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DINOFLAGELLATE TAXONOMY AND BIOSTRATIGRAPHY AT THE CRETACEOUS-TERTIARY BOUNDARY, ROUND BAY, MARYLAND[1]

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I. ABSTRACT

Dinoflagellate assemblages from the Monmouth (Cretaceous) and Brightseat (Paleocene) formations are described. The dinoflagellate assemblages support the placement of the Monmouth Formation by previous workers in the Maestrichtian Stage, and the assignment of the Brightseat Formation to the Paleocene series.

The Cretaceous-Tertiary boundary is characterized by a sudden change in the content of the dinoflagellate assemblage. Based on this sudden change the boundary is interpreted as a paraconformity.

Changes in the dinoflagellate assemblage within the Monmouth Formation of this area form the basis for the establishment of three provisional zones which may serve as a framework for future work in this region.

The dinoflagellate assemblages contain 35 genera and 66 species of which two genera and eight species are described for the first time. The new genera are *Cyclapophysis* and *Diversispina.*

II. INTRODUCTION

The Cretaceous-Tertiary boundary of the Atlantic Coastal Plain has been the subject of several investigations since Clark (1898) published his pioneer work on the Upper Cretaceous formations of New Jersey. Controversary has arisen as to the nature of the boundary with some studies supporting a gradational (conformable) relationship (Olsson, 1960, 1963; Jordan, 1963) and others an unconformable relationship (Minard *et al.,* 1969). Most work has been done on formations in the New Jersey and Delaware Coastal Plain. Of the little work done on the Maryland Coastal Plain, most has been concentrated on the eastern shore region.

The objectives of the present study are: to describe the dinoflagellate assemblages in the Monmouth and Brightseat formations; to determine the stratigraphic distribution of dinoflagellates relative to the Cretaceous-Tertiary boundary; and to contribute to an effort by the palynological group at V.P.I. & S.U. to establish a standard dinoflagellate succession for the Atlantic Coastal Plain.

Although the section under investigation affords one of the better exposures of the boundary and associated formations in Maryland, it has been leached and contains no calcareous fossils. The lack of calcareous fossils in this and other sections frequently precludes accurate correlations. In cases like this a palynological approach often is the only feasible paleontological method for accurate dating.

The biostratigraphic utility of dinoflagellates on the Grand Banks has been demonstrated (Upshaw *et al.,* 1974) and the establishment of a standard dinoflagellate succession for use in the Atlantic Coastal Plain would be of great value in correlating coastal plain and continental shelf sediments when offshore drilling begins along the Atlantic Coast.

Many studies have been carried out on Cretaceous and Paleocene dinoflagellate assemblages throughout the world. Few of these investigations have studied the dinoflagellate transition across the Cretaceous-Tertiary boundary. In addition, the utility of some previous investigations is diminished by poor stratigraphic definition of sample localities. However, the studies of Drugg (1967) on the Cretaceous-Tertiary boundary in Southern California, Stanley (1965) on the Cretaceous-Tertiary boundary in western South Dakota, and Zaitzeff and Cross (1966) on the Navarro Group in Texas were useful in the present work.

No reports on the palynology of the Monmouth Formation in Maryland have been published; however, Waanders (unpublished Ph. D. dissertation, 1974) has investigated pollen and spores and figured some dinoflagellates from the Monmouth Group, Monmouth County, New Jersey. No comparison can be made between the work of Waanders (1974) and this work because Waanders did not present ranges for his dinoflagellates.

Two other investigations are in progress on the Atlantic Coastal Plain, which are

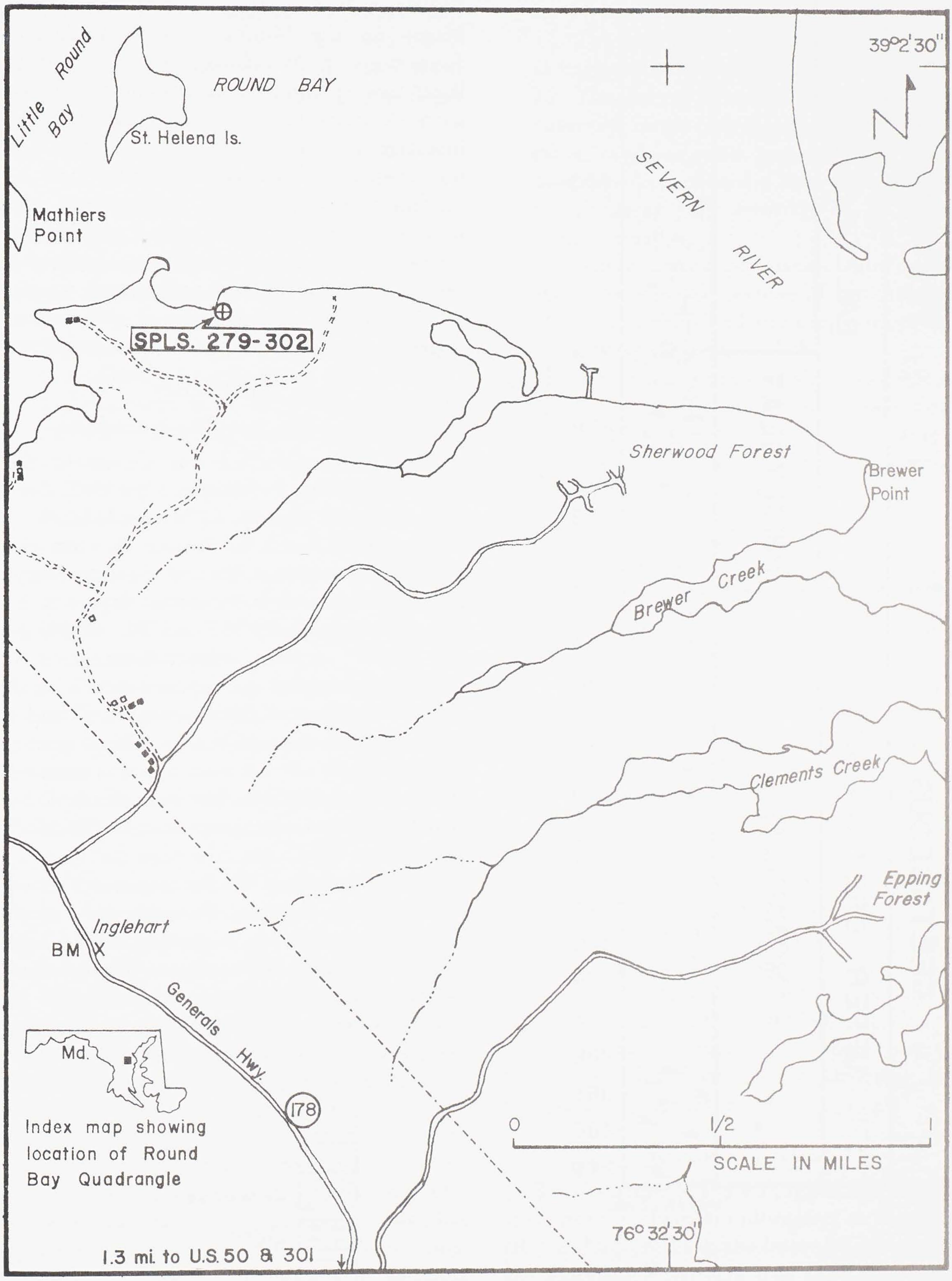


Figure 1. Sketch map showing sample locality.

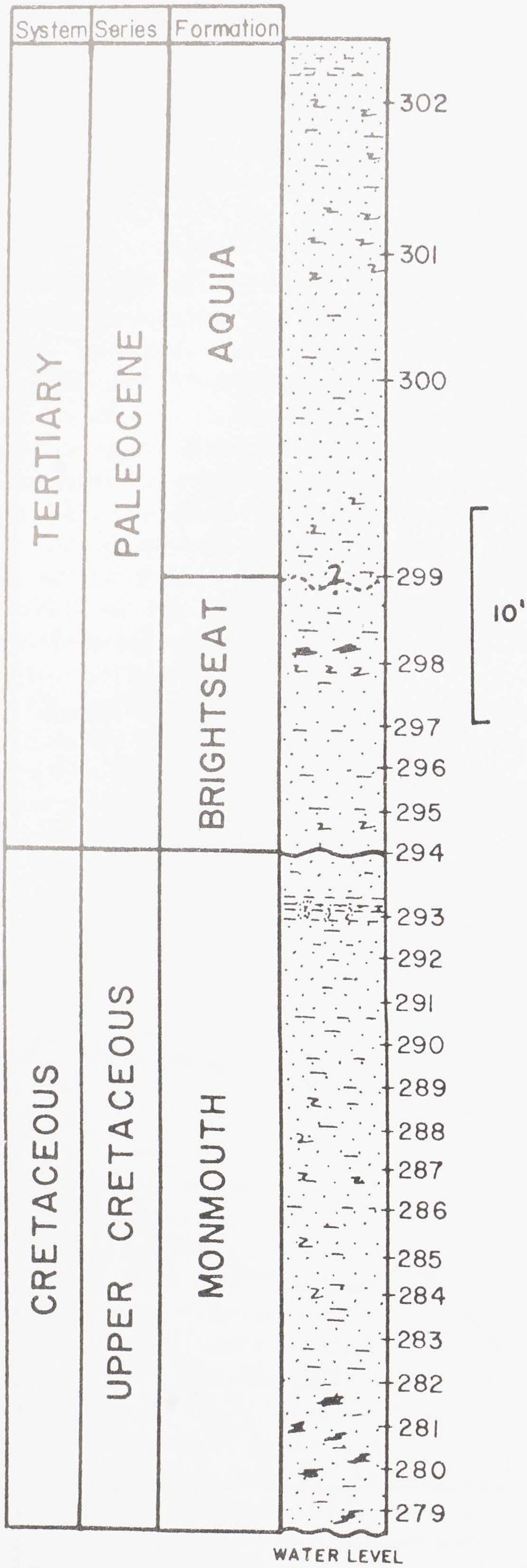


Figure 2. Columnar section Cretaceous and Tertiary sediments, Round Bay, Maryland.

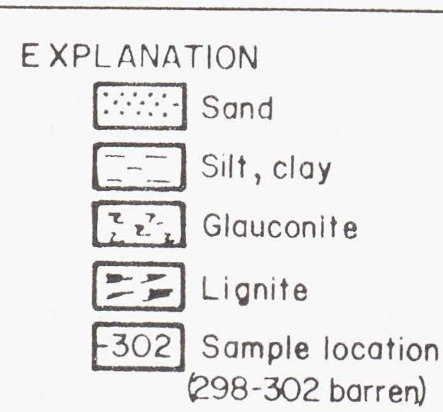
pertinent to the present study. Fred May of the U. S. Geological Survey is completing a study on the dinoflagellates of the Monmouth Group, New Jersey, and Barbara Whitney of the University of Washington at Seattle, is investigating dinoflagellate assemblages on the Monmouth and Brightseat formations in Maryland from locations at least twenty miles west and north of the author's study section. The results of these investigations are not as yet complete thus no comparison between distributions of dinoflagellates in those studies and the present work can be drawn. A publication by Groot and Groot (1962) on the Brightseat Formation treated pollen and spores. They included photographs of some dinoflagellates, but did not describe any species.

III. METHODS

Location and Sampling Procedures

The section studied was shown to the author by James P. Minard of the U. S. Geological Survey in July, 1974. It is located on the southern bank of Round Bay on the Severn River, Anne Arundel County, Maryland. The location is shown on Figure 1, its coordinates being 76° 33' 5.3"W, 39° 02' 2" N. Two sections, approximately two hundred feet apart are exposed at this locality: an easternmost northfacing bluff, and a westernmost exposure in an erosional ravine. For this study the latter section was sampled since it appeared to be less affected by weathering and slumping than is the bluff exposure.

Before sampling, the outcrop was cleaned of weathered sediment. Samples were taken at two-foot intervals beginning at the high water level of the Severn River. Twenty-four samples were taken at positions shown to scale on the section in Figure 2. The



sampling interval above sample 297 was greater than two feet because of vegetation cover and extensive weathering of the exposure. Approximately 750 cubic centimeters of sediment was collected for each sample with clean equipment to prevent contamination. The samples were placed in labeled plastic bags for storage and transportation. Nineteen contained dinoflagellates.

Sample Processing

Samples were disaggregated by crushing with a glass stirring rod in a plastic beaker following an overnight soaking in distilled water. Approximately 100 cubic centimeters of sediment was processed as follows:

1. Overnight exposure to distilled water to facilitate disaggregation.
2. Treatment with HC1 to remove calcareous material; wash with distilled water.
3. Overnight exposure to HF; wash with distilled water to remove dissolved silicates.
4. Resuspension of sediment in distilled water; decantation of fine sediment following 15 sec. of settling to remove coarse sand fraction.
5. Treatment of the fine sediment with hot concentrated HC1 to facilitate disaggregation of clay; wash with distilled water.
6. Oxidation with acidified commercial NaClO to remove susceptible organic material; wash with distilled water.
7. Treatment with NH_4OH to adjust pH to neutrality and facilitate clay removal.
8. Filtration through 20 micron mesh stainless steel sieve. The filtrate is discarded, and the retained material saved for further processing. The sieve was cleaned by an ultrasonic cleaner between samples.
9. Following treatment with glacial CH_3COOH and centrifugation, the samples were treated with $(CH_3CO)_2O$ acidified with H_2SO_4 for 15-20 minutes in a water bath at 90-100° C. The acetylation darkened the palynomorphs for microscopy and removed additional unwanted organic material. The samples were cooled and centrifuged successively with CH_3COOH and distilled water.
10. Palynomorphs were separated from inorganic debris by heavy liquid separation in $ZnBr_2$, sp. gr. 2.0, and centrifuged for 15 minutes.
11. The organic residue was filtered again as in step 8 to remove fine debris.
12. The palynomorphs were placed on a coverslip in glycerine jelly on a warming table, and allowed to dry for 20-30 minutes. The coverslip was then affixed by glycerine jelly onto the 1 X 3 inch glass microslide.
13. After about one week, the excess glycerine jelly was removed from the edge of the coverslip and the preparation was sealed with clear nail polish.

The slides are stored in slide box AN in the V.P.I. & S.U. Paleontological Collection. Each slide is inscribed with the sample numbers shown in Figure 2, slide box series AN, and the slide number.

Counting Procedures

Four slides were prepared for each sample and were scanned to establish the species of dinoflagellates present. Following completion of the taxonomic portion of the study the slides were scanned across uniformly spaced traverses to count the number of specimens. An average of two to three hundred dinoflagellate specimens were counted for each sample. The exact number of specimens counted, is summarized in Figure 3.

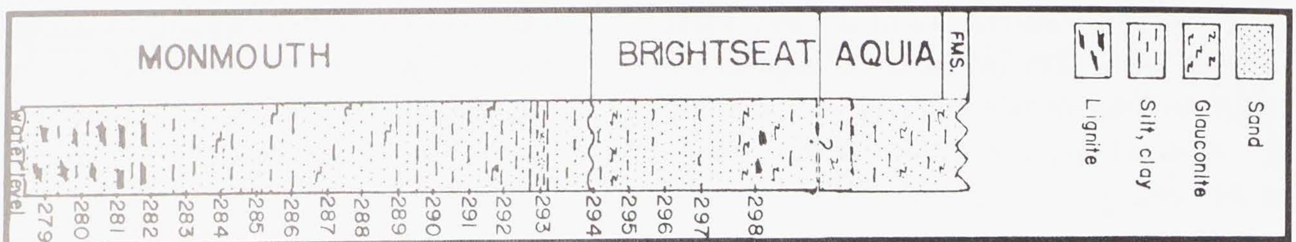
The relative abundance of dinoflagellate species is broken down as follows:

1% = very rare
4-5% = rare
5-25% = common
25% = abundant

Specimens observed during the course of microscopy but not during counting are designated by the letter "X".

Specimen Location

The location of the holotypes and figured specimens is given in millimeters to the right (R) and up (+) from the lower left corner of the coverslip.



"X" = KNOWN TO BE PRESENT, NOT OBSERVED IN COUNTING

	279	280	281	282	283	284	285	286	287	288	289	290	291	292	293	294	295	296	297	298
Dinogymnium sp.											X		X	X	X					
D. westralium		2	2	X	X	X	1				X									
Conosphaeridium cf. C. striatoconus															X					
Cordosphaeridium fibrospinosum		2	X			1	X		2							3				
Coronifera oceanica		2		2		1							1	1			X			
Cyclapophysis monmouthensis n. sp.												X	2	1	3	X		X?		
Cyst Forma A			X																	
Cyst Forma B														X						
Diphyes colligerum			X		X									1	2		4		X	
Diversispina truncata n. sp.				X	3	2	5	10		6		6	3	2	6	2				
Exochosphaeridium bifidum	3	4	18	12	15	2	1		2	6	4									
Exochosphaeridium sp. complex	32	26	30	60																
Gonyaulacysta orthoceras			X	2	11	6	5	2												
G. wetzelii											8	57	80	76	6	9				
Hystrichokolpoma ferox		1																		
H. fimbriata															X					
H. unispinum																	X			
Hystrichosphaeridium deanei																X	X			
H. tubiferum	25	18	7	1		1	1	3	4	24		3	7	6	4	7	3	10	6	
Lanternosphaeridium bipolare																4	4	6	X	
L. cf. L. lanosum											4	1	2	1		5	20	40	X	
Operculodinium centrocarpum																15	45	8	12	
Spiniferites cf. S. cornutus															X		X			
S. ramosus ramosus	12	44	X	1	4	4	10	21	22	15	13	45	32	23	44	6	18	4	9	
S. ramosus granosus	6	2		X	2	1		X	4	6	2	6	6	10	6	9	5	4	X	
Spongodinium delitiense		X	2																	
Trichodinium hirsutum																	5	44	52	
Deflandrea asymmetrica	35	32	36	27	1															
D. cooksonii	31	38	55	21	6		2		X											
D. dartmooria		X			3	4	4	2	10	10	10	40	8	9	X	3	1	X		
D. diebelii	1	X	1	4			2													
D. cf. D. diebelii								2			4			X	X	2	X			
D. dilwynensis																10	10	4	X	
D. echinoidea																62	65	10	X	
D. magnifica		2						3	2	4	4	8	1	X	2	9	6	X	X	
D. minor								4	5	4	2	X	5	3						
D. pannucea				4	X	X	1	8	X	X	3	2	2							
D. cf. D. pentaradiata																40	11	X	X	
D. pulchra n. sp.																	20	112	78	
D. rhombohedra n. sp.																2	X		X	
D. severnensis n. sp.						8	4	66	27	40	65	21	9	13	2					
D. cf. D. speciosa									4		6	4	6	2	3					
D. cf. D. striata						1			X		2	2	1	X	X	X	X	X	X	
D. sp. A				2	2	X														
Palaeoperidinium basilium																			35	
P. cf. P. deflandrei	19	14	5	12		6														
Spinidinium clavum		2	X										6	11	45	10	8	X		
Svalbardella australina	3	4	5	14	X	X		10	50	14	22	12	3	4	6	5	4	2		
Trithyrodinium striatum n. sp.		4	2																	
T. robustum n. sp.	6	22	25																	
Wetzeliella cf. W. pilata																	X	X	X	
Areoligera sp.	75	20	16	32	315	220	350	65	110	85	35	8	75	58	85	1	6	2	6	
Cyclonephelium distinctum							1	6	6	15										
Cyclopsiella vieta ?		X	X	X			1		X		X		X	1						
Diconodinium rhombiformis	1	7	10	2	1	1	4	X	X											
Fibradinium cf. F. annetorpense	9	X	1	X			1		X	2	2			1	3	15	10	4	9	
Fromea amphora	X	X	X	X																
Inversidinium caudatum n. sp.		X	X					X		X	2	X	1	X		5	2		X	
Microdinium setosum		X	X					X												
Genus A	X	X	1	X	X												X?			
Genus B	X	X	X																	
Systematophora cf. S. areolata					X		X													
S. placacantha					2		45													
Tanyosphaeridium variecalamum						X							1	7	X		4			
Xenikoon australis		2	5	8	X	2	X	10		4										
Ophiobolus lapidaris		10	2	2	3	1	X	5	4		10	2	1	1	X					

Assemblage Zones	A	B	C	(Paleocene, unnamed)
Series	Upper Cretaceous			Paleocene
System	Cretaceous			Tertiary

FIG. 3. Frequency of dinoflagellates, Round Bay, Md.

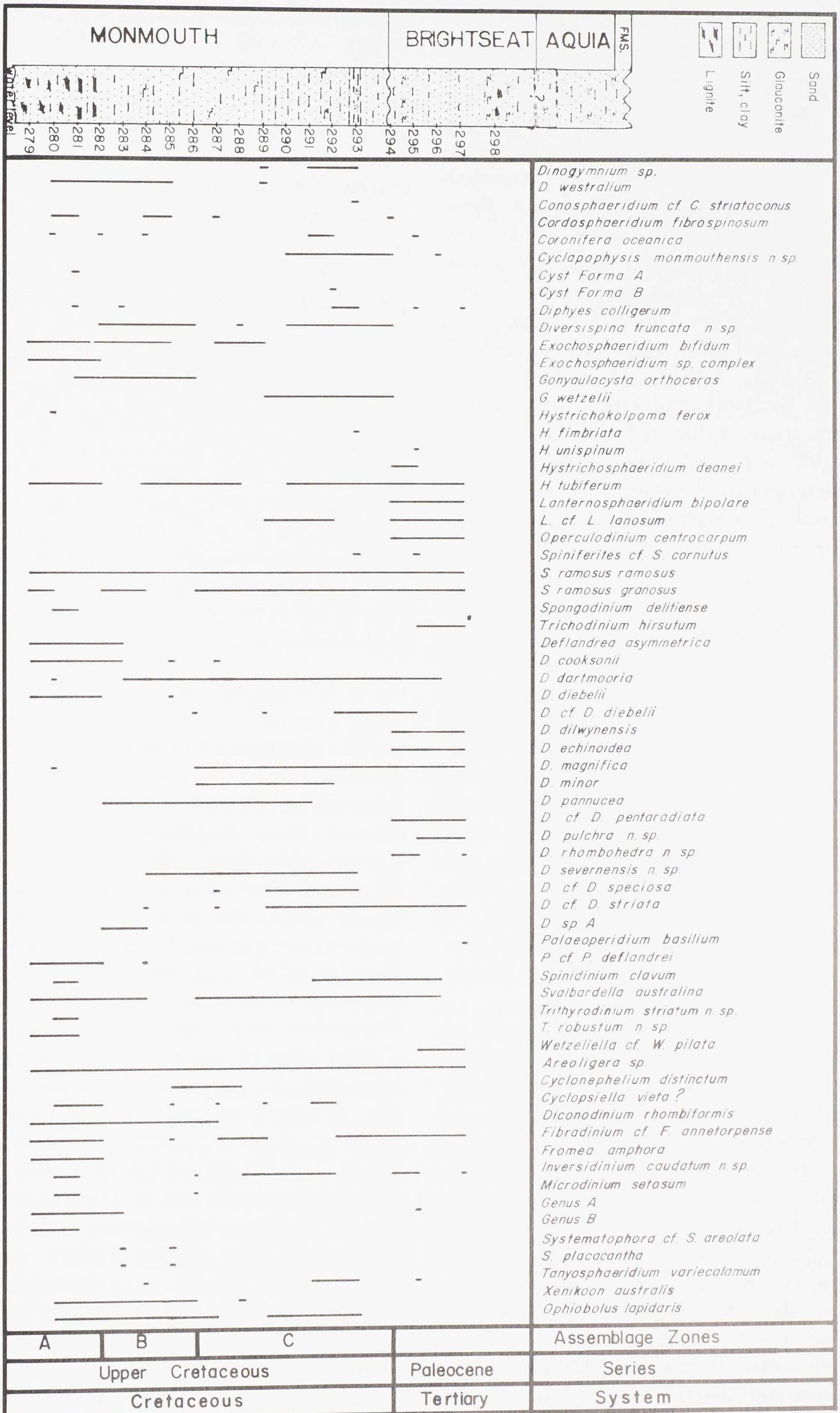


FIG. 4. Stratigraphic distribution of dinoflagellates, Round Bay, Md.

IV. STRATIGRAPHY

Monmouth Formation

The Monmouth Formation was named by Clark (1897) for exposures of Late Cretaceous glauconitic, silty sands located in Monmouth County, New Jersey. The Monmouth Formation was divided by Clark into three units: the basal Mt. Laurel sands, the Navesink marls; and the Redbank sands. These units were later elevated to formational rank and the Tinton Formation was separated from the uppermost Redbank (Weller 1905, 1907). The Mt. Laurel, Navesink, Redbank, and Tinton formations, although recognizable in New Jersey as the Monmouth Group, do not have the distinctive lithologies in Maryland where the name Monmouth Formation is used. Recent mapping by Minard (1974) near Betterton on the eastern shore of Maryland has, however, demonstrated the presence of the Mt. Laurel Formation. Minard (1974) states that a coarse glauconitic bed is "startingly similar to the coarse bed at the top of the Mt. Laurel and at the base of the Navesink" (p. 24); however, the lithologic evidence was insufficient to distinguish the presence of the Navesink Formation from the Mt. Laurel Formation. It remains to be seen if these lithologic units can be traced laterally and extended to the western shore of the Chesapeake Bay since Clark (1916) stated that the separation of the Monmouth Formation into members of more than just local extent in Maryland was not possible.

The Monmouth Formation in Maryland strikes northeasterly and dips to the southeast at 20 to 25 feet per mile. The thickness ranges from zero to 100 feet, the lower values tending to be more southwesterly and up dip in distribution. To the southwest along the strike, the Monmouth Formation rests on progressively older Cretaceous units (Clark, 1916) in an overstepping relationship. In the Round Bay region along the western edge of the Chesapeake Bay in Maryland, the Monmouth rests disconformably on the Matawan (?Merchantville) Formation of Campanian age; whereas, to the southwest near Brightseat, Maryland, it rests disconformably on sediments of the Lower Cretaceous Potomac Group (Clark, 1916).

The Monmouth Formation is overlain by strata of Paleocene, ?Eocene, and Miocene age in Maryland (Clark, 1916; Little, 1917; Vokes, 1957; Cooke, 1952) and it appears that in Maryland there can be little doubt as to the unconformable nature of the Cretaceous-Tertiary boundary. The extent of the hiatus decreases to the northeast with sediments of Paleocene age present near Betterton, Maryland (Minard, 1974). To the southwest, in Prince Georges County, overlying the Monmouth Formation are sediments as young as the Miocene Chesapeake Group (Cooke, 1952).

