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# Middle Cretaceous palynomorph assemblages from clays near the Horizon Beta deep-sea outcrop

## ABSTRACT

A total of 76 species of spores and pollen and 30 species of dinoflagellate cysts and acritarchs are reported from the clays of five piston cores collected from the submarine outcrop of beds stratigraphically near Seismic Reflector Horizon Beta. These well-preserved assemblages are considered to be of Middle Cretaceous age (Albian and Cenomanian). The number of types and individuals of palynomorphs, the latter ranging from approximately 4,000 to approximately 40,000 per gram of dried sediment, their close quantitative relationship with Middle Cretaceous assemblages from the Atlantic Coastal Plain of the United States, and the inferred paleoecology of acanthomorphitid acritarchs all suggest a source area originally fairly close to the locus of deposition.

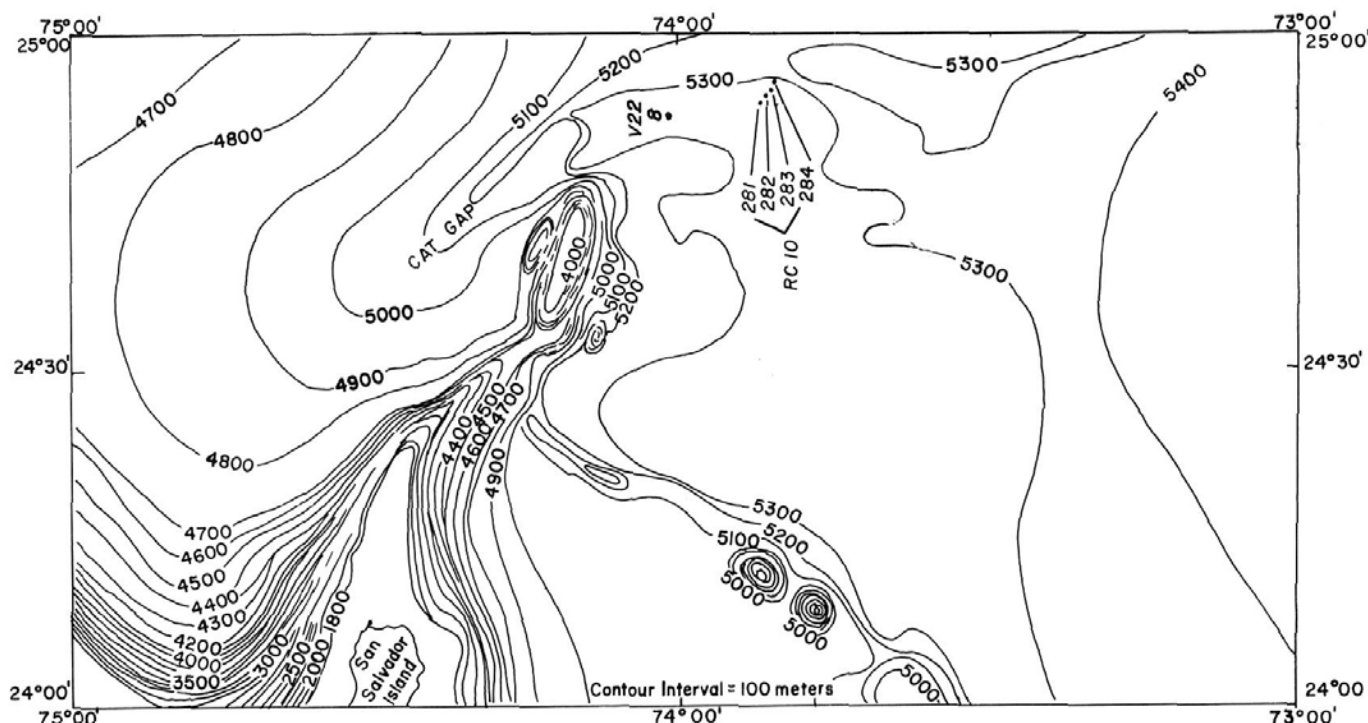
## INTRODUCTION

Palynomorph assemblages composed of numerous types and individuals of spores, pollen grains, dinoflagellate cysts, and acritarchs were recovered from highly organic lutite layers in five piston cores taken from beds of the submarine outcrop situated stratigraphically near Seismic Reflector Horizon Beta, a seismically defined horizon in an area located in the North Atlantic approximately 265 km. east of Cat Island in the Bahamas, at abyssal depths exceeding 5200 m. (text-figure 1). The palynomorph assemblages in the lutite layers of these cores indicate a Middle Cretaceous (Albian and Cenomanian) age for beds situated stratigraphically below Horizon A and near Horizon Beta. Geophysical evidence pertaining to Seismic Reflector Horizons A and Beta, including the areas of their occurrence, was presented by Ewing *et al.* (1966) and Windisch *et al.* (1968). Saito, Burckle and Ewing (1966) described the lithology and faunal stratigraphy of eight piston cores from the upper part of the section between Horizon A and Horizon Beta. A preliminary study and description of the palynomorphs in a single core from near Horizon Beta, and a summary of their distribution in the five piston cores, were reported by Habib (1968, 1969).

## PREVIOUS LITERATURE

Particularly useful for the study of Cretaceous palynomorphs in deep-sea sediments off the eastern shore of North America is the Cretaceous palynostratigraphy established for the Atlantic Coastal Plain of the United States.

The oldest known palynomorph assemblages described from the Coastal Plain occur in the formations comprising the nonmarine Potomac Group of Maryland. Brenner (1963, 1967) reported palynological evidence for the Barremian–Aptian age of the Patuxent and Arundel Formations, and for the Albian age of the Patapsco Formation. Stover (1962, 1964) described palynomorphs from the Arundel Formation and noted their striking similarity to those of the Lower Cretaceous Wealden assemblages of England. Groot and Penny (1960), Groot, Penny and Groot (1961), and Kimyai (1966) described and dated assemblages of Upper Cretaceous age from New Jersey, Maryland, Delaware, North Carolina, South Carolina and Georgia. Leopold and Pakiser (1964) reported the occurrence of spores, pollen and phytoplankton in the Upper Cretaceous pre-Selma subsurface of Alabama.



TEXT-FIGURE 1

Contour map of the Atlantic floor northeast of the Bahamas showing the core collection localities.

#### SAMPLE ANALYSIS

Seven samples were analyzed, each weighing approximately ten grams. A bottom sample was taken from each of the five Lamont cores, V22-8, RC10-281, RC10-282, RC10-283 and RC10-284 (text-figure 2). After their ages were determined, an additional two samples were taken from the 235-cm. and 205-cm. levels in the older core (RC10-284) in order to investigate any possible vertical variation. The samples were treated in the following manner.

- 1) Disaggregate sample with the aid of ultrasonic vibration.
- 2) Treat with ten per cent hydrochloric acid. (Reaction nil.)
- 3) Treat with concentrated hydrofluoric acid for approximately 24 hours.
- 4) Treat with concentrated laboratory grade nitric acid for approximately 12-24 hours, depending on rate of reaction.
- 5) Treat with five per cent potassium hydroxide for 1-2 hours.
- 6) Stain with methyl green.
- 7) Aliquot palynomorphous residue by mixing in commercial glycerine jelly to a specified level in a 2-dram vial.
- 8) Remove specified fraction with a calibrated pipette and prepare microslides.

- 9) Count all palynomorphs on slides and calculate number of palynomorphs per gram.

Because the preliminary report of the bottom sample in core RC10-284 was analyzed using the flotation method (Habib, 1969), this sample was analyzed a second time using the method described above.

#### DESCRIPTION OF PALYNOMORPH ASSEMBLAGES

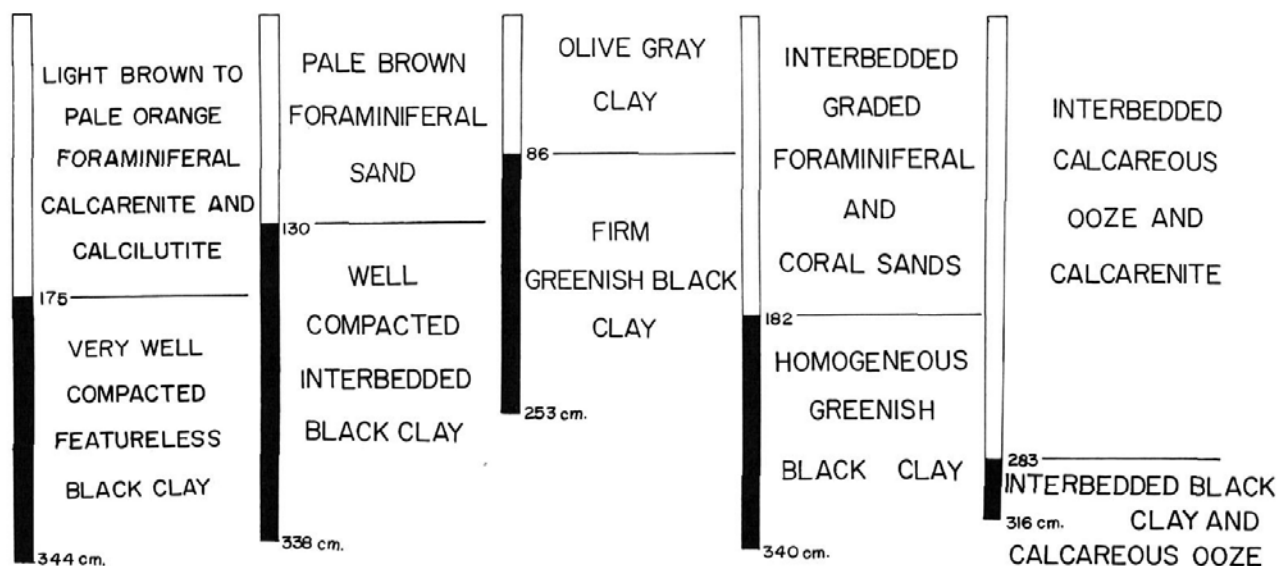
Table 1 lists the relative percentage distributions of the principal palynomorph types in cores V22-8, RC10-281, RC10-282, RC10-283 and RC10-284 (assemblages A-E). The relative frequencies of individual species are listed in tables 2 and 3. The symbol *P* is used to denote that the corresponding species were observed but not counted, or that only a few specimens were counted. All of the assemblages contain a large number of species and individuals (table 1).

##### Assemblage A, core V22-8, 316-cm. level

The assemblage at the bottom of core V22-8 is dominated by dinoflagellate cysts, notably *Palaeohystrichophora infusorioides* and *Pterodinium cornutum*, and by the acritarch species *Michrystidium inconspicuum* and *Baltisphaeridium stellatum*, n. sp. Spores and pollen are less well represented, the predominant species being *Tricolpopollenites minutus*. Pteridophyte spores are at a minimum.

RC10-C284    RC10-C283    RC10-C282    RC10-C281    V22-8

24°54' N	24°54' N	24°53' N	24°53.5' N	24°52' N
73°50.5' W	73°51.5' W	73°52' W	73°52' W	74°01' W
D. 5314 m.	D. 5305 m.	D. 5302 m.	D. 5340 m.	D. 5521 m.



TEXT-FIGURE 2  
Lithologic descriptions of the cores.

**Assemblage B, core RC10-281, 340-cm. level**

The principal species in assemblage B is *Michrystidium inconspicuum*, which forms more than 25 per cent of all palynomorphs. *Palaeohystrichophora infusorioides* is also well represented. Although dinoflagellate cysts and acritarchs are again the predominant elements, spores and pollen form higher percentages than in assemblage A. *Tricolpopollenites minutus* is again the most abundant species of spores and pollen.

**Assemblage C, core RC10-282, 253-cm. level**

This assemblage contains the greatest number of palynomorph types. The most abundant are the various species of the tricolpate pollen genera *Tricolpopollenites* and *Retitricolpites*. Also occurring in higher percentages are gymnospermous grains, including those of nonsaccate morphology, e.g., *Classopollis*, *Ephedripites* and *Perinopollenites*. Spores form 3.2 per cent of all palynomorphs but consist of numerous species, many of which are represented by only a few specimens. Dinoflagellates and acritarchs form less than 50 per cent of the assemblage. The most abundant species are *Michrystidium inconspicuum* and *Palaeohystrichophora infusorioides*.

**Assemblage D, core RC10-283, 338-cm. level**

The assemblage at the bottom of core RC10-283 reflects the progressive increase of pollen and spores in the relative frequencies. It is similar to assemblage C in the number of species and their relative proportions. Tricolpate grains are the most abundant of the spores and pollen. Bisaccate grains are more frequent than in assemblage C, as are also nonsaccate gymnospermous grains. Phytoplankton forms approximately 30 per cent of the palynomorphs.

**Assemblage E, core RC10-284, 344-cm. level**

This assemblage represents a marked departure from assemblages A-D. Spores and bisaccate grains form the majority of all palynomorphs. Moreover, most of the spores are assignable to *Cyathidites minor* and *Gleicheniidites circinidites*. This concentration on two species is in contrast to the diverse species but few individuals observed in assemblages C and D. Next most frequent are the species *Spheripollenites psilatus*, *Clavatipollenites hughesii*, *Liliacidites dividiuus*, and species of *Monosulcites*. Tricolpate grains, in contrast to the aforescribed assemblages, comprise only eight per cent of all palynomorphs. Of the phytoplankton, the predominant species are *Wallodinium inflatum* and

TABLE 1

Relative percentage distributions of principal plant microfossil groups  
P=Present in percentage less than 0.2.

	Assemblage				
	A	B	C	D	E
	VEMA 22-8	281	CONRAD 282	10 283	284
Spores	1.0	4.1	3.2	5.6	27.2
Bisaccates	1.6	5.1	4.5	8.4	29.4
Inaperturates and Monosulcates	1.0	3.9	5.6	6.4	25.5
<i>Classopollis</i>	2.0	1.0	6.1	12.0	P
<i>Ephedripites</i>	1.0	P	0.4	1.6	—
<i>Exesipollenites</i> and <i>Perinopollenites</i>	1.0	1.0	4.1	2.4	—
Tricolpates	16.4	15.9	28.7	31.2	8.0
Others	7.1	4.9	6.5	2.8	4.9
Total spores and pollen	30.1	35.9	59.1	70.4	95.0
Dinoflagellate cysts	48.9	32.6	18.0	8.4	3.1
Acritarchs	20.0	31.5	22.9	21.2	1.9
Total dinoflagellates and acritarchs	68.9	64.1	40.9	29.6	5.0
Total number of palynomorph species observed	74	73	87	83	53
Pollen and spore species observed	58	57	68	68	46
Average number of palynomorphs per gram of dried sediment	9,700	6,700	30,000	35,000	4,200

*Hystrichosphaeridium arundum*, *Microhystridium inconspicuum* and *Palaeohystrichophora infusorioides* were not observed. *W. inflatum* was not observed in assemblages A–D.

## CONCLUSIONS

### Age of assemblages

Assemblages A–E are considered to be of Middle Cretaceous age (Albian and Cenomanian) on the basis of palynomorph evidence and other microfossil data (Habib, 1968).

Assemblages A–D, corresponding respectively to the bottom samples of cores V22–8, RC10–281, RC10–282, and RC10–283, suggest an age no younger than Cenomanian because of the absence of triporate angiospermous pollen (Couper, 1964). They are considered to be not older than Cenomanian on the basis of the high relative frequencies and diversity of retipilate and psilate prolate tricolpate dicotyledonous grains, and the occurrence of species with restricted stratigraphic ranges. Although the seven species of tricolpate pollen vary from 15.9 to 31.2 per cent of all palynomorphs (table 1), they form from 44.3 to 50.4 per cent of the spores and pollen. If the relative percentages of dicotyledonous grains do reflect the expanding angiosperm flora during the Middle Cretaceous, and are not solely sedimentological phenomena, these data can be used in support of a Cenomanian age. The number of species and individuals of tricolpates in assemblages A–D correlates well with the number in the assemblages in the lower parts of the Raritan and Tuscaloosa Formations of the Atlantic Coastal Plain of the United States,

dated by Groot, Penny and Groot (1961) as Cenomanian. These authors reported 11 dicotyledonous species forming 61 per cent of the assemblage in the lowest member of the Raritan Formation, although they reported also a number of tricolpate grains and one triporate species.

