Drugg 1970 – Thomsen & Heilmann-Clausen, pl. 4, figs. 7, 8

Remarks. In his erection of the new species *Caligodinium amiculum* Drugg (1970) mentioned a “generally close resemblance to *Kalyptea aceras* Manum & Cookson 1964”. The only difference stated by Drugg was an apparently more membranous outer covering in *K. aceras* than in *C. amiculum*. In the view of the present author there is no clear difference in the outer covering, or in other characters. It is therefore proposed here to regard *C. amiculum* as a junior synonym of *Caligodinium aceras*.

The Danish specimens apparently have a more variable archaeopyle development than the almost contemporaneous specimens from southern U.S.A., described by Drugg (1970). Especially the shape, position, and possibly also the number of opercular plates, appear to

be quite variable, and it has not been possible to identify with certainty the same opercular plates on different specimens (fig. 6A, B). When fully developed, three opercular plates are present (fig. 6B), as in the American material.

Genus *Ceratiopsis* Vozzhennikova 1963 emend. Bujak et al. 1980

Ceratiopsis medcalfii (Stover 1973) comb. nov.
Pl. 3, figs. 4–6

1973: *Deflandrea medcalfii* – Stover, p. 175–176, pl. 3, figs. 3a–c

Remarks. The transfer of this species is appropriate in view of the shape of the peri-archaeopyle (style B-1 archaeopyle of Stover 1974). *C. medcalfii* differs from *C. speciosa* in having a stronger ornament of spinules or coni, and from *Deflandrea oebisfeldensis* in having better developed antapical horns (fig. 7).

Ceratiopsis speciosa subsp. *speciosa* (Alberti) Lentin & Williams 1977b
Pl. 2, figs. 12, 16

Remarks. This subspecies is not easy to differentiate from *Ceratiopsis striata*. The only difference seems to be a less clearly marked longitudinal striation of the periphragm in *C. speciosa* subsp. *speciosa*. *C. striata* displays strong striation of the periphragm, but *C. speciosa* subsp. *speciosa* may also show some striation, as clearly visible in Alberti's (1959b) illustration of the holotype.

In Viborg 1 most specimens assigned to *C. speciosa* subsp. *speciosa* are faintly striate, and a continuous intergradation apparently exists to strongly striate forms, assigned to *C. striata*.

Ceratiopsis speciosa subsp. *glabra* (Gocht) Lentin & Williams 1977b
Pl. 3, figs. 7–10

Remarks. In Viborg 1 this subspecies occurs at a higher stratigraphical level than *C. speciosa* subsp. *speciosa*. Subsp. *glabra* differs in being larger and non-striate. The periphragm is smoother and the pericoel tends to be better developed. The increased pericoel is especially seen in the post-cingular region where the endophragm and periphragm are clearly separated laterally, while in subsp. *speciosa* the phragma are closely appressed here. *C. speciosa* subsp. *glabra* seems to intergrade morphologically with *Deflandrea oebisfeldensis*.

Ceratiopsis striata (Drugg) Lentin & Williams 1977b
Pl. 2, figs. 13, 14, 17, 18

See remarks to *C. speciosa* subsp. *speciosa*.

Genus *Cyclapophysis* Benson 1976

Cyclapophysis monmouthensis Benson 1976
Pl. 9, figs. 12, 13

1968: *Cordosphaeridium inodes* (pars) – Morgenroth, p. 550; pl. 45, fig. 9
1971: ? *Cannosphaeropsis* sp. – Wilson, pl. 3, figs. 6, 10
1975a: ? *Cordosphaeridium* sp. A – De Coninck, p. 334, figs. 4A, B, C

	<i>Ceratiopsis striata</i>	<i>Ceratiopsis speciosa</i> subsp. <i>speciosa</i>	<i>Ceratiopsis speciosa</i> subsp. <i>glabra</i>	<i>Ceratiopsis medcalfii</i>	<i>Deflandrea oebisfeldensis</i>	<i>Deflandrea phosphorica</i>
striate periphragm	●	●				
spinules or coni on periphragm		●		●	●	
almost smooth periphragm			●		●	●
reduced antapical horns					●	
strong development of pericoel in the hypocyst						●

Fig. 7. Distribution of some diagnostic characters in closely related taxa of *Ceratiopsis* and *Deflandrea*.

- 1982: *Cyclapophysis lemniscata* – De Coninck & Smit, pl. 1, figs. 4a, b
 1985: *Cyclapophysis monmouthensis* – Thomsen & Heilmann-Clausen, pl. 6, figs. 1, 2

Remarks. The Danish specimens are closely comparable to the type material. The antapical and apical protuberance of the endocoel may frequently be observed.

Cyclapophysis lemniscata (Corradini 1973) comb. nov.

- 1973: *Cordosphaeridium lemniscatum* – Corradini, p. 152–153; pl. 22, figs. 4a, 4b, 5; pl. 33, figs. 2, 4; pl. 39, fig. 2

Remarks. This species is very similar to, if not synonymous with *C. monmouthensis*. The only significant difference is the possible lack of an apical protuberance of the endocoel in *C. lemniscata*. Unfortunately the presence or absence of this feature is not clearly indicated by the illustrated specimens. Until this uncertainty is better clarified it is proposed here that the two species remain separate.

Genus *Deflandrea* Eisenack 1938 emend. Lentin & Williams 1976

Deflandrea oebisfeldensis Alberti 1959b
 Pl. 4, figs. 1–6

Remarks. Typical specimens are easily distinguished from other species of *Deflandrea* and *Ceratiopsis* by the very reduced antapical horns (fig. 7). Forms with better developed antapical horns occur in the lower part of the range in Viborg 1. These forms (which occur together with typical specimens) are intermediary to *C. speciosa* subsp. *glabra*.

Deflandrea phosphoritica Eisenack 1938
 Pl. 4, figs. 7–9

Remarks. *D. phosphoritica* is distinguished from *D. oebisfeldensis* in having a smoother, hyaline periphragm and in having better developed antapical horns (fig. 7). The pericoel is especially well developed in the hypocyst and in the paracingular region, whereas the endophragm and periphragm are in much closer contact over much of the epicyst. The paracingulum is in a post-equatorial position relative to the endocyst.

Genus *Dinogymnium* Evitt, Clarke & Verdier 1967

Dinogymnium sibiricum (Vozzhennikova) Lentin & Williams 1973
 Pl. 15, figs. 5, 6

Remarks. Only a single specimen of *Dinogymnium* has been found. It agrees quite well with *D. sibiricum* in the relative length of epicyst and hypocyst (epicyst longer than hypocyst) and other characters. A small apical archaeopyle is visible. The paracingulum is deep and distinctly offset. The parasulcus is essentially limited to the hypocyst.

The genus *Dinogymnium* is known almost exclusively from Upper Cretaceous deposits. The single specimen is therefore regarded as reworked.

Genus *Diphyes* Cookson 1965a emend. Davey & Williams 1966b

Diphyes colligerum (Deflandre & Cookson) Cookson 1965a
 Pl. 12, figs. 31–35

Remarks. The specimens attributed here to *D. colligerum* differ somewhat from the Eocene type material from Australia, and also from specimens in the Danish Middle Eocene, by having a less inflated antapical process. The specimens shown from the Upper Paleocene in Belgium by Schumacher-Lambry (1978: pl. 4, fig. 15; pl. 5, fig. 19) are quite similar to the present material. The morphology of the antapical process is therefore presumably of some stratigraphical value – being slender in the Upper Paleocene, inflated in the Eocene.

Genus *Dracodinium* Gocht 1955 emend. Bujak et al. 1980

Dracodinium varielongitudum (Williams & Downie) Costa & Downie 1979 – *D. condylos* (Williams & Downie) Costa & Downie 1979 Group
 Pl. 6, figs. 9, 10, 12

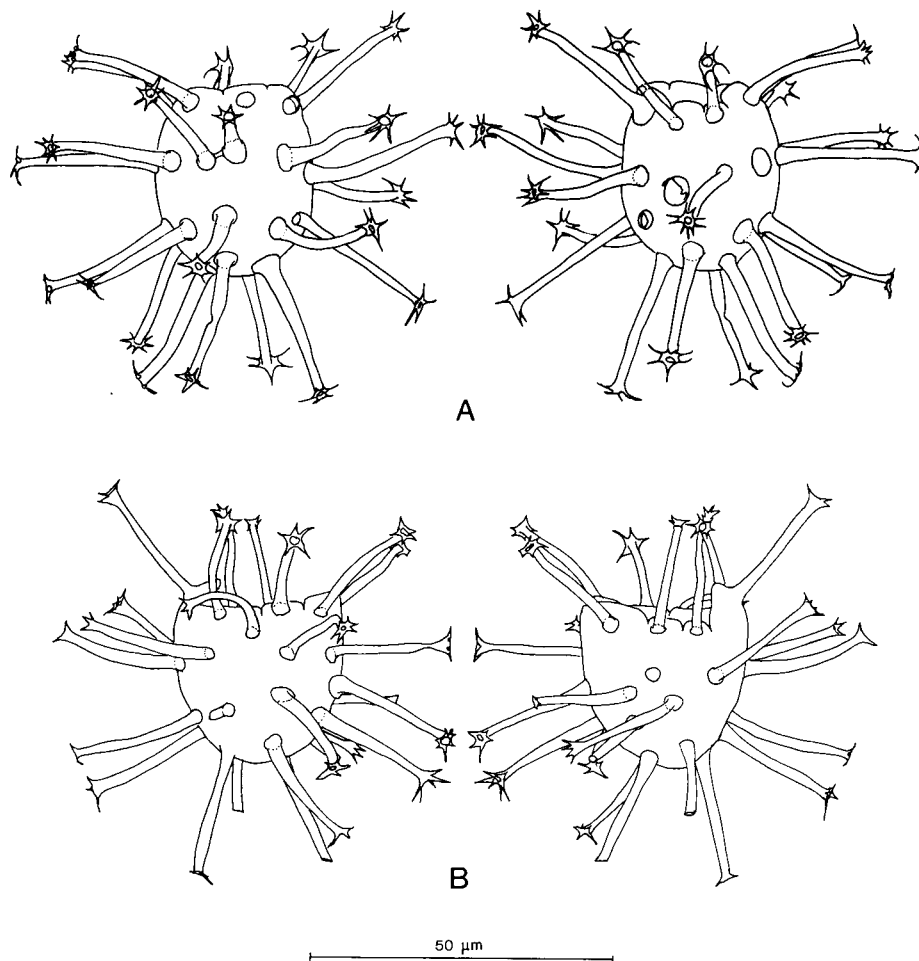
Remarks. *Dracodinium* is only present in one sample (no. 179, from the Røsnæs Clay Formation). A gradual transition exists between specimens with processes, assigned to *D. varielongitudum* (pl. 6, figs. 9, 10), and specimens with tubercles, referred to *D. condylos* (pl. 6, fig. 12).

Genus *Hystrichosphaeridium* Deflandre 1937b emend. Davey & Williams 1966b

Hystrichosphaeridium sp. 1
 Pl. 11, figs. 27, 32, 33

Remarks. Only a small number of specimens have been observed. They have an areolated surface sculpture, rather similar to that of *Alisocysta* sp. 1. *Hystrichosphaeridium* sp. 1 is distinguished from *Alisocysta* sp. 1 in having true processes similar to *Hystrichosphaeridium tubiferum* i.e. slender and tubiform processes

Fig. 8. *Hystrichosphaeridium* ? *palmatum*, camera lucida drawings. Two specimens from the Danian Limestone at Svejstrup, sample SV-1. A: specimen with 28 processes (same as Thomsen & Heilmann-Clausen 1985, pl. 4, figs. 11, 12). Note that two of the cingular processes (in the left figure) have almost fused bases, most likely representing only one paraplate. B: specimen with 27 processes (slide C1 Q35/2).



with more or less circular bases, also in the paracingulum.

Hystrichosphaeridium ? *palmatum* (White ex Bronn) Downie & Sarjeant 1965
Pl. 10, figs. 20, 21; text-fig. 8

1985: *Hystrichosphaeridium* ? *palmatum* – Thomsen & Heilmann-Clausen, pl. 4, figs. 9–14

Description. The specimens of this species, including those from the Danian Limestone at Svejstrup (Thomsen & Heilmann-Clausen 1985) have all been excysted. The archaeopyle is apical. The central body bears approximately 28 processes. The processes are slender, hollow, only gently tapering and terminate usually with 5–6 recurved spines.

The paratabulation is difficult to calculate and it seems that some plates are reflected by two processes. However, precingular, cingular and postcingular rows of processes are easily identified when specimens are favourably oriented (fig. 8). Several processes occupy the parasulcal and antapical portions of the surface.

Remarks. Due to the large number of processes that probably do not strictly reflect the tabulation, this spe-

cies should only provisionally be referred to *Hystrichosphaeridium*.

Genus *Hystrichostrogylon* Agelopoulos 1964 emend. Stover & Evitt 1978

Hystrichostrogylon coninckii Heilmann-Clausen 1985
Pl. 7, figs. 5–8

Remarks. *H. coninckii* is morphologically very similar to the Cenomanian species *Catastomocystis spinosa* Singh 1983 and is probably closely related phylogenetically to this species. The only significant difference seems to be in the position of the extra (i.e. non-archaeopyle) opening in the periphragm. In *C. spinosa* this hole is in a precisely antapical position, representing the antapical paraplate. In *H. coninckii* the opening is located mid-ventrally representing the parasulcal area (or part of it).

Genus *Impagidinium* Stover & Evitt 1978

Impagidinium sp. 1
Pl. 12, figs. 25–30

1985: *Impagidinium* sp. 1 – Thomsen & Heilmann-Clausen, pl. 6, figs. 4–6

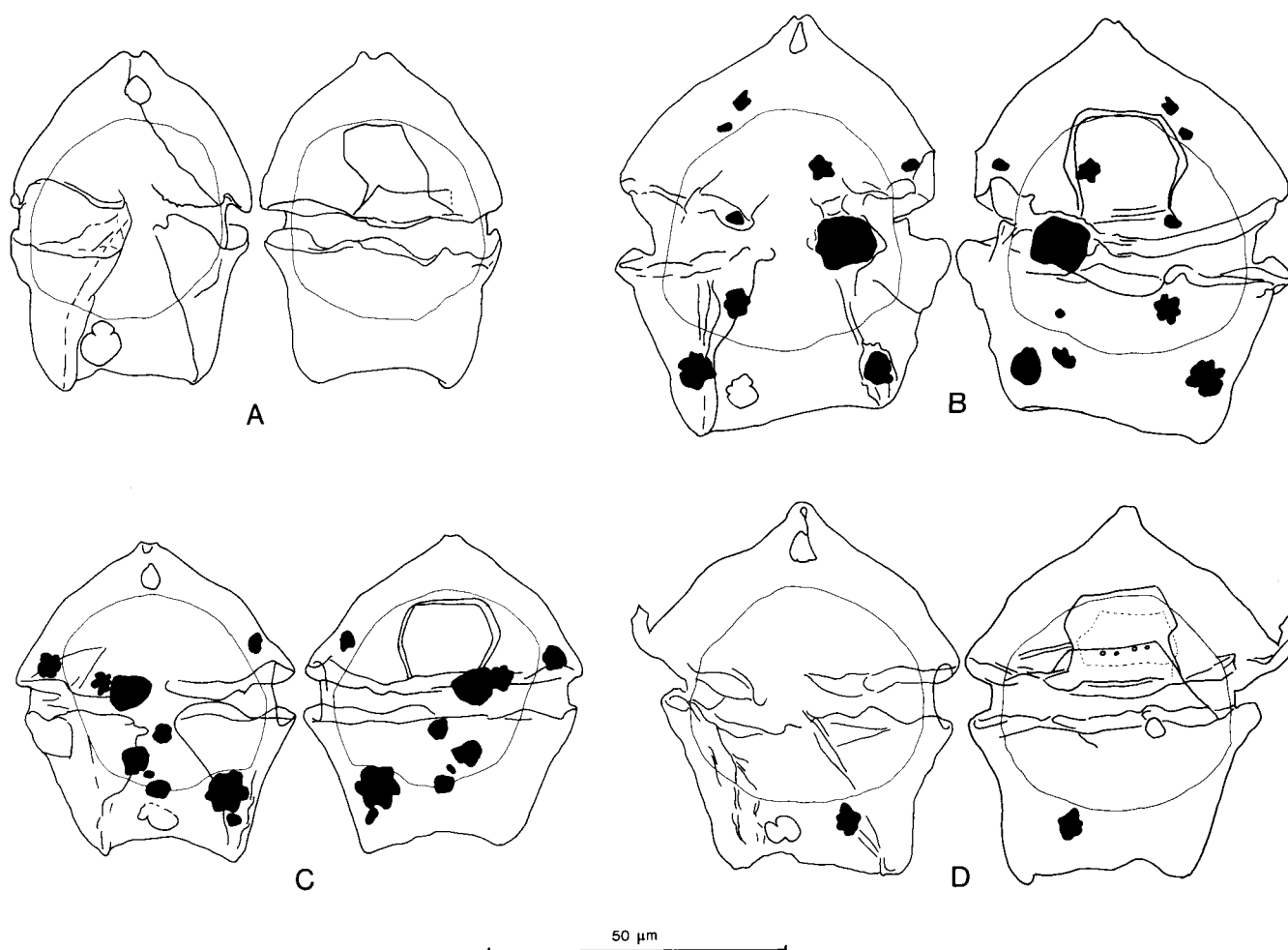


Fig. 9. *Isabelidinium ? viborgense* sp. nov., camera lucida drawings. A: holotype, sample 217 (also pl. 1, figs 24, 25). B: specimen from sample 216 (slide 19 P42/3)- MGUH 16839. C: specimen from sample 217 (also pl. 1, fig. 22). D: specimen from sample 216 (slide 18 U44/2). MGUH 16840.

Description. This is a smooth and thin-walled species of *Impagidinium*. The septa are relatively high with a smooth, or almost smooth, distal edge. The paracingulum may be very wide and the dorsal cingular paraplates may be hexagonal in shape. As typical in the genus, the paracingulum is strongly offset and paraplate 6'' is almost triangular in shape. It is often difficult to orientate and tabulate specimens of this transparent, flexible species.

Remarks. A lineage of three broadly similar species of *Impagidinium* is proposed by May (1980), involving the Upper Cretaceous species *I. cristatum* (May) Lentin & Williams 1981, the Eocene *I. victorianum* (Cookson & Eisenack) Stover & Evitt 1978 and the Neogene *I. patulum* (Wall) Stover & Evitt 1978. The three species display a gradual decrease in the expression of tabulation of the ventral surface.

Impagidinium sp. 1 is most closely comparable to *I. cristatum*, having a complete expression of sutures outside the parasulcus, and within the parasulcus a suture between paraplates ps and ms. *I. cristatum* and *Impagidinium* sp. 1 have equal size-ranges and the height of septa is the same. *Impagidinium* sp. 1 differs, however,

in having septa of equal height. In *I. cristatum* the septa are generally higher in gonal positions. Furthermore *I. cristatum* is thickwalled, the autophragm being about 2 μm thick, whereas it is less than 0.5 μm thick in *Impagidinium* sp. 1.

Genus *Isabelidinium* Lentin & Williams 1977

Isabelidinium ? viborgense sp. nov.

Pl. 1, figs. 21–25; text-fig. 9

Diagnosis. A smooth-walled, circumcavate, peridinian cyst. The pericyst-ambitus is almost pentagonal, the apical and both antapical horns being strongly reduced. Epi- and hypo-pericyst are of almost equal size. The broad and deeply depressed paracingulum gives rise to deep notches of the lateral margins of the cyst. The deep parasulcus extends to the antapical corners. The peri-archaeopyle is intercalary, or is an intercalary-precingular combination type. Two additional openings are present in the periphragm: one near the apex on the ventral surface, and an other opening is present in the posterior part of the parasulcus. The endocyst is subcircular in ambitus and thinner-walled than the pericyst.

Description. A circumcavate peridiniacean cyst.

Pericyst:

The pericyst is smooth-walled and sub-pentagonal in ambitus. The lateral margin between apex and paracingulum is convex, while the posterior margin between the strongly reduced antapical horns is concave. The apex is truncate or concave. A broad and deeply depressed, scarcely offset paracingulum is present in an equatorial position, and the epicyst and hypocyst are therefore almost equal in size. The parasulcus is broad and deep; it is mainly confined to the hypocyst, and extends to the two antapical corners. The peri-archaeopyle is either intercalary with an operculum attached at the posterior margin, type Ia(2a) (fig. 9B, C), or is a combination-archaeopyle, type IPa(2a, 4'') (fig. 9A, D). In addition to the archaeopyle two other openings are present in the periphragm (fig. 9). One opening is situated near the apex, on the ventral surface. The other is located in the posterior part of the parasulcus; it is offset to the right and often appears to be composed of two coalescent, round holes.

Endocyst:

The endocyst is thin-walled and smooth with a sub-circular ambitus. It is clearly separated from the periphragm in the ambital plane. An endo-archaeopyle is only rarely visible (fig. 9D). It appears to be a hexa I(2a) archaeopyle.

A few specimens without a detectable central body have been seen.

Dimensions

Pericyst, length, max., (mean), min.: 70, (59), 47 μm , width: 57, (48), 37 μm .

Endocyst, length: 41, (34), 27 μm , width: 41, (34), 26 μm .

(10 specimens measured). Holotype: pericyst length 58 μm , width 41 μm ; endocyst length 34 μm , width 33 μm .

Holotype. Fig. 9A; pl. 1, figs. 24, 25; slide Viborg 1-AD 217-H 20 μm 4, coordinates W 45, MGUH 16838. Type locality and type stratum: Viborg 1, grey non-calc. clay unit, Selandian (Upper Paleocene).

Remarks. In typical specimens of *Isabelidinium* the paracingulum is not distinct. The present species has a strongly developed paracingulum and is therefore only provisionally referred to *Isabelidinium*.

I. ? viborgense resembles, to some extent, *Senegalinium ? dilwynense* (Cookson & Eisenack) Stover & Evitt 1978. The latter species differs, however, in several respects: 1) the epicyst is much longer than the hypocyst, 2) a left antapical horn is well developed, 3) the endocyst is much larger, 4) the periphragm has a distinct pattern of longitudinal folds and 5) no additional openings seem to be present in the periphragm.

The possible functions of the additional openings in

the periphragm are not known. The small apical concavity probably corresponds to the position of the apical pore-platelet of the theca. The opening, which is placed ventrally and posterior to this concavity, may reflect the position of the ventral apical platelet of the theca.

