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DINOFLAGELLATE CYSTS FROM UPPER CRETACEOUS-LOWER TERTIARY SECTIONS, BYLOT AND DEVON ISLANDS, ARCTIC ARCHIPELAGO

N.S. Ioannides

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DINOFLAGELLATE CYSTS FROM UPPER CRETACEOUS-LOWER TERTIARY SECTIONS, BYLOT AND DEVON ISLANDS, ARCTIC ARCHIPELAGO

Abstract

Diverse dinoflagellate assemblages have been recovered from Upper Cretaceous and Lower Tertiary sediments on Bylot and Devon islands, Arctic Canada. The section studied consists of the Santonian-Maastrichtian Kanguk Formation and the Lower Paleocene Eureka Sound Formation. Distinctive palynological associations have been recognized for these formations, but it is difficult to make detailed comparisons with other assemblages because of extensive reworking. Most of the species recorded are described, including two that are regarded as new (*Laciniadinium williamsii* sp. nov. and *Palaeocystodinium bulliformum* sp. nov.). A full interpretation of the structure of *Thalassiphora pelagica* is presented. In addition, analyses of dinocyst variability suggest that species presently attributed to different genera may represent end members of a gradational morphological complex.

Résumé

Divers échantillons du Crétacé supérieur et du Tertiaire inférieur des îles de Bylot et de Devon, dans l'Arctique canadien ont fourni des assemblages variés de dinoflagellés. La coupe étudiée comprend des sédiments appartenant à la formation Kanguk, d'âge Santonien-Maastrichtien, et à la Formation Eureka Sound, d'âge Paléocene inférieur. Des assemblages palynologiques distincts caractérisent ces deux formations, mais les comparaisons avec d'autres assemblages d'âge équivalent sont rendues difficiles par l'importance des remaniements. Cette étude comprend des descriptions de la plupart des formes décrites, y compris deux espèces nouvelles (*Laciniadinium williamsii* sp. nov. and *Palaeocystodinium bulliformum* sp. nov.), ainsi qu'une interprétation structurale détaillée de *Thalassiphora pelagica*. Finalement, l'étude analytique de la variabilité des dinocysts suggère que divers genres pourraient représenter les termes extrêmes d'un complexe morphologique d'une manière graduelle.

INTRODUCTION

Bylot and Devon islands are geographically located in the eastern Canadian Arctic, between latitudes 72° and 76°N (Figs. 1, 2). On Bylot Island, outcrops of Cretaceous and Tertiary strata trend in a northwest-southeast direction, and are largely confined to the southwestern part of the island (Fig. 1). These deposits have been attributed by Miall et al. (1980) to the Kanguk and Eureka Sound formations. The sections used for this report were described by these authors, and the sample distribution is shown in Figure 3. The individual outcrops that occur at various stations (Fig. 1) were combined to form composite sections (Fig. 3 and Table 1). The three samples from Devon Island were collected from isolated outcrops preserved in grabens and are of mudstones lithologically similar to those in the Kanguk Formation. The locations of the samples studied are shown in Figure 2 and Table 1. Dinoflagellate cysts are locally abundant and well preserved in both the Kanguk and Eureka Sound formations of the Arctic Islands (Manum, 1963; Manum and Cookson, 1964; Doerenkamp et al., 1976; Felix and Burbridge, 1973, 1976). Because of the excellent preservation of the dinoflagellates in many of the available samples from Bylot Island, this study was undertaken to stimulate further research on the Upper Cretaceous and Tertiary of the Arctic Islands. It is recognized that the relatively limited number of samples and the lack of strong biostratigraphic control from other fossil groups weakens some of the more specific biostratigraphic conclusions drawn from this study. However, it is hoped that this will not detract unnecessarily from the descriptive part of the investigation.

Acknowledgments

I am grateful to G.L. Williams, A.R. Sweet and D.J. McIntyre for useful discussions during the preparation of this paper. D.J. McIntyre and A.R. Sweet also offered numerous valuable suggestions for the reorganization of the final manuscript. On a visit to Stanford, I benefited from discussions with W.R. Evitt on dinocyst morphology. Thanks are extended to L.E. Stover for valuable comments on taxonomy, and to R. Thorsteinsson for advice on the stratigraphy. G.P. Michael greatly assisted the study with his scanning electron microscope work. Finally, I would like to express my appreciation to the Director of the Geological Survey of Canada and Esso Production Research (European) for permission to publish this paper.

STRATIGRAPHY AND AGE OF FORMATIONS

Kanguk Formation

This formation was defined by Souther (1963, p. 442) in the Kanguk Peninsula area of western Axel Heiberg Island. It consists predominantly of silty shale, with a smaller amount of sandstone. Tuffaceous and bentonitic beds occur at the base. In the Arctic Islands, the Kanguk Formation is widely distributed, and is overlain by the Eureka Sound Formation and underlain by the Hassel Formation. On Bylot Island it rests disconformably on the Hassel and is followed disconformably by the Eureka Sound (Miall et al., 1980). Its thickness in the measured composite section ranges from 560 to 590 m.

The Kanguk Formation in the type area on the Kanguk Peninsula contains a number of species of *Inoceramus*. A Santonian to Campanian age was assigned to the formation (Souther, in Fortier et al., 1963). Subsequent studies have indicated that the formation might be as old as Cenomanian (Miall, 1979; Balkwill, 1983; Yorath et al., 1975) and as young as Campanian, or possibly Maastrichtian (Miall, 1979; Balkwill, 1983). Both the Cenomanian and Maastrichtian age assignments however, are equivocal. The presence of marine Cenomanian fossils in the lower part of the Kanguk was questioned by Jeletzky (1971, p. 49; 1978, p. 11), who considers the oldest age for the Kanguk Formation to be early Turonian. Jeletzky (1971) further stated that "the Santonian to ?Lower Campanian *Inoceramus lobatus-Cardissoides patootensis* fauna ranges up into the uppermost 120 feet of the Kanguk Formation on Axel Heiberg Island. This leaves hardly any room for the younger Campanian or Maastrichtian faunas beneath the nonmarine clastics of the Eureka Sound Formation even in the central part of the Sverdrup Basin".

Micropaleontological investigations of thick sections on west-central Ellesmere Island and the adjoining coastal area of Axel Heiberg Island revealed a late Turonian to late Campanian age (Wall, 1979) for the Kanguk Formation.

In summary, the most likely age for the Kanguk Formation is early Turonian to late Campanian. Additional evidence from palynological investigations is discussed in this paper.

Eureka Sound Formation

Troelsen (1950, p. 78) proposed the name Eureka Sound Group for a coaly and shaly sandstone unit in central Ellesmere Island and Axel Heiberg Island, without designating a type section or area. Subsequently, Tozer (1963, p. 92-95) renamed the unit the Eureka Sound Formation, and regarded the outcrops on Fosheim Peninsula, adjacent to Eureka Sound, as typical.

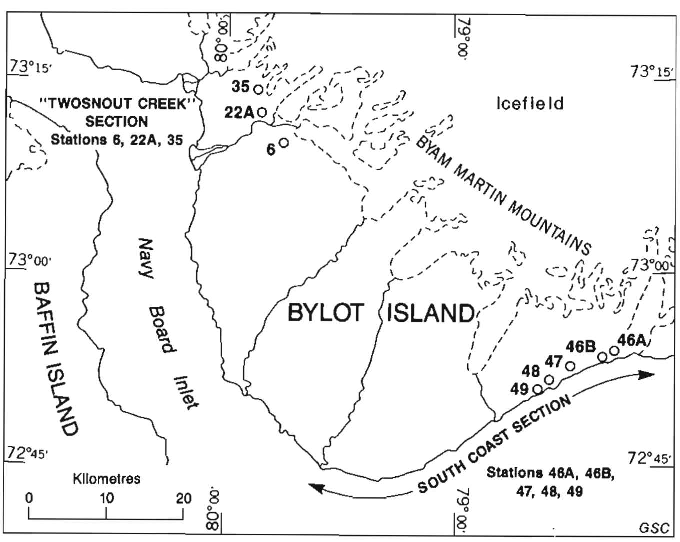

Figure 1. Bylot Island, locations of sections studied.

On Bylot Island, the formation reaches its maximum thickness of 1600 m along the south coast (Miall et al., 1980).

In the Arctic Islands, this formation is widespread, and was originally thought of as predominantly or entirely nonmarine in origin. Recent studies have shown that extensive marine beds may occur. West et al. (1975) convincingly demonstrated, on the basis of foraminifers and fish remains, that a significant portion of the Paleocene Eureka Sound Formation of western Ellesmere Island is marine in origin.

The age of the formation has been discussed by numerous authors. Here, only the most relevant papers have been considered. The first fossil plant collections from this formation were from the Fosheim Peninsula and adjacent areas, and were thought to be Late Cretaceous or Tertiary in age, the Tertiary part being Paleocene or Eocene (Fortier et al., 1963; p. 94). A comprehensive review of the Eureka Sound Formation was published by West et al. (1977). It was concluded that the formation was Maastrichtian to Eocene in age, with the upper part probably Middle Eocene (Bridgerian). A similar age range (Masstrichtian to Eocene) was given by Miall (1979). Rahmani and Hopkins (1977) established an age of approximately Late Cretaceous to Early Tertiary, based entirely on pollen and spores, for the oldest exposed strata of the Eureka Sound Formation on northern Melville Island. A Cretaceous-Tertiary transition was recognized about 15 m above the top of the Kanguk Formation.

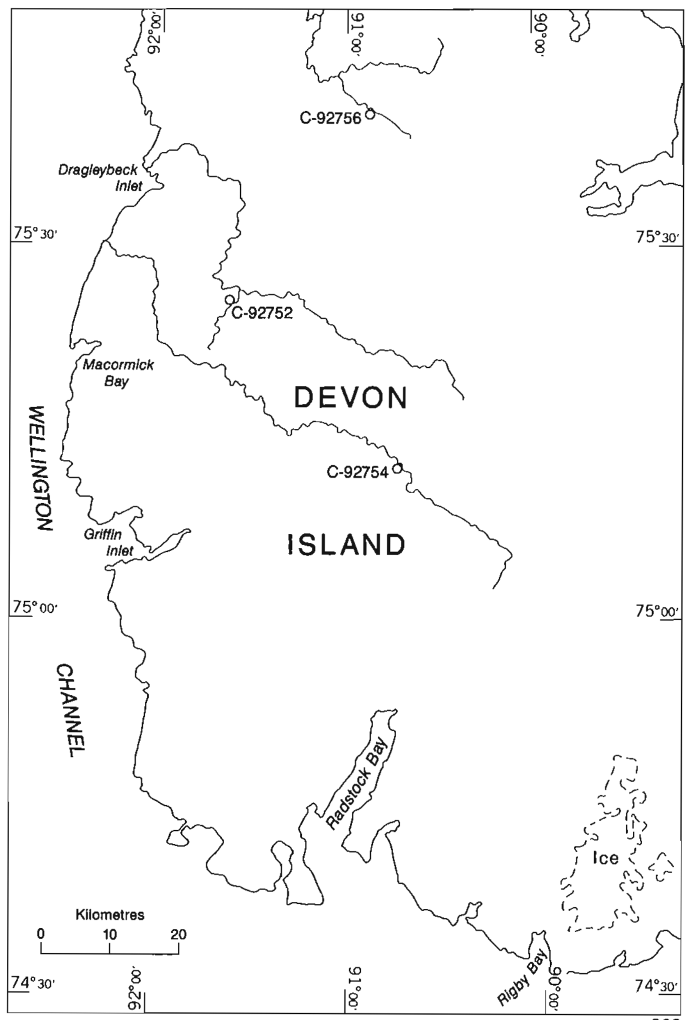

Figure 2. Devon Island, locations of samples studied.

Age of sections studied

In addition to the microplankton investigated for this report, the analyses of terrestrial spores and pollen, foraminifers, silicoflagellates, diatoms, radiolarians and sponge spicules, reported in Miall et al. (1980), were used as a basis for the biostratigraphic interpretations.

The conclusion from the studies of these microfossil groups was that Upper Cretaceous sedimentary rocks are present in both the South Coast section (C-60129 - C-60133), and the "Twosnout Creek" section (C-60110 - C-60114), although the interpreted age of individual samples varied from Santonian to Maastrichtian, depending on the discipline employed. Microfossils in the samples overlying the Cretaceous sequence were rare or absent and palynological age determinations were complicated by reworking. Age assignments based on pollen and spores (Hopkins, in Miall et al., 1980) may be summarized as follows:

South Coast section

C-60129-C-60133 Campanian to Maastrichtian
C-60134-C-60140 Late Paleocene to ?Early Eocene

"Twosnout Creek" section

C-60110-C-60114 Campanian to Maastrichtian
C-76012, C-60115, and C-60118-C-60127 Late Paleocene to ?Early Eocene

GSC LOCALITY NO.	STATION NO. (see Fig. 1)	LONGITUDE AND LATITUDE
'TWOSNOUT CREEK' SECTION		
C-60110 - C-60115	35	73°14'30"N, 79°49'W
C-60118 - C-60123	6	73°09'30"N, 79°42'30"W
C-60125 - C-60127, C-76012	22A	73°13'N, 79°53'W
SOUTH COAST SECTION		
C-60129 - C-60130	46A	72°53'30"N, 78°16'W
C-60131 - C-60133	46B	72°53'30"N, 78°16'W
C-60134 - C-60136	47	72°53'30"N, 78°25'W
C-60137 - C-60139, C-76021	48	72°52'N, 78°31'W
C-60140	49	72°52'N, 78°35'W
DEVON ISLAND		
C-92752		75°26'N, 91°35'W
C-92754		75°17'N, 90°35'W
C-92756		75°41'N, 90°35'W
IOE MARTIN HOUSE L50 (N.W.T.)		
C-1444		66°49'42"N, 133°24'08"W

GSC

TABLE 1. Locations of samples studied.

South Coast section

The South Coast section was selected as a reference section for comparisons with other assemblages dealt with in this paper and assemblages from elsewhere, for three reasons. Firstly, the palynofloras recovered from this section are well preserved, whereas those obtained from "Twosnout Creek" are commonly corroded and impoverished. Secondly, in the South Coast section, with the exception of sample C-60131, very little reworking had occurred, in contrast with the widespread reworking found in the "Twosnout Creek" section. Thirdly, because of the better preservation and lack of reworking, the palyno-sequence is better defined in the South Coast section and, in effect, appears more complete stratigraphically.

For convenience, the South Coast section is divided into four intervals based on the palynomorph assemblages. The intervals are numbered in ascending order from I to IV. It is pertinent to note here that in terms of dinocyst content, sample C-60131 has a close affinity with the assemblages obtained from Interval I (Fig. 4). This was not unexpected as the clay clast from which it was taken is considered to have been eroded from the underlying clay unit and incorporated in the sandstone at the base of Interval II (Fig. 3). The assemblage is, thus, treated with those from Interval I, although stratigraphically the sample is positioned within Interval II.

Microplankton composition and comparison with previous studies

In the following paragraphs, the microplankton composition in the South Coast section will be presented in some detail, followed by a discussion of coeval, or partly comparable, published descriptions of palynological assemblages. Detailed comparisons with distant assemblages are not attempted as it is realized that, more often than not, specific ranges may vary depending upon the study area; their vertical extent appears to be controlled by a variety of factors, including facies, rates of sedimentation, local discontinuities, and techniques of preparation and study. Provincialism also plays an important role in the geographical distribution of dinocysts, and recent attempts to restrict zonal schemes to certain areas or provinces seem justified (e.g. Bujak and Williams, 1978). The lack of direct free circulation between the Atlantic and Arctic oceans during early Campanian time must have affected microplankton distribution (Lentin and Williams, 1980; Gradstein and Srivastava, 1980). The extension of the interior sea from the Gulf of Mexico through western North America to the Arctic in the early Campanian (Williams and Stelck, 1975) contributed to a certain uniformity, but latitudinal climatic differences prevented complete intermixing. Consequently, correlations between local dinocyst schemes often give rise to problems. Young (1963) stressed that ". . . the ammonite zones of the standard European sequences cannot be set up in Texas with any great accuracy. Instead, a parallel zonation must be set up in each area . . . " Thus, correlations between Arctic assemblages and adjacent areas, in general terms, can be extremely effective, but for a more refined dating and subdivision of Upper Cretaceous sedimentary rocks in Arctic Canada, a local scheme is of the utmost necessity.

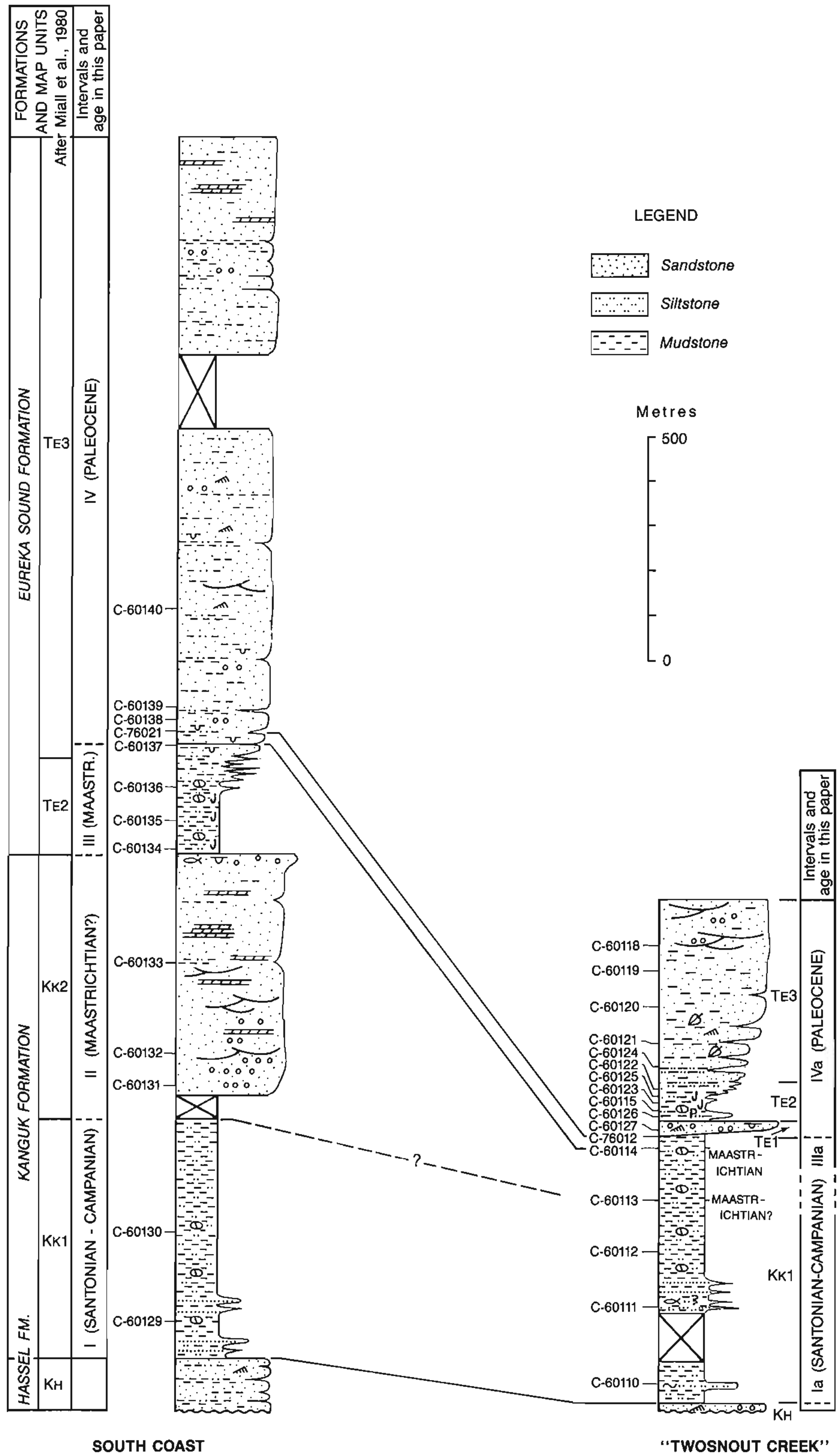

Figure 3. Composite stratigraphic sections of the South Coast and "Twosnout Creek", sections, Bylot Island, showing sample distribution and tentative correlations. Only main lithological units are given. Upper limit of Interval IV not defined because of absence of fossils (unfavourable rock types). Top of Hassel Formation as in Miall et al. (1980). For further information refer to Miall et al. (1980, Figs. 3, 4).

Before discussing the assemblages, it is pertinent to make some comments on Lentin and Williams' (1980) discussion of provincialism and how it relates to the microflora in question. These authors, on the basis of distribution of peridiniacean species, recognized three peridiniacean suites. Their Williams and McIntyre suites, occupying the north Atlantic and north Pacific provinces, respectively, are directly relevant to the present study. If Lentin and Williams' (1980) proposal of provincialism is accepted, the Bylot Island Late Cretaceous assemblages may be considered intermediate in peridiniacean species composition between the two suites, although a stronger link with the McIntyre suite is suggested by the often abundant *Chatangiella*, *Diconodinium*, *Laciniadinium* and *Spinidinium*. However, this interpretation should be viewed with caution because the apparent lack of certain elements may only be a reflection of their irregular stratigraphic distribution under the influence of the factors listed above. For instance, in the sections studied, it has been noted that a species, or association of species, may abound at one horizon, yet be absent from the horizon immediately above or below.

The evidence for provincialism notwithstanding, it has been shown that several species have practically no limits geographically, although variations in their relative abundance may be demonstrated. A few examples will suffice: species of *Dinogymnium* and *Palaeocystodinium* are widespread in both the northern and southern hemispheres, but the number of species appears to diminish poleward. *Deflandrea diebelii* and related forms, *Palaeohystricophora infusorioides*, *Xenascus ceratioides* and species of *Trichodinium* and *Odontochitina* are some of the dinocysts that may be used effectively as they show reasonably consistent age ranges from the Equator to the Arctic.

Interval I

Samples C-60129 to C-60130, and C-60131, which has been included in this interval because the fossils that it contains are considered to be derived from this interval

Microfloral composition

This interval, which spans the Kanguk Formation, a mudstone unit, has the most diverse assemblage in terms of number of species observed (Fig. 4). It is distinguished from the overlying assemblages by the occurrence, and often abundance, of species of *Chatangiella* (including *C. ditissima*, *C. granulifera*, *C. madura* and *C. verrucosa*), *Diconodinium arcticum*, *Chlamydophorella*? *grossa*, *Isabelidinium acuminatum*, *I. cooksoniae*, *I. microarmum*, *Laciniadinium williamsii*, sp. nov., species of *Odontochitina*, *Trithyrodinium* and *Spinidinium*. Other diagnostic forms, such as *Palaeohystrichophora infusorioides*, *Xenascus ceratioides*, Dinoflagellate sp. A, and "*Canningia*" sp. 1, are also well represented. The occurrence of species generally known from older sediments may be the result of reworking, although local extension of their stratigraphic ranges into this interval is possible. The most common species are *Dorocysta litotes*, *Scriniodinium*? *campanulum* and *Wallodinium lunum*. Spores and gymnosperm pollen are sparse.

Discussion

The pioneer works on Late Cretaceous dinocysts in the Arctic Islands are those by Manum (1963), and Manum and Cookson (1964). The former work is a purely morphological study and an age determination more specific than Middle Cretaceous was not attempted. Both papers dealt with the same Graham Island sample, which was poorly located both stratigraphically and geographically. By comparison with assemblages from two samples thought to be from the Hassel Formation on Ellef Ringnes Island, the Graham Island sample was assigned to the Hassel Formation and an early Late Cretaceous age was proposed. Felix and Burbridge (1976), in an investigation of microplankton extracted from reliably identified Kanguk shales, have shown that Manum and Cookson's material is remarkably similar to their assemblages, and bears no resemblance to known assemblages from the Hassel Formation. Furthermore, they proposed "that Manum and Cookson's collections best fits stratigraphically the lower Kanguk Formation", although this is equivocal. The qualitative differences observed by Felix and Burbridge (1976, p. 85, 86) between the upper and lower part of the Kanguk Formation may not be time significant, as the species they use to define this difference are found in association in Interval I. Material from the Bylot Coast section (Fig. 4) compares favourably with Manum and Cookson's material. The apparently less diverse assemblages of Manum and Cookson may be explained by the examination of fewer samples or possibly by the different preparation procedures. The most striking resemblance is the mutual abundance of species of *Chatangiella*, *Isabelidinium*, *Diconodinium* and those of the *Chlamydophorella*? *grossa*-*Scriniodinium*? *obscurum* complex.

McIntyre (1974, 1975), in a detailed study of the palynology of an Upper Cretaceous section along the Horton River, noted that Division H1 assemblages (Santonian to Campanian) are dominated by *Chatangiella ditissima* associated with *C. granulifera*, *C. spectabilis*, *Alterbia minor* and *Trithyrodinium suspectum*. *Isabelidinium acuminatum* occurs in the upper half of his Division H1, whereas *Dorocysta litotes* and *Trichodinium castaneum* occur in the lower part. In terms of these species, Division H1 assemblages closely compare with those obtained from Interval I of the South Coast section, and a comparable age is therefore indicated for Interval I. Younger elements, such as *Chatangiella coronnata*, *C. decorosa* and *Laciniadinium biconiculum*, reported by McIntyre from Division H2, are absent from Bylot Island.

Doerenkamp et al. (1976), in an investigation of Cretaceous and Tertiary microfloras from Banks Island and adjacent areas, proposed a zonation based upon terrestrial and marine palynomorphs. Their Upper Cretaceous CV and CVIa zones are discussed here in relation to the Bylot Island material, although some discrepancies between the text and the range charts make the comparisons difficult. For example, the range of *Chatangiella granulifera* (*ibid.*, p. 384, figs. 2, 4). Zones CV and CVIa (Santonian to Campanian) are considered in association, as more refined comparisons with Bylot Island assemblages cannot be made. This is partly due to the considerably less diverse assemblages reported by Doerenkamp et al. (1976). Species in zones CV and CVIa common to Interval I of the South Coast section include *Diconodinium arcticum*, *Spongodinium delitiense*, *Chatangiella* spp. and the common *Palambages* spp. The dinocyst, *Chatangiella coronata*, as well as pollen of the

Expressipollis complex, are absent from the Bylot Island sections. The former species was reported by Doerenkamp et al. (1976) from the slightly younger zones CVIb and c on Banks Island and was present, though intermittently, in zones CV and CVIa as well as zone CVIb in the Eglinton Island – Cape Nares section. These authors concluded that "in the area studied, the Upper Cretaceous sequence started in Santonian to Campanian times".

Ioannides and McIntyre (1980), in a preliminary study of the Caribou Hills outcrop section, have recognized four palynological associations. Their assemblage A, the oldest stratigraphically, was allocated a Campanian age. Most of the species they reported are exclusive to the Caribou Hills, although some similarities with species from Interval I, Bylot Island, demonstrate an age relationship. Qualitiative differences are believed to be caused by provincialism and/or other reasons, as discussed elsewhere in this report. Mutual occurrences include, "*Canningia*" sp. 1, *Chatangiella ditissima*, *C. granulifera*, *Cyclonephelium distinctum*, *Diconodinium? arcticum*, *Isabelidinium microarmum* and *Odontochitina operculata*.

Harland (1973) examined the microplankton from the Bearpaw Formation of southern Alberta, which was dated late Campanian on the basis of ammonites and radiometric data. Some of this material has been examined by the writer for comparative purposes. Although the Bylot Island assemblages appear somewhat older, they have the following species in common with the Bearpaw assemblages: *Chatangiella spectabilis*, *Oligosphaeridium pulcherrimum*, *Cyclonephelium distinctum* and *Odontochitina operculata*. The species *Lejeunecysta koslowskii*, present in the Bearpaw Formation and also reported together with *Chatangiella coronata* from the late Campanian of the Horton River by McIntyre (1974, 1975) suggests, on negative evidence, that late Campanian sediments may be absent from Bylot Island.

In a study of Cretaceous dinocysts from offshore southeastern Canada, Bujak and Williams (1978) established a zonation which they tentatively related to the standard European stages. Their oldest zone, which compares favourably with Interval I, is the *Odontochitina operculata* Assemblage Zone. Species in common include *Chatangiella granulifera*, *Palaeoperidinium pyrophorum*, *Spiniferites wetzelii*, *Chlamydophorella nyei*, *Odontochitina operculata*, *O. costata*, *Palaeohystrichophora infusorioides*, *Trichodinium castaneum* and *Xenascus ceratioides*. It is notable that some of the species reported by Bujak and Williams (1978) as having mutually exclusive ranges, occur together in Interval I of the South Coast section. This suggests that some of the ranges they recorded have only local significance on the east coast.

May (1980) presented a diverse Upper Cretaceous association from the Monmouth Group, New Jersey. He suggested that the Campanian-Maastrichtian boundary occurs within the uppermost Mount Laurel Sand. In May's section, *Delflandrea diebelii* therefore did not occur below the most probable position for the base of the Maastrichtian, and in this paper, *D. diebelii* is similarly used to mark the base of the Maastrichtian (Interval I-II boundary). Out of 56 species recorded by May up to the first occurrence of *D. diebelii*, only ten are observed in Interval I of the South Coast section. These include *Coronifera oceanica*, *Spinidinium uncinatum*, *Odontochitina costata*, *Xenascus ceratioides* and *Palaeohystrichophora infusorioides*. It is evident from differences in species composition that May's assemblages, as well as those of the Scotian Shelf and Grand Banks, are related more to the assemblages of Northern Europe than to those of Bylot Island.

Wilson (1971) examined the dinocysts from the Campanian stratotype at Aubeterre, southern France. He reported that *Odontochitina* and *Xenascus ceratioides* were common in the lower, but not in the upper, part of the section. A subsequent range chart from Wilson's thesis (1974) published by May (1980) shows that *Odontochitina operculata* and *Xenascus ceratioides* extend into the upper Campanian and basal Maastrichtian of the Maastricht region of Holland and Belgium. *Odontochitina* is common in Interval I of the South Coast section and it is associated with *Xenascus ceratioides*.

In a composite range chart based upon dinoflagellate assemblages from the northwestern European Continental Shelf and adjacent areas, Fisher and Denison (1977) show *Deflandrea diebelii* first occurs in the Maastrichtian, and *Odontochitina operculata* together with *Palaeohystrichophora infusorioides* do not range higher than Campanian. *Xenascus ceratioides* is shown to be present throughout the middle Maastrichtian.

Although one may expect close similarities between the Canadian Arctic region and Siberia in terms of microplankton assemblages, comparisons are virtually impossible to make because of the lack of readily available publications. The only significant work available is that by Vozzhennikova (1976) on peridiniacean fossils from the U.S.S.R. From the Campanian of Kazakhstan she listed the following dinocysts, which are also seen in Interval I of the South Coast section: *Dinogymnium kasachstanicum*, *Chatangiella granulifera* and *Isabelidinium cooksoniae*. From the Santonian she reported *C. granulifera* and *Trithyrodinium suspectum*.

From the above evidence, it is possible that a Santonian to probably early Campanian age is appropriate for Interval I of the South Coast section, Bylot Island.

Interval II

Samples C-60132 and C-60133 (only because of its stratigraphic relationships is sample C-60131 placed within this interval)

Microfloral composition

This interval spans an apparently nonmarine sandstone unit defined as the basal unit of the Eureka Sound Formation by Miall et al. (1980). The base of the sandstone contains reworked clasts from the underlying Kanguk Formation, and the dinoflagellates recovered are, therefore, reworked (Fig. 3, sample C-60131). This situation led the writer to assign a somewhat older age to the sandstone unit during the initial stages of this investigation. The remainder of the sandstone is characterized palynologically by the abundance of long-ranging, terrestrially derived palynomorphs, including fungal spores. The dominant forms are species of *Gleicheniidites*, *Lycopodiacidites* and *Sphagnum* (see Miall et al., 1980, for more detailed documentation). The highly distinctive boreal complex of spores and pollen decribed by Soviet palynologists from the Yenissey Province of Siberia, and subsequently by Felix and Burbridge (1973), McIntyre (1974) and Doerenkamp et al. (1976) from Canada, was not observed here or in the underlying and overlying intervals. So far it has not been possible to determine a precise age within the Cretaceous, but the probability of a Maastrichtian age was suggested by Miall et al. (1980).

Interval III

Samples C-60134 to C-60137

Microfloral composition

This interval spans a predominantly marine mudstone unit within the lower Eureka Sound Formation, and is marked by the initial occurrence of *Deflandrea diebelii*, *Elytrocysta druggii*, *Palaeocystodinium golzowense*, *Spinidinium uncinatum*, a single record of *Ophiobulus lapidaris* (C-60136), and the first appearance of *Thalassiphora pelagica* in the uppermost part of the interval (C-60137, rare). Many of the forms encountered in Interval I do not occur here, the most striking difference being the absence of species of *Chatangiella* and *Diconodinium*, *Chlamydophorella*? *grossa*, *C. nyei* and *Laciniadinium williamsii* sp. nov.

Discussion

Felix and Burbridge (1973) suggested that in their study area the contact between the Eureka Sound and the underlying marine Kanguk is gradational and the presence of some microplankton in the lower part of the Eureka Sound Formation could be expected. The presence of rare to abundant dinoflagellates in the lower Eureka Sound (Interval III) confirms the presence of a gradational Kanguk-Eureka Sound contact on Bylot Island.

The first appearance of *Deflandrea diebelii* is used to indicate the presence of Maastrichtian rocks on Bylot Island (see dicussion below). Earlier, Doerenkamp et al. (1976) characterized their probable Maastrichtian zones, CVIc and CVII, on Banks Island by the incoming of *D. diebelii* and *Lejeunecysta koslowskii* and the continued presence of species from lower in the section. The probable Maastrichtian zones of Doerenkamp et al. (1976) were included in the Kanguk Formation, and the Eureka Sound Formation was assigned a Paleocene age. This differs from the Kanguk Formation on Bylot Island, which appears to incorporate some rocks of questionable Maastrichtian age (Interval II – no dinocysts recovered); the lower part of the Eureka Sound Formation is of Maastrichtian age. This interpretation is made on the assumption that the formation limits were well established by Miall et al. (1980).

The most significant marine palynomorph marking the Maastrichtian in the Horton River section is *Deflandrea diebelii* (within microfloral Division H3; McIntyre, 1974, 1975). However, the ranges of a number of other species in the Horton River section seem to terminate within the Campanian or at approximately the Campanian-Maastrichtian boundary as defined by McIntyre (1974, 1975). Some of the features characterizing the Campanian-Maastrichtian boundary interval in the Horton River section and seen within the correlative part of the Bylot Island sections are as follows: the disappearance of several species of *Chatangiella* and *Isabelidinium* and the absence of *Odonotochitina costata* and *Diconodinium arcticum*. The Maastrichtian of the Horton River section differs in that *Lejeunecysta koslowskii* and some large species of *Chatangiella*, which seem to originate in the late Campanian, are present. The above evidence suggests that the Campanian-Maastrichtian unconformity on Bylot Island spans the late Campanian to early Maastrichtian. A zonation from the Maastrichtian of offshore southeastern Canada has been proposed by Bujak and Williams (1978). In their *Dinogymnium euclaensis* Assemblge Zone they selected, among others, *Deflandrea diebelii*, *Lejeunecysta koslowskii* and *Spongodinium delitiense* as defining the base of this Maastrichtian zone.

Staplin (1976) compiled extensive data obtained essentially from subsurface material. Although his work is statistically oriented, some qualitative data were used to supplement his biostratigraphic conclusions. The oldest sediments were characterized by *Wodehouseia*, aquiloid pollen, and dinocysts, including *Lejeunecysta koslowskii* and the ubiquitous *Deflandrea diebelii*. Only the latter species was seen in Bylot Island (Assemblage III). Further comparisons are hampered by the limited species documentation in Staplin's work and the absence of *Wodehouseia* and *Aquilapollenites* from the Arctic assemblages.

Wilson (1971) examined the lower Maastrichtian and lower upper Maastrichtian of Mons Klint, Denmark, which were dated with foraminfers and brachiopods. He recorded several species of *Deflandrea*, including *D. diebelii*. Wilson also studied the Maastrichtian-Danian boundary at Stevens Klint, the type section for the lower Danian. The Maastrichtian palynoflora is dominated by *Palynodinium grallator*. *Thalassiphora pelagica* and *Isabelidinium cretaceum* first appear within the top 5 m of the Maastrichtian. Hansen (1976, 1979) also recorded the first occurrence of *T. pelagica* in the late Maastrichtian. *Palynodinium grallator* is absent from Bylot Island, whereas *T. pelagica* is present and is tentatively considered also to mark the uppermost Maastrichtian on Bylot Island. *Isabelidinium cretaceum* has a more irregular distribution, although in both southeastern Canada and Denmark it is not encountered in rocks older than Maastrichtian. Wilson (1971) also examined the type Maastrichtian section from the Maastricht region in Holland, and the overlying lower Danian of the same area. The upper Maastrichtian assemblages were dominated by *Areoligera* and *Cyclonephelium* in the lower part, and moderately abundant *Cordosphaeridium* in the upper part. Specimens assigned questionably to *Thalassiphora* appear and become more abundant toward the top of the sequence. A morphologically similar association was recorded in Interval IV from what is thought to be Early Tertiary on Bylot Island. In addition to *Areoligera*, *Cyclonephelium* and *Cordosphaeridium*, *Thalassiphora pelagica* is represented in abundance, together with rare specimens of *Deflandrea speciosa*, in Interval IV.

Based on the above comparisons it may be concluded that Interval III is of Maastrichtian age, although its dating is based on limited evidence.

Interval IV

Samples C-76021, C-60138 to C-60140

Microfloral composition

This interval coincides with a predominantly sandstone sequence. Considerable microfloral differences are manifest between Interval IV and the preceding intervals. First, all diagnostic Late Cretaceous dinocysts disappear and new elements appear. Second, the assemblages are very restricted qualitatively, being generally dominanted by one or two species. The most important dinoflagellates are species of *Cordosphaeridium*, *Thalassiphora pelagica*, *Glaphyrocysta ordinata*, *Paleoperidinium pyrophorum* and rare *Deflandrea speciosa*. Elsewhere, these species are typically found in lowermost Tertiary rocks. The almost monospecific nature of these assemblages may reflect the often changing sedimentary environment in a nearshore, transitional facies, where salinity fluctuations were amplified by seasonal variations of the incoming runoff water. Thus, a particular species more tolerant of variable salinity, may have become overwhelmingly predominant in an environment less favoured by other phytoplankton.

Discussion

There have been few dinoflagellate studies on the Early Tertiary of the Arctic Islands and southwestern Canada. Hydrocarbon exploration in the Mackenzie Delta area and offshore Eastern Canada has drawn the attention of biostratigraphers to these regions (Williams and Brideaux, 1975; Brideaux and Myhr, 1976; Doerenkamp et al., 1976; Staplin, 1976; Williams and Bujak, 1977; Barss et al., 1979; Ioannides and McIntyre, 1980).

Brideaux and Myhr (1976), in their discussion on the dinoflagellate succession in the Gulf-Mobil Parsons N-10 well from the Mackenzie Delta, identified as Paleocene the part of the sequence containing *Glaphyrocysta ordinata*, *Cordosphaeridium exilimurum*, *C. inodes*, *Paleoperidinium pyrophorum* (as *P. basilium*) and the widespread *Apectodinium homomorphum* (as *Wetzeliella homomorpha*). With the exception of the latter species, this association occurs in Interval IV of the South Coast section. It is possible that the absence of *Apectodinium* from Bylot Island suggests an early Paleocene age for Interval IV, although this is a strictly negative argument.

Williams and Bujak (1977) in their Cenozoic palynostratigraphy of offshore Eastern Canada, reported a diverse dinocyst association from an interval with an age postulated as Paleocene. Their Lower Paleocene *Palaeoperidinium pyrophorum* Assemblage Zone contained, among others, *Deflandrea speciosa*, *Glaphyrocysta ordinata* and *Palaeoperidinium pyrophorum*, whereas *Thalassiphora pelagica* was first reported from the Upper Paleocene (*Deflandrea speciosa* Assemblage Zone).

Although common, *Thalassiphora pelagica* does not generally appear below the Eocene, its presence in the South Coast section, together with *Deflandrea speciosa*, *Deflandrea diebelii* and *Palaeoperidinium pyrophorum*, would indicate a general, possibly early Paleocene age. A more precise age determination is not attempted because of limited knowledge of dinoflagellate ranges in Arctic and Western Canada.

COMPARISON OF THE "TWOSNOUT CREEK" SECTION WITH THE SOUTH COAST SECTION

The intervals numbered I-IV in the South Coast section are numbered Ia-IVa in the "Twosnout Creek" section.

Interval Ia

Samples C-60110 to C-60112 (C-60113 is considered transitional between intervals I and III)

A number of important species are mutual components of intervals I and Ia. They include *Xenascus ceratioides*, *Stephodinium coronatum*, *Xiphophoridium alatum*, *Isabelidinium acuminatum*, *Odontochitina operculata* and other species plotted in Figures 4 and 5. The dinocysts exclusive to either section are generally the scarce species. Although these scarce species may be stratigraphically important, their absence from one section is not necessarily indicative of a time difference. Thus, in general terms, it

SPECIES \ INTERVALS	I	Ia	III	IIIa	IV	IVa
	OCCURRENCES					
Cyclonephelium membraniphorum	●					
Saeptodinium eurypylum	●					
Trithyrodinium fragile	●					
Palaeotetradinium silicorum	●					
Trichodinium castaneum	●					
Chatangiella ditissima	●					
Gillinia hymenophora		●				
Fromea chytra		●				
Deflandrea diebelii		?	●		●	●
Dinogymnium euclaense	●	●				
Chlamydophorella? grossa	●	●				
Xenascus ceratioides	●	●				
Diconodinium? arcticum	●	●				
Stephodinium coronatum	●	●				
Isabelidinium acuminatum	●	●				
Xiphophoridium alatum	●	●				
Odontochitina operculata	●	●				
Hystrichosphaeropsis sp.	●	●				
Isabelidinium cretaceum			●			
Ophiobolus lapidaris			●			
Deflandrea speciosa					●	●
Cordosphaeridium exilimurum					●	●
Cordosphaeridium inodes					●	●
Thalassiphora pelagica			●	●	●	●

GSC

Figure 5. *Occurrence of selected species in the South Coast and "Twosnout Creek" sections, Bylot Island.*

appears that intervals I and Ia can be correlated, but whether they span entirely the same time interval, cannot be established, using the present information (see discussion below).

