DINOFLAGELLATE CYSTS OF THE GYMNODINIACEAE, PERIDINIACEAE, AND GONYAULACACEAE FROM THE UPPER CRETACEOUS MONMOUTH GROUP, ATLANTIC HIGHLANDS, NEW JERSEY

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INTRODUCTION

General Statement

Extensive studies of fossil dinoflagellate assemblages of the mid-Atlantic Coastal Plain of Virginia, Maryland, and Delaware have demonstrated their value in biostratigraphy and paleoecology. To date, studies of Tertiary dinoflagellate assemblages have been completed for the Paleocene Brightseat Formation of Maryland and Virginia (Benson, 1975; Whitney, 1976), the Paleocene Aquia Formation of Virginia (McLean, 1971; Witmer, 1975), and the Eocene Nanjemoy Formation of Virginia (Goodman, 1975). Studies of Upper Cretaceous dinoflagellate assemblages have been carried out on the Campanian-Maestrichtian Monmouth Formation of Maryland and Virginia (Benson, 1975; Whitney, 1976) and the Mount Laurel Sand of Delaware (Whitney, 1976). To expand the taxonomic understanding and the biostratigraphic and paleoecologic potential of fossil dinoflagellates in the extensive Upper Cretaceous marine sequence of the northern Atlantic Coastal Plain, the author selected a recognized reference section, the Monmouth Group of Monmouth County, New Jersey, for a dinoflagellate study. Although the Monmouth Group crops out in a continuous band southwestward across New Jersey, the unit is best known from the excellent exposures within Monmouth where the formational stratotypes are located: (from oldest to youngest) the Mount Laurel Sand, Navesink Formation, Red Bank Sand, and Tinton Formation.

The bluffs at Atlantic Highlands, Monmouth County, have especially attracted paleontologists since the early 1800's, and some of the

classical paleontological works of the Upper Cretaceous Atlantic Coastal Plain have included this area (Say, 1820; Whitfield, 1892; Prather, 1905; Weller, 1907; Stephenson, 1920; Stephenson and others 1942). Recent efforts involving this locality have been carried out by Olsson (1960, 1963, 1964), Sohl and Mello (1970), and Cobban (1974). Although this present dinoflagellate study is primarily a taxonomic investigation, the author hoped to use paleoecologic and geologic-age data previously gathered by other workers from invertebrate assemblages within the county to aid in interpreting the stratigraphic distribution, species diversity, and relative frequencies of dinoflagellate species.

The study area selected is east of Atlantic Highlands, Monmouth County, where the high bluffs expose sections of the upper Mount Laurel Sand, Navesink Formation, and Red Bank Sand. During a preliminary field trip to this locality in March, 1972, samples were collected from these units and were later macerated for palynomorphs. The resulting residues contained highly-diverse and well-preserved dinoflagellate assemblages for all units except the Shrewsbury Member of the Red Bank Sand, a red bed sequence, which overlies the Sandy Hook Member of the Red Bank Sand; oxidation of the Shrewsbury Member appears to have destroyed the dinoflagellate assemblages. Because of the high species diversity and the taxonomic problems involved in the investigation of the recovered assemblages it was decided to limit the study to dinoflagellates of the families Gonyaulacaceae,

Peridiniaceae, and Gymnodiniaceae; it was also decided to exclude the lower Mount Laurel Sand and Tinton Formation from the study. Samples for this investigation were collected during a second trip to the study area in June, 1972. The outcrop selected, a continuous section of the upper Mount Laurel Sand, Navesink Formation, and Red Bank Sand, occurs approximately 450 meters east of the Atlantic Highlands Yacht Harbor compound. Samples were collected at 0.5 meter intervals from the upper Mount Laurel Sand (7 samples), the Navesink Formation (17 samples), and the Sandy Hook Member of the Red Bank Sand (13 samples). These samples yielded a highly diverse phytoplankton assemblage consisting of approximately 200 species of dinoflagellates and acritarchs. Although this study reports only on the 91 species of the Gonyaulacaceae, Peridiniaceae, and Gymnodiniaceae, the remaining species will be included in later publications.

Scope of This Investigation

Because so little data has been gathered on Campanian-Maestrichtian age dinoflagellate assemblages of the Atlantic Coastal Plain, this study is aimed primarily at fundamental results which will contribute to future biostratigraphic and paleoecological studies. The scope of this study is to:

a. identify, describe, discuss, and illustrate the fossil dinoflagellate cysts of the Gymnodiniaceae, Peridiniaceae, and Gonyaulacaceae in the upper Mount Laurel Sand, Navesink

Formation, and Sandy Hook Member of the Red Bank Sand of Atlantic Highlands, New Jersey.

b. illustrate population and lineage variability for selected species.

c. provide functional morphology studies of selected taxa and possible related paleoecological interpretations.

d. investigate the relationship between change in dinoflagellate relative frequency and accompanying change in paleoenvironment.

e. correlate the dinoflagellate assemblages of the units studied with those of eastern Europe, especially with type sections.

f. determine the stratigraphic position of the Campanian-Maestrichtian boundary on the basis of dinoflagellates.

g. add supporting information on the geologic ages of the upper Mount Laurel Sand, Navesink Formation, and Sandy Hook Member of the Red Bank Sand.

h. determine the stratigraphic ranges of fossil dinoflagellates in the units studied.

HISTORICAL SUMMARY OF THE MONMOUTH GROUP

A historical summary of the development of rock-stratigraphic terminology for the Upper Cretaceous Monmouth Group is given in text-fig. 1. The strata now referred to the Monmouth Group initially had formational status, being named the Monmouth Formation by Clark (1897) from exposures in Monmouth County, New Jersey. The Monmouth Formation included the following units which Clark had previously named and described: (oldest to youngest) the Mount Laurel Sands, the Navesink Marls, and the Red Bank Sands (Clark, 1897, 1894, and 1893, respectively). Weller, in 1907, elevated the Monmouth to Group rank, and also raised the Mount Laurel Sands, Navesink Marls, and Red Bank Sands to formational rank. The overlying Tinton Sand, named by Weller in 1904, was also included in the Monmouth Group. Thus, by 1907 the current rock-stratigraphic terminology had been established for these units in New Jersey. Later, the Red Bank Sand was subdivided by Olsson (1960) into 2 members: the basal Sandy Hook Member and the Shrewsbury Member. This study follows the terminology used by Olsson (1960) (text-fig. 1)

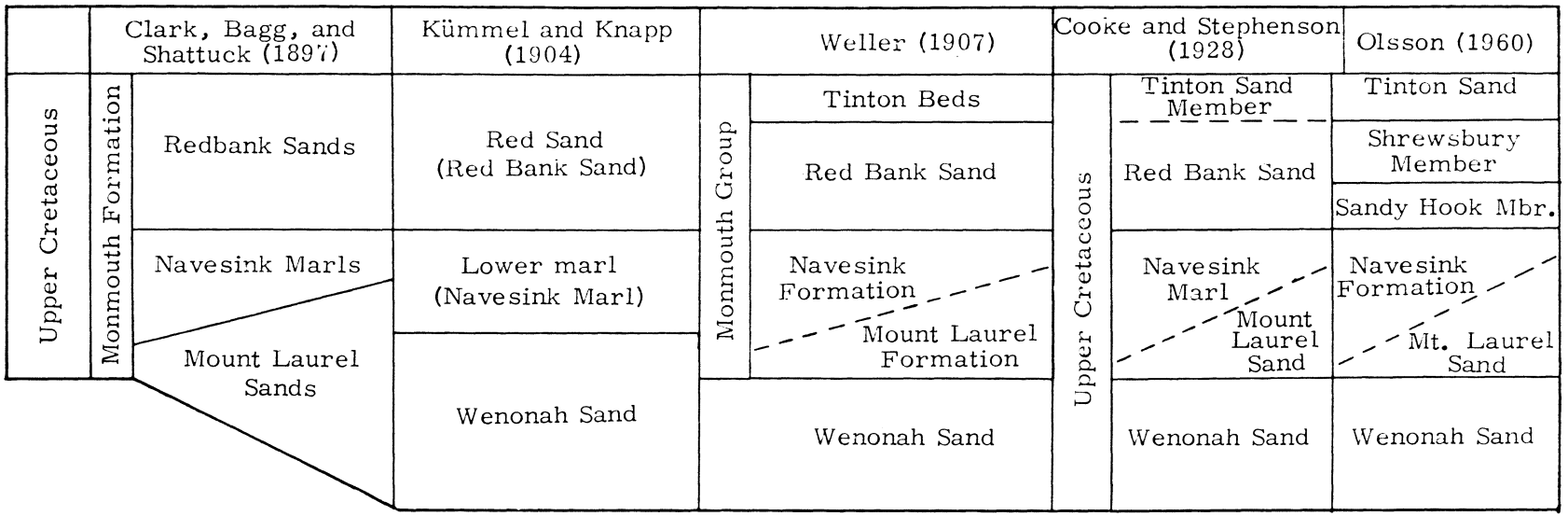


Figure 1. Historical development of rock stratigraphic terminology for the Monmouth Group (modified from Owens, Minard, Sohl, and Mello, 1970).

PREVIOUS STUDIES OF UPPER CRETACEOUS DINOFLAGELLATES

There have been few published studies of Upper Cretaceous dinoflagellates in North America. Drugg (1967) described assemblages of the Maestrichtian-Danian Upper Moreno Formation of California. Zaitzeff and Cross (1970) reported on dinoflagellate distribution in the Navarro Group of Texas. McIntyre (1974) reported on the dinoflagellate distribution in an Upper Cretaceous section of northern Canada. Williams (1975) published a preliminary study which included Upper Cretaceous dinoflagellate distribution in several wells on the Grand Banks and Scotian Shelf of eastern Canada.

Two unpublished studies have been completed to date on Upper Cretaceous dinoflagellate assemblages of the mid-Atlantic Coastal Plain. Benson (1975 unpub. m.s.) reported on the taxonomy and biostratigraphy of fossil dinoflagellates from the Campanian-Maestrichtian Monmouth Formation at Round Bay, Maryland. Whitney (1976 unpub. Ph.D.) investigated the taxonomy, biostratigraphy, and paleoecology of dinoflagellate assemblages of the Campanian age Mount Laurel Sand of northern Delaware and the Campanian-Maestrichtian age Monmouth Formation near Washington, D.C. A study by Waanders (1973) reported mainly on pollen and spores of the Monmouth Group of northern New Jersey and figured some dinoflagellates.

Upper Cretaceous dinoflagellates have received their greatest attention in Europe and Australia. Such studies (see bibliography for details) have been published by the following authors: Cookson and Eisenack (Australia), Deflandre and Lejeune-Carpentier (France and

Belgium), Alberti, Eisenack, Klement, Klumpp, Morgenroth, and O. Wetzel (Germany), Davey, Downie, Sarjeant, Clarke, Verdier, and Williams (England), and Wilson (Netherlands and Denmark).

GEOLOGIC SETTING AND STRATIGRAPHY OF THE MONMOUTH GROUP

General Statement

The Atlantic Coastal Plain physiographic province consists of a thick wedge of largely unconsolidated Mesozoic and Cenozoic sediments bordering the eastern United States. These sediments rest unconformably upon a basement of sedimentary, metamorphic, and igneous rocks of Precambrian through Triassic ages. Irregularities in the thickness of the wedge are controlled mainly by the configuration of the basement complex. The thickest accumulations of sediments occur in troughs and the thinnest on the arches. Two large structural elements which controlled sediment thickness during Upper Cretaceous times in the New Jersey area were the south New Jersey uplift and the Raritan Embayment. The south New Jersey uplift, a structural high, separated the Raritan Embayment on the north from the Salisbury Embayment on the south. The Campanian-Maestrichtian Monmouth Group was deposited within the Raritan Embayment and the group appears restricted to this area. Time-equivalent strata in the Salisbury Embayment are assigned to the Monmouth Formation. In New Jersey the Monmouth Group crops out as a narrow, continuous band which extends from the Atlantic Highlands-Sandy Hook area on the north, southwestward across the state toward northern Delaware. Because of the general low relief

and extensive vegetation over much of the state, well-exposed sections are relatively rare. The best developed exposures occur within Monmouth County where the formational stratotypes for the Monmouth Group are located.

Well-exposed sections of the Monmouth Group occur in the bluffs east of Atlantic Highlands, Monmouth County, New Jersey. Maximum relief along the bluffs is about 80 meters, and the frequent steep faces expose, in ascending order, most of the Mount Laurel Sand, the Navesink Formation, and the Red Bank Sand. These Upper Cretaceous units strike generally northeast and dip between 20 and 40 feet per mile southeast.

Rock-Stratigraphic Units

The Monmouth Group units at Atlantic Highlands, New Jersey, have been described in considerable detail by Minard (1969). They are:

Monmouth Group	Tinton Sand
	Red Bank Sand Shrewsbury Member Sandy Hook Member
	Navesink Formation
	Mount Laurel Sand

In the Atlantic Highlands area of northern New Jersey these formations are well-developed in thickness and have excellent exposure in the bluffs east of Atlantic Highlands. Because this study was limited to the

upper portion of the Mount Laurel Sand, Navesink Formation, and Sandy Hook Member of the Red Bank Sand, only their lithologies are given below (also, see Fig. 2):

The Mount Laurel Sand is subdivided into a lower and an upper part, the lower part being thin-bedded and the upper part being thick-bedded. The upper part, which is included in this study, is 1.5-3 meters thick, and is composed of medium-coarse to pebbly glauconitic quartz sand. The color ranges from light to olive gray and yellowish gray where weathered; it is dark gray and dark greenish black where fresh. The sediment at the base of the bluff at the collecting site was slightly weathered, appearing yellowish gray in color, with faint yellow iron streaks in the sand. A horizon of quartz pebbles and granules mixed with the sand occurs at the top of the Mount Laurel at the collecting site and over much of the northern part of the state. The quartz granules and small pebbles (6 to 9 mm in diameter) are abundant, and some pebbles up to 25 mm in diameter occur near the top of the formation. Minard (1969) reports a considerable amount of mica and glauconite within the top 0.6 to 0.8 meter of the formation. The average grain size in weight percent for the upper portion of the Mount Laurel Sand is:

clay to silt	Sand			Gravel
	Very fine to fine	Medium	Coarse to very coarse	Granule to pebble
31	32	32	2	3

The Navesink Formation in weathered outcrop is dark greenish gray to brownish gray and grayish brown; in fresh outcrop the unit is dark greenish gray to greenish black. The contact with the underlying Mount Laurel Sand is distinctive, the Navesink being massive in appearance, consisting of about 30 percent clay and silt and about 70 percent glauconite. The glauconite grains are coarse, dusky green to olive black, and are botryoidal. In the Atlantic Highlands area the formation is about 7.6 meters thick. The average grain size in weight percent for the Navesink Formation is:

Clay to silt	Sand			Gravel
	Very fine to fine	Medium	Coarse to very coarse	Granule to pebble
upper Mount Laurel 30	10	25	35	0
lower Mount Laurel 26	32	32	10	0

The Sandy Hook Member is the basal member of the Red Bank Sand. In fresh and weathered outcrop the unit is a compact dark-grayish and brownish-black massive-bedded feldspathic sand. The sand is fine to very fine, contains mica grains, and also contains clay and silt. The basal contact with the Navesink Formation is differentiated by the fact that the Sandy Hook Member bears a small, but visible, quantity of mica and glauconite, and a large quantity of quartz sand, whereas,

the Navesink Formation lacks the mica and quartz sand, and is about 70 percent glauconite. At Atlantic Highlands the Sandy Hook Member is 4.6-8.5 meters thick; at the collecting site it is about 6.1 meters thick. The average grain size in weight percent for the Sandy Hook Member of the Red Bank Sand is:

	Clay to silt	Sand		
		Very fine to fine	Medium	Coarse to very coarse
upper Sandy Hook Member	27	53	18	2
lower Sandy Hook Member	36	52	9	3

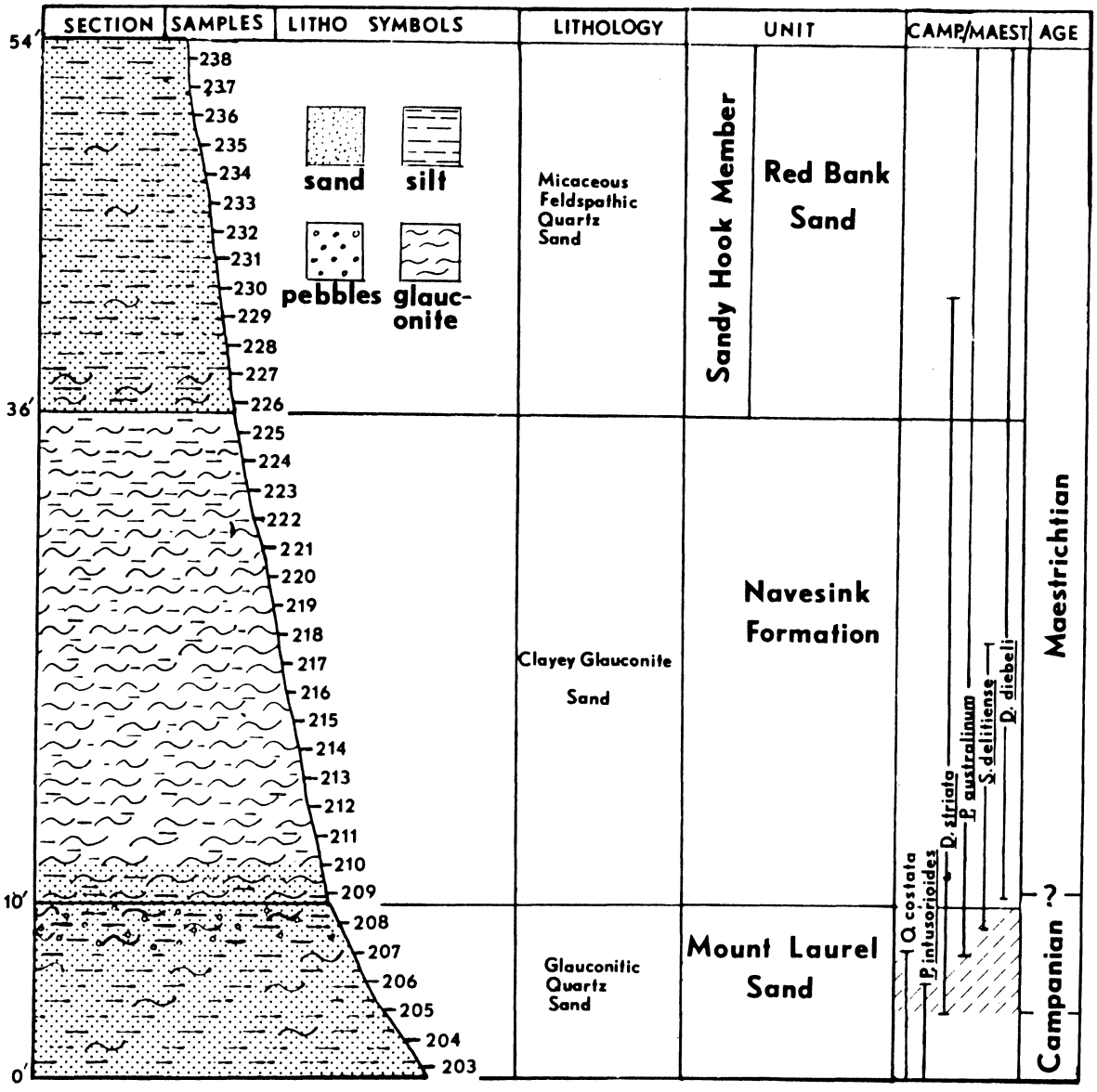


Figure 2. General columnar section of the Mount Laurel Sand, Navesink Formation, and Sandy Hook Member of the Red Bank Sand. The Campanian-Maestrichtian boundary is indicated by the concurrent ranges (within shaded area) of six dinoflagellate species: Odontochitina costata, Palaeohystrichophora infusorioides, Deflandrea striata, Palaeocystodinium australinum, Spongodinium delitiense, and Deflandrea diebeli (after Millioud, Williams, and Lentin, 1975).

Biostratigraphic Units and Correlation with the Navarro Group of Texas

The Exogyra costata Zone and the E. cancellata Zone, combined with invertebrate associations within these zones, are used as a main basis for correlation of the New Jersey Monmouth Group with the Texas Navarro Group (Stephenson, 1941). The presence of E. costata, which had been previously identified in the Navarro Group (ibid.), was first reported in the Monmouth Group by Weller (1907), providing the basis of correlation. Although Weller did not observe E. costata within the Navesink Formation, its stratigraphic position between the Mount Laurel and Red Bank indicates that it must also be within the zone. Therefore, based on the E. costata Zone, the Mount Laurel Sand, Navesink Formation, and Red Bank Sand appear time correlative with the Navarro Group of Texas. Correlation of individual Monmouth Group formations with particular formations of the Navarro Group is also possible. The presence of the Exogyra cancellata Zone within the Mount Laurel Sand suggests time equivalence with the Neylandville Marl, the oldest unit of the Navarro Group. The presence of Baculites claviformis Stephenson and Sphenodiscus in the Navesink Formation suggests that it is time equivalent with the Nacatoch Sand, which is the next younger unit of the Navarro Group. The presence of Pholas and Sphenodiscus in both the Red Bank Sand and the Tinton Sand suggests that they are time equivalent with the Corsicana Marl, the youngest unit of the Navarro Group (Owens and Sohl, 1973, p. 2814).

Time-Stratigraphic Units and the Position of the Campanian-Maestrichtian Boundary

Based on the presence of Navarro Group biostratigraphic zones and invertebrate associations the Monmouth Group is assigned to the provincial Navarroan Stage (Sohl and Mello, 1970).

The assignment of the Monmouth Group to European stages has been inconsistent, depending upon the author and the fossil group used. Although most workers agree that much of the Navesink Formation and all of the Red Bank Sand correlate with the Maestrichtian, controversy has arisen over the age of the Exogyra cancellata Zone of the Mount Laurel Sand. Stephenson (1923, pl. 8) first assigned an age of Campanian to this zone; however, later he indicated an age of late Campanian or early Maestrichtian (Stephenson, 1933, p. 1359). Finally, Stephenson, King, Monroe, and Imlay (1942, chart) suggested a Maestrichtian age. Olsson (1963, p. 647; 1964, p. 158), on the basis of planktonic foraminifera, regarded the Mount Laurel Sand in New Jersey as lower Maestrichtian. Jeletzky (1962, p. 160) considered the Mount Laurel and the overlying Navesink Formation to be of late Campanian age. Recently, Sohl and Mello (1970) studied the invertebrate faunas of the Upper Cretaceous formations of New Jersey and Delaware. Sohl concluded that the Mount Laurel is upper Campanian and that the Campanian-Maestrichtian boundary occurs within the Navesink Formation. Cobban (1974, p. 2-3) reported that several species of ammonites had been discovered near the base of the

Navesink Formation at Atlantic Highlands. The ammonites occur in 2 horizons, one about 27 inches from the base and another about 35 inches from the base. Cobban (1974) stated that the occurrence of a pachydiscid together with a schloenbachi-type of Nostoceras in the upper bed suggests an early Maestrichtian age; whereas, the hyatti-helicinum type of Nostoceras in the lower bed suggests a late Campanian age. Thus, the Campanian-Maestrichtian boundary probably occurs near the base of the Navesink Formation.

Age assignments, based on dinoflagellates, will be discussed later. The Campanian-Maestrichtian boundary as indicated by dinoflagellates agrees basically with that of Cobban (1974, p. 2-3).

Environment of Deposition

The Monmouth Group, according to Owens and Sohl (1969, p. 255-257), was deposited in nearshore gulf and inner to outer shelf marine environments based on a study of sediment types and fossil molluscs. Owens and Sohl (1973, p. 2833-2834), later determined water depths in which the formations of the Monmouth Group were deposited. The water depths were determined from Porrenga's (1967) study of authigenic mineral formation near the Niger Delta off coastal Africa and, also, from Shepard and Moore's (1955) Upper Cretaceous shelf zonation. Combining the information from these

two studies, Owens and Sohl (1973) suggested that the Mount Laurel Sand was deposited in less than 20 meters of water under inner shelf conditions (the upper part may be of nearshore gulf environments according to Owens and Sohl, 1969, text fig. 15); the Navesink Formation was deposited in water depths up to 80 meters under inner to outer shelf conditions; the Sandy Hook Member of the Red Bank Sand was deposited in water depths less than 30 meters under inner shelf conditions (Fig. 3).

Sohl (1969, unpub. data) has made several paleoecological determinations based on molluscan associations found in the Monmouth Group units. The upper Mount Laurel Sand contains an Exogyra-Lopha assemblage suggesting that it is nearer shore than the inner shelf Wenonah Formation which underlies the Mount Laurel. In some areas, such as the western shore of the Chesapeake Bay region, the shells found in the Mount Laurel are much fragmented within a coarse sand matrix, possibly suggesting beach or bar sands. Dinoflagellate evidence, which will be presented under the palynological results (see Paleoecological Determinations Based on Dinoflagellates) suggests a nearshore gulf, possibly estuarine paleoenvironment for part of the upper Mount Laurel Sand. The Navesink Formation is reported by Sohl (1969, unpub. data) to contain an Exogyra-Lopha assemblage at its base changing to a Pyncnodonta-Lopha assemblage toward the middle of the formation: Sohl (loc. cit.) interprets this change as suggestive of deepening water. In addition, the shell form of Pyncnodonta changes from a form with a low umbonal ridge in the Mount Laurel and lower Navesink to a form with a high umbonal ridge in the middle of the

Navesink: Sohl (loc. cit.) has interpreted this as an ecophenotypic response to deepening water. The environment of deposition suggested by Sohl (loc. cit.) is inner shelf at the base of the Navesink and outer shelf toward the middle of the Navesink. Dinoflagellate evidence, which will be presented later, agrees with these findings. Sohl reports that molluscan fossils of the Red Bank Sand are mainly restricted to the Sandy Hook Member. The assemblage in this unit contrasts sharply with that of the underlying Navesink Formation, in that infaunal molluscs of the Sandy Hook Member outnumber epifaunal forms, and deposit feeders are more prominent (16 percent of total number of specimens) in the Sandy Hook Member. Ostreids are the most common element in the Sandy Hook Member, and the mytilid Crenella and small pectins are also prominent. Sohl interprets this association (Ostrea-Crenella) as reflecting a change from the deeper water of Navesink times to the shallower, inner shelf waters of Red Bank times. Dinoflagellate evidence seemingly indicates that the Sandy Hook Member is of near shore deposition (see p. 47).

The types of environments suggested by Sohl (1969, unpub. data) is in agreement with lithologies observed in the upper Mount Laurel Sand, Navesink Formation, and Sandy Hook Member of the Red Bank Sand. These units comprise parts of two sedimentary cycles. The quartzose sand of the upper Mount Laurel culminates a shoaling sequence; the greensand of the Navesink Formation begins a new cycle, and suggests deeper water; and the silty sand of the Sandy Hook Member suggests the beginning of a shoaling sequence. Thus, the cycles represented

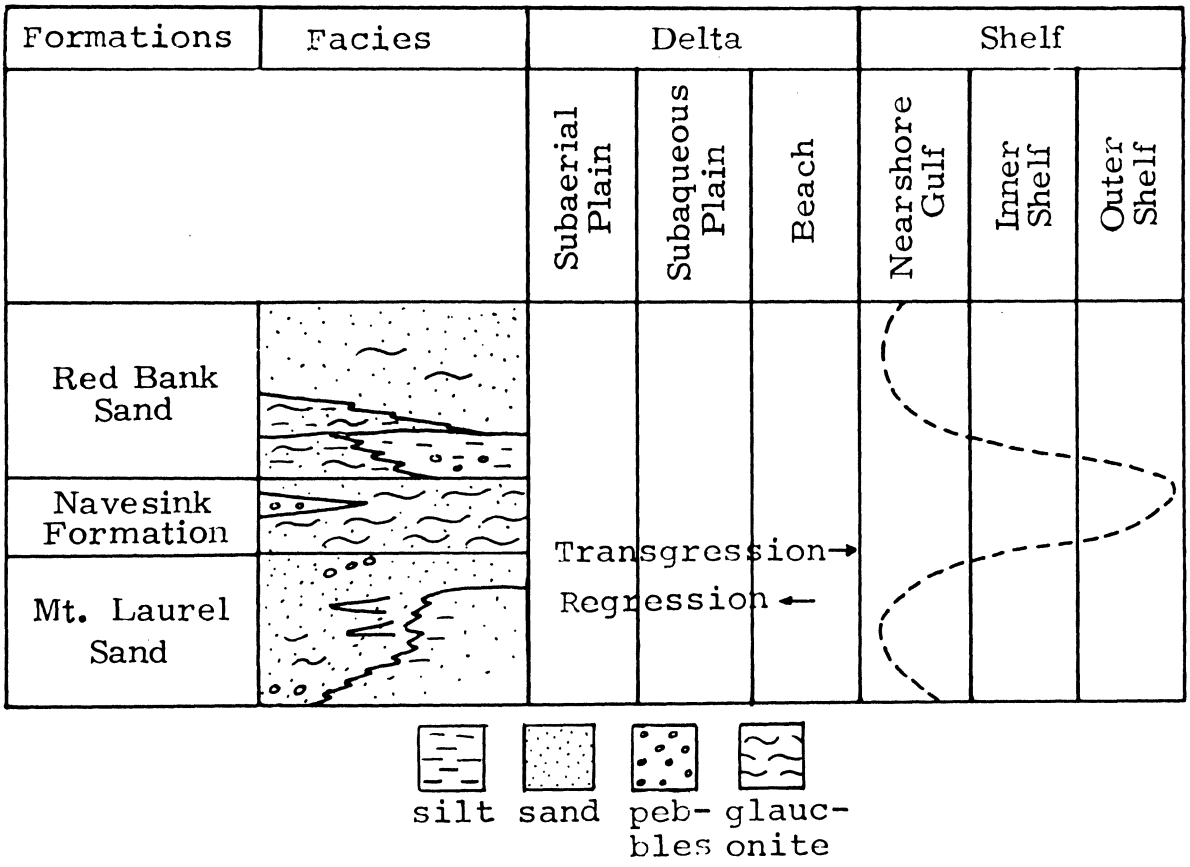


Figure 3. Generalized transgressive and regressive facies of the Mount Laurel Sand, Navesink Formation, and Red Bank Sand. Broken line at right illustrates relative change in distance from shore and associated environments of deposition (after Owens and Sohl, 1969).

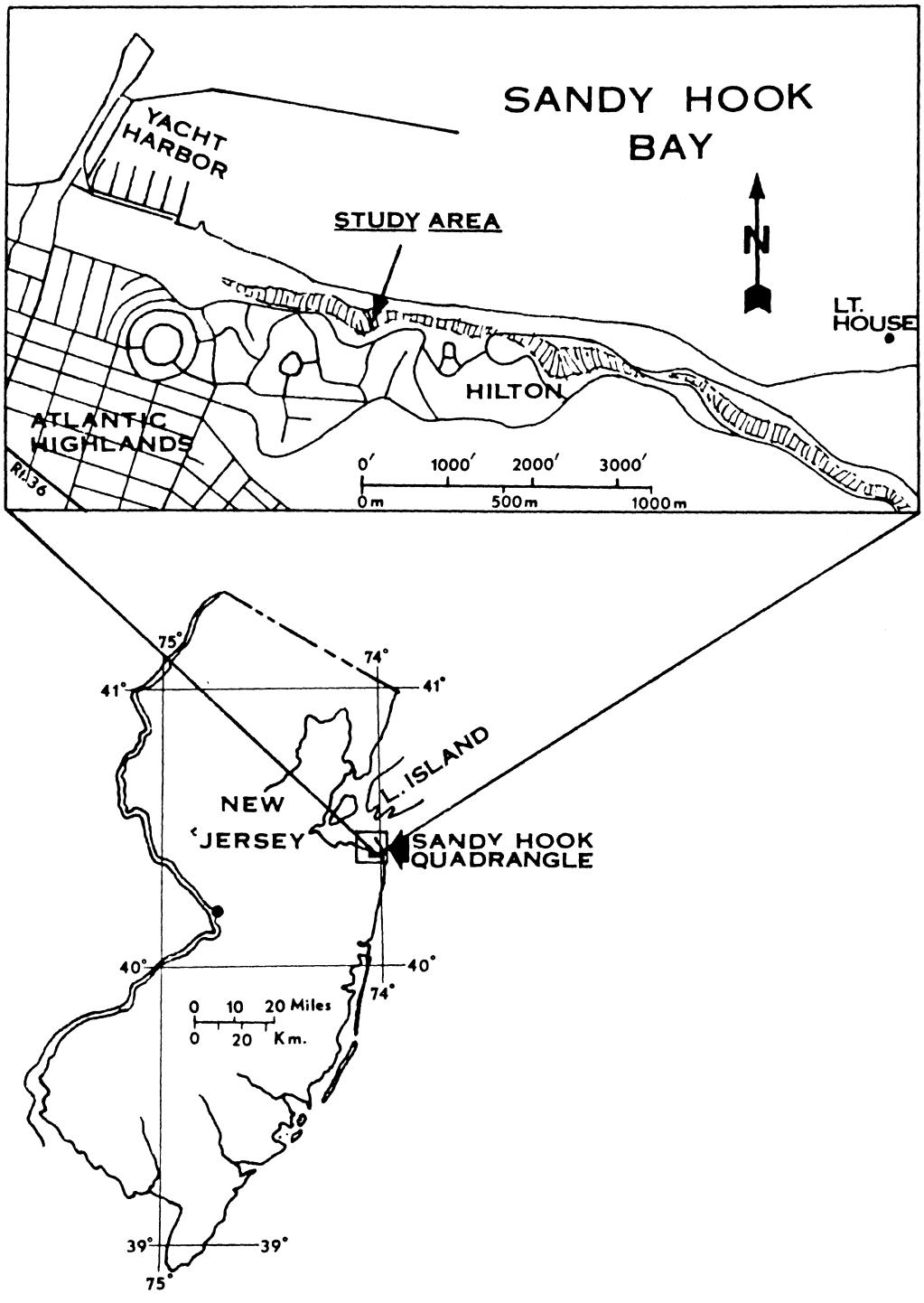


Figure 4. Map of study area near Atlantic Highlands, New Jersey. Hachured areas on expanded view indicate steep bluffs.

suggest the culmination of a marine regression at the top of the Mount Laurel, followed by a marine transgression beginning at the base of the Navesink, continuing upward through the Sandy Hook Member of the Red Bank Sand (Owens and Sohl, 1969).

COLLECTING LOCALITY

General Statement

Samples were collected from the bluffs at Atlantic Highlands approximately 450 meters east (74° 01' 30" W. Long., 40°22' 05" N. Lat.) of the yacht harbor compound (text-fig. 4), where an 18 meter section of the upper Mount Laurel Sand, Navesink Formation, and Sandy Hook Member of the Red Bank Sand is exposed (see Columnar Section, text-fig. 2).

METHODS OF STUDY

Sampling Procedure

Thirty-six samples were collected at 0.5 meter intervals from a trench excavated from the top to the bottom of the section. Samples were collected with clean implements and were sealed in plastic bags. Each sample was assigned a sample number (samples 203-238) which is recorded in the logs of the Virginia Polytechnic Institute and State University Palynology Laboratory.

Sample Preparation

All rock samples were unconsolidated, requiring only slight effort to disaggregate, and were macerated according to the following procedures. Uniform amounts of sediment were treated successively with cold concentrated hydrochloric acid and 52 percent hydrofluoric acid to completion. The samples were next oxidized in 5 percent sodium hypochlorite to remove some of the unwanted organic material. Separation of palynomorphs from other unwanted materials was accomplished by heavy liquid separation (zinc bromide, sp. gr. 2.0) and sieving through a 20 um mesh sieve. The organic fraction was then acetolyzed to darken the palynomorphs for study. Slides were prepared as strew mounts in glycerine jelly. The cover glasses were sealed with clear finger-nail polish.

Analytical Procedures

All 36 samples contained palynomorphs and 5 slides were prepared from each sample (180 slides). The slides were scanned and representatives of each species were sketched, measured, photographed, and evaluated in terms of their taxonomic concept, morphological development, intraspecific variation, and paleoecology.

Counts were made of all phytoplankton species in each sample to determine their relative frequencies. Three hundred dinoflagellates and

acritarchs were counted from each sample (150 grains each from 2 slides); a count of 300 grains can be demonstrated statistically to include most species present in an assemblage (Shaw, 1964, p. 109). Counts were made from 2 slides to minimize any bias introduced in placing the residue on individual slides. The data from the counts are presented in Appendix I. Relative frequency data were used in constructing text-fig. 6, which differentiates stratigraphic intervals into depositional environments.

The interpretation of relative frequencies of species as to general abundance within an assemblage is listed below.

Abundant: greater than 25 percent

Common: between 15 and 25 percent

Sparse: between 5 and 15 percent

Rare: between 3 and 5 percent

Extremely rare: less than 1 percent

Location of Specimens

All slides are stored in the Virginia Polytechnic Institute and State University Palynology Laboratory. On the upper left side of each slide is engraved the sample number and immediately below it is engraved the slide number. Specimens on a slide are located by measuring the horizontal and vertical distances from a small cross (the 0,0 reference point) engraved on the lower left-hand corner of the cover slip. The coordinates of a specimen are expressed in millimeters

to the right (R) or left (L), and above (+) or below (-) the reference point. Those of a specimen located 25 mm. to the right of the cross and 10 mm. below it are R25.0, +10.0, whereas, those of a specimen 5 mm. to the left of the cross and 3 mm. below it are L5.0, -3.0.

Photography

Photography was done with a Wild M-20 microscope and automatic camera MKa5 using Kodak High Contract Copy film and Kodak Panatomic X film. Panatomic X film was processed for 5 minutes in Rodinol developer, diluted 1:50 in distilled water. Kodak High Contrast Copy film was processed for 5 minutes in Ethol Tec thin emulsion developer, diluted 1:15 in distilled water. Prints were made on Kodal Poly-contrast F single weight paper, using filters to enhance contrast.

RESULTS OF PALYNOLOGICAL INVESTIGATION

General Statement

Thirty-six samples from the Atlantic Highlands section contained abundant dinoflagellate cysts, acritarchs, angiosperm and gymnosperm pollen, and spores. Sieves (20 um mesh) were used to concentrate

dinoflagellates by removing debris and pollen smaller than 20 um. The chemical maceration procedure also selectively dissolved siliceous and calcareous phytoplankton that may have been in the samples.

Although nearly 200 species of fossil dinoflagellates and acritarchs were observed in the samples, this study was restricted to the 37 genera and 91 species which were assignable to the families Gonyaulacaceae, Peridiniaceae, and Gymnodiniaceae.

Stratigraphic Distribution of Species

The stratigraphic ranges of dinoflagellates from the Monmouth Group are recorded below and in Range Charts I and II. Formational boundaries used are those defined by Minard (1969).

The top 3 meters of the Mount Laurel Sand (samples 203-208) was collected; it yielded 63 species. Seven of these species are restricted to this interval: Deflandrea corrugatella n. sp., Diconodinium sp., Spinitectulum sp., Deflandrea sp. D, Leptodinium sp., Dinogymnium sp. A, and Dinogymnium sp. D.

The 8 meter section of the Navesink Formation (samples 209-225) was collected; it yielded 74 species. Twenty-four of these species make their first appearance within the Navesink. Forty-nine species range from the Navesink into the overlying Sandy Hook Member of the Red Bank Sand. Spongodinium delitiense and Deflandrea asymmetrica first appear in the top-most sample of the Mount Laurel (sample 208);

however, they occur most frequently within the Navesink. Only 11 species, listed below, appear to be restricted to the Navesink Formation:

Cannosphaeropsis pusulosa

Conosphaeridium sp.

Dinogymnium acuminatum

Dinogymnium euclaensis

Dinogymnium sp. B

Deflandrea sp. B

Spinitectulum ramulus

Spinitectulum sp.

Trichodinium cf. T. hirsutum

Trithyrodinium evittii

Trithyrodinium pentagonum

The 5.5 meter section of the Sandy Hook Member of the Red Bank Sand (samples 226-238) was collected; it yielded 54 species. Five of these species make their first appearance within the Sandy Hook Member. Forty-nine species of dinoflagellates from the Sandy Hook Member have ranges extending upward from the underlying Navesink Formation, and 40 species have ranges which appear to extend into the younger (overlying) units. Only 2 species appear to be restricted to the Sandy Hook Member. They are: Dinogymnium westralium and Apteodinium baculatum.

Thirty-five species first appear between samples 206 and 209, an interval spanning the upper-most Mount Laurel Sand and basal Navesink Formation (Range Chart I). The great number of first appearances within this 1.5 meter interval suggests either missing beds or a change in paleoenvironment. The step-like nature of the first appearances suggests that a disconformity is not present, although some phosphate internal molds of bivalves are present at the top of the Mount Laurel. The phosphate internal molds probably indicate a diastem of relatively short duration, as the age of the upper Mount Laurel is considered to be late Campanian, while the age of the basal Navesink is considered to be early Maestrichtian. Minard (personal communication, 1975) feels that the Mount Laurel represents the top of a shoaling sequence, suggesting the possibility of a hiatus, in which the initial sedimentary units of the Navesink transgression are missing. This interval of first appearance spans the Campanian-Maestrichtian boundary as defined by ammonites (Cobban, 1974) and, also, as determined in this investigation by dinoflagellates. Thus, evolution at the time boundary may have been responsible for some of the first appearances. The paleoecological analysis included in this study, based primarily on dinoflagellate relative frequency and species diversity (see text-fig. 6) suggests an environmental change at this interval. Thus, it is difficult to select a single reason for the first appearances; it is possible that a combination of missing beds, evolution, and environment change is responsible for the large number of first appearances in the sample interval.

Species making their first appearance within the interval between samples 206 and 209 are (species which have been reported only from world-wide Maestrichtian or younger sediments are marked with an asterisk):

Cannosphaeropsis utinensis

Cordosphaeridium varians

* Deflandrea asymmetrica

Deflandrea cf. D. asymmetrica

* Deflandrea cooksoni

Deflandrea corrugatella

* Deflandrea diebeli

Deflandrea diebeli rigida

* Deflandrea cf. D. obscura

Deflandrea pannucea

Deflandrea cf. D. tripartita

Deflandrea sp. D

Diconodinium sp.

Dinogymnium elongatum

Dinogymnium lanceolatum

Dinogymnium sp. A

Dinogymnium sp. C

Diphyes recurvatum

Gonyaulacysta wetzeli

Hystrichosphaeridium recurvatum

* Hystrichosphaeridium tubiferum brevispinum

Hystrichosphaeridium sp.

Leptodinium cf. *L. multiplexum*

Oligosphaeridium complex

* *Palaeocystodinium australinum*

Prolixosphaeridium xanthiopyxides

* *Samlandia angustivela*

Spiniferites ramosus reticulatus

Spiniferites ramuliferus

* *Spiniferites* cf. *S. septatus*

Spinitectulum ferox

* *Spongodinium delitiense*

Systematophora placacantha

Triblastula borussica

Trithyrodinium striatum

Fifteen species, listed below, appear restricted to the Mount Laurel-Navesink interval, separating it from the Navesink-Sandy Hook interval.

Cannosphaeropsis utinensis

Deflandrea cf. *D. asymmetrica*

Deflandrea spicata

Deflandrea cf. *D. tripartita*

Dinogymnium elongatum

Dinogymnium lanceolatum

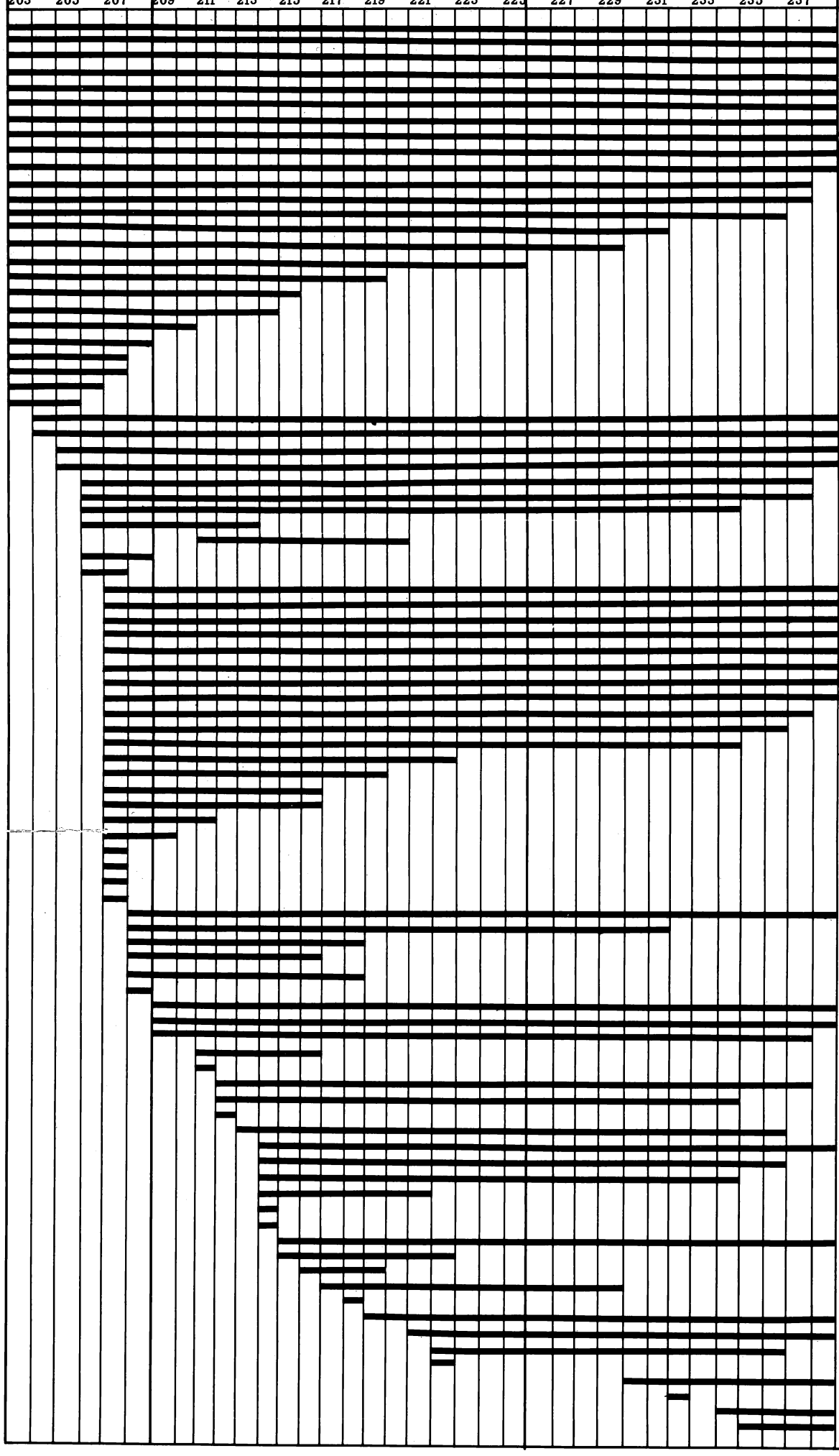
Dinogymnium pustulicostatum

Dinogymnium sp. C

SAMPLE NUMBERS

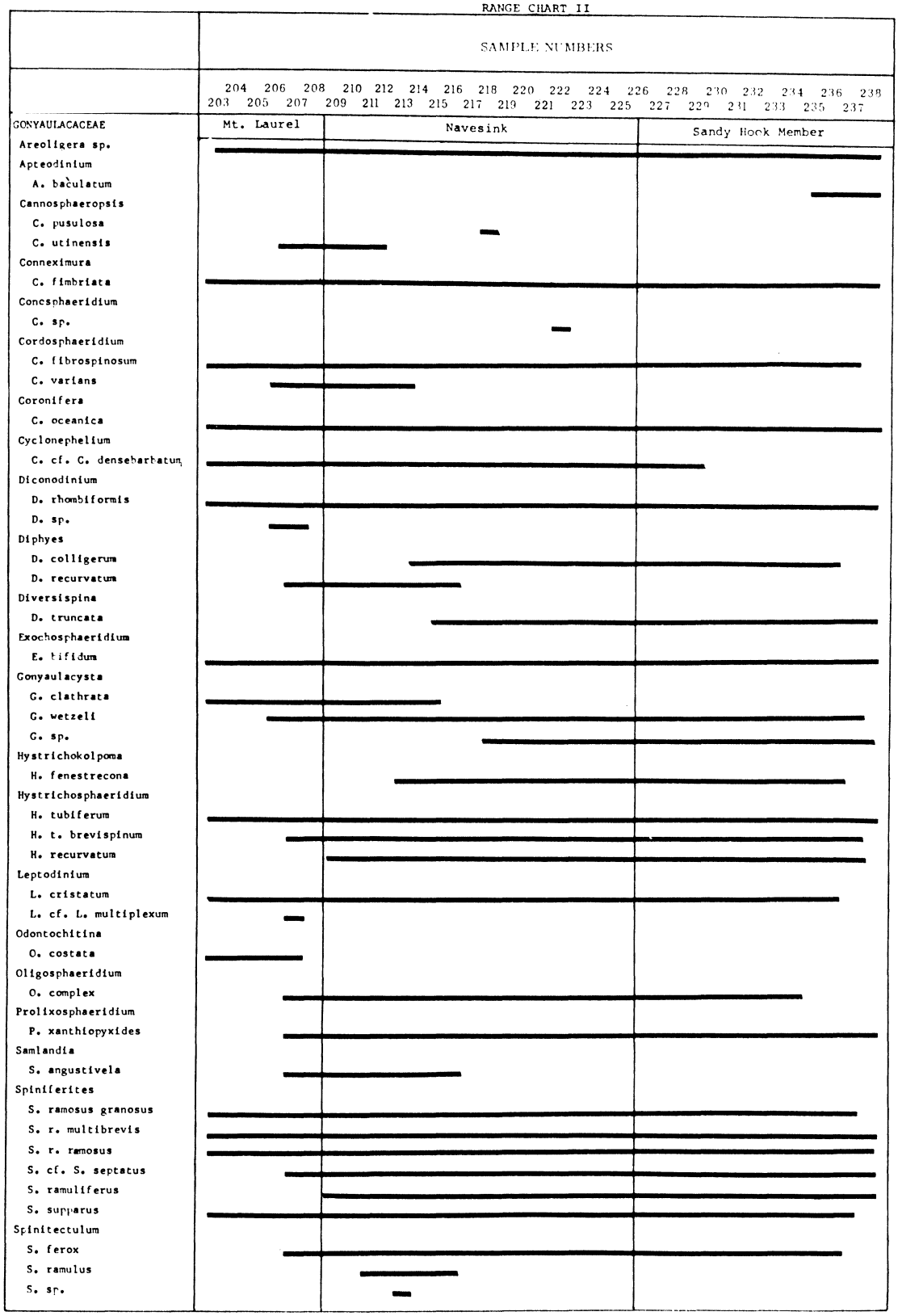
Mt. Laurel | Navesink | Red Bank

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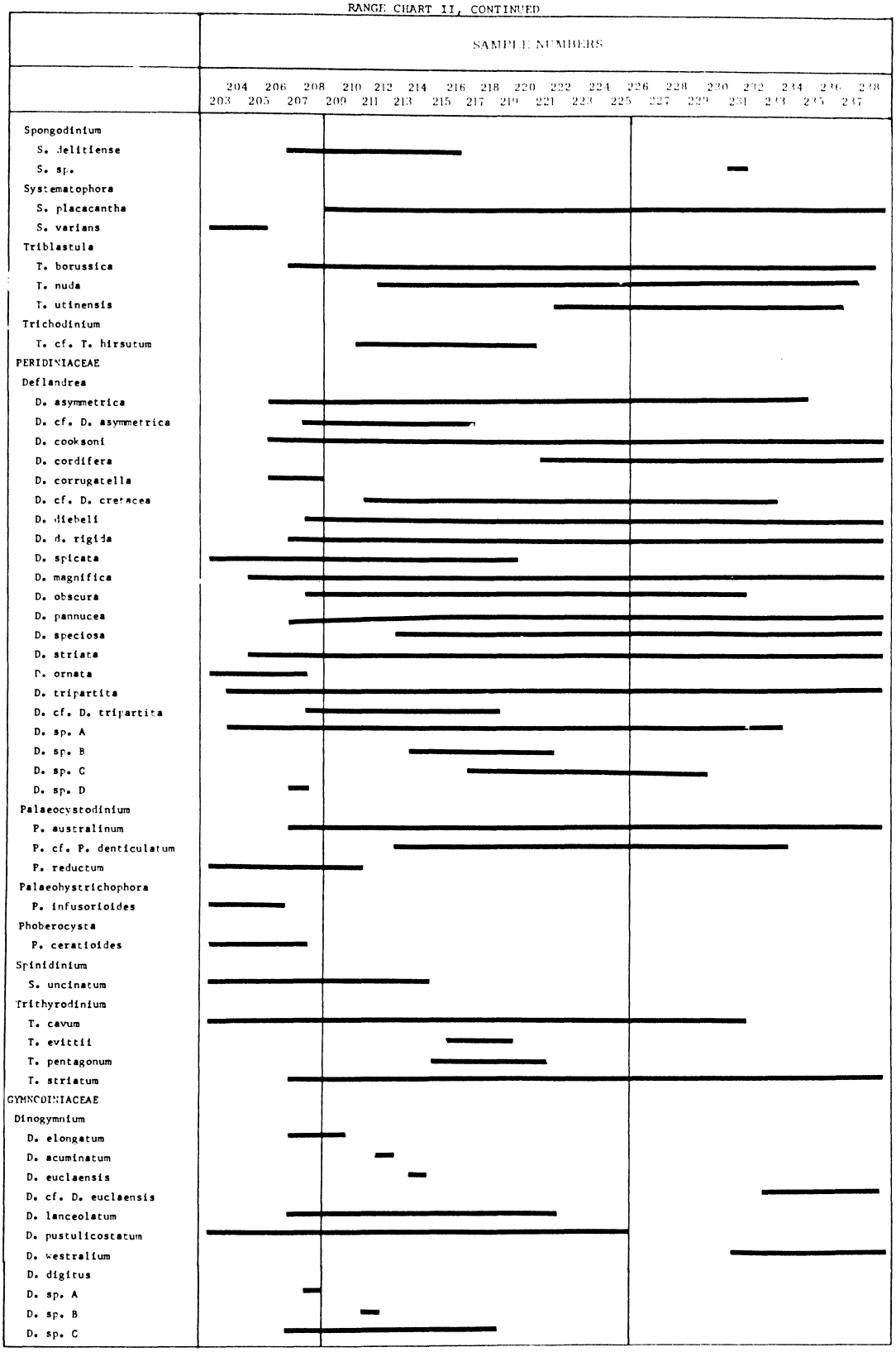


Other
Spiniferites ramosus ramosus
Exochosphaeridium bifidum
Areoligera sp.
Cordosphaeridium fibrospinosum
Hystrichosphaeridium tubiferum
Coronifera oceanica
Spiniferites ramosus multibrevis
Diconodinium rhombiformis
Conexímura fimbriata
Spiniferites ramosus granosus
Spiniferites supparus
Leptodinium cristatum
Trithyrodinium cavum
Cyclonephelium cf. C. densebarbatum
Dinogymnium pustulicostatum
Deflandrea spicata
Gonyaulacysta clathrata
Spinidinium uncinatum
Palaeocystodinium reductum
Deflandrea ornata
Odontochitina costata
Phoberocysta ceratioides
Palaeohystrichophora infusorioides
Systematophora varians
Deflandrea tripartita
Deflandrea sp. A
Deflandrea striata
Deflandrea magnifica
Spiniferites ramosus reticulatus
Gonyaulacysta wetzeli
Deflandrea asymmetrica
Cordosphaeridium varians
Trichodinium cf. T. hirsutum
Deflandrea corrugatella
Diconodinium sp.
Deflandrea diebeli rigida
Palaeocystodinium australinum
Trithyrodinium striatum
Deflandrea cooksoni
Deflandrea pannucea
Prolixosphaeridium xanthiopyxides
Spiniferites cf. S. septatus
Triblastula borrussica
Hystrichosphaeridium tubiferum brevispinum
Spinitectulum ferox
Oligosphaeridium complex
Dinogymnium lanceolatum
Dinogymnium sp. C
Samlandia angustivela
Diphyes recurvatum
Cannosphaeropsis utinensis
Dinogymnium elongatum
Hystrichosphaeridium sp.
Deflandrea sp. D
Leptodinium cf. L. multiplexum
Dinogymnium sp. D
Deflandrea diebeli
Deflandrea cf. D. obscura
Deflandrea cf. D. tripartita
Spongodinium delitiense
Deflandrea cf. D. asymmetrica
Dinogymnium sp. A
Systematophora placacantha
Spiniferites ramuliferus
Hystrichosphaeridium recurvatum
Spinitectulum ramulus
Dinogymnium sp. B
Triblastula nuda
Deflandrea cf. D. cretacea
Dinogymnium acuminatum
Hystrichokolpoma fenestrecona
Deflandrea speciosa
Diphyes colligerum
Palaeocystodinium cf. P. denticulatum
Deflandrea sp. B
Dinogymnium euclaensis
Spinitectulum sp.
Diversispina truncata
Trithyrodinium pentagonum
Trithyrodinium evittii
Deflandrea sp. C
Cannosphaeropsis pusulosa
Gonyaulacysta sp.
Deflandrea cordifera
Triblastula utinensis
Conosphaeridium sp.
Dinogymnium westralium
Spongodinium sp.
Dinogymnium cf. D. euclaensis
Apteodinium baculatum

RANGE CHART II



RANGE CHART II, CONTINUED



Diphyes recurvatum

Gonyaulacysta clathrata

Palaeocystodinium reductum

Samlandia angustivela

Spinidinium uncinatum

Spongodinium delitiense

Trichodinium cf. *T. hirsutum*

Five species, listed below, appear restricted to the Navesink-Sandy Hook Member interval; however, because they are extremely rare their stratigraphic value is suspect.

Deflandrea cf. *D. cretacea*

Deflandrea sp. C

Hystrichokolpoma fenestrecona

Triblastula nuda

Triblastula utinensis

Zonation of the Mount Laurel Sand, Navesink Formation, and Sandy Hook Member

Because only one continuous section from one locality was investigated no formal assemblage or range zones are proposed. A comparison is made with Wilson's (1974) dinoflagellate zonation of the Campanian and Maestrichtian of Maestricht, Holland, and Denmark (see pp. 34). Peak zones based on counts and relative frequencies of Monmouth Group dinoflagellates are presented in this

study (see Paleoecological Determinations Based on Dinoflagellates).

An Analysis of Wilson's (1974) Campanian-Maestrichtian Dinoflagellate Zones

Wilson (1974) reported on the taxonomy and biostratigraphic distribution of over 120 species of fossil dinoflagellates from the upper Campanian and Maestrichtian sediments of the Maestricht region, Holland, and Denmark. He subdivided his sections into five dinoflagellate-based concurrent range zones (Zones I-V), the boundaries of which were indicated by the first and last appearances of at least 3 species (Wilson, 1974, p. 426) (text-fig. 4). These zones were used by Wilson to correlate between the Maestricht region, Holland and northern Denmark (loc. cit.). Because these zones are based on boundaries defined by first and last appearances, it is of interest to compare the boundaries between the Maestricht region, Holland and Denmark to determine if they are time equivalent and to compare the first and last appearances between the two areas to determine what factors may have caused the first and last appearances (see text-fig. 5).

Because Wilson's (1974) Zone I occurs in the Maestricht region, but not in Denmark, a biostratigraphic comparison of dinoflagellate distribution about the boundary between zones I and II is not possible. It is possible that the first and last appearances of dinoflagellates marking the top of Zone I in Holland are environmentally

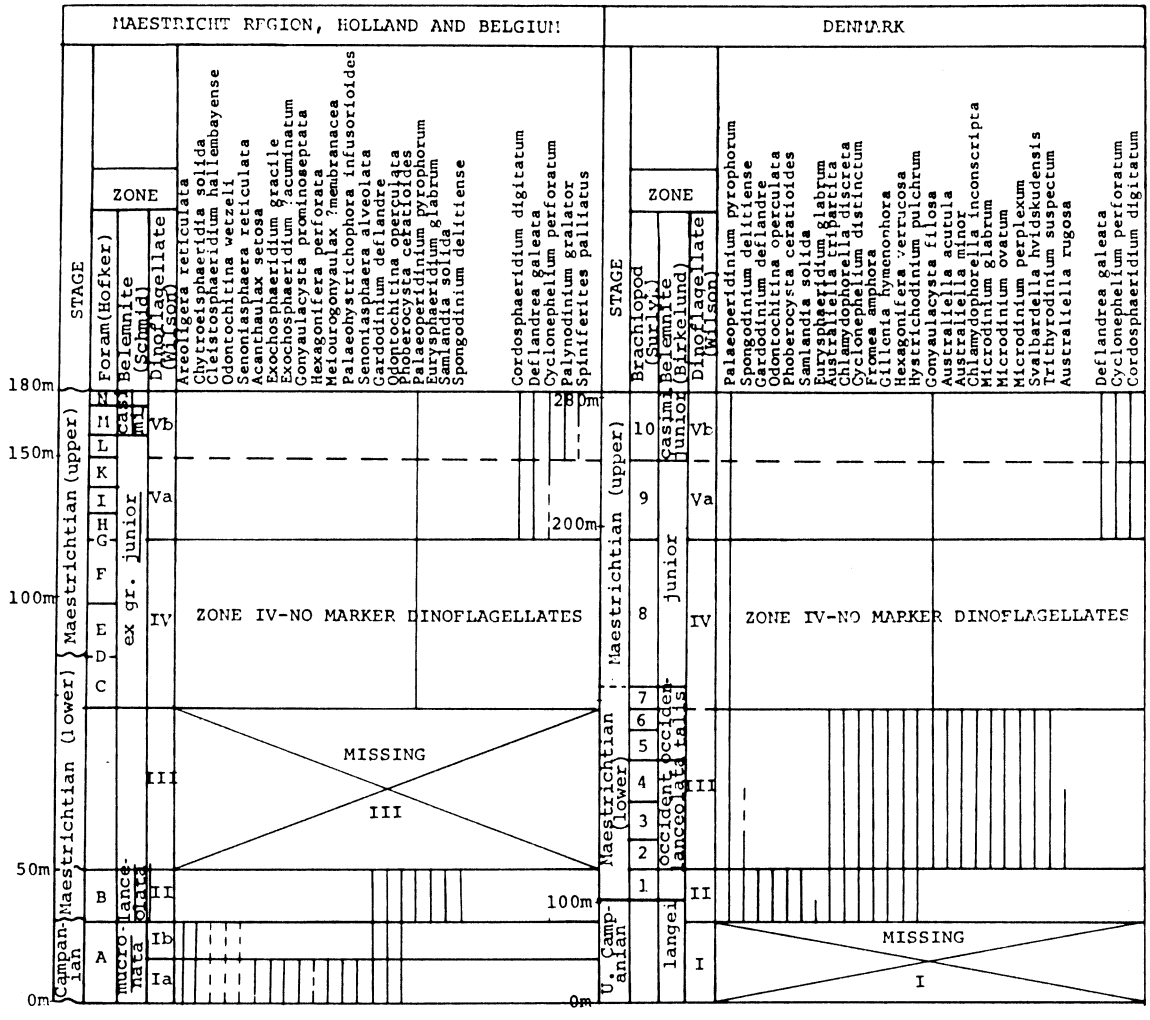


Figure 5. Wilson's (1974) dinoflagellate zones and associated invertebrate zones of the Maestricht Region, Holland and Belgium, and also of Denmark (after Wilson, 1974)

controlled, rather than temporally controlled. In Holland, the boundary between zones I and II corresponds to the Campanian-Maestrichtian boundary (Wilson, table 2), whereas the Campanian-Maestrichtian boundary in Denmark falls in the middle of Zone II. This relationship suggests that the boundary between zones I and II in the Maestricht region is not time equivalent with the bottom of Zone II in Denmark. This causes some doubt as to the importance of the first and last appearances marking the position of the boundary between zones I and II in the Maestricht region.

Wilson's (1974) Zone III only occurs in Denmark, not in the Maestricht region, Holland. Thus, in the Maestricht region, the boundary between zones II and IV represents a large diastem. For this reason, the first and last appearance marking the top of Zone II in the Maestricht region may be only apparent and not real. It is unlikely that the top of Zone II in the Maestricht region is time equivalent with the top of Zone II in Denmark, because the apparent period of erosion or lack of deposition which took place there represents the length of time needed to deposit Zone III in Denmark.

Because Wilson's (1974) Zone III is missing in the Maestricht region, it is difficult to determine the importance of the first appearances marking the bottom of Zone III in Denmark. There is no section available with which to compare these first appearances, and without a comparison it is not possible to determine that the first appearances are time controlled; they could be environmentally

controlled. The same problems apply to the first and last appearances marking the top of Zone III in Denmark. Because Zone III is missing in the Maestricht region, it is also likely that the first and last appearances marking the boundary between zones III and IV in Denmark cannot be correlated with great confidence to the Maestricht region, Holland. It also means that the boundary between zones III and IV in Denmark is probably not time equivalent with the base of Zone IV in the Maestricht region.