Holes with a well-defined antapical or posterior-ventral position are present in widespread cavate genera, such as the peridiniacean genera *Ovoidinium* and *Angustidinium* and the gonyaulacacean genera *Sirmiodinium*, *Tubotuborella* and *Hystriosphæropsis*. Sarjeant (1974) proposed that a posterior-ventrally placed hole be termed an opisthopyle, and that the function was to release internal pressures during excystment.

Occurrence. Upper part of Kerteminde Marl and lower part of the overlying non-calcareous clay unit, Viborg 1.

Genus *Melitasphaeridium* Harland & Hill 1979

Melitasphaeridium pseudorecurvatum (Morgenroth) Bujak 1980

Pl. 10, figs. 12–16

Remarks. This species is easily identified by its constantly small size and its very thin and strictly cylindrical processes which terminate with long, gently recurved, slender spines. In favourably oriented specimens the sub-triangular shape of the archaeopyle may be seen, verifying its precingular nature.

Melitasphaeridium ? sp. 1

Pl. 10, figs. 17–19

Remarks. The specimens differ from *M. pseudorecurvatum* in the following characters: The number of processes tends to be greater, and may be as much as 45–50; the processes are wider and tapering, and are sometimes shorter than in *M. pseudorecurvatum*. The distinct aculei tend to point outwards; they are short and broad, giving the process-tip a flower-like appearance.

The archaeopyle seems to be precingular, but has not been identified with certainty; the generic assignment is therefore uncertain.

Genus *Membranosphaera* Samoilovich ex Norris & Sarjeant 1965 emend. Drugg 1967

Membranosphaera sp. B De Coninck 1975a

Pl. 12, figs. 22–24

1967: *Membranosphaera* sp. – Drugg, p. 30; pl. 5, fig. 11

1967: *Microdinium* sp. – Vozzhennikova, pl. 38, fig. 3

Remarks. The present specimens compare quite well to the description of De Coninck (1975). The paratabula-

tion may be partly visible as accessoric archaeopyle sutures, or as fine parasutural lines on the epicyst. A rather broad paracingulum may be indistinctly outlined. It is sometimes difficult to distinguish this species from *Microdinium* cf. *ornatum*. The latter, however, always has complete paratabulation and a granular wall. In *Membranospaera* sp. B the wall bears club-shaped sculptural elements, which may coalesce distally to form a thin ectophragm.

Genus *Microdinium* Cookson & Eisenack 1960 emend. Stover & Evitt 1978

Microdinium cf. *ornatum* Cookson & Eisenack 1960
Pl. 12, figs. 19–21

Remarks: The cyst-wall always bears a dense cover of small tubercles, whereas typical *M. ornatum* is smooth-walled, or only ornamented with a few scattered tubercles. No other differences from *M. ornatum* have been observed.

Genus *Muratodinium* Drugg 1970b

Muratodinium fimbriatum (Cookson & Eisenack)
Drugg 1970b
Pl. 8, figs. 7, 8

Remarks. The specimens here attributed to *M. fimbriatum* show strong morphological affinity to *Thalassiphora pelagica* (Eisenack) Eisenack & Gocht 1960.

The main difference between *M. fimbriatum* and *T. pelagica* is in the wall relationships: In *M. fimbriatum* the periphragm is appressed to the endophragm between sutural septa, especially on the dorsal surface, whereas in *T. pelagica* the walls are widely separated over most of the cyst surface. The tabulation is consequently more clearly expressed in *M. fimbriatum* than it is in *T. pelagica*.

In the present study *M. fimbriatum* includes specimens in which the periphragm seems to be in contact with the endophragm in the central parts of the paraplates.

Both *M. fimbriatum* and *T. pelagica* were found in the present study. Their ranges are discrete: *M. fimbriatum* is confined to the Ølst Formation, *T. pelagica* to the Røsnæs Clay Formation.

Genus *Palaeocystodinium* Alberti 1961

Palaeocystodinium australinum (Cookson emend. Malloy) Lentin & Williams 1976
Pl. 6, figs. 4, 5

1985: *Palaeocystodinium australinum* – Thomsen & Heilmann-Clausen, pl. 3, figs. 4–6

Remarks. The specimens of this large species from the Danish Paleocene are robust forms with a rather thick periphragm. The antapical horn may be simple (pl. 6, fig. 5, Thomsen & Heilmann-Clausen 1985: pl. 3, fig. 4), but this is a rare condition. A short spine (a rudimentary second horn) is more often present about half-way along the antapical horn. The variability of this character falls within the range shown for this species (May 1980) from Upper Cretaceous deposits in North America.

The Danish specimens differ from the Australian type material only in minor details: The periphragm is thicker, and is sometimes lined on the inner side with a blackish, crackled material. The part of the cyst containing the endocyst is more rounded; it tends to be somewhat biconical in the type material.

Palaeocystodinium lidiae (Górka) Davey 1969
Pl. 6, figs. 1–3

Description. Specimens here referred to *P. lidiae* have a finely wrinkled periphragm. In addition to this feature, a few stronger ribs or folds extend longitudinally, but somewhat irregularly over the cyst surface. The colour is usually dark brown, due to pigmentation of the periphragm. The slender and tapering apical and antapical horns are flexible and may be folded or twisted in their distal parts.

The endocyst is ellipsoidal. The endophragm, which is closely appressed against the periphragm, except at the poles, is thin and therefore often difficult to see.

The archaeopyle is intercalary, elongate hexagonal, type I(2a). It is often difficult to identify the archaeopyle, or it may appear to be absent.

Remarks. The species was emended by Davey (1969) to include a description of the archaeopyle and the central body. According to Gorka's (1963) description, *P. lidiae* has no central body, but from her illustrations it appears that the holotype is cornucavate.

As noted by Gorka (1963) *P. lidiae* closely resembles *P. ? hyperxanthum* (Vozzhennikova) Vozzhennikova 1967. This species is stated by Vozzhennikova to have no archaeopyle, and this seems to be the only difference between the two species.

Genus *Phthanoperidinium* Drugg & Loeblich 1967 emend. Edwards & Bebout 1981 et emend. Islam 1982

Phthanoperidinium crenulatum (De Coninck) Lentin & Williams 1977 emend. herein
Pl. 2, figs. 1–7; text-fig. 10

Emended description. The outline of the cyst in dorso-ventral view is rounded-pentagonal. An apical horn, and usually one or two small antapical horns, are present. Small pericoels are developed beneath horns, or

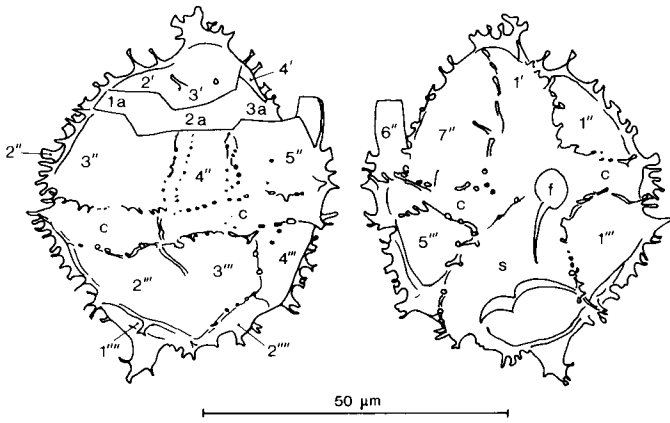


Fig. 10. *Phthanoperidinium crenulatum*. Camera lucida drawing of specimen from sample 198, also shown in pl. 2, figs. 1, 2. Note abnormal position of parasuture between 3'' and 4''. In other specimens this parasuture is more to the left, and meets the archaeopyle margin at the lateral angle of paraplate 2a. In the parasulcal area a round hole, probably the flagellar pore imprint (f), is present, in addition to rifts due to mechanical damage.

cysts may be circumcavate. The periphragm is smooth. Denticulate crests outline most paraplates. The crests are usually in a parasutural position, however, in the mid-dorsal part of the precingular series they are penitabular in some specimens (pl. 2, fig. 7; text-fig. 10) and parasutural in others (pl. 2, fig. 5). The paratabulation is 4', 3a, 7'', Xc, 5''', 2''', Xs. The paracingulum is moderately helicoidal; the parasulcus expands towards the antapex. The archaeopyle is intercalary, type 3I.

Remarks. The presence of a 3I archaeopyle was not mentioned in the original description, but is evident from the illustrations (De Coninck 1975b: pl. 17, figs. 13 (holotype) and 15). The 3I archaeopyle might also justify inclusion of this species in the genus *Ginginodinium* Cookson & Eisenack 1960. However, Edwards & Bebout (1981) expand *Phthanoperidinium* by including species with 3I archaeopyles and with intercalary-precingular combination archaeopyles. Consequently *Phthanoperidinium* and *Ginginodinium* are not well separated today. Species having parasutural sculpture have hitherto been referred to *Phthanoperidinium*. *P. crenulatum* is possibly the earliest species showing this feature. Only one Mesozoic species, the doubtful *P. ? illustrans* (O. Wetzel) Lentin & Williams 1976, may show parasutural sculpture.

Circumcavate specimens of *P. crenulatum* have only been seen in the material from the English Paleocene.

Occurrence. *P. crenulatum* is rare in Viborg 1; it is quite common in samples of units A and D of Ward (1978) from the Upper Paleocene Thanet Formation in Southern England. It is abundant in a sample from the Middle – Upper Eocene of the Wursterheide research

borehole, Northern Germany, and has been found in the Lower and Middle Eocene in Belgium and the Netherlands (De Coninck 1975b, 1977).

The patchy occurrence in time and space in the Upper Paleocene to Upper Eocene of the North Sea Basin indicates that *P. crenulatum* was probably an ecologically sensitive species.

Genus *Spinidinium* Cookson & Eisenack 1962b emend. Lentin & Williams 1976

Spinidinium cf. *clavum* Harland 1973

Pl. 1, figs. 16–20

Remarks. This species is similar to *Spinidinium clavum* in the strictly sutural arrangement of short spines and in the general shape of the cyst. A very faint central body is sometimes visible. Contrary to *S. clavum* an archaeopyle is infrequently seen (pl. 1, fig. 16). The archaeopyle is intercalary, type I(2a only).

Spinidinium densispinatum Stanley 1965 – *S. echinoideum* (Cookson & Eisenack) Lentin & Williams 1976 Group

Pl. 1, figs. 9–15

Remarks. A gradual transition exists between specimens with short spines (pl. 1, figs. 9–12), assigned to *S. densispinatum*, and specimens with long spines (pl. 1, figs. 13–15), assigned to *S. echinoideum*. The present material is therefore best treated as an informal species-group.

In many specimens the mid-dorsal precingular paraplate (4'') is incorporated in the operculum, frequently being attached at the paracingulum.

Genus *Thalassiphora* Eisenack & Gocht emend. Benedek & Gocht 1981

Thalassiphora inflata Heilmann-Clausen 1985

Pl. 7, figs. 4, 9, 12, 13

Remarks. A superficial resemblance exists between *T. inflata* Heilmann-Clausen 1985, *Gelatia inflata* Bujak 1984 and *Invertocysta tabulata* Edwards 1984. The endophragm and periphragm are partially separated in the three species, and a large opening is present in the expanded part of the periphragm. In *T. inflata* this opening is in the sulcal area, and the cyst walls are appressed in the mid-dorsal area. In *Gelatia inflata* and *Invertocysta tabulata* the cyst walls are separated in the mid-dorsal area and the large opening in the periphragm corresponds to paraplate 3''.

Group Acritarcha Evitt 1963

Subgroup uncertain

Genus *Fromea* Cookson & Eisenack 1958

Remarks. This genus is allocated with the dinoflagellates by Stover & Evitt (1978) and Lentin & Williams (1981). The proposal by Duxbury (1980), to include the genus with the acritarchs is followed here. This is based on the absence of diagnostic dinoflagellate characters. In the type species, *F. amphora*, the terminal aperture is sub-circular with a thickened rim, and therefore differs from a normal dinoflagellate archaeopyle. Furthermore, the single linear equatorial wall thickening on the holotype is apparently uninterrupted and therefore seems to differ from a dinoflagellate paracingulum.

Fromea resembles the acritarch genus *Ascostomocystis* Drugg & Loeblich 1967. The main difference between the two genera is the possession of a thin and flexible outer membrane in *Ascostomocystis*.

Fromea ? *laevigata* (Drugg) Stover & Evitt 1978
Pl. 15, figs. 1–4

Remarks. The specimens are closely comparable to the type material from the Paleocene in California. The rimmed aperture at one pole is sub-circular and frequently concave in lateral view. The tiny rimmed pores at the opposite pole, also mentioned by Drugg, are arranged in a circular pattern (pl. 15, fig. 2).

Incertae sedis 1
Pl. 15, figs. 7–10; text-fig. 11

1976: *Xenikoon australis* Cookson & Eisenack – Benson, p. 228; pl. 14, fig. 11
1977: *Incertae sedis* – Foucher & Robaszynski, pl. 7, figs. 3–7
1984: *Xenikoon australis*, Cookson & Eisenack – Edwards, Goodman & Witmer, pl. 1, fig. 6

Description. The fossil consists of a rounded – subangular body with a smooth and rigid wall. Another, smaller body, which is hemispherical in shape and thin-

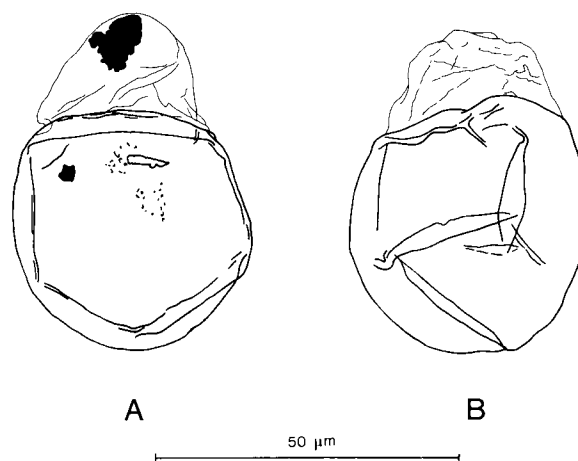


Fig. 11. *Incertae sedis* 1, camera lucida drawings. A: specimen from sample 217 (slide H 20μ5 J35). B: specimen from sample 216 (slide 18 F35/1).

ner walled, protrudes from the larger body. The folds of the surface, which are more pronounced in the thin-walled protrusion than on the main body, seem to be randomly distributed. There is no opening in the wall between the two bodies and no opening to the exterior from either body.

Remarks. The absence of an archaeopyle or tabulation probably rules out the possibility that this fossil is a dinoflagellate cyst. While Benson (1976) allocated this fossil with a dinoflagellate cyst, *Xenikoon australis* Cookson & Eisenack 1960, he noted that an archaeopyle was not observed.

Occurrence. Upper Cretaceous, and Upper? Paleocene, Maryland, and Virginia, U.S.A. (Benson 1976, Edwards et al. 1984); Upper Maastrichtian, Belgium (Foucher & Robaszynski 1977); Danian and Selandian, Viborg 1 borehole, Denmark. In Viborg 1, sample 228, this species comprises up to about 20% of the total organic-walled microplankton. The marginal-marine acritarch *Paralecaniella indentata* (Deflandre & Cookson) Cookson & Eisenack 1970b is also abundant here. Therefore *Incertae sedis* 1 may possibly also be derived from a brackish environment.

Dinoflagellate zones

The Upper Danian to Ypresian section has been subdivided into eight informal biozones as defined below.

Zone 1

(samples 227 and 228)

The upper boundary of Zone 1 is defined at the last occurrence of *Danea californica* and *Cyclapophysis monmouthensis*. *Spinidinium densispinatum* is present in the zone. A single reworked specimen of *D. californica* was found in sample 224.

Age: Danian sensu Thomsen & Heilmann-Clausen (1985), late NP4 or early NP5 nannoplankton Zone.

Zone 2

(samples 214 to 226)

Zone 2 represents the interval from the last occurrence of *Danea californica* and *Cyclapophysis monmouthensis* to the first occurrence of *Alisocysta* sp. 1. The range of *Isabelidinium ? viborgense* sp. nov. falls within this zone and the basal part of the overlying zone. *Thalassiphora delicata* occurs regularly from the upper part of Zone 2. *Palaeoperidinium pyrophorum* is common in the lower part, with a relative frequency in the samples 223, 224 and 226 of 11%, 3% and 2% respectively. In the upper part of this zone *P. pyrophorum* is rare, making up less than 1%, or is absent.

Age: Selandian.

Zone 3

(samples 203 to 213)

The lower boundary of Zone 3 is defined at the first occurrence of *Alisocysta* sp. 1. The upper boundary is placed at the last occurrence of *Palaeoperidinium pyrophorum*, *Ceratiopsis striata* and *Palaeocystodinium australinum*. (Two isolated specimens of *P. pyrophorum* found in higher levels are considered to be reworked). *Alisocysta margarita* appears close to the base, and *Diphyes colligerum* occurs consistently from the lower part of the zone. *P. pyrophorum* is very abundant near the top.

Age: Selandian.

Zone 4

samples 201 and 201A (samples 200 and 202 were barren)

The lower boundary of Zone 4 is defined at the last occurrence of *P. pyrophorum*, *Ceratiopsis striata* and *Palaeocystodinium australinum*. The upper boundary is at the first occurrence of *Apectodinium homomorphum*, *Phthanoperidinium crenulatum*, *Deflandrea oebisfeldensis* and *Lingulodinium machaeorophorum*. The assemblage in the zone is characterized by high frequencies of *Areoligera* spp. and *Glaphyrocysta ordinata*. *Deflandrea denticulata* and *Ceratiopsis medcalfii* are present in this zone.

Age: Selandian.

Zone 5

samples 193 to 198 (sample 199 was barren)

The base of Zone 5 is placed at the first occurrence of *Apectodinium homomorphum* (rare), *Phthanoperidinium crenulatum*, *Deflandrea oebisfeldensis* and *Lingulodinium machaeorophorum*. *Alisocysta* sp. 2 and *Adnatosphaeridium robustum* appear close to the base. The upper boundary is placed below a mass-occurrence of *Apectodinium homomorphum*, *A. augustum* and *A. quinquelatum*.

Age: Selandian.

Zone 6

(samples 187 to 192)

The lower boundary is placed at the first occurrence of *Apectodinium augustum*. *Apectodinium* is very abundant in the zone and usually represents more than 50% of the total organic-walled microplankton. The assemblage includes only a few other species, in particular *Glaphyrocysta divaricata*, *G. pastielsii*, *Diphyes colligerum* and *Ceratiopsis speciosa* subsp. *glabra*. Several long-ranging species, which are common below and above Zone 6, are absent, namely: *Hystrichosphaeridium tubiferum*, *Oligosphaeridium complex*, *Glaphyrocysta ordinata*, *Areoligera* spp. and *Thalassiphora delicata*. The upper boundary is placed where the frequency of the genus *Apectodinium* drops to less than 1% of the total assemblage, and where most of the

long-ranging species mentioned above are again present. Zone 6 may therefore be classified as an acme zone of *Apectodinium*, with the base of the zone additionally defined by the first occurrence of *Apectodinium augustum*.

Age: latest Paleocene and/or earliest Eocene.

Zone 7

(samples 181 to 186)

The lower boundary of the zone is placed at the point where the genus *Apectodinium* is reduced in frequency to less than 1% of the total assemblage and where most of the long-ranging species which are absent in Zone 6 returns. The upper boundary is placed at the first appearance of the genus *Wetzeliiella*. The most common species are: *Microdinium* cf. *ornatum*, *Membrano-*

sphaera sp. B De Coninck 1975a, *Glaphyrocysta ordinata*, *Hystrichoshaeridium tubiferum* and *Deflandrea oebisfeldensis*. *G. ordinata* accounts for 1–15% of the microplankton assemblage, while *D. oebisfeldensis* accounts for 2–7%.

Age: latest Paleocene and/or earliest Eocene.

Zone 8

sample 179 (samples 175 and 180 were barren)

The zone is characterized by the presence of *Achilleodinium biformoides*, *Deflandrea phosphoritica*, *Dracodinium condylos*, *D. varielongitudum*, *Eatonicysta ursulae*, *Hystrichokolpoma cinctum*, *Thalassiphora pelagica* and *Wetzeliiella meckelfeldensis*.

Age: Ypresian, NP11 nannoplankton Zone.

Discussion of zones and correlation

A correlation with deposits from localities in Denmark and various other parts of NW Europe is proposed in the correlation chart (fig. 12). The correlations are based on previously published information on dinoflagellate distribution and examination of samples by the present author.

Zone 1

A dinoflagellate zonation of the Danian Limestone from several localities has previously been established by Hansen (1977, 1979b, 1979c, 1980). The youngest of these sections (some of which included the Danian/Selandian boundary) contain *Palaeocystodinium australinum* and *Ceratiopsis striata*, which are both present also in the Danian of Viborg 1. None of Hansen's Danian sections included species of *Spinidinium*. Thomsen & Heilmann-Clausen (1985) reported the presence of *Spinidinium densispinatum* in the Danian of Viborg 1 and the Harre borehole (situated 40 km NW of Viborg 1). *S. densispinatum* occurs in the basal Selandian at several localities, and its presence at Harre and Viborg 1 indicate that the Danian Limestone at these two localities is younger than at the previously described boundary localities. This age-relationship is confirmed by the calcareous nannoplankton zonation (Thomsen & Heilmann-Clausen 1985).

Zone 2

The Selandian section at Svejstrup (Thomsen & Heilmann-Clausen 1985) probably represents most of the uncored, lowermost Selandian interval in Viborg 1. The assemblage at Svejstrup may be referred to the lower part of Zone 2. It differs from the higher levels of this zone in Viborg 1 by the presence of *Spinidinium densispinatum* (rare) in the initial layers, and by the successive peaks of *Areoligera* + *Glaphyrocysta*, *Palaeoperidinium pyrophorum*, *Palaeocystodinium australinum* and *Ceratiopsis speciosa* during the next four to five meters. *S. densispinatum* has previously been found in the basal Selandian in southern Sweden (De Coninck 1975a) and Denmark (Hansen 1980). The erratic "Turritella Sandstone", probably of basal Selandian age, from the western Baltic area includes a sparse

assemblage with, in particular, *S. densispinatum* (Andersen & Heilmann-Clausen 1984).

A few specimens of *Thalassiphora delicata* and one specimen of *Alisocysta* cf. *margarita* in the Kerteminde Marl at Svejstrup indicate that the two species occur sporadically before their regular appearances in the upper part of zone 2 and Zone 3 respectively.