Interval IIIa

Equal to upper part of Interval III (only sample C-60114 is correlated with sample C-60137 in the South Coast section)

The occurrence of *Thalassiphora pelagica* in samples C-60114 ("Twosnout Creek") and C-60137 (South Coast) indicates a correlation between these two samples. Furthermore, considering the questionable record of *Deflandrea diebelii* in sample C-60113 ("Twosnout Creek"), one may suspect a Maastrichtian influence in the uppermost part of the Kanguk Formation in the "Twosnout Creek" section.

Interval IVa

Samples C-76012, C-60115, and C-01118 to C-60127

Dinocyst diversity in the Tertiary of both sections is rather limited, but the species present may be represented by many specimens. Almost monospecific populations are predominant at certain levels, denoting specific environments of probable nearshore deposition. *Deflandrea diebelii*, *Deflandrea speciosa*, *Cordosphaeridium inodes*, *Cordosphaeridium exilimurum*, *Thalassiphora pelagica*, *Palaeoperidinium pyrophorum* and *Areologera*, together with *Glaphyrocysta*, occur in abundance alternately throughout the Tertiary intervals studied. Their frequent representation in both sections suggests a reasonable correlation of the mudstone members in intervals IV and IVa.

Conclusions

From the general microfloral composition, one may suggest that Interval I is partly represented in the "Twosnout Creek" section (Interval Ia) where the mudstone member (Kanguk Formation) may incorporate some Maastrichtian at the top; the sand unit (Interval II) and a large part of the mudstone unit above (Interval III) in the South Coast section are not present in the "Twosnout Creek" section. The upper portion of Interval III (C-60137) is directly correlated with sample C-60114 (Interval IIIa). Interval IV in the South Coast section closely compares with Interval IVa. Palynomorphs diminish and eventually disappear higher in the section, where the sequence consists of sandstones. Due to the depletion of palynomorphs, the upper limits of intervals IV and IVa are not defined.

Closer sampling throughout the sections would facilitate comparisons and perhaps clarify some of the problems encountered, such as recycling and microfacies (palynofacies).

QUANTITATIVE ANALYSES OF THE SECTIONS INVESTIGATED

Relative proportions of marine and nonmarine palynomorphs are plotted in Figures 6 and 7. Although a clear cut pattern that might provide additional evidence for comparing the two sections has not emerged (largely because of the wide spacing of the samples), some interesting generalities may be pointed out. The Kanguk Formation, which represents a Late Cretaceous marine transgression, contains rich and diverse dinocyst assemblages in both the "Twosnout Creek" and South Coast sections. The sandstone unit in the South Coast section (C-60132 and C-60133) has yielded only terrestrially derived palynomorphs, suggesting a nonmarine origin. This is in agreement with the interpretation of Miall et al. (1980). The abundance of fungal spores in C-60133 indicates a fluctuating water level, which possibly gave rise to swamp or deltaic conditions. Samples C-76012 and C-60127, obtained from a unit in "Twosnout Creek" interpreted by Miall et al. as a probable shoreline deposit, yielded abundant dinocysts, but as already mentioned, the assemblages are very limited qualitatively. The lower mudstone member of the Eureka Sound Formation also yielded populations rather limited in diversity. These were found in samples C-60134 and C-60127 in the South Coast and "Twosnout Creek" sections, respectively, as well as in samples immediately above.

Section	GSC LOCALITY NUMBER	MICRO-PLANKTON	SPORES POLLEN	BISACCATE POLLEN	FUNGAL SPORES
"TWOSNOUT CREEK" SECTION	C-60118	0	67	33	
	C-60119	0	86	14	
	C-60120	0	83	12	5
	C-60121	1	85	14	
	C-60124	8	77	15	
	C-60122	3	83	14	
	C-60125	poor recovery			
	C-60123	poor recovery			
	C-60115	poor recovery			
	C-60126	58	29	13	
	C-60127	57	36	7	
	C-76012	53	43	4	
	C-60114	32	64	4	
	C-60113	25	74	1	
	C-60112	84	9	7	
	C-60111	29	56	15	
	C-60110	57	37	6	
SOUTH COAST SECTION	C-60140	30	54	16	
	C-60139	11	75	14	
	C-76021	64	23	13	
	C-60137	poor recovery			
	C-60136	21	63	16	
	C-60135	35	51	14	
	C-60134	33	61	6	
	C-60133	0	74	7	19
	C-60132	0	94	6	
	C-60131	44	52	4	
	C-60130	27	39	34	
	C-60129	45	49	6	

GSC

Figure 6. *Percentages of major palynomorph groups based on counts of 500 specimens from each sample.*

Only the lower part of the upper sandstone member (Fig. 3) has yielded any dinoflagellates. The abundance of *Thalassiphora pelagica* in sample C-60138 probably represents the closing stages of this predominantly marine sedimentary cycle, which was replaced gradationally by fluvial sandy deposits (Miall et al., 1980). It has been suggested that open marine sediments alternated with shallow water, nearshore and subaerial deposits in the lower beds of the Eureka Sound Formation (Miall et al., 1980, p. 13); the palynological assemblages support this interpretation. A microfacies analysis of this part of the sequence, involving close sampling and detailed dinocyst documentation, would certainly provide useful and interesting data on the palynofacies.

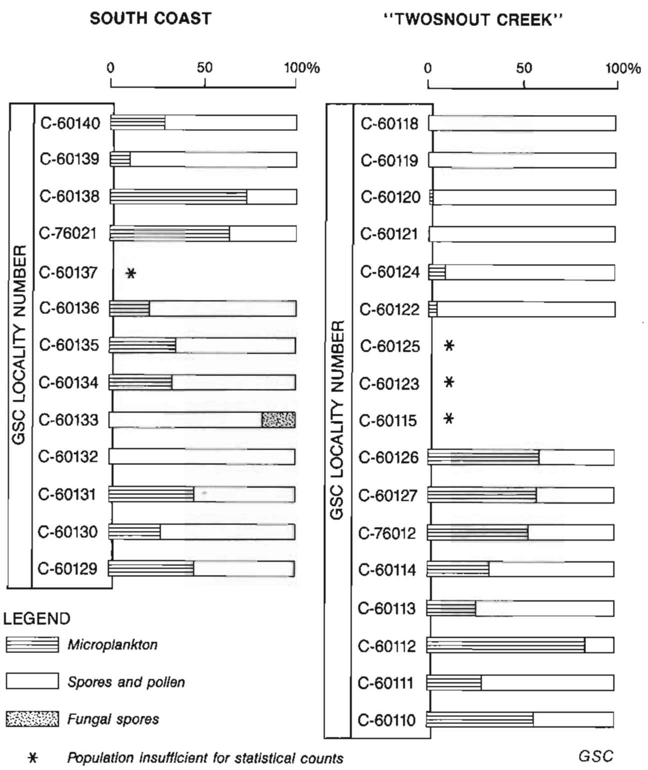

Figure 7. Bar graph showing relative proportions of terrestrial and marine palynomorphs, and fungal spores (based on the counts shown in Fig. 6).

DEVON ISLAND

Microfloral composition and comparison with the South Coast section, Bylot Island

The assemblages recovered from the three samples from Devon Island are considered collectively (Figs. 2, 8). Despite some qualitative differences observed among them, no age differentiation was attempted, because of the limited number of samples and their essentially similar composition in terms of diagnostic species.

Mutual occurrences included *Chatangiella granulifera*, *Chlamydophorella nyei*, *Dorocysta litotes*, *Exochosphaeridium striolatum*, *Heterosphaeridium difficile* comb. nov., *Odontochitina costata*, *Scriniodinium*? *obscurum* and *Trithyrodinium suspectum*. The exclusive records quoted below and the resulting permutations suggest that the three samples are more or less contemporaneous and the differences in composition were probably caused by environmental factors. Some of the occurrences are as follows: *Chatangiella spectabilis* (C-92752 and C-92754), *Dinogymnium euclaense* (C-92754), *Elytrocysta druggii* (C-92754 and C-92756), *Isabelidinium acuminatum* (C-92754 and C-92756), *Odontochitina operculata* (C-92752 and C-92754), *Palaeohystrichophora infusorioides* (C-92754) and *Palaeoperidinium pyrophorum* (C-92752 and C-92754).

Considered in association, these samples show a striking similarity with Interval I in the South Coast section and a similar age is inferred (Santonian to most likely early Campanian).

PALYNOMORPHS	GSC LOCALITY NO.		
	C-92752	C-92754	C-92755
Dinogymnium euclaense		●	
Achomosphaera ramulifera	●	●	
Adnatosphaeridium? sp.	●		
Canningia? *minor*	●	●	
Cleistosphaeridium? *aciculare*	●	●	●
Chatangiella granulifera	●	●	?
Chatangiella spectabilis	●	●	
Chatangiella verrucosa	?		
Chlamydophorella? *grossa*	●	●	
Chlamydophorella nyei	●	●	●
Cribroperidinium edwardsii	●		
Cribroperidinium sp. A		●	●
Cribroperidinium sp. B	●	●	
Cyclonephelium distinctum	●	●	●
Diconodinium? *arcticum*		●	
Dorocysta litotes	●	●	●
Elytrocysta druggii		●	●
Exochosphaeridium bifidum	●	●	●
Exochosphaeridium striolatum	●	●	●
Fibrocysta? sp. cf. *F. vectensis*	●	●	
Florentinia? *mantelli*	●		
Fromea fragilis	●	●	●
Heterosphaeridium difficile comb. nov.	●	●	●
Hystrichosphaeropsis sp.		●	
Isabelidinium acuminatum		●	●
Impletosphaeridium sp.	●	●	
Odontochitina costata	●	●	●
Odontochitina operculta	●	●	
Palaeohystrichophora infusorioides		●	
Palaeoperidinium pyrophorum	●	●	
Pterodinium sp.	●	●	
Scriniodinium? *campanulum*	●		
Scriniodinium? *obscurum*	●	●	●
Spinidinium uncinatum		?	
Spiniferites cingulatus	●	●	●
Spiniferites ramosus	●	●	●
Spongodinium? sp.	?		
Trichodinium castaneum			?
Trithyrodinium suspectum	●	●	●
Wallodinium lunum		●	
Dinoflagellate sp. A			●
Dinoflagellate sp. B	●	●	
Palambages spp.	●		

GSC

Figure 8. Microplankton distribution chart, Devon Island.

SYSTEMATIC PALEONTOLOGY

It is becoming increasingly evident that dinoflagellates can have high intraspecific variability and a few authors have already been concerned with its implications (e.g. May, 1980; Hochuli, pers. comm.). The author was faced with this problem throughout this investigation, and some of the implications are outlined in the following paragraphs. Newell (1947, 1956) and other paleontologists, emphasized the importance of dealing with sufficiently large populations in order to observe the inherent variability of the organism under consideration. Discontinuities in small populations may form conspicuous anomalies, but may be placed within gradational contemporaneous series as individual variants of large populations.

Such an observation has been verified in this work. For the trained palynologist, studying a single slide to assign separate individuals to respective species is a matter of routine, and generally presents no serious problems. This is largely because of the incompleteness of the record with respect to the potential range in morphological variablity. The extent of the variability becomes more apparent when several slides made from a sieved fraction, in which the dinoflagellates are concentrated, are examined. A good start toward a better understanding of these problems would be the precise description of the graded morphological series, the illustration of the full range of variation, and, whenever possible, the statistical and/or graphic representation of the variability.

It is pertinent to note here Arkell's (1956) observation on European ammonites. He stated that "in different geographical localities certain species that are easily separable in one locality may be linked by intermediates in another, the extent of gradation depending on local discontinuities". It would seem reasonable to assume that similar variations might be anticipated with dinoflagellate cyst morphology at different geographic localities. This infers that studies involving many geographic localities are essential for the understanding of fossil dinocysts, and projects of this nature should be pursued by researchers and encouraged by institutions.

In the systematic section, species are arranged alphabetically both in the text and plates, with the exception of morphologically related species that are provisionally treated as complexes, and algal cysts of uncertain origin, which are grouped at the end of the section. The complexes are illustrated in groups for immediate comparison, although individual species, which may form parts of a larger complex, are placed in alphabetical order.

The descriptive terminology used in this paper follows that of Stover and Evitt (1978), with a few additional terms of ornament morphology that were proposed by Davey et al. (1966).

Systematic descriptions are provided for species encountered in the palynological preparations, although the descriptions vary considerably in detail, depending on the material available. A few species, which are represented by only one or two specimens, have not been described because they are well documented in the literature and there is no additional information on their morphology available from the present work.

Due to the scarcity of palynological information from the Late Cretaceous of the Arctic Islands, and in particular that dealing with taxonomy, the above procedure was thought to be desirable in order to provide a more complete picture of the palynological spectrum of these rocks. Thus, it is hoped that the information presented here will provide a framework for future taxonomic clarifications of the material described in this report.

Division PYRRHOPHYTA Pascher, 1914

Class DINOPHYCEAE Fritsch, 1929

Order GYMNODINIALES Lindemann, 1928

Genus *Dinogymnium* Evitt, Clarke and Verdier, 1967

Dinogymnium euclaense Cookson and Eisenack, 1970

Plate 1, figures 1-4

1970 *Dinogymnium euclaense* Cookson and Eisenack, p. 139, Pl. 10, figs. 9-12.

Dimensions. Cyst length 28-36 µm, width at paracingular plane 24-32 µm (11 specimens measured).

Remarks. The specimens observed in this investigation have a slightly less conical epicyst than the type material, and either more or fewer longitudinal folds on the hypocyst. They are still considered to fall within the intraspecific variability of *Dinogymnium euclaense.*

Dinogymnium sp. cf. *D. kasachstanicum* (Vozzhennikova) Lentin and Williams, 1973

Plate 1, figure 5

Dimensions. Length of cyst 61-65 µm, width 28-32 µm (3 specimens measured).

Remarks. These specimens approximate those described by Vozzhenikova (1967, p. 45, 46, Pl. 2, figs. 4a, b, Pl. 3, figs. 9a, b) as *Gymnodinium kasachstanicum*, but they have a more rounded antapex. They probably represent an intraspecific variant of the species.

Dinogymnium sp. 1 of McIntyre, 1974

Plate 1, figure 6

1974 *Dinogymnium* sp. 1. McIntyre, Pl. 1, figs. 1-3.

Description. Shape compressed ovoid. Wall consists of autophragm only. No parasutural features observed. Longitudinal folds weakly developed or absent. Autophragm strongly punctate. Paratabulation indicated only by archeopyle. Archeopyle apical, with small attached operculum. Paracingulum indicated by a subequatorial depression (toward apex), delimited by prominent folds. Parasulcus indicated by well defined longitudinal concavity restricted to hypocyst and delimited by arcuate folds with convex side toward parasulcus. Antapical invagination may be developed at lowermost limit of sulcus.

Dimensions. Overall cyst length 67 and 64 µm, width at paracingular zone 50 and 48 µm, respectively; autophragm less than 1 µm thick (2 specimens measured).

Remarks. The overall shape, the prominent parasulcal depression and the sparse longitudinal folds are characteristic of this form.

Order PERIDINIALES Haeckel, 1894

Genus *Achomosphaera* Evitt, 1963

Achomosphaera ramulifera (Deflandre) Evitt, 1963

Plate 1, figure 10

1937 *Hystrichosphaeridium ramuliferum* Deflandre, p. 74, Pl. 14, figs. 5, 6, Pl. 17, fig. 10.

Dimensions. Body length 48-53 µm, width 39-44 µm; processes up to 20 µm high (8 specimens measured).

Remarks. Specimens conform to Evitt's description (1963).

Adnatosphaeridium? sp.

Plate 2, figures 2, 3; Figure 9

Description. Body spherical to subspherical. Autophragm, smooth to granular, bearing numerous slender processes, occasionally connected distally by trabeculae but normally intertwined; varying in structure from simple, acuminate to very complex, distal forms (Fig. 9); proximally may be locally arranged in linear complexes, but mostly joined irregularly due to dense distribution; processes apparently nontabular, generally solid, although dubious hollow processes seen. Paratabulation indicated by archeopyle only. Archeopyle apical, type (tAa) or (tA). Paracingulum and parasulcus not indicated.

Dimensions. Body length 82-110 µm, width 80-102 µm, length of processes up to 18 µm, but normally about 12 µm; autophragm 1 µm or less in thickness (10 specimens measured).

Figure 9. Adnatosphaeridium? *sp., diagrammatic representation of process structure.*

Comparison and remarks. Because of the indeterminate distribution of its processes, this form is only questionably assigned to the genus *Adnatosphaeridium*.

The short and complex processes and their dense distribution are characteristic of this species, and the erection of a new genus may be justifiable if further material becomes available.

Genus *Alterbia* Lentin and Williams, 1976

Alterbia minor (Alberti) Lentin and Williams, 1976

Plate 1, figures 7, 8

1959 *Deflandrea minor* Alberti, p. 98, Pl. 9, figs. 9-11.

1976 *Alterbia minor* (Alberti) Lentin and Williams, p. 49.

Dimensions. Length of pericyst 65-76 µm, width 52-59 µm; length of endocyst 42-60 µm, width 48-54 µm (10 specimens measured).

Remarks. Specimens comparable to those described by Alberti (1959).

Alterbia sp. cf. *A. foliacea* (Eisenack and Cookson) Lentin and Williams, 1976

Plate 1, figure 9

Dimensions. Pericyst 67-70 µm, long, 54-56 µm wide; endocyst 37-40 µm long, 45-48 µm wide (2 specimens measured).

Remarks. Specimens have an intercalary archeopyle type Ia (2a only). Otherwise, they are similar to *Subtilisphaera foliacea* (Eisenack and Cookson) Stover and Evitt, 1978.

Genus *Areoligera* Lejeune-Carpentier emend. Williams and Downie, in Davey et al., 1966.

Type species. Areoligera senonensis Lejeune-Carpentier, 1938.

Areoligera senonensis complex

Remarks. The species *Areoligera senonensis* Lejeune-Carpentier and related species were discussed, at some length, by Eaton (1976, p. 242-244), whose taxonomic approach has essentially been adopted here. The six types distinguished by Eaton (*ibid*., p. 244) and earlier workers are, however, not formally used here as distinct species for they are considered to represent morphological extremes of *A. senonensis* and *A. coronata* (*A. medusettiformis* was regarded by Morgenroth (1968) as a synonym of *A. coronata*), a fact also recognized by Eaton (1976, p. 243). Indeed, the process structure and distribution is not always evident and the degree of development of process complexes is highly variable. The majority of the specimens seen in dorsoventral orientation have process complexes on both surfaces, with the exception of the parasulcal region.

Areoligera senonensis Lejeune-Carpentier, 1938

Plate 1, figures 11, 12

1938 *Areoligera senonensis* Lejeune-Carpentier, B164, textfigs. 1-3.

Dimensions. Body length 47-64 µm (without operculum), 56-82 µm long (with operculum), 43-83 µm wide; autophragm less than 1 to 2.5 µm thick; processes 4-32 µm long (26 specimens measured).

Remarks. Specimens conform to original diagnosis. *Areoligera senonensis* is abundant in sample C-76012.

Genus *Caligodinium* Drugg, 1970

Caligodinium aceras (Manum and Cookson) Lentin and Williams, 1973

Plate 2, figure 4

1964 *Kalyptea aceras* Manum and Cookson, p. 27-28, Pl. 6, figs. 9-11.

1973 *Caligodinium aceras* (Manum and Cookson) Lentin and Williams, p. 21.

Dimensions. Body length 80-95 µm long, 67-74 µm wide; flocculent outer covering up to 24 µm high; autophragm 1.5-3 µm thick (7 specimens measured).

Remarks. Outer covering very irregular, often incomplete, occasionally approaching a fibrous structure reminscent of the hairy spines of *Impletosphaeridium whitei* (Deflandre and Courteville) Morgenroth, 1966. The type of archeopyle quoted by Stover and Evitt (1978, p. 24) has been observed in most specimens (operculum composed of three paraplates).

Caligodinium? sp.

Plate 2, figures 5, 6

Dimensions. Body length 68-94 µm, width 46-68 µm; flocculent outer covering very irregular but up to 17 µm high; autophragm 1-15 µm thick (9 specimens measured).

Remarks. A form similar to *Caligodinium* but with uncertain type of archeopyle.

Genus *Canningia* Cookson and Eisenack, 1960

Canningia? *minor* Cookson and Hughes, 1964

Plate 2, figures 10, 15

1964 *Canningia minor* Cookson and Hughes, p. 43-44, Pl. 8, figs. 1-3, 5.

Dimensions. Cyst length 48-78 µm, width, 46-74 µm (4 specimens measured).

Remarks. Most of the specimens fall within the description of *Canningia minor*, and are identical to the specimen illustrated by Cookson and Hughes (1964, Pl. 8, fig. 2). However, because of the lack of any protrusions and the dubiously lenticular shape of the cyst, they are only tentatively assigned to the genus.

Canningia? *ringnesiorum* Manum and Cookson, 1964

Plate 2, figure 7

1964 *Canningia ringnesii* Manum and Cookson, p. 15, Pl. 11, fig. 10.

1964 *Canningia ringnesiorum* Manum and Cookson, p. 15, Pl. 11, fig. 11, in Lentin and Williams, 1977, p. 17 (new ending).

Dimensions. Cyst length 76 and 80 µm, width 75 and 80 µm, respectively, including operculum (2 specimens measured).

Remarks. Specimens are essentially the same as the type specimen, but sparsely ornamented, with spinules up to 2 µm long. They are provisionally attributed to the species until further specimens are seen.

Genus *Cleistosphaeridium* Davey et al., in Davey et al., 1966

Cleistosphaeridium? aciculare Davey, 1969

Plate 3, figures 1-3

1969 ?*Cleistosphaeridium aciculare* Davey, p. 15, Pl. 6, figs. 11, 12.

Dimensions. Body length 30-56 µm, width 25-50 µm; processes 9-20 µm, usually between 10 and 15 µm long (17 specimens measured).

Remarks. Specimens identical in all respects to those described by Davey (1969).

Genus *Chatangiella* Vozzhennikova emend. Lentin and Williams, 1976

Chatangiella ditissima (McIntyre) Lentin and Williams, 1976

Plate 3, figures 5-9

1975 *Deflandrea ditissima* McIntyre, p. 62-63, Pl. 1, figs. 1-4.

1976 *Chatangiella ditissima* (McIntyre) Lentin and Williams, p. 54.

Dimensions. Endocyst 47-60 µm long, 60-82 µm wide; total length 90-130 µm (total width not measurable; it approximates width of endocyst; cingulum 4-7 µm wide (16 specimens measured).

Remarks. Specimens morphologically identical to those described by McIntyre (1975), but with a smaller size range. A complete gradation in the overall size has been observed and these smaller specimens are considered to be intraspecific variants of *C. ditissima*. They also show a superficial resemblance to *C.? scheii* Manum, 1963, but the latter form possesses prominent parasutures.

Chatangiella granulifera (Manum) Lentin and Williams, 1976

Plate 3, figures 10, 11;
Plate 4, figures 1, 2, 4, 9

1963 *Deflandrea granulifera* Manum, p. 61-62, Pl. 3, figs. 5-9.

1976 *Chatangiella granulifera* (Manum) Lentin and Williams, p. 54.

Description. Shape of cyst longitudinally elongate; at apex, pericyst broadly rounded with short, conical, sometimes truncate, horn; antapical margin between horns straight to convex, left horn usually differentiated; endocyst spherical to subspherical, often distinctly convex medially, filling the pericyst. Cyst bicavate, rarely faintly circumcavate. No parasutural features present. Periphragm strongly punctuate to coarsely granular, grana more or less uniformly distributed. Endophragm smooth to faintly granular. Paratabulation indicated by archeopyle and paracingulum, although some longitudinal folds may simulate plates on hypocyst. Archeopyle intercalary normally type I/3I, rarely I/I; perioperculum free, rounded to broadly hexagonal in outline. Endoarcheopyle composed of three, rarely one, intercalary plates; endopercula always attached, more so along their posterior margins; outline hexagonal (2a), subhexagonal or irregularly folded (1a and 3a). Paracingulum indicated by interrupted transverse parallel ridges, accentuated by grana, usually tripartite dorsally (Pl. 4, fig. 1), bipartite ventrally (Pl. 4, fig. 4). Parasulcus expressed as a poorly defined shallow depression, which may be delimited by folds; generally restricted on hypocyst but occasionally extending slightly onto preparacingular area of epicyst.

Dimensions. Endocyst length 49-72 µm, width 55-70 µm; total length 88-132 µm, total width 59-70 µm; grana 1 µm or less in dimensions (16 specimens measured).

Remarks. Although the specimens seen conform to Manum's (1963) diagnosis they are here described in order to emphasize the type of archeopyle that can also be seen in Manum's figured specimens (Pl. 3, figs. 5, 6, 8, 9). The intergradation between *Chatangiella granulifera* and *C. verrucosa* typifies the problems that the author has encountered throughout this investigation, namely, the intergradation between genera or species.

One feature of interest is the occasional opening observed between the antapical horns, also described by McIntyre (1975) as characterizing his species *C.? biapertura* (McIntyre) Lentin and Williams (1976). The same opening can be seen in Manum and Cookson's material (Pl. 1, figs. 7, 8: *C. verrucosa* and *C. granulifera*, respectively), and also on the specimens shown by Manum (1963, Pl. 3).

Chatangiella madura Lentin and Williams, 1976

Plate 4, figures 10-12

1970 *Deflandrea manumi* Cookson and Eisenack, p. 141-142, Pl. 11, figs. 10, 11.

1976 *Chatangiella madura* Lentin and Williams, p. 54, nom. subst. pro.

1976 *Chatangiella manumii* (Cookson and Eisenack) Lentin and Williams, p. 54.

Dimensions. Pericyst length 68-90 µm, width 39-45 µm; endocyst length 28-35 µm, width 43-45 µm (7 specimens measured).

Remarks. The specimens are essentially the same as those described by Cookson and Eisenack (1970); the ornament ranges from grana to almost rod-like elements up to 2 µm in height. The larger ornament is restricted to a medial zone, mainly on the paracingular sutures. In gross morphology, *Chatangiella tripartita* (Cookson and Eisenack) Lentin and Williams, 1976 is very similar; perhaps they all form part of the intraspecific variability of a single species.

Chatangiella spectabilis (Alberti)
Lentin and Williams, 1976

Plate 4, figures 7, 8

1959 *Deflandrea spectabilis* Alberti, p. 99, Pl. 9, figs. 7, 8.

1976 *Chatangiella spectabilis* (Alberti) Lentin and Williams, p. 55.

Dimensions. Endocyst length 39-62 µm, width 47-65 µm; total length 83-121 µm, total width 50-70 µm; archeopyle 28-36 µm x 16-32 µm.

Remarks. Specimen conforms to Alberti's diagnosis, except for the slightly greater range in size (86-110 µm long, 52-68 µm wide).

Chatangiella verrucosa (Manum)
Lentin and Williams, 1976

Plate 3, figure 4;
Plate 4, figures 3, 5, 6

1963 *Deflandrea verrucosa* Manum, p. 60, Pl. 3, figs. 1-4.

1976 *Chatangiella verrucosa* (Manum) Lentin and Williams, p. 55.

Dimensions. Endocyst length 45-68 µm, width 58-70 µm; total length 83-122 µm, total width 58-74 µm; verrucate ornament 1-1.5 µm in diameter (15 specimens measured).

Remarks. Specimens essentially conform to the original diagnosis of Manum (1963). Apart from the verrucate ornament, they are similar to *Chatangiella granulifera* in all respects, although occasionally grana may approach verrucae in size and a clear cut distinction between the two species may be difficult.

Genus *Chlamydophorella* Cookson and Eisenack, 1958

Chlamydophorella? grossa - Scriniodinium? obscurum *complex*

This group of fossils and morphologically related forms described here as *Spongodinium*? sp. (cf. *S.*? *delitiense*) are provisionally treated as part of the same complex because of the wide variability and apparent intergradation of the morphology of the specimens encountered. Essentially three distinct (or extreme) sets of characters might be isolated representing *Chlamydophorella*? *grossa*, *Scriniodinium*? *obscurum* and *Spongodinium*? sp., respectively, with a number of intermediate morphological variants between the three basic types. Thus, an apparent morphological continuity may be traced throughout this complex, partly illustrated in Plates 5-8. As many specimens, particularly those attributed to *Spongodinium*? sp., are not well preserved, it is possible that future findings may improve the knowledge of the taxonomic status of this group. However, for reasons explained under the heading *Diconodinium-Laciniadinium-Spinidinium* complex, they are now considered to represent a morphological continuity.

The three main sets of characters may be summarized as follows:

Chlamydophorella grossa	Spherical, with or without a short apical horn; autophragm with numerous nontabular, isolated processes more or less of same size, distally expanded to support an ectophragm, which is more or less equidistant from autophragm. Archeopyle never clearly observed, possibly precingular type P (or 2P?).
Scriniodinium obscurum	Subspherical to ovoid with a membranous horn; autophragm with isolated and proximally fused processes of varying width, forming an irregular reticulum in places; processes, often thin, attaining a fibril structure, support an outer membrane (ectophragm). Distance between autophragm and ectophragm variable. Archeopyle type P (2" only).

Spongodinium? sp. Subspherical to ovoid with a membranous horn; autophragm porous (spongiose), covered with a prominent reticulate to strongly foveolate structure; isolated (?) processes or processes rising from junctions of reticulum, fibrillar in structure, support an outer membrane (ectophragm); distance between autophragm and ectophragm variable. Archeopyle P, involves P or 2P.

Specimens possessing intermediate characters constitute a large part of the complex and the distinctions made above are based on arbitrarily chosen characters. In later sections, the three basic types, that is, *Chlamydophorella*? *grossa*, *Scriniodinium*? *obscurum* and *Spongodinium*? sp. are described but their descriptions are given in an extended form to incorporate variants as well. In the plate descriptions, all the extreme variants that are not easily assigned to either of these three types are provisionally assigned to the nearest type until further material can provide information to clarify their morphology.

Figure 10 represents an association of the *Chlamydophorella*? *grossa*-*Scriniodinium*? *obscurum* complex expressed as a scatter diagram based on size. Some specimens are evidently closer to the holotypes in size but a complete overlap can be seen. Continuity in size partly indicates that neither of the holotypes may be regarded as typical for the association. A comparable case was illustrated by Trueman and Weir (1946) employing nonmarine lamellibranchs.

From the above observations and the following descriptions, it is evident that a combination of the ornamentation, shape and size is, for this group of fossils, a more important taxonomic criterion than the type of archeopyle, provided we accept a precingular archeopyle formation for *C.*? *grossa*.

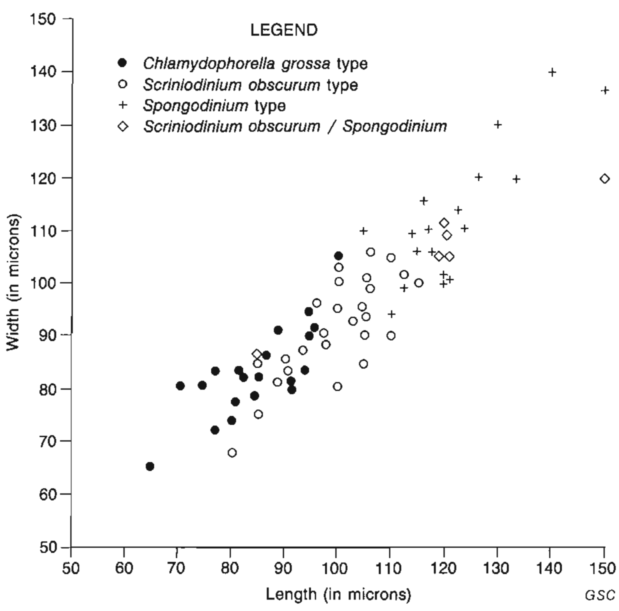

Figure 10. *Scatter diagram based on dimensions of 70 specimens attributable to the* ***Chlamydophorella? grossa - Scriniodinium? obscurum*** *complex.*

Chlamydophorella discreta Clarke and Verdier, 1967

Plate 5, figure 1

1967 *Chlamydophorella discreta* Clarke and Verdier, p. 24, Pl. 2, figs. 9, 10, Textfig. 9.

Dimensions. Autocyst 22-38 µm (usually 30-32 µm) long, 21-31 µm wide; processes 1-5 µm high with distal expansions up to 2.5 µm; autophragm 1 µm or less in thickness (13 specimens measured).

Comparison and remarks. This form is distinguished from *Chlamydophorella nyei* by its generally smaller size, lower and finer ornament and by the absence of apical protrusions. It may sometimes be difficult to assign atypical, small, specimens of *C. nyei* to either species, but in the Arctic assemblages the distinction is obvious.

It has been noted that adjacent ornamental features may be fused together along their length, whereas the outer membrane [or ectophragm (?)], which can be porate, was only occasionally defined. It is pertinent to mention here that when specimens of *Chlamydophorella* and related forms were being observed, it was difficult to decide whether there was actually an ectophragm or simply membranous reticulation (in profile), or whether there were distinct isolated processes or simply junctions of muri projecting beyond the wall. It appears that there is not always a clear cut distinction between these characters and a complete intergradation as well as intermixing of such characters may actually occur on the same specimen. Studies of this nature are to be pursued by the author.

Chlamydophorella? *grossa* Manum and Cookson, 1964

Plate 5, figures 6, 9-14, 16;
Plate 6, figure 1

1964 *Chlamydophorella grossa* Manum and Cookson, p. 17, 18, Pl. 5, figs. 1, 2.

Description. Shape spherical to subspherical with or without a small protrusion or horn. Cyst holocavate, both ectophragm and autophragm may form an apical protrusion; elsewhere ectophragm approximately equidistant from autophragm, although it may be more pronounced antapically and along paracingulum. No definite parasutural features, but apparently parasutural ridges may be locally defined. Autophragm with numerous nontabular, solid, isolated or proximally joined processes to form a reticulum in places; processes of essentially uniform size on same specimen but variable between specimens, sometimes being stouter; processes distally expanded to support a thin, often finely porous, ectophragm. Paratabulation occasionally indicated by archeopyle and a paracingulum. Archeopyle of dubious position, possibly precingular, type P (or 2P). Paracingulum often indicated by aligned processes, which may be joined proximally; parasulcus not clearly indicated.

Dimensions. Autocyst 65-115 µm in length, width 65-112 µm; processes 2-8 µm long, 0.5-3 µm wide; distal expansions 1-5 µm; apical protrusion up to 7 µm high (20 specimens measured).

Comparison and remarks. Difficulty in orientating *Chlamydophorella? grossa* was noted by Manum and Cookson (1964), who suggested that the archeopyle might be apical (or antapical in position). However, the presence of a small apical protrusion on several specimens enabled the determination of a better orientation for this form. Although it is not entirely clear, the position of the archeopyle opening appears to be precingular.

The variability observed in this form is mainly related to the size of the processes and to their proximal definition (isolated to locally connected). Processes may be broken down into smaller elements of variable configuration.

Chlamydophorella nyei Cookson and Eisenack, 1958

Plate 5, figures 2-5, 7, 8

1958 *Chlamydophorella nyei* Cookson and Eisenack, p. 56, 57, Pl. 11, figs. 1-3.

Revised description. Shape spherical to subspherical, with or without an apical protrusion on autocyst. Apical protrusion, when present, rounded subconical. Peripheral or irregular folds may be present on autophragm. Cyst holocavate, ectophragm may also form an apical horn, and thus, ectophragm more or less equidistant from autophragm. No parasutural features observed. Autophragm bears numerous, densely and evenly distributed, nontabular, apparently solid processes, supporting a finely and variably perforate ectophragm. Processes may have bulbous or expanded bases, sometimes two to three adjacent processes may be joined together proximally; sometimes they are very thin, sinuous and distally intertwined due to the often crumpled ectophragm. Paratabulation normally indicated by archeopyle only, and occasionally a vague cingulum. Archeopyle apical type (tA), operculum free or attached. Paracingulum occasionally indicated by a vague alignment, or sparsity of processes, or suggested by folds. Parasulcus rarely suggested by longitudinal folds and sparser ornament.

Dimensions. Autocyst length 36-56 µm, width 32-50 µm, processes 3-10 µm long, 0.5-1.5 µm thick, distal expansions 2-7 µm, apical protrusion up to 5 x 5 µm (17 specimens measured).

Remarks. Most of the specimens seen during this study are closer to the specimen shown by Cookson and Eisenack (1958, Pl. 11, fig. 3), in which the distal expansion of the processes is not pronounced enough to simulate the seemingly thicker ectophragm of the holotype. The perforations shown on the ectophragm can also be clearly seen in the specimens illustrated by Cookson and Eisenack (1958, Pl. 11, figs. 2, 3), although not mentioned by them.

The variation illustrated by these authors has also been observed here and it is partly demonstrated in Plate 5, figures 2-5, 7, 8. Subsequent illustrations of *Chlamydophorella nyei* by Cookson and Eisenack (1968, fig. 6, I, H) exhibit the same variability; the porous ectophragm is clearly seen in specimen H. Specimens with the outer membrane partly or totally torn have here been tentatively assigned to *C. nyei* (Pl. 5, fig. 3). In the original description, it is not mentioned whether the processes are hollow or solid. If they prove to be hollow, a re-evaluation of the genus will be necessary.

Genus *Cordosphaeridium* Eisenack emend. Davey, 1969

Cordosphaeridium exilimurum Davey and Williams, in Davey et al., 1966

Plate 8, figure 8

1966 *Cordosphaeridium exilimurum* Davey and Williams, in Davey et al., p. 87, 88, Pl. 11, fig. 2.

Dimensions. Body length 60-96 µm, width 57-82 µm; length of processes up to 42 µm; width of processes up to 24 µm (13 specimens measured).

Remarks. Specimens conform to original diagnosis of Davey and Williams (1966).

Cordosphaeridium inodes (Klumpp) Eisenack, 1963

Plate 8, figures 6, 7

1953 *Hystrichosphaeridium inodes* Klumpp, p. 391, Pl. 18, figs. 1, 2.

1953 *Hystrichosphaeridium truncigerum* Cookson, p. 114, Pl. 2, figs. 21-23.

1963 *Cordosphaeridium inodes* (Klumpp) Eisenack, p. 261, Pl. 29, fig. 3.

Dimensions. Body 52-82 µm long, 53-75 µm wide; processes 16-41 µm in length, 4-13 µm in basal width; autophragm 1 µm or less in thickness (30 specimens measured).

Remarks. Over 200 specimens attributable to this form were observed during this study. A striking morphological aspect was the variation in the size of the processes, some specimens approaching *C. gracilis* (Eisenack) Davey and Williams in Davey et al., 1966. Their associated occurrence, however, and the complete gradation in morphology observed, suggest that these individuals represented part of the intraspecific variability of *C. inodes*.

Genus *Coronifera* Cookson and Eisenack emend. Davey, 1974

Coronifera oceanica Cookson and Eisenack, 1958

Plate 8, figure 10

1958 *Coronifera oceanica* Cookson and Eisenack, p. 45, Pl. 12, fig. 6.

Dimensions. Body length 40-50 µm, width 38-48 µm; processes up to 20 µm long, antapical process 10-24 µm long, 11-15 µm wide (4 specimens measured).

Remarks. Specimens conform to the original description of Cookson and Eisenack (1958).

Genus *Cribroperidinium* Neale and Sarjeant emend. Davey, 1969

Cribroperidinium edwardsii (Cookson and Eisenack) Davey, 1969

Plate 8, figures 9, 11, 12

1958 *Gonyaulax edwardsii* Cookson and Eisenack, p. 32, 33, Pl. 3, figs. 5, 6; Textfig. 7.

1958 *Gonyaulax orthoceras* Eisenack, p. 388, Pl. 21, figs. 3-11, p. 24, fig. 1.

1969 *Cribroperidinium edwardsii* (Cookson and Eisenack) Davey, p. 128.

1969 *Cribroperidinium orthoceras* (Eisenack) Davey, p. 128, 129.

Dimensions. Cyst 68-116 µm long, 79-108 µm wide; apical horn 10-23 µm high; septa up to 7 µm high (16 specimens measured).

Remarks. Specimens conform to Davey's generic diagnosis. It appears that some specimens fall within the description of *Cribroperidinium intricatum*, but the continued distinction of the two species may be impossible, for the parasutural spines vary from distinct to almost indiscernible. Here the specimens are all provisionally referred to as *C. edwardsii*, although several specimens show much less prominent sutures and accessory ridges than any previously described *Cribroperidinium* species.

Cribroperidinium sp. A

Plate 9, figures 3, 4

Description. Shape subspherical to ellipsoidal, usually with a short apical horn formed by parallel fusion of spines. Wall thin, autophragm only. Parasutural ridges may be sinuous, serrate and spinulate, closely spaced spinules arranged in interrupted rows. On paraplates, accessory ridges and irregular, curved or straight rows of spinules are present, often masking actual parasutural ridges. Additionally spines may occur on plate surface, 1-6 µm apart. Surface between spines punctate to microrecticulate. Paratabulation indicated by parasutural features but often severely masked, or of intricate appearance because of accessory ridges and spines; gonyaulacaean, formula ?4, 6", Xc, 6"', 1p, 1"", Xs. Plate 1"' very small. Archeopyle precingular, type P (3" only), operculum free or attached. Paracingulum indicated by parallel transverse ridges, locally aligned with spines. Parasulcus demarcated by parasutural lines on hypocyst, poorly defined on epicyst. Faint parasutures may be locally traced, but plates not clearly determined, with the occasional exception of plates ps and as.

Dimensions. Body length 64-84 µm, width 53-76 µm; apical horn up to 5 µm high; body wall 1 µm thick; spines 1-4 µm high (10 specimens measured).

Remarks. The size and type of ornament easily distinguish this species from others of the genus. Unfortunately, due to the dense ornamentation, the relationship of the plates could not be precisely determined, and the paratabulation formula is mostly inferred. The variety of spine structures is interesting and they may be described as acuminate, oblate, bifid or mamillate (tipped with a minor spine), single, or fused together along their length.