The boundary between Wilson's (1974) zones IV and V appear to be in agreement in both the Maestricht region, Holland and in Denmark.

The large number of localities used to construct Wilson's (1974) composite sections in both the Maestricht and Danish study areas, the number of disconformities or diastems involved, and the large sampling intervals used create complexities in attempting to correlate other sections with Wilson's zones I-V as they are presently defined. In addition, the lack of paleoecological data makes it difficult to interpret the bulk of the first and last appearances illustrated on his range charts (Wilson, 1974, tables 2 and 3).

The helpful aspect of Wilson's (1974) range charts lies in the distribution of his dinoflagellates in relationship to the well-defined boundary between the lower and upper Maestrichtian. The boundary, in both the Maestricht region and Denmark, occurs in the middle of Wilson's Zone IV and is also associated with a disconformity or diastem. Based on restricted species and concurrent ranges of other

species it appears sound and useful to attempt correlations with Wilson's dinoflagellates of the lower and upper Maestrichtian. This procedure is attempted in the following section where the geologic age of the Mount Laurel Sand, Navesink Formation, and Sandy Hook Member of the Red Bank Sand is determined based on dinoflagellates.

Dinoflagelate Evidence Relating to the Age of the Monmouth Group

Wilson's (1974) differentiation of lower and upper Maestrichtian in the Maestricht region, Holland and Denmark based on dinoflagellates is useful in this present study for age dating much of the study section. Wilson (1974, tables 2 and 3) shows on his range charts that 11 species are restricted to the upper type Maestrichtian of the Maestricht region, Holland, and that 15 species are restricted to the upper Maestrichtian of Denmark. Only one of these species, Cordosphaeridium digitatum (= Diversispina truncata n. sp.), occurs in the units presented in this study, but it is also associated with species that Wilson shows as being restricted to the lower Maestrichtian. Therefore, it is suggested that none of the units reported on here are younger than early Maestrichtian. Species which are restricted to the lower Maestrichtian of the Maestricht region, Holland, and also the lower Maestrichtian of Denmark (Wilson, 1974), and which also occur in the units presented in this study are: Samlandea solida (= Samlandea angustivela), Triblastula utinensis (may extend a short distance into the upper Maestrichtian beds), Spongodinium delitiense,

and Hystrichosphaeropsis jubata (=Triblastula borrussica). In the Maestricht Region, Holland, both Samlandea angustivela and Spongodinium delitiense first appear at the base of the lower Maestrichtian, whereas Triblastula utinensis first appears stratigraphically higher in the lower Maestrichtian section. This pattern of appearance is the same in the units at the Atlantic Highlands study area; i. e., Samlandea angustivela and Spongodinium delitiense both first appear in sample 206 (uppermost Mount Laurel), but Triblastula utinensis first appears stratigraphically higher in sample 221 (middle Navesink). Triblastula borrussica is reported by Wilson (loc. cit.) to occur in association with Triblastula utinensis in the lower Maestrichtian of Denmark, but in the Atlantic Highlands section Triblastula borussica first appears with Samlandea angustivela and Spongodinium delitiense in sample 206. In conclusion, a comparison of Atlantic Highlands dinoflagellates with those of the Maestricht Region, Holland, and of Denmark, shows that Atlantic Highlands lower Maestrichtian sediments may occur from sample 206 (uppermost Mount Laurel Sand) upward, and that the Navesink Formation and Sandy Hook Member of the Red Bank Sand are both of early Maestrichtian age.

Because the lower half of the Mount Laurel Sand is not included in this study (this study includes the upper nine feet of the Mount Laurel), not enough data was available on the stratigraphic distribution of dinoflagellates to adequately date the Mount Laurel. Range Chart I shows that eight species have tops near the base of the lower Maestrichtian (uppermost Mount Laurel-basal Navesink, between samples 206 and 209); however, only three of these have a generally

recognized age significance that could be helpful in dating the Mount Laurel: Odontochitina costata (Cenomanian through Campanian), Phoberocysta ceratioides (Senonian: (?) Campanian into lower Maestrichtian), and Palaeohystrichophora infusorioides (Albian into Campanian). The presence of these species in the uppermost Mount Laurel would suggest an age older than Maestrichtian, but it cannot be specifically stated that the age of the Mount Laurel is Campanian. The presence of Phoberocysta ceratioides suggests that the Mount Laurel is not older than Senonian; i.e., Coniacian. At the same time, dinoflagellate evidence could not contradict the Campanian age assignment for the Mount Laurel as determined by various invertebrate fossils (Stephenson, 1923; Jeletzky, 1962; Sohl and Mello, 1970; Cobban, 1974). Sohl and Mello (1970, p. 39-49) report that the interval from the Mount Laurel down section to the Merchantville Formation is of Campanian age, and that the Mount Laurel is of late Campanian age.

If the Mount Laurel is late Campanian in age, then the Campanian-Maestrichtian boundary seemingly occurs in the uppermost Mount Laurel or basal Navesink. Concurrent ranges of "Campanian" and Maestrichtian age-indicating dinoflagellates (text fig. 2) suggest that the boundary lies between samples 205 and 209, an interval from 0.5 meter above the base of the Navesink Formation to 1.5 meters below the top of the Mount Laurel Sand. The Maestrichtian age-indicating dinoflagellates used are: Deflandrea diebeli, Deflandrea striata, Deflandrea magnifica Palaeocystodinium australinium, and Spongodinium delitiense. The

Campanian or older age-indicating dinoflagellates used are: Palaeohystrichophora infusorioides and Odontochitina costata. Based on the comparison of Atlantic Highlands dinoflagellates with those of Wilson's (1974) type Maestrichtian study (see discussion above), the Campanian-Maestrichtian boundary may lie close to sample 206 (uppermost Mount Laurel Sand); sample 206 lies near the base of the 2.0 meter interval mentioned above.

The species list included below gives previously reported ages for species cited in this investigation.

Species	Range and Occurrence
Dinogymnium acuminatum	Maestrichtian of California
Dinogymnium euclaensis	Senonian of Australia
Dinogymnium digitus	Senonian of Soviet Union; Campanian-Maestrichtian of eastern Canada
Dinogymnium westralium	Cenomanian to Maestrichtian of Australia; Campanian-Maestrichtian of New Jersey
Spiniferites ramuliferus	Cenomanian through Oligocene of Europe; Paleocene of Australia
Apteodinium baculatum	Paleocene of Virginia-Maryland Coastal Plain, U.S.A.
Cannosphaeropsis cf. C. pusulosa	Oligocene of Germany
Cannosphaeropsis utinensis	Senonian of Germany and France
Conneximura fimbriata n. comb.	Danian of Denmark
Cordosphaeridium fibrospinosum	Campanian-Maestrichtian of South Africa; Lower Eocene of England

Coronifera oceanica	Albian of Australia; Albian and Cenomanian of England
Cyclonephelium cf. C. densebarbatum	Middle Cretaceous of England
Diphyes colligerum	Senonian to Eocene of Australia
Exochosphaeridium bifidum	Senonian of England
Gonyaulacysta clathrata	Upper Jurassic of Australia
Gonyaulacysta wetzeli	Senonian of France; Danian of Europe
Hystrichosphaeridium tubiferum	widely reported from most Cretaceous and Tertiary localities
H. tubiferum var. brevispinum	Eocene of England
Hystrichosphaeridium recurvatum	Senonian of France, Belgium, and England
Oligosphaeridium complex	Lower and Upper Cretaceous of England, France, Germany, Rumania, Africa, and Australia; Eocene of England
Prolixosphaeridium xanthiopyxides	Senonian of Baltic area and France
Samlandia angustivela	Eocene of Australia
Spiniferites ramosus ramosus	Widely reported from Cretaceous and Tertiary
Spiniferites ramosus granosus	Eocene of England
Spiniferites ramosus multibrevis	Eocene of England
Spiniferites ramosus reticulatus	Cenomanian of England
Spiniferites cf. S. septatus	Paleocene of Virginia-Maryland Coastal Plain, U.S.A.; Paleocene, Australia
Spiniferites supparus	Maestrichtian-Danian of California, U.S.A.

Spinitectulum ferox n. comb.	Neocomian of Germany; Cenomanian of England; Senonian of France
Spongodinium delitiense	Senonian of France; Maestrichtian of eastern Canada; Danian of Germany
Systematophora placacantha	Miocene of Australia
Triblastula borussica	Middle Cretaceous of England; Upper Cretaceous to Paleocene of Australia; Oligocene of Germany; Miocene of Australia
Triblastula nuda	Cretaceous of Baltic Sea
Triblastula utinensis	Cretaceous of Baltic area; considered a Maestrichtian index in Lentin and Williams (1973)
Trichodinium cf. T. hirsutum	Paleocene of Australia
Deflandrea asymmetrica	Eocene of Antarctica
Deflandrea cooksoni	Upper Senonian of Germany
Deflandrea cf. D. cretacea	Upper Cretaceous of Australia
Deflandrea diebeli	Upper Senonian of Germany; Maestrichtian of Poland
Deflandrea magnifica	Maestrichtian of Sweden; Paleocene of South Dakota, U.S.A.
Deflandrea cf. D. obscura	Maestrichtian-Danian of California, U.S.A.
Deflandrea pannucea	Paleocene of South Dakota, U.S.A.
Deflandrea speciosa	Paleocene of Germany; Danian of California, U.S.A.
Deflandrea striata	Danian of California, U.S.A.
Deflandrea tripartita	Turonian to middle Senonian of Australia
Diconodinium rhombiformis	Upper Cretaceous of Soviet Union

Odontochitina costata	Cenomanian through Campanian of England; Cenomanian and Turonian of Germany; Albian to Cenomanian of Australia
Palaeocystodinium australinum	Paleocene of Australia; Maestrichtian into Tertiary (Williams and Lentin, 1975)
Palaeocystodinium cf. P. denticulatum	Turonian of Germany
Palaeohystrichophora infusorioides	Senonian of France; Albian into Campanian (Williams and Lentin, 1975)
Phoberocysta ceratioides	Senonian of France
Trithyrodinium evittii	Danian of California, U.S.A.

Paleoecological Determinations Based on Dinoflagellates

General Statement

Changes in relative frequency upward in the section, plotted for 25 species (text fig. 6), are compared with previously determined paleoenvironments for these formations - nearshore gulf and inner and outer shelf (Owens and Sohl, 1969). These species were selected because they demonstrate an increase in numbers at particular stratigraphic intervals in the section, or because they have restricted stratigraphic ranges, both features suggesting a

possible environmental influence. A visual scan of text fig. 6 shows four major subdivisions of the section corresponding to peak zones and first or last appearances of the 25 species. The peak zones are named below.

Interval I

Dinogymnium pustulicostatum Peak Zone (samples 203-206, upper Mount Laurel Sand): identified by high relative frequencies of *D. pustulicostatum*, *Deflandrea ornata*, *Palaeohystrichophora infusorioides*, and *Trithyrodinium cavum*. The low species diversity (see Range Chart I), 36 species, and dominance by one or two species suggests abnormal marine conditions, probably estuarine (Hulbert, 1963). Owens and Sohl (1969, text fig. 15) believe the upper Mount Laurel Sand represents a nearshore gulf environment.

Interval II

Deflandrea tripartita Peak Zone (samples 207-219, uppermost Mount Laurel Sand - basal Navesink Formation): identified by high relative frequencies of *Hystrichosphaeridium tubiferum*, *Samlandia angustivela*, *Spiniferites ramosus ramosus*, *Spongodinium delitiense*, *Deflandrea striata*, *Deflandrea* cf. *D. asymmetrica*, *Deflandrea tripartita*, and *Trithyrodinium cavum*. This interval has high species diversity, 82 species, and suggests a return to normal

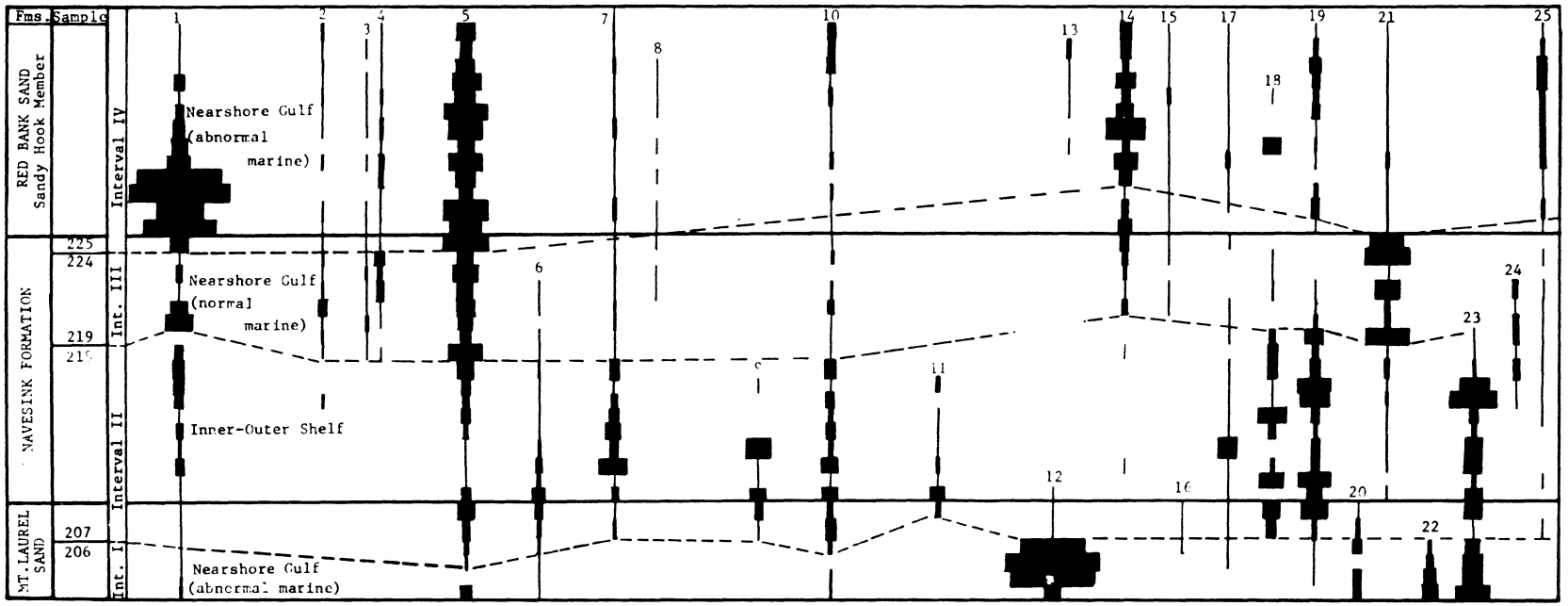
marine conditions (Hulbert, 1963). Owens and Sohl (1969, text fig. 15) show an inner to outer shelf environment for this interval; text fig. 6 shows it as inner shelf.

Interval III

Palaeocystodinium australinum Peak Zone (samples 219-225, upper Navesink Formation): identified by high abundances of Diversispina truncata, Gonyaulacysta wetzeli, Gonyaulacysta sp., Palaeocystodinium australinum, and Trithyrodinium pentagonum. This interval has relatively high species diversity, 55 species, and would suggest normal marine conditions (Hulbert, 1963). The drop in species diversity, for interval III, compared with 82 species in interval II, could indicate a near shore environment for interval III, and not outer shelf. Owens and Sohl (1969, text fig. 15) indicate an outer shelf environment for this part of the Navesink Formation. Sohl (1969, p. 8) reports that molluscan associations, including ecophenes, suggest that water deepened from Mount Laurel times into middle Navesink times (see discussion p. 17). It is suggested here that a marine regression occurred during late Navesink times, and that the dinoflagellate associations in this stratigraphic interval (upper Navesink) represent normal marine waters of a nearshore gulf environment.

Interval IV

Areoligera sp. - Exochosphaeridium bifidum Peak Zone (samples



1. Areoligera sp.
2. Diversispina truncata
3. Gonyaulacysta wetzeli
4. Gonyaulacysta sp.
5. Exochosphaeridium bifidum
6. Cordosphaeridium varians
7. Hystrichosphaeridium tubiferum
8. Triblastula utinensis
9. Samlandia angustivela
10. Spiniferites ramosus ramosus
11. Spongodinium delitiense
12. Dinogymnium pustulicostatum
13. Dinogymnium westralium
14. Systematophora placantha
15. Deflandrea cordifera
16. Deflandrea corrugatella
17. Deflandrea striata
18. Deflandrea asymmetrica
19. Deflandrea tripartita
20. Deflandrea ornata
21. Palaeocystodinium australinum
22. Palaeohystrichophora infusorioides
23. Trithyrodinium cavum
24. Trithyrodinium pentagonum
25. Trithyrodinium striatum

Figure 6. Relative frequencies plotted for 25 dinoflagellate species showing associations of peak abundances, minimal abundances, and restricted ranges suggesting four changes in paleoenvironment. Assigned paleoenvironments are taken from Owens and Sohl (1969). Dashed line connects major associated changes in relative frequency.

225-235, most of Sandy Hook Member of the Red Bank Sand): identified by high abundances of Areoligera sp., E. bifidum, Systematophora placacantha, Deflandrea cf. D. asymmetrica, Deflandrea tripartita, and Trithyrodinium striatum. This interval has relatively high species diversity, 53 species; however, the assemblage is dominated by Areoligera (35-68 percent in samples 226-229, basal Sandy Hook Member) and E. bifidum (6-28 percent in entire Sandy Hook Member). McLean (1971), comparing dinoflagellate distribution with information obtained from a study of Foraminifera (Nogan, 1964), reports that high relative frequencies of Areoligera may reflect abnormal marine waters. This agrees with Hulbert (1963), who has shown that modern phytoplankton populations dominated by a few species are near the shore, and if species diversity is low enough are probably estuarine. It is suggested, therefore, that interval IV was deposited in abnormal marine waters of a nearshore gulf environment.

Fine Structure, Paleoecology, and Functional Morphology of Dinogymnium Evitt 1967

General Statement of Fine Structure

Scanning electron microscopy has revealed in detail fine morphological structures of Dinogymnium tests which may prove of taxonomic value and which may change some fundamental views concerning fossil dinoflagellates. Under light microscopy

Dinogymnium tests frequently appear relatively nondistinctive, demonstrating few morphological features that could be considered taxonomically important. The paucity of distinctive features is often further complicated by lateral and longitudinal distortion of Dinogymnium tests. Two morphological features which can now be observed with the scanning electron microscope are: 1) previously unreported flagellar pore structures occurring at the cingulum-sulcus intersection, and 2) wall canals, which penetrate the Dinogymnium test wall. A discussion of these features follows.

Morphology at the Cingulum-Sulcus Intersection

The cingulum-sulcus intersection on modern dinoflagellates bears the flagellar pores: one anterior pore which allows the transverse flagellum to pass outward to the cingulum, and one posterior flagellar pore which allows the longitudinal flagellum to pass outward to the sulcus. For the first time, scanning electron microscopy of fossil Dinogymnium tests has revealed pore structures at the cingulum-sulcus intersection. In each case there are two pore structures, one anterior and one posterior. The pores have the appearance of definitely penetrating the test wall, suggesting that they are not merely surface features. If these are actual flagellar pores, the important implication is that Dinogymnium tests represent remains of motile stages, and not cysts. This is significant, because the general concept is that fossil dinoflagellates represent

nonmotile encysted stages.

The flagellar pore structures observed thus far are of three types. The first type (pl. 23, figs. 3-4a), which is characteristic of D. pustulicostatum, consists of two broad tube-like projections which appear hollow and terminate with a pore. The anterior tube and pore (AT and AP) appear to be directed posteriorly and lie adjacent to the higher, terminal end of the cingulum (Cl). It appears that a flagellum could have passed from this pore onto the higher end of the cingulum. The posterior tube and pore (PT and PP) is directed posteriorly toward the sulcus (S), and possibly allowed passage for the longitudinal flagellum onto the sulcus. Evidence that the anterior and posterior tube-like projections are hollow and penetrate through the test wall can be seen in Plate 23, figs. 4-4a, where both tubes (AT and PT) are torn and collapsed, suggesting underlying passages. The second type (pl. 23, figs. 5-6a) is found on tests that are otherwise very much like D. pustulicostatum, but which may not be taxonomically identical with D. pustulicostatum. These specimens are referred to here and on the plate explanations as D. cf. D. pustulicostatum. On these specimens the relatively long and slender anterior tube (AT) is directed laterally toward the higher terminal end of the cingulum (Cl), and appears to have allowed the transverse flagellum to pass in one line onto the cingulum. The posterior pore structure (PP) lacks a tube, having, instead, a narrow longitudinal slit, which apparently allowed the longitudinal flagellum to pass in one line onto the sulcus (S). The third type (pl. 23, figs. 7-7a) occurs on D. westralium

and consists of both an anterior and a posterior flagellar pore structure. The anterior pore (AP) lies behind a curved ridge (R), both structures sitting on the higher terminal end of the cingulum (C1). The flagellum appears to have passed ventrally from the pore, encountering the curved ridge where it was then directed to the dinoflagellate's left onto the cingulum. The posterior flagellar pore (PP) is a broad opening at the top of the sulcus (S) which appears to have allowed the longitudinal flagellum to pass posteriorly onto the sulcus.

Other features at the cingulum-sulcus intersection appear to be associated with the flagellar pores. For example, two sets of curved ridges and depressions on D. pustulicostatum may have functioned as directing and confining mechanisms for the transverse flagellum. The specimen on Plate 23, fig. 4a illustrates these structures, one of which, the initial groove (IG), may have directed the transverse flagellum from the anterior flagellar pore onto the higher terminal end of the cingulum (C1). The final groove (FG), which is found on the upper part of the lower terminal end of the cingulum (C2) of the same specimens, may have restricted the distal end of the transverse flagellum. The final groove (FG) can also be observed on the specimen of D. pustulicostatum shown on Plate 23, figs. 3 and 3a; however, the initial groove is not visible, possibly because of distortion at the left side of the sulcus. At this point it is interesting to note that Evitt (1967, p. 362) reported that both the cingulum and sulcus in species of Dinogymnium lack

transverse structures that would inhibit the operation of a flagellum. Considering this, together with evidence of the existence of flagellar pores and various associated directing and confining features on Dinogymnium tests, it appears possible that such tests may represent motile stages. This raises the question as to which part of the dinoflagellate life cycle these tests would belong. The dinoflagellate life cycle as described by Wall and Dale (1968, p. 267-268), which consists of a motile planktonic stage and a nonmotile benthonic stage, seemingly applies to many known living dinoflagellates, even some unarmored species (Wall and Dale, 1968, p. 281). Fossil dinoflagellates have been considered, almost without exception, to represent the nonmotile benthonic stage. Fossil Dinogymnium tests bear archeopyle-like apical openings and have the same chemical resistance as fossil dinoflagellate cysts, suggesting that they are cysts; however, evidence presented here suggests that they may instead be motile stage tests. In addition to other features suggestive of motility, they bear features similar to trichocyst pores, which are known to occur only on modern motile stages, and not on the benthonic encysted stages. Therefore the evidence at hand suggests that Dinogymnium tests may not represent any part of a known dinoflagellate life cycle. Although it would be pure speculation to suggest an alternative life cycle, perhaps more can be said about the possibility of Dinogymnium representing an unknown stage of Wall and Dale's life cycle.

Fossil Dinogymnium forms are morphologically more like modern Gymnodinium forms than they are like any other modern genus. The motile stage of Gymnodinium is generally considered to

be naked; however, this is not necessarily true. G. fuscum (Ehrenberg) Stein, the type species of the genus Gymnodinium is reported to have plate-like structures homologous with the plates of armored dinoflagellates (Dodge and Crawford, 1969, p. 613, 616-617). If Dinogymnium and Gymnodinium are related it is important to note any such armored structures occurring in either. Wall and Dale (1968) reported that Gymnodinium produces at least three kinds of cysts. Thus we see that Gymnodinium has the capability of producing both a theca, though rudimentary, and, also, a cyst. Assuming some evolutionary relationship between Dinogymnium and Gymnodinium, we can now consider the Dinogymnium motile stage test in terms of both theca and cyst.

The term theca was used by Evitt (1967, p. 5) "solely in reference to the external plates that cover certain dinoflagellates in their actively-swimming stage." Although it appears that Dinogymnium tests did form on the exterior of an actively-swimming stage, scanning electron microscopy reveals that no plates are present. Lebour (1925, p. 2) suggested that the term "theca" be restricted to tests composed of cellulose or some closely related substance. It would appear that the Dinogymnium test is not made of a substance closely related to cellulose. One may say, however, that members of the modern family Actiniscaceae develop tests of silica or some other rigid substance. These tests are internal skeletons, rather than external plates, and therefore do not qualify as thecae by this definition. Motile stage Dinogymnium tests, therefore, should not be identified as thecae, even though they bear flagellar pores

and trichocyst pores.

The term "cyst," as it applies to dinoflagellates, was used by Evitt and Davidson (1964, p. 7-8) in reference to acid-resistant, organic-walled, impervious bodies which may bear an archeopyle, but not flagellar pores. The Dinogymnium tests reported here are penetrated by many trichocyst pores and also have flagellar pores. Thus, even though the Dinogymnium tests are acid resistant and bear an archeopyle-like opening, it seems unreasonable to consider them as cysts.

Evitt (Personal communication, January, 1976) in reference to Dinogymnium tests states that it appears reasonable that many dinoflagellates have a capacity of forming 2 types of tests [other than cysts]: one composed of cellulosic plates [theca] formed in cavities within a complex wall, the other composed of sporopollenin and not necessarily comprising separable plates. Perhaps a term other than "theca" or "cyst" should be applied to such motile stage sporopollenin tests. It is not practical at this stage to suggest a new term; it is only practical to point out the existence of fossil dinoflagellate tests which appear to be intermediate between, and different from, motile thecate stages and nonmotile encysted stages.

Wall Canals

Wall canals are small (generally less than 0.2 um across) openings or passages that penetrate the test wall, either partially or completely (pl. 23, fig. 2). They generally appear to be associated with pustules or bumps on the test exterior, but not on the test interior (pl. 21, fig. 16, pl. 23, fig. 2). Only about 50 percent of the pustules of D. pustulicostatum have wall canals that appear to penetrate to the test exterior; however; small depressions in the rest of the pustules suggest that a wall canal also lies beneath each of those (pl. 21, fig. 16). Thus, it appears that wall canal formation may begin from within, and that their development proceeds toward the exterior. As seen on plate 23, fig. 2, most wall canals pass perpendicularly through the test wall, while others pass through at differing angles.

A comparison of the wall canal surface patterns of D. pustulicostatum and D. westralium (pl. 23, fig. 1; pl. 12, figs. 3, 4, respectively) illustrates that each species has a distinctive pattern. On D. pustulicostatum the wall canals are uniformly distributed on and between the longitudinal ribs, and each canal that penetrates to the exterior of the test passes through a low bump (pustule). At the test apex, including the operculum, the canals are densely and randomly arranged, and most of the canals are of great diameter (generally about 0.2 um). The canals of D. westralium are sparse and randomly arranged between

the longitudinal ribs; however, they are aligned in a single row along the crest of each rib where the pustules have low relief and also in a single row along each side of the ribs where the pustules have great relief. At the test apex, the wall canals are most numerous, being arranged in irregular, dorso-ventrally aligned rows on the operculum. Also, on the operculum the wall canal size differential is about 2-3X; whereas, it is more uniform on the operculum of D. pustulicostatum. If similar differences occur among other species, then such patterns will prove taxonomically valuable.

The purpose of wall canals is not known; however, a comparison with the fine surface structure of certain modern forms suggests that they may have functioned as trichocyst pores. Several modern dinoflagellates bear such pores, including unarmored forms; e.g., Amphidinium carteri and Gymnodinium nelsonii (Dodge and Crawford, 1968; Bouck and Sweeney, 1965; respectively). Trichocyst pores in modern dinoflagellates bear trichocysts (one per pore), which are long rigid, rodlike structures that can be quickly discharged into the external environment. The function of trichocysts is nct known; however, several ideas have been suggested. Bouck and Sweeney (1965, p. 221) reported that the design of the whole charged trichocyst is suggestive of a mechanical sensing device, and that their discharge may be triggered by impact. Evidence that trichocysts may function as osmoregulators was supported by the presence of salt crystals along the shafts discharged from cells grown at high salt concentrations (Wohlfarth-Bottermann, 1952). This latter idea idea will be elaborated on in

the paleoecological section of this discussion on Dinogymnium.

If wall canals which completely penetrate the test wall of Dinogymnium do represent trichocyst pores, then by comparison with modern forms they would have been lined laterally and basally by at least two membranes; this is the case with the living Ceratium hirundinella (Dodge and Crawford, 1970, p. 143). It seems unlikely that the cytoplasmic membrane would have had uninhibited communication with the outside water.

Dinogymnium Paleoecology

Dinogymnium pustulicostatum occurs with relative frequencies of 45 to 64 percent in three consecutive samples taken at 0.5 meter intervals in the upper Mount Laurel Sand at the study area. The average species diversity of all dinoflagellates for these three samples is 19. The next two samples above, also taken at 0.5 meter intervals, have relative frequencies for D. pustulicostatum of 0.7 to 1.3 percent, and an average species diversity of 41. Such patterns of low species diversity coupled with dominance by one or two forms versus high species diversity with low dominance has been reported by Hulbert (1963). The high concentration of D. pustulicostatum and low species diversity in this part of the upper Mount Laurel Sand

satisfies Hulbert's (1963) description of an estuarine phytoplankton assemblage. In this environment, the lower salinity (and probably greater salinity fluctuation) appears to be unfavorable to much of the marine phytoplankton. Physical evidence of a possible estuarine depositional environment for the upper Mount Laurel Sand is the shoaling sequence that terminates at the top of the Mount Laurel with phosphatized fossil remains. Owens and Sohl (1969, p. 256) have suggested that the Mount Laurel Sand is of nearshore gulf origin, and, because of Callianassa borings, was probably deposited in very shallow water; this evidence supports the possibility of estuarine environments. It is therefore suggested that high concentrations of D. pustulicostatum (and perhaps most Dinogymnium species) combined with low species diversity is an indication of estuarine conditions.

Possible Functional Morphology of Dinogymnium as Related to Paleoenvironment

The estuarine environment with its wide, and often rapid, fluctuations in salt content presents its inhabitants with severe problems in adaptation (Perkins, 1974, p. 26). Salinity varies with depth and distance in most estuaries at any one time, and changes rapidly depending on the tides and terrestrial runoff. Daily changes of 18-30 0/00 can occur at the mouths of estuaries (Perkins, 1974, p. 27). Because of the problem of osmoregulation and plasmolysis in

such extreme salinity changes, some algae are known to have mechanisms to compensate either size or cellular salt content. Dawson (1966, p. 253) reports that some intertidal red algae have cell walls that swell and contract in harmony with expansion or shrinkage of the cell contents as water is taken in or withdrawn, and that others have an osmoregulatory mechanism for accumulating salts against a diffusion gradient, thereby either preventing plasmolysis or reversing it. Considering these two mechanisms, certain morphological features of Dinogymnium tests come to mind. First is the accordian-like construction of the test, which appears to be designed for expansion and contraction, presumably in harmony with cell size; various degrees of test expansion and contraction are shown for D. pustulicostatum (pl. 21, figs. 1-14) Wohlfarth-Bottermann (1952) reported that discharged shafts of trichocysts from cells grown in high salt concentrations bore salt crystals, leading him to believe that the trichocysts may function as osmoregulators. Such a feature could be comparable to the salt accumulating mechanisms of certain red algae that prevent or reverse plasmolysis. The wall canals of fossil Dinogymnium tests have been discussed in terms of trichosyst pores in the previous discussion. Thus, both the accordian-like ribbing and wall canals may suggest two methods by which Dinogymnium adapted to an environment of widely varying and rapidly fluctuating salinity.

Variation in Species

General Statement

Cordosphaeridium varians n. sp. and Exochosphaeridium bifidum (Clarke and Verdier) Clarke et al. 1968, discussed below, display considerable morphologic variability in the Atlantic Highlands study section. Two types of variability are encountered: morphologic variability within individual samples (approximating population variability at one point in time) and upsection morphologic variability (suggesting a phylogenetic lineage). A consideration of each type of variability leads to recommendations on the taxonomic treatment of morphologically variable fossil dinoflagellate cysts.

Explanation of problem

The taxonomic treatment of populations displaying a high degree of morphologic variability at one point in time is not only of concern to paleopalynologists working with fossil dinoflagellates, but is also of concern to phycologists working with modern algae. The concept of the biological species, as it applies to living organisms, is such that a high degree of morphologic variability observed in one population (one species) is not necessarily a criterion for speciation. Modern algal species are often highly variable, but the variability can be shown to be natural within the population, stemming from

different stages of a life cycle, ecophenotypic response, or genetic recombination. Likewise, a high degree of natural morphologic variability observed within a fossil dinoflagellate population could be accommodated within a biological species, and it should not be used as a reason for creating separate species. It is recommended, therefore, that a natural population of fossil dinoflagellate cysts which occurred at approximately the same point in time not be divided into separate species.

Concerning morphologic variability within a phylogenetic lineage, the ideas of Dobzhansky (1970), given below, suggest that the taxonomy of such lineages should be treated differently than the taxonomy of highly variable species existing at one point in time (discussed above).

Dobzhansky (1970, p. 354-360) states that organisms resemble each other because they are descendents of common ancestors and that the species of a genus or the genera of a family are related by common descent, usually many generations back. Most animals and plants are complexes of local populations, such as races, which differ from each other genetically, and species evolve from such races by the accumulation of genetic change. Dobzhansky further points out that some races have not completely diverged; e.g., the alley cat and the siamese cat. Thus, incipient species, the species in statu nascendi, will always involve a residue of borderline cases with the parent species. This difficulty comes from the species not

being fixed, but evolving. The taxonomic treatment of such evolving species is somewhat arbitrary, but species succeeding each other in time should be so defined as to make the morphologic difference between them at least as great as the sequential difference among contemporary species of the same group or closely allied groups, according to Dobzhansky. The conclusions that I draw from these ideas are: 1) a phylogenetic lineage may be subdivided into a succession of species or higher taxa, 2) a residue of borderline cases will exist between succeeding species or higher taxa, 3) the cut-off point between succeeding species or higher taxa may be difficult to define and will depend upon the workers judgment, and 4) the differences between succeeding species or higher taxa should be at least as great as the difference that exists between contemporary species or higher taxa of the same group.

Cordosphaeridium varians variability

Cordosphaeridium varians n. sp. (pl. 2, figs. 4, 7, 8; pl. 14, figs. 1-3; pl. 15, figs. 1a-5d; pl. 16, figs. 6a-10d) occurs in the upper Mount Laurel Sand and lower Navesink Formation (samples 206-211). The degree of intraspecific variability and gradation are illustrated on pl. 16, figs. 9a-d. Extreme variants, figs. 9a and 9d, if observed as isolated specimens, would likely be assigned to different taxa. Specimen 9a displays surface ornamentation

composed of thickly-matted fibrils which are slightly integrated into individual process groupings. Figs. 9b-d show the continued, progressive integration of the fibrils into process groupings, producing the distinctive Cordosphaeridium form seen in fig. 9d. The Gonyaulax-type tabulation of C. varians is determined from forms, such as 9d, which display well-developed fibrous, intratabular processes. Scanning electron micrographs (pl. 14, figs. 1-3) best illustrate surface ornamentation and the integration of fibrils into processes.

C. varians changes radically in morphology upsection (between samples 206-213, upper Mount Laurel-basal Navesink), grading into Trichodinium cf. T. hirsutum Cookson 1965. This lineage is best illustrated in figs. 10a-d of pl. 16, which represents the morphologic change which takes place between samples 206 and 213. Fig. 10a of this sequence illustrates a specimen of C. varians with matted fibrils; whereas, figs. 10b-d show the progressive change of fibrils into stiff, bristly spines and the development of the larger apical and antapical spines which are typical of T. cf. T. hirsutum. In sample 206 no. T. cf. T. hirsutum forms were observed; however, upsection in sample 213 they become the dominant part of the population, having replaced C. varians. The surface ornamentation and spine morphology of T. cf. T. hirsutum are best illustrated in the scanning electron micrograph (pl. 14, fig. 4).

Pl. 15, figs. 1a-5d, and pl. 16, figs. 6a-8d, show the detailed intraspecific variability of C. varians and T. cf. T. hirsutum from

samples 206-213. Each row of figures corresponds to the variability observed in one sample. Thus, rows 1-8 correspond respectively to samples 213-206 (see plate explanations for details).

Exochosphaeridium bifidum Variability

Exochosphaeridium bifidum (Clarke and Verdier) Clarke et al. 1968 (pl. 2, figs. 9-12; pl. 12, fig. 11; pl. 17, figs. 1-20; pl. 18, figs. 1-20; pl. 19, figs. 1-12; and pl. 20, figs. 13-20) occurs throughout the study section, and seems to possess the same degree of variability in all samples. Pl. 17, figs. 1-20 illustrate a sequence of 20 specimens from sample 227. Each photomicrograph is an optical cross-sectional view and the sequence is arranged so that specimens with smaller spines appear first. A typical E. bifidum is shown in fig. 2, which shows the slender, solid, rod-like processes and the apical tuft. The apical tuft in most of the other specimens is out of the plane of focus. Most of the processes shown in figs. 1-10 are slender, solid, and rod-like; whereas, many of those shown in the rest of the sequence are broad, solid to hollow, and tubular in appearance. These broader processes are fibrous in construction and give the entire cyst the general appearance of a Cordosphaeridium.

The apical tufts of E. bifidum also show a high degree of variability in size and shape. Pl. 18, figs. 1-20, illustrates the tufts corresponding to the respective specimens shown on pl. 17, figs. 1-20. In general, as process length increases the tufts also

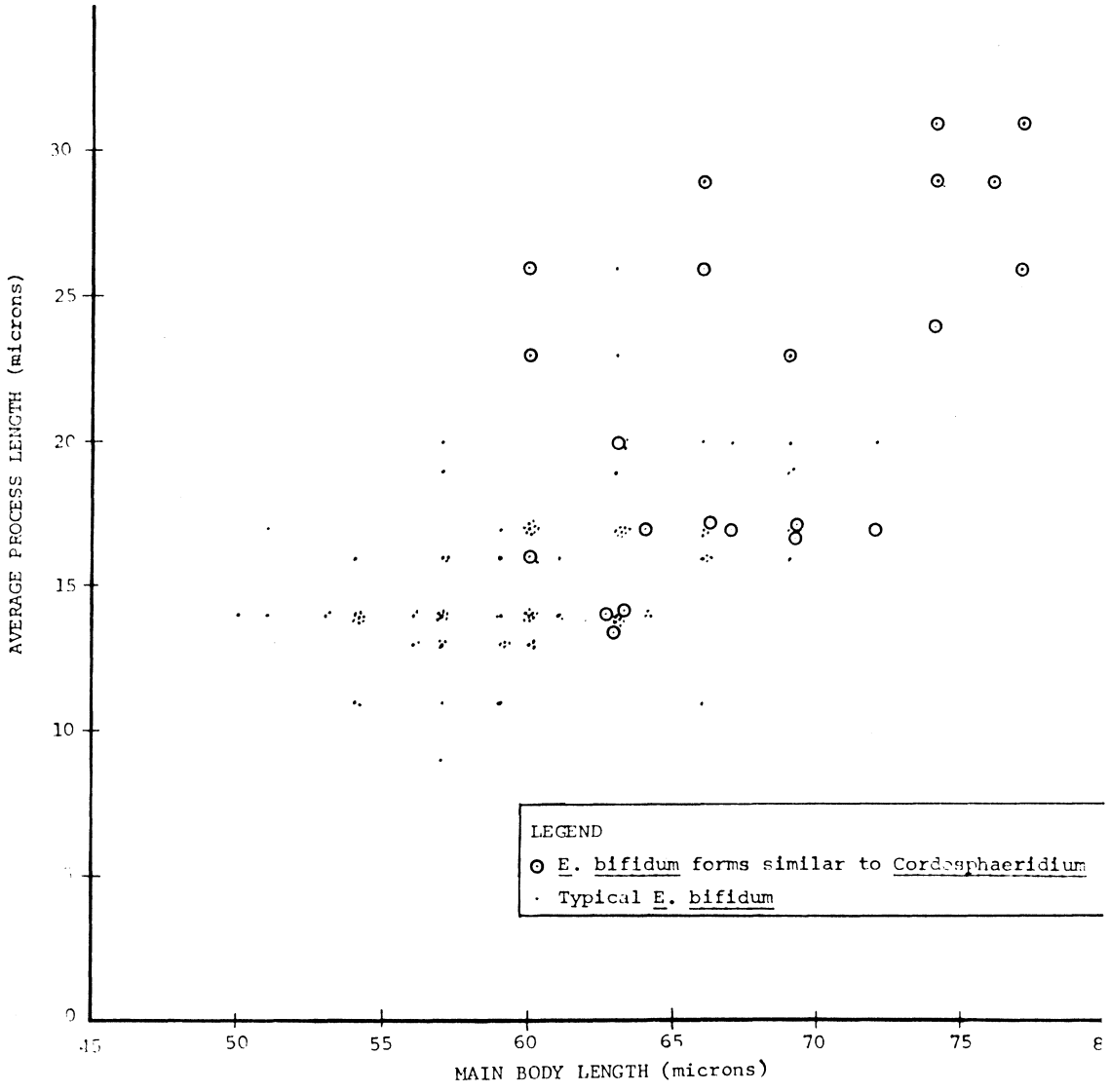


Figure 7. Scatter diagram of average process length versus main body length for Exochosphaeridium bifidum (Clarke and Verdier) Clarke et al. 1968. A gradation exists between typical E. bifidum forms and morphological variants similar in structure to Cordosphaeridium.

increase in length, and the branching becomes more complex.

A detailed representation of process variability for E. bifidum is shown on pls. 19 and 20. The 20 process groupings illustrated there correspond respectively to the 20 specimens shown on pl. 17. Each process grouping shows the degree of variability associated with the processes for each specimen. As process length increases in the sequence, a larger number of broad and tubular processes are observed. The process structure and surface ornamentation for a typical E. bifidum is best shown in the scanning electron micrograph (pl. 12, fig. 11).

A scatter diagram of average process length plotted against main body length for E. bifidum is shown in text-fig. 7. Data points for specimens possessing broad, fibrous, and tubular processes, which could be identified as Cordosphaeridium if observed as isolated specimens, are circled. Their positions in the scatter show that they are likely morphologic end members of the same species.

SUMMARY AND CONCLUSIONS

This investigation reports on fossil dinoflagellates of the Gonyaulacaceae, Peridiniaceae, and Gymnodiniaceae, from a continuous and complete section of the upper Mount Laurel Sand, Navesink Formation, and Sandy Hook Member of the Red Bank Sand of the Upper Cretaceous Monmouth Group of the northern New Jersey Coastal Plain. Samples were collected from the bluffs overlooking Sandy Hook Bay, approximately 1500 feet east of the Atlantic Highlands Yacht Harbor, Thirty-seven genera and 91 species were recovered, of which 3 genera and 19 species are described as new, and 4 new combinations are presented. Dinoflagellate occurrence and stratigraphic distribution are recorded on Range Charts I and II, and also in Appendix I.

Major changes in the relative frequency of dinoflagellate species are interpreted as corresponding to changes in the depositional environment. A paleoecological study of the Mount Laurel Sand and Navesink Formation by Sohl (1969) indicated that water depth increased from Mount Laurel into mid-Navesink times. Owens and Sohl (1973), basing their conclusions on glauconite studies, reported that the Mount Laurel was deposited in about 20 meters of water, the Red Bank in about 30 meters, and the Navesink in about 80 meters. Thus, they concluded that water depth increased from Mount Laurel into Navesink times and then decreased from late Navesink into Red Bank times, indicating a marine transgression and regression.

A comparison of Range Chart I (stratigraphic distribution according to first appearances) and text fig. 6 (stratigraphic arrangement of relative frequencies for 25 species) suggests that four main depositional environments are represented in the section. Most of the upper Mount Laurel Sand has low species diversity (only 36 species are present) and the assemblage is dominated by Dinogymnium pustulicostatum n. sp. It is suggested that the near-shore gulf environment assigned by Owens and Sohl (1969, text-fig. 15) is correct, and that abnormal marine conditions existed there. The sequence from uppermost Mount Laurel to middle Navesink has high species diversity (72 species) and relative frequencies are more evenly distributed. It is suggested that a marine transgression occurred during this time and that normal marine conditions existed. The sediments in this interval were probably deposited in inner to outer-shelf environments as has been suggested by Owens and Sohl (ibid.). The upper Navesink has lower species diversity (58 species), but no single species dominates the assemblage. The environment represented by this interval is thought to be nearer shore than that of the lower Navesink, and the sediments were possibly deposited in a nearshore gulf environment under nearly-normal marine conditions. The Sandy Hook Member of the Red Bank Sand is comparable to the upper Navesink in having a high species diversity (53 species), but in the lower part of the unit the assemblages are strongly dominated by Areoligera sp. McLean (1971) suggested that such a condition indicated abnormal

marine conditions. It is suggested here that all of the Sandy Hock Member was deposited in the nearshore gulf environment, and that the lower part especially, was deposited in abnormal marine waters.

Formational boundaries are considered conformable for all units studied. The step-like nature of first appearances for some 37 species spanning the Mount Laurel-Navesink boundary diminishes the possibility of a disconformity. Minard (personal communication, 1975) feels that a shoaling upward sequence exists through the Wenonah Formation and Mount Laurel Sand, and that the pebbly horizon at the top of the Mount Laurel, together with phosphatized fossils at the base of the Navesink Formation could indicate a disconformity. If a gap in the section exists there it is possibly diastemic.

Several dinoflagellate species show great intraspecific morphological variability. When better understood, the variants may have value in paleoecological, taxonomic, and biostratigraphic analysis. Specimens of Cordosphaeridium varians n. sp. in the upper Mount Laurel and lower Navesink have extreme population variants, which if observed as isolated specimens would probably be identified as different taxa. One extreme variant has well-developed intratabular processes composed of matted fibrils, which are not integrated into processes. Specimens of Exochosphaeridium bifidum, occurring throughout the section, have extreme variants which are quite different in appearance. One variant has numerous, small, solid processes, while the other variant has a mixture of large solid processes and fibrous tubular processes.

The writer recommends that such highly variable fossil species should be treated taxonomically the same as are highly variable living species; namely, that they should not be divided into two or more species, even though morphologic end members appear distinctively different. Contemporaneous morphologic end members of one population should be identified by the same taxonomic name.

Two lineages are reported. Cordosphaeridium varians is shown to grade upward in the section into Trichodinium cf. T. hirsutum. This morphological gradation occurs within the lower Navesink Formation. Leptodinium cristatum n. sp., which has well-developed ventral tabulation, is considered ancestral to L. victorianum Cookson and Eisenack 1965 of Eocene age and L. patulum Wall 1967 of Miocene to Holocene age which lack several ventral plate boundaries. This succession is characterized by a progressive decrease in the number of sutural crests bordering ventral plates.

The writer recommends that phylogenetic lineages may be divided into a succession of species or genera, depending upon the degree of evolutionary change encountered in the lineage. Dobzhansky (1970) discussed this procedure at some length, and concluded that species evolve into incipient or derived species, and that a succession of taxa may be used to divide the lineage where appropriate. Borderline cases will probably occur between successive species; however, the successive species should be at least as different morphologically as are contemporary species of the same group. Although Dobzhansky's

(1970) discussion on the taxonomic subdivision of lineages was directed at subdivision into successive species, he also discussed the relationship of species to genera and genera to families, suggesting that evolution involves a succession of genera and families as well.

It is shown that physical distortion in Dinogymnium pustulicostatum n. sp. and D. westralium (Evitt) emend. masks the actual degree of natural variability. Cingulum index, which appears to be independent of most distortional effects, is useful when statistically evaluating natural variability within such species. Scanning electron microscopy of D. pustulicostatum and D. westralium reveals that the wall canals open to the exterior and are often associated with pustules.

Scanning electron microscopy of the cingulum-sulcus intersection of Dinogymnium pustulicostatum and D. westralium has demonstrated the presence of flagellar pore structures: one anterior pore and one posterior pore. These pores have the appearance of penetrating into the test wall, thereby appearing as more than surface features. The presence of these pores gives the best evidence to date that motile stage dinoflagellate tests are preserved as fossils; fossil dinoflagellates have heretofore been considered to be of the nonmotile encysted stage. This raises the possibility that other dinoflagellate tests, which to date have been considered to be nonmotile cysts, may in fact be motile stage tests. Whether these motile stage tests are thecae or cysts or some unknown type of test depends upon the definition of the theca and the cyst. The published and accepted definition of the theca states that it is composed of cellulosic plates (Evitt, 1967); whereas,

the definition of the cyst states that the test wall must be impervious and that it cannot bear flagellar pores (Evitt, 1967). Because the Dinogymnium tests studied were not cellulosic and did not bear plates they cannot be considered thecae, and because they bear possible trichocyst pores which penetrate the test, and also flagellar pores, they cannot be considered cysts. It is possible that a new term will need to be defined for tests such as those observed in Dinogymnium.

Scanning electron microscopy of the fine wall structure of Dinogymnium pustulicostatum and D. westralium has given the first detailed view of wall canals. Wall canals appear to be related to trichocyst pores of modern motile dinoflagellates, suggesting once again that the Dinogymnium tests reported on here are motile stages. Detailed views of cross sections of Dinogymnium test walls show that the pores penetrate through the test walls. This is an unusual feature because dinoflagellate cysts are considered to be impervious (Evitt and Davidson 1964).

The placement of the Campanian-Maestrichtian boundary, based on dinoflagellates, within an interval of the upper Mount Laurel and basal Navesink is supported by new ammonite evidence (Cobban, 1974). Beneath this interval the Mount Laurel is considered of late Campanian age, and above it the Navesink and Sandy Hook Member are considered of early Maestrichtian age.

Biostratigraphic correlation with Wilson's (1974) dinoflagellate zones of the type Maestrichtian of the Maestricht Region, Holland, and also of the Maestrichtian of Denmark was found to be difficult. His zones (I-V) are based on first and last appearances; however, no paleoecological determinations were made in his study which could help the reader to interpret the first and last appearances. Other potential problems are: 1) all or parts of the various zones are missing in one or the other of his study areas, 2) there are numerous disconformities involved, 3) the first and last appearances often don't correspond in both study areas, 4) there are frequent gaps in the composite sections, 5) and an irregular and widely-spaced sampling interval was used. This research seems to indicate that the Atlantic Highlands, New Jersey, study section corresponds to Wilson's zones I-III; however, this determination is based on a comparison of the stratigraphic distribution of relatively few species. Wilson's (1974) stratigraphic distribution of dinoflagellates in the Maestricht Region, Holland, was, however, useful in dating lower and upper Maestrichtian sediments in the Atlantic Highlands, New Jersey study section. Based on the common occurrence of Samlandia angustivela, Spongodinium delitiense, Triblastula utinensis, and Triblastula borussica it is determined that the Navesink Formation and Sandy Hook Member of the Red Bank Sand are early Maestrichtian in age. The upper Mount Laurel Sand appears to be of late Campanian age; however, biostratigraphic correlation with the type Campanian is not possible at present.

SYSTEMATIC PALYNOLOGY

Introduction

In this chapter 37 genera including 91 species of fossil dinoflagellates assigned to the families Gymnodiniaceae, Gonyaulacaceae, and Peridiniaceae are presented. A summary of the taxonomy is listed below:

Genera emended	1
New genera	3
New species	20
New subspecies	1
Species emended	5
New combinations	4
Species cited	63
Total species	91

Classification Used in This Study

Several classifications have been proposed for fossil dinoflagellates. Wall and Dale (1968) suggested that fossil and modern dinoflagellates be included under a single classification. This is highly desirable because it allows dinoflagellate taxonomy to be influenced by modern biological concepts, especially as they apply to populations. Sarjeant and Downie (1966) proposed an artificial classification based completely on fossil dinoflagellate cysts. This

method of classification isolates dinoflagellate taxonomy from past, present, and future findings relating to natural relationships among living dinoflagellates. Although Sarjeant and Downie's (1966) classification offers a ready made pigeon-hole for most any fossil dinoflagellate, it leads a taxonomist away from possible biological relationships that may exist between fossil and living dinoflagellates. The writer would hope that future dinoflagellate research would tend to link the past with the present, rather than keep it separated. Norris and McAndrews (1970) proposed a separate scheme of classification for cyst and theca; however, modern phycology has tended to consider all phases of a life cycle the same species.

The classification used in this study is based on natural families, and, for this reason, the species are considered to be biological species, each displaying a natural degree of variability. Although, in many cases, not much is known about the populations which these species represent; still, future studies will undoubtedly reveal more information which will make more meaningful the assignment of these species to natural families. For this reason some assignments made in this systematics chapter can be considered tentative, until more information is known about the respective dinoflagellate populations. The purpose of using the natural families, listed below, at this stage in the science is to set a direction toward linking the past with the present.

Gymnodiniaceae: for <u>Dinogymnium</u> forms representing the modern <u>Gymnodinium</u> forms.

Gonyaulacaceae: for genera that can be reasonably construed to have reflected tabulation of the general sort that is represented in Gonyaulax relatives today.

Peridiniaceae: same with respect to Peridinium.

An Explanation of Stratigraphic Occurrence

The stratigraphic occurrence for each species is given in general terms for each species entry in the systematics sections; i.e., common, rare, etc. A detailed representation of the stratigraphic occurrence; i.e., number of specimens observed in a 300 count and relative frequency, is given in Appendix I.

Morphological Terms

Definitions of dinoflagellate cyst morphological terms used in this dissertation follow:

Cingulum index: the two-digit integer expressing the distance from the apex to the middle of the cingulum divided by the pole to pole distance, times 100.

Wall canal: perforations in or through the cyst wall of certain species of Dinogymnium.

Cyst: the entire fossil entity including all wall layers, processes, septa, etc.

Main body: in process-bearing or septate cysts this is the central body that bears the processes or septa.

Periphragm: the outer wall layer of a bi-layered cyst.

Endophragm: the inner wall layer of a bi-layered cyst.

Periblast: the individual body formed of the periphragm in bi-layered cysts.

Endoblast: the body formed of the endophragm in bi-layered cysts.

Pericoel: any cavity between the periphragm and the endophragm, including spaces under sutural folds. Can be referred to as posterior, anterior, lateral, etc.

Endocoel: the interior cavity of the endoblast.

Sutural folds: outward folds of the periphragm that appear to coincide in position with the plate boundaries of the theca within which the cyst formed.

Sutural ridges: low, solid walls which extend perpendicularly from the exterior of the main body, in the position of the thecal sutures. They do not involve folding of the periphragm in bilayered cysts.

Septa: relatively high, thin, solid and perhaps membraneous walls that extend perpendicularly from the exterior of the main body, often along suture lines, that do not involve folding at the wall layers.

Left and right: used with the sulcus taken as ventral and the apex taken as anterior.

Ventral: the sulcal side of the cyst.

Dorsal: the side of the cyst opposite the sulcus.

Heterocostate: longitudinal ribs or costae of two size ranges in Dinogymnium.

Homocostate: longitudinal ribs or costae of one size range in Dinogymnium.

Costae: longitudinal ribs in Dinogymnium caused by accordian-like folding of cyst wall.

Species List

Dinoflagellate species recovered from the upper Mount Laurel Sand, Navesink Formation, and Sandy Hook Member of the Red Bank Sand are included in the following list, which is arranged in the order in which each species is discussed in this systematics chapter.

Class DINOPHYCEAE Fritsch

Order Gymnodiniales Lindemann

Family Gymnodiniaceae Schutt

Dinogymnium acuminatum Evitt 1967

D. digitus (Deflandre) Evitt et al. 1967

D. elongatum n. sp.

D. euclaensis Cookson and Eisenack 1970

D. cf. *D. euclaensis* Cookson and Eisenack 1970

D. lanceolatum n. sp.

D. pustulicostatum n. sp.

D. westralium (Cookson and Eisenack) Evitt et al. emend.

D. sp. A

D. sp. B

D. sp. C

D. sp. D

Order Peridiniales Haeckel

Family Gonyaulacaceae

Apteodinium baculatum n. sp.

Areoligera sp.

Cannosphaeropsis cf. C. pusulosa Morgenroth 1966

C. utinensis O. Wetzel 1933, emend.

Conneximura fimbriata (Morgenroth) n. gen., n. comb.

Conosphaeridium sp.

Cordosphaeridium fibrospinosum Davey and Williams 1966

Cordosphaeridium varians n. sp.

Coronifera oceanica Cookson and Eisenack 1958, emend.

Cyclonephelium cf. C. densebarbatum Cookson and Eisenack 1960

Diconodinium rhombiformis Vozzhennikova 1967

D. sp.

Diphyes colligerum (Deflandre and Cookson) Davey and Williams 1966

Diphyes recurvatum n. sp.

Diversispina truncata n. gen., n. sp.

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

Gonyaulacysta clathrata Cookson and Eisenack 1960

G. wetxeli (Lejeune-Carpentier) Sarjeant 1969

G. sp.

Hystrichokolpoma fenestrecona n. sp.

Hystrichosphaeridium recurvatum (White) Davey and Williams 1966

Hystrichosphaeridium tubiferum (Ehrenberg) Davey and Williams 1966

H. tubiferum var. brevispinum Davey and Williams 1966

H. sp.

Leptodinium cristatum n. sp.

L. cf. L. multiplexum Wall and Dale 1968

Odontochitina costata Alberti 1961

Oligosphaeridium complex (White) Davey and Williams 1966

Phoberocysta ceratioides (Deflandre) Millioud 1969

Prolixosphaeridium xanthiopyxides (O. Wetzel) Davey et al. 1969

Samlandia angustivela (Deflandre and Cookson) Eisenack 1963

Spiniferites ramosus (Ehrenberg) Loeblich and Loeblich 1966 var. ramosus (Ehrenberg) Davey and Verdier 1971

S. ramosus (Ehrenberg) Loeblich and Loeblich 1966 var. granosus Davey and Williams 1966 (not formally effected)

S. ramosus (Ehrenberg) Loeblich and Loeblich 1966 var. multibrevis Davey and Williams 1966 (not formally effected)

S. ramosus (Ehrenberg) Loeblich and Loeblich 1966 var. reticulatus (Davey and Williams) Davey and Verdier 1971

S. ramuliferus (Deflandre 1937) n. comb.

S. cf. S. septatus (Cookson and Eisenack) McLean 1971

S. supparus (Drugg) Sarjeant 1970

Spinitectulum ferox (Deflandre) n. gen., n. comb.

S. ramulus n. sp.

S. sp.

Spongodinium delitiense (Ehrenberg) Deflandre 1936

S. sp.

Systematophora placacantha (Deflandre and Cookson) Davey et al. 1969

S. varians n. sp.

Triblastula borussica (Eisenack) Morgenroth 1966

Triblastula nuda (O. Wetzel) Morgenroth 1966

Triblastula utinensis O. Wetzel 1933

Trichodinium cf. T. hirsutum Cookson 1965

Family Peridiniaceae Kent

Deflandrea asymmetrica Wilson 1967

D. cf. D. asymmetrica Wilson 1967

D. cooksoni Alberti 1959

D. cordifera n. sp.

D. corrugatella n. sp.

D. cf. D. cretacea Cookson 1956

D. diebeli Alberti 1959

D. diebeli Alberti 1959 subsp. rigida n. subsp.

D. magnifica Stanley 1965

D. cf. D. obscura Drugg 1967

D. ornata n. sp.

D. pannucea Stanley 1965

D. speciosa Alberti 1959

D. spicata n. sp.

D. striata Drugg 1967

D. tripartita Cookson and Eisenack emend. Cookson and Manum 1964

D. cf. D. tripartita Cookson and Eisenack emend. Cookson and Manum 1964

D. sp. A

D. sp. B

D. sp. C

D. sp. D

Palaeocystodinium australinum (Cookson) n. comb.

P. cf. P. denticulatum Alberti 1961

P. reductum n. sp.

Palaeohystrichophora infusorioides Deflandre 1934

Spinidinium uncinatum n. sp.

Trithyrodinium cavum n. sp.

T. evittii Drugg 1967

T. pentagonum n. sp.

T. striatum n. sp.

Systematic Descriptions

Division PYRRHOPHYTA Pascher 1914

Class DINOPHYCEAE Fritsch 1935

Order GYMNODINIALES Lindemann 1928

Family GYMNODINIACEAE Schutt 1896

Genus Dinogymnium Evitt et al. 1967

Dinogymnium acuminatum Evitt 1967

Pl. 21, fig. 19

1967. Dinogymnium acuminatum Evitt, Stanford Univ. Pub. (Geol. Sci.), vol. 10, no. 4, p. 8-16, pl. 1, figs. 1-24, pl. 2, figs. 1-22, pl. 3, figs. 1-12, 20.

Comments: One specimen of D. acuminatum Evitt 1967 was observed in sample 212 (lower Navesink Formation). The cyst is rhomboidal in outline with a rounded apex and ventrally directed acuminate antapex. Hypotract is more heterocostate than epitract. Cingulum is deeply indented and appears levorotatory. Sulcus is restricted to hypotract. Archeopyle is apical and narrow; operculum is ventrally and dorsally attached. Surface ornamentation is faintly pustulose.

Dimensions: Length 73 um; width 50 um. Cingulum index 45. Wall thickness less than 1 um.

Occurrence: Navesink Formation, extremely rare.

Previously reported occurrence: Maestrichtian of California (Evitt, 1967).

Dinogymnium digitus (Deflandre) Evitt et al. 1967

Pl. 11, fig. 20

1935. Gymnodinium digitus Deflandre, Bull. Biol. Fr. Belg., vol. 69, p. 225, text-fig. 7-8.

1967. Dinogymnium digitus (Deflandre) Evitt et al., Stanford Univ. Publ., Geol. Sci., vol. 10, p. 18-19.

Comments: Two specimens observed in the Mount Laurel Sand have somewhat expanded epitracts and elongate, but conical, and antapically rounded hypotracts. Although the Mount Laurel specimens lack straie or costae on the epitract, Deflandre's (1935, p. 225, text-figs. 7-8) specimen apparently has faint longitudinal markings. The presence or absence of the markings on the epitract is likely a factor of intra-specific variability or lateral distortion. Vozzhennikova (1967, pl. V, figs. 5, 6, and 12) illustrated epitracts devoid of longitudinal striae and others with faint straie. The Mount Laurel specimens, as with Deflandre's (ibid.), have longitudinal striae on the hypotract. Surface ornamentation is faintly pustulose. Archeopyle is apical and narrow and the operculum appears ventrally attached.

Dimensions: Two specimens observed and measured: length 74-77 um, width 25-28 um. Epitract length 34-37 um, hypotract length 40 um.

Occurrence: Mount Laurel Sand, extremely rare.

Previously reported occurrence: Senonian of France (Deflandre, 1935), of Australia (Cookson and Eisenack), Upper Cretaceous of the Soviet Union (Vozzhennikova, 1967).

Dinogymnium elongatum n. sp.

Pl. 11, figs. 1-2

Name derivation: Latin, elongatum, elongate. Referring to the great length of the cyst relative to its width.

Holotype: AI-21, R6.9; +11.2 (Pl. 11, figs. 1-2).

Type locality: Atlantic Highlands, New Jersey.

Type stratum: Mount Laurel Sand.

Description: Delicate elongate cyst, ca. 10 times longer than wide; appears single layered. Epitract is less than 1/3 total cyst, is narrow, digitate, and tapers to a point. Hypotract is immediately broader across the cingulum; however, is markedly narrow also, expanding slightly posterior of the cingulum, then tapering to an acuminate antapex. Cingulum well-defined, slightly elevated on hypotract side, and laevorotatory; offset ca. 1/2 cingulum width. Sulcus is short, extending a short distance onto both epitract and hypotract. Surface smooth to finely scabrate. No archeopyle observed.

Discussion: Because of the excessive length and delicacy of the cyst most specimens are usually folded, collapsed, or torn; therefore, it is difficult to find adequate specimens for measuring. Although these specimens share certain affinities with some modern Gymnodinium forms, as well as some fossil Dinogymnium forms, they

appear to lack the costate wall construction, apical archeopyle with attached operculum, and wall canals.

Affinity: Dinogymnium elongatum shares certain morphological features with some modern Gymnodinium species. Features resembling the modern G. filum Lebour 1917 are: the smooth noncostate cyst; high, well-defined cingulum; sulcus extending into both hypotract and epitract; and tapering apex and antapex. Gymnodinium massarti (Conrad) Schiller 1926 resembles D. elongatum, having a high cingulum, smooth walls, tapering hypotract (epitract is rounded), and sulcus extending onto both hypotract and epitract.

Dimensions: Observed range (2 specimens measured): length 186-300 um, width 11-28 um near cingulum, Cyst wall ca. 0.5 um thick.

Occurrence: Mount Laurel Sand, extremely rare; Navesink Formation, extremely rare. Greatest occurrence, sample no. 209. Occurred in 2 samples.

