31. PRELIMINARY DINOFLAGELLATE BIOSTRATIGRAPHY FOR THE MIDDLE EOCENE TO LOWER OLIGOCENE FROM THE SOUTHWEST ATLANTIC OCEAN[1]

David K. Goodman, Exxon Production Research Company, Houston, Texas
and
Leonard N. Ford, Jr., Department of Earth and Space Science, University of California, Los Angeles, California

ABSTRACT

A preliminary examination of Paleogene dinoflagellate cysts from core holes drilled on DSDP Leg 71, Falkland Plateau, indicates that dinoflagellates may be useful for recognizing the Eocene/Oligocene boundary in the southwestern Atlantic Ocean. In addition, data from Hole 511 provide evidence for establishing tentative limits to the age of type material for several dinoflagellate taxa described by Wilson (1967) from erratics at McMurdo Sound, Antarctica. Illustrations and brief comments about morphology or taxonomic relationships are presented for all taxa discussed in this chapter, including informal and undescribed forms.

INTRODUCTION

Cores from Holes 511, 512, and 513A from Leg 71 of the Deep Sea Drilling Project (Fig. 1) were analyzed to provide a preliminary survey of dinoflagellate distribution for the Eocene and Oligocene in the southwestern Atlantic Ocean. A composite lower Miocene to upper Eocene section, apparently lacking major hiatuses and including the Eocene/Oligocene and Oligocene/Miocene boundaries, was drilled in Holes 511 and 513A. Unfortunately, upper Oligocene and lower Miocene sediments, present only in Hole 513A, are barren of palynomorphs. Therefore, we have no data for later than the early Oligocene and were able to examine dinoflagellate distribution across only the Eocene/Oligocene boundary. A very preliminary survey was made for middle Eocene (Lutetian) species in Hole 512.

Data resulting from the present investigation provide the only published analysis of middle Eocene to early Oligocene dinoflagellate biostratigraphy in the southwestern Atlantic. DSDP Site 327, drilled during Leg 36 and located about 10 km north of Site 511, penetrated sediments that were no younger than middle to late Paleocene and that contained a very low diversity dinoflagellate assemblage (Harris, 1976). In terms of general floral characteristics, intervals cored at DSDP Site 274 (Leg 28) in the Ross Sea (Kemp, 1975) and Sites 280 and 283 (Leg 29) off the coast of southeastern Australia (Haskell and Wilson, 1975) contain floras similar to the late Eocene and early Oligocene assemblages in Holes 511 and 513A. The Browns Creek Clays in southeastern Australia also contain species which occur in the middle to upper Eocene sequence in Holes 511 and 512 (Cookson and Eisenack, 1965; L. E. Stover, pers. comm. to DKG, 1981). In addition, six of the several dinoflagellate species described by Wilson (1967) from glacial erratics in McMurdo Sound, Antarctica, occur in Leg 71 samples. The stratigraphic distribution of Wilson's species at Sites 511–513 makes it possible to assign a tentative late Eocene age to his material.

The studies just mentioned represent nearly the entire data base for middle Eocene to early Oligocene dinoflagellates in the middle and upper latitudes of the Southern Hemisphere (see Wrenn and Beckman, 1982, for a recent review of mid-Tertiary southern high-latitude dinoflagellates, in which all pertinent literature and fossil sites are noted). The present report expands this fragmentary data base in both geographic range and stratigraphic coverage. Our results, however, are preliminary in scope, and we plan a more detailed analysis of selected aspects of the flora at Sites 511–513 in the future.

METHODS AND MATERIALS

Of 32 core samples collected during DSDP Leg 71 and processed for palynomorphs, 12 were barren, but the 20 fossiliferous ones contained well-preserved and moderately diverse dinoflagellate cyst assemblages. We did not record quantitative data, other than noting unusually abundant or dominant species in particular intervals, because of the preliminary nature of the study.

Standard palynological acid maceration procedure was used to prepare the samples. Palynomorphs were concentrated by centrifugation in a zinc bromide solution (sp. gr. = 2.0) and were treated with a boiling solution of acetic anhydride and sulfuric acid to darken the cysts for examination and photomicrography. Strewn slides contain residue fractions retained on a 20 μm sieve and mounted in glycerine jelly.

BIOSTRATIGRAPHY

Hole 511

Hole 511 is located at 51°00.28′S; 46°58.30′W in the South Atlantic Ocean (Fig. 1), on the eastern margin of the Falkland Plateau. It was drilled in 2589 meters of water and penetrated a lower Oligocene to upper Eocene section to a sub-bottom depth of 632 meters. The Eocene/Oligocene boundary sequence is apparently free of disconformities, and Hole 511 thus provides the first

[1] Ludwig, W. J., Krasheninnikov, V. A., et al., *Init. Repts. DSDP*, 71: Washington (U.S. Govt. Printing Office).

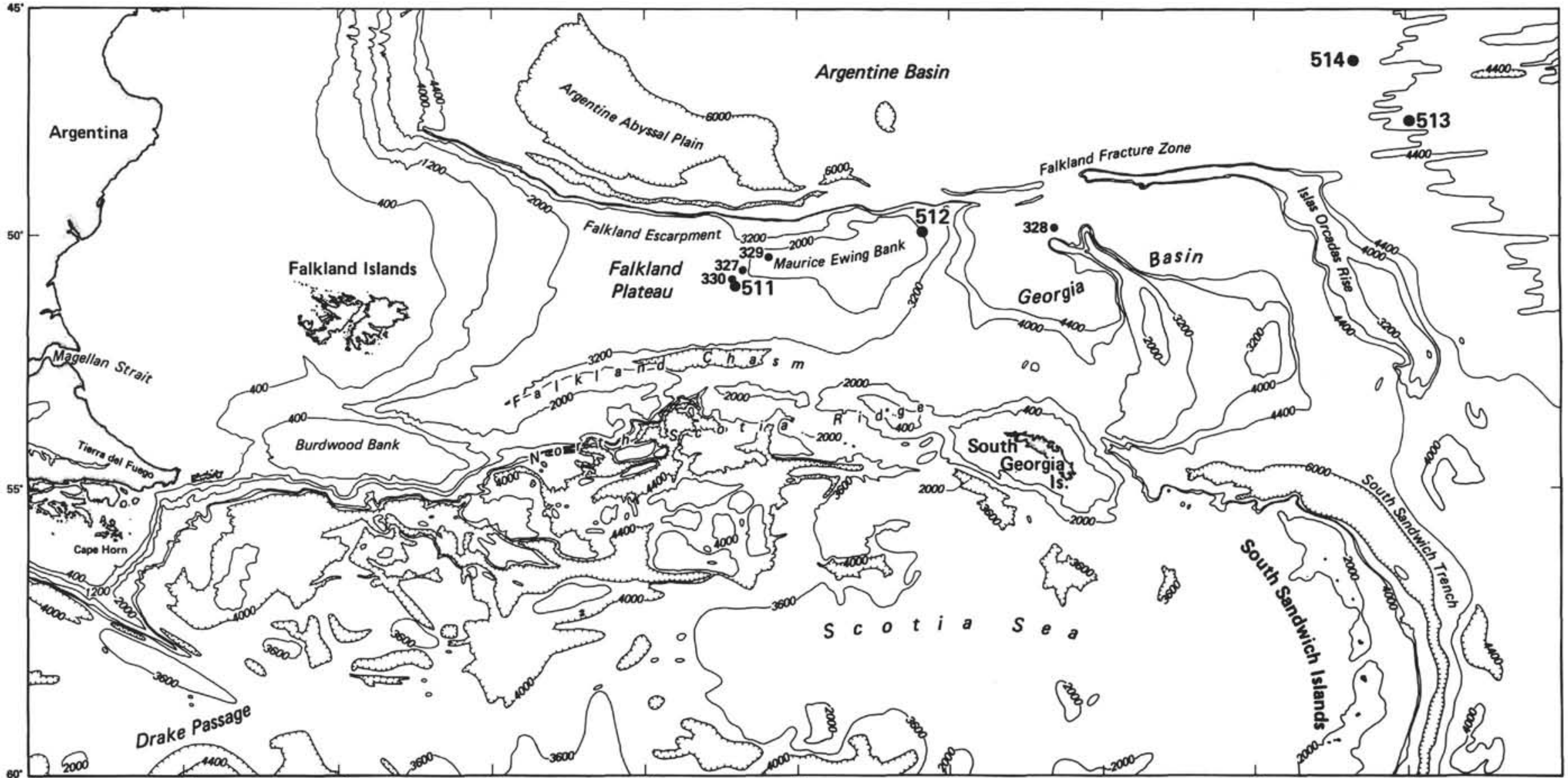

Figure 1. Location map for DSDP Sites 511, 512, and 513.

opportunity in the Southern Hemisphere to relate dinoflagellate biostratigraphy to this boundary where it has been established by independent age controls (Wise, this volume; ages based on calcareous nannofossils).

Dinoflagellate cysts are common to abundant in the samples analyzed and are generally well preserved. Rarer acritarchs and terrestrial palynomorphs are also present. The distribution of selected dinoflagellate species in Hole 511 is shown on Figure 2.

The interval from Sample 511-3-2, 96–98 cm to Sample 511-9-2, 102–104 cm contains a rather uniform cyst assemblage dominated by *Impagidinium victorianum* and Forma P. *Kallosphaeridium capulatum, Hystrichokolpoma rigaudiae*, and *Corrudinium incompositum* are restricted to this interval. *Phthanoperidinium comatum* and *P. eocenicum* occur only in Sample 511-5-2, 55–57 cm.

In Samples 511-11,CC and 512-12,CC, the assemblage is dominated by the undescribed form *P.* sp. A. The underlying interval (Samples 511-15-1, 38–40 cm to 511-18-2, 40–42 cm) contains relatively high numbers of *Vozzhennikovia apertura, Elytrocysta* sp., *Alterbia distincta*, and Forma P. The lowermost fossiliferous sample (511-20-2, 44–46 cm) contains abundant specimens of an undescribed form here assigned to *Eurydinium* sp.

Calcareous nannofossil data (Wise, this volume) place the position of the Eocene/Oligocene boundary between the top of Core 17 and the top of Core 18. Dinoflagel-

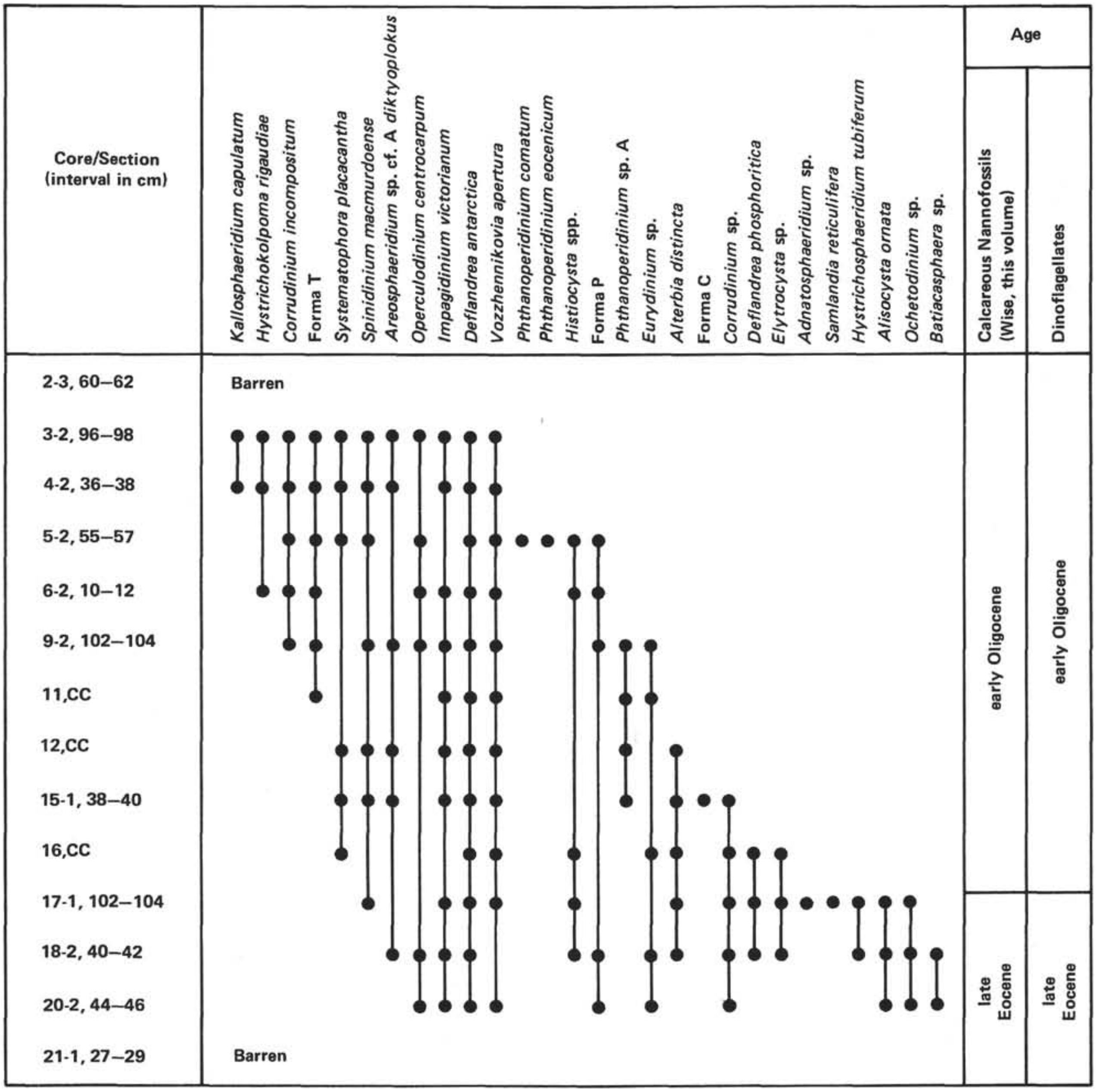

Figure 2. Stratigraphic distribution of selected dinoflagellate species in Hole 511. Inferred top of the upper Eocene section based on dinoflagellates is stratigraphically higher than that based on calcareous nannofossils (Wise, this volume).