Cribroperidinium sp. B

Plate 9, figures 1, 2

Description. Shape subspherical, usually with a short apical horn. Wall thin and granular, autophragm only. Parasutural ridges or low membranous, finely perforate septa, locally indeterminate. On paraplates, accessory ridges or rows of more prominent grana run parallel or subparallel to parasutures, often masking the latter. Plate surface strongly punctate to granular, scattered with minute spines. Paratabulation indicated by parasutural features but often of intricate appearance because of accessory ridges; gonyaulacaean, formula 4', 6", ?6C, 6"', 1p, 1"", Xs. Plate 1"' very small, usually incorporated in sulcus. Archeopyle precingular, type P (3" only), operculum free or attached. Paracingulum indicated by parallel transverse ridges, or apparently divided into six plates. Parasulcus demarcated by parasutural lines on hypocyst, poorly defined on epicyst. Faint parasutures may be traced locally but plates not clearly determined, with the exception of plates ps and ls and rs.

Dimensions. Body length 82-67 µm long, 60-76 µm wide; body wall 1 µm thick; apical horn up to 4 µm high; spines 1-2 µm long (8 specimens measured).

Comparison and remarks. This species is characterized by its shape, type of parasutural ridges, and small horn.

Genus *Cyclonephelium* (Deflandre and Cookson)
Stover and Evitt, 1978

Cyclonephelium distinctum Deflandre and Cookson, 1955

Plate 9, figures 5-7

1961 *Circulodinium deflandrei* Alberti, p. 29, Pl. 4, figs. 7-13.

1955 *Cyclonephelium distinctum* Deflandre and Cookson, p. 285, 286, Pl. 2, fig. 14, Textfigs. 47, 48.

Dimensions. Cyst 54-93 µm long, 67-96 µm wide; autophragm 1-2 µm thick (14 specimens measured).

Remarks. Specimens identical to those described by Deflandre and Cookson (1955).

Cyclonephelium membraniphorum
Cookson and Eisenack, 1962

Plate 9, figure 8

1962 *Cyclonephelium membraniphorum* Cookson and Eisenack, p. 495, Pl. 6, figs. 8-14.

Dimensions. Cyst 73-82 µm long, 64-69 µm wide; membranous structures extend beyond equator by up to 15 µm but, measured from base, can be as high as 35 µm (4 specimens measured).

Remarks. Specimens conform to original diagnosis of Cookson and Eisenack (1962b).

Genus *Deflandrea* Eisenack emend.
Lentin and Williams, 1976

Deflandrea diebelii Alberti, 1959

Plate 11, figures 6, 7 10, 11

1959 *Deflandrea diebelii* Alberti, p. 99, Pl. 9, figs. 18-21.

1967 *Ceratiopsis diebelii* (Alberti) Vozzhennikova, p. 158.

Dimensions. Endocyst 59-104 µm in length, 42-65 µm in width; width at midpoint of archeopyle 40-58 µm; archeopyle 25-43 µm x 17-37 µm; apical horn 43-62 µm long, 8-30 µm wide; antapical horns 10-55 µm wide (40 specimens measured).

Remarks. The dimensions given for the endocyst apply also to the pericyst (horns excluded). Occasionally, the endocyst may project into the base of the apical horn. The longitudinal striations, which appear in the form of folds, vary in prominence from indistinct to highly discernible. Occasionally, specimens have shown incomplete tabulation on the dorsal surface (Pl. 11, fig. 7 clearly shows plates 3'', 4'', 5'' and 1a, 2a, 3a).

Specimens of *Deflandrea diebelii* display an extremely variable archeopyle shape, and whenever the operculum is preserved by falling inside the cyst, its outline rarely corresponds to the outline of the archeopyle. Evidently, syndepositional or other factors following the release of the operculum may have caused distortion of the overall shape of the cyst and of the archeopyle. This observation led the writer to believe that quantitative data based on shape values should be used with caution. For instance, although the transverse archeopyle ratio may be broadly used for numerically describing the archeopyle of distinctly different genera, its application for differentiating the various types of archeopyle as defined by different authors, e.g. Lentin and Williams (1976), may not always be justified. It has often been observed that monospecific populations of peridinoid dinocysts can exhibit archeopyles ranging in outline from standard hexa to omegaform hexa. Similar observations were made by W.R. Evitt (pers. comm.).

Deflandrea speciosa Alberti, 1959

Plate 11, figure 9

1959 *Deflandrea speciosa* Alberti, p. 97, Pl. 9, figs. 12, 13.

1977 *Ceratiopsis speciosa* (Alberti) Lentin and Williams, p. 21.

Dimensions. Endocyst length 52-70 µm, width 56-70 µm; apical horn 20-40 µm x 17-34 µm; antapical horns 24-40 µm x 15-30 µm (11 specimens measured).

Remarks. Due to the closely appressed phragmas, only the size of the endocyst is given. The horn width is measured at the base.

Genus *Diconodinium* Eisenack and Cookson emend.
Morgan, 1977

Diconodinium-Laciniadinium-Spinidinium *complex*

Remarks. A large number of specimens representing this complex have been seen during this investigation. Often identifications at the specific level have been impossible or highly subjective, due to the wide variability of such apparently important characters as wall relationships, ornament, and size distribution, overall shape, and also the frequent lack, or poor development, of the archeopyle. Part of the observed variation is shown diagramatically in figures 11 and 12 and in Plate 10. As the heading of this section indicates, some specimens can be easily attributed to the respective genera of this complex, that is to *Diconodinium*, *Laciniadinium* or *Spinidinium*. However, other specimens exhibit characteristics found in two or sometimes three genera. Of course, there is the alternative of introducing infraspecific categories for those intermediate forms, but since the variants are often recovered from the same sample, this solution was not favoured at this stage. On the other hand, the extent of variation could be defined by employing Trueman and Weir's (1946) approach to nontypical material using the prefixes "aff." or "cf." to indicate the relationship to the holotype. This artificial treatment, however, is considered convenient only for isolated examples. When one deals with the gradual interchange of characters through numerous specimens, this solution can only provide endless lists of names defined by arbitrary boundaries.

Instead, until further material from various geographic localities becomes available, a less definitive or less finalized approach will be employed.

All distinct specimens have been assigned to the appropriate taxa, together with morphologically similar individuals; tentatively, therefore, the descriptive morphology of the taxon has been expanded to incorporate variants, which, it may be subsequently proved, do not belong there. By describing this graded series and illustrating the variation present in the population, rather than just the more typical specimens, one provides the basis for more definitive future speciation, thereby enhancing the future biostratigraphic potential of this, and other complexes.

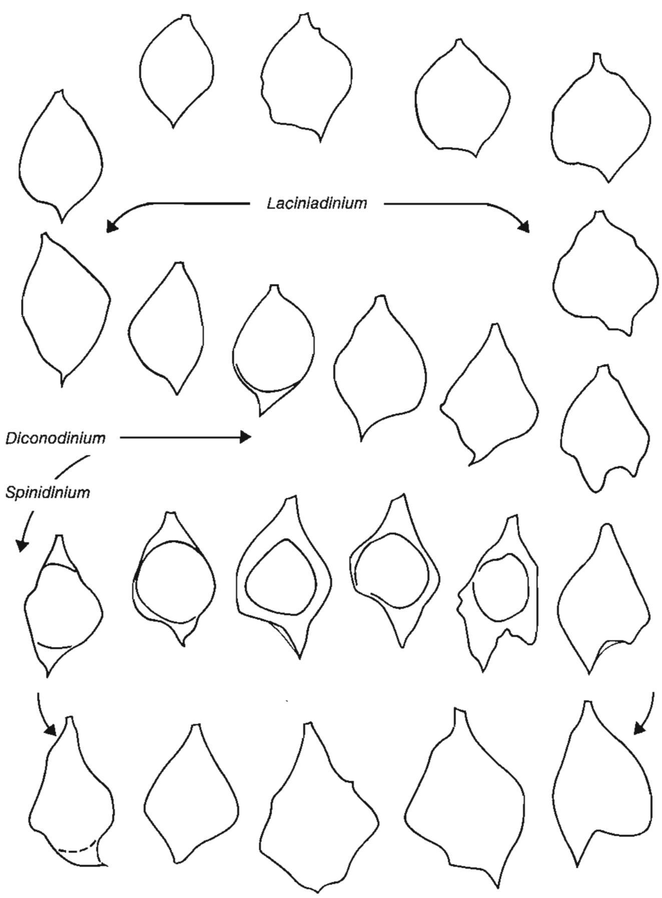

***Figure 11. Diconodinium-Laciniadinium-Spinidinium** complex. Diagram showing gradation in shape and differential development of endocyst.*

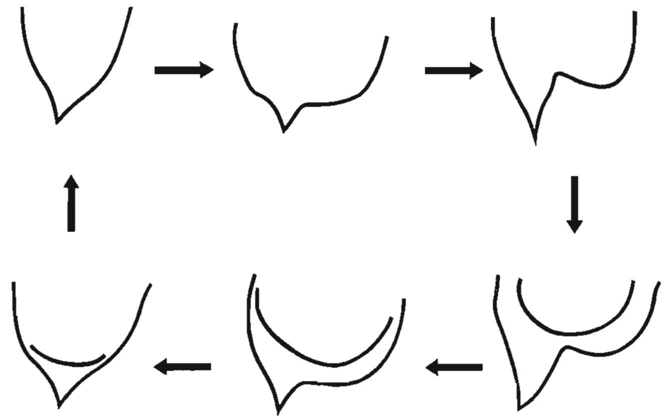

***Figure 12. Diconodinium-Laciniadinium-Spinidinium** complex. Diagrammatic representation of hypocyst showing shape, and wall relationships.*

Details for graded characters are illustrated in Figure 11. It becomes apparent that for this particular complex the archeopyle alone, or in conjunction with other characters, is the most important taxonomic feature. This is a different conclusion from that reached in the study of the *Chlamydophorella grossa* - *Scriniodinium*? *obscurum* complex, where the archeopyle was found to be less useful taxonomically than other characteristics.

Diconodinium arcticum Manum and Cookson, 1964

Plate 10, figure 7

1964 *Diconodinium arcticum* Manum and Cookson, p. 18, 19, Pl. 6, figs. 1-4.

1973 *Diconodinium acutum* Jain and Millepied, p. 30, Pl. 3, figs. 41, 42.

Dimensions. Cyst 46-72 µm long, 33-48 µm wide; apical and antapical horns, 2-6 µm long; apical horn 2-4 µm wide.

Remarks. The wall is sparsely granular, and grana occasionally form minute spines less than 1 µm high; this feature may be observed in Manum and Cookson (1964, Pl. 6, fig. 4). An elongate intercalary archeopyle type I (2a) was seen in some specimens. Both specimens with or without an endocyst have been attributed to *Diconodinium* sp. ?*D. arcticum*. The shape of the hypocyst ranges from a typically conical, to an antapical outline delimiting a bulge suggesting a rudimentary or reduced, right(?), second horn. The outline between the two horns varies from oblique to horizontal (Fig. 12) (see discussion under *Palaeoperidinium*, and under the *Diconodinium-Laciniadinium-Spinidinium* complex, and also the description of the *Diconodinium-Spinidinium* complex).

Diconodinium-Spinidinium complex

Plate 9, figure 13;
Plate 10, figures 8-20, 25, 26;
Plate 11, figure 1

Description. Shape nearly biconical to subpentagonal peridinoid with a truncate apical horn, which is essentially an extension of the apical portion of pericyst. Left antapical horn usually well developed, often prominently bulging medially, frequently attentuated into, or surmounted by, a spiny projection. Right antapical horn absent or reduced but an indefinable low bulge may occur. Size difference between antapical horns yields an antapical outline with a variable configuration ranging from distinctly angular (oblique) to horizontal. Antapical opening between antapical horns frequently occurs, appearing as sutural rupture along antapical contact (or throughout antapical margin) or plates 1'''' and 2''''. Endocyst, when discernible, subcircular; may fill pericyst laterally; frequently indiscernible or observed only at base of horns. Cyst proximate to circumcavate. Periphragm ornamented with peritabular to intratabular features consisting of grana, and small oblate acuminate to occasionally bifid spines in varying proportions, sometimes arranged in linear complexes, particularly along the paracingular and apical regions. Spines appear hollow in structure. Inner side or pericyst possibly also ornamented in a similar fashion. Paratabulation vaguely and incompletely indicated by peritabular and intratabular features; paratabulation peridiniacean, formula: 4', 3a, ?7'', 6c, ?5''', 2''''. Archeopyle intercalary, type Ia (2a only), hexa elongate to hoof-shaped, operculum free or attached antapically. Paracingulum indicated by transverse, interrupted, linear complexes. Parasulcus expressed by a shallow depression, sometimes delineated by longitudinal folds mainly on hypocyst, but extending slightly onto epicyst. Parasulcal area smooth to sparsely granular.

Dimensions. Overall cyst length 52-74 µm, width 32-43 µm (18 specimens measured); endocyst length 27-40 µm, width 27-39 µm (9 specimens measured); apical horn difficult to measure but approximately between 4 and 8 µm high; antapical acuminate process up to 6 µm high, 1-2 µm wide at base; distance between distal point of antapical horns (perpendicular) 0-25 µm.

Remarks. The description of this complex is based on a combination of characters observed on forms tentatively referred to as *Diconodinium* sp. ?*D. arcticum* and *Spinidinium* sp. The gradation in development and distribution of ornament, the configuration of hypocyst and the differential development of an endocyst, are discussed under the *Diconodinium-Laciniadinium-Spinidinium* complex.

Genus *Dinopterygium* Deflandre emend.
Stover and Evitt, 1978

Dinopterygium sp.

Plate 9, figures 9, 10

Description. Shape subspherical to subpolyhedral; outline in apical and antapical views almost circular. Cyst proximochorate; endophragm and periphragm widely separated, more so along parasutural folds (septa). Wall layers thin, smooth, having a minutely ragged edge. Parasutural folds (septa) smooth; in approximate dorsoventral orientation radiating toward outline. Paratabulation indicated by parasutural folds or septa but difficult to interpret because of thin and highly folded cyst walls. Formula 4', 6'', Xc, 6''', ?1p, 1''''. Archeopyle combination epicystal, type tAtP. Paracingulum expressed by two transverse parallel septa. Parasulcus poorly suggested by ?parasutural folds.

Dimensions. Pericyst 85-114 µm in total length (including septa), 82-110 µm in total width; endocyst 60-90 µm long; 53-80 µm wide (11 specimens measured).

Comparison and remarks. Dinopterygium cladoides Deflandre, 1935 has distinct intratabular tubercules. *Dinopterygium medusoides* is very similar to *Dinopterygium* sp., but has more prominent septa. In *D. medusoides* no mention was made of any structural ornament, and following Stover and Evitt's redefinition of *Dinopterygium*, this species would perhaps be more appropriately placed in *Heteraulacysta* Drugg and Loeblich, 1967. *Dinopterygium cooksoniae* (Kimyai) Lentin and Williams, 1973 may also be a species of *Heteraulacysta*, but the inadequate original description prevents direct comparison.

Genus *Dorocysta* Davey, 1970

Dorocysta litotes Davey, 1970

Plate 9, figures 11, 12

1970 *Dorocysta litotes* Davey, p. 358, 359, Pl. 5, figs. 6, 7, Textfig. 2A.

Dimensions. Cyst length 26-33 µm; cyst width anteriorly 11-14 µm, posteriorly 26-31 µm; cingulum 3 µm wide; process length usually 8-12 µm, but occasionally as short as 3 µm, process width 0.5-3 µm; bases of sharply pointed processes as wide as 8 µm (8 specimens measured).

Remarks. Processes more varied than those of type material; they can be pointed or truncate, parallel-sided or sharply tapering, simple, bifurcate or branched.

Genus *Elytrocysta* Stover and Evitt, 1978

Remarks. The diagnostic criteria, on the basis of which the genus *Elytrocysta* was proposed by Stover and Evitt (1978, p. 43, 44), appear to be inadequate. *Elytrocysta* was differentiated from *Chlamydophorella* on the basis of process structure and on the absence of apical protrusions in *Elytrocysta*, although they may both possess solid processes. Forms without apical horns have been assigned to *Chlamydophorella* (e.g. *C. discreta*).

The mode of the archeopyle formation may be more significant than the aforementioned criteria in differentiating the two genera. The great majority of the specimens observed during this study had a tAa archeopyle, or the archeopyle was not developed at all. In a few specimens the operculum was simply broken off. The specimens illustrated by Drugg (1967, Pl. 5, figs. 12, 13) and his statement that "The operculum is angular and usually remains attached to the test along one edge" tend to verify the above observation.

Elytrocysta druggii Stover and Evitt, 1978

Plate 12, figures 1-4, 8

1967 *Membranosphaera maastrichtica*, in Drugg, p. 29, 30, Pl. 5, figs. 12, 13 (not *M. maastrichtica* Samoilovich, 1961 ex Norris and Sarjeant, 1965, p. 40).

1978 *Elytrocysta druggii* Stover and Evitt, p. 43, 44.

Dimensions. Autocyst length 32-54 μm, width 20-38 μm; height of ornament up to 2 μm (15 specimens measured).

Remarks. The outer wall is only occasionally defined (see remarks under *Chlamydophorella discreta*).

Genus *Endoceratium* Vozzhennikova, 1965

Endoceratium sp.

Plate 11, figure 12

Dimensions. Endocyst length 75-90 μm, width 80-120 μm; apical horns 58 μm x 37 μm long and wide at base, lateral horns 28-32 μm x 20-30 μm; antapical horn 20-30 μm x 20-30 μm (3 specimens measured).

Remarks. The specimens seen show no tabulation but otherwise conform to the generic description of Stover and Evitt (1978, p. 45). In that sense, they belong to an intermediate form between *Endoceratium* and *Pseudoceratium* Gocht, 1957.

Genus *Escharisphaeridia* Erkmen and Sarjeant, 1980

Escharisphaeridia sp.

Plate 2, figures 9, 11, 12, 14

Description. Cyst subspherical to ovoidal in shape. Wall composed of autophragm only, although an outer flocculent layer may be present occasionally. Surface of autophragm smooth to scabrate. Paratabulation usually indicated by archeopyle only. Archeopyle apical tA, operculum normally attached; position of archeopyle sometimes dubious. Paracingulum and parasulcus not indicated.

Dimensions. Cyst length 46-76 μm, width 44-73 μm; outer flocculent layer up to 14 μm high (13 specimens measured).

Remarks. Although in some specimens the archeopyle is apical, in others it is of uncertain position. As variation in the position of the archeopyle occurred within single populations, all specimens have provisionally been included here in the same species. Several other specimens show an enclosing kalyptra which may assume a more definite structure approaching an outer wall (Pl. 2, figs. 8, 13). These, and also specimens showing no archeopyle (Pl. 2, fig. 16) are questionably assigned to the genus.

Genus *Exochosphaeridium* Davey et al., in Davey et al., 1966

Exochosphaeridium bifidum (Clarke and Verdier) Clarke et al., 1968

Plate 12, figure 11

1967 *Baltisphaeridium bifidum* Clarke and Verdier, p. 72, 73, Pl. 17, figs. 5, 6, Textfig. 30.

1968 *Exochosphaeridium bifidum* (Clarke and Verdier) Clarke et al., p. 182.

Dimensions. Body length 46-71 μm, width 44-64 μm; processes 12-23 μm long; distal expansions 1-3 μm (16 specimens measured).

Remarks. Processes are thin, striated, bifid to aculeate, and rarely branched or confluent along part of their length. The wall surface is pitted to punctostriate, and striations are more prominent at the bases of processes. The body wall can be as thin as 1 μm, as opposed to the thickness given by Clarke and Verdier (2-3 μm).

The intraspecific variability reported by May (1980) has also been partly observed here.

Exochosphaeridium striolatum (Deflandre) Davey, 1969

Plate 12, figures 6, 9, 10

1838 *Xanthidium hirsutum* (?) Ehrenberg, p. 1, fig. 13.

1937 *Hystrichosphaeridium striolatum* Deflandre, p. 72, 73, Pl. 15, figs. 1, 2.

1941 *Hystrichosphaeridium hirsutum* Lejeune-Carpentier, p. B72-76, Textfigs. 1-4.

1952 *Hystrichosphaeridium* cf. *striolatum* (Ehrenberg) Deflandre, Wetzel, p. 399, figs. 13, 14.

1958 *Hystrichosphaeridium* cf. *hirsutum* (Ehrenberg) Deflandre, Cookson and Eisenack, p. 44, 45, Pl. 11, figs. 5, 6 (not fig. 13).

1963 *Hystrichosphaeridium* cf. *striolatum* (Ehrenberg) Deflandre, in Gorka, p. 68-70, Pl. 10, figs. 6, 7, textpl. VII, figs. 5, 6.

1963 *Baltisphaeridium hirsutum* (Ehrenberg) Downie and Sarjeant, p. 91.

1963 *Baltisphaeridium striolatum* (Deflandre) Downie and Sarjeant, p. 92.

1969 *Exochosphaeridium striolatum* (Deflandre) Davey, p. 164.

Dimensions. Body length 42-76 µm, width 43-73 µm; processes variable in length, 5-24 µm; wall thickness 1-2.5 µm (24 specimens measured).

Remarks. More than one prominent process may be found on individual specimens resulting from lateral fusion of adjacent processes; up to four confluent processes have been observed, and they do not appear to have any significance with regard to orientation. This character is illustrated by Deflandre's line drawing. Therefore, the transfer of the species to *Coronifera* by Stover and Evitt (1978, p. 148) is rejected. The tips of the processes on a single specimen may be pointed or truncate, rarely aculeate. The validity of the taxonomic status of *Exochosphaeridium striolatum* subsp. *truncatum* (Davey) Lentin and Williams, 1973 is questioned here.

The archeopyle is precingular with one plate, but sometimes two plates may be involved.

Genus *Fibrocysta* Stover and Evitt, 1978

Remarks. The taxonomic status of *Fibrocysta* has been discussed by Stover and Evitt (1978, p. 282), under the heading *Lanternosphaeridium* complex.

Fibrocysta? sp. cf. *F. vectensis* (Eaton) Stover and Evitt, 1978

Plate 12, figures 5, 7, 12, 13

Dimensions. Length of cyst body 56-99 µm, width 51-80 µm; length of processes up to 34 µm; autophragm 1.5-3 µm thick (22 specimens measured).

Remarks. The specimens seen here are compared with this species only because both the apical process and protrusion are not always distinctly differentiated.

Genus *Florentinia* Davey and Vertier, 1973

Florentinia? *mantellii* (Davey and Williams) Davey and Verdier, 1973

Plate 12, figures 14-16

1966 *Hystrichosphaeridium mantelli* Davey and Williams, p. 66, Pl. 6, fig. 6.

1968 *Hystrichosphaeridium stellatum* Maier, in Cookson and Eisenack, p. 119, fig. 6, J.

1973 *Florentinia mantelli* (Davey and Williams) Davey and Verdier, p. 188, Pl. 1, figs. 1, 4, 7; Pl. 4, figs. 1, 3.

Dimensions. Body length 40-70 µm, width 41-62 µm (one specimen measures 30 x 27 µm); paracingular and parasulcal processes 18-37 µm long, 2-8 µm wide at base; other processes 15-35 µm long, 7-23 µm wide (20 specimens measured).

Remarks. Specimens essentially conform to the emended diagnosis of Davey and Verdier (1973, p. 188) but much wider variability has been observed. Some specimens apparently have four apical processes interconnected along their length to form a large apical process. In most specimens the archeopyle is poorly developed or absent. In one specimen, a combination archeopyle involving plate 3'' and the apical plates was seen (Pl. 12, fig. 15), whereas another specimen apparently displayed an apical archeopyle (Pl. 12, fig. 16). The former specimen would fall within the diagnosis of *Florentinia*, the latter within that of *Hystrichokolpoma* (processes of two distinctly different widths).

For the above reasons the present specimens are only tentatively assigned to *Florentinia*.

The specimen of *Hystrichosphaeridium stellatum* illustrated by Manum and Cookson (1964, p. 3, fig. 4), appears identical to the material seen during this study. The holotype of *Hystrichosphaeridium stellatum* Maier, 1959 shows the two types of process, but no other characters can be deduced from his illustrations.

Genus *Fromea* Cookson and Eisenack, 1958

Fromea chytra (Drugg) Stover and Evitt, 1978

Plate 13, figures 1, 2, 4, 5

1967 *Paleostomocystis chytra* Drugg, p. 35, Pl. 6, fig. 12.

1978 *Fromea chytra* (Drugg) Stover and Evitt, p. 48.

Dimensions. Cyst length 24-37 µm; cyst width 17-23 µm; longest diameter of archeopyle 4-10 µm; autophragm thickness 1 µm or less (17 specimens measured).

Remarks. Specimens conform to Drugg's (1967) description.

Fromea fragilis (Cookson and Eisenack)
Stover and Evitt, 1978

Plate 13, figures 8-10, 12

1962 *Palaeostomocystis fragilis* Cookson and Eisenack, p. 496, Pl. 7, figs. 10, 11.

1978 *Fromea fragilis* (Cookson and Eisenack) Stover and Evitt, p. 48.

Dimensions. Length 56 (106) 180 µm, width 29 (53) 78 µm (28 specimens measured).

Remarks. The specimens seen in this study have a wider range in length and much narrower mean width than those described by Cookson and Eisenack (1962) (their respective dimensions were 82-157 µm long, 70-105 µm wide). This is probably due to local paleoenvironmental variations.

It is noteworthy that a few specimens, two of them measuring 158 and 180 µm in length, respectively, have a surface ornament consisting of hairy spines, which are from 5 to 20 µm in height, but normally about 10 µm (Pl. 13, figs. 9, 10). The remaining specimens are smooth to minutely granular or, at best, have 1 to 2 hairy processes. The nature of the processes suggests that all specimens may originally have been ornamented, but that processes were lost during deposition or sample processing. Several specimens apparently do not have the medial constriction displayed by the majority of specimens (Pl. 13, fig. 12). Another aspect of importance is the possible presence of an incomplete paratabulation on several specimens, although the paratabulation formula was not determined. Future investigation in this region, or perhaps elsewhere, may reveal features that will warrant a reappraisal of the genus.

Genus *Gillinia* Cookson and Eisenack, 1960

Gillinia hymenophora Cookson and Eisenack, 1960

Plate 13, figure 3

1960 *Gillinia hymenophora* Cookson and Eisenack, p. 12, Pl. 3, figs. 4-6, Textfig. 5.

Dimensions. Cysts 30 and 33 µm in length, and 25 and 28 µm in width, respectively (2 specimens measured); height of apical membranous structures about 7 µm.

Remarks. Specimens conform to original description of Cookson and Eisenack (1960), and to the modified description of Stover and Evitt (1978).

Genus *Glaphyrocysta* Stover and Evitt, 1978

Glaphyrocysta ordinata (Williams and Downie, in Davey et al.) Stover and Evitt, 1978

Plate 1, figures 13-16; Plate 2, figure 1

1966 *Cyclonephelium ordinatum* Williams and Downie, in Davey et al., p. 225-227, Pl. 25, fig. 3, Textfig. 62.

1978 *Glaphyrocysta ordinata* (Williams and Downie, in Davey et al.) Stover and Evitt, p. 50.

Dimensions. Body length 47-73 µm, width 50-71 µm, processes extremely variable in length, up to 55 µm long; autophragm 1 µm, or less, to 2 µm thick (25 specimens measured).

Remarks. Part of the variability observed is shown in Plate 1, figures 13-16 and Plate 2, figure 1. *Glaphyrocysta ordinata* is abundant in sample C-60127. Variants of this form are often indistinguishable from *Areoligera coronata* (O. Wetzel) Lejeune-Carpentier, 1938. The similarity was also emphasized by Williams and Downie (in Davey et al., 1966, p. 226), who stated that "the processes are not unlike those of *Areoligera medusettiformis* (O. Wetzel)" (a junior synonym of *A. coronata*). Stover and Evitt (1978, p. 18) noted that *Glaphyrocysta* differs from *Areoligera* by "an intricate network of distal trabeculae between process complexes". However, this character is highly variable, and a complete gradation frequently occurs.

Genus *Heterosphaeridium* Cookson and Eisenack, 1968

Heterosphaeridium difficile
(Manum and Cookson) comb. nov.

Plate 13, figures 11, 13-16; Plate 14, figure 1

1964 *Hystrichosphaeridium difficile* Manum and Cookson, p. 12-14, Pl. 3, figs. 1-3, 7.

Dimensions. Cyst body 58-84 µm in length, 58-81 µm in width; processes 6-30 µm long, 1-8 µm wide at midlength of process; apical projection 2-5 µm high (30 specimens measured).

Remarks. *Hystrichosphaeridium difficile* is transferred to *Heterosphaeridium* on the basis of the structure and distribution of the processes. *Hystrichosphaeridium* possesses a well defined number of hollow intratabular processes of more or less similar shape. The processes of the type species of *Heterosphaeridium* Cookson and Eisenack (1968, Pl. 116, fig. H) appear very similar in structure to those of *Heterosphaeridium difficile* (Cookson and Eisenack) comb.

nov. In *Systematophora* Klement, 1960, the penitabular process complexes are composed of slender solid projections. Specimens essentially conform to Manum and Cookson's description (1964, p. 12-14) but a few additional remarks clarifying some morphological characters are considered necessary. The wall surface is finely fibroreticulate, whereas the actual wall of processes is smooth. Commonly there appear to be two types of process: simple, thin, apparently solid ones, and more complex processes composed of two or more of the former type partly joined along their length or by a membranous, often fenestrate, structure. Proximally, they are arranged in complexes, which may be arcuate or soleate or without any preferred arrangement. Distally they may be bifid, digitate, foliate, branched, often bearing small acuminate elements. In the latter type of process the arrangement of the component members may be rather tubular but not a continuous tube (as for example in the processes of *Oligosphaeridium*), except in the case where the component elements are partly joined by a membrane.

Paratabulation incompletely expressed by processes or groups of processes (process complexes), 1pr, 4', X", XC, X6‴, Xp, 1'''', XS. Several opercula have the plate and process arrangement seen in Plate 13, figure 13. The small circular delineations at the bases of the processes represent a pre-apical plate.

Genus *Hystrichodinium* Deflandre emend.
Clarke and Verdier, 1967

Hystrichodinium pulchrum Deflandre, 1935

1935 *Hystrichodinium pulchrum* Deflandre, p. 229, 230, Pl. 5, fig. 1, Textfigs. 9-11.

Dimensions. Body length 45-66 µm, width 42-67 µm; processes 8-22 µm long, 1-8 µm wide at base; cingulum 4-5 µm wide; tuberculae, when present, 1 µm in diameter (6 specimens measured).

Remarks. The specimens seen resemble the type material, although two of them have no ornament between processes.

Genus *Hystrichosphaeridium* Deflandre emend.
Davey and Williams, in Davey et al., 1966

Hystrichosphaeridium sp. *H.*? *palmatum*
(White ex Bronn) Downie and Sarjeant, 1965

Plate 13, figure 7

Dimensions. Body length and width 38-43 µm; process length 17-23 µm (4 specimens measured).

Remarks. The specimens seen certainly belong to *Hystrichosphaeridium*, and closely resemble the species *H.*? *palmatum*. However, as the validity of the generic assignment of this species is uncertain, the arctic specimens are questionably assigned to the species (cf. Stover and Evitt, 1978, p. 56, 57).

Hystrichosphaeridium tubiferum (Ehrenberg)
Deflandre emend. Davey and Williams,
in Davey et al., 1966

Plate 14, figure 2, 7

1838 *Xanthidium tubiferum* Ehrenberg, Pl. 1, fig. 16.

1904 *Ovum hispidium* (*Xanthidium tubiferum*) Ehrenberg, Lohmann, p. 21.

1933 *Hystrichosphaera tubifera* (Ehrenberg) O. Wetzel, p. 40, Pl. 4, fig. 16.

1937 *Hystrichosphaeridium tubiferum* (Ehrenberg) Deflandre, p. 68, (the figured specimens are *H. recurvatum*).

Dimensions. Length of cyst body 37-57 µm, width 40-53 µm; length of processes up to 33 µm (14 specimens measured).

Remarks. A large number of specimens assignable to the species were observed during this study. The few specimens with apparently tubular processes are attributed with confidence to *H. tubiferum* (Pl. 14, figs. 1, 7). However, specimens possessing both tubular and subquadrate processes are also assigned to this species here, but provisionally (Pl. 14, fig. 8). All specimens characteristically show perforate terminal expansions, which can be fenestrate.

Hystrichosphaeridium tubiferum subsp. *brevispinum*
Davey and Williams, in Davey et al., 1966

Plate 14, figures 4-6

Dimensions. Body length 34-58 µm, width 30-58 µm; processes up to 12 µm long and wide; one specimen measures 70 µm in length and width, with processes as wide as 20 µm (22 specimens measured).

Remarks. Specimens having tubiform processes sometimes with round, but more usually with subquadrate distal openings were observed. If the holotype of *H. tubiferum* subsp. *brevispinum* possesses no processes with subquadrate ends, it may be more appropriate to assign these specimens to a new subspecies.

Hystrichosphaeridium salpingophorum Deflandre emend. Davey and Williams, in Davey et al., 1966

Plate 14, figures 3, 9

1935 *Hystrichosphaeridium salpingophorum* Deflandre, p. 232, Pl. 9, fig. 1.

Dimensions. Length of cyst body 40-55 µm, width 33-52 µm; processes up to 25 µm long (22 specimens measured).

Remarks. Specimens possessing smooth processes with subquadrate distal ends have been attributed to *Hystrichosphaeridium salpingophorum*. Processes terminate in foliaceous perforate outgrowths but edges can be denticulate to serrate. Characteristically, parasulcal and often paracingular processes are considerably thinner than the remaining processes.

Distinguishing between *H. salpingophorum* and *H. tubiferum* is often impossible; a complete gradation in the type of process structure has been observed. The cross-section can be entirely tubular, as in the latter species, or entirely to partially subquadrate, as in *H. salpingophorum*. Both types of process may be found on an individual specimen, although distortion of form due to compression should be borne in mind. In well preserved specimens, if a process is subquadrate, there is the potential for each corner of the quadrangle to appear as a darkened line within, or at the border of, the process (Pl. 14, figs. 3, 8, 9). Therefore, without directly observing the quadrate shape at the distal end of the process, one may suspect a quadrate process by the presence of the darkened lines (nonstructural features, i.e. striations or ridges) within the boundaries of the process. However, this is not a reliable criterion for differentiating the two species, and examination of type material may well prove their synonymy.

Genus *Hystrichosphaeropsis* Deflandre emend. Sarjeant, in Davey et al., 1966

Hystrichosphaeropsis sp.

Plate 14, figures 10, 11; Plate 15, figure 3

Description. Shape of cyst elongate-ellipsoidal with rounded to truncated apex and antapex; apex may bear a usually truncate horn formed by extension of pericyst or folding. Periphragm well separated from endophragm except for the paracingular region, where they are closely appressed or invaginated. Low parasutural ridges may appear membranous, outer edge undulating, apparently minutely folded giving a "tuberculate" appearance. Periphragm and endophragm punctate to granular. Paratabulation incompletely developed, indicated by parasutural ridges; apparently gonyaulacacean, formula: 6'', Xc, ?6''', ?1p, 1''''. Plate 1p distinctly triangular and small. Apical plates very small and indecipherable. Archeopyle precingular, type P (3'' only), operculum free, distinctly elongate, almost reaching apex. Paracingulum indicated by parasutural ridges and folds; spiral. Parasulcus poorly suggested by parasutural ridges.

Dimensions. Length of pericyst 63-86 µm, width 50-74 µm; length of endocyst 51-71 µm, width 40-62 µm; apical horn 5-10 µm high (10 specimens measured).

Comparison. Hystrichosphaeropsis complanata Eisenack, 1965 has a more elongate pericyst both at the apex and antapex. *Hystrichosphaeropsis ovum* Deflandre, 1935 has an ovoidal endocyst completely filling the pericyst except in apical and antapical areas; it also has a more prominent apical horn. *Hystrichosphaeropsis* sp. in McIntyre 1974 (Pl. 12, figs. 7-9) is identical with the present species.

Genus *Impagidinium* Stover and Evitt, 1978

Impagidinium sp. cf. *I. dispertitum* (Cookson and Eisenack) Stover and Evitt, 1978

Plate 15, figures 11, 12

Dimensions. Cyst 57-80 µm long, 54-77 µm wide; septa 2-5 µm, normally 2-3 µm, high (15 specimens measured).

Comparison. Impagidinium dispertitum differs from *I. victorianum* (Cookson and Eisenack) Stover and Evitt, 1978 in being smaller (*I. victorianum*: length 80-120 µm, width 80-123 µm), and in having the parasulcus clearly divided into three plates of similar size. *Impagidinium* sp. cf. *I. dispertitum* differs from the type material only in having a less elongate body and lower parasutural septa.

Genus *Impletosphaeridium* Morgenroth, 1966

Impletosphaeridium sp.

Plate 15, figures 10, 13

Dimensions. Body length 52-82 µm, width 41-71 µm; processes 6-29 µm (18 specimens measured).

Remarks. As no archeopyle or other traces of paratabulation were observed, this form is provisionally attributed to *Impletosphaeridium* following Stover and Evitt's approach (see Stover and Evitt, 1978, p. 232). The fine hairy processes are highly variable in length, even within associations recovered from the same horizon. Occasional specimens show an unusual structure in the form of apparent verrucae (1-2 µm in diameter), for which no external relief has been confirmed. These may represent either extremely low bases of spines or internal thickenings.

Genus *Isabelidinium* Lentin and Williams, 1977

Isabelidinium acuminatum (Cookson and Eisenack) Stover and Evitt, 1978

Plate 14, figures 12, 13; Plate 15, figures 1, 2

1958 *Deflandrea acuminata* Cookson and Eisenack, p. 27, Pl. 4, figs. 5-8.

1976 *Alterbia acuminata* (Cookson and Eisenack) Lentin and Williams, p. 48.

1978 *Isabelidinium acuminatum* (Cookson and Eisenack) Stover and Evitt, p. 109.

Dimensions. Pericyst length 75-102 µm, width 59-74 µm; endocyst length 50-56 µm, width 48-54 µm (15 specimens measured).

Description. Shape of outline subpentagonal; endocyst subcircular to subquadrate in outline; conical apical protrusion developed by expansion of pericyst, but never clearly defined. Left antapical horn reduced or giving rise to a rounded protrusion. Cyst circumcavate with endocyst occupying central part of pericyst. No parasutural features observed. Periphragm smooth, punctate to granular; endophragm smooth. Paratabulation indicated by archeopyle and paracingulum. Archeopyle intercalary type I or Ia/oI or 3I; perioperculum, when present, attached along antapical margin; endoarcheopyle may be developed by partial removal of the three intercalary plates, which may be attached either laterally or along their antapical margin. Paracingulum indicated by transverse folds or ridges. Parasulcus not indicated, or expressed by longitudinal folds.

Remarks. The variable endoarcheopyle development (as in *Chatangiella granulifera* and *C. verrucosa*) may be related to the degree of syn- or postdepositional compression.

Isabelidinium bakerii (Deflandre and Cookson)
Lentin and Williams, 1977

Plate 14, figures 14, 15

1966 *Deflandrea bakerii* Deflandre and Cookson, p. 25, Pl. 4, figs. 1, 2, 4.

1977 *Isabelidinium bakerii* (Deflandre and Cookson) Lentin and Williams, p. 167.

Dimensions. Endocyst length 40-52 µm, width 45-51 µm; total length 93-102 µm, total width 47-54 µm (7 specimens measured).

Remarks. Specimens conform to original diagnosis, but archeopyle involves both walls.

Isabelidinium belfastense (Cookson and Eisenack)
Lentin and Williams, 1977

1961 *Deflandrea belfastensis* Cookson and Eisenack, p. 71, Pl. 11, figs. 1, 2, 4.

1977 *Isabelidinium belfastense* (Cookson and Eisenack) Lentin and Williams, p. 167.

Dimensions. Endocyst 35-42 µm long, 38-40 µm wide; total length 91-96 µm, total width 41-45 µm (7 specimens measured).

Remarks. Specimens identical to those described by Cookson and Eisenack (1961).

Isabelidinium cooksoniae (Alberti)
Lentin and Williams, 1977

Plate 15, figure 4

1959 *Deflandrea cooksonii* Alberti, p. 97, Pl. 9, figs. 1-6.

1967 *Australiella cooksoni* Vozzhennikova, p. 132.

1977 *Isabelidinium cooksoniae* (Alberti) Lentin and Williams, p. 167.

Dimensions. Endocyst 43-55 µm long, 36-49 µm wide; total length 71-98 µm, width 34-50 µm (13 specimens measured).

Remarks. Specimens conform to the original diagnosis of Alberti (1959). The variation noted by Alberti has also been observed here.

Isabelidinium cretaceum Cookson
Lentin and Williams, 1977

Plate 15, figures 5-7

1956 *Deflandrea cretacea* Cookson, p. 217, 218, Pl. 19, figs. 1-3.

1977 *Isabelidinium cretaceum* (Cookson) Lentin and Williams, p. 167.

Dimensions. Endocyst 29-45 µm long, 42-50 µm wide; total length 50-70 µm (one specimen measures 80 µm), total width 34-53 µm; endophragm less than 1 µm thick; periphragm 1-2 µm thick (14 specimens measured).

Remarks. Specimens conform to the original description of Cookson (1956), and include the variation in outline as indicated by the original author. Examination of the type material of both *Amphidiadena nucula* (Cookson and Eisenack) Lentin and Williams, 1976 and *Xenikoon australis* Cookson and Eisenack, 1960 would be desirable, as they appear to be very similar to *Isabelidinium cretaceum*.

Isabelidinium microarmum (McIntyre)
Lentin and Williams, 1977

Plate 15, figure 9

1975 *Deflandrea microarma* McIntyre, p. 65, Pl. 1, figs. 5-8.

1977 *Isabelidinium microarmum* Lentin and Williams, p. 168.

Dimensions. Endocyst 39-48 µm long; total length 97-109 µm, total width 47-56 µm (4 specimens measured).

Remarks. Specimens conform to McIntyre's (1975) description.

Genus *Laciniadinium* McIntyre, 1975

Laciniadinium williamsii sp. nov.