The absence of *Danea californica* and *Cyclapophysis monmouthensis* at the localities discussed above (apart from a few probably reworked specimens) confirms, that the ranges of the two species are restricted to the Danian and Maastrichtian.

The Kerteminde Marl at the type locality Lundsgård Klint in eastern Fyn and sections in a more sandy marl facies at Rugård, eastern Jylland, were described by Hansen (1980). The general composition of the dinoflagellate assemblages compares well with those of the Kerteminde Marl at Svejstrup and of Zone 2 in Viborg 1. The only significant difference seems to be the presence of *Spinidinium densispinatum* in one of the Rugård sections.

The Gurnigel-Flysch in Switzerland includes a dinoflagellate assemblage (van Stuijvenberg, Morel & Jan du Chene 1976), resembling the one in the lower part of Zone 2 in Viborg 1 and in the Selandian at Svejstrup, sharing in particular the species *Ceratiopsis striata*, *Palaeoperidinium pyrophorum* and *Palaeocystodinium australinum*. The Gurnigel-Flysch is referred to the calcareous nannoplankton zone NP5 and is therefore approximately of the same age as Viborg Zone 2.

The occurrence (and local abundance) of *Isabelidium* ? *viborgense* sp. nov. in the upper part of Zone 2 seems to be a useful feature for correlation in the North Sea area.

Zone 3

The assemblages of this zone are very similar to those of Zone 2, except for the regular occurrence of *Alisocysta* in Zone 3. A prominent feature in the upper part of the zone is the high frequencies of *Palaeoperidinium pyrophorum* in several samples. (Sample 205 is almost monotypic; *P. pyrophorum* makes up 80% of the total dinoflagellates, and the number of dinoflagellates is extremely high, 770,000 specimens/gram sediment.)

An outcrop section at Østerhoved Spids, on the

VIBORG 1	DENMARK outside of Viborg area	NORTH SEA	BELGIUM	NORTHERN FRANCE	SOUTHEAST ENGLAND	WESTERN ALPS	NP ZONE IN VIBORG 1
DINO- ZONE	LITHO- UNIT						
8	Røsnæs Clay Formation	Røsnæs Clay Formation		Argile d'Ypres	Cuisian		11
no data	?				London Clay Formation		
7	Ølst Formation	Fur Form.	Balder formation				
6	Ølst Formation	Sele Formation & Forties Form., (Unit D only) (Knox et al. 1981)	Upper Landenian (Sables d'Ostende- ter-Streep) (De Coninck 1969, 1972, 1975b)	Spamacian	Woolwich Beds	Lower part of 'Association a W. homomorpha', Cres des Voirons (Jan Du Chene et al. 1975)	
5	Grey clay	?	Sables d'Erquelines, unit D (De Coninck et al. 1981)	Upper part of Sables de Bracheux (Upper part of Thanetien III)	? Thanet Forma- tion, upper part (units A-I), Herne Bay		
4	Holmehus Formation	Paleocene plas- tic clay at Albækøved and Æbelø (Heilmann- Clausen 1980)	Lower Landenian (Heersian) Marnes de Gelinden (Schumacher- Lambry 1978)		Thanet Formation, lower part, Pegwell Bay	'Association a Deflandrea speciosa', Gres des Voirons (Jan Du Chene et al. 1975)	
3	Grey clay	Grey clay at Østerhoved Spids, Æbelø, NW Fyn					
2	Kerteminde Marl	Kerteminde Marl at Lundsgård and Svejstrup. Lellingel Greensand and 'Turritella Sandstone' (Hansen 1980, Andersen & Heilmann-Clausen 1984, Thomsen & Heilmann-Ci. 1985)	?				
no data						'Association a Deflandrea striata', Flysch du Gurnigel (van Stuijvenberg et al. 1976)	5/4
1	Danian Limestone	Danian L., Harre					

Fig. 12. Correlation chart.

small island of Æbelø, off northwestern Fyn, includes a 10–12 m thick sequence of grey, silty clay with silicified layers, probably identical to the "Æbeløformation" of Bøggild 1918. The presence of *P. pyrophorum* (frequent), *Ceratiopsis striata* and *Alisocysta margarita* permits a correlation of this sequence to Viborg Zone 3. The locality is of importance, since it seems to be the only outcrop representing this stratigraphical interval.

According to L. I. Costa (written comm. 1982), the youngest acme of *P. pyrophorum* in the North Sea is found in the Upper Paleocene Lista Formation. This acme is, according to L. I. Costa, widespread and stratigraphically consistent. It is highly probable that it can be correlated with the acme of *P. pyrophorum* in Zone 3 of the Viborg 1 boring.

The last occurrence of *P. pyrophorum*, *Ceratiopsis striata* and *Palaeocystodinium australinum* in the North Sea has previously been placed at the top of the Danian

(Ioakim 1979, Knox, Morton & Harland 1981). The observations from the Lista Formation and Viborg 1 shows, that this event takes place much later.

Zone 4

This zone falls within the Holmehus Formation, which usually yields only a small number of dinoflagellates. In some localities it is completely barren of organic matter, probably due to pre-diagenetic oxidation (cf. Heilmann-Clausen et al. 1985). Only two samples yielded dinoflagellates of this zone. The assemblage in sample 201 is corroded and includes only a few species, however sample 201A contained well preserved dinoflagellates.

Productive samples from other localities of the Hol-

mehus Formation (Albækhoed, Æbelø, Holmehus and LB 38 boring) also falls in Zone 4.

The dinoflagellates in the lower part of the Thanet Formation (Pegwell Bay section, southeast England) have been examined briefly. The assemblage is fairly similar to that of Viborg Zone 4, and the two sequences can probably be correlated.

The stratotype of the "Heersian Stage" or Lower Landenian, the marls of Gelinden, Belgium, seems to correspond to Zone 4. The dinoflagellates have been described by Schumacher-Lambry & Chateaneuf (1976), and more in detail by Schumacher-Lambry (1978). The assemblages include *Alisocysta margarita*, *Ceratiopsis* cf. *medcalfii* (as *D. speciosa*) and *Conneximura fimbriata*, but exclude the index species of Viborg Zone 3, *P. pyrophorum* and *C. striata*, and also exclude *Apectodinium homomorphum* appearing in Viborg Zone 5.

Zone 5

Apectodinium is rare in Zone 5, and makes up less than one percent of the total assemblage. From the base of Zone 6, however, a strong proliferation of *Apectodinium* takes place.

A similar distributional pattern, comprising a lower interval with rare *Apectodinium*, followed by an overlying zone with mass-occurrence of this genus has previously been described from the Paleocene of France and Belgium, and is summarized below.

The first occurrence of *Apectodinium* is distinctly earlier in the Alpine area than in the North Sea Basin. Jan du Chene, Gorin & van Stuijvenberg (1975, figs. 7, 8, 10) showed the presence of *Apectodinium* in samples of NP6, 7 and 8 age in the Alpine Flysch of Eastern France. A massive appearance of the genus follows higher in the sequence.

In northern France *A. homomorphum* appears in the upper part of "Thanetian III" (Sables de Bracheux) (Gruas-Cavagnetto 1976a, 1976b, Chateaneuf & Gruas-Cavagnetto 1978). The Sables de Bracheux appear to be no older than the NP9 Zone (Curry, Adams, Boulter et al. 1978: 40). *Apectodinium* becomes more frequent towards the overlying Sparnacian deposits.

From Belgium an assemblage with rare *Apectodinium homomorphum* has been described by De Coninck, De Deckler, de Heinzelin & Willems (1981) from the Sables d'Erquelinnes. The similarity with Zone 5 is emphasized by the presence of *Adnatosphaeridium robustum*, *Deflandrea oebisfeldensis* and probably also *Alisocysta* sp. 2 (recorded as *Alisocysta margarita*?). This locality is of importance, since it yields a calcareous nannoplankton assemblage definitely belonging in the NP9 Zone (De Coninck et al. 1981).

The upper part of the Thanet Formation (units A – I of Ward 1978), exposed at Herne Bay, southeastern

England, has been examined. It includes *Phthanoperidinium crenulatum*, which is quite frequent in units A and D, and possibly indicates contemporaneity of these deposits with Viborg Zone 5. A difference, however, is the absence of *Apectodinium* until the uppermost unit.

Zone 6

This zone is invariably present in the lower, laminated and almost ash-free part of the Ølst Formation, and in the equivalent, basal part of the Fur Formation where the *Apectodinium* acme is previously described by Hansen (1979a) and Heilmann-Clausen et al. (1985). A similar zone with abundant *Apectodinium* and sometimes even monotypic assemblages is widely distributed in northwestern Europe. Well known formations with a similar association are: the Woolwich Beds of southeast England (Downie, Hussain & Williams 1971, Costa & Downie 1976), the Upper Landenian Sables d'Ostende-ter-Streep in Belgium (De Coninck 1969, 1972, 1975b), the Sparnacian deposits of the Paris Basin (Gruas-Cavagnetto 1976a, 1976b, Chateaneuf & Gruas-Cavagnetto 1978) and most of the Forties Formation (Unit D) and the lower part of the Sele Formation in the North Sea (Knox & Harland 1979, Knox et al. 1981).

The Woolwich Beds and the Belgian and French deposits with this association are of estuarine and lagoonal origin, and Downie et al. (1971) suggested that their restricted dinoflagellate associations could be used as an indicator of estuarine environment. The occurrence of similar associations in clearly offshore deposits in the North Sea and Denmark may therefore point to a lowered salinity in the whole North Sea (Knox et al. 1981). The fine lamination and the complete lack of benthonic fossils indicate that bottom waters were anoxic (Bonde 1966, Pedersen 1981). A stratified water body with surface water of low salinity seems to be a likely model for the North Sea during this period, as it permits the combination of a stagnant bottom environment and a rich planktonic life in the surface waters.

A zone with frequent *Apectodinium* in the central and southwest Europe seems to be simultaneous, at least in part, with Viborg Zone 6. This is the "association a *W. homomorpha*" in the alpine flysch (Jan du Chene et al. 1975, Jan du Chene 1977) and a similar zone in the section at Campo in the Pyrenees (Caro 1973, Caro, Luterbacher, Perch-Nielsen et al. 1975). A correlation with the nannoplankton zones at these localities shows, that the base of the zone with frequent *Apectodinium* is in the lower part of NP9 in the Alps and in the uppermost part of NP8 in the Pyrenees.

Zone 7

This zone is rather similar to Zone 5, but can be distinguished by the abundance of *Glaphyrocysta ordinata* and the absence of *Ceratiopsis speciosa* subsp. *glabra* and *Areoligera* spp.

Assemblages with abundant *G. ordinata* and often also frequent *Deflandrea oebisfeldensis* have previously been described from the Fur Formation and upper part of the Ølst Formation at outcrops by Hansen (1979a) and Heilmann-Clausen et al. (1985). Knox & Harland (1979) compared the assemblage in the Mo Clay (i.e. Fur Formation), in the "ash series" of the North Sea, and in the ash bearing London Clay at Harwich, eastern England and pointed out the abundance of *Deflandrea oebisfeldensis* in this interval.

Also the zone based on frequent *G. ordinata* established by Ioakim (1979) in the North Sea is, at least partially, identical to Viborg Zone 7. The similarity is emphasized by the almost entire absence of *Apectodinium*.

Assemblages corresponding to Viborg Zone 7 are absent in Belgium and northern France, apparently due to a stratigraphical hiatus at the base of the Argile d'Ypres and equivalent strata (e.g. in the Kallo borehole in Belgium, in which the dinoflagellates have been described in detail by De Coninck 1969, 1972, 1975b). The same hiatus is present at the base of the London Clay in southeast England (Knox & Harland 1979, Knox, Harland & King 1983).

Zone 8

The assemblage in sample 179 is very diverse and includes a large number of species not present in lower levels. Only the stratigraphically most important species have been included in the range chart. Similar assemblages are known from the Røsnæs Clay Formation at other localities, and several of the species also appear in the London Clay (Costa & Downie 1976, Bujak, et al. 1980), the Argile d'Ypres (De Coninck 1969, 1975b) and the Cuisian deposits of the Paris Basin (Chateauneuf & Gruas-Cavagnetto 1978).

The successive appearances of *Wetzeliella astra*, *W. meckelfeldensis* and *Eatonicysta ursulae* take place in the Knudshoved Member (basal Røsnæs Clay Formation) at Fur, northern Jylland. A hiatus, or a condensed sequence is developed at this level at other Danish localities (Heilmann-Clausen et al. 1985). This is probably also the case in Viborg 1, judging from the lithology in this interval. Unfortunately the spacing of the available samples is not fine enough to establish the biostratigraphical extension of a hiatus at the Ølst Formation/Røsnæs Clay Formation boundary in Viborg 1.

Comparison with Paleogene dinoflagellate zonations, NW Europe

During the last 10–15 years a considerable number of dinoflagellate zonation schemes have been proposed for various parts of north-western Europe, in particular for the North Sea Basin. In order to facilitate a comparison of the relative ages of the various zones (which are often used as biostratigraphical references in the geological literature), and to show the position of the Viborg zones relatively to other zonations, the various schemes are tentatively correlated in fig. 13.

It should be stressed, that difficulties are encountered in the determination of the relative time-stratigraphical position of the zones. This is due to the evidently different stratigraphical ranges of a number of dinoflagellate species over north-western Europe (e.g. *Apectodinium homomorphum*, as discussed above). Newer studies (e.g. Williams 1971, Wall et al. 1977, Harland 1983 and Dale 1983) show that many recent cyst-producing dinoflagellates are closely associated with specific marine water masses. During the Paleogene, the complex paleogeographic evolution in NW Europe gave rise to an ever-changing mosaic-like pattern of marine and brackish environments. Specific dinoflagellate cyst associations therefore have been present locally at quite different times, and long-distance correlation, especially when based on a limited number of species, should therefore be considered with caution. Good control of the age of the dinoflagellate zones by stratigraphically better established fossil groups, like calcareous nannoplankton and planktonic foraminifera, is only available for a limited part of the sequences, due to unfavourable facies or poor preservation in the deposits. An exception is in particular the Pyrenees (Caro 1973, Caro et al. 1975), the western Alps (Jan du Chene et al. 1975, van Stuijvenberg et al. 1976) and the Rockall Plateau (Costa & Müller 1978, Morton et al. 1983), where correlations to calcareous nannoplankton zones (in the Pyrenees also to planktonic foraminifera) are well established.

Some zone-boundaries were originally defined in incomplete sections and are coincident with stratigraphical hiatus. Subsequent studies of sections in areas with a more complete sedimentation in some cases have led to inclusion of younger strata than was originally proposed. In fig. 13 the position of the original sections is shown with thick vertical lines, for zones that have been extended. These cases are explained below.

The zonation of the Danian from Denmark (Hansen 1977) was established in truncated sections of the Danian Limestone, not including time-equivalents of the younger Danian in the Viborg 1 borehole (Viborg Zone 1), as discussed above. The *Danea mutabilis* Zone of Hansen (1977) is defined by the presence of *Danea californica* (Previously also named *D. mutabilis*)

AGE	NP ZONES	VIBORG 1 this study	DENMARK Hansen 1977	NW EUROPE Costa & Downie 1976 Costa et al. 1978	SOUTHERN ENGLAND Bujak et al. 1980	NORTH SEA Knox & Harland 1979 Knox et al. 1981 Knox & Morton 1983	NORTH SEA Jacqué & Thouvenin 1975	NORTH SEA Isakim 1979	ROCKALL PLATEAU Costa & Downie 1979 Costa & Müller 1978	PARIS BASIN Chateaufort & Cruas Cavagnetto 1978	WESTERN APLS Jan Du Chene et al. 1975; van Stuijven- berg et al. 1976	PYRENEES Caro 1973 Caro et al. 1975
YPRESIAN (PARS)	12			Wetzelia coleothrypa Zone	Kisselovia reticulata Assemblage Zone (LC-3)			Zone á Kisselovia edwardsii et Membranilarnacia ursulae	II	Zone á Kisselovia coleothrypa	Association á Wetzelia coleothrypa	Zone á Wetzelia coleothrypa
	11	8		W. varilongituda Zone	Membranilarnacia ursulae Zone (LC-2)		nt 2 b		I b	Zone á Dracodinium varilongituda Zone á Dracodini- similis		Zone á Wetzelia unicaudata
	10?	no data		W. meckelfeld. Zone	Dell. phosphor. Ass. Zone (LC-1)				I a 1	Zone á Wetzelia meckelfeldensis		Zone á Wetzelia articulata
	10-9?	7		W. astra Zone		acme of Delland. oebis- feldensis.	upper nt 2 a	Zone á Cyclonephelium ordinatum		Zone á W. astra	Association á Wetzelia homomorpha	unzoned interval
		6		Wetzelia hyperacantha Zone		Apectodinium hyperacanthum Zone	middle nt 2 a	Zone á Apectodinium hyperacanthum	I a	Zone á Apectodinium homomorphum		Zone á Wetzelia hyperacantha
	9?	5					lower nt 2 a	?				
		4										
		3				Alisocysta nargarita informal zone	nt 1 b	Zone á Dellandrea speciosa			Association á Dellandrea speciosa	Zone á Dellandrea speciosa
	8-5?						?					
	5 or 4	no data										
		1										
SELANDIAN												
THANETIAN												
DANIAN												
Sensu Thomsen & Heilmann-Clausen 1985												

Fig. 13. Compilation of dinoflagellate zonations in the Lower Paleogene of north-western Europe. Heavy vertical lines indicate extension of sections originally included in the zones (see text for further explanation). Calcareous nannoplankton zones (NP Zones) which have not been identified in the Viborg 1 borehole are shown with a questionmark.

and has therefore been expanded to include in its upper part Viborg Zone 1, where *D. californica* is also present.

Similarly, the *Wetzelietta hyperacantha* Zone of Costa & Downie (1976) was based on sections in marginal areas of the North Sea Basin, and the upper boundary coincides with a hiatus (cf. Costa et al. 1978, fig. 1, and this study fig. 12), above which follows the *W. astra* Zone. In more complete sections of the North Sea Knox & Harland (1979) described the *Deflandrea oebisfeldensis* acme in the Balder Formation, which is coincident with the hiatus mentioned above. The *W. hyperacantha* Zone is defined from the first occurrence of the genus *Apectodinium* to the first occurrence of *Wetzelietta astra*. Since the *D. oebisfeldensis* acme is above strata with *Apectodinium* and beneath strata with *W. astra*, Knox & Harland (1979) expanded the *W. hyperacantha* Zone upwards to include in its upper part the *D. oebisfeldensis* acme.

Four zonal schemes (Costa & Downie 1976, Knox et al. 1981, Ioakim 1979 and probably also Jacqu   & Thouvenin 1975) include a lowermost zone characterized by the presence of *Palaeoperidinium pyrophorum*, *Palaeocystodinium australinum* and *Ceratiopsis striata*, or one of these species. The top of the zones were in all four cases suggested to correspond approximately to the Danian–Thanetian boundary. In Viborg 1 the essential disappearance of these three species is at the top of Zone 3 which is at a considerably younger stratigraphical level. There is little doubt, however, that the disappearance of the three species took place simultaneously over the North Sea, and the four zonal tops have therefore been correlated to the top of Viborg Zone 3 in fig. 13. It is uncertain, whether the original correlation to the Danian is due to truncations in the sections originally studied or due to a lack of precise age-determinations in the youngest part of these zones.

Stratigraphical conclusion

The studied interval of the Viborg 1 borehole appears to be an almost continuous sequence of Danian to Ypresian sediments in an offshore facies closely comparable to much of the North Sea sequence. At most levels it contains well preserved dinoflagellate assemblages. The successive assemblages permit the introduction of a relatively detailed zonation which seems to be applicable not only in Denmark, but also in equivalent strata of the North Sea.

The Viborg 1 section, together with the section at Svejstrup documents a marked change in assemblages (albeit only few species disappear or appear) at the Danian–Selandian boundary even where only a minor hiatus is present.

The simultaneous disappearance of *Palaeocystodi-*

nium australinum, *Ceratiopsis striata* and essentially also of *Palaeoperidinium pyrophorum* takes place well above the Danian and seems to be an easily recognized event throughout the North Sea.

Higher in the sequence an episode with rare *Apectodinium homomorphum* is documented to precede the acme and morphologic proliferation of this genus. The *Apectodinium* acme itself precisely coincides with the most anoxic, basal part of the Ølst Formation.

Finally it is shown that a suite of genera and species well known in younger Eocene strata (including *Wetzeliiella*, *Dracodinium*, *Eatonicysta ursulae*, *Hystricholpoma cinctum* and *Achilleodinium bififormoides*) first appear in the Røsnæs Clay Formation.

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(All references to dinocysts mentioned in the text, but not listed below are to be found in Lentin & Williams 1981)

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Plates

Photographed specimens are localized in the slides with “England Finder” coordinates. For location of specimens with the “England Finder”, the following procedure must be followed: Align right edge of specimen-slides with right edge of “England Finder”, and also align specimen-slides with the upper edge of “England Finder”. The right edge of a specimen-slide is defined as the edge, towards which the top of letters and figures in labels point.

PLATE 1

Magnifications: $\times 500$.

- Fig. 1. *Alterbia circula* sp. nov., holotype. Sample 228, slide 10: L 46. MGUH 16829.
- Fig. 2. Same specimen as fig. 1.
- Fig. 3. *Alterbia circula* sp. nov. Sample 228, slide 10: J 30. MGUH 16830.
- Fig. 4. Same specimen as fig. 3.
- Fig. 5. *Alterbia circula* sp. nov. Sample 228, slide 8: Y 43. MGUH 16831.
- Fig. 6. *Alterbia circula* sp. nov. Sample 228, slide 10: J 45. MGUH 16832.
- Fig. 7. *Alterbia circula* sp. nov. Sample 228, slide 8: P 44. MGUH 16833.
- Fig. 8. *Alterbia circula* sp. nov. Sample 228, slide 10: J 33. MGUH 16834.
- Fig. 9. *Spinidinium densispinatum* Stanley. Sample 228, slide 11: W 40.
- Fig. 10. *Spinidinium densispinatum* Stanley. Sample 228, slide 7: J 44.
- Fig. 11. *Spinidinium densispinatum* Stanley. Sample 228, slide 7: S 35.
- Fig. 12. *Spinidinium densispinatum* Stanley. Sample 228, slide 11: X 31.
- Fig. 13. *Spinidinium echinoideum* (Cookson & Eisenack) Lentin & Williams. Sample 228, slide 10: K 31.
- Fig. 14. *Spinidinium echinoideum* (Cookson & Eisenack) Lentin & Williams. Sample 228, slide 7: G 42.
- Fig. 15. *Spinidinium echinoideum* (Cookson & Eisenack) Lentin & Williams. Sample 228, slide 10: N 29.
- Fig. 16. *Spinidinium* cf. *clavum* Harland. Dorsal focus showing archaeopyle. Sample 228, slide 10: R 32.
- Fig. 17. Same specimen as fig. 16. Ventral focus.
- Fig. 18. *Spinidinium* cf. *clavum* Harland. Sample 228, slide 10: M 47.
- Fig. 19. *Spinidinium* cf. *clavum* Harland. Sample 228, slide 10: K 28.
- Fig. 20. *Spinidinium* cf. *clavum* Harland. Sample 227, slide 18: H 31.
- Fig. 21. *Isabelidinium* ? *viborgense* sp. nov. Sample 217, slide H 20 μ 4: N 48. MGUH 16835.
- Fig. 22. *Isabelidinium* ? *viborgense* sp. nov. Sample 217, slide H 20 μ 1: F 42. MGUH 16836.
- Fig. 23. *Isabelidinium* ? *viborgense* sp. nov. Sample 217, slide H 20 μ 4: O 35. MGUH 16837.
- Fig. 24. *Isabelidinium* ? *viborgense* sp. nov., holotype. Sample 217, slide H 20 μ 4: W 45. MGUH 16838.
- Fig. 25. Same specimen as fig. 24.