late data, however, indicate that the boundary may be somewhat higher, because Sample 511-17-1, 102–104 cm contains several species which are not known to occur in sediments younger than late Eocene. These forms include *Adnatosphaeridium* sp., which occurs in the middle and upper Eocene at DSDP Site 283 (L. E. Stover, pers. comm. to DKG, 1981), and several species that occur in the upper middle and upper Eocene Browns Creek Clays of Victoria, Australia. The latter include *Alisocysta ornata*, recorded by Cookson and Eisenack (1965), as well as *Batiacasphaera* sp. and *Ochetodinium* sp. (L. E. Stover, pers. comm. to DKG, 1981).

In general terms, the assemblage in Hole 511 is very similar to that in the Browns Creek Clays. Cookson and Eisenack (1965) illustrated, among other species, *Alisocysta ornata, Deflandrea phosphoritica, Hystrichokolpoma rigaudiae, Impagidinium victorianum, Phthanoperidinium eocenicum, Samlandia reticulifera*, and *Systematophora placacantha*, all of which occur in Hole 511. In addition, L. E. Stover (pers. comm. to DKG, 1981) reports *Batiacasphaera* sp., *Corrudinium incompositum, Corrudinium* sp., *Ochetodinium* sp., and *Phthanoperidinium comatum* from samples taken from the Browns Creek Clays.

The assemblages from DSDP Sites 280 (Cores 10–14) and 283 (Cores 6–9) are interpreted (Haskell and Wilson, 1975) as late Eocene in age and have several species in common with the Hole 511 flora. At Site 280, these are *Alterbia distincta, Areosphaeridium* sp. cf. *A. diktyoplokus, Deflandrea antarctica, D. phosphoritica, Spinidinium macmurdoense*, and *Vozzhennikovia apertura*. At Site 283, species also found in Hole 511 are *A*. sp. cf. *A. diktyoplokus, Corrudinium* sp. (identified by Haskell and Wilson as *Leptodinium* sp.), *D. phosphoritica, Impagidinium victorianum, S. macmurdoense*, and *V. apertura*. No definitive correlation can be made to Hole 511 on the basis of Haskell and Wilson's floral lists, except that the intervals indicated as upper Eocene at Sites 280 and 283 are most similar to the interval from Sample 511-15-1, 38–40 cm to Sample 511-20-2, 44–46 cm, or upper Eocene to lower lower Oligocene, in Hole 511.

In 1967, Wilson described several new species of dinoflagellate cysts from Tertiary erratics in McMurdo Sound, Antarctica, and in the same paper reported the occurrence of several other previously described species. Wilson's material consisted of several samples collected from two localities, Minna Bluff and Black Island, for which he postulated a probable Eocene age. Previously, Cranwell (1964) had indicated a Paleocene to Oligocene age for the Minna Bluff erratics, and McIntyre and Wilson (1966) suggested that the Black Island material was Eocene. The species common to Wilson's samples and Hole 511 are *Adnatosphaeridium* sp. (identified by Wilson as *Aiora fenestrata*), *Alterbia distincta, Areosphaeridium* sp. cf. *A. diktyoplokus, Hystrichosphaeridium tubiferum, Spinidinium macmurdoense*, and *Vozzhennikovia apertura*. Based on the stratigraphic distribution of these species in Hole 511, Wilson's (1967) material correlates best with the interval from Sample 511-17-1, 102–104 cm to Sample 511-18-2, 40–42 cm, thus indicating a most likely age of late Eocene for the McMurdo Sound samples.

Hole 512

Hole 512 was drilled on the northeast flank of the Maurice Ewing Bank (Fig. 1) in 1846 meters of water. It is located at 49°52.19′S; 40°50.71′W and was drilled to a sub-bottom depth of 78 meters. Cores 1 through 5 are Miocene and were not examined for palynomorphs. Cores 6 through 19 are early middle Eocene (Lutetian; see Site 512 site chapter, this volume). Six middle Eocene samples were processed for a preliminary survey of dinoflagellate recovery, diversity, and abundance. Results (Fig. 3) show the interval from Sample 512-10-3, 26–28 cm to Sample 512-19-3, 29–31 cm to be fossiliferous. Preservation of the cysts is good, and abundance and diversity are low to moderate.

Nine of the species recovered in Hole 512 also occur in younger sediments in Hole 511. *Hystrichosphaeridium tubiferum* and *Adnatosphaeridium* sp. occur in the upper Eocene of Hole 511 (age based on dinoflagellates; using calcareous nannofossil data, the top of this interval is dated as youngest early Oligocene: see Wise, this volume, and Fig. 2). The stratigraphically highest occurrences of *Deflandrea phosphoritica, Phthanoperidinium comatum, Histiocysta* spp., *Vozzhennikovia apertura, Corrudinium* sp., *Impagidinium victorianum*, and *Deflandrea antarctica* are in the lower Oligocene of Hole 511. These data provide some upper limits to the ranges of these species for middle Eocene to early Oligocene time in the southwestern Atlantic.

We hesitate to make many statements regarding interpretation of the dinoflagellate distribution in Hole 512, for two reasons. First, the sampling interval is very large, and any analysis would probably be greatly modified after a more detailed study. Secondly, a number of the forms reported here are new, and their stratigraphic distribution is therefore unknown for other areas (to our knowledge, no other middle Eocene dinoflagellate assemblage has been described from the southern Atlantic Ocean). We prefer simply to plot species distribution against independent age determination and postpone interpretation until a more complete study is made.

Hole 513A

Hole 513A is located at 47°34.99′S; 24°38.40′W on the flank of the lower Mid-Atlantic Ridge near the eastern edge of the Argentine Basin (Fig. 1). It was drilled in 4373 meters of water, and a lower Miocene through lower Oligocene section was recovered.

Twelve samples were processed for organic microfossils (Fig. 4). The upper nine are barren, and the lower three contain a low-diversity dinoflagellate flora comprising six species, all present in the upper two-thirds of the lower Oligocene section in Hole 511. Correlation between Holes 511 and 513A is based on the stratigraphically highest occurrence of *Isthmolithus recurvus*, a calcareous nannofossil (Wise, this volume). This datum occurs at the top of Core 4 in Hole 511 and at the top of Core 31 in Hole 513A. Therefore, Cores 31–33 in Hole 513A are correlative to Cores 4–6 in Hole 511. The dis-

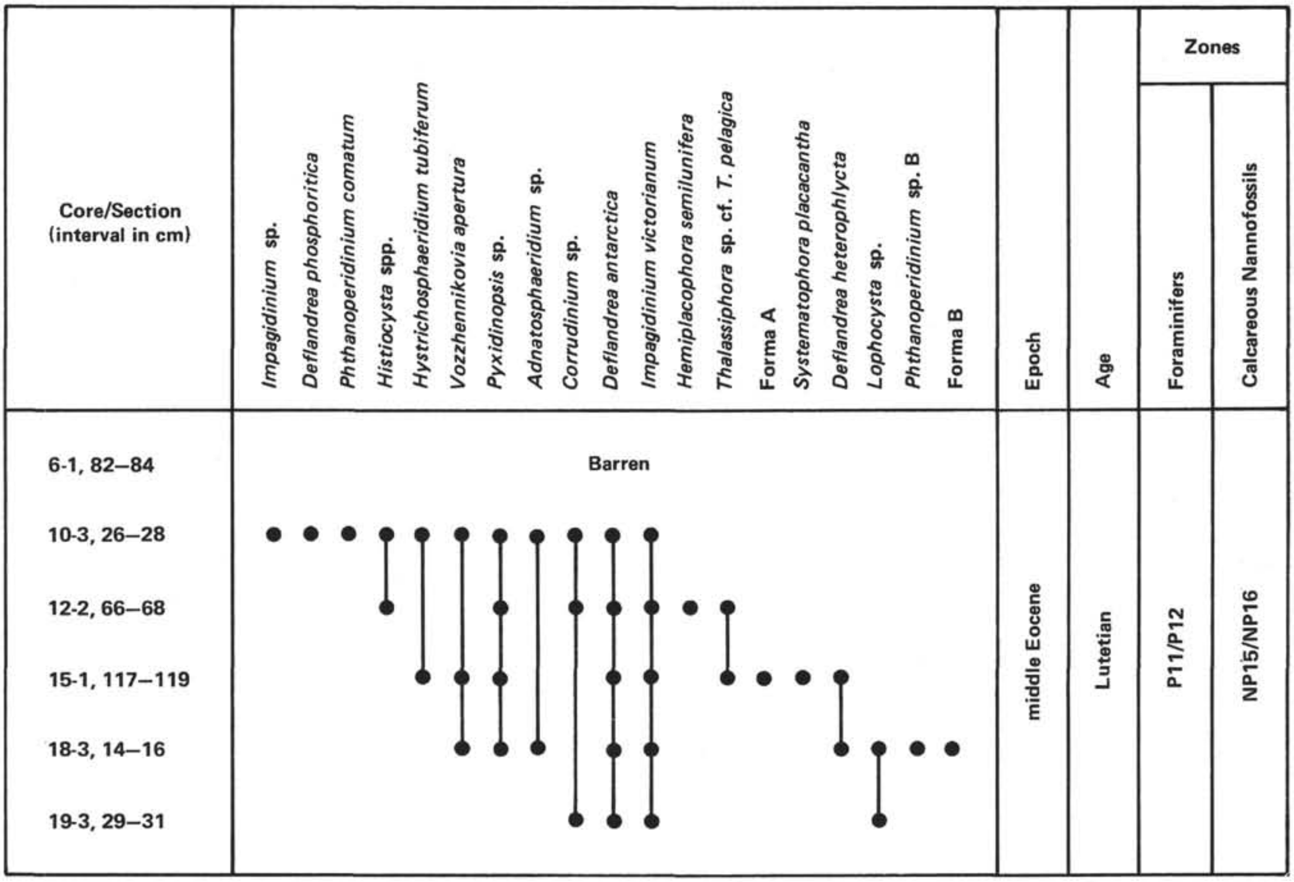

Figure 3. Stratigraphic distribution of selected dinoflagellate species in the middle Eocene of Hole 512. Miocene section (Cores 1–5) was not examined for organic microfossils.

tribution of dinoflagellate cysts in the two holes does not conflict with that correlation.

CONCLUSIONS

The stratigraphic distribution of dinoflagellate cysts in Holes 511, 512, and 513A indicates that the group has biostratigraphic potential for delimiting the Eocene/Oligocene boundary in the southwestern Atlantic Ocean.