Plate 10, figures 1-6; Plate 11, figure 5

Material. Holotype. Plate 10, figure 1, GSC 65215, slide P2047-23D, 20.3 x 125.0; GSC locality C-60129; Kanguk Formation, Section 77-HFA-46A, South Coast section, Bylot Island, District of Franklin; Santonian-Campanian. Pericyst length, 49 µm, pericyst width, 35 µm.

Derivation of name. In honour of G.L. Williams, Geological Survey of Canada.

Diagnosis. Shape of cyst compressed subspherical to convexly biconical. Apical and antapical horns short. Autophragm smooth to finely ornamented. Archeopyle combination, type tI3Pa. Detachment of operculum from 3' marked by an angular concavity of operculum along the original contact.

Description. Cyst proximate; shape compressed subspherical to convexly biconical; apical, and probably a left antapical, horn present; right (?) antapical horn absent or, rarely, slightly developed. Apical horn short, parallel-sided to almost truncated conical, sometimes topped with two or more minute papillae. Left (?) antapical horn short, hollow, acuminate. Wall consists of autophragm only, except at apex and antapex where two layers may be present. No parasutural features observed, although some folds may simulate some plate boundaries. Autophragm smooth to minutely ornamented with grana and/or small spines, about 1 µm high. Paratabulation indicated by archeopyle and paracingulum only. Archeopyle combination, type tI3Pa, involves paraplates 1a to 3a and 3" to 5"; operculum flap-like, simple, and attached antapically along paracingulum. Detachment from 3' marked by angular concavity of operculum along original contact. Paracingulum indicated by low transverse parallel ridges or folds. Parasulcus delimited by low ridges or attenuated folds, which extend two thirds onto both epicyst and hypocyst.

Dimensions. Cyst length 39-54 µm, with 31-43 µm; apical horn 2-6 µm high, 2-4 µm wide; antapical horn 2-7 µm high; cingulum about 4 µm wide; autophragm 1 µm or less in thickness (24 specimens measured).

Comparison. *Laciniadinium orbiculatum* McIntyre, 1975 is larger (70-100 µm long), has no visible antapical horns and is oval to spherical in shape. *Laciniadinium biconiculum* McIntyre, 1975 is larger (55-85 µm long), is more distinctly biconical and has a rather prominent, striated ornamentation.

Genus *Leberidocysta* Stover and Evitt, 1978

Leberidocysta chlamydata (Cookson and Eisenack)
Stover and Evitt, 1978

Plate 16, figures 1, 2

1962 *Hexagonifera chlamydata* Cookson and Eisenack, p. 496, Pl. 7, fig. 2.

1978 *Leberidocysta chlamydata* Stover and Evitt, p. 59.

Description. Shape of endocyst subspherical, ellipsoidal to subcylindrical; pericyst normally conforms to shape of endocyst. Periphragm thin, frequently folded, often torn and incomplete; periphragm appears to be in contact with endophragm along archeopyle margin. Occasional specimens develop incomplete parasutural features, apparently delimiting six precingular plates, the number of which may be suggested by the archeopyle formation (Pl. 16, fig. 2); there are probably six postcingular plates. Endophragm ornamentation consists of thickenings in the form of low verrucae and ridges, free-terminating or coalescing to form a pseudoreticulate pattern; ornament, in plan view, circular to irregular; close luminae up to 7 µm in longest diameter, 1.5 µm high, almost reduced to grana near periphery. Archeopyle apical, type tA; operculum free, often missing, rarely attached. Paracingulum and parasulcus may be weakly defined by reduced ornamentation.

Dimensions. Length of endocyst 49-80 µm, width 41-77 µm; total length 54-100 µm without operculum, up to 108 µm with operculum; total width 52-88 µm. Periphragm less than 1 µm thick, endophragm 1-2 µm thick (32 specimens measured).

Remarks. Although Cookson and Eisenack's specimens showed a smaller range in length (overall length: 68-75 µm, endocyst length: 56-68 µm), the Bylot Island material is considered to belong to the same species.

Genus *Lejeunecysta* Artzner and Dörhöfer, 1978

Lejeunecysta sp.

Plate 15, figure 8

Description. Shape subpentagonal to subcircular with slightly developed apical protrusion; antapical horns not observed.

No parasutural features seen; autophragm smooth. Paratabulation indicated by archeopyle only. Archeopyle intercalary, type I (2a only); operculum free. Posterior margin of archeopyle coincides with paracingular zone but anterior margin high enough to suggest an intercalary archeopyle. Paracingulum poorly indicated by transverse folds. Parasulcus not indicated.

Dimensions. Cyst length 52-58 µm, width 53-59 µm (4 specimens measured).

Comparison and remarks. The shape of the cyst distinguishes this species. The archeopyle index also suggests a generally larger archeopyle opening. It is noteworthy that at the apex an almost indiscernible separation of the two walls may occur.

Genus *Microdinium* Cookson and Eisenack emend. Stover and Evitt, 1978

Microdinium ornatum Cookson and Eisenack, 1960

Plate 15, figure 18

1960 *Microdinium ornatum* Cookson and Eisenack, p. 6, 7, Pl. 2, figs. 3-8, Textfigs. 2-4.

Dimensions. Cyst length 36 and 43 µm, width 37 and 29 µm, respectively (2 specimens measured).

Remarks. Unfortunately, the small number of specimens observed precluded a detailed morphological description of the species. Although the parasutural crests are indeed perforate, the plate ornament referred to as tubercles by Cookson and Eisenack (1960) was not observed.

Microdinium sp. A

Plate 15, figures 14, 15, 17

Description. Shape of cyst subspherical; cyst wall consists of autophragm only. Parasutural, membranous, perforate ridges delimit plate boundaries. Autophragm densely punctate, granular to microrugulate. Paratabulation indicated by parasutural ridges, often highly sinuous, formula apparently gonyaulacacean x', ?a, 6'', 6c, 6''', ?1p, 1'''' (2''''), plate 1''' small and typically elongate triangular. Archeopyle apical, type tA, operculum free or attached. Paracingulum indicated by six elongate transverse plates; paracingulum divides cyst into equal parts or occasionally epicyst may be slightly shorter than hypocyst. Parasulcus delimited laterally by parasutural ridges, but number of plates indecipherable.

Dimensions. Cyst length 28-39 µm, width 29-36 µm; membranous crests up to 5 µm high; perforations about 0.5 µm in diameter (15 specimens measured).

Comparison. *Microdinium irregulare* Clarke and Verdier, 1967 lacks the prominent membranous perforate crests and is distinctly unequally divided by the paracingulum. *Microdinium ornatum* Cookson and Eisenack, 1960 has low parasutures perforated by a single row of holes, and the plates are ornamented by a varying number of small tubercles.

The dense ornamentation and the high, sinuous parasutural crests prevented a more detailed interpretation of the paratabulation, in particular that of the epicyst.

Microdinium sp. B

Plate 15, figure 16

Description. Cyst shape subpherical to ellipsoidal. Wall consists of autophragm only, rugulate to imperfectly reticulate, aligned with minute spines about 1 µm in height: ornament projecting beyond margin by up to 1.5 µm, in profile sometimes expanded distally. Paratabulation poorly defined due to the crowded wall ornamentation. Formula apparently 4', ?6'', 6c, ?6''', ?1p, ?1'''' (2'''') Xs, archeopyle apical, type ta, operculum free. Paracingulum transversely located at one third the distance between apex and antapex, indicated by interrupted parasutural ridges, apparently delimiting six plates. Parasulcus suggested by irregularly defined areas, but plates indecipherable.

Dimensions. Cyst length 39-48 µm, with 38-43 µm (7 specimens measured).

Remarks. The seven specimens observed are very similar to the illustrated specimen. A specific name is not allocated because of the limited number of specimens seen, and the imprecise definition of the tabulation. *Ellipsoidictym circulatum* (Clarke and Verdier) Lentin and Williams, 1977 appears similar, but according to the original authors it has reticulate ornamentation, and an angular archeopyle.

Genus *Odontochitina* Deflandre emend. Davey, 1970

Odontochitina costata Alberti, 1961

Plate 16, figure 6

1962 *Odontochitina striatoperforata* Cookson and Eisenack, p. 440, Pl. 3, figs. 14-19.

1961 *Odontochitina costata* Alberti, p. 31, Pl. 6, figs. 10-13.

Dimensions. Endocyst 38-68 µm long, 36-66 µm wide; length of apical horn 160-265 µm, width at base 9-20 µm; length of antapical horn 90-132 µm, width at base 19-41 µm; length of postcingular horn 66-102 µm, width at base 6-21 µm; horn perforations 1-3 µm in greatest diameter; longitudinal striations 0.5-1 µm high (32 specimens measured).

Remarks. Pericyst punctate, sometimes punctae have a microreticulate pattern. Perforations frequently oval in outline, sometimes subquadrate or circular, extremely variable in number and distribution.

Odontochitina operculata (O. Wetzel) Deflandre and Cookson, 1955

Plate 16, figures 3-5, 7, 10

1933 *Ceratium operculatum* O. Wetzel, Pl. 2, fig. 21.

1933 *Ceratium* (*Euceratium*) *operculatum* O. Wetzel, p. 170, Pl. 2, figs. 21, 22.

1937 *Odontochitina silicorum* Deflandre, in Deflandre, p. 95, Pl. 18, figs. 8-13.

1950 Dreihörnige Hüllen mit Stachelkeid?, in O. Wetzel, p. 170, Pl. 13, fig. 6.

1952 *Odontochitina operculatum* (O. Wetzel) Deflandre, in Firtion, p. 160, 161, Pl. 8, fig. 9.

1955 *Odontochitina operculata* (O. Wetzel) Deflandre and Cookson, p. 291.

Description. Shape ceratoid with three horns, apical, antapical and postcingular in position: horns rather short with broad bases and pointed ends. Endocyst subspherical, ovoidal, subtriangular or pear-shaped with longest side aligned with apical and antapical horns. An apical horn, 4 x 4 µm, was seen on endocyst of a single specimen. Cyst circumcavate to cornucavate, endophragm and periphragm usually appressed together in area between apical and antapical horns, sometimes only an antapical pericoel may develop slightly. A pericoel may be slightly to well developed antapically, and frequently between apical and lateral horns. No parasutural features observed; endophragm thin or thick, smooth; periphragm punctate, scabrate to minutely granular with outer edge often finely ragged, sometimes dentate between lateral and antapical horns. A small protrusion, 2-3 µm high, may be seen on inner side of antapical horn. Periphragm often highly folded in central region; folds with tapering ends or with one or more spurs along their edge. Two types of perforation present on pericyst, mainly confined to horns: small, circular to irregular perforations, normally 1-3 µm in diameter, and large, elongate vacuoles restricted to the distal half of horns. Distal ends of horns sometimes unravelled and deflated due to the density of perforations. Paratabulation indicated only by archeopyle with angular margin. Archeopyle apical, type tA with suture frequently angular, operculum free; perioperculum supports apical horn; endoperculum normally without protrusion. Paracingulum rarely suggested by narrow, interrupted folds running along a medial plane. Parasulcus not indicated.

Dimensions. Endocyst with operculum 55-81 µm long, without operculum 40-60 µm long, 37-70 µm wide; length of apical horn extremely variable 50-252 µm, width at base 11-40 µm; length of antapical horn 35-138 µm, width at base 22-55 µm; length of postcingular horn 25-112 µm, width at base 12-43 µm; horn vacuoles up to 18 µm, but normally 6-10 µm long, endocyst wall up to 3 µm thick (46 specimens measured).

Remarks. Many specimens essentially conform to the description given by Deflandre and Cookson (1955) for this species. A complete gradation has been observed between specimens with horn perforations (referable to *Odontochitina costata* Alberti, 1961) and those lacking horn perforations (*O. operculata*). In fact, perforations can be very irregular in distribution or almost lacking in some specimens. This feature is at variance with the consistent and regular occurrence of perforations in *O. porifera* Cookson, 1956. This latter species is usually easily differentiated from others of the genus. Perhaps a more valid criterion for distinguishing *O. costata* is the presence of prominent striations often observed in assemblages encountered elsewhere, e.g. in the North Sea Basin. It appears that the inconsistent development of pores in *Odontochitina* may be the result of environmental variation. Although different stratigraphic levels are reported for the two forms (Millioud, pers. comm.), a similar situation occurs with species of *Xenascus* and *Wetzeliella*. Studies of the pores of geographically different populations may subsequently prove that *O. operculata* and *O. costata* are synonymous.

Other variable characters observed are the endocyst shape and thickness and its relationship to the pericysts, and also the structure and shape of the horns. In fact, extreme variants viewed in isolation may appear different from *O. operculata*, whereas others are intermediate between typical species of *Odontochitina* and *Odontochitinopsis molesta* (Deflandre) Eisenack, 1961. The validity of the latter genus, however, is disputable, since it was erected on the basis of a single specimen embedded in chert.

For the above reasons, it seemed appropriate to provide here a broader description based on the specimens observed, in order to discuss their variability.

Genus *Oligosphaeridium* Davey and Williams, in Davey et al., 1966

Oligosphaeridium anthophorum (Cookson and Eisenack) Davey, 1969

Plate 18, figures 4, 7

1958 *Hystrichosphaeridium anthophorum* Cookson and Eisenack, p. 11, figs. 12, 13.

1969 *Oligosphaeridium anthophorum* (Cookson and Eisenack) Davey, p. 147.

Dimensions. Body length 36-52 µm, width 48-52 µm, processes up to 34 µm high (6 specimens measured).

Remarks. Specimens same as those described by Cookson and Eisenack (1958).

Oligosphaeridium complex (White) Davey and Williams, in Davey et al., 1966

1842 *Xanthidium tubiferum* complex White, p. 39, Pl. 4, div. 3, fig. 11.

1848 *Xanthidium complexum* (White) Bronn, p. 1375.

1940 *Hystrichosphaeridium elegantulum* Lejeune-Carpentier, p. 22, Textfigs. 11, 12.

1952 *Hystrichosphaeridium* complex (White) Firtion, p. 156, Pl. 9, figs. 2, 4, 5, Textfigs. 1A-F.

1962 *Hystrichosphaeridium tubiferum* (Ehrenberg) Pocock, p. 83, Pl. 15, fig. 230.

1966 *Oligosphaeridium complex* (White) Davey and Williams, in Davey et al., p. 71, Pl. 7, figs. 1, 2; Pl. 10, fig. 3, Textfig. 14.

Dimensions. Body length 33-50 µm, width 34-48 µm; length of processes 18-32 µm, width at base 2-4.5 µm (14 specimens measured).

Remarks. Most specimens conform to the diagnosis of Davey and Williams (in Davey et al., 1966, p. 71). Others (Pl. 18, fig. 3) with wider processes and symmetrical distal ends, are also tentatively assigned to the species.

Oligosphaeridium pulcherrimum (Deflandre and Cookson) Davey and Williams, in Davey et al., 1966

Plate 18, figures 1, 2

1955 *Hystrichosphaeridium pulcherrimum* Deflandre and Cookson, p. 270, Pl. 1, fig. 8, Textfigs. 21, 22.

1966 *Oligosphaeridium pulcherrimum* (Deflandre and Cookson) Davey and Williams, in Davey et al., p. 75, 76, Pl. 10, fig. 9, Pl. 11, fig. 5.

Dimensions. Body 39-55 µm long, 43-55 µm wide; processes 21-34 µm long, 1.5-6 µm wide at base; autophragm less than 1 µm thick (15 specimens measured).

Remarks. Autophragm smooth or finely granular. Processes on individual specimens may vary considerably in width.

Genus *Palaeocystodinium* Alberti, 1961

Palaeocystodinium bulliformum sp. nov.

Plate 17, figures 2-5

1971 ?*Svalbardella* sp. in Wilson, Pl. 2, fig. 14.

Material. Holotype, Plate 17, figure 4, GSC 65334, slide P2047-34W, 23.1 x 119.2; GSC locality C-60140, Eureka Sound Formation, Section 77-HFA-49, South Coast section, Bylot Island, District of Franklin; Paleocene. Pericyst length, 226 µm, pericyst width, 91 µm.

Derivation of name. Latin *bulla*, bubble; forma, shape; with reference to the large endocyst.

Diagnosis. Cyst proximate, cornucavate to circumcavate; endocyst distinctly turgid, ellipsoidal to subspherical. Apical and antapical horns broad based, having pointed or rounded distal ends. No parasutural features observed. Archeopyle intercalary, type I (2a only). Paracingulum and parasulcus not indicated.

Description. Shape elongate, subspherical to ellipsoidal, often found in lateral orientation. Endocyst conforms to pericyst in general shape. Apical and antapical horns broad based with pointed or rounded distal ends, often surmounted by a spine more frequently seen on apical horn.

Cyst cornucavate to circumcavate; pericoel greater at horn bases, can be indiscernible along remainder of cyst. No parasutural features observed. Periphragm smooth to finely granular. Endophragm thin, smooth and highly folded. An offset indentation or spur may occur on antapical horn. Paratabulation indicated by archeopyle only. Archeopyle occasionally developed; intercalary, type I (2a only), apparently involves only periphragm; height greater than width, narrowly rounded apically or distinctly hexagonal. Operculum free or attached, often along its base, but sometimes elsewhere. Paracingulum and parasulcus not indicated.

Dimensions. Total length (excluding end spine) 179-240 µm, total width 64-120 µm; endocyst 80-125 µm long, 60-102 µm wide; end spine up to 7 µm high; pericoel up to 6 µm wide but attains maximum width at horn bases, 28 µm; periphragm 1.5 µm, or less, in thickness (25 specimens measured).

Comparison and remarks. The shape of the endocyst and horns distinguish this species from others of the genus. The specimens illustrated by Wilson (1971, Pl. 2, fig. 14), and subsequently by Williams and Brideaux (1975, Pl. 10, fig. 3) are considered to belong to *P. bulliformum* sp. nov. *Palaeocystodinium stockmansii* Boltenhagen, 1977 has a more elongate endocyst, shorter horns and generally smaller size. *Palaeocystodinium* sp. aff. *P. golzowense* in Boltenhagen (1977, Pl. 23, figs. 5-8), is similar in gross morphology, but with considerably narrower horns and a more elongate endocyst.

Paleocystodinium golzowense Alberti, 1961

Plate 17, figure 6

1961 *Palaeocystodinium golzowense* Alberti, p. 20, Pl. 7, figs. 10-12; Pl. 12, fig. 16.

Dimensions. Endocyst 94-124 µm in length, 35-52 µm in width; total length 170-270 µm, total width 36-61 µm (9 specimens measured).

Remarks. Both periphragm and endophragm are thin and folded; endocyst may project slightly into the pericyst in the apical and antapical areas.

Genus *Palaeohystrichophora* Deflandre emend. Deflandre and Cookson, 1955

Palaeohystrichophora infusorioides Deflandre, 1935

Plate 19, figures 1-3

Dimensions. Length of endocyst 2-44 µm, width 20-38 µm; total length 40-60 µm; width of cingulum 3-7 µm, normally about 5 µm; hairy processes 5-15 µm long (16 specimens measured).

Remarks. Both phragmas thin, less than 1 µm thick, often folded, particularly the endocyst on periphery; paracingulum strongly spiral. Recently, Harker (1979) suggested that *Palaeohystrichophora* possesses a combination archeopyle of type 313 Pa/313 Pa. The Bylot Island specimens display wall fractures, which may be the result of an opercular displacement. In one specimen, an archeopyle, which seems to incorporate precingular and intercalcary paraplates, was seen in oblique view.

Genus *Palaeoperidinium* Deflandre emend. Lentin and Williams, 1976

Palaeoperidinium pyrophorum (Ehrenberg) Sarjeant, 1967

Plate 16, figure 8; Plate 17, figure 1; Plate 18, figures 8-10

1938 *Peridinium pyrophorum* Ehrenberg, Pl. 1, figs. 1, 4.

?1934 *Palaeoperidinium* cf. *pyrophorum* Deflandre, Textfig. 1.

1967 *Peridinium basilium* Drugg, p. 13, Pl. 1, figs. 9-11; Pl. 9, figs. 1a, 1B.

1973 *Palaeoperidinium deflandrei* Lentin and Williams, p. 105.

1967 *Palaeoperidinium pyrophorum* (Ehrenberg) Sarjeant, p. 246, 247.

Dimensions. Endocyst 64-99 µm long, 49-92 µm wide; pericyst 70-119 µm long (from midpoint between antapical horns to distal point of apical horn), 50-102 µm wide; cingulum of variable width, ranging from 3-10 µm; antapical horns 4-20 µm long.

Remarks. In some instances the endocyst may project slightly, apically and antapically, into the base of the corresponding horns. Occasional specimens have an archeopyle with the dorsal surface of the epicyst missing, i.e. paraplates 3', 1a-3a and 3''-5'' (Pl. 18, fig. 9) and the operculum often preserved separately (Pl. 18, fig. 10). Dorsal paratabulation has been observed on some specimens, defined by intratabular grana and striated parasutural bands (Pl. 18, fig. 8).

At some horizons most specimens possessed an endocyst, at others they did not, but mixed populations were often discovered. They are all considered to belong to the same species and are here assigned to *Palaeoperidinium pyrophorum*. Studies on modern dinoflagellates have shown comparable cyst development. Evitt and Wall (1968) demonstrated that the extant freshwater dinoflagellate *Peridinium limbatum* may produce cysts with or without an endocyst.

Genus *Palaeotetradinium* Deflandre emend. Stover and Evitt, 1978

Palaeotetradinium silicorum Deflandre, 1936

Plate 18, figures 11, 12

1936 *Palaeotetradinium silicorum* Deflandre, p. 189, Pl. 9, fig. 11.

Dimensions. Overall cyst length 47-61 µm, width 30-54 µm; endocyst 20-25 µm long, 20-26 µm wide (6 specimens measured).

Remarks. The specimens observed resemble the holotype closely, the only difference being their larger but overlapping size. A cingulum may be present, as suggested by a well defined transverse fold (3-5 µm wide). The lateral horns are inconsistently developed in the specimens seen.

Genus *Pareodinia* Deflandre emend. Stover and Evitt, 1978

Pareodinia? ceratophora subsp. *scopaea* (Sarjeant) Lentin and Williams, 1973

Plate 18, figures 5, 6, 15

1972 *Pareodinia ceratophora* var. *scopaea* Sarjeant, p. 26, Pl. 2, fig. 4.

1973 *Pareodinia ceratophora* subsp. *scopaea* (Sarjeant) Lentin and Williams, p. 108.

Dimensions. Overall body length 54-71 µm, width 38-58 µm; apical horn 4-8 µm long; outer covering, when present, up to 14 µm high (8 specimens measured).

Remarks. The specimens seen during this study, although larger than those described by Sarjeant (1972), are considered at present to belong to the subspecies. In fact, the author is in agreement with Sarjeant who states, ". . . future studies will show them to fall within the extremes of variation of the variable species *P. ceratophora*". They are here questionably assigned to the genus because of the uncertain position of the archeopyle.

The specimens illustrated by Wiggins (1975, Pl. 1, figs. 7, 8), and *Kalyptea* cf. *monoceras* in Manum and Cookson (1964, Pl. 6, fig. 13) are identical to the Bylot Island material. It is possible that the occurrences in the assemblages documented by Manum and Cookson (*ibid.*) and in the material from Bylot Island may be derived specimens.

The enclosing kalyptra, which may be present in *Pareodinia* and related genera, in some specimens appears to attain a pseudofibrous structure (Pl. 18, fig. 15), which is idealized in the form of extremely fine processes, as shown in the specimens referred to here as *Impletosphaeridium*. Whether the surrounding amorhous cloak represents a decaying fibrous or process structure cannot be assessed from the material available.

It is relevant to note that the synonymy of *Pareodinia nuda* (Downie) Sarjeant, 1967 with *P. ceratophora* Deflandre, 1947 (in Wiggins, 1975, p. 103) is rejected (cf. discussion on *Gonyaulacysta longicornis* Downie emend. Gitmez and Sarjeant, 1972, in Ioannides et al., 1977, p. 454).

Genus *Prolixosphaeridium* Davey, Downie, Sarjeant and Williams

Prolixosphaeridium granulosum (Deflandre) Davey, Downie, Sarjeant, and Williams, in Davey et al., 1966

Plate 18, figure 14

1935 *Hystrichosphaeridium xanthiopyxides* Deflandre, Pl. 9, fig. 7.

1937 *Hystrichosphaeridium xanthiopyxides* var. *granulosum* (Deflandre) Deflandre, p. 77, Pl. 16, fig. 4.

1962 *Baltisphaeridium xanthiopyxides* var. *granulosum* (Deflandre) Sarjeant, p. 624, Pl. 2, fig. 14, Textfig. 8C, tables 3, 4.

1966 *Prolixosphaeridium granulosum* (Deflandre) Davey, Downie, Sarjeant, and Williams, p. 172, 173.

Dimensions. Body length 58-69 µm, width 32-35 µm; processes 6-12 µm long (3 specimens measured).

Remarks. Specimens conform to the original description of the species (in Davey et al., 1966). Identical specimens have been reported by Ioannides, Stavrinos and Downie (1977) from the Kimmeridgian of southern England (?derived in Bylot Island).

Prolixosphaeridium sp.

Plate 19, figure 4

Description. Body shape elongate ellipsoidal with autophragm only. Autophragm covered with numerous, thin, close processes having simple and occasionally bifurcate, or even branched, tips. Autophragm between processes smooth to punctate. Paratabulation indicated by archeopyle only. Archeopyle apical, type tA, operculum free. Paracingulum and parasulcus not indicated.

Dimensions. (Whole specimens) body length 35-40 µm, width 17-22 µm; one specimen with free operculum measures 30 x 17 µm; length of processes 4-14 µm, generally 8-10 µm (9 specimens measured).

Remarks. The small size, smooth autophragm and fine processes characterize these specimens.

Genus *Pterodinium* Eisenack, 1958

Pterodinium sp.

Plate 18, figure 13

Description. Shape of cyst subspherical, with a rounded apex and rounded to truncated antapex. Wall with autophragm (?) only. Parasutural septa high with denticulate crests. Autophragm smooth to finely granular. Paratabulation poorly developed or masked by heavy folding of the septa (?); probably gonyaulacacean. Archeopyle precingular, type P (3" only), operculum free. Paracingulum indicated by parasutural crests. Parasulcus poorly defined by longitudinal septa.

Dimensions. Total length 62-72 µm, total width 50-70 µm; body length 50-63 µm, width 38-58 µm; septa up to 11 µm high (5 specimens measured).

Comparison and remarks. The presence or absence of a periphragm could not be determined with certainty. The high septa, apparent at the plate boundaries, seem to support an outer membrane, the dorsal and ventral surfaces of which overlap beyond the body margin. In addition, the density and complexity of folds observed could only result from a folded periphragm. Therefore, the species is provisionally assigned to *Pterodinium* until further material becomes available. The specimens illustrated by McIntyre (1974, Pl. 12, figs. 4, 5) are identical with the present species. The species referred to by Vozzhennikova (1967), *Pterodinium* cf. *magnoserratum* Cookson and Eisenack, 1962 and *Pterodinium* sp. A (*ibid.*, Pl. 111, figs. 1-3, 4-6, respectively), appear very similar to the form described here.

Genus *Saeptodinium* Harris, 1974

Saeptodinium eurypylum (Manum and Cookson) Stover and Evitt, 1978

Plate 19, figures 5, 6

1964 *Scriniodinium eurypylum* Manum and Cookson, p. 20, 21, Pl. 4, figs. 7-13.

1975 *Palaeoperidinium eurypylum* (Manum and Cookson) Evitt, p. 81.

1978 *Saeptodinium eurypylum* (Manum and Cookson) Stover and Evitt, p. 220.

Dimensions. Endocyst 46-52 µm long and wide; pericyst 55-62 µm long (3 specimens measured).

Remarks. *Saeptodinium eurypylum* was described in detail by Evitt (1975, p. 81-83, figs. 1-12). The archeopyle is defined as type At13p comprising paraplates 3', 1a-3a and 3"-5", and is separated from the cyst along a transapical suture situated at the upper margin of the paracingulum. The difference between this species and *Luxadinium propatulum* Brideaux and McIntyre, 1975 lies in the inclusion of plate 3' in the archeopyle of *S. eurypylum*. However, this is not always evident, and the generally smaller antapical pericoel in *S. eurypylum* may sometimes help in differentiating the two species.

Genus *Scriniodinium* Klement, 1957

Scriniodinium? *campanulum* Gocht, 1959

Plate 20, figures 2, 3

1959 *Scriniodinium campanulum* Gocht, p. 61, Pl. 4, fig. 6, Pl. 5, fig. 1.

1967 *Endoscrinium campanulum* (Gocht) Vozzhennikova, p. 175.

Dimensions. ?Endocyst 58-72 µm long, 53-62 µm wide; ?pericyst 70-97 µm long, 68-81 µm wide (9 specimens measured).

Remarks. It is difficult to decide whether the line running parallel to the periphragm represents an endophragm. Some degree of separation was observed along this "contact" on both apical and anatapical regions in some specimens. The slightly darkened central portion in most specimens may also suggest the presence of an endocyst.

Scriniodinium? *obscurum* Manum and Cookson, 1964

Plate 6, figures 3-10

1964 *Scriniodinium obscurum* Manum and Cookson, p. 21, 22, Pl. 4, figs. 5, 6.

Description. Shape subspherical to ovoidal. Cyst holocavate, periphragm forms a membranous horn of variable configuration. Endophragm and periphragm locally in contact but normally well separated antapically and often equatorially. Parasutural features absent or consisting of discontinuous ridges developed locally. Endophragm ornamented with isolated and proximally fused processes of varying width, forming an irregular, often broken reticulum, in places. In profile, processes resemble a scrollwork pattern. Junctions of reticulum elevated giving rise to fibril structures of uncertain nature supporting the periphragm locally. Periphragm variably folded. Paratabulation indicated partially by archeopyle, paracingulum, parasulcus and occasionally discontinuous parasutural ridges defining plate 3", and possibly plates 2'" and 4'". Archeopyle precingular, type P (3" only), operculum free or attached. Paracingulum indicated by transverse folds or linear process complexes. Parasulcus sometimes expressed as a faint depression devoid of ornament.

Dimensions. Endocyst length 80-115 µm, width 68-106 µm; processes 4-18 µm long, 0.5-6 µm thick; apical horn up to 20 µm high; endophragm normally thin, 1 µm in thickness, but specimens with coarser ornament possess a thicker endophragm 1-3 µm, rarely up to 5 µm thick. Periphragm very thin, 1 µm or less (20 specimens measured).

Comparison and remarks. This form is provisionally assigned to *Scriniodinium* (following Stover and Evitt, 1978, p. 188), because of the structures connecting the two phragmas. The true nature of these structures, running between two layers, is not completely understood, an observation also stressed by Manum and Cookson (1964). Intergradation between *S.*? *obscurum*, *Chlamydophorella*? *grossa* and *Spongodinium*? sp. is shown in plates 5-8. Certain variants are identical to those illustrated by Manum and Cookson (1964, Pl. 4, figs. 5, 6).

Genus *Senegalinium* (Jain and Millepied) Stover and Evitt, 1968

Senegalinium macrocystum (Cookson and Eisenack) Stover and Evitt, 1978

1960 *Deflandrea macrocysta* Cookson and Eisenack, p. 3, Pl. 11, figs. 7, 8.

1976 *Alterbia macrocysta* (Cookson and Eisenack) Lentin and Williams, p. 49.

1978 *Senegalinium macrocystum* (Cookson and Eisenack) Stover and Evitt, p. 123.

Dimensions. Endocyst 48-54 µm long, 43-50 µm wide; total length 62-67 µm, total width 50-54 µm; periphragm less than 1 µm thick; endophragm 1-2 µm thick (13 specimens measured).

Remarks. Specimens have a smaller size range than those described by Cookson and Eisenack (1960, p. 3: range 80-109 µm and 55-70 µm in total length and width, respectively), but are otherwise identical.

Senegalinium sp. cf. *S. microgranulatum* (Stanley) Stover and Evitt, 1978

Plate 19, figures 7, 8

Dimensions. Cyst length 52-61 μm, width 52-56 μm (3 specimens measured).

Remarks. These specimens are only compared with this species because of the lack of grana on the pericyst (although the size of the grana, 0.3 μm quoted by Stanley, 1965, p. 219, is negligible) and the slight extension of the pericoel beyond the apical and antapical regions toward the paracingular region. *Senegalinium obscurum* (Drugg) Stover and Evitt, 1978 and probably *Subtilisphaera ventriosa* (Alberti) Jain and Millepied, 1973 appear to be conspecific with *Senegalinium microgranulatum* (Stanley) Stover and Evitt, 1978. Before such a transfer is undertaken, however, examination of the type material would be desirable.

Genus *Spinidinium* Cookson and Eisenack emend. Lentin and Williams, 1976

Comparison and remarks. Here, *Spinidinium* is accepted as having parasutural ridges aligned with spines or linear complexes of spines as there is often no clear-cut distinction between these two states. Stover and Evitt (1978, p. 125) questioned the assignment of *S. clavum* Harland, 1973, on this basis but there was no alternative genus in which to incorporate the species. The type material of *S. clavum* has been examined by the writer and indeed possesses parasutural ridges, and an ornament, as defined by Harland.

Spinidinium balmei (Cookson and Eisenack) comb. nov.

Plate 19, figures 10, 11

1960 *Deflandrea minor* Cookson and Eisenack, p. 2, Pl. 1, figs. 1-4.

1962 *Deflandrea balmei* Cookson and Eisenack, p. 4, 6.

1976 *Alterbia balmei* (Cookson and Eisenack) Lentin and Williams, p. 48.

1978 *Isabelidinium balmei* (Cookson and Eisenack) Stover and Evitt, p. 109.

Description. Shape compressed peridinoid, subpentagonal with a truncate apical horn and a left antapical horn; right antapical horn reduced. Antapical outline, between horns, straight to concave. Endocyst subcircular to elongate ovoidal. Cyst circumcavate but pericoel reduced medially. Parasutural features consist of cones and acuminate to oblate spines arranged in penitabular rows; periphragm otherwise smooth and thin, 1 μm or less. Endophragm thin, punctate to granular, grana more prominent on periphery when viewed dorsoventrally. Paratabulation peridiniacean, indicated by penitabular rows of ornament, formula ?4, 3a, 7", 5 or 6c, 5"', 2"". Archeopyle intercalary, type I or Ia (2a only). Paracingulum indicated by transverse folds and ornament arranged into two parallel interrupted rows suggesting the presence of at least 5 plates, dividing the cyst into a slightly larger epicyst than the hypocyst. Parasulcus indicated by longitudinal disposition of ornament, which delimits sulcal depression and may extend on epicyst.

Dimensions. Overall cyst length 62-74 μm, width 43-48 μm; endocyst length 40-50 μm, width 33-40 μm; apical horn up to 9 x 7 μm in height and width, antapical horn 10 x 10 μm; cingulum 8-10 μm wide, ornament up to 3 x 2 μm in height and width (3 specimens measured).

Remarks. This form is transferred to *Spinidinium* on the basis of ornament distribution.

Spinidinium uncinatum May, 1980

Plate 10, figures 21-24, 27, 28;
Plate 11, figures 2-4, 8

1980 *Spinidinium uncinatum* May, p. 85, 86, Pl. 10, figs. 5-7, Pl. 13, figs. 9, 10.

Description. Shape peridinoid, generally pentagonal in outline when viewed dorsoventrally, with epicyst more conical than hypocyst. Apical horn truncate, left antapical horn well developed, distally pointed to a narrow spine, occasionally topped by a minute spinule. Cyst cornucavate to barely circumcavate, frequently with well developed apical and antapical pericoels. Parasutural features consist of incomplete ridges or aligned ornament. Parasutural crests aligned with generally capitate to bifid processes, less commonly with oblate and acuminate processes. Locally, ornament may occur in intratabular positions and also may be present on horns. Periphragm otherwise smooth to punctate. Paratabulation incompletely indicated by parasutural features in the form of ridges, which often fade away, and aligned spines. Formula peridiniacean ?4, ?3a, 7", Xc, 5"', 2"". Archeopyle intercalary, type Ia (2a only), but rarely formed, normally elongate, but still of hexa type; operculum attached. Paracingulum spiral, positioned at one third of length from antapex dorsally, slightly higher ventrally; position indicated by interrupted parasutures aligned with spines. Parasulcus poorly expressed by longitudinal folds apparently delimiting a shallow depression extending over part of both epicyst and hypocyst.

Dimensions. Overall cyst length 37-70 μm, width 24-58 μm (two specimens measure 85 x 58 μm and 85 x 56 μm, respectively); endocyst 29-62 μm long, width 21-54 μm; apical horn variable in size, 3-20 μm long, 4-16 μm wide at base; left antapical horn 5-12 μm long, 2-10 μm wide at base; right antapical greatly reduced or absent; spines 1-6 μm high, distal expansion 1-2.5 μm, paracingulum 3-4 μm wide (35 specimens measured).

Comparison and remarks. *Spinidinium uncinatum* May, 1980 differs from *S. clavum* Harland, 1973 in having a more variable process structure, including processes with bifid distal ends. However, the small number of specimens and poorer preservation of Harland's material should be noted. The two populations either represent parts of the same intraspecific variability or perhaps closely related subspecies of different geographic and ecological sites. Bylot Island specimens are, at present, referred to *S. uncinatum* May, 1980, despite the additional occurrence of barbed spines and the better developed tabulation in the type material.

Genus *Spiniferites* Mantell emend. Sarjeant, 1970

Spiniferites? cingulatus (O. Wetzel) Sarjeant, 1970

Plate 19, figure 13

1933 *Cymatiosphaera cingulata* O. Wetzel, p. 28, Pl. 4, fig. 10.

1954 *Hystrichosphaera cingulata* (O. Wetzel) Deflandre, p. 258.

1970 *Spiniferites cingulatus* (O. Wetzel) Sarjeant, p. 76.

Dimensions. Length of cyst body 47-53 µm, width 40-46 µm; height of septa ranges from 2 to 18 µm, the maximum height being reached at plate boundaries, where they rise to form the (?) processes (5 specimens measured).

Remarks. The writer is in agreement with Stover and Evitt who stated that "*S.? cingulatus* . . . either lacks processes or the processes have exceptionally short stalks, which do not extend much above the parasutural septa". Indeed, the few specimens studied do not show definite processes but "folds" extending slightly beyond the edges of the septa. Further material is needed before reinterpretation of this form can be undertaken.

Spiniferites porosus (Manum and Cookson) Harland, 1973

Plate 19, figures 16, 18

1964 *Hystrichosphaera porosa* Manum and Cookson, p. 11, 12, Pl. 2, figs. 1-5, Textfig. 2.

1973 *Spiniferites porosus* (Manum and Cookson) Harland, p. 690, 692, Pl. 87, fig. 5.

Dimensions. Cyst body 66-79 µm long, 48-79 µm wide; processes up to 27 µm long and 10 µm wide at base (11 specimens measured).

Remarks. The specimens are the same as the type material.

Spiniferites ramosus (Ehrenberg) Loeblich and Loeblich, 1966

Plate 19, figure 12

1838 *Xanthidium ramosum* Ehrenberg, Pl. 1, figs. 1, 2, 5.

1838 *Xanthidium furcatum* Ehrenberg, Pl. 1, figs. 12, 14.

1933b *Hystrichosphaera furcata* (Ehrenberg) O. Wetzel, p. 34.

1933b *Hystrichosphaera ramosa* (Ehrenberg) O. Wetzel, p. 35.

1966 *Spiniferites ramosus* (Ehrenberg) Loeblich and Loeblich, p. 56, 57.

Dimensions. Length of cyst body 46-56 µm, width 40-54 µm; processes range in height from 6 to 18 µm (26 specimens measured).

Remarks. Following Davey and Williams (in Davey et al., 1966), and Lentin and Williams (1973, 1977), the following subspecies are recognized:

Spiniferites ramosus subsp. *ramosus* (Ehrenberg) Loeblich and Loeblich, 1966.

Spiniferites ramosus subsp. *multibrevis* (Davey and Williams) Lentin and Williams, 1973.

Spiniferites sp. cf. *S. scabrosus* (Clarke and Verdier) Lentin and Williams, 1975

Plate 19, figures 14, 17

Dimensions. Length of cyst body 45-52 µm, width 38-44 µm; processes up to 20 µm high (9 specimens measured).

Remarks. The present specimens are similar to those described by Clarke and Verdier (1967, p. 49, 50, Pl. 9, figs. 7-10), but the processes lack the scabrate ornamentation.

Spiniferites wetzelii (Deflandre) Sarjeant, 1970

Plate 20, figure 4

1933b *Hystrichosphaera* cf. *furcata* (Ehrenberg) O. Wetzel, Pl. 5, fig. 13.

1935 *Hystrichosphaera wetzeli* Deflandre, p. 232, Pl. 8, fig. 5.

1970 *Spiniferites wetzelii* (Deflandre) Sarjeant, p. 77.

Dimensions. Cyst body length 53-59 μm, width 53-58 μm; height of septa up to 20 μm (5 specimens measured).

Remarks. Specimens conform to the original description.

Genus *Spongodinium* Deflandre, 1936

Spongodinium? sp. (cf. *S.*? *delitiense*)

Plate 7, figures 4-11; Plate 8, figures 2-5

Description. Shape subspherical, ovoidal to broadly biconical with a variably developed apical horn. Autophragm smooth to finely porous, covered with prominent muri of varying width yielding both reticulate and foveolate sculptures. Luminae and fovae extremely variable in size and shape, circular to subpolygonal, often five- or six-sided, up to 14 μm in longest diameter. Muri often broken into irregularly shaped ridges. Apparently junctions of muri may be highly elevated and vary considerably in width, from well defined processes with distal expansions to fibril structures, both supporting a thin "ectophragm" in antapical, apical and equatorial positions; "ectophragm" widely separated from autophragm. Fibrils normally entangled and of undetermined nature. Paratabulation indicated by archeopyle and a paracingulum but faint ridges may be locally traced, particularly in position of plate 3'''. Archeopyle precingular type P. Paracingulum indicated by transverse folds or aligned ornament. Parasulcus occasionally indicated by less well developed or absent ornament.

Dimensions. Cyst length 105-150 μm, width 94-110 μm; apical horn 8-30 μm high; autophragm 1-3 μm thick; processes (and fibrils) up to 30 μm long (20 specimens measured).