The foraminifers *Schackoina cenomana* (Schacko) and *Hedbergella amabilis* Loeblich and Tappan, amongst others, date the assemblage from core V22–8 (assemblage A) as Cenomanian (Saito, Burckle and Ewing, 1966).

The palynomorphs comprising assemblage E have been described by Habib (1969), who then assigned an Albian or early Cenomanian age to it. The low percentage of dicotyledonous pollen, the occurrence of palynomorphs characteristic of the upper Lower Cretaceous, and the close quantitative approximation of the assemblage to spores and pollen in the nonmarine Patapsco Formation of Maryland, assigned to the Albian by Brenner (1963), formed the basis for this designation.

Five species of prolate dicotyledonous pollen constitute eight per cent of all palynomorphs and 8.5 per cent of the spores and pollen in assemblage E. By comparison, seven species of tricolpate pollen comprise six per cent of the spores and pollen in the Patapsco Formation (Brenner, 1963). In both cases the tricolpates are smooth or retipilate, and are related species of *Tricolpopollenites* and *Retitricolpites*.

Of the 76 species of spores and pollen observed in assemblages A–E, 37, or 48.7 per cent, occur also in the Potomac Group of Maryland. Of these, nine species are restricted to the Patapsco Formation, five of which, *Matonisporites excavatus*, *Apiculatisporis bab-sae*, *Monosulcites chaloneri*, *Rugubivesiculites reductus* and *Tricolpopollenites minutus*, are listed by Brenner (1963) as primary species, i.e., those occurring in high percentages. An additional 15 species are described or have been described (Habib, 1969) as new. Most of the remaining species have been reported in Cretaceous assemblages of the United States, Great Britain and Australia.

Because of the disparate relationship between assemblage E and assemblages A–D, and the possibility that assemblage E might in fact be purely sedimentological in origin and otherwise contemporaneous with assemblages A–D, samples from the 235-cm. and 205-cm. levels in core RC10–284 were investigated. Because of the close similarity in composition and relative frequencies, the palynomorphs from these levels were treated as a single assemblage, assemblage F (table 6). Assemblage F correlates very closely with assemblages A–D and supports the stratigraphic relationships inter-



TABLE 2

Relative percentage distribution of pollen and spores in core samples. P=Present in percentage less than 0.2

	VEMA					CONRAD 10						VEMA					CONRAD 10				
	22-8	281	282	283	284	22-8	281	282	283	284		22-8	281	282	283	284					
<i>Stereosporites antiquasporites</i>	P	P	0.2	P	—	<i>Alisporites bilateralis</i>	3.5	1.3	1.8	2.0	9.1										
<i>Lycopodiumsporites austroclavatidites</i>	P	P	P	P	—	<i>Abietinaepollenites microreticulatus</i>	P	3.5	1.8	3.3	8.7										
<i>L. clavatooides</i>	P	0.2	P	P	P	<i>A. dunrobinensis</i>	P	P	0.2	2.0	5.0										
<i>Camarozonosporites rudis</i>	—	P	1.2	P	—	<i>Rugbivesiculites reductus</i>	2.0	2.3	2.0	1.7	—										
<i>Verrucatosporites ? rugulatus</i>	—	P	P	P	—	<i>Parvisaccites radiatus</i>	P	0.7	1.8	2.0	0.7										
<i>Lycopodioidites ambifoveolatus</i>	P	—	P	P	—	<i>P. majesticus</i>	P	P	P	P	P										
<i>Cf. Calamospora mesozoica</i>	P	P	P	P	P	<i>Pteruchipollenites crenulatus</i>	—	—	—	—	1.5										
<i>Cyathidites minor</i>	1.2	1.8	1.5	3.3	9.0	<i>P. transversus</i>	—	—	—	—	0.7										
<i>C. australis</i>	P	P	0.5	P	1.5	<i>Tsugaepollenites dampieri</i>	P	P	P	P	1.8										
<i>Todisporites minor</i>	P	0.7	P	P	1.0	<i>T. discoides</i>	—	—	P	—	P										
<i>Matonisporites equixinous</i>	—	P	0.7	P	—	<i>Araucariacites limbatus</i>	P	P	0.2	P	0.7										
<i>M. excavatus</i>	—	—	P	P	—	<i>Taxodiaceapollenites hiatus</i>	P	1.2	2.0	3.0	2.1										
<i>M. impensus</i>	P	P	P	P	—	<i>Ginkgocycadophytus nitidus</i>	P	P	—	P	—										
<i>M. sp. A</i>	—	—	—	P	—	<i>Ephedripites multicostatus</i>	0.2	0.2	0.4	0.7	—										
<i>Gleichenioidites circinidites</i>	0.2	0.7	0.2	1.5	7.1	<i>E. fusiformis</i>	—	P	P	P	—										
<i>G. senonicus</i>	P	0.2	P	0.7	0.5	<i>Classopollis torosus</i>	4.6	10.3	11.0	16.6	P										
<i>G. severus</i>	P	0.2	P	0.7	1.5	<i>Clavatipollenites hughesii</i>	P	0.3	0.5	3.0	8.5										
<i>G. apilobatus</i>	P	P	P	P	P	<i>C. maximus</i>	P	—	P	P	0.7										
<i>G. marciae</i>	—	—	—	—	P	<i>Eucommiidites troedssonii</i>	P	P	P	3.0	P										
<i>G. lamontensis</i>	P	P	P	P	—	<i>Cf. Exesipollenites tumulus</i> and															
<i>G. triangulus</i>	P	—	P	P	—	<i>Perinopollenites elatoides</i>	3.0	6.3	7.4	9.0	—										
<i>Hymenophyllumsporites pseudoreticulatus</i>	P	—	P	P	—	<i>Inaperturopollenites dubius</i>	P	1.2	0.4	0.5	P										
<i>Cicatricosisporites australiensis</i>	P	P	1.4	P	P	<i>Laricoidites magnus</i>	P	P	P	P	—										
<i>Appendicisporites tricornitatus</i>	P	0.4	P	P	P	<i>Liliacidites dividuus</i>	P	1.2	0.4	1.5	2.5										
<i>Ischyosporites punctatus</i>	—	—	P	—	—	<i>Monosulcites minimus</i>	1.3	4.2	3.6	1.5	9.0										
<i>Apiculatisporis babsae</i>	P	P	P	P	—	<i>M. epakros</i>	P	0.5	0.4	P	1.0										
<i>Concavisporites lamontis</i>	—	—	—	—	0.7	<i>M. chaloneri</i>	—	0.4	P	P	—										
<i>Concavisporites verrucosus</i>	P	P	P	P	—	<i>Palmaepollenites asymmetricus</i>	P	P	P	P	—										
<i>Echinatisporis longechinus</i>	P	P	P	—	—	<i>Cf. Palmidites maximus</i>	—	—	—	P	—										
<i>Endosporites sp. A</i>	—	—	—	P	—	<i>Spheripollenites psilatus</i>	P	0.3	0.2	1.7	9.3										
<i>Foraminisporis dailyi</i>	P	P	P	P	—	<i>Tricolpites auritus</i>	P	4.4	3.6	2.3	0.3										
<i>Laevigatosporites ovatus</i>	P	P	P	P	P	<i>Psilatricolpites psilatus</i>	P	0.6	0.6	2.0	—										
<i>L. scabratus</i>	P	—	P	P	P	<i>Tricolpoidipollenites minutus</i>	14.0	7.1	10.0	7.3	6.4										
<i>Tauropusporites reduncus</i>	P	P	P	P	P	<i>T. polyhedrus</i>	1.7	4.0	0.2	2.5	0.7										
<i>T. segmentatus</i>	P	P	0.2	P	—	<i>Retitricolpites sphaeroides</i>	38.4	36.3	34.0	12.0	1.1										
<i>Triplanosporites sinuosus</i>	—	—	P	P	—	<i>R. georgensis</i>	1.2	1.0	3.0	3.3	P										
<i>Cf. Undulatisporites sinuosus</i>	—	—	P	P	—	<i>R. magnificus</i>	5.9	0.7	4.0	4.0	—										
<i>Vitreisporites pallidus</i>	1.5	2.0	1.8	5.2	4.3	<i>Galeacornea sp. A</i>	—	—	—	—	P										
<i>Platysaccus elizabethae</i>	P	1.5	P	2.2	2.2	<i>Discoidella hanna</i>	P	P	0.2	0.7	0.7										
						<i>Schizosporis burcklei</i>	—	—	—	—											

preted from the bottom samples. The superposed position of the two types of assemblages in a uniform black clay section in a single core suggests that the composition of the source vegetation was more important a factor in forming the final spore and pollen assemblages than were sedimentological processes. Brenner (1967) reported a similar stratigraphic variation in Albian-Cenomanian core samples from the subsurface in Delaware, where, through a short stratigraphic interval measured in terms of a few feet of section, a radical change in the composition of the spore and pollen assemblages takes place. Brenner (1967) found the lower assemblage to be chiefly composed of pteridophyte spores and gymnospermous pollen, with only a small number of small tricolpate grains, and the higher assemblage to be more than 60 per cent composed of tricolpate specimens.

#### Guide palynomorphs

Tables 4 and 5 list the species with more-or-less restricted stratigraphic ranges. The overlap of stratigraphic ranges and the occurrence in assemblages A-F

of species reported only from the Albian and/or Cenomanian Stages point to a Middle Cretaceous age. Of the 37 species which are useful as stratigraphic guides, several appear especially helpful for distinguishing the Albian and Cenomanian Stages. The most valuable groups of palynomorphs are the dinoflagellate cysts and the acritarchs, particularly *Palaeohystrichophora infusorioides* and *Wallodinium inflatum*. *P. infusorioides* occurs in each of the Cenomanian assemblages, reaching as high as 28.3 per cent of the phytoplankton in assemblage A, but was not observed in assemblage E. Sarjeant (1967) reported the known range of this species to extend from middle Albian through Coniacian, although the Albian occurrence appears to be represented by a single specimen, according to Clarke and Verdier (1967). The species has been reported also from lower Upper Cretaceous marine strata in the subsurface in western Alabama (Leopold and Pakiser, 1964) and in England (Cookson and Hughes, 1964). Species of *Wallodinium* range from Upper Jurassic through Lower Cretaceous (Alberti, 1961), except for a distinctive species, *W. luna*, which has been found in

TABLE 3

Relative percentage distribution of dinoflagellate cysts and acritarchs in core samples

P=Present in percentage less than 0.5

	VEMA		CONRAD 10		
	22-8	281	282	283	284
<i>Scrinodinium heusseri</i>	P	P	P	P	—
<i>Gonyaulax orthoceras</i>	P	P	P	P	—
<i>Spiniferites ramosus</i>	—	3.4	1.6	2.5	—
<i>Canningia minor</i>	—	—	—	—	6.3
<i>Scrinodinium</i> sp. A	—	—	—	—	P
<i>Palaeohystrichophora infusorioides</i>	28.3	14.8	15.7	18.2	—
<i>Aptodinium granulatum</i>	P	P	P	P	—
<i>A. maculatum</i>	—	—	P	—	—
<i>Cleistosphaeridium huguonioti</i>	2.0	2.0	1.5	P	—
<i>Fromea amphora</i>	—	P	P	P	—
<i>Hystrichosphaeridium arundum</i>	5.4	3.0	1.3	2.1	28.3
<i>Palaeostomocystis fragilis</i>	P	—	—	—	1.5
<i>Pterodinium cornutum</i>	P	P	P	P	—
<i>Cf. Tenua hystricella</i>	P	P	0.7	P	—
<i>Stephodinium europaeum</i>	—	—	—	—	1.3
<i>Xenikoon americanus</i>	P	—	—	—	—
<i>Michrystidium fragile</i>	0.7	1.3	0.5	0.6	—
<i>M. inconspicuum</i>	45.0	49.0	40.0	54.9	—
<i>Cf. Baltisphaeridium pilosum</i>	—	—	—	—	—
<i>longispinosum</i>	1.2	P	0.7	P	—
<i>Cf. B. stimuliferum</i>	—	P	P	—	—
<i>B. pseudohystrichodinium</i>	—	P	P	P	—
<i>B. stellatum</i>	5.5	3.6	1.5	P	—
<i>Prismatocystis ewingii</i>	—	—	—	—	5.7
<i>P. cylindrica</i>	P	—	P	P	—
<i>Wallodinium inflatum</i>	—	—	—	—	30.0
Acritarch type A	—	—	P	—	—

the Cenomanian. *W. inflatum* is the principal phytoplankton species in assemblage E but was not observed in assemblages A–D and F.

*Rugubivesiculites reductus* apparently is the single most important guide fossil among the spores and pollen. It was found in each of the Cenomanian assemblages, but was not observed in assemblage E. *Rugubivesiculites* is typical of lower Upper Cretaceous assemblages in New Jersey, Alabama, Minnesota and Oklahoma (Groot, Penny and Groot, 1961; Leopold and Pakiser, 1964; Pierce, 1961; Hedlund, 1966). Groot and Groot (1962) reported *Rugubivesiculites* in abundance throughout the Upper Cretaceous of New Jersey and Delaware. The genus is generally lacking in Albian sediments (Couper, 1958; Hedlund and Norris, 1968). Brenner (1963) reported *R. reductus* to be restricted to the uppermost zone (subzone IIb) of the Patapsco Formation.

Two additional species, *Clavatipollenites hughesii* and *Spheripollenites psilatus*, are useful for distinguishing assemblage E from the Cenomanian assemblages. Although both occur in all of the investigated samples, they are most abundant in assemblage E. *C. hughesii* has been reported as a useful guide fossil in the upper Lower Cretaceous sediments of England, the Atlantic Coastal plain of the United States and elsewhere (Couper, 1958, 1964; Brenner, 1963). *S. psilatus* has also been found most frequently in upper Lower Cretaceous sediments (Couper, 1958).

TABLE 4

Guide species of spores and pollen. Ranges taken principally from Muller, 1968; Brenner, 1963; Leopold and Pakiser, 1964; Groot, Penny and Groot, 1961; Kimyai, 1966; Couper, 1958, 1964; Stover, 1966

Species	Stratigraphic range
<i>Matonisporites excavatus</i>	Albian
<i>Matonisporites equixinuous</i>	Jurassic – Lower Cretaceous
<i>Gleichenioidites apilobatus</i>	Aptian – Albian
<i>Cicatricosisporites australiensis</i>	Cretaceous
<i>Appendicisporites tricornitatus</i>	Jurassic – Cretaceous
<i>Lycopodiumsporites clavatoideus</i>	Jurassic – Cretaceous
<i>Tauropollenites segmentatus</i>	Lower Cretaceous
<i>Apiculatisporis babsae</i>	Albian – Cenomanian
<i>Vitreisporites pallidus</i>	Jurassic – Cenomanian
<i>Parvisaccites radiatus</i>	Wealden – Cenomanian
<i>Rugubivesiculites reductus</i>	Cenomanian – Senonian
<i>Tsugaepollenites dampieri</i>	Jurassic – Lower Cretaceous
<i>Tsugaepollenites discoides</i>	Cenomanian
<i>Ginkgocycadophytus nitidus</i>	Jurassic – Lower Cretaceous
<i>Ephedripites multicostatus</i>	Aptian – Turonian
<i>Clavatipollenites hughesii</i>	Upper Hauterivian – Cenomanian
<i>Liliacidites dividius</i>	Aptian – Cenomanian
<i>Eucommiidites troedssonii</i>	Jurassic – Campanian
<i>Monosulcites epakros</i>	Aptian – Albian
<i>Monosulcites chaloneri</i>	Aptian – Albian
<i>Palmaepollenites asymmetricus</i>	Aptian – Cenomanian
<i>Perinopollenites elatoides</i>	Jurassic – Lower Cretaceous
<i>Spheripollenites psilatus</i>	Wealden – Aptian
<i>Tricolpites auritus</i>	Albian – Cenomanian
<i>Tricolpopenites minutus</i>	Albian
<i>Retitricolpites sphaeroides</i>	Cenomanian
<i>Retitricolpites georgensis</i>	Albian

#### Origin of assemblages

In marine environments, it appears that most modern pollen grains and spores are deposited relatively close to the continents, and are especially common in areas adjacent to major stream discharge. Muller (1959) and Cross, Thomson and Zaitzeff (1966) reported numbers of grains in the order of tens of thousands per gram opposite streams entering the Gulf of Paria and Gulf of California, respectively. Numbers in excess of 20,000 per gram were discovered in Holocene sediments of the Middle America Trench, opposite the Tehuantepec River of Mexico (Habib *et al.*, MS. in press). Pollen grains and spores are also transported considerable distances in the open oceans, and have been reported from red clays and biogenic oozes of the western Pacific (Koreneva, 1964). These assemblages are invariably composed of few species, and only a few grains per gram of sediment. At distances of 200–500 km. from land, moreover, relatively few grains occur, and only a few basic morphologic types are present (Koreneva, 1964, 1966). Stanley (1965b) reported an average of 1900 grains per gram in a single sample as far as 180 nautical miles from the east coast of the United States but did not give the number of species present.