The late Eocene and early Oligocene assemblages in Holes 511 and 513A have several species in common with assemblages from Antarctica and Australia–New Zealand, suggesting the existence of a recognizable mid-dle- to high-latitude southern dinoflagellate flora for this period. Identification and definition of such a flora should increase the usefulness of dinoflagellates in future paleoceanographic studies. Taxonomic inconsistencies regarding some of these species (e.g., reported occurrences in the northern latitudes, possibly as the result of misidentification or of imprecise species definition or differentation) require further investigation before their utility as paleoceanographic indicators can be fully realized.

The dinoflagellates in Hole 512 represent the first independently dated middle Eocene (Lutetian) dinoflagellate flora described from the southern Atlantic Ocean.

ACKNOWLEDGMENTS

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SPECIES REFERENCE LIST

The species reference list represents those forms which, in our opinion, are most useful in a biostratigraphic sense because of their high relative abundance, consistent stratigraphic occurrence, distinctive morphology, or previous mention in the published literature. Listed taxa are divided into three general categories: those with peridiniacean affinities, those with gonyaulacalean affinities, and those with unknown affinities. Within each major category, taxa are arranged alphabetically, with the exception of those designated as "Forma," which are listed at the end of each category.

This section is not intended to be a formal, exhaustive description of the assemblage. Rather, it is meant briefly to outline the major aspects of species distribution and to highlight interesting morphological characters of certain taxa. The authors plan to publish a formal, detailed systematic and morphologic treatment of selected species from this assemblage in the near future.

Peridinialean Group

Alterbia distincta **(Wilson, 1967) Lentin and Williams, 1976** (Plate 3, Figs. 6–8).

Reference. Wilson, 1967, pp. 63–64, figs. 9–10.

Comments. Recovered in the upper Eocene and lower Oligocene from Hole 511. It is abundant in Samples 511-17-1, 102–104 cm and

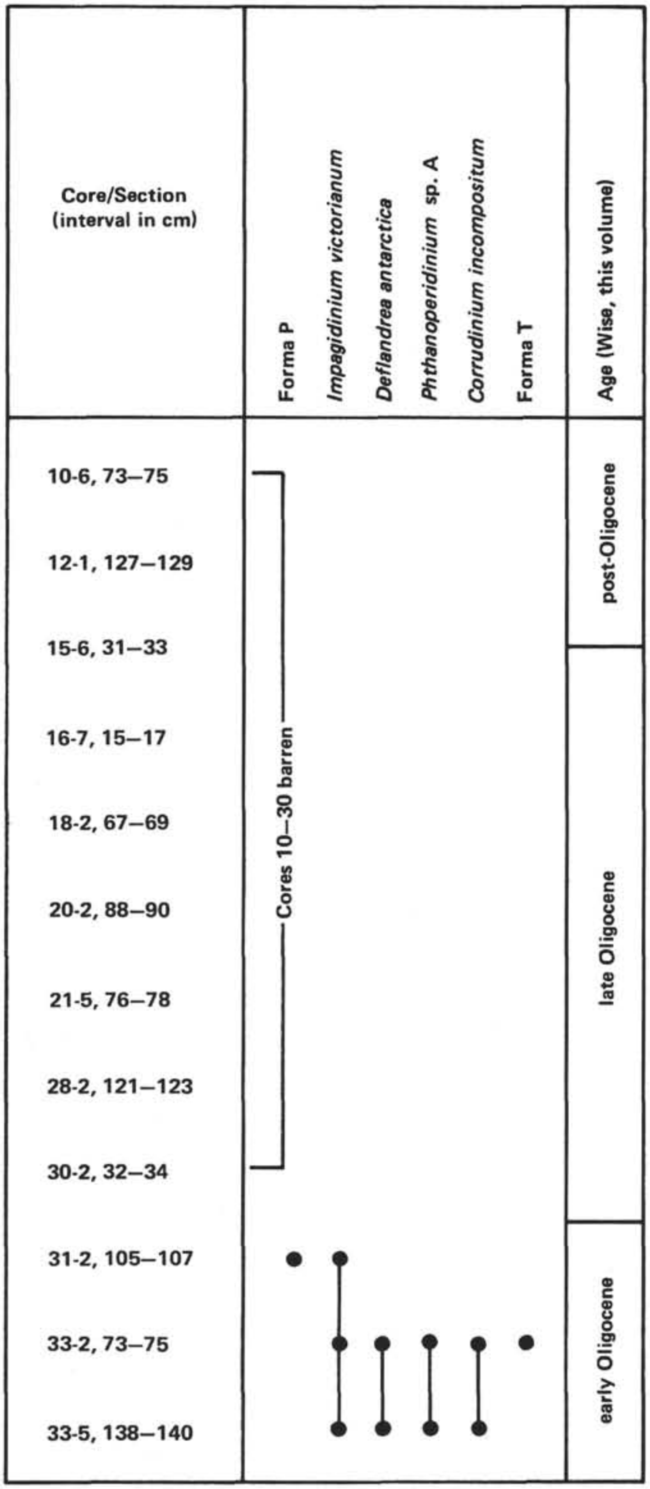

Figure 4. Stratigraphic distribution of selected dinoflagellate species in Hole 513A.

511-18-2, 40–42 cm (upper Eocene). Populations of this species display archeopyles that vary from ones characteristic of *Alterbia* (epipericoel in communication with exterior through the archeopyle) to ones more typical of *Senegalinium* (epipericoel not in communication with exterior), according to the generic analyses of Stover and Evitt (1978, pp. 93, 122–123). This suggests that archeopyle morphology should possibly be treated as an intergeneric variable rather than a generic character for these taxa.

Deflandrea antarctica **Wilson, 1967** (Plate 1, Figs. 4–6).
Reference. Wilson, 1967, pp. 58, 60, figs. 23–24, 26–27.
Comments. This species occurs consistently throughout Holes 511, 512, and 513A. Occasional specimens appear to have parasutural markings which are similar to the intercalary growth bands present on modern thecate forms and which are indicated on the fossil cyst genus *Palaeoperidinium* Deflandre. Details of this phenomenon have not been explored, and the morphology and distribution of these markings need to be resolved. The forms identified by Cookson and Cranwell (1967, p. 205, pl. 1, figs. 1–4) and Kemp (1975, p. 604, pl. 1, figs. 1–6) as *Deflandrea oebisfeldensis* Alberti are here considered assignable to *D. antarctica*.

Deflandrea heterophlycta **Deflandre and Cookson, 1955** (Plate, 1, Fig. 3).
Reference. Deflandre and Cookson, 1955, pp. 249–250, pl. 5, fig. 6, fig. 5.
Comments. This species occurs in low numbers in Hole 511.

Deflandrea phosphoritica **Eisenack, 1938** (Plate 1, Figs. 1–2).
Reference. Eisenack, 1938, p. 187, text-figure 6.
Comments. *D. phosphoritica* occurs sporadically in Holes 511 and 512 (Lutetian to lower Oligocene).

Eurydinium **sp.** (Plate 3, Figs. 1–5).
Comments. This form occurs in the upper Eocene to lower Oligocene of Hole 511. The cyst is circumcavate with an ellipsoidal endocyst (length greater than width) and a pericyst of highly variable shape which generally lacks hornlike protrusions. The endocyst and pericyst are attached at the mid-ventral and mid-dorsal regions. The periarcheopyle is a longitudinally attenuated hexa type attached to the pericyst along its posterior margin; details of the endoarcheopyle are not clear, but it may consist of a vaguely defined crescent-like slit (Plate 3, Fig. 2). No indication of paratabulation is expressed other than the archeopyle shape and, on some specimens, a weakly delimited paracingulum (Plate 3, Fig. 4).

Phthanoperidinium comatum (Morgenroth, 1966) **Eisenack and Kjellstrom, 1971** (Plate 4, Figs. 7–8).
Reference. Morgenroth, 1966, p. 1, pl. 1, figs. 1–2.
Comments. One specimen was recovered from Sample 511-5-2, 55–57 cm, and one from Sample 511-10-3, 26–28 cm.

Phthanoperidinium eocenicum **(Cookson and Eisenack, 1965) Lentin and Williams, 1973** (Plate 3, Figs. 10–12).
Reference. Cookson and Eisenack, 1965, pp. 119–120, pl. 11, figs. 1–5.
Comments. One specimen was recovered from Sample 511-5-2, 55–57 cm.

Phthanoperidinium **sp. A** (Plate 2, Figs. 1–8).
Comments. This undescribed form occurs in the lower Oligocene in Holes 511 and 513A; it is most abundant in Samples 511-11,CC and 511-12,CC. Characteristic features of this small peridiniacean cyst are (a) a single wall layer (autophragm); (b) parasutural ridges which indicate a paratabulation formula of 4′, 3a, 7″, Xc, 5‴, 2⁗, ?s (sulcal paratabulation could be resolved with scanning electron microscopy); (c) an ortho-hexa epicystal paratabulation style; (d) an archeopyle formed by the loss of three anterior intercalary paraplates (1–3a); and (e) a more or less peridinioid outline with a poorly developed, short, blunt apical horn and a rounded antapical margin.

Phthanoperidinium **sp. B** (Plate 1, Figs. 7–11).
Comments. This undescribed form occurs only in Sample 511-18-3, 14–16 cm (Lutetian). This species has an epicystal paratabulation style of the para-hexa configuration (Fig. 5). This style has not previously been known for fossil cysts, but is represented in many modern thecate forms.

Spinidinium macmurdoense **(Wilson, 1967) Lentin and Williams, 1976** (Plate 3, Fig. 9).
Reference. Wilson, 1967, pp. 60, 62, figs. 2a, 11–16, 22.
Comments. *S. macmurdoense* occurs in low numbers in Hole 511.

Vozzhennikovia apertura **(Wilson, 1967) Lentin and Williams, 1976** (Plate 4, Fig. 1–6).
Reference. Wilson, 1967, pp. 64–65, figs. 3–5, 8.
Comments. In Hole 511, the species is an abundant component of the assemblage in the interval from Sample 511-15-1, 38–40 cm to

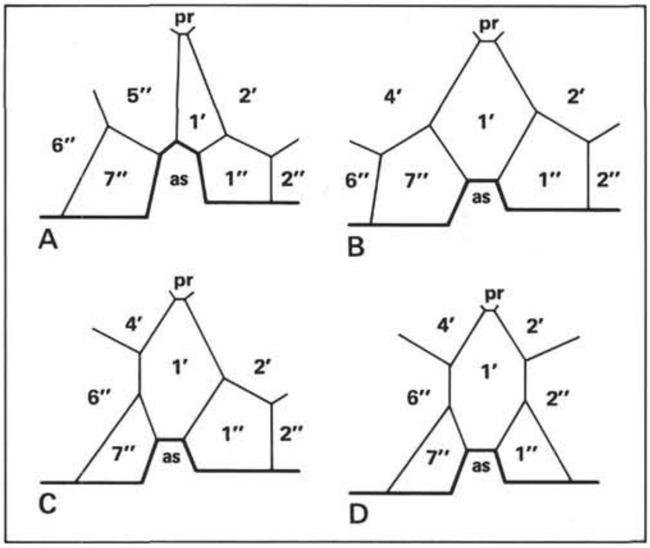

Figure 5. Comparison of four styles of ventral paratabulation in fossil peridiniacean dinoflagellate cysts. In (A), 1′ is four-sided (if the short line of contact with the preapical paraplate is not counted) and contacts a single precingular paraplate. This style, for which no particular descriptive term is used, occurs in the mid-Cretaceous cyst genus *Angustidinium* Goodman and Evitt and in the modern motile genus *Heterocapsa* Stein. In the ortho style (B), 1′ is five-sided and contacts two precingulars. This is the dominant style among fossil cysts and is common in recent thecae. The meta style (C) is characterized by a six-sided 1′ that contacts three precingulars. A single fossil species, the middle to late Eocene *Phthanoperidinium brooksii* Edwards and Bebout, has this style, and it is present in many modern species. The para style (D), demonstrated on *Phthanoperidinium* sp. B here, has previously been reported only for recent thecae. The seven-sided 1′ in this style contacts four precingular paraplates.