Dinogymnium euclaensis Cookson and Eisenack 1970

Pl. 11, figs. 5, 6

1970. Dinogymnium euclaensis Cookson and Eisenack, Proc. Roy. Victoria, vol. 83, pt. 2, p. 139, pl. 10, figs. 9-12.

Comments: One specimen is reported from the lower Navesink. As also reported by Cookson and Eisenack, it possesses longitudinal striae on the epitract (caused by longitudinal folding of cyst wall), but not on the hypotract. Although this specimen has a

rounded epitract, whereas that of the type species is conical, I feel that the difference is not significant. Surface ornamentation is finely pustulose. Archeopyle is apical and narrow and the operculum appears to be attached ventrally.

Dimensions: Length 42 um, width 33 um.

Occurrence: One specimen is lower portion of Navesink Formation.

Previously reported occurrence: Senonian of Australia (Cookson and Eisenack, 1970.

Dinogymnium cf. *D. euclaensis* Cookson and Eisenack 1970

Pl 11, fig. 7

1970. *Dinogymnium euclaensis* Cookson and Eisenack, Proc. Roy. Soc. Victoria, vol. 83, pt. 2, p. 139, pl. 10, figs. 9-12.

Comments: Three specimens similar to *Dinogymnium euclaensis* Cookson and Eisenack 1970 were observed in the middle to upper Sandy Hook Member. Each of these possesses the characteristic conical epitract and rounded hypotract, but differ from *D. euclaensis* by having longitudinal striae on both epitract and hypotract; the striae on the hypotract are irregular and wavey. Surface ornamentation, not reported on by Cookson and Eisenack for the species, is faintly but densely pustulose. Archeopyle is apical and narrow and the operculum appears to be ventrally attached.

Dimensions: Observed range (3 specimens measured): length 37-38 um, width 31-32 um. Epitract and hypotract of equal length.

Occurrence: Sandy Hook Member of Red Bank Sand, extremely rare. Occurred in 2 samples.

Previously reported occurrence: Identical forms not previously reported. D. euclaensis reported from Senonian of Australia (Cookson and Eisenack, 1970).

Dinogymnium lanceolatum n. sp.

Pl. 11, figs. 3, 4

Name derivation: Latin, lanceolatum, lanceolate. Referring to the lanceolate shape of the epitract.

Holotype: AI-24, R12.0; +9.4 (pl. 11, figs. 3, 4).

Type locality: Atlantic Highlands, New Jersey

Type stratum: Mount Laurel Sand.

Description: Delicate, elongate cyst, ca. 8-12 times longer than wide; appears single layered. Epitract lanceolate, tapering to a point, is 1/4 to 1/5 of total cyst, separated from hypotract by shallow, weakly-defined, levorotatory cingulum; offset ca. 1/2 cingulum width. Epitract nearly as broad as hypotract across cingulum. Hypotract tapers to a rounded antapex. No archeopyle observed. Surface finely scabrate.

Discussion: Dinogymnium lanceolatum compares with certain modern Gymnodinium species in the same manner as reported for D. elongatum (p.). The long, delicate hypotract tends to fold and collapse. Four specimens of good quality, and six of useable quality were found. From the four good specimens a mean cingulum index of 24 was determined.

Affinity: Same as D. elongatum (p.

Dimensions: Holotype 140 X 13 um. Observed range (4 specimens measured): length 140-165 um, width 13-20 um. Cyst wall ca. 0.5 um thick. Cingulum index range 21-26.

Occurrence: Mount Laurel Sand, extremely rare to rare. Navesink Formation, extremely rare. Greatest occurrence, sample no. 207. Occurred in 5 samples.

Dinogymnium pustulicostatum n. sp.

Pl. 11, figs. 8-11, pl. 21,

figs. 1-19, pl. 12, figs. 5, 6

Name derivation: Latin, pustula, pustule, low projection like a blister. Referring to the blistered appearance of the cyst surface. Latin, costatum, costate. Referring to the ribbed or costate nature of the cyst wall.

Holotype: AI-7, R14.3; +11.8 (pl. 11, figs. 9, 10).

Type locality: Atlantic Highlands, New Jersey

Type stratum: Mount Laurel Sand.

Description: Cyst elongate, width generally greater than 1/2 length, divided approximately midway by cingulum. Epitract and hypotract tapering; apex narrow and rounded; antapex broad and rounded. Sparse, narrow, longitudinal costae may be heterocostate, especially on hypotract; the longer costae extend toward, but not into the polar areas and become shorter on the ventral hypotract toward the sulcus. Cyst wall

single layered; ca. 0.5 um thick; accordian-like in transverse section; bears pustules densely arranged. Pustules which penetrate cyst wall occur between and on the costae, causing a blistered appearance. Pustules bear wall canals; wall canals mainly concentrated near apex. Cingulum well-defined, deeply indented, levorotatory with ca. 1 cingulum width offset. Well-defined, comma-shaped sulcus extends about halfway down the hypotract, terminating in a point. Possible anterior and posterior flagellar pores consisting of 2 broad tubes with terminal pores visible at cingulum-sulcus intersection. Archeopyle apical; operculum biconvex, ca. twice as long as wide, tapering ventrally and dorsally to a narrow isthmus, and is attached at the dorsal and ventral tips.

Discussion: High numbers (45-64 percent) of D. pustulicostatum n. sp. occur in Mount Laurel Sand samples 204-206. The high numbers of D. pustulicostatum found provides an opportunity to describe this species in great detail. Ninety-four specimens were measured and studied.

Constant features of D. pustulicostatum appear to be the biconical shape of the epi and hypotract; the broadly rounded antapex and narrowly rounded apex; cingulum position at or slightly beneath the equator; heterocostae best developed on hypotract; pustules densely arranged on external cyst surface; wall canals penetrating most pustules near apex, penetrating fewer pustules over most of remaining cyst surface; and costae slanting towards sulcus on ventral hypotract giving a chevron appearance.

The surface of the cingulum and sulcus appears to be granular; however scanning electron microscopy reveals the granae to be pustules bearing wall canals (pl. 12, fig. 5, 6; pl. 21, figs. 15, 16). The sulcus is entirely limited to the hypotract (pl. 11, fig. 8; pl. 21, figs. 2, 3, 4, 10, and 13). All specimens observed lacked a ventrally directed antapical point (i.e. D. acuminatum, Evitt et al. 1967), instead, being rounded.

Size is quite variable among the Mount Laurel Sand specimens. The smallest specimen measuring 46 x 26 um and the largest measuring 69 x 37 um, a length difference of 1.5X. Variation in size appears to have little or nothing to do with the number of costae. For example specimens ca. 1.3 times different in length (pl. 21, figs. 2, 6, 7 versus pl. 21, figs. 3, 5, 8, 10) display the same number of costae on the hypotract. It does appear, however, that larger specimens do display better developed costae.

Distortion is common in D. pustulicostatum, and generally is the result of collapsing along the cingulum, causing a reduction in length by as much as 18 percent. Dorso-ventral compression is also common, possibly caused by compression in the sediment. Because of the corrugate nature of the cyst wall, both lateral expansion and contraction are possible. Cysts are frequently observed in an expanded state, such that the costae are very low in relief, and cyst width is greatly increased. Also, cysts are frequently observed in a contracted state, such that the costae have high relief and cyst width is greatly decreased. Thus, for studies

involving natural variability nondistorted specimens should be selected, or specimens measured which display distortion should be compensated for.

For statistical analysis 94 specimens were measured from samples 204 and 205. The features measured were overall length, distance from apex to middle of cingulum, and width at the cingulum. This data was used to determine width-length ratios and cingulum indices (cingulum index=two digit integer expressing the distance from the apex to the middle of the cingulum divided by the pole to pole length, times 100; after Evitt et al., 1967, p. 7). A summary of the data is listed below and plotted in text figures 8 and 9.

	Minimum	Maximum	Mean	Holotype
Length	46 um	69 um	56 um	60 um
Width	21 um	46 um	34 um	31 um
CI	45	62	53	50

Correlation Coefficient of length and width: 0.37

Significance of C. C. for length and width: 49.75

Correlation Coefficient of length and CI: -0.01

A comparison of length and width and cingulum index illustrates the effects of distortion on the various statistics summarized above. Variability between length and width has a rather low correlation coefficient (0.37), agreeing with the nearly nonlinear scatter of

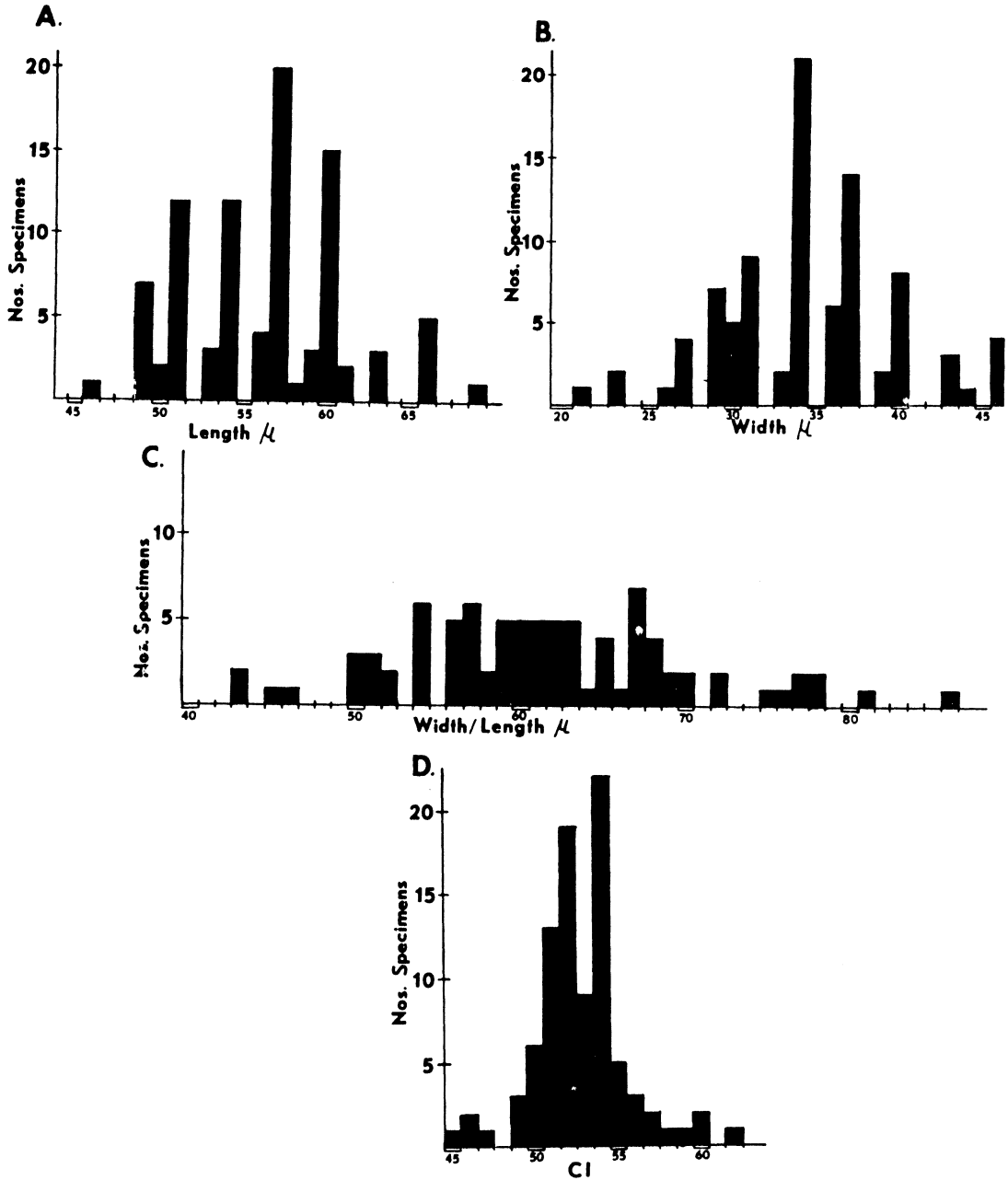


Figure 8. Histograms of data plotted for Dinogymnium pustulicostatum n. sp.: A. length, B. width, C. width/length, and D. cingulum index (CI).

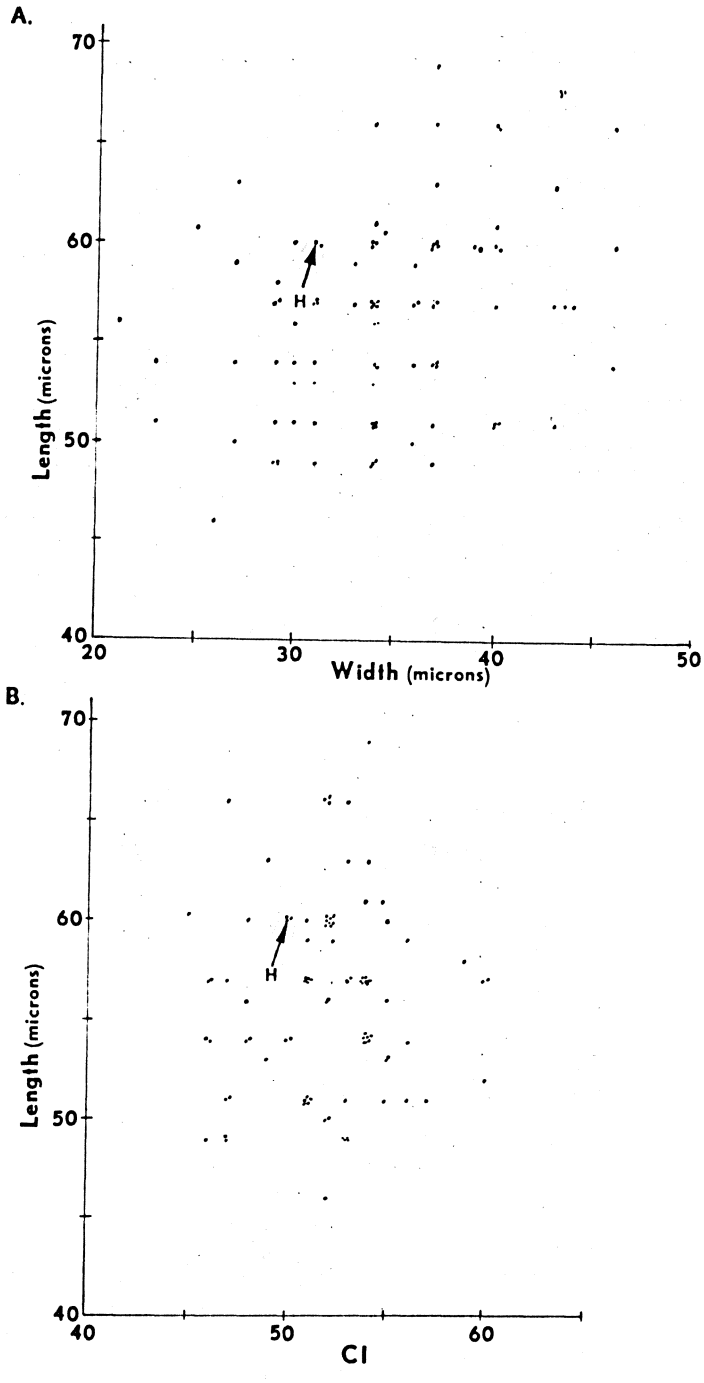


Figure 9. Scatter diagrams plotted for Dinogymnium pustulicostatum n. sp.: A. length versus width, B. length versus cingulum index (CI). "H" represents holotype.

points seen in figure 9a, caused by various types of distortion of the cyst length and width. It is likely that distortion has greater effect on width than on length because of the lateral flexibility of the accordian-like costae, which apparently causes most of the length-width variability. Thus, it is difficult to understand the meaning of this statistic; i. e., how much of the variability is natural and how much is caused by distortion. The scatter diagram of cingulum index (CI) versus length (figure 9b) shows a very low correlation coefficient (-0.01) indicating that one is not likely dependent upon the other. Evitt (1967, p. 14) indicated that this is important when the largest and smallest specimens differ by a marked factor. Evitt also concludes that the CI is essentially not affected by many distortions that apparently alter the cyst width, and that it is affected less than might be expected by longitudinal compression or extension of the cingulum. This applies only for specimens with a cingulum index near 50. A comparison of histograms for length, width, width-length ratio, and CI (text figure 8) illustrates the degree of normality of these statistics, suggesting that all measurements were made on one species. Width-length ratio has a much more expanded distribution with low amplitude, and is barely normal, suggesting distortion mainly of width.

Ornamentation consists of pustules densely arranged on the costae and in the depressions between the costae. The pustules bear wall canals which are especially concentrated near the apex. The wall canals, measuring about 0.1 um across, pass from the cyst interior

toward the exterior, and many of them open to the exterior, especially near the apex. On most of the epitract and hypotract only about 50 percent of the wall canals actually penetrate through the pustules to the experior. The porous nature of the wall of D. pustulicostatum illustrates a striking similarity with the trichocyst pore bearing tests of living motile stages of dinoflagellates. Evitt (1967, p. 362) reported the possibility that Dinogymnium fossils could possibly be motile stages. Further evidence of possible motility is found in the presence of openings similar in position to anterior and posterior flagellar pores. The anterior pore could have directed a flagellum onto the cingulum, while the posterior pore could have directed one onto the sulcus.

Affinity: D. pustulicostatum lacks a ventrally directed antapical point, and therefore differs from D. acuminatum Evitt et al. 1967. It is similar to D. acuminatum in that both species are somewhat biconical, heterocostate, bear numerous pustules and wall cords, and have similar cingulum index ranges (50 - 60).

D. pustulicostatum has marked levorotatory cingulum displacement and narrow, pustulate ridges, distinguishing it from D. microgranulosum Clark and Verdier 1967. It is also generally smaller than D. microgranulosum.

Dimensions: Holotype L x W, 60 x 31 um; epitract length 30 um. Observed range (94 specimens measured): length 49-66 um, width including dorsoventrally compressed specimens 23-56 um, width of noncompressed specimens 23-43 um. Epitract length given as percent total length (Cingulum Index) 50-62%. Width--length ratio 43-98.

Occurrence: Mount Laurel Sand, extremely rare to abundant; Navesink Formation, extremely rare. Greatest occurrence, sample nos. 204, 205, and 206. Occurred in 14 samples.

Dinogymnium westralium (Cookson and Eisenack) Evitt emend.

Pl. 11, figs. 12-16; pl. 12, figs. 1-4

1958. Gymnodinium westralium Cookson and Eisenack, Proc. Roy. Soc. Victoria, vol. 70, pt. 1, p. 25-26, pl. I, fig. 9.

1967. Dinogymnium westralium, Evitt et al., Stanford Univ. Publ. Geol. Sci., vol. 10, pt. 1, p. 24.

Emended description: Cyst elongate; average width ca. 1/2 length; cyst wall single layered. Epitract generally larger than hypotract, being separated by well-defined, levorotatory cingulum ca. 7 um wide and offset about one cingulum width. Epitract tapers from cingulum, and is capped by a broad, spoon-shaped operculum. Hypotract tapers from cingulum and terminates at the antapex with a ventrally directed sharp point. Longitudinal costae, ca. 25-30 per cone, extend from cingulum to operculum on epitract, and from cingulum to the point on hypotract, except for shorter alternating costae. The costae on the ventral surface exhibit a graded decrease in size and slant toward the sulcus, above and below the cingulum, giving a chevron pattern on both the hypotract and epitract. Small pustules occur on both sides of the crests of the costae, giving a distinctively

corrugated appearance to the individual costae. Scanning electron microscopy shows that the pustules are arranged alternating to opposite on both sides of the crests, and the crests and pustules are perforated with systematically-spaced wall canals. Sulcus comma-shaped near cingulum, but extends in a narrow strip downward to the antapical point and in a narrow fissure upward toward the apex. An anterior and posterior pore at the cingulum sulcus intersection suggests flagellar pores. Archeopyle apical; operculum formed into spoon-shaped cap on epitract, generally broadly attached dorsally, narrowly attached ventrally, extending 3-4 um down onto ventral surface.

Discussion: Evidence that Monmouth Group specimens are D. westralium is derived mainly from Lewis Stover's reanalysis of the holotype (Evitt, et al., 1967, p. 24). Stover reports three features not mentioned in the original description: 1. the longitudinal ribs bear conspicuous small pustules, 2. the ribs on the ventral surface of the hypotract exhibit a graded increase in length away from the sulcus, combined with a slight convergence toward the antapex, and 3. there is the suggestion of an antapical point slightly ventral from the antapex. Stover also reports that Evitt's specimens of D. westralium have the antapical point. The original description by Cookson and Eisenack (1958, p. 25-26) is herein emended to include these points. In the synonomy Evitt, Clarke, and Verdier (Evitt, 1967, p. 24) refer to some illustrated specimens (Evitt, 1967, pl. I, figs. D, E, L, V) as D. westralium. These specimens

exhibit the opercular cap, large epitract, sharply pointed antapex, and the pustulate ornamentation described above.

Several specimens of Dinogymnium westralium were observed in the upper part of the Sandy Hook Member of the Red Bank Sand. These comprised between .3-2.3 percent of the assemblages between samples 231 and 238; the greatest concentration being in sample 238. Twenty-nine specimens from samples 237 and 238 were measured and analyzed according to variation in length, width, and cingulum index.

Constant features among the specimens observed are the ventrally-directed thorny antapical point; flatly rounded apex; well-defined cingulum; heterocostae developed on the hypotract; pustules appearing only on costae (not in between), and on the operculum, cingulum and sulcus; wall canals perforating most pustules, opening to the exterior; pustules giving costae a corrugated appearance; and costae decreasing in size on the ventral surface towards the sulcus. Flagellar pore structure may also appear constant within the species.

Variable features are mainly length, width, and cingulum index. A summary of these statistics is given below

	Minimum	Maximum	Mean(16 specimens)
Length	47 um	64 um	55 um
Width	23 um	33 um	28 um
CI	53	59	56.50

Correlation coefficient of length and width: 0.78

Correlation coefficient of length and CI: 0.13

Variation in length is 1.4X; variation in width is 1.4X. The high correlation coefficient of length and width indicates that length and width are dependent (a nearly linear trend), and that little distortion has taken place. The low correlation coefficient of length and CI indicates marked independence; CI is independent of length, and therefore essentially independent of longitudinal distortion for this cingulum index range. Since CI is not related to width, it is also independent of any lateral distortion.

Length plotted against width (text figure 10b) illustrates an approximately linear trend with only slight scatter. It appears that the degree of scatter is controlled mainly by distortion. The more rigid construction of the costae and cyst of D. westralium apparently prevent any great degree of longitudinal distortion, except at the cingulum. Evitt (1967, pl. 1, figs. D, E. L. V) illustrated the degree of lateral distortion that this species could undergo; expanded specimens are peanut-shaped.

The histogram plot for CI and length (text figure 10a) displays a somewhat normal distribution. Since CI represents the shift of the cingulum relative to the epitract, the maximum shift is about 53 to 59, or 6 percent shift. This amount is not readily detectable unless measurements are made.

Affinity: D. westralium is dissimilar from D. acuminatum Evitt et al., 1967 by having a broad opercular cap, pustulate ornamentation on the sides of the costae in alternating and opposite fashion, higher mean cingulum index, and a sharp, thorny antapical point. It also lacks the distinctive granulation, the crested apex,

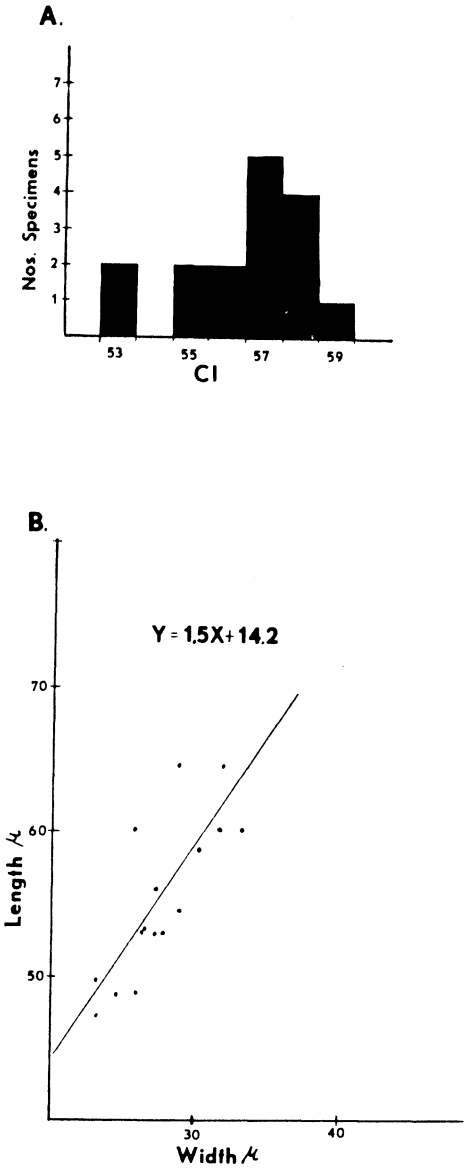


Figure 10. Data plotted for Dinogymnium westralium (Cookson and Eisenack) Evitt et al. 1967: A. histogram of cingulum index, B. scatter diagram of length versus width.

and the heterocostate ribbing that is characteristic of D. acuminatum. It is similar to D. acuminatum in that it is somewhat biconical, has a ridge-like thickening on the epitract side of the cingulum, has a similar cingulum index range (ca. 53-59), has a similar cingulum displacement, and has a ventrally directed antapex.

Although D. westralium exhibits some similarity with D. denticulatum Alberti 1961, it is difficult to compare the two, based on information given in the description of the latter.

Dimensions: Observed range (29 specimens measured): length 47-64 um, width 23-33 um. Cingulum index (percent epitract) 53-58, mean 56.5. Width-length ratio 44-53, mean 50.

Occurrence: Sandy Hook Member of Red Bank Sand, extremely rare to rare. Greatest occurrence, sample nos. 237 and 238. Occurred in 5 samples.

Previously reported occurrence: Cenomanian to Maestrichtian of Australia (Cookson and Eisenack, 1958). Campanian-Maestrichtian of New Jersey (Evitt, 1967).

Dinogymnium sp. A

Pl. 11, fig. 17

Comments: The single specimen observed in the upper Mount Laurel Sand is exceptionally well-preserved. However, because only 1 specimen was observed it is impractical to assign it a new species name. Because of its unique morphological features a detailed description is offered below.

Description: Elongate cyst, ca. three times longer than wide; appears single layered. Epitract ca. 1/7 of total cyst, greatly reduced, separated from hypotract by well-defined cingulum. Hypotract expands broadly beneath cingulum to about mid-length, then tapers to a bluntly-terminated antapex. Both epitract and hypotract longitudinally striate or folded. Sulcus extends slightly above cingulum into epitract; extends ca. 1/3 distance downward onto hypotract. Cyst surface finely scabrate or pustulose. No archeopyle observed.

Dimensions: A single specimen observed. Length 179 um, width 60 um at mid-length. Epitract 26 um, hypotract length 153 um.

Occurrence: Single specimen in Mount Laurel Sand, sample 208.

Previously reported occurrence: None.

Dinogymnium sp. B

Pl. 11, fig. 18

Comments: Because only one specimen was observed it is considered impractical to assign it a new species name; however, to aid future workers a detailed description is offered below.

Description: Cyst extremely long. Epitract much reduced, tapering, conical, bluntly terminated, and separated from hypotract by well-defined cingulum. Cyst appears single layered. Hypotract wider than epitract across cingulum, broadening slightly beneath cingulum. The single specimen observed is torn some distance below the cingulum and lacks the antapex. The hypotract broadens to a maximum width of

87 um, and is longitudinally striate or folded. Sulcus extends slightly into epitract, but extends ca. 70 um downward into hypotract. Cyst surface is finely scabrate. No archeopyle was observed. This specimen is similar to D. sp. A; however, is much larger in size.

Dimensions: A single specimen was observed. Length to broken end 223 um, maximum width 87 um. Epitract length 50 um.

Occurrence: Mount Laurel Sand, extremely rare.

Previously reported occurrence: None.

Dinogymnium sp. C

Pl. 11, fig. 19

Comments: Because only three specimens having few distinctive morphological features were observed it is considered impractical to assign them to a new species. However, a detailed description is given below to aid future workers who may observe these forms.

Description: Elongate cyst, 3-6 times longer than wide. Epitract only slightly shorter than hypotract; very faint cingulum observed separating tracts. Sides of cyst nearly parallel, however, epitract may taper slightly. Apex and antapex rounded. Sulcus extends a short distance onto epitract; extends well into hypotract, nearly to antapex. A notch is observed in the sulcus at the intersection with the cingulum. No archeopyle observed.

Dimensions: Three specimens observed: length 83-91 um, width 15-25 um. Epitract length 35-40 um, hypotract length 48-51 um.

Occurrence: Mount Laurel Sand, extremely rare; Navesink Formation, extremely rare. Occurred in two samples.

Previously reported occurrence: None.

Order PERIDINIALES Haeckel

Family Gonyaulacaceae Lindemann

Genus Apteodinium Eisenack 1958

Apteodinium baculatum n. sp.

Pl. 5, figs. 1-4

Name derivation: Latin; baculatum, referring to baculate ornamentation on periphragm.

Holotype: 5ML7-4, 22.4 x 95.0 (pl. 5, figs. 1-4).

Type locality: Atlantic Highlands, New Jersey

Type stratum: Mount Laurel Sand (Campanian)

Description: Cyst angularly ovoidal with short, slender apical horn; circular in equatorial section. Cyst wall bilayered; endophragm smooth, ca. 1 um thick; periphragm composed of bacula and trabeculae; bacula ca. 2 um long, trabeculae less than 1 um thick. Trabeculae impart a mesh-like appearance to cyst exterior. Slightly enlarged bacula weakly outline plate equivalents; tabulation 4', 6", 6c?, 5"", 1p, 1"". Cingulum well defined by high ridges, ca. 3 um high, strongly levorotatory, ends separated vertically about three cingulum widths; transversely about one cingulum width. Sulcus well defined, tapering anteriorly, and deflecting sharply around 6c (to right as

observed dorsally), and terminating adjacent to 1c. Archeopyle precingular (Type P) with simple, free operculum corresponding to plate 3''.

Affinities: A. baculatum resembles the Lower Cretaceous species A. conjunctum Eisenack and Cookson 1960 (pl. 1, figs. 7-8) and A. granulatum Eisenack 1958 (pl. 23, figs. 8-14), but the bilayered, baculate wall construction of A. baculatum differentiates it from the latter two species. Eisenack (1958) states that Apteodinium has no tabulation, ornamentation, and that the cingulum is not offset. Further study of more specimens is necessary prior to finalizing the generic affinity. Minor differences between the Monmouth Group specimens and those of McLean (1971, p. 52-53) are: Monmouth Group specimens cingulum offset about two times greater, and Monmouth Group specimens are generally 1/5 to 1/4 smaller.

Dimensions: Holotype L x W: 49 x 40 um. Observed range (3 specimens): length 46-60 um; width 40-46 um.

Occurrence: Sandy Hook Member of Red Bank Sand, extremely rare.

Genus Areoligera Lejeune-Carpentier 1938

Areoligera sp.

Pl. 7, figs. 17-20, pl. 14, figs. 8-9

Comments: Most samples from the Monmouth Group contained specimens of Areoligera, which displayed a remarkable degree of variability within the population. Although a thorough study of Areoligera was

undertaken, it could not be shown that any given variant was restricted within the section. In samples where Areoligera is dominant, e.g., the lower part of the Sandy Hook Member of the Red Bank Sand, such great variation occurs that it was not practical to divide the "population" into separate species. Four of the morphological extremes are shown on plate 7, figs. 17-20.

Morphological characteristics common to Areoligera are: a lack of spine and process development on the ventral surface; a sulcal notch on the left ventral surface; best process development along lateral, apical, and antapical margins, and to a lesser degree on the dorsal surface (although dorsal tabulation was frequently delineated by the processes). Most specimens display a slight left antapical protuberance. Apical tabulation is generally well-developed, showing 4 apical plates. A single antapical plate is often suggested at the antapex. Process development ranges from short, hair-like, generally separate but sometimes net-like spines, to forms with long, net-like to membraneous and trabeculate spines and processes. Archeopyle is apical, laterally broad, and frequently has accessory sutures extending downward along the precingular plate margins. Because ventral plate-equivalents are not developed, a complete tabulation cannot be presented; however 4 apical plates equivalents, 3 precingular and 3 postcingular plates on the dorsal surface, and one antapical plate equivalent are discernible. Accessory sutures separate each of the precingular plates, suggesting that there are six precingular plate equivalents. Although the ventral plate

boundaries are not discernible, the overall reflected tabulation is suggested to be standard Gonyaulax-type: 4", 6", 6c, 5'", 1P, 1"".

Areoligera dominance may be important in paleoenvironmental analysis. McLean (1971, p. 30) reported that high concentrations of Areoligera in the Aquia Formation (Paleocene) of the Virginia-Maryland Coastal Plain corresponded to a foraminifera assemblage (Nogan, 1964), which indicated abnormal conditions. The lower portion of the Sandy Hook Member of the Red Bank Sand contains 36 to 68 percent Areoligera, and may have been deposited in abnormal marine waters of a nearshore gulf environment (Owens and Sahl, 1969, text fig. 15).

Dimensions: Observed range (30 specimens measured): length 60-77 um, with 65-89 um, spine length 5-36 um.

Occurrence: Mount Laurel Sand, extremely rare to rare; Navesink Formation, rare to common; Sandy Hook Member of the Red Bank Sand, rare to abundant. Greatest occurrence, sample nos. 226, 227, 228, and 229. Occurred in 33 samples.

Previously reported occurrence: Since the degree of gradation among the highly variable population does not presently allow division into species, it is difficult to discuss previously reported occurrence.

Genus Cannosphaeropsis O. Wetzel 1933

Cannosphaeropsis cf. C. pusulosa Morgenroth 1966

Pl. 2, fig. 3

1966. Cannosphaeropsis pusulosa Morgenroth, N. Jb. Geol. Palaont., Abh. 127. p. 8, pl. 2, fig. 6.

Comments: A single specimen was observed in the Navesink Formation. Although the cyst agrees basically with the originally described size and general morphology of C. pusulosa, the processes are often of greater diameter, and are generally joined laterally by thin, solid to perforate, fibrous appearing walls. Morgenroth's illustration (pl. 2, fig. 6) shows a slightly lesser degree of such wall construction.

Dimensions: Length central body 43 um, width 39 um; total length 87 um, total width 81 um.

Occurrence: Single specimen in Navesink Formation.

Previously reported occurrence: Lower Oligocene of Germany (Morgenroth, 1966).

Genus Cannosphaeropsis O. Wetzel 1933

Cannosphaeropsis utinensis O. Wetzel, emend.

Pl. 2, figs. 1, 2

1933. Cannosphaeropsis utinensis O. Wetzel, Paleontographica, Abt. A, vol. 78, p. 6-9, pl. 3, figs. 9-17, text fig. 12.

1966. Cannosphaeropsis utinensis (O. Wetzel) Williams and Downie, Bull. Brit. Mus. Nat. Hist. (Geol.), Suppl. 3, p. 222.

Emended description: Cyst main body ellipsoidal bearing tubular processes and trabeculae; tubular processes occur only in polar areas. Main body circular in polar view. Endophragm and periphragm thin (ca. 0.5 um) and appressed over entire cyst. Periphragm formed into two or more branching, tubular processes at each pole, which are distally trabeculate. Trabeculae form an areal network above the central body, extending from pole to pole, forming somewhat polygonal fields, and bearing bifurcating or trifurcating, thorny gonally positioned barbs. No processes observed between polar areas. Tabulation may be reflected by polygonal fields in areal network of trabeculae; however, the tabulation scheme is difficult to determine. Archeopyle precingular (Type P).

Discussion: A few excellently preserved specimens observed in the Monmouth Group samples resemble the specimens illustrated by Deflandre (1937, pl. 16, fig. 12). Main diagnostic features are the presence of processes only at polar areas, and the areal network of trabeculae (These features are well illustrated by Deflandre (ibid.) O. Wetzel (1933, p. 7) reported that processes arose from three axes, although Downie and Williams (1966, p. 222) reported that the genus Cannosphaeropsis has Hystrichosphaera process type and arrangement. The writer suggests that the species be restricted to forms with only polar processes, a trabeculate network bearing thorny barbs at gonal

positions, and a precingular archeopyle (Type P).

Dimensions: Observed range (4 specimens measured): length central body 48-50 um; width 43-45 um; overall diameter 90-98 um.

Occurrence: Mount Laurel Sand, extremely rare; Navesink Formation, extremely rare. Occurred in 4 samples: 206, 207, 208, & 209.

Previously reported occurrence: Senonian of Germany (O. Wetzel, 1933), Senonian of France (Deflandre, 1937).

Genus Conneximura n. gen.

Name derivation: Latin; connexus, connected or joined; mura, wall. Referring to the numerous interconnected walls.

Type species: Conneximura fimbriata (Morgenroth, 1968, p. 547-548, pl. 45, figs. 7-8) n. comb.

Description: Chorate, bilayered cyst, bearing simulate, broadbased, parallel sided, polygonal, hollow, and distally open processes which reflect all plate equivalents. Walls of similar construction and size as process walls frequently connect process corners with adjacent gonal positions of plate equivalents, imparting a complex net-like appearance to the cyst surface. Apical and antapical processes may be different in size and construction from the other processes. Reflected tabulation 1', 6", 6c, 5"', 1p, 1"". Archeopyle precingular (Type P).

Discussion: Because walls connect the corner positions of the broad-based polygonal, simulate processes with the gonal positions of the plate margins, single plate equivalents generally appear to be composed of several small plate-like fields. Each of the smaller

plate-like field does not, however, reflect an actual plate equivalent. The most effective way to determine the positions and actual number of plate equivalents is to locate the broad-based simulate processes; and to visually isolate these from the smaller, adjacent fields. The arrangement of the larger, broad-based processes indicates a standard Gonyaulax-type tabulation.

Affinity: Morgenroth (1968, p. 547-548) assigned C. fimbriata to Hystrichokolpoma (Klumpp 1953) Williams and Downie 1966. Because C. fimbriata has a precingular archeopyle (Type P) it is transferred from Hystrichokolpoma, and placed into Conneximura n. gen. Process arrangement and development slightly resembles that of Systematophora placacantha (Deflandre and Cookson) Davey et al. 1969; however, S. placacantha has an apical archeopyle and lacks the additional walls between the process corners and gonal positions.

Conneximura fimbriata (Morgenroth, 1968) n. comb.

Pl. 1, figs. 11-15

1968. ?Hystrichokolpoma fimbriata Morgenroth, Geol. Jb., vol. 86, p. 547-548, pl. 45, figs. 7-8.

Revised description: Cyst bilayered, spherical to ovoidal, bearing simulate, broad-based, polygonal, parallel-sided, hollow, fimbriate, and open processes. Fimbriate walls often connect corner positions of processes with adjacent gonal positions of plate equivalents, and also outline cingular and sulcal areas. Endophragm and periphragm

generally closely appressed. Endophragm smooth, thicker than periphragm, measuring ca. 2 um; periphragm smooth to faintly scabrate, often wrinkled or rippled near base of fimbriate walls, measures ca. 1 um thick. Processes, formed of periphragm, may be completely intratabular except where they abut against the margin of cingulum and sulcus; reflect tabulation of 1', 6", 6c, 5"', 1p, 1"". Processes formed of thin, delicate, somewhat distally-shredded walls, draped between more solid, spine-like corner supports. Similar walls also outline cingulum and sulcus.

The combination of process walls and all additional walls imparts a complex, net-like appearance to cyst surface. A large triradiate apical spine, located between the 4 apical plate equivalents, possibly reflects the position of an apical pore closing platelet. Antapical process bears a thick, punctate inner base, and is noticeably thicker walled and more solidly constructed than the other processes. Cingulum levorotatory, composed of 6 plate equivalents, outlined by fimbriate walls and low sutural ridges. Sulcus, angularly outlined by high fimbriate walls, extends from near the apex to near the antapex. Archeopyle precingular (Type P), horseshoe-shaped, often slightly gabled at anterior margin.

Discussion: Although many of the basic morphological features of C. fimbriata (Morgenroth, 1968) were reported by Morgenroth (1968, p. 547 to 548), the complex positioning of the many walls was not discussed. This unique feature distinguishes Conneximura from other genera, and C. fimbriata from other species. Morgenroth (1968) observed a precingular archeopyle, and therefore placed a question

mark before his generic assignment, identifying it as ?Hystrichokolpoma fimbriata n. sp..

Affinities: In certain respects, such as process development, C. fimbriata (Morgenroth) n. comb. is similar to Hystrichokolpoma or Systematophora, but it is separated from these because of its precingular archeopyle (Type P). The closest relationships are seen in other Gonyaulax types with precingular archeopyles, and walls about plate-margins, e. g. Acanthogonyaulax, Leptodinium, and Psaligonyaulax. These, however, lack simulate processes and fimbriate secondary walls connecting gonal positions of plate margins with corner positions of polygonal processes.

Dimensions: Observed range (30 specimens measured): length main body 40-60 um; width 37-54 um; process length 13-19 um. Wall layers ca. 3 um; endophragm thicker than periphragm.

Occurrence: Mount Laurel Sand, extremely rare; Navesink Formation, extremely rare; Sandy Hook Member of Red Bank Sand, extremely rare to sparse. Greatest occurrence: sample nos. 211, 229, 237, and 238. Occurred in 13 samples.

Previously reported occurrence: Danian of Denmark (Morgenroth, 1968).

Genus Conosphaeridium Cookson and Eisenack 1969

Conosphaeridium sp.

Pl. 7, figs. 4, 5

Comments: A single specimen, observed near the top of the Navesink

Formation, corresponds in basic form with the Australian specimens illustrated by Cookson and Eisenack (1969, fig. 2, a-f). The conical processes of the Navesink specimen are plate centered, irregularly developed in size, and generally bear bifurcate distal terminations. Tabulation is not discernible as the specimen is broken; each plate equivalent appears to bear a single intratabular process. The archeopyle is apical (Type $\overline{A}a$).

Dimensions: Length main body, 62 um, width 51 um. Process length 12-26 um.

Occurrence: One specimen observed near the top of the Navesink Formation.

Previously reported occurrence: None.

Genus Cordosphaeridium Eisenack 1963

Cordosphaeridium fibrospinosum Davey and Williams, 1966

Pl. 2, figs. 5, 6

1966. Cordosphaeridium fibrospinosum Davey and Williams, The genus Hystrichosphaeridium and its allies; in Davey, R. J. Downie, C., Sarjeant, W.A.S., and Williams, G. L., "Studies on Mesozoic and Cainozoic Dinoflagellate cysts;" Bull. Br. Mus. Nat. Hist. (Geol.), Suppl. 3, p. 86, pl. 5, fig. 5.

1969. Cordosphaeridium fibrospinosum Davey and Williams 1966, emend. Davey, Palaeontologia Africana, vol. 12, p. 36.

Comments: The Monmouth specimens display a thicker fibrous wall (ca. 3 um vs 0.5 um), and slightly greater length variation (54 - 90 um vs 59 - 72 um) than the previously reported English and South American specimens. Tabulation is difficult to determine because of process fusion; however, four fused apicals, six precingulars, and one antapical process can be identified. Processes are generally expanded in width, and are often basally fused, being difficult to separate visually. Tabulation reported by Davey and Williams (1966) for the genus Cordosphaeridium is 1', 6", 6c, 6"', (1p), 1"". Morgenroth (1968) emended Cordosphaeridium, giving a tabulation of 5', 6", 6c, 6"', ?2π (?ππλ), 1"". Davey (1969) gave an amended diagnosis of Cordosphaeridium with no mention of tabulation. Having observed other species of Cordosphaeridium from the Paleocene Aquia Formation (C. bipolare Wilson, C. marylandense McLean, and C. virginianum McLean), I feel that the genus Cordosphaeridium does exhibit a typical Gonyaulax type tabulation (4', Oa, 6", 6c, 5"', 1p, 1""). Archeopyle is precingular (Type P).

Dimensions: Observed range (27 specimens): length main body 61 - 90 um; width 54 - 83 um . Process lengths 17-32 um.

Occurrence: Extremely rare to rare in Mount Laurel Sand, Navesink Formation, and Sandy Hook Member of Red Bank Sand. Greatest abundance, although still extremely rare was in sample 212 at base of Navesink Formation.

Previously reported occurrences: Campanian and Maestrichtian of northern Natal, South Africa (Davey, 1969). Lower Eocene London

Clay of southern England (Davey and Williams, 1966).

Cordosphaeridium varians n. sp.

Pl. 2, figs. 4, 7, 8; pl. 14, figs. 1-3; pl. 15, figs. 2a-b, 3a-5d; pl. 16, figs. 6a-10b

Name derivation: Latin, varians, varying. Referring to the highly variable cyst morphology.

Holotype: AI-32, R15.2, +15.2 (pl. 2, figs. 4, 7, 8)

Type locality: Atlantic Highlands, New Jersey.

Type stratum: Navesink Formation.

Description: Highly variable spheroidal to ovoidal chorate cyst. Bilayered; endophragm smooth, ca. 1 um thick; periphragm ca. 1 um thick, bears densely arranged fibrils of varying length (up to 30 um) and arrangement. Fibrils may be matted into low, poorly isolated clusters or be arranged into indistinct to well-formed process groupings, the latter being distinctively Cordosphaeridium-like in appearance, displaying one fibrous, plate-centered process per plate equivalent which may be as broad as long, distal ends being fibrous to shredded. Adjacent processes may be fused, especially in apical and ventral areas. Process arrangement suggests a reflected tabulation of ?4', 6", ?6c, 5"', ?1p, 1"". Cingular processes (when formed) narrow, being elongate and aligned in the direction of the cingulum; cingulum levorotatory. Sulcus indistinct, bears irregularly positioned, slender, fibrous processes. Archeopyle precingular (Type P).

Specimens of C. varians having fibrils loosely arranged on cyst surface (not arranged into process groupings) appear to evolve upsection into forms bearing long (up to 19 um), somewhat stiff, bristly spines and a distinctively long (up to 25 um) slender, and fibrous apical and antapical spine, resembling Trichodinium hirsutum Cookson 1965; however, lacking the extra long, lateral cingular spines characteristic of T. hirsutum.

Discussion: The highly different variants of the species C. varians if observed as isolated specimens, would likely not be associated with each other. One extreme variant displays low, irregular mounds of matted fibrils (pl. 16, fig. 9a), while the other extreme variant displays fibrils confluescing into well-developed, rather solid looking, fibrous, Cordosphaeridium-like processes (pl. 16, fig. 9d). Only when intermediate forms (pl. 16, figs. 9b, c) are observed can one determine that both extreme variants are, in fact, part of the same species. Intermediate forms of the population display randomly oriented fibrils to fibrils confluescing into indistinct, isolated groupings.

The cause of such great intraspecific variability in this, and other, dinoflagellate species is not known. Possible causes could be a mixture of mutants, a mixture of ecophenes, or genetic recombination from sexual reproduction. I feel that the latter 2 causes are probably working simultaneously, causing at least part of the variability.

The degree of variability in C. varians and its morphologic

transition to T. cf. T. hirsutum is illustrated on pls. 15-16, figs. 1a-10d. Each row of figures on the 2 plates illustrates the degree of variability observed in one sample, and the rows are arranged stratigraphically to illustrate the upsection change in morphology from C. varians to T. cf. T. hirsutum. A more detailed discussion of these intra and interspecific relationships is given on p. 62.

Dimensions: Observed range (36 specimens measured): length of main body 64-93 um; width 64-93 um. Fibril and process length up to 31 um.

Occurrence: Mount Laurel Sand, rare to sparse; base of Navesink Formation, rare to common.

Genus Coronifera Cookson and Eisenack, emend.

1958. Coronifera Cookson and Eisenack, Proc. Roy. Soc. Victoria, vol. 70, pt. 1, p. 45.

1969. Coronifera (Cookson and Eisenack) Davey, Bull. Brit. Mus. Nat. Hist. (Geol.), vol. 18, p. 161.

Emended description: Cyst spherical to ovoidal: bilayered; bearing numerous simple, slender, acuminate, bifurcating, or trifurcating, nontabulate processes, which may be solid or hollow. Processes joined proximally by low sutural folds. Apical process distinctively long, simple or branched. Antapical process large, tubular, often terminating with denticulate margin. Combination archeopyle, (Type $\bar{A}a$ + P.)

Type species: Coronifera oceanica Cookson and Eisenack 1958.

Discussion: The purpose of this emendation is to point out the presence of a combination archeopyle, (Type $\overline{A}a$ + P). Although, the apex is dislodged, and sometimes removed, a precingular plate equivalent is also involved in excystment. This plate, possibly corresponding to 3", appears to be the main excystment aperture, as it is generally missing, while the apical plate is generally only dislodged.

Coronifera oceanica, Cookson and Eisenack 1958, emend.

Pl. 1, figs. 5-8

1958. Coronifera oceanica Cookson and Eisenack, Proc. Roy. Soc. Victoria, vol. 70, pt. 1, p. 45, pl. XII, figs. 5-6.

1969. Coronifera oceanica (Cookson and Eisenack) Davey, Bull. Brit. Mus. Nat. Hist. (Geol.), vol. 18, p. 162, pl. 8, figs. 8, 11.

Emended description: Cyst spherical to ovoidal, circular in polar view. Periblast and endoblast very closely appressed overall; no pericoels observed. Endophragm smooth; periphragm formed into numerous, slender, tapering, apparently nontabular spines, which are simple, bifurcate, or trifurcate, and often proximally joined by low sutural folds and/or high, thin membranes. Periphragm also formed into a distinctive apical and antapical process, and a small apical nipple. Apical process not distinctively large; however, sets on the apical nipple, giving it additional height; divides distally into three or more prongs, and is slender in appearance. Antapical

process smooth, large, and tubular, and terminating with a denticulate margin. No sulcus or cingulum observed. Cyst surface markedly wrinkled, not fibrous, and bears numerous low nontabular crests which connect basal portions of processes. Combinations archeopyle, (Type $\overline{A}a$ + P): apical series dislodges as a unit, seldom missing; plate equivalent 3'' probable main excystment aperture, generally missing.

Discussion: The main purpose for this emendation is to point out the wrinkled, as opposed to fibrous, periblast surface, the combination archeopyle (Type $\overline{A}a$ + P), and tightly appressed nature of periphragm and endophragm.

Dimensions: Observed range (21 specimens measured): length main body 46-66 um, width 44-66 um; apical process length 16-17 um; antapical process length 18-22 um; nontabular process length 22-26 um.

Occurrence: Mount Laurel Sand, extremely rare; Navesink Formation, extremely rare to rare; Sandy Hook Member of Red Bank Sand, rare. Occurred in 21 samples.

Previously reported occurrence: Albian of Australia (Cookson and Eisenack, 1958), Albian and Cenomanian of England (Davey, 1969).

Genus Cyclonephelium Deflandre and Cookson, emend.
Williams and Downie 1966

Cyclonephelium cf. C. densebarbatum Cookson and Eisenack 1960

Pl. 1, figs. 1, 10; pl. 14, figs. 5-7

1960. Cyclonephelium densebarbatum Cookson and Eisenack, Palaeontology, vol. 2, p. 253, pl. 38, figs. 9-10.

Comments: Monmouth Group specimens differ slightly in overall process structure from those described by Cookson and Eisenack (1960, p. 253); however, they are quite similar in overall structure to those identified as C. cf. C. densebarbatum by Cookson and Hughes (Paleontology, vol. 7, p. 44, pl. 10, fig. 10). As described by Cookson and Hughes (ibid.) and as observed in the Monmouth Group specimens, the periphery of the cyst is ornamented with short, rather densely arranged appendages with relatively broad apices. The tops of the processes are truncated somewhat uniformly about the periphery, and are frequently joined by trabeculae. Additional features of interest in the Monmouth Group specimens are: occasional and poorly reflected tabulation, slightly developed left antapical horn, cingulum occasionally and irregularly developed. Archeopyle is apical (Type $\overline{A}$).

Dimensions: Observed range (24 specimens measured): length of main body difficult to measure because apical operculum rarely observed in place; width 51 - 57 um; process length 3-11 um.

Occurrence: Mount Laurel Sand, extremely rare; Navesink Formation, extremely rare to rare; Sandy Hook Member of Red Bank Sand, extremely rare. Greatest occurrence, sample nos. 213 and 216. Occurred in 15 samples.

Previously reported occurrence: Middle Cretaceous of England (Cookson and Hughes, 1964).

Genus Diconodinium Eisenack and Cookson 1970

Diconodinium rhombiformis Vozzhennikova 1967

Pl. 9, fig. 12

1967. Diconodinium rhombiformis Vozzhennikova, Akad. Nauk SSR, sib. otd., Inst. Geol. Geofiz., Tr., p. 50, pl. VII, figs. 1-4.

Comments: Cyst outline in dorso-ventral view is rhomboidal, with apical and antapical spikes. In polar view the cyst outline is hexagonal caused by linear longitudinal folds in cyst wall, possibly reflecting tabulation. Endophragm and periphragm closely appressed over much of cyst; however, small anterior and posterior pericoels exist within the short polar spikes. Periphragm slightly granular, endophragm appears smooth. Cingulum broad, ca. 1/8 cyst length, measuring 10 um for specimens 80 um long; bordered top and bottom by well-defined ridges. Where the cingulum intersects the longitudinal periphragm folds small spikes can be seen projecting outward. Sulcus is vague, but a break can be observed between terminal ends of cingulum, indicating a rather broad sulcal area, which does not appear to extend above the cingulum. Archeopyle is vague, but appears to be precingular, (Type P).

Dimensions: Observed range (10 specimens measured): length 41-52 um, width 27-38 um.

Occurrence: Mount Laurel Sand, extremely rare; Navesink Formation, extremely rare to rare. Greatest occurrence, sample nos. 213 and 220.

Occurred in 8 samples.

Previously reported occurrence: Upper Cretaceous of Russia (Vozzhennikova, 1967).

Diconodinium sp.

Pl. 9, figs. 13

Comments: Cyst morphology agrees basically with the generic description (Eisenack and Cookson, 1960, p. 3); however, the cyst lacks any indication of a cingulum. Epitract is terminated by a brief, pointed horn; hypotheca is terminated by a bluntly rounded horn. Endoblast is free of periblast, forming a continuous peripheral pericoel. Endophragm slightly granular; periphragm smooth, but delicate and folded. No archeopyle observed.

Dimensions: Observed range (2 specimens measured): length 37-38 um, width 33-37 um. Apical horn length 4-5 um; antapical ca. 4 um.

Occurrence: Mount Laurel Sand, extremely rare.

Previously reported occurrence: Not previously reported.

Genus Diphyes (Cookson 1965) Davey and Williams 1966

Diphyes colligerum (Deflandre and Cookson 1955) Davey and Williams 1966

Pl. 1, figs. 16,17

1953. Hystrichosphaeridium sp. Cookson, Mem. Nat. Mus. Melbourne, vol. 18, pl. 2, figs. 29-30.

1955. Hystrichosphaeridium colligerum Deflandre and Cookson, Aust. Jour. Mar. Freshw. Res., vol. 6, p. 278-279, pl. 7, fig. 3.

1963. Baltisphaeridium colligerum (Deflandre and Cookson 1955) Downie and Sarjeant, Paleontology, vol. 6, p. 91.

1965. Diphyes colligerum (Deflandre and Cookson 1955) Cookson, Proc. Roy. Soc. Vict., vol. 78, p. 86, pl. 9, figs. 1-12.

1966. Diphyes colligerum (Deflandre and Cookson 1955) Davey and Wiliams, (in Davey, Downie, Williams, and Sarjeant), in Bull. Brit. Mus. Nat. Hist. (Geol.), Suppl. 3, p. 96-97, pl. 4, figs. 2-3.

Comments: Six specimens were observed. Each compares favorably in size and morphology with the Australian specimens originally described by Cookson and Deflandre (1955). Although no tabulation was observed, the apparent arrangement of processes in five parallel rows (parallel to equator) may in some way express tabulation. The spines do not generally exceed one-half the main body diameter, appear hollow, distally open, and slightly fibrous. The large antapical process is slightly fibrous, appears hollow, is closed distally, and accomodates about four small tubules near the distal end; the tubules appear closed and measure about 2um in length each. Archeopyle is apical (Type $\overline{A}$).

Dimensions: Observed range (6 specimens measured): length main body 31-47 um, width 29-33 um. Antapical process length 15-16 um, width ca. 9 um at mid-length, tubule length ca. 2 um. All other processes 12-13 um in length X 1 um distally to 6 um proximally.

Occurrence: Extremely rare in samples 214, 222, 234, and 236.

Previously reported occurrence: From Upper Cretaceous (Senonian) to Upper Eocene (Cookson and Eisenack, 1967, p. 251).

Diphyes recurvatum n. sp.

Pl. 1, figs. 18-20

Holotype: Slide 206-1, 13.8 x 104.0 (Pl. 1, figs. 18-20).

Type locality: Atlantic Highlands, New Jersey.

Type stratum: Navesink Formation (Campanian-Maestrichtian).

Description: Cyst sphaeroidal; bilayered, endophragm and periphragm closely appressed; endophragm (ca. 1 um thick) appears smooth; periphragm (less than 1 um thick) faintly microreticulate on main body, formed into long (ca. 15 um) slender (ca. 1 um diam.), tapering, hollow, distally open, and finely striate or fibrous processes bearing distally trifurcate and recurved prongs. Tabulation difficult to determine; 5 rows of slender processes are aligned parallel to equator and may express tabulation. A single large hollow and distally open process (ca. 6 um diam. at mid-length; ca. 15 um long) is located at the antapical position. The large antapical process bears small lateral tubules and spines at the distal end. A cingulum may be indicated by the middle-most row of slender processes. No sulcus observed. Archeopyle is apical (Type $\overline{A}$).

Affinities: D. recurvatum differs from other species of this genus by having slender processes which taper distally, then trifurcate as

three recurved prongs.

Dimensions: Holotype L x W (main body): 35 x 35 um. Process length up to 15 um. Observed range (2 specimens measured) same as holotype.

Occurrence: Mount Laurel Sand, extremely rare; Navesink Formation, extremely rare.

Genus Diversispina n. gen.

Derivation of name: Latin, diversi, different, variable; spina, spine.

Type species: Diversispina truncata n. sp.

Description: Spherical to ovoidal, bilayered, nonfibrous chorate cysts, bearing smooth to slightly granular or finely striate processes. Processes intratabular, one process per plate equivalent, hollow to partially solid, expanded proximally and distally, and open or closed, variably developed in size and shape, irregularly branching both laterally and distally, and reflecting tabulation 4', 6", 6c, 5"', 1p, 1"". Archeopyle precingular (Type P).

Discussion: It is intended that this new genus be distinct from Cordosphaeridium Klumpp. The periphragm is not fibrous on either the main body or the processes. Otherwise the features are similar, e.g., intratabular processes with Gonyaulax type tabulation and a precingular archeopyle (Type P).

Affinities: Diversispina differs from Hystrichosphaeridium by lacking an apical archeopyle, and differs from Cordosphaeridium by lacking the fibrous wall and processconstruction. It differs from Hystrichokolpoma by lacking the apical archeopyle and general process structure, i.e., processes of two types.

Diversispina truncata n. sp.

Pl. 3, figs. 1-5

Name derivation: Latin, truncata, cut-off, indicating the truncated or cut-off appearance of the ends of the distal branches of the processes.

Holotype: Slide AJ-69, coords. R4.6,+16.4 (Pl. 3, figs. 1-2, 4-5).

Type locality: Atlantic Highlands, New Jersey.

Type stratum: Sandy Hook Member of the Red Bank Sand.

Description: Spheroidal to ovoidal chorate cyst. Bilayered; endophragm smooth; periphragm microreticulate on central body, slightly thinner than endophragm (both layers together measure ca. 1 um), formed into intratabular, hollow to partially solid, open to closed, slightly granular to finely striate tubular processes. Processes within any particular series variably constructed. A single intratabular process occurs per plate equivalent. Processes broad and hollow at the base (except at sulcus, cingulum, and apex where they are more slender overall and appear solid), tapering distally to about ¼ process length, then parallel-sided to flaring toward distal end; distal end variably branched, with terminal and lateral branch tips truncated and often pinched-shut or remaining open. Cingular process bases elongate in direction of cingulum, and may be double-pronged. Sulcal processes are reduced slender "rods", often paired in lower to mid-ventral position, single in anterior and posterior positions. Archeopyle precingular (Type P), is horseshoe-shaped, and appears gabled on the upper part.

Discussion: The processes appear plate-centered, with one process per plate equivalent. They are variably constructed and of variable size

within any particular series, except perhaps the apical series. Within a given series the processes may bifurcate near their bases, or be branched, except at the distal ends where they may divide into several truncated tubules. Although some processes appear to be hollow and open, others become solid about midway or higher, while others only close at the distal termination of the tubules. High magnification indicates that the processes are finely striate, and/or granular, giving a pseudo-fibrous texture; the central body of the cyst is faintly microreticulate. Processes in the sulcal area are consistently arranged with a single anterior sulcal and posterior sulcal process, with two somewhat medially placed pairs of sulcal processes. Reduced processes are found in the apical, sulcal, and cingular series. The 6" and 1"' and 1p processes are generally reduced also. The remaining pre and postcingular processes and, also apical processes all fall within the same larger size range, and are generally highly variable in shape. The antapical process is long and slender but is not characteristically different from most of the pre and postcingular processes.

Affinity: Maier (1959, p. 320-321, pl. 33, figs. 3-4) described and illustrated Hystrichosphaeridium stellatum; however, the description is based heavily on morphological criteria not generally used at present, and therefore is not helpful for comparison. The illustrations of Maier do show, however, the variably truncated processes as in D. truncata. Maier also describes a fibrous wall structure. Authors have illustrated specimens such as H. stellatum under a variety of names: H. mantelli Davey and Williams 1966, H. readii Davey and Williams 1966, and H. simplicispinum Davey and Williams 1966. All these species are described, however, as having apical archeopyles.

The general process development of Cordosphaeridium gracilis (Eisenack 1954) Davey and Williams 1966 is similar to that of D. truncata, but its wall structure and processes are markedly fibrous. Cordosphaeridium inodes (Klumpp 1953) Eisenack 1963 displays similar processes, but is described as having fibrous body-wall and processes. The illustration by Klumpp (1953, pl. 18, figs. 1-2) seems to show a reticulate central body wall.

Dimensions: Holotype L x W (main body) 57 x 51 um; processes, apical 20-24 um long x less than 3 um wide at mid-length; all other processes 22-29 um long x ca. 10 um wide at mid-length. Observed range (17 specimens measured: Main body length 51-69 um, width 41-69 um. Processes: length rarely exceeds ½ main body diameter; width variable, generally less than 10 um at mid-length. Wall layers ca. 1 um thick; endophragm slightly thicker than periphragm.

Occurrence: Navesink Formation, extremely rare to rare; Sandy Hook Member of Red Bank Sand, extremely rare to rare. Greatest occurrence, sample 219.

Genus Exochosphaeridium Davey et al. 1966

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

Pl. 2, fig. 12; pl. 12, fig. 11; pl. 17, figs. 1-20; pl. 18, figs. 1-20; pl. 19, figs. 1-12; pl. 20, figs. 13-20

1967. Baltisphaeridium bifidum Clarke and Verdier, Verh. Kon. Nederl. Akad. Wetensch., Afd. Natuurk., Eerste Reeks, vol. 24, No. 3, p. 72-73, pl. 17, figs. 5-6, text fig. 30.

1968. Exochosphaeridium bifidum (Clarke and Verdier) Clarke, Davey, Sarjeant, and Verdier, Taxon, vol. 17, p. 182.

Comments: Cysts morphologically similar to the Isle of Wight specimens reported by Clarke and Verdier (1967) occur throughout the study section. Because of the high numbers of specimens, expecially in the uppermost Navesink and lower Sandy Hook Member of the Red Bank (9-31 percent) it was possible to determine the degree and type of intraspecific variability. The degree of variability was shown to be high; however, it remained much the same from sample to sample, and did not suggest any particular evolutionary trend. Extreme variants of the species, if observed as isolated specimens, would likely not be associated with each other. One extreme variant has numerous, very short, (ca. 8 um), slender processes (pl. 17, fig. 1), while the other extreme has fewer, broad, solid to tubular, fibrous, longer (up to 29 um), Cordosphaeridium-like processes (bearing 1 to a few processes per plate equivalent) (pl. 17, fig. 14). Because of the newly observed morphological variance a revised description is given below.

Revised description: Cyst main body ovoidal. Bilayered; endophragm ca. 1.5 um thick, formed of vertical fibers or bacula; periphragm ca. 0.5 um thick, formed of short fibers matted or arranged into a fine reticulum (lacunae measuring ca. 0.4 um across). Processes formed of periphragm, generally spaced more than 5 um apart. Process bases formed of coarse elongate fibers; process shafts striate to finely to coarsely fibrous. Processes taper distally to a bifid or minutely

capitate distal tip. Apical process tuft-like, being of broad base, more or less parallel sided, up to 8 um wide, coarsely fibrous, distally branching into 2 to several tapering branchlets; each branchlet distally bifid to minutely capitate. Process arrangement appears nontabular; tabulation unknown. Cingulum not observed, except along the posterior edge of the precingular archeopyle; indicated by a relatively smooth strip bordered beneath by a row of processes aligned in the direction of the cingulum. Sulcus not observed. Archeopyle precingular (Type P).