The abundance of palynomorphs, ranging in core RC10–284 from 4200 per gram in assemblage E to 42,300 in assemblage F, the diversity of morphological types, and the close approximation in relative frequencies of the spores and pollen to nonmarine and marine

TABLE 5

Guide species of dinoflagellate cysts and acritarchs. Ranges taken principally from Sarjeant, 1967; Davey, Downie, Sargeant and Williams, 1966; Alberti, 1961; Leopold and Pakiser, 1964

Species	Stratigraphic range
<i>Palaeohystrichophora infusorioides</i>	Middle Albian – Coniacian
<i>Apteodinium granulatum</i>	Aptian
<i>Cleistosphaeridium huguonioti</i>	Albian – Cenomanian
<i>Fromea amphora</i>	Hauterivian – Cenomanian
<i>Hystrichosphaeridium arundum</i>	Albian – Middle Cenomanian
<i>Palaeostomocystis fragilis</i>	Albian – Cenomanian
<i>Pterodinium cornutum</i>	Aptian – Albian
<i>Tenua hystricella</i>	Hauterivian – Aptian
<i>Stephodinium europaeum</i>	Middle Albian – Cenomanian
<i>Wallodinium</i> spp.	Upper Jurassic – Cenomanian

Middle Cretaceous assemblages in the Atlantic Coastal Plain all suggest that the locus of deposition was relatively close to the source vegetation. This interpretation requires a source area closer to the locus of deposition than any now in existence.

The high percentages of the acanthomorphitid acritarchs *Michrhystridium* and *Baltisphaeridium* in assemblages A–D and F suggest an original near-shore marine environment. Wall (1965) interpreted high percentages of Acanthomorpha in Liassic sediments of England and Wales to have apparently indicated coastal environments, on the basis of the study of the modern distribution of marine phytoplankton off the eastern United States made by Hulburt (1963). Staplin (1961) reported similar high concentrations of acanthomorphitids near Devonian reefs in Alberta, Canada. The large number of species of spores and pollen in assemblages A–D and F also support a near-shore interpretation.

No interpretation of the original depth of water can be suggested, since it is quite possible for shelf assemblages to be swept by contemporaneous marine currents into deeper water (David Wall, personal communication). It does not appear that the assemblages could have been transported long distances along the sea bottom and have still maintained their quantitative nature, however.

It is not likely that the lutite layers represent large-scale redeposition as turbidites because of the composition of the assemblages and their relation to continental assemblages, their excellent preservation, the lack of a stratigraphically "mixed" palynomorph flora, and the orderly Albian–Cenomanian sequence in core RC10–284 (assemblages E and F).

The limited number of piston cores available for this investigation and the comparative lack of vertical control make substantiating evidence for the interpretations presented here highly desirable. This confirmation may perhaps be realized through the study of long cores

TABLE 6

Relative frequencies of palynomorph groups in Assemblage F, Core RC10–284. Average composition of microflora from 205-cm. and 235-cm. levels

Spores and pollen	Percentage
Pteridophyte spores	9.5
Bisaccate and inaperturate pollen	11.7
Monosulcate pollen	10.7
<i>Classopollis</i>	8.0
<i>Exesipollenites</i> and <i>Perinopollenites</i>	5.0
Tricolpate pollen	21.9
Others	15.2
Total	81.3
Dinoflagellate cysts and acritarchs	
Dinoflagellate cysts	3.5
Acritarchs (principally <i>Michrhystridium inconspicuum</i> )	15.2
Total	18.7

Calculated number of grains per gram: 42,300.

drilled through the Cretaceous section in the area of this investigation by the JOIDES deep-drilling program (Leg 1).

#### SYSTEMATIC PALEONTOLOGY

Seventy-six species of spores and pollen and thirty species of dinoflagellate cysts and acritarchs are described. The following eleven species and one genus, *Discoidea*, are formally proposed as new.

##### 1) Spores

*Verrucatosporites? rugulatus*

*Gleicheniidites lamontensis*

*Hymenophyllumsporites pseudoreticulatus*

##### 2) Pollen

*Ephedripites fusiformis*

*Psilatricolpites psilatus*

*Retitricolpites magnificus*

##### 3) Palynomorphs of uncertain affinity

*Discoidea hanna*

##### 4) Dinoflagellate cysts

*Scriniodinium heusseri*

*Xenikoon americanus*

##### 5) Acritarchs

*Baltisphaeridium stellatum*

*Prismatocystis cylindrica*

The classification of dispersed Cretaceous pollen and spores has varied in the literature from one in which most or many of the palynomorphs are placed in modern genera and families (Bolkhovitina, 1953; Stanley, 1965a) to one based wholly on morphologic characteristics (Dettmann, 1963). Either scheme, when adopted exclusively, is felt to be lacking in several important respects. Attempts at a completely natural system, especially at the generic level, can be misleading when there are insufficient data. For example, dispersed cicatricose spores belonging to the species *Appendicisporites tri-*

*cornitatus* of schizaeaceous affinity have been placed in the modern genus *Anemia* (Stanley, 1965), although other genera (e.g., *Ceratopteris*) of the family Schizaeaceae produce cicatricose spores as well (van der Hammen and González, 1960). The legitimate placing of dispersed spores and pollen in modern genera must await direct evidence from fossil fructifications. Pollen and spore morphology is more or less consistent at the family and higher levels but may vary among species of a single genus.

Also, the generic characters of plants producing pollen and spores similar to modern plants can not be assumed to have been fixed through the last 110 million years without additional supporting macrofossil evidence. The evidence from macrofossil studies that has come to bear on this problem has shown that fossil spores similar to those produced by modern genera often should be assigned to fossil taxa. Couper (1958), for example, has shown that spores similar to those of *Anemia* were produced by the Mesozoic plant *Ruffordia goepperti*.

A completely morphographic suprageneric system for Cretaceous palynomorphs leaves as much to be desired, since it does not take into account that macro-paleobotanical knowledge which is available. Also, it forms unnatural relationships between types which are morphologically similar but evidently of different origin.

The writer prefers to follow the scheme of Brenner (1963), who used a natural suprageneric classification where he felt confident, while acknowledging that the palynomorphs must otherwise be placed in form genera and species.

The dinoflagellate cysts are placed in natural families only where the natural family appears to be well known in the literature. The descriptive terminology defined by Evitt (1961) and Davey, Downie, Sarjeant and Williams (1966) is followed for the most part. The acritarchs are classified according to the scheme proposed by Downie, Evitt and Sarjeant (1963).

Division BRYOPHYTA  
Class MUSCI  
Order SPHAGNALES  
Genus STEREISPORITES Pflug, 1953

***Stereisporites antiquasporites*** (Wilson and Webster) Dettmann  
Plate 1, figure 1

**Remarks:** This species is similar to *Sphagnumsporites psilatus* (Ross) but is readily distinguished by its distal polar thickening.

**Occurrence:** Rarely counted, but most frequently observed in core RC10-282.

Division LYCOPODOPHYTA  
Class LYCOPODOPSIDA  
Order LYCOPODIALES  
Genus LYCOPODIUMSPORITES Thiergart ex Delcourt and Sprumont, 1955

***Lycopodiumsporites austroclavatidites*** (Cookson) Potonié  
Plate 3, figure 3

**Occurrence:** Observed only in core RC10-284. Dettmann (1963) reports this species as widely distributed in Jurassic and Cretaceous sediments.

***Lycopodiumsporites clavatoides*** Couper  
Plate 3, figure 2

**Occurrence:** Rare.

Genus CAMARAZONOSPORITES Potonié, emend. Klaus, 1960

***Camarazonosporites rudis*** (Leschik) Klaus  
Plate 3, figure 5

**Occurrence:** Observed in cores RC10-281, RC10-282, RC10-283.

Genus VERRUCATOSPORITES Pflug, 1952

***Verrucatosporites? rugulatus*** Habib, n. sp.  
Plate 3, figure 6

**Diagnosis:** Bilaterally symmetrical monolete spores, suboval in equatorial view, with markedly convex distal surface and slightly convex to flat proximal surface, elliptical in polar view. Monolete mark distinct, extending more than two-thirds of the maximum diameter of the specimen, attended by secondary folds. Ornamentation rugulate, covering the distal surface and the peripheral part of the proximal surface. Exine frequently torn in the haptotypic area.

Seven specimens range from 31 to 52 microns in maximum diameter.

**Holotype:** Plate 3, figure 6. 48×35 microns. Slide RC10282B11.

**Remarks:** This species is provisionally assigned to *Verrucatosporites*, which apparently contains no other rugulate species. Except for differences in symmetry and type of tetrad scar, *V? rugulatus* is almost identical with *Camarazonosporites rudis* (Leschik). The similar range in size and similar rugulate ornamentation raise the likelihood that these forms were produced by the same plant species. Selling (1946) described the spores of extant *Lycopodium*, to which *Camarazonosporites rudis* is very similar, and showed that several species, e.g., *L. haleakalae* and *L. erubescens*, produce both trilete and monolete spores.

**Occurrence:** Less than one per cent, but found in the same cores as *C. rudis*.

Genus LYCOPODIACIDITES Leschik, emend. Potonié, 1956

**Lycopodiacidites ambifoveolatus** Brenner

Plate 2, figure 13

*Occurrence:* Rare.

Division ARTHROPHYTA

Genus CALAMOSPORA Schopf, 1944

Cf. **Calamospora mesozoica** Couper

Plate 1, figure 7

Cf. *Calamospora mesozoica* COUPER, 1958, p. 132.

*Occurrence:* Found in core RC10-284.

Division PTERIDOPHYTA

Class PTEROPSIDA

Order FILICALES

Family CYATHEACEAE

Genus CYATHIDITES Couper, 1953

**Cyathidites minor** Couper

Plate 1, figures 2, 4

*Remarks:* Several specimens which were discovered to be folded into a subcircular outline are included in this species. Dettmann (1964) has emphasized the importance of the outline, in polar view, for distinguishing *Cyathidites*, *Deltoidospora* and *Leiotriletes*.

*Occurrence:* Present in all of the cores.

**Cyathidites australis** Couper

Plate 1, figure 5

*Occurrence:* Irregularly distributed.

Family OSMUNDACEAE

Genus TODISPORITES Couper, 1953

**Todisporites minor** Couper

Plate 1, figure 3

*Occurrence:* Couper (1958) originally reported this species from the Middle Jurassic of England.

Family MATONACEAE

Genus MATONISPORITES Couper, emend. Dettmann, 1963

**Matonisporites equixinous** Couper

Plate 1, figures 9-10

*Occurrence:* Rare. A few specimens were counted.

**Matonisporites excavatus** Brenner

Plate 1, figure 12

*Occurrence:* Rare. Four specimens were found, three in core RC10-283 and one in RC10-282.

**Matonisporites impensus** Hedlund

Plate 2, figure 12

*Occurrence:* Rare. A few specimens were found in cores RC10-282, RC10-283, and V22-8.

**Matonisporites** sp. A

Plate 1, figure 11

*Description:* Trilete spore. Outline in polar view oblate-triangular, with gently convex interrational margins and well-rounded, slightly thickened, radial corners. Trilete mark distinct, extending more than three-fourths of the distance to the radial corners. The sutures are undulatory in the polar area but bifurcate and straight near the corners. Thin undulatory lips attend the sutures. Interrational crassitude is vague, becoming more distinct towards the corners. Exine smooth, approximately 2 microns thick, thickening at the radial corners to form rounded valvae which only slightly interrupt the smooth outline of the grain. The specimen measures 29×29 microns.

*Occurrence:* The specimen was recovered from core RC10-283.

Family GLEICHENIACEAE

Genus GLEICHENIIDITES Ross ex Delcourt and Sprumont, 1955

**Gleicheniidites circinidites** (Cookson) Brenner

Plate 2, figure 1

*Occurrence:* The most abundant species of *Gleicheniidites* in the cores, and the second most abundant spore species in core RC10-284. *G. circinidites* is a long-ranging species, and has been reported from Jurassic, Cretaceous, and Tertiary assemblages.

**Gleicheniidites senonicus** Ross

Plate 2, figure 2

*Occurrence:* This species was most frequently observed in core RC10-284. It occurs commonly in Mesozoic assemblages.

**Gleicheniidites severus** Habib

Plate 2, figure 3

*Occurrence:* Infrequent, but observed in all cores.

**Gleicheniidites apilobatus** Brenner

Plate 2, figure 4

*Occurrence:* Frequent in core RC10-284. Rare in the other cores.

**Gleicheniidites marciae** Habib

Plate 2, figure 5

*Occurrence:* This species was observed only in the bottom sample from core RC10-284

**Gleicheniidites lamontensis** Habib, n. sp.

Plate 2, figures 6-8

*Diagnosis:* Trilete spores. Outline in polar view triangular with concave to nearly straight interrational



margins and rounded radial corners. Trilete mark distinct, extending to the radial corners; sutures straight or slightly undulatory. The sutures are attended by raised, smooth, wide lips, which are widest (up to 7 microns) in the polar areas. Equatorial crassitudes occur at the interrational margins. They vary from pronounced (4 microns thick in polar view) to barely discernible (1.5 microns thick) and tend to reduce the concavity of the interrational margins. Exine outside of crassitudinous areas relatively thin, measuring approximately 1 micron in thickness, covered with grana. Ten measured specimens range from 18 to 32 microns.

**Holotype:** Plate 2, figure 6. 22×18 microns. Slide RC10282B12.

**Remarks:** *Gleicheniidites lamontensis* is distinguished by its small size, interrational crassitudes, smooth lips, and granulate ornamentation.

**Occurrence:** Frequent in core RC10–282. Rare in RC10–283, RC10–281, and V22–8. It was not found in core RC10–284.

***Gleicheniidites triangularis*** (Stanley) Habib, n. comb.  
Plate 2, figure 10

*Gleichenia triangularis* STANLEY, 1965, p. 247, pl. 28, figs. 17–19.

**Remarks:** As Stanley's species apparently was not described from sporangia of fossil *Gleichenia*, it is placed in the form genus *Gleicheniidites*.

**Occurrence:** Rare. The species was found only in samples from cores RC10–282, RC10–283 and V22–8.

Family HYMENOPHYLLACEAE  
Genus HYMENOPHYLLUMSPORITES Rouse, 1957

***Hymenophyllumsporites pseudoreticulus*** Habib, n. sp.  
Plate 2, figure 9

**Diagnosis:** Trilete spores, circular to subcircular in polar view. Trilete mark sutures straight, extending to the periphery where they bifurcate, bordered by slightly raised and wide (up to 2.5 microns) lips which also bifurcate at the periphery and then join with the lips of the other two sutures. Exine ornamented with grana or infracratae. With slight focusing in either direction the grana give the appearance of a microreticulate pattern. At the periphery is a zone of spore wall thickening which measures approximately 2.5 microns. On the distal surface there is an arcuate foveolate structure in the polar area which measures approximately 10 microns in diameter. Eight specimens range from 45 to 53 microns in diameter.

**Holotype:** Plate 2, figure 9, 50×47 microns. Slide RC10282B1.

**Remarks:** *Hymenophyllumsporites pseudoreticulus* is characterized by its ornamentation, bifurcating sutures and distal foveolae. It resembles species of *Taurocuspites* in its possession of distal foveolae.