Sample 511-17-1, 102–104 cm. This species is possibly conspecific with *Vozzhennikovia rotundata* (Wilson, 1967) Lentin and Williams, 1976, as intermediate forms are present. In Hole 511, morphs similar to *V. apertura* are more common in Sections 511-15-1 through 511-20-2, whereas those more similar to *V. rotundata* are more common in Sections 511-2-3 to 511-12,CC. The periarcheopyle is a variable feature, but it has not been previously reported as such. One, two, or all three of the anterior intercalary paraplates are lost during archeopyle formation. This can be interpreted either as a variable archeopyle of Types I, 2I, or 3I, or as a Type 3I in which the loss of the three paraplates is progressive. Details of the endoarcheopyle are not known. There is a great amount of variation in the distribution and density of coni on the periphragm.

Forma C (Plate 5, Figs. 3–4).
Comments. This form occurs in Sample 511-15-1, 38–40 cm. The small cysts (less than 35 μm maximum dimension) have indications of a peridiniacean paratabulation; however, no archeopyle was observed. The outer wall is ornamented with numerous, apparently nontabular, short coni.

Gonyaulacalean Group

Adnatosphaeridium **sp.** (Plate 7, Figs. 5–9).
Comments. This species is confined to the middle and upper Eocene in Holes 511 and 512. Characteristic features are an ellipsoidal main body with an apical archeopyle; a large, bulbous antapical process; and seven processes (1-6″, and a.s.) attached to the main body which support a thick, rather simple trabecular ectophragm. No paracingular, postcingular, posterior intercalary, or other parasulcal processes are present. Although this form is superficially similar to some species of *Adnatosphaeridium* in having this type of trabecular network, the morphological features just enumerated make it quite distinct and separate from that genus. We have nonetheless tentatively placed it in *Adnatosphaeridium* pending a more detailed study.

Note added in proof: We have recently discovered that this species is being described under the name "*Arachnodinium antarcticum*" by Wilson and Clowes (in press).

Alisocysta ornata **(Cookson and Eisenack, 1965) Stover and Evitt, 1978** (Plate 7, Figs. 10–11).
References. Cookson and Eisenack, 1965, p. 124, pl. 13, figs. 1–8; Stover, 1975, pp. 40–41, pl. 2, figs. 6–11.
Comments. The species is present only in the lower part of Hole 511. It is known only from upper Eocene sections (Stover, 1975).

Areosphaeridium **sp. cf.** *A. diktyoplokus* **(Klumpp, 1953) Eaton, 1971** (Plate 8, Fig. 4).
References. Klumpp, 1953, p. 392, pl. 18, figs. 3–7; Eaton, 1971, pp. 358–359.
Comments. This species occurs from the uppermost Eocene through lower Oligocene in Hole 511. Specimens unequivocally attributable to *Areosphaeridium diktyoplokus* (i.e., those whose polygonal, fenestrate, platformlike terminations at the process tips have complete margins) are confined to the middle and upper Eocene of the Northern Hemisphere. The process terminations on the forms previously referred to *A. diktyoplokus* from Southern Hemisphere localities (Wilson, 1967, p. 67, figs. 33, 35; Kemp, 1975, p. 605, pl. 3, figs. 5–8; Haskell and Wilson, 1975, pl. 1, fig. 1; and Cookson and Cranwell, 1967, pp. 205–206, pl. 1, figs. 12–13; pl. 2, figs. 1–3) have incomplete margins similar to those on specimens herein referred to *A.* sp. cf. *A. diktyoplokus*. We believe that none of the Southern Hemisphere forms reported to date should be attributed to *A. diktyoplokus* s.s.

Batiacasphaera **sp.** (Plate 9, Fig. 4).
Comments. This species occurs in the upper Eocene of Hole 511. *Batiacasphaera* sp. is similar to *B. compta* Drugg, but lacks the low, rodlike elements of that species. On *B. compta*, the relative density of the rods on the autophragm forms a reticulate pattern, whereas on *B.* sp. a similarly appearing reticulate surface pattern is formed by shallow subcircular depressions on the autophragm.

Corrudinium incompositum **(Drugg, 1970) Stover and Evitt, 1978** (Plate 5, Figs. 1–2).
Reference. Drugg, 1970, pp. 810–811, figs. 1E–10, 2A.
Comments. *C. incompositum* occurs in the lower Oligocene in Holes 511 and 513A.

Corrudinium **sp.** (Plate 10, Figs. 6–10).
Comments. In Holes 511 and 512, this species occurs from the middle Eocene to the lower half of the lower Oligocene section. The species is characterized by a gonyaulacacean paratabulation expressed by continuous parasutural ridges, a precingular archeopyle (Type P; 3″ only), and by numerous discontinuous ridges (of lower relief than the parasutural ridges) which occur within the paraplate boundaries. It is larger than *Corrudinium incompositum* (Drugg) Stover and Evitt and has a more complex development of the intratabular ornament.

Elytrocysta **sp.** (Plate 6, Figs. 11–12).
Comments. *Elytrocysta* sp. is present in the upper Eocene and lower Oligocene of Hole 511. Surface ornamentation consists of a low, incomplete reticulum. The archeopyle is apical, and two wall layers (autophragm and ectophragm) are present; the ectophragm is supported by the elements forming the reticulum.

Hemiplacophora semilunifera **Cookson and Eisenack, 1965** (Plate 9, Figs. 1–3).
Reference. Cookson and Eisenack, 1965, p. 126, pl. 14, figs. 4–9, 16.
Comments. *Hemiplacophora semilunifera* occurs only in Sample 512-12-2, 66–68 cm.

Histiocysta **spp.** (Plate 7, Figs. 1–2; Plate 9, Figs. 7–8).
Comments. This group of forms is present in Holes 511 and 513. Three or four species may be included in this species complex, but differentiation among them is beyond the intent of this report. Two of the more common morphotypes are illustrated and indicate the variation in the development of ornamentation on the paraplates. The cysts are generally less than 30 μm in length.

***Hystrichokolpoma rigaudiae* Deflandre and Cookson, 1955** (Plate 8, Fig. 9).
Reference. Deflandre and Cookson, 1955, pp. 279–281, pl. 6, figs. 6, 10, text-figure 42.
Comments. Several specimens are present in Samples 511-2-3, 60–62 cm to 511-6-2, 10–12 cm. This represents a local range.

***Hystrichosphaeridium tubiferum* (Ehrenberg, 1836) Deflandre, 1937** emend. Davey and Williams, 1966 (Plate 8, Fig. 5).
References. Deflandre, 1937, p. 68; Davey and Williams, 1966, pp. 56–58.
Comments. Occurrence of *Hystrichosphaeridium tubiferum* is restricted to the middle and upper Eocene in Holes 511 and 512.

***Impagidinium victorianum* (Cookson and Eisenack, 1965) Stover and Evitt, 1978** (Plate 6, Figs. 1–6).
Reference. Cookson and Eisenack, p. 123, pl. 12, figs. 8–9.
Comments. The species occurs throughout the three sections examined.

***Impagidinium* sp.** (Plate 6, Figs. 7–8).
Comments. This species occurs only in the Lutetian of Hole 512 (Sample 512-10-3, 26–28 cm.

***Kallosphaeridium capulatum* Stover, 1977** (Plate 6, Figs. 9–10).
Reference. Stover, 1977, p. 74, pl. 1, figs. 11–13.
Comments. The species is confined to the upper lower Oligocene section in Hole 511.

***Lophocysta* sp.** (Plate 4, Fig. 9–17).
Comments. *Lophocysta* sp. is confined to the Lutetian of Hole 512. A large ventral pericoel and a gonyaulacacean paratabulation indicated by faint parasutural ridges characterize this form and differentiate it from *L. sulcolimbata* Manum. The latter species has a much narrower zone of endophragm/periphragm separation (which is confined essentially to the parasulcal area) and lacks parasutural features on the main body. The archeopyle on both species is precingular (Type P; 3″ only). The parasutural features on the specimens reported here suggest a possible relationship between *Lophocysta* and *Impagidinium* Stover and Evitt.

***Ochetodinium* sp.** (Plate 9, Figs. 9–11).
Comments. This form occurs only in Sections 511-17-1, 511-18-2, and 511-20-2. Faint indications of a paracingulum and adjoining pre- and postcingular parasutures are present.

***Operculodinium centrocarpum* (Deflandre and Cookson, 1955) Wall, 1967** (Plate 8, Fig. 8).
References. Deflandre and Cookson, 1955, p. 272, pl. 8, figs. 3–4; Wall, 1967, p. 111.
Comments. In Hole 511, the species occurs in the upper Eocene and lower Oligocene. It is of little stratigraphic value.

***Pyxidinopsis* sp.** (Plate 9, Figs. 5–6).
Comments. This form occurs in the middle Eocene of Hole 512. Characteristic features are an apparently random network of ridges and a precingular archeopyle (Type P; 3″ only). No indication of paratabulation other than the archeopyle could be discerned. Several other forms referrable to *Pyxidinopsis* occur in the sections examined, but they are not included in this report because of their sporadic occurrence and unknown variability.

***Samlandia reticulifera* Cookson and Eisenack, 1965** (Plate 10, Figs. 4–5).
Reference. Cookson, and Eisenack, 1965, pp. 126–127, pl. 15, figs. 10–15.
Comments. One specimen was recovered in Sample 511-17-1, 102–104 cm. The specimen recovered lacks the apical and antapical protrusions of the periphragm present on Cookson and Eisenack's illustrated specimens, but otherwise its morphology conforms to their description.

***Systematophora placacantha* (Deflandre and Cookson, 1955) Davey et al., 1969** (Plate 8, Figs. 6–7).
Reference. Deflandre and Cookson, 1955, p. 276, pl. 9, figs. 1–3.
Comments. This species has a known global range of lower Eocene to Miocene and is of little stratigraphic utility. It occurs in Holes 511 and 512.

***Thalassiphora* sp. cf. *T. pelagica* (Eisenack, 1954) Eisenack and Gocht, 1960** (Plate 8, Figs. 1–3).
Comments. This form is present in the Lutetian of Hole 512. The species differs from *Thalassiphora pelagica* in having a periphragm in which the ventral opening is very nearly circular in outline and which has a very sharp termination. The periphragm on many specimens also bears a distinctive antapical projection. Forms intermediate between those illustrated here and more typical *T. pelagica* were not found.

Forma A (Plate 7, Figs. 3–4).
Comments. A single specimen occurs in Sample 511-15-1, 38–40 cm. Characteristic features are a spheroidal main body, faint indications of paratabulation, and a precingular archeopyle formed by the loss of paraplates 2″ and 3″ (Type 2P).

Cysts of Unknown Affinities

Forma B (Plate 10, Figs. 1–3).
Comments. This form occurs in Sample 512-18-3, 14–16 cm in moderate abundance. Forma B is small (less than 35 μm in total diameter, including processes), has an apical archeopyle, and bears numerous nontabular processes whose bases are connected by faint linear features (Plate 10, Figs. 1–3) and whose tips expand rapidly into distally open, goblet-shaped (caliculate) tips.

Forma P (Plate 5, Figs. 5–13).
Comments. The form is present in the upper Eocene and lower Oligocene of Holes 511 and 513A. This small (less than 35 μm maximum dimension) cyst has an apical archeopyle; an apical structure of variable form may be present on the operculum. The two wall layers are in contact along the paracingular and antapical areas but are separated in the pre- and postcingular areas to form a small pericoel or series of processlike structures encircling the main body in these regions. There is a great degree of variation in the pericoel development, and this will be documented in a subsequent report.

Forma T (Plate 6, Figs. 13–16).
Comments. This enigmatic form occurs in the lower Oligocene of Holes 511 and 513A. The cyst consists of an autophragm with an apical archeopyle; it is typically folded or otherwise distorted. Faint parasutural ridges indicate a paratabulation but a complete formula and paraplate configuration have not been determined because of severe folding in most specimens. Typical specimens present only a hint of the pattern in the form of a triple paraplate junction (Plate 6, Figs. 15) or as an indication of a portion of the paracingulum (Plate 6, Figs. 15–16) or parasulcus.