The most variable feature of this species is process number and shape. One extreme variant may display numerous, short, slender (up to 8 um) processes, while another extreme variant may display long (up to 29 um) relatively broad (up to 12 um wide), hollow to solid, proximally and distally flaring, fibrous Cordosphaeridium-like processes. Both extremes are relatively rare; most specimens being as described in the above paragraph. Intermediate forms bear a combination of the broad and slender processes.

Discussion: Twenty specimens were selected to illustrate the morphological gradation within the species. These specimens are shown on plate 17, figs. 1-20, each photograph being an optical cross-sectional view illustrating cyst main body outline and process development. The apical tufts for the same 20 specimens are illustrated in the same sequence on plate 18, figs. 1-20. The process variability for the same 20 specimens is also illustrated in the same sequence on plates 19 and 20, figs. 1-20. See plate explanations for details. Thus, by observing figs. 1-20 of plates

17-20 one can simultaneously compare the degree of variability in general cyst outline, apical tuft development, and process development for the 20 specimens. Detailed discussion is also given on p. 64.

Text fig. 7 is a scatter diagram plotting main body length versus average process length. Generally, the less the main body length the fewer broad, fibrous, Cordosphaeridium-like processes are observed. Specimens with the largest main body length generally bear more of the heavier, and longer Cordosphaeridium-like processes.

Dimensions: Observed range (approximately 200 specimens measured): length main body 50-77 um, width 43-77 um; spine length 8-31 um.

Occurrence: Throughout Mount Laurel Sand, extremely rare to sparse; throughout Navesink Formation, extremely rare to abundant; throughout Sandy Hook Member of Red Bank Sand, sparse to abundant. Greatest occurrence, sample nos. 225, 227, 233. Occurred in 35 samples.

Previously reported occurrence: Senonian of England (Clarke and Verdier, 1967). Williams and Lentin (1975, p. 68) report E. bifidum from mid-Albian through Campanian.

Genus Gonyaulacysta Deflandre 1964

Gonyaulacysta clathrata Cookson and Eisenack 1960

Pl. 5, figs. 5-8

1960. Gonyaulax clathrata Cookson and Eisenack, Palaeont., vol. 2, pt. 2, p. 246-247, pl. 37, fig. 5.

1966. Gonyaulacysta clathrata (Cookson and Eisenack) Sarjeant 1966, Bull. Brit. Mus. Nat. Hist. (Geol.), Suppl. 3, p. 130.

Comments: The Monmouth Group specimens agree with those described originally by Cookson and Eisenack (1960). As reported by them, the plates are bordered by rather high ledges with radially arranged perforations. The perforations, at least under oil immersion, appear to be spaces between bacula, the bacula distally joined along the plate boundaries by trabeculae. This gives the palisade appearance reported by Cookson and Eisenack (1960, p. 246). Specimens from the Monmouth Group appear to have growth bands parallel to plate margins, and these bands are bordered also by palisade-like ridges. Reflected tabulation 4', 6", 6c, 5'", 1P, 1"". Archeopyle precingular (Type P).

Dimensions: Observed range (3 specimens measure): length 63-80, width 57-69 um; wall layers ca. 2 um, endophragm thicker than periphragm; baculate ridges ca. 4 um high.

Occurrence: Mount Laurel Sand, extremely rare to rare; Navesink Formation, extremely rare. Observed in 7 samples.

Previously reported occurrence: Upper Jurassic (?Tithonian), Western Australia (Cookson and Eisenack, 1960).

Gonyaulacysta wetzeli (Lejeune-Carpentier 1939) Sarjeant 1969

Pl. 5, figs. 9-12

1939. Gonyaulax wetzeli Lejeune-Carpentier, Ann. Soc. Geol. Belg., vol. 62, p. B525-B529, figs. 1-2.

1964. Gonyaulacysta wetzeli Lejeune-Carpentier, C. R. Acad. Sci., Paris, v. 258, p. 5027-5030.

1969. Gonyaulacysta wetzeli (Lejeune-Carpentier) Sarjeant, Bull. Brit. Mus. Nat. Hist. (Geol.), Appendix to Suppl. 3, p. 11.

Comments: Plate equivalents are separated by broad, parallel, low sutural folds which give the appearance of parallel bands separating plate equivalents. In fact, these broad bands have been suggested by other workers (Neale and Sarjeant, 1962) to be extra equivalents. To accommodate such forms they (ibid.) set up a new genus Cribroperidinium Neale and Sarjeant 1962. It is suggested that the parallel bands may be related to growth bands on the parent theca, and are not extra plate equivalents. Davey (1969, p. 128, figs. 13a, b) discussed similar features of G. orthoceras Eisenack, and also felt that they were not extra plate-equivalents. Based on information to date, the author feels that such "banding" does not require the formation of a new genus and that such forms should be assigned to Gonyaulacysta. Additional features observed on the Monmouth Group specimens are the thorny points at gonal positions of sutural folds, especially near the apex, and the relatively long (up to ca. 10 um) digitate to

acuminate apical horn. Reflected tabulation 4', 6", 6c, 5"', 1P, 1"". Archeopyle precingular (Type P).

Dimensions: Observed range (34 specimens): length 89-117 um; width 74-86 um.

Occurrence: Mount Laurel Sand, extremely rare; Navesink Formation, extremely rare to rare; Sandy Hook Member of Red Bank Sand, extremely rare. Greatest abundance is at top of Navesink Formation and base of Red Bank Sand.

Previously reported occurrence: Senonian of France (Lejeune-Carpentier, 1939, 1946). Danian of northern Europe (Morgenroth, 1968).

Gonyaulacysta sp.

Pl. 5, fig. 13

Comments: Cyst is spheroidal to egg-shaped, bears a short apical horn, and a cingulum and sulcus. Periphragm and endophragm may be separated forming a pericoel, especially at apex. Periphragm is thick (ca. 3 um) scabrate to granular, and is formed into the apical horn and sutural folds outlining cingulum and sulcus and rarely plate equivalents. Endophragm is not as thick (1-1.5 um), is smooth, and does not reflect plate outlines. Tabulation is generally not evident; except that occasional and irregular folding of the periphragm seemingly indicates some plate edges. Gocht (1969, p. 30, pl. 6, figs. 6a-6b) reported a similar form as Apteodinium sp, probably because of its lack of tabulation. Archeopyle is precingular (Type P).

Dimensions: Observed range (8 specimens measured): length 100-120 um, width 74-109 um.

Occurrence: Upper part of Navesink Formation, extremely rare to rare; Sandy Hook Member of Red Bank Sand; extremely rare to rare. Occurred in 19 samples.

Previously reported occurrence: A similar form reported from the Upper Eocene of Germany (Gocht, 1969).

Genus Hystrichokolpoma Klumpp 1953

Hystrichokolpoma fenestrecona n. sp.

Pl. 3, figs. 6-11

Name derivation: Latin; fenestra, window; cona, cone; referring to smooth, window-like, basal areas of the conical processes.

Holotype: AJ-46, Coords. R3.1, + 17.3 (pl. 3, figs. 6-8).

Type locality: Atlantic Highlands, New Jersey.

Type stratum: Sandy Hook Member of Red Bank Sand.

Description: Chorate cyst with spherical to ovoidal main body. Bilayered; endophragm smooth; periphragm rugulate between circular and smooth-based processes; formed into processes of two types: larger circular-based, intratabular, conical, hollow, and distally open processes which characterize the pre and postcingular and antapical plate equivalents; and slender circular-based, slightly-tapering, intratabular, hollow, and distally open processes which characterize the apical, cingular, 1p, and often 6" plate positions. Both types

of processes of relatively equal length, differing mainly in diameter and degree of tapering. The 6'' is a slender process located immediately below and to the left of the larger 5''. The 1P is a slender process nearly contacting the lower, sulcal side of the 1'''. Circular process bases encompass smooth areas on the central body, appearing as circular windows. Each plate equivalent is represented by a single plate centered process, and is well-separated from the adjacent processes. The reflected tabulation is ?4, 6'', ?c, 5''', 1P, 1''''. Cingulum levorotatory, represented by 3-4 widely spaced, laterally and dorsally positioned, slender processes. Archeopyle apical (Type $\overline{A}$), corresponding to the position of 3-4 apical plates, represented by only 3 slender processes; the ventral-most appears to be the result of a fusion of the 1' and 4' processes, and may appear single or double-pronged, or ribbon-like.

Discussion: Six specimens were oriented solely to examination of the apical series. The apex is unusual in that it consistently shows only three slender apical processes. One specimen displays suture lines on the apex, which outlined 4 plate equivalents; the ventral-most apical process lies on the suture line between the 1' and 4'. This process appears to be the result of a fusion of the processes of both plates (1' and 4'). Frequently this ventral-most process is in some way different from the other two, i. e., being double pronged (sharing one base but bifurcating) or ribbon-like. The 3-4 cingular processes were only observed laterally and dorsally. The antapical process is generally not larger than the other

larger-type processes, but may be more parallel sided. No sulcal processes were observed, the position of the sulcus being determined by the apical notch in the archeopyle, which appears to be mid-ventrally aligned, the position of the reduced 6" and 1p, and the larger antapical process. The sulcal area also appears to be broad and open. The ornamentation on the central body between the processes is rugulate; beneath the processes the main body is smooth, forming a smooth circular window on the central body. The processes themself are generally smooth, but may be finely striate.

Affinities: H. fenestrecona differs from H. bulbosa (Ehrenberg 1838) Morgenroth 1968 by having rugulate ornamentation, 3 apical processes, no sulcal processes, cingular processes with circular bases, and well-spaced processes. Morgenroth (1968, p. 546-547, pl. 44, figs. 1-6), describing H. bulbosa, reported granular ornamentation, 6 apical plates (two of which possibly reflect an anterior sulcal plate and an apical pore closing platelet) flaring or trumpet-like processes, and cingular processes with bases elongate in the direction of the cingulum. Lejeune-Carpentier (1940, p. 220, fig. 10) described and illustrated specimens similar to Ehrenberg's originals. These had processes which abutted against each other, such that the main body was barely visible. H. fenestrecona is different from most other representatives of the genus because it lacks the quadrate to polygonal type processes which delineate their respective plate boundaries.

Dimensions: Holotype - L x W (Main Body) 34 x 34 um; larger process diameter 9-12 um at base, tapering distally, length 20-25 um;

slender process diameter 2-4 um at base, length 15-20 um; wall layers ca. 2 um, endophragm thicker than periphragm. Observed range (10 specimens measured): main body length 29-34 um, width 29-34 um; larger type process length 14-20 um, diameter 7-12 um at base, tapering distally; slender type process length 15-20 um, diameter 2-4 um at base.

Occurrence: Navesink Formation extremely rare; Sandy Hook Member of Red Bank Sand extremely rare to rare. Greatest occurrence, sample nos. 222, 226, and 214.

Genus Hystrichosphaeridium (Deflandre 1937) Davey and Williams 1966

Hystrichosphaeridium recurvatum (White 1844)

Pl. 3, figs. 18-20

1844. Xanthidium tubiferum palmatum White, Trans. Microsc. Soc. London, p. 39, pl. 4, fig. 12.

1937. Hystrichosphaeridium tubiferum Deflandre, Ann. de Paleont., vol. 26, p. 65, pl. 13, figs. 2 and 4.

1940. Hystrichosphaeridium recurvatum Lejeune-Carpentier, Ann. Soc. Geol. Belg., vol. 63, p. 221, fig. 6.

Comments: Cysts recovered appear identical with those described and illustrated by Deflandre (1937) and LeJeune-Carpentier (1940). The cysts are spherical to ovoidal, chorate, and bilayered. Endophragm smooth; periphragm smooth to finely scabrate on main body and

processes. Processes slender, slightly tapering, hollow, open, terminating distally as a rosette of 4-6 short, recurved spines. Reflected tabulation 4', 6", 6c, 5"', 1p, 1"". Cingular processes have rounded bases, as do those of the other processes, are of similar length, and are not easily recognized on disoriented specimens. Sulcus has single anterior and a posterior (no paired processes). Archeopyle is apical (Type $\overline{A}$), corresponding to the position of all four apical plates; operculum is simple and free. The apical processes are similar in shape and size to all others on the cyst.

Dimensions: Observed range (7 specimens measured): main body diam. 31-34 um; process width ca. 3 um, length 26-34 um.

Occurrence: Navesink Formation, extremely rare to rare; Sandy Hook Member of Red Bank Sand, extremely rare. Greatest occurrence in sample no. 217. Occurred in 11 samples.

Previously reported occurrences: Senonian of France (Deflandre, 1935, 1937), Belgium (Lejeune-Carpentier, 1940), and England (Davey and Williams, 1966).

Hystrichosphaeridium tubiferum (Ehrenberg 1838)

Pl. 3, figs. 12-14

1838. Xanthidium tubiferum Ehrenberg, Abh. preuss. Akad. Wiss., pl. 1, fig. 16.

1937. Hystrichosphaeridium tubiferum (Ehrenberg) Deflandre, Ann. Paleont., vol. 26, p. 69, pl. 13, figs. 2, 4, 5.

1966. Hystrichosphaeridium tubiferum (Ehrenberg) Davey and Williams, Bull. Brit. Mus. Nat. Hist. (Geol.), Suppl. 3, p. 56-58.

Comments: Numerous H. tubiferum specimens from the Monmouth Group are excellently preserved, and display standard Gonyaulax type tabulation. The tabulation scheme indicates 4 apical plates (Davey and Williams, 1966, p. 56-58, report 4-5 apical plates), and 5 post cingular plates (Davey and Williams, ibid., report 5-6). The complete tabulation scheme for the Monmouth Group specimens is 4', 6", 6c, 5"', 1p, 1''''. The sulcus is characterized by single anterior and posterior sulcal processes, and two pairs of somewhat medially situated sulcal processes. Specimens identified by Deflandre (1937, pl. 13, figs. 2, 4, and 5) as H. tubiferum are more closely associated with H. recurvatum (White 1842) Davey and Williams 1966. Archeopyle apical (Type $\bar{A}$).

Dimensions: Observed range (24 specimens measured): main body length 37-51 um, width 34-54 um; process length 22-26 um, diam. 2-5 um at mid-length.

Occurrence: Mount Laurel Sand, extremely rare to rare; Navesink Formation, extremely rare to common; Sandy Hook Member of Red Bank Sand, extremely rare to rare. Greatest occurrence, sample nos. 211, 213, 214, and 215. Occurred in 29 samples.

Previously reported occurrences: Widely reported from Lower to Upper Cretaceous, Tertiary to Pleistocene sediments.

Hystrichosphaeridium tubiferum (Ehrenberg) var. brevispinum
Davey and Williams 1966
Pl. 3, figs. 15-17

1966. Hystrichosphaeridium tubiferum (Ehrenberg) var. brevispinum Davey and Williams, Bull. Brit. Mus. Nat. Hist. (Geol.), p. 58, pl. 10, fig. 10.

Comments: The few specimens recovered from the Monmouth Group agree in size and morphology with those described by Davey and Williams (1966). The cyst main body is spheroidal to ovoidal and bilayered. Endophragm smooth; periphragm slightly granular on main body, gives rise to short, some nearly as wide as long, open, hollow, tubular processes. The distal ends of the processes may flare, or have short, recurved spines. In the original description Davey and Williams (1966, p. 58) report 23 processes for H. tubiferum (Ehrenberg) var. brevispinum. Specimens from the Monmouth Group exhibit 29, one per plate equivalent. Tabulation of the Monmouth Group specimens is 4', 6", 6c, 4"', 1p, 1"", 6s. Cingular process bases and shafts are elongate in the direction of the cingulum, the flaring distal ends also retaining some effect of the elongation. The bases of the processes are well-marked in all series. Sulcal processes are more slender. Single anterior and posterior sulcal processes are separated

by two pairs of medially placed sulcal processes. Archeopyle is apical (Type $\bar{A}$), formed by the loss of a simple, free operculum, corresponding to all four plates of the apical series; a sulcal notch is present at the ventral side of the archeopyle, and is mid-ventrally aligned.

Dimensions: Observed range (3 specimens measured): main body diam. 40 um; process length 8-14 um, width 8-14 um.

Occurrence: Mount Laurel Sand, extremely rare; Navesink Formation, extremely rare; Sandy Hook Member of Red Bank Sand, extremely rare. Occurred in 8 samples.

Previously reported occurrence: Eocene of Enborne, Berkshire, England (Davey and Williams, 1966).

Hystrichosphaeridium sp.

Pl. 6, figs. 17-20

Comments: Because only two specimens were observed this form was not given a new species name. It is also quite similar to *H. tubiferum brevispinum*, and could be a variant of that subspecies. Because of the morphological differences with *H. t. brevispinum* a detailed description is given below.

Description: Spherical to ovoidal chorate cyst. Bilayered; endophragm (ca. 1.5 um thick) smooth; periphragm (ca. .5 um thick) microreticulate on main body and on process walls. Periphragm formed into large based, short (8-15 um) simulate processes (one process per plate equivalent), which are parallel sided to basally flaring, then tapering to a slender

neck then distally flaring, or being somewhat cushion-shaped. Process bases roundly polygonal in outline; cingular process bases elongate in direction of cingulum; apical and antapical processes somewhat longer than the others. Apical series, in addition to the 4 apical processes, displays a reduced, centrally positioned process, likely representing an apical pore closing platelet. Sulcal processes are in 2 pairs in the mid-ventral to lower ventral area, also bearing a single anterior and posterior sulcal process. Reflected tabulation 4', 6", 6c, 5"', 1p, 1"", 6s. Cingulum levorotatory, offset ca. ½ cingulum width. Sulcus indicated anteriorly by mid-ventrally aligned sulcal notch, and sulcal processes. Archeopyle precingular (Type $\overline{A}$), formed by the loss of a simple, free operculum.

Dimensions: Observed range (2 specimens measured): length central body 52-60 um, width 50 um on one specimen; process height 8-15 um.

Occurrence: Mount Laurel Sand, extremely rare. Occurred in one sample.

Previously reported occurrence: Not previously reported.

Genus Leptodinium (Klement 1960) Sarjeant 1969

Leptodinium cristatum n. sp.

Pl. 5, figs. 16-20

Name derivation: Latin; cristata, crested. Referring to the high crests which border each plate-equivalent.

Holotype: 16NS7-1, 25.1 x 101.4 (pl. 5, figs. 16-20).

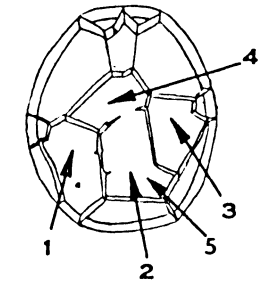
Type locality: Atlantic Highlands, New Jersey.

Type stratum: Navesink Formation.

Description: Spheroidal cysts, circular in equatorial section. Bilayered; endophragm smooth; periphragm smooth, formed into sutural folds at plate boundaries, which generally appear as high, thin, uneven crests, and are generally higher at gonal positions. Crests often incompletely developed in the apical and sulcal series: boundary between 1' and 4' not evident; boundary between as and ms weakly developed. Reflected tabulation 3-4', 6", 6c, 5"', 1p, 1"", as, ms, ps. Cingular plates hexagonal on dorsal surface, more quadrolateral on ventral surface; cingulum levorotatory, ca. one cingulum width offset. Sulcus begins ca. one cingulum width above 1c, extends to 1"", and is 1-2 cingulum widths wide, widening antapically. Archeopyle precingular (Type P). Sutural folds of 3"' offset to left of those of 3", giving asymmetrical appearance to dorsal surface.

Discussion: Tabulation is probably standard Gonyaulax-type tabulation; however, 4 apical plates have not yet been observed. Because other sutural folds in the apical series are occasionally incompletely developed, and because the as-ms is incompletely developed, it is assumed that the 1'-4' boundary is likely also undeveloped in this species, but does exist.

Affinities: Leptodinium victorianum Cookson and Eisenack 1965 is similar to L. cristatum in overall construction, plate shape and arrangement. L. victorianum differs by lacking the lower sutural sutural folds of the 1c and 6c plate equivalents, being about twice

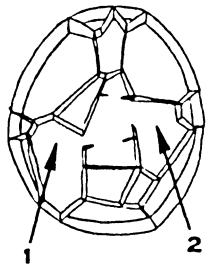


Miocene-Holocene

Leptodinium patulum Wall 1967:

Sutural crests missing

1. 6c lower crest
2. ms-ps boundary
3. 1c lower crest
4. 6'-as boundary
5. ps-1p boundary



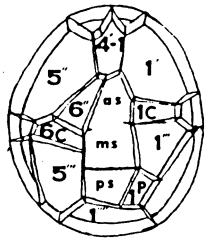
Younger

Eocene

Leptodinium victorianum Cookson and Eisenack

Sutural crests missing

1. 6c lower crest
2. 1c lower crest



Campanian-Maestrichtian

Leptodinium cristatum n. sp.:

Ventral plate-equivalent development most complete.

Lacks ps-ms boundary

Figure 11. Proposed Leptodinium lineage. Leptodinium cristatum n. sp. observed in the Monmouth Group appears to be ancestral to L. victorianum Cookson and Eisenack 1965 of Eocene age and to L. patulum Wall .1967 of Miocene to Recent age. The younger specimens have fewer ventral plate crests.

as large, and generally displaying 4 apical plates, although the ventrally directed 1'-4' boundary may also occasionally be lacking. L. patulum Wall (1967) is also similar to L. cristatum in overall construction, plate-shape and arrangement, size range, and has complete or incomplete suture development in the apical and sulcal series. L. patulum, however, lacks the lower sutural folds on the 1c and 6c, and lacks a sutural fold on the sulcal-side of the 6''. Because L. cristatum has complete sutural fold development on all ventral plates of the precingular, cingular, and postcingular series, and 1p, it is apparently distinctive. Considering the close relationships with the above compared species a lineage is suggested. The more complete tabulation of L. cristatum being ancestral (Campanian-Maestrichtian), the slightly less complete ventral tabulation of L. victorianum Cookson and Eisenack being somewhat younger (Eocene), and the much less complete ventral tabulation of L. patulum Wall being youngest (Miocene-Holocene) (Text-fig. 11).

Dimensions: Holotype - L x W 43 x 40 um. Observed range (18 specimens measured): length 37-50 um, width 31-49 um; crest height 3-7 um; wall layers ca. 2 um, endophragm thicker than periphragm.

Occurrence: Mount Laurel Sand, extremely rare; Navesink Formation, extremely rare; Sandy Hook Member of Red Bank Sand extremely rare. Greatest occurrence, sample nos. 221, 224. Occurred in 16 samples.

Leptodinium cf. L. multiplexum Wall and Dale 1968

Pl. 14, fig. 12; pl. 16, figs. 11, 12

1968. Leptodinium multiplexum Wall and Dale, New Phytol., vol. 67, p. 319, pl. 1, figs. 1-7.

Comments: A single, slightly deformed specimen was observed in the upper Mount Laurel Sand. It agrees morphologically with those described by Wall and Dale in that the sutural crests display distally pointed projections at gonal positions. A scanning electron micrograph (pl. 14, fig. 12), taken of another specimen at the same horizon, shows incomplete sutural development on the ventral surface, lacking various boundaries within the sulcus, cingulum, and the sulcal boundary of the 6". Archeopyle precingular (Type P).

Dimensions: A single specimen was measured: length of central body 50 um, width 41 um, height of sutural crests ca. 6 um at gonal positions, otherwise ca. 3 um.

Occurrence: Mount Laurel Sand, extremely rare.

Previously reported occurrence: Pleistocene of England (Wall and Dale, 1968).

Genus Odontochitina Deflandre, emend. Davey 1970

Odontochitina costata Alberti 1961

Pl. 9, figs. 14, 15

1961. Odontochitina costata Alberti, Palaeontographica, Abt. A, vol. 116, p. 31, pl. 6, figs. 10-13.

Comments: Odontochitina costata is assigned herein to the family Gonyaulacaceae, because of its possible evolutionary relationship to the modern genus Ceratium Schrank, 1793 (Wall and Evitt, 1975, p. 14). Wall and Evitt (1976, p. 15) has shown that the tabulation for several species of Ceratium is gonyaulacacean, suggesting that ancestral ceratioid cysts are also of that family.

Clarke and Verdier (1967, p. 58-59) state that O. striatoperforata Cookson and Eisenack 1962 is a junior synonym of O. costata Alberti 1961. Since both species were published only one year apart, it is doubtful that Cookson and Eisenack (1962, p. 490, pl. 3, figs. 14-19) were aware of Alberti's new species. A comparison of the two species descriptions shows very close similarities. Alberti refers to parallel, longitudinal ribs; Cookson and Eisenack refer to longitudinal striae. Although, Cookson and Eisenack report the presence of perforations of varying size and number along the striae, Alberti does not. Clarke and Verdier (1967, p. 58-59) report that after observing several hundred specimens, they were unable to separate the two species, and considered them to be in synonomy, O. costata Alberti 1961 having priority. Specimens observed in Monmouth Group samples are faintly striated longitudinally, bear pores to various degrees, and are difficult to differentiate from either of the above species description. The writer feels that both species are probably

synonymous, O. costata having priority.

Several apical opercula and a few complete specimens of O. costata were observed in the Monmouth Group. The long horn on the apical operculum is generally faintly striate or ribbed and bears few to many longitudinally aligned pores. The apical portion of the endoblast is always present within the base of the apical operculum, and both appear fused. The endoblast is granular to microreticulate, and is distinctively thicker (ca. 2.0 um) than the periphragm. The apical horn is hollow, and generally the distal end is broken.

Dimensions: Observed range (2 specimens measured): length 305-324 um, width 49-64 um; length of apical operculum (5 specimens measured) 124-143 um, width 34-49 um; antapical horn length 131 um; postcingular horn length ca. 86 um; endophragm thickness 1.5-2.5 um, periphragm thickness less than 1 um.

Occurrence: Mount Laurel Sand, extremely rare. Occurred in 4 samples, sample nos. 203, 204, 205, and 207. Greatest occurrence, sample no. 207.

Previously reported occurrence: Albian to Cenomanian of Australia (Cookson and Eisenack, 1962), Lower Cenomanian of England (Cookson and Hughes, 1964), Cenomanian and Turonian of Germany (Alberti, 1961), and Cenomanian into Senonian of England (Clarke and Verdier, 1967).

Genus Oligosphaeridium Davey and Williams 1966

Oligosphaeridium complex (White) Davey and Williams 1966

Pl. 7, figs. 1-3

1842. Xanthidium tubiferum complex White, Microsc. J. London, vol. 2, p. 39, pl. 4, div. 3, fig. 11.

1848. Xanthidium complexum (White) Bronn, Handbuch einer Geschichte der Natur. Index palaeontologicus, p. 1375. Stuttgart.

1946. Hystrichosphaeridium complex (White) Deflandre, Fichier Micropaleont., vol. 6, p. 11.

1966. Oligosphaeridium complex (White) Davey and Williams, Bull. Brit. Mus. Nat. Hist. (Geol.), Suppl. 3, p. 71-74, pl. 10, fig. 3.

Comments: Because of the excellent state of preservation observed in the Monmouth Group specimens, a detailed description is given below.

Description: The cyst wall is bilayered and delicate; most specimens are distorted. Cyst main body spherical; periphragm and endophragm completely fused; both layers smooth. Periphragm formed into slender tubular, hollow, and distally opened and flared processes, bearing aculeate to secate and often perforate tips. Processes are 18 in number (not counting sulcal processes, which may number 2 or more). No cingular processes present. Reflected tabulation 4', 6", ?c, 5"', 1p, 1"", 2+s. Archeopyle apical (Type $\bar{A}$).

Dimensions: Observed range (9 specimens measured): length 31-40 um,

process length 22-37 um.

Occurrence: Mount Laurel Sand, extremely rare; Navesink Formation, extremely rare to rare; Sandy Hook Member of Red Bank Sand, extremely rare. Greatest occurrence, sample no. 216. Occurred in 12 samples.

Previously reported occurrence: Widely reported. Lower to Upper Cretaceous of England, France, Germany, Rumania, Africa, Australia; Eocene of England.

Genus Phoberocysta Millioud 1969

Phoberocysta ceratioides (Deflandre)

Pl. 10, figs. 4

1937. Hystrichosphaera ceratioides Deflandre, Ann. Paleont., vol. 26, p. 66-67, pl. 12, fig. 7-8.

1969. Phoberocysta ceratioides (Deflandre) Millioud, Proc. First Int. Conf. Planktonic Microfossils, Geneva, 1967, E. J. Brill, Leiden, vol. 2, p. 432.

Comments: The genus Phoberocysta Millioud 1969 is herein assigned to the family Gonyaulacaceae because of its possible evolutionary relationships with the modern genus Ceratium Schrank 1793 (Wall and Evitt, 1975, p. 32-34). Wall and Evitt (1974) have shown that several species of the modern genus Ceratium have gonuaulacacean tabulation, suggesting the ancestral relationships of certain, if not all, ceratioid cysts.

Only four specimens were observed from the Mount Laurel Sand, each specimen lacking the apical operculum. Although the specimens lack the well-developed cingulum illustrated by Deflandre (1937, pl. XII, fig. 7) they do bear similar antapical and postcingular horns and, also, appear similarly ornamented on the endoblast, being faintly granular.

Dimensions: Observed range (2 specimens measured); length of central body 50-56 um, width 49-52 um; length antapical horn 52-55 um; longer postcingular horn extends 37 um laterally; shorter postcingular horn extends 9 um laterally.

Occurrence: Mount Laurel Sand, extremely rare. Occurred in 4 samples.

Previously reported occurrence: Senonian of France (Deflandre, 1937).

Genus Prolixosphaeridium Davey, Downie, Sarjeant, and Williams 1966

Prolixosphaeridium xanthiopyxides (O. Wetzel)

Pl. 4, figs. 1-3

1933. Hystrichosphaera zanthiopyxides O. Wetzel, Paleontographica, Abt. A, 78, p. 44, pl. 4, fig. 25.

1937. Hystrichosphaeridium zanthiopyxides (O. Wetzel) Deflandre, Ann. Paleont., v. 26, p. 77, pl. 13, fig. 5.

1966. ?Prolizosphaeridium zanthiopyxides (O. Wetzel) Davey, Bull. Brit. Mus. Nat. Hist. (Geol.), Suppl. 3, p. 193.

1968. ?Hystrichosphaeridium zanthiopyxides (O. Wetzel) Morgenroth,

Geol. Jb., p. 556, pl. 48, figs. 5-6.

Comments: Monmouth Group specimens conform best with those described by Morgenroth (1968); however, the generic assignment of ?Hystrichosphaeridium (in Morgenroth, 1968) is not satisfying. The generic description of Prolixosphaeridium Davey, Downie, Sarjeant, and Williams (1966) includes most morphological features observed, e.g., ellipsoidal cyst, apical archeopyle, processes arranged in distinct rows encircling test, number of processes exceeding 30, processes may be distally open and flaring or briefly furcate, and shell surface may bear granules. In addition to those features listed under Prolixosphaeridium (ibid.), the Monmouth Group specimens possess some 4 processes immediately above and encircling the antapical process; these appear to be part of the antapical component. At the apex some 6 processes on the posterior fringe of the operculum encircle 3-4 terminating processes, indicating that the apical series may consist of some 9-10 processes. Between the apical and antapical components are 5 rows of processes; the middlemost row possibly representing the cingulum; the two rows anterior of the cingulum possibly representing precingular components; and the two rows posterior of the cingulum possibly representing postcingular components. Even with this simplification, tabulation is not readily apparent.

Dimensions: Observed range (7 specimens measured): length (central body) 40-43 um, width 20-22 um; process length 10-15 um, width ca. 1.5 um at base, tapering distally. Wall layers ca. 1 um.

Occurrence: Mount Laurel Sand, extremely rare; Navesink Formation, extremely rare to rare; Sandy Hook Member of Red Bank Sand, extremely rare to rare. Greatest occurrence, sample nos. 214, 220. Occurred in 12 samples.

Previously reported occurrences: Senonian of Baltic area (O. Wetzel, 1933), Senonian of France (Deflandre, 1937).

Genus Samlandia Eisenack 1954

Samlandia angustivela (Deflandre and Cookson) Eisenack 1963

Pl. 6, figs. 1-5

1955. Membranilarnax angustivelum Deflandre and Cookson, Austral. J. Mar. Freshw. Res., vol. 6, no. 2, p. 290, pl. 7, figs. 4-5.

1963. Samlandia angustivela (Deflandre and Cookson) Eisenack, N. Jb. Geol. Paläont., Mh. 1963, p. 99.

Comments: Cysts agree in morphology and size with the Australian specimens described by Deflandre and Cookson (1955, p. 290). No mention was made by Deflandre and Cookson (1955, p. 290) of archeopyle type, and their illustrations (pl. 7, figs. 4-5) do not show an archeopyle; however, Monmouth Group specimens exhibit a well-formed precingular archeopyle (Type P), occasionally with operculum in plate. The wall structure is essentially as reported by Deflandre and Cookson; however, it does appear to have a wall layer not mentioned by them. The single membrane which they report as "rather thick"

represents both endophragm and periphragm; the "2nd delicate membrane," which they reported is an ectophragm, enclosing the "rather thick" central body (endophragm and periphragm). Thus, the cyst wall appears three-layered, housing an endophragm, periphragm, and ectophragm. The endophragm appears fibrous or micro-baculate, with rods normal to endophragm surface, measuring ca. 1.5 um thick. The periphragm is closely appressed to the endophragm, is generally thinner than the endophragm, measuring ca. 1 um, and is smooth to slightly granular. Irregularly arranged on the periphragm surface are worm-like thickenings, which enclose circular, elongate, or polygonal areas, and support the ectophragm, creating an alveolar appearance. In optical cross-section view these worm-like thickenings appear as rods or short processes. These may be the "short processes" reported by Deflandre and Cookson (p. 290). The ectophragm and worm-like thickenings appear continuous with the periphragm; however, the ectophragm may include only the outermost layer. No cingulum or sulcus was observed.

Dimensions: Observed range (11 specimens measured): length including ectophragm 63-80 um, width 57-72. Ectophragm at apex 5-7 um, at antapex 3-6 um.

Occurrence: Top of Mount Laurel Sand, extremely rare to sparse; bottom of Navesink Formation, rare to common.

Previously reported occurrence: Lower Eocene of Australia (Deflandre and Cookson, 1955).

Genus Spiniferites (Mantell) Sarjeant 1970

Spiniferites ramosus (Ehrenberg) Loeblich and Loeblich 1966

var. ramosus (Ehrenberg) Davey and Verdier 1971

Pl. 4, figs. 11-13; pl. 12, fig. 10

1838. Xanthidium ramosum Ehrenberg, Abh. Preuss. Akad. Wiss., 1836, Pl. 1, figs. 1-3. No description given.

1937. Hystrichosphaera ramosa Lejeune, Ann. Soc. Geol. Belg., vol. 60, p. 239, Pl. 1, fig. 2-4, Pl. 2, figs. 5-10.

1966. Hystrichosphaera ramosa (Ehrenberg) var. ramosa Davey and Williams, Bull. Brit. Mus. Nat. Hist. (Geol.), Suppl. 3, p. 33, pl. 1, figs. 1, 6, pl. 3, fig. 1.

1966. Spiniferites ramosus (Ehrenberg) Mantell, fixed by Loeblich and Loeblich, Stud. Trop. Oceanogr. Miami, no. 3, p. 56-57.

1971. Spiniferites ramosus (Ehrenberg) Loeblich and Loeblich 1966, var. ramosus (Ehrenberg) Davey and Verdier, Verh. Kon. Nederl. Akad. Wetensch., Afd. Natuurk., Eerste Reeks, vol. 26, p. 33.

Comments: Excellently preserved specimens from the Monmouth Group were observed under both light and scanning electron microscopy. Because the morphology was so closely studied a detailed description is given below.

Description: The main body is ovoidal and bilayered. Endophragm is smooth. Periphragm smooth, formed into gonal processes and intergonal

sutural folds. Processes long (12-24 um), triangular in cross section, trifurcate distally, bearing bifurcations at extreme distal tips; no intergonal processes observed. Sutural folds (2-3 um high) outline plate equivalents. Reflected tabulation 4', 6", 6c, 5"', 1p, 1"", ?s (no plates were observed in the sulcus). Cingulum levorotatory; cingular plates generally hexagonal in outline. Sulcus sinuous, curving around the offset ends of the cingulum, bearing an anterior sulcal plate, beneath which (in the antapical direction) is a larger open area, apparently devoid of plates. Archeopyle precingular (Type P).

Dimensions: Observed range (25 specimens measured): length (central body) 43-57 um, width 33-52 um; process length 12-24 um.

Occurrence: Mount Laurel Sand, extremely rare to sparse; Navesink Formation, extremely rare to sparse; Sandy Hook Member of Red Bank Sand, extremely rare to sparse. Greatest occurrence, sample no. 211. Occurred in 33 samples.

Previously reported occurrence: This variety first described from Eocene London Clay, Kent, England; however, prior to this similar specimens recorded as Hystrichosphaera ramosa were reported from Middle Barremian to Ypresian.

Spiniferites ramosus var. granosus Davey and Williams 1966

Pl. 4, figs. 7, 8; pl. 12, figs. 7-9

1966. Hystrichosphaera ramosa var. granosa Davey and Williams, Bull. Brit. Mus. Nat. Hist. (Geol.), Suppl. 3, p. 35, pl. 4, fig. 9.

1966. Spiniferites ramosus (Ehrenberg) Loeblich and Loeblich.

Variety granosus has not been formally effected.

Comments: The granular ornamentation observed on Monmouth Group specimens is distinctly different from the smooth surface of S. ramosus var. ramosus. The granules may be solitary, appearing as distinct granules, or may be variously aligned, appearing somewhat irregularly reticulate. Scanning electron microscopy shows (Pl. 12, figs. 7-9) isolated to fused arrangements of granules, the fused granules appearing as short strings of beads, generally less than seven granules long. As reported by Davey and Williams (1966, p. 35), specimens from the Eocene London Clay have several to very few intergonal processes per specimen. Specimens observed from the Monmouth Group generally have few or no intergonal processes. Archeopyle precingular (Type P).

Dimensions: Observed range (10 specimens measured): length (central body) 34-57 um, width 31-46 um; process length 10-20 um.

Occurrence: Mount Laurel Sand, extremely rare to rare; Navesink Formation, extremely rare to rare; Sandy Hook Member of Red Bank Sand, extremely rare to rare. Greatest occurrence, sample nos. 209 and 211. Occurred in 19 samples.

Previously reported occurrence: Eocene London Clay of England.

Spiniferites ramosus var. multibrevis Davey and Williams 1966

Pl. 4, figs. 9, 10

1966. Hystrichosphaera ramosa var. multibrevis Davey and Williams, Bull. Brit. Mus. Nat. Hist. (Geol.), Suppl. 3, p. 35-37, pl. 1, fig. 4, pl. 4, fig. 6.

1966. Spiniferites ramosus (Ehrenberg) Loeblich and Loeblich. Variety multibrevis has not been formerly effected.

Comments: Specimens observed from the Monmouth Group agree in morphology and size with those described by Davey and Williams (1966, p. 35-37). Gonal and intergonal processes are generally less than half the central body diameter in length. Intergonal processes generally number 2 or less per suture; most sutures exhibit intergonal processes.

Dimensions: Observed range (4 specimens measured): length (central body) 40-49 um, width 32-41 um; process length 9-20 um.

Occurrence: Mount Laurel Sand, rare; Navesink Formation, extremely rare to rare; Sandy Hook Member of Red Bank Formation, extremely rare to rare. Occurred in 17 samples.

Previously reported occurrence: Eocene London Clay, Enborne, Berkshire, England.

Spiniferites ramosus var. reticulatus (Davey and Williams) Davey and Verdier 1971

Pl. 4, figs. 19, 20

1966. Hystrichosphaera ramosus reticulatus Davey and Williams 1966, British Mus. Nat. Hist. (Geol.), p. 38, pl. 1, figs. 2-3.

1971. Spiniferites ramosus reticulatus (Davey and Williams) Davey and Verdier, Verh. Kon. Nederl. Akad. Wetensch., Afd. Natuurk., vol. 26, p. 34.

Comments: Monmouth Group specimens correspond morphologically with the English Cenomanian specimens described by Davey and Williams (1966, p. 38). The endophragm is smooth and the periphragm is reticulate. Several specimens appeared to be transitional between S. ramosus granosus and S. ramosus reticulatus as is evidenced by the scanning electron micrographs (pl. 12, figs. 7-9). In these specimens the muri are incomplete, and appear to be composed of connected chains of 6 or 7 beads or granae each. Sutural folds are generally well developed, supporting gonal and intergonal processes.

Dimensions: Observed range (10 specimens measured): length 37-55 um; width 37-48 um; process length 11-26 um.

Occurrence: Mount Laurel Sand, extremely rare; Navesink Formation, extremely rare; Sandy Hook, extremely rare to rare.

Previously reported occurrence: Cenomanian of England (Davey and Williams, 1966); Barremian-Cenomanian (Millioud, 1975).

Genus Spiniferites ramuliferus (Deflandre 1937) n. comb.

Pl. 1, figs. 1-4

1937. Hystrichosphaeridium ramuliferum Deflandre, Ann. Paleont., vol. 26, p. 74, pl. 14, fig. 5-6, pl. 17, fig. 10.

1963. Baltisphaeridium ramuliferum (Deflandre) Downie and Sarjeant, Paleont. vol. 6, p. 92.

1963. Achomosphaera ramulifera (Deflandre) Evitt, Proc. Nat. Acad. Sci., vol. 49, p. 103.

Comments: Because no sutural ridges had been observed on cysts of this species several workers considered them originally to be of the genus Hystrichosphaeridium Deflandre 1937 - rather than Hystrichosphaera O. Wetzel 1933 (now called Spiniferites Mantell 1850). Evitt (1963, p. 163) recognized that the processes of these cysts were similar in structure and distribution to Hystrichosphaera; however, because they appeared to lack sutural ridges (as was required for Hystrichosphaera) he created a new genus, Achomosphaera Evitt 1967, and transferred H. ramuliferum into it. Nine specimens encountered during this study displayed occasional sutural ridges on the dorsal surface. The recognized presence of these ridges now makes it necessary to transfer this species into Spiniferites. Because of the importance of this feature to the overall understanding of this species, and in order to clarify the relationship of this species to Spiniferites a revised description is given below.

Revised description: Chorate cyst with angularly ovoidal main body, expanded at equator. Bilayered; endophragm and periphragm closely appressed on main body, except at sutural ridges and process bases. Endophragm smooth, thicker (ca. 1.0 um thick) than periphragm (ca. 0.5 um thick) on main body; periphragm smooth to faintly reticulate, formed into gonally distributed processes and occasional, faintly to well-formed, intergonal sutural ridges. Processes generally hollow, may be distally open or closed, irregularly triangular in cross section, distally furcate, generally trifurcate with secondary bifurcations at extreme distal tips. Cingular process pairs often fused, especially at lateral margins of cyst, appearing of unusually heavy construction, unequally furcate with extremely long, reflexed primary furcations. Other processes generally less complex, formed of simple, hollow shafts, primary trifurcations, and secondary, brief bifurcations. Infrequent and well to faintly developed sutural ridges occur, especially on dorsal surface, connecting process bases, being intergonal in distribution. Combined positions of gonally distributed processes and infrequent intergonal sutural ridges suggests a reflected tabulation of 4', 6", 6c, 5"', 1p, 1''''. Archeopyle precingular (Type P).

Discussion: Diagnostic features are the Spiniferites-like processes, which in the area of the cingulum may be of heavy appearance and bear long and unequally recurved trifurcations. Nonfrequent intergonal sutural ridges and a precingular archeopyle are also diagnostic. The most striking feature, seen in optical cross-sectional view is the

dominant equatorial zone, formed of the expanded equatorial cyst margin and the unusually heavy cingular processes.

Considering the degree of intraspecific variability found in many dinoflagellate species it is suggested that poorly developed or absent sutural ridges are simply one of the many morphological variables found in the genus Spiniferites. Thus, specimens with Spiniferites-like processes which lack sutural ridges are likely Spiniferites variants and should be assigned into the genus Spiniferites.

A taxonomic problem is possibly created by transferring this species, which was the type species of the genus Achomosphaera Evitt 1963, into Spiniferites. To date some 16 other species are also assigned to Achomosphaera. Transferring a type species suggests that both genera are synonymous, and that the genus to which the species is transferred has priority. Thus, Achomosphaera is considered a junior synonym of Spiniferites.

Other species: It is difficult, without closely observing the holotypes, to satisfactorily determine proper assignments for the other 16 species assigned to Achomosphaera. Considering the species descriptions and illustrations the following suggestions are made. A. sagena Davey and Williams 1966 is suggested to be conspecific with Spiniferites crassipellis Deflandre and Cookson 1955; A. alcicornu (Eisenack 1954) Downie and Williams 1966 is suggested to be conspecific with Spiniferites pseudofurcatus (Klumpp) Sarjeant 1970. Sah, Kar, and Singh (1970, p. 144-146, pl. 1, figs. 1-15) described and illustrated 7 new species of Achomosphaera. No mention is made by

Sah et al. (ibid.) of sutural ridges, except for A. cambra: A. cambra has "cingular processes joined together [meaning at their bases] to form a girdle-like appearance [typical Spiniferites cingulum?]." Thus, it is suggested that this species be transferred into Spiniferites. Sah's et al. (ibid.) other six species should be reexamined prior to reassignment as their affinities are difficult to determine based on their descriptions and illustrations. A. neptuni (Eisenack) Davey and Williams 1966 is reported (Davey and Williams, 1966, p. 51) to have fibrous thickenings reflecting plate boundaries, a feature that not only distinguishes it from Achomosphaera but possibly allows it to be assigned into Spiniferites. A. triangulata (Gerlach) Davey and Williams 1969, as originally illustrated (Gerlach, 1961, pl. 29, fig. 1) appears to have dorsal, cingular, and sutural ridges and also a ridge along the left margin of the archeopyle suggesting a strong similarity to Spiniferites. A. tridactylites (Valensi) Deflandre and Sarjeant 1970 is very similar in morphology to either Florentinia Davey and Verdier 1973 or Spinitectulum n. gen. (see page). A. hirundo (Eisenack) Davey and Williams 1969 has only been illustrated by Eisenack (1958, p. 404-405, pl. 24, fig. 12; however, the specimen which is Spiniferites like in outline, was only illustrated in optical cross-sectional view, and therefore no evidence of sutural ridges could be seen. A. hypercantha (Eisenack) Davey and Williams 1969, which is also Spiniferites-like, was described (Deflandre and Cookson, 1955, p. 264) as having "fine, sometimes almost indistinguishable outlines" bordering plate

equivalents; therefore, it is suggested that this species be transferred into Spiniferites. A. graeleforme (Brosius) Davey and Williams 1969 has not been described nor illustrated to the extent that an assignment could presently be determined without reexamination of the original specimens. A. ramulifera subsp. perforata Davey and Williams 1966 (Davey and Williams, 1966, p. 50, pl. 5, figs. 1, 4) has Spiniferites-like processes, and is likely best assigned as a separate species to Spiniferites.

Dimensions: Observed range (8 specimens measured): length (central body) 44-60 um, width 36-52 um; process length 13-32 um.

Occurrence: Navesink Formation, extremely rare; Sandy Hook Member of Red Bank Sand, extremely rare. Occurred in 8 samples.

Previously reported occurrences: Upper Oligocene of northwest Germany (Gerlach, 1961); Eocene of Belgium (Pastiels, 1948); Paleocene of Australia (Cookson and Eisenack, 1967); Danian of northwest Germany (W. Wetzel, 1952); Senonian of France (Deflandre, 1937); Cenomanian of England (Cookson and Hughes, 1964); and Neocomian of northwest Germany (Gocht, 1959).

Spiniferites cf. S. septatus (Cookson and Eisenack) McLean 1971

Pl. 4, figs. 14-16

1967. Baltisphaeridium septatum Cookson and Eisenack, Roy. Soc. Victoria Procs., vol. 80, p. 253, pl. 42, figs. 6-10.

1971. Spiniferites septatus (Cookson and Eisenack) McLean, Jour. Paleo., vol. 45, no. 4, p. 729-730, pl. 88, figs. 1-9.

Comments: Specimens observed are very similar to those described by McLean (1971) from the Upper Paleocene Aquia Formation of the Virginia Maryland Coastal Plain. Process construction of bubble-like elements or shafts bearing cross-septal partitions on gonally and intergonally positioned processes is much the same in the Monmouth specimens. Some differences with the Monmouth Group specimens are the better-developed intergonal sutural ridges, and the more reticulate-like surface ornamentation, as opposed to the bubble-like surface ornamentation of the Aquia specimens. Gonal processes generally trifurcate distally, while intergonal processes generally bifurcate. Most intergonal positions exhibit one or two processes. Reflected tabulation is 4', 6", 6c, 5'", 1p, 1"", ?s. Cingulum levorotatory, ca. 1 cingulum width offset. Sulcus sinuous, curving around the ends of the cingulum. Archeopyle precingular (Type P).

Dimensions: Observed range (8 specimens measured): length (central body) 37-43 um, width 34-37 um; process length 8-12 um.

Occurrence: Mount Laurel Sand, extremely rare; Navesink Formation, extremely rare; Sandy Hook Member of Red Bank Sand, extremely rare. Occurred in 9 samples.

Previously reported occurrence: Upper Paleocene of Australia (Cookson and Eisenack, 1967), and Upper Paleocene of Virginia-Maryland Coastal Plain U.S.A. (McLean, 1971).

Spiniferites supparus (Drugg) Sarjeant 1970

Pl. 4, figs. 17-18

1967. Hystrichosphaera suppara Brugg, Palaeontographica, vol. 120, abt. B, pt. 1, p. 24, pl. 4, figs. 5-6.

1970. Spiniferites supparus (Drugg) Sarjeant, Grana, vol. 10, p. 77.

Comments: Specimens agree basically with the California specimens described by Drugg (1967, p. 24). The processes are short, rising from gonal and intergonal positions of the sutural folds, and are hollow, tubular, tapering distally, and terminating with bi- and trifurcations. Sutural folds delineate plate boundaries, indicating Gonyaulax-type tabulation. Archeopyle is precingular (Type P).

Dimensions: A single specimen observed and measured: length central body 38 um, width 37 um: process length 5-6 um.

Occurrence: Mount Laurel Sand, extremely rare to rare; Navesink Formation, extremely rare to rare; Sandy Hook, extremely rare to rare.

Previously reported occurrence: Maestrichtian-Danian of California (Drugg, 1967).

Genus Spinitectulum n. gen.

Name derivation: Latin, spini, spiney; tectulum, diminuitive for roof, e.g., little roof. Referring to the nature of the closed and distally pronged processes.

Type species: Spinitectulum ferox (Deflandre) n. comb.

Description: Cyst spheroidal, bilayered, bearing two types of intratabular, hollow, distally closed processes. Larger-based processes, which distally bear 3 or more prongs, characterize most of the pre- and postcingular series. Smaller-based, slender processes which distally bear 1 to a few prongs, characterize the apex, antapex, sulcus, posterior intercalary, and cingular plate equivalents. Combination archeopyle (Type $\overline{A}a$+P) consists of 3", which is generally removed, and accessory sutures extending about the periphery of the apical series, which generally remains attached ventrally. Sulcus extends well into the epitract from hypotract. Reflected tabulation 4', 6", 6c, 5"', 1p, 1"", ca. 8s.

Discussion: The genus appears related to Florentinia Davey and Verdier 1973, which also has a combination archeopyle formed of the 3" and apical series, and Gonyaulax type tabulation reflected by hollow intratabular processes of two types. Florentinia, however, has open processes, and exhibits a distinctively large, tubular, antapical process. S. ferox has closed processes, and the antapical process is generally reduced to a small, single, slender prong. S. ferox differs from Hystrichokolpoma by having a combination archeopyle and closed processes. It differs from Hystrichosphaeridium by having the combination archeopyle and two types of processes.

Spinitectulum ferox (Deflandre) n. comb., emend.

Pl. 2, figs. 17-20

1937. Hystrichosphaeridium ferox Deflandre, Ann. Paleo., vol. 26, p. 16-17, pl. 14, fig. 3.

1963. Baltisphaeridium ferox (Deflandre) Downie and Sarjeant, Paleontology, vol. 6, no. 1, p. 91.

1966. Hystrichokolpoma ferox (Deflandre) Williams and Downie, Bull. Brit. Mus. Nat. Hist. (Geol.), Suppl. 3, p. 181.

Emended description: Cyst main body spherical to ovoidal. Bilayered; endophragm appears smooth; periphragm is reticulate on main body, and is formed into relatively short, smooth to finely striate processes, which are hollow, closed distally, intratabular, and of two basic forms. The larger form is broad and roundly polygonal at the base, nearly as wide as long, cylindrical or gently tapering, terminating as 3 or more distally closed prongs with bifid tips, and characterizes the pre- and postcingular series. The prongs are separated by depressions in the periphragm covering which distally closes each process. The smaller form is narrow at the base, long and slender, and may be a single prong, but generally bears not more than 3 prongs with bifid tips: this type characterizes the apical and antapical processes, as well as the cingular and sulcal processes. In the pre- and postcingular series the 6" and 1"' are quite reduced.

Reflected tabulation 4', 6", 6c, 5"', 1p, 1"", 2-3S. Cingulum is indicated by processes with bases elongate in direction of cingulum, and from which may arise two prongs with bifid tips. The sulcus is generally represented by isolated sulcal processes, or by a sutural fold bearing ca. 7 single-pronged processes, which borders the edge of the sulcus. A single isolated posterior sulcal process is generally present beneath the main sulcal area, near the antapex. The sulcal area extends from low on the hypotract to high on the epitract. Combination archeopyle (Type $\overline{A}a + P$) consists of 3", which is generally separated from the cyst, and primary sutures extending about the periphery of the apical series and generally remains attached ventrally.

Discussion: This species is excluded from the genus Hystrichokolpoma by possessing a combination archeopyle, in which the main element is the 3". Deflandre (1937, p. 16-17, pl. 14, figs. 4-5) first described S. ferox, calling it Hystrichosphaeridium ferox, and illustrated it with a photograph and a drawing. His drawing, when slightly reoriented, appears to show a right lateral to slightly apical view. The features of the epitract, which are visible in his drawing, and which aid in proper orientation are: a precingular archeopyle with accessory sutures extending apically: precingular plate fields, cingular processes with bases elongate in direction of cingulum, and four apical plates. The presence of a combination archeopyle is indicated on Deflandre's (ibid) drawing by two tears extending from the top of the "precingular archeopyle," which are

directed about the periphery of the apical series. Downie and Sarjeant (1963, p. 91) transferred H. ferox into Baltisphaeridium, but because it has dinoflagellate characteristics, such as Gonyaulax-type tabulation, and an archeopyle, it is characteristically a dinoflagellate. Williams and Downie (1966, p. 181) transferred B. ferox into Hystrichokolpoma, but with little explanation. Evitt (1967, p. 76, pl. 8, figs. 1-5) illustrated Hystrichosphaeridium ferox, with emphasis on the archeopyle. His illustration showed Gonyaulax-like arrangements, short, distally closed and pronged processes, and the combination archeopyle. Since Hystrichokolpoma is characterized by an apical archeopyle (Type $\overline{A}$), it is distinctively different from the form illustrated by Deflandre (1937) and Evitt (1967), and S. ferox forms reported on here from the Monmouth Group. Davey and Verdier (1973, p. 193, pl. 2, fig. 2) reported the combination archeopyle of Hystrichokolpoma ferox (Deflandre 1937), which they observed on "one poorly preserved specimen," and compared it with Evitt's (1967) illustrations. They suggested that a generic allocation distinct from Florentinia and Hystrichokolpoma should be later erected. Florentinia is characterized by a combination archeopyle (Type $\overline{A}a$ + p) Gonyaulax type tabulation, processes of two types, but has a distinctively large antapical process, and open processes. Twenty-seven specimens have been studied from the Monmouth Group of northern New Jersey, and several were oriented for purposes of illustration and examination.

Affinities: See discussion above for affinities with Florentinia

Davey and Verdier 1973 and Hystrichokolpoma Klumpp 1953.

Dimensions: Observed range (19 specimens measured): length (central body) 40-49 um, width 40-49 um; process length 10-16 um.

Occurrence: Mount Laurel Sand, extremely rare; Navesink Formation, extremely rare; Sandy Hook Member of Red Bank Sand, extremely rare. Occurred in 14 samples.

Previously reported occurrence: Neocomian of northwest Germany (Gocht, 1959), Cenomanian of England (Cookson and Hughes, 1964), Senonian of France (Deflandre, 1937).

Spinitectulum ramulus n. sp.

Pl. 2, figs. 13-16

Name derivation: Latin, ramulus, branchlet; referring to the small, branch-like tubules occurring at distal ends of processes.

Holotype: Slide AI-61; R5.7; + 16.5 (Pl. 2, figs. 13,14)

Type locality: Atlantic Highlands, New Jersey.

Type stratum: Navesink Formation.

Description: Cyst main body spherical to ovoidal, circular in polar view, bearing processes of two sizes. Bilayered; endoblast smooth, slightly thicker than periblast (both layers ca. 2 um). Periblast includes microreticulate surface, and hollow, generally distally closed, smooth to slightly striate processes of two basic size ranges and types. Broad, roundly-polygonal-based processes bearing a few to several branchlets which are closed at the tips

(the branchlets appearing truncate); and slender processes, which may be simple and basally joined by low crests. The larger type processes characterize the pre- and postcingular series, while the slender type characterize the apex, sulcus, cingulum, antapex, 1p and 6". Cingulum bears paired, slender, basally-joined processes, indicating 6 cingular plates, and is slightly levorotatory, having ca. 1 cingulum width offset. Sulcus bears 4 or more slender processes; including anterior and posterior sulcals. Apical series may bear 3 to ca. 6 slender processes; however, apex shape and process arrangement on some specimens indicate four apical plates and an apical pore closing platelet. Each apical plate generally bears a single process; whereas, the apical pore closing platelet may have two or more. Antapex characterized by one to a few slender processes; when more than one is involved, they are closely associated at their bases. Reflected tabulation 4', 6', 6c, 5"', 1p, 1"", 2-6s. Archeopyle is combination (Type $\bar{A}a$ + P): plate equivalent 3" generally missing; apical series dislodged as a unit, but generally remains in place.

Discussion: S. ramulus differs from S. ferox by having more deeply divided branchlets, which are distally truncate, as opposed to the pointed or acuminate branchlets seen in S. ferox. It differs from members of the genus Florentinia Davey and Verdier 1973, by having a slender distally closed, antapical process as opposed to the distinctively large, tubular, antapical process of Florentinia.

Characteristic features of S. ramulus are: Gonyaulax-type tabulation; combination archeopyle (Type $\bar{A}a$ + P); processes of two sizes, with slender processes at cingulum, sulcus, apex, and antapex.

Affinity: See "discussion" above. Members of the genus Spinitectulum are considered closely related to those of the genus Florentinia; however, they lack the large antapical process, and have distally closed processes. Members are differentiated from Hystrichokolpoma Klumpp 1953 by possessing a combination archeopyle.

Dimensions: Holotype L X W main body 51 x 50 um, process length 17-20 um. Observed range (9 specimens measured): length main body 47-52 um, width 47-52 um; process length 16-20 um; wall thickness ca. 27, endophragm thicker than periphragm.

Occurrence: Navesink Formation, extremely rare. Occurred in 5 samples.

Spinitectulum sp.

Pl. 7, figs. 6, 7

Comments: The cyst has a spherical main body, which is bilayered. The periphragm is closely appressed to the endophragm about the main body, and is formed into distally enlarging, or bulbous, club-shaped processes, which distally are closed and bear small, distal, hair-like spines. Larger processes are located in pre- and postcingular series, while a slender set of processes mark the cingulum, sulcus, 1p, and apparently the 6'' and 5'''. Tabulation is?, 6'', 5-6c, 5''', 1p, 1''''. Cingulum levorotatory with ca. 1 cingulum width offset. Sulcus

bears 2-6 slender processes. Archeopyle is combination (Type $\overline{A}a$ + P).

Dimensions: A single specimen observed and measured: length 56 um, width 43 um. Processes 15-17 um long. Slender processes ca. 1 um wide, broad processes 15-25 um wide distally, ca. 15 um wide proximally.

Occurrence: A single specimen observed in sample 214 of Navesink Formation.

Previously reported occurrence: None.

Genus Spongodinium Deflandre 1936

Spongodinium delitiense (Ehrenberg) Deflandre 1936

Pl. 6, figs. 6-8; pl. 13, figs. 11-12

1838. Peridinium delitiense Ehrenberg, Abh. Kgl. Akad. Wiss. Berlin (1836), p. 110, pl. 1, figs. 1, 6.

1936. Spongodinium delitiense (Ehrenberg) Deflandre n. comb., Ann. Paleont., vol. 26, p. 170, pl. 4, figs. 1-3.

Comments: Excellently preserved specimens were studied in detail using both light and scanning electron microscopy. Because of the potential value of S. delitiense as a lower Maestrichtian index fossil, a detailed description is given below.

Description: Specimens observed are rhomboidal to ovoidal in outline and circular in polar view. The endophragm is smooth,

and at the apex is formed into a small nipple. The periphragm is alveolar, and is thickened to a lesser degree at the antapex (antapex is rounded) and cingulum. The alveolar or spongy periphragm construction is generally developed over most of the cyst; however, some specimens were observed with few alveolae on the epitract and/or sulcal area. The cingulum, which is formed by a thickening of the alveolar tissue, is slightly levorotatory. The archeopyle is precingular (Type P); extending from the cingulum nearly to the apex, and is nearly as wide as high.

Discussion: No tabulation is evident; however, these cysts are assigned under the family Gonyaulacaceae because of their Gonyaulax-like outline and precingular archeopyle (Type P).

Dimensions: Observed range (15 specimens measured): length (including apical horn) 114-189 um, width 103-140 um. Apical horn generally measures ca. 30 um.

Occurrence: Occurs only at top of Mount Laurel Sand, extremely rare; and in bottom half of Navesink Formation, extremely rare to sparse. Greatest occurrence, sample nos. 209, 211, 216. Occurred in 8 samples.

Previously reported occurrence: Senonian of France (Deflandre, 1937), Danian of northwest Germany (O. Wetzel, 1933).

Spongodinium sp.

Pl. 6, figs. 9, 10

Comments: One specimen was observed. Cyst wall structure is similar to S. delitiense (Ehrenberg) Deflandre 1936, in that the periphragm is alveolar in construction. Alveolae measure ca. 3 to 12 um across, and the periphragm is several alveolae deep. Periphragm forms a single antapical horn, and a broadly truncated antapex exhibiting two somewhat reduced horns. Ovoidal endoblast appears smooth, occupying central part of periblast. Cingulum formed by equatorial thickening of periphragm; where alveolae are at a maximum depth. No sulcus observed. No archeopyle or tabulation observed.

Dimensions: Single specimen observed. L x W, 86 X 86 um. Thickness of alveolae at apex ca. 31 um; at cingulum 18 um; at antapical horns 12 um.

Occurrence: Single specimen, sample no. 232.

Previously reported occurrence: None.

Genus Systematophora Klement 1960

Systematophora placacantha (Deflandre and Cookson 1955)

Davey, et al. 1966, emend.

Pl. 7, figs. 8-11

1955. Hystrichosphaeridium placacanthum Deflandre and Cookson

Austral. J. Mar. and Freshw. Res., vol. 6, p. 276-277, pl.

9, figs. 1-3.

1963. Baltisphaeridium placacanthum (Deflandre and Cookson) Downie and Sarjeant, Palaeont., vol. 6, p. 92.

1966. Systematophora placacantha (Deflandre and Cookson) Davey, Downie, Sarjeant, and Williams, Bull. Brit. Mus. Nat. Hist. (Geol.), Suppl. 3, p. 173.

1969. Systematophora placacantha (Deflandre and Cookson) Davey, Downie, Sarjeant, and Williams, Bull. Brit. Mus. Mat. Hist. (Geol.), Appendix to Suppl. 3, p. 17.

Emended description: Cyst spherical to slightly ovoidal, circular in equatorial section, and bilayered. Endophragm appears thicker (ca. 1.0 um thick) than periphragm (ca. 0.5 um thick) and is composed of closely arranged bacula imparting a reticulate appearance to cyst surface. Periphragm smooth, closely appressed to the endophragm, and is formed into sutural folds supporting long, distally bifid spines which outline intratabular fields representing plate equivalents. Spines are flexuous, slender, proximally expanded, simple or branched, and distally bifid. Reflected tabulations 4', 6", 6c, 5"', 1p, 1"", 6s. Antapical plate distinctively jelly bean-shaped. Cingulum identified by a single row of paired or unpaired spines, with bases elongate in direction of cingulum. Sulcus contains isolated sets of spines representing intratabular plate fields, outlining a posterior sulcal plate, two medial plate pairs, and an anterior sulcal plate.

The ps is generally a well-developed plate field. The sulcus lies directly beneath a sulcal notch of the archeopyle. Archeopyle is apical (Type $\bar{A}$), formed by removal of simple, free operculum, corresponding to plates 1', 2', 3', and 4'.

Comments: Although S. placacantha (Deflandre and Cookson) Davey, et al. 1966, has been transferred through two genera prior to its assignment to Systematophora only the original specific description stands as the criterion for identification. The main reason for this emended description is to better describe the wall structure and plate arrangement, and to identify the tabulation as standard Gonyaulax type.