**Occurrence:** Rare. No specimens were counted.

Family SCHIZAEACEAE  
Genus CICATRICOSISPORITES Potonié and Gellertich, 1933

***Cicatricosisporites australiensis*** (Cookson) Potonié  
Plate 3, figure 10

**Occurrence:** Rare. Although the species was rarely encountered, it was found in all cores.

Genus APPENDICISPORITES Weyland and Kreiger, 1953

***Appendicisporites tricornitatus*** Weyland and Greifeld  
Plate 3, figure 9

**Occurrence:** Rare. The species was most frequently encountered in the sample from core RC10–283.

Genus ISCHYOSPORITES Balme, 1957

***Ischyosporites punctatus*** Cookson and Dettmann  
Plate 3, figure 1

**Occurrence:** A single specimen was found in the sample of core RC10–282.

SPORAE INCERTAE SEDIS  
Genus APICULATISPORIS Potonié and Kremp, 1956

***Apiculatisporis babsae*** Brenner  
Plate 2, figure 15

**Remarks:** Six specimens were discovered, all of which agree well with the diagnosis given by Brenner (1963).

**Occurrence:** The species was observed in cores V22–8, RC10–282, and RC10–283.

Genus CONCAVISPORITES Pflug, 1953

***Concavisporites lamontis*** Habib  
Plate 1, figure 6

**Occurrence:** Found only in core RC10–284.

***Concavisporites verrucosus*** (Delcourt and Sprumont) Pocock  
Plate 3, figure 7

**Occurrence:** Rarely counted. *C. verrucosus* was found most frequently in cores RC10–281, RC10–282, and RC10–283. It was not observed in core RC10–284. Pocock (1962) reported this species from the Upper Jurassic and Lower Cretaceous (Neocomian) of western Canada.

Genus ECHINATISPORIS Krutzsch, 1959

**Echinatisporis longechinus** Krutzsch

Plate 2, figure 14

*Occurrence:* Rare.

Genus ENDOSPORITES Wilson and Coe, 1940

**Endosporites** ? sp. A

Plate 3, figure 13

*Description:* Monosaccate trilete spore. Outline in polar view roundly triangular, with convex interrational margins and rounded acute radial corners. Central body roundly triangular, generally conforming to outline of specimen, relatively thin, measuring one micron in thickness or less, occupying approximately one-half of the area of the saccus in outline. Saccus thin, measuring approximately one micron in thickness, covered throughout its surface with an infragranulate ornamentation. Trilete mark distinct, reaching the radial corners, irregularly undulatory, with attending lips which are high but not wide. The specimen measures  $37 \times 30$  microns.

*Remarks:* The single specimen is provisionally assigned to *Endosporites*, although the lack of a distinct limb suggests assignment to another genus. From this single specimen, the position of the central body on the distal or proximal surface of the saccus could not be determined. It is very similar to the species described by Drugg (1967) as *Applanopsis dettmannae*.

Genus FORAMINISPORIS Krutzsch, 1959

**Foraminisporis dailyi** (Cookson and Dettmann) Dettmann

Plate 2, figure 11

*Occurrence:* A few specimens were observed.

Genus LAEVIGATOSPORITES Ibrahim, 1933, emend. Schopf, Wilson and Bentall, 1944

**Laevigatosporites ovatus** Wilson and Webster

Plate 3, figure 11

*Occurrence:* Found in all cores, this species has been reported in assemblages ranging from Lower Cretaceous to Paleocene.

**Laevigatosporites scabratus** (Couper) Habib, n. comb.

Plate 3, figure 12

*Marattisporites scabratus* COUPER, 1958, p. 133.

*Remarks:* Couper (1958, p. 133) erected the genus *Marattisporites* for dispersed monolete spores with scabrate or finely granulate ornamentation. Schopf, Wilson, and Bentall (1944) had previously emended *Laevigatosporites* Ibrahim to include spores assigned by Couper to *Marattisporites*.

According to Couper (1958), *L. scabratus* occurs in Jurassic and Lower Cretaceous assemblages. He noted its morphological similarity to spores produced by extant *Marattia* and by Mesozoic species of *Marattiopsis*.

*Occurrence:* Rare.

Genus TAUROCUSPORITES Stover, 1962

**Taurocosporites reduncus** (Bolkhovitina) Stover

Plate 3, figure 4

*Occurrence:* Rare. This species has been reported from assemblages ranging in age from Middle Jurassic to Senonian.

**Taurocosporites segmentatus** Stover

Plate 3, figure 8

*Occurrence:* Rare. This species has been reported from the Lower Cretaceous of the Atlantic Coastal Plain and western Canada.

Genus TRIPLANOSPORITES Pflug, 1953

**Triplanosporites sinuosus** Pflug

Plate 1, figure 8

*Occurrence:* Only a few specimens were found.

Genus UNDULATISPORITES Thomson and Pflug, 1953

Cf. **Undulatisporites sinuosus** Groot and Groot

Plate 2, figure 16

*Remarks:* Several specimens agreeing generally with the species *U. sinuosus* described by Groot and Groot (1962) were found, however, to have their sutures bifurcate at their radial tips. Couper (1958) compared spores of this morphology with immature forms produced by *Aneimia phyllidites*.

*Occurrence:* A few specimens were observed in cores RC10-282 and RC10-283. Groot and Groot (1962) reported *Undulatisporites sinuosus* from the Cenomanian of Portugal.

Division GYMNOSPERMOPHYTA

Class CYCADOPSIDA

Order CAYTONIALES

Genus VITREISPORITES Leschik, 1955

**Vitreisporites pallidus** (Reissinger) Brenner

Plate 5, figure 2

*Occurrence:* Frequent in cores RC10-281 to RC10-284. Rare in V22-8.

INCERTI ORDINIS

Genus GINKGOCYCADOPHYTUS Samilovich, 1953

**Ginkgocycadophytus nitidus** (Balme) de Jersey

Plate 6, figure 3

*Occurrence:* Irregularly distributed in the samples.

Genus MONOSULCITES Cookson ex Couper, 1953

***Monosulcites minimus*** Cookson ex Couper  
Plate 6, figure 1

**Occurrence:** *Monosulcites minimus* is most common in the sample from core RC10–284. Couper (1958) reported this species as having been recovered from Jurassic, Cretaceous, and Tertiary assemblages. In the Atlantic Coastal Plain, the species has been observed in Albian and Cenomanian assemblages (Groot, Penny and Groot, 1961).

***Monosulcites glottus*** Brenner  
Plate 5, figure 8

*Monosulcites glottus* BRENNER, 1963, p. 75, pl. 25, fig. 7.  
*Monosulcites inspissatus* HEDLUND, 1966, p. 28, pl. 8, fig. 6a–b. — HABIB, 1969, p. 87, pl. 3, fig. 2.

**Remarks:** Brenner (1963) and Hedlund (1966) described new species of small monocolpate grains which were characterized by bordering secondary folds. The range in size, occurrence of folds, and ornamentation indicate that these two forms are conspecific.

**Occurrence:** Rare.

***Monosulcites epakros*** Brenner  
Plate 5, figure 9

**Occurrence:** Irregularly distributed. Brenner (1963) discovered this species in assemblages of the Potomac Group of Maryland.

***Monosulcites chaloneri*** Brenner  
Plate 6, figure 9

**Occurrence:** Rarely counted but distributed through the five cores. Brenner (1963) reported this species as abundant to rare, but restricted to Zone II (Albian) of the Potomac Group in Maryland.

Class CONIFEROPSIDA  
Order CONIFERALES  
Genus PLATYSACCUS Naumova ex Potonié and Klaus, 1954

***Platysaccus elizabethae*** Habib  
Plate 4, figure 3

**Remarks:** The species is similar to *Podocarpidites multesimus* (Bolkhovitina) but differs in the more circular sacchi, and closer attachment of sacchi to the polar region of the central body.

**Occurrence:** Rare in all samples.

Genus ALISPORITES Daugherty, 1941

***Alisporites bilateralis*** Rouse  
Plate 5, figure 6

**Occurrence:** Frequent in core RC10–284. Elsewhere rare.

Genus ABIETINEAE-POLLENITES Potonié, 1951

***Abietinaepollenites microreticulatus*** Groot and Penny  
Plate 4, figure 4

**Occurrence:** Ubiquitous in its distribution. *Abietinaepollenites microreticulatus* is abundant in core RC10–284, and rare in RC10–281, RC10–282, RC10–283, and V22–8.

***Abietinaepollenites dunrobinensis*** Couper  
Plate 4, figure 6

**Occurrence:** Frequent in core RC10–284. Rare in the other cores.

Genus RUGUBIVESICULITES Pierce, 1961

***Rugubivesiculites reductus*** Pierce  
Plate 4, figure 7

**Remarks:** Specimens assigned to *R. reductus* in this study measure slightly larger than the species illustrated by Pierce (1961), Brenner (1963), and Muller (1968), but fall within the size range described by Pierce (1961).

**Occurrence:** The species comprises less than 2.5% of the microflora in any of the samples. It was not observed in core RC10–284.

Species of *Rugubivesiculites* have been used as guide fossils of the Cenomanian–Turonian section in the Atlantic Coastal Plain. Brenner (1963) and Groot (personal communication) have observed the genus in Cenomanian deposits of Maryland and New Jersey, and in upper Albian ? sediments. Leopold and Pakiser (1964, pl. 7, figs. 8–13) have discovered rugulate bisaccate grains corresponding to *Rugubivesiculites* in the pre-Selma subsurface of the Alabama plain.

The genus has also been reported from the mid-continent in assemblages interpreted to be of Cenomanian age (Pierce, 1961; Hedlund, 1966). Muller (1968), however, described a biostratigraphic zone in northwest Borneo defined by *R. reductus* as most likely of Senonian age.

Genus PARVISACCITES Couper, 1958

***Parvisaccites radiatus*** Couper  
Plate 5, figures 3–4

**Occurrence:** The most widely distributed species of *Parvisaccites*, *P. radiatus*, is rare.

***Parvisaccites majesticus*** Habib

Plate 4, figure 5a–b; plate 5, figure 1

**Remarks:** Habib (1969) distinguished *Parvisaccites majesticus* by its greater over-all length compared to

width. The central body of *P. radiatus* was found to be oval to subcircular, whereas the central body of *P. majesticus* is elliptical. Furthermore, the central body of *P. majesticus* has a large and irregular margin.

*Occurrence:* Rare in investigated cores.

Genus PTERUCHIPOLLENITES Couper, 1958

***Pteruchipollenites crenulatus*** Habib

Plate 5, figure 5

*Occurrence:* Restricted to core RC10–284. Couper (1958) reported species of *Pteruchipollenites* from the Jurassic of Great Britain.

***Pteruchipollenites transversus*** Habib

Plate 5, figure 13

*Occurrence:* This species was observed only in the bottom sample from core RC10–284.

Genus TSUGAEPOLLENITES Potonié and Venitz, emend. Potonié, 1958

***Tsugaepollenites dampieri*** (Balme) Dettmann

Plate 4, figure 2

*Occurrence:* This species was observed in all of the investigated samples.

***Tsugaepollenites discoides*** (Kiyai) Habib, n. comb.

Plate 4, figure 1

*Discisporites discoides* KIMYAI, 1966, p. 468, pl. 1, fig. 16.

*Remarks:* Monosaccate trilete pollen grains described by Kiyai (1966) as a species of *Discisporites* conform well with the generic diagnosis of *Tsugaepollenites* given by Potonié (1958) and Dettmann (1963).

*Occurrence:* Present in samples from cores RC10–282 and RC10–284.

Genus LARICOIDITES Potonié, Thomson and Thiergart, 1950

***Laricoidites magnus*** (Potonié) Potonié, Thomson and Thiergart

Plate 5, figure 11

*Occurrence:* This species occurs in all samples except the one from the bottom of core RC10–284.

Family ARAUCARIACEAE

Genus ARAUCARIACITES Cookson ex Couper, 1953

***Araucariacites limbatus*** (Balme) Habib

Plate 6, figure 14

*Occurrence:* This species is irregularly distributed.

Order TAXODIALES

Family TAXODIACEAE

Genus TAXODIACEAEPOLLENITES Kremp, 1949

***Taxodiaceapollenites hiatus*** (Potonié) Kremp

Plate 5, figure 10

*Occurrence:* This species becomes most common in core RC10–283.

Class CHLAMYDOSPERMOPSIDA

Order GNETALES

Family EPHEDRACEAE

Genus EPHEDRIPITES Bolkhovitina, 1953

***Ephedripites multicostatus*** Brenner

Plate 6, figures 4–5

*Occurrence:* The most abundant species of *Ephedripites*, *E. multicostatus*, was most frequently observed in core RC10–283.

***Ephedripites fusiformis*** Habib, n. sp.

Plate 6, figure 7

*Diagnosis:* Polyplicate pollen grains, elongate fusiform in outline. Exine approximately 1.0–1.5 microns thick, covered with from four to six psilate plications which extend the entire maximum diameter and taper towards the polar areas. The plications are distinct and measure approximately 3–5 microns in width in the equatorial area. Five specimens range from 30 to 34 microns along the polar axis.

*Holotype:* Plate 6, figure 7. 34×9 microns. Slide RC10 282B1.

*Remarks:* This species can be identified by its slender fusiform outline and few plications.

*Occurrence:* Five specimens were observed, in cores RC10–281, RC10–282, and RC10–283. None was counted.

POLLEN INCERTAE SEDIS

Genus CLASSOPOLLIS Pflug, emend. Couper, 1958

***Classopollis torosus*** (Reissinger) Couper

Plate 6, figure 12

*Occurrence:* *Classopollis torosus* forms 16.6% of the spores and pollen in core RC10–283, where it is most abundant. It is also abundant in cores RC10–281 and RC10–282.

Genus CLAVATIPOLLENITES Couper, 1958

***Clavatipollenites hughesii*** Couper

Plate 6, figure 10

*Occurrence:* This species is most abundant in the sample from core RC10–284, where it amounts to 8.5% of the assemblage. It is less than one per cent in the other cores except in RC10–283, where it is 3.0%.

Couper (1964) listed *Clavatipollenites hughesii* as a guide form for the upper Lower Cretaceous (upper Hauterivian–Albian). The general absence of this species in Upper Cretaceous assemblages (Drugg, 1967; Muller, 1968; Stanley, 1965) supports its value as a key species for the Middle Cretaceous.

***Clavatipollenites maximus* Habib**

Plate 6, figure 11

**Occurrence:** This species was observed in cores RC10–282, RC10–283, RC10–284, and V22–8. It was counted only in core RC10–284.

Genus LILIACIDITES Couper, 1953

***Liliacidites dividius* (Pierce) Brenner**

Plate 6, figure 6

*Retimonocolpites dividius* PIERCE, 1961, p. 47, pl. 3, fig. 87.

*Liliacidites dividius* (Pierce). – BRENNER, 1963, p. 93, pl. 40, figs. 7–10.

*Clavatipollenites rotundus* KEMP, 1968, p. 424, pl. 79, figs. 1–19; pl. 80, figs. 1–8.

**Remarks:** Kemp (1968) distinguished *Clavatipollenites rotundus* from *Liliacidites dividius* by the former species' tendency to fold more easily. Specimens of both types occur together and are considered to be conspecific.

**Occurrence:** *Liliacidites dividius* is most abundant in core RC10–284. Pierce (1961) first described it from Cenomanian deposits in Minnesota, and it has subsequently been reported from Middle Cretaceous assemblages in the Atlantic Coastal Plain and Great Britain. It is apparently lacking in upper Upper Cretaceous assemblages.

Genus EUKOMMIIDITES Erdtman, 1948, emend. Hughes, 1961

***Eukommiidites troedssonii* Erdtman ex Hughes**

Plate 6, figure 2

**Occurrence:** This species forms less than one per cent in every core except RC10–283, where it reaches 3.0%.

Genus INAPERTUROPOLLENITES Pflug, emend. Potonié, 1958

***Inaperturopollenites dubius* (Potonié and Venitz) Thomson and Pflug**

Plate 5, figure 7

**Occurrence:** The species is rare in all cores.

Genus PALMAEPOLLENITES Potonié, 1958

***Palmaepollenites asymmetricus* (Pierce) Habib, n. comb.**

Plate 6, figure 15

*Granamonocolpites asymmetricus* PIERCE, 1961, p. 46, pl. 3, fig. 85.

*Monosulcites scabrus* BRENNER, 1963, p. 95, pl. 42, fig. 1.