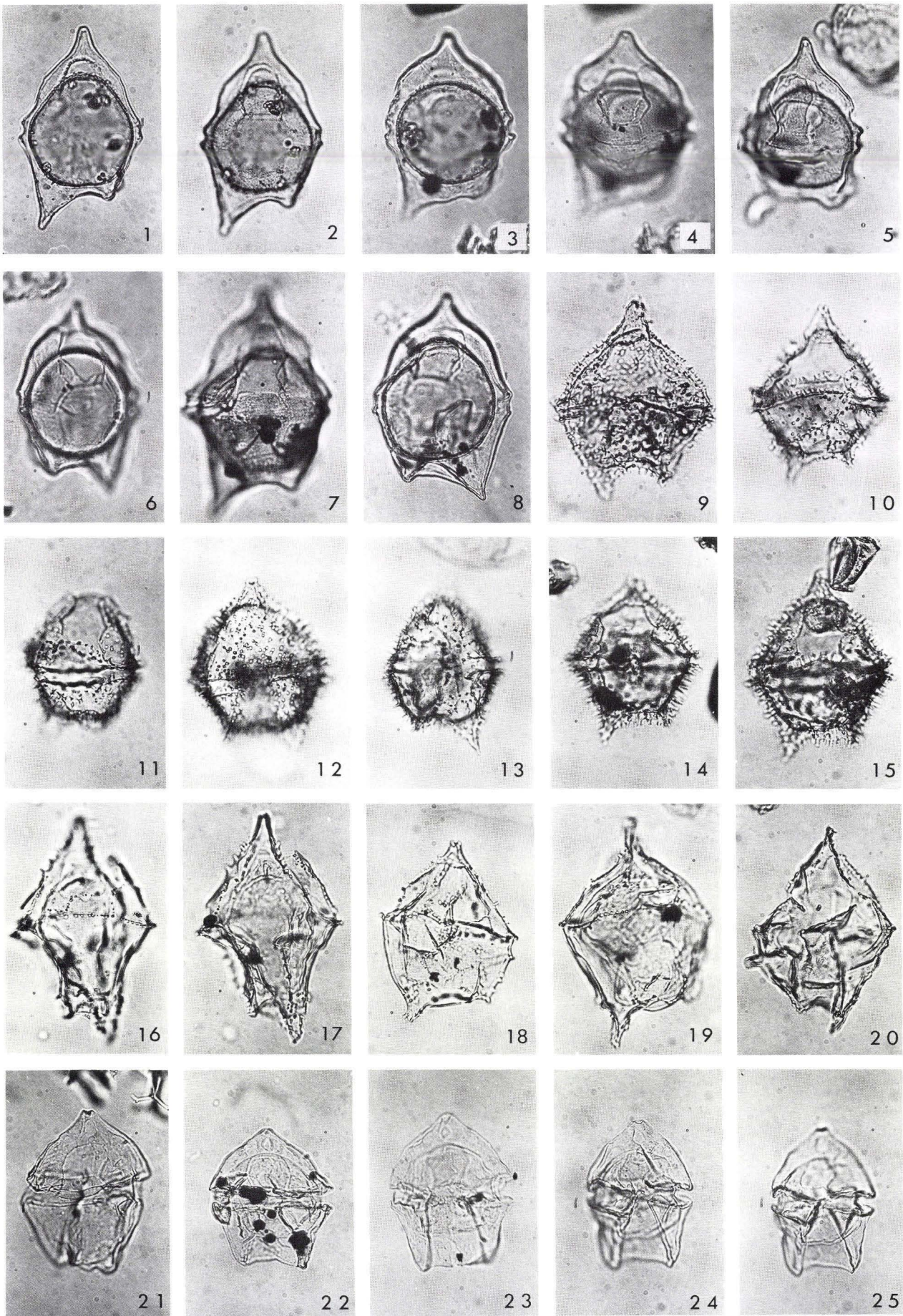


PLATE 2

Magnifications: $\times 500$.

- Fig. 1. *Phthanoperidinium crenulatum* (De Coninck) Lentin & Williams. Dorsal focus. Sample 198, slide H 10 μ 5: F 22.
Fig. 2. Same specimen as fig. 1. Ventral focus.
Fig. 3. *Phthanoperidinium crenulatum* (De Coninck) Lentin & Williams. Dorsal focus. Sample 196, slide H 20 μ 7: V 36.
Fig. 4. Same specimen as fig. 3. Ventral focus.
Fig. 5. *Phthanoperidinium crenulatum* (De Coninck) Lentin & Williams. Sample 198, slide H 10 μ 4: W 40.
Fig. 6. *Phthanoperidinium crenulatum* (De Coninck) Lentin & Williams. Oblique apical view. Sample 197, slide 27: V 40.
Fig. 7. *Phthanoperidinium crenulatum* (De Coninck) Lentin & Williams. Specimen from Thanet Formation, unit A, Herne Bay. Sample 550, slide E 20 μ 2: T 24.
Fig. 8. *Ceratiopsis depressa* (Morgenroth) Lentin & Williams. Sample 184, slide E 20 μ 5: T 39.
Fig. 9. *Ceratiopsis depressa* (Morgenroth) Lentin & Williams. Sample 182, slide E 20 μ 2: Q 42.
Fig. 10. *Ceratiopsis depressa* (Morgenroth) Lentin & Williams. Sample 183, slide 20 μ 1: P 33.
Fig. 11. *Ceratiopsis diebelii* (Alberti) Vozzhennikova. Sample 215, slide H 20 μ 3: R 29.
Fig. 12. *Ceratiopsis speciosa* subsp. *speciosa* (Alberti) Lentin & Williams. Sample 207, slide E 20 μ 5: L 26.
Fig. 13. *Ceratiopsis striata* (Drugg) Lentin & Williams. Sample 221, slide 17: M 29.
Fig. 14. *Ceratiopsis striata* (Drugg) Lentin & Williams. Sample 205, slide E 20 μ 2: H 34.
Fig. 15. *Ceratiopsis diebelii* (Alberti) Vozzhennikova. Sample 228, slide 7: S 27.
Fig. 16. *Ceratiopsis speciosa* subsp. *speciosa* (Alberti) Lentin & Williams. Sample 225, slide 18: U 38.
Fig. 17. *Ceratiopsis striata* (Drugg) Lentin & Williams. Sample 228, slide 7: E 43.
Fig. 18. *Ceratiopsis striata* (Drugg) Lentin & Williams. Sample 222, slide H 10 μ 3: R 42.

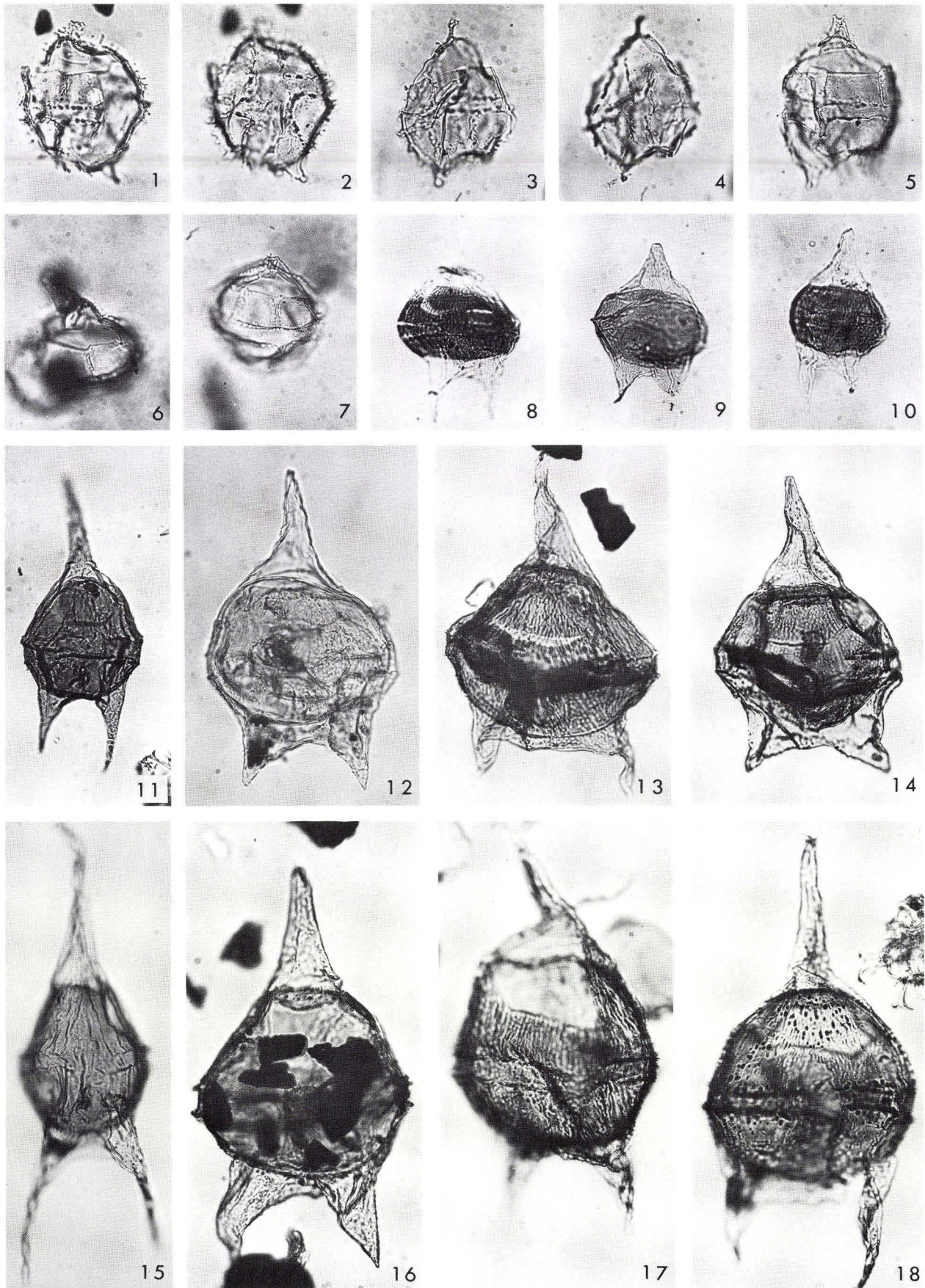


PLATE 3

Magnifications: $\times 500$.

- Fig. 1. *Deflandrea denticulata* Alberti. Sample 201 A, slide E 10μ 2: S 23.
Fig. 2. *Deflandrea denticulata* Alberti. Sample 201 A, slide J 10μ 1: S 46.
Fig. 3. *Deflandrea denticulata* Alberti. Sample 179, slide F 10μ 7: K 36.
Fig. 4. *Ceratiopsis medcalfii* (Stover) comb. nov. Sample 201 A, slide 1: S 29.
Fig. 5. *Ceratiopsis medcalfii* (Stover) comb. nov. Sample 201 A, slide 2: J 31.
Fig. 6. *Ceratiopsis medcalfii* (Stover) comb. nov. Sample 201 A, slide 3: W 31.
Fig. 7. *Ceratiopsis speciosa* subsp. *glabra* (Gocht) Lentin & Williams. Sample 195, slide H 20μ 6: F 32.
Fig. 8. *Ceratiopsis speciosa* subsp. *glabra* (Gocht) Lentin & Williams. Sample 196, slide H 20μ 5: J 44.
Fig. 9. *Ceratiopsis speciosa* subsp. *glabra* (Gocht) Lentin & Williams. Sample 197, slide G 20μ 2: N 47.
Fig. 10. *Ceratiopsis speciosa* subsp. *glabra* (Gocht) Lentin & Williams. Sample 192, slide E 20μ 5: M 23.

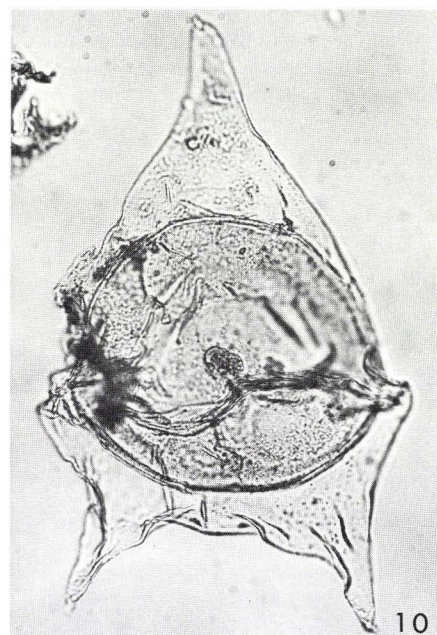
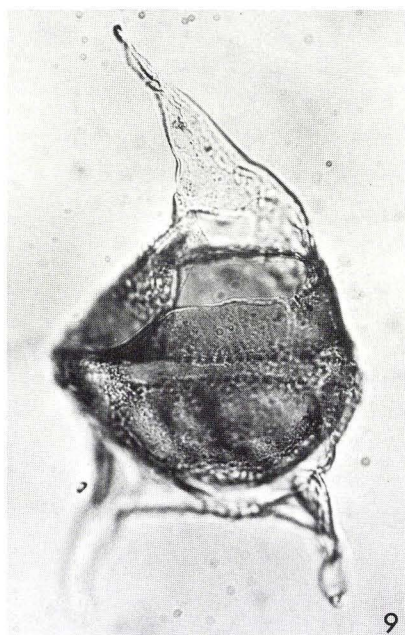
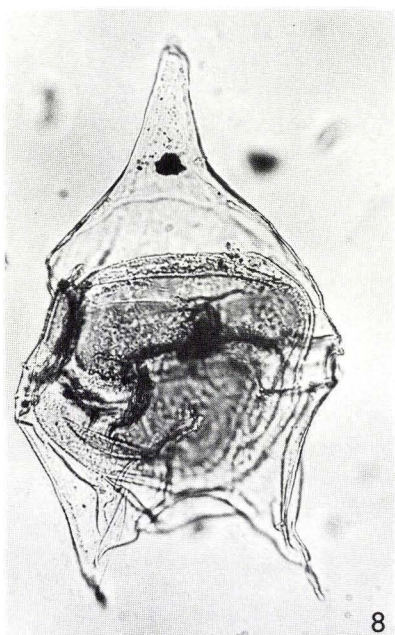
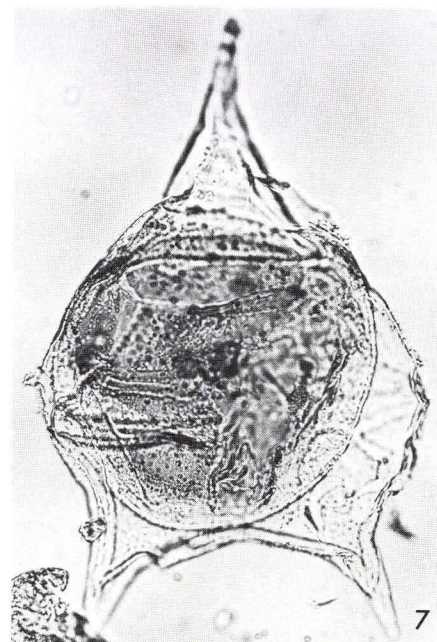
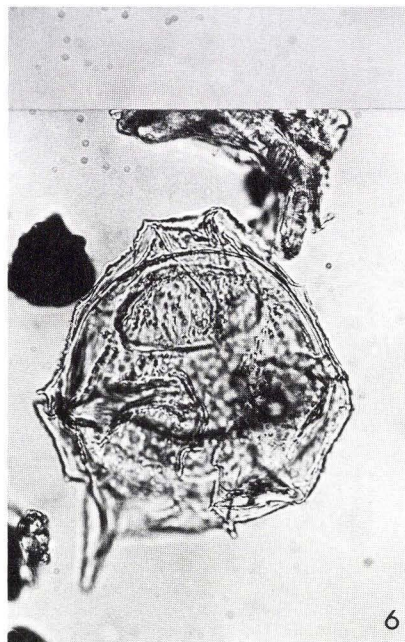
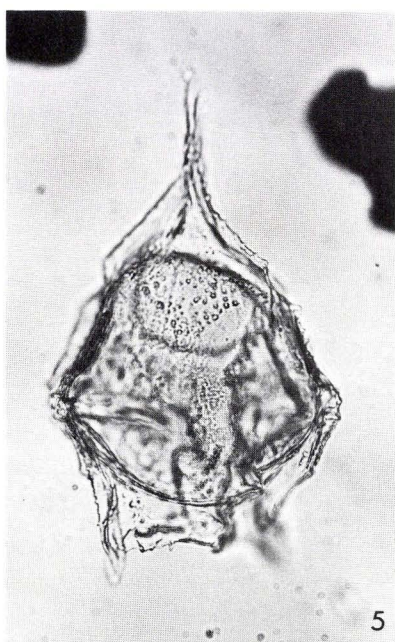
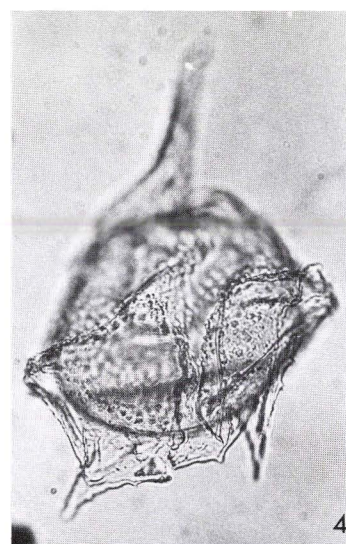
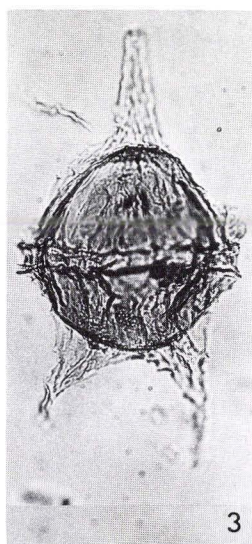
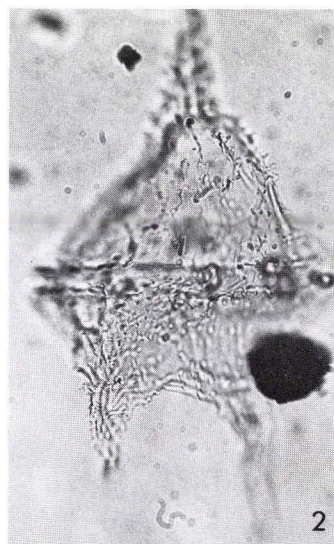
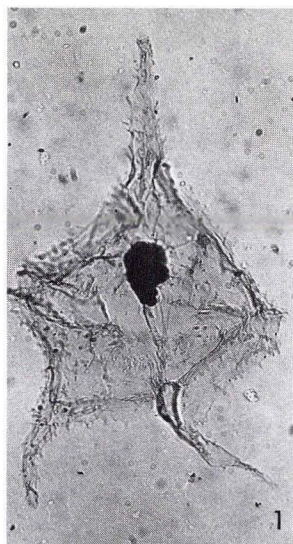


PLATE 4

Magnifications: $\times 500$.

- Fig. 1. *Deflandrea oebisfeldensis* Alberti. Sample 197, slide 25, H 33.
Fig. 2. *Deflandrea oebisfeldensis* Alberti. Sample 196, slide H 20μ 1: V 24.
Fig. 3. *Deflandrea oebisfeldensis* Alberti. Sample 194, H 20μ 3: V 39.
Fig. 4. *Deflandrea oebisfeldensis* Alberti. Sample 186, slide F 20μ 4: K 38.
Fig. 5. *Deflandrea oebisfeldensis* Alberti. Sample 182, slide E 20μ 5: U 39.
Fig. 6. *Deflandrea oebisfeldensis* Alberti. Sample 181, slide F 20μ 3: S 27.
Fig. 7. *Deflandrea phosphoritica* Eisenack. Sample 179, slide F 10μ 4: V 47.
Fig. 8. *Deflandrea phosphoritica* Eisenack. Samples 179, slide F 10μ 4: G 52.
Fig. 9. *Deflandrea phosphoritica* Eisenack. Sample 179, slide F 10μ 7: R 21.