Comparison and remarks. This species is referred to *Spongodinium* because the structure of its ornament conforms with that found in *Spongodinium*, but its assignment is questioned as *Spongodinium*? sp. It differs from the type [*S. delitiense* (Ehrenberg) Deflandre, 1936] in having an outer membranous wall ("ectophragm"). In rare occasions internal linear ridges have been observed, normally originating from the paracingulum. Certain variants (Pl. 7, fig. 4) are morphologically similar and possibly belong to *S. delitiense* (Ehrenberg) Deflandre, 1936. For an additional discussion of *Spongodinium*? sp. see the discussion of the *Chlamydophorella*? *grossa*-*Scrinodinium*? *obscurum* complex (p. 15).

Genus *Stephodinium* Deflandre emend. Davey, 1970

Stephodinium coronatum Deflandre, 1936

Plate 19, figure 9

1936 *Stephodinium coronatum* Deflandre, p. 59, Textfig. 104.

1962 *Stephodinium australicum* Cookson and Eisenack, p. 491, Pl. 2, figs. 5-10.

1964 *Stephodinium europaicum* Cookson and Hughes, p. 50, 51, Pl. 8, figs. 9-17.

Dimensions. Endocyst length 27-40 μm, width 27-54 μm; pericyst length 42-66 μm, width 58-75 μm (4 specimens measured).

Remarks. Specimens conform to the original description and subsequent emendation of Davey (1970, p. 347). It is noteworthy that the specimens obtained from sample C-60131 remained unstained (?derived).

Genus *Surculosphaeridium* Davey et al., in Davey et al., 1966

Surculosphaeridium? *longifurcatum* (Firtion) Davey et al., in Davey et al., 1966

Plate 19, figure 15

1957 *Hystrichosphaeridium longifurcatum* Firtion, Pl. 9, fig. 1, Textfig. 1, H, K, L, M.

1963 *Baltisphaeridium longifurcatum* (Firtion) Downie and Sarjeant, p. 91.

1966 *Surculosphaeridium longifurcatum* (Firtion) Davey et al., in Davey et al., p. 163, 164, Pl. 8, figs. 7, 11, Textfigs. 43, 44.

Dimensions. Cyst body 38-49 μm long, 38-55 μm wide; length of processes 15-35 μm, width at base 1-3 μm (9 specimens measured).

Remarks. The specimen illustrated by Firtion (1952, Pl. 9, fig. 1) is poorly preserved and his description is inadequate. Davey et al. (1966) subsequently defined *Surculosphaeridium* as having an apical archeopyle. Two of the specimens seen probably have an apical archeopyle. Therefore, they are questionably assigned to the genus.

Genus *Tanyosphaeridium* Davey and Williams, in Davey et al., 1966

Tanyosphaeridium variecalamum Davey and Williams, in Davey et al., 1966

Plate 19, figure 22

1966 *Tanyosphaeridium variecalamum* Davey and Williams, in Davey et al., p. 98, 99, Pl. 6, fig. 7, Textfig. 20.

Dimensions. Body length 30-36 µm, width 13-24 µm; processes 7-15 µm long (7 specimens measured).

Remarks. Specimens essentially the same as those described by Davey and Williams, (in Davey et al., 1966). It is possible that these specimens may be derived.

Genus *Thalassiphora* Eisenack and Gocht emend. Gocht, 1968

Thalassiphora? sp. cf. *T. delicata* Williams and Downie, in Davey et al., 1966 emend. Eaton, 1976

Plate 22, figures 6, 8

Dimensions. Endocyst 35-60 µm long, 30-56 µm wide; pericyst 85-125 µm long, 80-110 µm wide; apical (?) protrusion of endocyst 6-8 µm high (8 specimens measured).

Remarks. The specimens seen are poorly preserved and often broken. The archeopyle was not observed. It has been assumed that the protrusion on the endocyst is apical, and three of the specimens have been orientated accordingly.

Thalassiphora pelagica (Eisenack) Eisenack and Gocht, 1960

Plate 21, figures 1-7; Plate 22, figures 1-5, 7

1937 *Bion pelagicum* Eisenack, p. 187 (nomen nudum).

1954 *Pterospermopsis pelagica* Eisenack, p. 71, Pl. 12, figs. 17, 18.

1971 *Thalassiphora balcanica* Baltes, p. 6, Pl. 3, figs. 3-7.

1966 *Thalassiphora sueroi* Pothe de Baldis, p. 224, Pl. 2, fig. d.

1966 *Eriknia dynamica* Morgenroth, p. 27, 28, Pl. 6, figs. 7, 8.

1960 *Thalassiphora pelagica* (Eisenack) Eisenack and Gocht, p. 513, 514.

Dimensions. Endocyst 53-102 µm long, 36-97 µm wide; pericyst 104-176 µm long, 103-176 µm wide; archeopyle 25-50 x 30-43 µm; antapical projection 10-16 µm long (one specimen's projection measures 27 µm long) (40 specimens measured).

Remarks. A large number of specimens of *Thalassiphora pelagica* sensu Eisenack and Gocht, 1960 (withouth obvious paratabulation) were encountered in sample C-60138. They essentially conform to Stover and Evitt's (1978, p. 194) synopsis for the genus *Thalassiphora*. The morphology of these specimens, based on both transmission and scanning electron microscope studies may be summarized as follows: the two wall layers appear appressed or in close proximity dorsally and the outer limit of their contact is marked by a thickened zone, which is formed by the attachment of the two layers (Pl. 21, figs. 3, 5). The dorsal connection of the periphragm and endophragm is made by means of fibrils, as shown in Plate 22, figs. 1, 5. Approximately the whole ventral surface is open, exposing the central body. This is highly ornamented, at least ventrally (Pl. 21, figs. 6, 7), and most likely dorsally (as shown in Pl. 22, fig. 4), with a coarsely fibrovermiculate to fibroreticulate structure (Pl. 21, fig. 6). A similar but less prominent ornament is present on the inner side of the periphragm [Pl. 21, fig. 7; Pl. 22, fig. 2 (detail) and 3], whereas the outer surface is variably folded but otherwise smooth [Pl. 22, fig. 2 (lower part)]. The inner surface of the endophragm is apparently smooth (Pl. 22, fig. 7). The precingular archeopyle present on the endocyst is delimited by a thickened rim formed by the attachment of the two wall layers (Pl. 21, fig. 5). A paracingulum may occasionally occur as a narrow belt running immediately below the archeopyle (Pl. 22, fig. 5). *Thalassiphora pelagica* is abundant in sample C-60138.

Genus *Trichodinium* Eisenack and Cookson emend. Clarke and Verdier, 1967

Trichodinium castaneum (Deflandre) Clarke and Verdier, 1967

Plate 19, figure 23; Plate 20, figure 5

1935 *Palaeoperidinium castaneum* Deflandre, Pl. 6, fig. 8.

1957 ?Dinoflagellaten gen. et sp. ind. in Gocht, p. 171, Pl. 20, figs. 9, 10.

1957 *Apteodinium ciliatum* Gocht, p. 65, Pl. 8, figs. 5, 6.

1960 *Trichodinium intermedium* Eisenack and Cookson, p. 6, Pl. 2, figs. 5, 6.

1964 *Trichodinium ciliatum* (Gocht) Eisenack and Klement, p. 811.

1967 *Trichodinium castaneum* (Deflandre) Clarke and Verdier, p. 19, 20, Pl. 1, figs. 1, 2.

Dimensions. Cyst length 55-65 µm, width 54-63 µm; processes up to 3.5 µm high (13 specimens measured).

Remarks. The writer has followed Clarke and Verdier's (1967, p. 19) interpretation. Specimens with or without a paracingulum have been observed.

Genus *Trigonopyxidia* Cookson and Eisenack, 1961

Trigonopyxidia ginella (Cookson and Eisenack) Downie and Sarjeant, 1965

Plate 19, figures 19, 21

1960 *Trigonopyxis ginella* Cookson and Eisenack, p. 11, Pl. 3, figs. 19, 20.

1965 *Trigonopyxidia ginella* (Cookson and Eisenack) Downie and Sarjeant, p. 149.

Dimensions. Pericyst 48-62 µm in length, 40-62 µm in width; endocyst 28-48 µm and 23-58 µm, respectively (6 specimens measured).

Remarks. Specimens conform to the original description of Cookson and Eisenack (1961).

Genus *Trithyrodinium* Drugg emend.
Lentin and Williams, 1976

Trithyrodinium fragile Davey, 1969

Plate 20, figures 10, 12, 17, 21, 22

1969 *Trithyrodinium fragile* Davey, p. 11, 12, Pl. 3, figs. 3, 6, 9.

Description. Shape subspherical to eillipsoidal, rarely with a short apical protrusion. Some specimens compressed on an axis parallel to the poles. Cyst cornucavate to circumcavate but periphragm partly, or in most specimens completely, missing. No parasutural features observed. Endophragm thin, smooth, punctate to minutely granular and conate. Periphragm smooth and membranous. Paratabulation indicated by archeopyle and sometimes a parasulcus. Archeopyle intercalary, type 3I/3I, periarcheopyle rarely discernible, endoarcheopyle formed by release of three paraplates, which often fall within the endocyst; endoperculum free or attached mainly along antapical margin. Paracingulum not observed but may be simulated by transverse folds. Parasulcus occasionally indicated by a depression delimited by folds mainly on the hypocyst.

Dimensions. Endocyst 45-61 µm long, 52-62 µm wide; traces of periphragm project beyond endophragm by up to 16 µm (preservational remains); endophragm 0.5-1.0 µm thick (12 specimens measured).

Comparison and remarks. The thin endocyst, the lack of prominent protrusions and the smooth, or minutely ornamented, endocyst characterize this species, although affinity to *Trithyrodinium suspectum* was noted by Davey (1969). The crescentic cracks referred to as "a network of curved areas" by Davey (1969), are probably preservational and have not been observed in the arctic species.

Trithyrodinium pentagonum May, 1980

Plate 20, figures 1, 8, 16

1980 *Trithyrodinium pentagonum* May, p. 87, 88, Pl. 10, figs. 13, 14.

Dimensions. Cyst length (measured from mid-antapical region to apex) 70-90 µm, width 53-70 µm; apical horn (measured from top of 2a) 11-22 µm, right antapical horn 4-8 µm long (6 specimens measured).

Remarks. Specimens essentially conform to May's description but the following additional observations were made: traces of periphragm may be seen in places (Pl. 20, fig. 1), a character that suggests the possible cavate nature of the cyst. The wall (endophragm?) is thin, smooth to granular, with grana better developed on periphery, when specimen viewed dorsoventrally. Paratabulation indicated by archeopyle (as stated by May), and occasionally plates 3' and 2'', 3'', 4'' and 5'' may be defined.

Trithyrodinium suspectum (Manum and Cookson)
Davey, 1969

Plate 20, figures 6, 7,11, 14, 15, 18

1964 *Hexagonifera suspecta* Manum and Cookson, p. 9, 10, Pl. 1, figs. 9-13.

1969 *Trithyrodinium suspectum* (Manum and Cookson) Davey, p. 12.

Description. Shape subspherical to ovoidal, in uncompressed specimens, with a small apical pericystal protrusion. Some specimens are compressed on an axis parallel to the poles, rarely found in polar orientation. Cyst cornucavate to partly circumcavate, with periphragm partly or totally missing. No parasutural features observed. Endophragm thick to moderately thick, normally densely and rather coarsely granular to finely clavate to microrugulate, giving the outline a ragged appearance. Periphragm smooth and membranous, often torn locally but usually closely appressed to the endophragm, apart from an occasional periphragmal protrusion and the better development of the periphragm antapically. Paratabulation indicated by archeopyle and sometimes a parasulcus. Endoarcheopyle intercalary, type ?/3I; periarcheopyle not discernible; endoarcheopyle formed by release of the paraplates, which frequently fall within the endocyst; endoperculum free, or attached mainly along antapical margin. Paracingulum not observed but may be simulated by transverse folds. Parasulcus sometimes indicated by a longitudinal depression delimited by folds, mainly confined to the hypocyst.

Dimensions. Endocyst 55-75 µm long, 55-72 µm wide; apical horn (pericystal) up to 6 µm high; endophragm 1.5-3.5 µm thick (irregularly defined due to ornamentation) (12 specimens measured).

Comparison and remarks. *Trithyrodinium suspectum* is characterized by its thick wall and dense and irregular ornamentation. Although the endophragm is usually coarsely ornamented, the ornament does not project beyond the outline because of the periphragm being appressed to the endophragm. As a result of the close proximity of the walls and the almost membranous nature of the periphragm, the periarcheopyle is rarely discernible. Thus the author is in agreement with Lentin and Williams' (1976) emendation of the genus, and rejects Davey's (1969) interpretation.

Trithyrodinium sp.

Plate 20, figures 9, 13, 19, 20

Description. Shape subspherical to ellipsoidal, sometimes with a short pericystal protrusion. Some specimens compressed parallel to polar axis. When periphragm intact, cyst cornucavate to circumcavate. Periphragm often partly or completely missing, but when present appears closely appressed to endophragm. No parasutural features observed, although in some places, an apparently aligned ornamentation may run parallel to folds, simulating plate boundaries. Endophragm variously ornamented with essentially two types and sizes of element, although these intergrade. A fine densely set ornamentation consists of grana and apparently microrugulae, and a coarser ornament, less densely and evenly distributed (usually 2-3 µm apart), consists mainly of verrucae, interspersed with clavate and wart-like elements. Paratabulation indicated by endoarcheopyle and sulcus. Archeopyle intercalary, type ?/3I, periarcheopyle not observed (it could be inferred by periphragmal traces overlapping the still attached endoperculum). Endoarcheopyle formed by release of three paraplates with operculum free, or attached mainly along their antapical margin by transverse folds. Parasulcus expressed as a prominent depression delineated by longtudinal folds.

Dimensions. Endocyst length 53-74 µm, width 51-72 µm; apical protrusion up to 2.5 µm high and wide; endophragm 1-2.5 µm thick (14 specimens measured).

Comparison and remarks. The type and distribution of ornamentation distinguishes this form.

Genus *Turbiosphaera* Archangelsky, 1969

Turbiosphaera filosa (Wilson) Archangelsky, 1969

Plate 23, figure 1

1967 *Cordosphaeridium filosum* Wilson, p. 66, figs. 2b, 31, 32, 34.

1969 *Turbiosphaera filosa* (Wilson) Archangelsky, p. 408-411.

Dimensions. Body length 64-69 µm, width 49-52 µm; processes up to 18 µm, polar processes up to 28 µm high (3 specimens measured).

Remarks. Specimens conform to the original diagnosis of Wilson (1967).

Genus *Wallodinium* Loeblich and Loeblich, 1968

Wallodinium lunum (Cookson and Eisenack) Lentin and Williams, 1973

Plate 23, figures 5, 6

1960 *Diplotesta luna* Cookson and Eisenack, p. 1011, Pl. 3, fig. 21.

1973 *Wallodinium luna* (Cookson and Eisenack) Lentin and Williams, p. 140.

Dimensions. Pericyst 72-96 µm in length, 32-40 µm in width; endocyst length 39-62 µm, width 22-32 µm (10 specimens measured).

Remarks. Specimens essentially conform to the original description, but some parasutural lines (?folds) observed mainly in mid-dorsal and mid-ventral regions; no tabulation determined. The degree of concavity can be variable and, therefore, the differentiation of *Wallodinium anglicum* (Cookson and Hughes) Lentin and Williams, 1973 seems to be superfluous.

Genus *Xenascus* Cookson and Eisenack, 1969

Xenascus ceratioides (Deflandre) Lentin and Williams, 1973

Plate 23, figure 3

1937 *Hystrichosphaera ceratioides* Deflandre, p. 66, 67, Pl. 12, figs. 7, 8.

1950 *Ceratium operculatum* O. Wetzel, <u>in</u> O. Wetzel, p. 169-171, Pl. 13, fig. 6.

1961 Forma H, <u>in</u> Evitt, p. 400, Pl. 6, fig. 9.

1966 *Pseudoceratium ceratioides* (Deflandre) Deflandre, p. 6.

1967 *Endoceratium perforatum* Vozzhennikova, p. 188, 189, Pl. 112, figs. 1-3, Pl. 113, fig. 1.

1971 *Phoberocysta ceratioides* (Deflandre) Davey and Verdier, p. 26, 27, Pl. 5, fig. 12.

1970 *Odontochitina blastema* Davey, p. 356-357, Pl. 5, figs. 4, 5.

1973 *Xenascus ceratioides* Lentin and Williams, p. 144.

Dimensions. Endocyst 54-68 µm long (operculum missing), 49-78 µm wide; length of postcingular horn 18-23 µm; antapical horn 41-51 µm long (6 specimens measured).

Remarks. Width of horns difficult to measure as they are formed by extension of pericyst; horns, mainly antapical, may be porous, with pore diameter 1-2 µm. Processes vary in size and shape, ranging from simple to bifurcate, or branched spines; bases occasionally fused together into a continuous ridge aligned with various types of process.

Genus *Xiphophoridium* Sarjeant, in Davey et al., 1966

Xiphophoridium alatum (Cookson and Eisenack) Sarjeant, in Davey et al., 1966

Plate 23, figure 4

1962 *Hystrichodinium alatum* Cookson and Eisenack, p. 487, Pl. 2, figs. 1-4.

1967 *Pyramidium alatum* Clarke and Verdier, p. 40, Pl. 6, figs. 5, 6.

1966 *Xiphophoridium alatum* (Cookson and Eisenack) Sarjeant and Davey et al., p. 147, 148.

Dimensions. Cyst 52-64 µm in length; 44-54 µm in width; processes up to 20 µm long; tubercles in plan view, up to 2 µm in longest diameter (6 specimens measured).

Remarks. Specimens conform with the original description of Sarjeant (1966).

Indeterminate dinoflagellate cysts

Dinoflagellate type A

Plate 23, figure 17; Plate 24, figures 1, 2, 6

Description. Shape typically ovoidal, peridinioid in outline, apex slightly protruding. Wall usually composed of autophragm only. No parasutural features present. Autophragm smooth or minutely granular to almost microrugulate. Broken specimens suggest that ornament at apex may be internally located. Paratabulation indicated only by archeopyle, but occasionally plate 4''' simulated by folds. Archeopyle intercalary, type I (2a only, in specimens seen) but 1a and 3a may be faintly, to clearly, suggested by the gaping wall; in other populations a type 3I archeopyle was also found (see remarks). Paracingulum may be suggested by a transverse fold but usually not observed. Parasulcus not indicated.

Dimensions. Cyst length 50-86 µm, width (maximum) 55-74 µm; autophragm about 1 µm thick (9 specimens measured).

Remarks. The shape and organization of the cyst may suggest that it represents the endocyst of a peridinioid form with a deflandrioid or a trithyrodinioid affinity. It is worth noting that samples from the Mackenzie Delta area (seen by the writer), and a Campanian shale unit in the Caribou Hills (Ioannides and McIntyre, 1980) yielded abundant identical forms in a mixed population containing cysts. These forms were either with or without a periphragm and had either a type I or 3I intercalary.

Dinoflagellate type B

Plate 23, figures 2, 7-12

Description. Shape variably peridinioid, often broadly pentagonal, with a short rounded to subconical apical horn, which may be reduced to a rounded apex. Left antapical horn usually developed, pointed or rounded right antapical horn reduced to indistinguishable. Wall apparently consists of autophragm only, although a darker central region observed in some specimens suggests the possibility of an indecipherable endocyst. Traces of parasutures may be followed by alignment of ornament. Autophragm smooth to variably ornamented with grana, minute scattered spines, or verrucate to ridge-like elements, often assuming a pseudoreticulate to spongiose structure, often more prominent in mid-dorsal and mid-ventral regions. Paratabulation indicated by archeopyle, paracingulum and local alignment of ornament. Paratabulation formula indeterminate. Archeopyle intercalary, type I (2a only) omegaform to subhexagonal in outline. Operculum free or attached, normally along antapical margin, rarely along apical margin. Paracingulum indicated by transverse folds (or ridges) aligned with verrucae and thus assuming a distinctly corrugated appearance. Parasulcus may be delimited by longitudinal folds on antapical area.

Dimensions. Overall length 73-93 µm, width 51-71 µm; apical horn, when developed, 3-10 µm long, 7-15 µm wide at base; left antapical horn up to 13 µm long (14 specimens measured).

Remarks. Some specimens contain material which may be degraded endophragm or cell contents (Pl. 23, fig. 9).

Dinoflagellate type C

Plate 24, figures 5, 7-9, 11, 12

Description. Shape spherical to eillipsoidal. Wall apparently consists of autophragm only. Surface ornamented with simple to complex, short processes with highly variable distal expansions. They may be acuminate bifid, foliate, digitate, aculeate to orthogonal, or of more complex configuration. Sometimes joined distally; aculei 1-3 µm long, may be acuminate or bifid. Processes solid or hollow and distally closed or open. Paratabulation expressed only by archeopyle. Archeopyle apparently precingular, type P (3'' only) although sometimes it appears intercalary or even apical depending on the fragility and displacement of operculum, which often breaks into more than one piece. Operculum free or attached. Paracingulum and parasulcus not indicated.

Dimensions. Cyst length 40-60 μm, width 32-58 μm, length of processes 1.5-8 μm, autophragm 0.5-1.5 μm thick (20 specimens measured).

Comparison and remarks. This form is not assigned to any known genus because of the complexity of the processes and the indeterminate type of archeopyle. *Operculodinium* or *Exochosphaeridium* are the most closely related genera, to either of which this form might subsequently be assigned.

Dinoflagellate? type D

Plate 24, figures 1-4, 6

Dimensions. Body length 70-90 μm, width 70-87 μm; flocculent outer covering imcompletely preserved, up to 26 μm high (11 specimens measured).

Remarks. On the basis of ornamentation, this group of fossils may be differentiated into more than one taxa, but because of the ambiguity of their morphology and structure they are temporarily treated collectively. The ornament varies from granular to minutely verrucate and rugulate, and they are variably surrounded by an outer flocculent layer. In some specimens, a number of "slits" have been observed along the autophragm. Although a weak plate attachment may be suggested, no definite regular pattern has been determined. Occasionally, six paraplates (precingular or postcingular) may be visualized as shown in Plate 25, figs. 1, 3 (apical or antapical view). A similar but larger form (140 x 119 μm) was described by Cookson and Eisenack (1971, p. 223, Pl. 11, fig. 1) as *Eyrea* sp.

Dinoflagellate type E

Plate 23, figures 13-16

Description. Cyst cornucavate to slightly circumcavate; shape elongate ellipsoidal to biconical; apical and left antapical horns normally well developed, right antapical horn reduced or absent. Cyst essentially circumcavate; endocyst subcircular to ovoidal, more or less conforming to the pericyst outline except at base of horns. Periphragm, and perhaps endophragm, finely reticulate; luminae four sided to polygonal. Endocyst, mainly on periphery, shows a sparse granulose to tuberculate ornament, 1-2 μm long, seen mainly on periphragm. Paratabulation indicated by archeopyle and parasutural lines or aligned ornament on both pericyst and endocyst. Peridiniacean, incompletely defined: ?1pr, ?', 3a, 7'', Xc, X''', X'''' (?2 ''''). On endocyst, a narrow, parallel-sided, apical extension of the 1' is present but its upper limit lacks definition; it probably represents a preapical paraplate. Endocyst paraplate 2a, six sided, but apical side highly reduced. Pericyst paraplate 2a typically six sided. Archeopyle intercalary, type I/I (2a only). Perioperculum free or attached, sometimes fallen within the cyst. Endoperculum always attached. Paracingulum indicated by transverse lines; paracingular plates biconical with the lateral joints of the cones connected with pre- and post-paracingular plates. Parasulcus forms a depression extending halfway onto both epicyst and hypocyst; parasulcul plates not indicated.

Dimensions. Pericysts length 70-98 μm, width 50-64 μm; endocyst length 45-70 μm, width 42-66 μm; apical horn up to 15 μm long; left antapical horn up to 12 μm long; luminae 1-5 μm in longest diameter (14 specimens measured).

Remarks. The majority of specimens seen are pale, poorly preserved and highly compressed. The four levels of paratabulation (never seen on one specimen) have given rise to great confusion in tracing the parasutures, and in no specimen could complete paratabulation be determinated on any one side. In fact only rarely could some plates be defined on the hypocyst.

Incertae sedis

Genus *Ophiobolus* O. Wetzel emend. Evitt, 1968

Ophiobolus lapidaris O. Wetzel, 1933

1967 *Scuticabolus lapidaris* (O. Wetzel) Loeblich, p. 68, 69.

1933a, b *Ophiobolus lapidaris* O. Wetzel, p. 176-178, Pl. 2, figs. 30-34, Textfigs. 5-7.

Dimensions. Body 35-39 μm long, 10-15 μm wide (3 specimens measured).

Remarks. Specimen identical to those described by Evitt (1968, p. 4-8).

Genus *Palambages* O. Wetzel, 1961

Palambages spp.

Plate 24, figures 3, 13, 16;
Plate 25, figures 7, 8

Remarks. Approximately 500 specimens of *Palambages* were observed, showing a wide range of variability. No attempt has been made to differentiate them at the specific level (cf. Corrandini, 1972, p. 189 for relevant discussion).

Genus *Paralecaniella* Cookson and Eisenack emend. Elsik, 1975

Paralecaniella indentata (Deflandre and Cookson) Cookson and Eisenack emend. Elsik, 1975

Plate 24, figures 4, 10

1955 *Epicephalopyxis indentata* (Deflandre and Cookson) p. 292, Pl. 9, figs. 5-7, Textfig. 56.

1970 *Paralecaniella indentata* (Deflandre and Cookson) Cookson and Eisenack, p. 323.

Dimensions. ?Endocyst 47-77 µm long, 44-67 µm wide; ?pericyst 54-86 µm long, 52-75 µm wide (16 specimens measured).

Remarks. Specimens conform to Elsik's emended description (1975, p. 96-100). A paracingulum is suggested by an invagination and folds in the medial region of the cyst, which is suggestive of the Dinophyceae. However, until further dinocyst characters are observed, this species is included under incertae sedis.

Genus *Schizocystia* Cookson and Eisenack, 1962

Schizocystia laevigata Cookson and Eisenack, 1962

Plate 24, figures 14, 15

1962 *Schizocystia laevigata* Cookson and Eisenack, p. 270, 271, Pl. 37, figs. 13, 14.

Dimensions. Length (perpendicular to median slit) of apical half (without horn) 31 µm (one specimen); width (parallel to the slit) 63-84 µm (4 specimens); apical horn 16 µm high; wall thickness 1-2.5 µm.

Remarks. The specimen shown by Cookson and Eisenack, 1962a (Pl. 37, fig. 13) is an incomplete specimen and identical to those observed in this study. With the information available, it is impossible to conclude whether their complete specimen (Pl. 37, fig. 14) belongs to the same species. As shown in Plate 24, figure 15, the two halves, most likely of the same specimen, exhibit a projection with its wider surface apparently transverse to the dorsoventral plane.

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PLATES 1-25

In the following plate decriptions, the species name is followed by the GSC locality number (prefixed C), the slide number (prefixed P), stage co-ordinates, GSC type number (prefixed GSC), an explanation (if necessary) and the magnification if it is other than x500.

The stage co-ordinates are for Reichart Zetopan Microscope no. 56395 at the Institute of Sedimentary and Petroleum Geology, Geological Survey of Canada, Calgary, Alberta, Canada.

All samples used in this study, as well as the palynological slides that do not contain type or figured specimens, are stored at the Institute of Sedimentary and Petroleum Geology, Geological Survey of Canada, 3303 - 33rd Street N.W., Calgary, Alberta, Canada T2L 2A7. Slides containing the types and figured specimens are in the type collection of the Geological Survey of Canada, 601 Booth Street, Ottawa, Ontario, Canada K1A 0E8.

PLATE 1

All figures x500

Figures 1-4. *Dinogymnium euclaense* Cookson and Eisenack

1. C-60129, P2047-23B: 39.7 x 120.5, GSC 65097.
2. C-60129, P2047-23B: 39.0 x 129.3, GSC 65098.
3. C-60131, P2047-25K: 34.5 x 120.7, GSC 65099.
4. C-60129, P2047-23G: 31.8 x 124.7, GSC 65100; specimens showing variation in shape and fold arrangement.

Figure 5. *Dinogymnium* sp. cf. *D. kasachstanicum* (Vozzhennikova) Lentin and Williams

C-60130, P2047-24F: 27.6 x 123.6, GSC 65101.

Figure 6. *Dinogymnium* sp. 1 of McIntyre 1974

C-60130, P2047-24D: 25.3 x 126.0, GSC 65102.

Figures 7, 8. *Alterbia minor* (Alberti) Lentin and Williams

7. C-60129, P2047-23E: 25.0 x 126.3, GSC 65103.
8. C-60111, P2047-5D: 30.2 x 130.8, GSC 65104; specimens showing variation in horn development.

Figure 9. *Alterbia* sp. cf. *A. foliacea* (Eisenack and Cookson) Lentin and Williams

C-60129, P2047-23E: 18.8 x 131.2, GSC 65105.

Figure 10. *Achomosphaera ramulifera* (Deflandre) Evitt

C-60129, P2047-23E: 41.1 x 133.7, GSC 65106.

Figures 11, 12. *Areoligera senonensis* Lejeune-Carpentier

11. C-76021, P2050-03C: 17.5 x 128.7, GSC 65107.
12. C-76012, P2050-02B: 34.5 x 123.0, GSC 65108.

Figures 13-16. *Glaphyrocysta ordinata* (Williams and Downie in Davey et al.) Stover and Evitt

13. C-60127, P2047-21D: 21.1 x 130.2, GSC 65109.
14. C-60127, P2047-21D: 27.7 x 133.1, GSC 65110.
15. C-60126, P2047-20A: 30.9 x 126.8, GSC 65111.
16. C-60126, P2047-20F: 19.0 x 126.3, GSC 65112; specimens showing variation in process development and structure.

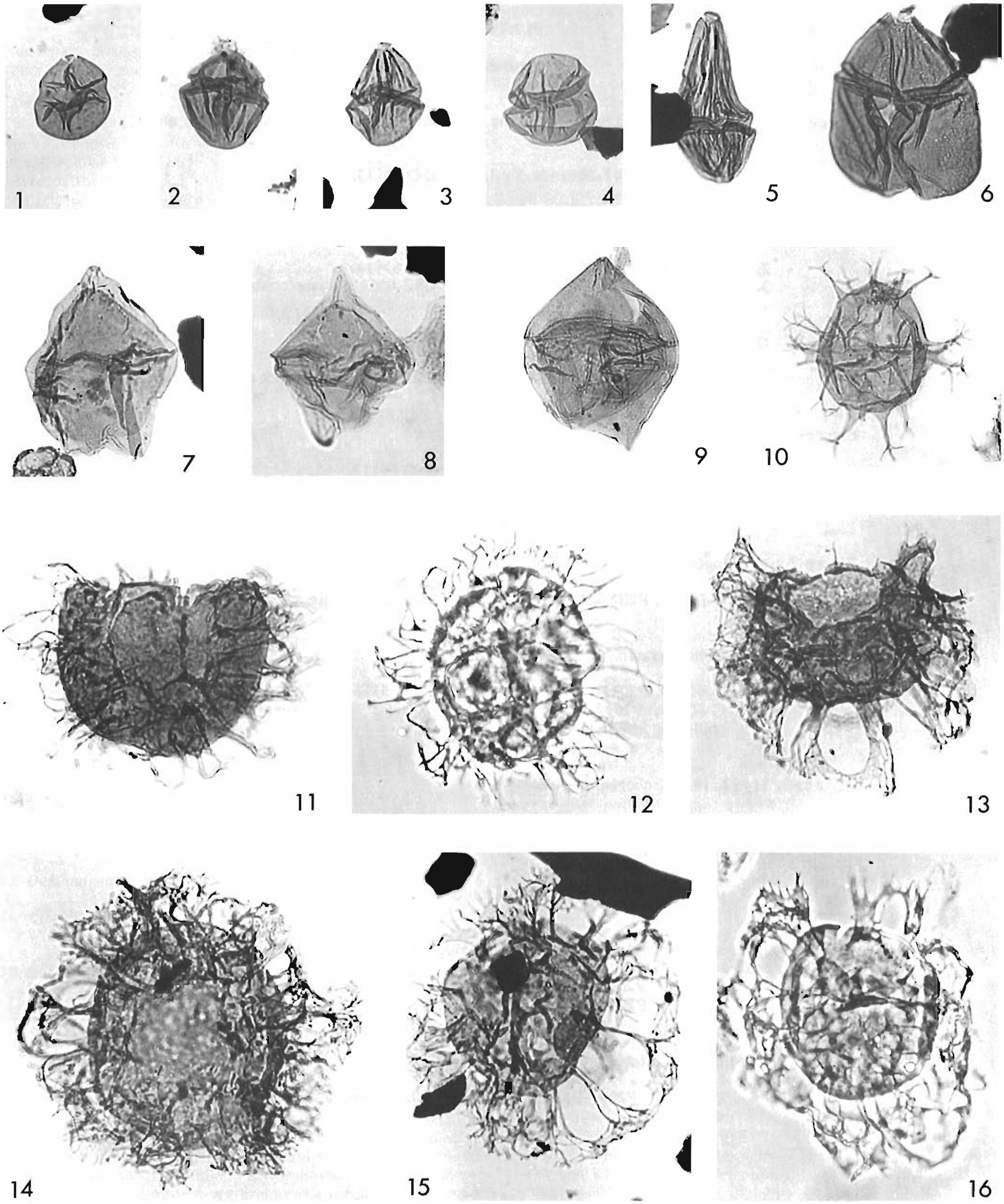
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PLATE 2

All figures x500

Figure 1. *Glaphyrocysta ordinata* (Williams and Downie in Davey et al.) Stover and Evitt

C-60126, P2047-20E: 28.5 x 115.0, GSC 65113.

Figures 2, 3. *Adnatosphaeridium*? sp.

2. C-60129, P2047-23E: 34.0 x 116.5, GSC 65114.
3. C-60129, P2047-23/5: 26.5 x 112.6, GSC 65115; phase contrast.

Figure 4. *Caligodinium aceras* (Manum and Cookson)

C-60131, P2047-25D: 33.0 x 130.0, GSC 65116; note thick autophragm.

Figures 5, 6. *Caligodinium*? sp.

5. C-60140, P2047-34D: 08.3 x 131.7, GSC 65117.
6. C-60140, P2047-34D: 17.3 x 129.7, GSC 65118; note thin autophragm and uncertain type of archeopyle.

Figure 7. *Canningia*? *ringnesiorum* Manum and Cookson

C-60129, P2047-23E: 40.3 x 121.6, GSC 65119; note sparse ornament.

Figures 8, 13. *Escharisphaeridia*? sp.

8. C-60129, P2047-23E: 31.2 x 129.6, GSC 65126.
13. C-60129, P2047-23F: 09.3 x 130.7, GSC 65127; specimens showing enclosing kalyptra.

Figures 9, 11, 12, 14. *Escharisphaeridia* sp.

9. C-60129, P2047-23F: 33.7 x 127.9, GSC 65122.
11. C-60129, P2047-23F: 30.2 x 121.3, GSC 65123.
12. (?) GSC 65124.
14. C-60129, P2047-23D: 22.4 x 131.3, GSC 65125; specimens showing variation in shape; apical or dubiously apical archeopyle may be noted.

Figures 10, 15. *Canningia*? *minor* Cookson and Hughes

10. C-60129, P2047-23D: 17.1 x 125.4, GSC 65120.
15. C-60129, P2047-23/2: 33.0 x 119.6, GSC 65121.

Figure 16. *Escharisphaeridia*? sp.

C-60129, P2047-23/2: 15.0 x 120.6, GSC-65128; archeopyle not developed.

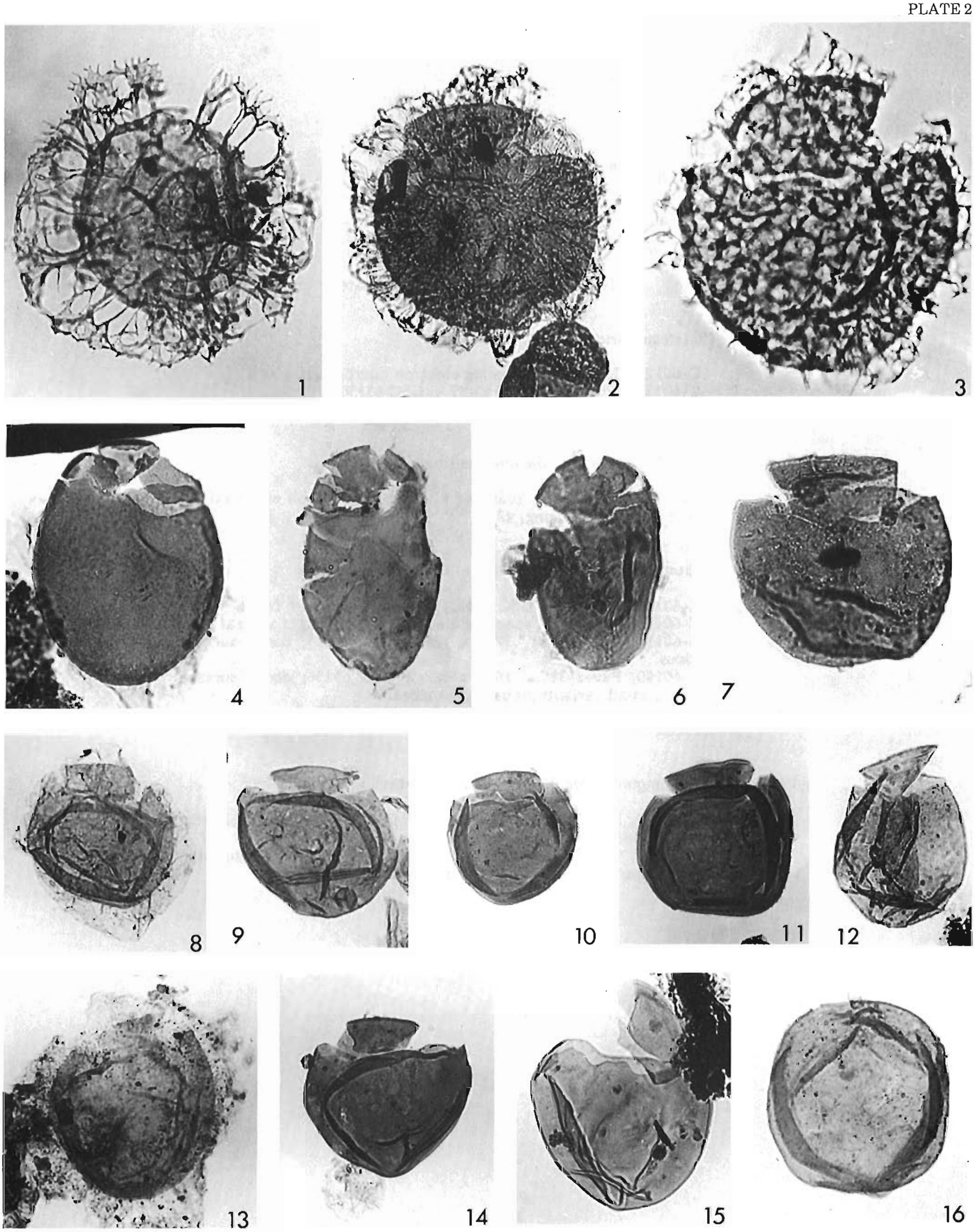
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PLATE 3

All figures x500, unless otherwise stated

Figures 1-3. *Cleistosphaeridium*? *aciculare* Davey

1. C-60129, GSC 65129; scanning electron micrograph, x1000.
2. C-60129, P2047-23E: 30.3 x 117.4, GSC 65130.
3. C-60129, P2047-23F: 12.6 x 118.2, GSC 65131.

Figure 4. *Chatangiella verrucosa* (Manum) Lentin and Williams

C-60129, GSC 65132; scanning electron micrograph of dorsal surface; note antapical opening, x750.

Figures 5-9. *Chatangiella ditissima* (McIntyre) Lentin and Williams

5. C-60130, P2047-24B, GSC 65133; dorsal surface; high focus.
6. C-60130, GSC 65134, scanning electron micrograph of ventral surface.
7. C-60130, P2047-24D: 27.2 x 124.4, GSC 65135; dorsal surface; low focus.
8. C-60140, P2047-34C: 16.3 x 127.5, GSC 65136; dorsal surface; low focus; small variant; probably reworked.
9. C-60130, P2047-24D: 20.7 x 117.8, GSC 65137; ventral surface; high focus; small variant.

Figures 10, 11. *Chatangiella granulifera* (Manum) Lentin and Williams

10. C-60129, P2047-23F: 38.7 x 117.5, GSC 65138; dorsal surface; high focus; specimen virtually devoid of grana.
11. C-60129, P2047-23F: 28.7 x 129.8, GSC 65139; dorsal surface; high focus; specimen showing prominent grana.