**Remarks:** Potonié (1958) described *Palmaepollenites* as monocolpate pollen grains with a marked oval, asymmetric outline in polar view, and with infra-granulate ornamentation. The species *Granamonocolpites asymmetricus* Pierce conforms well with the generic diagnosis given by Potonié (1958). *Monosulcites scabrus* Brenner is considered to be a junior synonym of *Palmaepollenites asymmetricus*, as specimens ranging down to 30 microns maximum diameter were observed in the samples.

**Occurrence:** Irregularly distributed through the cores, but not found in RC10–284. Fourteen specimens were observed, but only one was counted. Brenner (1963) listed this species as restricted to the Patapsco Formation (Albian). Pierce (1961) described it from the Cenomanian of Minnesota.

Genus PALMIDITES Couper, 1953

**Cf. *Palmidites maximus* Couper**

Plate 6, figure 16

**Remarks:** A single specimen corresponding closely to *Palmidites maximus* was observed.

**Occurrence:** Core RC10–283.

PLATE 1

Magnification approximately  $\times 850$

- |   |  |
|---|--|
| 1 <i>Stereisporites antiquasporites</i> (Wilson and Webster) Dettmann | 6 <i>Concavisporites lamontis</i> Habib      |
| 2, 4 <i>Cyathidites minor</i> Couper                                  | 7 Cf. <i>Calamopsora mesozoica</i> Couper    |
| 3 <i>Todisporites minor</i> Couper                                    | 8 <i>Triplanosporites sinuosus</i> Pflug     |
| 5 <i>Cyathidites australis</i> Couper                                 | 9–10 <i>Matonisporites equixinous</i> Couper |
|   | 11 <i>Matonisporites</i> sp. A               |
|   | 12 <i>Matonisporites excavatus</i> Brenner   |





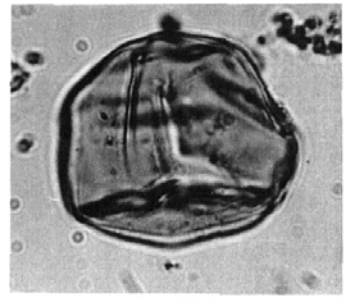
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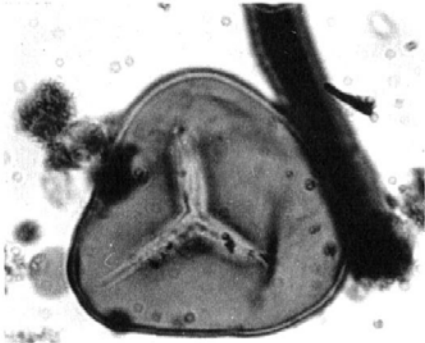
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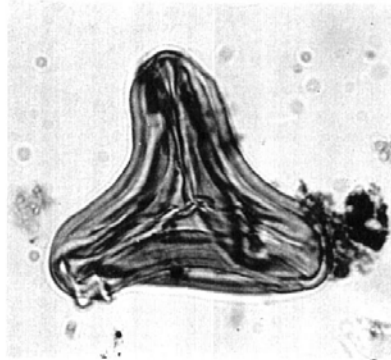
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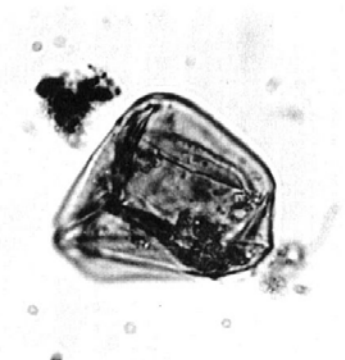
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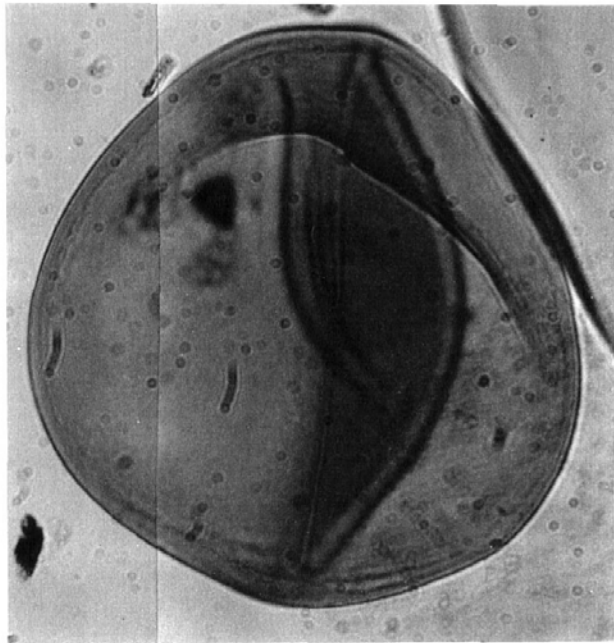
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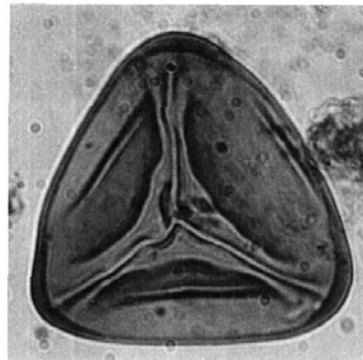
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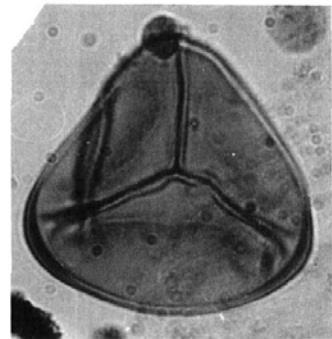
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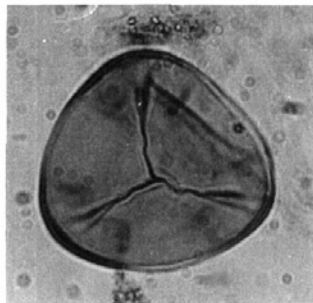
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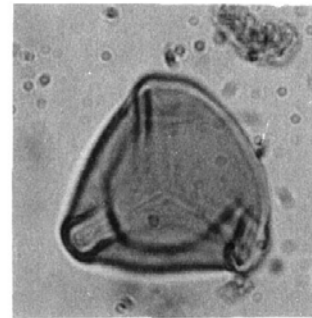
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Genus PERINOPOLLENITES Couper, 1958

**Perinopollenites elatoides** Couper  
Plate 6, figure 13

**Remarks:** Couper (1958) described *Perinopollenites elatoides* as double-layered monoporate pollen grains with a thin, easily folded, loosely covering outer layer and slightly thicker inner layer. He noted its morphological resemblance to pollen grains of the Middle Jurassic gymnosperm *Elatides williamsoni* (Brongniart) Seward. From his photographs of the pollen of *E. williamsoni* (pl. 27, figs. 7–8) and the dispersed grains *P. elatoides* (pl. 27, figs. 9–11), the pore of the outer layer appears at least twice the diameter of that in the inner layer. This is also illustrated in plate 6, figure 13 of the present study. The form and size of the pore of the outer layer, as well as the morphology of the entire layer itself, correspond closely with those of the specimens provisionally assigned to *Exesipollenites tumulus* in this study and elsewhere (Brenner, 1963; Muller, 1968). It may well be possible, therefore, that the species *E. tumulus* may be conspecific with *P. elatoides*.

**Occurrence:** Counted together with cf. *Exesipollenites tumulus*, these species are most abundant in cores RC10–281, RC10–282, and RC10–283.

Genus EXESIPOLLENITES Balme, 1957

Cf. **Exesipollenites tumulus** Balme  
Plate 6, figure 8

**Remarks:** Although all specimens assigned to *Exesipollenites tumulus* in this study possess the circular opening typical of this species, not all were darkened around the opening.

**Occurrence:** Present in all cores but RC10–284, this species was counted together with *Perinopollenites elatoides*.

Genus SPHERIPOLLENITES Couper, 1958

**Spheripollenites psilatus** Couper  
Plate 5, figure 12

**Occurrence:** Very common in core RC10–284, *Spheripollenites psilatus* forms 7.1 per cent of the total palynomorph assemblage and 9.3 per cent of the spores and pollen. It is the most abundant nonsaccate pollen species. Rare in the remaining cores, the species was counted in cores RC10–281, RC10–282, and RC10–283.

Couper (1958) discovered this species in Wealden and Aptian assemblages of Great Britain. Brenner (1963) recorded a species of *Spheripollenites* (*S. perinatus*) from the Potomac Group of Maryland. Dettmann (1964) reported *S. psilatus* from Valanginian–Albian sediments in southeastern Australia.

Division ANGIOSPERMOPHYTA

Class DICOTYLEDONAE

Genus TRICOLPITES Cookson ex Couper, 1953

**Tricolpites auritus** (Bolkhovitina) Habib, n. comb., emend.  
Habib  
Plate 7, figures 8–9

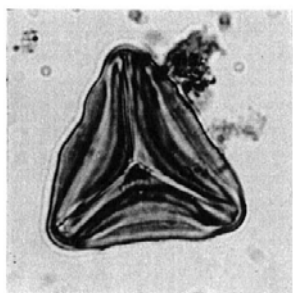
*Quercus aurita* BOLKHOVITINA, 1953, p. 92, pl. 15, figs. 19–28.

**Emended diagnosis:** Prolate, tricolpate pollen grains. Outline in equatorial view rounded-elliptical or flattened semicircular for two-thirds the outline, the remainder gently convex to almost straight; polar area slightly flattened; in polar view, the outline is more-or-less

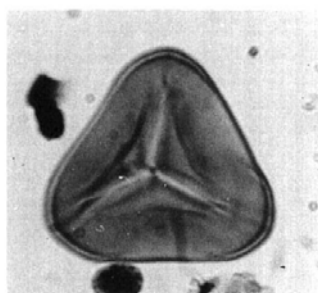
## PLATE 2

Magnification approximately  $\times 850$

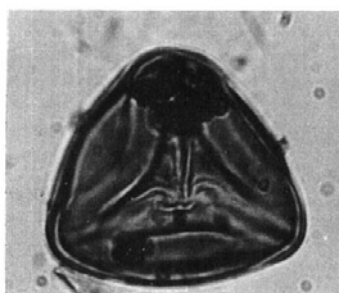
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|--|--|
| 1 <i>Gleicheniidites circinidites</i> (Cookson) Brenner  | 9 <i>Hymenophyllumsporites pseudoreticulatus</i> Habib, n. sp. Holotype. |
| 2 <i>Gleicheniidites senonicus</i> Ross  | 10 <i>Gleicheniidites triangulus</i> (Stanley) Habib, n. comb.           |
| 3 <i>Gleicheniidites severus</i> Habib   | 11 <i>Foraminisporis dailyi</i> (Cookson and Dettmann) Dettmann          |
| 4 <i>Gleicheniidites apilobatus</i> Brenner  | 12 <i>Matonisporites impensus</i> Hedlund                                |
| 5 <i>Gleicheniidites marciae</i> Habib   | 13 <i>Lycopodiacidites ambifoveolatus</i> Brenner                        |
| 6–8 <i>Gleicheniidites lamontensis</i> Habib, n. sp.<br>6, holotype. Note variation in thickness of inter-radial crassitude from pronounced in figure 6 to barely discernible in figure 8. | 14 <i>Echinatisporis longechinus</i> Krutzsch                            |
|  | 15 <i>Apiculatisporis babsae</i> Brenner                                 |
|  | 16 Cf. <i>Undulatisporites sinuosus</i> Groot and Groot                  |



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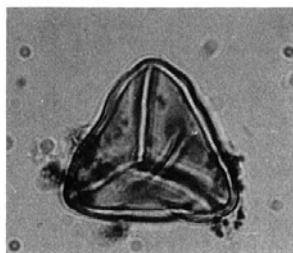
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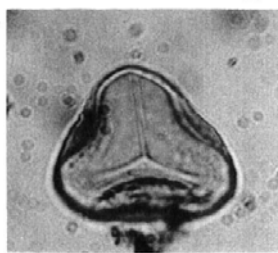
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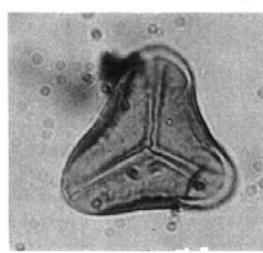
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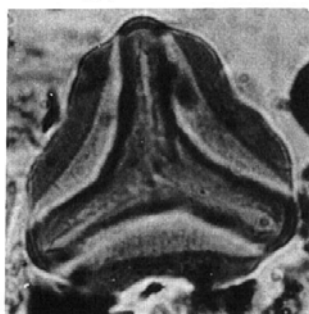
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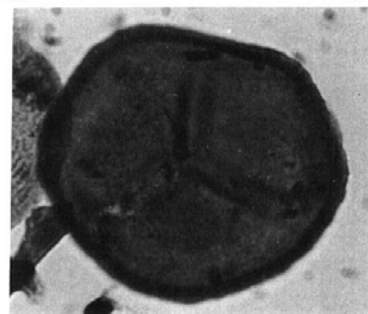
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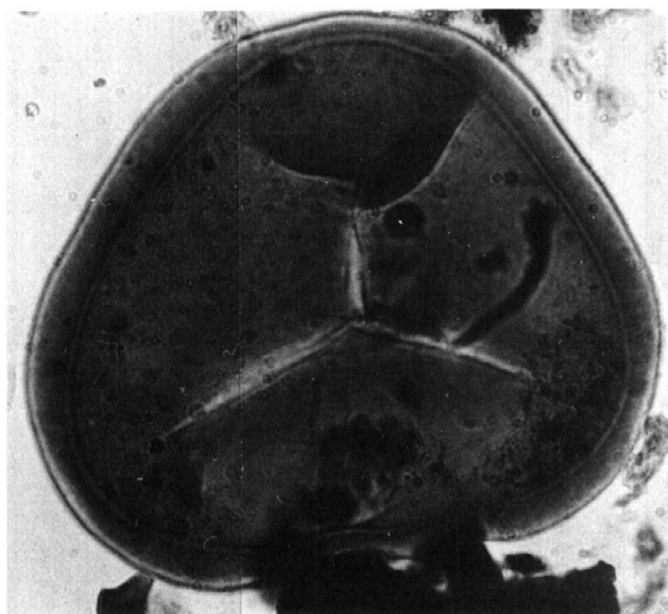
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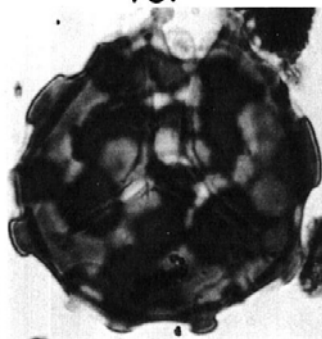
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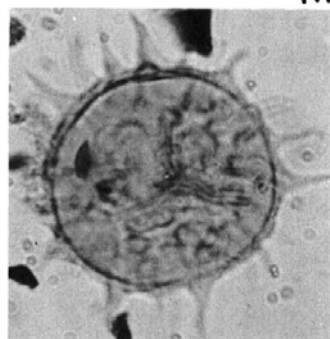
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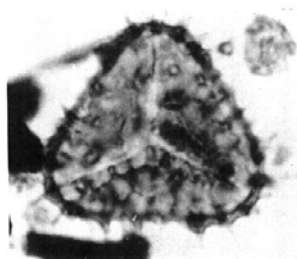
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circular, with three colpi separated by 120°. Colpi are long, thin and straight, extending more than three-fourths of the maximum dimension of the grains. They are frequently opened, but are not attended by any annulate structure and consequently appear thickened by secondary folds. Ektexine scabrate or infracolumellate, approximately 2 to 2.5 microns thick. Endexine psilate, approximately 1.5 to 2 microns thick, invariably darker than the ektexine and always thinner.

Twenty measured specimens range in size from 25 to 42 microns.

**Remarks:** The flattened shape of many specimens is due to their compression with one colpus at the outline in profile (plate 7, figure 8a–b). Although the holotype specimen was not observed prior to the emended diagnosis, Bolkhovitina's (1953) drawings relate her species to the specimens observed in this study. The species is assigned to *Tricolpites*, since its correct natural position, whether in *Quercus* or any other extant genus, must await valid macropaleobotanical evidence. On the basis of morphology alone, *T. auritus* could be placed in any of several genera of the dicotyledons.