The Monmouth Formation is considered to be Maestrichtian in age based on the presence within it of the *Exogyra costata* and *E. cancellata* Zones (Stephenson *et al.*, 1942). That age assignment has been supported by Mumby (1962) on the basis of foraminiferal data.

Brightseat Formation

The Brightseat Formation was named by Bennett and Collins (1952) for a dark gray, micaceous, sandy clay unit of Paleocene age located near Brightseat, Prince Georges County, Maryland. The exposures of the Brightseat Formation are scattered and relatively thin (eight to ten feet). In the subsurface, thicknesses of 50 to 75 feet have been reported (Bennett and Collins, 1952). The contact with the underlying Monmouth Formation was observed by Bennett and Collins only at one locality; however, they suggested that it is unconformable based on the presence in the basal Brightseat of pebbles, reworked Monmouth Formation fossils, and the abrupt nature of the contact. The Brightseat Formation has been placed in the *Globigerina daubjergensis - Globorotalia compressa* Zone of the Danian stage by Hazel (1968), based on ostracodes. Hazel (1968) stated that the Brightseat Formation is equivalent to Clark and Martin's (1901) Zone 1 of the Aquia Formation. The upper contact of the Brightseat Formation with the overlying Aquia was considered by Bennett and Collins (1952) to be disconformable. However, Nogan (1964) and Drobnyk (1965) throught that the contact was gradational. Hazel (1969), on the basis of ostracode studies, supported a disconformable relationship.

V. RESULTS OF INVESTIGATION

Biostratigraphy

Of the 66 species described in this study, twelve are restricted to the Paleocene, 35 restricted to the Cretaceous sediments, and 19 cross the Cretaceous-Tertiary boundary. The distribution of the fossils throughout the section is summarized in Figure 4. Several species including *?Achomosphaera* sp., *?Oligosphaeridium* sp., *Membranosphaera* sp. and *Cladopyxidium* sp. were not studied due to problems of preservation and low recovery. Several species are apparently reworked. Cases of probable reworking are noted in the Systematic Palynology section.

Zonation

The author feels that provisional zones can be proposed for the Monmouth Formation, even though only a single section was studied. The zones are provisional since further work probably will extend the range of some of the species involved. They were established by utilizing the first or last appearance of a species, or restriction of a species to a particular zone. The zones are informally named, in ascending order: Monmouth Assemblage Zones A, B, and C. The floral characteristics of Zones A, B, and C are summarized in Figure 4.

Monmouth Assemblage Zone A is not defined basally. Reconnaissance examination of samples provided to the author by Jim Minard (U. S. Geological Survey) from exposures on the eastern bank of the Severn River approximately 1.5 miles northeast of the Round Bay locality, at which the base of the Monmouth Formation is exposed indicates that the base of zone A coincides roughly with the base of the Monmouth Formation. *Trithyrodinium robustum* n. sp. and *Spongodinium delitiense* exhibit local extinction within the zone. The top of the zone is characterized by the last appearance of *Fromea amphora.*

Monmouth Assemblage Zone B is distinguished by the first appearance of *Deflandrea pannucea, Deflandrea* cf. *D. speciosa,* and *Deflandrea* sp. A at its base and the local extinction of *Deflandrea cooksonii* and *Gonyaulacysta orthoceras* at its top.

The base of Monmouth Assemblage Zone C is marked by the first appearance of *Deflandrea* cf. *D. diebelii, Deflandrea minor,* and *Lanternosphaeridium* cf. *L. lanosum. Dinogymnium* sp. and *Cyclapophysis monmouthensis* gen. et sp. nov. are distinctive species first seen within the zone. *Deflandrea minor, Deflandrea severnensis* n. sp., *Deflandrea pannucea* and *Dinogymnium westralium* become locally extinct near the top of the zone. The last appearance of *Dinogymnium* sp. and *Ophiobolus lapidaris* marks the top of the zone.

The usefulness of the microfloral changes used in establishing the zones remains to be demonstrated. The simultaneous disappearance of some species and the first appearance of other species may represent diastems or environmental change.

No correlations can be drawn between the provisional zones and the studies of others in this region which are, as yet, unfinished. Also, correlation with established calcareous microfossil zones is not possible due to the leaching of microfossils from the Round Bay section.

Several species recovered in the present study, exhibit restricted stratigraphic ranges but are known to occur higher and/or lower in the geologic record in other areas, for example *Gonyaulacysta orthoceras* (Lower Cretaceous to Oligocene), *Spongodinium delitiense* (Senonian to Danian), *Fromea amphora* (Albian to Upper Cretaceous) and *Deflandrea diebelii* (Maestrichtian to Eocene). Thus, the accompanying range chart and proposed zones must be used with caution since many of the range restrictions are undoubtedly due to environmental rather than evolutionary phenomena.

Microfloral Characteristics of the Cretaceous-Tertiary Boundary

Although 19 dinoflagellate species occur in both Cretaceous and Paleocene sediments of the Round Bay area, the change in the assemblage at the boundary is rather marked. Of the twelve species making their first appearance above the boundary, several have not been reported in pre-Paleocene studies elsewhere. Seven species are considered by the author as being possibly diagnostic of Paleocene sediments in Maryland. They are listed in Table I with the age of the oldest previously reported occurrence and the location. Excepting *Deflandrea pulchra* n. sp., the remaining species are cosmopolitan.

The relatively distinctive change in the dinoflagellate assemblages at the Cretaceous-Tertiary boundary in Maryland would seem to indicate an unconformable relationship; however, the extent of the hiatus is not clear. The 19 species crossing the boundary would tend to indicate a diastem of rather minor proportions; however, it should be noted that some of the species which range across the boundary: *Deflandrea magnifica, Svalbardella australina, Spiniferites ramosus ramosus, S. ramosus granosus, Hystrichosphaeridium tubiferum,* and *Areoligera* spp. have ranges covering a considerable time interval on either side of the boundary (Drugg and Stover, 1975; Millioud, Williams and Lentin, 1975), and therefore they are probably species with a wide range of environmental tolerance.

The author believes on the basis of the previously discussed species distributions that a paraconformity exists at the Cretaceous-Tertiary boundary in the Round Bay, Maryland area. The extent of the hiatus is indeterminate in the present study and additional fossil phytoplankton data are necessary before an accurate determination can be made.

Comparison of the Dinoflagellate Assemblage with Assemblages of other Areas

The dinoflagellate assemblage of the Monmouth Formation is comparable to that described by Zaitaeff and Cross (1966) for the Navarro Group of Texas. Species in common include *Dinogymnium westralium, Deflandrea cooksonii, D. pannucea, D. magnifica* and *Cordosphaeridium fibrospinosum.* Although Zaitzeff and Cross (1966) illustrated other species resembling many encountered in the present study, their taxonomic treatment was insufficient to allow a more complete assemblage comparison.

The report by Wilson (1971) illustrated many European species which were found in the present study including: *Gonyaulacysta wetzelii, Deflandrea diebelii, D. minor, Spongodinium delitiense, Cyclonephelium distinctum* and *Cyclapophysis monmouthensis* n. sp. (identified by Wilson as *?Cannosphaeropsis* sp.).

The strata studies by Zaitzeff and Cross (1966) and Wilson (1971) are Navarroan and Maestrichtian in age respectively, and the similarity of their assemblages to the one described herein for the Monmouth Formation tends to support the placement of the Monmouth Formation in the Maestrichtian by Stephenson *et al.* (1942).

Table I

Diagnostic Paleocene Species
Round Bay, Maryland

Species	Oldest Previously Reported Age	Location
Deflandrea dilwynensis	Paleocene	Australia
Wetzeliella cf. *W. pilata*	Paleocene	S. Dakota, USA
Trichodinium hirsutum	Paleocene	Australia
Lanternosphaeridium bipolare	Paleocene	Australia
Deflandrea cf. *D. pentaradiata*	Paleocene	Australia
Palaeoperidinium basilium	Paleocene	California, USA
Deflandrea pulchra n. sp.	Paleocene	Maryland, USA

The dinoflagellate assemblage of the Brightseat Formation is comparable in part to various Australian localities described by Cookson and Eisenack (1965b, 1967) with regard to *Deflandrea dilwynensis, Deflandrea* cf. *D. pentaradiata, Lanternosphaeridium bipolare,* and *Trichodinium hirsutum.* The assemblage is also similar, although to a lesser extent, to those reported by Drugg (1967) and Morgenroth (1968). Only the reports by Drugg (1967) and Morgenroth (1968) identified their sediments as being Danian. The studies from Australia reported the age as Paleocene. The Brightseat Formation is apparently equivalent to the Australian Paleocene (see Table I); however, the definitive stage assignment must await completion of the study by Whitney on the Brightseat type locality.

VI. CONCLUSIONS

The Monmouth and Brightseat formations contain a rich and diverse dinoflagellate assemblage. Thirty-five genera and 66 species, of which two genera and nine species are new, are described in this study. The stratigraphic distribution of the taxa is summarized in Figure 4. The content of the assemblage changes suddenly at the Cretaceous-Tertiary boundary with 13 species making their first appearance at or just above the boundary. Nineteen species cross the boundary and 35 species are restricted to the Cretaceous. The rather sudden change in the nature of the dinoflagellate assemblage at the boundary is interpreted by the author to indicate a paraconformable relationship between the Cretaceous and Paleocene strata. The term paraconformity is used since there is little field evidence (a few pebbles, some lignite, and evidence of boring) indicating any extensive period of erosion at the boundary.

Changes in the dinoflagellate assemblages within the Monmouth Formation, which form the basis for provisional zones, are discussed in detail in the section on Biostratigraphy and are summarized in Figure 4. The zones are provisional and will be tested by future work in this region.

The dinoflagellate assemblage described herein supports the placement of the Monmouth Formation in the Maestrichtian by Stephenson *et al.* (1942), and corroborates the Paleocene age for the Brightseat Formation (Bennett and Collins, 1952).

VII. NOMENCLATURE AND TAXONOMY

The descriptive nomenclature used herein is derived primarily from the works of Downie and Sarjeant (1966) and Sarjeant (1974). The measurements presented in the systematic section are designed to convey the most significant features of the species under consideration. Rather than measure the apical horn length, a feature which is somewhat interpretative in the sense of where one places the base of the apical horn, the apical pericoel length was determined. The apical pericoel is defined as the distance from the distal end of the apical horn to the anterior edge of the endoblast. The remaining measurements are self explanatory.

A generalized family breakdown is employed. A list of genera, species and familial affinities follows. They are arranged in the same order in which they appear in the section on Systematic Palynology.

VIII. ACKNOWLEDGMENTS

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IX. SYSTEMATIC PALYNOLOGY

Phylum PYRRHOPHYTA
Class DINOPHYCEAE Fritsch 1935
Order GYMNODINIALES
(Poche) Lindemann 1928
Family GYMNODINIACEAE
(Berg) Schutt 1896

Dinogymnium sp.
Dinogymnium westralium (Cookson and Eisenack 1958) Evitt *et al.* 1967

Order PERIDINIALES Schutt 1896
Family GONYAULACACEAE Lindemann 1928

Conosphaeridium cf. *C. striatoconus* (Deflandre and Cookson) Cookson and Eisenack 1969
Cordosphaeridium fibrospinosum Davey and Williams 1966b
Coronifera oceanica Cookson and Eisenack 1958
Cyclapophysis monmouthensis gen. et sp. nov.
Cyst Forma A
Cyst Forma B
Diphyes colligerum (Deflandre and Cookson) Cookson 1965
Diversispina truncata gen. et sp. nov.
Exochosphaeridium bifidum (Clarke and Verdier 1967) Clarke *et al.* 1968
Exochosphaeridium sp. complex
Gonyaulacysta orthoceras (Eisenack) Sarjeant 1966
Gonyaulacysta wetzelii (Lejeune-Carpentier) Sarjeant 1966
Hystrichokolpoma ferox (Deflandre) Davey 1969a
Hystrichokolpoma fimbriata Morgenroth 1968
Hystrichokolpoma unispinum Williams and Downie 1966a
Hystrichosphaeridium deanei Davey and Williams 1966b
Hystrichosphaeridium tubiferum (Ehrenberg) Davey and Williams 1966b
Lanternosphaeridium bipolare (Cookson and Eisenack) deConinck 1968
Lanternosphaeridium cf. *L. lanosum* Morgenroth 1966
Operculodinium centrocarpum (Deflandre and Cookson) Wall 1967
Spiniferites cf. *S. cornutus* (Gerlach) Davey and Williams 1966a
Spiniferites ramosus ramosus (Ehrenberg) Lentin and Williams 1973
Spiniferites ramosus granosus (Davey and Williams) Lentin and Williams 1973
Spongodinium delitiense (Ehrenberg) Deflandre 1936
Trichodinium hirsutum Cookson 1965b

Family PERIDINIACEAE
(Ehrenberg) Engler 1892

Deflandrea asymmetrica Wilson 1967
Deflandrea cooksonii Alberti 1959
Deflandrea dartmooria Cookson and Eisenack 1965a
Deflandrea diebelii Alberti 1959
Deflandrea cf. *D. diebelii* Alberti 1959
Deflandrea dilwynensis Cookson and Eisenack 1965b
Deflandrea echinoidea Cookson and Eisenack 1960
Deflandrea magnifica Stanley 1965
Deflandrea minor Alberti 1959
Deflandrea pannucea Stanley 1965
Deflandrea cf. *D. pentaradiata* Cookson and Eisenack 1965b
Deflandrea pulchra n. sp.
Deflandrea rhombohedra n. sp.
Deflandrea severnensis n. sp.
Deflandrea cf. *D. speciosa* Alberti 1959
Deflandrea cf. *D. striata* Drugg 1967
Deflandrea sp. A.
Palaeoperidinium basilium (Drugg) Drugg 1970
Palaeoperidinium cf. *P. deflandrei* (Deflandre) Lentin and Williams 1973
Spinidinium clavum Harland 1973
Svalbardella australina Cookson 1965b
Trithyrodinium striatum n. sp.
Trithyrodinium robustum n. sp.
Wetzeliella cf. *W. pilata* Stanley 1965

Family Uncertain

Aeroligera sp. (Lejeune-Carpentier) Williams and Downie 1966b
Cyclonephelium distinctum Deflandre and Cookson 1955
Cyclopsiella vieta(?) Drugg and Loeblich 1967
Diconodinium rhombiformis Vozzhennikova 1967
Fibradinium cf. *F. annetorpense* Morgenroth 1968
Fromea amphora Cookson and Eisenack 1958
Inversidinium caudatum n. sp.
Microdinium setosum Sarjeant 1966
Genus A
Genus B
Systematophora cf. *S. areolata* Klement 1960
Systematophora placacantha (Deflandre and Cookson) Davey *et al.* 1969
Tanyosphaeridium variecalamum Davey and Williams 1966b
Xenikoon australis Cookson and Eisenack 1960

Phylum PROTOZOA
Family OPHIOBOLIDAE Deflandre 1952

Ophiobolus lapidaris Wetzel 1933

Phylum PYRRHOPHYTA
Class DINOPHYCEAE Fritsch 1935
Order GYMNODINIALES (Poche) Lindemann 1928
Family GYMNODINIACEAE (Berg) Schutt 1898
Genus DINOGYMNIUM Evitt *et al.* 1967

DINOGYMNIUM sp.
Plate 15, figures 1-3

Description: Fragile elongate cyst, dorsoventrally flattened, and tapering to a rounded point at both the apex and antapex. Cingulum observed only on lateral margins; separates short epitract from elongate hypotract. Hypotract to epitract length ratio 3-4.6:1. Sulcus weakly developed; extends onto epitract up to one third of epitract length. Cyst wall less than 1 micron thick, single layered, microreticulate. Archeopyle not observed.

Comments: This species of *Dinogymnium* is not formally named herein since it and related species are being extensively treated by F. May in a forthcoming publication. *Dinogymnium* sp. is commonly distorted because of its apparent fragility. Only three specimens were intact of which two were folded. The figured specimen is slightly folded anteriorly; however, it is the best preserved specimen. Although an archeopyle was not observed in the Round Bay specimens, Evitt *(in litt.)* reports that the archeopyle is on what is herein interpreted to be the posterior portion of the cyst in specimens from another locality (Texas). Reexamination of specimens from Round Bay, Maryland, and the Peedee Formation of North Carolina with both conventional light and scanning electron microscopy did not resolve the apparent discrepancy and at this time the author's interpretation of the cyst orientation remains unchanged.

Comparison with other species: Dinogymnium sp. does not appear similar to previously described fossil species in that it is flattened dorsoventrally, possesses indistinct sculpture and is extremely long. The high cingulum, sulcus on both epitract and hypotract, and the thin cyst wall would seem to indicate possible relationship with the modern form *Gymnodinium filum* (Lebour, 1917, plate 80, figure 6) and is a major factor in the maintainence of the author's original interpretation of the cyst orientation.

Dimensions: Three specimens measured; length 171-263 micra; width 20-28 micra; cyst wall thickness greater than 0.5 micron; less than 1 micron.

Occurrence: Very rare in samples 289, 291-293, Monmouth Formation.

DINOGYMNIUM WESTRALIUM
(Cookson and Eisenack)
Evitt, Clark and Verdier 1967
Plate 1, figures 1-3

1955 *Gymnodinium* cf. *G. heterocostatus* (Deflandre) DEFLANDRE and COOKSON, p. 248, plate 1, figure 7.

1958 *Gymnodinium westralium* COOKSON and EISENACK, p. 25, plate 1, figure 9.

1967 *Dinogymnium westralium* (Cookson & Eisenack) EVITT, CLARK and VERDIER, p. 23.

Comments: Only minor differences from the description of Cookson and Eisenack (1958) are seen on specimens of *Dinogymnium westralium* from the Monmouth samples. The fine punctations reported by Cookson and Eisenack (1958) are not clearly evident and a conspicuous sulcus, indeterminate in the original specimens, is present. An apical archeopyle is present. The epitract is slightly longer than the hypotract in some specimens. The cingulum is slightly levorotary and the sulcus is narrow. The longitudinal ridges possess an undulatory sculpture.

Dimensions: Six specimens measured; length 44-59 micra; width 26-35 micra.

Occurrence: Very rare in samples 280-285, 289, Monmouth Formation.

Previous Reported Occurrence: ?Upper Albian-Campanian, Australia (Cookson and Eisenack, 1960); Senonian, W. Siberia (Vozzhennikova, 1967); Maestrichtian, U.S.A. (Zaitzeff and Cross, 1968); Cretaceous, Australia (Cookson and Eisenack, 1970); Late Cretaceous, Australia (Deflandre and Cookson, 1955; Cookson and Eisenack, 1958).

Order PERIDINIALES Schutt 1896
Family GONYAULACACEAE
Lindemann 1928

Genus CONOSPHAERIDIUM
Cookson and Eisenack 1969

CONOSPHAERIDIUM cf.
C. STRIATOCONUS
(Deflandre and Cookson)
Cookson and Eisenack 1969
Plate 1, figures 4,5

Comments: A single, poorly preserved specimen resembling *Conosphaeridium striatoconus* was recovered. The ribs responsible for the striated appearance of the cones are not obvious in the specimen and it is slightly smaller than the range recorded for the original specimens. The cyst wall is bilayered, each layer less than 1 micron in thickness. The archeopyle is apical. The tabulation appears to be 6'', 6c, 6''', 1 p, 1''''. The apical tabulation could not be determined because the operculum was missing.

Dimensions: One specimen measured; cyst main body diameter – 47 micra; process length 8-9 micra.

Occurrence: Single specimen in sample 293, Monmouth Formation.

Genus CORDOSPHAERIDIUM
Eisenack 1963 emend. Davey 1969c

CORDOSPHAERIDIUM FIBROSPINOSUM
Davey and Williams 1966b
Plate 1, figures 6, 7

1966b *Cordosphaeridium fibrospinosum* DAVEY and WILLIAMS, p. 86, plate 5, fig. 5.

Comments: Cordosphaeridium fibrospinosum encountered in this study resembles the original description with a few exceptions. The diameter of the central body ranges from 58-80 micra, slightly larger than the range of 59-70 micra given by Davey and Williams (1966b). The processes of the specimens recovered did not reach the maximum length of 39 micra of the topotypes and several examples exceeded the maximum process width of the topotypes. The wall is bilayered and its thickness in Monmouth-Brightseat specimens is up to 2 micra. The wall in the original description was cited as being 0.5 micron in thickness and bilayered. A precingular (Type P) archeopyle is always present.

Dimensions: Seven specimens measured; central body diameter 58-80 micra; process length up to 30 micra; process width up to 36 micra; wall thickness 2 micra; endophragm 0.5-1 micron; periphragm 1-1.5 micra.

Occurrence: Very rare in samples 280, 281, 284, 285, 287, 294, Monmouth Formation and Brightseat Formation.

Previous Reported Occurrence: Maestrichtian, U.S.A. (Zaitzeff and Cross, 1968); Maestrichtian, Holland (Wilson, 1971); Eocene, England (Davey and Williams, 1966b); middle-upper Oligocene, Germany (Benedek, 1972).

Genus CORONIFERA
Cookson and Eisenack 1958

CORONIFERA OCEANICA
Cookson and Eisenack 1958
Plate 1, figure 8

1958 *Coronifera oceanica* COOKSON and EISENACK, p. 45, plate 12, figures 5, 6.
For detailed synonomy see Davey and Verdier (1971, p. 16).

Comments: Coronifera oceanica is rare and occurs only in a few samples. The numerous flexuous processes appear to be hollow at the base and are acuminate to finely capitate distally. Several processes on the epitract are fused proximally, up to 5.5 micra above the surface; the width of larger processes being about 4.5 micra. The tips of the larger processes are acuminate. An apical (Type A) or combination (Type A+P) archeopyle is frequently present.

Dimensions: Six specimens measured; central body 43-47 micra diameter; process length 15-17 micra; antapical process length 15-17.5 micra; width distally 12-13 micra; wall thickness 0.5 micron.

Occurrence: Very rare in samples 280, 282, 284, 291, 292, 295, Monmouth Formation and Brightseat Formation.

Previous Reported Occurrence: upper Hauterivian-lower Aptian, France (Millioud, 1969); Aptian, Germany (Eisenack, 1958); Albian, Canada (Davey, 1969a); Albian, France (Davey and Verdier, 1971); Albian – basal Coniacian, England (Cookson and Hughes, 1964; Clarke and Verdier, 1967; Davey, 1969a); Albian, Cenomanian, Santonian-lowest Campanian, Australia (Cookson and Eisenack, 1958, 1968, 1969); upper Campanian, Canada (Harland, 1973).

CYCLAPOPHYSIS n. gen.

Derivation of name: cycl- (Gr) circle, *apophysis* (Gr) offshoot, process.

Type Species: Cyclapopyhsis monmouthensis.

Description: Chorate cyst with precingular (Type P) archeopyle. Cyst main body spheroidal to sub-oval. Distinct apical and antapical protuberance of cyst main body wall developed, surrounded by fibrous processes. Processes filamentous, plate centered. Precingular and postcingular processes bend toward cingulum with the tips fusing forming an equatorial tunnel continuous around cyst main body with indistinct interruption in sulcal region. Tabulation reflected by processes of 4', 0a, 6'', 0c, 6-7''', ?1p, 1''''.

CYCLAPOPHYSIS MONMOUTHENSIS
n. sp.

Plate 1, figures 9-12; Plate 2, figure 1

Derivation of name: Monmouth Formation, Maryland.

Holotype: Sample 291, slide AN 52, R 7.8, + 10.1.

Description: As for genus with the following additions: Apical protuberance generally longer than antapical, the ratio being as great as 3:1 and as small as 1.2:1. Cyst wall about 1 micron thick, its outer surface appearing microreticulate. Cyst wall bi-layered, the internal layer accounting for approximately 90% of its thickness. The outer microreticulate layer forms the process bases.

Dimensions:

Holotype: Cyst main body length 75 micra; width 65 micra. Apical: antapical protuberance ratio 2.4:1; processes in equatorial area 35 micra in length; total width in equatorial area 135 micra

Range: 17 specimens measured; cyst main body length 74-97 micra; width 58-71 micra. Apical: antapical ratio 3:1-1.2:1. Equatorial process length 24-40 micra. Equatorial width with processes 106-150 micra.

Comments: C. monmouthensis is distinctive in its equatorial distribution of fused precingular and postcingular processes. The cyst wall appears single layered; however, a thin periphragm is present. It is responsible for the microgranulate surficial texture, which upon close examination is seen to be the extensions of the filamentous process bases. The endophragm appears to be composed of fine fibers that are normal to the cyst surface.

Comparison with similar species: Cyclapophysis monmouthensis appears to be very similar to the specimen identified as *?Cannosphaeropsis* sp., that was illustrated by Wilson (1971, pl. 3, fig. 10). Both *C. monmouthensis* and *?Cannosphaeropsis* occur in sediments of highest Maestrichtian age. *C. monmouthensis* differs from *Cannosphaeropsis* in that the latter possesses sutural and gonal processes and distal trabeculae interconnecting all processes; whereas, in *C. monmouthensis* the processes are plate centered and the distal connections between processes are fused fibrils rather than trabeculae. *C. monmouthensis* is unique among the Pyrrhophyta. Cookson and Eisenack (1960) described *Codonia* (now *Codoniella* Downie and Sarjeant, 1964) *campanulata* which possesses trumpet-shaped processes only in the lateral portion of the equatorial region. The apical and atapical protuberances in conjunction with the precingular archeopyle are similar to those described for the genus *Lanternosphaeridium* (Morgenroth, 1966) and it seems possible that *C. monmouthensis* is related to that genus. In addition, the filamentous structure of the processes would appear to be additional support for a possible relationship of *C. monmouthensis* to *Lanternosphaeridium*, particularly *L. lanosum*.

Occurrence: Very rare to rare in samples 290-294, 296, Monmouth Formation and Brightseat Formation.

Cyst Forma A

Plate 2, figures 2-4

Comments: Two specimens were recovered. The cyst is spherical, bilayered and the periphragm is elevated into short, simulate processes. Some of the fields are open distally whereas others are closed. The archeopyle is an A + P type, although in the absence of more specimens the loss of the precingular plate equivalent may be coincidental. The reflected tabulation is ?, 6'', 6c, 6''', ?2s, 1p, 1''''. This pattern is the same as that of *Eisenackia* (McLean, 1973a); however, it differs from that genus is apparently possessing a combination (Type A + P) archeopyle. Additional specimens are necessary before the systematic position of this form can be understood.

Dimensions: Cyst main body diameter 40-42 micra; Periphragm plate equivalents up to 6 micra in height, 20 micra in width.

Occurrence: Two specimens in sample 281, Monmouth Formation.