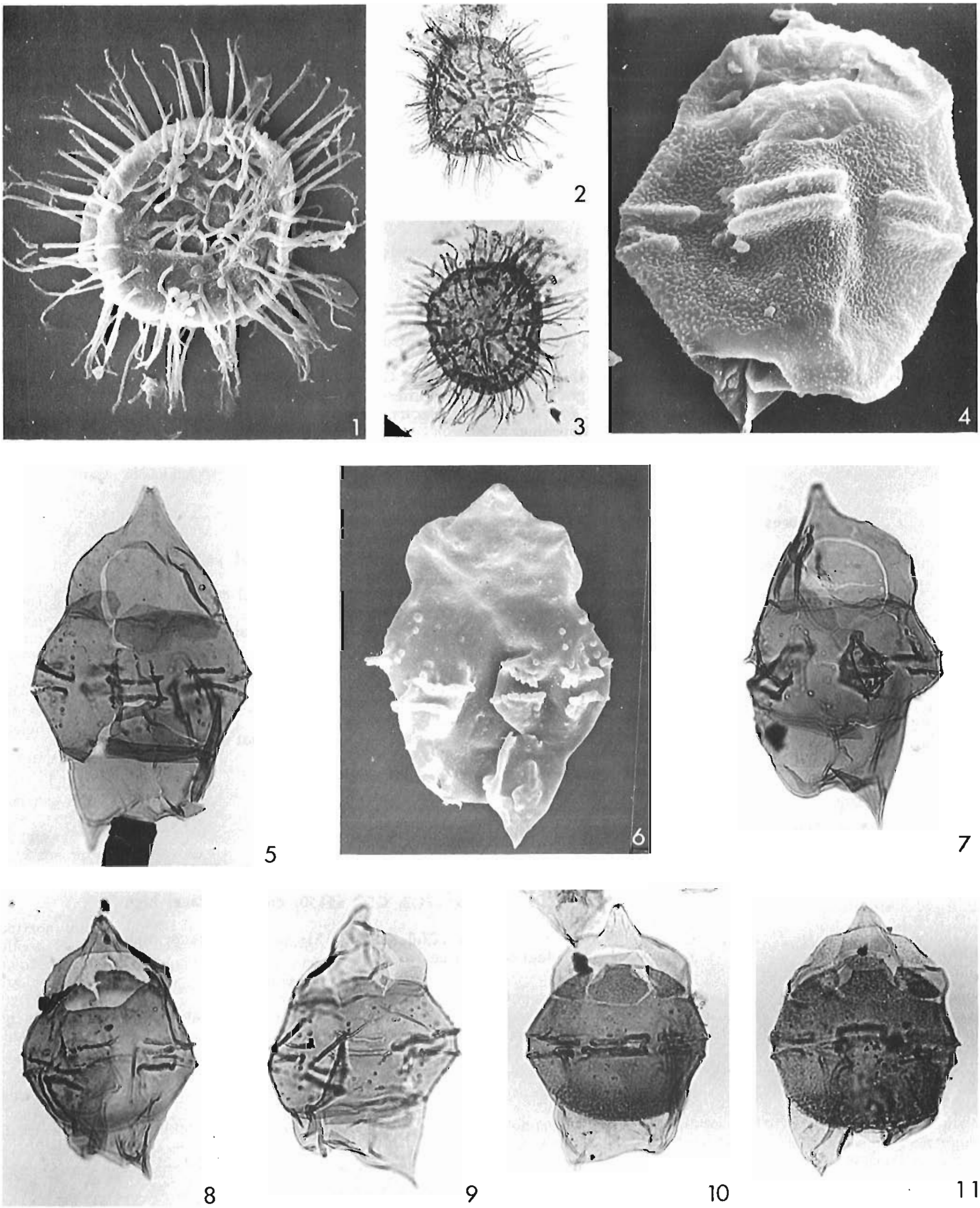
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PLATE 4

All figures x500, unless otherwise stated

Figures 1, 2, 4, 9. *Chatangiella granulifera* (Manum) Lentin and Williams

1. C-60129, GSC 65140; scanning electron micrograph of dorsal surface, x750.
2. C-60129, P2047-23D: 20.1 x 130.1, GSC 65141; ventral surface; high focus; note slight displacement of intercalary plates 1a and 3a.
4. C-60129, GSC 65142; scanning electron micrograph of ventral surface; note antapical opening, x750.
9. C-60129, P2047-23?: 31.4 x 126.4, GSC 65143; dorsal surface; high focus; note coarse grana, and archeopyle type 1I/3I.

Figures 3, 5, 6. *Chatangiella verrucosa* (Manum) Lentin and Williams

3. C-60129, GSC 65144; scanning electron micrograph of paracingular region showing verrucate ornament, x2000.
5. C-60129, P2047-23/2: 43.2 x 124.9, GSC 65145; dorsal surface; high focus; note anatpical opening, and archeopyle type 1I/3I.
6. C-60130, P2047-24B: 37.7 x 122.5, GSC 65146; ventral surface; low focus; note archeopyle type 1I/3I.

Figures 7, 8. *Chatangiella spectabilis* (Alberti) Lentin and Williams

7. C-60129, P2047-23/3: 17.0 x 121.2, GSC 65147; dorsal surface; high focus.
8. C-60110?, P2047-4?: 14.3 x 112.7, GSC 65148.

Figures 10-12. *Chatangiella madura* Lentin and Williams

10. C-60129, P2047-23/5: 31.2 x 126.0, GSC 65149; low focus; dorsal surface; note antapical opening.
11. C-60129, P2047-23/1: 25.4 x 121.3, GSC 65150; dorsal surface; high focus.
12. C-60129, P2047-23/2: 21.9 x 127.0, GSC 65151; ventral surface; high focus; note parasulcal delineation.

PLATE 4

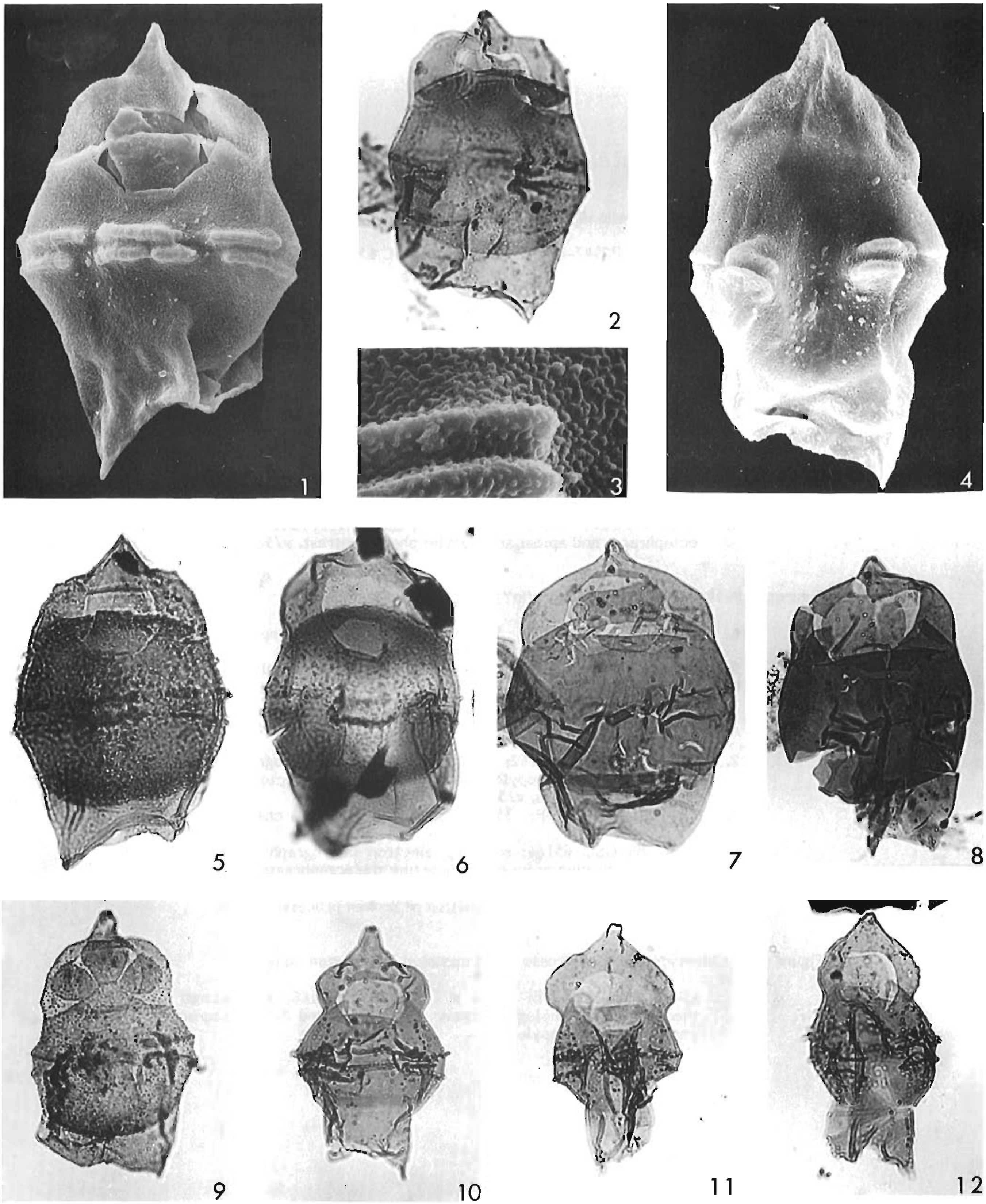

PLATE 5

All figures x500, unless otherwise stated

Figure 1. *Chlamydophorella discreta* Clarke and Verdier

C-60129, P2047-23E: 16.7 x 133.9, GSC 65152.

Figures 2-5, 7, 8. *Chlamydophorella nyei* Cookson and Eisenack

2. C-60129, P2047-23D: 15.9 x 118.1, GSC 65153; specimen without apical horn.
3. C-60129, P2047-23B: 09.4 x 117.1, GSC 65154; specimen showing coarse processes and collapsed ectophragm.
4. C-60129, P2047-23D: 31.4 x 119.7, GSC 65155; specimen showing apical projection on endophragm.
5. C-60129, P2047-23D: 32.2 x 123.1, GSC 65156; specimen showing apical archeopyle.
7. C-60129, P2047-23D: 32.2 x 123.1; note finely porous ectophragm, x750.
8. C-60129, P2047-23/4: 54.0 x 129.2, GSC 65157; note irregularly porous ectophragm and apical archeopyle; phase contrast, x750.

Figures 6, 9-14, 16. *Chlamydophorella*? *grossa* Manum and Cookson

6. C-60129, P2047-23N: 16.1 x 128.2, GSC 65158; operculum showing processes and enclosing membrane (?ectophragm).
9. C-60129, P2047-23O: 31.5 x 133.2, GSC 65159; a small variant.
10. C-60129, P2047-23B: 13.2 x 133.2, GSC 65160; a typical form without apical projection.
11. C-60129, P2047-23E: 25.1 x 131.0?, GSC 65161; specimen showing small apical projection.
12. C-60129, GSC 65162; scanning electron micrograph showing a precingular(?) archeopyle (probably 2P), and an ectophragm covering supporting processes, x750.
13. C-60129, P2047-23F: 35.4 x 124.0, GSC 65163; archeopyle of dubious position.
14. C-60129, GSC 65164; scanning electron micrograph of a compressed specimen showing processes supporting the ectophragm, x750.
16. C-60129, GSC 65165; scanning electron micrograph showing locally collapsed ectophragm and position of broken processes, x750.

Figure 15. *Chlamydophorella*? *grossa* - *Scriniodinium*? *obscurum* complex

C-60129, P2047-23E: 16.6 x 118.2, GSC 65166; a specimen intermediate in morphology between *C.*? *grossa* and *S.*? *obscurum*; note precingular archeopyle.

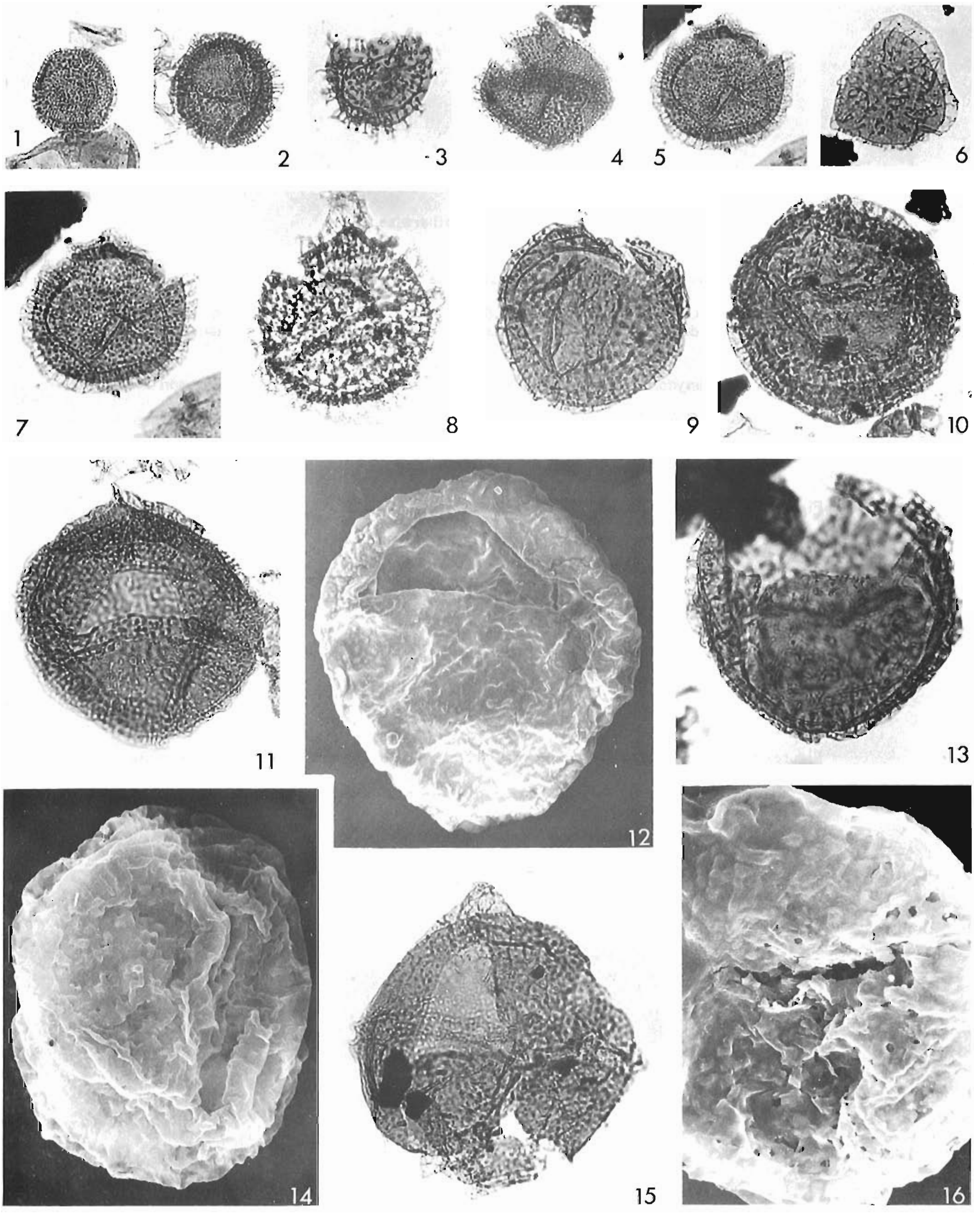
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PLATE 6

All figures x500, unless otherwise stated

Figure 1. *Chlamydophorella? grossa* Manum and Cookson

C-60129, P2047-23F: 10.8 x 121.0, GSC 65167; specimen showing dubiously positioned archeopyle (precingular?) and coarser ornament.

Figure 2. *Chlamydophorella? grossa - Scriniodinium? obscurum* Manum and Cookson

C-60129, P2047-23O: 38.8 x 124.0, GSC 65168; specimen showing dubiously positioned archeopyle and an outline approaching *S.? obscurum.*

Figures 3-10. *Scriniodinium? obscurum* Manum and Cookson

3. C-60129, P2047-23O: 14.6 x 122.7, GSC 65169; specimen with coarse processes and a precingular archeopyle.
4. C-60135, GSC 65170; scanning electron micrograph showing coarser processes than those of "typical" *C.? grossa*, x2000.
5. C-60129, P2047-23O: 24.8 x 127.4, GSC 65171; a "typical" *S.? obscurum.*
6. C-60129, P2047-23O: 09.3 x 126.6, GSC 65172; disposition of processes in plan view, x1000.
7. C-60135, GSC 65173; scanning electron micrograph showing partially collapsed ectophragm (periphragm?), x750.

Figures 8-10. *Chlamydophorella? grossa - Scriniodinium? obscurum* complex

Specimens intermediate in morphology: ornament closer to that of *C.? grossa*, orientation same as *S.? obscurum.*

8. C-92752, P2334-2B: 17.8 x 133.8, GSC 65174.
9. C-92752, P2334-2?: 14.2 x 127.6, GSC 65175.
10. C-60139, P2047-33F: 34.2 x 130.9, GSC 65176.

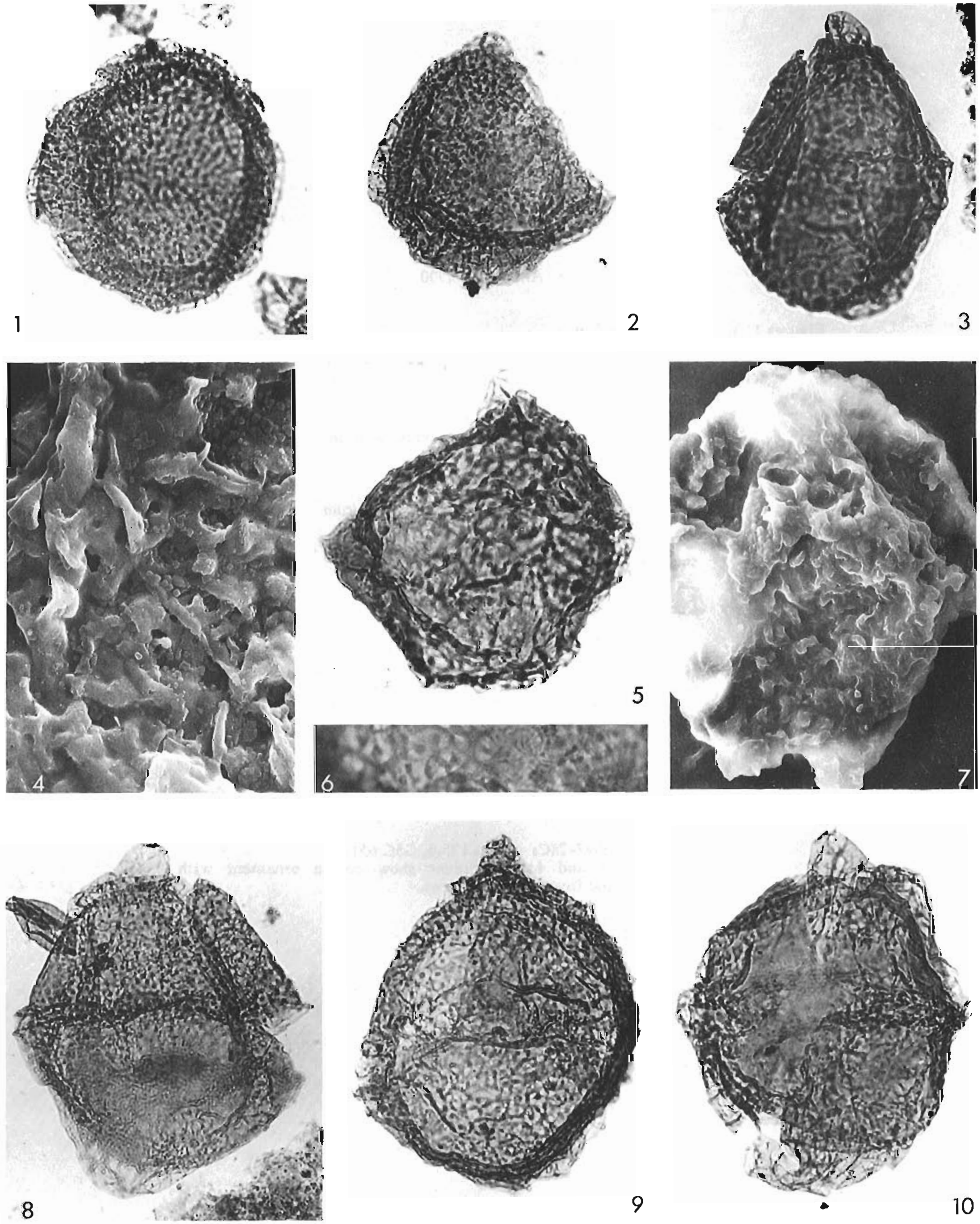

PLATE 7

All figures x500

Figures 1, 3. *Scriniodinium*? sp.

1. C-60129, P2047-23N: 42.9 x 126.0, GSC 65177; specimen in antapical orientation; parasulcus low, in centre; paracingular membranous crest in plan view.
3. C-60129, P2047-23A: 34.3 x 128.1, GSC 65178; specimen with highly reduced ornament between two layers; well defined apical horn on both layers.

Figure 2. *Chlamydophorella*? *grossa* - *Scriniodinium*? *obscurum*

C-60129, P2047-23?: 36.4 x 117.4, GSC 65179; an intermediate form showing a precingular archeopyle.

Figures 4-11. *Spongodinium*? sp. (cf. *S.*? *delitiense*)

4. C-60135, P2047-29D: 21.1 x 129.2, GSC 65180; a form approaching *S. delitiense* (Ehrenberg) Deflandre.
5. C-60135, P2047-29D: 29.1 x 122.6, GSC 65181.
6. C-60135, P2047-29D: 15.8 x 126.7, GSC 65182.
   Figures 5 and 6: opercula showing a predominantly foveolate structure.
7. C-60134, P2047-28D: 35.8 x 126.2, GSC 65183.
8. C-60129, P2047-23F: 19.4 x 120.0, GSC 65184.
9. C-60129, P2047-23B: 31.4 x 126.9, GSC 65186.
10. C-92754, P2334-4?: 41.9 x 123.7, GSC 65187.
    Figures 9 and 10: opercula showing a predominantly reticulate structure.
11. C-60134, P2047-28C: 34.5 x 125.0, GSC 65185.
    Figures 7, 8 and 11: specimens show coarse ornament with both reticulate and foveolate structures.

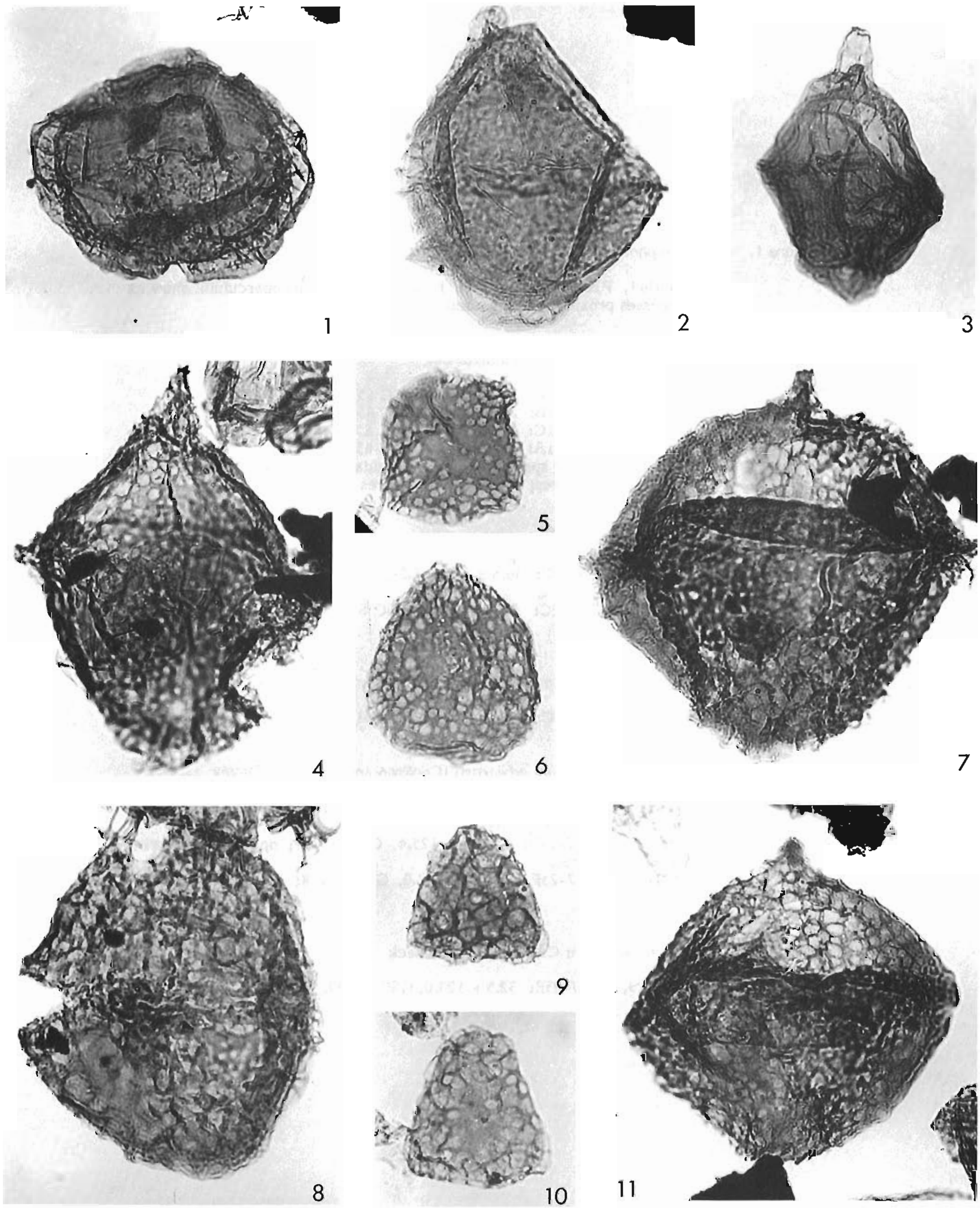
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PLATE 8

All figures x500, unless otherwise stated

Figure 1. *Chlamydophorella? grossa - Scriniodinium? obscurum*

C-60111, P2047-5C: 41.7 x 178.5, GSC 65188; operculum showing processes proximally connected, x1000.

Figures 2-5. *Spongodinium?* sp. (cf. *S. delitiense*)

2. C-60137, P2047-31B: 35.5 x 125.5, GSC 65189; x1000.
3. C-60137, P2047-31B: 22.5 x 119.8, GSC 65190.
4. C-60137, P2047-31C: 34.2 x 121.7, GSC 65191; x1000.
5. C-60137, P2047-31A: 29.1 x 116.4, GSC 65192.

Figures 2 and 5: specimens show irregularly developed reticulate and foveolate structures; note fibril structures on specimens 3 and 5, x1000.

Figures 6, 7. *Cordosphaeridium inodes* (Klumpp) Eisenack

6. C-76012, P2050-2C: 36.8 x 115.4, GSC 65193; specimen showing narrow processes.
7. C-76012, P2050-2C: 32.8 x 130.8, GSC 65194; specimen showing wide processes.

Figure 8. *Cordosphaeridium exilimurum* Davey and Williams in Davey et al.

C-76021, P2050-3C: 31.7 x 122.4, GSC 65195.

Figures 9, 11, 12. *Cribroperidinium edwardsii* (Cookson and Eisenack) Davey

9. C-60110, P2047-4?: 33.6 x 123.3, GSC 65196; dorsal surface; high focus; operculum displaced.
11. C-60129, P2047-23D: 25.2 x 125.4, GSC 65197; operculum showing accessory sutures.
12. C-60129, P2047-23F: 24.0 x 127.0, GSC 65198; dorsal surface; high focus.

Figure 10. *Coronifera oceanica* Cookson and Eisenack

C-60129, P2047-23E: 32.9 x 123.0, GSC 65199.

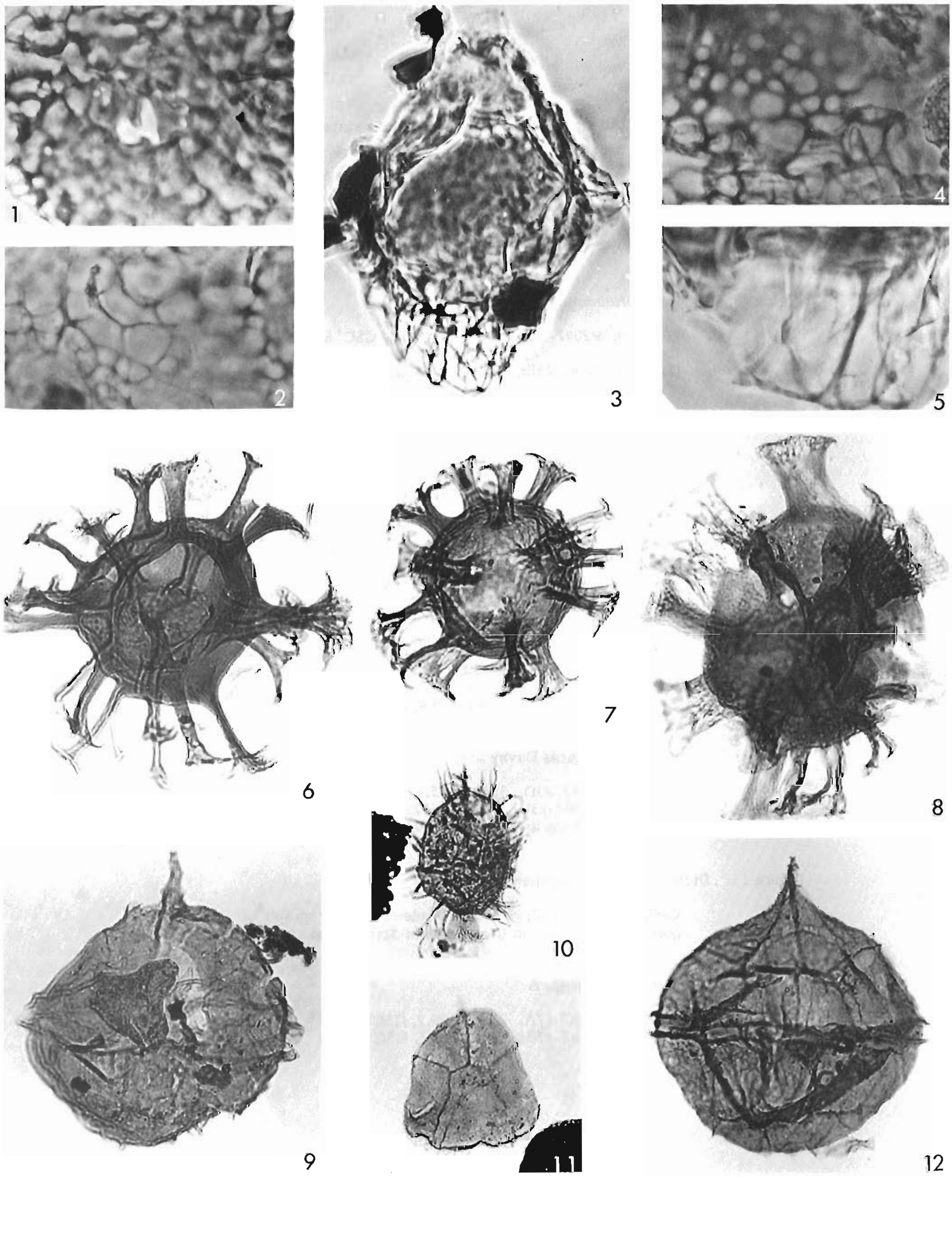
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PLATE 9

All figures x500, unless otherwise stated

Figures 1, 2. *Cribroperidinium* sp. B

1. C-92752, P2334-2C: 24.2 x 127.1, GSC 65200; left oblique view; high focus.
2. C-60129, P2047-23E: 26.7 x 121.3, GSC 65201; ventral view; low focus.

Figures 3, 4. *Cribroperidinium* sp. A

3. C-60129, P2047-23F: 40.5 x 120.2, GSC 65202; ventral view; high focus.
4. C-60129, P2047-23E: 18.7 x 118.2, GSC 65203; dorsal view; high focus.

Figures 5-7. *Cyclonephelium distinctum* Deflandre and Cookson

5. C-60129, P2047-23F: 36.7 x 120.1, GSC 65204.
6. C-60129, P2047-23F: 41.4 x 115.8, GSC 65205.
7. C-60129, P2047-23F: 28.8 x 131.4, GSC 65206.

Figure 8. *Cyclonephelium membraniforum* Cookson and Eisenack

C-60129, P2047-23F: 41.1 x 121.3, GSC 65207.

Figures 9, 10. *Dinopterygium* sp.

9. C-60129, P2047-23E: 38.8 x 114.5, GSC 65208; dorsal view; high focus(?).
10. C-60129, P2047-23E: 24.4 x 119.4, GSC 65209; antapical view.

Figures 11, 12. *Dorocysta litotes* Davey

11. C-60129, P2047-23D: 35.7 x 125.4, GSC 65210.
12. C-60129, P2047-23H: 30.4 x 125.6, GSC 65211; specimens showing variation in shape and process development.

Figure 13. *Diconodinium-Spinidinium* group

C-60110, GSC 65212; scanning electron micrograph of apex showing horn pore structure in *Diconodinium-Spinidinium* group, x10 000.

Figures 14, 15. *Diconodinium* sp. A

14. C-60123, P2047-17A: 21.8 x 129.2, GSC 65213.
15. C-60123, P2047-17B: 27.7 x 131.7, GSC 65214.

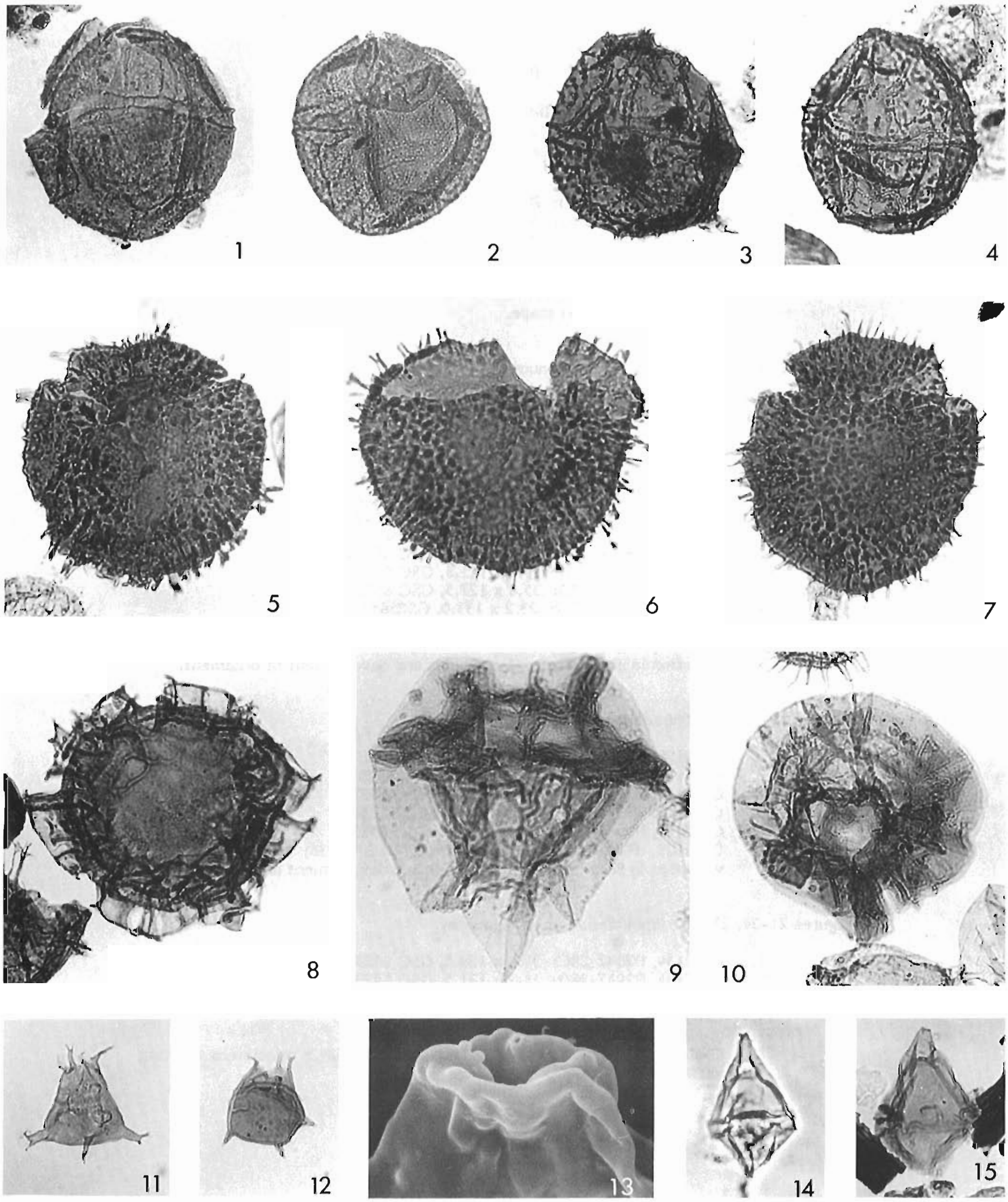
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PLATE 10

All figures x500

Figures 1-6. *Laciniadinium williamsii* sp. nov.

1. C-60129, P2047-23D: 20.3 x 125.0, GSC 65215.
2. C-60129, P2047-23G: 36.4 x 126.2, GSC 65216.
3. C-60129, P2047-23E: 16.4 x 118.9, GSC 65217.
4. C-60131, P2047-25/1: 15.2 x 120.3, GSC 65218.
5. C-60129, P2047-23/3: 39.1 x 132.7, GSC 65219.
6. C-60130, P2047-24D: 28.5 x 126.0, GSC 65220; specimens showing variation in size and shape.

Figure 7. *Diconodinium arcticum* Manum and Cookson

7. C-60129, P2047-23E: 39.1 x 124.5, GSC 65221.

Figures 8-15, 25. *Diconodinium* sp.? *D. arcticum* Manum and Cookson

8. C-60129, P2047-23H: 19.5 x 128.2, GSC 65222.
9. C-60129, P2047-23H: 14.1 x 131.2, GSC 65223.
10. C-60129, P2047-23F: 28.8 x 120.4, GSC 65224.
11. C-60129, P2047-23G: 27.1 x 126.0, GSC 65225.
12. C-60127, P2047-21D: 16.1 x 121.8, GSC 65226.
13. C-60129, P2047-23D: 35.8 x 127.5, GSC 65227.
14. C-60129, P2047-23/2: 23.2 x 133.0, GSC 65228.
15. C-60110, P2047-4C: 40.7 x 124.0, GSC 65229.
25. C-60129, P2047-23D: 43.0 x 126.2, GSC 65230; specimens showing variation in shape, wall relationships and development of ornament.

Figures 16-20, 26. *Spinidinium* sp.

16. C-60129, P2047-23D: 29.6 x 126.2, GSC 65231.
17. C-60129, P2047-23F: 36.8 x 120.7, GSC 65232.
18. C-60129, P2047-23/1: 27.7 x 129.5, GSC 65233.
19. C-60110, P2047-4/5: 46.0 x 121.8, GSC 65234.
20. C-60129, P2047-23/1: 40.1 x 128.5, GSC 65235.
26. C-60129, P2047-23D: 24.4 x 130.2, GSC 65236; specimens showing variation in shape, wall relationships and development of ornament.

Figures 21-24, 27, 28. *Spinidinium uncinatum* May

21. C-60134, P2047-28C: 34.0 x 129.5, GSC 65237.
22. C-60134, P2047-28D: 14.2 x 131.5, GSC 65238.
23. C-60135, P2047-29D: 10.4 x 119.0, GSC 65239.
24. C-60135, P2047-29D: 10.0 x 128.0, GSC 65240.
27. C-60134, P2047-28C: 13.7 x 131.9, GSC 65241.
28. C-60134, P2047-28C: 42.4 x 128.2, GSC 65242; specimens showing variation in shape.

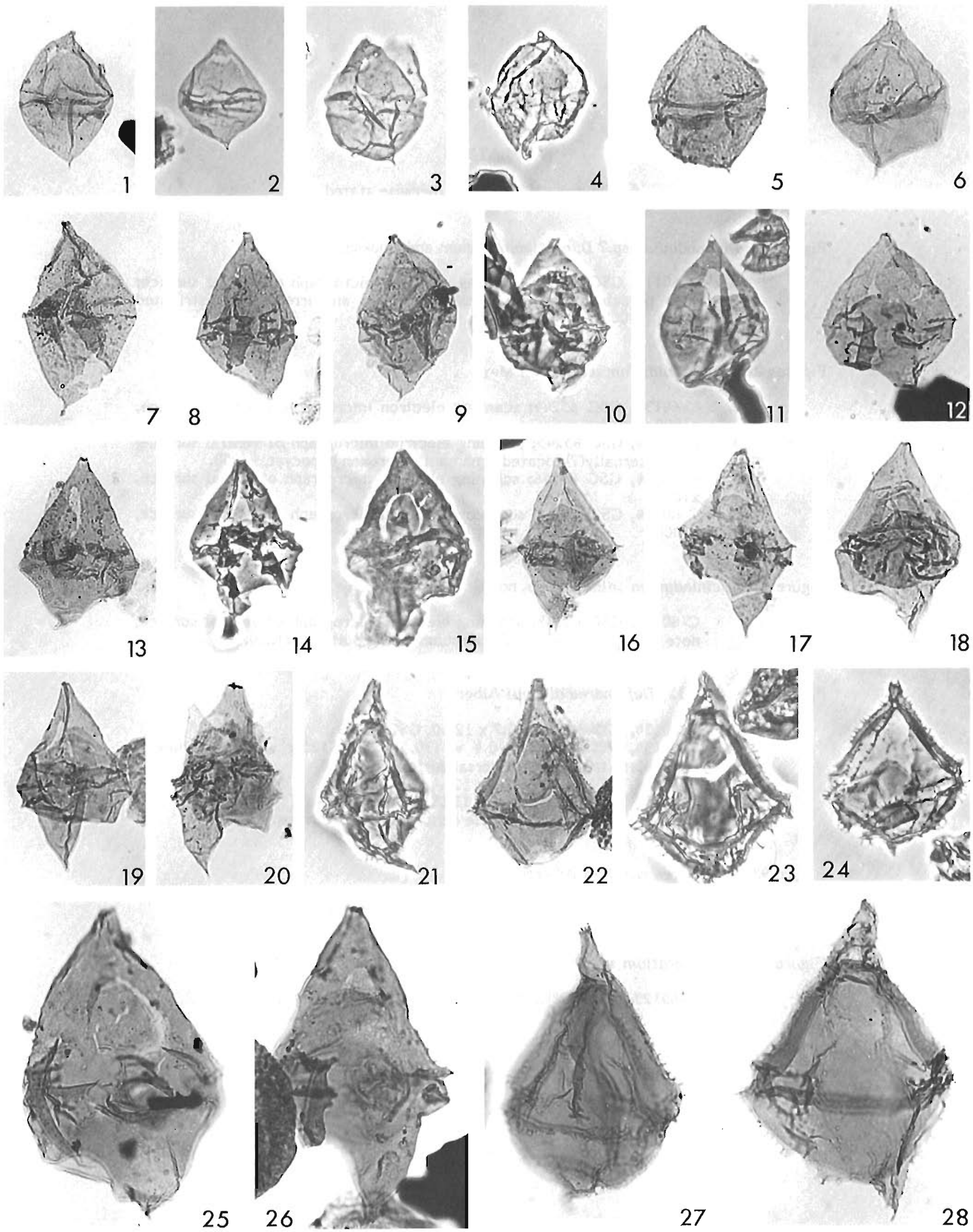
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PLATE 11

All figures x500, unless otherwise stated

Figure 1. *Diconodinium* sp.? *D. arcticum* Manum and Cookson

C-60110, GSC 65243; scanning electron micrograph of ventral surface; note paracingulum, parasulcal depression and irregularly distributed grana, x1000.