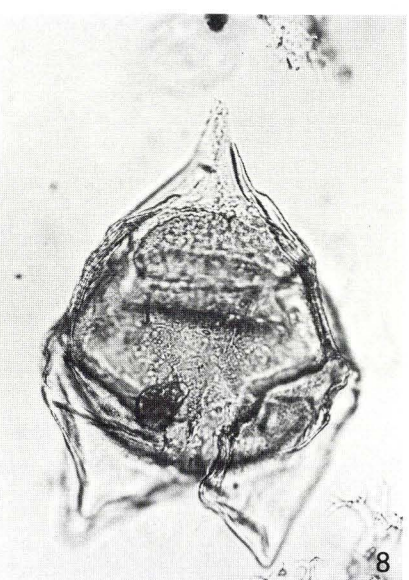
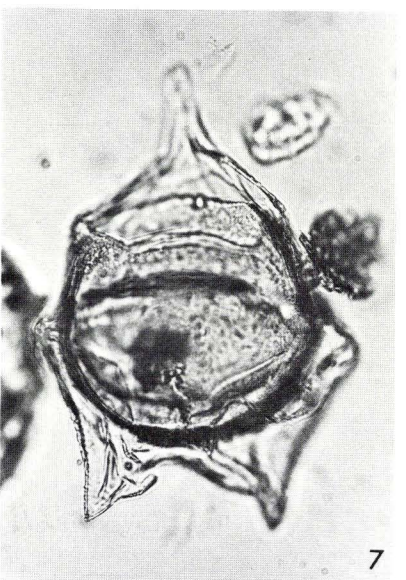
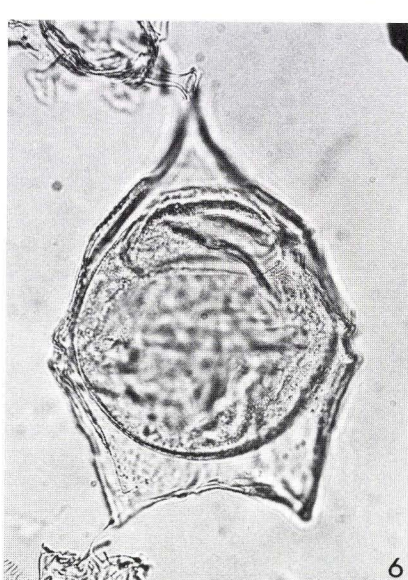
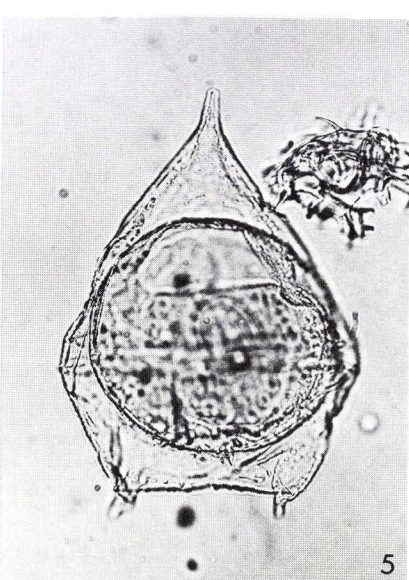
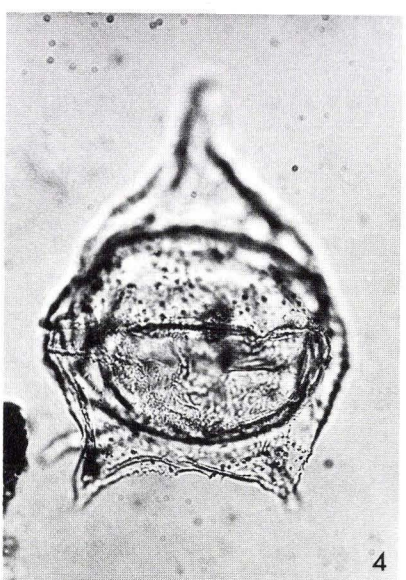
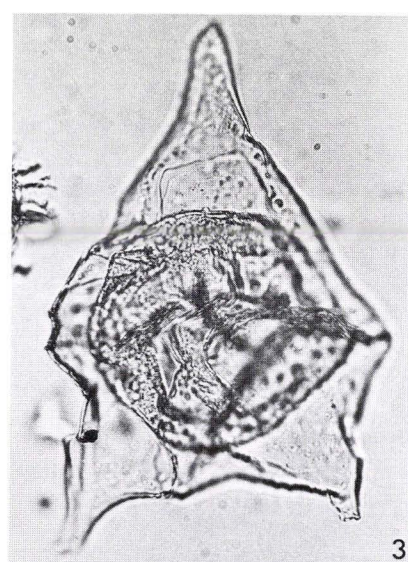
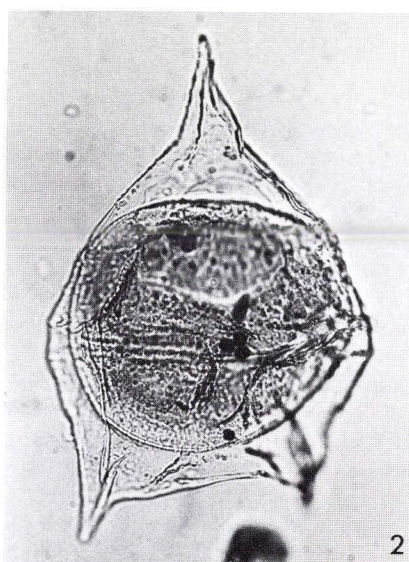
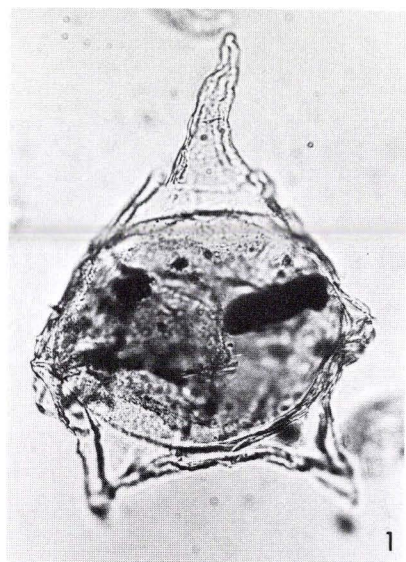


PLATE 5

Magnifications: $\times 500$.

- Fig. 1. *Palaeotetradinium minusculum* (Alberti) Stover & Evitt. Sample 228, slide 8: W 47.
Fig. 2. *Palaeotetradinium minusculum* (Alberti) Stover & Evitt. Sample 227, slide 20: G 44.
Fig. 3. *Palaeotetradinium minusculum* (Alberti) Stover & Evitt. Sample 227, slide 20: Q 53.
Fig. 4. *Palaeotetradinium minusculum* (Alberti) Stover & Evitt. Sample 216, slide 15: P 35.
Fig. 5. *Palaeotetradinium minusculum* (Alberti) Stover & Evitt. Sample 182, slide E 20 μ 3: R 31.
Fig. 6. *Apectodinium augustum* (Harland) Lentin & Williams. Sample 188, slide E 20 μ 3: J 42.
Fig. 7. *Apectodinium augustum* (Harland) Lentin & Williams. Sample 192, slide E 20 μ 8: G 36.
Fig. 8. *Apectodinium homomorphum* (Deflandre & Cookson) Lentin & Williams emend. Harland.
Sample 190, slide F 20 μ 7: W 40.
Fig. 9. *Apectodinium homomorphum* (Deflandre & Cookson) Lentin & Williams emend. Harland.
Sample 192, slide E 20 μ 8: K 18.
Fig. 10. *Apectodinium homomorphum* (Deflandre & Cookson) Lentin & Williams emend. Harland. Sample 189, slide 16: M 35.
Fig. 11. *Apectodinium parvum* (Alberti) Lentin & Williams emend. Harland. Sample 181, slide F 20 μ 3: E 25.
Fig. 12. *Apectodinium sumisum* (Harland) Lentin & Williams. Sample 191, slide 18: Q 29.
Fig. 13. *Apectodinium sumisum* (Harland) Lentin & Williams. Sample 190, slide F 20 μ 9: G 35.
Fig. 14. *Apectodinium quinquelatum* (Williams & Downie) Costa & Downie. Sample 190, slide F 20 μ 6: N 30.
Fig. 15. *Apectodinium quinquelatum* (Williams & Downie) Costa & Downie. Sample 190, slide F 20 μ 7: E 31.
Fig. 16. *Apectodinium quinquelatum* (Williams & Downie) Costa & Downie. Sample 188, slide E 20 μ 7: M 32.
Fig. 17. *Apectodinium quinquelatum* (Williams & Downie) Costa & Downie. Sample 181, slide F 20 μ 1: J 44.

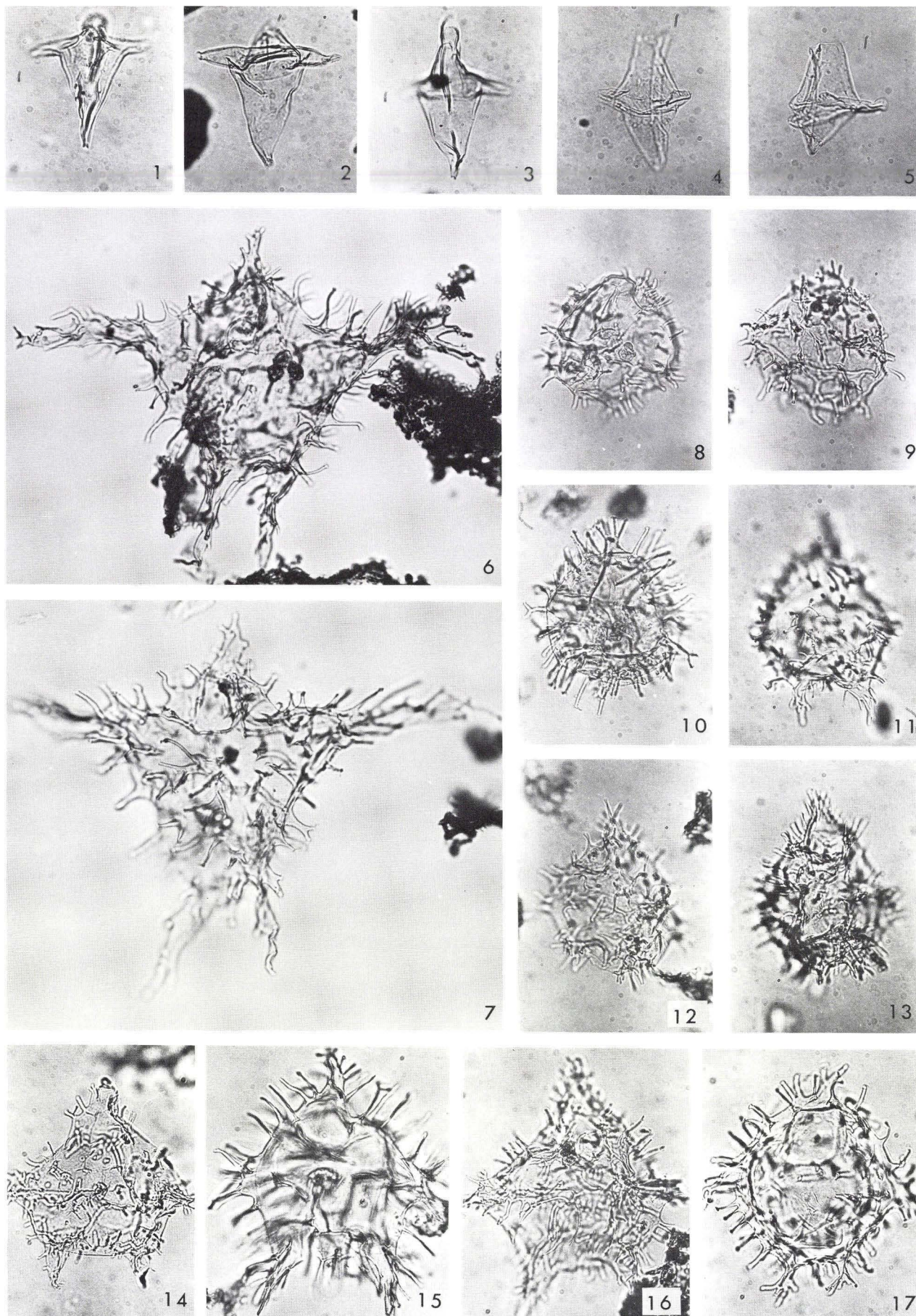


PLATE 6

Magnifications: $\times 500$.

- Fig. 1. *Palaeocystodinium lidiae* (Gorka) Davey. Specimen showing periachaepyle and pericoel. Sample 184, slide E 20 μ 8: T 41.
- Fig. 2. *Palaeocystodinium lidiae* (Gorka) Davey. Sample 197, slide 27: M 44.
- Fig. 3. *Palaeocystodinium lidiae* (Gorka) Davey. Note periarchaepyle. Sample 195, slide 24: O 47.
- Fig. 4. *Palaeocystodinium australinum* (Cookson) Lentin & Williams. Sample 208, slide H 20 μ 5: V 45.
- Fig. 5. *Palaeocystodinium australinum* (Cookson) Lentin & Williams. Sample 206, slide 22: O 48.
- Fig. 6. *Wetzeliiella meckelfeldensis* Gocht. Sample 179, slide F 10 μ 1: V 32.
- Fig. 7. *Apectodinium paniculatum* (Costa & Downie) Lentin & Williams. Sample 190, slide F 20 μ 7: T 34.
- Fig. 8. *Apectodinium hyperacanthum* (Cookson & Eisenack) Lentin & Williams. Sample 190, slide F 20 μ 7: T 41.
- Fig. 9. *Dracodinium varielongitudum* (Williams & Downie) Costa & Downie. Sample 179, slide F 10 μ 1: U 28.
- Fig. 10. Same specimen as fig. 9.
- Fig. 11. *Dracodinium condylos* (Williams & Downie) Costa & Downie. Sample 179, slide F 10 μ 4: V 47.

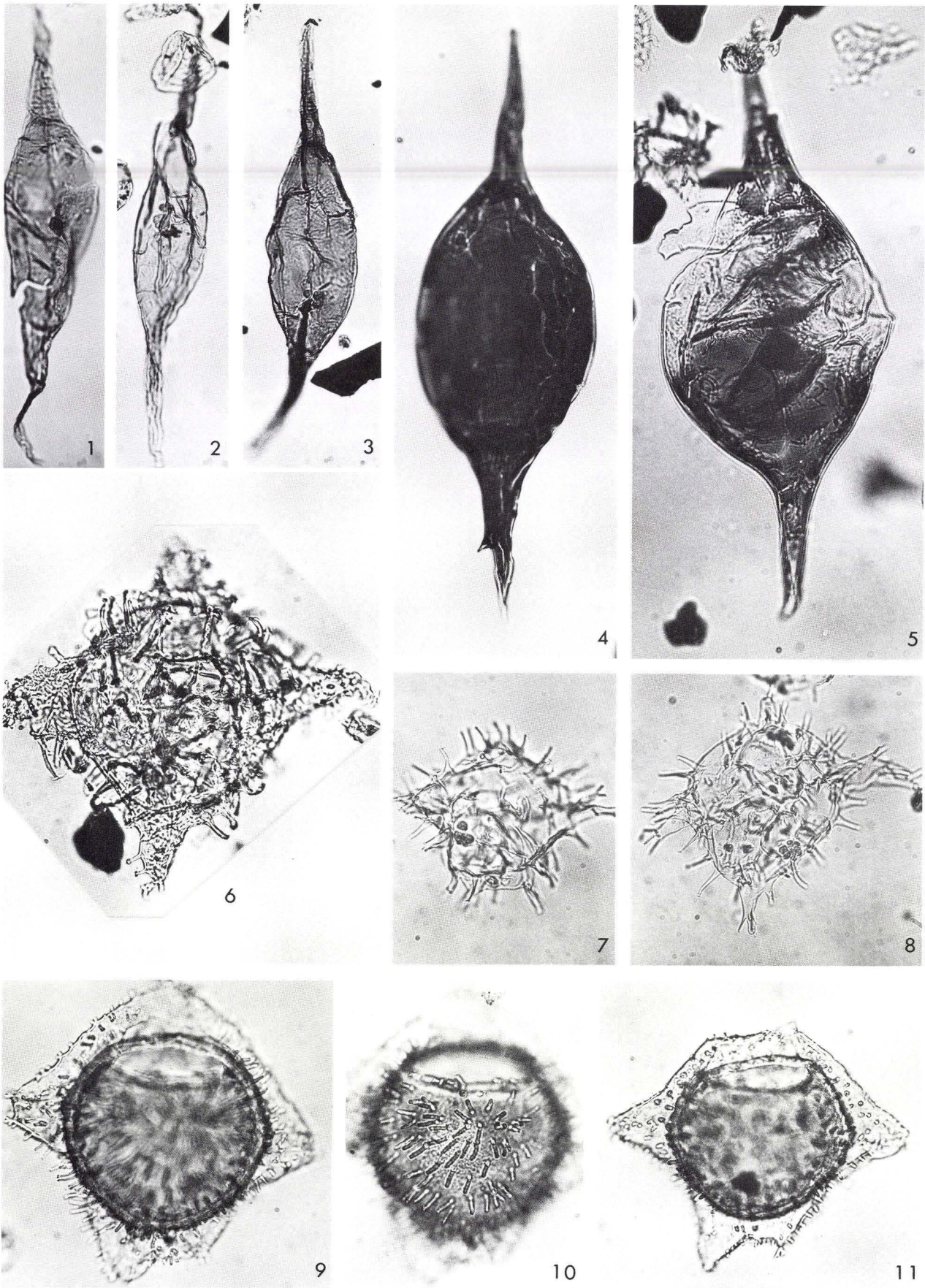


PLATE 7

Magnifications: $\times 500$.

- Fig. 1. *Palaeoperidinium pyrophorum* (Ehrenberg) Sarjeant. Specimen with operculum partly attached at paracingulum. Ventral wall of epicyst broken off. Sample 224, slide 18: O 29.
- Fig. 2. *Palaeoperidinium pyrophorum* (Ehrenberg) Sarjeant. Sample 225, slide 14: S 40.
- Fig. 3. *Palaeoperidinium pyrophorum* (Ehrenberg) Sarjeant. Sample 207, slide E 20μ 5: T 27.
- Fig. 4. *Thalassiphora inflata* Heilmann-Clausen. Dorsal side (low focus) showing precingular archaeopyle and paraplates 2' and 3'. Sample 215, slide H 20μ 3: Q 50.
- Fig. 5. *Hystrichostrogylon coninckii* Heilmann-Clausen. Sample 227, slide 18: J 37.
- Fig. 6. *Hystrichostrogylon coninckii* Heilmann-Clausen. High focus, dorsal side. Sample 227, slide 14: O 44.
- Fig. 7. Same specimen as fig. 6. Intermediary focus, showing reduced processes at ambitus.
- Fig. 8. Same specimen as fig. 6. Low focus, showing the hole in ventral part of periphragm.
- Fig. 9. Same specimen as fig. 4. Ventral side (high focus) showing the hole in the periphragm.
- Fig. 10. *Hafniasphaera septata* (Cookson & Eisenack) Hansen. Sample 221, slide 19: N 27.
- Fig. 11. *Hafniasphaera septata* (Cookson & Eisenack) Hansen. Sample 194, slide H 10μ 1: R 35.
- Fig. 12. *Thalassiphora inflata* Heilmann-Clausen. Dorsal focus. Sample 224, slide 13: M 44.
- Fig. 13. Same specimen as fig. 12. Ventral focus.
- Fig. 14. *Hafniasphaera septata* (Cookson & Eisenack) Hansen. Sample 216, slide 19: T 45.
- Fig. 15. *Achomosphaera crassipellis* (Deflandre & Cookson) Stover & Evitt. Sample 181, slide F 20μ 2: R 42.
- Fig. 16. Same specimen as fig. 15.

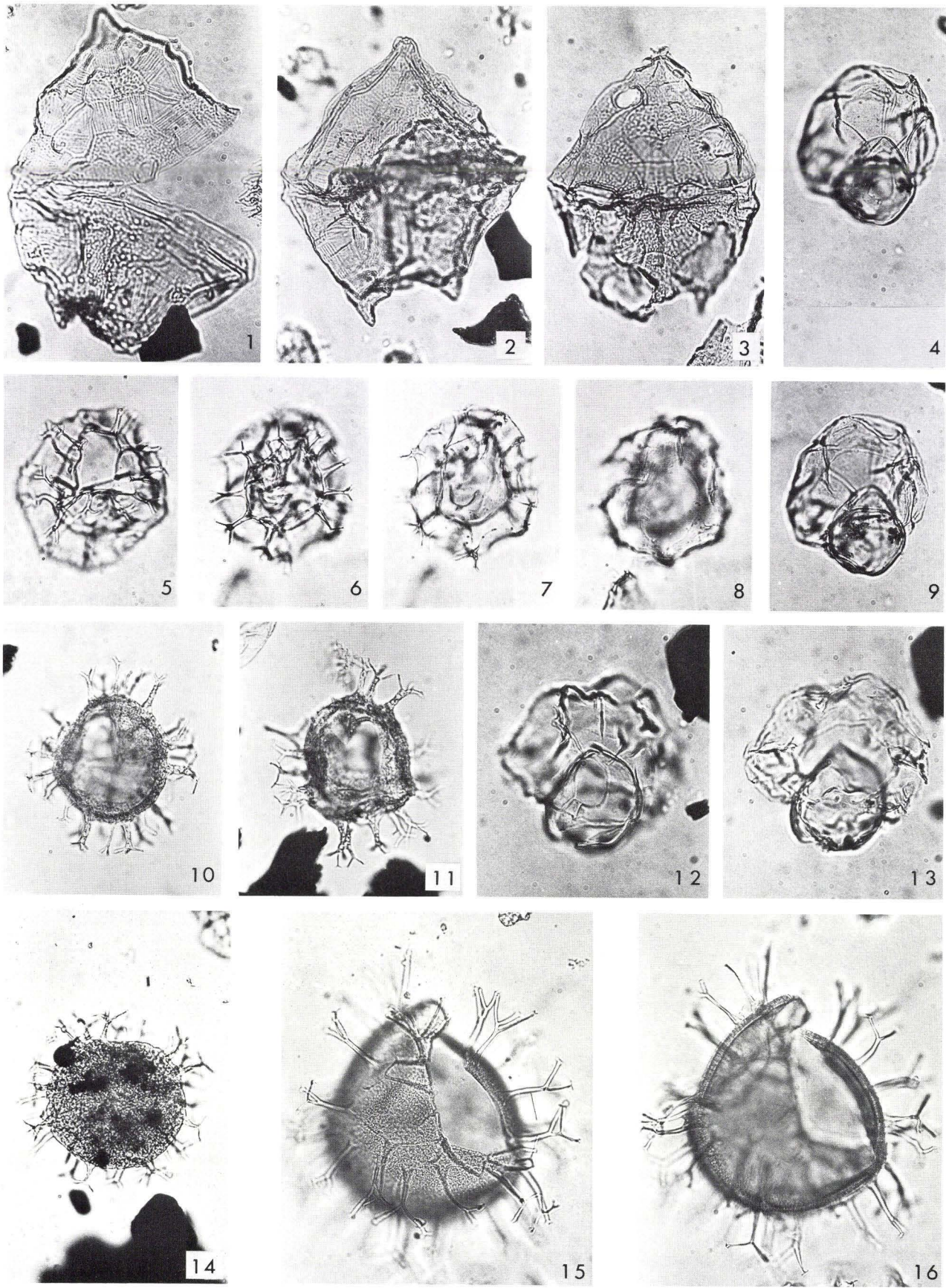


PLATE 8

Magnifications: $\times 500$.