Cyst Forma B

Plate 2, figures 10-12

Comments: A single specimen was recorded from the upper Monmouth Formation. The cyst is spheroidal, bilayered, and possesses an apical (Type A) archeopyle. The periphragm is elevated into fields reflecting plate equivalents. The free operculum was observed within the cyst. The tabulation observed is ?4', 6'', 6c, 6''', 3s, 1p, 1''''. Although the tabulation corresponds to that published by McLean (1973a) for the genus *Eisenackia,* the processes are hollow rather than the elevated pad-like plate equivalents discussed by McLean (1973a).

Dimensions: Cyst main body diameter 35 micra; periphragm plate equivalents up to 5 micra in height, 14 micra in width.

Occurrence: Single specimen in sample 292, Monmouth Formation.

Genus DIPHYES Cookson 1965a

DIPHYES COLLIGERUM (Deflandre & Cookson) Cookson 1965a
Plate 2, figure 5

1955 *Hystrichosphaeridium colligerum* DEFLANDRE and COOKSON, p. 278, plate 7, figure 3.
1963 *Baltisphaeridium colligerum* (Deflandre and Cookson) DOWNIE and SARJEANT, p. 91.
1965a *Diphyes colligerum* (Deflandre and Cookson) COOKSON, p. 86, plate 9, figures 1-12.
1966b *Diphyes colligerum* (Deflandre and Cookson) Cookson 1965a; DAVEY and WILLIAMS, p. 96, plate 14, figures 2, 3.

Comments: Diphyes colligerum is rare in the Round Bay section. The specimens generally conform to the original description. The archeopyle is apical (Type A) and the operculum is invariably missing. The cyst wall is bilayered, the endophragm being extremely thin (less than 0.5 micron), the periphragm being 1.5-2 micra. The processes are hollow, continuous with the periphragm, and closed distally by a finely capitate tip.

Dimensions: Five specimens measured; central body diameter 30-36 micra; process length 14-16 micra; antapical process length 16-19 micra; width (maximum) 10-14 micra.

Occurrence: Very rare to rare in samples 281, 283, 292, 293, Monmouth Formation; and 295, 297, Brightseat Formation.

Previous Reported Occurrence: Upper Cretaceous, Australia (Cookson, 1965a, 1967b); Danian, Argentina (Heisecke, 1970); lower Eocene, N. Germany, Belgium (Morgenroth, 1966); Eocene, Belgium (DeConinck, 1968); lower Eocene, England (Davey and Williams, 1966b); lower Eocene, Australia (Deflandre and Cookson, 1955).

DIVERSISPINA n. gen.

Derivation of name: diversi- (L) various, *spina* (L) spine, in reference to the variety of processes on each individual cyst.

Type species: Diversispina truncata.

Description: Chorate cyst with plate centered hollow processes of varying sizes and morphology. Processes abruptly terminated and of aculeate, denticulate, and recurved-patulate types. Processes reflect tabultion of 4', 6'', 6c, 5''', 1p, 1'''', 4-5s. Archeopyle precingular (Type P). Cyst wall bilayered, periphragm giving rise to processes. Cingulum indicated by processes with flattened bases. Position of sulcus marked by small flexuous processes. Processes composed of fused hyaline fibrils.

DIVERSISPINA TRUNCATA n. sp.
Plate 2, figures 6-9

Derivation of name: truncata (L), in reference to the abrupt termination of the processes.

Holotype: Sample 285, slide AN 27, R 9.8 + 4.7.

Description: As for genus with the following additions: Cyst main body subspheroidal, cyst wall about 1 micron in thickness, the processes arising from the thin periphragm. Periphragm exhibits microreticulate sculpture. Apical plate equivalents distinguished by four small processes of varying distal termination. Antapical process is larger than others with complex termination.

Dimensions:

Holotype: Cyst main body length 58 micra; width 54 micra; process length 33-35 micra; width 5-12 micra.

Range: 12 specimens measured; cyst main body length 51-58 micra; width 44-54 micra; process length 23-35 micra; width 2-13 micra.

Comments: Diversispina truncata is distinctive in its possession of a variety of process types. The specimens usually occur in lateral view and in this orientation the archeopyle appears apical. The presence of the flattened cingular processes, distinctive sulcal and antapical processes, however, facilitates the correct orientation and the precingular nature of the archeopyle is clear.

Comparison with similar species: Diversispina truncata resembles *Hystrichosphaeridium stellatum* Maier (1959), both forms bearing processes of varying size and morphology; however, the latter species has an apical archeopyle. In view of the fibrous nature of the processes (even though the fibrous character is obscure) *Diversispina truncata* is most likely related to the genus *Cordosphaeridium* (Davey, 1969a); however the lack of a fibrous periphragm in *D. truncata* and its varied process morphology would appear to be sufficient justification for making *Diversispina truncata* a separate taxon.

Occurrence: Very rare to rare in samples 282-286, 288, 290-294, Monmouth Formation and Brightseat Formation.

Genus EXOCHOSPHAERIDIUM
Davey *et al.* 1966

EXOCHOSPHAERIDIUM BIFIDUM
(Clarke & Verdier)
Clarke *et al.* 1968
Plate 3, figures 1, 2

1967 *Baltisphaeridium bifidum* CLARKE and VERDIER, p. 72, plate 17, figures 5-6, text figure 30.

1968 *Exochosphaeridium bifidum* (Clarke and Verdier) CLARKE, DAVEY, SARJEANT and VERDIER, p. 182.

Comments: The Monmouth specimens resemble those described by Clarke and Verdier (1967); however, there are several differences. The apical process in the Monmouth specimens is variably developed in both length and degree of branching and on some specimens is nearly indistinguishable from the normal process. The remaining processes are bifurcate distally and frequently bear fine accessory spines. The cyst is bilayered, with the periphragm being very fibrous and pitted. The archeopyle is precingular (Type P).

Dimensions: Ten specimens measured; main cyst body 50-61 micra; processes 16-20 micra; apical process up to 21 micra.

Occurrence: Very rare to rare in samples 279-284, 289, 290, Monmouth Formation.

Previous Reported Occurrence: Cenomanian-upper Campanian, England (Clarke and Verdier, 1967); Upper Cretaceous, S. Africa (Davey, 1969c).

EXOCHOSPHAERIDIUM sp. complex
Plate 3, figures 3-9

Comments: A complex population of variable chorate cysts with precingular archeopyles (Type P) was encountered in the lower samples of the Round Bay section. Individual specimens resemble *Exochosphaeridium phragmites* (Davey, Downie, Sarjeant, and Williams, 1966), *Amphorosphaeridium* sp. (Davey, 1969c) and *Trichodinium hirsutum* (Cookson, 1965b). Due to the intergradation observed, the variable degree of development of distinctive processes (apical, antapical, and cingular) and co-occurrence it was felt best to treat these forms as a variable population. The intergradation is the result of varying degrees of fusion of processes to form the apical, antapical and cingular processes. The mechanism causing this fusion is not understood; however, a distinct sequence appeared to exist. The fusion of processes to form distinct cingular processes was not observed in those specimens lacking an antapical process. Thus the developmental sequence would appear to be apical; to apical and antapical; to apical, antapical and cingular in terms of distinctive processes. The "end members" of the sequence are presented in Plate 3, figures 3, 4-6, 7-9, to allow the reader to visualize the sequence.

Dimensions: 20 specimens measured; cyst central body diameter 86-72 micra; process length up to 18 micra; apical process 16-21 micra; antapical process 18-22 micra; cingular process 15-18 micra.

Occurrence: Common to abundant in samples 279-282, Monmouth Formation.

Genus GONYAULACYSTA (Deflandre)
Sarjeant 1969

GONYAULACYSTA ORTHOCERAS
(Eisenack) Sarjeant 1966
Plate 3, figures 10, 11

1958 *Gonyaulax orthoceras* EISENACK, p. 388, plate 21, figures 3-14, plate 24, figure 1, text figure 29.
1966 *Gonyaulacysta orthoceras* (Eisenack) SARJEANT, p. 121, plate 114, figures 5, 6, text figure 29.
1969a *Cribroperidinium orthoceras* (Eisenack) DAVEY, p. 128.
1971 *Gonyaulacysta orthoceras* (Eisenack) Sarjeant; SINGH, p. 307.

Comments: Gonyaulacysta orthoceras conforms both in size and form to the type description by Eisenack (1958) with the exception of the plate boundaries, which are slightly wider than those of the original specimens. The author concurs with Singh (1971) who stated that the transfer to *Cribroperidinium* (Davey, 1969a) was unwarranted and apparently was the result of misinterpretation of the wide plate boundaries as additional plates. The tabulation of the Monmount specimens is 4', 6'', 6c, 6''', 1p, 1'''', archeopyle (Type P) precingular.

Dimensions: Ten specimens measured; length, 97-104 micra; width 82-86 micra.

Occurrence: Very rare to rare in samples 281-286, Monmouth Formation.

Previous Reported Occurrence: Valanginian-lower Aptian, Czechoslovakia (Vavrdova, 1964); Barremian, England (Sarjeant, 1966a); Barremian, U.S.S.R. (Vozzhennikova, 1967); Barriasian-lower Aptian, Switzerland, France (Millious, 1967, 1969); upper Aptian, Turonian, Barremian, Cenomanian, Germany (Alberti, 1959); Aptian, Germany (Eisenack, 1958, 1959); Albian, France (Davey and Verdier, 1971); Lower Cretaceous, Canada (Singh, 1971); middle-upper Albian, Canada (Brideaux, 1971); Turonian, Cenomanian, Poland (Gorka, 1963); Cretaceous, Germany (Gocht, 1959); Paleocene, Antarctica (Wilson, 1967b); middle Oligocene, Germany (Gocht, 1969); middle-upper Oligocene, German (Benedek, 1972).

GONYAULACYSTA WETZELII (Lejeune-Carpentier) Sarjeant 1969
Plate 3, figure 12; Plate 4, figure 1

1939 *Gonyaulax wetzelii* LEJEUNE-CARPENTIER, p. 525, text figures 1, 2.
1969 *Gonyaulacysta wetzelii* (Lejeune-Carpentier) SARJEANT, p. 11.

Comments: G. wetzelii resembles *G. orthoceras* and it is difficult to separate the two species. Their tabulation of 4', 6'', 6c, 6''', 1p, 1'''', is identical. Plate boundaries in both are relatively wide and are represented by delicate sutural folds. There appears, however, to be a consistent difference in the lateral margin of the sulcus between the two species, that of *G. wetzelii* being lobate in appearance. In addition there is a difference in both the size and shape of plate 1''', that of *G. wetzelii* being small and narrowly trapezoidal in shape; whereas, the 1''' of *G. orthoceras* is larger and triangular. A minor difference exists with regard to the apical horn, which in *G. orthoceras* is consistently pronounced, whereas that of *G. wetzelii* is reduced. Both have a precingular (Type P) archeopyle.

Dimensions: Ten specimens measured; length, 75-89 micra; width, 65-75 micra.

Occurrence: Rare to abundant in samples 289-294, Monmouth Formation and Brightseat Formation.

Previous Reported Occurrence: Campanian-Maestrichtian, Belgium (Wilson, 1971); Maestrichtian, Denmark (Wilson, 1971); Upper Cretaceous, Baltic (Lejeune-Carpentier, 1939); Upper Cretaceous, Belgium (Lejeune-Carpentier, 1946); Danian, N. Europe (Morgenroth, 1968).

Genus HYSTRICHOKOLPOMA Klumpp 1953 emend. Williams and Downie 1966a

HYSTRICHOKOLPOMA FEROX (Deflandre) Davey 1969a
Plate 4, figures 2, 3

1937 *Hystrichosphaeridium ferox* DEFLANDRE, p. 72, plate 14, figures 3, 4.
1966a *Hystrichokolpoma ferox* (Deflandre) WILLIAMS and DOWNIE, p. 181.
1967 *Baltisphaeridium ferox* (Deflandre) CLARKE and VERDIER, p. 73, plate 15, figure 4.
1969a *Hystrichokolpoma ferox* (Deflandre) DAVEY, p. 159, plate 9, figures 5-7.

Comments: A single specimen of *H. ferox* was recovered. It has an apical (Type A) archeopyle. The main cyst body is granular conforming with the description by Deflandre (1937). The size of the specimen also conforms to Deflandre's (1937) measurements.

Dimensions: Cyst main body diameter 46 micra, process length 16-17 micra.

Occurrence: Single specimen in sample 280, Monmouth Formation, probably reworked.

Previous Reported Occurrence: lower Hauterivian, Germany (Gocht, 1959); upper Aptian, Germany (Eisenack, 1959); Albian-Cenomanian, Australia (Cookson and Eisenack, 1962); Albian-Cenomanian, England (Cookson and Hughes, 1964); Lower Cretaceous, Germany (Eisenack, 1958); Lower Cretaceous, Canada (Singh, 1971); Turonian-Cenomanian, England (Davey, 1969a); Cenomanian, France (Davey, 1969a); Cenomanian-Santonian, England (Clarke and Verdier, 1967); Senonian, France (Deflandre and Courteville, 1939); Cretaceous, Australia (Cookson and Eisenack, 1968); Danian, Germany (Wetzel, 1952); Danian, Argentina (Heisecke, 1970); Eocene, Belgium (DeConinck, 1968).

HYSTRICHOKOLPOMA FIMBRIATA
Morgenroth 1968
Plate 4, figures 4-6

1968 *Hystrichokolpoma fimbriata* MORGENROTH, p. 547, plate 45, figures 7-8.

Comments: Two specimens assignable to *H. fimbriata* were recovered. Several other poorly preserved specimens were observed. The membrane connecting the adjacent acuminate processes is thin, delicate and frequently absent. The reflected tabulation appears to be ?', 6'', ?c, 6''', 1p, 1'''', the apical tabulation being indeterminate since the operculum is absent. An apical archeopyle (Type A) is present.

Dimensions: Two specimens measured; main cyst body diameter 37-38 micra; process height 17-19 micra.

Occurrence: Very rare in sample 293; possibly present in 294, Monmouth Formation and Brightseat Formation, probably reworked.

Previous Reported Occurrence: Lower Cretaceous, Australia (Deflandre and Cookson, 1955); Cretaceous, Germany (Gocht, 1959); Danian, N. Europe (Morgenroth, 1968).

HYSTRICHOKOLPOMA UNISPINUM
Williams & Downie 1966a
Plate 4, figures 7-9

1966a *Hystrichokolpoma unispinum* WILLIAMS and DOWNIE, p. 179, plate 17, figures 6, 7.

Comments: H. unispinum compares closely with the original description. The tabulation is ?', 6'', 6c, 5''', 1p, 1''''. The number of sulcal processes appears to be four to five. The apical tabulation is indeterminate due to the loss of the apical operculum. An apical archeopyle (Type A) is present.

Dimensions: Two specimens measured; cyst body 40-44 micra; large processes, 26 micra; small processes, 19 micra (sulcal).

Occurrence: Restricted to sample 295, very rare, Brightseat Formation.

Previous Reported Occurrence: Eocene, England (Williams and Downie, 1966a); Eocene, Belgium (DeConinck, 1968).

Genus HYSTRICHOSPHAERIDIUM
Deflandre 1937
emend. Davey and Williams 1966b

HYSTRICHOSPHAERIDIUM DEANEI
Davey and Williams emend.
Davey and Verdier 1971
Plate 4, figures 10-12; Plate 5, figure 1

1966b *Hystrichosphaeridium deanei* DAVEY and WILLIAMS, p. 58, plate 6, figures 4, 8.
1971 *Hystrichosphaeridium deanei* Davey and Williams; DAVEY and VERDIER, p. 22.

Comments: Two specimens of *H. deanei* were recovered; they compare favorably with the original descriptions. The processes are, as noted in the original description, variable in both size and shape. The diameter of the central body (35-37 micra) is slightly smaller than the original material (41-54 micra). The archeopyle is apical (Type A).

Dimensions: Cyst body diameter 35-37 micra; process length 14-28 micra, 16-23 micra; process width 2-16 micra, 2-14 micra.

Occurrence: Single specimens in samples 294 and 295, Brightseat Formation, reworked.

Previous Reported Occurrence: Albian, France (Davey and Verdier, 1971); middle to upper Cenomanian, France (Davey, 1969a); middle Cenomanian-Turonian, England (Davey and Williams, 1966b; Clarke and Verdier, 1967; Davey, 1969a).

HYSTRICHOSPHAERIDIUM TUBIFERUM
(Ehrenberg) Davey and Williams 1966b
Plate 5, figure 2

1966b *Hystrichosphaeridium tubiferum* (Ehrenberg) DAVEY and WILLIAMS, p. 56, plate 6, figures 1, 2; plate 8, figure 5; plate 10, figure 2, text figure 13.
For detailed synonymy prior to 1966 see Davey and Williams (1966b).

Comments: Hystrichosphaeridium tubiferum occurs throughout the section studied in this investigation and is of little value in a biostratigraphic sense. The specimens encountered agree with the description given by Davey and Williams (1966b) and are well within the published size range.

Dimensions: Ten specimens measured; diameter of central body 35-47 micra; process length 18-26 micra.

Occurrence: Very rare to common in samples throughout the section studied with exceptions of samples 283 and 289, where it was absent.

Previous Reported Occurrence: Barremian-Senonian, Canada (Pocock, 1962); Aptian, Germany (Eisenack, 1958); Albian, France (Davey and Verdier, 1971); Turonian, Maestrichtian, Campanian, Poland (Gorka, 1963); Senonian, Germany (Ehrenberg, 1838, 1854; Wetzel, 1933); Maestrichtian, Belgium (Lejeune-Carpentier, 1940); Maestrichtian, Belgium (Conrad, 1941); Maestrichtian-Danian, U.S.A. (Drugg, 1967); Cretaceous, Australia (Cookson and Eisenack, 1970); Paleocene, U.S.A. (Stanley, 1965); Danian, N. Europe (Morgenroth, 1968); Danian, Argentina (Heisecke, 1970); Early Cenozoic, S.E. Australia, W. New Zealand (Haskell and Wilson, 1975); Tertiary, Antarctica (Wilson, 1967); lower Eocene, N. Germany, Belgium (Morgenroth, 1966); Eocene, Belgium (DeConinck, 1969); lower Oligocene, Germany (Gocht, 1952); middle-upper Oligocene, Germany (Benedek, 1972); middle Oligocene-middle Miocene, Germany (Gerlach, 1961).

Genus LANTERNOSPHAERIDIUM
Morgenroth 1966

LANTERNOSPHAERIDIUM BIPOLARE
(Cookson & Eisenack) DeConinck 1968
Plate 5, figures 3-6

1965b *Cordosphaeridium bipolare* COOKSON and EISENACK, p. 135, plate 16, figures 7, 8.
1968 *Lanternosphaeridium bipolare* (Cookson and Eisenack) DeCONINCK, p. 38, plate 11, figures 1-6, 15, 16.
1969b *Amphorosphaeridium bipolare* (Cookson and Eisenack) DAVEY, p. 35.
1972 *Lanternosphaeridium bipolare* (Cookson and Eisenack) DeConinck; BENEDEK, p. 34, plate 5, figure 6.
1973 *Lanternosphaeridium bipolare* (Cookson and Eisenack) DeConinck; LENTIN and WILLIAMS, p. 85.

Comments: The specimens of *Lanternosphaeridium bipolare* are morphologically variable. Only a few specimens were observed that are identical with the type specimens figured by Cookson and Eisenack (1965b). The majority of the specimens are much more fusiform, as in Cookson and Eisenack (1967, plate 39, figures 1-5), than the originally described specimens and the antapical protuberance of the main cyst body is very pronounced and is up to 17 micra in length. The processes are composed of fused fibrils, exhibit varying degrees of basal fusion, and may be acuminate, capitate or flared. An apical fibrous extension of the periblast is frequently present, virtually identical to those figured by Cookson and Eisenack (1967). Although the specimens of this species are morphologically variable it is felt by the author that they represent a normal, variable population.

Dimensions: Ten specimens measured; cyst main body length 93-112 micra; width 44-62 micra; process length 12-17 micra; endophragm thickness greater than 0.5 micron; periphragm thickness less than 1 micron.

Occurrence: Rare in samples 294-297, Brightseat Formation.

Previous Reported Occurrence: Paleocene, Australian (Cookson and Eisenack, 1965); Paleocene, Australia (Cookson and Eisenack, 1967); Eocene, Belgium (DeConinck, 1969); middle-upper Oligocene, Germany (Benedek, 1972).

LANTERNOSPHAERIDIUM cf. L. LANOSUM Morgenroth 1966

Plate 5, figures 7-9

Comments: Specimens resembling *Lanternosphaeridium lanosum* (Morgenroth, 1966) occur in both the upper Monmouth Formation and the lower Brightseat Formation. The Cretaceous specimens do not exhibit the apical and antapical protuberances reported by Morgenroth, and their central body size, like the Paleocene specimens, is slightly larger than the originally described forms. The Cretaceous forms exhibit a higher degree of fusion of the filamentous processes than the Paleocene specimens. The organized grouping of the filamentous processes in the Paleocene forms suggests that tabulation is present but it could not be determined from the specimens encountered. The central body is bilayered with a smooth, thin (slightly less than 1 micron) endophragm and a fibrous periphragm which is about 1.5 micra thick. The periphragm serves as the base of filamentous processes. Archeopyle is precingular (Type P).

Dimensions: Ten specimens measured; central body length 65-82 micra; width 53-71 micra; process height 18-34 micra; endophragm thickness greater than 0.5 less than 1 micron; periphragm thickness about 1.5 micra.

Occurrence: Very rare to common in samples 286, 289-292, 294-297, Monmouth Formation and Brightseat Formation.

Genus OPERCULODINIUM Wall 1967

OPERCULODINIUM CENTROCARPUM (Deflandre & Cookson) Wall 1967
Plate 5, figures 10-12

1955 *Hystrichosphaeridium centrocarpum* DEFLANDRE and COOKSON, p. 272, plate 8, figures 3, 4.
1961 *Baltisphaeridium centrocarpum* (Deflandre and Cookson) GERLACH, p. 192, plate 28, figure 9.
1967 *Operculodinium centrocarpum* (Deflandre and Cookson) WALL, p. 111, plate 16, figures 1, 2, 5.
See Wall (1967, p. 111) for detailed synonymy.

Comments: Operculodinium centrocarpum is generally similar to the specimens described by Wall (1967). Adjacent processes are proximally fused; however, there is no regular distribution of the fused processes. The archeopyle is precingular (Type P).

Dimensions: Ten specimens measured; cyst body diameter 35-47 micra; process length 9-16 micra.

Occurrence: Rare to common in samples 294-297, Brightseat Formation.

Previous Reported Occurrence: Upper Cretaceous, S. Africa (Davey, 1969b); lower Eocene, N. Germany, Belgium (Morgenroth, 1966); Eocene, Belgium (DeConinck, 1969); middle Oligocene – middle Miocene, Germany (Gerlach, 1961); middle Oligocene – upper Miocene, Germany (Maier, 1959); Miocene, Sea of Japan (Shimakura *et al.*, 1971); Recent, Caribbean Sea (Wall, 1967).

Genus SPINIFERITES
Mantell 1850 emend. Sarjeant 1970

SPINIFERITES cf. S. CORNUTUS (Gerlach) Davey and Williams 1966a
Plate 6, figures 1-3

Comments: A few specimens resembling *Spiniferites cornutus* (Gerlach, 1961; Davey and Williams, 1966a) were encountered. The specimens possess a finely to coarsely granular periphragm and variable development of the apical process. A precingular archeopyle (Type P) is present.

Dimensions: Two specimens measured; cyst body length 44, 58 micra; width 40, 43 micra; apical process 16, 35 micra.

Occurrence: One each in samples 293 and 295, Monmouth Formation and Brightseat Formation.

SPINIFERITES RAMOSUS RAMOSUS (Ehrenberg) Lentin and Williams 1973
Plate 6, figures 4, 5

1838 *Xanthidium ramosum* EHRENBERG, plate 1, figures 1, 2, 5.
1938 *Hystrichosphaera ramosa* (Ehrenberg) WETZEL, p. 144.
1966a *H. ramosa* var. *ramosa* (Ehrenberg) DAVEY and WILLIAMS, p. 33, plate 1, figures 1, 6; plate 3, figure 1, text figure 8.
1973 *Spiniferites ramosus ramosus* (Ehrenberg) LENTIN and WILLIAMS, p. 130.
For detailed synonymy see Davey and Williams (1966a).

Comments: Specimens of *S. ramosus ramosus* are variable in their morphology and appear to intergrade with forms that can be attributed to other subspecies, such as *S. ramosus membranaceus* and *S. ramosus multibrevis.* They frequently exhibit abnormal development of sutural ridges similar to those figured by Davey and Verdier (1971). The central body is generally round to ovoidal. The archeopyle is precingular (Type P). The processes are gonal in position; however, intergonal processes are present in a few instances. Davey and Williams (1966a) suggested that the various subspecies of *S. ramosus* were of biostratigraphic importance; however, this is not apparent in the present study.

Dimensions: Ten specimens measured; central body diameter 37-48 micra; process length 10-15 micra.

Occurrence: Very rare to common in all samples examined, Monmouth Formation and Brightseat Formation.

Previous Reported Occurrence: Barremian-Eocene, England (Davey and Williams, 1966a); Oxfordian, England (Sarjeant, 1962); Albian, Canada (Brideaux, 1971); Cenomanian-Santonian, England (Clarke and Verdier, 1967); Turonian-Maestrichtian, Poland (Gorka, 1963); Mesozoic, Italy (Serpagli, 1964); Lower Cretaceous, Canada (Singh, 1971); upper Campanian, Canada (Harland, 1973); Maestrichtian, U.S.A. (Zaitzeff and Cross, 1968); Upper Cretaceous, lower Eocene-Miocene, Australia (Deflandre and Cookson, 1955); Upper Cretaceous, Canada (McIntyre, 1974); Danian, U.S.A. (Drugg, 1967); Danian, Argentina (Heisecke, 1970); Tertiary, Antarctica (Wilson, 1967); Early Cenozoic, S.E. Australia, W. New Zealand (Haskell and Wilson, 1975); lower Eocene, N. Germany, Belgium (Morgenroth, 1966); lower Oligocene, Germany (Gocht, 1952); middle Oligocene-upper Oligocene, Germany (Benedek, 1972); middle Oligocene-middle Miocene, Germany (Gerlach, 1961); Miocene, Japan (Shimakura *et al.,* 1971).

SPINIFERITES RAMOSUS GRANOSUS
(Davey and Williams)
Lentin and Williams 1973
Plate 6, figure 6

1966a *Hystrichosphaera ramosa* var. *granosa* DAVEY and WILLIAMS, p. 35, plate 4, figure 9.
1973 *Spiniferites ramosus granosus* (Davey and Williams) LENTIN and WILLIAMS, p. 130.