Figures 2-4, 8. *Spinidinium uncinatum* May

2. C-60134, GSC 65244; scanning electron micrograph of dorsal surface, x1000.
3. C-60134, GSC 65245; scanning electron micrograph of ventral surface; note internally(?) located ornament on broken hypocyst, x1000.
4. C-60134, GSC 65246; scanning electron micrograph of dorsal surface, x1000.
8. C-60134, GSC 65247; scanning electron micrograph of ventral surface, x1000.

Figure 5. *Laciniadinium williamsii* sp. nov.

C-60131, GSC 65248; scanning electron micrograph of ventral surface; note angular concavity of operculum along plate 3', x1250.

Figures 6, 7, 10, 11. *Deflandrea diebelii* Alberti

6. C-60134, P2047-28B: 38.7 x 122.0, GSC 65249.
7. C-60134, P2047-28B: 40.4 x 130.5, GSC 65250; specimen showing incomplete tabulation on dorsal surface.
10. C-60134, P2047-28C: 22.4 x 125.4, GSC 65251.
11. C-60134, P2047-28C: 37.5 x 132.9, GSC 65252.

Figures 6-11: note archeopyle distortion on specimens.

Figure 9. *Deflandrea speciosa* Alberti

C-60140, P2047-34C: 33.8 x 132.2, GSC 65253.

Figure 12. *Endoceratium* sp.

C-60129, P2047-23E: 45.0 x 115.6, GSC 65254.

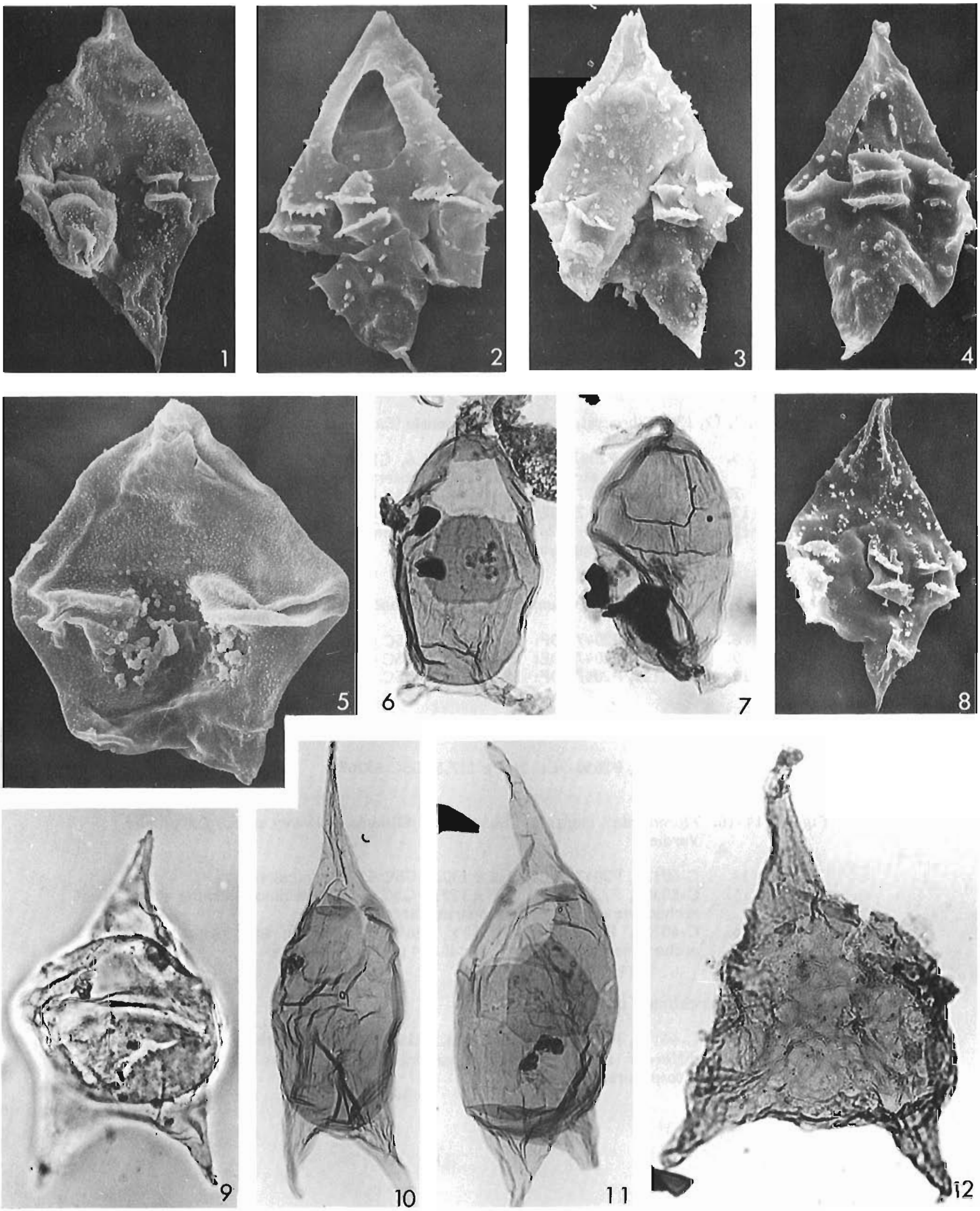
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PLATE 12

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Figures 1-4, 8. *Elytrocysta druggii* Stover and Evitt

1. C-60134, P2047-28A: 40.8 x 119.5, GSC 65255.
2. C-60134, P2047-28B: 41.8 x 121.0, GSC 65256.
3. C-60134, P2047-28B: 44.3 x 127.7, GSC 65257.
4. C-60134, P2047-28B: 23.2 x 115.7, GSC 65258.
8. C-60112, P2047-6F: 23.4 x 123.8, GSC 65259; specimens showing consistent mode of opercular attachment.

Figures 5, 7, 12, 13. *Fibrocysta*? sp. cf. *F. vectensis* (Eaton) Stover and Evitt

5. C-60140, P2047-34A: 33.8 x 121.6, GSC 65260; a specimen showing coarser wall structure than usually observed, x1000.
7. C-60126, P2047-20F: 14.4 x 131.0, GSC 65261.
12. C-60126, P2047-23E: 19.1 x 116.0, GSC 65262.
13. C-60126, GSC 65263; scanning electron micrograph showing wall and process structures, x750.

Figures 6, 9, 10. *Exochosphaeridium striolatum* (Deflandre) Davey

6. C-60129, P2047-23F: 36.0 x 114.2, GSC 65264.
9. C-60129, P2047-23E: 20.0 x 129.5, GSC 65265.
10. C-60129, P2047-23F: 12.9 x 124.2, GSC 65266.

Figure 11. *Exochosphaeridium bifidum* (Clarke and Verdier) Clarke et al.

C-76021, P2050-3C: 21.5 x 117.5, GSC 65267.

Figures 14-16. *Florentinia*? *mantellii* (Davey and Williams in Davey et al.) Davey and Verdier

14. C-60129, P2047-23E: 21.6 x 130.8, GSC 65268; apical view.
15. C-80502, P2204-37B: 41.8 x 125.5, GSC 65269; specimen showing apical archeopyle and operculum bearing large process.
16. C-60129, P2204-23E: 19.0 x 116.0, GSC 65270; specimen showing archeopyle involving both apical and percingular plates.

Figure 17. *Florentinia*? sp.

C-60110, P2204-4B: 31.0 x 130.3, GSC 65271; an extreme variant (or a different species) showing parallel-sided processes reminiscent of *Litosphaeridium*.

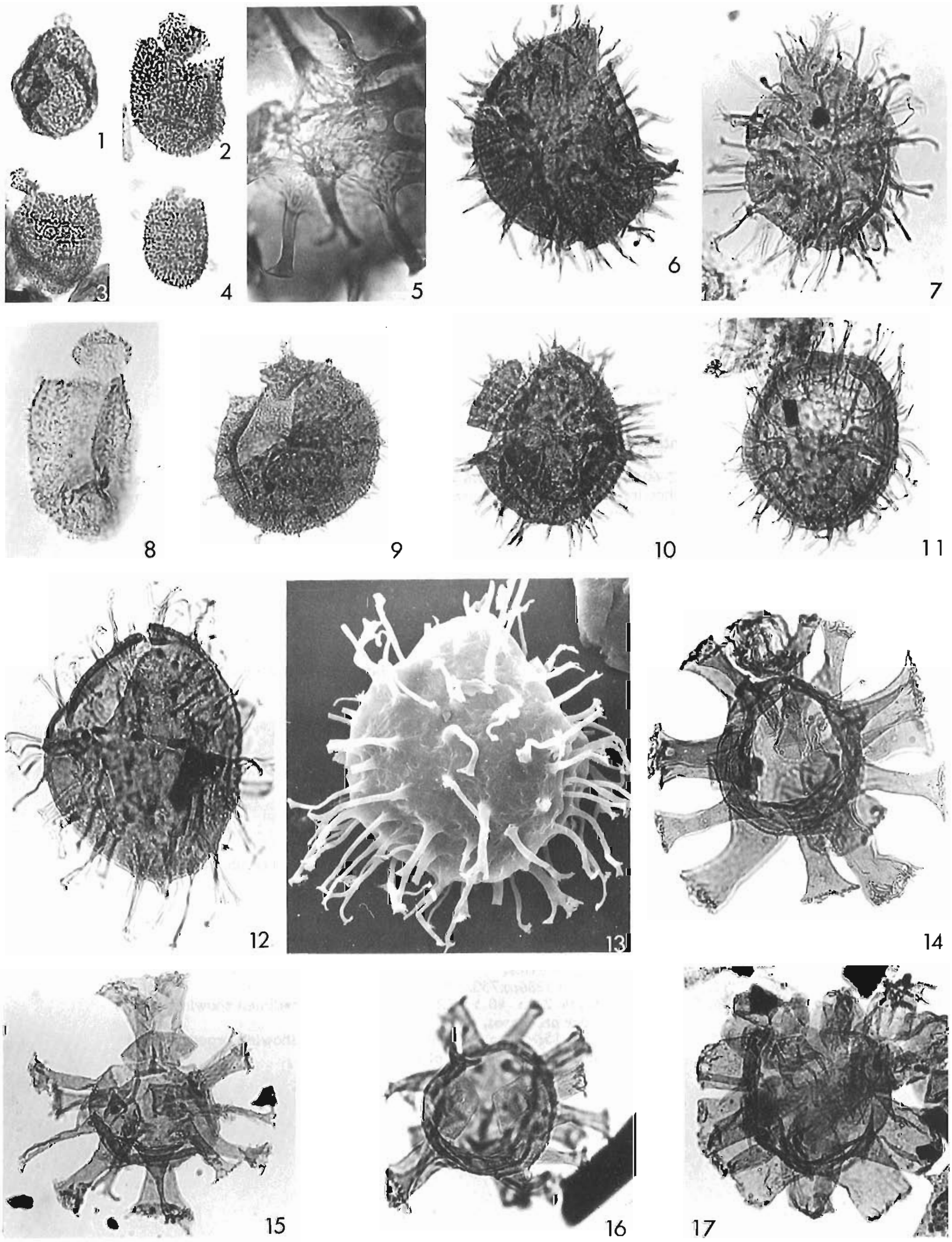
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PLATE 13

All figures x500, unless otherwise stated

Figures 1, 2, 4, 5. *Fromea chytra* (Drugg) Stover and Evitt

1. C-60111, P2047-5E: 31.1 x 126.4, GSC 65272.
2. C-60111, P2047-5A: 25.4 x 130.7, GSC 65274.
4. C-60111, P2047-5A: 34.7 x 120.3, GSC 65273.
5. C-60136, P2047-30F: 16.6 x 126.0, GSC 65275.

Figure 3. *Gillinia hymenophora* Cookson and Eisenack

C-60112, P2047-6D: 23.7 x 123.2, GSC 65276.

Figure 6. *Florentinia*? sp.

C-60111, P2047-5B: 30.6 x 128.9, GSC 65277; detail of process showing perforate but closed distal end, a structure seen in many processes of both *F.*? sp. and *F.*? *mantelli*, x1000.

Figure 7. *Hystrichosphaeridium* sp. *H.*? *palmatum* (White ex Bronn) Downie and Sarjeant

C-60129, P2047-23E: 40.0 x 125.5, GSC 65278.

Figures 8-10, 12. *Fromea fragilis* (Cookson and Eisenack) Stover and Evitt

8. C-60125, P2047-19C: 16.2 x 132.3, GSC 65279.
9. C-60129, P2047-23E: 13.4 x 129.0, GSC 65280; a specimen showing hairy processes.
10. C-60129, P2047-23F: 35.8 x 120.2, GSC 65281; a large specimen showing hairy processes.
12. C-92752, P2334-2C: 17.8 x 119.1, GSC 65282; a specimen without medial constriction.

Figures 11, 13-16. *Heterosphaeridium difficile* (Manum and Cookson) comb. nov.

11. C-60129, GSC 65283; x750.
13. C-60129, P2334-23B: 33.2 x 123.4, GSC 65284; opercular plate showing four apical processes and position of pre-apical plate.
14. C-60129, P2334-23B: 34.1 x 119.7, GSC 65285; specimen showing simple, thin, processes.
15. C-60129, GSC 65286; x750.
16. C-60129, P2334-23C: 40.5 x 127.3, GSC 65287; specimen showing more complex, wider processes.

Figures 11 and 15: scanning electron micrograph showing processes and wall structure and distribution of processes.

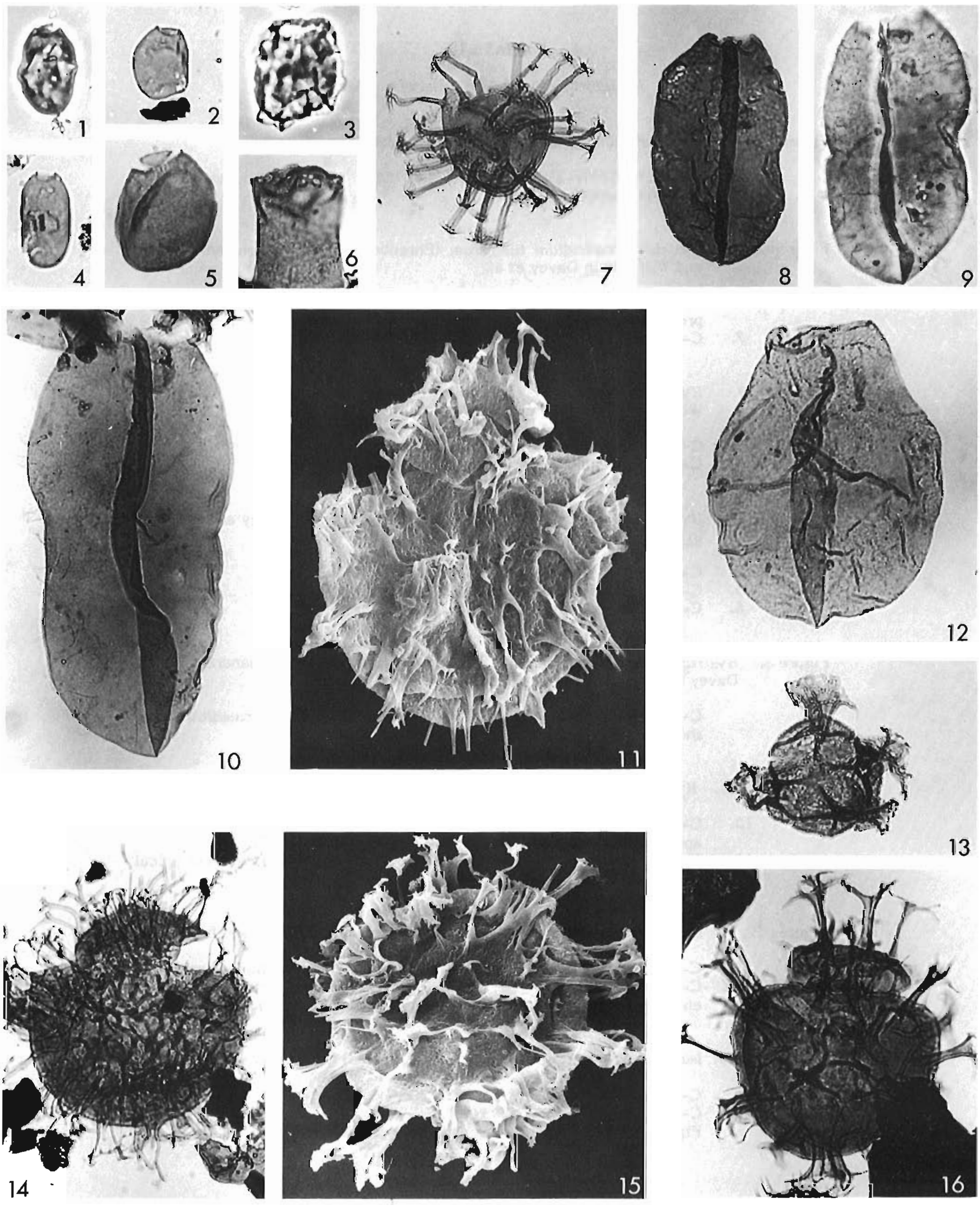
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PLATE 14

All figures x500, unless otherwise stated

Figure 1. *Heterosphaeridium difficile* (Manum and Cookson) comb. nov.

C-60129, P2047-23F: 22.6 x 128.4, GSC 65288; specimen showing complex processes.

Figures 2, 7. *Hystrichosphaeridium tubiferum* (Ehrenberg) Deflandre emend. Davey and Williams in Davey et al.

2. C-76021, GSC 65289; scanning electron micrograph showing detail of processes, x2000.
7. C-76021, P2050-3A: 19.4 x 127.1, GSC 65290.

Figures 3, 9. *Hystrichosphaeridium salpingophorum* Deflandre emend. Davey and Williams in Davey et al.

3. C-60136, P2047-30D: 29.9 x 128.8, GSC 65291.
9. C-76012, P2050-2A: 11.1 x 130.2, GSC 65292.

Figures 4-6. *Hystrichosphaeridium tubiferum* subsp. *brevispinum* Davey and Williams in Davey et al.

4. C-60136, P2047-30D: 41.0 x 129.2, GSC 65293.
5. C-76012, P2050-2A: 30.1 x 121.5, GSC 65294.
6. C-76012, P2050-2A: 41.5 x 119.1, GSC 65295.

Figure 8. *Hystrichosphaeridium* sp. ?*H. tubiferum* (Ehrenberg) Deflandre emend. Davey and Williams in Davey et al.

C-76012, P2050-2B: 29.2 x 115.7, GSC 65296; an intermediate form showing both tubular and subquadrate processes.

Figures 10, 11. *Hystrichosphaeropsis* sp.

10. C-60129, P2047-23E: 19.2 x 116.1, GSC 65297; specimen showing an apical protrusion.
11. C-60125, P2047-19C: 42.5 x 125.0, GSC 65298; specimen without apical protrusion.

Figures 12, 13. *Isabelidinium acuminatum* (Cookson and Eisenack) Stover and Evitt

12. C-60129, P2047-23D: 36.4 x 126.8, GSC 65299; note antapical opening.
13. C-60129, P2047-23F: 32.5 x 125.8, GSC 65300; variation in peri- and endo-archeopyle formation seen in figs. 12, 13, and in Pl. 15, figs. 1, 2.

Figures 14, 15. *Isabelidinium bakerii* (Deflandre and Cookson) Lentin and Williams

14. C-60124, P2047-18D: 21.1 x 123.0, GSC 65301.
15. C-60140, P2047-34C: 37.7 x 131.6, GSC 65302.

Figures 14 and 15: specimens probably reworked.

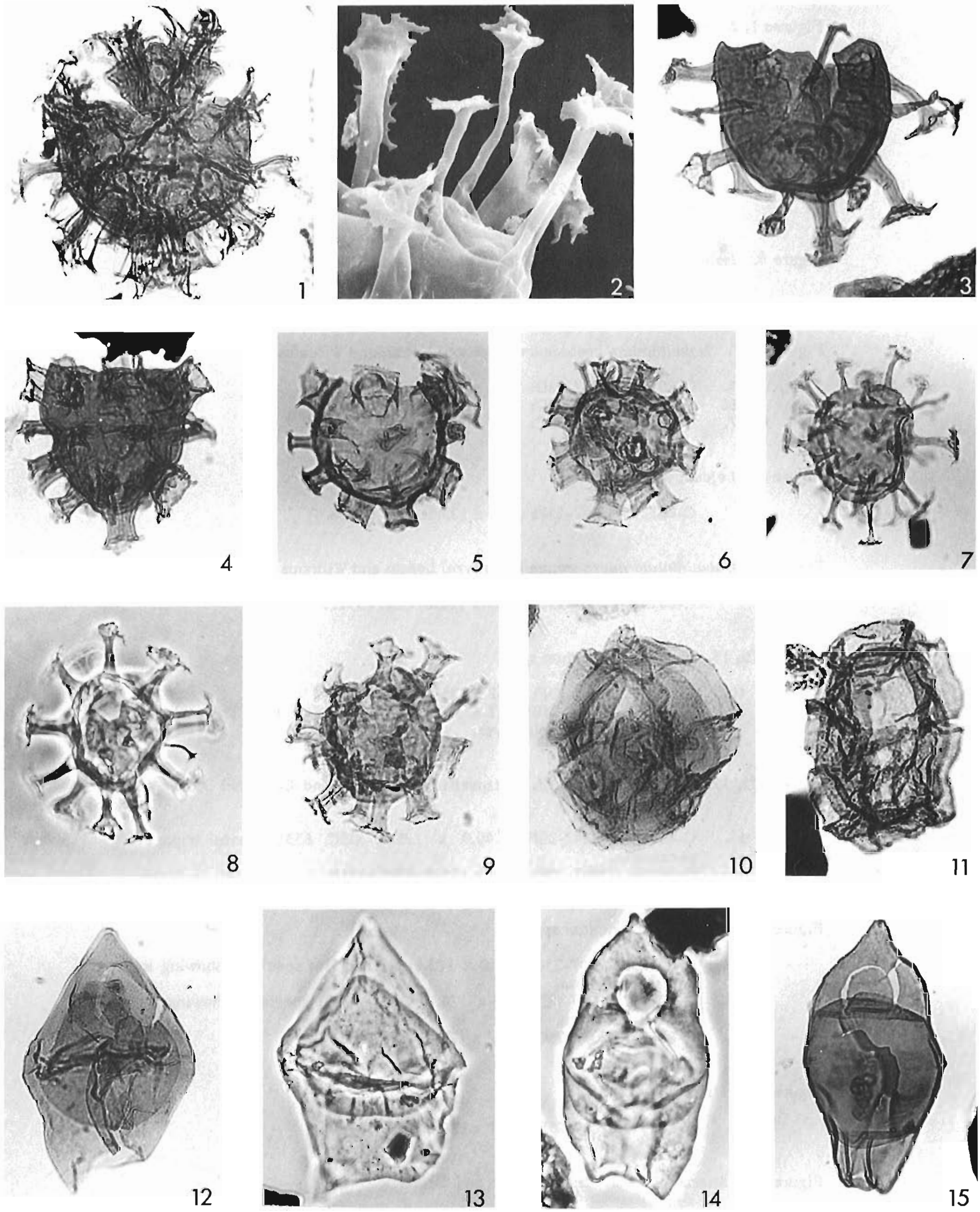
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PLATE 15

All figures x500, unless otherwise stated

Figures 1, 2. *Isabelidinium acuminatum* (Cookson and Eisenack) Stover and Evitt

1. C-60110, GSC 65303; scanning electron micrograph of dorsal surface; note apical protrusion on endocyst, x750.
2. C-60129, P2047-23I: 36.5 x 130.0, GSC 65304.

Figure 3. *Hystrichosphaeropsis* sp.

C-60129, GSC 65305; scanning electron micrograph of dorsal surface, x750.

Figure 4. *Isabelidinium cooksoniae* (Alberti) Lentin and Williams

C-60126, P2047-20A: 13.3 x 128.3, GSC 65306.

Figures 5-7. *Isabelidinium cretaceum* (Cookson) Lentin and Williams

5. C-60134, P2047-28D: 37.5 x 119.0, GSC 65307.
6. C-60134, P2047-28D: 14.8 x 130.3, GSC 65308.
7. C-60134, P2047-28C: 19.6 x 137.6, GSC 65309.

Figure 8. *Lejeuncysta* sp.

C-60131, P2047-25E: 36.3 x 125.5, GSC 65310.

Figure 9. *Isabelidinium microarmum* (McIntyre) Lentin and Williams

C-60131, P2047-25D: 18.8 x 126.6, GSC 65311.

Figures 10, 13. *Impletosphaeridium* sp.

10. C-60129, P2047-23F: 32.2 x 125.8, GSC 65312.
13. C-60129, P2047-23B: 18.6 x 117.0, GSC 65313; note spines locally yielding an amorphous layer.

Figures 11, 12. *Impagidinium* sp. cf. *I. dispertitum* (Cookson and Eisenack) Stover and Evitt

11. C-60136, P2047-30F: 40.9 x 129.5, GSC 65314; note tripartite parasulcus.
12. C-60136, P2047-30F: 25.9 x 125.7, GSC 65315.

Figures 14, 15, 17. *Microdinium* sp. A

14. C-60129, P2047-23G: 33.0 x 123.0, GSC 65316; specimen showing low parasutural septa.
15. C-60111, P2047-5E: 20.4 x 126.7, GSC 65317; specimen showing high parasutural septa.
17. C-60134, P2047-28C: 42.7 x 126.9, GSC 65318.

Figure 16. *Microdinium* sp. B

C-60131, P2047-25E: 39.1 x 126.1, GSC 65319.

Figure 18. *Microdinium ornatum* Cookson and Eisenack

C-60122, P2047-16C: 14.3 x 121.6, GSC 65320; specimen probably reworked.

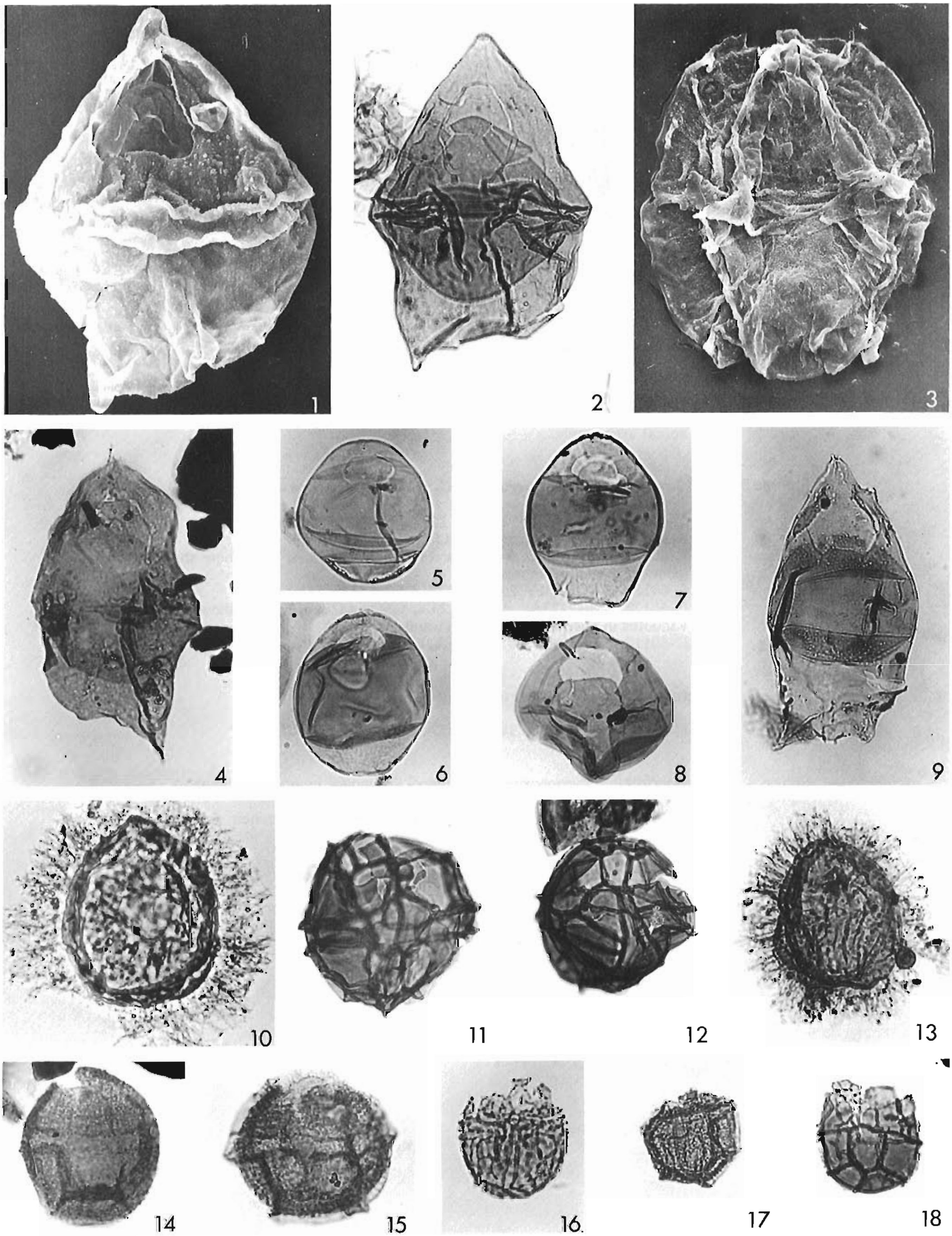
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PLATE 16

All specimens x500

Figures 1, 2. *Leberidocysta chlamydata* (Cookson and Eisenack) Stover and Evitt

1. C-60134, P2047-28C: 37.4 x 128.6, GSC 65321; specimen with operculum attached.
2. C-60134, P2047-28D: 36.9 x 128.1, GSC 65322; specimen showing apical archeopyle.

Figures 3-5, 7, 10. *Odontochitina operculata* (O. Wetzel) Deflandre and Cookson

3. C-60129, P2047-23D: 35.3 x 127.0, GSC 65323; antapical horn of an extreme variant showing irregular vacuoles.
4. C-60129, P2047-23D: 17.5 x 116.3, GSC 65324; specimen showing granular horns (periphragm).
5. C-60129, P2047-23F: 29.2 x 122.8, GSC 65325; holotype.
7. C-60129, P2047-23A: 30.0 x 123.6, GSC 65326; specimen showing horn vacuoles in position higher than usual.
10. C-60110, P2047-4C: 20.1 x 121.8, GSC 65327.

Figure 6. *Odontochitina costata* Alberti

C-60129, P2047-23F: 34.3 x 125.6, GSC 65328.

Figure 8. *Palaeoperidinium pyrophorum* (Ehrenberg) Deflandre emend. Sarjeant

C-60129, P2047-23E: 12.7 x 127.6, GSC 65329; specimen showing an endocyst.

Figure 9. *Odontochitina* sp.

C-60111, P2047-5D: 22.8 x 126.2, GSC 65330.

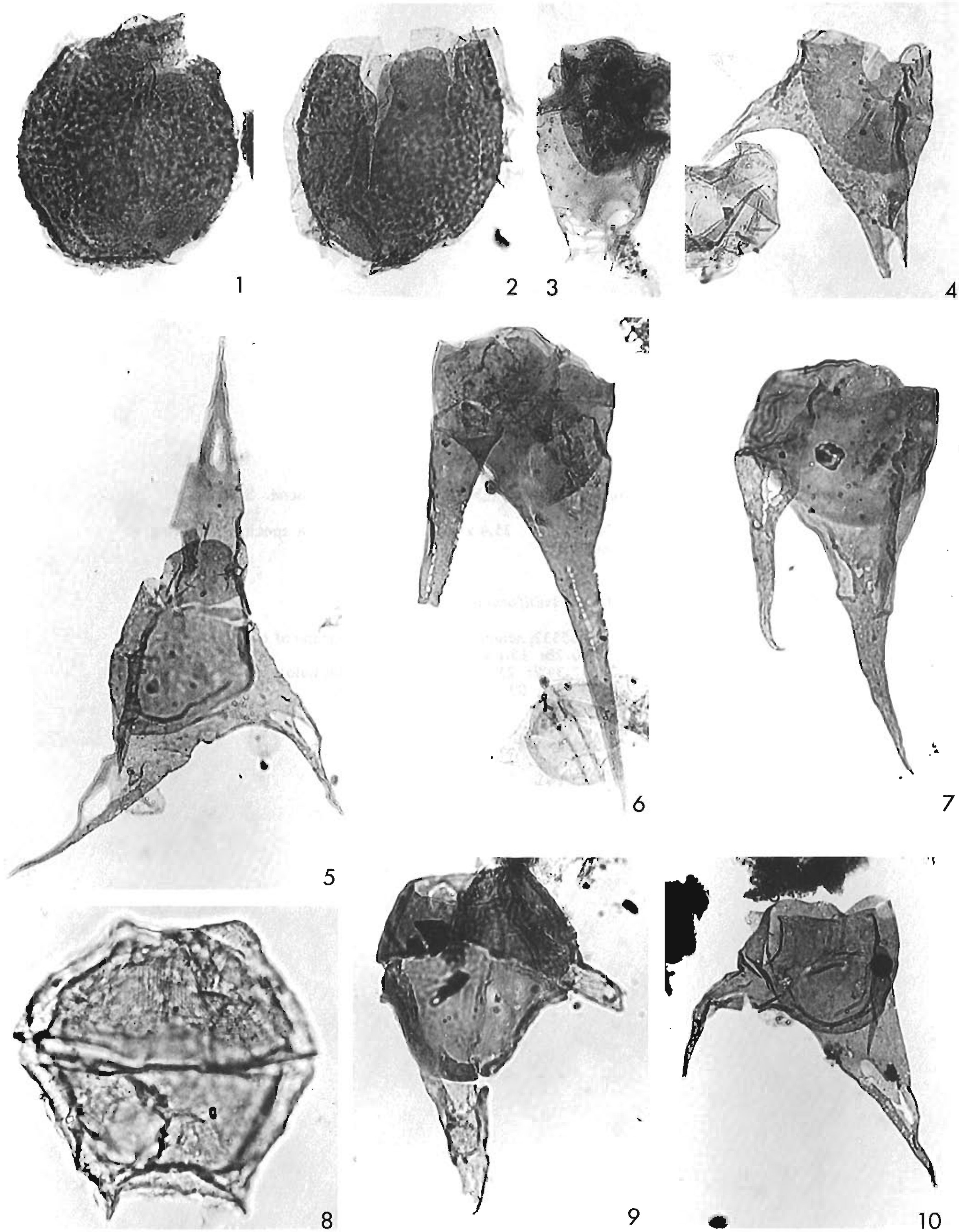
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PLATE 17

All figures x500

Figure 1. *Palaeoperidinium pyrophorum* (Ehrenberg) Deflandre emend. Sarjeant

C-60129, P2047-23F: 35.4 x 119.2, GSC 65331; a specimen showing a large pericoel.

Figures 2-5. *Palaeocystodinium bulliformum* sp. nov.

2. C-60140, GSC 65332; scanning electron micrograph of oblique view.
3. C-76012, P2050-2B: 15.1 x 119.3, GSC 65333.
4. C-60140, P2047-34W: 23.1 x 119.2, GSC 65334; holotype.
5. C-76021, P2050-3A: 09.8 x 125.6, GSC 65335.

Figure 6. *Palaeocystodinium golzowense* Alberti

C-60122, P2047-16C: 21.5 x 119.2, GSC 65336.

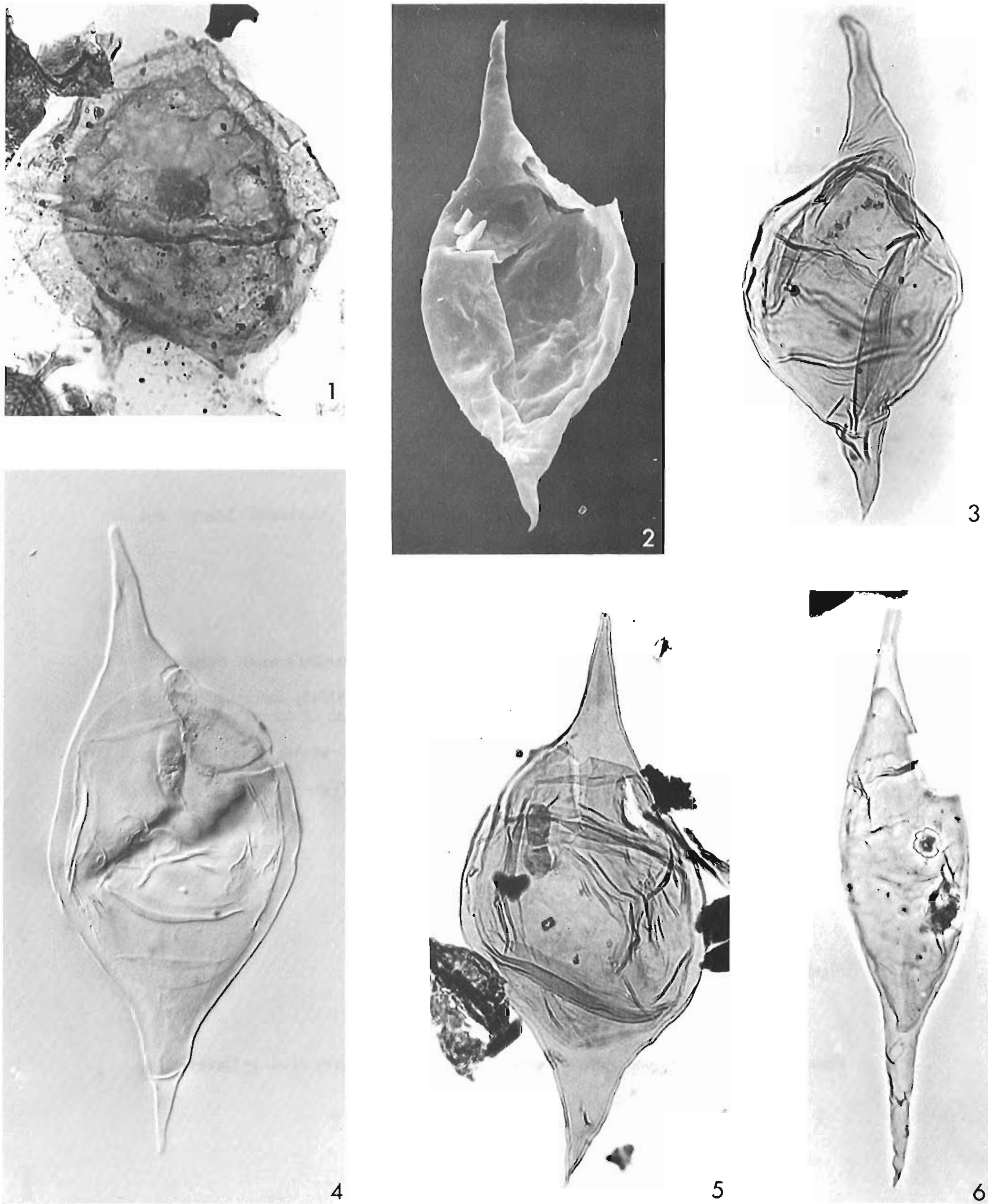
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PLATE 18

All figures x500

Figures 1, 2. *Oligosphaeridium pulcherrimum* (Deflandre and Cookson) Davey and Williams in Davey et al.

1. C-60129, P2047-23F: 30.4 x 132.7, GSC 65337.
2. C-60129, P2047-23F: 12.3 x 123.3, GSC 65338.

Figure 3. *Oligosphaeridium* sp. cf. *O. complex* (White) Davey and Williams in Davey et al.

C-60129, P2047-23F: 27.7 x 127.8, GSC 65339.

Figures 4, 7. *Oligosphaeridium anthophorum* (Cookson and Eisenack) Davey

4. C-60129, P2047-23E: 22.5 x 132.9, GSC 65340.
7. C-60110, P2047-4C: 20.1 x 121.8, GSC 65341.

Figures 5, 6, 15. *Pareodinia? ceratophora* subsp. *scopaea* (Sarjeant) Lentin and Williams

5. C-60129, P2047-23E: 26.5 x 118.7, GSC 65342.
6. C-60129, P2047-23E: 10.8 x 132.1, GSC 65343.
15. C-60129: 26.3 x 118.6, GSC 65344.

Figures 8-10. *Palaeoperidinium pyrophorum* (Ehrenberg) Deflandre emend. Sarjeant

8. C-60134, P2047-28/3: 24.4 x 132.6, GSC 65345; specimen without visible endocyst, showing incomplete tabulation of dorsal surface; low focus.
9. C-60134, P2047-28/3: 38.3 x 122.5, GSC 65346; dorsal surface, operculum missing.
10. C-60135, P2047-29/3: 33.2 x 132.3, GSC 65347; free operculum showing tabulation.

Figures 11, 12. *Palaeotetradinium silicorum* Deflandre

11. C-60129, P2047-23D: 16.5 x 126.2, GSC 65348.
12. C-60129, P2047-23D: 13.1 x 115.5, GSC 65349.

Figure 13. *Pterodinium* sp.

C-60129, P2047-23F: 36.4 x 129.2, GSC 65350.

Figure 14. *Prolixosphaeridium granulosum* (Deflandre) Davey et al. in Davey et al.

C-60110, P2047-4C: 11.4 x 133.7, GSC 65351.