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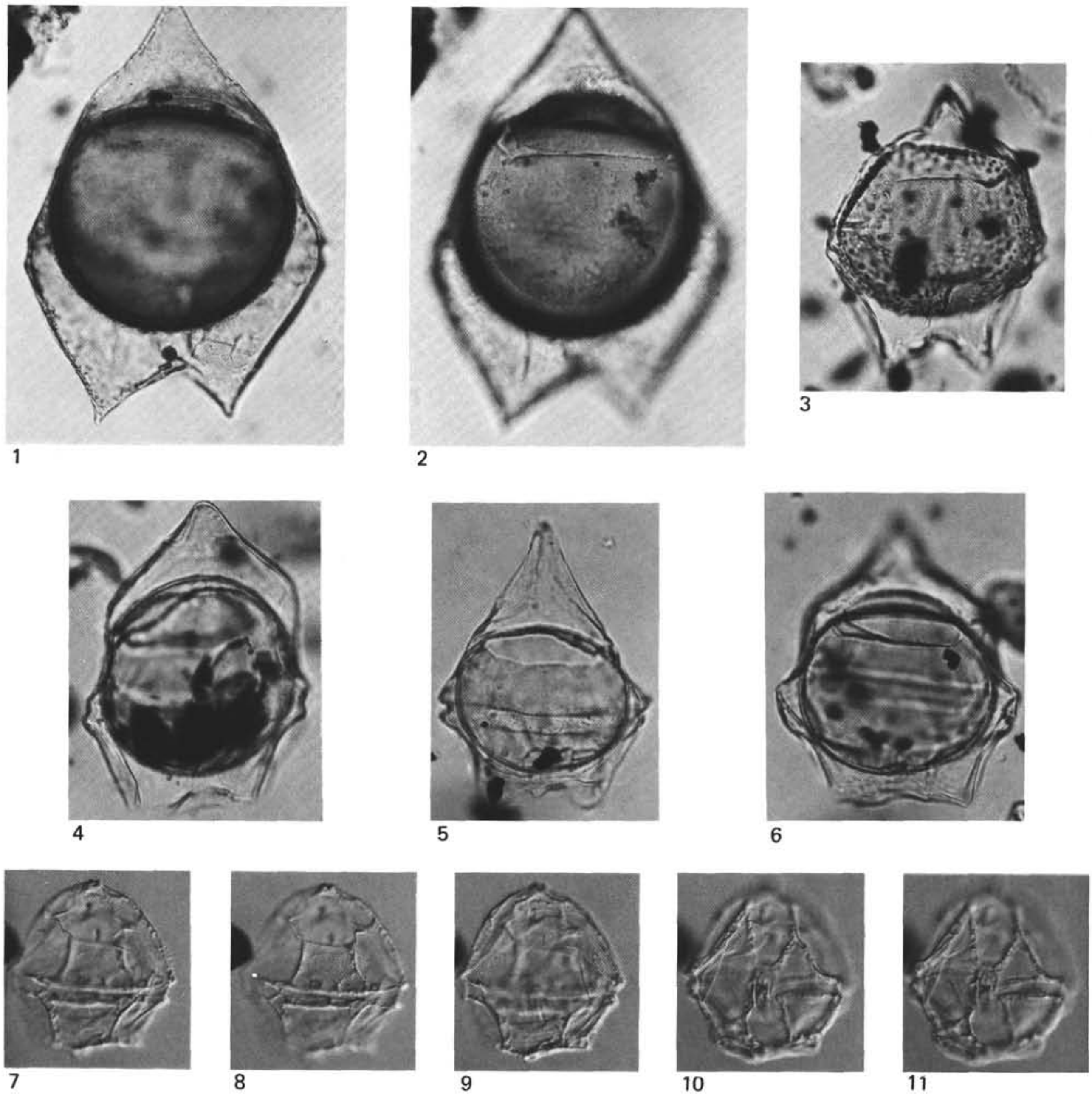

Plate 1. (Figs. 1–6 magnified ×400, photographed using bright field; Figs. 7–11 magnified ×480, photographed using Nomarski interference contrast.) 1–2. *Deflandrea phosphoritica* Eisenack, 1938; ventral view. Sample 511-16,CC (1) optical section (2) dorsal focus. 3. *Deflandrea heterophlycta* Deflandre and Cookson, 1955; ventral view, optical section. Sample 512-15-1, 117–119 cm. 4–6. *Deflandrea antarctica* Wilson, 1967; several representative specimens (4) ventral view, optical section. Sample 512-18-3, 14–16 cm (5) dorsal view, optical section; Sample 512-10-3, 26–28 cm (6) ventral view, dorsal focus. Sample 512-18-3, 14–16 cm. 7–11. *Phthanoperidinium* sp. B; focus series through specimen in dorsal view. Sample 512-18-3, 14–16 cm (7) dorsal focus, showing 3–5″ and 2–4‴ (8) dorsal focus, somewhat lower than Fig. 7: 4″ and archeopyle are in focus (9) optical section (10) ventral view, showing gabled upper margins of triangular 1″ and 7″; first apical paraplate contacts 1″, 2″, 6″, and 7″ (11) ventral focus, somewhat lower than Fig. 10: 1″ and 7″ are in focus; note offset ends of paracingulum.

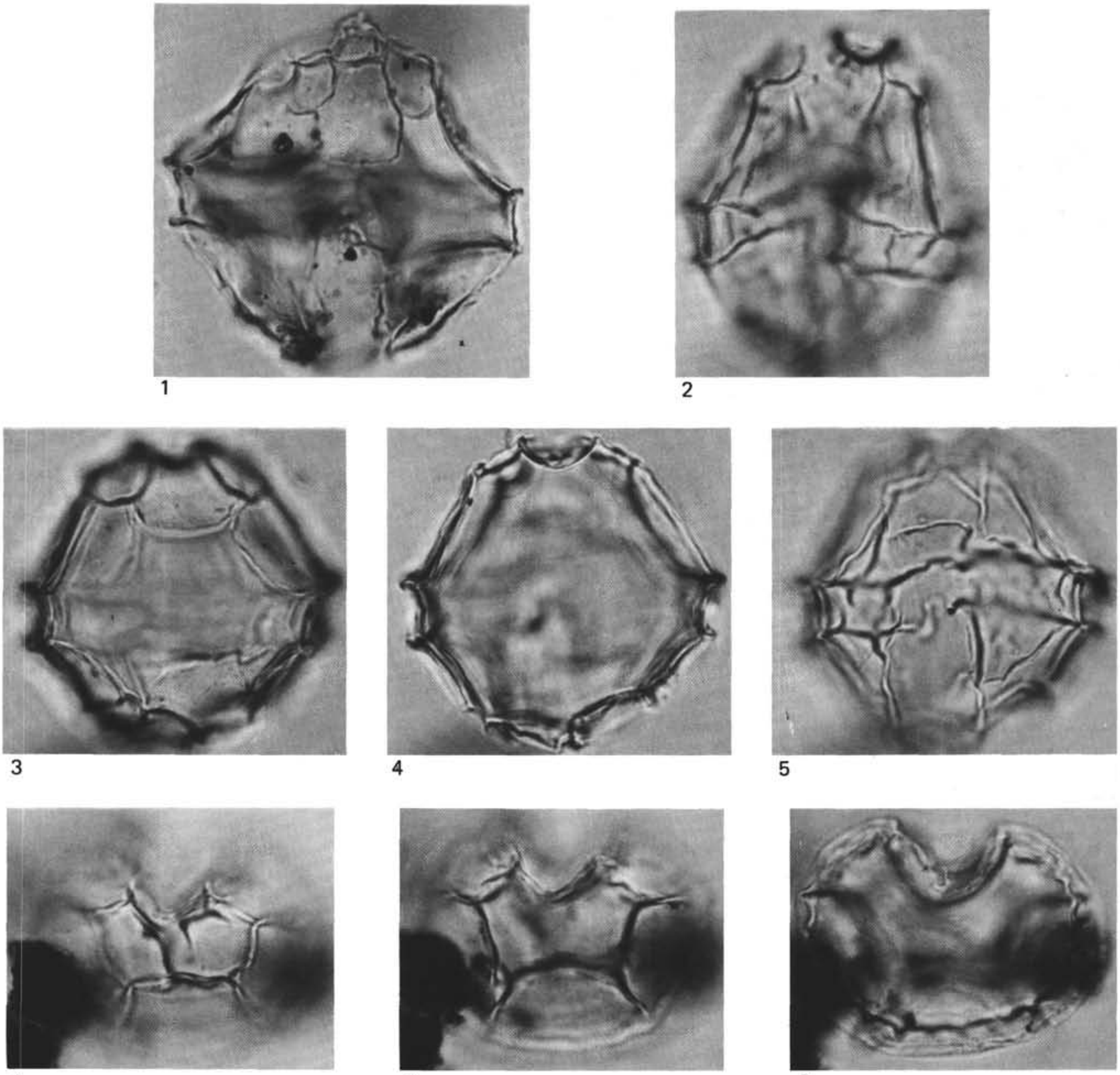

Plate 2. (All specimens magnified ×1000, bright field illumination.) 1–8. *Phthanoperidinium* sp. A., (1) dorsal view; dorsal focus showing three anterior intercalary paraplates. Sample 511-11,CC (2) dorsal view, ventral focus of epicyst showing ortho configuration of paraplates $1'$, $1''$, and $7''$. Sample 511-12,CC (3–5) focus series through specimen in ventral view. Sample 511-12,CC (3, dorsal focus; 4, optical section; 5, ventral focus). (6–8) focus series through specimen in antapical view. Sample 511-12,CC (6, antapical focus showing paraplates $1''''$ and $2''''$; 7, somewhat lower focus level showing five postcingulars; 8, equatorial section showing lenticular outline).