Dimensions: Observed range (33 specimens measured): length main body 57-63 um, width 48-63 um. Spine length 5-20 um. Wall thickness ca. 3 um; endophragm thicker than periphragm.

Occurrence: Navesink Formation, extremely rare to rare; Sandy Hook Member of Red Bank Sand, extremely rare to abundant. Greatest occurrence, sample nos. 230, 232, 233, 235.

Previously reported occurrence: Middle Miocene of Australia (Deflandre and Cookson, 1955, p. 276-277, pl. 9, figs. 1-3.

Systematophora varians n. sp.

Pl. 7, figs. 12-16

Name derivation: Latin, varians, varying. Referring to the variable morphology observed within a population.

Holotype: 3ML7-3, 52.4 X 18.6 (pl. 7, figs. 12-14).

Type locality: Atlantic Highlands, New Jersey.

Type stratum: Mount Laurel Sand.

Description: Cyst main body ovoidal. Bilayered; endophragm appears baculate (bacula ca. 1 um long), thicker (ca. 1.5 um thick) than periphragm; (ca. 1.0 um thick) periphragm micro- to macroreticulate over cyst main body, also formed into highly variable simulate process groups. Each process group is supported proximally by a broad-based simulate sutural ridge, and is composed of well-spaced, somewhat vertically arranged, simple to compound, slender, string-like processes. A "simulate" network of simple or compound trabeculae connect the distal tips of the processes of each process group. Both the processes and trabeculae are similar in construction, appearing as simple or compound string-like elements; the compound elements being separate, anastomosing, reticulate, or fused into porous, membrane-like elements. Lateral and polar process groups appear longest. The average height of process groups varies greatly (a few to ca. 17 um) from specimen to specimen: specimens at both extremes appearing morphologically quite different at first glance, especially when process groups of very low relief blend in with the highly variable, reticulate surface of the periphragm. Process arrangement suggests a

reflected tabulation of ?', 6", 5-6c, 5"', ?1p, 1"", ?s. Cingular process groups are poorly to well-developed, appear simulate, and are elongate in the direction of the cingulum. Cingulum levorotatory, having ca. 1 cingulum width offset. Sulcus located beneath midventrally aligned sulcal notch of the archeopyle, and bears an undetermined number of poorly developed sulcal processes. Archeopyle apical (Type A); opercula not observed.

Discussion: Although most specimens observed are identifiable as Systematophora Klement 1960, a great degree of variability exists in the height and development of the process groups. Dorso-ventral process groups which are not as well-developed as the lateral and polar process groups, are often reduced in height, and may be nearly lacking, giving a distinctive Cyclonephelium appearance. Other specimens bear reduced process groups marginally and dorso-ventrally, appearing vaguely as Cyclonephelium and distinctively different from Systematophora. The assignment of this form into Systematophora was based on the morphology of most specimens, which bear simulate (sometimes appearing annulate) process groups reflecting Gonyaulax-type tabulation, and exhibiting an apical archeopyle (Type A).

Affinity: S. varians is similar to S. schindewolfi (Alberti) Downie and Sarjeant 1964 and S. complicata Neale and Sarjeant 1962. S. schindewolfi, however, has longer process groups which expand distally, and are rather constricted proximally S. complicata bears process groups of rather small base, and individual process groups are composed of numerous, long, simple spines, which are joined distally

by branches or trabeculae. S. varians, has broad-based process groups and much more variability in process and trabeculum structure.

Dimensions: Holotype - Main body 74 x 70 um; process length 12-16 um. Observed range (11 specimens measured): main body length 56-74 um; width 67-87 um; process length 3-17 um; wall layers, endophragm ca. 1.5 um, periphragm less than 1 um.

Occurrence: Mount Laurel Sand, extremely rare. Greatest occurrence, sample 205. Occurred in 3 samples.

Genus Triblastula O. Wetzel 1933

Comments: A close comparison of the generic descriptions of Triblastula O. Wetzel 1933, Hystrichosphaeropsis (Deflandre 1935) Sarjeant 1966, and Rottnestia Cookson and Eisenack 1961 demonstrates that a great degree of morphologic overlap occurs between these genera. All three genera, for example, can accommodate forms with a spherical to ovoidal main body (endoblast); a large anterior and posterior pericoel; longitudinal folds possibly outlining plate equivalents; a smooth to spiney periblast; and a precingular archeopyle (Type P).

The genus Triblastula has priority over Hystrichosphaeropsis and Rottnestia, and until population studies are performed on the type species of all three genera I suggest that all such cysts be assigned to the genus Triblastula. As the name "Triblastula" implies, it

refers to cysts with three-bodied (actually, three-compartmented) morphology (having an endocoel, and well separated anterior and posterior pericoel). In addition, the presence of a precingular archeopyle (Type P) would be the other main criterion for assignment to Triblastula. The presence or lack of spines may, in many cases, be the result of intraspecific variability: population studies should clarify this.

Triblastula borussica (Eisenack, 1954) Morgenroth 1966

Pl. 4, figs. 4-6

1954. Hystrichosphaera (Hystrichosphaeropsis) borussica Eisenack, Palaeontographica Abt. A, vol. 105, p. 62, pl. 9, figs. 5-7.

1961. Rottnestia borussica (Eisenack) Cookson and Eisenack, J. Roy. Soc. West. Austral., vol. 44, p. 42, pl. 1, figs. 8-10, pl. 2, figs. 1-2, text figs. 1a-d.

1966. Hystrichosphaeropsis borussica (Eisenack) Sarjeant, Bull. Brit. Mus. Nat. Hist. (Geol.), Suppl. 3, p. 139.

1966. Triblastula borussica (Eisenack) Morgenroth, Palaeontographica, Abt. B, vol. 119, p. 15.

Comments: Since Rottnestia Cookson and Eisenack 1961 was described, several workers have felt that it might be a junior synonym of either Hystrichosphaeropsis (Deflandre, 1935) Sarjeant 1966, or Triblastula O. Wetzel 1933. Eisenack (1965, p. 152; and 1969, p. 106-108) has maintained that Rottnestia is distinctive and separate. Sarjeant (1966)

and Deflandre (in Sarjeant, 1966) report that Rottnestia is a junior synonym of Hystrichosphaeropsis. Morgenroth (1966, p. 15-16) reports that both Rottnestia and Hystrichosphaeropsis are junior synonyms of Triblastula. An analysis of all three generic descriptions reveals a marked degree of morphologic overlap. As no population studies have been performed which define the separation of the three genera, I feel a conservative approach is in order; namely, that all cysts with a spherical or ovoidal central capsule and large separate, anterior and posterior pericoels (no lateral pericoel), and a precingular archeopyle (Type P) be assigned to the older genus Triblastula. As more becomes learned about intra-specific variability, especially with relationship to spine or process development, it may be possible to continue the use of Hystrichosphaeropsis and Rottnestia. For this reason I am here including Rottnestia borussica in Triblastula, as was also done by Morgenroth (1966, p. 15).

Specimens of Triblastula borussica observed in the Monmouth Group have a central body formed of the endophragm (central capsule), which bears an apical nipple. The periphragm is fused to the endophragm in a broad equatorial zone. Beyond the fused zone, toward the poles, are box-like structures which are hollow and lack horns. The antapical box is aligned with the polar axis; however, the apical box is ventrally canted, occupying most of the ventral epitract. Although the apical box has been previously reported as being also aligned with the polar axis, the orientation of the box may be

somewhat variable within the species. Longitudinal sutural folds occur in the fused zone, continuing poleward onto the folded edges of the boxes, while other sutural folds outline the cingulum and sulcus. Processes appear at the gonal or intersecting positions of these folds suggesting that the fields reflect tabulation. The processes are long, generally less than ½ the central capsule diameter, often triangular in cross-section, and are distally variable; being bifurcate, trifurcate, or flaring. No intergonal processes were observed. Discernible tabulation is ?', 6", 6c, 5"', ?p, ?1''''. Archeopyle precingular (Type P).

Dimensions: Observed range (11 specimens measured): length (central body) 69-69 um, width (central body) 63-71 um; length (antapical box) 18-22 um; apical box generally smaller; process length 8-28 um.

Occurrence: Mount Laurel Sand, extremely rare; Navesink Formation, extremely rare; Sandy Hook Member of Red Bank Sand, extremely rare. Occurred in 10 samples.

Previously reported occurrence: Lower Oligocene of East Preussia (Eisenack, 1954, p. 62); Mid-Miocene of Australia (Deflandre and Cookson, 1955, p. 268), Mid-Cretaceous of England (Cookson and Hughes, 1964, p. 53); Upper Cretaceous to Paleocene of Western Australia (Cookson an Eisenack, 1961, p. 42).

Triblastula nuda O. Wetzel 1961

Pl. 5, figs. 14-15

1961. Triblastula nuda O. Wetzel, Micropaleo., vol. 7, p. 340, pl. 2, fig. 2.

Revised description: Cyst elongate in polar direction, somewhat rectangular in outline, bearing "pole caps" formed of periphragm equatorially attached to spherical to ovoidal endoblast. Each pole cap forms a large pericoel: 1 anterior and 1 posterior. The anterior polecap bears a small apical horn; the posterior polecap is basally flattened. Both pericoels separated from each other by a narrow to broad fused, or closely appressed equatorial zone around the central body. Longitudinal periphragm folds mainly on "pole caps" outline 4-5 fields on hypotract and 5-6 fields on epitract; no other tabulation suggested. Periphragm finely granular, thin (ca. 0.5 um); endophragm finely granular, thicker than periphragm (less than 1 um). Cingulum can be observed at the points where the longitudinal, periphragm folds intersect the mid-equatorial area. At these positions the periphragm folds are indented, a feature which can be observed at each intersept position around the equator. Cingulum ends show no offset. Archeopyle precingular (Type P).

Discussion: Diagnostic features of T. nuda are the apical and antapical pole caps and broad fused zone about equator (endoblast fused to periblast), slightly rectangular outline, longitudinal

folds on nonfused portions of periblast possibly outlining plate equivalent, marked indentation of longitudinal folds where they intersect cingulum, the lack of spines, and the precingular archeopyle (Type P).

Dimensions: Observed range (9 specimens measured); diameter (central body) 60-75 um; length (anterior pericoel above apex of endoblast) 20-25 um, width (midway) 60-63 um; length (posterior pericoel below antapex of central body) 23-26 um, width (midway) 58-61 um.

Occurrence: Navesink Formation, extremely rare; Sandy Hook Member of Red Bank Sand, extremely rare. Greatest occurrence, sample nos. 234, 236. Occurred in 9 samples.

Previously reported occurrence: Cretaceous of Baltic area.

Genus Triblastula O. Wetzel 1933

Triblastula utinensis O. Wetzel 1933

Pl. 6, figs. 11-16

1933. Triblastula utinensis O. Wetzel, Palaeontographica, Abt. A, vol. 78, p. 54, pl. 6, figs. 5-6.

Comments: Several excellently preserved specimens were observed and studied in detail. Because previous descriptions have not included the degree of variability in spine and sutural fold ornamentation, a detailed description, including these features, is given below.

Description: Cyst elongate, consisting of an elongate periblast and a centrally located, spherical endoblast. Endoblast smooth, fused equatorially to periblast, forming two large pericoels: one anterior pericoel and one posterior pericoel. Periblast bears an apical and an antapical horn, the apical being longer. Spines are variously arranged, occurring mainly on the central portion of the cyst, generally not reflecting tabulation. Occasionally, however, the spines may be aligned along sutural folds outlining a few plate equivalents and the cingulum and sulcus. Cingulum generally not completely developed; is levorotatory, being offset ca. ½ cingulum width. Sulcus generally not well developed; appears to extend about one cingulum width above the cingulum and, also, beneath the cingulum to near the base of the central body. In optical cross-sectional view the spines are longest near the cingulum. Archeopyle precingular (Type P).

Dimensions: Observed range (25 specimens measured) length (central body) 68-71 um, width 45-60 um; length (anterior pericoel from apex of central body) 40-43 um, width generally slightly less than equatorial central body; length (posterior pericoel from antapex of central body) 19-32 um, width slightly less than equatorial central body; spine length 9-23 um.

Occurrence: Top of Navesink Formation, extremely rare; Sandy Hook Member of Red Bank Formation, extremely rare to rare. Occurred in 10 samples.

Previously reported occurrence: Seldom reported in the literature. Cretaceous of Baltic area (O. Wetzel, 1933, 1966). Williams and Lentin (1975) give the range as Maestrichtian.

Genus Trichodinium Eisenack and Cookson 1960, emend.

Clarke and Verdier 1967

Trichodinium cf. T. hirsutum Cookson 1965

Pl. 14, fig. 4; pl. 15, figs. 1c, d and 2c, d; pl. 16, figs. 10c, d

1965. Trichodinium hirsutum Cookson, Proc. Roy. Soc. Victoria, vol. 78, pt. 2, p. 139, pl. 25, figs. 5-13.

Comments: Monmouth Group specimens generally resembling Trichodinium hirsutum Cookson 1965, identified here as Trichodinium cf. T. hirsutum Cookson 1965, appear to grade morphologically downsection into forms described in this systematics section as Cordosphaeridium varians n. sp. This proposed lineage can be traced through the study section from samples 203-219 (upper Mount Laurel Sand and lower Navesink Formation). The actual stratigraphic interval in which the morphologic changeover takes place is between (and including) samples 209-213. The morphologic gradation is illustrated on Pl. 16, figs. 10a-d: fig. 10a is a variant of C. varians; fig. 10b is a variant of C. varians bearing a distinctive apical process; fig. 10c is a variant of T. cf. T. hirsutum bearing both a distinctive apical and antapical process; fig. 10d is a well-developed specimen of T. cf. T. hirsutum bearing both a distinctive apical and antapical process, and less densely arranged, stiff, bristly spines. The latter specimen has all the characteristic features of T. hirsutum Cookson 1965, except for the slightly longer cingular spines. A description of T. cf. T.

hirsutum forms is given below.

Description: Cyst main body ovoidal. Bilayered; endophragm ca. 1.5 um thick, appears baculate; periphragm ca. 0.5 um thick, finely reticulate (lacunae ca. 0.2 um across) between processes and fibrously reticulate near process bases. Processes formed of periphragm; apical and antapical process distinctively long (up to 22 um and 27 um, respectively), parallel sided (ca. 4 um wide), distally furcate into some 2-4 short, acuminate branchlets, and is fibrously reticulate. All other processes generally spaced 2-5 um apart in well-developed specimens, have broad bases, are fibrously reticulate, stiff, and bristly in appearance, and often bifurcate, seldom trifurcating. Process distal tips acuminate to minutely capitate. Forms transitional with C. varians n. sp. have more densely arranged, flexuous, fibril-like processes. Processes, other than the apical and antapical process, appear nontabular; tabulation unknown. No cingulum observed, except at posterior edge of precingular archeopyle where a relatively smooth strip may be observed, bearing a few linear arrangements of processes aligned in the direction of the cingulum. Sulcus not observed. Archeopyle precingular (Type P).

Discussion: Although T. cf. T. hirsutum does not display Gonyaulax-type tabulation it is tentatively placed into the Gonyaulacaceae for the following reasons: presence of a precingular archeopyle (Type P); possible lineage relationships with

Cordosphaeridium varians n. sp. which does display Gonyaulax-type tabulation. Additional information is given on p. 63.

Specimens which can first be identified as T. cf. T. hirsutum appear in sample 211 (lower Navesink Formation). The criterion used for the cut-off point between C. varians and T. cf. T. hirsutum is the first appearance of a distinctively long apical and antapical process (Pl. 15, figs. 2c and d), indicating the first appearance of T. cf. T. hirsutum. T. cf. T. hirsutum is found in the study section from sample 211 through sample 219, and is not present in the rest of the section. Between samples 215 and 219 the relative frequency of T. cf. T. hirsutum ranges between 8-10 percent.

Plates 15 and 16 (rows 1-8) represent a stratigraphically arranged sequence of specimens which display the morphologic change downsection. Each row of figures represents one sample; the 4 specimens illustrated in each row represent the degree of morphologic variability observed in that one sample: rows 1-8 correspond, respectively, to samples 213-206 (lower Navesink downward into the upper Mount Laurel). As can be observed from the plates (15 and 16) variants of C. varians occur as high as sample 213 (Pl. 15, figs. 1a and b): they do not occur stratigraphically higher, being replaced by T. cf. T. hirsutum.

Dimensions: Observed range (25 specimens measured): length main body 87-105 um, width 77-96 um; length apical process 20-25 um; length antapical process 15-19 um; length of all other processes 13-19 um.

Occurrence: Upper Mount Laurel Sand, extremely rare; lower to

middle portions of Navesink Formation, extremely rare to sparse. Greatest occurrence, sample nos. 215-219. Occurred in 8 samples.

Previously reported occurrence: Paleocene of Australia (Cookson, 1965).

Family PERIDINIACEAE Kent

Genus Deflandrea Eisenack, emend. Williams and Downie 1966

Deflandrea asymmetrica Wilson 1967

Pl. 8, fig. 1

1967. Deflandrea asymmetrica Wilson, New Zealand Jour. Botany, vol. 5, p. 62, figs. 17-21.

Comments: Because of the large number of excellently preserved specimens observed and studied a detailed description is given below.

Description: Cyst bilayered. Periblast rhomboidal in dorso-ventral view; dorso-ventrally flattened; tapering apically from cingulum in near-linear fashion to base of short, vertically directed apical horn; taper interrupted midway by very reduced shoulders. Periblast tapers antapically from cingulum in near-linear to slightly-flexed fashion to narrowly truncated antapex bearing an extended left antapical horn. Apical horn vertically directed, short (ca. 8 um long), gently tapering, flatly truncated. Left antapical horn extended (ca. 10 um long), acuminate. Right antapical horn reduced to small (ca. 3 um long), acuminate projection at right margin of narrow antapex. Outline between antapical horns slanting downward to left

antapical horn. Periphragm smooth, nontabulated. Endoblast angularly ovoidal in dorso-ventral view, smaller in outline than periblast, leaving a more or less continuous lateral, anterior, and posterior pericoel. Endophragm smooth to faintly granular. Cingulum only evident on periblast; formed of 2 low, continuous, parallel folds, having slight to no levorotatory offset. Sulcus formed of a shallow depression in periphragm, extending vertically beneath cingulum to antapex, intersecting antapical margin between antapical horns. Archeopyle intercalary (Type Ia/Ia), roundly hexagonal in outline; operculum on both wall layers attached along posterior margin.

Dimensions: Observed range (45 specimens measured): length 54-86 um, width 40-63 um.

Occurrence: Mount Laurel Sand, extremely rare to rare; Navesink Formation, extremely rare to common; Sandy Hook Member, extremely rare to sparse.

Previously reported occurrence: Eocene of Antarctica (Wilson, 1967); Campanian-Maestrichtian of Denmark (Wilson, 1970).

Deflandrea cf. *D. asymmetrica* Wilson 1967

Pl. 8, fig. 2; pl. 13, fig. 1

1967. *Deflandrea asymmetrica* Wilson, New Zealand Jour. Botany, vol. 5, p. 62, figs. 17-21.

Comments: Cysts are of similar shape as D. asymmetrica; however, they appear to be single layered. The exterior is finely and densely granular under scanning electron microscopy. Specimens are of similar size as D. asymmetrica; however, horn length appears to be more variable. Archeopyle intercalary (Type Ia); operculum hexagonal in outline, attached posteriorly.

Dimensions: Observed range (4 specimens measured): length 57-72 um, width 40-63 um.

Occurrence: Mount Laurel Sand, extremely rare; Navesink Formation, extremely rare. Occurred in 5 samples.

Previously reported occurrence: Monmouth Group specimens are cited as D. cf. D. asymmetrica; however, are perhaps distinct enough to be eventually a new species. Because of the small number of specimens this is not presently practical. Identical specimens have not been reported from other localities.

Deflandrea cooksoni Alberti 1959

Pl. 8, fig. 3; pl. 13, fig. 2

1959. Deflandrea cooksoni Alberti, Mitt. Geol. Staatsinst. Hamburg, vol. 28, p. 97-98, pl. 9, figs. 1-6.

Comments: The usage of Deflandrea cooksoni Alberti 1959 and Deflandrea tripartita Cookson and Eisenack 1960 emend. Cookson and Manum 1964 for morphologically similar forms has resulted in some degree of confusion

in the literature. Although Alberti had named D. cooksoni in 1959, Cookson and Eisenack (1960) and later Cookson and Manum (1964, p. 521-522 pl. LXXVI, figs. 1-2) named very similar forms D. tripartita, making no reference to D. cooksoni. Eisenack (1967, p. 237), however, reported that D. tripartita has a clearly developed cingulum and that D. cooksoni lacks a cingulum. Alberti (1959, p. 98), however, had reported that the cingulum of D. cooksoni was generally lacking; however, when present, that it was very slightly impressed. Cookson and Manum (1964, p. 521) reported that D. tripartita has an inconspicuous cingulum. Therefore, cingulum development in both species seems quite similar. Perhaps the main difference between D. cooksoni and D. tripartita is their surface ornamentation. According to the original description of D. cooksoni it has a granular periphragm, whereas, the original description of D. tripartita reports that it has only a fine pattern on the periphragm. Although it is probable that these differences in surface ornamentation are intraspecific variables, it has not yet been demonstrated. Monmouth Group specimens are observed with distinctively granular periblasts and distinctively smooth periplasts. Until further work is done I feel it necessary to assign the granular forms to D. cooksoni and the smooth (faintly granular forms) to D. tripartita.

Monmouth Group specimens are generally broad-shouldered on the periblast, bearing an abrupt, short apical horn. The lateral margins of the periblast are roughly parallel, having a slight equatorial bulge where the spherical to ovoidal endoblast is

appressed against the periblast. The antapex is broadly truncated, having an extended, acuminate, left antapical horn, and a reduced right antapical horn. The generally ovoidal endoblast (ca. 2 um thick) is thicker than the periblast (both measuring ca. 3 um). The endoblast is faintly granular; periphragm coarsely granular, granules measuring up to 1.5 um high and 2 um wide. The cingulum is generally only visible at the cyst lateral margin, formed by a slight outfolding of the periphragm, or by occasionally-aligned granules reflecting the boundary of the cingulum; only rarely is the cingulum complete. The sulcus extends from between the terminal ends of the cingulum downward between the antapical horns; occasionally it extends slightly above the cingulum onto the epitract. The sulcus widens slightly posteriorly. Archeopyle is intercalary (Type Ia/-); no opening is observed on the endoblast.

Dimensions: Observed range (15 specimens measured): length 111-138 um, width 63-71 um. Wall layers ca. 3 um, endophragm thicker than periphragm.

Occurrence: Mount Laurel Sand, extremely rare to rare; Navesink Formation, extremely rare to sparse; Sandy Hook Member of Red Bank Sand, extremely rare to rare. Greatest occurrence, sample no. 212. Occurred in 25 samples.

Previously reported occurrence: Upper Senonian of Germany (Alberti, 1959).

Deflandrea cordifera n. sp.

Pl. 8, figs. 4

Name derivation: Latin; cordifer, heart-carrying, i. e., with a heart-shaped structure of some kind, referring to the inverted heart-shape of the endoblast.

Holotype: AJ-11, R11.1, +2.6 (pl. 8, fig. 4).

Type locality: Atlantic Highlands, New Jersey.

Type stratum: Sandy Hook Member of Red Bank Sand.

Description: Cyst triangular in outline; slightly expanded at cingulum; bearing long, slender, equal, gently-tapering, irregularly-striate, sharp-tipped, apical and antapical horns, measuring ca. 1/2-2/3 central body length; antapical horns diverging. Central body occupies most of cyst interior, extending a few microns into apical and antapical horn cavaties, imparting a somewhat inverted heart-shaped appearance. Cyst dorso-ventrally flattened. Periphragm longitudinally striate, striae continuing to tips of horns; nontabulate. Endophragm smooth; closely appressed to periphragm, except within the horns where long pericoels are developed. Cingulum formed of parallel, discontinuous, equatorial folds in periphragm; bears numerous, closely-spaced, vertical striae; levorotatory offset ca. ½ cingulum width. Sulcus outlined by low folds in periphragm, beginning between terminal ends of cingulum, broadening posteriorly to tips of antapical horns. Archeopyle intercalary (Type I/I); large, occupying ca. 2/3 or more of medial dorsal epitract; excystment

opening in endophragm of similar shape and size.

Discussion: The most diagnostic feature is general shape of periblast and endoblast. The roughly triangular periblast with slightly convex-outward lateral margins and long, slender, pointed apical and antapical horns are distinctive. The inverted, heart-shaped endoblast sets it apart from similar species, e.g., D. diebeli Alberti 1959, and D. striata Drugg 1967.

Affinity: Monmouth Group specimens are somewhat similar to D. diebeli Alberti 1959 (p. 99, pl. 9, figs. 18-21); however, are distinctive in being less striate, having generally shorter apical and antapical horns, and having the inverted heart-shaped endoblast. D. diebeli is narrower in appearance in the hypotract area. D. cordifera differs from D. striata Drugg 1967 by having an inverted heart-shaped endoblast.

Dimensions: Holotype L x W, 160 x 70 um; apical horn from apex of endoblast 43 um, antapical horns from antapex of endoblast 32 um. Observed range (15 specimens measured): length 158-186 um, width 63-70 um; apical horns ca. 1/2 to 2/3 central body length; wall layers ca. 1 um, each of similar thickness.

Occurrence: Navesink Formation, extremely rare in upper part; Sandy Hook Member of Red Bank Sand, extremely rare to rare. Occurred in 17 samples.

Deflandrea corrugatella n. sp.

Pl. 8, figs. 5-7

Name derivation: Latin, corrugatus, wrinkled-ridged; ella, diminuitive form; referring to the relatively small-sized tripartite cyst with well-formed longitudinal wrinkles or striae.

Holotype: AI-24, R16.4, +12.7 (pl. 8, figs. 5, 7).

Type locality: Atlantic Highlands, New Jersey.

Type stratum: Mount Laurel Sand.

Description: Periblast peridinioid in outline; epitract tapering from the cingulum, occasionally displaying slightly expanded shoulders, bearing slightly extended and roundly terminated apical horn, which bears a distal pore, and terminates 25-28 um above apex of endoblast; hypotract tapering from cingulum, generally slightly shorter than epitract; broadly truncated posteriorly, left antapical horn extended and acuminate, right antapical horn forms approximate right angle with periblast margin. Periblast longitudinally and finely wrinkled; wrinkles occurring on all surfaces, except generally the sulcus. Endoblast smooth, ovoidal, generally somewhat compressed in polar direction, closely appressed equatorially to periblast. Anterior pericoel larger than posterior. Nontabulated. Cingulum levorotatory, ca. 1 cingulum width offset, formed of folds in both periblast and endoblast. Bears closely-spaced, vertical striae or wrinkles in periphragm layer. Sulcus extends a short distance

above cingulum and is tapered; extends and broadens beneath terminal ends of cingulum, reaching lower periblast margin; bears a small arcuate feature (ca. 5 um long) slightly beneath left terminal end of cingulum, indicating position of flagellar pore (on theca). Archeopyle intercalary (Type IA/-); no excystment opening observed on endoblast. Operculum attenuated hexagonal having alternating long and short sides, the anterior edge being longer than the posterior.

Discussion: Diagnostic characteristics are the broadly truncate antapical margin, striate periphragm, large anterior and posterior pericoels, antero-posteriorly flattened endoblast, and the well-marked cingulum and sulcus. The cyst generally appears robust, only rarely being distorted or otherwise impaired.

Affinity: D. corrugatella shares similarities with D. cincta Cookson and Eisenack 1958 (p. 26, pl. IV, figs. 1-3), and D. dilwynensis Cookson and Eisenack 1965 (p. 141, pl. 18, figs. 6-9. D. cincta, however, lacks the wrinkled surface and the antero-posteriorly flattened endoblast. D. dilwynensis differs in general outline, being not much longer than broad, has a much reduced hypotract and posterior pericoel, and has an endoblast which nearly fills the cyst cavity and is not antero-posteriorly flattened.

Dimensions: Holotype L x W, 91 x 62 um; endoblast length 40 um; apical horn length above endoblast apex 28 um; antapical horn length beneath endoblast antapex, left 11 um, right 19 um; wall thickness ca. 2 um, endophragm thicker than periphragm. Observed range (7 specimens measured): length 80-91 um, width 32-55 um; apical horn

length above endoblast apex 25-28 um; antapical horn length below endoblast antapex, left 10-13 um, right 17-20 um; wall thickness ca. 2 um, endophragm thicker than periphragm.

Occurrence: Mount Laurel Sand, extremely rare. Occurred in 3 samples, 205, 206, 207.

Deflandrea cf. *D. cretacea* Cookson 1956

Pl. 8, fig. 8; pl. 13, fig. 3

1956. *Deflandrea cretacea* Cookson, Austral. J. Mar. and Freshw. Res. vol. 7, no. 1, p. 184-185, pl. 1, figs. 1-7.

Comments: Cyst morphology agrees with the australian specimens described by Cookson (1956, p. 184-185); however, the Monmouth Group specimens are generally larger. Only three specimens were observed, one of which is slightly granular on the periphragm. Specimens observed conform best to the specimen illustrated by Cookson (ibid., Pl. 1, fig. 5). Archeopyle intercalary (Type I/-).

Dimensions: Observed range (3 specimens measured): length 74-80 um, width 50-56 um.

Occurrence: Navesink Formation, extremely rare; Sandy Hook Member of Red Bank Sand, extremely rare. Occurred in 5 samples.

Previously reported occurrence: Upper Cretaceous of Australia (Cookson, 1956).

Deflandrea diebeli Alberti 1959

Pl. 8, figs. 16

1959. Deflandrea diebeli Alberti, Mitt. Geol. Staatsinst. Hamburg, vol. 28, p. 99-100, pl. 9, figs. 18-21.

Comments: Periblast and endoblast morphology agrees with the description of Alberti (1959, p. 99-100); however, the Monmouth specimens are somewhat larger (218-284 um x 49-63 um as compared to 110-220 um x 40-50 um). The most distinctive features are the apical and antapical horns, each being exceedingly long, slender, slightly tapering, somewhat flexuous, and delicate. The apical horn is frequently the longer; however, all horns are generally longer than the endoblast length. The cingulum is generally present, formed by a shallow equatorial depression, and is narrow (8-10 um). The sulcus is poorly developed. The wall layers are delicate in appearance, the periphragm often appearing draped over the endoblast; the periphragm is longitudinally wrinkled. Archeopyle is intercalary (Type I/I).

Vozzhennikova (1967, p. 159-160, pl. CXIX, fig. 4) transferred D. diebeli into Ceratiopsis Vozzhennikova 1967. Ceratioipsis brings to mind a cyst with a ceratioid outline; namely, having a postcingular horn. I suggest that D. diebeli is not ceratioid in outline, rather being clasically peridinioid. I therefore feel that the genus Deflandrea is a satisfactory assignment for the species.

Dimensions: Observed range (7 specimens measured): length

218-284 um, width 49-63 um.

Occurrence: Mount Laurel Sand, extremely rare; Navesink Formation, extremely rare to rare. Greatest occurrence, sample no. 209. Occurred in 21 samples.

Previously reported occurrence: Upper Senonian of Germany and Maestrichtian of Poland (Alberti, 1959).

Deflandrea diebeli Alberti 1959 subsp. rigida n. subsp.

Pl. 8, figs. 9, 10, 15

Name derivation: Latin; rigida, rigid or firm; referring to the strongly developed structure of the cyst.

Holotype: AJ-59, coords. R10.5,+5.7 (Pl. 8, figs. 9, 15).

Type locality: Atlantic Highlands, New Jersey.

Type stratum: Navesink Formation:

Description: Periblast rigid in construction, peridinioid, triangular in outline, bearing extended apical and antapical horns of similar length, which are generally broader-based and more tapering than in D. diebeli. Equatorial margins are enlarged slightly outward, terminating in oblique angles at lateral margins of cingulum. Periphragm finely wrinkled longitudinally, except within sulcus. Endoblast ovoidal, loosely filling the central cavity, leaving small lateral pericoels and large anterior and posterior pericoels within the horns, beginning near the bases of the horns, measuring roughly the same length as the endoblast. Endophragm

is smooth. No tabulation observed on either wall layer. Cingulum strongly developed on periphragm and faintly developed on endophragm, formed of parallel periphragm equatorial folds somewhat crenulated by intersecting longitudinal wrinkles of periphragm. Vertical, closely-spaced wrinkles occur within cingulum. Cingulum weakly levorotatory; occasionally nonspiral. Sulcus extends from terminal ends of cingulum, broadening posteriorly, bounded by subtle folds directed toward antapical horn tips. Archeopyle intercalary (Type I/I), attentuated hexagonal with alternating long and short sides, occupying ca. 2/3 of medial dorsal epitract; operculum seldom found in place.

Discussion: D. diebeli var. rigida differs from D. diebeli mainly in its robust, regularly striate structure. Periphragm is not "draped" over endoblast, but rather forms a rigid, generally nonflexuous periblast, with a well-marked and striate cingulum.

Dimensions: Holotype L x W, 292 x 115 um; endoblast length 103 um, apical horn above endoblast 103 um; antapical horns beneath endoblast ca. 103 um each. Observed range (45 specimens measured): length 237-248 um, width 71-118 um; apical and antapical horn length approximately equal to endoblast length.

Occurrence: Mount Laurel Sand, extremely rare to rare; Navesink Formation, extremely rare to sparse to rare; Sandy Hook Member of Red Bank Sand, extremely rare to rare. Greatest occurrence, sample nos. 209, 211, 216, 231, and 236. Occurred in 31 samples.

Deflandrea magnifica Stanley 1965

Pl. 8, figs. 11, 12

1965. Deflandrea magnifica Stanley, Bull. Amer. Paleont., vol. 49, p. 218-219, pl. 20, figs. 1-6.

Comments: In addition to the features reported by Stanley (1965, p. 218-219), the Monmouth Group specimens exhibit small pericoels near the tips of the horns, where the endoblast extends into the short horn cavities, terminating ca. 10-12 um inward from the horn tip. The archeopyle is intercalary (Type I/I), corresponding to the 2a intercalary plate of the periblast, and is hexagonal in outline. Frequently because of downward collapsing of the epitract about the cingulum the archeopyle is drawn toward the cingulum, giving the appearance of a precingular archeopyle (Type P) (Pl. 8, fig. 12). The collapsing is controlled mainly by the position of the rigid cingulum. If identified as a precingular archeopyle (Type P), the cyst could be identified as Lejeunia hyalina (Gerlach 1961) Kjellstrom 1972 (Geol. Foren. Stockholm, Forh., vol. 94, pt. 3, no. 550, p. 469, figs. 1-2). Although Kjellstrom identified his specimens as L. hyalina, they appear identical with the D. magnifica forms observed in the Monmouth Group. Kjellstrom reports a precingular archeopyle (Type P) for his specimens, however, he only illustrated a single specimen, which is collapsed at the cingulum. The archeopyle shown on his specimen (ibid., fig. 1) does encroach on the cingulum, but this may be due

to collapsing of the epitract downward into the hypotract, as has been observed in some Monmouth Group specimens. Typically intercalary archeopyles (Type I) are hexagonal in outline, with alternating long and short sides; whereas, precingular archeopyles (Type P) are generally somewhat pentagonal in outline, having an anterior gable and straight lateral margins. The method used in recognizing intercalary archeopyles (Type I) in Monmouth Group specimens with downwardly collapsed epitracts is to see if a slanted corner can be located low on either of the lateral sides of the archeopyle. If a slanted corner can be located in that position it is then hexagonal in outline, and therefore intercalary (Type I). Kjellstrom's specimen illustrated in his fig. 1, appears to have slanted corners low on the lateral margins of the archeopyle. Thus, it seems likely that his specimen may have been D. magnifica, rather than L. hyalina.

Dimensions: Observed range (22 specimens measured): length 126-190 um, width 111-134 um; pericoel lengths in tops of horn cavities 10-12 um.

Occurrence: Mount Laurel Sand, extremely rare; Navesink Formation, extremely rare; Sandy Hook Member of Red Bank Sand, extremely rare to rare.

Previously reported occurrence: Paleocene of South Dakota (Stanley, 1965); Middle Maestrichtian of southern Sweden (Kjellstrom, 1972).

Deflandrea cf. D. obscura Drugg 1967

Pl. 8, figs. 13

1967. Deflandrea obscura Drugg, Palaeontographica Abt. 8, vol. 120, p. 17, pl. 2, figs. 8-9; pl. 9, fig. 5

Comments: Specimens observed agree in general form with those described by Drugg (1967, p. 17); however, they do not appear to have tabulation, and are generally larger. Drugg reported that phase microscopy showed tabulation, which otherwise was not apparent. Monmouth Group specimens measure 71-87 um x 54-70 um as compared with those reported by Drugg 45-60 um x 40-54 um. Similar features seen in both specimens are ovoidal outline, short apical horn and two short unequally developed antapical horns, endoblast which nearly fills periblast (see Drugg, pl. 2, fig. 8), thin and smooth cyst walls, cingulum and sulcus formed by low and discontinuous flanges, and intercalary archeopyle (Type I/I). Monmouth Group specimens have continuous lateral pericoels measuring 1-3 um, illustrating the extent to which the endoblast fills the periblast, and rarely attached opercula, being attached along the posterior edge.

Dimensions: Observed range (9 specimens measured): length 71-87 um, width 54-70 um; apical horn length above apex of endoblast 6-12 um; antapical horn lengths from antapex of endoblast, left 2-4 um, right ca. 1 um. Lateral pericoels 1.5-2 um.

Occurrence: Navesink Formation, extremely rare; Sandy Hook Member of Red Bank Sand, extremely rare. Occurred in 13 samples.

Previously reported occurrence: Maestrichtian and Danian of central California (Drugg, 1967).

Deflandrea ornata n. sp.

Pl. 9, figs. 3, 4, 5

Name derivation: Latin, *ornatus*, adorned or embellished. Referring to the highly variable spine ornamentation outlining the plate equivalents.

Holotype: AI-30, coords. R14.2, +6.1 (Pl. 9, figs. 3-4).

Type locality: Atlantic Highlands, New Jersey.

Type stratum: Mount Laurel Sand.

Description: Periblast peridinioid, slightly rhomboidal, tapering apically from cingulum in nearly linear fashion, forming a relatively short, flatly-truncated, apical horn, bearing a terminal pore; tapering antapically from cingulum to short, slightly conical, pointed, antapical horns. Outline between antapical horns concave. Left antapical horn larger than right. Periphragm generally smooth, and is formed into triangle to trapezoid-shaped, high, sutural fold arrangements; each fold bearing short to long (up to 3 um), closely-spaced, solid, simple to bifurcate spines. The triangular to trapezoidal fields which also may bear intratabular coni, are well-separated from each other and outline plate equivalents. The lateral separation of the

pre- and postcingular fields creates marked interruptions in the cingulum. Apical tabulation reflected by a slender diamond-shaped pattern of intratabular coni on the ventral apex, and paired, longitudinal rows of spines extending down the lateral sides of the apex outlining the remaining apical plate fields. Precingular and postcingular series reflected by triangle to trapezoid-shaped, sutural fold arrangements bearing spines; triangular fields on the ventral surface, trapezoidal fields on the lateral and dorsal surfaces. Antapical series marked by rows of spines encompassing the antapical horns, suggesting that the lower portions of each horn represent one plate equivalent. Reflected tabulation 4', ?3a, 7'', 6-7c, 5''', 2''''. Endoblast large, angularly-ovoidal, closely appressed to periblast, filling nearly all of the central cavity, forming pericoels only within the short horns and under the elevated ridges of the cingulum and plate equivalents. Endophragm smooth, slightly indented along cingulum. Cingulum levorotatory, terminal ends offset ca. 1 cingulum width; interrupted due to separation of adjacent pre- and postcingular plate equivalents, formed of high sutural folds bearing long spines (up to 3 um), pericoels occurring beneath the sutural folds. Sulcus extends antapically from between terminal ends of cingulum as two rows of spines which intersect the posterior periblast margin a short distance inward from the antapical horns. At each intersection a small, spike-like projection is directed posteriorly. Archeopyle intercalary (Type Ia/Ia); accessory sutures extend downward along the lateral margins of the 4''.

Although most specimens are characteristically like those described in the above paragraph, the high degree of variability in the height of the sutural folds and spines can greatly change the general appearance of the cyst surface. Although cyst outline and plate shapes do not change, the overall relief of the margins of the plates, cingulum, and sulcus may be reduced, the sutural folds being altogether missing, except along the cingulum and sulcus. The spike-like projections at the base of the sulcus may also be lacking.

Discussion: Diagnostic features are the rhomboid outline, tabulation reflected by variable sutural folds and peritabular spines and occasional to frequent intratabular coni, well-separated plate fields, interrupted cingulum, and accessory sutures extending down lateral margins of 4''''.

Affinities: D. ornata is similar to D. sverdrupiana Manum 1963 and D. scheii Manum 1963. Both D. sverdrupiana and D. scheii, however, lack the long, bifurcating spines, spines on the antapical horns, diverging antapical horns. D. sverdrupiana lacks the accessory sutures along the lateral sides of the 4''.

Dimensions: Holotype L x W, 64 x 45 um; apical horn above endoblast 16 um; left antapical horn beneath endoblast 13 um; spine length up to 3 um; wall layers, endoblast ca. 1 um, periblast ca. 1 um. Observed range (23 specimens measured): length 53-72 um, width 39-47 um.

Occurrence: Mount Laurel Sand, extremely rare to sparse. Greatest occurrence, sample no. 206. Occurred in 5 samples.

Deflandrea pannucea Stanley 1965

Pl. 8, fig. 14

1965. Deflandrea pannucea Stanley, Bull. Amer. Paleontol., vol. 49, p. 220, pl. 22, figs. 1-4, 8-10.

Comments: Specimens agree in basic morphology with those described by Stanley (1965, p. 220); however, two differences exist: the Monmouth Group specimens are larger (115-160 um x 68-95 um as compared to 80-100 um x 55-78 um), and they do not have diverging antapical horns, rather being parallel to slightly converging in most specimens observed. Strong similarities exist in the type of longitudinal wrinkling, relative length of horns, shape of endoblast, intercalary archeopyle (Type I/I), and the possession of a distal pore on the apical horn.

Dimensions: Observed range (20 specimens measured): length 115-160 um, width 68-95 um.

Occurrence: Mount Laurel Sand, extremely rare; Navesink Formation, extremely rare to rare; Sandy Hook Member of Red Bank Sand, extremely rare to rare.

Previously reported occurrence: Paleocene of South Dakota (Stanley, 1965).

Deflandrea speciosa Alberti 1959

Pl. 8, figs. 17, 18

1959. Deflandrea speciosa Alberti, Mitt. Geol. Staatsinst. Hamburg, vol. 28, p. 97, pl. 9, figs. 12-13.

Comments: Specimens agree in most details with those described by Alberti (1959, p. 97); however, the Monmouth Group specimens are slightly larger (137-190 um x 85-107 um as compared to 110-130 um x 60-80 um). Both the Monmouth Group specimens and those of Alberti (ibid.) have similar pentagonal outlines, broadly tapering horns, diverging antapical horns, slightly denticulate, longitudinal crests apparently related to tabulation, frequent tuberculate or granular surface ornamentation, large and somewhat spherical central body closely associated with main periblast body, and trapezoidal intercalary archeopyle (Type I/I) occupying roughly 1/3 of dorsal epitract. One notable feature of the Monmouth Group specimens is the large excystment aperture on the endoblast, which on most specimens appears to occupy most of the apical area of the endoblast.

Dimensions: Observed range (25 specimens measured): length 135-190 um, width, 85-107 um.

Occurrence: Navesink Formation, extremely rare to rare; Sandy Hook Member of Red Bank Sand, extremely rare to sparse. Greatest occurrence, sample nos. 224, and 227. Occurred in 19 samples.

Previously reported occurrence: Upper Paleocene of Germany (Alberti, 1959), and Danian of Central California (Drugg, 1967).

Deflandrea spicata n. sp.

Pl. 9, figs. 18-20

Name derivation: Latin, spicatus, spiked or bearing a spike; referring to the small, spike-like right antapical horn.

Holotype: AI-1, R3.7, +17.7 (Pl. 9, fig. 19).

Type locality: Atlantic Highlands, New Jersey.

Type stratum: Mount Laurel Sand.

Description: Periblast rhomboidal to ovoidal in dorso-ventral view, dorso-ventrally flattened, bearing a long (up to 30 um), conical, apical horn and 2 shorter conical, antapical horns which are closely associated, having immediately adjacent bases; the left horn being longer (ca. 20 um long) than the right; the right antapical horn being short (ca. 8 um long) and spike-like. Periphragm granular. Endoblast rhomboidal to ovoidal in outline, closely associated with periblast throughout main body area, forming a continuous lateral pericoel, and also anterior and posterior pericoels within the horns. Endophragm smooth. No tabulation observed. Cingulum levorotatory with ca. 1 cingulum width offset; bordered by faint, but continuous sutural folds on periphragm. The interior of the cingulum is also granular. Sulcus narrow and depressed, extending antapically a short distance from between

terminal ends of cingulum; bears a small arcuate mark slightly beneath terminal ends of cingulum indicating the position of the 1 flagellar pore (on theca). Archeopyle intercalary (Type I/I), hexagonal in outline, having alternating long and short sides; occupies more than 2/3 medial dorsal epitract; operculum frequently in place, but doesn't appear attached.

Discussion: Specimens observed in the Mount Laurel Sand are generally wider at the cingulum than those observed in the Navesink Formation, and they also exhibit the elliptical sulcal mark, and cingulum, which the Navesink Formation specimens appear to lack.

Affinity: Although the Monmouth Group specimens are Deflandrea-like in appearance they bear certain features not unlike Palaeocystodinium australinum (Cookson 1965) n. comb.: somewhat fusiform outline with extended apical and antapical horns, and a short, spike-like horn attached onto the right side of the main antapical horn. Perhaps the closest resemblance is shared with Svalbardella polymorpha Malloy (1972, p. 63, pl. 1, figs. 14, 15); however, D. spicata displays the granular ornamentation, cingulum, and sulcus (which, S. polymorpha lacks). In general, D. spicata appears quite distinct from previously described Deflandrea forms.

Dimensions: Observed range (10 specimens measured): length 154-200 um, width 60-97 um; wall layers ca. 2 um, endophragm thicker than periphragm; distance from apex of endoblast to apical horn tip ca. 30 um, from base of endoblast to antapical horn tip ca. 25 um.

Occurrence: Mount Laurel Sand, extremely rare to rare; Navesink Formation, extremely rare. Greatest occurrence, sample no. 205. Occurred in 5 samples.

Deflandrea striata Drugg 1967

Pl. 9, fig. 1; pl. 13, fig. 5

1967. Deflandrea striata Drugg, Palaeontographica, Abt. B, vol. 120, p. 18, pl. 2, figs. 13-14.

Comments: Specimens observed are generally similar in size (although some were larger) as those reported by Drugg (1967, p. 18). Although the specimens do appear to lack the parallel rows of grana reported by Drugg, they do possess the parallel wrinkling which imparts the markedly striate appearance. The cingulum is frequently bordered by denticulate ridges or by irregular folds, and exhibits short, vertical, and often close-set vertical wrinkles. The archeopyle is frequently as large as those reported by Drugg, however, the size is variable, and may also be smaller. Monmouth Group specimens exhibit intercalary archeopyles (Type I/I) which occupy from ca. 1/2 to most of the dorsal epitract. Openings with opercula in place have been observed in both endoblast and periblast, and both openings appear of similar size in single specimens. The endoblast is generally pentagonal, being rounded at the corners, and is closely appressed to periblast about the large central area.

Dimensions: Observed range (10 specimens measured): length 139-221 um, width 81-116 um.

Occurrence: Mount Laurel Sand, extremely rare to rare; Navesink Formation, extremely rare to sparse; Sandy Hook Member of Red Bank Sand, extremely rare to rare. Occurred in 28 samples.

Previously reported occurrence: Danian of central California (Drugg, 1967).

Deflandrea tripartita Cookson and Eisenack 1960 emend.
Cookson and Manum 1964
Pl. 9, fig. 6; pl. 13, fig. 4

1960. Deflandrea tripartita Cookson and Eisenack, Micropaleont., vol. 6, p. 2, pl. 1, fig. 10.

1964. Deflandrea tripartita Cookson and Eisenack emend. Cookson and Manum, Proc. Roy. Soc. Victoria, vol. 77, p. 521-522, pl. LXXVI, figs. 1-2.

Comments: Although D. tripartita Cookson and Eisenack 1960 emend. Cookson and Manum 1964 is very similar to D. cooksoni Alberti 1959 (p. 97-98, pl. 9, figs. 1-6), neither Cookson and Eisenack (1960) nor Cookson and Manum (1964) made reference to it. It is difficult to determine a basic difference between the two species, except perhaps for the degree of periphragm ornamentation and a slight size difference (D. tripartita being the larger). Alberti (ibid.Pl. 9, figs. 1-6) illustrated a marked degree of variation among his specimens, which

appear uniform enough to be a natural sequence, possibly encompassing D. tripartita. Specimens observed in the Monmouth Group are also highly variable in size. In order to treat these variable tripartite cysts I propose to use both species names temporarily, until variability studies can be performed on specimens of both species from the type areas. D. tripartita will here represent specimens with smooth to faintly ornamented periblasts; D. cooksoni will be used for specimens with distinctively granular periblasts: a gradation was not observed in the Monmouth Group specimens.

Monmouth Group specimens have periblasts which are long, somewhat parallel sided, expanded slightly at the equator where the large endoblast is appressed against the periblast, are broad shouldered, and bear a short, tapering apical horn and two somewhat vertical, short antapical horns: the left horn being slightly longer. Periphragm is essentially smooth. Endoblast ovoidal and large, closely appressed against periblast about a broad equatorial zone. Endophragm essentially smooth. No tabulation observed. Cingulum seldom seen, except at cyst lateral margins where a slight indentation in the periblast may be observed. Sulcus shallow, vertical, essentially nontapering, extends posteriorly to the inner edges of the antapical horns, bears an arcuate feature on the left, upper side, suggesting the position of the flagellar pore (on theca). Archeopyle intercalary (Type Ia/-), horseshoe-shaped; operculum generally attached along posterior edge; no opening seen in endoblast. Dimensions: Observed range (25 specimens measured): length 111-156 um, width 52-74 um; wall layers, periphragm ca. 1 um, endophragm

ca. 1 um.

Occurrence: Mount Laurel Sand, extremely rare to common; Navesink Formation, extremely rare to common; Sandy Hook Member of Red Bank Sand, extremely rare to sparse. Greatest occurrence, sample nos., 208, 214, 215, 216, and 219. Occurred in 32 samples.

Previously reported occurrence: Turonian to middle Senonian of Australia (Cookson and Eisenack, 1960).

Deflandrea cf. D. tripartita Cookson and Eisenack 1960 emend. Cookson and Manum 1964

Pl. 9, fig. 7

1960. Deflandrea tripartita Cookson and Eisenack, Micropaleontology, vol. 6, p. 2, pl. 1, fig. 10.

1964. Deflandrea tripartita Cookson and Eisenack emend. Cookson and manum, Proc. Roy. Soc. Victoria, vol. 77, p. 521-522, p. LXXVI, figs. 1-2.

Comments: Cysts are basically D. tripartita forms; however, the endoblast is greatly enlarged longitudinally, filling much of the central cavity of the periblast. The endoblast and periblast are closely associated throughout this mid-region, but are not fused. Specimens similar to these, and identified as Australiella tripartita, were reported by Vozzhennikova (1967, p. 129, pl. LXIX, fig. 4).

One specimen was observed which bore a centrally located mesoblast.

Dimensions: Observed range: (4 specimens measured): length 112-118 um, width 54-67 um; endoblast length 60-74 um.

Occurrence: Mount Laurel Sand, extremely rare; Navesink Formation extremely rare. Occurred in 5 samples.

Previously reported occurrence: Cretaceous of Soviet Union (Vozzhennikova, 1967).

Deflandrea sp. A

Pl. 9, fig. 10

Comments: Only three specimens were observed; therefore it was not practical to assign these forms to a new species. However, the three specimens observed were well preserved, and, for this reason, a detailed description is given below.

Description: Cyst broadly oval in dorso-ventral outline; flattened dorso-ventrally. Apex tapers to a point, lacking an apical horn. Antapex broadly truncate, bearing reduced left antapical horn (measuring less than 3 um long) and slight deflection at position of right antapical horn. Periblast and endoblast closely appressed; no evidence of pericoels. No tabulation. Cingulum only evident at lateral margins of periblast where weakly developed folds may be seen. Sulcus not evident. Archeopyle intercalary (Type I/I); endophragm and periphragm both have openings of same size and shape; endophragm and periphragm may be separated along posterior edge of

cingulum. Due to the few numbers of specimens no new specific name was assigned to these forms.

Dimensions: Observed range (3 specimens measured): length 50-60 um, width 43-50 um; wall layers both of ca. equal thickness, ca. 0.5 um each.

Occurrence: Mount Laurel Sand, extremely rare; Navesink Formation extremely rare. Occurred in 7 samples.

Deflandrea sp. B

Pl. 9, fig. 8

Comments: Because only two specimens were nondistorted enough to measure and study in detail they were not assigned to a new species. However, their morphology was unique and could be determined, therefore, a detailed description is given below.

Description: Cyst rhomboidal in dorso-ventral view, ca. twice as long as wide; tapering apically and antapically from cingulum, somewhat diamond shaped. Small apical horn ca. 5 um long, bluntly terminated. Left antapical horn ca. 15 um long, broadly V-shaped; right antapical horn reduced ca. 6 um long, distally rounded; outline between antapical horns deeply and roundly concave. Endoblast and periblast closely appressed with small pericoels only at horn tips. Periphragm faintly granular; endophragm faintly to coarsely granular. Cingulum marked by very low folds and aligned granae; levorotatory, less than 1 cingulum width offset. Sulcus formed by a shallow fold extending nearly vertically

between antapical horns. Archeopyle intercalary (Type Ia/Ia).

Dimensions: Observed range (2 specimens measured): length 100-103 um, width 55-56 um; apical horn ca. 5 um, left antapical horn 13-15 um, right antapical horn ca. 5 um; wall layers, endophragm ca. 0.5 um, periphragm ca. 0.5 um.

Occurrence: Navesink Formation, extremely rare.

Deflandrea sp. C

Pl. 9, fig. 9

Comments: Only two specimens were observed; therefore, they were not assigned to a new species. Because one of the specimens was excellently preserved a detailed description of it is given below.

Description: Periblast peridinioid, somewhat triangular in dorso-ventral outline; being widest at the cingulum, tapering apically from the cingulum to narrow, roundly-expanded shoulders, then tapering abruptly to base of short apical horn; slightly tapering antapically from cingulum to well-separated antapical horns. Apical horn short (ca. 6 um), parallel-sided, bluntly-terminated, bearing terminal pore. Left antapical horn longer (ca. 12 um) than right, has a markedly broad and roundly-expanded base, V-shaped, tapering to a point; right antapical horn reduced to small (ca. 5 um) pointed projection. Outline between antapical horns nearly linear, slanted downward toward left antapical horn. Endoblast occupies nearly all of central cavity, closely appressed to periblast along most of lateral margins; anterior pericoel longer than posterior. Endophragm smooth,

periphragm faintly to coarsely granular. Cingulum best developed at lateral equatorial margins; formed of well-developed folds in periphragm at lateral positions, but weakly developed on ventral and dorsal surfaces; slightly levorotatory with ca. ½ cingulum width offset. Sulcus shallow; extends from between terminal ends of cingulum toward tips of antapical horns; bordered by low folds of periphragm; bears a small arcuate feature on upper right sulcus margin indicating position of flagellar pore (on theca). Archeopyle intercalary (Type Ia/Ia), hexagonal in outline.

Dimensions: Two specimens observed (1 specimen measured): length 87 um, width 45 um; apical horn length 6 um; right antapical horn length 5 um; left antapical horn length 12 um; wall layers, endophragm ca. 0.5 um, periphragm ca. 0.5 um.

Occurrence: Navesink Formation, extremely rare; Sandy Hook Member of Red Bank Sand, extremely rare. Occurred in 2 samples, sample nos. 217 and 229.

Deflandrea sp. D

Pl. 9, fig. 11; pl. 13, fig. 6

Comments: Because only two specimens were observed they are not assigned to a new species. Observations made with both light and scanning electron microscopy yielded enough information for a tentative description.

Description: Periblast rhomboidal with flatly-truncated corner positions. Apex concave with centrally positioned apical boss. Antapex obliquely truncated; one specimen bears a slightly extended left antapical horn. Periblast ovoidal in polar view; periphragm faintly granular; nontabulated. Endoblast rhomboidal with rounded corner positions; endophragm smooth. Endoblast and periblast not touching in optical cross-section; however, are closely associated along equatorial lateral margin; pericoel appears more or less continuous, anterior and posterior pericoel areas nearly equal in size. Cingulum best observed at lateral equatorial positions; however, is also well-developed ventrally; formed of two low folds of periphragm and small aligned granae; poorly developed dorsally; levorotatory with ca. ½ cingulum width offset. Sulcus extends from apex to antapex, formed by deep, narrow, somewhat parallel-sided depression in periblablast, and appears deepest between terminal ends of cingulum. Archeopyle intercalary (Type Ia/Ia), roundly hexagonal in outline.

Dimensions: Single specimen measured: length 48 um, width 36 um;

lateral pericoels ca. 2 um in optical section, anterior pericoel 6 um high, posterior pericoel 7 um high.

Occurrence: Two specimens observed from Mount Laurel Sand.

Previously reported occurrence: Not previously reported.

Genus Palaeocystodinium Alberti 1961

Palaeocystodinium australinum (Cookson) n. comb.

Pl. 9, fig. 16; pl. 22, figs. 1-10

1965. Svalbardella australina Cookson, Proc. Roy. Soc. Victoria, vol. 78, pt. 2, p. 140, pl. 25, figs. 1-4.

Comments: Monmouth Group specimens conform well with the Australian specimens described by Cookson (1965, p. 140). The generic assignment of this form should be reconsidered because of basic morphological differences between it and the type species of Svalbardella cooksoniae Manum (1960, p. 21). Manum (ibid.) intended the genus Svalbardella to include forms with blunt-ended horns and main bodies which display cingulum and sulcus and possibly tabulation. Palaeocystodinium Alberti 1961, however, is intended to include forms similar to its type species, P. golzowense Alberti 1961, which have longer and distally pointed horns, weakly-developed to no cingulum and sulcus, and lack tabulation. Although Cookson (1965, p. 140) reported a cingulum and possible sulcus for S. australina, no such features were observed on several hundred specimens from

the Monmouth Group: the specimen illustrated on Plate 9, fig. 16 is folded equatorially, simulating a cingulum.

Cysts observed from the Monmouth Group exhibit 2 features not mentioned by Cookson (ibid.): the presence on some specimens of small granules located on the apical and antapical horns and occasionally on the main body (Drugg, in 1967, reported fine hairs or processes up to 3 um long on specimens very similar to P. australina, calling it P. benjaminii. These forms may all be within the intraspecific variability of P. australina); secondly is the degree of variability observed in the shape of the lateral antapical accessory spike (Pl. 22, figs. 1-10). The spike may appear as a barely noticeable barb on the right side of the antapical horn, or be as large as ½ the size of the antapical horn from the point of branching. Although several hundred specimens were observed, no right lateral spikes were observed to be larger than this, and a few specimens were observed to lack spikes.

Dimensions: Observed range: 35 specimens measured: length 152-270 um, width 43-66 um.

Occurrence: Mount Laurel Sand, extremely rare; Navesink Formation, extremely rare to rare; Sandy Hook Member of the Red Bank Sand, extremely rare to rare. Occurred in 30 samples. Greatest occurrence, sample nos. 219, 222, 224, 225.

Previously reported occurrence: Paleocene of Australia (Cookson, 1965). Williams and Lentin (1975, p. 71) report it from Maestrichtian into the Tertiary.

Palaeocystodinium cf. P. denticulatum Alberti 1961

Pl. 9, figs. 17, 21

1961. Palaeocystodinium ? denticulatum Alberti, Palaeontographica, Abt. A, vol. 116, p. 20, pl. 7, fig. 9.

Comments: Only two specimens were observed: one in excellent condition and one distorted. The latter exhibits longitudinal wrinkling on the apical and antapical horn, thus appearing ribbed, as was reported by Alberti (1961, p. 20). The better preserved specimen does not, however, appear ribbed on the horns, the entire cyst being smooth. Similarities with Alberti's specimens are: the spindle shape of the periblast; the long, centrally positioned, digitate apical horn; and the rounded archeopyle beneath the apical process. The Monmouth Group specimens differ from Alberti's by lacking the ovoidal endoblast, and by having a well-developed cingulum and sulcus.

Monmouth Group cysts are spindled shaped, the periblast forming the digitate apical horn, the acuminate hypotract with pointed antapical horn, and the cingular and sulcal folds; periphragm is smooth. The endoblast is fused to most of the periblast; however, does not pass into the apical horn, thus creating an anterior pericoel within the apical horn; endophragm is smooth. Cingulum has slight levorotatory offset, and is formed of low folds in the periphragm. Sulcus is distinctly formed on the better preserved specimen,

bordered by well-marked folds, extending somewhat vertically toward the antapex. Archeopyle is intercalary (Type I/I) and is large and roundly hexagonal.

Dimensions: Observed range (2 specimens measured): length 70-74 um, width 36-38 um; apical horn length 24 um; antapical horn beneath cingulum 30-34 um.

Occurrence: Only two specimens observed; samples 214 and 234.

Previously reported occurrence: Turonian of Germany (Alberti, 1969).

Palaeocystodinium reductum n. sp.

Pl. 21, figs. 20

Name derivation: Latin, reductus, reduced. Referring to the smaller size relative to other Palaeocystodinium forms.

Holotype: AI-36, R5.9, +13.6 (Pl. 21, figs. 20).

Type locality: Atlantic Highlands, New Jersey.

Type stratum: Mount Laurel Sand.

Description: Periblast spindle-shaped with extended apical and antapical horns; slightly compressed dorso-ventrally, and ovoidal in polar view; periphragm smooth. Horns not as long as endoblast; are pointed to digitate. Antapical horn bears slight deflection similar in position to the accessory spike of P. australinum. Endoblast ovoidal, separated from periblast by continuous lateral and polar pericoels; occupies central bulge of spindle; endophragm smooth. Nontabulated. Cingulum formed of low folds in periphragm;

especially noticeable in optical cross section; slightly levorotatory less than 1 cingulum width offset. Sulcus barely traceable, formed of slight periphragm depression extending antapically from between terminal ends of cingulum. Archeopyle not observed.

Discussion: The characteristic features of P. reductum are the reduced size and abbreviated horns as compared to P. golzowense Alberti 1961 and P. australinum (Cookson 1965) n. comb. The presence of cingulum and sulcus, and the absence of an archeopyle are also distinctive. The assignment of this species into Palaeocystodinium is tentative, until further forms are observed which may display the archeopyle type.

Affinity: P. reductum is similar in appearance to P? denticulatum Alberti 1961; however, it lacks the ribbing or striae on the horns, and bears a consistent pericoel about the entire margin of the endoblast. P. australinum and P. golzowense both have much extended horns, giving greater length; whereas P. reductum has relatively abbreviated horns. The apparent lack of an archeopyle, at least the difficulty in detecting it, the size, and the presence of cingulum and sulcus would generally separate D. reductum from P. golzowense and P. australinum.

Dimensions: Holotype - L X W, 113 X 42 um; endoblast L X W, 43 X 36 um; apical horn 27 um; antapical horn 27 um; lateral pericoels ca. 4 um on each side in optical section. Observed range (4 specimens measured from top of endoblast 27-29 um; antapical horn measured from bottom of endoblast 24-29 um;

endoblast L x W, 42-43 um x 35-36 um. Endophragm less than 1 um; periphragm less than 1 um.

Occurrence: Mount Laurel Sand, extremely rare; Navesink Formation, extremely rare. Greatest occurrence, sample 205. Occurred in 5 samples.

Genus Palaeohystrichophora Deflandre, emend.

Deflandre and Cookson 1955

Palaeohystrichophora infusorioides Deflandre 1934

Pl. 10, figs. 1,2

1934. Palaeohystrichophora infusorioides Deflandre, C. R. Acad. Sci., Paris, vol. 199, p. 967, fig. 8.

Comments: Because numerous excellently preserved specimens were studied in detail a description is given below.