- Fig. 1. *Thalassiphora pelagica* (Eisenack) Eisenack & Gocht. Sample 179, slide F 10 μ 4: X 45.
Fig. 2. *Thalassiphora pelagica* (Eisenack) Eisenack & Gocht. Sample 179, slide F 10 μ 8: V 30.
Fig. 3. *Thalassiphora delicata* Williams & Downie. Sample 182, slide E 20 μ 5: V 31.
Fig. 4. *Thalassiphora delicata* Williams & Downie. High focus, dorsal side. Precingular archaepyle is visible.
Sample 217, slide H 20 μ 4: F 31.
Fig. 5. Same specimen as fig. 4. Low focus, showing the hole in ventral part of periphragm.
Fig. 6. *Eatonicysta ursulae* (Morgenroth) Stover & Evitt. Sample 179, slide F 10 μ 4: V 47.
Fig. 7. *Muratodinium fimbriatum* Drugg. Sample 188, slide E 20 μ 3: Q 31.
Fig. 8. *Muratodinium fimbriatum* Drugg. Sample 181, slide F 20 μ 3: O 30.

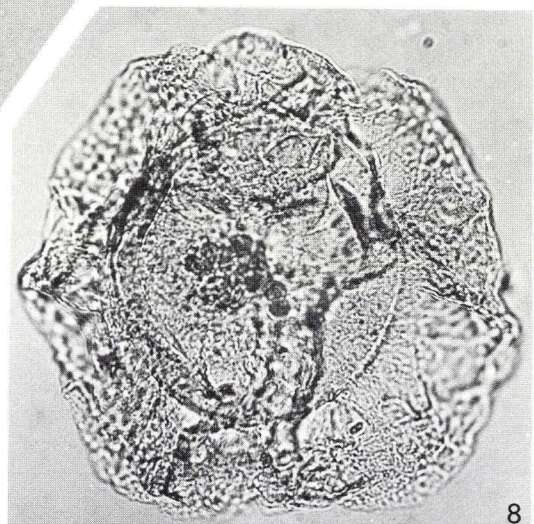
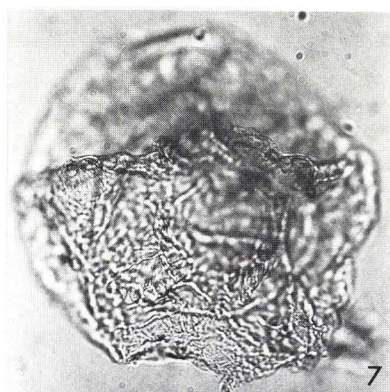
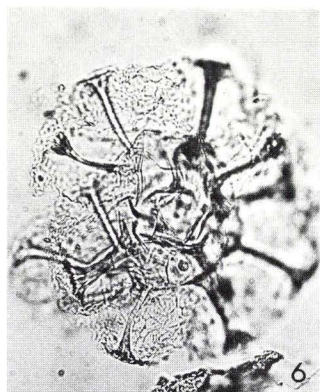
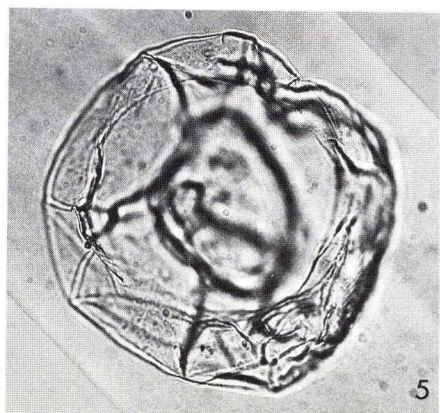
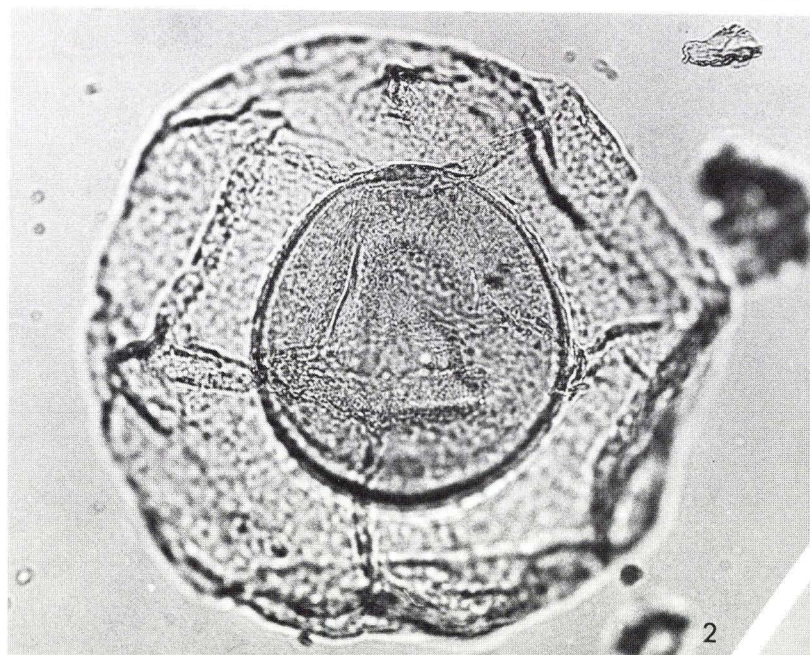
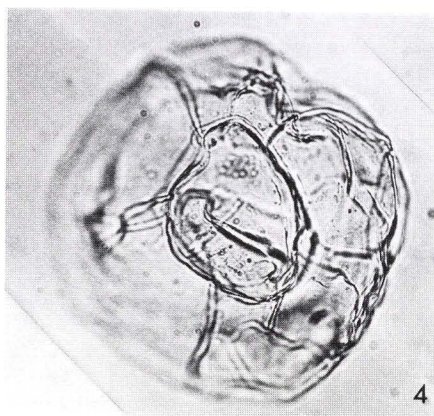
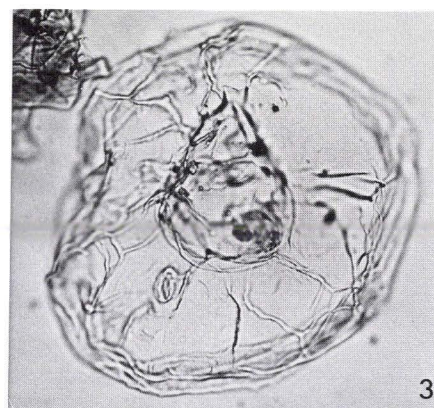
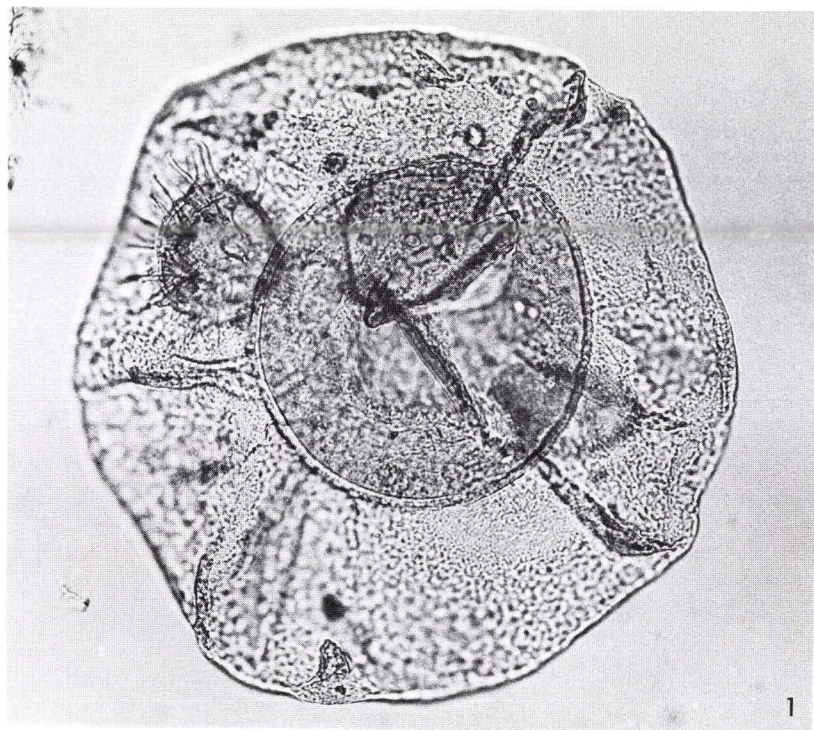


PLATE 9

Magnifications: $\times 500$.

- Fig. 1. *Florentinia ferox* (Deflandre) Duxbury. Sample 201 A, slide 1: J 48.
Fig. 2. *Florentinia ferox* (Deflandre) Duxbury. Sample 210, slide G 20 μ 4: U 31.
Fig. 3. *Florentinia ferox* (Deflandre) Duxbury. Sample 228, slide 7: Q 40.
Fig. 4. Same specimen as fig. 3. Optical section.
Fig. 5. *Achilleodinium biformoides* (Eisenack) Eaton. Sample 179, slide F 10 μ 7: K 31.
Fig. 6. *Achilleodinium biformoides* (Eisenack) Eaton. Sample 179, slide F 10 μ 8: O 27.
Fig. 7. *Achilleodinium biformoides* (Eisenack) Eaton. Sample 179, slide F 10 μ 8: R 21.
Fig. 8. *Gonyaulacysta wetzelii* (Lejeune-Carpentier) Sarjeant. High focus showing ventral part of hypocyst.
Sample 228, slide 10: T 36.
Fig. 9. Same specimen as fig. 8. Dorsal part of epicyst.
Fig. 10. *Danea californica* (Drugg) Stover & Evitt. Sample 227, slide 20: K 51.
Fig. 11. *Danea californica* (Drugg) Stover & Evitt. Broken specimen. Sample 227, slide 20: P 52.
Fig. 12. *Cyclapophysis monmouthensis* Benson. High focus. Sample 227, slide 14: S 49.
Fig. 13. Same specimen as fig. 12. Optical section showing small protrusion of endocyst into the isolated antapical process.

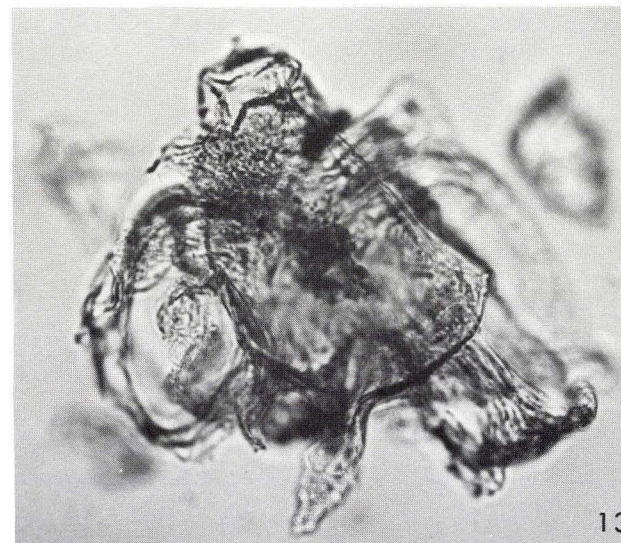
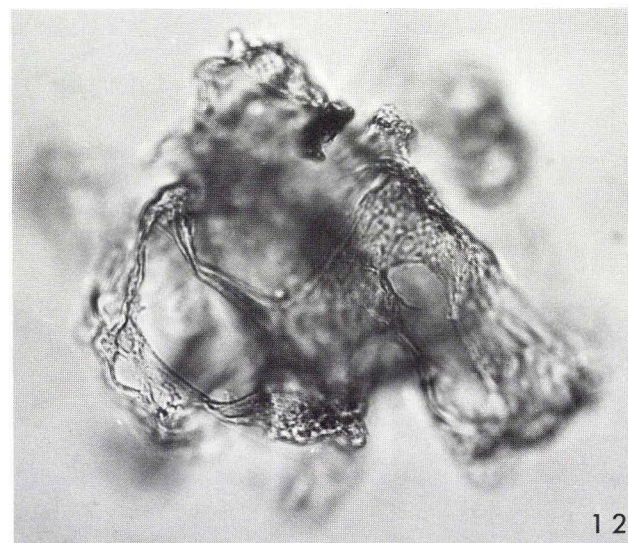
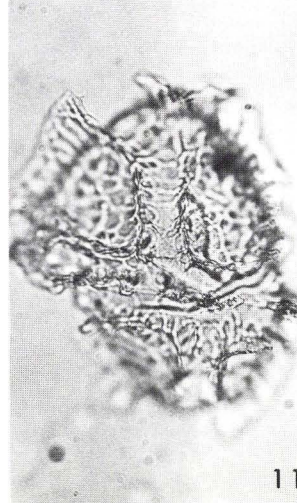
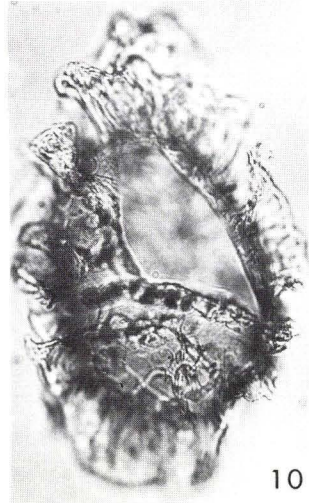
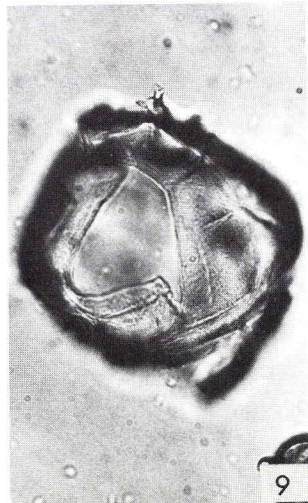
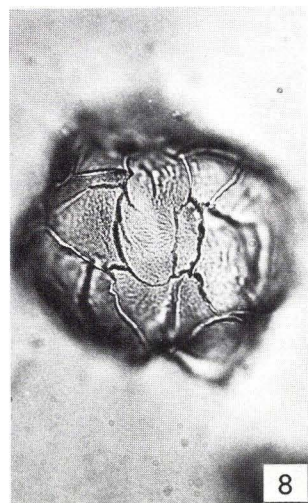
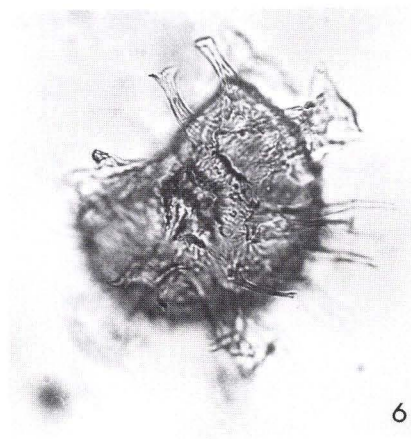
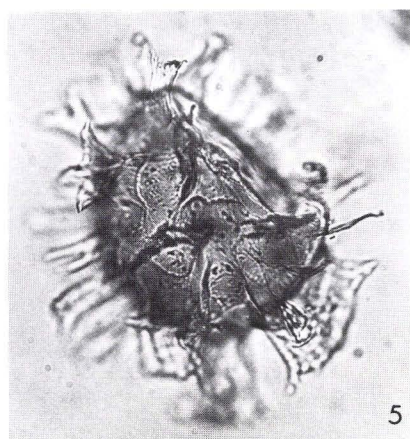
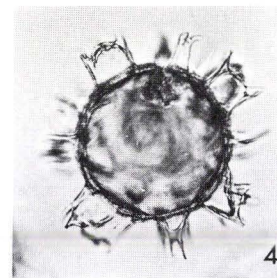
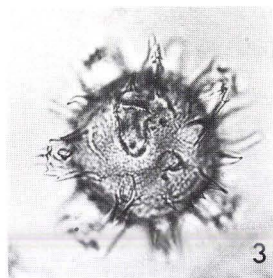
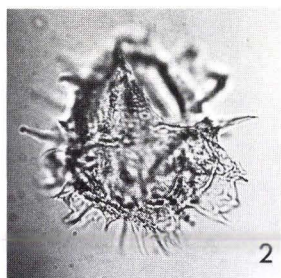
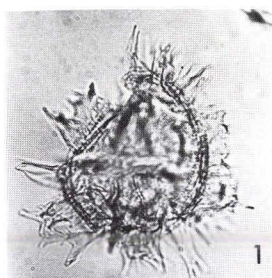


PLATE 10

Magnifications: $\times 500$.

- Fig. 1. *Hystrichokolpoma cinctum* Klumpp. Sample 179, slide F 10 μ 4: X 40.
Fig. 2. *Hystrichokolpoma cinctum* Klumpp. Ventral side (high focus). Sample 179, slide F 10 μ 7: F 25.
Fig. 3. Same specimen as fig. 2. Dorsal side.
Fig. 4. *Oligosphaeridium complex* (White) Davey & Williams. Sample 221, slide 19: O 28.
Fig. 5. *Oligosphaeridium complex* (White) Davey & Williams. Sample 201, slide E 10 μ 2: N 32.
Fig. 6. *Oligosphaeridium complex* (White) Davey & Williams. Sample 194, slide H 20 μ 5: P 31.
Fig. 7. Same specimen as fig. 6. Low focus.
Fig. 8. *Hystrichosphaeridium tubiferum* (Ehrenberg) Deflandre emend. Davey & Williams. Sample 201 A, slide J 10 μ 5: G 43.
Fig. 9. *Hystrichosphaeridium tubiferum* (Ehrenberg) Deflandre emend. Davey & Williams. Sample 228, slide 7: U 38.
Fig. 10. *Hystrichosphaeridium tubiferum* (Ehrenberg) Deflandre emend. Davey & Williams. Ventral side.
Sample 181, slide F 20 μ 2: P 31.
Fig. 11. Same specimen as fig. 10. Dorsal side (low focus).
Fig. 12. *Melitasphaeridium pseudorecurvatum* (Morgenroth) Bujak. Sample 184, slide E 20 μ 5: Y 41.
Fig. 13. *Melitasphaeridium pseudorecurvatum* (Morgenroth) Bujak. The precingular archaeopyle is visible.
Sample 181, slide F 20 μ 2: T 34.
Fig. 14. Same specimen as fig. 13.
Fig. 15. *Melitasphaeridium pseudorecurvatum* (Morgenroth) Bujak. The archaeopyle is visible. Sample 201 A, slide 1: J 32.
Fig. 16. *Melitasphaeridium pseudorecurvatum* (Morgenroth) Bujak. Sample 181, slide F 20 μ 3: E 37.
Fig. 17. *Melitasphaeridium* ? sp. 1. Sample 214, slide 18: T 34.
Fig. 18. *Melitasphaeridium* ? sp. 1. Sample 213, slide H 20 μ 2: T 41.
Fig. 19. *Melitasphaeridium* ? sp. 1. Sample 215, slide H 10 μ 2: R 46.
Fig. 20. *Hystrichosphaeridium* ? *palmatum* (White ex Bronn) Downie & Sarjeant. Sample 210, slide G 20 μ 4: P 51.
Fig. 21. *Hystrichosphaeridium* ? *palmatum* (White ex Bronn) Downie & Sarjeant. Sample 218, slide 14: O 48.

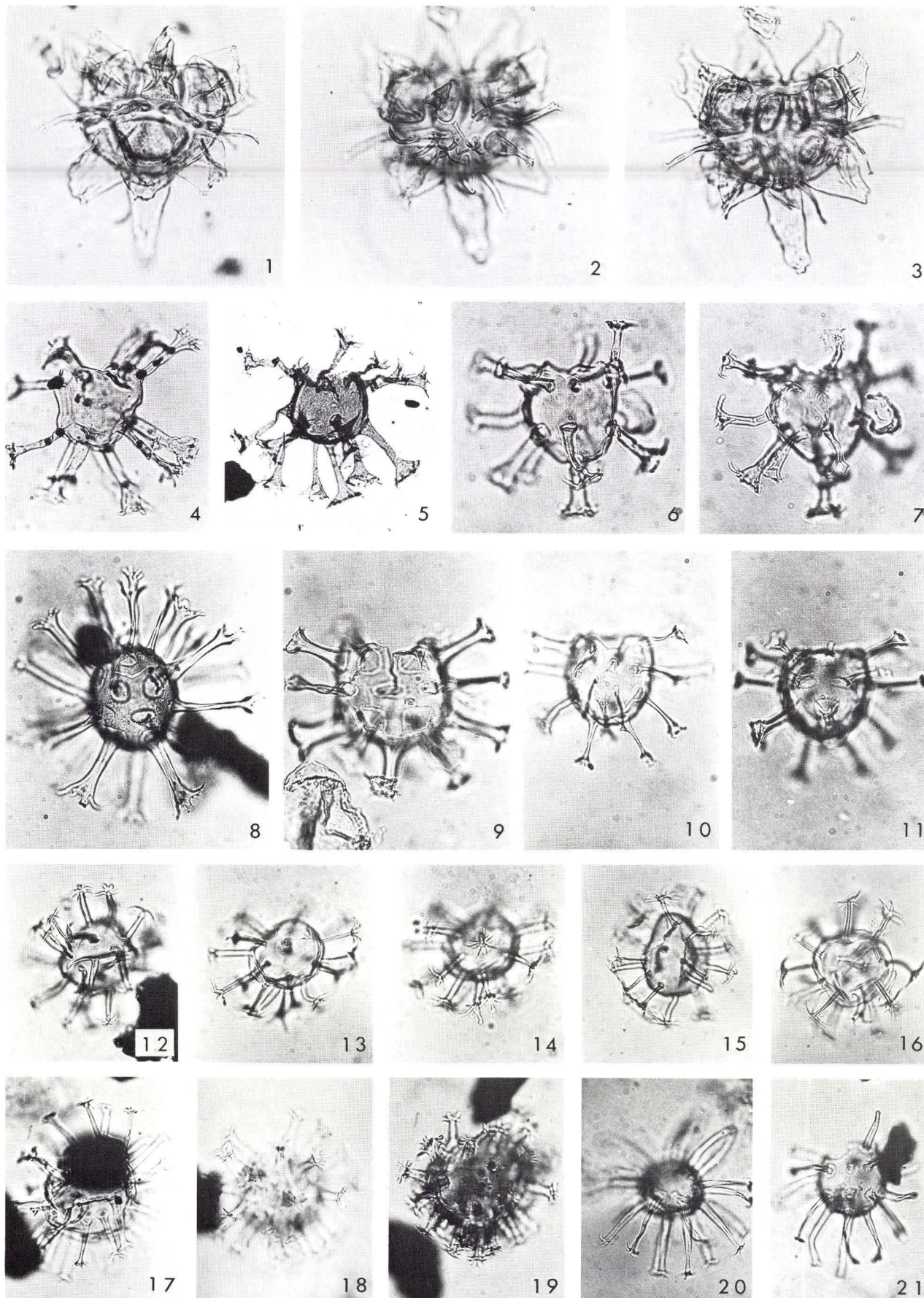


PLATE 11

Magnifications: $\times 500$.