**Occurrence:** This species was counted in all of the cores, but in none of them did it exceed 5%.

Bolkhovitina (1953) described *Tricolpites auritus* in assemblages ranging from lower Albian to Cenomanian in age.

Genus PSILATRICOLPITES van der Hammen, 1956

***Psilatricolpites psilatus* Habib, n. sp.**  
Plate 7, figure 5–6

**Description:** Prolate tricolpate pollen grains. Outline in equatorial view elliptical, flattened in the polar areas; outline in polar view subcircular, each colpus approximately 120° separated from each of the other two. Colpi long, extending three-fourths and more of the

distance to the poles, frequently opened. Ektexine psilate; endexine invariably darker than the ektexine and thinner, measuring approximately 1.5 microns thick.

Fifteen measured specimens range in size from 30 to 36 microns.

**Holotype:** Plate 7, figure 5. 33×22 microns. Slide RC10283B3.

**Remarks:** *Psilatricolpites psilatus* is distinguished by its size, long colpi, and lack of ornamentation. The species is similar to *T. auritus*, except that the latter possesses a structured ektexine.

**Occurrence:** Present in all of the cores except RC10–284.

Genus TRICOLPOPOLLENITES Thomson and Pflug, 1953

***Tricolpopollenites minutus* Brenner**  
Plate 7, figure 3

**Occurrence:** Present in all of the cores, *T. minutus* is the most abundant species of *Tricolpopollenites*.

***Tricolpopollenites polyhedrus* Habib**  
Plate 7, figure 4

**Occurrence:** Present in all of the cores. The species was only rarely counted, however.

Genus RETITRICOLPITES (van der Hammen), ex Pierce, 1961

***Retitricolpites sphaeroides* Pierce**  
Plate 7, figures 1–2

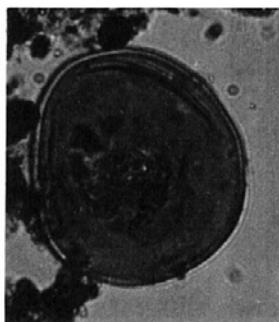
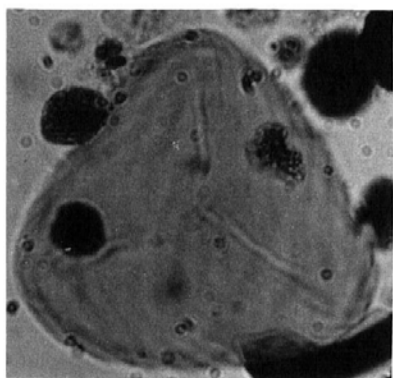
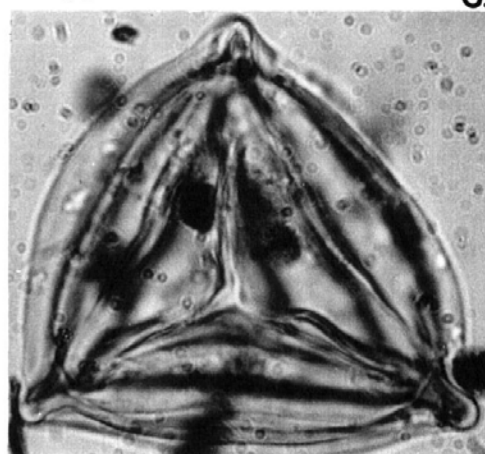
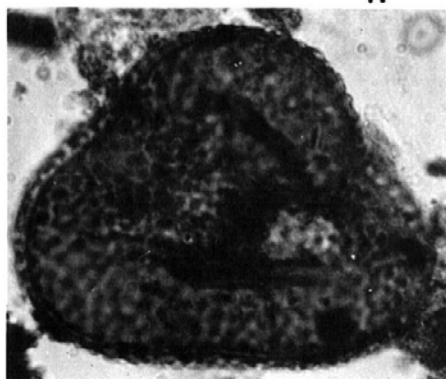
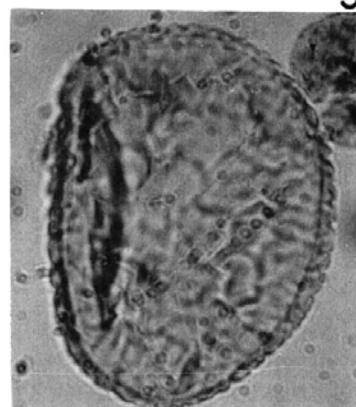
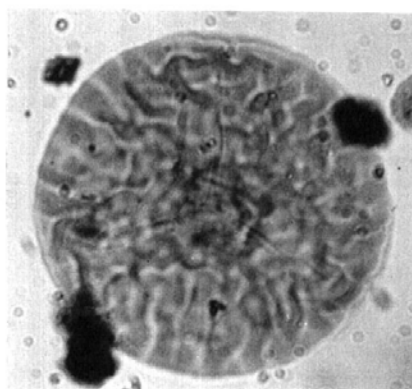
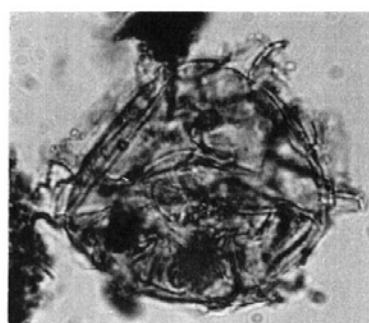
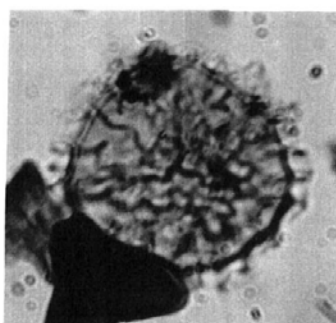
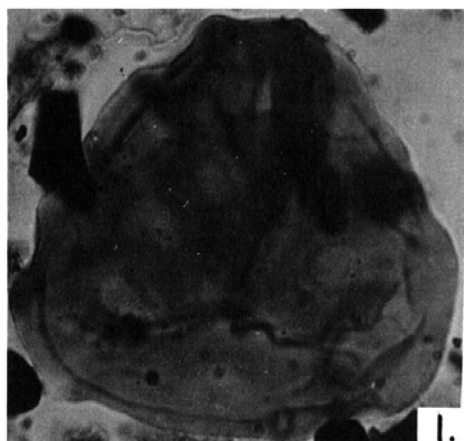
**Occurrence:** The most abundant species of *Retitricolpites*, *R. sphaeroides* is also the most abundant pollen species in cores RC10–281, RC10–282, and V22–8. It forms only 1.1 per cent of spores and pollen in core RC10–284. Pierce (1961) described *R. sphaer-*

### PLATE 3

Magnification approximately ×850

- |   |  |
|---|--|
| 1 <i>Ischyosporites punctatus</i> Cookson and Dettmann  | 7 <i>Concavisporites verrucosus</i> (Delcourt and Sprumont) Pocock |
| 2 <i>Lycopodiumsporites clavatoides</i> Couper  | 8 <i>Taurocusporites segmentatus</i> Stover                        |
| 3 <i>Lycopodiumsporites austroclavatidites</i> (Cookson) Potonié  | 9 <i>Appendicisporites tricornitatus</i> Weyland and Greifeld      |
| 4 <i>Taurocusporites reduncus</i> (Bolkhovitina) Stover   | 10 <i>Cicatricosisporites australiensis</i> (Cookson) Potonié      |
| 5 <i>Camazonosporites rudis</i> (Leschik) Klaus   | 11 <i>Laevigatosporites ovatus</i> Wilson and Webster              |
| 6 <i>Verrucatosporites? rugulatus</i> Habib, n. sp.<br>Holotype. Note similarity in all but symmetry to <i>Camazonosporites rudis</i> . | 12 <i>Laevigatosporites scabratus</i> (Couper) Habib, n. comb.     |
|   | 13 <i>Endosporites? sp. A</i>                                      |







*oides* from lower Upper Cretaceous deposits in Minnesota.

***Retitricolpites georgensis* Brenner**

Plate 7, figure 7

**Occurrence:** The least commonly occurring species of *Retitricolpites*, *R. georgensis* nevertheless occurs in all cores.

***Retitricolpites magnificus* Habib, n. sp.**

Plate 7, figures 10–13

**Description:** Prolate tricolpate and tetracolpate pollen grains. Outline in equatorial view elliptical to asymmetrically oval, with flattened poles. In polar view the grains are subcircular, with colpi each 120° separated (tricolpate) or 90° separated (tetracolpate) from the next. Colpi are straight and frequently closed. When open, they appear to be widest at their polar ends. They extend between two-thirds and three-fourths of the distance to the poles. Ektexine retipilate, the columellae forming a broken microreticulate pattern, the lumina becoming as large as 1.5 to 2 microns in diameter. It is approximately 2.5 microns in thickness. Endexine psilate?, relatively thin (1.5 microns) but thickens at the poles.

Twenty-five measured specimens range from 27 to 38 microns.

**Holotype:** Plate 7, figure 11. 31×20 microns. Slide RC10283B1.

**Remarks:** *Retitricolpites magnificus* is distinguished by its size, microreticulate ektexine, and polar thickening of the endexine. It is similar to *R. geranioides* (Couper) Brenner, but possesses a finer reticulation of the ektexine. It is similar also to *Tricolpites auritus* (Bolkhovitina)

Habib, but the infracolumellate structure of the latter species does not form a reticulate pattern.

Tetracolpate pollen grains have been included in *Retitricolpites magnificus* because of their otherwise identical morphology. Groot and Groot (1962, pl. 10, fig. 11) have portrayed a tetracolpate grain which is similar to those of *R. magnificus*.

**Occurrence:** Present in all of the cores, *R. magnificus* is the second most abundant species of *Retitricolpites*.

**PALYNOMORPHAE INCERTAE SEDIS**

Genus GALEACORNEA Stover, 1963

***Galeacornea* sp. A.**

Plate 8, figure 10

**Remarks:** A single specimen of *Galeacornea* was recovered from core RC10–284 and described by Habib (1969). This genus has been discovered in Middle Cretaceous sediments in northern West Africa (Stover, 1963) and in the Orito Basin of Colombia, South America (H. L. Cousminer, personal communication).

**Genus *Discoidea* Habib, n. gen.**

**Type species:** *Discoidea hanna* Habib, n. sp.

**Generic diagnosis:** Discoidal palynomorphs with a circular or subcircular outline. Wall presumed to be organic in composition. Surface covered with rows of tubular bacula with closed distal ends. Central area concave as opposed to the gentle convexity of the remainder of either surface of the disc.

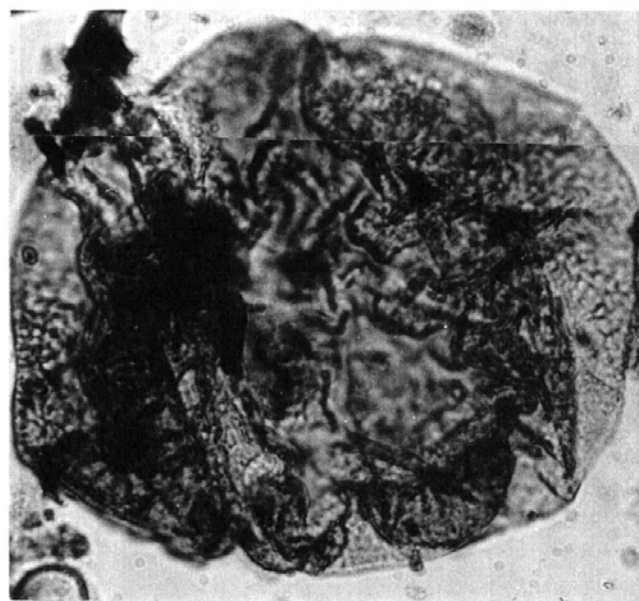
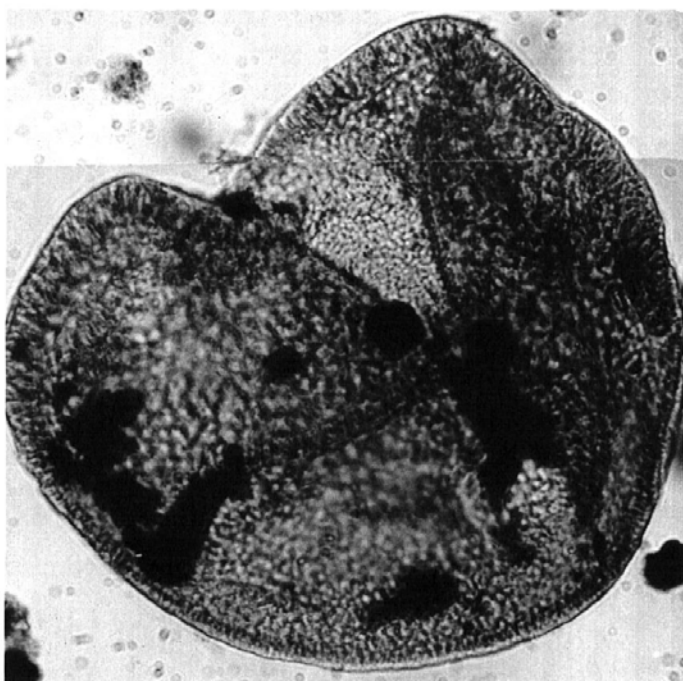
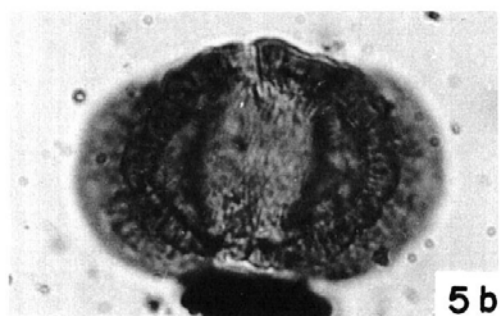
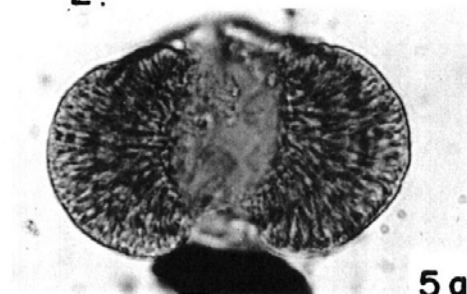
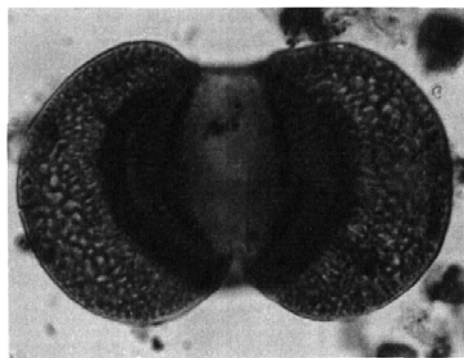
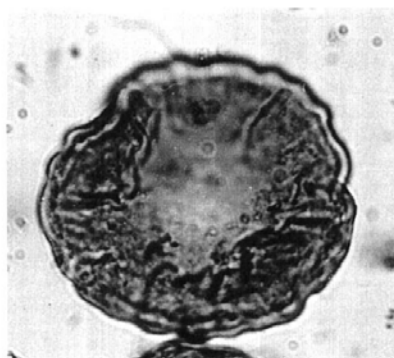
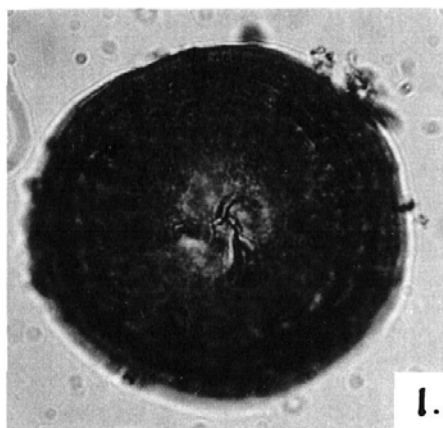
**Remarks:** These enigmatic fossils occur in sufficient numbers to warrant a formal scientific designation. Although most specimens are preserved as circular compressions, several are folded, obviating the possi-

PLATE 4  
Magnification approximately ×850

- 1 *Tsugaepollenites disoides* (Kimyai) Habib, n. comb.
- 2 *Tsugaepollenites dampieri* (Balme) Dettmann
- 3 *Platysaccus elizabethae* Habib
- 4 *Abietinaepollenites microreticulatus* Groot and Penny
- 5 *Parvisaccites majesticus* Habib

Note larger length :width ratio than in *P. radiatus* Couper and elliptical outline of central body. a, focus on striatoreticulate sacs; b, focus on thick-walled central body.