Description: Periblast peridinioid, roughly rhomboidal in dorso-ventral view; dorso-ventrally flattened; tapering apically from cingulum with a linear to slightly concave outline to base of long (up to 31 um) apical horn; tapering antapically from cingulum to a truncated antapex. Epitract longer than hypotract. Apical horn long (up to 31 um), conical, delicate; left antapical horn long (up to 22 um), conical, delicate, flexuous, and much more slender than apical horn; right antapical horn short, often indicated by an oblique deflection at right side of antapex, however, may be extended a few microns. Outline between antapical

horns slanted downward toward left antapical horn, nearly linear or slightly concave. Periphragm smooth, very thin (less than 0.5 um); bears numerous hair-like spines, which generally appear randomly arranged, but occasionally are intratabularly arranged reflecting tabulation, especially in intercalary, precingular, and postcingular series; suggesting 3 anterior intercalary, 7 precingular, and 5 postcingular plate equivalents. Endoblast ovoidal to rhomboidal; large, filling entire central cavity of periblast, forming separate pericoel in each horn. Endophragm finely granular; thicker than periphragm (measuring ca. 0.5 um). Cingulum nonspiral; generally well-developed, formed of wrinkled, parallel folds in periphragm. Sulcus very faintly developed, formed of shallow depression extending antapically from between terminal ends of cingulum to the antapex, terminating between the antapical horns. Archeopyle intercalary (Type I?a/Ia); hexagonal in outline on both periblast and endoblast; operculum was always observed in place on endoblast, however, difficult to see on periblast due to thin nature of periphragm and close appression with thicker endophragm.

Dimensions: Observed range (25 specimens measured): length 116-120 um, width 53-58 um.

Occurrence: Mount Laurel Sand, extremely rare to common. Greatest occurrence, sample nos. 203 and 204. Occurred in 4 samples.

Previously reported occurrence: Senonian of France (Deflandre, 1934).

Genus Spinidinium Cookson and Eisenack 1962

Spinidinium uncinatum n. sp.

Pl. 10, figs. 5-7; pl. 13, figs. 9, 10

Name derivation: Latin uncinatus, meaning hooked or barbed; referring to the hooked or barbed distal ends of the spines.

Holotype: AI-25, coords. R0.4,-2.6 (Pl. 10, figs. 5-7).

Type locality: Atlantic Highlands, New Jersey.

Type stratum: Mount Laurel Sand.

Description: Periblast pentagonal in dorso-ventral outline; dorso-ventrally flattened; tapering apically from cingulum in near-linear fashion to base of short apical horn; tapering antapically from cingulum in near-linear fashion to truncated antapex bearing 2 reduced antapical horns. Short apical horn projects abruptly from apex, tapering and bluntly terminating,bearing 2 terminal lateral spines. Left antapical horn variable in size, may be slightly shorter or longer than apical horn, is conical, and tapers to a point. Right antapical horn generally appears as oblique deflection at right side of antapex. Periphragm smooth, formed into well-developed sutural folds bearing numerous, short, tapering, distally barbed spines, the sutural folds outlining plate equivalents. Plate equivalents well separated by intercalary areas on ventral and dorsal surfaces (except on dorsal epitract), causing the cingulum to be regularly interrupted. Plate equivalents on dorsal epitract

positioned immediately adjacent to each other, lacking intercalary areas. Plate areas triangular on ventral surface, trapezoidal on lateral and dorsal surfaces. Reflected tabulation 4', ?3a, 7", ?c, 5"', 2"". Endoblast ovoidal, filling central cavity of periblast; anterior pericoel occurring in and a short distance beneath the apical horn; broad posterior pericoel occurring at base of apical region. Endophragm smooth. Cingulum interrupted, except on antero-dorsal side; levorotatory with ca. ½ cingulum width offset. Sulcus deep, bordered by sutural folds bearing spines, extends ca. 1 cingulum width above cingulum and broadens posteriorly to antapex, terminating between the antapical horns. Archeopyle intercalary (Type Ia/Ia) and is horshoe-shaped.

Discussion: Diagnostic characteristics of S. uncinatum are the pentagonal outline, extended left antapical horn, separated plate fields, the barbed or hooked sutural spines and peridinioid tabulation. Scanning electron microscopy also shows that the periphragm is smooth between sutures, that the spines are capitate, barbed or hooked, and that small apical and antapical plates exist on the horn areas.

Affinity: S. uncinatum is similar in morphology to S. clavum Harland 1973, S. styloniferum Cookson and Eisenack 1962, and S. lanternum Cookson and Eisenack 1970. S. clavum, however, has oblate and acuminate processes along sutural positions, plate fields apparently not separated, and cingulum not interrupted or offset. S. styloniferum differs by having intratabular spines, which are

bluntly pointed, and a more expanded outline in dorso-ventral view. S. lanternum is most similar to S. uncinatum in overall morphology; however, differs by possessing distinctly pointed spines, and an apparently larger endoblast.

Dimensions: Holotype - L x W, 56 x 31 um; posterior pericoel length 10 um, anterior 11 um; spine length 1.5 um maximum. Observed range (16 specimens measured): length 50-75 um, width 29-47 um; spine length less than 1.5 um; wall layers, periphragm ca. 0.5 um, endophragm ca. 0.5 um.

Occurrence: Mount Laurel Sand, rare; Navesink Formation, extremely rare. Greatest occurrence, sample no. 207. Occurred in 6 samples.

Genus Trithyrodinium Drugg 1967, emend. Davey 1969

Trithyrodinium cavum n. sp.

Pl. 10, figs. 8-10

Name derivation: Latin, cavus, hollow. Referring to the large anterior and posterior pericoels.

Holotype: AI-65, R2.4, +11.4 (Pl. 10, figs. 8, 9).

Type locality: Atlantic Highlands, New Jersey.

Type stratum: Mount Laurel Sand.

Description: Periblast peridinioid in dorso-ventral view, elongate, expanded equatorially; slightly dorso-ventrally compressed; tapering apically without interruption from cingulum to rounded tip of

apical horn; taper may be linear or slightly concave; tapering antapically from cingulum to narrow, parallel-sided antapex which bears 2 antapical horns. Apical horn long (ca. 40 um), formed by uninterrupted tapering of anterior periblast; somewhat digitate, distally rounded. Left antapical horn conical, distally pointed, vertical, shorter than apical horn (ca. 20 um). Right antapical horn short (ca. 5 um), conical, distally pointed. Both antapical horn bases separated by only ca. 5 um; outline between antapical horns concave. Periphragm (ca. 0.5 um thick) faintly granular, nontabulated. Endoblast large, round to ovoidal in dorso-ventral view, closely appressed to periblast, filling central cavity, leaving no lateral pericoels. Anterior pericoel large, beginning beneath apical horn; posterior pericoel smaller, beginning above apical horns. Endophragm (1-3 um thick) granular; appears single layered, but bears thickening of finely matted material at apical and antapical positions of endoblast. Cingulum reflected only on periblast by well-developed, parallel, sutural folds bearing granular edges; levorotatory offset ca. 1 cingulum width. Sulcus formed of deep depression in both periblast and endoblast, extends slightly above cingulum and vertically beneath cingulum, terminating between antapical horns at cyst margin. A small arcuate feature on the upper sulcus indicates the position of the flagellar pore (on theca). Archeopyle intercalary (Type I/3I); formed of the roundly hexagonal 2a plate equivalent on the periblast, which is generally missing; and of the 3 anterior intercalary plates on the endoblast, which are

often found in place.

Discussion: Characteristic features are the large anterior and posterior pericoels, the large, round (in dorso-ventral view) endoblast and equatorially expanded periblast, broadly tapering apical horn, narrow antapex, and relatively short antapical horns. The archeopyle is especially distinctive; formed by the loss of the 2a plate equivalent on the periblast and all 3 anterior intercalary plates on the endoblast.

Affinity: T. cavum is similar in basic form to other distinctively tripartite peridinioid cysts bearing tripartite intercalary archeopyles on their endoblasts (Manum and Cookson, 1964, Pl. I, figs. 5-9); however, is unique as it lacks the broad shouldered epitracts of specimens observed by Manum and Cookson. T. cavum is different from other Trithyrodinium species named to date as it possesses such large pericoels and horns: T. evittii Drugg 1967 has small horns and very small pericoels; T. fragile Davey 1969 apparently has no pericoels.

Dimensions: Holotype - L x W, 134 x 65 um; apical horn from endoblast apex, 40 um; left antapical horn from endoblast antapex, 32 um. Observed range (15 specimens measured): length 124-151 um, width 60-69 um; apical horn from endoblast apex, 30-42 um; left antapical horn from inner body antapex, 25-34 um; wall layers, endophragm 1-3 um, periphragm ca. 1 um.

Occurrence: Mount Laurel Sand, extremely rare to common; Navesink Formation, extremely rare to common; Red Bank Sand, extremely rare. Greatest occurrence, samples 203, 204, 215, and 216. Occurred in 21 samples.

Trithyrodinium evittii Drugg 1967

Pl. 10, figs. 11, 12

1967. Trithyrodinium evittii Drugg, Palaeontographica, vol. 120, Abt. B, p. 20, pl. 3, figs. 2-3, pl. 9, fig. 2.

Comments: Monmouth Group specimens agree with those from California described by Drugg (1967, p. 20). The cyst is bilayered; the periphragm forming the very small apical and antapical horns and the low folds outlining the sulcus and cingulum. No archeopyle was observed in the periphragm. The endophragm is granular, and is closely appressed to the periphragm. An intercalary archeopyle (Type ?/3I) is evident; corresponding to the 1a, 2a, and 3a plates of the endoblast.

Dimensions: Observed range (4 specimens measured): length 60-89 um, width 50-71 um.

Occurrence: Occurs only in the Navesink Formation; extremely rare. Occurred in 3 samples.

Previously reported occurrence: Danian of California (Drugg, 1967).

Trithyrodinium pentagonum n. sp.

Pl. 10, figs. 13, 14

Name derivation: Greek, pentagonia, five-cornered. Referring to the general five-cornered and five-sided appearance of the cyst outline.

Holotype: AI-90, coords. R7.8, +6.9.

Type locality: Atlantic Highlands, New Jersey.

Type stratum: Navesink Formation.

Description: Cyst single layered autoblast, pentagonal in dorso-ventral outline; dorso-ventrally flattened; tapering apically from cingulum in near linear fashion, deviating at apex to form short, rounded apical horn; tapering antapically from cingulum with slightly concave sides to broadly truncated antapex bearing 2 short antapical horns. Apical horn relatively short (up to 19 um long), tapering, distally rounded. Left antapical horn relatively short (up to 15 um long), broadly tapering, V-shaped, blunt-tipped. Right antapical horn short (up to 5 um long), broad, rounded protrusion. Outline between antapical horns concave and slanting downward to left antapical horn. Autophragm faintly granular to microrugulate; nontabulated. Cingulum slightly levorotatory, ca. ½ cingulum width offset, visible mainly dorsally and ventrally, but generally not laterally; formed of 2 parallel folds in autophragm. Sulcus shallow; extends nearly vertically from between terminal ends of cingulum to antapex, intersecting antapex between antapical horns. Archeopyle intercalary (Type 3I); opercular pieces (1a, 2a, and 3a plate equivalents) generally in place, but don't appear attached; 2a plate equivalent hexagonal in outline; 1a and 3a pentagonal.

Discussion: Characteristic features of T. pentagonum are the pentagonal outline, single wall layer, intercalary archeopyle (Type 3I), and broad blunt antapical processes.

Affinity: T. pentagonum is dissimilar from T. evittii Drugg 1967 by lacking a distinct endoblast and anterior and posterior pericoels. It is dissimilar from T. fragile Davey 1969 by possessing cingulum and sulcus in some specimens, and in being single layered.

Dimensions: Holotype - L x W, 67 x 49 um, apical horn length 9 um, left antapical horn length 8 um. Observed range (20 specimens measured): length 62-87 um, width 50-62 um, apical horn length 9-19 um, left antapical horn length 2-15 um, right antapical horn length 3-5 um. Wall layer, less than 1 um thick.

Occurrence: Navesink Formation, extremely rare to sparse. Greatest occurrence 217. Occurred in 8 samples.

Trithyrodinium striatum n. sp.

Pl. 10, figs. 15-20; pl. 13, figs. 7-8; pl. 14, figs. 10-11

Name derivation: Latin, striatus; striate. Referring to the striate markings on much of the inner body, especially within the cingulum.

Holotype: AJ-59, coords. R1.1,+5.0 (Pl. 10, figs. 15, 16).

Type locality: Atlantic Highlands, New Jersey.

Type stratum: Sandy Hook Member of Red Bank Sand.

Description: Cyst bilayered. Periblast thin, delicate, more or less draped around more solid, robust endoblast; pentagonal to angularly ovoidal in dorso-ventral outline; ovoidal in polar view; tapering linearly to convexly from cingulum to variable apex; tapering nearly linearly from cingulum to narrow, bluntly truncated, variable antapex. Apex may be rounded, but generally bears a short (up to 10 um long), broad to narrow-based, broadly V-shaped to slender and pointed apical horn. Antapex may be rounded, but generally is narrowly truncate, bearing a short (up to 6 um long), broadly conical to spike-like left antapical horn. Right antapical horn only indicated by widely-oblique deflection at right side of antapex. Periphragm smooth to faintly granular, irregularly wrinkled, longitudinally wrinkled in cingulum; nontabulated. Endoblast nearly circular in dorso-ventral outline; ovoidal in polar view; loosely fills periblast cavity, leaving a more or less continuous lateral, anterior, and posterior pericoel; anterior pericoel larger. Endoblast faintly granular, longitudinally wrinkled in cingulum; nontabulated. Cingulum reflected more or less equally on both periblast and endoblast; wide, well-developed; levorotatory with ca. 1½ cingulum width offset; bears close-set, vertical wrinkles (generally only present in cingulum). Sulcus reflected nearly equally on both periblast and endoblast; well-developed, extending nearly vertically from between

terminal ends of cingulum to antapical margin, terminating between antapical horn positions. Archeopyle intercalary (Type I/?3I). Operculum on endoblast compound, formed by removal of three plate equivalents appearing superficially to represent the 1a, 2a, and 3a. Close inspection reveals that the two outside plate equivalents (1a and ?3a) join together anterior of the triangular ?2a, separating the ?2a from the apical series. Operculum on periblast only observed with scanning electron microscopy; composed of 2a plate equivalent which is hexagonal.

Discussion: The most diagnostic feature is the unusual compound operculum on the endoblast. Superficially it appears to be composed of the 1a, 2a, and 3a plate equivalents; however, a detailed examination reveals an unusual and previously unreported relationship. By definition an anterior intercalary plate equivalent is positioned between the precingular and apical series; however, the ?2a plate equivalent on these specimens (see pl. 10, fig. 17) does not abut against the apical series. Instead, the 1a and ?3a join or meet anterior of the ?2a, separating it from the apical series. Thus, the 1a and ?3a are true anterior intercalary plate equivalents, but the ?2a is not. Further studies will have to be performed on a larger number of specimens to see how transitional this type of compound is with a standard tripartite operculum (Type 3I) of age-equivalent specimens. If this variation can be shown to be intraspecific, then the generic description of Trithyrodinium will need to be emended to include such variation. If this type compound operculum cannot be demonstrated

to be transitional with typical Trithyrodinium forms, then a series of complexities arise; namely, what should this ?2a plate equivalent be called (is it really intercalary, etc.), what type of compound operculum is this, and should a new genus be erected to accommodate such forms. For the present I am assuming that this variation is intraspecific, and am assigning these forms to Trithyrodinium.

Other diagnostic features are the wide, gaping archeopyle on the endoblast which occupies more than two thirds of the dorsal epitract; the sutural folds on both endoblast and periblast delineating the cingulum; and the striate to wrinkled ornamentation: scanning electron microscopy demonstrates these features to best advantage (pl. 13, figs. 7-8, ; pl. 14, figs. 10-11).

Dimensions: Holotype L x W: 87 x 74 um; wall layers, periphragm less than 0.5 um, endophragm ca. 1.5 um. Observed range (16 specimens measured): length 74-99 um, width 62-78 um.

Affinity: T. striatum is dissimilar from T. fragile Davey 1969 by lacking the crescentic markings, and by exhibiting well-marked cingulum and sulcus. It is dissimilar from T. suspecta Manum and Cookson 1964 by lacking the thick wall structure composed of rod-like elements.

Occurrence: Mount Laurel Sand, extremely rare: Navesink Formation, extremely rare to rare; Sandy Hook Member of Red Bank Sand, extremely rare to rare. Greatest occurrence, sample no. 232. Occurred in 24 samples.

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FOSSIL PLATES

EXPLANATION OF PLATES

All slides are stored in the Virginia Polytechnic Institute and State University Palynology Laboratory (VPISUPL). Specimens are coordinated in millimeters to the right (R) or left (L), and above (+) or below (-) a cross on the lower left hand corner of the cover slip (Example: R15.2;+10.0). Dimensions of specimens are designated as L X W. Microns are indicated by the symbol "u" following numbers (Example: 42u).

PLATE I

Figs. 1-4: Spiniferites ramuliferus (Deflandre 1937) n. comb. Two focus levels of 1 specimen. Fig. 1: Optical cross-sectional view. Fig. 4.: Dorsal view, showing precingular archeopyle (Type P) and sutural folds about archeopyle and cingular plate equivalents. Main body L X W: 54u X 47u; process lengths up to 25u. VPISUPL Sample 232, Slide AJ-45, Coords. R6.7;+17.0. Figs. 2-3: Two focus levels of 1 specimen. Fig. 2: Dorsal view, showing precingular archeopyle (Type P) and sutural folds about cingular plate equivalents. Fig. 3: Optical cross-sectional view, showing fused pairs of cingular processes. Main body L X W: 63u X 52u; process lengths up to 32u. VPISUPL Sample 236, Slide AJ-64, Coords. R14.3;+10.9.

Figs. 5-8: Coronifera oceanica (Cookson and Eisenack) Davey 1969 Different focus levels of 1 specimen. Fig. 5: Optical cross-sectional view. Fig. 6: Left-lateral view (focused part-way through specimen, showing combination archeopyle (Type $\overline{A}$a+P). Fig. 7: Left-lateral view (focused through specimen) showing rippled surface ornamentation and combination archeopyle (Type $\overline{A}$a+P). Fig. 8: Right-lateral view showing surface with sutural folds connecting processes. Main body L X W: 50u X 44u; process length up to 26u; antapical process 21u. VPISUPL Sample 230, Slide AJ-37, Coords. R11.2;+11.0.

Figs. 9-10: Cyclonephelium cf. C. densebarbatum Cookson and Eisenack 1960. Two focus levels of 1 specimen. Fig. 9: Optical cross-sectional view showing uniform, flattened distal tips of processes. Fig. 10: High focus showing peritabular spines delineating plate equivalents on epitract near apical archeopyle (Type $\bar{A}$). Main body length (not including apex) 56u, width 57u; process length up to 14u. VPISUPL Sample 216, Slide AI-65, Coords. R6.8;+11.2.

Figs. 11-15: Conneximura fimbriata (Morgenroth, 1966) n. gen., n. comb. Fig. 11: High focus ventral view showing angular outline of sulcus, which extends nearly from apex to antapex. Main body L X W: 60u X 55u; process lengths up to 16u. VPISUPL Sample 236, Slide A5-69, Coords. R19.4;+8.9. Figs. 12-15: Different focus levels of 1 specimen. Fig. 12: Optical cross-sectional view showing large apical spine and cross section of inwardly collapsed operculum (bearing intratabular, fimbriate process). Figs. 13,14: Dorsal view showing Archeopyle (Type P) and fimbriate wall network. Fig. 15: Sub-ventral view (focused through specimen) showing large, fimbriate, antapical process. Main body L X W: 53u X 51u; process lengths up to 18u. VPISUPL Sample 234, Slide AJ-69, Coords. R4.8;+7.8.

Figs. 16-17: Diphyes colligerum (Deflandre and Cookson, 1955) Davey and Williams 1966. Two focus levels of 1 specimen. Fig. 16: Optical cross-sectional view. Fig. 17: High focus showing processes arranged in 5 rows. Main body L X W: 31u X 31u; process lengths up to 14u. VPISUPL Sample 236, Slide AJ-68, Coords. L2.4;+11.0.

Figs. 18-20: Diphyes recurvatum n. sp. HOLOTYPE; Different focus levels. Fig. 18: Optical cross-sectional view. Fig. 19: Medium high focus showing large antapical process and hollow processes with distally closed and recurved tips. Fig. 20: Focused through specimen showing processes arranged in rows. Main body L X W: 35u X 35u; process lengths up to 16u. VPISUPL Sample 216, Slide AI-65, Coords. R14.3;+5.9.

Plate 1

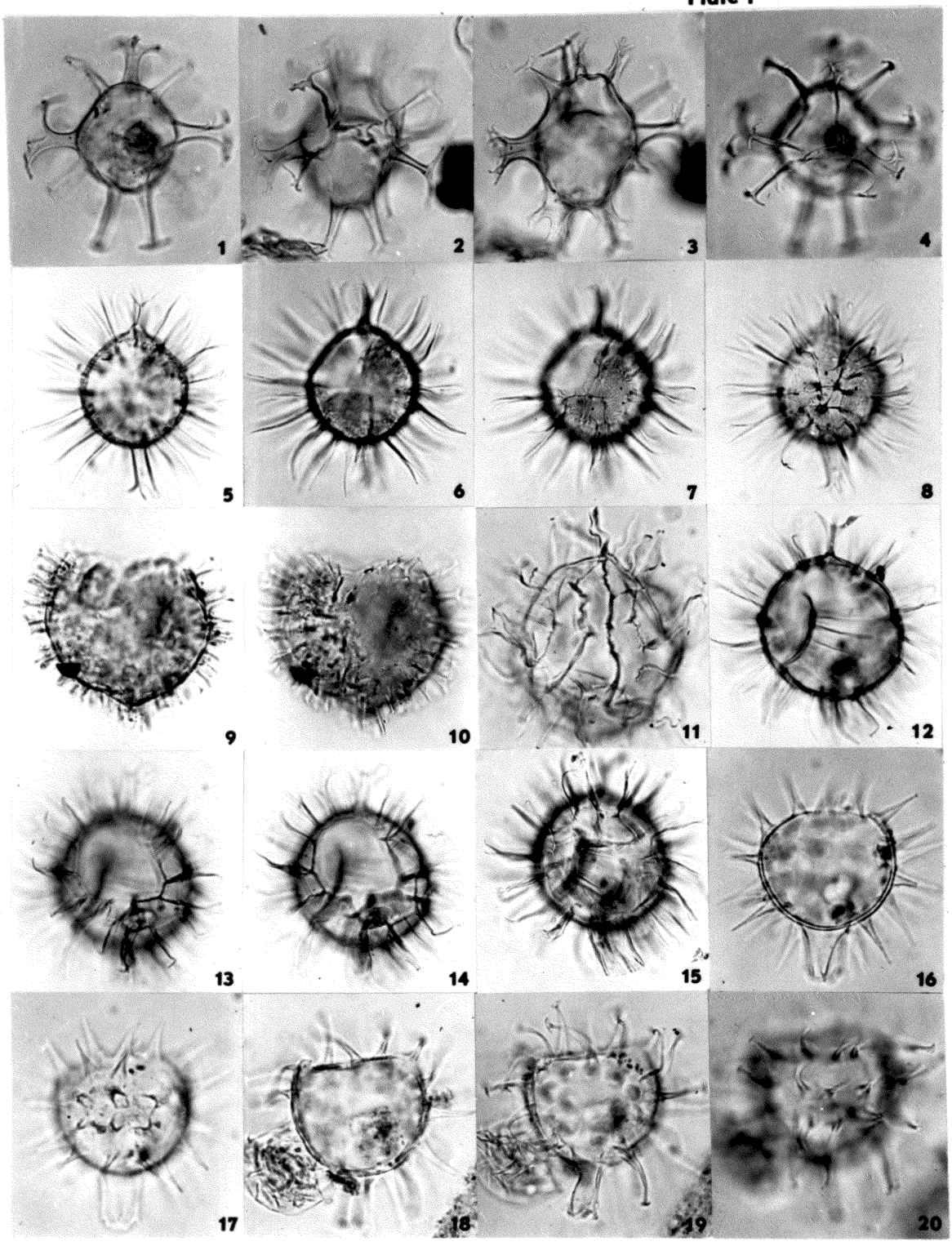


PLATE 2

Figs. 1-2: Cannonsphaeropsis utinensis O. Wetzel emend. Fig. 1: Optical cross-sectional view showing processes attached to main body at apex and antapex, and periphery of trabeculate network. Main body L X W: 51u X 44u; outer diameter (equatorially across trabeculae) 92u. VPISUPL Sample 208, Slide AI-27, Coords. R1.9;+9.9. Fig. 2: Detailed view of trabeculate network and small, thorny spines on the trabeculae (measure up to 5u): VPISUPL Sample 207, Slide AI-25, Coords. R12.9;+10.5.

Fig. 3: Cannosphaeropsis cf. C. pusulosa Morgenroth 1966. Optical cross-sectional view showing complex network of spines and trabeculae. Main body L X W: 43u X 39u; outer diameter up to 87u. VPISUPL Sample 218, Slide AJ-77, Coords. R18.3;+1.1.

Figs. 4, 7, 8: Cordosphaeridium varians n. sp. HOLOTYPE; different focus levels. Fig. 4: Dorsal view (focused through specimen) showing precingular archeopyle (Type P) with operculum in place. Fig. 7: Ventral view showing sulcal processes and fibrous nature of cyst. Fig. 8: Optical cross-sectional view showing process shapes and irregular distal edges of processes. Main body L X W: 87u X 83u; process lengths up to 32u. VPISUPL Sample 209, Slide AI-32, Coords. R15.2;+15.2.

Figs. 5-6: Cordosphaeridium fibrospinosum Davey and Williams 1966. Two focus levels of 1 specimen. Fig. 5: Left-lateral view showing precingular archeopyle (Type P). Fig. 6: Optical cross-sectional view showing operculum (on inside) bearing a single, intratabular process. Main body L X W: 83u X 87u; process lengths up to 25u. VPISUPL Sample 210, Slide AI-40, Coords. R5.2;-1.6.

Figs. 9-12: Exochosphaeridium bifidum (Clarke and Verdier, 1967) Clarke et al. 1968. Figs. 9-11: Different focus levels of 1 specimen. Fig. 9: Ventral view focused through specimen. Fig. 10: Optical cross-sectional view showing variability in process development. Fig. 11: Dorsal view showing precingular archeopyle (Type P) and apical process grouping (complex tuft). Main body L X W: 62u X 62u; process lengths up to 21u. VPISUPL Sample 227, Slide AJ-21, Coords. R10.7;+4.0. Fig. 12: Optical cross-sectional view of typical E. bifidum showing slender processes, as compared to the highly variable processes seen in figs. 9-11. Main body L X W: 58u X 53u; process lengths up to 16u. VPISUPL Sample 227, Slide AJ-23, Coords. R4.2;+16.5.

Figs. 13-16: Spinitectulum ramulus n. gen., n. sp. Fig. 13-14: HOLOTYPE; Different focus levels. Fig. 13: Right ventral view (focused through specimen). Fig. 14: Optical cross-sectional

view showing process outlines and combination archeopyle (Type $\bar{A}a+P$). Main body L X W: 51 um X 55 um; process lengths up to 23 um. VPISUPL Sample 215, Slide AI-61, Coords. R5.7; +11.0. Fig. 15: Apical view showing combination archeopyle (Type $\bar{A}a+P$). Number 3 precingular plate equivalent missing; apical series in place showing accessory sutures. Main body diameter 48 um; process lengths up to 21 um. VPISUPL Sample 215, Slide AI-61, Coords. R7.1; +16.4: Apical view showing combination archeopyle (Type $\bar{A}a+P$). Main body diameter 48 um; process lengths up to 21 um. VPISUPL Sample 214, Slide AI-58, Coords. R13.9; +4.8.

Figs. 17-20: Spinitectulum ferox n. gen., n. comb. Figs. 17, 19: Two different focus levels of 1 specimen. Fig. 17: Ventral view at high focus showing sutural folds bordering sulcus. Fig. 19: Slightly different focus showing outline of processes. Main body L X W: 44 um X 44 um; process lengths up to 15 um. VPISUPL Sample 236, Slide AJ-64, Coords. R7.5; +12.2. Fig. 18: Left hypotract at high focus showing base of sulcus, 1''', pls, 1p, and 1''''processes. Main body diameter 44 um; process lengths up to 16 um. VPISUPL Sample 234, Slide AJ-59, Coords. R7.2; +6.9. Fig. 20: View of combination archeopyle (Type $\bar{A}a+P$) (focused through specimen); 3'' plate equivalent is missing, apical series in place, but showing accessory sutures. Main body diameter 44 um; process lengths up to 21 um. VPISUPL Sample 230, Slide AJ-36, Coords. R4.8; +9.0.

Plate 2

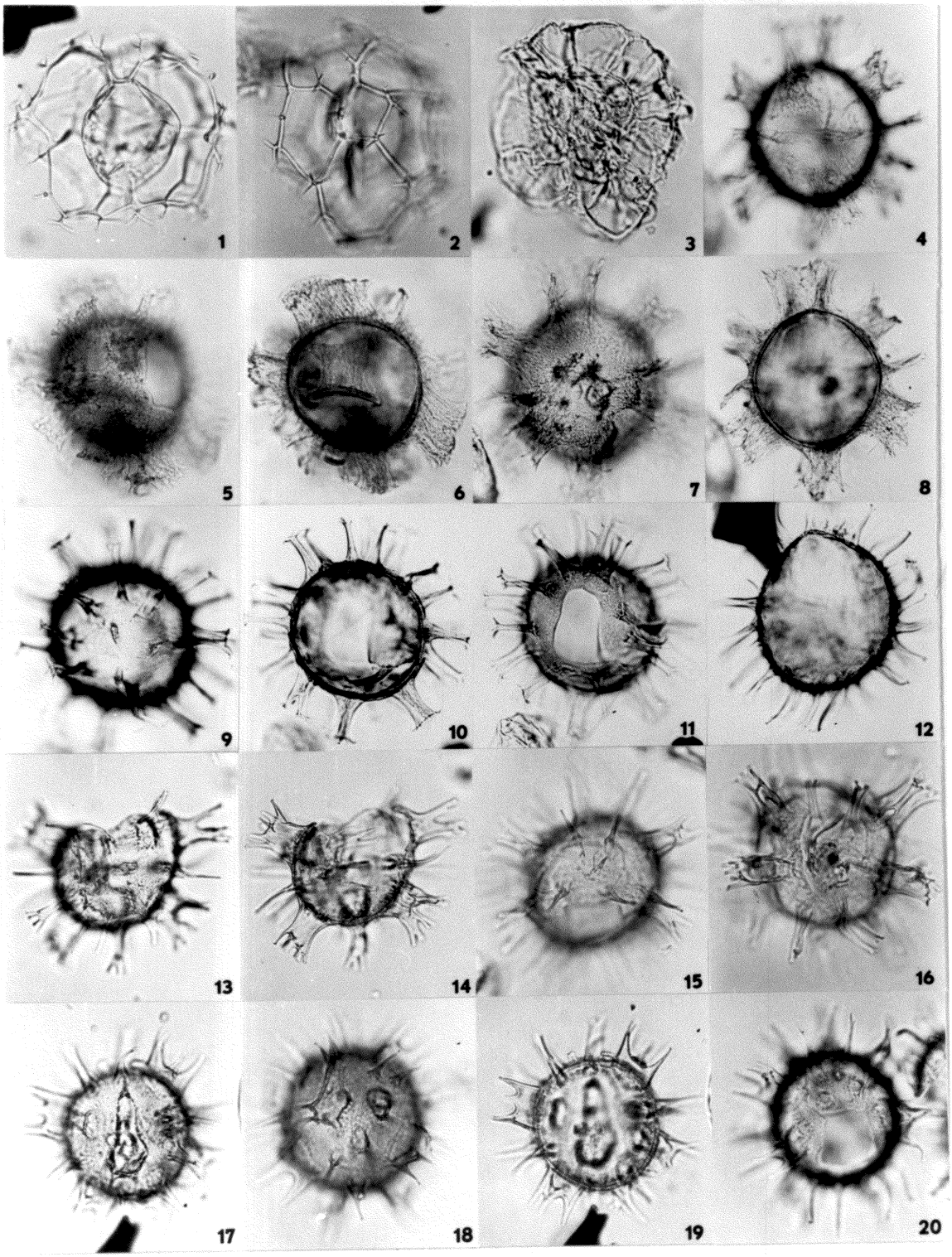


PLATE 3

Figs. 1-5: Diversispina truncata n. gen., n. sp. HOLOTYPE; Figs. 1, 2, 4, and 5: Different focus levels. Fig. 1:Ventral view (high focus) showing sulcal processes. Fig. 2: Optical cross-sectional view. Fig. 4: Detailed view of one process (25u long). Fig. 5: Detailed view of another process (25u long) shows degree of variability among processes. Main body L X W: 60u X 55u; process length up to 25u. VPISUPL Sample 236, Slide AJ-69, Coords. R4.6;+16.4. Fig. 3: Dorsal view (focused through specimen) showing precingular archeopyle (Type P) and 4 apical processes. Main body width 51u; process lengths up to 25u. VPISUPL Sample 236, Slide AJ-65, Coords. R7.8;+13.0.

Figs. 6-11: Hystrichokolpoma fenestrecona n. sp. HOLOTYPE; Figs. 6-8, 11: Different focus levels of 1 specimen. Fig. 6: Right lateral view showing reduced 6" process immediately to the lower left of the larger 5" process. Fig. 7: Optical cross-sectional view. Fig. 8: Left lateral view (focused through specimen) showing reduced cingular processes. Fig. 11: Detailed view of open process tips. Main body L X W: 38u X 30u; process lengths up to 23u. VPISUPL Sample 232, Slide AJ-46, Coords. R3.1;+17.3. Fig. 9: Apical view showing apical archeopyle (Type $\bar{A}$, with operculum in place, bearing 3 apical processes. Transdiameter 32u; process lengths up

21u. VPISUPL Sample 234, Slide AJ-59, Coords. R6.2;+17.5. Fig. 10: Detailed apical view showing 3 apical processes. Process length (apical) ca. 14u. VPISUPL Sample 236, Slide AJ-68, Coords. R12.2;+8.3.

Figs. 12-14: Hystrichosphaeridium tubiferum (Ehrenberg) Davey and Williams 1966. Fig. 12: Apical view showing apical archeopyle (Type $\bar{A}$). Transdiameter 41u; process lengths up to 28u. VPISUPL Sample 237, Slide AJ-71, Coords. R3.4;+8.8. Fig. 13: Apical-ventral view showing sulcal notch and apical archeopyle (Type $\bar{A}$). Diameter 39u; process lengths up to 28u. VPISUPL Sample 237, Slide AJ-71, Coords. R3.4;+10.7. Fig. 14: Antapical view showing antapical process (1"") with pentagonal base, surrounded by a ring of postcingular processes. Long Diameter 50u; process lengths up to 45u. VPISUPL Sample 230, Slide AJ-37, Coords. R15.1;+9.2.

Figs. 15-17: Hystrichosphaeridium tubiferum var. brevispinum Davey and Williams 1966. Different focus levels of 1 specimen. Fig. 15: Right lateral view. Fig. 16: Optical cross-sectional view showing apical archeopyle (Type $\bar{A}$) and short processes. Fig. 17: Left lateral view (focused through specimen). Main body L X W: 44u X 39u; process lengths up to 18u. VPISUPL Sample 237, Slide AJ-75, Coords. R11.0;+7.7.

Figs. 18-20: Hystrichosphaeridium recurvatum (White) Davey and Williams 1966. Different focus levels of 1 specimen. Fig. 18: Apical view showing operculum in place bearing 4 apical processes. Fig. 19: Optical cross-sectional view. Fig. 20: Slightly different focus level showing recurved process tips. Transdiameter 35u; process lengths up to 35u. VPISUPL Sample 227, Slide AJ-22, Coords. R1.3;+2.8.

Plate 3

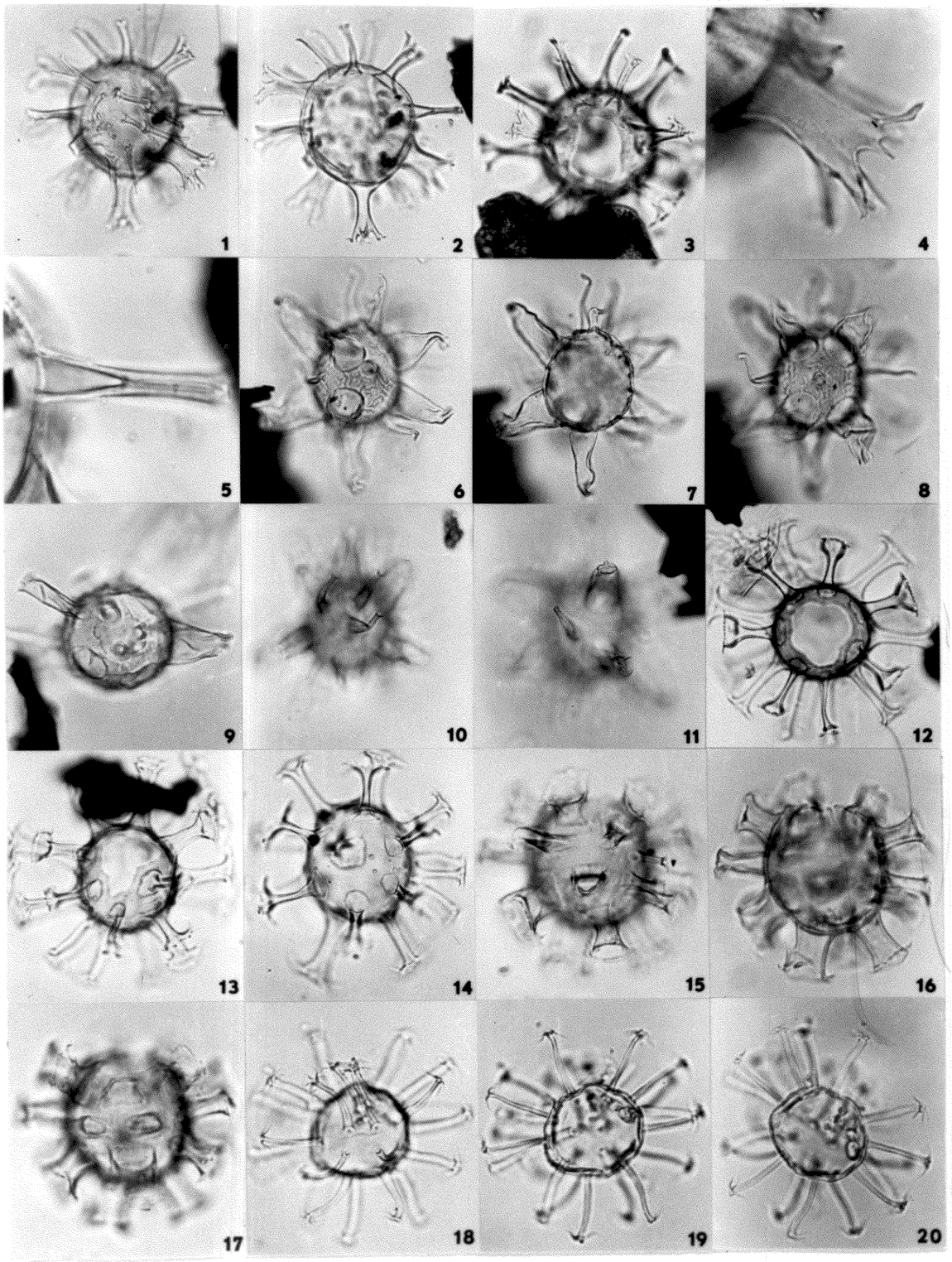


PLATE 4

Figs. 1-3: Prolixosphaeridium xanthiopyxides (O. Wetzel) Davey et al. 1969. Fig. 1: Specimen showing apical archeopyle (Type $\overline{A}$) with operculum in place. Main body L X W: 41u X 22u; process lengths up to 14u. VPISUPL Sample 234, Slide AJ-57, Coords. R16.6;+14.6. Figs. 2-3: Different focus levels of 1 specimen. Fig. 2: Optical cross-sectional view showing spine density and apical archeopyle (Type $\overline{A}$) with operculum missing. Fig. 3: Focused through specimen showing spine arrangement in rows. Main body L X W: 44u X 23u; process lengths up to 16u. VPISUPL Sample 211, Slide AI-41, Coords. R3.5;-1.7.

Figs. 4-6: Triblastula borussica (Eisenack 1954) Morgenroth 1966. Fig. 4: Left lateral view of epitract showing precingular archeopyle (Type P), sutural folds, and apical nipple. Main body diameter 48u. VPISUPL Sample 210, Slide AI-36, Coords. R5.5;+3.4. Figs. 5-6: Different focus levels of 1 specimen. Fig. 5: Right lateral view showing sutural folds and antapical box. Fig. 6: Optical cross-sectional view showing ventrally directed apical box. Main body L X W: 55u X 46u; process lengths up to 18u. VPISUPL Sample 212, Slide AI-50, Coords. R5.1;+7.8.

Figs. 7-8: Spiniferites ramosus (Ehrenberg) Loeblich and Loeblich 1966 var. granosus Davey and Verdier 1971. Two different views of 1 specimen. Fig. 7: Right lateral view. Fig. 8: Detailed view of

surface ornamentation. Main body L X W: 53u X 48u; process lengths up to 23u. VPISUPL Sample 234, Slide AJ-54, coords. R1.6;+17.9.

Fig. 9: Spiniferites ramosus (Ehrenberg) Loeblich and Loeblich 1966 var. multibrevis Davey and Williams 1966. Dorsal view showing precingular archeopyle (Type P). Main body L X W: 44u X 37u; process lengths up to 14u. VPISUPL Sample 214, Slide AI-55, Coords. R17.8;+16.9.

Figs. 10, 14-16: Spiniferites cf. S. septatus (Cookson and Eisenack) McLean 1971. Different views of 1 specimen. Fig. 10: Optical cross-sectional view. Fig. 14: Right lateral view (focused through specimen) showing gonal and intergonal processes. Fig. 15: Optical cross-sectional view at slightly different focus level. Fig. 16: Detailed view of processes showing alveolar nature of processes. Main body L X W: 40u X 37u; process lengths up to 12u. VPISUPL Sample 234, Slide AJ-59, Coords. R11.1;+6.0.

Figs. 17-18: Spiniferites supparus Drugg 1967. Two different focus levels of 1 specimen. Fig. 17: Optical cross-sectional view showing tubular processes. Fig. 18: Dorsal view (focused through specimen) showing sutural folds bordering plate equivalents and gonal processes. Main body L X W:38u X 37u; process lengths up to 9u. VPISUPL Sample 213, Slide AJ-51, Coords. R12.0;+6.6.

Figs. 19-20: Spiniferites ramosus (Ehrenberg) Loeblich and Loeblich 1966 var. reticulata Davey and Verdier 1971. Fig. 19: Left lateral view showing reticulate ornamentation. Main body L X W: 43u X 41u; process lengths up to 16u. VPISUPL Sample 206, Slide AI-16, Coords. R5.2;+6.7. Fig. 20: Dorsal view showing precingular archeopyle (Type P). Main body L X W: 55u X 43u; process lengths up to 18u (not including apical process). VPISUPL Sample 209, Slide AI-31, Coords. R5.1;+18.0.

Figs. 11-13: Spiniferites ramosus (Ehrenberg) Loeblich and Loeblich 1966 var. ramosus Davey and Verdier 1971. Three different views of same specimen. Fig. 11: Right ventral view (focused through specimen). Fig. 12: Optical cross-sectional view. Fig. 13: Left dorsal view. VPISUPL Sample 232, Slide AJ-46, Coords. R5.6;+10.5.

Plate 4

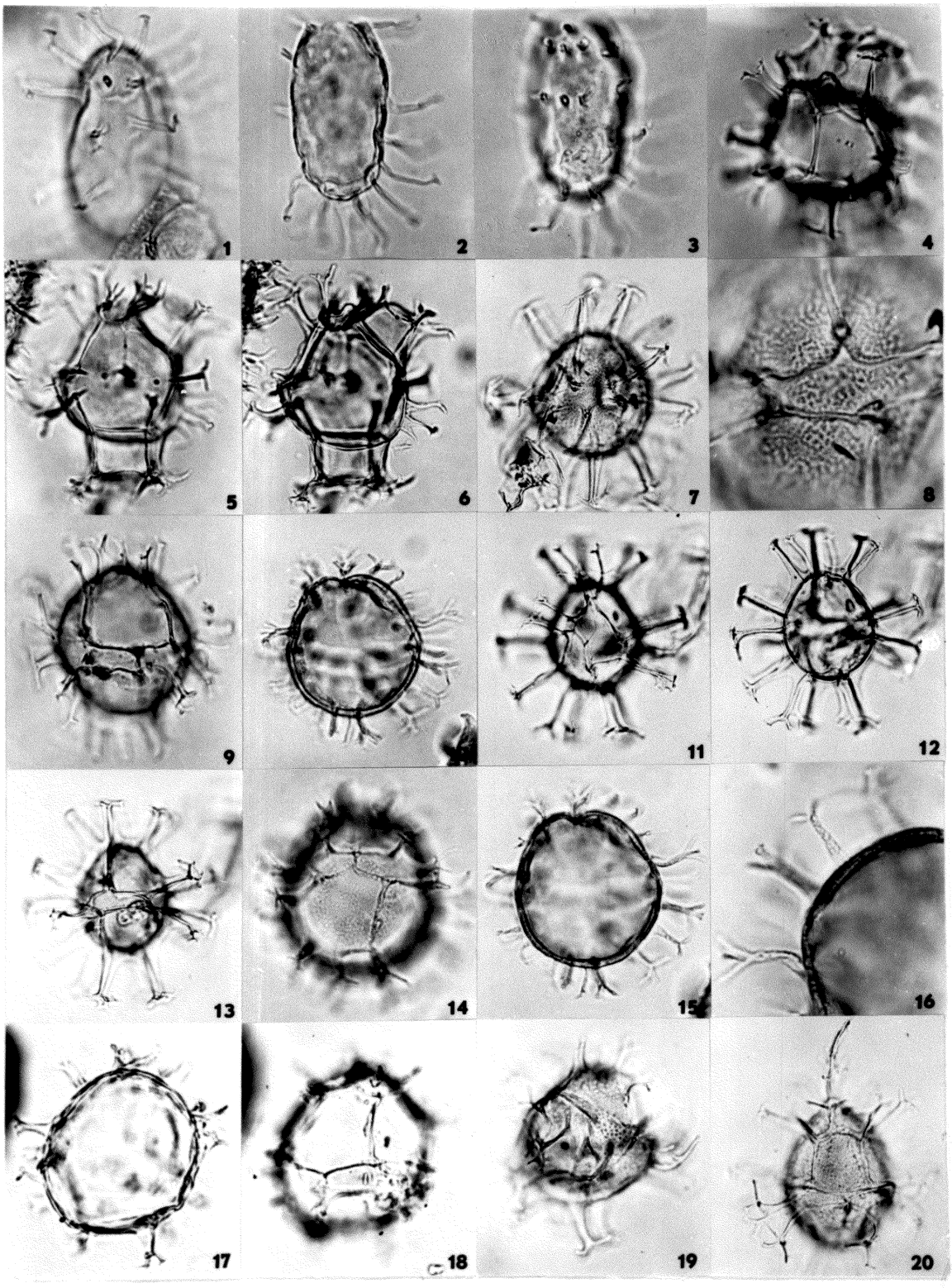


PLATE 5

Fig. 1-4: Apteodinium baculatum n. sp. HOLOTYPE; Fig. 1: Ventral view showing ventral tabulation and cingulum offset. Overall L X W: 53u X 44u. VPISUPL Sample 207, Slide AI-24, Coords. R5.3;+14.8. Figs. 2-4: Different focus levels of 1 specimen. Fig. 2: Optical cross-sectional view. Fig. 3: Dorsal view of baculate ornamentation (bacula up to 2u long). Overall L X W: 63u X 48u. VPISUPL Sample 208, Slide AI-30, Coords. R15.2;+4.4.

Figs. 5-8: Gonyaulacysta clathrata Cookson and Eisenack 1960. Different focus levels of 1 specimen. Fig. 5: Left ventral view showing nature of tabulation (focused through specimen). Fig. 6: Optical cross-sectional view showing clathrate ornamentation (clathrate walls up to 5u high). Fig. 7: Right lateral view showing precingular archeopyle (Type P) and clathrate ornamentation reflecting tabulation. Overall L X W: 97u X 81u. VPISUPL Sample 208, Slide AI-30, Coords L0.3;+8.6. Fig. 8: Detailed view showing clathrate ornamentation (clathrate walls measure ca. 4u high). VPISUPL Sample 207, Slide AI-24, Coords. R11.1;+16.6.

Figs. 9-12: Gonyaulacysta wetzeli (Lejeune-Carpentier) Sarjeant 1969. Figs. 9, 12: Two different focus levels of 1 specimen. Fig. 9: Ventral view showing sulcus, cingulum offset, and plate equivalents of ventral hypotract. Fig. 12: Dorsal view (focused through specimen) showing precingular archeopyle (Type P) and apical horn (ca. 14u long).

Overall L X W: 94u X 76u. VPISUPL Sample 207, Slide AI-22, Coords R7.1;+8.5. Figs. 11-12: Two different focus levels of 1 specimen. Fig. 11: Right lateral view (focused through specimen) showing banding between plate equivalents. Fig. 12: Left lateral view. Overall L X W: 104u X 76u; apical horn 25u. VPISUPL Sample 207, Slide AI-25, Coords. R5.1;+10.7.

Fig. 13: Gonyaulacysta sp. Ventral view showing cingulum offset and sulcus. Archeopyle (Type P) is visible and operculum is in place. Overall L X W: 127u X 97u. VPISUPL Sample 222, Slide AI-95, Coords. R5.7;+4.1.

Figs. 14-15: Triblastula nuda O Wetzel 1961. Two different focus levels of 1 specimen. Fig. 14: Optical corss-sectional view showing indentation at cingulum and also tripartite nature of cyst. Fig. 15: Dorsal view (focused through specimen) showing precingular archeopyle (Type P) and contact line of periphragm and endophragm about the equatorial zone. Overall L X W: 101u X 60u. VPISUPL Sample 237, Slide AJ-70, Coords. R3.0;+10.8.

Figs. 16-20: Leptodinium cristatum n. sp. HOLOTYPE; Figs. 16, 19: Two different focus levels. Fig. 16: Ventral view (focused through specimen) showing sutural crests bordering all plate equivalents except those within the sulcal area. Fig. 19: Dorsal view showing precingular archeopyle (Type P). Overall L X W: 53u X 51u. VPISUPLE Sampel 224, Slide AJ-5, Coords, R2.5;+8.0.

Fig. 17: Ventral view (focused through specimen) showing antapical plate equivalent 1"" and posterior intercalary plate equivalent 1p. Overall length 53u. VPISUPL Sample 207, Slide AI-24, Coords. R6.1;+1.3. Figs. 18, 20: Two different focus levels of 1 specimen. Fig. 18: Optical corss-sectional view showing height of crests (ca. 7u). Fig. 20: Apical view showing incomplete suture development in apical series and 3 apical plate equivalents. Transdiameter 51u. VPISUPL Sample 222, Slide AI-95, Coords. R10.9;+7.4.

Plate 5

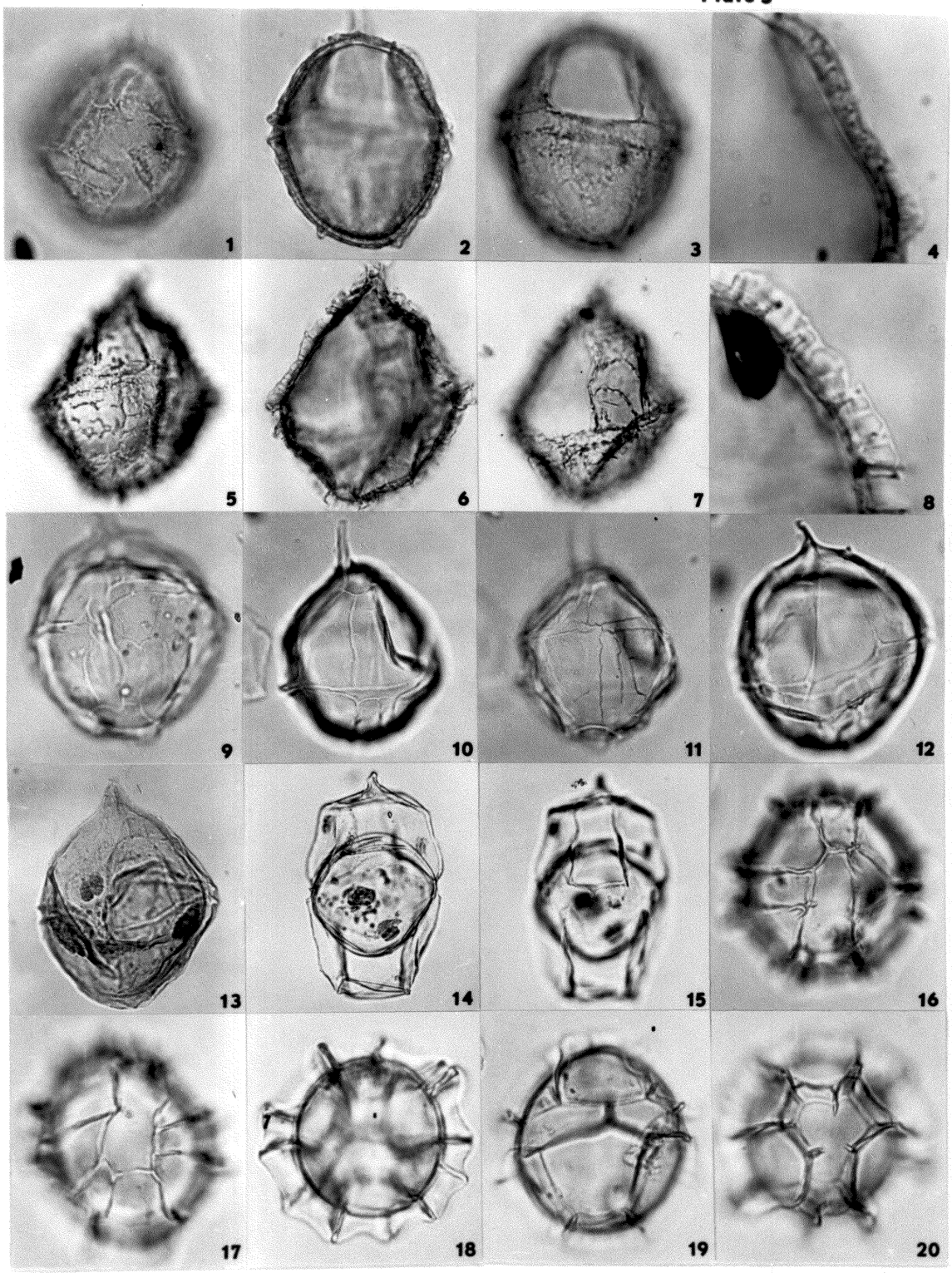


PLATE 6

Figs. 1-5: Samlandia angustivela (Deflandre and Cookson 1955) Eisenack 1963. Figs. 1- 5: Different focus levels of 1 specimen. Fig. 1: Left ventral view showing rugulate surface ornamentation produced by alveolar periphragm. Fig. 2: Optical cross-sectional view showing alveolar periphragm. Fig. 3: Right dorsal view (focused through specimen) showing precingular archeopyle (Type P). Fig. 5: Detailed view of alveolar ornamentation (alveolae up to 9u high). Overall L X W: 76u X 28u. VPISUPL Sample 207, Slide AI-24, Coords. R11.5;+3.9. Fig. 4: Dorsal view showing precingular archeopyle (Type P). Overall L X W: 74u X 58u. VPISUPL Sample 209, Slide AI-31, Coords. R15.0;+9.6.

Figs. 6-8: Spongodinium delitiense (Ehrenberg) Deflandre 1936. Different focus levels of 1 specimen. Fig. 6: Ventral view. Fig. 7: Optical cross-sectional view showing alveolar ornamentation of periphragm. Fig. 8: Dorsal view (focused through specimen) showing precingular archeopyle (Type P). Overall L X W: 143u X 124u. VPISUPL Sample 208, Slide AI-30, Coords. R7.8;+10.8.

Figs. 9-10: Spongodinium sp. Two different focus levels os 1 specimen. Fig. 9: Dorsal view. Fig. 10: Optical cross-sectional view. Overall L X W: 87u X 90u. VPISUPL Sample 232, Slide AJ-45, Coords. R4.2;+4.2.

Figs. 11-12: Leptodinium cf. L. multiplexum Wall and Dale 1968. Two different focus levels of 1 specimen. Fig. 11: Dorsal view showing precingular archeopyle (Type P). Fig. 12: Optical cross-sectional view. Overall L X W: 55u X 58u. VPISUPL Sample 207, Slide AI-25, Coords. R3.1;+5.5.

Figs. 13-16: Triblastula utinensis O Wetzel 1933. Figs. 13-15: Different focus levels of 1 specimen. Fig. 13: Ventral view showing sutural folds indicating position of sulcus. Fig. 14: Optical cross-sectional view showing process arrangement on central portion of cyst. Fig. 15: Dorsal view (focused through specimen) showing precingular archeopyle (Type P). Overall L X W: 129u X 55u. Process arrangement L X W: 129u X 55u. Process length up to 21u. VPISUPL Sample 230, Slide AJ-36, Coords. R10.0;+15.4. Fig. 16: Left dorsal view showing sutural folds bordering plate equivalents and precingular archeopyle (Type P). Overall L X W: 101u X 46u, process length up to 5u. VPISUPL Sample 234, Slide AJ-54, Coords. R2.5;+4.3.

Figs. 17-20: Hystrichosphaeridium sp. Fig. 17: Left lateral view showing cushioned processes. Overall L X W: ca. 51u X 51u, process lengths up to 7u. VPISUPL Sample 207, Slide AI-23, Coords R2.8;+1.3. Figs. 18-20: Different focus levels of 1 specimen. Fig. 18: Ventral view showing sulcal processes. Fig. 19: Optical cross-sectional view showing process lengths. Fig. 20: Dorsal view. Main body L X W: 44u X 41u, process lengths up to 7u. VPISUPL Sample 234, Slide AJ-57, Coords. R17.3;+13.2.

Plate 6

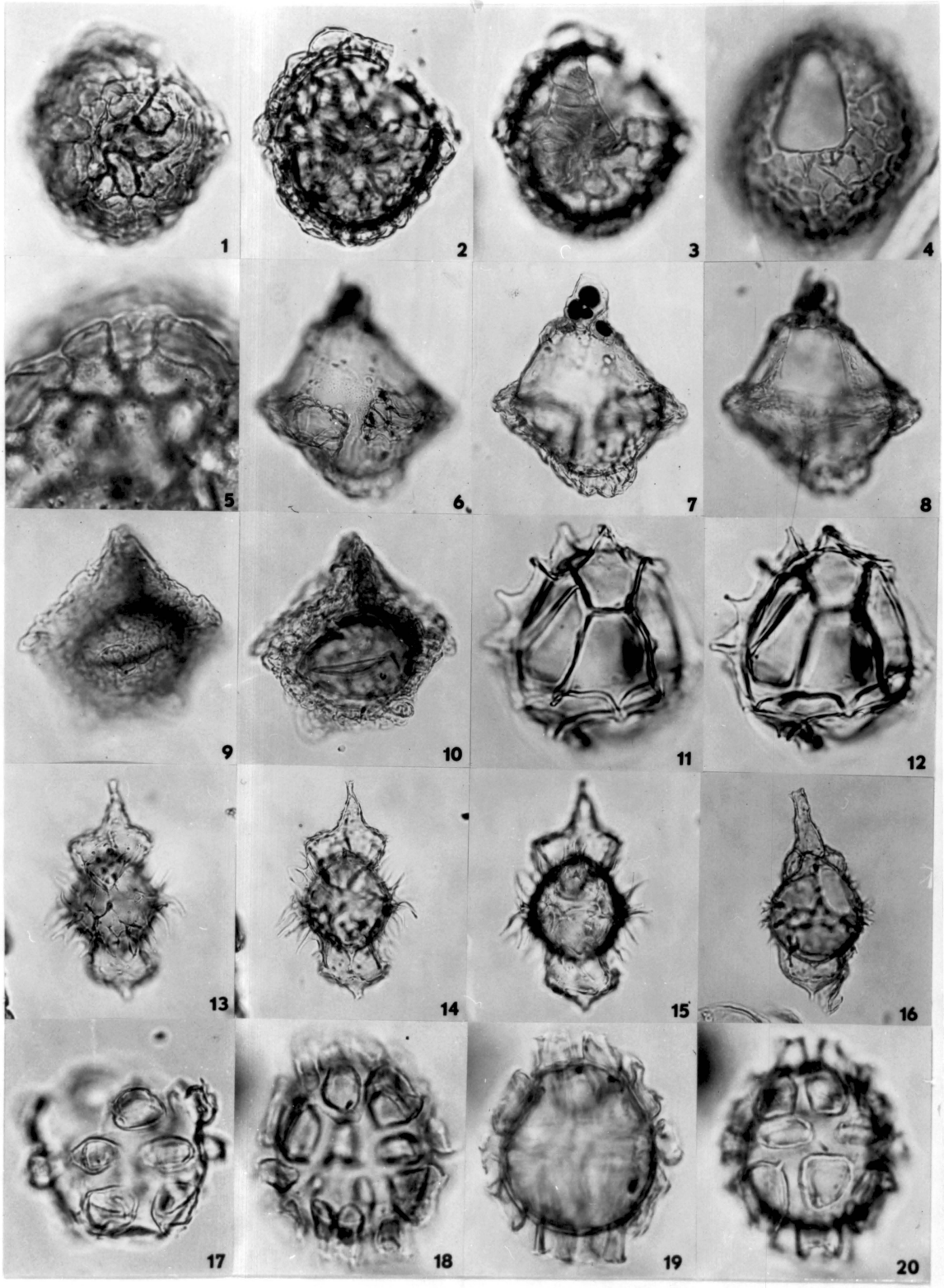


PLATE 7

Figs. 1-3: Oligosphaeridium complex (White) Davey and Williams 1966. Different focus levels of 1 specimen. Fig. 1: optical cross-sectional view showing the lack of cingular processes and apical archeopyle (Type $\overline{A}$). Fig. 2: Dorsal view (focused through specimen). Fig. 3: Distal ends of processes showing aculeate terminations. Main body L X W: 41u X 39u, process lengths up to 30u. VPISUPL Sample 232, Slide AJ-45, Coords. R4.2;+18.2.

Figs. 4-5: Conosphaeridium sp. Two different focus levels of 1 specimen. Fig. 4: View of broken specimen. Optical cross-sectional view showing conical processes. Main body L X W: 58u X 51u; process lengths up to 28u. VPISUPL Sample 222, Slide AI-96, Coords. R2.6;+2.0.

Figs. 6-7: Spinitectulum sp. Two different focus levels of 1 specimen. Fig. 6: Dorsal view showing combination archeopyle (Type $\overline{A}$a+P) and club-shaped processes bearing distal spines. Fig. 7: Optical cross-sectional view. Main body L X W: 56u X 44u; process lengths up to 23u. VPISUPL Sample 214, Slide AI-55, Coords. R15.2;+5.9.

Figs. 8-11: Systematophora placacantha (Deflandre and Cookson 1955) Davey et al. 1969. Fig. 8: Operculum showing 4 apical plate equivalents. VPISUPL Sample 234, Slide AJ-59, Coords. R4.0;+6.0. Figs. 9-10: Two different focus levels of 1 specimen. Fig. 9: Right lateral view showing peritabular sutural folds and processes. Fig. 10: Optical cross-sectional view. Main body L X W: 55u X 58u; process length up to 18u. VPISUPL Sample 232, Slide AJ-46, Coords. R9.4;+3.9. Fig. 11: Antapical view (focused through specimen) showing "jelly bean"-shaped antapical plate equivalent 1"", which is concave on the ventral side. Transdiameter 48u. VPISUPL Sample 234, Slide AJ-59, Coords. R7.4;+7.1.

Figs. 12-16: Systematophora varians n. sp. Figs. 12-14: Different focus levels of 1 specimen. Fig. 12: Ventral view. Fig. 13: Optical cross-sectional view showing length of peritabular spine arrangement and apical archeopyle (Type $\bar{A}$). Fig. 14: Dorsal view (focused through specimen). Main body L X W: 69u (not including simple free operculum) X 78u; spine lengths up to 18u. VPISUPL Sample 203, Slide AI-3, Coords. R8.5;+3.0. cross-sectional detailed view of reduced spines and trabeculae (spines up to 3u long). VPISUPL Sample 205, Slide AI-13, Coords. R10.6;+5.5. Fig. 16: Optical cross-sectional view showing spine groupings reduced to about 1u in length, illustrating the variability within this species. VPISUPL Sample 205, Slide AI-13, Coords. R16.6;+1.9.

Figs. 17-20: Areoligera sp.; illustrating the variety of forms observed in the Monmouth Group. All appear to be intergradational. Fig. 17: Ventral view showing thick network of trabeculae. Main body L X W: 64u X 85u, process lengths up to 51u. VPISUPL Sample 207, Slide AI-24, Coords. R7.0;+18.4. Fig. 18: Optical cross-sectional view showing membraneous processes. Main body L X W: 67u X 67u, process lengths up to 16u. VPISUPL Sample 207, Slide AI-24, Coords. L2.2;+15.1. Fig. 19: Optical cross-sectional view showing membraneous processes. Main body L X W: 69u X 67u, process lengths up to 41u. VPISUPL Sample 230, Slide AJ-37, Coords. R11.3;+18.9. Fig. 20: Optical cross-sectional view showing membraneous network about cyst circumference. Main body L X W: 133u X 120u (outer dimensions). VPISUPL Sample 212, Slide AI-46, Coords. R12.4;+7.0.