Comments: The specimens of *S. ramosus granosus* resemble those described by Davey and Williams (1964a). The surficial granulation of the central body is variable in coarseness. The archeopyle is precingular (Type P).

Dimensions: Ten specimens measured; central body diameter 35-48 micra; process length 11-17 micra.

Occurrence: Very rare to rare in samples 279, 280, 282-284, 286-297, Monmouth Formation and Brightseat Formation.

Previous Reported Occurrence: middle-late Albian, Canada (Brideaux, 1971); upper Campanian, Canada (Harland, 1973); upper Maestrichtian-lower Danian, Denmark (Wilson, 1971); Danian, Argentina (Heisecke, 1970); Eocene, England (Davey and Williams, 1966a).

Genus SPONGODINIUM Deflandre 1936

SPONGODINIUM DELITIENSE
(Ehrenberg) Deflandre 1936
Plate 6, figures 7-9

1838 *Peridinium delitiense* EHRENBERG, p. 110, plate 1, figures 1, 6.
1936 *Spongodinium delitiense* (Ehrenberg) DEFLANDRE, p. 170.

Comments: The specimens of *S. delitiense* are generally well preserved. The vesicular appearance of the periphragm is distinctive and the specimens fit the original description closely. The archeopyle is precingular (Type P).

Dimensions: Five specimens measured; periblast length 125-130 micra, width 101-111 micra; endoblast diameter 89 micra; apical pericoel 32-36 micra.

Occurrence: Very rare in samples 280-281, Monmouth Formation.

Previous Reported Occurrence: Upper Cretaceous, Germany (Ehrenberg, 1838, 1854); Upper Cretaceous, Germany (Wetzel, O., 1933); Upper Cretaceous, France (Deflandre, 1936); Upper Cretaceous, Germany (Wetzel, W., 1952); Upper Cretaceous, Canada (McIntyre, 1974); Maestrichtian, Holland (Wilson, 1971); Danian, N. Europe (Morgenroth, 1968).

Genus TRICHODINIUM
Eisenack and Cookson 1960
emend. Clarke and Verdier 1967

TRICHODINIUM HIRSUTUM
Cookson 1965b
Plate 6, figures 10, 11

1965b *Trichodinium hirsutum* COOKSON, p. 139, plate 25, figures 5-13.

Comments: The specimens of *T. hirsutum* observed in this study closely resemble the original description. They differ in that the cyst wall is thicker (4-4.5 micra as opposed to 2.5 micra), the lateral cingular process are more prominent and the apical process is equal to or slightly longer than the antapical. They are different from the specimens of the *Exochosphaeridium* sp. complex in the Monmouth Formation in the consistently strong development of the cingular processes. The archeopyle is precingular (Type P).

Dimensions: Ten specimens measured; cyst main body 82-93 micra; cyst process length 18-20 micra; cingular process 19-38 micra; wall thickness-endophragm: 1 micron periphragm; 2.5-3.5 micra.

Occurrence: Rare to common in samples 295-297, Brightseat Formation.

Previous Reported Occurrence: Paleocene, Australia (Cookson, 1965b).

Family PERIDINIACEAE
(Ehrenberg) Engler 1892
Genus DEFLANDREA Eisenack 1938

Type species: Deflandrea phosphoritica Eisenack 1938.

Comments: The genus contains over 100 species, many of them probably being environmental variants of previously named species. In 1967 Vozzhennikova transferred some members of the genus into newly erected genera. The author feels that some of these transfers were unwarranted. In this paper the genus *Deflandrea* is used to contain those species which are cavate cysts, possess two antapical horns (one of which may be highly reduced) and exhibit an intercalary archeopyle in both the endoblast and periblast. Those forms exhibiting three intercalary plates involved in archeopyle formation either in the endoblast, periblast, or both, are placed in the genus *Trithyrodinium.*

DEFLANDREA ASYMMETRICA
Wilson 1967
Plate 6, figure 12

1967 *Deflandrea asymmetrica* WILSON, p. 67, figures 17-21.

Comments: Deflandrea asymmetrica is common in the lower part of the Round Bay section and closely resembles the description by Wilson (1967). Many specimens are finely granulate on the periphragm due to numerous small randomly distributed coni less than 0.5 micron in height. The endoblast is laterally separated from the periblast by a pericoel ranging from 2-2.5 micra in width. The left antapical horn is strongly developed whereas the right antapical horn is reduced to absent. The archeopyle is intercalary (Type I/Ia) and is attached or hinged along its posterior margin.

Dimensions: Ten specimens measured; periblast length 59-82 micra; width 37-56 micra; endoblast length 32-47 micra; width 29-50 micra; apical pericoel 10-21 micra.

Occurrence: Very rare to common in samples 279-283, Monmouth Formation.

Previous Reported Occurrence: ?Maestrichtian, Denmark (Wilson, 1971); Tertiary, Antarctica (Wilson, 1967); Early Cenozoic, S.E. Australia, W. New Zealand (Haskell and Wilson, 1975).

DEFLANDREA COOKSONII Alberti 1959
Plate 7, figures 1, 2

1959 *Deflandrea cooksonii* ALBERTI, p. 97, plate 9, figures 1-6.

Comments: This species is variable with regard to both the development of the epithecal "shoulders" and ornamentation of the periblast. Specimens occur in which the epitheca is slightly tapered; whereas, others exhibit strong "shoulder" development. Other specimens are ornamented with granules, small spines at the cingulum or on the hypotheca, or unornamented. All specimens have an intercalary archeopyle (Type I) on the periblast; whereas, the endoblast archeopyle is not obvious although it is presumed to be intercalary. The author interprets these differences as representing environmental variation and herein considers them to be an intergradative complex. Many of the variants have been set aside into separate species by previous workers, such as *D. tripartita* and

D. granulifera, however, they are treated in this study as belonging to the species *D. cooksonii*. The author hopes in the future to obtain the type specimens of the problematic species herein considered to belong to one complex, so that a detailed analysis of this problem can be undertaken.

Dimensions: Twenty specimens measured; periblast length 76-108 micra; width 40-54 micra; endoblast length 35-53 micra; width 34-64 micra; apical pericoel 6-12 micra.

Occurrence: Very rare to common in samples 279-283, 285, 287, Monmouth Formation.

Previous Reported Occurrence: Cretaceous, Australia (Cookson and Eisenack, 1960); upper Senonian, Germany (Alberti, 1959); Upper Cretaceous, U.S.S.R. (Vozzhennikova, 1967); Maestrichtian, U.S.A. (Zaitzeff and Cross, 1968); Maestrichtian, Denmark (Wilson, 1971); Maestrichtian-Danian, U.S.A. (Drugg, 1967).

DEFLANDREA DARTMOORIA
Cookson and Eisenack 1965a
Plate 8, figures 1-3

1965a *Deflandrea dartmooria* COOKSON and EISENACK, p. 132, plate 16, figures 1, 2, text figure 1.

Comments: The specimens of *Deflandrea dartmooria* resemble the original description quite closely. The tabulation as indicated by intratabular fields of coni is 4', 3a, 7'', 5c, 5''', 2''''. The tabulation of the sulcal plates is indeterminate in the specimens observed; however, Stover (1973) reported that seven sulcal plates are probably represented. The archeopyle is intercalary (Type I).

Dimensions: Ten specimens measured; periblast length 114-117 micra; width 62-91 micra; endoblast length 58-68 micra; width 56-70 micra; apical pericoel 35-46 micra.

Occurrence: Very rare to common in samples 280, 283-296, Monmouth Formation and Brightseat Formation.

Previous Reported Occurrence: Paleocene, Australia (Cookson and Eisenack, 1967); early Eocene, Australia (Cookson and Eisenack, 1965a; Stover, 1973).

DEFLANDREA DIEBELII Alberti 1959
Plate 8, figures 4-6

1959 *Deflandrea diebelii* ALBERTI, p. 99, plate 9, figures 18-21.

1967 *Ceratiopsis diebelii* (Alberti) VOZZHENNIKOVA, p. 159.

Comments: The transfer of *Deflandrea diebelii* to the genus *Ceratiopsis* by Vozzhennikova (1967) is herein rejected. Although the apical and antapical horns are elongate as pointed out by Vozzhennikova (1967), the archeopyle is clearly anterior intercalary (Type I) in position and not "equatorially" located as mentioned in the generic description by Vozzhennikova (1967). The present author feels that the species in question has greater affinities with *Deflandrea* and treats it as such. *Deflandrea diebelii* is rare in the study area. It is very distinctive due to its elongate apical and antapical horns, the distinct longitudinal folds and its large size. The cingulum is equatorial, and the sulcus, although indistinct, has a concavo-convex flagellar scar on the left side.

Dimensions: Ten specimens measured; periblast length 211-261 micra; width 58-73 micra; endoblast length 58-73 micra; width 65-73 micra; apical pericoel 83-107 micra; antapical pericoel 52-72 micra; periphragm less than 0.5 micron; endophragm less than 1 greater than 0.5 micron.

Occurrence: Very rare to rare in samples 279-282, 285, Monmouth Formation.

Previous Reported Occurrence: Upper Cretaceous, Canada (McIntyre, 1974); upper Senonian, Germany (Alberti, 1959); Maestrichtian, Poland (Gorka, 1963); Maestrichtian, Denmark (Wilson, 1971); Paleocene, U.S.S.R. (Vozzhennikova, 1967).

DEFLANDREA cf. D. DIEBELII
Alberti 1959
Plate 8, figures 7-9

Comments: A few specimens of *Deflandrea* are present which are similar to *D. diebelii;* however, their size is about half that of the typical *D. diebelii*. The periphragm is thin and longitudinally wrinkled, the endophragm is about twice as thick as the periphragm and is externally smooth. The apical and antapical horns are elongate as in *D.*

diebelii. The archeopyle is intercalary (Type I). This species is present in both Cretaceous and Paleocene strata and its local range overlaps that of *D. diebelii* and extends much higher (into the Paleocene) in the section. This form may be the same as the *Deflandrea* sp. cf. *D. diebelii* reported by Stover (1973) and may represent aberrant individuals of that species.

Dimensions: Five specimens measured; periblast length 117-147 micra; width 41-55 micra; endoblast length 57-67 micra; width 35-41 micra; apical pericoel 47-58 micra; antapical pericoel 41-47 micra; endoblast wall greater than 0.5 and less than 1 micron; periblast wall greater than 0.2 and less than 0.5 micron.

Occurrence: Very rare to rare in samples 286, 289, 292-295, Monmouth Formation and Brightseat Formation.

DEFLANDREA DILWYNENSIS
Cookson and Eisenack 1965b
Plate 7, figures 3-5

1965b *Deflandrea dilwynensis* COOKSON and EISENACK, p. 141, plate 18, figures 6-9.

Comments: Deflandrea dilwynensis resembles the original specimens closely. The archeopyle is intercalary (Type I). It is considered by the author to be an excellent Paleocene indicator.

Dimensions: Ten specimens measured; periblast length 53-62 micra; width 41-47 micra; endoblast length 35-50 micra; width 35-41 micra; apical pericoel 11-18 micra.

Occurrence: Rare in samples 294-297, Brightseat Formation.

Previous Reported Occurrence: Paleocene, Australia (Cookson and Eisenack, 1965b; Stover, 1973).

DEFLANDREA ECHINOIDEA
Cookson and Eisenack 1960
emend. Sverdlove and Habib 1974
Plate 7, figures 6, 7

1960 *Deflandrea echinoidea* COOKSON and EISENACK, p. 2, plate 1, figures 5-6.
1971 *Deflandrea limpida* SINGH, p. 359, plate 61, figures 1-12.
1974 *Deflandrea echinoidea* Cookson and Eisenack; SVERDLOVE and HABIB, p. 58, plate 1, figures 1-6.

Comments: The specimens resemble those described by Cookson and Eisenack (1960) and Sverdlove and Habib (1974). Many of the specimens were poorly preserved and the accessory sutures described by Sverdlove and Habib (1974) were not seen. The tabulation appears to be 4', 3a, 7'', ?c, 5''', 2''''. The archeopyle is intercalary.

Dimensions: Ten specimens measured; periblast length 59-74 micra; width 44-56 micra; endoblast length 37-56 micra; width 32-49 micra; apical pericoel 6-12 micra.

Occurrence: Rare to abundant in samples 294-297, Brightseat Formation.

Previous Reported Occurrence: Lower Cretaceous, Canada (Singh, 1971); middle-late Albian, Canada (Brideaux, 1971); Albian, Canada (Davey, 1970); Turonian-lower Senonian, England (Davey, 1970): Santonian, England (Clarke and Verdier, 1967); Cretaceous, Australia (Cookson and Eisenack, 1970); upper Campanian, Canada (Harland, 1973).

DEFLANDREA MAGNIFICA Stanley 1965
Plate 7, figures 8, 9

1965 *Deflandrea magnifica* STANLEY, p. 218, plate 20, figures 1-6.

Comments: Deflandrea magnifica recovered in this investigation conforms morphologically closely to the description given by Stanley (1965). The archeopyle is intercalary (Type I). It is more variable in size than the specimens described by Stanley (1965).

Dimensions: Ten specimens measured; overall length range 88-118 micra; overall width range 82-102 micra; apical horn length 4-9 micra.

Occurrence: Very rare to rare in samples 280, 286-297, Monmouth Formation and Brightseat Formation.

Previous Reported Occurrence: Maestrichtian-Danian, U.S.A. (Drugg, 1967); Maestrichtian, U.S.A. (Zaitzeff and Cross, 1968); Paleocene, U.S.A. (Stanley, 1965); Eocene, Belgium (DeConinck, 1967).

DEFLANDREA MINOR Alberti 1959
Plate 7, figure 10

1959 *Deflandrea minor* ALBERTI, p. 98, plate 9, figures 9-11.

Comments: The specimens of *Deflandrea minor* generally resemble those described by Alberti and are poorly preserved. The antapical horns are greatly reduced in the Monmouth specimens.

Dimensions: Ten specimens measured; periblast length 47-49 micra; width 35-45 micra; endoblast length 35-40 micra; width 33-41 micra; apical pericoel 7 micra.

Occurrence: Rare in samples 286-292, Monmouth Formation.

Previous Reported Occurrence: Upper Cretaceous, Canada (McIntyre, 1974); upper Senonian, Germany (Alberti, 1959); Maestrichtian, Denmark (Wilson, 1971).

DEFLANDREA PANNUCEA Stanley 1965
Plate 7, figures 11, 12

1965 *Deflandrea pannucea* STANLEY, p. 220, plate 22, figures 1-4, 8-10.

Comments: Deflandrea pannucea specimens are similar to those described by Stanley (1965). Some show a distinct sulcus, a feature noted as usually indistinct in the original description. The endoblast is variable in its posterior development ranging from being slightly flattened to strongly protruding into the antapical horns of the periblast. The endoblast appears to be externally microreticulate. The cingulum of the Monmouth Formation specimens is equatorial to slightly levorotary; the archeopyle is intercalary (Type I).

Dimensions: Ten specimens measured; periblast length 79-88 micra; width 53-60 micra; endoblast length 37 micra, width 47 micra.

Occurrence: Very rare to rare in samples 282-291, Monmouth Formation.

Previous Reported Occurrence: Maestrichtian, U.S.A. (Zaitzeff and Cross, 1968); Paleocene, U.S.A. (Stanley, 1965).

DEFLANDREA cf. D. PENTARADIATA
Cookson and Eisenack 1965b
Plate 9, figures 1-3

Comments: Deflandrea cf. *D. pentaradiata* is variable in its morphology. The lateral projections at the cingulum are frequently poorly developed and the endoblast is pentagonal to rounded in morphology. The longitudinal striae reported by Cookson and Eisenack (1965b) and Stover (1973) are absent. The periphragm is finely granular and the endophragm finely to coarsely granular. Specimens are illustrated in plate 9, figures 1-3, to show the typical range of variation.

Dimensions: Eight specimens measured; periblast length 82-124 micra; width 70-91 micra; endoblast length 54-93 micra; width 57-80 micra; apical pericoel 9-26 micra.

Occurrence: Rare to common in samples 294-297, Brightseat Formation.

DEFLANDREA PULCHRA n. sp.
Plate 9, figures 4-9

Derivation of name: pulchra (L) beautiful.

Holotype: Sample 296, slide AN 69, R 3.7 + 6.2.

Description: Cavate cyst, peridinoid outline with intratabularly arranged coni on periblast. Periphragm and endophragm each about 0.5 micron in thickness. Reflected tabulation 4', 3a, 7'', ?c, 5''', 2''''. Apical horn with two short spines on antero-lateral margin, the spines directed anteriorly. Archeopyle intercalary (Type I/I) with posteriorly and occasionally laterally directed accessory sutures. Cingulum levorotary, offset up to 4 micra. Sulcus strongly developed, may extend up to 5 micra on epitract. Left antapical horn longer than right. Endoblast closely appressed to periblast, may protrude slightly into antapical horns.

Dimensions:

Holotype: Periblast length 69 micra; width 50 micra; endoblast length 46 micra; width 46 micra; apical pericoel 13 micra.

Range: 20 specimens measured; periblast length 56-74 micra; width 43-57 micra; endoblast length 40-54 micra; width 38-51 micra; apical pericoel 7-13 micra.

Comments: D. pulchra resembles *D. echinoidea* (Sverdlove and Habib, 1974); however, it differs in that the tabulation of *D. pulchra* is reflected by the intratabular rather than peritabular arrangement of the coni. Also it is Paleocene rather than Cretaceous in age.

Occurrence: Common to abundant in samples 295-297, Brightseat Formation.

DEFLANDREA RHOMBOHEDRA n. sp.
Plate 9, figures 10-12

Derivation of name: rhombus + hedra (Gr.), in reference to the shape of the cyst.

Holotype: Sample 294, slide AN 62, R 8.3 + 11.2.

Description: Cavate cyst with left antapical horn strongly developed giving a rhomboid periblast shape. Cyst bilayered, endophragm slightly less than 1 micron, periphragm very delicate and considerably less than 0.5 micron. Endoblast closely appressed to periblast with lateral pericoel being less than 1 micron. Endoblast protrudes into left antapical horn, position of right antapical horn frequently represented by a slight bulge or flattening on endoblast. Atabulate. Archeopyle intercalary (Type I/I). Cingulum weakly developed, slightly levorotary, slightly depressed sulcus faintly evident with concavo-convex flagellar scar just posterior to plane of cingulum. Endophragm smooth to microreticulate, periphragm smooth, may have faint wrinkles.

Dimensions:

Holotype: Periblast length 72 micra; width 35 micra; endoblast length 49 micra; width 33 micra; apical pericoel 9 micra.

Range: Eight specimens measured; periblast length 75-82 micra; width 33-40 micra; endoblast length 49-63 micra; width 30-37 micra; apical pericoel 9-19 micra.

Discussion: This species was previously described by McLean (1971) and is herein redescribed since the description was never validly published. McLean's (1971) name "rhombohedra" is retained since the forms are considered to be conspecific.

Comparison with other species: In its general appearance *D. rhombohedra* is somewhat similar to *D. asymmetrica* (Wilson, 1967); however, *D. rhombohedra* has a free operculum whereas *D. asymmetrica* possesses a posteriorly hinged operculum and frequently developes a right antapical horn. The elongate rhomboid shape with an endoblast of similar shape allows differentiation of *D. rhombohedra* from *D. acuminata* (Cookson and Eisenack, 1958) in that the endoblast of *D. acuminata* is circular and not closely appressed.

Occurrence: Very rare in samples 294, 295, 297, Brightseat Formation.

DEFLANDREA SEVERNENSIS n. sp.
Plate 10, figures 1-3

Derivation of name: Severn- for the Severn River in Maryland.

Holotype: Sample 288, slide AN 37, R 15.8 + 13.4.

Description: Cavate cyst with reduced apical and antapical horns. Periphragm and endophragm thin, each less than 0.9 micron in thickness. Periblast ornamented with varying numbers of short spines, frequently but not always intratabulary arranged reflecting a tabulation of 4', 3a, 7'', ?c, ?5''''', 2''''. Tabulation generally incomplete on individual specimens. Archeopyle intercalary (Type I/I). Cingulum equatorial; slightly levorotary. Sulcus strongly developed. Endoblast closely appressed to periblast.

Dimensions:

Holotype: Periblast length 71 micra, width 65 micra; endoblast length 52 micra; width 61 micra; apical pericoel 9 micra.

Range: 15 specimens measured; periblast length 61-78 micra; width 56-65 micra; endoblast length 40-58 micra; width 51-61 micra; apical pericoel 6-13 micra.

Comments: Deflandrea severnensis is variable in the density of ornamentation, which frequently masks the tabulation. Tabulation was determined by examining many specimens. Because of the delicate walls, specimens are commonly distorted.

Comparison with similar species: Deflandrea severnensis resembles *D. ventriosa* (Alberti, 1959), differing from the latter in possessing tabulation as reflected by the spinose ornamentation. It also resembles *D. microgranulata* Stanley (1965); however, *D. severnensis* does not possess the fine granulations on the endoblast surface and tabulation is not evident on *D. microgranulata*. These three species are perhaps closely related and may reflect an evolutionary lineage or variation.

Occurrence: Very rare to abundant in samples 284-293, Monmouth Formation.

DEFLANDREA cf. D. SPECIOSA
Alberti 1959
Plate 10, figures 4-6

Comments: Several specimens of *Deflandrea* resemble *D. speciosa* (Alberti, 1959). They bear denticulated longitudinal ridges on the periblast; however, they differ from *D. speciosa* in that they are slightly smaller, the endoblast is more angular and the antapical horns do not diverge from the midline as much as in the original described and illustrated specimens. The archeopyle is intercalary (Type I).

Dimensions: Ten specimens measured; periblast length 82-105 micra; width 53-65 micra; endoblast length 48-52 micra; width 50-54 micra; apical pericoel 14-22 micra.

Occurrence: Very rare to rare in samples 287, 289-292, Monmouth Formation.

DEFLANDREA sp. A
Plate 10, figures 7-9

Description: Cavate cyst, peridinioid outline with intratabular coni. Periphragm and endophragm each about 0.6 micron thick. Reflected tabulation 4', 3a, 7'', ?c, 5''', 2''''. Archeopyle intercalary (Type I). Cingulum equatorial to levorotary with maximum offset of 3 micra. Endoblast closely appressed to periblast and protruding slightly into antapical horns. Lateral margins of epitract and hypotract slightly concave yielding an angular outline. Apical and antapical horns well developed.

Comments: Deflandrea sp. A. is unique in its appearance; however, insufficient specimens were recovered to establish the range of variation and thus to erect a new species. The intratabular coni vary from less than 1 micron to greater than 2 micra in height.

Dimensions: Five specimens measured; periblast length 74-88 micra; width 53-73 micra; endoblast length 43-53 micra; width 50-64 micra; apical pericoel 14-19 micra.

Occurrence: Very rare in samples 282-284, Monmouth Formation.

Genus PALAEOPERIDINIUM
Deflandre 1935 *ex* Sarjeant 1967

PALAEOPERIDINIUM BASILIUM
(Drugg) Drugg 1970
Plate 10, figures 10, 11

1967 *Peridinium basilium* DRUGG, p. 13, plate 1, figures 9-11.
1970 *Palaeoperidinium basilium* (Drugg) DRUGG, p. 810, plate 1, figure D.

Comments: The specimens of *Palaeoperidinium basilium* resemble those of Drugg (1967, 1970). The tabulation is indistinct and archeopyle development is not clear. Drugg stated that the archeopyle is epitractal and that appears to be the case in the majority of specimens observed, in that many specimens are split at the cingulum. However, some specimens are encountered that suggest transapical excystment. This may have been, however, a function of poor preservation and/or damage to the cyst.

Dimensions: Ten specimens measured; periblast length 103-119 micra; width 91-106 micra.

Occurrence: Common in sample 297, Brightseat Formation.

Previous Reported Occurrence: Upper Cretaceous, Canada (McIntrye, 1974); lower Danian, U.S.A. (Drugg, 1967); Danian, U.S.A. (Drugg, 1970).

PALAEOPERIDINIUM cf. P. DEFLANDREI (Deflandre)
Lentin and Williams 1973
Plate 10, figure 12; Plate 11, figure 1

Comments: Several poorly preserved specimens of *Palaeoperidinium* were recovered. The "growth lines" delineating plate boundaries are only faintly visible; however, their distribution resembles that of *P. deflandrei.* The specimens recovered are larger than those of 70-80 micra in length described by Deflandre (1936). Archeopyle not observed.

Dimensions: Six specimens measured; length 95-120 micra; width 90-110 micra.

Occurrence: Rare in samples 279-282, 284, Monmouth Formation.

Genus SPINIDINIUM
Cookson and Eisenack 1962

SPINIDINIUM CLAVUM Harland 1973
Plate 11, figures 2, 3

1973 *Spinidinium clavum* HARLAND, p. 674, plate 84, figures 5, 6, 10, text figure 9.

Comments: The cingulum is slightly levorotary in some of the specimens recovered from the Monmouth Formation. The spines of the Monmouth specimens are between 1 and 1.5 micra in length and are rarely bifid distally. The branches of the bifid tip lie at about right angles to the main body of the process, yielding a T-shaped process. The archeopyle is intercalary (Type I).

Dimensions: Ten specimens measured; periblast length 44-59 micra; width 31-37 micra; endoblast length 32-28 micra; width 29-34 micra; apical pericoel 6-10 micra.

Occurrence: Very rare to common in samples 280, 281, 291-295, Monmouth Formation and Brightseat Formation.

Previous Reported Occurrence: upper Campanian, Canada (Harland), 1973).

Genus SVALBARDELLA Manum 1960

SVALBARDELLA AUSTRALINA Cookson 1965b
Plate 15, figures 5, 6

1965b *Svalbardella australina* COOKSON, p. 140, plate 25, figures 1-4.

1972 *Svalbardella australina* Cookson; MALLOY, p. 63.

Comments: Svalbardella australina exhibits variation in both size and ornamentation. Most specimens possess a smooth periphragm; however, slight granulation is present in some specimens. The specimens observed in the Paleocene portion of the section exhibit a reduction in the length of the antapical horn; however, the accessory spike is well developed. The archeopyle is (Type I) intercalary.

Dimensions: Ten specimens measured; periblast length 158-215 micra; width 38-63 micra; endoblast length 79-117 micra; width 36-61 micra.

Occurrence: Very rare to common in all samples except 285 and 297, Monmouth Formation and Brightseat Formation.

Previous Reported Occurrence: Upper Cretaceous, W. Africa (Malloy, 1972); Maestrichtian, Denmark, (Wilson, 1971); Paleocene, Australia (Cookson, 1965b).