- Fig. 1. *Alisocysta* sp. 2. Sample 183, slide 20 μ 1: L 46.
- Fig. 2. *Alisocysta* sp. 2. Sample 182, slide E 20 μ 7: G 37.
- Fig. 3. *Alisocysta* sp. 2. Dorsal side. Sample 182, slide H 20 μ 3: X 47.
- Fig. 4. Same specimen as fig. 3. Ventral side (low focus). Operculum in place.
- Fig. 5. *Alisocysta* sp. 2. Sample 182, slide E 20 μ 7: N 21.
- Fig. 6. *Alisocysta* sp. 2. Sample 181, slide F 20 μ 2: Q 31.
- Fig. 7. *Alisocysta margarita* (Harland) Harland. Specimen with high septa. Sample 201, slide F 10 μ 2: F 36.
- Fig. 8. *Alisocysta* sp. 2. Specimen with high septa. Sample 194, slide H 20 μ 5: Z 29.
- Fig. 9. *Alisocysta* sp. 2. Sample 184, slide E 20 μ 8: Y 25.
- Fig. 10. *Alisocysta* sp. 2. Sample 184, slide H 20 μ 7: G 27.
- Fig. 11. *Alisocysta* sp. 2. Broken specimen in apical view. Sample 184, slide E 20 μ 8: X 24.
- Fig. 12. *Alisocysta margarita* (Harland) Harland. Specimen with high septa. Sample 210, slide G 20 μ 3: L 34.
- Fig. 13. *Alisocysta margarita* (Harland) Harland. Sample 206, slide 14: R 32.
- Fig. 14. *Alisocysta margarita* (Harland) Harland. Sample 201 A, slide 2: K 26.
- Fig. 15. *Alisocysta margarita* (Harland) Harland. Sample 201 A, slide J 10 μ 5: O 40.
- Fig. 16. Same specimens as fig. 15. Low focus.
- Fig. 17. *Alisocysta margarita* (Harland) Harland. Sample 201 A, slide 2: H 24.
- Fig. 18. *Alisocysta* sp. 1. Holmehus Formation, LB 38 boring, sample 320, slide E 10 μ 2: H 30.
- Fig. 19. Same specimen as fig. 18. Slightly different focus.
- Fig. 20. *Alisocysta* sp. 1. Sample 203, slide 7: H 43.
- Fig. 21. Same specimen as fig. 20. Slightly different focus.
- Fig. 22. *Alisocysta margarita* (Harland) Harland. Sample 210, slide H 20 μ 2: N 33.
- Fig. 23. *Alisocysta reticulata* Damassa. Danian Limestone, Vejrum 4 boring. Sample V26-1, slide C 4: V 35.
- Fig. 24. *Alisocysta* sp. 1. Sample 206, slide 20: T 32.
- Fig. 25. *Alisocysta* sp. 1. Sample 213, slide H 20 μ 1: Y 49.
- Fig. 26. *Alisocysta* sp. 1. Sample 213, slide H 20 μ 2: M 33.
- Fig. 27. *Hystrichosphaeridium* sp. 1. Sample 216, slide 18: N 46.
- Fig. 28. *Alisocysta circumtabulata* (Drugg) Stover & Evitt. Dorsal side. Sample 228, slide 8: G 41.
- Fig. 29. Same specimen as fig. 28. Ventral side (low focus).
- Fig. 30. *Alisocysta circumtabulata* (Drugg) Stover & Evitt. Sample 222, slide H 20 μ 1: T 40.
- Fig. 31. *Alisocysta circumtabulata* (Drugg) Stover & Evitt. Sample 213, slide H 20 μ 2: R 41.
- Fig. 32. *Hystrichosphaeridium* sp. 1. Sample 213, slide H 20 μ 2: J 31.
- Fig. 33. Same specimen as fig. 32. Optical section to show the morphology of the processes.

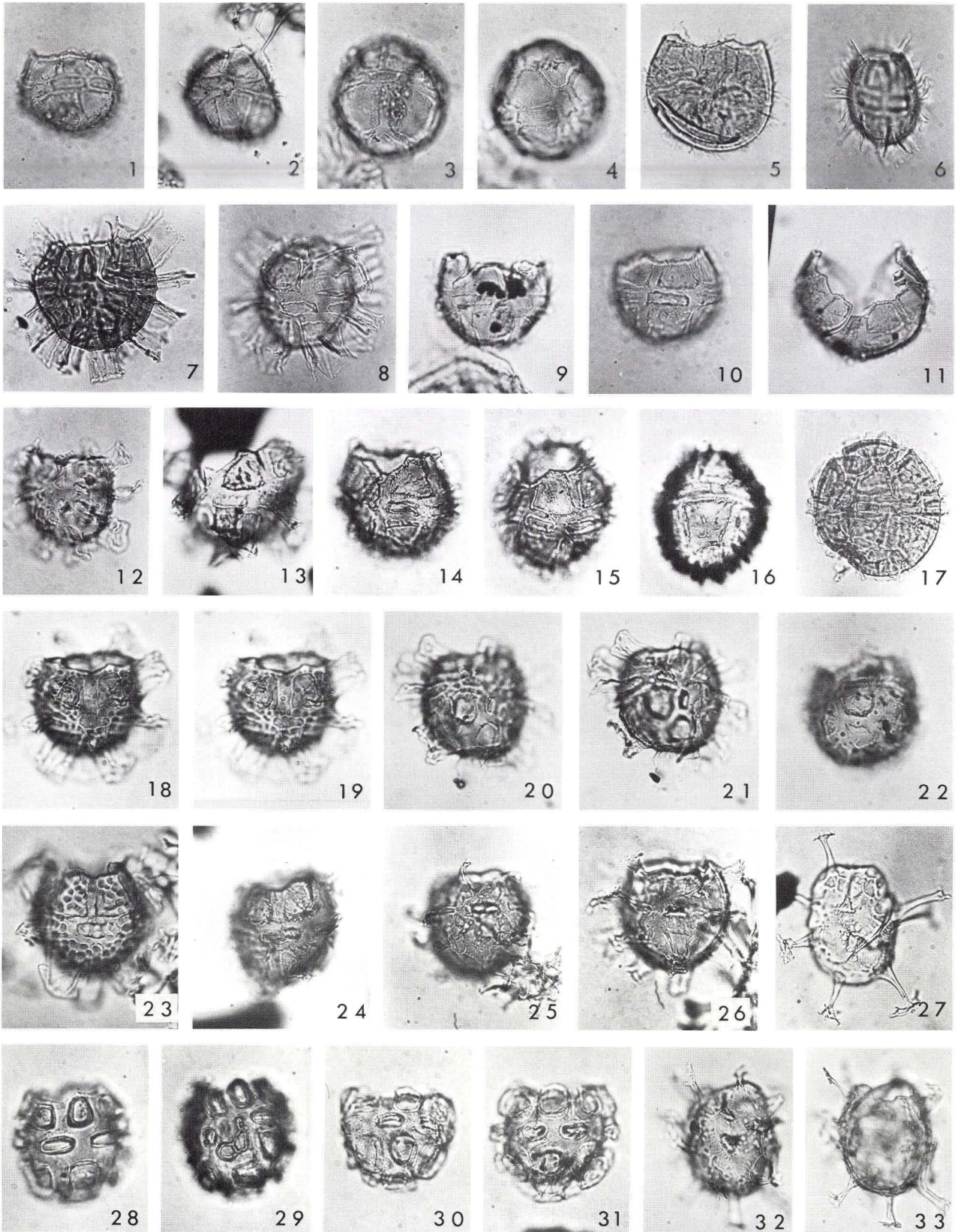


PLATE 12

Magnifications: $\times 500$.

- Fig. 1. *Tanyosphaeridium xanthiopyxides* (O. Wetzel) Stover & Evitt. Sample 227, slide 19: M 45.
- Fig. 2. *Tanyosphaeridium xanthiopyxides* (O. Wetzel) Stover & Evitt. Sample 210, slide H 20 μ 2: D 39.
- Fig. 3. *Tanyosphaeridium xanthiopyxides* (O. Wetzel) Stover & Evitt. Sample 210, slide H 20 μ 2: T 28.
- Fig. 4. *Tanyosphaeridium xanthiopyxides* (O. Wetzel) Stover & Evitt. Sample 201 A, slide J 10 μ 5: E 29.
- Fig. 5. *Cladopyxidium saeptum* (Morgenroth) Stover & Evitt. Lateral position. Sample 215, slide H 10 μ 2: Y 38.
- Fig. 6. Same specimen as fig. 5. Apical position, showing the archaeopyle.
- Fig. 7. *Cladopyxidium saeptum* (Morgenroth) Stover & Evitt. Ventral side. Sample 222, slide H 10 μ 3: N 26.
- Fig. 8. Same specimen as fig. 7. Dorsal side (low focus).
- Fig. 9. *Cladopyxidium saeptum* (Morgenroth) Stover & Evitt. Left side (high focus). Sample 215, slide H 10 μ 2: X 46.
- Fig. 10. Same specimen as fig. 9. Right side (low focus).
- Fig. 11. *Cladopyxidium saeptum* (Morgenroth) Stover & Evitt. Ventral side. Sample 203, slide 9: L 29.
- Fig. 12. Same specimen as fig. 11. Dorsal side (low focus).
- Fig. 13. *Fibradinium annetorpense* Morgenroth. Ventral side. Sample 228, slide 7: H 35.
- Fig. 14. Same specimen as fig. 13. Dorsal side (low focus).
- Fig. 15. *Fibradinium annetorpense* Morgenroth. Sample 227, slide 18: W 39.
- Fig. 16. *Fibradinium annetorpense* Morgenroth. Sample 228, slide 7: J 33.
- Fig. 17. Same specimen as fig. 16. Different orientation.
- Fig. 18. *Fibradinium annetorpense* Morgenroth. Sample 216, slide 19: R 38.
- Fig. 19. *Microdinium* cf. *ornatum* Cookson & Eisenack. Sample 196, slide H 10 μ 3: Y 40.
- Fig. 20. *Microdinium* cf. *ornatum* Cookson & Eisenack. Sample 184, slide F 20 μ 5: S 39.
- Fig. 21. *Microdinium* cf. *ornatum* Cookson & Eisenack. Sample 184, slide F 20 μ 5: O 33.
- Fig. 22. *Membranosphaera* sp. B. De Coninck, 1975. Sample 184, slide E 20 μ 5: M 33.
- Fig. 23. *Membranosphaera* sp. B. De Coninck, 1975. Sample 214, slide 18: L 43.
- Fig. 24. *Membranosphaera* sp. B. De Coninck, 1975. Sample 227, slide 18: H 43.
- Fig. 25. *Impagidinium* sp. 1. Dorsal side, showing 3' archaeopyle. Sample 214, slide 15: J 37.
- Fig. 26. Same specimen as fig. 25. Ventral side (low focus).
- Fig. 27. *Impagidinium* sp. 1. The archaeopyle is seen to the right. Sample 203, slide 12: K 43.
- Fig. 28. Same specimen as fig. 27. Low focus. The small sub-triangular paraplate 6'' is seen to the left.
- Fig. 29. *Impagidinium* sp. 1. Sample 203, slide 9: V 28.
- Fig. 30. Same specimen as fig. 29. Low focus.
- Fig. 31. *Diphyes colligerum* (Deflandre & Cookson) Cookson. Sample 227, slide 19: M 44.
- Fig. 32. *Diphyes colligerum* (Deflandre & Cookson) Cookson. Sample 210, slide G 20 μ 4: E 39.
- Fig. 33. *Diphyes colligerum* (Deflandre & Cookson) Cookson. Archaeopyle in focus. Sample 184, slide 7: R 27.
- Fig. 34. Same specimen as fig. 33. Antapical process in focus.
- Fig. 35. *Diphyes colligerum* (Deflandre & Cookson) Cookson. Sample 184, slide E 20 μ 6: R 23.

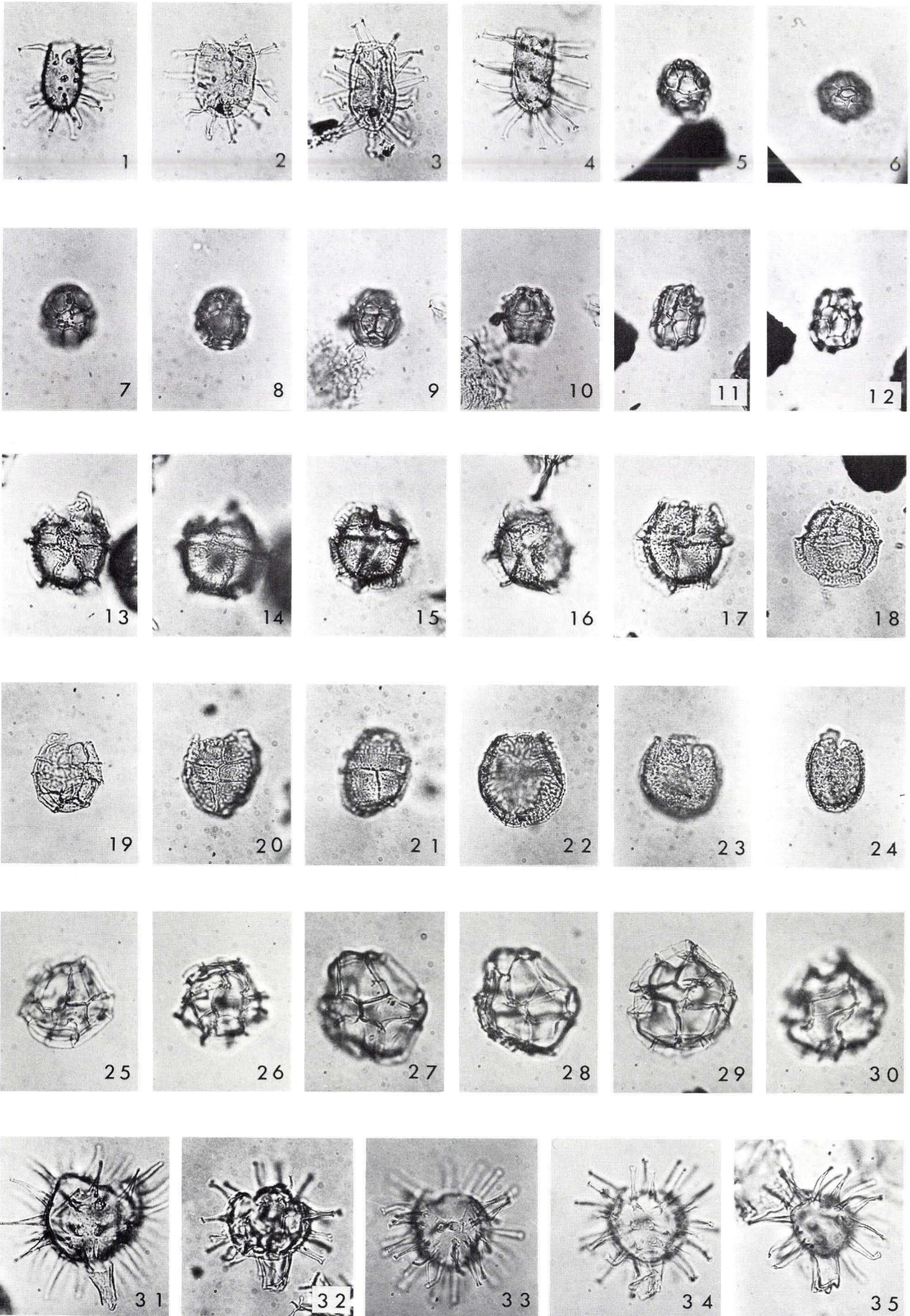
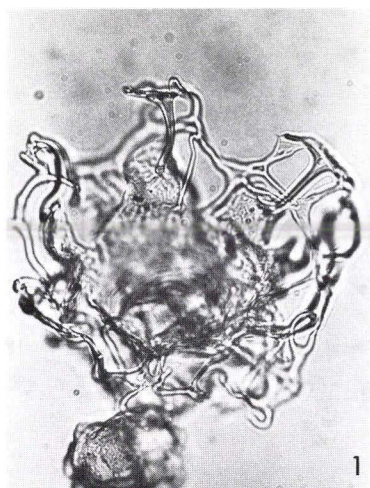


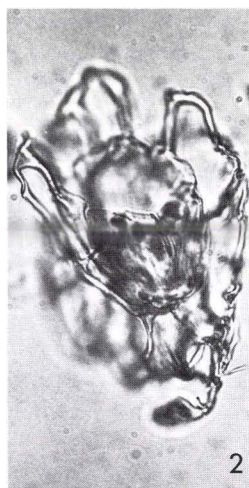
PLATE 13

Magnifications: $\times 500$.

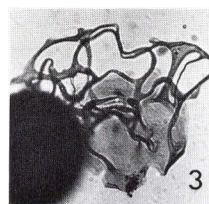
- Fig. 1. *Adnatosphaeridium robustum* (Morgenroth) De Coninck. Sample 197, slide G 20 μ 2: J 34.
Fig. 2. *Adnatosphaeridium robustum* (Morgenroth) De Coninck. Sample 194, slide H 20 μ 5: L 43.
Fig. 3. *Adnatosphaeridium robustum* (Morgenroth) De Coninck. Operculum. Sample 197, slide F 20 μ 5: S 28.
Fig. 4. *Adnatosphaeridium* cf. *vittatum* Williams & Downie. Sample 179, slide F 10 μ 2: Q 52.
Fig. 5. *Adnatosphaeridium* cf. *vittatum* Williams & Downie. Sample 179, slide F 10 μ 4: V 32.
Fig. 6. *Glaphyrocysta ordinata* (Williams & Downie) Stover & Evitt. Sample 201 A, slide 2: Y 27.
Fig. 7. *Glaphyrocysta ordinata* (Williams & Downie) Stover & Evitt. Sample 184, slide E 20 μ 5: J 40.
Fig. 8. *Glaphyrocysta ordinata* (Williams & Downie) Stover & Evitt. Sample 181, slide F 20 μ 3: P 36.
Fig. 9. *Glaphyrocysta divaricata* (Williams & Downie) Stover & Evitt. Sample 210, slide G 20 μ 1: Q 48.
Fig. 10. *Glaphyrocysta divaricata* (Williams & Downie) Stover & Evitt. Sample 185, slide 28: Y 33.
Fig. 11. *Glaphyrocysta divaricata* (Williams & Downie) Stover & Evitt. Sample 188, slide E 10 μ 5: S 31.
Fig. 12. *Glaphyrocysta pastielsii* (Deflandre & Cookson) Stover & Evitt. Sample 226, slide 13: U 49.
Fig. 13. *Glaphyrocysta pastielsii* (Deflandre & Cookson) Stover & Evitt. Sample 215, slide H 20 μ 3: R 28.
Fig. 14. *Glaphyrocysta pastielsii* (Deflandre & Cookson) Stover & Evitt. Sample 179, slide F 10 μ 7: H 33.



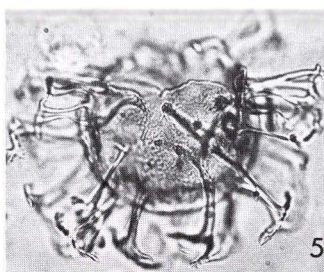
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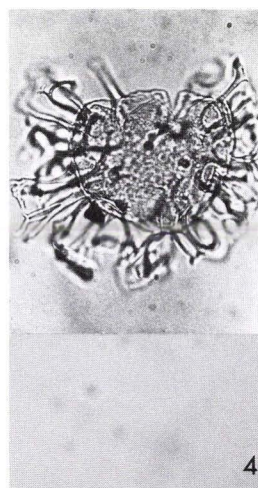
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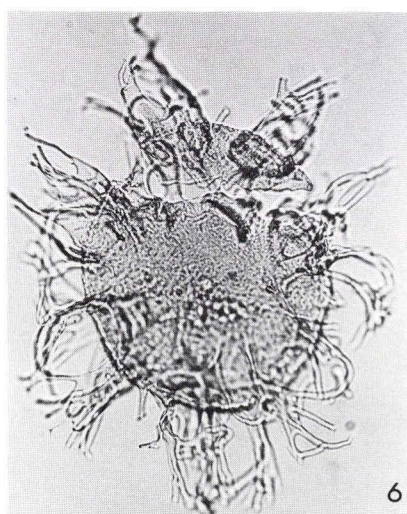
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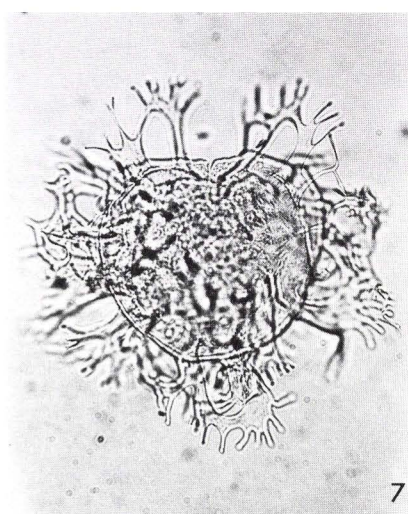
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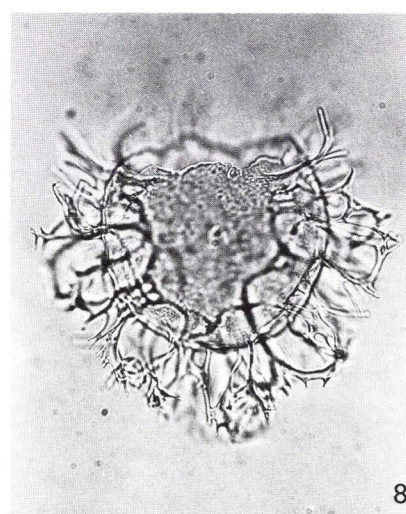
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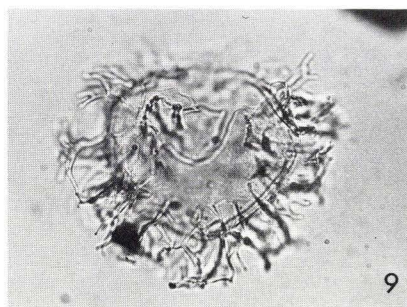
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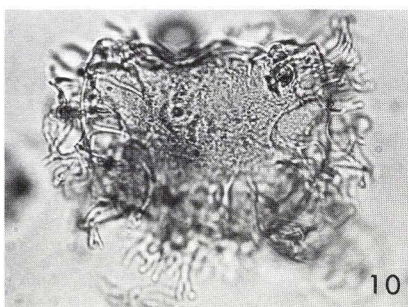
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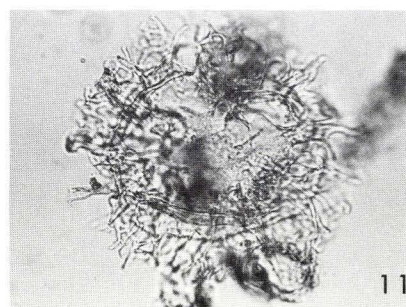
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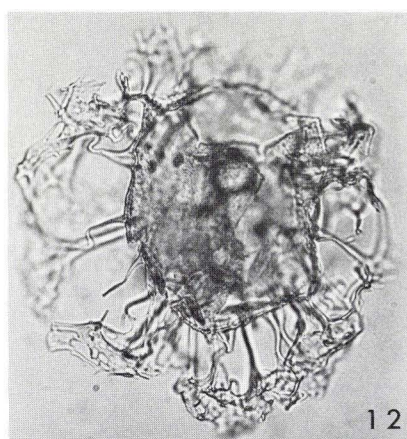
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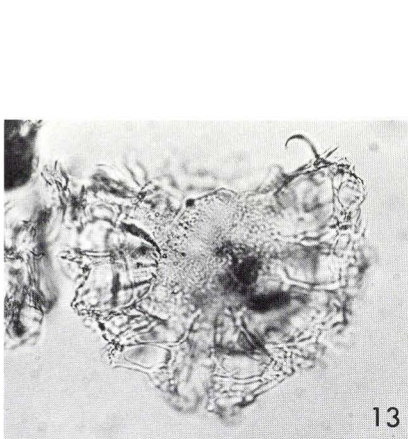
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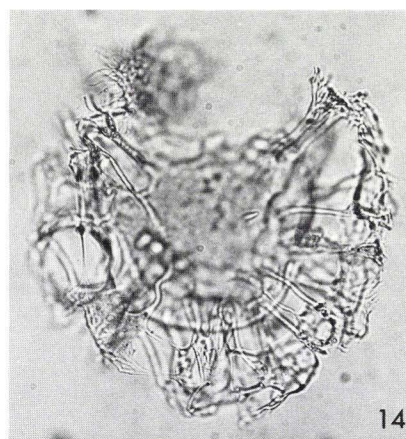
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12



13



14

PLATE 14

Magnifications: $\times 500$.

