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

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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 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 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...
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, Elytrocyta 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.

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**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 *Alisocyta 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, *Alisocyta ornata*, *Deflandrea phosphoritica*, *Hystrichokolpoma rigaudiae*, *Impagidinium victorianum*, *Phthano- peridinium 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 in- compostum*, *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*, *Arenosphaeridium* sp. cf. *A. diktypolokus*, *Deflandrea antarctica*, *D. phosphoritica*, *Spindinium macmurodense*, and *Vozzhennikovia apertura*. At Site 283, species also found in Hole 511 are *A.* sp. cf. *A. diktypolokus*, *Corrudinium* sp. (identified by Haskell and Wilson as *Leptodinium* sp.), *D. phosphoritica*, *Impagidinium victorianum*, *S. macmurodense*, 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*, *Arenosphaeridium* sp. cf. *A. diktypolokus*, *Hystrichosphaeridium tubiferum*, *Spindinium macmurodense*, 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°34.99' S; 40°38.40' 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*, *Phthano- peridinium comatum*, *Histiocysta* sp., *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.

**Hole 513B**

Hole 513B was drilled on the northeast flank of the Maurice Ewing Bank (Fig. 1) in 1846 meters of water. It is located at 49°34.99’ S; 40°38.40’ 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 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*, *Phthano- peridinium comatum*, *Histiocysta* sp., *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**

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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-
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 middle- 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 differentiation) 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

We wish to thank R. W. Harris, Jr., and F. E. May for reviewing the manuscript and offering constructive criticism. Discussions with L. E. Stover supported our morphologic interpretations of several taxa, and we thank him, Exxon Production Research Company granted permission to DKG to publish this article.

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.

Peridiniacean Group

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


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

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

<table>
<thead>
<tr>
<th>Core/Section (interval in cm)</th>
<th>Forms P</th>
<th>Impagidinium victorianum</th>
<th>Deflandrea antarctica</th>
<th>Phthanoportidinium sp. A</th>
<th>Coryninae Incognitum</th>
<th>Forms T</th>
<th>Age (This, this volume)</th>
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511-18-2, 40-42 cm (upper Eocene). Populations of this species display archaeopyle that vary from ones characteristic of Alterbia (epipericoel in communication with exterior through the archaeopyle) 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 archaeopyle 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).
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 indicative of 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, fig. 1-4) and Kemp (1975, p. 604, pl. 1, figs. 1-6) as Deflandrea oebisfeldensis Alberti are here considered assignable to D. antarctica.

Deflandrea heterophylla Deflandre and Cookson, 1955 (Plate 1, Fig. 3).
Comments. This species occurs in low numbers in Hole 511.

Deflandrea phosphoritica Eisenack, 1938 (Plate 1, Figs. 1-2).
Comments. D. phosphoritica occurs sporadically in Holes 511 and 512 (Lutetian to lower Oligocene).

Eurydinium sp. (Plate 3, Figs. 1-5).
Comments. This species occurs in low numbers in Hole 511.
Reference. Wilson, 1967, pp. 60, 62, figs. 2a, 11-16, 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 indicative of 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, fig. 1-4) and Kemp (1975, p. 604, pl. 1, figs. 1-6) as Deflandrea oebisfeldensis Alberti are here considered assignable to D. antarctica.
Figure 5. Comparison of four styles of ventral paratabulation in fossil peridinianacean 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* Goodwin and Evitt and in the modern diatom 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 *Phthi- noperidinium brooksi* Edwards and Bebout, has this style, and it is present in many modern species. The para style (D), demonstrated on *Phthi- noperidinium* 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 periarchoype 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 archoype formation. This can be interpreted either as a variable archoype of Types I, 21, or 31, or as a Type 31 in which the loss of the three paraplates is progressive. Details of the endarchoype are not known. There is a great amount of variation in the distribution and density of coni on the peripher amy.

**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 peridinianacean paratabulation; however, no archoype was observed. The outer wall is ornamented with numerous, apparent-ly nontabular, short coni.

**Gonystlaulacean 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 elliptoidal main body with an apical archoype; 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 paracircular, postcircular, posterior intercalary, or other paraxial 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.

**Albocysta 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. This 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 Hemispheric localities (Wilson, 1967, p. 67, figs. 33, 35; Kemp, 1975, p. 605, pl. 3, figs. 5-8; Haskell and Wilson, 1975, pi. 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* p.s.

**Batiasphaera sp.** (Plate 9, Fig. 4).
**Comments.** This species occurs in the upper Eocene of Hole 511. *Batiasphaera* 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 in 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.

**Corrubinum 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 512A.

**Corrubinum 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 paranugal ridges, a precingular archoype (Type P; 3' only), and by numerous discontinuous ridges (of lower relief than the paranugal ridges) which occur within the paraplate boundaries. It is larger than *Corrubinum 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 archoype 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.

Comments. This form is present in the Lutetian of Hole 512. The (Deflandre and Cookson, 1955) Davey Systematophora placacantha sp. (Plate 9, Figs. 5-6).

Pyxidinopsis Deflandre, 1937, p. 68; Davey and Williams, 1966, pp. 5-66.

References. 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).


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).

Kallosporella capitatum Stover, 1977 (Plate 6, Figs. 9-10).


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 gonyaulacaceous paratabulation indicated by faint parasutural ridges characterize this form and differentiate it from L. sulcolumbata Manum. The latter species has a much narrower zone of endophragm/periphragm separation (which is confined essentially to the parascalcal 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 paracingulae 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 referable 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).


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 piaccartha (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.


Comments. This form is present in the Lutetian of Hole 512. The species differs from Thalasiosphora pelagica in having a peri-


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 heterophylcta* 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 archepyle 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.)
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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–endozyst 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 511-18-2, 40-42 cm (6) dorsal focus (7) optical section (8) ventral focus. 9. Spinidinium macmurdoense (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. 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 31 archeopyle; 5, optical section; 6, ventral focus). 7-8. *Phthano-peridinium 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. Corradiniun 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 pericoel; 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 ellipsoidal 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 poeculum, ×480. Sample 511-17-1, 102-104 cm.
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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).