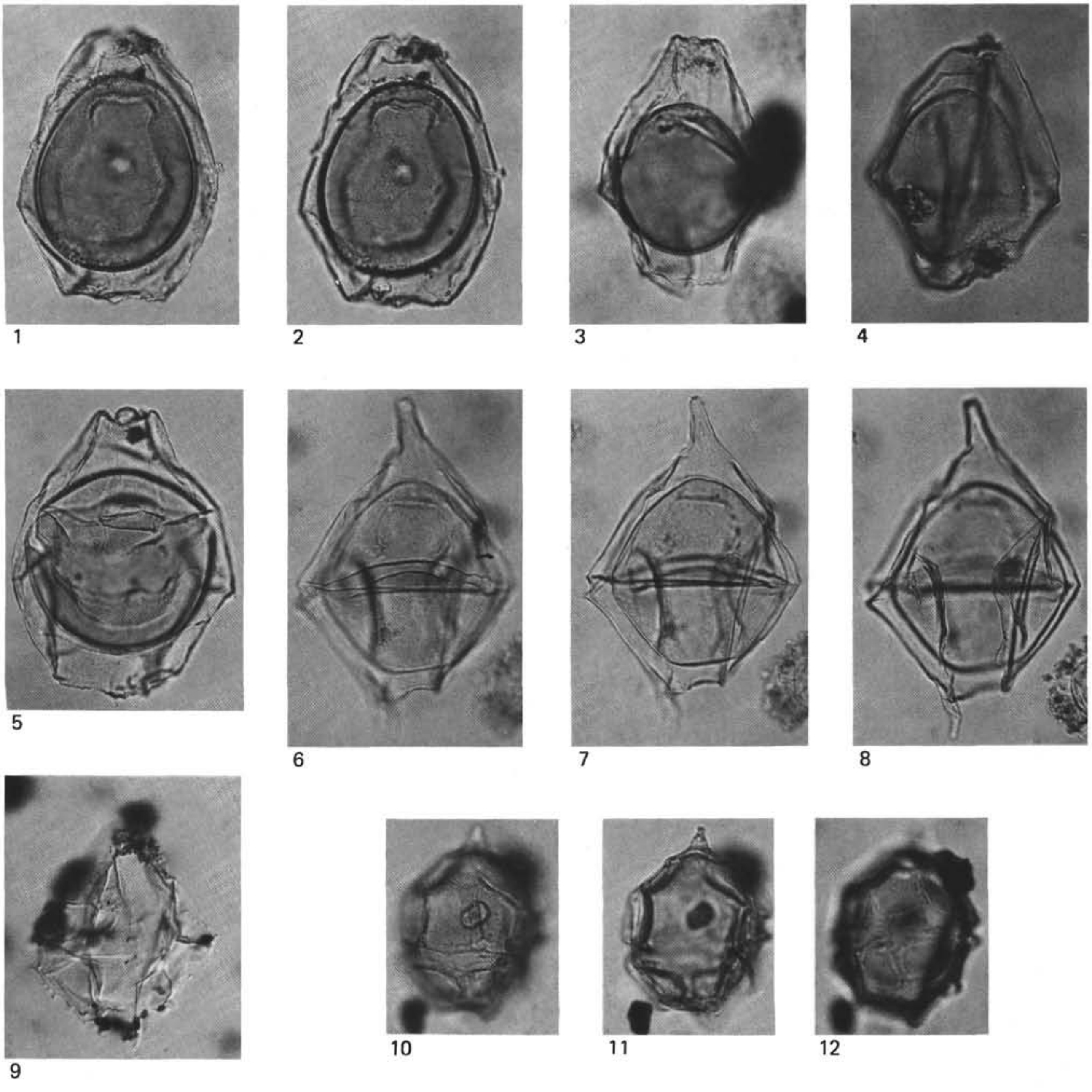

Plate 3. (Figs. 1–8 magnified ×400; Figs. 9–12 magnified ×480. Bright field illumination unless otherwise indicated.) 1–5. *Eurydinium* sp. Several specimens shown to illustrate variation in pericyst shape (1) dorsal focus and (2) optical section of specimen in dorsal view; note attenuated periarcheopyle and zone of pericyst-endocyst contact in (1); in (2) note crescent-shaped endoarcheopyle. Sample 511-20-2, 44–46 cm (3) dorsal view, optical section. Sample 511-20-2, 44–46 cm (4) ventral view, optical section. Sample 511-16,CC (5) ventral view, dorsal focus. Sample 511-20-2, 44–46 cm. 6–8. *Alterbia distincta* (Wilson, 1967) Lentin and Williams, 1976; focus series through specimen in dorsal view. Sample 511-18-2, 40–42 cm (6) dorsal focus (7) optical section (8) ventral focus. 9. *Spinidinium macmurdoense* (Wilson, 1967) Lentin and Williams, 1976; ventral view, optical section in Nomarski interference contrast. Sample 511-15-1, 38–40 cm. 10–12. *Phthanoperidinium eocenicum* (Cookson and Eisenack, 1965) Lentin and Williams, 1973; oblique right lateral view. Sample 511-5-2, 55–57 cm. (10) high focus (11) optical section (12) low focus.

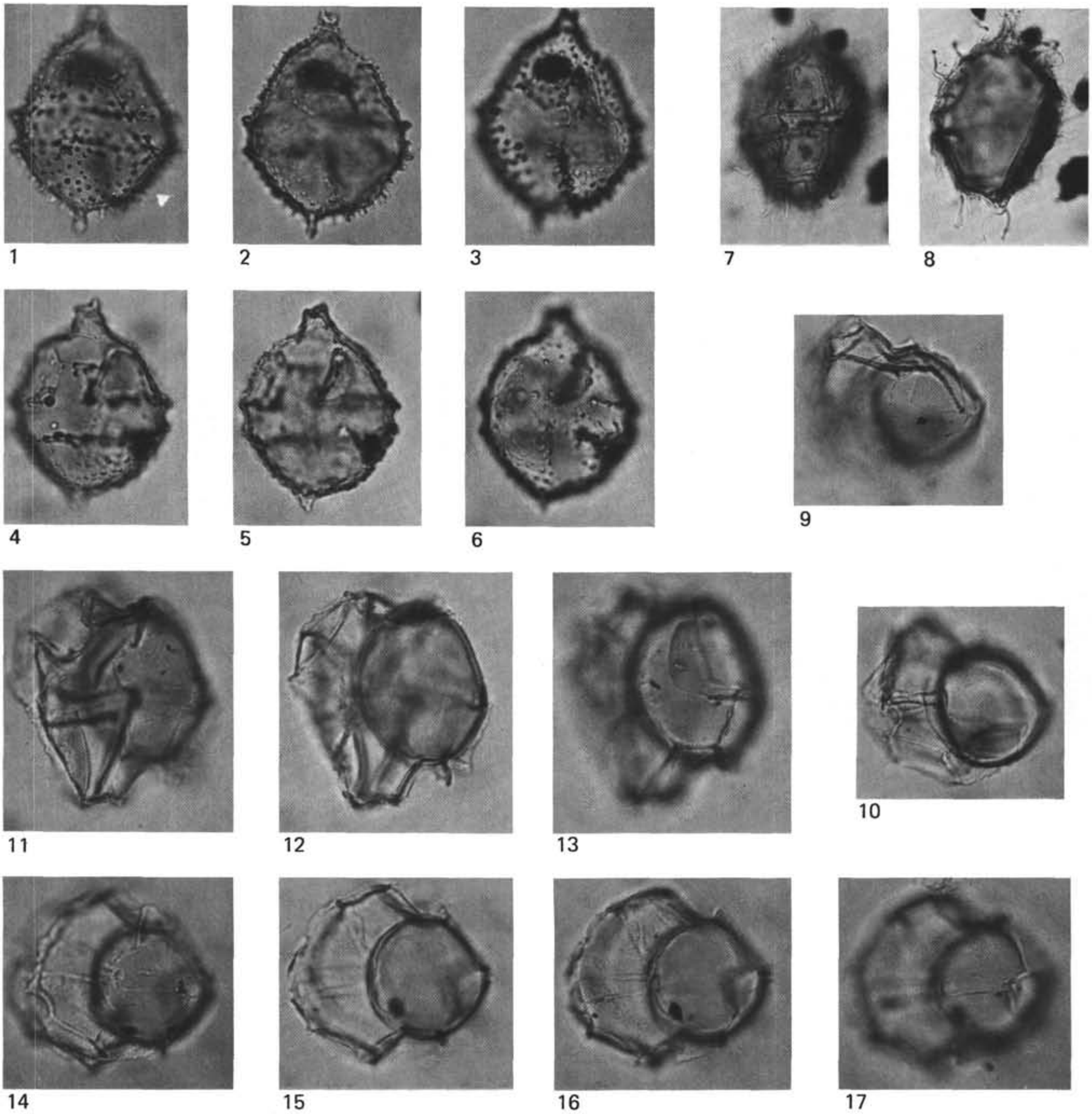

Plate 4. (Figures magnified ×480 unless otherwise indicated; bright field illumination.) 1-6. *Vozzhennikovia apertura* (Wilson, 1967) Lentin and Williams, 1976 (1-3) focus series of specimen in dorsal view. Sample 511-17-1, 102-104 cm (1, dorsal focus; 2, optical section; 3, ventral focus) (4-6) Dorsal view, focus series. Sample 511-16,CC (4, dorsal focus—note Type 3I archeopyle; 5, optical section; 6, ventral focus) 7-8. *Phthanoperidinium comatum* (Morgenroth, 1966) Eisenack and Kjellström, 1971; ×400. Sample 511-5-2, 55-57 cm (7) high focus (8) optical section. 9-17. *Lophocysta* sp.; several specimens illustrated (9-10) left lateral view. Sample 512-12-2, 66-68 cm (9, left lateral focus showing dislodged operculum; 10, optical section). (11-13) focus series through specimen in left lateral view. Sample 512-12-2, 66-68 cm (11, left lateral focus; 12, optical section; 13, right lateral focus) (14-17) focus series through specimen in left lateral view. Sample 512-18-3, 14-16 cm (14, left lateral focus; 15, optical section; 16, right lateral focus showing parasutural ridges developed on ventrally separated periphragm; 17, right lateral focus at a slightly lower level, showing parasutural ridges on main body).

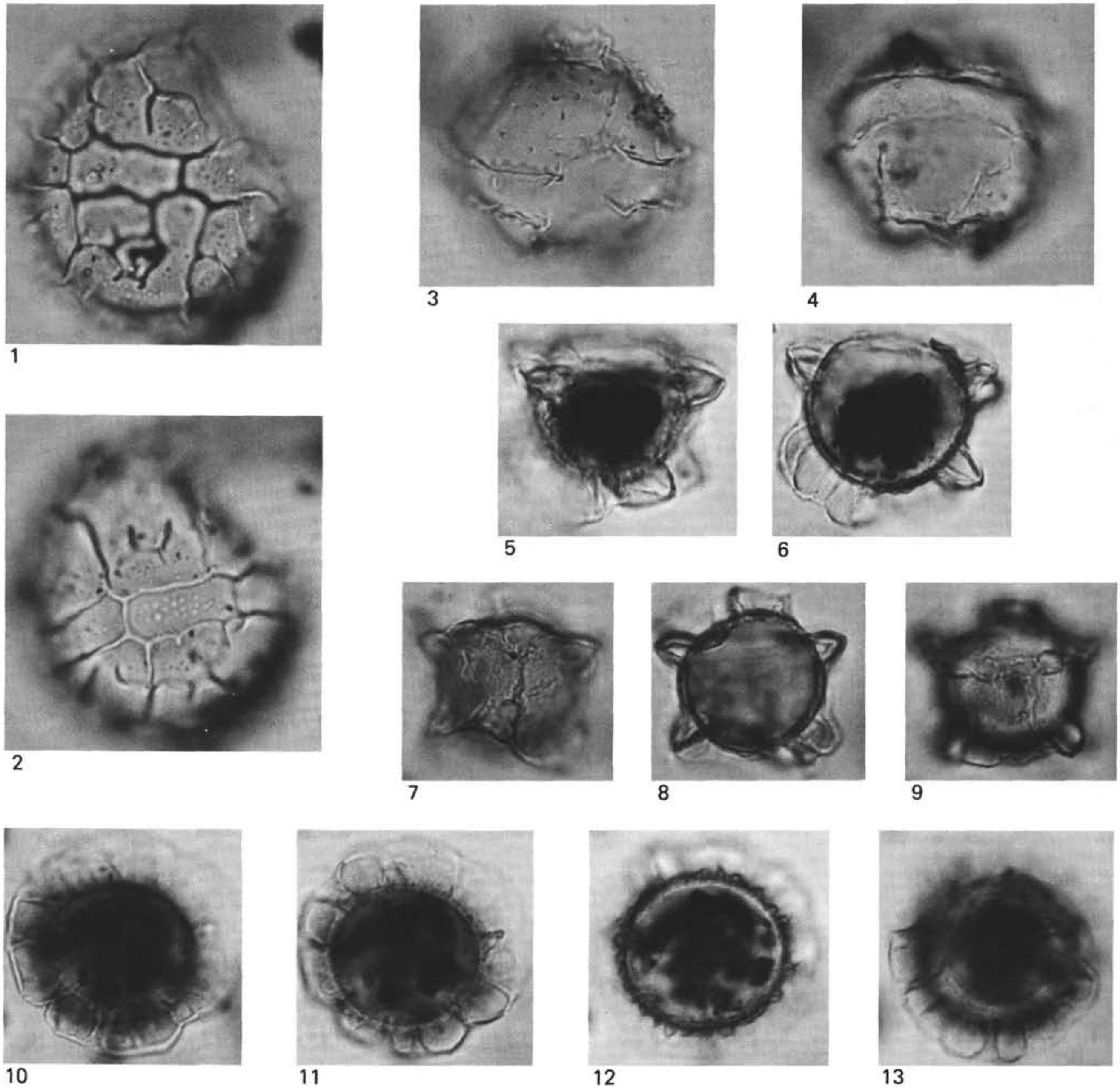

Plate 5. (All figures magnified ×1000; bright field illumination.) 1–2. *Corrudinium incompositum* (Drugg, 1970) Stover and Evitt, 1978; left lateral view. Sample 511-9-2, 102–104 cm (1) left lateral focus (2) right lateral focus. 3–4. Forma C; oblique ventral view. Sample 511-15-1, 38–40 cm (3) oblique ventral focus of epicyst (4) oblique dorsal focus of hypocyst. 5–13. Forma P; several specimens are shown to illustrate morphology, but dorsal-ventral orientation has not been determined. All are from Sample 511-5-2, 55–57 cm (5–6) two focus levels through a specimen showing pre- and postcingular separation of wall layers (5, high focus; 6, low focus) (7–9) three focus levels of a specimen with operculum in place (apical archeopyle) (7, high focus; 8, optical section showing pre- and postcingular separation of wall layers and apical structure on operculum; 9, low focus) (10–13) four focus levels through specimen in apical view (10, apical focus showing archeopyle suture and precingular pericoels; 11, slightly lower focus level on epicyst with precingular pericoel ring in focus; 12, equatorial section showing contact of wall layers; 13, antapical focus with part of postcingular pericoel ring in focus).