Plate 7

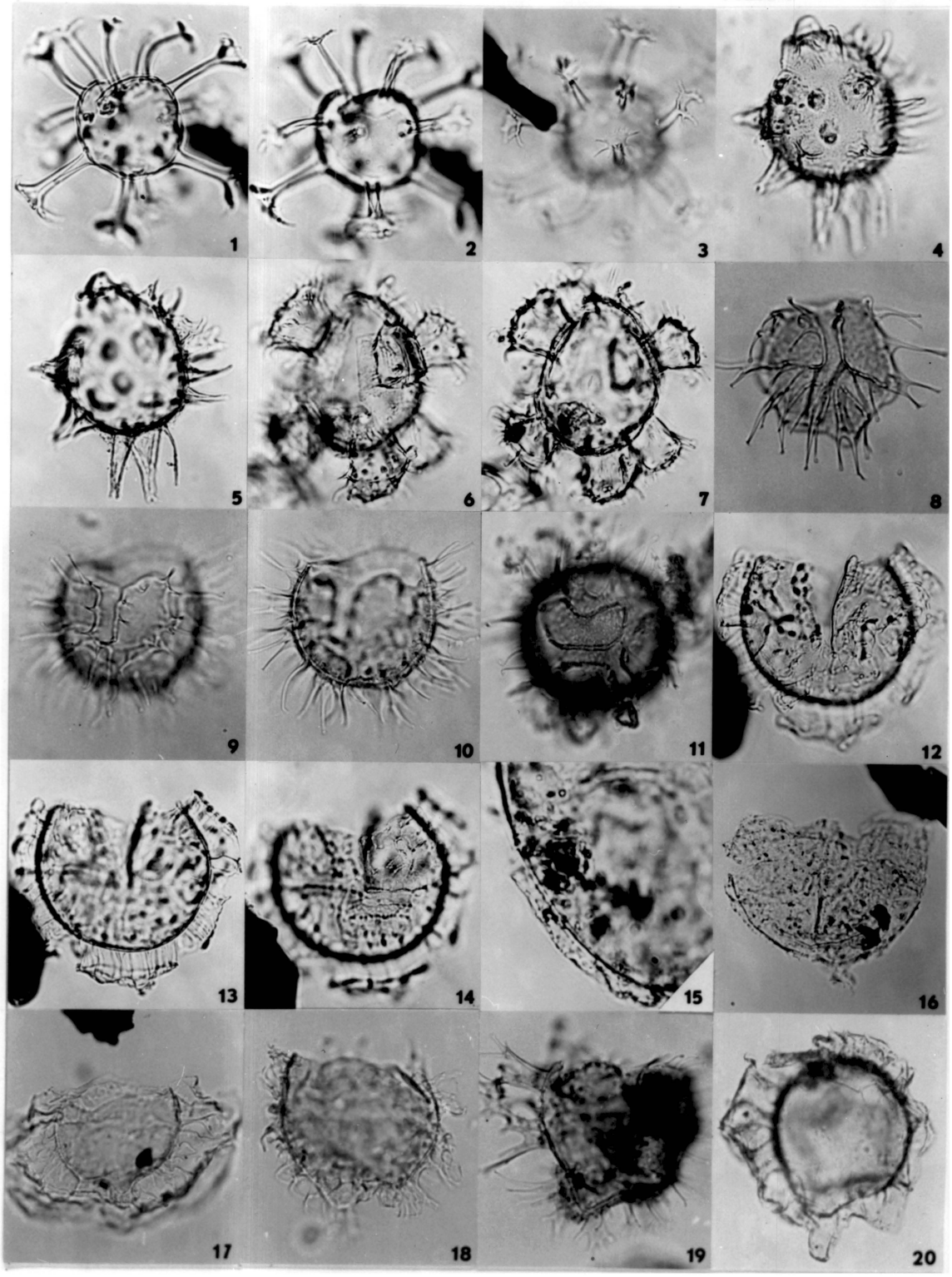


PLATE 8

Fig. 1: Deflandrea asymmetrica Wilson 1967. Optical cross-sectional view showing intercalary archeopyle (Type Ia/Ia). Overall L X W: 71u X 48u. VPISUPL Sample 214, Slide AI-55, Coords. R16.9;+16.2.

Fig. 2: Deflandrea cf. D. asymmetrica Wilson 1967. Optical cross-sectional view showing outline and anterior intercalary archeopyle (Type Ia). Overall L X W: 71u X 48u. VPISUPL Sample 214, Slide AI-55, Coords. R15.9;+10.6.

Fig. 3: Deflandrea cooksoni Alberti 1959. Optical cross-sectional view showing anterior intercalary archeopyle (Type I/-) and surface ornamentation of coarse granules. Overall L X W: 108u X 53u. VPISUPL Sample 230, Slide AI-36, Coords. R12.6;+6.6.

Fig. 4: Deflandrea cordifera n. sp. HOLOTYPE; Dorsal view showing anterior intercalary archeopyle (Type I/I) and weakly developed cingulum. Overall L X W: 136u X 55u. VPISUPL Sample 225, Slide AJ-11, Coords R11.1;+2.6.

Figs. 5-7: Deflandrea corrugatella n. sp. HOLOTYPE; Figs. 5, 7: Different focus levels of 1 specimen. Fig. 5: Ventral view showing well-marked cingulum and striations. Fig. 7: Dorsal view (focused through specimen). Overall L X W: 64u;+44u. VPISUPL Sample 207, Slide AI-24, Coords. R16.4;+12.7. Fig. 6: Optical cross-sectional view,

including a view of anterior intercalary archeopyle (Type Ia/-). Overall L X W: 74u X 48u. VPISUPL Sample 207, Slide AI-24, Coords. R13.3;+10.0.

Fig. 8: Deflandrea cf. D. cretacea Cookson 1956. Dorsal view shwoing anterior intercalary archeopyle (Type I/-). Overall L X W: 81u X 56u. VPISUPL Sample 232, Slide AJ-45, Coords. R17.6;+16.3.

Figs. 9-10, 15: Deflandrea diebeli subsp. rigida n. subsp. HOLOTYPE; Figs. 9, 15: Different focus levels. Fig. 9: Ventral view showing rigid, striate periblast. Fig. 15: Dorsal view (focused through specimen) showing anterior intercalary archeopyle (Type I/I). Overall L X W: 232u X 85u. VPISUPL Sample 234, Slide AJ-59, Coords. R10.5;+5.7. Fig. 10: Optical cross-sectional view showing expanded equatorial zone. Overall L X W: 264u X 92u. VPISUPL Sample 232, Slide AJ-46, Coords. R5.8;+8.1.

Figs. 11-12: Deflandrea magnifica Stanley 1965. Fig. 11: Ventral view (focused through specimen) showing narrow sulcus and slight levorotatory offset. Overall L X W: 92u X 92u. VPISUPL Sample 234, Slide AJ-54, Coords. R14.3;+18.3. Fig. 12: Dorsal view (focused through specimen) showing hexagonal-shaped anterior intercalary archeopyle (Type I/I) collapsed toward cingulum, appearing as precingular archeopyle (Type P). Overall L X W: 108u X 104u. VPISUPL Sample 237, Slide AJ-71, Coords. L1.8;+9.3.

Fig. 13: Deflandrea cf. D. obscura Drugg 1967. Optical cross-sectional view. Overall L X W: 62u X 55u. VPISUPL Sample 210, Slide AI-36, Coords. R18.5;+14.9.

Fig. 14: Deflandrea pannucea Stanley 1965. Optical cross-sectional view showing slight levorotatory offset of cingulum, a striate periblast, and an anterior intercalary archeopyle (Type Ia/Ia). Overall L X W: 97u X 62u. VPISUPL Sample 223, Slide AJ-1, Coords. R7.7;+4.5.

Figs. 17-18: Deflandrea speciosa Alberti 1959. Two different focus levels of 1 specimen. Fig. 17: Ventral view showing slight levorotatory offset of cingulum and diverging antapical horns. Fig. 18: Dorsal view (focused through specimen) showing large anterior intercalary archeopyle (Type I/I). Overall L X W: 127u X 78u. VPISUPL Sample 232, Slide AJ-45, Coords. R9.4;+8.8.

Fig. 16: Deflandrea diebeli Alberti 1959. Dorsal view. Overall L X W: 216u X 45u. VPISUPL Sample 209, Slide AI-32, Coords. R17.4;+15.0.

Plate 8

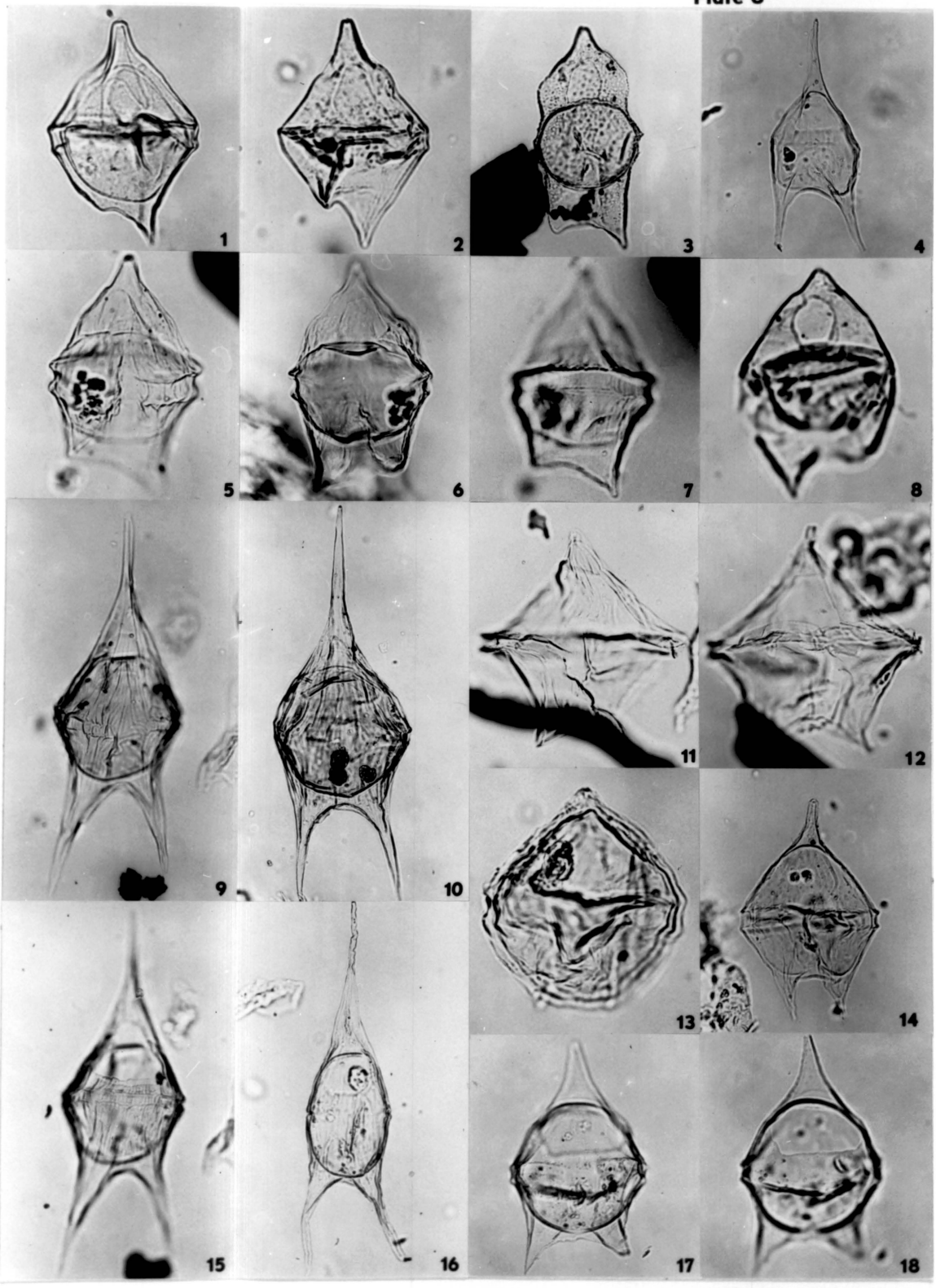


PLATE 9

Figs. 1-2: Deflandrea striata Drugg 1967. Fig. 1: Optical cross-sectional view showing expanded equatorial area, slight levorotatory offset of cingulum, and anterior intercalary archeopyle (Type I/I). Overall L X W: 143u X 74u. VPISUPL Sample 230, Slide AJ-36, Coords. R7.2;+4.2. Fig. 2: Detailed view of cingulum on dorsal surface showing denticulate margins. Cingulum width up to 9u. VPISUPL Sample 211, Slide Al-41, Coords. R15.0;+11.7.

Figs. 3-5: Deflandrea ornata n. sp. HOLOTYPE; Figs. 3-4: Different focus levels. Fig. 3: Left ventral view showing sulcus and interrupted cingulum. Fig. 4: Optical cross-sectional view showing extended left antapical horn. Overall L X W: 62u X 46u; spine length up to 5u. VPISUPL Sample 208, Slide AI-30, Coords. R14.2;+6.1. Fig. 5: Ventral view of specimen having only slight spine development, demonstrating degree of variability within the species. Overall L X W: 69u X 51u. VPISUPL Sample 207, Slide Ai-25, Coords. R15.1;+12.9.

Fig. 6: Deflandrea tripartita Cookson and Eisenack emend. Cookson and Manum 1964. Optical cross-sectional view showing tripartite nature of cyst and also anterior intercalary archeopyle (Type Ia/-). Overall L X W: 115u X 51u. VPISUPL Sample 216, Slide AI-65, Coords. R14.7;+15.0.

Fig. 7: Deflandrea cf. D. tripartita Cookson and Eisenack emend. Cookson and Manum 1964. Optical cross-sectional view showing trilayered cyst, bearing a mesoblast. Overall L X W: 120u X 55u. VPISUPL Sample 312, Slide AI-65, Coords. R10.5;+16.7.

Fig. 8: Deflandrea sp. B. Optical cross-sectional view. Overall L X W: 104u X 51u. VPISUPL Sample 215, Slide AI-60, Coords. R2.6;+10.7.

Fig. 9: Deflandrea sp. C. Optical cross-sectional view showing well-developed cingulum and enlarged left antapical horn. Overall L X W: 87u X 44u. VPISUPL Sample 217, Slide AI-70, Coords. R9.7;+16.0.

Fig. 10: Deflandrea sp. A. Dorsal view showing hexagonal anterior intercalary archeopyle (Type Ia/Ia). Overall L X W: 48u X 44u. VPISUPL Sample 210, Slide AI-36, Coords. R0.0;13.6.

Fig. 11: Deflandrea sp. D. Ventral view showing slight levoratory offset of singulum and broad sulcus. Overall L X W: 51u X 38u. VPISUPL Sample 207, Slide AI-25, Coords. R16.5;+15.5.

Fig. 12: Diconodinium rhombiformis Vozzhennikova 1967. Optical cross-sectional view showing short apical and antapical horns (each ca. 2.5u long) and broad cingulum. Overall L X W 35u. VPISUPL Sample 220, AI-84, Coords. R3.0;+6.5.

Fig. 13: Diconodinium sp. Optical cross-sectional view showing round outline of cyst and short apical and antapical horns. Overall L X W: 43u X 35u. VPISUPL Sample 207, Slide AI-25, Coords. R8.1;-2.2.

Figs. 14-15: Odontochitina costata Alberti 1961. Fig. 14: Optical cross-sectional view showing long apical and antapical horns (post-cingular horn out of focal plane), and apical archeopyle (Type A). Overall L X W: 281u (to top of broken apical horn) X 53u. VPISUPL Sample 203, Slide AI-5, Coords. R12.2;+15.4. Fig. 15: Isolated operculum. Length 150u. VPISUPL Sample 207, Slide AI-24, Coords. R13.2;-4.7.

Fig. 16: Palaeocystodinium australinum (Cookson) n. comb. Optical cross-sectional view showing equatorial folds indicating possible position of cingulum and long apical and antapical horns. Overall L X W: 207u X 67u. VPISUPL Sample 222, Slide AI-95, Coords. R12.2;+4.1.

Figs. 17, 21: Palaeocystodinium cf. P. denticulatum Alberti 1961. Two different focus levels of 1 specimen. Fig. 17: Optival cross-sectional view showing digitate apical horn and reduced antapical horn. Fig. 21: Dorsal view (focused through specimen) showing wide anterior intercalary archeopyle (Type I/I) and weakly developed cingulum. Sulcus is seen as a shadow. Overall L X W: 74u X 37u. VPISUPL Sample 231, Slide AJ-41, Coords. R0.3;+4.7.

74u X 37u. VPISUPL Sample 231, Slide AJ-41, Coords. R0.3;+4.7.

Figs. 18-20: Deflandrea spicata n. sp. HOLOTYPE; Fig. 19: Optical cross-sectional view showing 2 spike-like antapical horns and rhomboidal outline. Overall L X W: 166u X 90u. VPISUPL Sample 203, Slide AI-1, Coords. R3.7;+1717. Fig. 18: Ventral view (focused through specimen)showing well-developed cingulum and broad sulcus. Overall L X W: 173u X 90u. VPISUPL Sample 204, Slide AI-8, Coords. R14.4;+1.4. Fig. 20: Dorsal view showing granular surface ornamentation and faint outline of anterior intercalary archeopyle (Type Ia/-). Overall LX W: 207u X 99u. VPISUPL Sample 204, Slide AI-7, Coords. R15.7;+16.9.

Plate 9

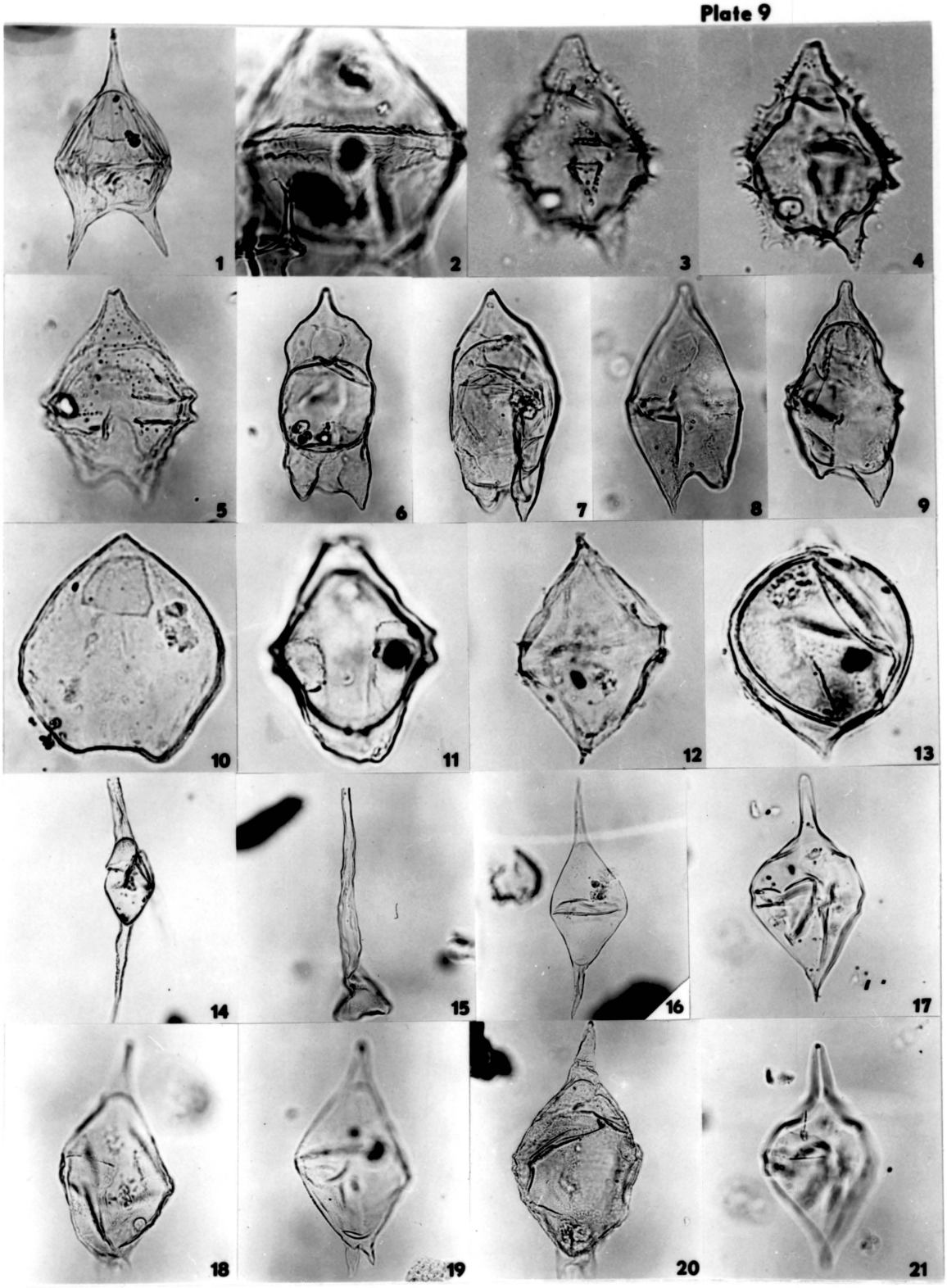


PLATE 10

Figs. 1-3: Palaeohystrichophora infusorioides Deflandre 1934. Figs. 1-2: Two different focus levels of 1 specimen. Fig. 1: Optical cross-sectional view showing hair-like spines. Fig. 2: Dorsal view (focused through specimen) showing well-marked cingulum. Overall L X W: 127u X 55u, spine length up to 6u. VPISUPL Sample 206, Slide AI-16, Coords. R10.1;+11.7. Fig. 3: Detailed view showing intratabular arrangement of hair-like spines. Width 67u. VPISUPL Sample 204, Slide AI-7. Coords. L2.2;+12.5.

Fig. 4: Phoberocysta ceratioides (Deflandre) Millioud 1969. Ventral view showing sulcus, antapical horn, 2 post-cingular processes, and an apical archeopyle (Type $\bar{A}$). Endoblast width 51u; length of apical horn 53u. VPISUPL Sample 207, Slide AI-24, Coords. R7.9;+14.1.

Figs. 5-7: Spinidinium uncinatum n. sp. HOLOTYPE; Fig. 5: Ventral view (focused through specimen) showing broad sulcus. Fig. 6: Optical cross-sectional view showing spine length (up to 2.5u). Fig. 7: Dorsal view showing peritabular spines. Overall L X W: 58u X 39u; spine length up to 2.5u. VPISUPL Sample 207, Slide AI-25, Coords. R0.4;2.6.

Figs. 8-10: Trithyrodinium cavum n. sp. HOLOTYPE; Figs. 8-9: Two different focus levels of 1 specimen. Fig. 8: Ventral view (focused through specimen) showing levorotatory cingulum, narrow sulcus, and

faint outline of anterior intercalary archeopyle (Type I/3I). Fig. 9: Dorsal view showing well-formed cingulum and antapical horn. Overall L X W: 127u X 69u. VPISUPL Sample 216, Slide AI-65, Coords. R2.4;+11.4. Fig. 10: Dorsal view showing tripartite anterior intercalary archeopyle on endoblast. Endoblast L X W: 64u X 62u. VPISUPL Sample 207, Slide AI-23, Coords. R5.0;+15.2.

Figs. 11-12: Trithyrodinium evittii Drugg 1967. Fig. 11: Optical cross-sectional view. Fig. 12: Dorsal view (focused through specimen) showing endoblast excystment aperture corresponding to 3 anterior intercalary plate equivalents. Overall L X W: 58u X 58u. VPISUPL Sample 218, Slide AI-77, Coords. R0.8;+16.3.

Figs. 15-20: Trithyrodinium striatum n. sp. HOLOTYPE: Figs. 15-16: Two different focus levels. Fig. 15: Ventral view (focused through specimen) showing parallel-sided sulcus and moderately offset cingulum. Fig. 16: Optical cross-sectional view showing complete pericoel. Overall L X W: 87u X 74u. VPISUPL Sample 234, Slide AJ-59, Coords. R1.1; 5.0. Fig. 17: Dorsal view showing dislodged anterior intercalary plate equivalents (1a, 2a, 3a) on the endoblast. Archeopyle is anterior intercalary (Type I/3I). Endoblast width 64u. VPISUPL Sample 232, Slide AJ-45, Coords. R13.5;+17.0. Figs. 18-20: Different focus levels of 1 specimen. Fig. 18: Ventral view of endoblast showing cingulum and sulcus. Fig. 19: Optical cross-sectional view showing apparent single layer of endoblast. Fig. 20: Dorsal view (focused through specimen) showing excystment aperture corresponding to 3 anterior intercalary plate equivalents and cingulum.

Overall L X W: 67u X 60u. VPISUPL Sample 216, Slide AI-65, Coords. R14.5;+15.2.

Figs. 13-14: Trithyrodinium pentagonum n. sp. HOLOTYPE. Fig. 13:Ventral view. Fig. 14: Dorsal-optical cross-sectional view. Overall L X W: 67u X 49u. VPISUPL Sample 221, Slide AI-90, Coords. R7.8;+6.9.

Plate 10

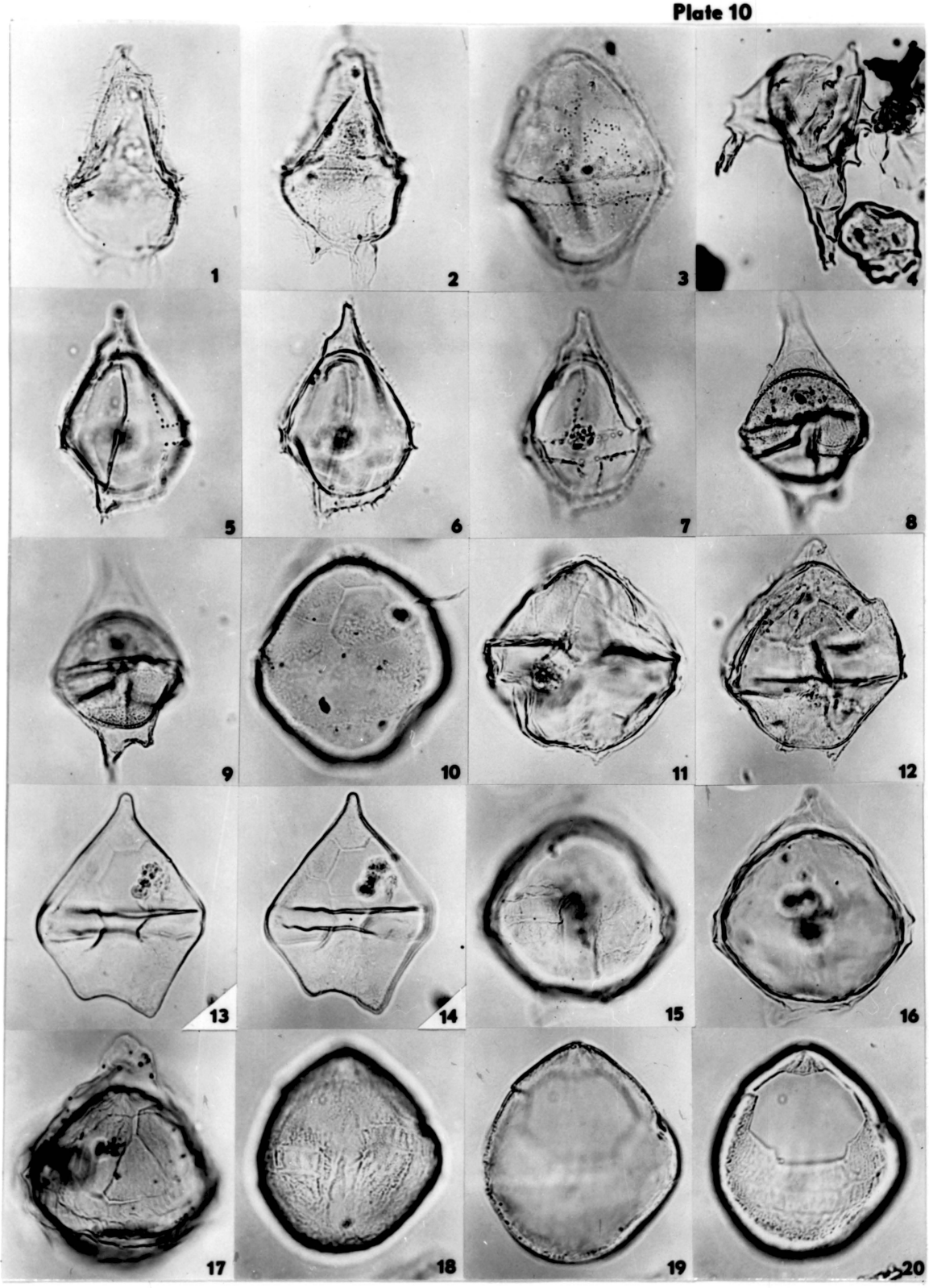


PLATE 11

Figs. 1-2: Dinogymnium elongatum n. sp. HOLOTYPE; Fig. 1: Optical cross-sectional view showing short epitract and long hypotract. Fig. 2: Detailed view of cingulum and epitract. Overall L X W: 304u X 28u. VPISUPL Sample 207, Slide AI-21, Coords. R6.9;+11.2.

Figs. 3-4: Dinogymnium lanceolatum n. sp. HOLOTYPE; Fig. 3: Optical cross-sectional view showing short lanceolate epitract and long hypotract. Fig. 4: Detailed view showing cingulum and epitract. Overall L X W: 175u X 18u. VPISUPL Sample 207, Slide AI-24, Coords. R12.0;+9.4.

Figs. 5-6. Dinogymnium euclaensis Cookson and Eisenack 1970. Two different focus levels of 1 specimen. Fig. 5: Ventral view (focused through specimen) showing costate epitract and smooth hypotract. Fig. 6: Dorsal view showing well-developed cingulum and near-equal size of epitract and hypotract. Overall L X W: 39u X 32u. VPISUPL Sample 214, Slide AI-55, Coords. R12.0;+8.6.

Fig. 7: Dinogymnium cf. D. euclaensis Cookson and Eisenack 1970. Ventral view showing epitract with well developed costae and hypotract with irregularly developed costae. Overall L X W: 37u X 32u. VPISUPL Sample 238, Slide AJ-76, Coords. R14.8;+17.6.

Figs. 8-11: Dinogymnium pustulicostatum n. sp. Fig. 8: Ventral view showing well-developed cingulum and sulcus. Overall L X W: 62u X 35u. VPISUPL Sample 204, Slide AI-7, Coords. R14.3;+11.8. Figs. 9-10: HOLOTYPE; Two different focus levels of 1 specimen. Fig. 9: Optical cross-sectional view showing bluntly rounded apex and antapex. Fig. 10: Dorsal view (focused through specimen) showing heterocostate ribbing mainly on hypotract. Overall L X W: 64u X 35u. VPISUPL Sample 204, Slide AI-8, Coords. R13.6;+19.2. Fig. 11: Right lateral view showing heterocostae best developed on hypotract. Overall L X W: 58u X 30u. VPISUPL Sample 204. Slide AI-8, Coords. R5.7;+2.1.

Figs. 12-16: Dinogymnium westralium (Cookson and Eisenack) Evitt et al. 1967 emend. Figs. 12-14: Different focus levels of 1 specimen. Fig. 12: Ventral view (focused through specimen) showing decreasing size of costae intersecting sulcus and apical archeopyle (Type Aa). Fig. 13: Optical cross-sectional view showing well-developed thorny antapical point. Fig. 14: Dorsal view showing well-developed cingulum. Fig. 15: Detailed view of epitract showing pustules aligned along sides of costae. Fig. 16: Detailed view of hypotract showing costae intersecting sulcus. Overall L X W: 64u X 39u. VPISUPL Sample 237, Slide AJ-73, Coords. R10.7;-0.4.

Fig. 17: Dinogymnium sp. A. Right lateral view showing much reduced epitract and large hypotract. Overall L X W: 173u X 58u. VPISUPL Sample 208, Slide AI-28, Coords. R7.8;+8.6.

Fig. 18: Dinogymnium sp. B. Ventral view of incomplete specimen. Width at cingulum 46u. VPISUPL Sample 211, Slide AI-41, Coords. R4.1;+0.9.

Fig. 19: Dinogymnium sp. C. Optical cross-sectional view showing bluntly rounded apex and antapex and weakly developed cingulum and sulcus. Overall L X W: 85u X 23u. VPISUPL Sample 219, Slide AI-79, Coords. R15.3;+12.1.

Fig. 20: Dinogymnium digitus (Deflandre) Evitt et al. 1967. Right lateral view showing costate hypotract and smooth epitract. Overall L X W: 78u X 25u. VPISUPL Sample 207, Slide AI-25, Coords. R9.0;+0.1.

Plate 11

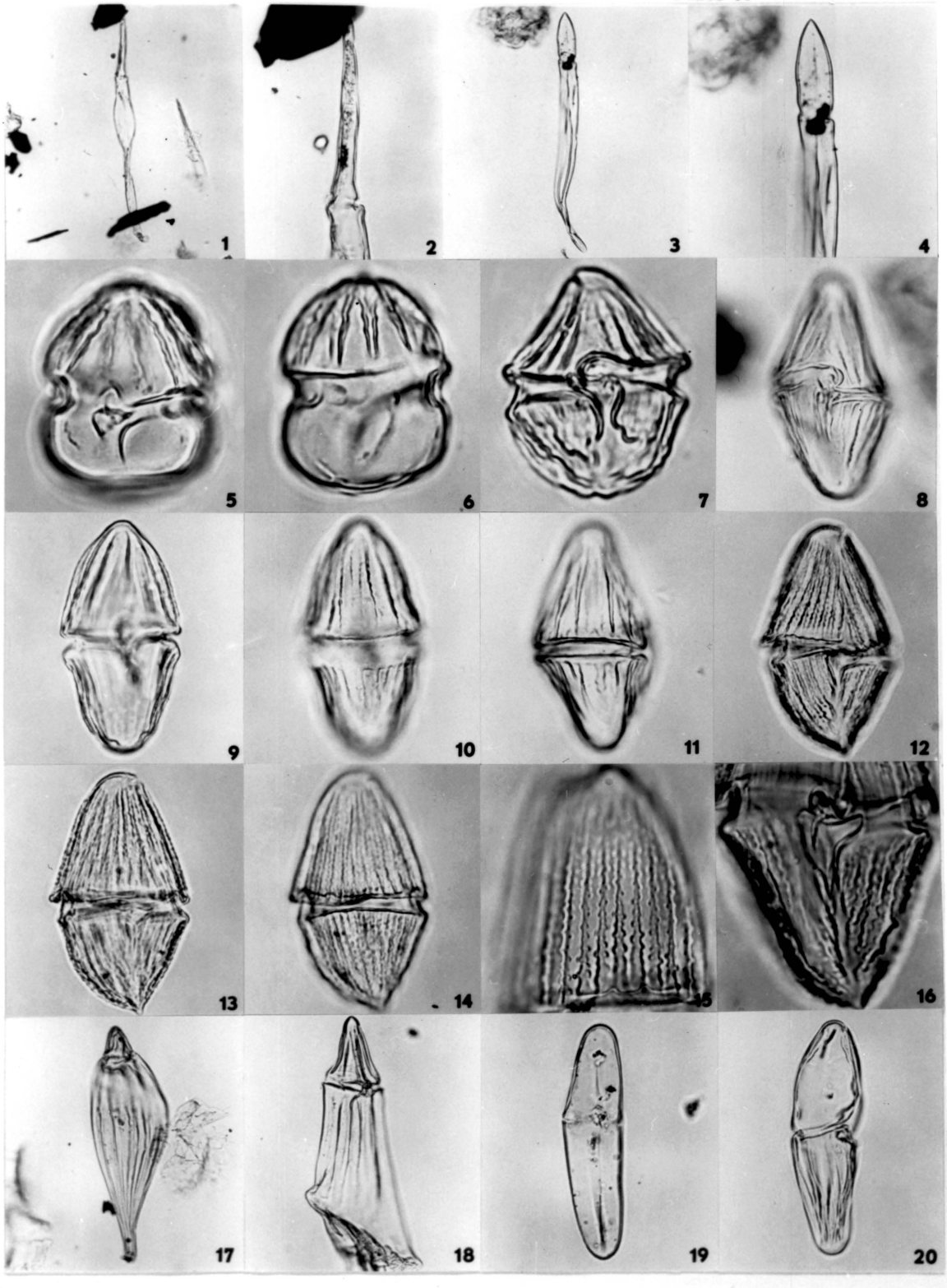


PLATE 12

Scanning electron micrographs of several Monmouth Group Specimens

Figs. 1-4: Dinogymnium westralium (Cookson and Eisenack) Evitt et al. 1967 emend. Fig. 1: Ventral view showing deeply incised costae, well-developed cingulum and sulcus, and antapical point. Specimen recovered from VPISUPL Sample 236. X870. Fig. 2: Right lateral view. VPISUPL Sample 236. X867. Fig. 3: Detailed view of apex showing apical archeopyle (Type Aa) and wall canals (measuring up to 0.2u). VPISUPL Sample 236. X3744. Fig. 4: Detailed view of mid-ventral area showing possible flagellar pore structures and wall canals on costae. VPISUPL Sample 236. X3343.

Figs. 5-6. Dinogymnium pustulicostatum n. sp. Fig. 5: Dorsal view showing well-developed heterocostae. VPISUPL Sample 205. X1000. Fig. 6: Detailed view of apex showing dense pustules and wall canals. Operculum has not been dislodged suggesting that the cell died before excysting. VPISUPL Sample 205. X4550.

Figs. 7-9: Spiniferites ramosus var. granosus Davey and Williams 1966. Fig. 7: Dorsal view showing precingular archeopyle (Type P) and gonally distributed processes. X790. Fig. 8: Detailed view of 1 plate equivalent showing high sutural folds and densely arranged granae. X2700. Fig. 9: Detailed view of granae showing

short chains of fused granae. X8700. VPISUPL Sample 234.

Fig. 10: Spiniferites ramosus var. ramosus (Ehrenberg) Davey and Verdier 1971. Right lateral view showing high sutural folds outlining plate equivalents and gonally distributed processes. Periphragm surface is smooth. VPISUPL Sample 209. X633.

Fig. 11: Exochosphaeridium bifidum (Clarke and Verdier) Clarke et al. 1968. Left lateral view showing coarsely fibrous periphragm and distally bifid to capitate processes. VPISUPL Sample 234. X600.

Fig. 12: Systematophora placacantha (Deflandre and Cookson) Davey et al. 1966 emend. Dorsal view showing intratabular sutural folds and processes. Archeopyle is apical (Type A). VPISUPL Sample 234. X660.

Plate 12

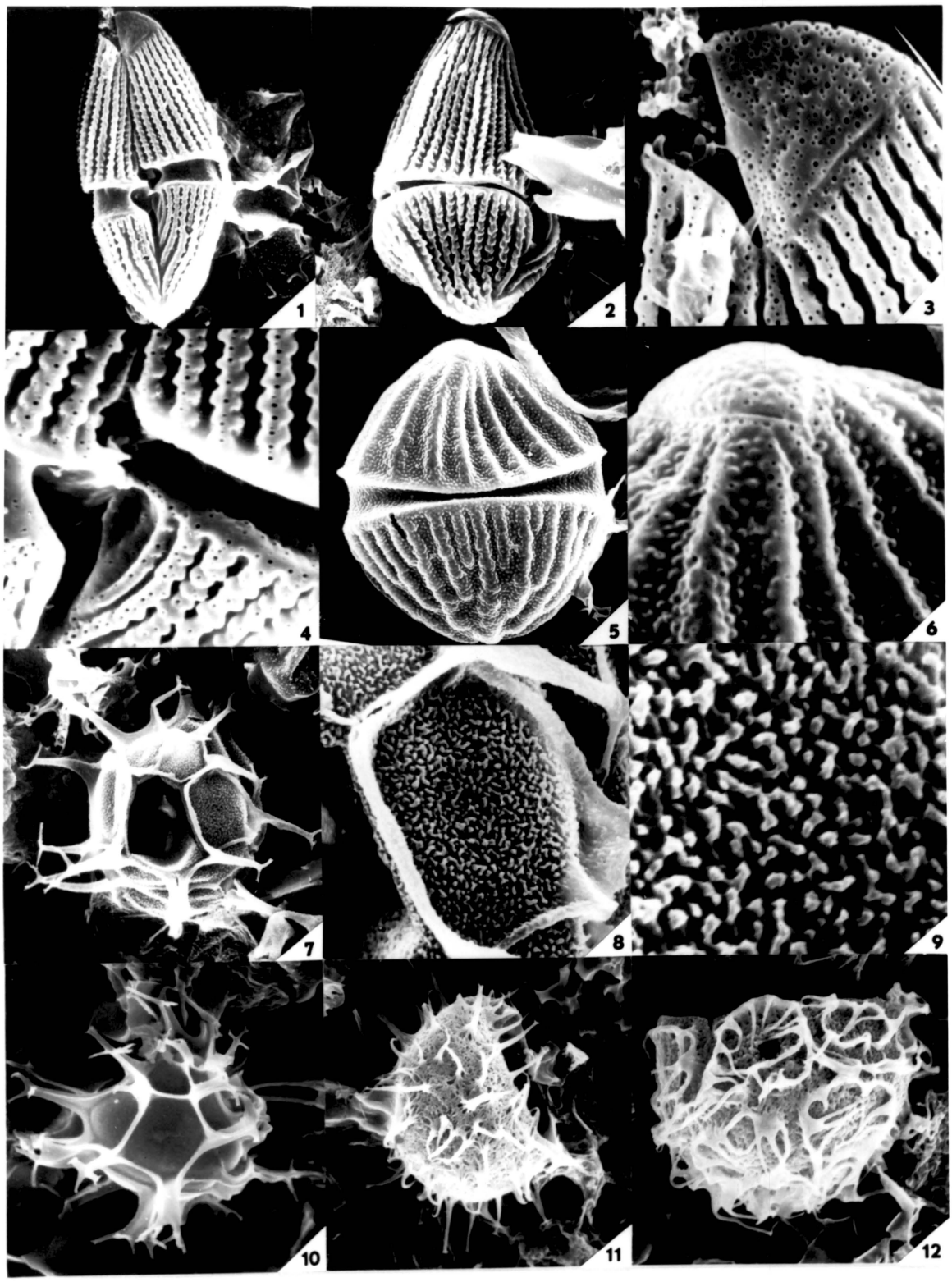


PLATE 13

Scanning electron micrographs of several Monmouth Group specimens

Fig. 1: Deflandrea cf. D. asymmetrica Wilson 1967. Ventral view. VPISUPL Sample 210. X750.

Fig. 2: Deflandrea cooksoni Alberti 1959. Dorsal view showing anterior intercalary archeopyle (Type Ia/-) and cingulum. VPISUPL Sample 207. X630.

Fig. 3: Deflandrea cf. D. cretacea Cookson 1956. Ventral view. VPISUPL Sample 234. X500.

Fig. 4: Deflandrea tripartita Cookson and Eisenack 1960 emend. Dorsal view showing anterior intercalary archeopyle (Type Ia/-). VPISUPL Sample 234. X475.

Fig. 5: Deflandrea diebeli Alberti 1959. Dorsal view showing deep longitudinal wrinkles in periphragm and anterior intercalary archeopyle (Type I/I). VPISUPL Sample 209. X270.

Fig. 6: Deflandrea sp. D. Ventral view showing sulcal depression extending from apex to antapex. VPISUPL Sample 207. X760.

Figs. 7-8: Trithyrodinium striatum n. sp. Fig. 7: Endoblast showing striate cingulum and broad tripartite artheopyle, corresponding to plate equivalents 1a, 2a, 3a. Fig. 8: Near-apical view showing tripartite anterior intercalary archeopyle. VPISUPL Sample 234. Both micrographs X900.

Figs. 9-10: Spinidinium uncinatum n. sp. Fig. 9: Ventral view showing plate equivalents outlined by sutural folds and distally-barbed spines. Note interrupted cingulum. X850. Fig. 10: Dorsal view showing interrupted cingulum on hypotract side of cingulum. Archeopyle anterior intercalary (Type Ia/Ia). X860. VPISUPL Sample 207.

Figs. 11-12: Spongodinium delitiense (Ehrenberg) Deflandre 1936. Fig. 11: Ventral view showing thick, loose, alveolar periphragm. X350. Fig. 12: Right lateral view showing precingular archeopyle (Type P) and long, nearly-tubular apical horn. X380. Both specimens from VPISUPL Sample 209.

Plate 13

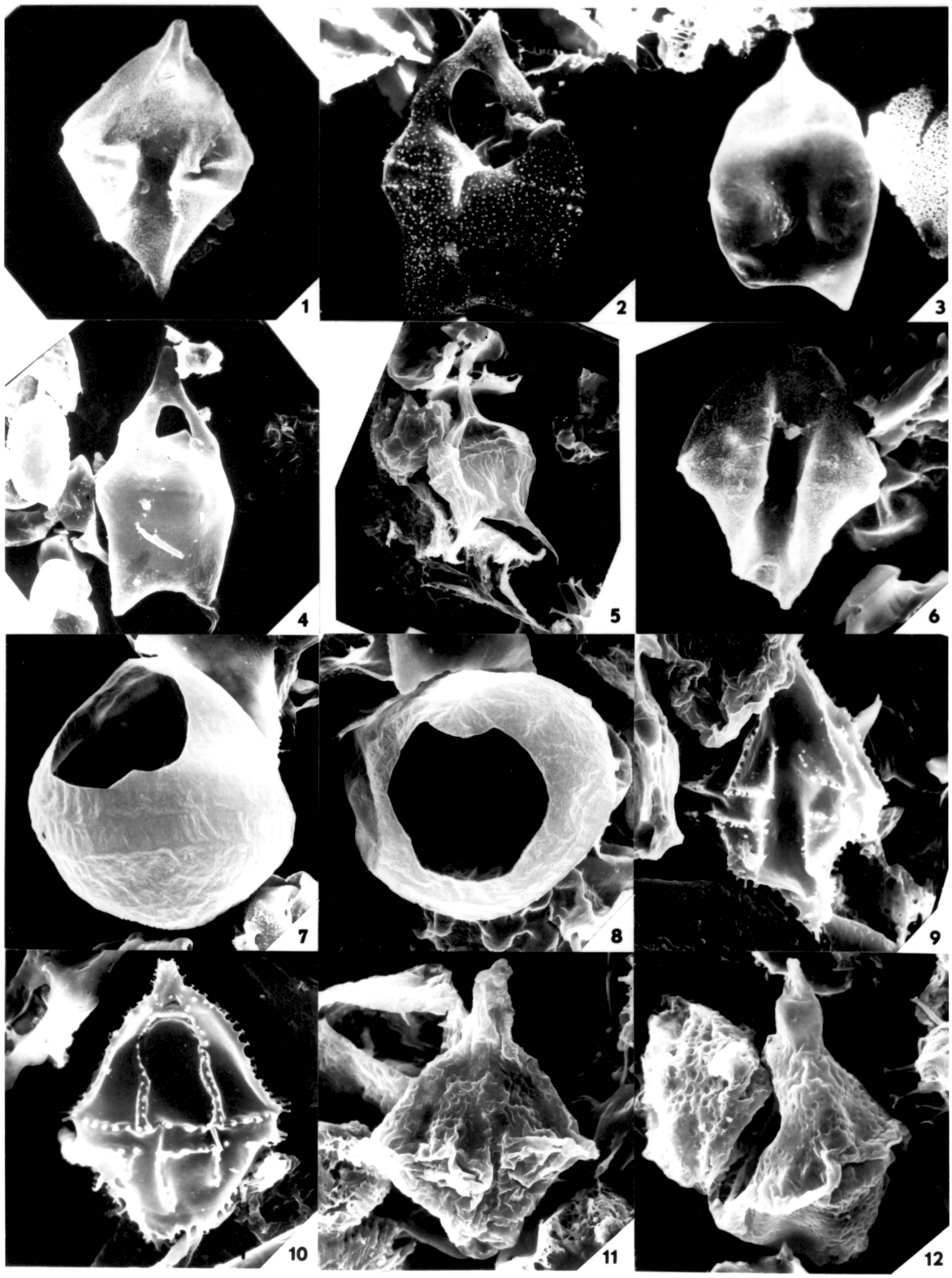


PLATE 14

Scanning electron micrographs of several Monmouth Group specimens

Figs. 1-3: Cordosphaeridium varians n. sp. showing variability in fibril development and arrangement. Fig. 1: Fibrils irregularly arranged into indistinct clumps and clusters. VPISUPL Sample 209. X400. Fig. 2: Fibrils arranged into better-defined clusters and process groupings. VPISUPL Sample 209. X380. Fig. 3: Fibrils arranged into well developed process groupings which suggest Gonyaulax-type tabulation. VPISUPL Sample 209. X520.

Fig. 4: Trichodinium cf. T. hirsutum Cookson 1965 is shown on pls. 15-16 to be intergradational with C. varians (above). Note similarity in fibril type between C. varians and T. cf T. hirsutum (compare figs. 1-3 with fig. 4). T. cf. T. hirsutum has fibrils fused into well-separated spines, and also has a distinctively long apical and antapical process. The antapical process is visible in fig. 4. VPISUPL Sample 217. X600.

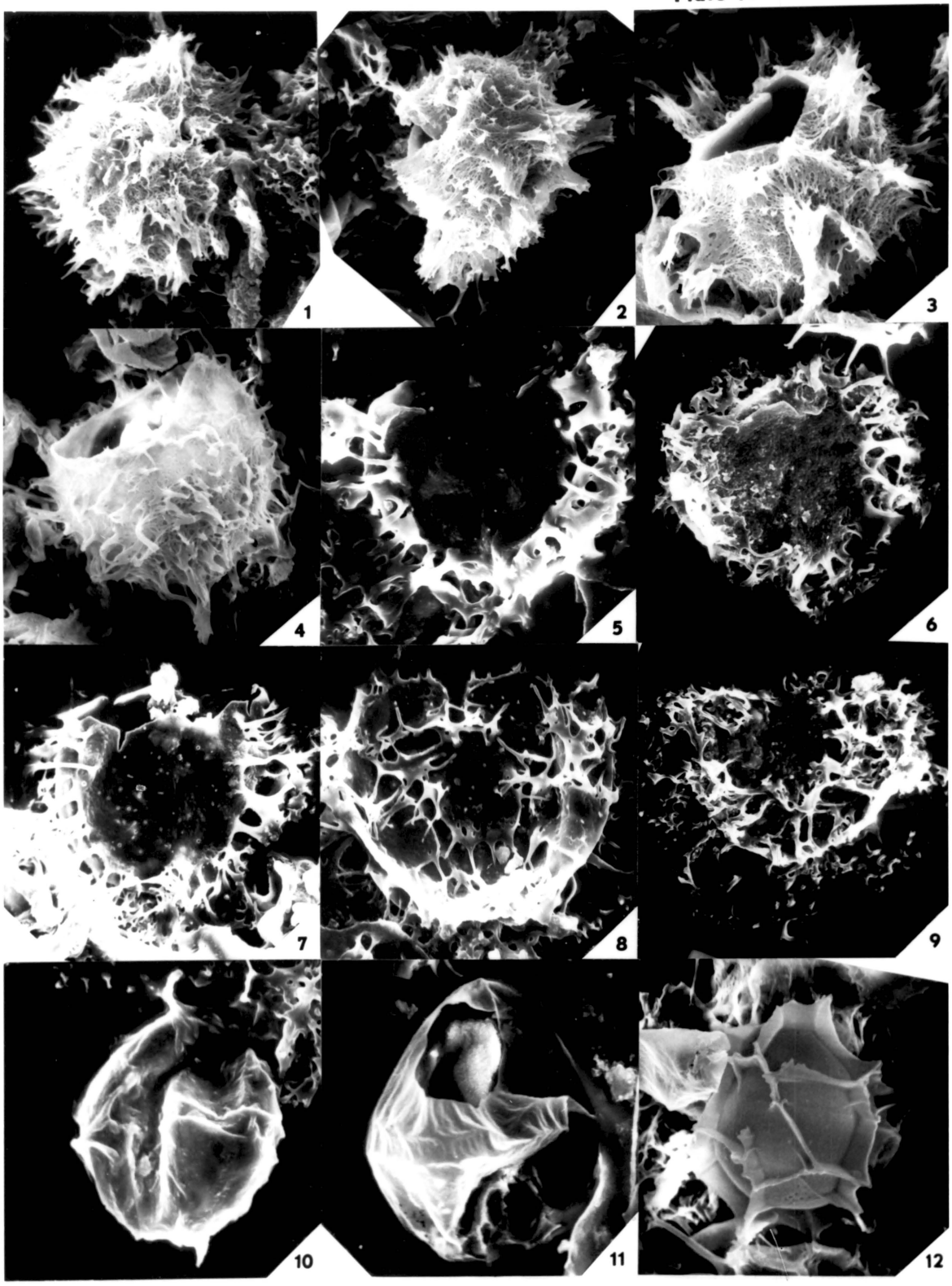
Figs. 5-7: Cyclonephelium cf. C. densebarbatum Cookson and Eisenack 1960. Fig. 5: Ventral view showing membraneous and trabeculate process network arranged about cyst circumference. Fig. 6: Similar to fig. 5, except operculum is in place. Archeopyle apical (Type $\overline{A}$). Fig. 7: Similar to fig. 5, however, placing emphasis on archeopyle outline to show sutures. VPISUPL Sample 228. X550, 490, 580, respectively.

Figs. 8-9: Areoligera sp. Fig. 8: Dorsal view showing soleate to simulate process groupings suggesting Gonyaulax-type tabulation. VPISUPL Sample 228. X590. Fig. 9: Ventral view showing central area devoid of process groupings. VPISUPL Sample 228. X440.

Figs. 10-11: Trithyrodinium striatum n. sp. Fig. 10: Possible T. striatum, however, lacking longitudinal striations. VPISUPL Sample 228. X590. Fig. 11: Typical T. striatum bearing longitudinal wrinkles (striae) on periblast. Note anterior intercalary archeopyle (Type I) on periblast; endoblast (not visible) bears 31 artheopyle. VPISUPL Sample 217. X815.

Fig. 12: Leptodinium cf. L. multiplexum Wall and Dale 1968 showing high crests extended as points at gonal positions. Note lack of several plate-margin crests on ventral surface. VPISUPL Sample 217. X800.

Plate 14



PLATES 15-16

Highly variable specimens of Cordosphaeridium varians n. sp. which first appear in the upper Mount Laurel Sand (Sample 206) can be shown to grade morphologically upsection into Trichodinium cf. T. hirsutum Cookson 1956. This lineage can be traced upsection to sample 220 (upper Navesink Formation) where it appears to terminate. Rows 1-8 of plates 15-16 illustrate the degree of variability observed within samples 213 to 206, respectively. Thus, each row contains the degree of variability observed within a particular sample; the rows being arranged stratigraphically. Following this variability upsection (i.e. beginning with row 8 and working toward row 1) one can observe the morphological gradation. A summary of this gradation is shown in figs. 10a-10d, where fig. 10a illustrates a variant of C. varians; fig. 10b illustrates a variant of C. varians bearing a long apical process; Fig. 10c illustrates a variant of T. cf. T. hirsutum bearing both an apical and antapical process; and Fig. 10d illustrates a bona-fide T. cf. T. hirsutum bearing the apical and antapical processes and the stiff, bristly nontabular spines. Also, refer to p. 62.

Figs. 9a-9d illustrate the degree of variation observed within the species C. varians. Although figs. 9c and 9d would likely be identified with the genus Cordosphaeridium, figs. 9a and 9b do not have sufficient process development to be immediately recognized as such. Process development is the result of integration of dense fibrils into clusters; well-formed clusters being intratabular processes.

All specimens shown below are optical cross-sectional views, magnified 275 times.

Figs. 1a-1d: Specimens of C. varians and T. cf. T. hirsutum from VPISUPL Sample 213. Fig. 1a: C. varians with densely arranged fibrils. Slide AI-51, Coords. R14.1;+11.6. Fig. 1b. C. varians with distinctive apical process, but lacking antapical process. Slide AI-51, Coords. R16.6;-0.4. Fig. 1c: T. cf. T. hirsutum having less dense fibrils and distinctive apical and antapical process. Slide AI-51, Coords. R7.2;+28.2. Fig. 1d: T. cf. T. hirsutum with relatively sparsely arranged spines and well-developed apical and antapical processes. Slide AI-52, Coords. R13.1;-1.1.

Figs. 2a-2d: Specimens of C. varians and T. cf T. hirsutum from VPISUPL Sample 212. Fig. 2a: C. varians with densely arranged fibrils faintly arranged into process groupings. Slide AI-49, Coords. R1.8;+8.1. Fig. 2b: C. varians showing short, densely-arranged fibrils not arranged into groupings. Slide AI-47, Coords. R15.3;+9.0 Fig. 2c: T. cf. T. hirsutum with short, densely arranged fibrils and distinctive apical and and antapical processes. Slide AI-50, Coords. R8.5;+5.2. Fig. 2d: T. cf. T. hirsutum with dense fibrils similar to C. varians, however, bearing distinctive apical and antapical processes. Slide AI-49, Coords. R7.0;+17.4.

Figs. 3a-3d: C. varians from VPISUPL Sample 211 showing variability in fibril arrangement. Fig. 3a: Fibrils randomly arranged. Slide AI-44, Coords. R11.4;+10.6. Fig. 3b: Fibrils faintly arranged into process

groupings. Slide AI-44, Coords. R10.3;+5.9. Fig. 3c: Fibrils grouped into several process groupings. Slide AI-41, Coords. R13.3;+9.5. Fig. 3d: Fibrils developed into distinctive Cordosphaeridium-like processes. Slide AO-44, Coords. R1.8;-0.3.

Figs. 4a-4d: C. varians from VPISUPL Sample 210 showing variability in fibril arrangement. Fig. 4a: Short fibrils weakly clustered into non-tabular arrangements. Slide AI-36, Coords. R7.4;+4.7. Fig. 4b: Long fibrils irregularly clustered. Slide AI-36, Coords. LO.6;+2.3. Fig. 4c: Long fibrils arranged into distinctive Cordosphaeridium-like processes. Note slender cingular processes in equatorial plane. Slide AI-36, Coords. R3.7;+6.5. Fig. 4d: Long fibrils well-developed into processes. Slide AI-36, Coords. R18.3;+5.6.

Figs. 5a-5d: C. varians from VPISUPL Sample 209 showing variability in fibril arrangement. Fig. 5a: Fibrils faintly arranged into irregular groupings. Note single apical process. Slide AI-32, Coords. R4.5;+5.8. Fig. 5b: Medium-length fibrils arranged into broad, irregular-appearing groupings. Slide AI-33, Coords. R9.3;+1.7. Fig. 5c: Long fibrils arranged into exceptionally well-developed process groupings illustrating Cordosphaeridium appearance. Slide AI-34, Coords. R18.2;+3.1. Fig. 5d: Specimen very similar to that seen in Fig. 5c. Slide AI-32, Coords. R15.2;+15.2.

Figs. 6a-6d: C. varians from VPISUPL Sample 208 showing variability in fibril development and arrangement. Fig. 6a: Densely matted fibrils

arranged into irregular, low clumps. Slide AI-30, Coords. R15.3;+10.1. Fig. 6b: Medium-length fibrils arranged into a few poorly-formed process groupings. Slide AI-27, Coords. R2.9;+10.0. Fig. 6c: Long fibrils arranged into loose, but distinctive process groupings. Slide AI-28, Coords. R5.3;+11.2. Fig. 6d: Medium-length fibrils arranged into distinctive, but not clearly separated process groupings. Slide AI-27, Coords. R5.3;+3.2.

Figs. 7a-7d: C. varians from VPISUPL Sample 207 showing variability in fibril development and arrangement. Fig. 7a: Fibrils dense, loose, and randomly arranged. Slide AI-22, Coords. R3.8;+15.9. Fig. 7b: Medium-length fibrils loosely arranged into indistinct process groupings. Slide AI-24, Coords. R2.6;+5.4. Fig. 7c: Medium-length fibrils loosely arranged into indistinct process groupings. Slide AI-24, Coords. L0.1; +12.8. Fig. 7d: Long fibrils arranged into distinctive but not completely separated process groupings. Slide AI-24, Coords.R12.9;14.1.

Figs. 8a-8d: C. varians from VPISUPL Sample 206 showing variability in fibril arrangement. Fig. 8a: Broken specimen bearing short fibrils which are matted and irregularly arranged into low, indistinct groupings. Slide AI-18, Coords. R5.5;+14.6. Fig. 8b: Relatively long fibrils arranged into irregular, but distinct process groupings. Slide AI-18, Coords. R13.6;+17.1 Fig. 8c: Broken specimen with long fibrils arranged into distinctly-separate process groupings. Slide AI-20, Coords. R15.2;+5.8. Fig. 8d: Broken specimen showing a few indistinct to distinct process groupings. Slide AI-16, Coords. R9.6;-0.3.

Figs. 9a-9b: C. varians specimens selected from the various samples illustrated in rows 1-8 to show the gradation in fibril arrangement. Fig. 9a: Densely matted fibrils arranged into irregular low clumps (see fig. 6a above). Fig. 9b: Fibrils faintly arranged into process groupings (see fig. 3b above). Fig. 9c: Medium-length fibrils arranged into distinctive, but not clearly separated process groupings (see fig. 6d above). Fig. 9d: Long fibrils arranged into exceptionally well-developed process groupings illustrating Cordosphaeridium appearance (see fig. 5c above).

Figs. 10a-10d: Sequence illustrates possible morphological gradation of C. varians into T. cf. T. hirsutum. Fig. 10a: Variant of C. varians having loosely arranged fibrils and no process groupings (see fig. 3a above). Fig. 10b: Variant of C. varians having medium-length fibrils loosely arranged into irregular clumps. Note distinctive apical process and lack of similar antapical process. Fig. 10c: Variant of T. cf. T. hirsutum having dense but loosely arranged fibrils. Note distinctive apical and antapical process. The morphological criterion used to separate T. cf. T. hirsutum from C. varians is the presence of both an apical and an antapical process in T. cf. T. hirsutum (see fig. 2c above). Fig. 10d: T. cf. T. hirsutum having well-separated, stiff, bristly spines. Note distinctive apical and antapical process (see fig. 1d above).