- 6 *Abietinaepollenites dunrobinensis* Couper
- 7 *Rugubivesiculites reductus* Pierce



bility that they are of mineral composition. Also, several specimens accepted safranin O and methyl green organic stains.

***Discoidea hanna* Habib, n. sp.**

Plate 8, figures 1–2

Palynomorph type A HABIB, 1969, p. 100, pl. 4, fig. 8a–b.

**Description:** Discoidal palynomorphs with a circular outline. Surface covered with nearly concentric to straight, discontinuous rows of short cylindrical bacula or verrucae. These processes are hollow, but closed at the distal ends. From five to eight processes occur in a single straight row; approximately 40–50 are present at the outline. Concave central area approximately one-fifth the diameter of the entire specimen. Wall approximately three to five microns thick.

Twenty measured specimens range from 18 to 65 microns in diameter.

**Holotype:** Plate 8, figure 1. 22×20 microns. Slide RC10 283B3.

**Remarks:** The species is named in honor of G. D. Hanna of the California Academy of Sciences.

**Occurrence:** Found in all of the investigated samples.

Genus SCHIZOSPORIS Cookson and Dettmann, 1959

***Schizosporis burcklei* Habib**

Plate 10, figure 12

**Occurrence:** Observed only in core RC10–284.

Division PYRROPHYCOPHYTA

Class DINOPHYCEAE

Order PERIDINIALES

Family GONYAULACEAE

Genus GONYAULAX Diesing, 1866

***Gonyaulax orthoceras* Eisenack**

Plate 8, figure 8

**Occurrence:** Rare. This species was found in cores RC10–281, RC10–282, RC10–283, and V22–8.

Genus SPINIFERITES Mantell, 1850

***Spiniferites ramosus* (Ehrenberg) Mantell**

Plate 9, figure 10

**Occurrence:** *Spiniferites ramosus* occurs in all of the cores but RC10–284. It was only rarely counted.

Family AREOLIGERACEAE

Genus CANNINGIA Cookson and Eisenack, 1960

***Canningia minor* Cookson and Hughes**

Plate 9, figure 11

**Occurrence:** Observed only in core RC10–284. Cookson and Hughes (1964) reported this species from the Cambridge Greensand (basal Cenomanian?) of England.

Family DEFLANDREACEAE

Genus SCRINIODINIUM Klement, 1957

***Scriniodinium heusseri* Habib, n. sp.**

Plate 8, figure 4

**Description:** Tabulated proximate dinoflagellate cysts. Periphragm oblate spherical, with a horn at either apex. Tabulation is incomplete, but appears to have the formula 3' 6'' 6''' 2''' P. Cingulum well-developed, its width approximately one-eighth or more of the length of the cyst. Transverse furrow extending the length of the precingular and postcingular tabulation; offset to the right in the hypotract. Endophragm circular but flattened in the apical regions. It occupies approximately 85% of the pericoel but does not appear to be in contact with the periphragm.

Eight specimens range in size from 27 to 40 microns.

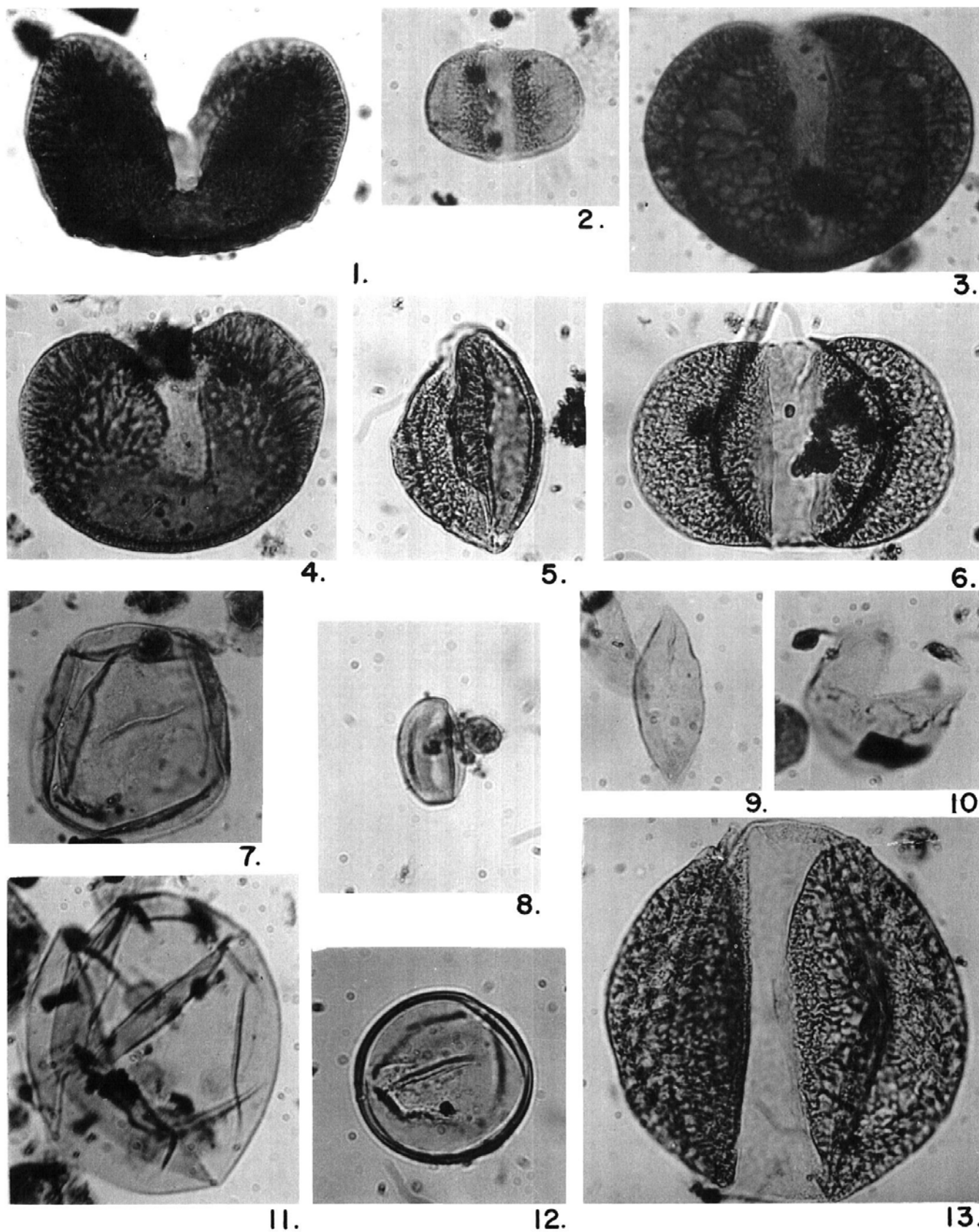
**Holotype:** Plate 8, figure 4. 32×28 microns. Slide RC10 282B1.

**Remarks:** *Scriniodinium heusseri* is similar to *S. crystallinum* (Deflandre) but is considerably smaller. The species is named after Calvin J. Heusser, palynologist at New York University.

PLATE 5

Magnification approximately ×850

- |   |   |
|---|---|
| 1 <i>Parvisaccites majesticus</i> Habib   | 6 <i>Alisporites bilateralis</i> Rouse                                      |
| Equatorial view. Note outline of central body, thick proximal cap, and tightly knit striatoreticulate structure of the sacs. Compare with <i>P. radiatus</i> (figures 3 and 4). | 7 <i>Inaperturopollenites dubius</i> (Potonié and Venitz) Thomson and Pflug |
| 2 <i>Vitreisporites pallidus</i> (Reissinger) Brenner   | 8 <i>Monosulcites glottus</i> Brenner                                       |
| 3–4 <i>Parvisaccites radiatus</i> Couper  | 9 <i>Monosulcites epakros</i> Brenner                                       |
| 3, oblique polar view; 4, equatorial view.  | 10 <i>Taxodiaceapollenites hiatus</i> (Potonié) Kremp                       |
| 5 <i>Pteruchipollenites crenulatus</i> Habib  | 11 <i>Laricoidites magnus</i> (Potonié) Potonié, Thomson and Thiergart      |
|   | 12 <i>Spheripollenites psilatus</i> Couper                                  |
|   | 13 <i>Pteruchipollenites transversus</i> Habib                              |





**Occurrence:** Four specimens were recovered from core RC10-282, two from RC10-283, and one each from RC10-281 and V22-8.

***Scriniodinium* sp. A**

Plate 9, figure 6

**Description:** Single proximate dinoflagellate cyst. Well-defined cingulum separates epitract and hypotract into more-or-less equal halves. Epitract extended into single apical horn, hypotract into short antapical horns. Endophragm oval, occupying more than one-half of the area of the periphragm. No evidence of archeopyle or tabulation.

**Remarks:** *Scriniodinium* sp. A resembles *S. apatelum* Cookson and Eisenack. It also is similar to species of *Wallodinium*, but differs in the occurrence of a cingulum and apical horns.

**Occurrence:** A single specimen was recovered from core RC10-284.

Family HYSTRICHODINIACEAE

Genus PALAEOHYSTRICHOPHORA Deflandre, 1934

***Palaeohystrichophora infusorioides* Deflandre**

Plate 8, figure 11; plate 9, figure 5

*Palaeohystrichophora infusorioides* DEFLANDRE, 1934, p. 967, text-fig. 8.

**Description:** Proximate dinoflagellate cysts. Periphragm oval in outline, with apical and antapical horns; cingulum and longitudinal furrow well developed on many specimens. Archeopyle situated in an apical position; in many specimens operculum only partially detached or not detached at all. The endophragm outline varies from subcircular to oval and in the latter form is closely appressed to the periphragm. Combined thick-

ness of both layers approximately 1.5–3 microns. Slender, deeply bifurcated processes extend from the outline of the periphragm, where a minimum of 50 can be counted. The cysts appear to be untabulated, although in some specimens (plate 8, figure 11) the processes are partially attached at the bases, which may reflect the tabulation.

**Remarks:** The specimens of *Palaeohystrichophora infusorioides* observed in this study conform well with the description of the species given by Deflandre and Cookson (1955), except for the evidence of tabulation in some specimens.

**Occurrence:** *P. infusorioides* is the single most abundant dinoflagellate species in cores RC10-281, RC10-282, RC10-283 and V22-8. It was not observed in core RC10-284.

Alberti (1961) records this species from middle Albian and Upper Cretaceous sediments from Australia, England, France and Germany. The species appears to be most abundant in lower Upper Cretaceous assemblages. It has also been reported from pre-Selma (Cenomanian–Turonian) Upper Cretaceous sediments in the Gulf Coastal Plain of Alabama (Leopold and Pakiser, 1964).

DINOFLAGELLATA INCERTAE SEDIS

Genus APTEODINIUM Eisenack, 1958

***Apteodinium granulatum* Eisenack**

Plate 8, figure 3

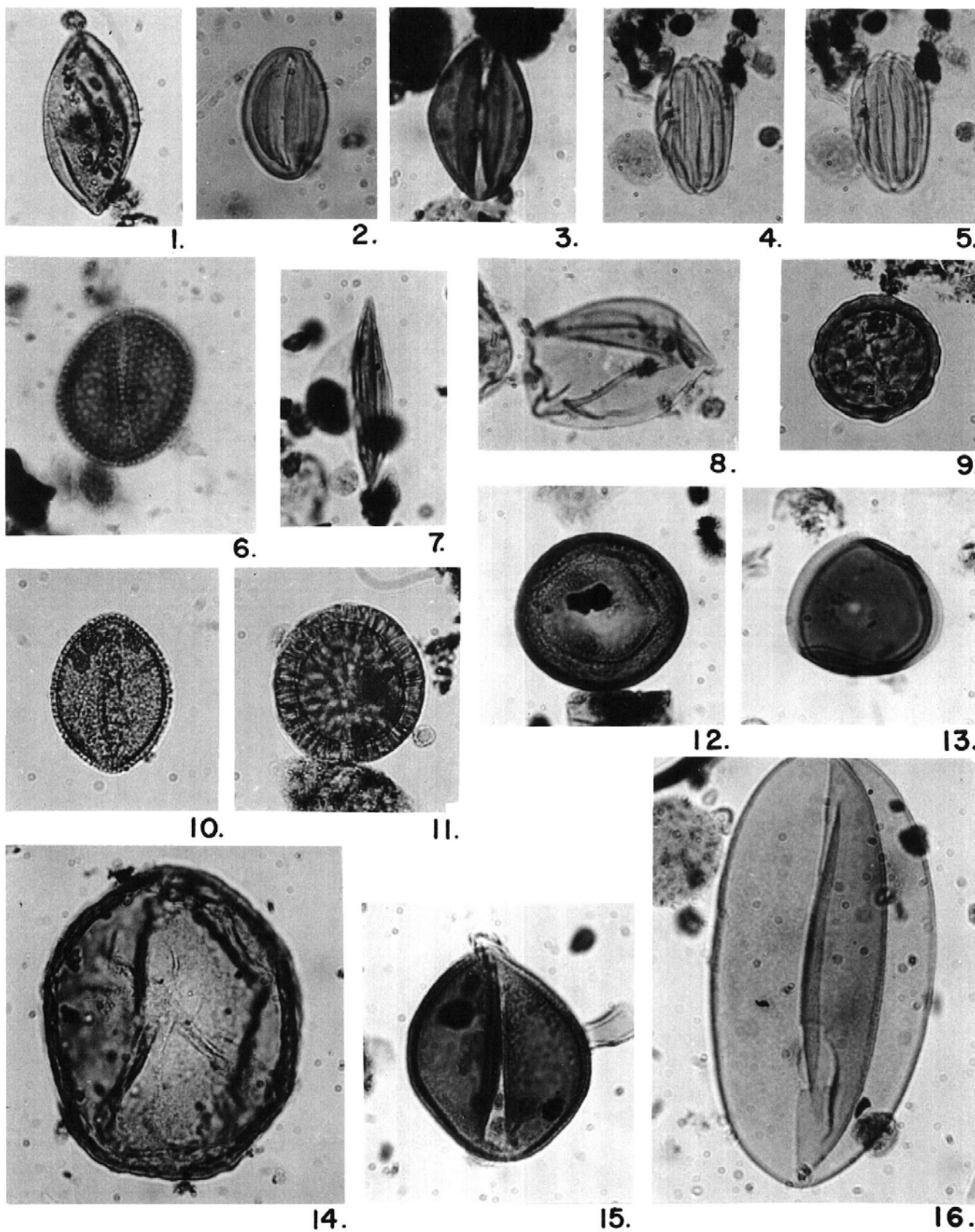
**Remarks:** The granulate periphragm and archeopyle identify the investigated specimens as *A. granulatum*. Several specimens (e.g., plate 8, figure 3) show an incomplete development of the apical horn.

**Occurrence:** Found in all cores except RC10-284.

PLATE 6  
Magnification approximately  $\times 850$

- |  |   |
|--|---|
| 1 <i>Monosulcites minimus</i> Cookson ex Couper            | 9 <i>Monosulcites chaloneri</i> Brenner                             |
| 2 <i>Eucommiidites troedssoni</i> Erdtman ex Hughes        | 10 <i>Clavatipollenites hughesii</i> Couper                         |
| 3 <i>Ginkgocycadophytus nitidus</i> (Balme) de Jersey      | 11 <i>Clavatipollenites maximus</i> Habib                           |
| 4–5 <i>Ephedripites multicostatus</i> Brenner              | 12 <i>Classopollis torosus</i> (Reissinger) Couper                  |
| 6 <i>Liliacidites dividius</i> (Pierce) Brenner            | 13 <i>Perinopollenites elatoides</i> Couper                         |
| 7 <i>Ephedripites fusiformis</i> Habib, n. sp.<br>Holotype | 14 <i>Araucariacites limbatus</i> (Balme) Habib                     |
| 8 Cf. <i>Exesipollenites tumulus</i> Balme                 | 15 <i>Palmaepollenites asymmetricus</i> (Pierce) Habib,<br>n. comb. |
|  | 16 Cf. <i>Palmidites maximus</i> Couper                             |





***Apteodinium maculatum*** Eisenack and Cookson  
Plate 8, figure 7

**Remarks:** Specimens attributed to *A. maculatum* are slightly smaller than those described in Eisenack and Cookson (1960) but agree well with specimens described by Davey *et al.* (1966).