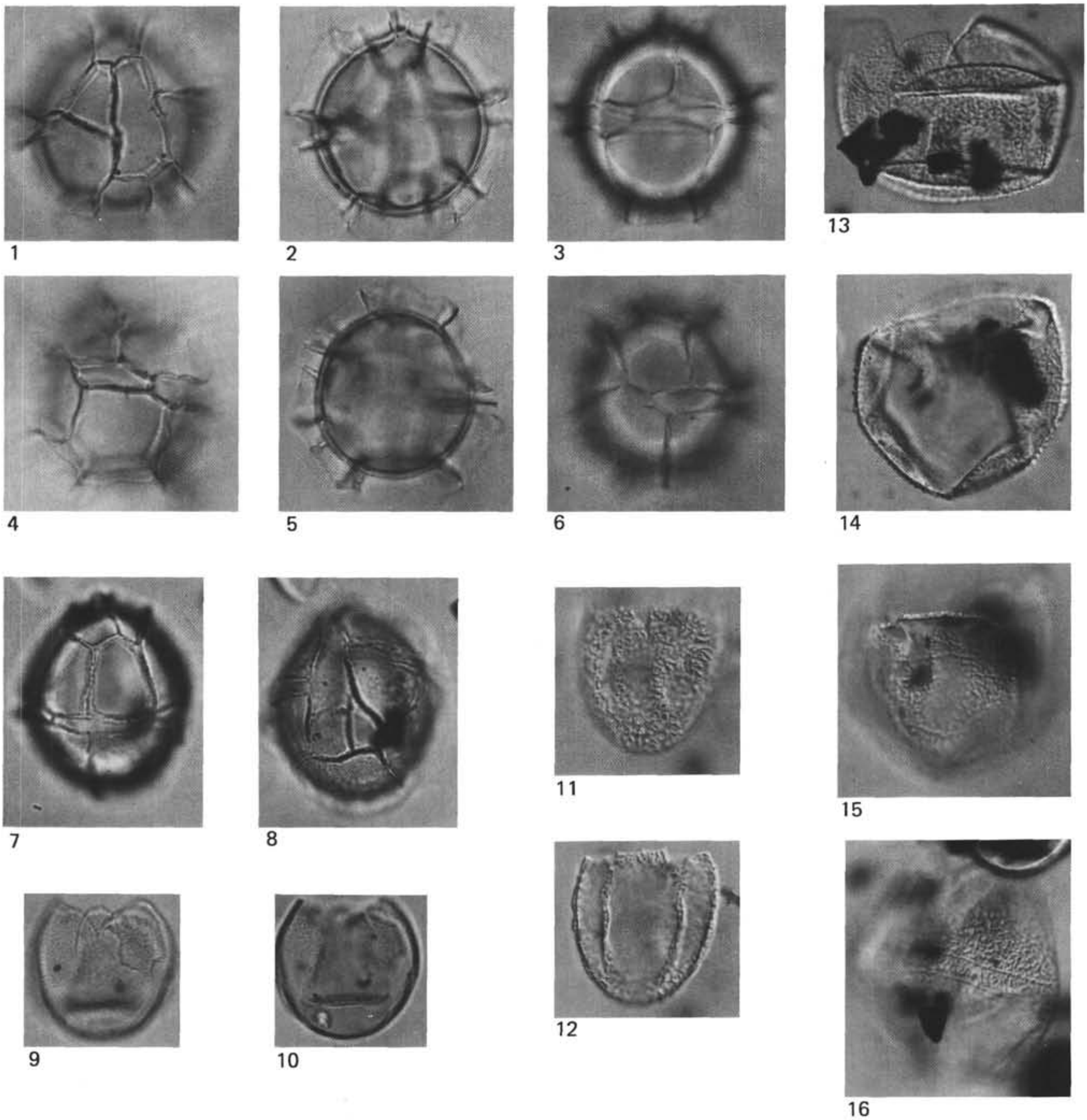

Plate 6 (All figures magnified ×480; Figs. 1-10, bright field illumination; Figs. 11-16, Nomarski interference contrast.) 1-6. *Impagidinium victorianum* (Cookson and Eisenack, 1965) Stover and Evitt, 1978 (1-3) focus series through specimen in ventral view. Sample 512-12-2, 66-68 cm (1, ventral focus showing absence of parasutures between 6c and 6‴ on specimen's right, and between 1c and 2‴ on specimen's left; 2, optical section; 3, dorsal focus), (4-6) focus series through specimen in left lateral view. Sample 512-18-3, 14-16 cm (4, left lateral focus showing loss of parasutural septum between paraplates 1c and 2‴; 5, optical section; 6, right lateral focus showing loss of parasutural septum between 6c and 6‴). 7-8. *Impagidinium* sp.; ventral view. Sample 512-10-3, 26-28 cm (7) dorsal focus (8) ventral focus. 9-10. *Kallosphaeridium capulatum* Stover, 1977; ventral view. Sample 511-3-2, 96-98 cm (9) ventral focus showing attached operculum bent back into cyst cavity (10) optical section. 11-12. *Elytrocysta* sp.; dorsal-ventral orientation not determined. Sample 511-16,CC (11) high focus (12) optical section showing two wall layers. 13-16. Forma T; several specimens shown to illustrate morphology and indications of paratabulation; dorsal-ventral orientation not determined. All specimens occur in Sample 511-4-2, 36-38 cm (13) high focus level of specimen showing probable apical archeopyle (14) optical section and (15) high focus of one specimen (16) high focus of specimen with paracingulum indicated by two parallel parasutural ridges.

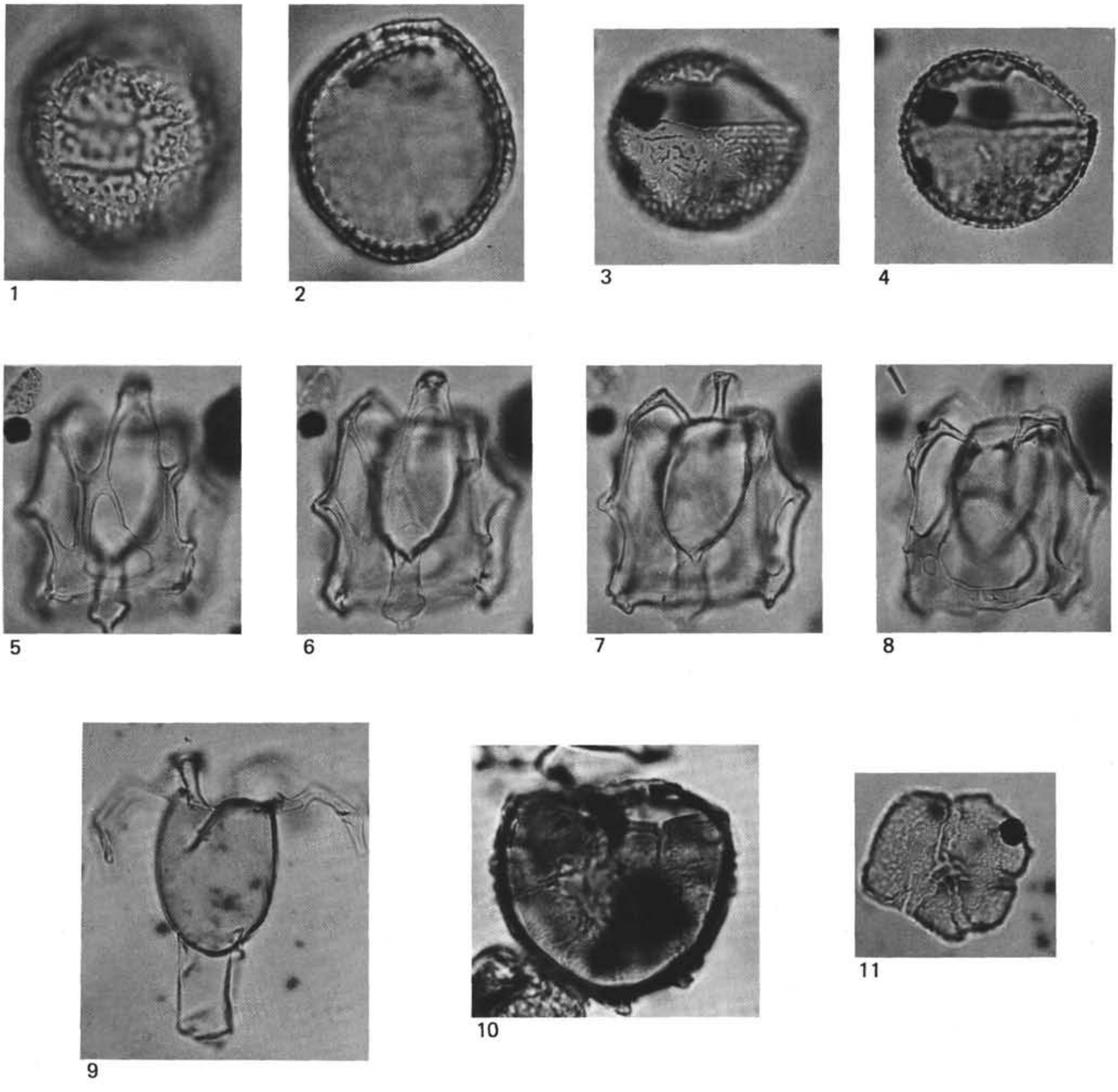

Plate 7. (All figures photographed using bright field illumination.) 1–2. *Histocysta* sp., ×1000. Sample 512-10-3, 26–28 cm (1) high focus (2) optical section. 3–4. Forma A; dorsal view, ×480. Sample 512-15-1, 117–119 cm. (3) dorsal focus (4) optical section. 5–9. *Adnatosphaeridium* sp.; orientation not determined; focus series, ×400. Sample 512-18-3, 14–16 cm (5) low focus showing trabeculae (6) higher focus level showing antapical process (7) optical section showing ellepsoidal main body and precingular processes (8) high focus (9) optical section; trabeculae are missing. Sample 511-17-1, 102–104 cm. 10–11. *Alisocysta ornata* (Cookson and Eisenack, 1965) Stover and Evitt, 1978 (10) dorsal view, ventral focus, ×480. Sample 511-17-1, 102–104 cm (11) antapical view of poerculum, ×480. Sample 511-17-1, 102–104 cm.