Genus TRITHYRODINIUM Drugg 1967 emend. Davey 1969b

TRITHYRODINIUM STRIATUM n. sp.
Plate 11, figures 4-8

Derivation of name: striatum (L), in reference to the striated appearance of the endoblast.

Holotype: Sample 281, slide AN 9, R 18.3 + 7.6.

Description: Cavate cyst with very thin, delicate periblast, which is frequently missing. Apical horn short, antapical horns unequally developed. Tabulation absent. Archeopyle intercalary, type 3I/3I. Periphragm thin, less than 0.5 micron thick with no distinct sculpture, endophragm about 1 micron thick, longitudinally striate with clear indication of cingulum.

Dimensions:

Holotype: Periblast length 82 micra; width 73 micra; endoblast length 65 micra; width 62 micra; apical pericoel 8 micra.

Range: No additional intact specimens for periblast measurements; endoblast length 61-66 micra; width 59-63 micra (ten specimens).

Comments: Trithyrodinium striatum is most frequently seen as an isolated endoblast due to the delicate nature of the periphragm. One of the specimens illustrated (plate 11, fig. 7) demonstrates the unusual nature of the intercalary plate relationship in this species. Plates 1a and 3a are fused in the midline anterior to the anterior edge of plate 2a. J. Lentin *(in litt.)* feels that the pentagonal nature of the 2a plate and the relationship of the 1a and 3a plates warrants the erection of a new genus; however, Evitt *(in litt.)* states that he has observed this morphology as one end member of a range of variation. Since the specimens are derived from a single locality the total variation cannot be determined and the author feels that the erection of a new genus would be premature. A fuller discussion of the variation in *T. striatum* is the subject of a forthcoming paper.

Comparison with similar species: Trithynodinium striatum is similar to *T. fragile* (Davey 1969b) and *T. evittii* (Drugg, 1967f) in general morphologic aspects and size. All three species possess a thin periphragm; however, the fine punctae reported by Drugg (1967) are absent on *T. striatum*, and the endoblast is single layered rather than bilayered as reported by Davey (1969b) for *T. fragile*.

Occurrence: Very rare to rare in samples 280, 281, Monmouth Formation.

TRITHYRODINIUM ROBUSTUM n. sp.
Plate 11, figures 9-12; Plate 12, figure 1

Derivation of name: robustum (L), in reference to its appearance.

Holotype: Sample 281, slide AN 9, R 15.9 + 6.4.

Description: Cavate cyst with pronounced apical horn, antapical horns, and large circular to elliptical endoblast. Left antapical horn twice as long as right. Tabulation reflected by intratabular coni: 4', 3a, 6-7'', ?c, 5''', 1p, 2''''. Archeopyle type 3I on endoblast, type I on periblast. Cingulum levorotary, slightly greater than 1 cingulum width. Sulcus restricted to hypotract, up to 15 micra in width. Endoblast microreticulate to microgranulate. Endophragm 1 micron in thickness, increasing to 2 micra at apical and antapical ends. Periphragm slightly less than 1 micron in thickness.

Dimensions:

Holotype: Periblast length 153 micra; width 78 micra; endoblast length 69 micra; width 71 micra; apical pericoel 43 micra.

Range: 20 specimens measured; periblast length 101-153 micra; width 53-82 micra;

PLATE 1

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Figures 1-3. *Dinogymnium westralium* 181
Sample 283, slide AN 17, R 5.6, + 9.6. L x W 50 x 35 micra. Fig. 1: dorsal view. Fig. 2: ventral (transparency) view showing distinct sulcus. Fig. 3: enlargement showing apical archeopyle and undulatory sculpture of longitudinal ribs.

Figures 4,5. *Conosphaeridium* cf. *C. striatoconus* 181
Sample 293, slide AN 57, R 9.1, + 9. Diameter 47 micra, processes up to 9 micra. Fig. 4: optical section. Fig. 5: surface detail showing microreticulate sculpture.

Figures 6,7. *Cordosphaeridium fibrospinosum* 182
Sample 281, slide AN 10, R 14.3, + 4.5. Cyst body L x W 80 x 70 micra, processes up to 28 micra. Fig. 6: dorsolateral view showing precingular archeopyle and fibrous periphragm. Fig. 7: optical section showing wide fibrous processes.

Figure 8. *Coronifera oceanica* 182
Sample 284, slide AN 23, R 12, + 7.8. Cyst L x W 49 x 42 micra, antapical process 14 micra, optical section showing antapical process, apical operculum still in place.

Figures 9-12. *Cyclapophysis monmouthensis* gen. et sp. nov. 183
Holotype, Sample 291, slide AN 52, R 7.7, + 10. Cyst body L x W 75 x 65 micra. Figs. 9-11: dorsal, optical section and ventral (transparency) views respectively. Note the distal interconnection of precingular and postcingular processes to form the equatorial "tunnel". Fig. 12: Periphragm and process detail.

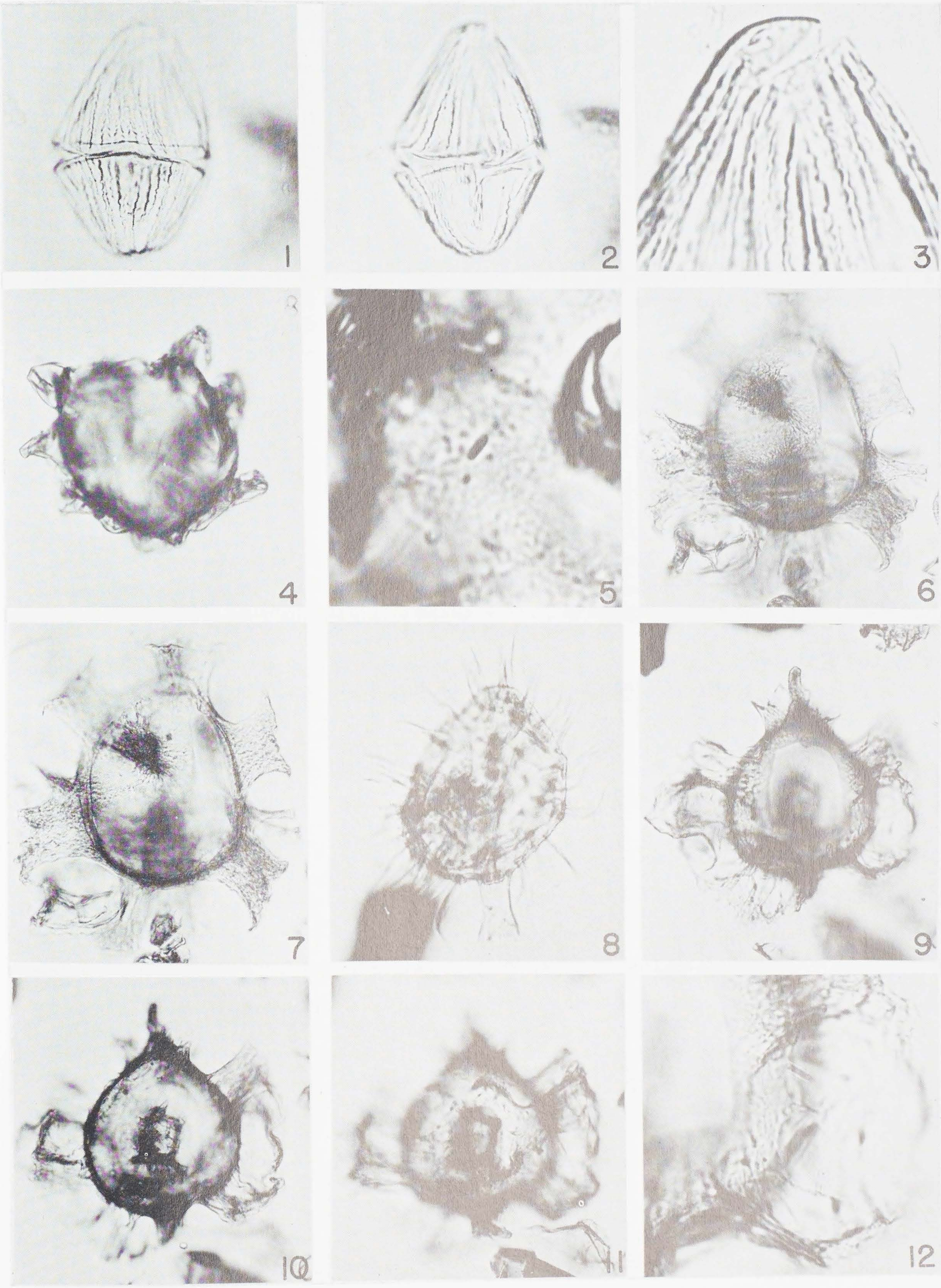

PLATE 1

endoblast length 44-79 micra; width 46-75 micra; apical pericoel 29-47 micra.

Comments: Only rarely does a specimen exhibit complete tabulation because of the dense distribution of coni. The 3I archeopyle is observed with difficulty since the operculum is most frequently present. The thickening of the endoblast at its apical and antapical ends is apparently due to a localized increase in the height of the sculpturing and in those regions the endoblast appears to be bilayered and the outer layer may represent a mesophragm.

Comparison with similar species: The shape of *T. robustum* resembles the forms which Vozzhennikova (1967) placed in the genus *Australiella;* however, it lacks the strong development of epithecal "shoulders" as exhibited by the other members of that genus. Vozzhennikova's transfer included *Deflandrea tripartita* (Cookson and Eisenack, 1960), *D. thomasii* (Cookson and Eisenack, 1961), etc. All of these species possess a similar periblast shape, particularly with regard to the strong development of epithecal "shoulders." There is, however, a fundamental difference present within the above mentioned species. The archeopyle of *D. granulifera* and *D. thomasii* is type 3I with regard to the endoblast and type I with regard to the periblast (Manum and Cookson, 1964, plate 1, figures 5, 6, 8). *D. cooksonii* (Manum and Cookson, 1964, plate 1, figures 2, 3) and *D. tripartita* (Cookson and

PLATE 2

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Figure 1. *Cyclapophysis monmouthensis* gen. et sp. nov. 183
Morphology of distal interconnections between precingular and postcingular processes.

Figures 2-4. Cyst Forma A 183
Sample 281, slide AN 9, R 12.3 + 12.6. Cyst body diameter 40 micra. Dorsal (transparency), optical section and ventral views respectively. Fig. 2: illustration of the combination archeopyle.

Figure 5. *Diphyes colligerum* 184
Sample 281, slide AN 9, R 15.2, + 5.5. Cyst diameter 33 micra, antapical process 12 micra. Optical section illustrating antapical process, bilayered wall, apical archeopyle and finely capitate processes.

Figures 6-9. *Diversispina truncata* gen. et sp. nov. 184
Holotype, Sample 285, slide AN 27, R 9.8, + 4.7. Cyst body L x W 58 x 54 micra, processes up to 35 micra. Figs: 6-8: Dorsal (transparency), optical section, and ventral views respectively. Note precingular archeopyle and flattened cingular process on Fig. 6, subtle fibrosity of process at 7 o'clock in Figs. 6,7, variable process termination and microreticulate sculpture on Fig. 8. Fig. 9: illustration of detail of process termination.

Figures 10-12. Cyst Forma B 183
Sample 292, slide AN 54, R 9.7, + 14.8. Cyst body diameter 35 micra. Figs. 10, 11: Dorsal and optical section views respectively. Note apical archeopyle and hollow processes. Fig. 12: Illustration of details of process base.

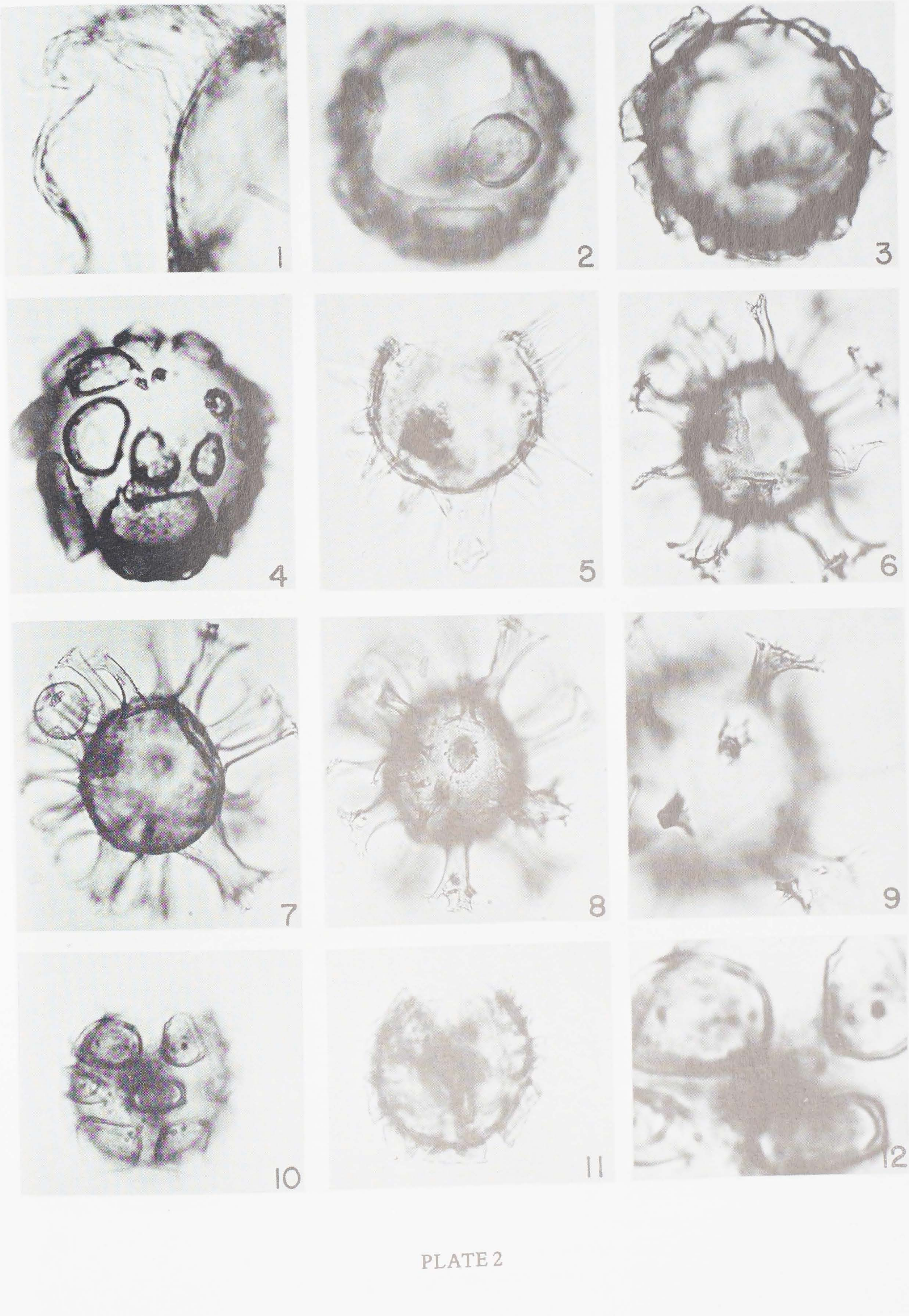

PLATE 2

Eisenack, 1960, plate 1, figure 10), on the other hand, possess a type I archeopyle in both the endoblast and periblast. The transfer of species that have a similar periblast shape but different mode of archeopyle formation into the same genus appears to be questionable and will be dealt with in a separate publication.

It would appear that the affinities of *T. robustum* lie with those species of *Australiella* that exhibit a type 3I/I archeopyle. It differs from those species; however, in the weak development of epithecal "shoulders," and the presence of tabulation and larger antapical horns.

Occurrence: Rare to common in samples 279-281, Monmouth Formation.

Genus WETZELIELLA Eisenack 1938
emend. Williams and Downie 1966b

WETZELIELLA cf. W. PILATA
Stanley 1965

Plate 12, figures 2, 3

PLATE 3

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Figures 1,2. *Exochosphaeridium bifidum* 185
Sample 285, slide AN 25, R 10.2, + 12.7. Cyst body diameter 58 micra, processes up to 13 micra, apical process 11 micra. Fig. 1: dorsal view showing precingular archeopyle, branched apical process and fibrous periphragm. Fig. 2: illustration of process termination, note spinelets on process at 2 o'clock.

Figures 3-9. *Exochosphaeridium* sp. complex 185
Fig. 3: Sample 281, slide AN 9, R 11.9, + 9.3, L x W 72 x 70 micra, apical process 14 micra, Figs. 4-6: Sample 281, slide AN 12, R 11.0, + 13.7. L x W 72 x 65 micra, apical process 14 micra, antapical process 16 micra. Figs. 7-9: Sample 281, slide AN 11, R 10.2, + 5.4. L x W 72 x 63 micra, apical process 14 micra, antapical process 21 micra, cingular process 16 micra. Fig. 3: dorsal view of specimen exhibiting apical process and precingulat archeopyle. Figs. 4-6: dorsolateral (transparency), optical section and ventrolateral views of specimen respectively, with apical and antapical processes. Note precingular operculum still in place, apical and antapical process visible in Figs. 5,6 respectively. Figs. 7-9: Dorsolateral (transparency), optical and ventrolateral views of specimen respecitvely, with apical antapical and cingular processes. Note tendency of cingular processes to be aligned in Fig. 7.

Figures 10,11. *Gonyaulacysta orthoceras* 185
Sample 285, slide AN 25, R 18.8, + 5.6. L x W 104 x 86 micra, Dorsal (transparency) and ventral views. Note apical horn and precingular archeopyle in Fig. 10. Ventral view illustrates surficial sculpture, plate boundaries and sulcal detail, compare with Plate 4, Fig. 1.

Figure 12. *Gonyaulacysta wetzelii* 186
Sample 289, slide AN 44, R 11, + 4.8. L x W 77 x 67 micra. Dorsal (transparency) view, note precingular operculum.

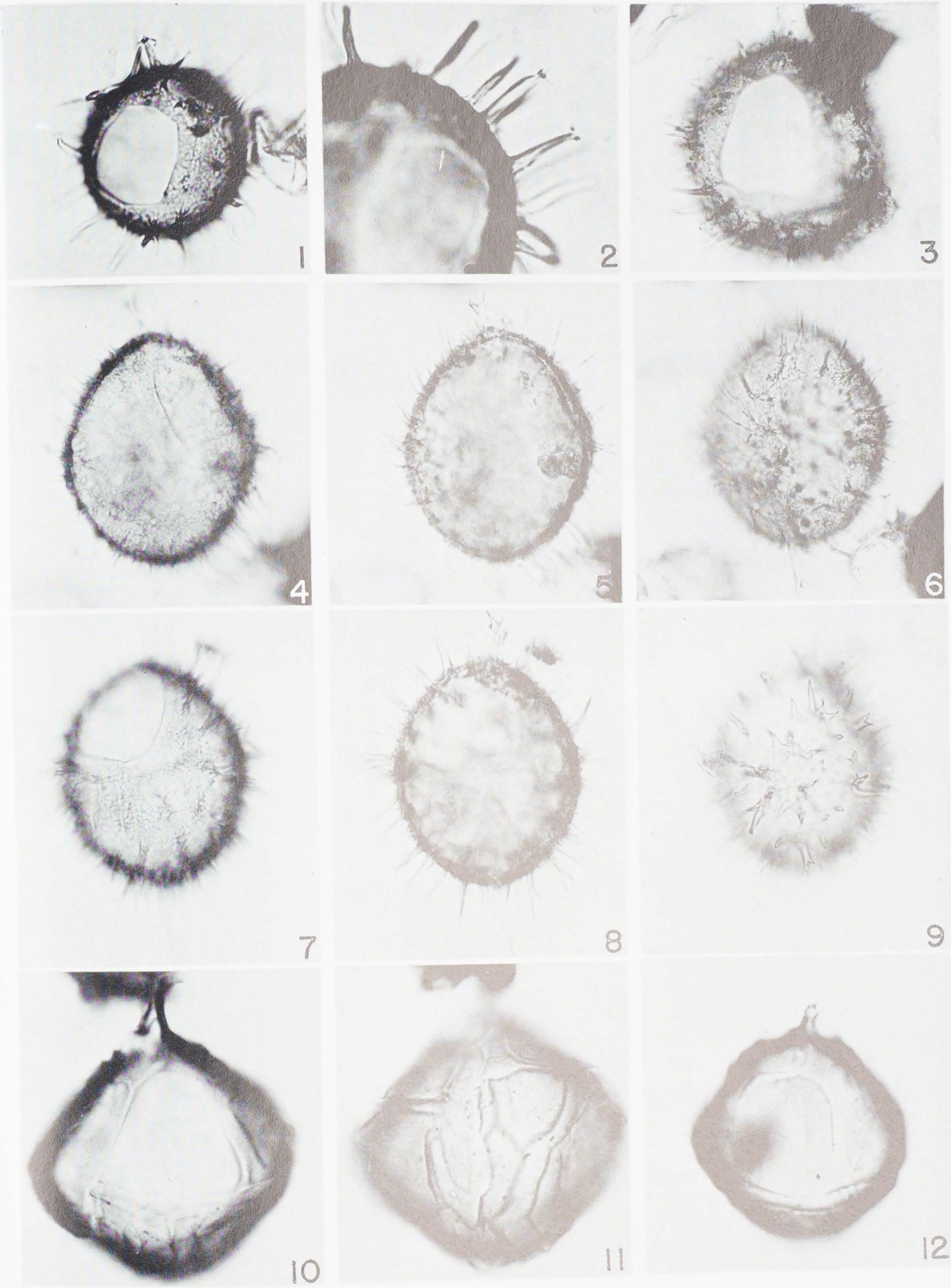

PLATE 3

Comments: The specimens observed in this work resemble closely the original figures of Stanley (1965). They are slightly larger and the right antapical horn is more reduced than in Stanley's specimens. Although the distinctive capitate baculae are, or appear to be, primarily sutural in position the tabulation could not be determined with certainty. The epitract appears to be 4', 3a, 5-6'', (?)c. The hypotract could not be determined in the Monmouth specimens. The archeopyle is indistinct and appears to be intercalary (2a) in position. The periphragm and endophragm are thin, less than 0.5 micron and are separated by a pericoel about 2 micra in width.

Dimensions: Five specimens measured; periblast length 55-68 micra; width 42-51 micra; endoblast length 44-54 micra; width 38-47 micra; apical pericoel 7-9 micra.

Occurrence: Very rare in samples 295, 297, Brightseat Formation.

Family Uncertain
Genus AREOLIGERA
Lejeune-Carpentier 1938
emend. Williams and Downie 1966b

AREOLIGERA sp. (Lejeune-Carpentier)
Williams and Downie 1966b
Plate 12, figures 4-6

Comments: Several samples contained very large numbers of *Areoligera.* The population encountered is variable and intergradative forms with *Systematophora* sp. were observed. Due to the intergradation of forms

PLATE 4

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Figure 1. *Gonyaulacysta wetzelii* 186
Ventral view, same specimen as Plate 3, fig. 12. Compare sulcal details with Plate 3, fig. 11.

Figures 2, 3. *Hystrichokolpoma ferox* 186
Sample 280, slide AN 6, R 10.8, + 15.6. Cyst body diameter 47 micra, processes up to 17.5 micra. Fig. 2: Optical section showing apical archeopyle. Fig. 3: Enlargement illustrating process morphology.

Figures 4-6. *Hystrichokolpoma fimbriata* 187
Sample 293, slide AN 57, R 14.1, + 4.3. Cyst body diameter 38 micra, processes up to 19 micra. Figs. 4, 5: dorsal (transparency), and optical section views respectively. Fig. 6: Illustrates the morphological detail of the processes and periphragm.

Figures 7-9. *Hystrichokolpoma unispinum* 187
Sample 295, slide AN 67, R 11.7, + 7.2. Cyst body diameter 44 micra, large processes up to 26 micra in length, small processes up to 19 micra in length. Figs. 7, 8: Dorsal (transparency) and ventral views respectively. Fig. 9: View of ventral surface illustrating process bases and surficial detail.

Figures 10-12. *Hystrichosphaeridium deanei* 187
Sample 294, slide AN 64, R 17, + 13.2. Cyst body diameter 35 micra, processes up to 23 micra in length. Figs. 10-12: Dorsal, optical and ventral (transparency) views respectively. The process at 3 o'clock in Fig. 11 is illustrated in greater detail in Plate 5, fig. 1.

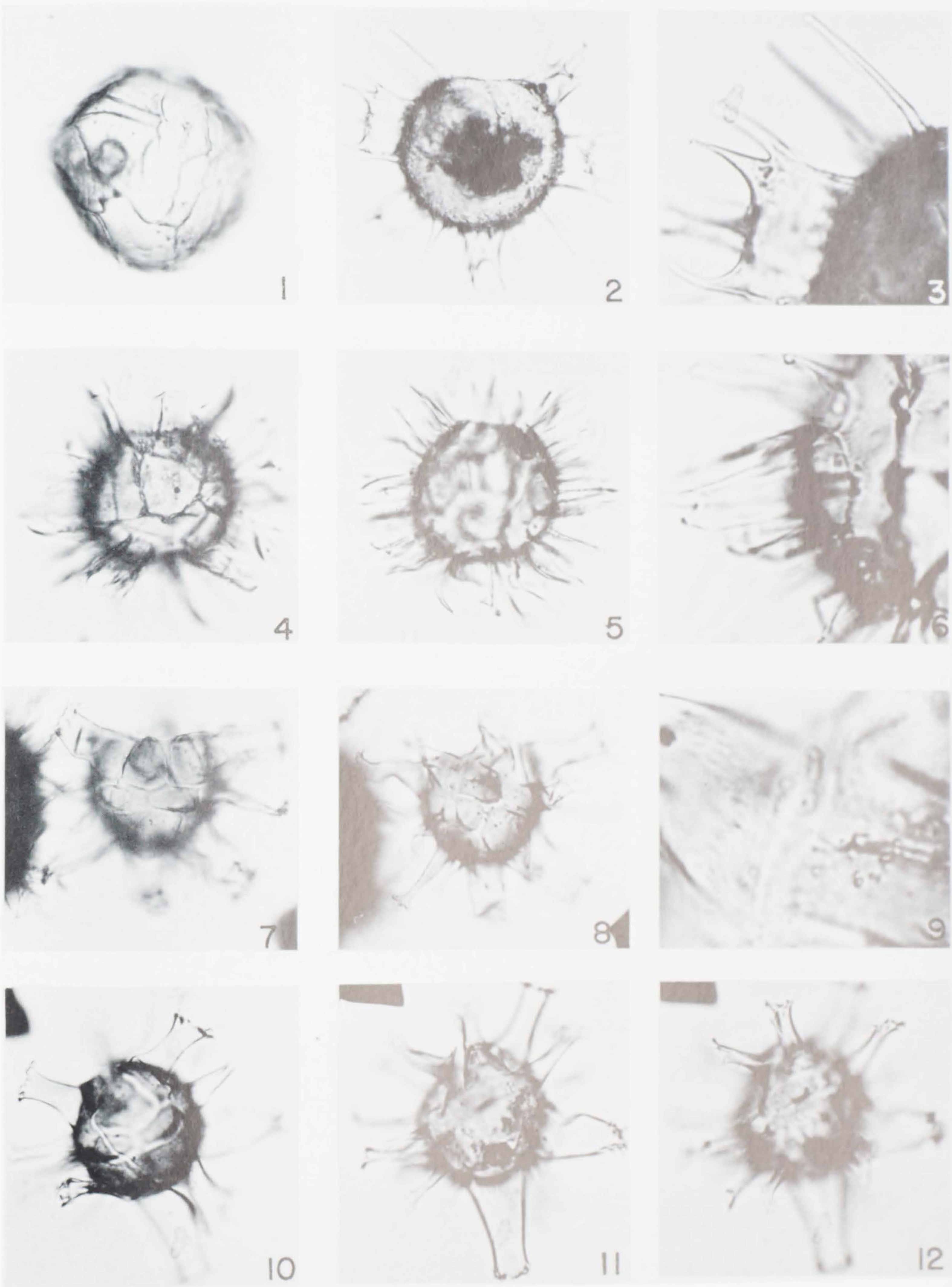

PLATE 4

and the apparent lack of stratigraphic utility it was considered to be impractical to separate them at the specific level. For the purposes of this study, the cysts are combined as *Areoligera* sp. All specimens have an apical archeopyle (Type A).