- Fig. 1. *Glaphyrocysta pastielsii* (Deflandre & Cookson) Stover & Evitt. Sample 207, slide E 20 μ 4: R 43.
Fig. 2. *Areoligera* cf. *coronata* (O. Wetzel) Lejeune-Carpentier. Sample 222, slide H 10 μ 3: W 25.
Fig. 3. *Areoligera* cf. *coronata* (O. Wetzel) Lejeune-Carpentier. Sample 201, slide E 10 μ 2: Y 35.
Fig. 4. *Areoligera* cf. *senonensis* Lejeune-Carpentier. Sample 201, slide H 20 μ 8: Q 29.
Fig. 5. *Areoligera* cf. *senonensis* Lejeune-Carpentier. Sample 201, slide E 10 μ 2: F 28.
Fig. 6. *Areoligera* cf. *senonensis* Lejeune-Carpentier. Sample 196, slide H 20 μ 8: Q 29.
Fig. 7. *Areoligera* cf. *senonensis* Lejeune-Carpentier. Sample 179, slide F 10 μ 2: Q 51.
Fig. 8. *Impletosphaeridium severinii* (Cookson & Cranwell) Liengjaren et al. Sample 198, slide H 10 μ 8: U 27.
Fig. 9. Same specimen as fig. 8. Optical section.
Fig. 10. *Impletosphaeridium severinii* (Cookson & Cranwell) Liengjaren et al. Sample 193, slide 24: F 33.
Fig. 11. *Impletosphaeridium severinii* (Cookson & Cranwell) Liengjaren et al. Sample 181, slide F 20 μ 3: T 30.
Fig. 12. *Impletosphaeridium severinii* (Cookson & Cranwell) Liengjaren et al. Sample 181, slide F 20 μ 2: Q 43.

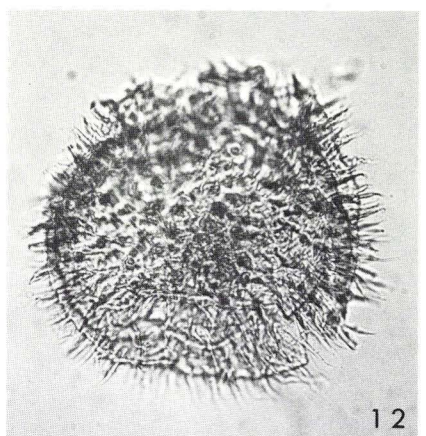
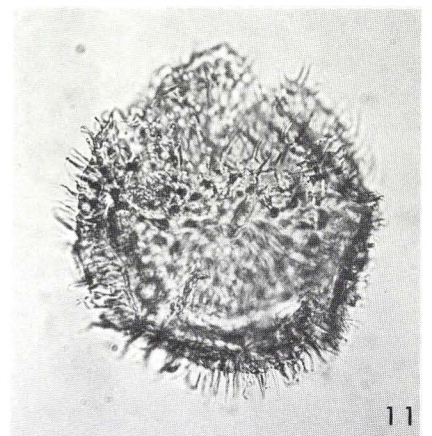
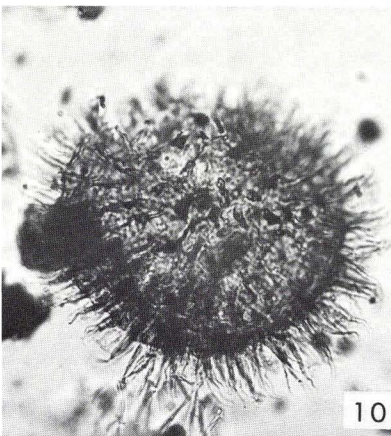
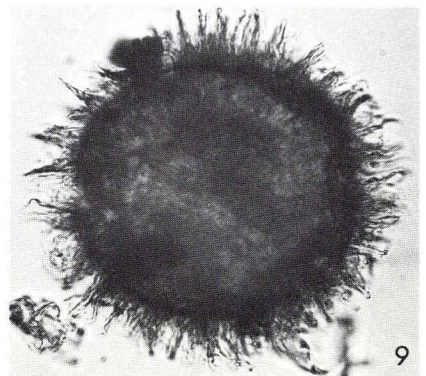
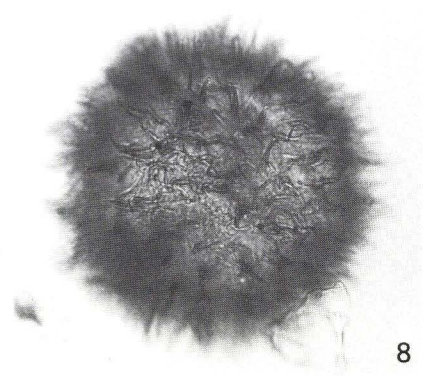
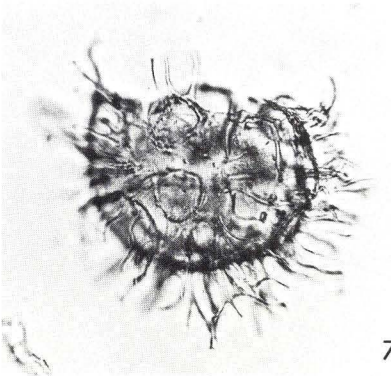
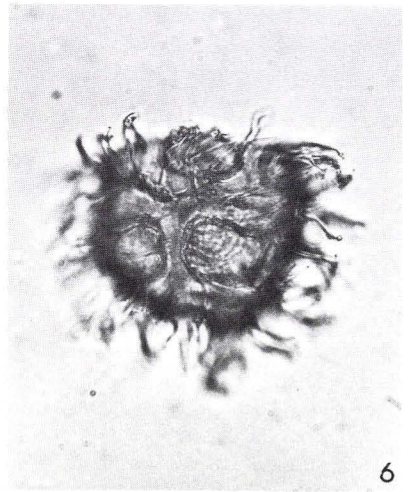
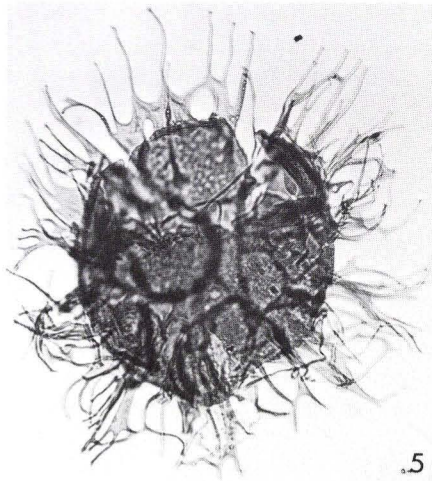
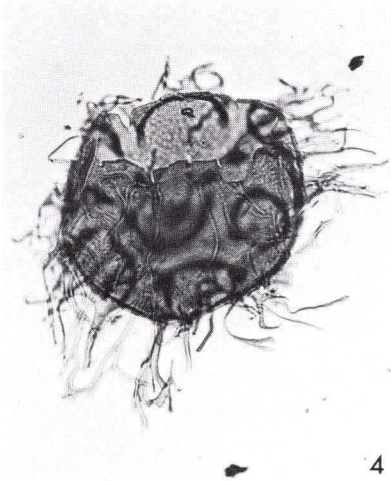
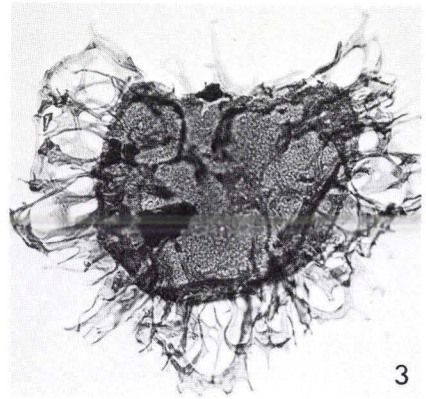
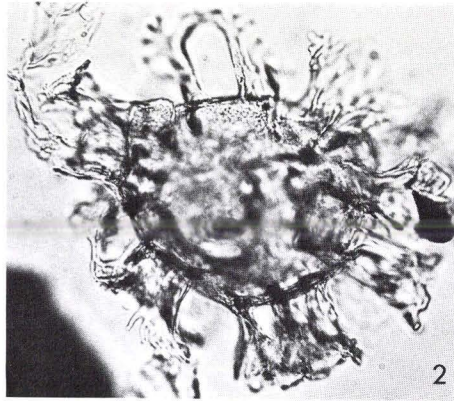
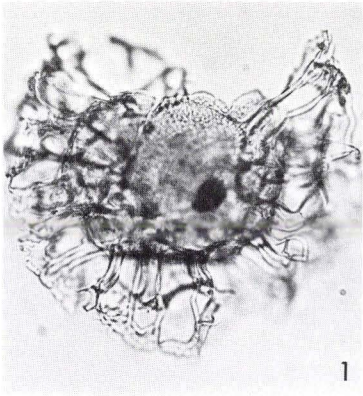
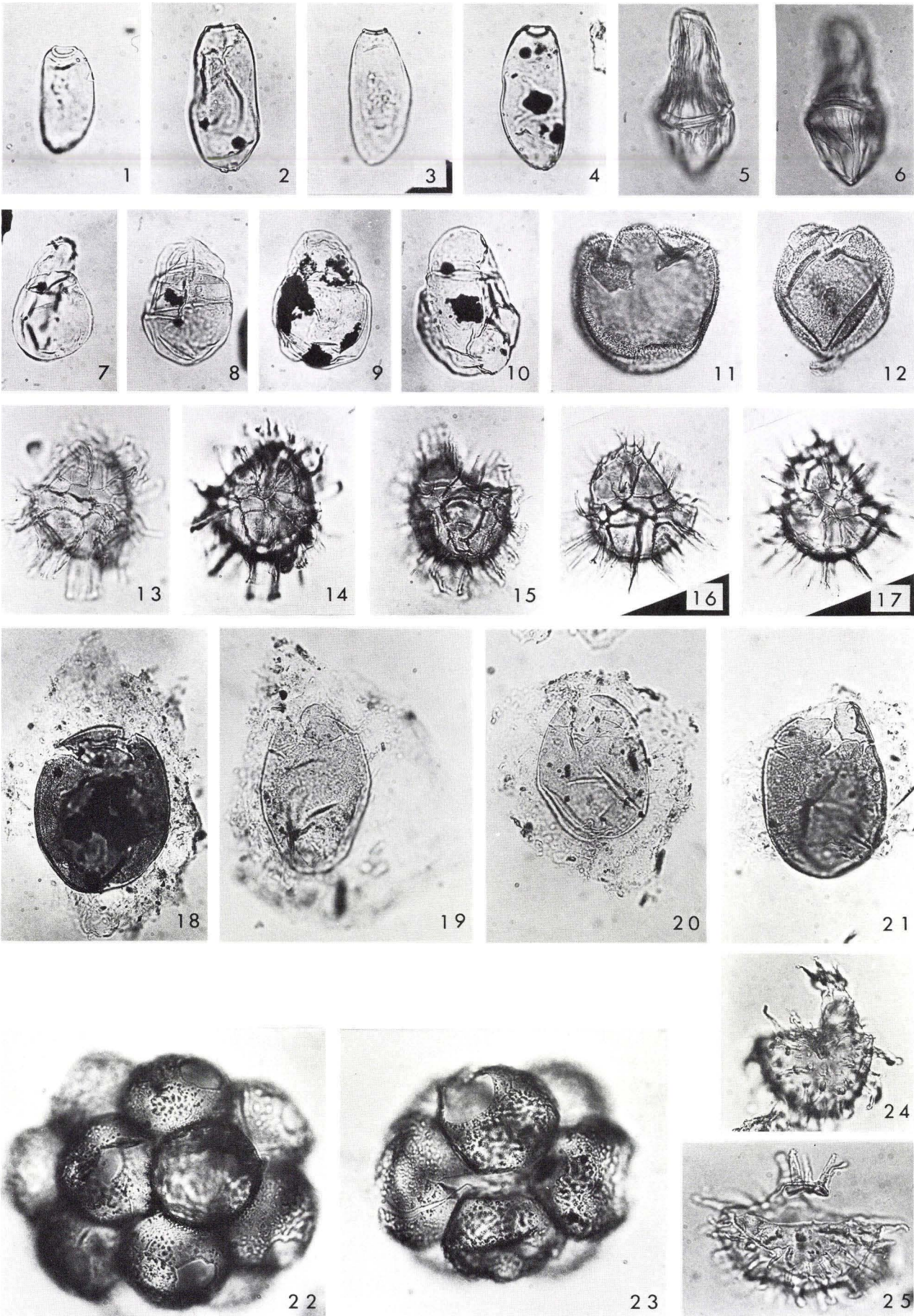
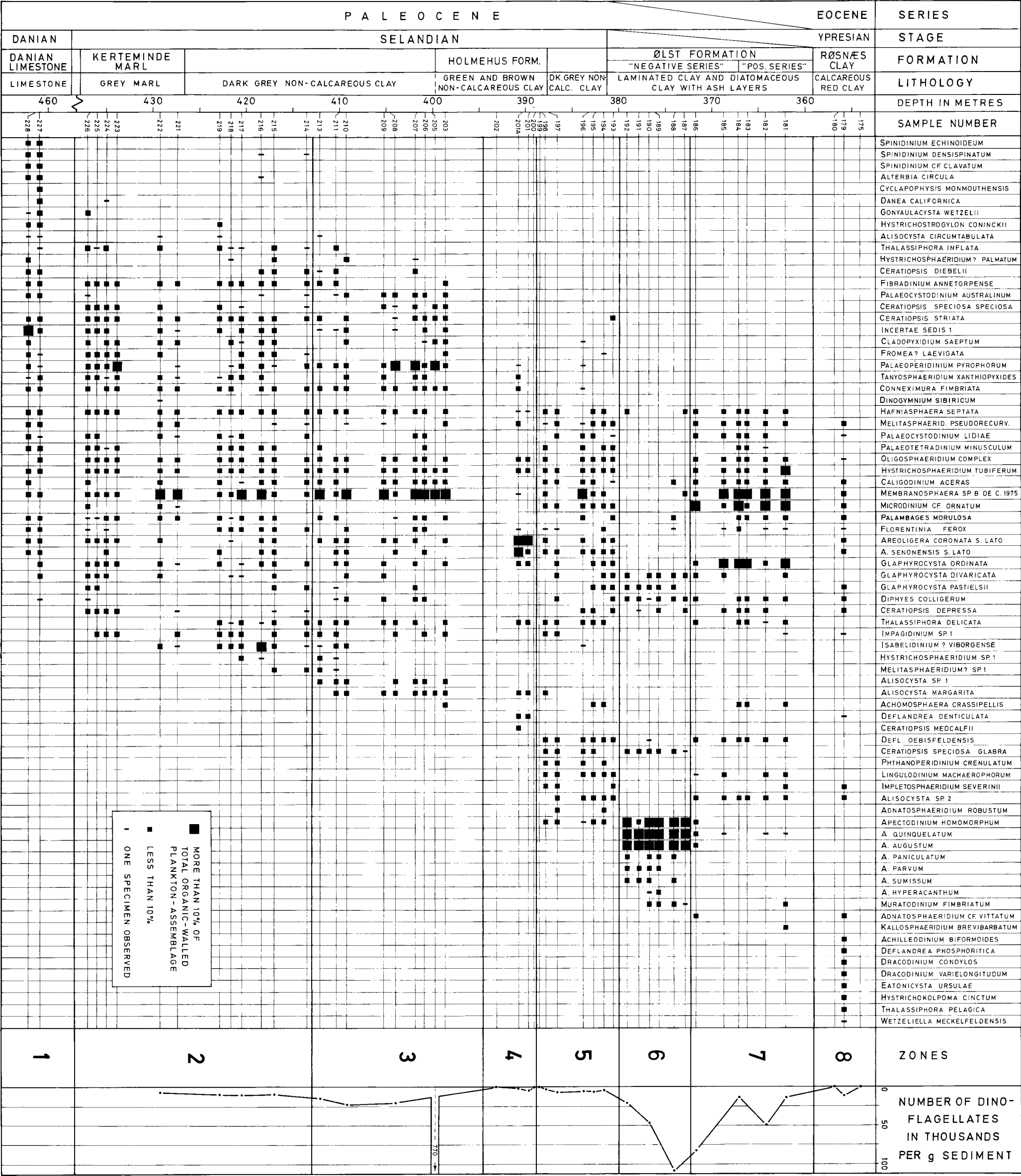


PLATE 15

Magnifications: $\times 500$.

- Fig. 1. *Fromea* ? *laevigata* (Drugg) Stover & Evitt. Sample 214, slide 18: T 40.
- Fig. 2. *Fromea* ? *laevigata* (Drugg) Stover & Evitt. Note circular arrangement of rimmed pores at antapical pole. Sample 224, slide 15: S 39.
- Fig. 3. *Fromea* ? *laevigata* (Drugg) Stover & Evitt. Sample 217, slide H 10 μ 4: U 28.
- Fig. 4. *Fromea* ? *laevigata* (Drugg) Stover & Evitt. Sample 223, slide 21: E 42.
- Fig. 5. *Dinogymnium sibiricum* (Vozzhennikova) Lentin & Williams. Sample 222, slide H 10 μ 3: C 43.
- Fig. 6. Same specimen as fig. 5.
- Fig. 7. Incertae sedis 1. Sample 217, slide H 20 μ 4: V 40.
- Fig. 8. Incertae sedis 1. Sample 217, slide H 10 μ 4: U 34.
- Fig. 9. Incertae sedis 1. Sample 210, slide G 20 μ 1: Y 39.
- Fig. 10. Incertae sedis 1. Sample 219, slide H 20 μ 2: U 36.
- Fig. 11. *Kallosphaeridium brevibarbatum* De Coninck. Sample 181, slide F 20 μ 2: O 32.
- Fig. 12. *Kallosphaeridium brevibarbatum* De Coninck. Sample 181, slide F 20 μ 2: Q 34.
- Fig. 13. *Conneximura fimbriata* (Morgenroth) May. Sample 201 A, slide 1: Z 41.
- Fig. 14. Same specimen as fig. 13. Low focus.
- Fig. 15. *Conneximura fimbriata* (Morgenroth) May. Sample 207, slide E 20 μ 5: M 36.
- Fig. 16. *Conneximura fimbriata* (Morgenroth) May. Sample 207, slide E 20 μ 5: W 27.
- Fig. 17. Same specimen as fig. 16. Low focus.
- Fig. 18. *Caligodinium aceras* (Manum & Cookson) Lentin & Williams. Sample 207, slide E 20 μ 4: K 43.
- Fig. 19. *Caligodinium aceras* (Manum & Cookson) Lentin & Williams. Sample 186, slide F 10 μ 5: Q 32.
- Fig. 20. *Caligodinium aceras* (Manum & Cookson) Lentin & Williams. Sample 182, slide E 20 μ 2: Q 50.
- Fig. 21. *Caligodinium aceras* (Manum & Cookson) Lentin & Williams. Sample 179, slide F 20 μ 2: T 41.
- Fig. 22. *Palambages morulosa* O. Wetzel emend. Gocht & Wille. 16-celled colony. Sample 228, slide 8: T 33.
- Fig. 23. *Palambages morulosa* O. Wetzel emend. Gocht & Wille. 8-celled colony. Sample 224, slide 18: P 38.
- Fig. 24. *Lingulodinium machaerophorum* (Deflandre & Cookson) Wall. Sample 194, slide H 20 μ 4: X 46.
- Fig. 25. *Lingulodinium machaerophorum* (Deflandre & Cookson) Wall. Sample 198, slide H 20 μ 7: K 38.





This book gives a comprehensive review of the Danish Paleocene stratigraphy. The author's detailed knowledge of Danish outcrops and the description of samples from the Viborg 1 deep boring, gives a most complete profile of Danish Paleocene deposits. The work also gives a qualified division of the Paleocene, in particular the Selandian, with correlations to the well known NW-European Paleocene localities. The correlations are made on basis of the author's studies of dinoflagellates, but also based on published material.