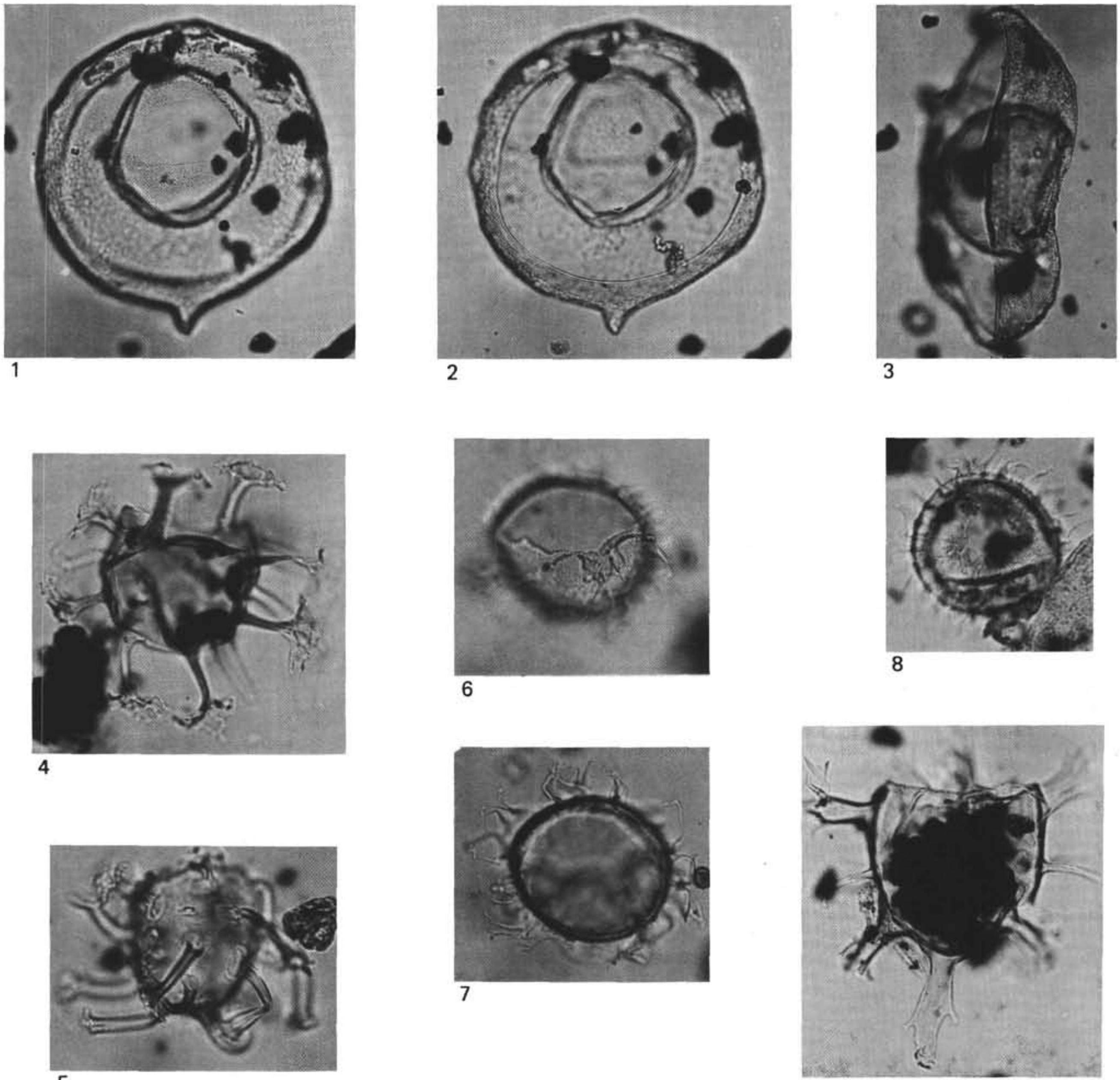

Plate 8. (All figures photographed using bright field illumination.) 1–3. *Thalassiphora* sp. cf. *T. pelagica* (Eisenack, 1954) Eisenack and Gocht, 1960; ×250. Sample 512-15-1, 117–119 cm (1) and (2) are, respectively, dorsal and ventral focus levels of a specimen in ventral view (3) apical view, apical focus. 4. *Areosphaeridium* sp. cf. *A. diktyoplokus* (Klumpp, 1954) Eaton, 1971; ×480. Optical section; orientation not determined. Sample 511-17-1, 102–104 cm. 5. *Hystrichosphaeridium tubiferum* (Ehrenberg, 1836) Deflandre, 1937 emend. Davey and Williams, 1966; ×480. High focus; orientation not determined. Sample 512-15-1, 117–119 cm. 6–7. *Systematophora placacantha* (Deflandre and Cookson, 1955) Davey et al., 1969; ×400. Ventral view. Sample 512-15-1, 117–119 cm (6) ventral focus (7) optical section. 8. *Operculodinium centrocarpum* (Deflandre and Cookson, 1955) Wall, 1967; ×400. Dorsal view, dorsal focus. Sample 511-18-2, 40–42 cm. 9. *Hystrichokolpoma rigaudiae* Deflandre and Cookson, 1955; dorsal view, optical section; ×400. Sample 511-4-2, 36–38 cm.

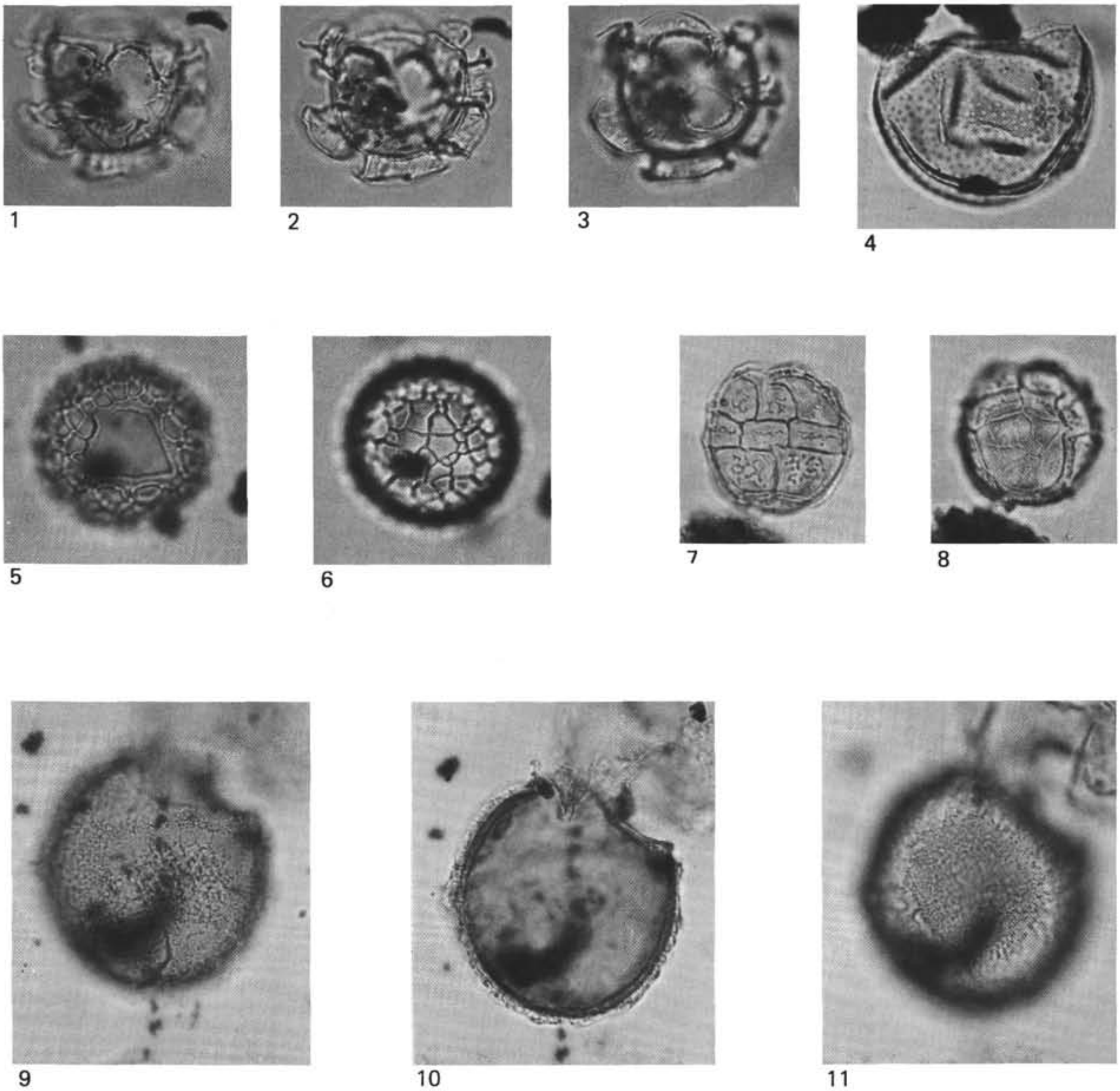

Plate 9. (Figures magnified ×480 unless otherwise indicated; bright field illumination.) 1–3. *Hemiplacophora semilunifera* Cookson and Eisenack, 1965; right lateral view. Sample 512-12-2, 66–68 cm (1) right lateral focus (2) optical section (3) left lateral focus. 4. *Batiacasphaera* sp.; optical section, orientation not determined. Sample 511-18-2, 40–42 cm. 5–6. *Pyxidinopsis* sp.; dorsal view. Sample 512-18-3, 14–16 cm. (5) dorsal focus (6) ventral focus. 7–8. *Histiocysta* sp.; oblique dorsal view. Sample 511-17-1, 102–104 cm (7) oblique dorsal focus, (8) oblique ventral focus. 9–11. *Ochetodinium* sp.; oblique left lateral view, ×400. Sample 511-17-1, 102–104 cm (9) oblique left lateral focus (10) optical section (11) oblique right lateral focus.

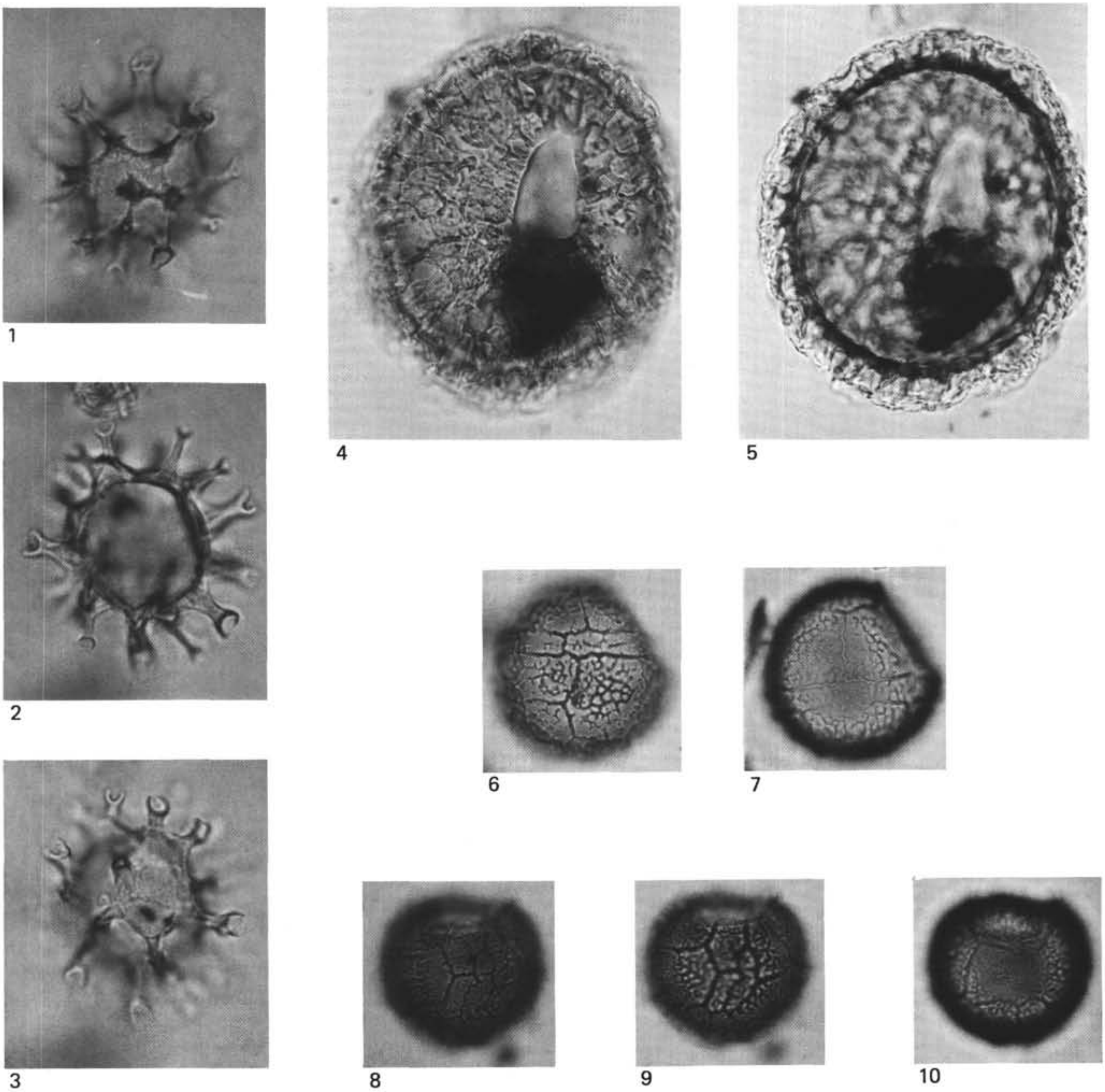

Plate 10. (All figures magnified ×400 unless otherwise indicated; bright field illumination.) 1–3. Forma B; orientation not determined, ×1000 (1) high focus. Sample 512-18-3, 14–16 cm (2) optical section and (3) high focus of one specimen. Sample 512-18-3, 14–16 cm. 4–5. *Samlandia reticulifera* Cookson and Eisenack, 1965; dorsal view. Sample 511-17-1, 102–104 cm (5) dorsal focus (6) optical section. 6–10. *Corrudinium* sp. (6–7) left lateral view. Sample 511-18-2, 40–42 cm (6, left lateral focus; 7, right lateral focus) (8–10 apical view. Sample 511-18-2, 40–42 cm (8, apical focus, showing 4 apical paraplates and 1 preapical paraplate; 9, slightly lower focus level on epicyst, showing 6 precingulars and anterior sulcal—apical margin of archeopyle is in focus at top of photomicrograph; 10, antapical focus).