Occurrence: Very rare to abundant in all samples, Monmouth Formation and Brightseat Formation.

Genus CYCLONEPHELIUM
Deflandre and Cookson 1955
emend. Williams and Downie 1966b

CYCLONEPHELIUM DISTINCTUM
Deflandre and Cookson 1955
Plate 12, figure 7

1955 *Cyclonephelium distinctum* DEFLANDRE and COOKSON, p. 285, plate 12, figure 14.

PLATE 5

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Figure 1. *Hystrichosphaeridium deanei* 187
Illustration of process at 3 o'clock in Fig. 11, Plate 4. Note accessory spinelets.

Figure 2. *Hystrichosphaeridium tubiferum* 188
Sample 297, slide AN 74, R 7.8, + 11.2. Central body diameter 47 micra, processes up to 35 micra long. Dorsal view showing apical archeopyle.

Figures 3-6. *Lanternosphaeridium bipolare* 188
A series of photomicrographs to illustrate the variation of the species in this study. Fig. 3: Sample 294, slide AN 63, R 7.5, + 10.6, L x W 73 x 47 micra. Fig. 4: Sample 295, slide AN 67, R 10.1, + 18.4, L x W 103 x 54 micra. Figs. 5, 6: Sample 295, slide AN 65 R 8.9, + 7.4, L x W 106 x 49 micra. Fig. 3: Dorsal view of specimen showing precingular archeopyle, antapical protuberance and abbreviated ramose apical process. This specimen is similar to the holotype figured by Cookson and Eisenack (1965). Fig. 4: Dorsolateral view of a specimen illustrating the apical elongation of the Brightseat specimens. Fig. 5: Lateral view of specimen with extreme apical elongation and fibrous extension of periblast identical to that illustrated by Cookson and Eisenack (1967). Fig. 6: Illustration of fibrous apical extension.

Figures 7-9. *Lanternosphaeridium* cf. *L. lanosum* 189
Sample 295, slide AN 67, R 6, + 12.4. Cyst L x W 71 x 61 micra, processes up to 23 micra long. Figs. 7, 8: Dorsal optical section views showing precingular archeopyle, fibrous periphragm, bilayered cyst wall. Fig. 9: View of dorsal surface illustrating surface and process detail.

Figures 10-12. *Operculodinium centrocarpum* 189
Sample 295, slide AN 67, R 11.4, + 11.2. Cyst L x W 44 x 40 micra, processes up to 10.5 micra long. Figs. 10, 11: Dorsal (transparency) and optical section views respectively. Note precingular archeopyle. Fig. 12: Illustrates details of process termination.

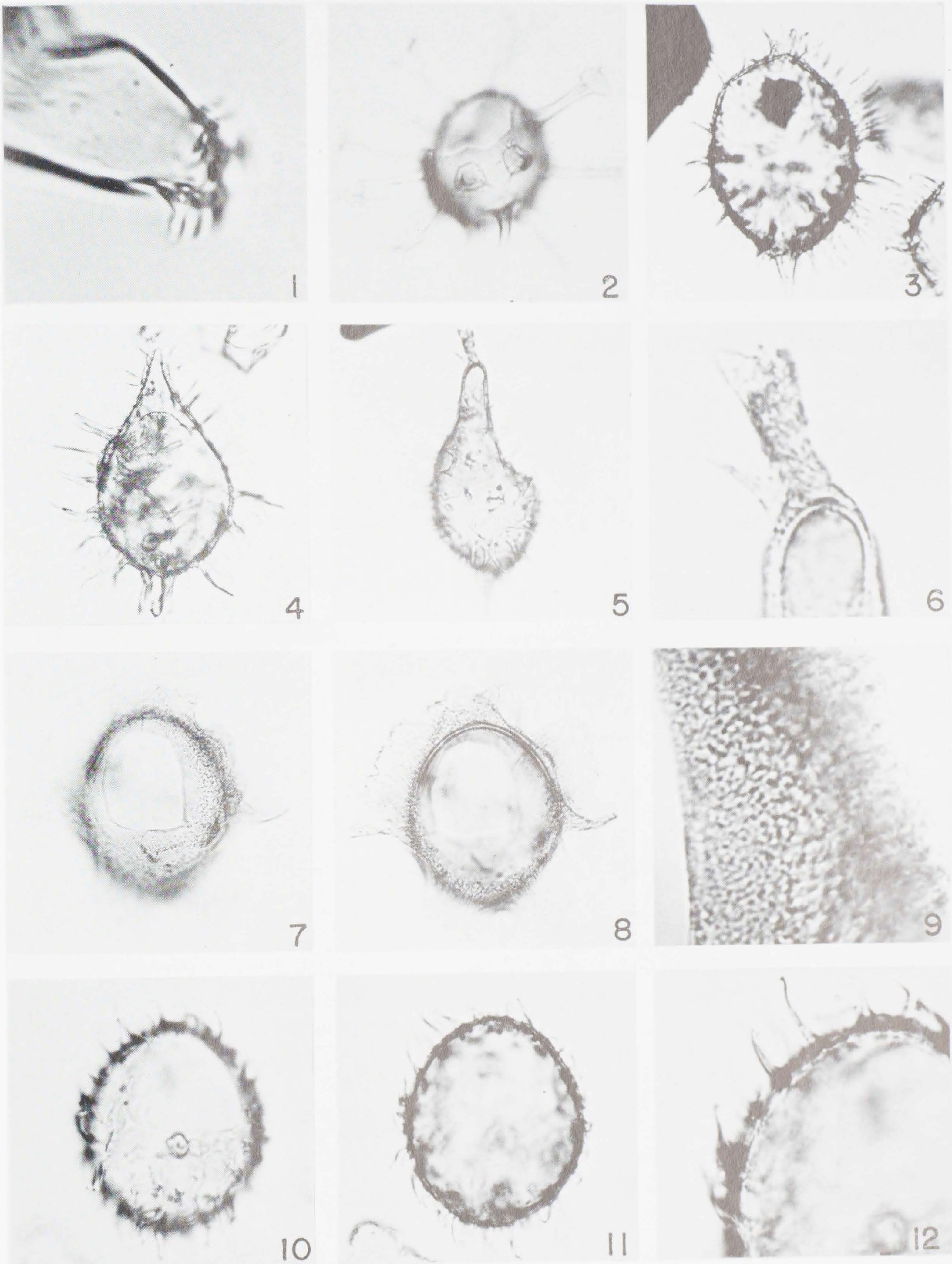

PLATE 5

1961 *Circulodinium deflandrei* ALBERTI, p. 587, plate 6, figures 9-11.

1967 *Cyclonephelium distinctum* Deflandre and Cookson; CLARKE and VERDIER, p. 22, plate 1, figures 6, 7 — see also for earlier references.

Comments: Cyclonephelium distinctum possesses a variety of process types. The processes range up to 10 micra in length and vary from 0.5 micron to 3 micra in width. The wider processes are flared in form, their tips aculeate and appear to be composed of fine fibrils or filaments. The narrow processes are generally tapering to either an acuminate, capitate or digitate tip. The cyst wall is bilayered, about 1 micron in thickness, the periphragm giving rise to the processes and possessing a microreticulate sculpture. An apical archeopyle (Type A) is invariably present.

Dimensions: Ten specimens measured; cyst body diameter 39-58 micra; process length up to 10 micra in length; process width 0.5-3 micra.

Occurrence: Very rare to rare in samples 280, 281, 285-288, Monmouth Formation.

Previous Reported Occurrence: Lower Cretaceous, Canada (Singh, 1971); Berrias-

PLATE 6

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Figures 1-3. *Spiniferites* cf. *S. cornutus* 189
Sample 295, slide AN 67, R 14.6, + 1.8. Cyst L x W 58 x 43 micra, apical process 35 micra. Figs. 1, 2: Dorsal and optical section views respectively; Fig. 3: Illustration of dorsal surface showing coarse granules in cingular and post-cingular plate equivalents.

Figures 4, 5. *Spiniferites ramosus ramosus* 189
Sample 294, slide AN 61, R 14.6, + 12.2. Cyst L x W 44 x 40 micra, processes up to 16 micra long. Dorsal and ventral views (transparency) respectively.

Figure 6. *Spiniferites ramosus granosus* 190
Sample 295, slide AN 67, R 13.7, + 13.4. Cyst L x W 44 x 40 micra, processes up to 14 micra long. Dorsolateral view showing granular periphragm and gonal process placement.

Figures 7-9. *Spongodinium delitiense* 190
Sample 280, slide AN 5, R 13.4, + 9.1. Periblast L x W 129 x 112 micra, Endoblast diameter 89 micra. Dorsal (transparency), optical section and ventral views respectively. Note precingular archeopyle and vesicular periphragm. Note sulcal details in Fig. 9.

Figures 10, 11. *Trichodinium hirsutum* 191
Sample 296, slide AN 70, R 12.5, + 9.3. Cyst diameter 85 micra, apical process 35 micra, antapical process 32 micra, cingular process 23 micra. Dorsal (transparency) and optical section views respectively.

Figure 12. *Deflandrea asymmetrica* 191
Sample 279, slide AN 1, R 10, + 11.9. Periblast L x W 80 x 42 micra, Endoblast L x W, 46 x 37 micra. Dorsal view. The posteriorly hinged operculum is faintly visible on the epitract.

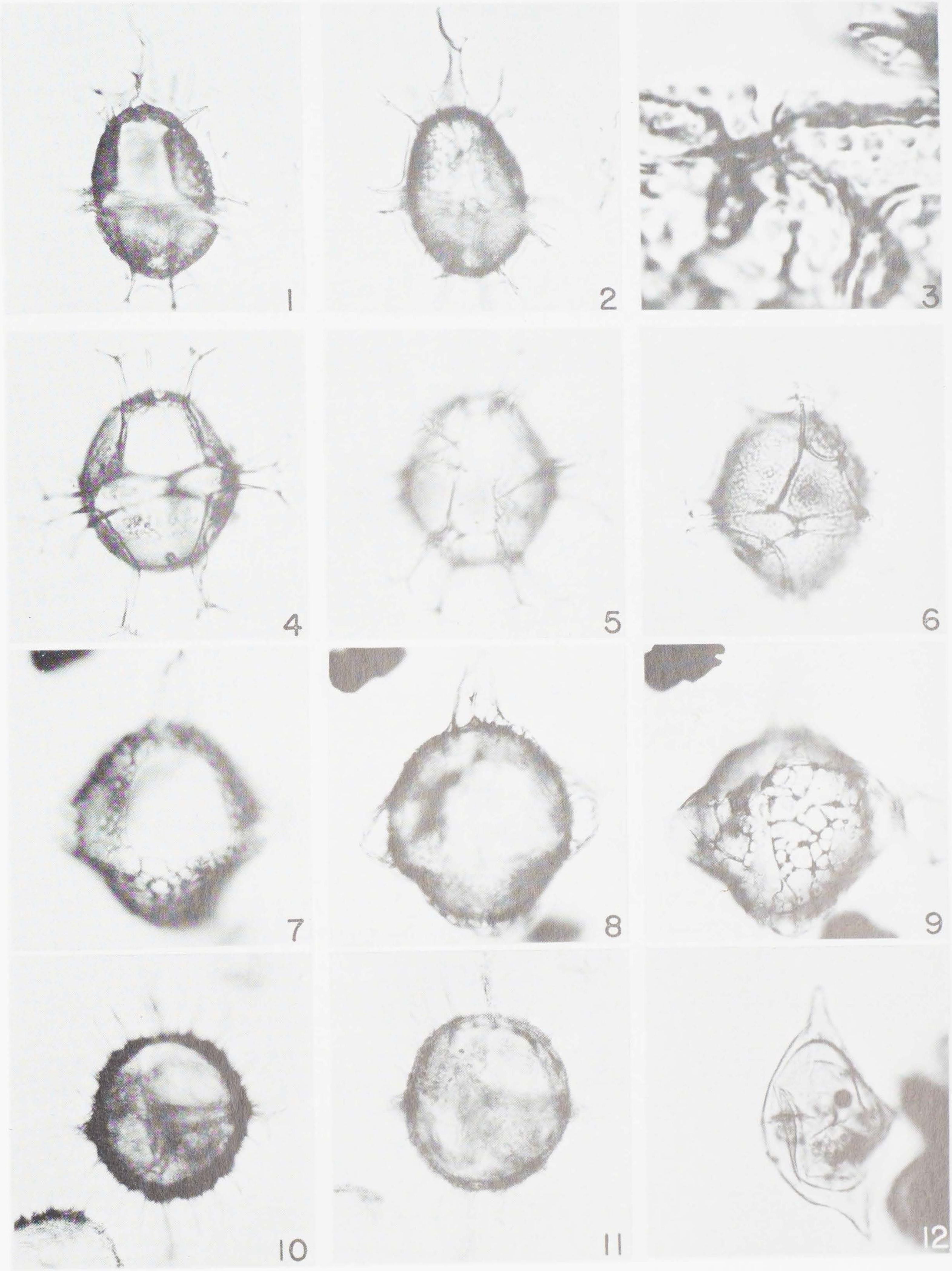

PLATE 6

ian-lower Aptian, France, Switzerland (Millioud, 1967, 1969); Valanginian-Hauterivian, Germany (Gocht, 1959); Valanginian-lower Aptian, Czechoslovakia (Vavrdova, 1964); upper Hauterivian-Aptian (?), lower Albian, Germany (Alberti, 1961); Albian, Australia (Cookson and Eisenack, 1962); Albian, France (Davey and Verdier, 1971); Cenomanian, Canada, England, France (Davey, 1969a); Cenomanian-Senonian, England (Clarke and Verdier, 1967); Santonian-lower Campanian, Australia (Cookson and Eisen-

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PLATE 7

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Figure 1. *Deflandrea cooksonii* 191
Sample 281, slide AN 9, R 9, + 6.2. Periblast L x W 103 x 47 micra, endoblast L x W 41 x 45 micra. Dorsal view, an example of the specimens observed with poorly developed epithecal shoulders.

Figure 2. *Deflandrea cooksonii* 191
Sample 281, slide AN 9, R 9, + 6.1. Periblast L x W 100 x 50 micra, endoblast L x W 41 x 49 micra. Dorsal view, an example of the specimens observed with strong epithecal shoulder development.

Figures 3-5. *Deflandrea dilwynensis* 193
Sample 294, slide AN 61, R 16.4, + 6.7. Periblast L x W 58 x 44 micra, endoblast L x W 35 x 40 micra. Dorsal (transparency), optical section, and ventral views, respectively. Note the archeopyle and longitudinal wrinkles in Fig. 3.

Figures 6, 7. *Deflandrea echinoidea* 193
Sample 294, slide AN 61, R 3.8, + 8.6. Periblast L x W 65 x 49 micra, endoblast L x W 47 x 40 micra. Optical section and ventral (transparency) views respectively.

Figures 8, 9. *Deflandrea magnifica* 193
Sample 291, slide AN 49, R 7.7, + 16.6. L x W 93 x 83 micra. Ventral and dorsal (transparency) views respectively. Note the longitudinal wrinkling and scattered fine granules. An intercalary archeopyle fine granules. An intercalary archeopyle is faintly visible on Fig. 9.

Figure 10. *Deflandrea minor* 193
Sample 287, slide AN 33, R 11.2, + 12.7. L x W 47 x 40 micra. Optical section. Note the weak development of the left antapical horn.

Figures 11, 12. *Deflandrea pannucea* 194
Sample 285, slide AN 25, R 15.7, + 9. Periblast L x W 85 x 53 micra, endoblast L x W 54 x 52 micra. Optical section ventral (transparency) views respectively. The outline of the archeopyle is evident in Fig. 11, as is the equal antapical horn development. Note the longitudinal wrinkles and widely scattered granules on Fig. 12.

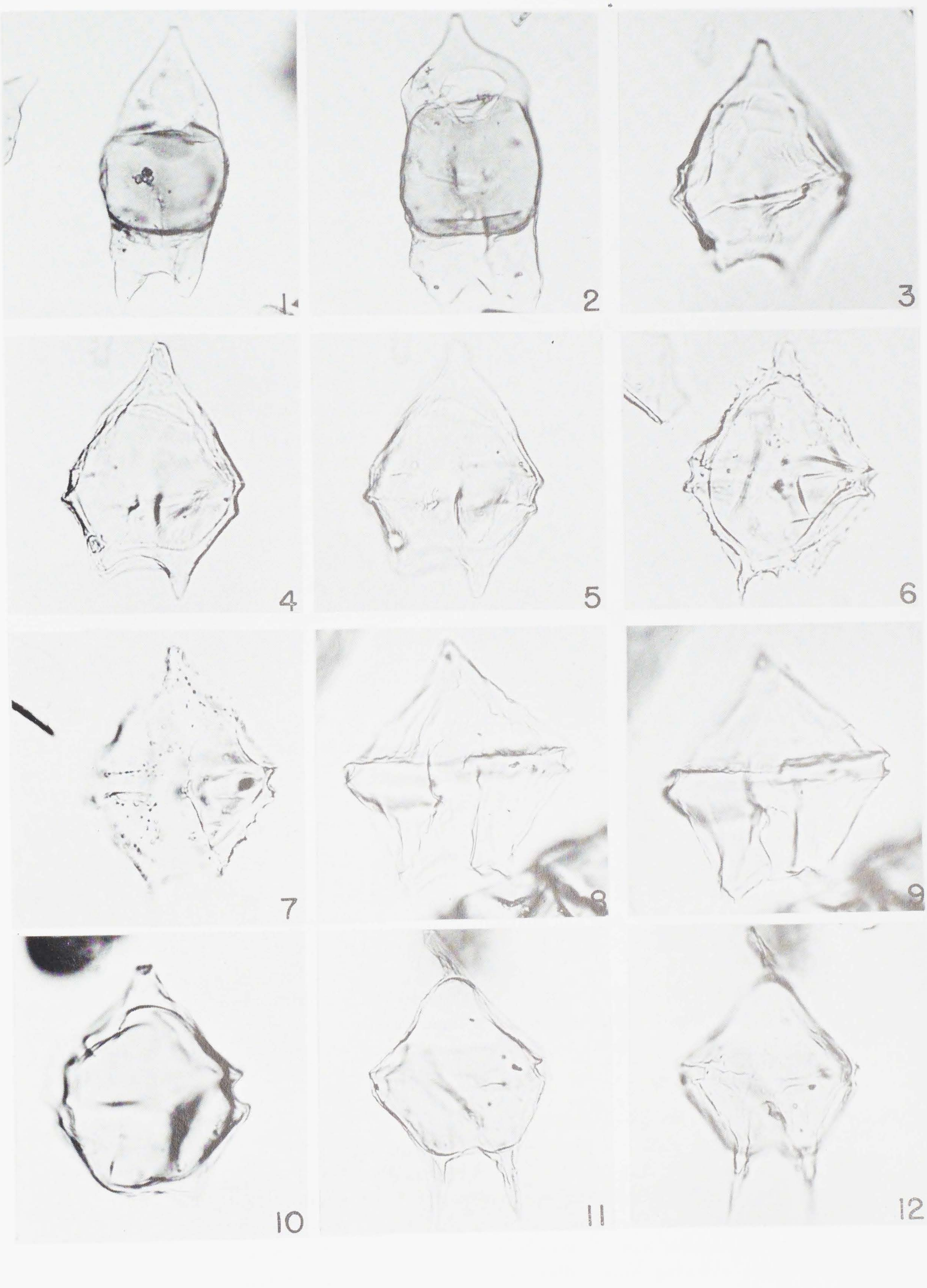

PLATE 7

ack, 1968); Senonian, Australia (Deflandre and Cookson, 1955); Upper Cretaceous, Canada (Manum and Cookson, 1964; McIntyre, 1974); upper Campanian, Canada (Harland, 1973); Maestrichtian, Holland (Wilson, 1971); Danian, U.S.A. (Drugg, 1967).

CYCLOPSIELLA VIETA (?)
Drugg and Loeblich 1967

Plate 12, figures 8, 9

1967 *Cyclopsiella vieta* DRUGG and LOEBLICH, p. 192, plate 3, figure 7-9, text figure 8.

Comments: The specimens of *Cyclopsiella vieta(?)* recovered are generally broader than long. The equatorial fold reported by Drugg and Loeblich (1967) is not evident in these specimens. In some specimens the periphragm has very fine filaments on its outer surface extending not more than 1 micron off the surface. The filamentous extensions are random in distribution and their significance is not clear.

Dimensions: Ten specimens measured; overall length 45-49 micra; overall width 49-55 micra; endophragm thickness 1 micron; periphragm thickness less than 0.5 micron.

Occurrence: Very rare in samples 280-282, 285, 287, 289, 291-292, Monmouth Formation.

Previous Reported Occurrence: Oligocene, U.S.A. (Drugg and Loeblich, 1967).

Genus DICONODINIUM
Eisenack and Cookson 1960

DICONODINIUM RHOMBIFORMIS
Vozzhennikova 1967
Plate 12, figures 10-12

1967 *Diconodinium rhombiformis* VOZZHENNIKOVA, p. 50, plate 7, figures 1-4; plate 15, figure 5.

Comments: Diconodinium rhombiformis is present in the Monmouth samples. It appears to be nearly identical with the figured specimens of Vozzhennikova (1967).

PLATE 8

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Figures 1-3. *Deflandrea dartmooria* 192
Sample 287, slide AN 33, R 10.8, + 12.2. Periblast L x W 127 x 61 micra, endoblast L x W 86 x 56 micra. Figs. 1, 2: Ventral (transparency) and dorsal views respectively. Fig. 3: Illustration of ventral surface showing intratabular arrangement of coni on the epitract.

Figure 4-6. *Deflandrea diebelii* 192
Sample 281, slide AN 10, R 17.6, + 11.4. Periblast L x W 245 x 70 micra, endoblast L x W 68 x 65 micra. Figs. 4, 5: Dorsal and optical section views. An operculum is faintly visible on Fig. 4. Note the shape of the closely appressed endoblast. Fig. 6: Enlargement of dorsal surface to illustrate longitudinal wrinkles, faintly indicated cingulum, and outline of operculum.

Figures 7-9. *Deflandrea* cf. *D. diebelii* 192
Sample 286, slide AN 29, R 4, + 12.3. Periblast L x W 147 x 44 micra, endoblast L x W 59 x 38 micra. Figs. 7, 8: Dorsal (transparency) and ventral views respectively illustrating the archeopyle and faint indication of the sulcus. A concavo-convex flagellar scar (?) may be seen in Fig. 8. Fig. 9: Dorsal surface showing longitudinal striations, weakly impressed cingulum and faint microreticulate sculpture.

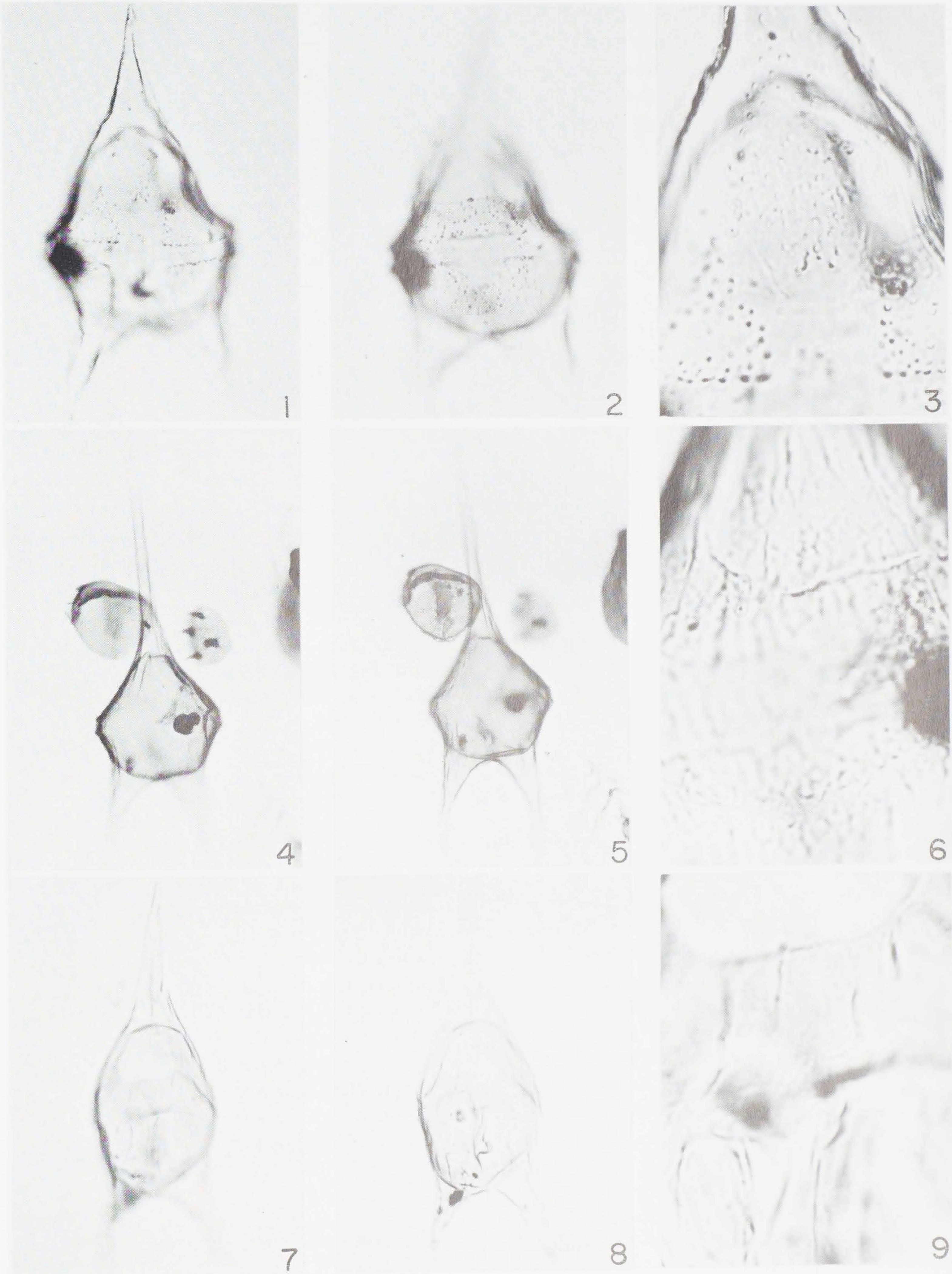

PLATE 8

The cyst wall is single-layered and is faintly microreticulate. Tabulation could not be observed; however, very faint plate boundaries appeared to be present on the epitract. The cingulum is equatorial and is interrupted by a wide (up to 10 micra) sulcus, which extends up to 5 micra on the epitract. A concavo-convex flagellar scar is present in the sulcus. The apical process is distinctive, appears to be composed of intertwined fibers, and exhibits a braided appearance. A similar appearance is occasionally observed on the antapical process. The archeopyle is not observable on these specimens.