Plate 15

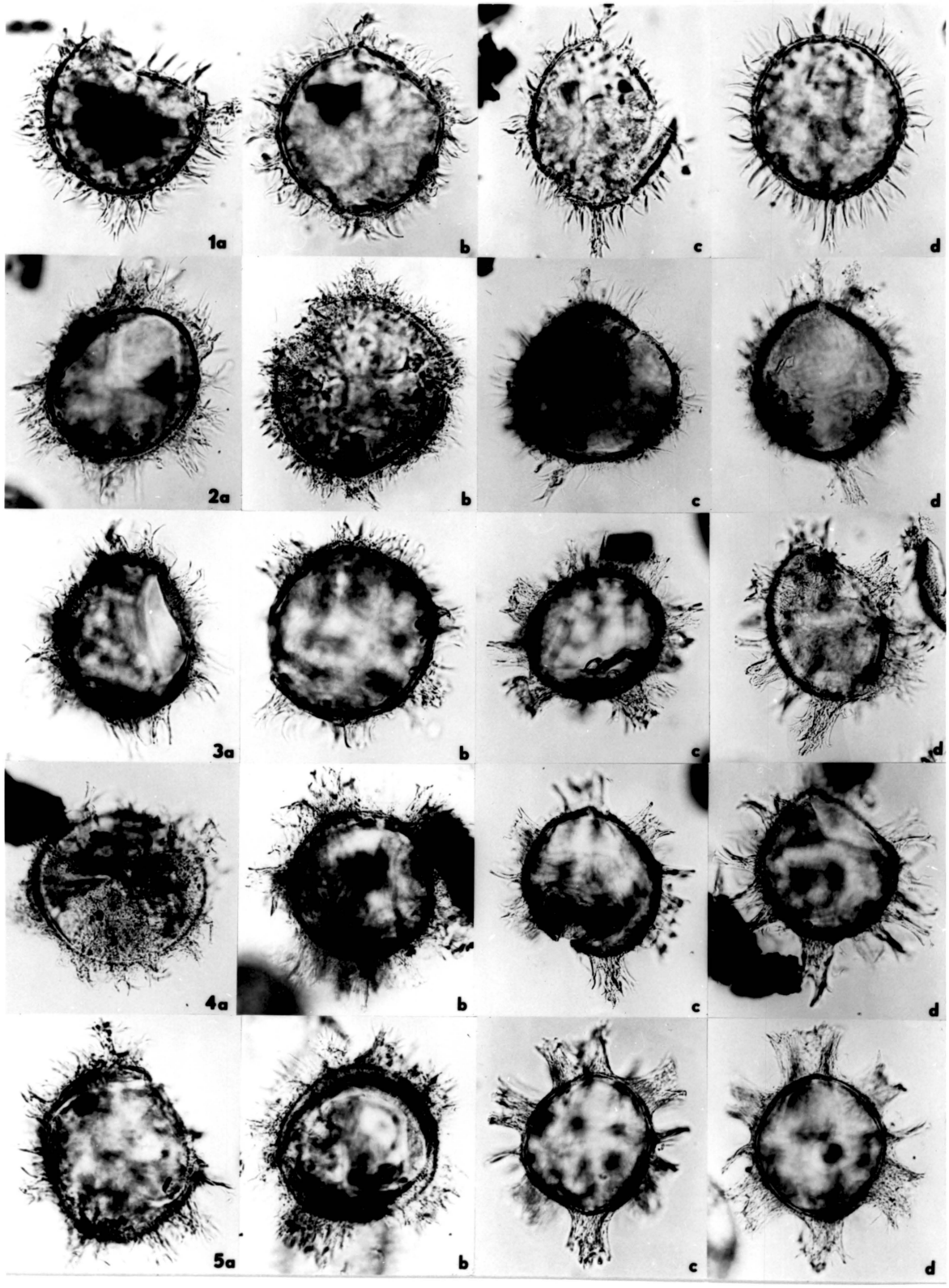


Plate 16

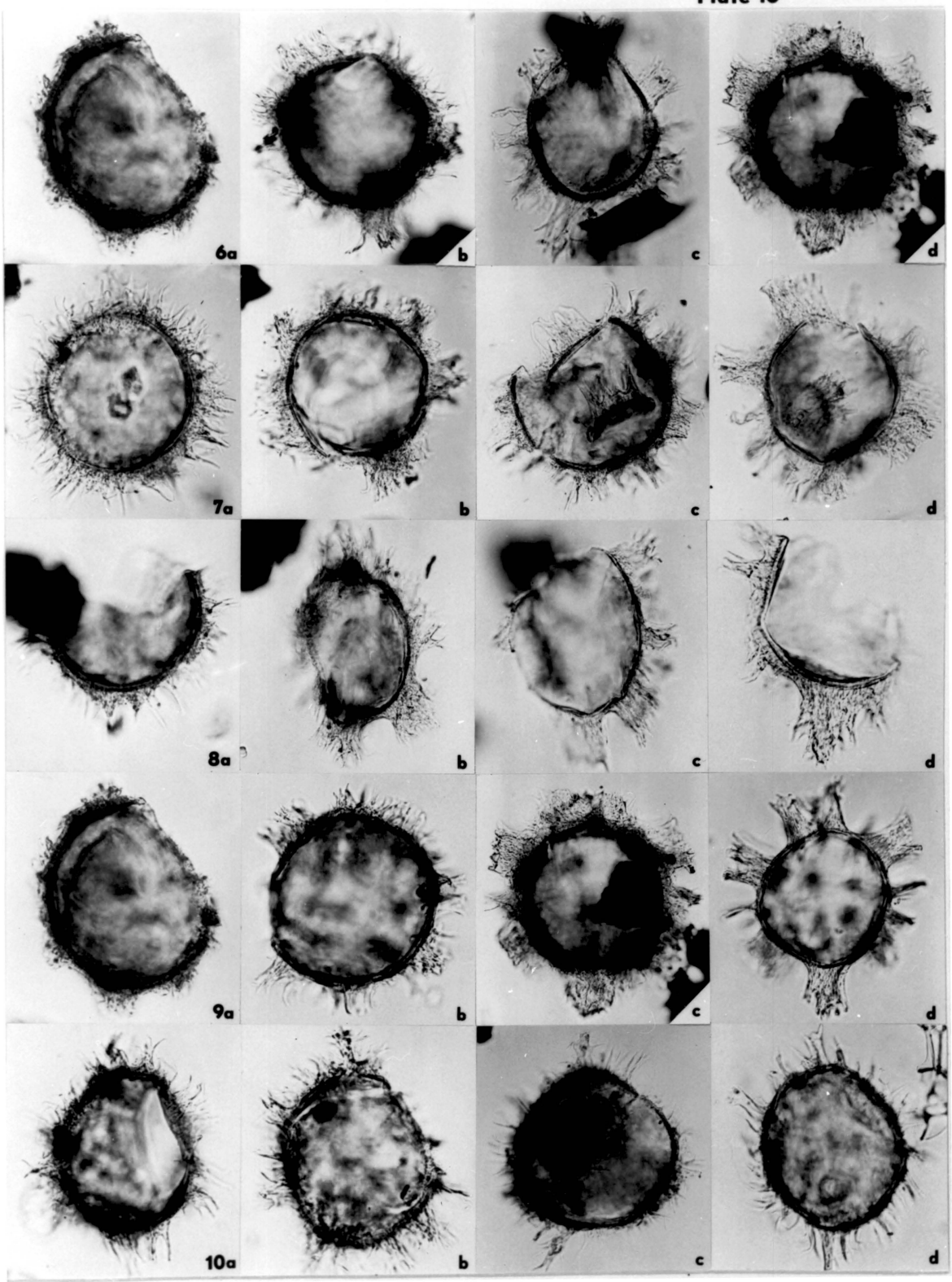


PLATE 17

Optical cross-sectional views of 20 specimens of Exochosphaeridium bifidum (Clarke and Verdier) Clarke et al. 1968 showing the gradational morphological variability in process development. Figs. 1-20 are arranged in a sequence which generally shows the changeover from very small, slender processes to large, solid to tubular processes. Specimens such as that seen in fig. 14 would likely not be associated with specimens similar to that seen in fig. 1, unless one was aware of the intermediate forms. Also, refer to p. 63.

All specimens shown are E. bifidum photographed in optical cross section, and are from sample 227 (lower Sandy Hook Member of the Red Bank Sand).

Fig. 1: Processes short, slender, and solid. Main body L X W: 49u X 49u, process lengths up to 7u. Slide AJ-20, Coords. R7.1;+17.2.

Fig. 2: Processes long, slender, and solid. Main body L X W: 54u X 50u, average process length 11u. Slide AJ-23, Coords. R4.1;+16.2.

Fig. 3: Processes long, slender, and solid. Main body L X W: 57u X 49u, average process length 11u. Slide AJ-22, Coords. LO.4;+6.1.

Fig. 4: Processes somewhat broader and are solid to hollow, several being partially hollow. Main body L X W: 59u X 51u, average process length 13u. Slide AJ-22, Coords. R11.2;+14.1.

Fig. 5: Processes mainly slender and solid. Main body L X W: 63u X 56u, average process length 14u. Slide AJ-22, Coords. R13.8;+15.2.

Fig. 6: Processes mainly slender and solid, however, a few partially hollow, tubular-shaped processes exist. Main body L X W: 60u X 49u, average process length 14u. Slide AJ-22, Coords. R17.1;+4.9.

Fig. 7: Processes mainly slender and solid, however, a few hollow, tubular processes exist. Main body L X W: 60u X 49u, average process length 16u. Slide AJ-23, Coords. R10.3;+0.6.

Fig. 8: Processes mainly slender and solid, however, a few partially hollow processes exist. Main body L X W: 66u X 57u, average process length 17u. Slide AJ-23, Coords. R8.9;+4.4.

Fig. 9: Processes mainly slender and solid, however, a few partially hollow and hollow processes exist. Main body L X W: 64u X 56u, average process length 17u. Slide AJ-23, Coords. R11.7;+0.4.

Fig. 10: Most processes slender and solid to partially hollow, however, a few are tubular and hollow and appear distinctively fibrous (see processes at 4:00 position). Main body L X W: 66u X 57u, average process length 17u. Slide AJ-23, Coords. R2.4;+2.3.

Fig. 11: Several processes are tubular and partially to completely hollow. Main body L X W: 67u X 57u, average process length 17u. Slide AJ-23, Coords. R18.5;+11.3.

Fig. 12: Several processes tubular in shape and are partially to completely hollow. Main body L X W: 69u X 60u, average process length 17u. Slide AJ-21, Coords. R5.5;+3.9.

Fig. 13: Several processes are tubular, but are mostly only partially hollow to completely solid. Main body L X W: 63u X 60u, average process length 19u. Slide AJ-23, Coords. R13.4;+0.1.

Fig. 14: Many broad, hollow, and fibrous processes. The number of processes is greatly reduced, and in many respects the form is similar in appearance to Cordosphaeridium. Main body L X W: 63u X 60u, average process length 20u. Slide AJ-21, Coords. R10.7;+3.9.

Fig. 15: Many partially to completely hollow, tubular processes. Main body L X W: 60u X 54u, average process length 23u. Slide AJ-22, Coords. R17.4;+6.1.

Fig. 16: Many long, partially to completely hollow, tubular processes which in general are fibrous. Main body L X W: 66u X 63u, average process length 26u. Slide AJ-24, Coords. R7.4;+0.2.

Fig. 17: Many long, partially to completely hollow, tubular processes which in general are fibrous. Main body L X W: 77u X 66u, average process length 26u. Slide AJ-21, Coords. R15.7;+13.1.

Fig. 18: Processes slender in comparison to length. Most are partially to completely hollow and many are fibrous. Main body L X W: 66u X 57u, average process length 29u. Slide AJ-20, Coords. R8.1;+10.5.

Fig. 19: Most processes hollow and tubular. Number of processes reduced and the specimen is of Cordosphaeridium appearance. Main body L X W: 77u X 72u, average process length 29u. Slide AJ-20, Coords. R2.3;+10.5.

Fig. 20: Processes slender in comparison to length. Most are partially hollow. Main body L X W: 74u X 72u, average process length 31u. Slide AJ-20, Coords. R5.1;+12.6.

Plate 17

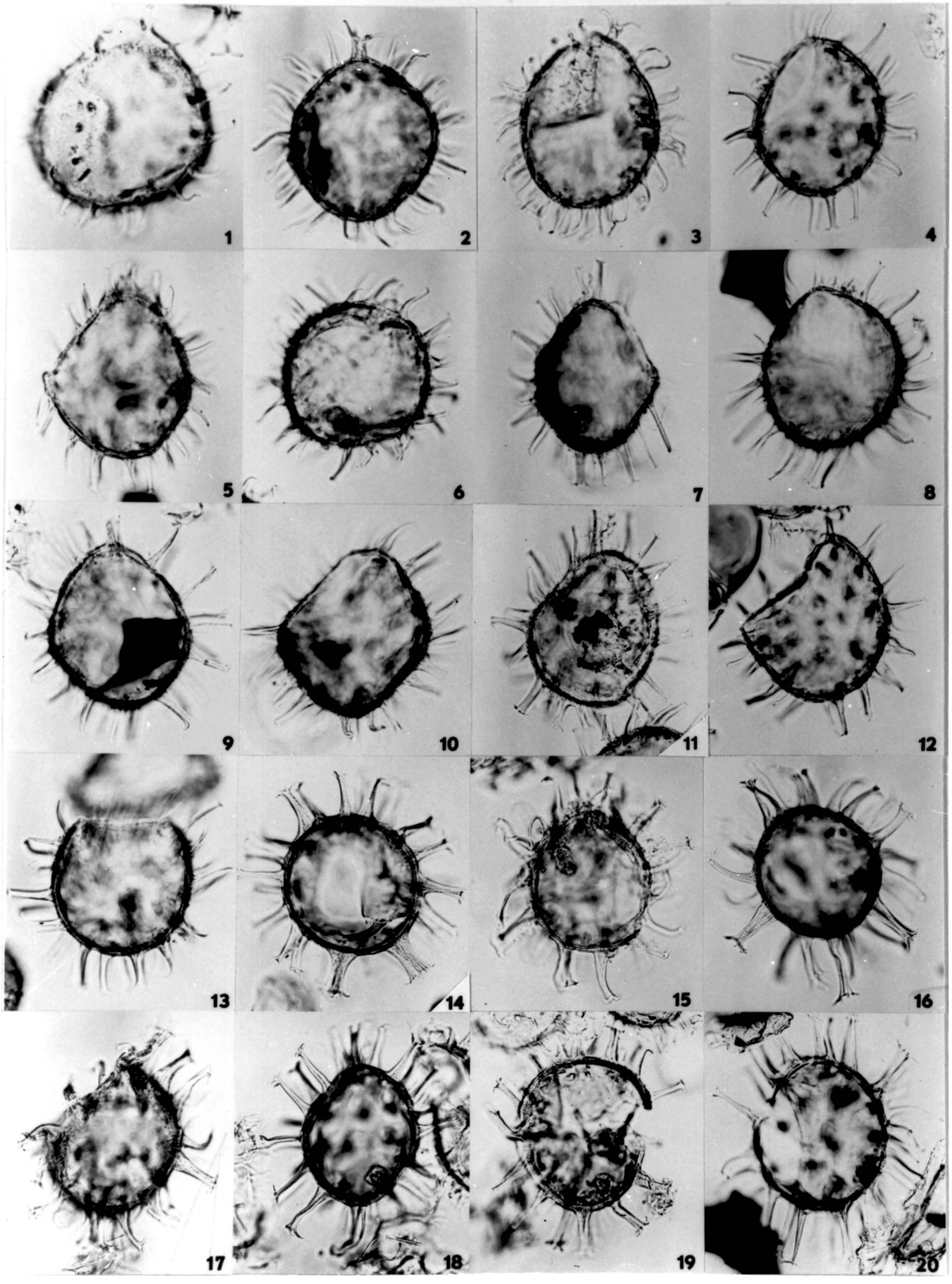


PLATE 18

Figs. 1-20 illustrate apical tuft complexes of the 20 specimens of Exochosphaeridium bifidum (pl. 17, figs. 1-20). Because the plane of focus did not always intersect the apical tufts on the specimens of plate 17 they are sketched here in detail. Thus, each figure-number on this plate corresponds to the same figure-number on plate 17 (i.e. the apical tuft figured as fig. 1 on this plate (plate 18) corresponds to the specimen of E. bifidum figured as fig. 1 on plate 17). The apical tufts are all drawn at the same scale. As the main body diameter increases for the specimens on plate 17 one can see how the apical tufts generally become larger, but not necessarily more complex. The tufts are fibrous in ornamentation and are quite variable in construction.

Fig. 1: Height 8u

Fig. 2: Height 14u

Fig. 3: Height 11u

Fig. 4: Height 14u

Fig. 5: Height 11u

Fig. 6: Height 11u

Fig. 7: Height 17u

Fig. 8: Height 14u

Fig. 9: Height 9u

Fig. 10: Height 15u

Fig. 11: Height 17u

Fig. 12: Height 15u

Fig. 13: Height 17u

Fig. 14: Height 29u

Fig. 15: Height 23u

Fig. 16: Height 26u

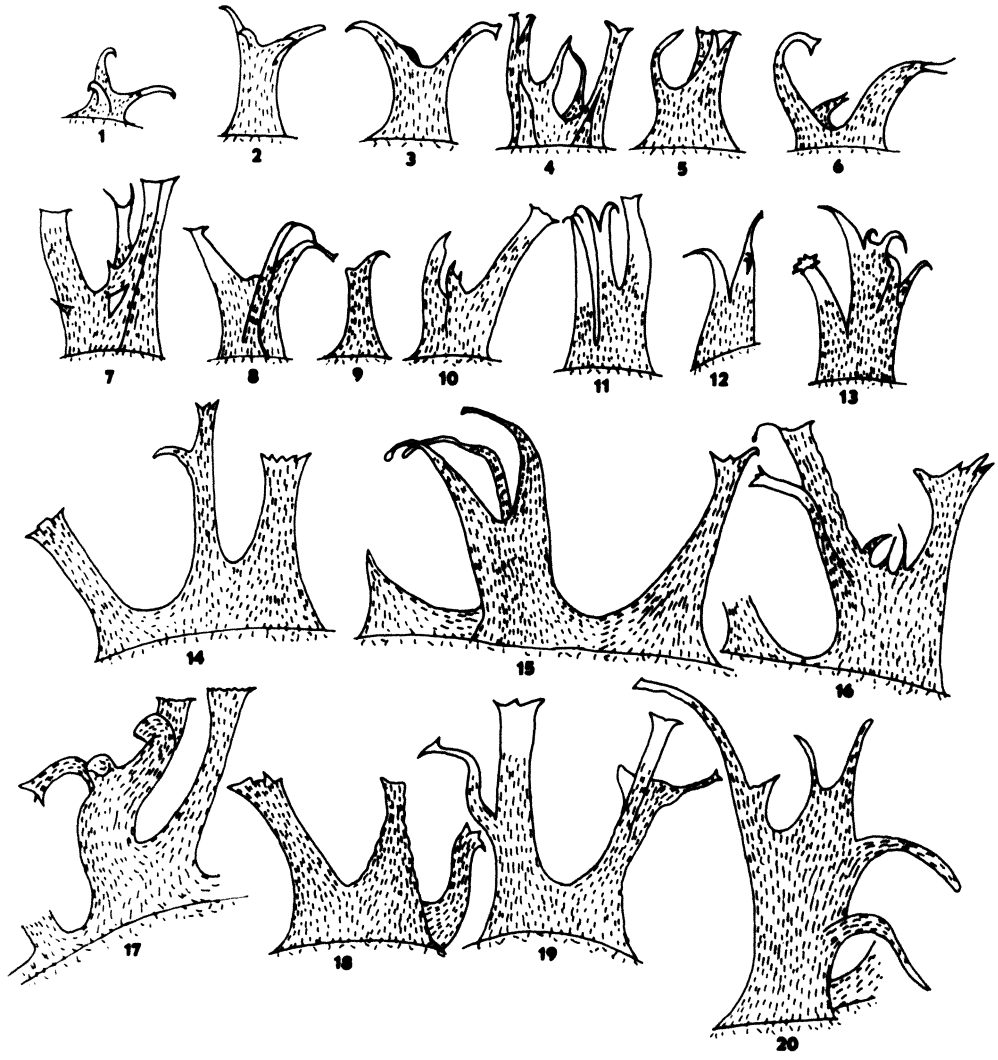
Fig. 17. Height 22u

Fig. 18: Height 17u

Fig. 19: Height 23u

Fig. 20: Height 27u

Plate 18



PLATES 19-20

Figs. 1-20 illustrate the process variability seen on the specimens of Exochosphaeridium bifidum from plate 17, and the figure numbers of this plate correspond to those of plate 17. Each figure below contains 3-4 processes representing the variability in process development for each specimen of plate 17. For example, one can compare the processes shown in fig. 6 of this plate with the specimen shown in fig. 6 of plate 17. All processes are drawn at the same scale. In general, as cyst main body diameter increases and as average process length increases the more partially to completely hollow, tubular processes appear on the cyst. The hollow, tubular processes are generally fibrous and frequently have a Cordosphaeridium appearance to them. See plate explanation for plate 17 for details.

Fig. 1: Longest process 10u.

Fig. 2: Longest process 14u.

Fig. 3: Longest process 13u.

Fig. 4: Longest process 16u.

Fig. 5: Longest process 14u.

Fig. 6: Longest process 14u.

Fig. 7: Longest process 17u.

Fig. 8: Longest process 19u.

Fig. 9: Longest process 18u.

Fig.10: Longest process 19u.

Fig. 11: Longest process 20u.

Fig. 12: Longest process 15u.

Fig. 13: Longest process 20u.

Fig. 14: Longest process 17u.

Fig. 15: Longest process 21u.

Fig. 16: Longest process 31u.

Fig. 17: Longest process 25u.

Fig. 18: Longest process 23u.

Fig. 19: Longest process 21u.

Fig. 20: Longest process 31u.

Plate 19

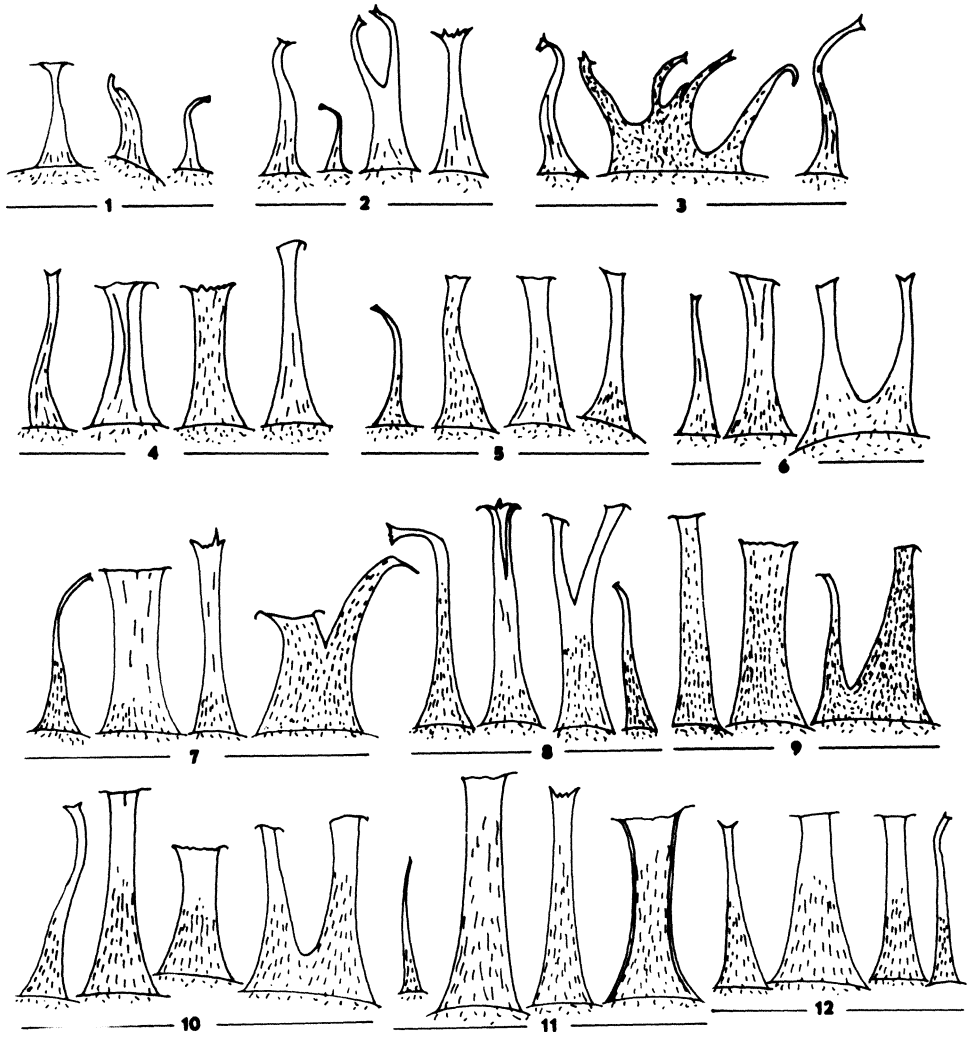


Plate 20

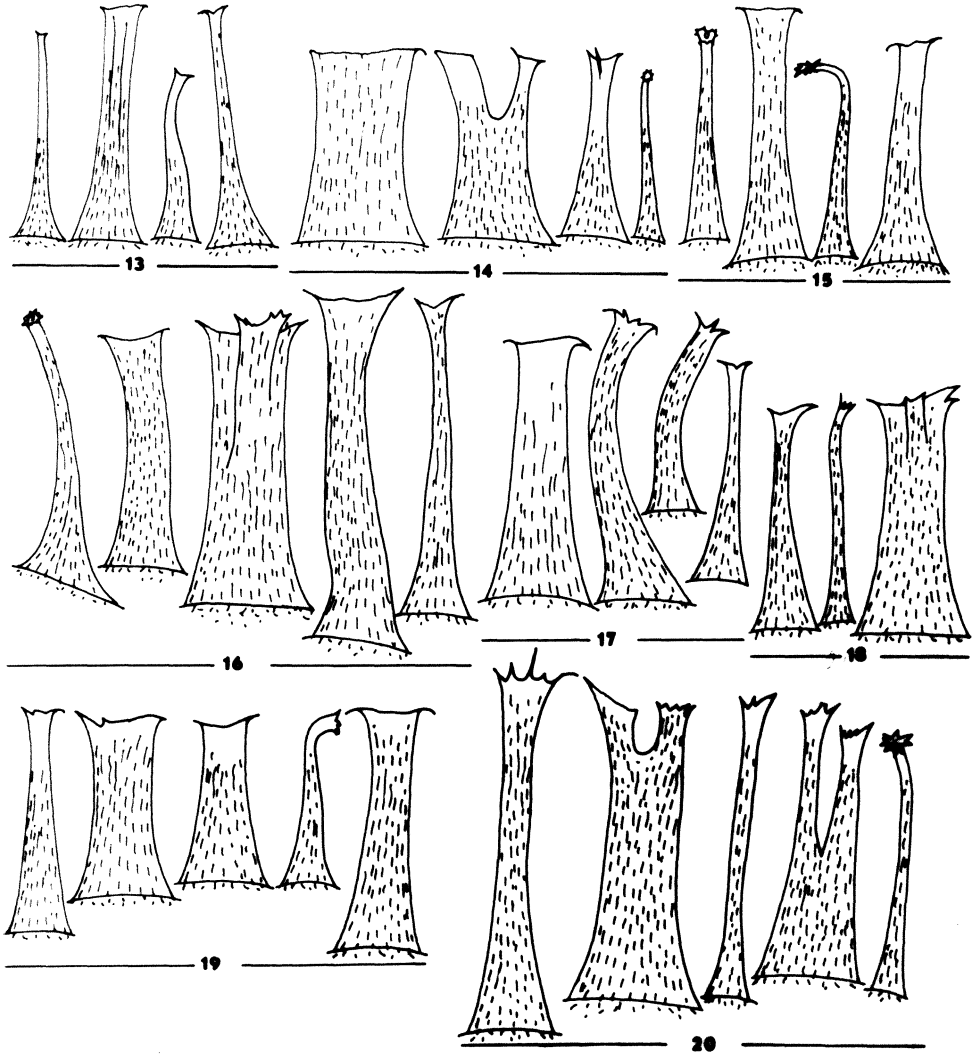


PLATE 21

Figs. 1-16: Scanning electron micrographs of Dinogymnium pustulicostatum n. sp. illustrating the variety of morphological variation which results from distortion. All specimens are from sample 205.

Fig. 1: Specimen contracted, costae tightly folded together; cingulum collapsed. X750.

Fig. 2: Specimen contracted, costae folded together; cingulum partially collapsed. X670.

Fig. 3: Specimen slightly contracted; cingulum slightly expanded. X810.

Fig. 4: Specimen laterally expanded, costae spread apart; cingulum expanded. X850.

Fig. 5: Specimen mildly contracted, costae folded together; cingulum collapsed. X910.

Fig. 6: Specimen nondistorted laterally; cingulum collapsed. X780.

Fig. 7: Specimen nondistorted laterally; cingulum partially collapsed. X800.

Fig. 8: Specimen nondistorted laterally; cingulum slightly distorted due to dorso- ventral compression. X910.

Fig. 9: Specimen slightly expanded, costae spread slightly; cingulum partially collapsed. X1060.

Fig. 10: Specimen slightly collapsed; cingulum collapsed near sulcus. X865.

Fig. 11: Specimen nearly nondistorted; cingulum slightly collapsed. X830.

Fig. 12: Specimen expanded, costae nearly spread open; cingulum collapsed. X900.

Fig. 13: Specimen expanded, costae nearly spread open; cingulum slightly expanded. X825.

Fig. 14: Specimen nearly nondistorted, except on hypotract. X810.

Fig. 15: Detailed view of cingulum showing wall canals and associated pustules. Wall canals measure ca. 0.2u. X3600.

Fig. 16: Detailed view of a costa and intercostal depression showing pustules and wall cansls. X8300.

Fig. 17: Ventral view of Dinogymnium pustulicostatum n. sp. taken in bright field for comparison showing nondistorted specimen. X750. See Plate 11, fig. 8 for details.

Fig. 18: Optical cross-sectional view of D. pustulicostatum taken in bright field for comparison. X750. See Plate 11, fig. 9 for details.

Fig. 19: Dinogymnium acuminatum Evitt et al. 1967. Optical cross-sectional view showing ventrally directed antapical point. Overall L X W: 71u X 48u. VPISUPL Sample 212, Slide AI-50, Coords. R11.4;+13.0.

Fig. 20: Palaeocystodinium reductum n. sp. HOLOTYPE; optical cross-sectional view showing poorly developed cingulum, bluntly rounded apical horn, and pointed antapical horn. Overall L X W: 101u X 41u. VPISUPL Sample 210, Slide AI-36, Coords. R5.9;+13.6.

Plate 21

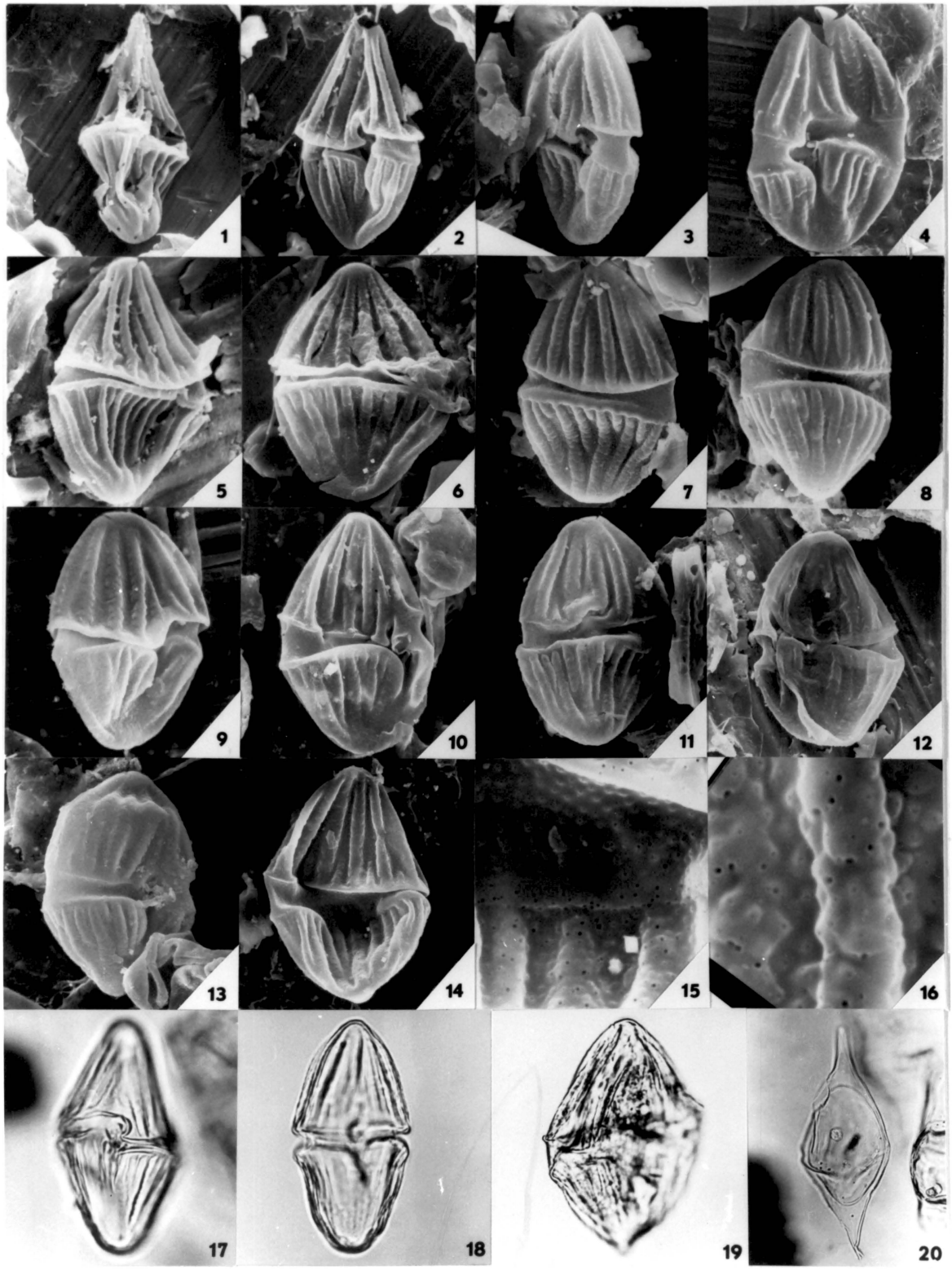


PLATE 22

Scale drawings of antapical horn and accessory spike of Palaeocystodinium australinum (Cookson) n. comb. Accessory spike is highly variable in length, and may appear as a barely noticeable barb on the right side of the antapical horn, or may be as large as ca. ½ the size of the antapical horn from the point of branching. Magnification for all specimens is 1085X. All specimens from VPISUPL Sample 222.

Fig. 1: Slightly developed accessory spike. Slide AI-95, Coords. RO.4;+7.6.

Fig. 2: Slightly developed accessory spike. Slide AI-95, Coords. RO.4;+6.5.

Fig. 3: Moderately developed accessory spike. Slide AI-96, Coords. R11.6;+0.7.

Fig. 4: Moderately developed accessory spike. Slide AI-95, Coords. R3.5;+13.3.

Fig. 5: Well developed accessory spike. Slide AI-95, Coords, R.1.6;+6.5.

Fig. 6: Well developed accessory spike. Slide AI-97, Coords. R11.9;+6.6.

Fig. 7: Well developed accessory spike. Slide AI-96, Coords. R1.4;+18.1.

Fig. 8: Well developed accessory spike. Slide AI-96, Coords. RO.1;+3.3.

Fig. 9: Exceptionally long accessory spike. Slide AI-96, Coords. R11.3;+4.2.

Fig. 10: Exceptionally long accessory spike. Slide AI-97, Coords. R14.1;+11.5.

Plate 22

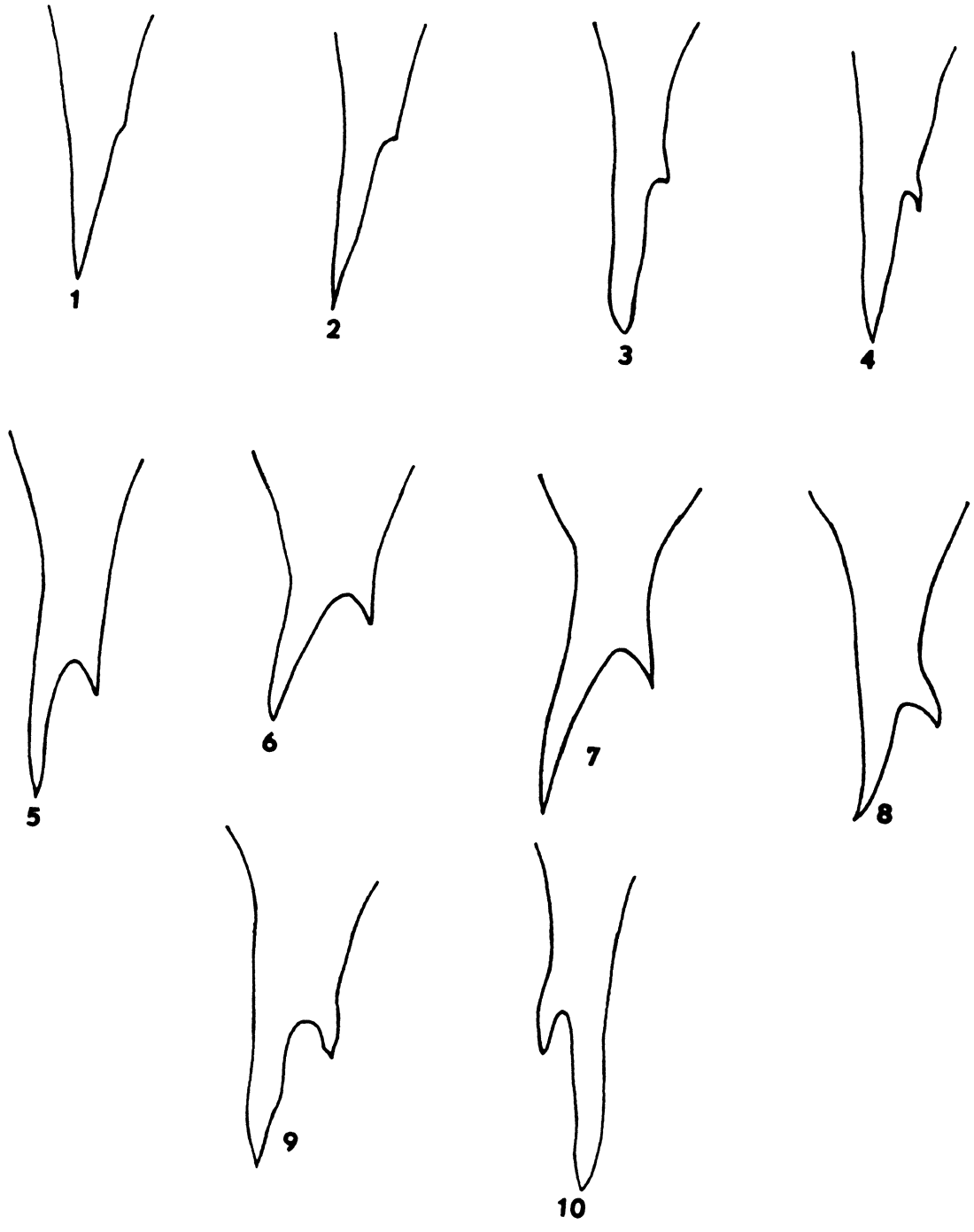


PLATE 23

Scanning Electron Micrographs

Figs. 3-7a illustrate flagellar pore structures and associated features in Dinogymnium as discussed on p. 49. Abbreviations used on this plate are: AT (anterior tube), AP (anterior flagellar pore), PT (posterior tube), PP (posterior flagellar pore), C1 (higher terminal end of cingulum). C2 (lower terminal end of cingulum), FG (final groove), IG (initial groove), S (sulcus), and R (ridge).

Figs. 1-6a illustrate specimens from the upper Mount Laurel Sand. VPISUPL Sample 205.

Fig. 1: Dinogymnium pustulicostatum n. sp. Dorsal epitract showing greater concentration of wall canals near apex. X3000.

Fig. 2: D. pustulicostatum. Cross section of test wall showing wall canals penetrating through test wall. Wall canals (W) measure ca. 0.2um across; test wall measures ca. 0.5 um thick.

Figs. 3-3a: D. pustulicostatum. Two different magnifications of same specimen. Fig. 3: Ventral view of entire specimen. Fig. 3a: Detailed view of mid-ventral area showing anterior and posterior flagellar pore structures. X1000 and 2275, respectively.

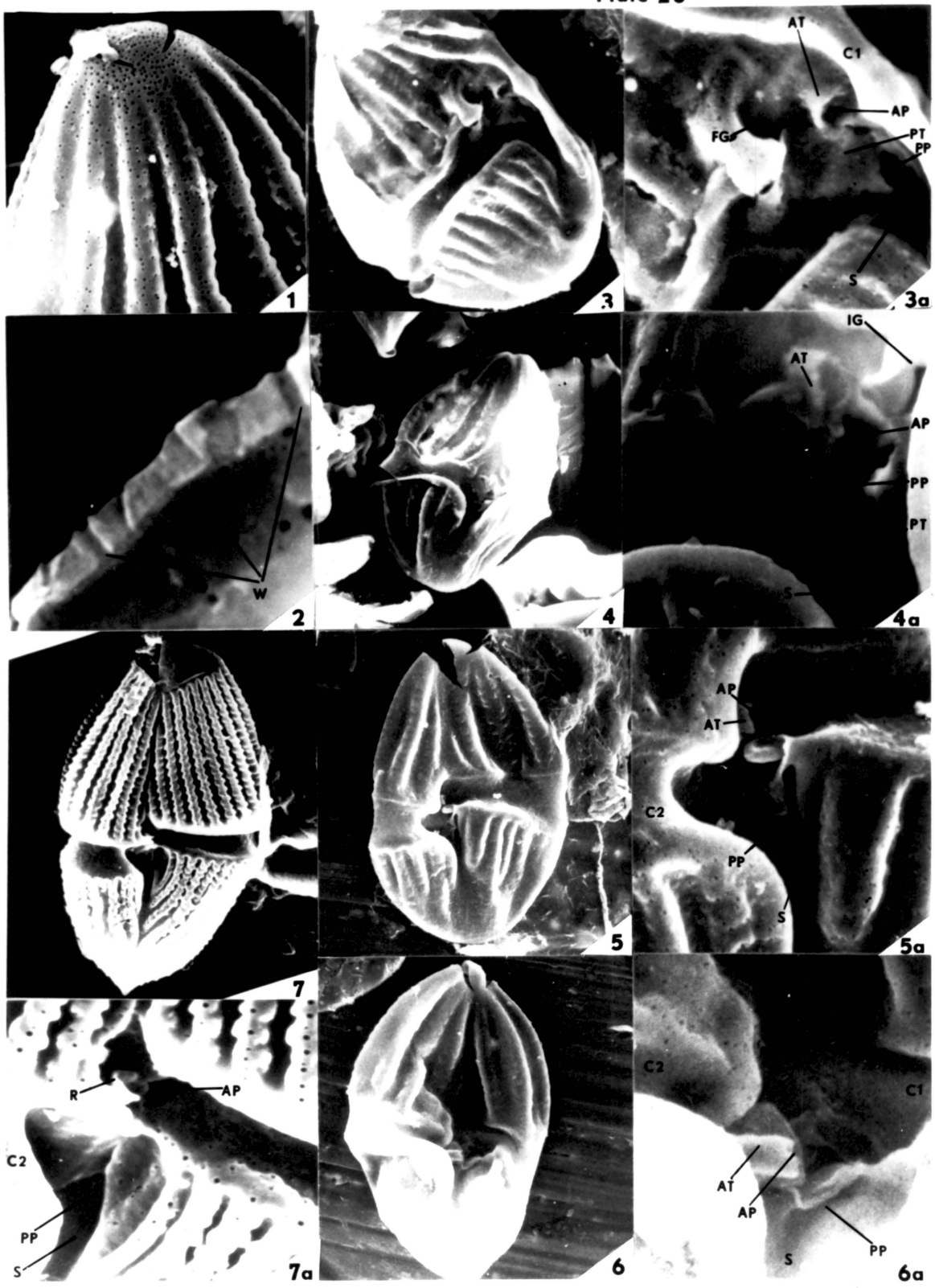
Figs. 4-4a: D. pustulicostatum. Two different magnifications of same specimen. Fig. 4: Ventral view of entire specimen. Fig. 4a: Detailed view of mid-ventral area showing collapsed anterior and posterior flagellar pore structures. X850 and 5480, respectively.

Figs. 5-5a: D. cf. D. pustulicostatum: Two different magnifications of same specimen. Fig. 5: Ventral view of entire specimen. Fig. 5a: Detailed view of mid-ventral area showing flagellar pore structures. X1130 and 3725, respectively.

Figs. 6-6a: D. cf. D. pustulicostatum: Two different magnifications of same specimen. Fig. 6: Ventral view of entire specimen. Fig. 6a: Detailed view of mid-ventral area showing flagellar pore structures. X1300 and 4600, respectively.

Figs. 7-7a: Dinogymnium westralium (Cookson and Eisenack) Evitt 1967. Two different magnifications of same specimen. Fig. 7: Ventral view of entire specimen. Fig. 7a: Detailed view of mid-ventral area showing flagellar pore structures. X850 and 3743, respectively. Sandy Hook Member of Red Bank Sand. VPISUPL Sample 236.

Plate 23


1
3
AT
C1
AP
FG
PT
PP
S
3a
W
2
4
IG
AT
AP
PP
PT
S
4a
7
5
AP
AT
C2
PP
S
5a
R
AP
C2
PP
S
7a
6
C2
C1
AT
AP
S
PP
6a

Appendix I

Appendix I contains counting data for species discussed in the systematics portion of the text. Three hundred specimens were counted per sample for all 36 samples (a total of 10,800 specimens). Data is presented in rows, from left to right, according to species and sample. Each row contains two entries: the top entry is the actual count for that sample, and the bottom entry is the relative percentage of that number based on the 300 counts. Asterisks indicate specimens recorded for that sample which were not observed during the count. Vertical lines through the numbers indicate formation boundaries: left group= Mount Laurel Sand, middle group= Navesink Formation, and right group= Shrewsbury Member of the Red Bank Sand. Ninety-three taxa are represented in alphabetical order within familial and generic groups, beginning with the Gonyaulacaceae, followed by the Peridineaceae, and lastly by the Gymnodineaceae. The bottom row of the last page entitled "other" indicates all observed forms which are considered of marine origin, and which cannot be assigned to the three families mentioned above.

The method of data presentation on the appendix tables can be followed by examining the first entry Areoligera sp. The row to the right shows that specimens are present in most every sample. The figures in this row are the actual counts and relative percentages per sample. For example, the first set of figures state the actual count (8 specimens) and relative percentage (2.7 percent) of Areoligera sp. in sample 203. Blank spaces indicate that no specimens were observed in that sample.

APPENDIX

COUNTS AND RELATIVE FREQUENCIES OF DINOFLAGELLATE CYSTS OBSERVED IN THE MOUNT LAUREL SAND, NAVESINK FORMATION, AND SANDY HOOK MEMBER OF THE RED BANK SAND, ATLANTIC HIGHLANDS, NEW JERSEY

Species \ Sample Nos.	203	204	205	206	207	208	209	210	211	212	213	214	215	216	217	218	219	220	221	222	223	224	225	226	227	228	229	230	231	232	233	234	235	236	237	238
GONYAULACACEAE																																				
Areoligera sp.	8 2.7		2 .7	2 .7	3 1.0	2 .7	4 1.3		20 6.7	8 2.7	12 4.0	3 1.0	17 5.7	20 6.8	20 6.8	16 5.3		55 183	36 120	7 2.4	16 5.3	6 2.0	45 150	147 491	107 356	205 684	171 572	46 154	29 9.7	23 7.7	19 6.3	5 1.7	21 7.0	6 2.0	5 1.7	6 2.0
Apteodinium																																				
A. baculatum																																	1 .3			1 .3
Cannosphaeropsis																																				
C. pusulosa																*																				
C. utinensis					*	*	*		2 .7																											
Conneximura																																				
C. fimbriata	*		*		*				1 .3		*	*																1 .3		*	*	*		*	1 .3	1 .3
Conosphaeridium																																				
C. sp.																				*																

APPENDIX CONTD.

Sample Nos. / Species	203	204	205	206	207	208	209	210	211	212	213	214	215	216	217	218	219	220	221	222	223	224	225	226	227	228	229	230	231	232	233	234	235	236	237	238
Cordosphaeridium																																				
C. fibrospinosum	2 .6		*	4 1.3	*	1 .3	1 .3	*	1 .3	6 2.0	3 1.0	2 .7	*				*			*		1 .3	*	2 .7	3 1.0	2 .7	*	2 .7	1 .3	4 1.3	*		1 .3		1 .3	*
C. varians				4 1.3	4 1.3	11 3.7	23 6.8	4 1.3	12 4.0	9 3.0	*																										
Coronifera																																				
C. oceanica	1 .3					*			2 .7	1 .3		2 .7	1 .3	2 .7	6 2.0	2 .7	*			*		*	*	*		*	*	3 1.0		3 1.0		*		*		*
Cyclonephelium																																				
C. densebarbatum	1 .3	1 .3	1 .3	2 .7	1 .3				*	1 .3	4 1.3	3 1.0	1 .3	3 1.0	2 .7	3 1.0				1 .3							*									
Diconodinium																																				
D. rhombiformis	1 .3				*						3 1.0	2 .7						3 1.0	1 .3												2 .7			1 .3	3 1.0
D. sp.				1 .3	*																														
Diphyes																																				
D. colligerum												*								*											1 .3		*		
D. recurvatum					*									*																					

APPENDIX CONTD.

Species \ Sample Nos.	203	204	205	206	207	208	209	210	211	212	213	214	215	216	217	218	219	220	221	222	223	224	225	226	227	228	229	230	231	232	233	234	235	236	237	238
Diversispina																																				
D. truncata													2 .7			1 .3	6 2.0	5 1.7	13 4.3	1 .3		7 2.3	4 1.3	4 1.3	2 .7	*	*	2 .7		*	1 .3	1 .3	1 .3	2 .7	2 .7	5 1.7
Exochosphaeridium																																				
E. bifidum	22 7.4		5 1.7	8 2.7	13 4.3	35 11.7	18 6.0	1 .3	4 1.3	3 1.0	9 3.0	14 4.7	13 4.3	14 4.8	42 14.0	70 23.3	22 7.3	28 9.4	38 12.7	34 11.4	51 17.0	41 13.7	94 31.4	65 21.9	84 28.0	28 9.3	44 14.7	73 24.3	27 9.0	65 21.9	85 28.3	42 14.0	58 19.4	40 13.1	18 6.0	31 10.3
Gonyaulacysta																																				
G. clathrata	3 1.0	1 .3	3 1.0		1 .3	*					*		1 .3																							
G. wetzeli				*	*												*	*	5 1.7	4 1.3	1 .3	4 1.3	*	*	*	*		2 .7		*	*	*	*		*	
G. sp.																	1 .3		1 .3	4 1.3	14 4.7	9 3.0	22 7.3	3 1.0	7 2.3	3 1.0	3 1.0	4 1.3	5 1.7	4 1.3	7 2.3	2 .7	6 2.0	2 .7	1 .3	2 .7

APPENDIX CONTD.

Species \ Sample Nos.	203	204	205	206	207	208	209	210	211	212	213	214	215	216	217	218	219	220	221	222	223	224	225	226	227	228	229	230	231	232	233	234	235	236	237	238
Hystrich-okolpoma																																				
H. fene-strecona											*								*	1 .3			*	1 .3	*	*				*		1 .3		*	
Hystricho-sphaeridium																																				
H. tubiferum	1 .3				5 1.7	4 1.3	15 5.0		51 17.0	15 5.0	24 8.0	22 7.3	13 4.3	4 1.3	16 5.3	1 .3		5 1.7	6 2.0	3 1.0	2 .7		1 .3	5 1.7	8 2.5	2 .7	1 .3	2 .7		7 2.3	4 1.3	3 1.0	2 .7	6 2.0	4 1.3	5 1.7
H. t. brevi-spinum					*				1 .3					1 .3	*										*	*					*			*	
H. recurva-tum							*	*	*				2 .7		3 1.0			2 .7	1 .3						*						1 .3		1 .3	2 .7	
H. sp.					1 .3																										*				
Lepto-dinium																																				
L. cristatum	1 .3				1 .3	2 .7							1 .3	*	1 .3		1 .3	1 .3	*	1 .3	*	*	1 .3	*	1 .3									1 .3		

APPENDIX CONTD.

Species \ Sample Nos.	203	204	205	206	207	208	209	210	211	212	213	214	215	216	217	218	219	220	221	222	223	224	225	226	227	228	229	230	231	232	233	234	235	236	237	238
L. sp.					*																															
Odonto-chitina																																				
O. costata	*	*	*		1 .3																															
Oligo-sphaeridium																																				
O. complex					1 .3	*				1 .3	1 .3		1 .3	4 1.3	*	2 .7		1 .3	1 .3											1 .3	1 .3					
Phobero-cysta																																				
P. cera-tioides	*			*	*																															
Prolixo-sphaeridium																																				
P. xanthio-pyxides					2 .7				*		3 1.0	9 3.0		1 .3	2 .7			13 4.3										*				*	*		5 1.7	3 1.0
Samlan-dia																																				
S. angusti-vela					3 1.0	17 5.7	33 11.0	2 .7	5 1.7	53 17.7				1 .3																							

APPENDIX CONTD.

Sample Nos. / Species	203	204	205	206	207	208	209	210	211	212	213	214	215	216	217	218	219	220	221	222	223	224	225	226	227	228	229	230	231	232	233	234	235	236	237	238
Spiniferites																																				
S. ramosus granosus	3 1.0				3 1.0	2 .7	5 1.7	1 .3	5 1.7		*		1 .3					1 .3	2 .7				1 .3			*		3 1.0		1 .3	1 .3	*	2 .7	1 .3	1 .3	
S. r. multi-brevis	3 1.0				3 1.0		4 1.3		5 1.7	5 1.7	4 1.3	1 .3	2 .7	1 .3	1 .3				2 .7	1 .3										*	5 1.7		5 1.7	3 1.0	1 .3
S. r. ramosus	8 2.7	1 .3		6 2.0	18 6.0	9 3.0	27 9.0	1 .3	31 10.4	8 2.7	14 4.8	10 3.3	15 5.0	4 1.3	23 7.7	2 .7	4 1.3	3 1.0	17 5.7	6 2.0		5 1.7	5 1.7	4 1.3	2 .7	*		10 3.3	1 .3	5 1.7	4 1.3	8 2.7	3 1.0	15 5.0	11 3.8	18 6.0
S. r. reticulatus				1 .3			1 .3		1 .3		2 .7	1 .3	1 .3																		2 .7		1 .3	3 1.0	
S. cf septatus					2 .7					2 .7	1 .3	1 .3							1 .3				*									1 .3	1 .3		2 .7
S. ramuliferus							2 .7		1 .3	1 .3	1 .3	1 .3	1 .3	1 .3	1 .3				6 2.0				1 .3						1 .3		3 1.0		4 1.3		1 .3
S. supparus	3 1.0		1 .3	2 .7	3 1.0		3 1.0		7 2.3	2 .7	2 .7	2 .7	4 1.3	1 .3	2 .7				1 .3												1 .3			3 1.0	1 .3	
Spinitectulum																																				
S. ferox					1 .3				*		*	*		1 .3	1 .3					1 .3			1 .3		1 .3	*		1 .3		*		*		

APPENDIX CONTD.

Species \ Sample Nos.	203	204	205	206	207	208	209	210	211	212	213	214	215	216	217	218	219	220	221	222	223	224	225	226	227	228	229	230	231	232	233	234	235	236	237	238
S. ramulus									2 .7		2 .7	*	*	*																						
S. sp.												*																								
Spongodinium																																				
S. delitiense						9 3.0	37 12.4	2 .7	6 2.0	2 .7	1 .3	1 .3		6 2.0																							
S. sp.																														*						
Systemato-phora																																				
S. placa-cantha							*		1 .3							2 .7			12 4.0	4 1.3	6 2.0	10 3.3	11 3.7	24 8.0	13 4.1	7 2.3	29 9.7	45 15.0	16 5.3	87 27.0	43 14.4	20 6.7	44 14.8	17 5.7	19 6.3	23 7.7
S. varians	*	*	*																																	
Triblas-tula																																				
T. utinen-sis																				1 .3		3 1.0		1 .3	*	2 .7		*		1 .3		*	*	1 .3		
T. borus-sica					*			*	*	*					1 .3										*								*	1 .3	*	2 .7
T. nuda										1 .3	1 .3						1 .3			*					*			*				*		*	*	

APPENDIX CONTD.

Sample Nos. / Species	203	204	205	206	207	208	209	210	211	212	213	214	215	216	217	218	219	220	221	222	223	224	225	226	227	228	229	230	231	232	233	234	235	236	237	238
Trichodinium																																				
T. hirsutum									3 1.0	4 1.3	12 4.0	10 3.3	25 8.4	29 9.7	28 9.4	27 9.0	24 8.0	11 3.7																			
PERIDINEACEAE																																				
Deflandrea																																				
D. asymmetrica				* 6.7	20 9.7	29		53 17.7	11 3.7		15 5.0	56 18.7	2 .7	2 .7	19 6.3	21 7.0	12 4.0		* 2.3	7 .7	2 .3	1		1 .3						41 13.8			3 1.0				
D. cf. assymetrica						*			2 .7			*			2 .7	*																			
D. cooksoni					7 2.3	1 .3	1 .3	3 1.0	2 .7	19 6.4	5 1.7	3 1.0	*	2 .7	1 .3	2 .7	11 3.7		2 .7						1 .3	1 .3	1 .3	1 .3	4 1.3	6 2.0	2 .7	2 .7		2 .7	1 .3	1 .3
D. cordifera																			* 1.3	4		4 1.3	2 .7	*	3 1.0	1 .3	1 .3	*	1 .3	1 .3	3 1.0	5 1.7	2 .7	2 .7	4 1.3	3 1.0
D. corrugatella				2 .7	2 .7	*																														
D. cf. cretacea										*	1 .3			*			2 .7													1 .3	1 .3				

APPENDIX CONTD.

Sample Nos. / Species	203	204	205	206	207	208	209	210	211	212	213	214	215	216	217	218	219	220	221	222	223	224	225	226	227	228	229	230	231	232	233	234	235	236	237	238
D. diebeli						1 .3	11 3.7	3 1.0	4 1.3	*		3 1.0	2 .7	6 2.0	1 .3	3 1.0	2 .7		2 .7	1 .3		3 1.0	*					2 .7	1 .3	1 .3	1 .3	3 1.0			1 .3	5 1.7
D. d. rigida					3 1.0	2 .7	11 3.7	3 1.0	9 3.0	3 1.0	4 1.3	1 .3	3 1.0	9 3.0	3 1.0	1 .3	2 .7	*	2 .7	*	2 .7	2 .7	*	1 .3	1 .3	*	4 1.3	4 1.3	6 2.0	3 1.0	5 1.7	5 1.7	4 1.3	8 2.7	3 1.0	5 1.7
D. spicata	2 .7	2 .7	3 1.0	1 .3			1 .3										*																			
D. magnifica			*	1 .3					*		1 .3	1 .3		*	2 .7	*	*		1 .3				*	*	*	*		*		3 1.0		1 .3			*	*
D. cf obscura						1 .3		*	*						1 .3	1 .3			*	1 .3	*	1 .3	*	1 .3	*				2 .7							
D. pannucea					*			*				1 .3			1 .3	1 .3	3 1.0	3 1.0	5 1.7	3 1.0	*	1 .3	4 1.3	1 .3	2 .7	1 .3	3 1.0	*	2 .7	*	*	2 .7				1 .3
D. speciosa												*						1 .3	9 3.0	16 5.4	6 2.0	35 11.7	15 5.0	15 5.0	20 6.6	7 2.3	10 3.3	12 4.0	12 4.0	14 4.7	14 4.7	7 2.3	13 4.3	5 1.7	22 7.4	15 5.0
D. striata			1 .3	3 1.0	5 1.7	1 .3	5 1.7	2 .7	4 1.3	42 14.0	2 .7	2 .7	2 .7	1 .3	1 .3		2 .7	2 .7	1 .3					1 .3		4 1.3	2 .7	1 .3	9 3.0	8 2.7	7 2.3	4 1.3	2 .7	4 1.3	4 1.3	1 .3	1 .3
D. ornata	20 6.7	20 6.7		22 7.3	11 3.7	5 1.7																														
D. tripartita		1 .3	1 .3	1 .3	11 3.7	58 19.4	28 9.4	68 22.7	20 6.7	20 6.7	9 3.0	19 6.4	60 20.0	70 23.3	22 7.3	11 3.7	43 14.4	10 3.3	8 2.8	1 .3		*		2 .3	17 5.6	13 4.3	*	5 1.7	7 2.3	2 .7	16 5.3	13 4.3	19 6.3	25 8.3	12 4.0	8 2.7

APPENDIX CONTD.

Sample Nos. / Species	203	204	205	206	207	208	209	210	211	212	213	214	215	216	217	218	219	220	221	222	223	224	225	226	227	228	229	230	231	232	233	234	235	236	237	238
D. cf. tripartita						1 .3							1 .3	*	*	1 .3																			
D. sp. A		1 .3				1 .3		1 .3				1 .3										*						1 .3			1 .3				
D. sp. B												2 .7	*	1 .3					1 .3																	
D. sp. C															1 .3												1 .3									
D. sp. D					*																															
Palaeocystodinium																																				
P. australinum					*		1 .3		1 .3	4 1.3	1 .3	2 .7	8 2.8	6 2.0	10 3.3	5 1.7	84 280	13 4.3	10 3.3	53 179	9 3.0	101 338	68 228	6 2.0	5 1.7	5 1.7	1 .3	7 2.3	2 .7	3 1.0	3 1.0	*	1 .3	2 .7	5 1.7	5 1.7
P. cf denticulatum												*																				1 .3				
P. reductum	*	*	*	*				*																												
Paleohystrichophora																																				
P. infusorioides	37 123	35 117	20 6.7	15 5.0																																

APPENDIX CONTD.

Sample Nos. / Species	203	204	205	206	207	208	209	210	211	212	213	214	215	216	217	218	219	220	221	222	223	224	225	226	227	228	229	230	231	232	233	234	235	236	237	238
Spinidinium																																				
S. uncinatum	1 .3			*	5 1.7	3 1.0			*			*																								
Trithyro-dinium																																				
T. cavum	67 22.4	49 16.4	50 16.7	26 8.8	3 1.0	43 14.3	30 10.0	11 3.7	31 10.4	39 13.0	12 4.0	18 6.0	96 32.0	59 19.7	9 3.0	2 .7	4 1.3	*	*								*		*							
T. evittii														*		*	*																		
T. penta-gonium													1 .3	2 .7	20 6.8	4 1.3	16 5.3	17 5.7	7 2.3	9 3.0																
T. stria-tum					2 .7				*				3 1.0	4 1.3	5 1.7	2 .7	2 .7	1 .3	1 .3	3 1.0		1 .3		*	7 2.3	2 .7	3 1.0	15 5.0	15 5.0	18 6.0	15 5.0	7 2.3	21 7.0	7 2.3	6 2.0	7 2.3
GYMNODIN-IACEAE																																				
Dinogymnium																																				
D. elong-atum					*		2 .7																													
D. acumin-atum										1 .3																										

APPENDIX CONTD.

Sample Nos. / Species	203	204	205	206	207	208	209	210	211	212	213	214	215	216	217	218	219	220	221	222	223	224	225	226	227	228	229	230	231	232	233	234	235	236	237	238
D. euclaensis												*																								
D. cf. euclaensis																															*					1 .3
D. lanceolatum					4 1.3	2 .7	2 .7	1 .3	*										*	*																
D. pustulicostatum	40 134	174 580	193 643	135 450	2 .7	4 1.3		*	*		*	*					*			*		*	*												
D. westralium																													1 .3		1 .3	*	2 .7	2 .7	2 .7	7 2.3
D. sp. A						*																														
D. sp. B									*																											
D. sp. C					*												*																			
D. sp. digitus					*																															
Other	77 25.7	15 5.0	20 6.7	60 20.0	156 52.0	49 16.3	29 9.7	143 47.7	55 18.3	51 17.0	148 49.5	107 35.7	21 7.0	44 14.7	53 17.7	120 40.0	60 20.0	125 41.7	108 36.0	133 44.4	191 63.6	65 21.7	25 8.3	17 5.9	15 5.0	18 6.0	27 9.0	49 16.3	117 39.0	45 15.0	71 23.9	150 50.0	94 31.3	137 45.9	165 55.0	135 45.0

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DINOFLAGELLATE CYSTS OF THE GYMNODINIACEAE, PERIDINIACEAE, AND GONYAULACACEAE FROM THE UPPER CRETACEOUS MONMOUTH GROUP, ATLANTIC HIGHLANDS, NEW JERSEY

by

Fred Eugene May

(ABSTRACT)

The taxonomy, paleoecology, and biostratigraphy of fossil dinoflagellate cysts belonging to three families (Gymnodiniaceae, Peridiniaceae, and Gonyaulacaceae) are investigated from the Campanian-Maestrichtian Mount Laurel Sand, Navesink Formation, and Sandy Hook Member of the Red Bank Sand of Atlantic Highlands, New Jersey. Thirty-seven genera and 91 species belonging to these families were recovered of which 3 genera and 20 species are described as new.

Dinoflagellate peak zones, restricted ranges, relative frequencies, and species diversity suggest that environments changed four times during deposition of the units studied. The stratigraphic intervals representing these four paleoenvironments correspond closely to intervals assigned to particular paleoenvironments based on invertebrate fossils and lithology (Owens and Sohl, 1969; Sohl, 1969). Thus, correlation of this previously determined paleoecological data and that of the dinoflagellates allows for interpretation of dinoflagellate distribution relative

to particular marine to brackish water paleoenvironments.

Cordosphaeridium varians n. sp. and Exochosphaeridium bifidum (Clarke and Verdier) Clarke et al. 1968 are shown to be highly variable in morphology, each having distinctively different morphologic end members. It is suggested that such variability is natural and that extreme morphologic end members be assigned to the same species, as is done with living populations. C. varians is also shown to grade morphologically upsection into forms similar to Trichodinium hirsutum Cookson 1965 and which are referred to in this study as T. cf. T. hirsutum.

Scanning electron microscopy of Dinogymnium pustulicostatum n. sp. and D. westralium (Cookson and Eisenack) Evitt et al. 1967 has revealed the fine structure at the cingulum-sulcus intersection, consisting of apparent flagellar pores (one anterior and one posterior) and associated ridges and grooves which may have confined or directed the passage of the flagella. The presence of flagellar pores suggests that motile stage dinoflagellate tests may be preserved as fossils. Scanning electron microscopy also illustrates the detailed morphology of Dinogymnium wall canals (Evitt, Clarke, and Verdier, 1967), which are interpreted here as being trichocyst pores, such as are found on several modern dinoflagellates.

Campanian and Maestrichtian age-indicating dinoflagellates suggest that the Campanian-Maestrichtian boundary lies within the uppermost Mount Laurel Sand or lower Navesink Formation. This stratigraphic interval is in agreement with the position of the

Campanian-Maestrichtian boundary at the study area as indicated by Ammonites (Cobban, 1974). Above this interval the Navesink Formation and Sandy Hook Member contain dinoflagellate assemblages which are comparable to those observed by Wilson (1974) in lower Maestrichtian sediments of the Maestricht Region, Holland, and of Denmark. Below this interval the Mount Laurel Sand is considered of late Campanian age.