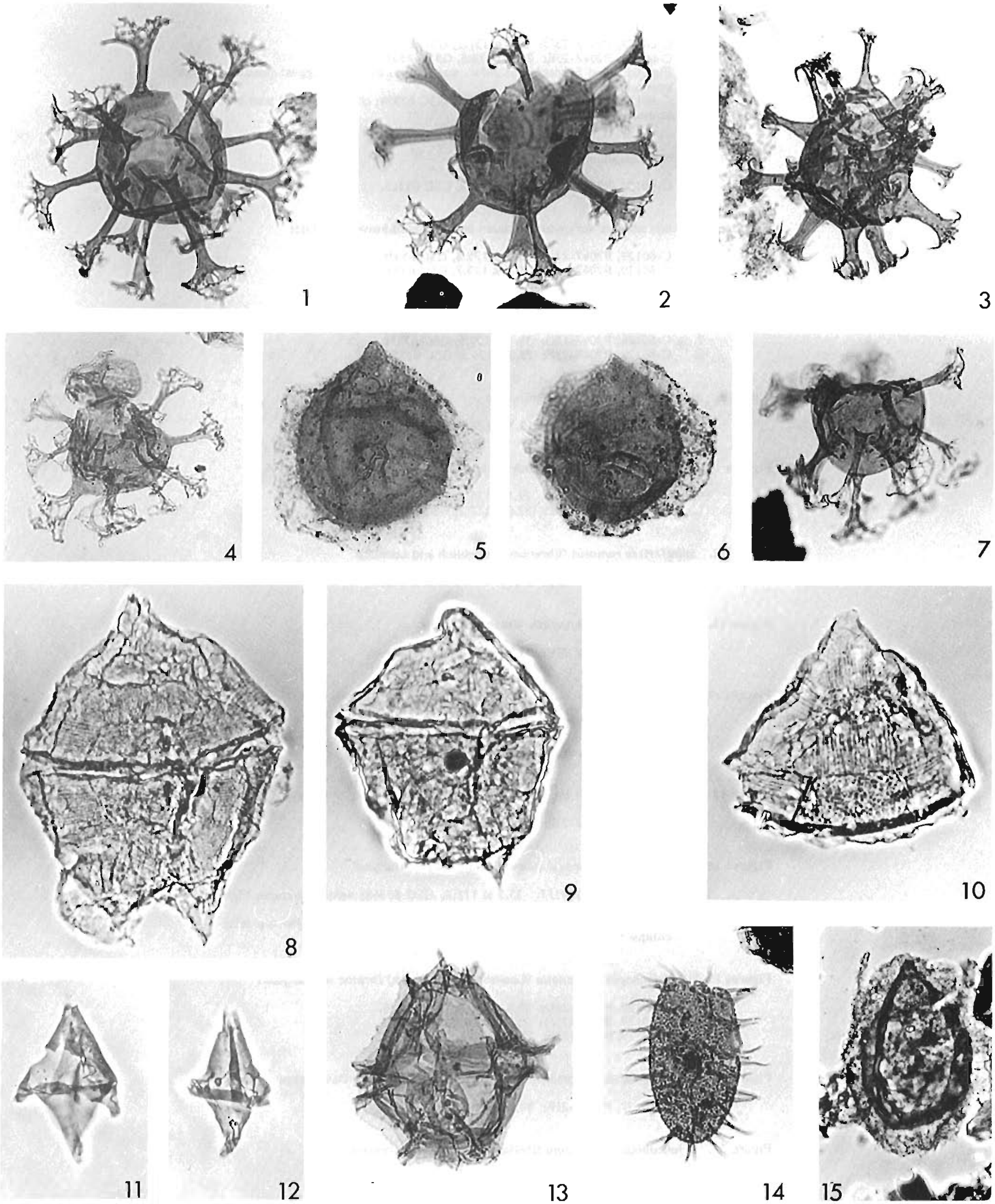
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PLATE 19

All figures x500, unless otherwise stated

Figures 1-3. *Palaeohystrichophora infusorioides* Deflandre

1. C-60129, P2047-23/5: 32.0 x 131.3, GSC 65352.
2. C-60129, P2047-23E: 21.8 x 133.5, GSC 65353.
   Figures 1 and 2: specimens show wall fractures which suggest possible opercular displacement.
3. C-60129, P2047-23/1: 13.1 x 118.0, GSC 65354; oblique view of possible archeopyle formation.

Figure 4. *Prolixosphaeridium* sp.

C-60136, P2047-30B: 42.1 x 119.2, GSC 65355.

Figures 5, 6. *Saeptodinium eurypylum* (Manum and Cookson) Stover and Evitt

5. C-60129, P2047-23/1: 26.3 x 125.8, GSC 65356.
6. C-60129, P2047-23/3: 30.7 x 125.7, GSC 65357.

Figures 7, 8. *Senegalinium* sp. cf. *S. microgranulatum* (Stanley) Stover and Evitt

7. C-60124, P2047-18D: 30.5 x 135.3, GSC 65358.
8. C-60129, P2047-23F: 29.3 x 134.3, GSC 65359.

Figure 9. *Stephodinium coronatum* Deflandre

C-60129, P2047-23E: 18.5 x 127.1, GSC 65360.

Figures 10, 11. *Spinidinium balmei* (Cookson and Eisenack) comb. nov.

10. C-60130, P2047-24D: 29.5 x 125.8, GSC 65361.
11. C-60130, P2047-24D: 37.6 x 117.2, GSC 65362.

Figure 12. *Spiniferites ramosus* (Ehrenberg) Loeblich and Loeblich

C-60129, P2047-23E: 09.4 x 123.9, GSC 65363.

Figure 13. *Spiniferites*? *cingulatus* (O. Wetzel) Sarjeant

C-60129, P2047-23E: 25.0 x 124.6, GSC 65364.

Figures 14, 17. *Spiniferites* sp. cf. *S. scabrosus* Clarke and Verdier

14. C-60129, P2047-23E: 27.6 x 133.9, GSC 65365.
17. C-60110, GSC 65366; scanning electron micrograph showing granular to microrugulate ornament, x2000.

Figure 15. *Surculosphaeridium*? *longifurcatum* (Firtion) Davey et al. in Davey et al.

C-60129, P2047-23F: 20.8 x 127.2, GSC 65367.

Figures 16, 18. *Spiniferites porosus* (Manum and Cookson) Harland

16. C-60127, P2047-21/3: 35.3 x 118.6, GSC 65368; ventral surface; high focus (specimen probably reworked).
18. C-60129, P2047-23/6: 29.0 x 127.2, GSC 65369; archeopyle top left; oblique view.

Figures 19-21. *Trigonopyxidia ginella* (Cookson and Eisenack) Downie and Sarjeant

19. C-60129, P2047-23D: 30.0 x 128.4, GSC 65370.
20. C-60129, P2047-23/1: 29.2 x 130.2, GSC 65371.
21. C-60129, P2047-23F: 21.1 x 125.7, GSC 65372.

Figure 22. *Tanyosphaeridium variecalamum* Davey and Williams in Davey et al.

C-60127, P2047-21F: 32.6 x 128.8, GSC 65373.

Figure 23. *Trichodinium castaneum* (Deflandre) Clarke and Verdier

C-60129, P2047-23/3: 35.5 x 132.9, GSC 65374.

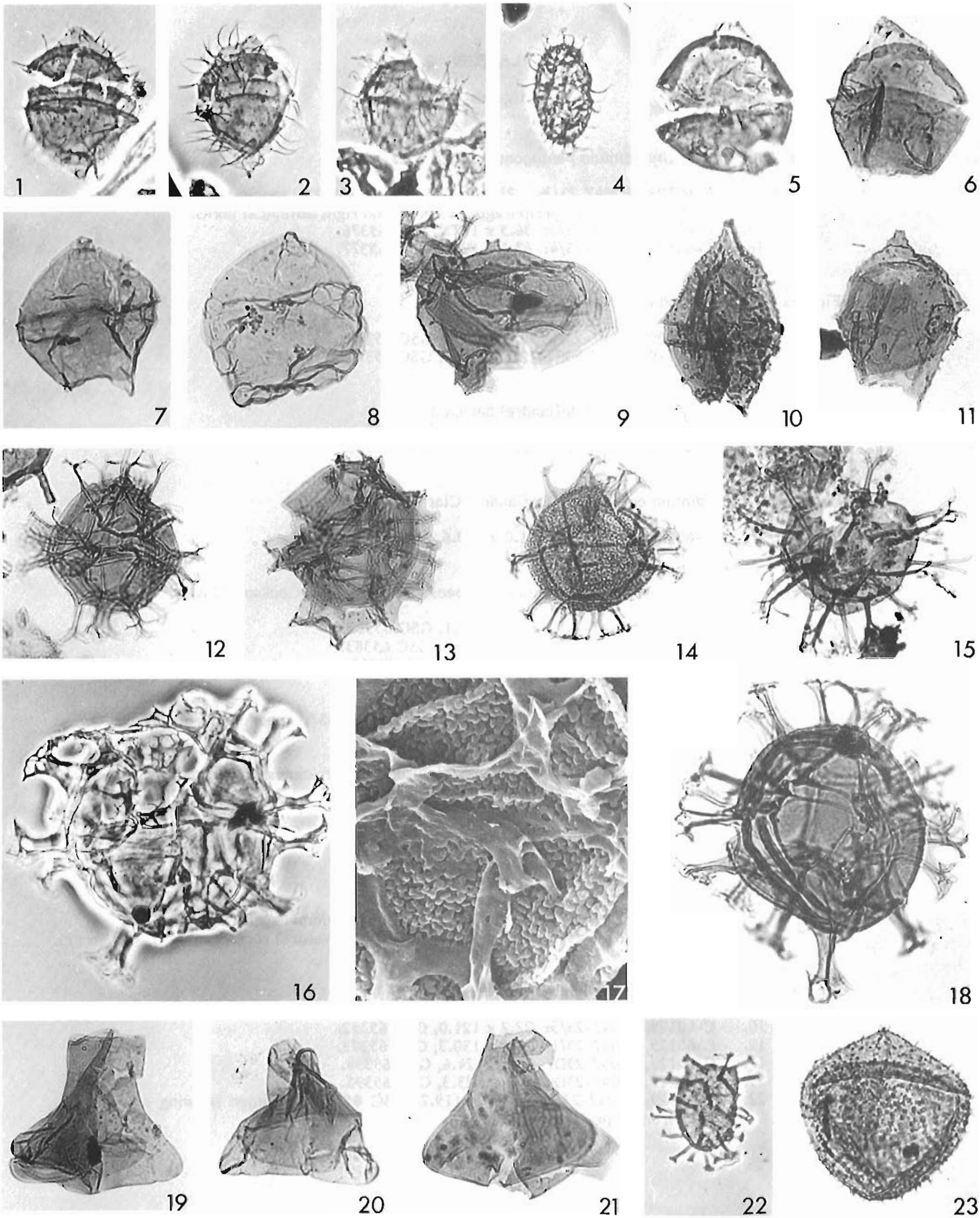

PLATE 20

All figures x500

Figures 1, 8, 16. *Trithyrodinium pentagonum* May

1. C-60129, P2047-23/3: 21.1 x 133.4, GSC 65375; specimen showing traces of collapsed periphragm at apical and right antapical horns.
8. C-60129, P2047-23/5: 36.5 x 127.2, GSC 65376.
16. C-60129, P2047-23/4: 63.3 x 126.3, GSC 65377.

Figures 2, 3. *Scriniodinium? campanulum* Gocht

2. C-60129, P2047-23F: 36.6 x 127.1, GSC 65378.
3. C-60129, P2047-23F: 22.3 x 118.2, GSC 65379.

Figure 4. *Spiniferites wetzelii* (Deflandre) Sarjeant

C-60129, P2047-23F: 26.4 x 125.3, GSC 65380.

Figure 5. *Trichodinium castaneum* (Deflandre) Clarke and Verdier

C-60129, P2047-23C: 31.0 x 129.6, GSC 65381.

Figures 6, 7, 11, 14, 15, 18. *Trithyrodinium suspectum* (Manum and Cookson) Davey

6. C-60129, P2047-23F: 11.9 x 129.1, GSC 65382.
7. C-60131, P2047-25D: 30.5 x 127.6, GSC 65383.
11. C-60129, P2047-23/2: 21.5 x 124.2, GSC 65384.
14. C-60129, P2047-23D: 31.1 x 119.3, GSC 65385.
15. C-60129, P2047-23E: 40.3 x 121.6, GSC 65386.
18. C-60125, P2047-19B: 37.0 x 121.9, GSC 65387; specimen probably reworked.

Specimens show variation in shape, autophragm thickness, and ornament development.

Figures 9, 13, 19, 20. *Trithyrodinium* sp.

9. C-60129, P2047-23/2: 41.2 x 117.2, GSC 65388.
13. C-60129, P2047-23/2: 26.6 x 124.2, GSC 65389.
19. C-60129, P2047-23/1: 23.4 x 117.2, GSC 65390; dorsal surface.
20. C-60129, P2047-23/1: 23.4 x 117.2, GSC 65391; ventral surface.

Figures 10, 12, 17, 21, 22. *Trithyrodinium fragile* Davey

10. C-60129, P2047-23/3: 22.2 x 121.0, GSC 65392.
12. C-60129, P2047-23/1: 28.3 x 130.3, GSC 65393.
17. C-60129, P2047-23D: 33.7 x 124.6, GSC 65394.
21. C-60129, P2047-23D: 25.3 x 123.3, GSC 65395.
22. C-60129, P2047-23/2: 38.1 x 119.2, GSC 65396; specimen showing a membranous periphragm.

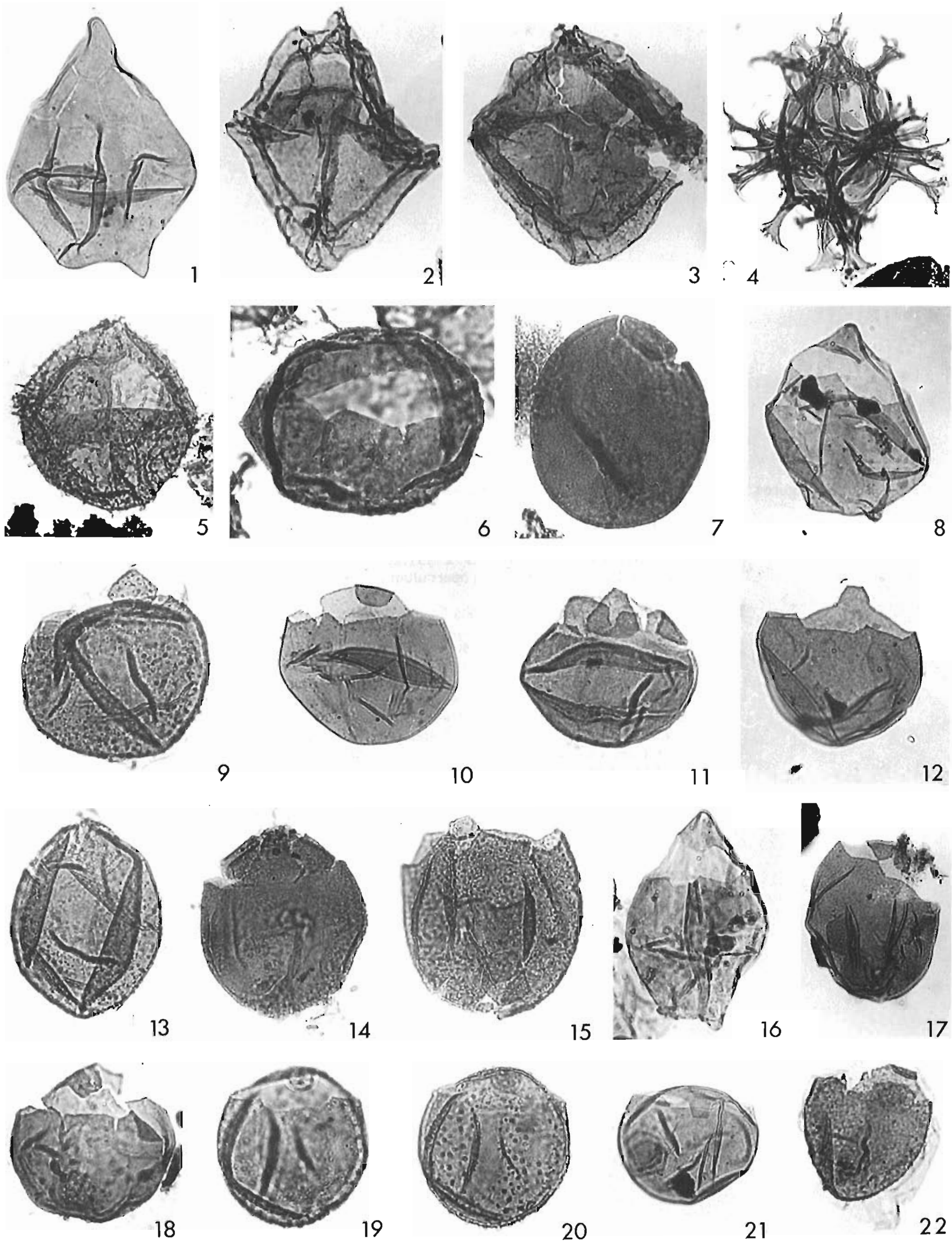
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PLATE 21

All figures x500, unless otherwise stated

Figures 1-7. *Thalassiphora pelagica* (Eisenack) Eisenack and Gocht

1. C-60138, P2047-32D: 23.3 x 117.8, GSC 65397; specimen showing precingular archeopyle.
2. C-60138, P2047-32D: 15.5 x 131.2, GSC 65398; specimen showing precingular archeopyle with operculum in place.

3-7. Scanning electron micrographs

3. C-60138, GSC 65399; dorsal surface, smooth.
4. C-60138, GSC 65400; specimen showing ornamented endophragm and inner side of periphragm, and smooth outer side of periphragm.
5. C-60138, GSC 65401; specimen showing thickened rim surrounding the archeopyle, and paracingular "belt" running below the archeopyle.
6. C-60138, GSC 65402; detail of endophragm surface showing ornament structure, x2000.
7. C-60138, GSC 65402.

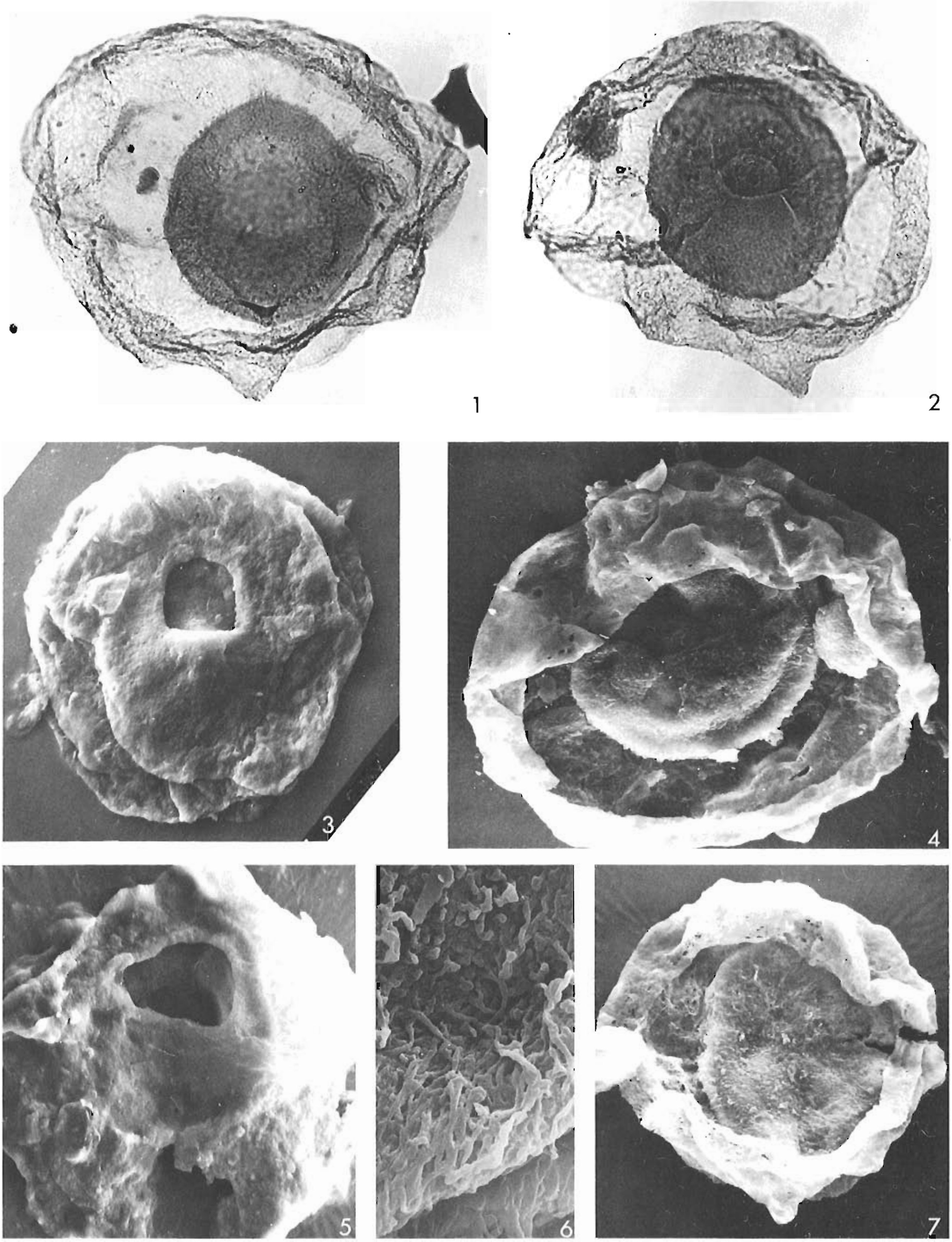
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PLATE 22

All figures x500, unless otherwise stated

Figures 1-5, 7. *Thalassiphora pelagica* (Eisenack) Eisenack and Gocht

1-7. Scanning electron micrographs

1. C-60138, GSC 65403; specimen showing fibrous structures connecting the two phragms.
2. C-60138, GSC 65403; detail showing inner and outer sides of periphragm, x2000.
3. C-60138, GSC 65404.
4. C-60138, GSC 65405; specimen showing dorsal surface with archeopyle; ornamented operculum in place.
5. C-60138, GSC 65402; detail showing fibrous structures connecting the two phragms, x2000.
7. Detail showing smooth inner side of endocyst (through archeopyle).

Figures 6, 8. *Thalassiphora*? sp. cf. *T. delicata* Williams and Downie in Davey et al., emend. Eaton

6. C-60129, P2047-23/1: 42.3 x 119.6, GSC 65406.
8. C-60129, P2047-23F: 24.4 x 128.0, GSC 65407.

PLATE 22

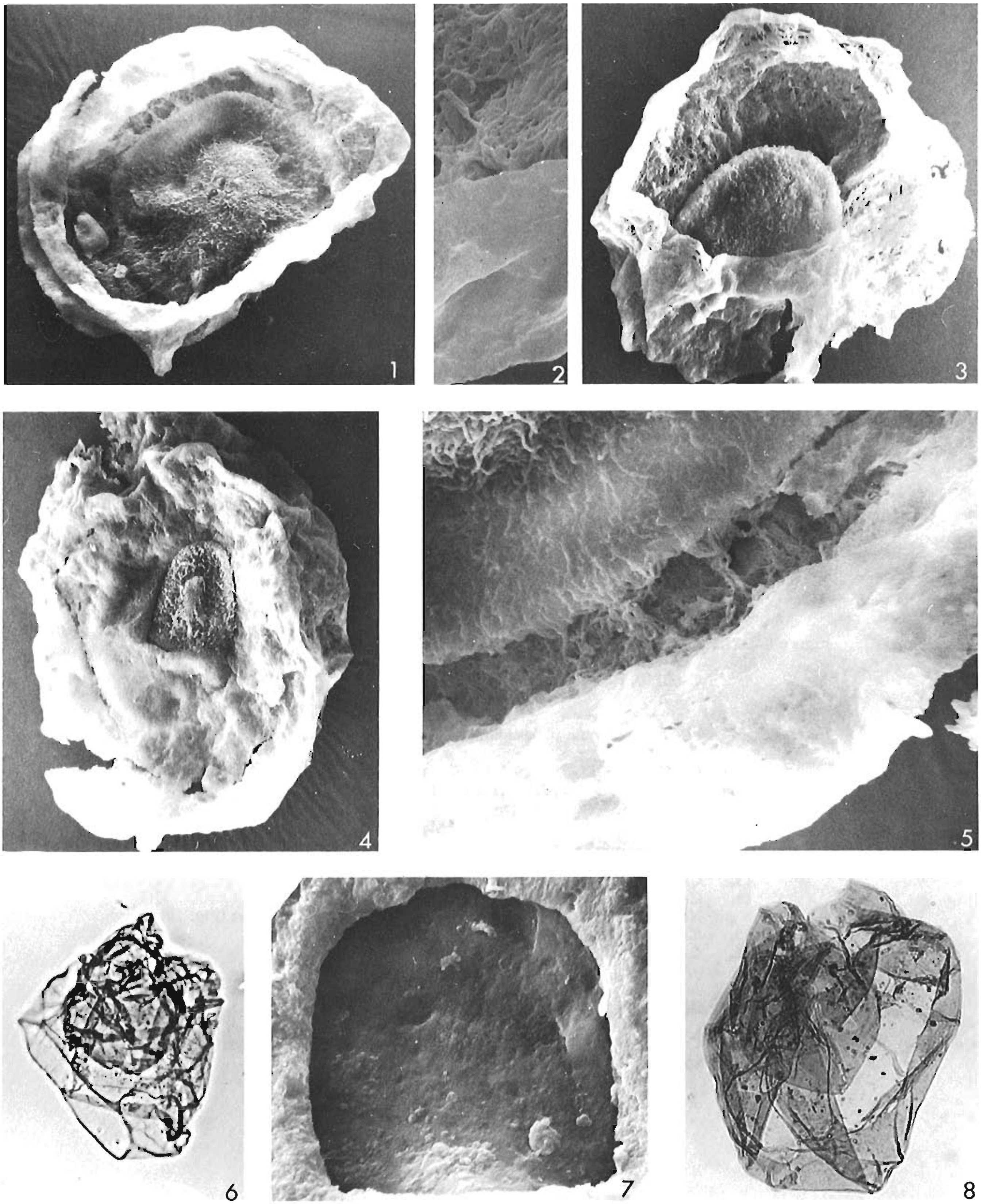

PLATE 23

All figures x500, unless otherwise stated

Figure 1. *Turbiosphaera filosa* (Wilson) Archangelsky

C-60127, P2047-21D: 33.0 x 128.5, GSC 65408.

Figures 2, 7-12. Dinoflagellate type B

2. C-60129, GSC 65409; scanning electron micrograph of dorsal surface showing spongiose structure of uneven size and distribution, x750.
7. C-60129, P2047-23/1: 41.2 x 122.9, GSC 65410.
8. C-60129, P2047-23/1: 13.9 x 128.9, GSC 65411.
9. C-60129, P2047-23/6: 24.1 x 122.2, GSC 65412.
10. C-60129, P2047-23/6: 26.6 x 128.7, GSC 65413.
11. C-60129, P2047-23/1: 38.7 x 120.8, GSC 65414.
12. C-60129, P2047-23F: 12.8 x 118.1, GSC 65415; specimens showing variation in shape of cyst and archeopyle, and ornament size and distribution. 9, specimen showing contents possibly representing degraded cell.

Figure 3. *Xenascus ceratioides* (Deflandre) Lentin and Williams

C-60129, P2047-23F: 44.5 x 115.0, GSC 65416.

Figure 4. *Xiphophoridium alatum* (Cookson and Eisenack) Sarjeant in Davey et al.

C-60110, P2047-4B: 14.4 x 119.5, GSC 65417.

Figures 5, 6. *Wallodinium lunum* (Cookson and Eisenack) Lentin and Williams

5. C-76012, P2047-2A: 29.3 x 128.7, GSC 65418.
6. C-60129, P2047-23O: 20.1 x 126.1, GSC 65419.

Figures 13-16. Dinoflagellate type E

13. C-60131, P2047-25D: 38.8 x 127.7, GSC 65420.
14. C-60131, P2047-25D: 38.8 x 127.7, GSC 65420.
    Note same tabulation (?) on endocyst (Fig. 13), and pericyst (Fig. 14).
15. C-60131, P2047-25E: 10.2 x 132.3, GSC 65421.
16. C-60131, P2047-25D: 22.5 x 127.8, GSC 65422.

Figure 17. Dinoflagellate type A

C-60129, P2047-23/4: 51.5 x 121.5, GSC 65423; endocyst(?) showing apex of intercalary archeopyle.

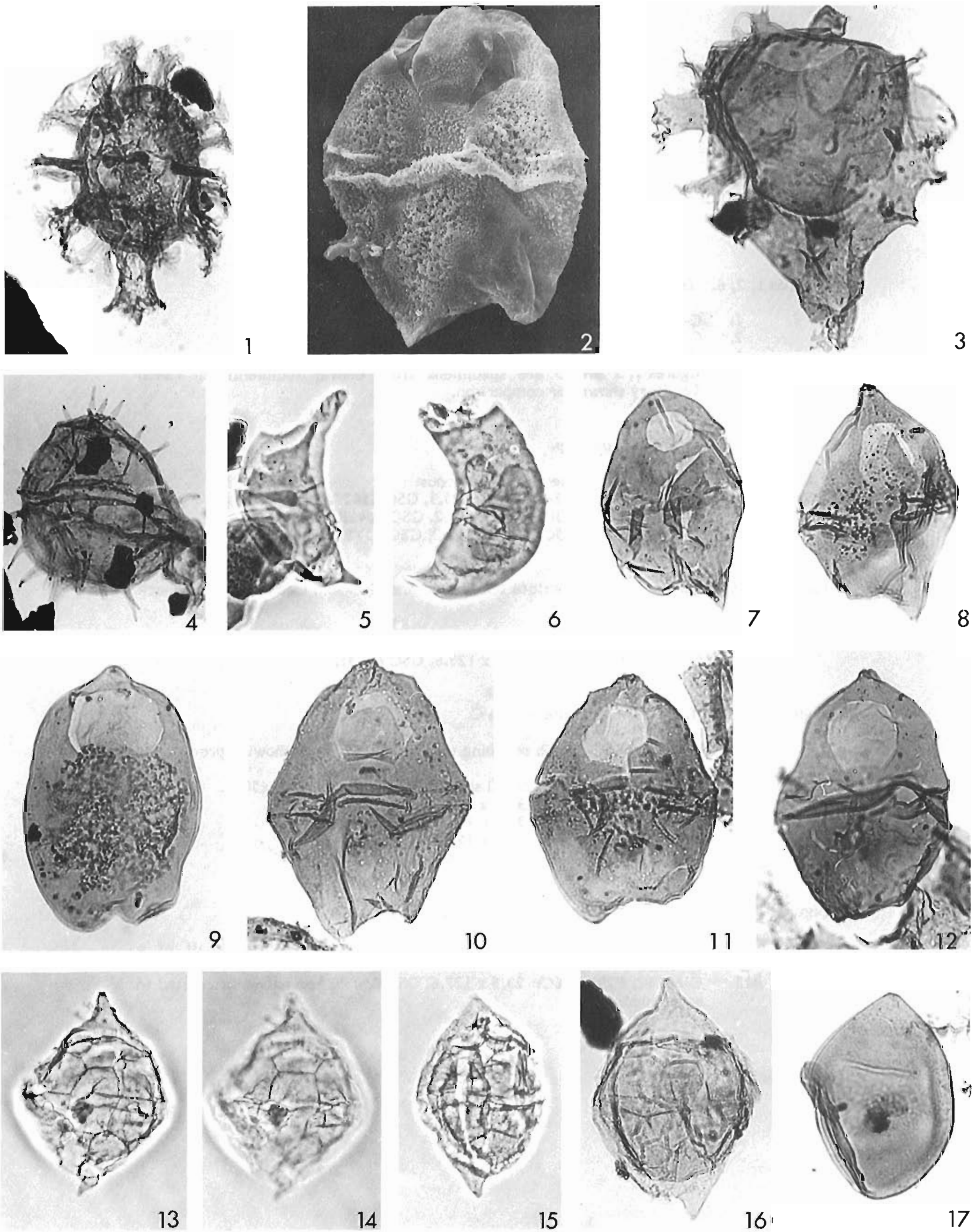
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PLATE 24

All figures x500, unless otherwise stated

Figures 1, 2, 6. Dinoflagellate type A

1. C-1444, P2259-?: 40.8 x 125.0, GSC 65424.
2. C-1444, P2259-?: 41.5 x 119.5, GSC 65425.
6. C-1444, P2259-?: 37.2 x 121.1, GSC 65426; entire cyst preserved; figures 1, 2 and 3 are specimens from coeval sediments in Yukon Territory shown for comparison.

Figures 3, 13, 16. *Palambages* spp.

Three different species of the genus:

3. C-60129, P2047-23/6: 50.7 x 125.3, GSC 65427.
13. C-60129, P2047-23F: 13.1 x 125.2, GSC 65428.
16. C-60121, P2047-15C: 44.4 x 117.2, GSC 65429.

Figures 4, 10. *Paralecaniella indentata* (Deflandre and Cookson) Cookson and Eisenack emend. Elsik

4. C-60129, P2047-23F: 38.8 x 117.4, GSC 65430.
10. C-60131, P2047-25E: 16.6 x 129.6, GSC 65431.

Figures 5, 7-9, 11, 12. Dinoflagellate type C

5. C-60123, GSC 65432; scanning electron micrograph showing precingular archeopyle, x1000.
7. C-60123, GSC 65433; detail showing process structure, x5000.
8. C-60123, P2047-17C: 32.7 x 133.0, GSC 65434.
9. C-60123, P2047-17C: 32.5 x 126.7, GSC 65435.
11. C-60123, P2047-17C: 15.4 x 120.0, GSC 65436.
12. C-60123, P2047-17C: 19.6 x 128.5, GSC 65437.

Figures 14, 15. *Schizocystia laevigata* Cookson and Eisenack

14. C-60129, P2047-23/4: 51.9 x 127.9, GSC 65438; lower half of a specimen.
15. C-60132, P2047-26C: 23.5 x 127.6, GSC 65439; two halves attributed to same specimen.

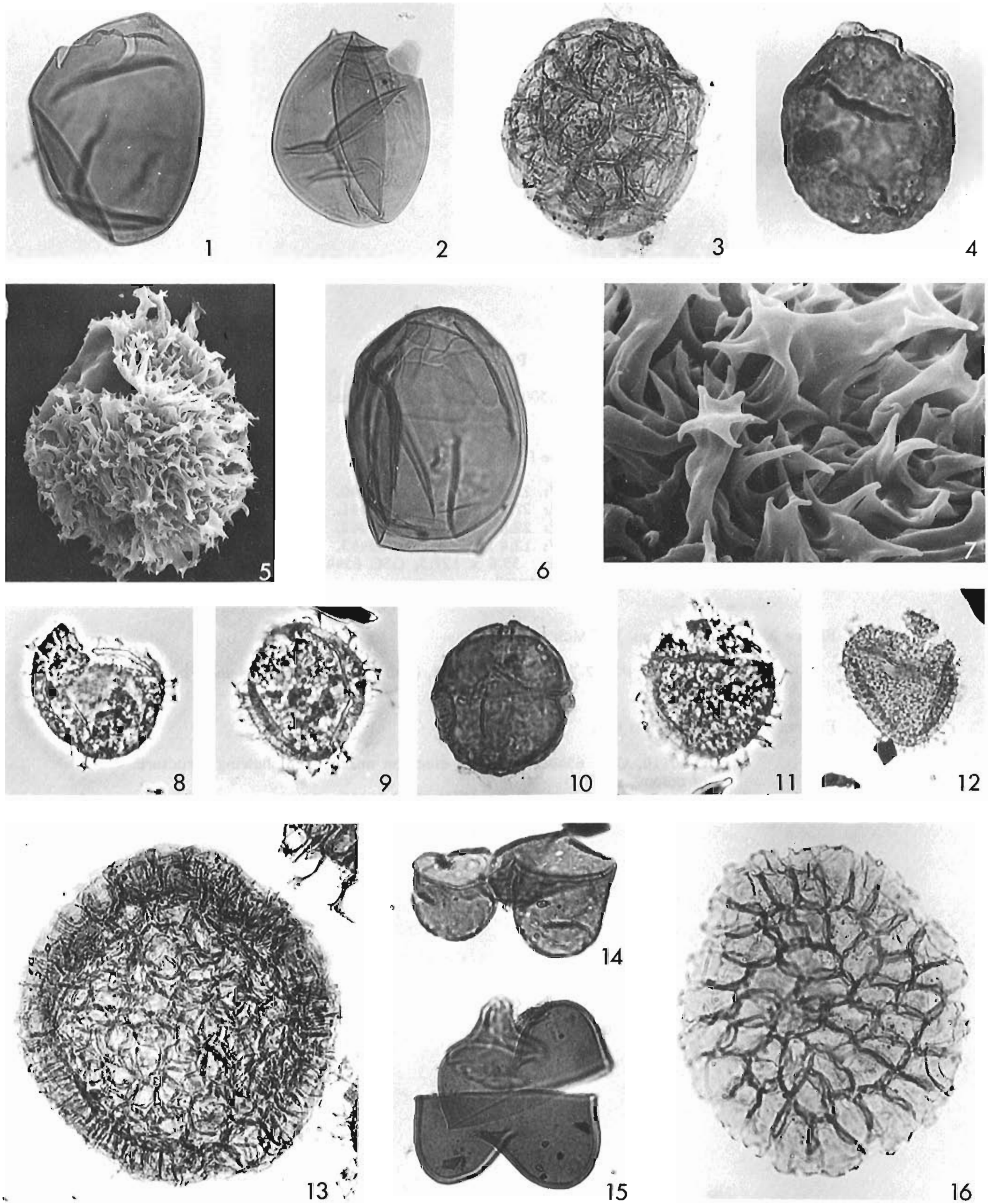


PLATE 25

All figures x500, unless otherwise stated

Figures 1-4, 6. Dinoflagellate? type D

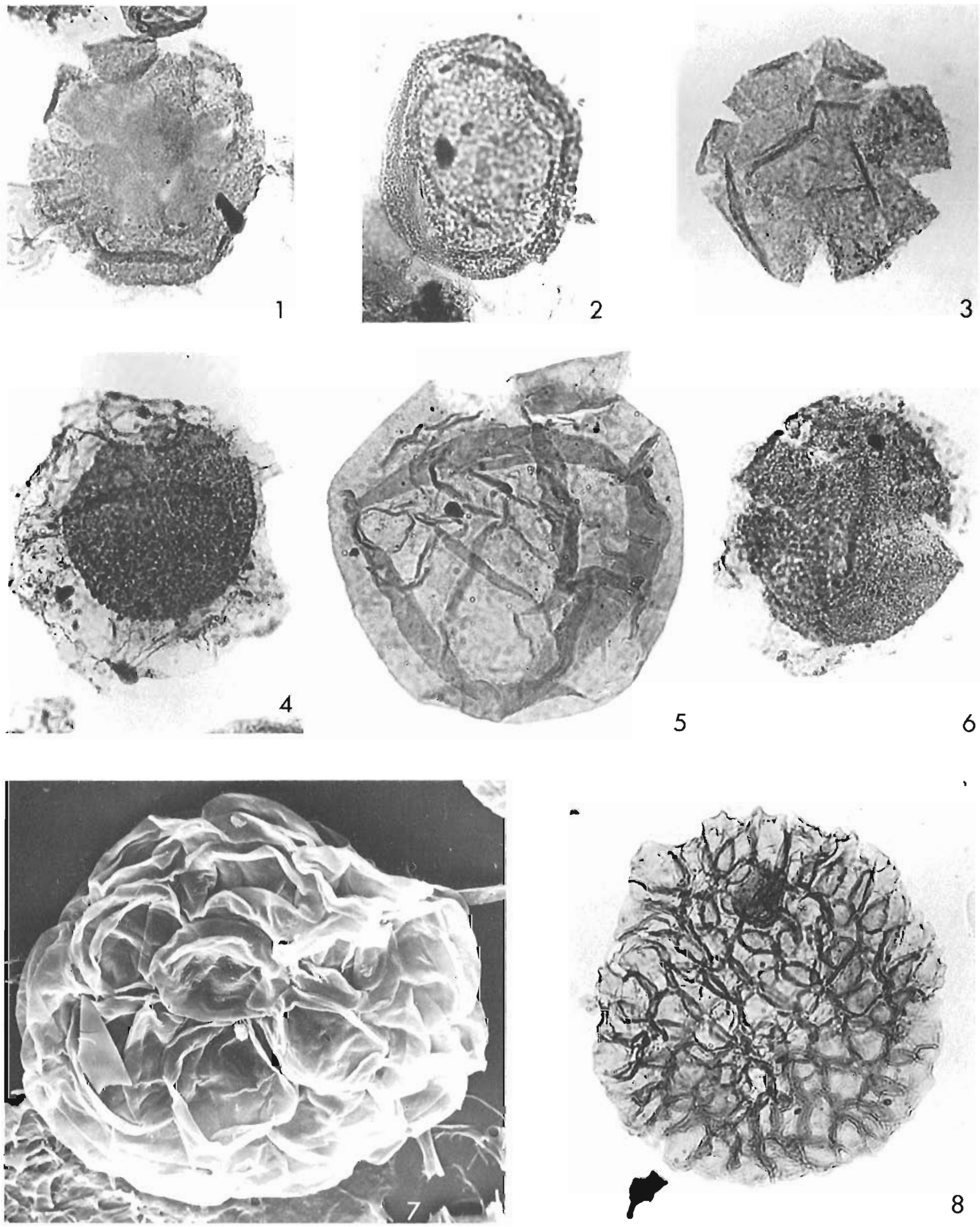
1. C-60129, P2047-23F: 25.9 x 126.4, GSC 65440.
2. C-60129, P2047-23E: 27.8 x 125.0, GSC 65441.
3. C-60129, P2047-23E: 22.0 x 121.8, GSC 65442.
4. C-60129, P2047-23F: 12.4 x 130.5, GSC 65443.
6. C-60129, P2047-23E: 39.6 x 127.5, GSC 65444; specimens showing a variable "splitting pattern".

Figure 5. "*Canningia*" sp. 1 of McIntyre

C-60129, P2047-23/1: 41.1 x 128.8, GSC 65445; archeopyle uncertain.

Figures 7, 8. *Palambages* spp.

7. C-60110, GSC 65446; scanning electron micrograph showing structure of colony, x1000.
8. C-60129, P2047-23F: 31.0 x 131.4, GSC 65447.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