Dimensions: Ten specimens measured; overall length 35-44 micra; width 25-29 micra; apical process length 2-3 micra; antapical process length 1-4.5 micra; thickness of cyst wall about 0.5 micron.

Occurrence: Very rare to rare in samples 279-287, Monmouth Formation.

Previous Reported Occurrence: Turonian, U.S.S.R. (Vozzhennikova, 1967).

Genus FIBRADINIUM Morgenroth 1968

FIBRADINIUM cf. F. ANNETORPENSE
Morgenroth 1968
Plate 13, figures 1-3

Comments: Specimens resembling *Fibradinium annetorpense* were distributed throughout the Round Bay section. They exhibited a tabulation of ?', ?a, 6'', 6c + 1tr, 6''', 1p, 1'''' which is different from the tabulation of Morgenroth. Many specimens were reoriented in an attempt to observe the apical tabulation; however, it is indeterminate. The archeopyle is apical (Type A). The

PLATE 9

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Figures 1-3. *Deflandre* cf. *D. pentaradiata* 194
Illustrations showing intraspecific variation. Fig. 1: Sample 295, slide AN 67, R 11.8, + 10.2. Periblast L x W 126 x 105 micra, endoblast L x W 91 x 93 micra. Fig. 2: Sample 295, slide AN 65, R 9.1, + 5.3. Periblast L x W 126 x 93 micra, endoblast L x W 82 x 77 micra. Fig. 3: Sample 294, slide AN 63, R 11.6, + 5.2. Periblast L x W 121 x 103 micra, endoblast L x W 68 x 77 micra.

Figures 4-9. *Deflandrea pulchra* n. sp. 194
Figs. 4-7: Holotype, Sample 296, slide AN 69, R 3.7, + 6.2. Periblast L x W 69 x 50 micra, endoblast L x W 46 x 46 micra. Figs. 4-6: Dorsal (transparency), optical section and ventral views respectively. Fig. 7: Higher magnification to illustrate endoblast wall. Fig. 8: Paratype, Sample 297, slide AN 73, R 5.8, + 18.7. Periblast L x W 70 x 53 micra, endoblast L x W 50 x 49 micra. Dorsal view showing development of accessory sutures. Fig. 9: Paratype, Sample 295, slide AN 65, R 7.7, + 4.3. Periblast L x W 70 x 53 micra, endoblast L x W 47 x 47 micra. Dorsal view showing loss of precingular plate.

Figures 10-12. *Deflandrea rhombohedra* n. sp. 195
Holotype, Sample 294, slide AN 62, R 8.3, + 11.2. Periblast L x W 72 x 35 micra, endoblast L x W 49 x 33 micra. Figs. 10, 11: Dorsolateral, optical section views. Fig. 12: Enlargement of hypotract showing microreticulate surficial sculpture.

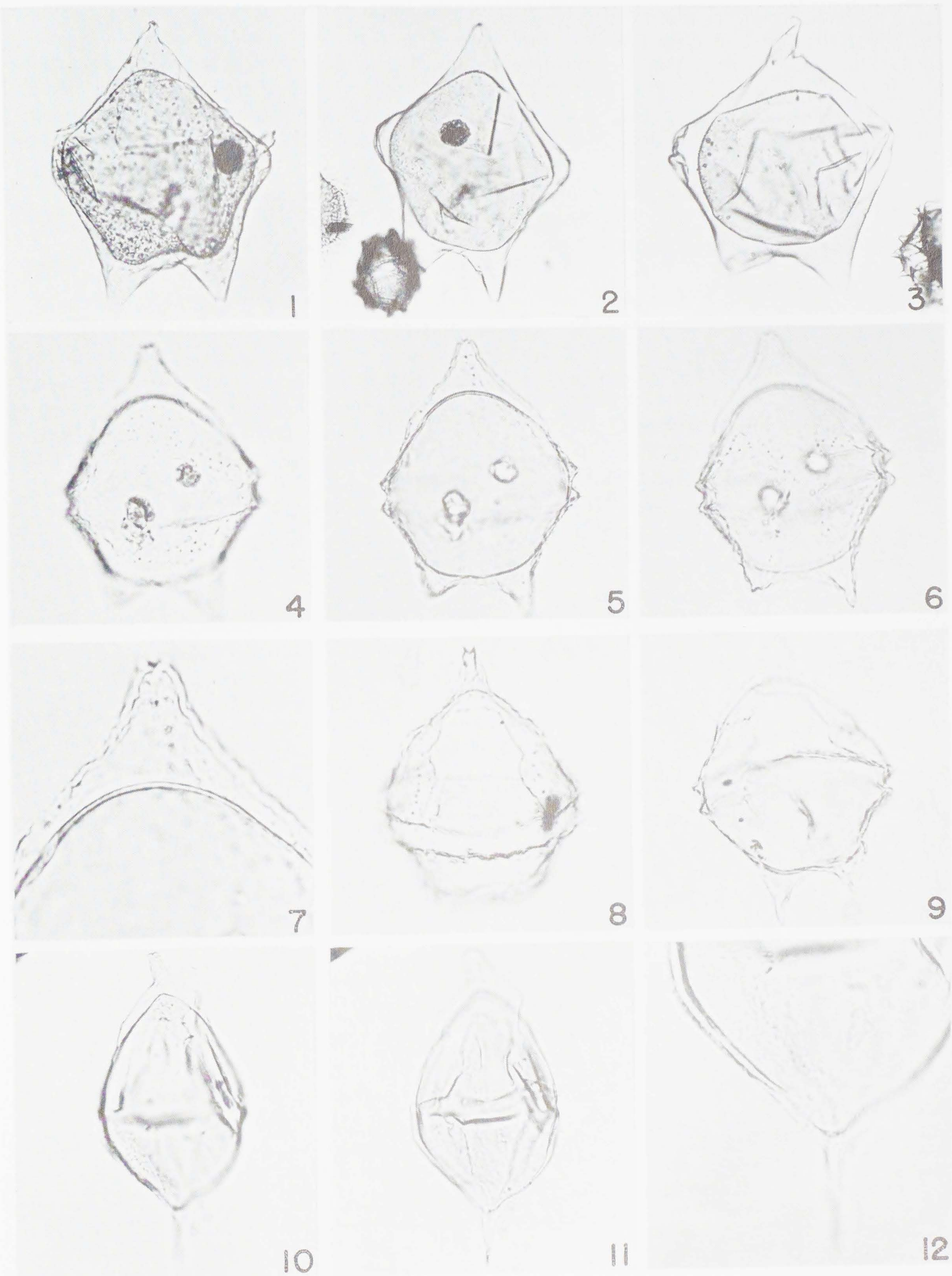

PLATE 9

questionable apical tabulation and differences in the remaining tabulation makes the definitive assignment to *F. annetorpense* questionable.

Dimensions: Eleven specimens measured; length 29-35 micra; width 25-33 micra; sutural crest height 2-3 micra.

Occurrence: Very rare to rare in samples 279-282, 285, 289, 292-297, Monmouth Formation and Brightseat Formation.

Genus FROMEA
Cookson and Eisenack 1958

FROMEA AMPHORA
Cookson and Eisenack 1958
Plate 15, figure 4

1958 *Fromea amphora* COOKSON and EISENACK, p. 56, plate 5, figures 10-11.

Comments: Specimens resembling *Fromea amphora* are encountered only in the lower portion of the Round Bay section. They, like the forms reported by Davey (1969a), differ from the specimens described by Cookson and Eisenack (1958) in that a cingulum is absent; however, they conform in other respects to the original description.

Dimensions: Six specimens measured; length 79-103 micra; width 58-72 micra.

Occurrence: Very rare in samples 279-282, Monmouth Formation.

Previous Reported Occurrence: Barremian, Germany (Alberti, 1961); Barremian, England (Sarjeant, 1966b); Lower Cretaceous, Canada (Singh, 1971); Aptian-Cenomanian, Australia (Cookson and Eisenack, 1958); Albian, France (Davey and Verdier, 1971); Albian-Cenomanian, England (Cookson and Hughes, 1964, Davey, 1969a); Albian, Canada (Brideaux, 1971); Cenomanian, France (Davey, 1969a); Upper Cretaceous, Canada (Manum and Cookson, 1964;

PLATE 10

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Figures 1-3. *Deflandrea severnensis* n. sp. 195
Holotype, Sample 288, slide AN 37, R 15.8, + 13.4. Periblast L x W 71 x 65 micra, endoblast L x W 52 x 61 micra. Dorsal, optical section, and ventral (transparency) views respectively.

Figures 4-6. *Deflandrea* cf. *D. speciosa* 196
Sample 290, slide AN 45, R 6, + 14.1. Periblast L x W 103 x 58 micra, endoblast L x W 60 x 55 micra. Figs. 4, 5: Dorsal (transparency), ventral views respectively. Fig. 6: Illustration to show the semi-linear arrangement of denticulated ridges.

Figures 7-9. *Deflandrea* sp. A 196
Sample 284, slide AN 22, R 13.2, + 11. Periblast L x W 86 x 61 micra, endoblast L x W 53 x 53 micra. Figs. 7, 8: Dorsal (transparency) and optical section views respectively. Fig. 9: Enlargement of optical section to show endoblast wall and short spines on periblast surface.

Figures 10, 11. *Palaeoperidinium basilium* 196
Sample 297, slide AN 73, R 16.3, + 16.2. L x W 119 x 104 micra. Dorsal (transparency) and ventral views respectively. The "growth lines" deliniating plate boundaries are apparent.

Figure 12. *Palaeoperidinium* cf. *P. deflandrei* 196
Sample 284, slide AN 21, R 16.5, + 13.3. L x W 105 x 89 micra. Dorsal view (transparency), plate boundaries barely discernable.

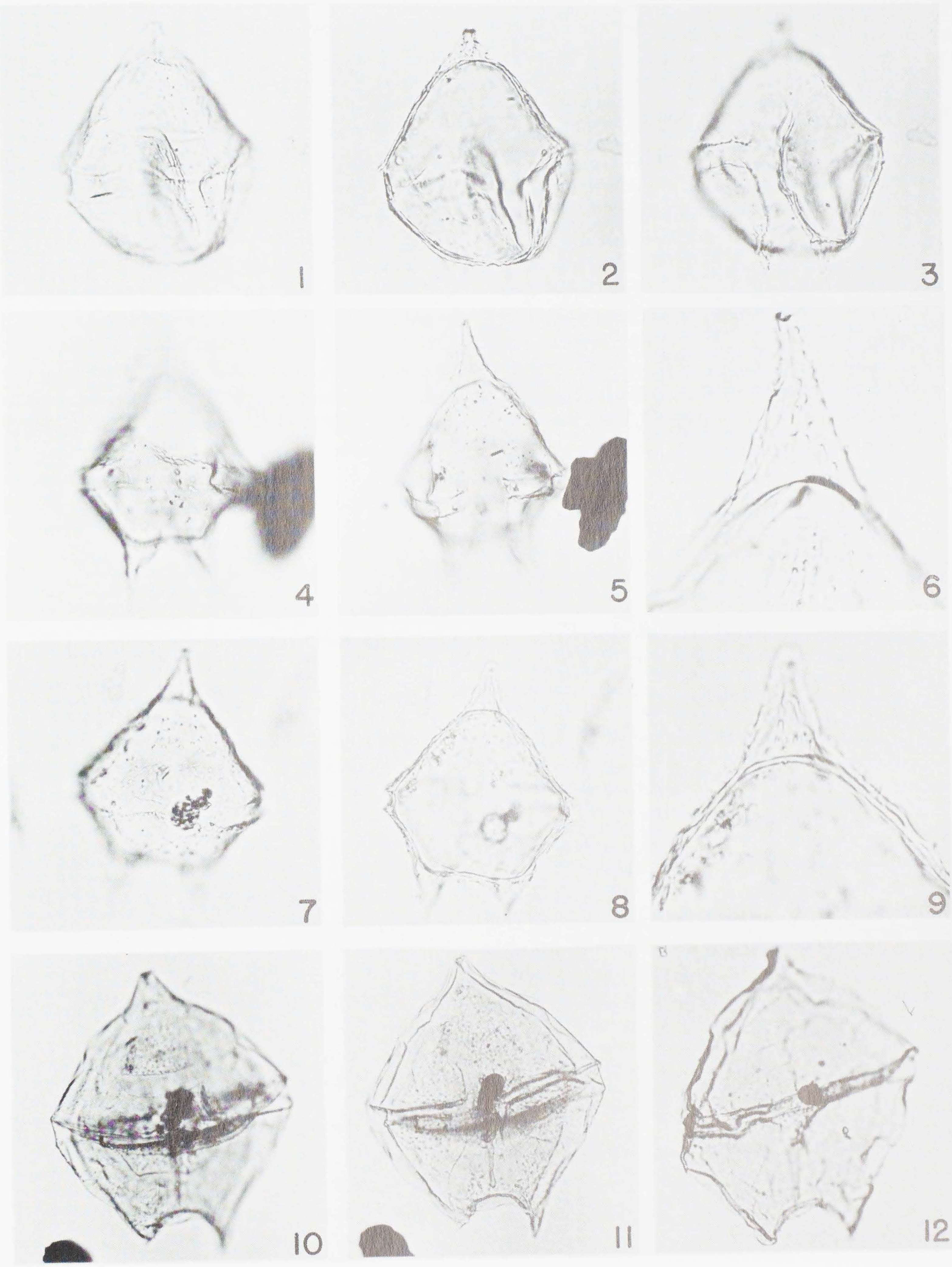

PLATE 10

McIntyre, 1974); Upper Cretaceous, U.S.S.R. (Vozzhennikova, 1967).

Genus INVERSIDINIUM McLean 1973b

INVERSIDINIUM CAUDATUM n. sp.
Plate 13, figures 4-6

Derivation of name: cauda (L) tail, in reference to the elongate hypotract.

Holotype: Sample 292, slide AN 53, R 16.7 + 12.6.

Description: Bilayered cyst with peridinoid outline. Apex and antapex pointed to slightly rounded, hypotract longer than epitract. Tabulation absent. Periphragm exhibits microreticulate sculpture, both periphragm and endophragm less than 0.5 micron thick. Sulcus (?) and cingulum (?) reflected by evaginations of periphragm. Endoblast roughly triangular in shape, broader than long, and confined to hypotract. Archeopyle indeterminate.

Dimensions:

Holotype: length 54 micra; width 47 micra.

Range: 14 specimens measured; length 40-68 micra; width 35-56 micra.

Comments: Inversidinium caudatum does not exhibit a defined archeopyle. It is thought to be posterior in position and may be formed by transverse fission of the hypotract. A small pore is frequently seen to be associated with the antapex; however, its possible function in excystment is not clear.

Comparison with other species: Inversidinium caudatum resembles *I. exilimurum* (McLean, 1973b). Both species possess the periphragm evaginations and trinagular endoblast which is restricted to the hypotract; however, the hypotract of *I. exilimurum* is

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PLATE 11

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Figure 1. *Palaeoperidinium* cf. *P. deflandrei* 196
Ventral view of same specimen as plate 10, Fig. 12.

Figures 2, 3. *Spinidinium clavum* 196
Sample 295, slide AN 65, R 20.5, + 2.6. Periblast L x W 51 x 35 micra, endoblast L x W 33 x 31 micra. Dorsolateral (transparency) and ventrolateral views respectively. The peritabular arrangement of the spines is clear.

Figures 4-8. *Trithyrodinium striatum* n. sp. 197
Figs. 4-6: Sample 281, slide AN 9, R 18.3, + 7.6. Periblast L x W 82 x 73 micra, endoblast L x W 65 x 62 micra. Dorsal, ventral (transparency) and optical section views respectively. Note the 3I archeopyle, striated endoblast and delicate periblast. Fig. 7: Sample 281, slide AN 9, R 13.5, + 6.4. L x W 65 x 60 micra. Isolated endoblast with operculum (by transparency) still in place. Fig. 8: Sample 281, slide AN 10, R 9.6, + 7. L x W 67 x 59 micra. Typical specimen with 3I archeopyle and periblast crumpled.

Figures 9-12. *Trithyrodinium robustum* n. sp. 198
Holotype, Sample 281, slide AN 9, R 15.9, + 6.4. Periblast L x W 153 x 78 micra, endoblast L x W 69 x 71 micra. Figs. 9-11: Dorsal (transparency), optical section, and ventral views respectively. The outline of plate equivalents on Fig. 9 is clear and shows the postion of the 2a archeopyle with operculum still in place. Fig. 12: Endoblast all showing the granular mesoblast (?).

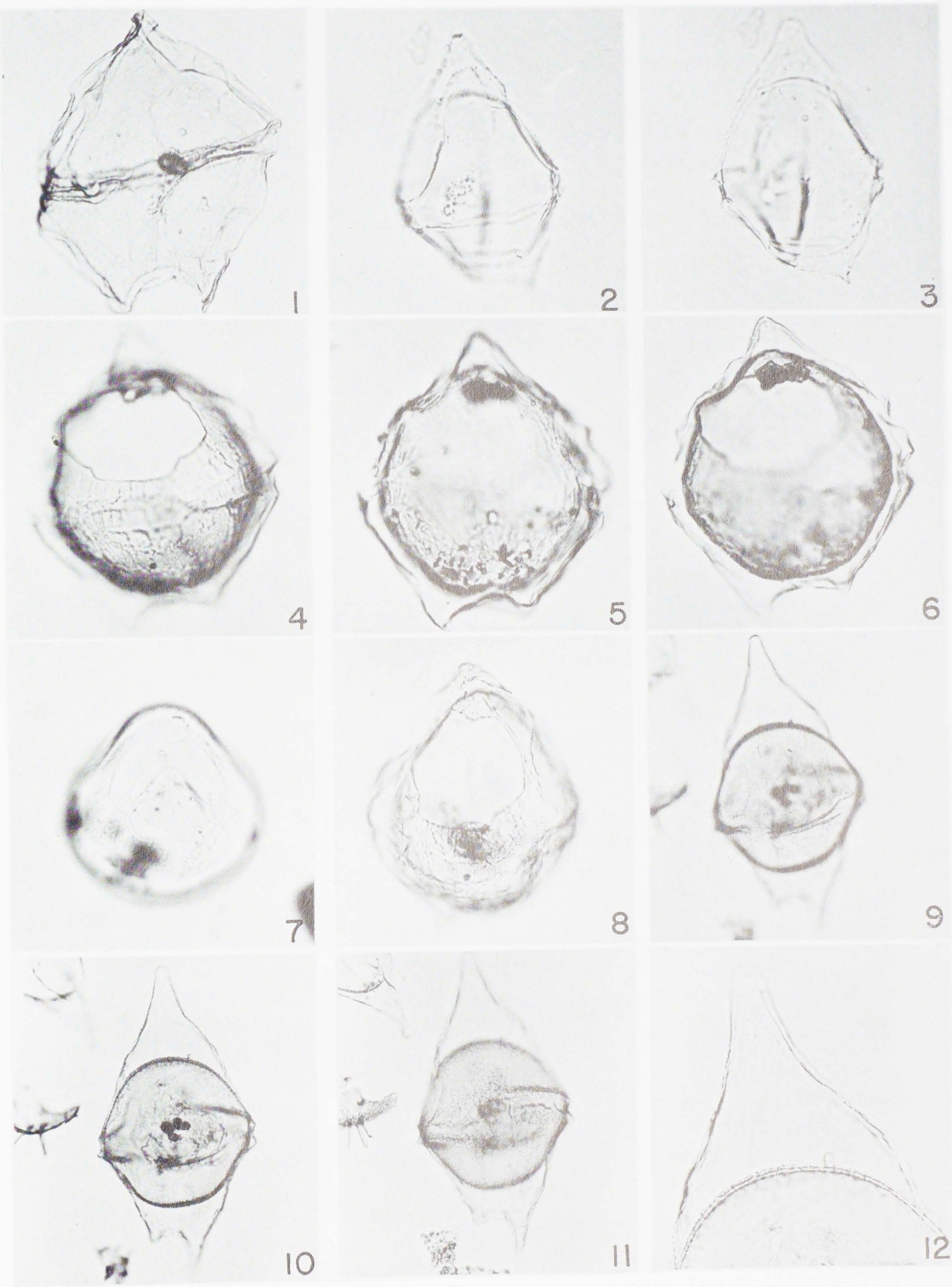

PLATE 11

strongly truncated as opposed to the elongate hypotract of *I. caudatum.*

I. caudatum strongly resembles *Paleotetradinium silicorum* (Deflandre, 1936) in size, shape, and its stratigraphic position. However, the original description by Deflandre (1936) does not mention an archeopyle or excystment structure, or the presence and/or shape of the endoblast. Until a re-examination is done of the type of *P. silicorum,* or of topotype material, it is thought best to treat *I. caudatum* as a distinctive form.

Occurrence: Very rare to rare in samples 280, 281, 286, 288-292, 294, 295, 297, Monmouth Formation and Brightseat Formation.

Genus MICRODINIUM
Cookson and Eisenack 1960
emend. Sarjeant 1966

MICRODINIUM SETOSUM Sarjeant, 1966
Plate 13, figures 7-9

1966 *Microdinium setosum* SARJEANT, p. 151, plate 16, figures 9, 10, text figure 39.
1967 *Microdinium echinatum* CLARKE and VERDIER, p. 64, plate 1, figures 9, 10, text figure 26.
1967 *Microdinium dentatum* VOZZHENNIKOVA, p. 94, plate 38, figure 2.

PLATE 12

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Figure 1. *Trithyrodinium robustum* n. sp. 198
Holotype, Illustration of surface of endoblast. The 3I operculum is faintly visible and is still in place.

Figures 2, 3. *Wetzeliella* cf. *W. pilata* 202
Fig. 2: Sample 294, slide AN 61, R 14, + 5. L x W 60 x 45 micra. Dorsal (transparency) view. Fig. 3: Sample 295, slide AN 68, R 9.1, + 7.5. Spine morphology. The termination is identical to that illustrated by Stanley (1965).

Figures 4-6. *Areoligera* spp. 204
Sample 284, slide AN 21, R. 12, + 9.7, Cyst diameter 51 micra, processes up to 19 micra long. Dorsal, optical section and ventral (transparency) views respectively. An apical operculum is present, the lack of processes on the ventral surface is apparent.

Figure 7. *Cyclonephelium distinctum* 206
Sample 280, slide AN 6, R 18, + 3.1. Cyst diameter 42 micra, processes up to 7 micra long. Dorsal view. An apical archeopyle is present.

Figures 8, 9. *Cyclopsiella vieta(?)* 212
Sample 280, Slide AN 7, R 19.4, + 13.6. L x W 47 x 50 micra. Dorsal and ventral (transparency) views respectively. The circular aperture (archeopyle?) is readily visible on the dorsal surface.

Figures 10-12. *Diconodinium rhombiformis* 212
Sample 281, slide AN 10, R 16.8, + 8.6. L x W 44 x 25 micra. Dorsal, optical section and ventral (transparency) views respectively. The faint outline of plate equivalents is apparent.

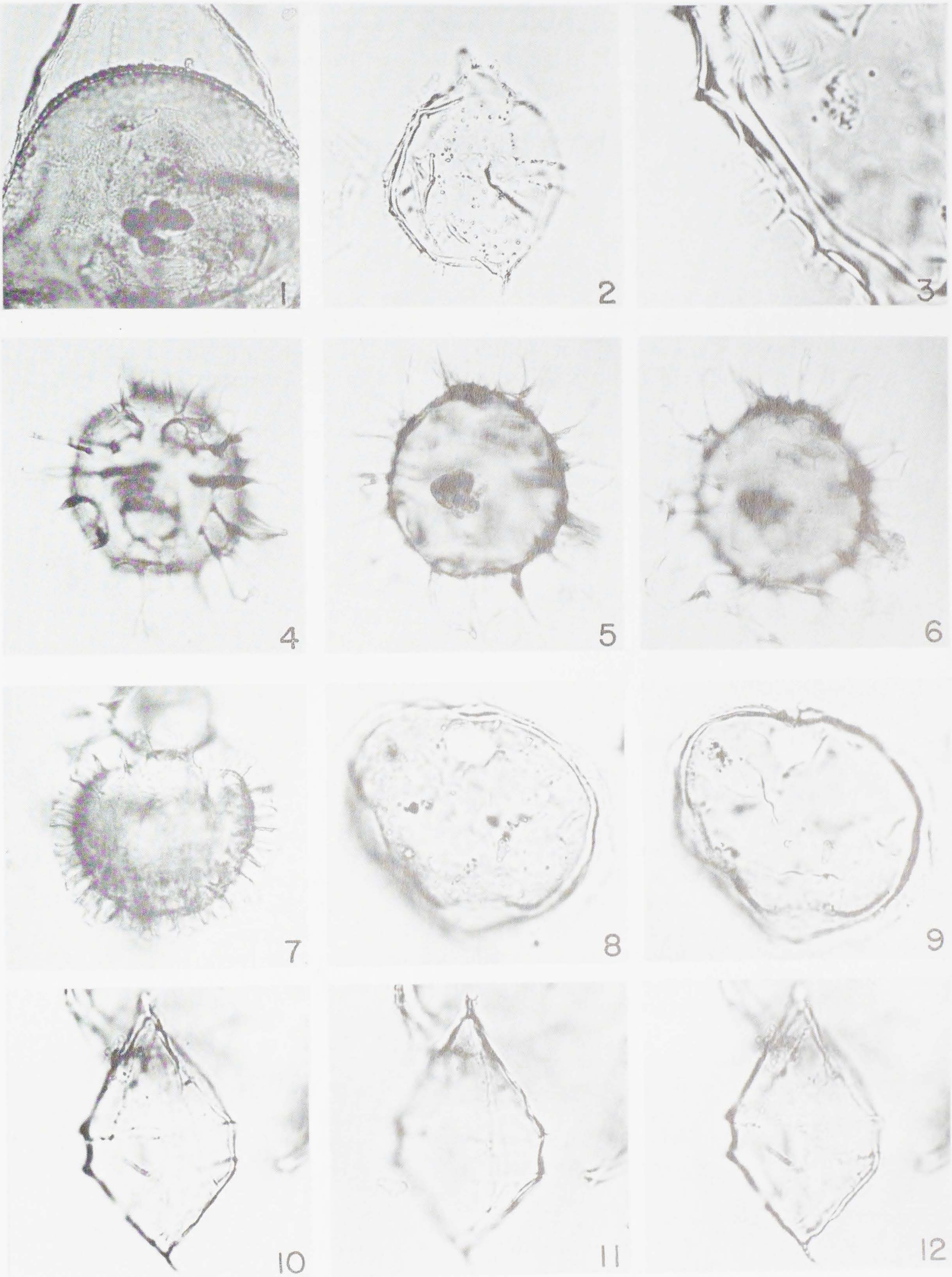

PLATE 12

1969a *Microdinium setosum* Sarjeant; DAVEY, p. 133, plate 2, figure 4, text figure 13H.

Comments: Several specimens of *Microdinium setosum* were recovered, one of which is badly crumpled. The specimens are somewhat smaller than the originally described forms but resemble them in most aspects except that the tabulation observed on the single intact specimen differs from that given by Sarjeant (1966) and is similar to that described by McLean (1973a). Sarjeant's (1966) tabulation was ?1', 0a, 6", 6c, 6''', 1p, 1''''. The tabulation observed on the Monmouth specimen was ?', ?a, 7", 7c (or 6c + 1/tr), 6''', 1p, 1''''. In addition, at least two sulcal plate equivalents appear to be present (1 anterior, 1 posterior). An examination of text figure 39 of Sarjeant (1966) clearly shows the seventh cingular (or transitional) plate equivalent, which apparently was not recognized as such by that author. The seventh precingular plate equivalent is not evident on either text figure 39 or the photographs of the holotype (Sarjeant, 1966). Although only a single specimen illustrates tabulation clearly, it is felt by the author that such information should be presented in hopes of assisting in the resolution of tabulation discrepancies. The archeopyle is apical (Type A).

Dimensions: Nine specimens measured; length 27 micra; width 25 micra; crest height up to 3 micra; spine length 2 micra.

Occurrence: Very rare in samples 280, 281, 286, Monmouth Formation.

Previous Reported Occurrence: Albian-Cenomanian, England (Clarke and Verdier, 1967; Sarjeant, 1966a; Davey, 1969a); Albian, France (Davey and Verdier, 1971); Cenomanian, France (Davey, 1969a).

Genus A

Plate 13, figures 10-12; Plate 14, figure 1

Description: Proximate cyst, subspherical to oval with plate boundaries reflected by sutural crests. Wall bilayered, 1-1.5 micra

PLATE 13

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Figures 1-3. *Fibradinium* cf. *F. annetorpense* 214
Sample 294, slide AN 61, R 6.3, + 17.2. L x W 32 x 28 micra. Dorsal (transparency), optical section and ventral views respectively.

Figures 4-6. *Inversidinium caudatum* n. sp. 218
Holotype, Sample 292, slide AN 53, R 16.7, + 12.6. L x W 54 x 47 micra. Dorsal, optical section and ventral (transparency) views respectively. The microreticulate surficial sculpture is apparent as is the longitudinal evagination (= sulcus?). On Fig. 6. a faint indication of the distal pore on the hypotract is present.

Figures 7-9. *Microdinium setosum* 220
Sample 280, slide AN 8, R 17.3, + 12.4. L x W 27 x 25 micra. Dorsal (transparency), optical section and ventral views respectively. The details of tabulation in the sulcal region are apparent.

Figures 10-12. Genus A 222
Sample 283, slide AN 19, R 20.7, + 15, Diameter 40 micra. Dorsal, optical section and ventral (transparency) view respectively. The columnar support for the periphragm is evident at 9:30 and 7 o'clock on Fig. 11. See also Plate 14, Fig. 1.

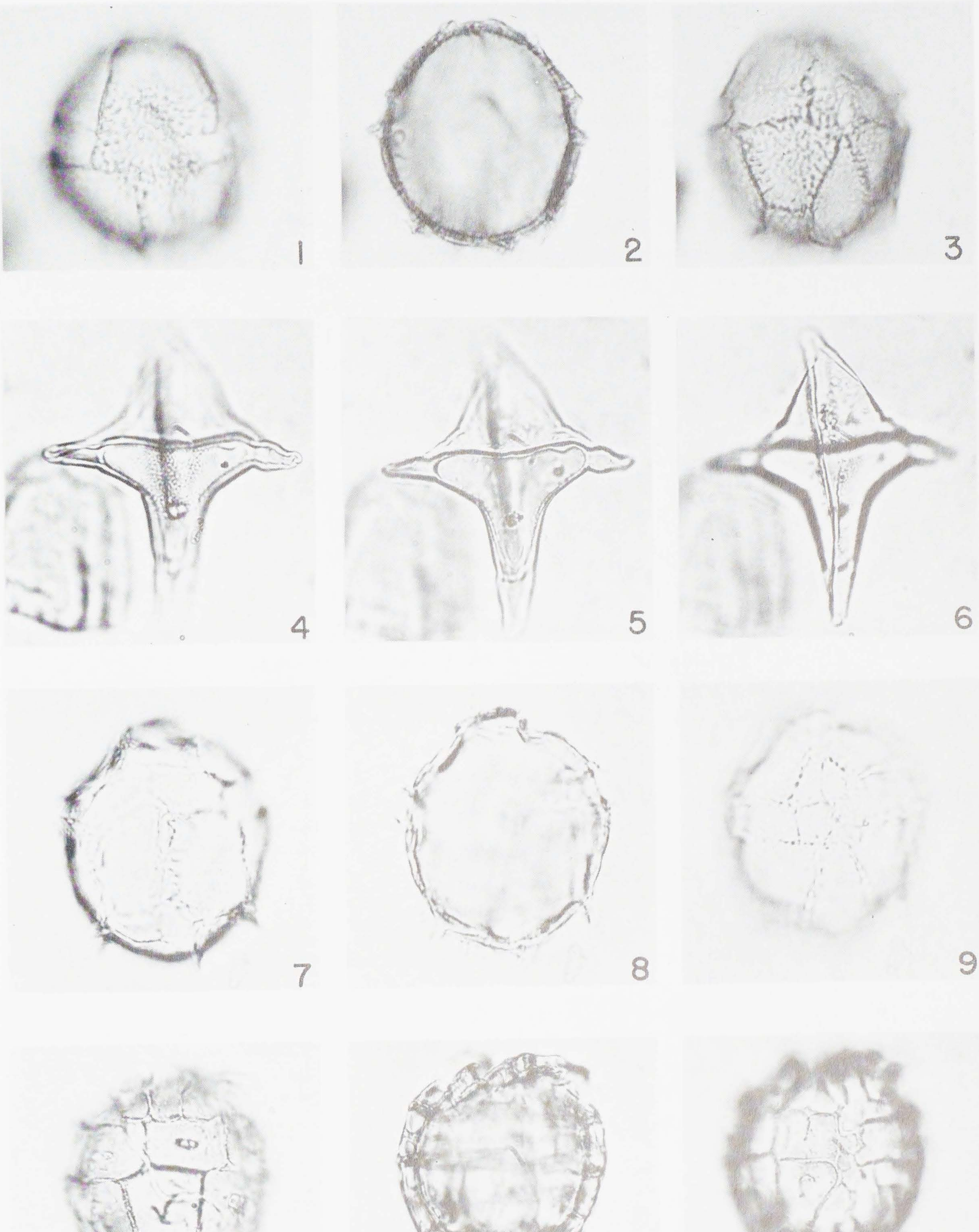

PLATE 13

thick with periphragm apparently being supported by a columnar structure emanating from the endophragm. Reflected tabulation of ?', ?a, 7'', 6c + 1 tr., 6''', ?2p, 1''''. Archeopyle apical, cingulum slightly dextrorotary, offset less than one half cingulum width. Distinctive ornamentation located roughly in center of plate support.

Comments: Although certainly a member of the Microdiniaceae, the placement of this species in *Microdinium* is uncertain. The apparent supportive structure emanating from the endophragm is certainly a fundamental difference in this species' mode of construction from the normal *Microdinium*. This, coupled with the incomplete apical tabulation, makes the author hesitant to treat this species in a more complete taxonomic sense. This species is under investigation in a study separate from this work.

Dimensions: Six specimens measured; length 36-43 micra; width 35-40 micra; height of sutural crests 3-4.5 micra.

Occurrence: Very rare in samples 279-283, 295, Monmouth and Brightseat Formations. The single specimen recovered from sample 295 is somewhat altered and may be reworked from the Monmouth Formation.

PLATE 14

Page

Figure 1. Genus A 222
Enlargement of optical section illustrating columnar support of periphragm.

Figures 2-5. Genus B 226
Sample 279, slide AN 3, R 5.0, + 9.0. L x W 27 x 25 micra. Figs. 2-4: dorsal (transparency), optical section and ventral views respectively. The arch of the periphragm is evident in Fig. 5, an enlargement of the optical section.

Figures 6, 7. *Systematophora* cf. *S. areolata* 226
Sample 285, slide AN 25, R 5.8, + 7.9. Cyst diameter 49 micra, processes up to 26 micra long. Apical and antapical (transparency) views respectively.

Figures 8, 9. *Systematophora placacantha* 228
Sample 285, slide AN 25, R 5.8, + 7.9. Cyst diameter 49 micra, processes up to 20 micra long. Dorsal and ventral (transparency) views respectively.

Figure 10. *Tanyosphaeridium variecalamum* 228
Sample 293, slide AN 60, R 17.5, + 17.8. Cyst L x W 29 x 17 micra, processes up to 14 micra. Dorsal view. Note the apical archeopyle.

Figure 11. *Xenikoon australis* 228
Sample 281, slide AN 9, R 3.6, + 12.7. L x W 77 x 58 micra. Dorsal view.

Figure 12. *Ophiobolus lapidaris* 228
Sample 285, slide AN 25, R 14.2, + 2.8. L x W 37 x 16 micra. Illustration showing microreticulate surficial sculpture. Pseudoflagella coiled on surface.

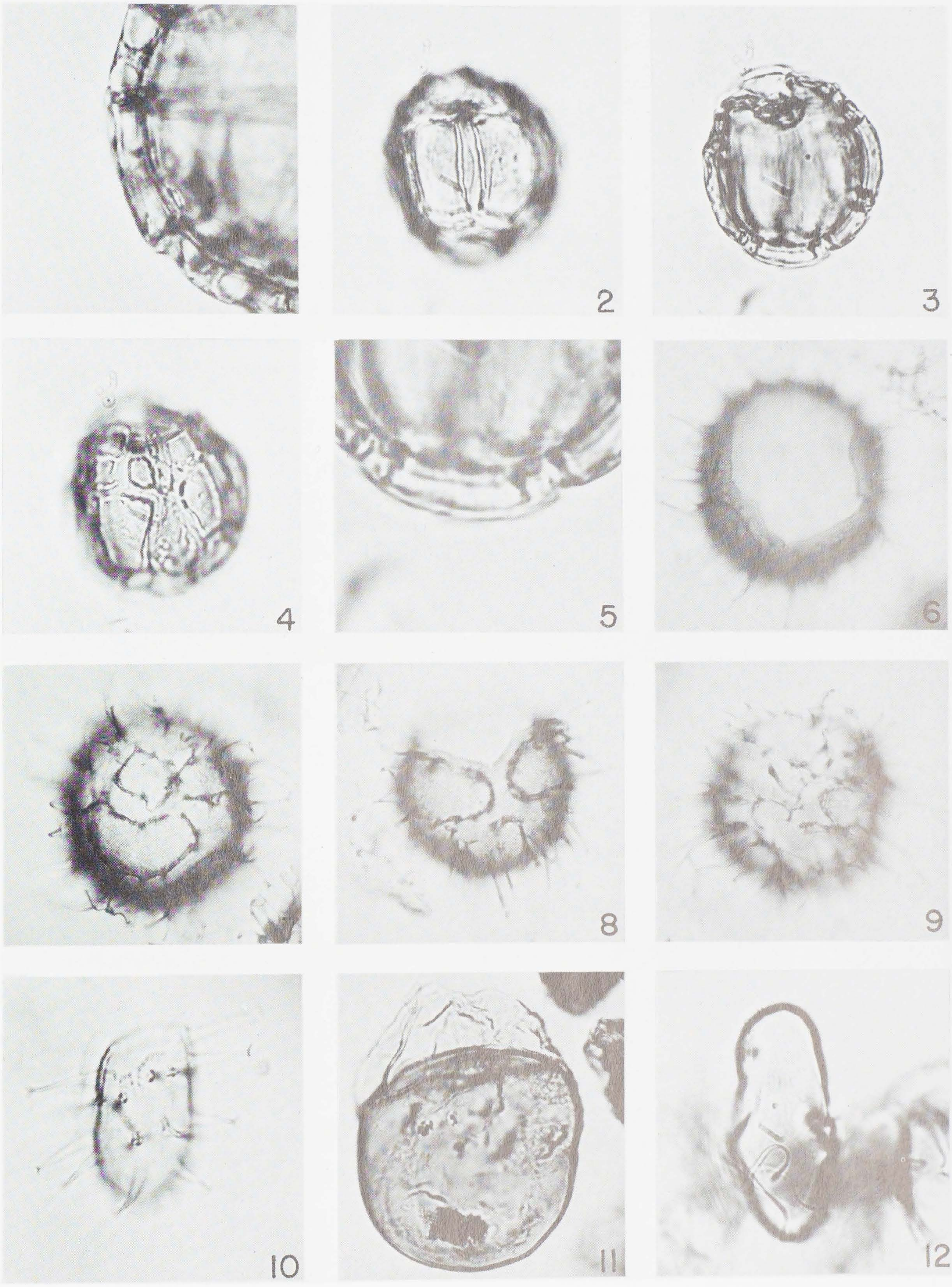

PLATE 14

Genus B
Plate 14, figures 2-5

Description: Proximate cyst, subspherical to oval. Plate boundaries reflected by low arch of periphragm. Boundaries may be complete or variably dissected. The region between the arch and the endophragm appears hollow. Reflected tabulation of ?', ?a, 6'', 6c + 1 tr, 6''', 1p, 1''''. Archeopyle apical, hexagonal in outline. Cingulum nonrotary. Wall bilayered 1.5-2 micra thick. Endophragm exhibits variably developed microreticulate sculpture. Periphragm appears restricted to the low arches.

Comments: Although certainly allied with the Microdiniaceae, this species differed in its construction from *Microdinium*. The low arches formed by the periphragm with the apparently hollow space beneath the arch separating the periphragm and endophragm is distinctive. Due to the low recovery and incomplete apical tabulation the author feels that more complete taxonomic treatment would be premature. This species does appear to be a good indicator of lower Monmouth sediments. This species is under investigation in a study separate from this work.

Dimensions: Six specimens measured; length 26-28 micra; width 25-26 micra; arch height about 2 micra.

Occurrence: Very rare in samples 279, 280, 281, Monmouth Formation.

Genus SYSTEMATOPHORA Klement 1960

SYSTEMATOPHORA cf. S. AREOLATA
Klement 1960
Plate 14, figures 6, 7

Comments: Cysts very similar to those described by Klement (1960) occur in the Monmouth Formation. They possess a greater number of processes per field than was apparent in Klement's figures; however, the tabulation of ?', 6'', 6c, 4''', 1-2p, 1'''' agreed with that published by Klement (1960). The archeopyle is apical (Type A).

Dimensions: Five specimens measured; main cyst body diameter 58-60 micra; process length up to 25 micra.

Occurrence: Very rare in samples 283, 285, Monmouth Formation.

PLATE 15

Page

Figures 1-3. *Dinogymnium* sp. 180
Sample 289, slide AN 42, R 14, + 9. L x W 171 x 23 micra. Fig. 1: Dorsal view. Fig. 2: enlargement illustrating the high cingulum and faint sulcus. Fig. 3: wall morphology. Note the punctate surface.

Figure 4. *Fromea amphora* 216
Sample 281, slide AN 10, R 8.5, + 11.6, L x W 82 x 58 micra. Specimen showing the aperture (archeopyle ?).

Figures 5, 6. *Svalbardella australina* 197
Sample 286, slide AN 29, R 9.2, + 16.6. Periblast L x W 89 x 56 micra, Endoblast L x W 114 x 51 micra. Dorsolateral and optical section views. An intercalary archeopyle is visible. The accessory spike is well developed.

Figures 7-9. *Deflandrea* cf. *D. striata* 180
Sample 293, slide AN 60, R 5.1, + 16.2. L x W 170 x 80 micra. Figs. 7, 8: Dorsal (transparency) and ventral views respectively. Fig. 9: Enlargement to illustrate the longitudinal striations.

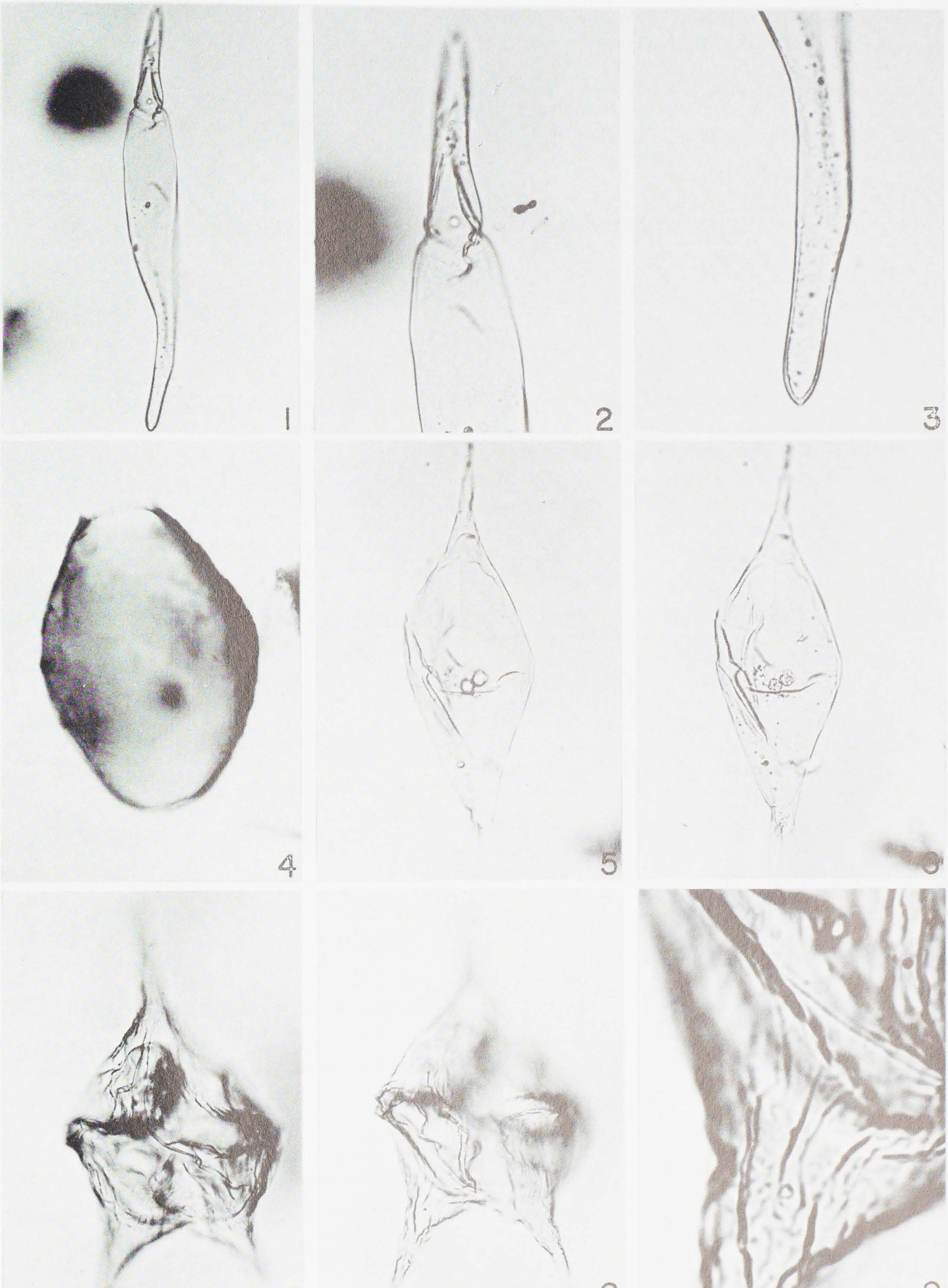

PLATE 15

SYSTEMATOPHORA PLACACANTHA
(Deflandre and Cookson)
Davey *et al.* 1969
Plate 14, figures 8, 9

1955 *Hystrichosphaeridium placacanthum* DEFLANDRE and COOKSON, p. 276, plate 19, figures 1-3.
1963 *Baltisphaeridium placacanthum* (Deflandre and Cookson) DOWNIE and SARJEANT, p. 92.
1969 *Systematophora placacantha* (Deflandre and Cookson) DAVEY, DOWNIE, SARJEANT and WILLIAMS, p. 17.

Comments: The specimens of *S. placacantha* resemble the original description. Most specimens are poorly preserved. The fields of processes are not defined on the ventral surface and tabulation is indeterminate; however, the accessory sutures of the apical archeopyle (Type A) indicate the presence of six precingular plate equivalents.

Dimensions: Five specimens measured; cyst main body diameter 58-65 micra; process length 14-21 micra.

Occurrence: Very rare to common in samples 283, 285, Monmouth Formation.

Previous Reported Occurrence: Upper Cretaceous, Germany (Gocht, 1959); Early Cenozoic, S.E. Australia, W. New Zealand (Haskell and Wilson, 1975); lower Eocene, N. Germany, Belgium (Morgenroth, 1966); middle-upper Oligocene, Germany (Benedek, 1972); Miocene, Australia (Deflandre and Cookson, 1955).

Genus TANYOSPHAERIDIUM
Davey and Williams 1966b

TANYOSPHAERIDIUM VARIECALAMUM
Davey and Williams 1966b
Plate 14, figure 10

1966b *Tanyosphaeridium variecalamum* DAVEY and WILLIAMS, p. 98, plate 6, figure 7, text figure 20.

Comments: The specimens of *Tanyosphaeridium variecalamum* conform precisely to the original description. No complete specimens were recovered, all having lost the apical operculum.

Dimensions: Ten specimens measured; cyst body length 28-30 micra; width 16-17 micra; process length 12-14 micra.

Occurrence: Very rare to rare in samples 284, 291-293, 295, Monmouth Formation and Brightseat Formation.

Previous Reported Occurrence: Albian, Canada (Davey, 1969a); Albian, France (Davey and Verdier, 1971); Albian-Turonian, England (Davey and Williams, 1966b; Davey, 1969a); Cenomanian, France (Davey, 1969a); upper Campanian, Canada (Harland, 1973).

Genus XENIKOON
Cookson and Eisenack 1960

XENIKOON AUSTRALIS
Cookson and Eisenact 1960
Plate 14, figure 11

1960 *Xenikoon australis* COOKSON and EISENACK, p. 16, plate 3, figures 16-17.

Comments: The specimens of *Xenikoon australis* recovered in this study conform to the original description; however, an archeopyle is not observable in the Monmouth specimens.

Dimensions: Ten specimens measured; periblast length 52-75 micra; width 40-58 micra; endoblast length 40-56 micra; width 40-56 micra; apical pericoel 11-18 micra.

Occurrence: Very rare to rare in samples 280-286, 288, Monmouth Formation.

Previous Reported Occurrence: Cretaceous, Australia (Cookson and Eisenack, 1960).

Phylum PROTOZA
Family OPHIOBOLIDAE Deflandre 1952
Genus OPHIOBOLUS Wetzel 1933

OPHIOBOLUS LAPIDARIS Wetzel 1933
Plate 14, figure 12

1933 *Ophiobolus lapidaris* WETZEL, p. 167, plate 2, figures 5-7.
1967 *Scuticabolus lapidaris* (Wetzel) LOEBLICH, p. 68.
1968 *Ophiobolus lapidaris* Wetzel; EVITT, p. 4, plate 1, text figures 1-6.

Comments: Specimens of *Ophiobolus lapidaris* identical to those described by Wetzel (1933) were observed in the Monmouth Formation. They are frequently found to be entangled by their pseudoflagellae in clumps of *Spiniferites* and *Hy-*

strichosphaeridium. It is considered to be an excellent Upper Cretaceous marker in Maryland sediments.

Dimensions: Ten specimens measured; length 37-42 micra; width 12-18 micra; pseudoflagellae up to 90 micra in length.

Occurrence: Rare to very rare in samples 280-287, 289-293, Monmouth Formation.

Previous Reported Occurrence: Upper Cretaceous, Germany (Wetzel, 1933); Upper Cretaceous, U.S.A. (Evitt, 1968); Upper Cretaceous, Canada (McIntyre, 1974); Danian, N. Europe (Morgenroth, 1968).

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REVIEW

GEOTHERMICS, by Jean Goguel. Translated from the French edition by Alan Rite, and edited by Sydney P. Clark, Jr. Published by Mc-Graw Hill Book Company, New York, 1976, xi + 200 pp., $15.00

This book is an English edition of *La Géothermie,* originally published in Paris. It is intended as an advanced text and reference book which covers the theories, practical exploration, and economics of geothermal energy. The text deals with first principles and the thermal regime near the earth's surface with particular attention to the interaction between the temperature field and circulating ground waters. The practical and political problems of extracting usable heat and power from geothermal sources are discussed and the operation of generating plants is described. Many subjects of direct interest to earth scientists are included throughout this work.

—H.C.S.