**Occurrence:** Several specimens were found in core RC10–282.

Genus CLEISTOSPHAERIDIUM Davey, Downie, Sarjeant and Williams, 1966

***Cleistosphaeridium huguonioti*** (Valensi) Davey  
Plate 9, figures 1, 4, 7

*Hystrichosphaeridium huguonioti* VALENSI, 1955, p. 38, text-fig. 2a.

*Hystrichosphaeridium ancoriferum* COOKSON and EISENACK, 1960, p. 8, pl. 2, fig. 11. – COOKSON and HUGHES, 1964, p. 47, pl. 9, fig. 7.

*Cleistosphaeridium ancoriferum* (Cookson and Eisenack). – DAVEY, DOWNIE, SARJEANT and WILLIAMS, 1966, p. 167, pl. 9, fig. 1.

*Cleistosphaeridium huguonioti* (Valensi). – DAVEY, 1969, p. 155, pl. 7, fig. 10.

**Description:** Untabulated chorate dinoflagellate cysts, with oval to elliptical outline. Hollow processes constricted at distal apices and bifurcate in a recurving fashion. The bifurcated tips appear lighter than the remainder of the process, and commonly touch those of other processes. Processes always numbering more than 45 at the outline. Archeopyle irregular, appearing to possess an apical position, although in some specimens it may be intercalary.

**Remarks:** Specimens of *C. huguonioti* (Valensi) observed in this study are very similar to *Chlamydomphorella wallala* (Cookson and Eisenack) but do not possess the delicate external membrane characteristic of the latter genus. The apparent method by which the operculum dehisces is similar to that described for *Chlamydomphorella* by Evitt (1967).

**Occurrence:** This species occurs in cores RC10–281, RC10–282, RC10–283 and V22–8, but was seldom counted. Davey, Downie, Sarjeant and Williams (1966) reported *C. huguonioti* from the Albian and Cenomanian of England and Australia.

Genus FROMEA Cookson and Eisenack, 1958

***Fromea amphora*** Cookson and Eisenack  
Plate 8, figure 9

**Occurrence:** Irregularly distributed through cores RC10–281, RC10–282 and RC10–283.

Genus HYSTRICHOSPHAERIDIUM Deflandre, 1937

***Hystrichosphaeridium arundum*** Eisenack and Cookson  
Plate 10, figure 11

**Occurrence:** Present in all cores, *H. arundum* is most abundant in core RC10–284.

Genus PALAEOSTOMOCYSTIS Deflandre, 1937

***Palaeostomocystis fragilis*** Cookson and Eisenack  
Plate 9, figure 8

**Occurrence:** Observed only in core RC10–284. Cookson and Eisenack (1962) recorded *P. fragilis* from Aptian–Cenomanian sediments in Australia.

Genus PTERODINIUM Eisenack, 1958

***Pterodinium cornutum*** Cookson and Eisenack  
Plate 8, figure 6

**Remarks:** Because the specimens of *Pterodinium cornutum* encountered in the samples were folded, it was difficult to accurately determine their tabulation. The tabulation appears to correspond with the 3' 6'' 6''' 1'''' formula stated by Cookson and Eisenack (1962), however.

**Occurrence:** Reported from Aptian–Albian? deposits in Australia. This species was observed in cores RC10–281, RC10–282, RC10–283 and V22–8.

Genus TENUA Eisenack, 1958

Cf. ***Tenua hystricella*** Eisenack  
Plate 9, figures 2–3

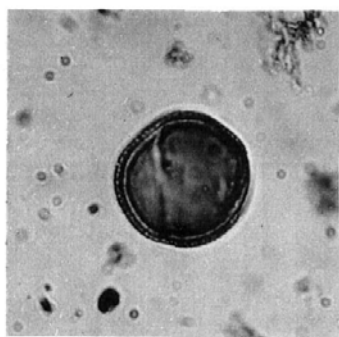
**Remarks:** The specimens compared with *Tenua hystricella* correspond closely with the species described by Eisenack (1958), but possess in addition a longitudinal tear extending the entire diameter.

**Occurrence:** Cf. *T. hystricella* was observed in all cores except RC10–284.

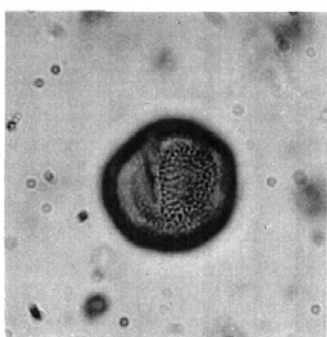
# PLATE 7 Magnification approximately $\times 850$

- 1–2 *Retitricolpites sphaeroides* Pierce
- 3 *Tricolpopollenites minutus* Brenner
- 4 *Tricolpopollenites polyhedrus* Habib
- 5–6 *Psilatricolpites psilatus* Habib, n. sp.  
5, holotype.

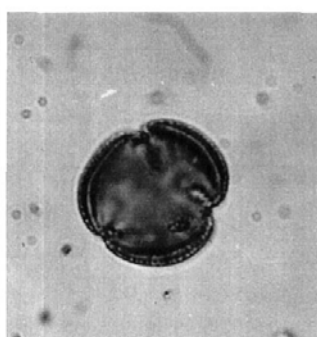
- 7 *Retitricolpites georgensis* Brenner
- 8–9 *Tricolpites auritus* (Bolikhovitina) Habib, n. comb.
- 10–13 *Retitricolpites magnificus* Habib, n. sp.  
11, holotype; 13, tetracolpate grain.



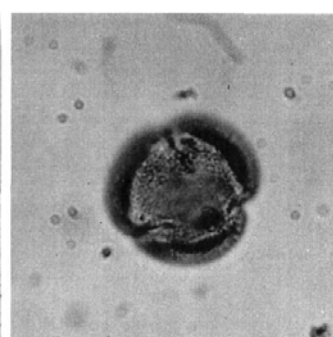
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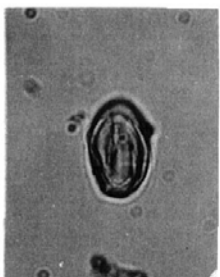
1b.



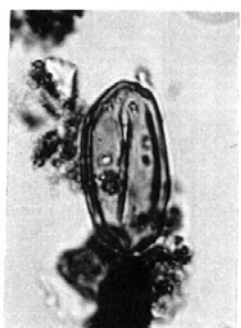
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2b.



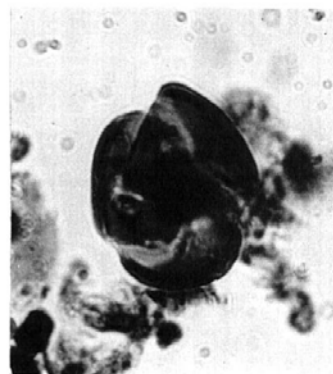
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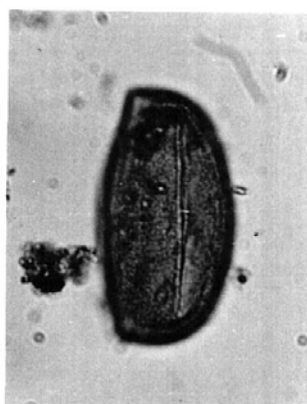
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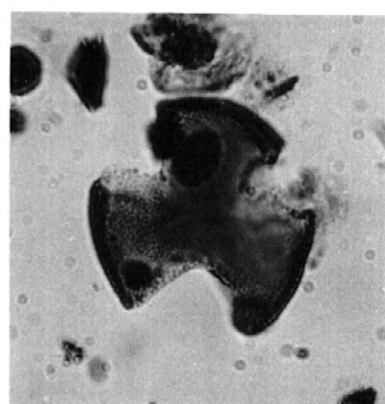
7.



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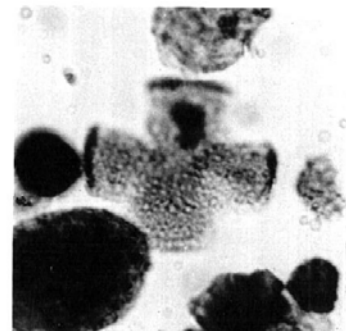
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12.



13.

Genus STEPHODINIUM Deflandre, 1936

**Stephodinium europaicum** Cookson and Hughes  
Plate 8, figure 5

**Occurrence:** Four specimens were found, all in core RC10-284.

Genus XENIKOON Cookson and Eisenack, 1960

**Xenikoon americanus** Habib, n. sp.  
Plate 10, figure 10

**Description:** Untabulated dinoflagellate cysts with an oval outline. Periphragm smooth to scabrate, without discernible processes. Archeopyle in apical position. Cingulum narrow but encircling entire periphragm. Endophragm circular in outline, closely appressed to periphragm at cingulum but free at antapical region and presumably also at apical region. A thin (one micron or less) envelope with scabrate ornamentation encloses the hypotractal part of the periphragm, extending in some specimens to the archeopyle. The envelope is torn longitudinally exposing part of the hypotract. Seven specimens range in size from 40 to 52 microns.

**Holotype:** Plate 10, figure 10. 49×45 microns. Slide RC10V228B1.

**Remarks:** *Xenikoon americanus* conforms well with the diagnosis of the genus given by Cookson and Eisenack (1960b). All seven specimens observed in this study possess the thin membrane found in a single specimen of *X. australis* by Cookson and Eisenack. None of the seven specimens retained the operculum.

**Occurrence:** Found only in core V22-8.

#### INCERTAE SEDIS

Group ACRITARCHA

Subgroup ACANTHOMORPHITAE

Genus MICRHYSTRIDIUM Deflandre, emend. Downie and Sarjeant, 1963

**Micrhystridium fragile** Deflandre  
Plate 10, figure 6

**Occurrence:** This species was frequently encountered.

**Micrhystridium inconspicuum** Deflandre  
Plate 10, figure 8

**Occurrence:** The most abundant single palynomorph in all of the cores except RC10-284, *Micrhystridium inconspicuum* is known from Jurassic and Cretaceous deposits in France and England.

Genus BALTISPHAERIDIUM Eisenack, 1958, emend. Downie and Sarjeant, 1963

Cf. **Baltisphaeridium pilosum** (Ehrenberg), var. **longispinosum** Sarjeant  
Plate 10, figure 1

**Remarks:** Specimens observed in this study are similar to the variety described by Sarjeant (1961) but possess slightly larger processes.

**Occurrence:** Most common in core RC10-282.

Cf. **Baltisphaeridium stimulierum** (Deflandre) Sarjeant  
Plate 10, figure 5

**Occurrence:** Only a single specimen was discovered.

**Baltisphaeridium pseudohystrichodinium** (Deflandre) Downie and Sarjeant  
Plate 10, figure 9

**Occurrence:** Rare in cores RC10-282 and RC10-283. Drugg (1967) reported this species from Danian sediments in California.

**Baltisphaeridium stellatum** Habib, n. sp.  
Plate 10, figure 7

*Sporites echinosporus* R. Potonié. — LEOPOLD and PAKISER, 1964, p. 75, pl. 9, fig. 9.

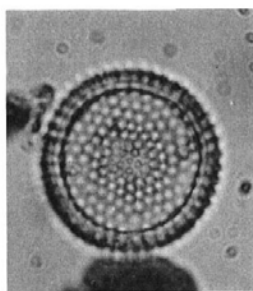
**Description:** Spinose acritarchs, polygonal in outline. From 5 to more than 15 tapering and gently recurving radiating spinose processes extend from the outline, and appear to lie within a single longitudinal zone. Other processes, fewer in number, are irregularly distributed on the surface. The processes broaden widely near the base, concavely, and taper gently towards their apices. They are commonly connected along a low ridge in the

#### PLATE 8

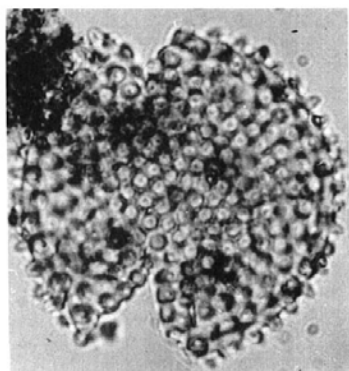
Magnification approximately ×850

- |   |  |
|---|--|
| 1-2 <i>Discoideella hanna</i> Habib, n. sp.<br>1, holotype. | 6 <i>Pterodinium cornutum</i> Cookson and Eisenack                                     |
| 3 <i>Apteodinium granulatum</i> Eisenack                    | 7 <i>Apteodinium maculatum</i> Eisenack and Cookson                                    |
| 4 <i>Scriniodinium heusseri</i> Habib, n. sp.<br>Holotype.  | 8 <i>Gonyaulax orthoceras</i> Eisenack   |
| 5 <i>Stephodinium europaicum</i> Cookson and Hughes         | 9 <i>Fromea amphora</i> Cookson and Eisenack   |
|   | 10 <i>Galeacornea</i> sp. A  |
|   | 11 <i>Palaeohystrichophora infusorioides</i> Deflandre<br>Note evidence of tabulation. |





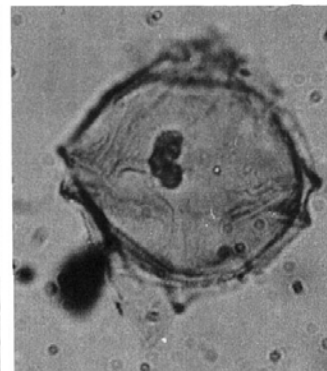
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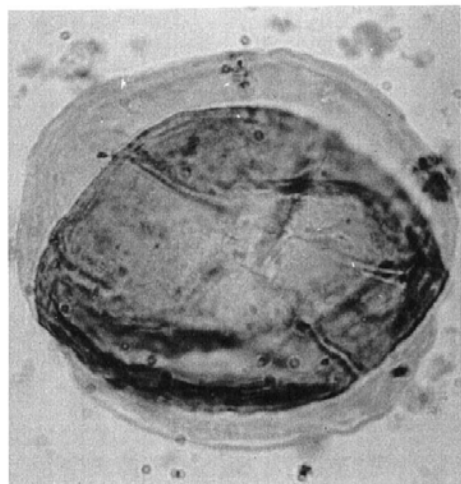
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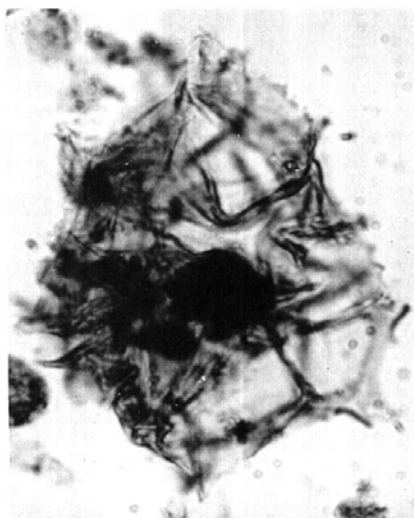
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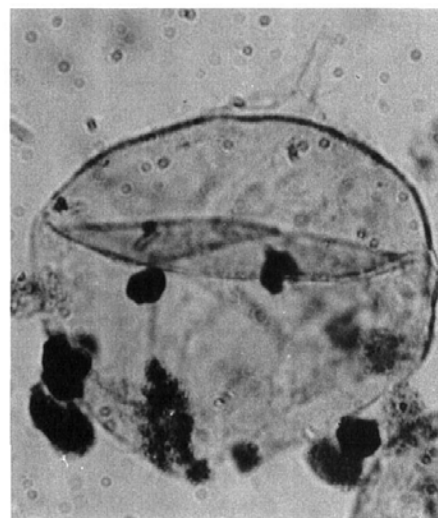
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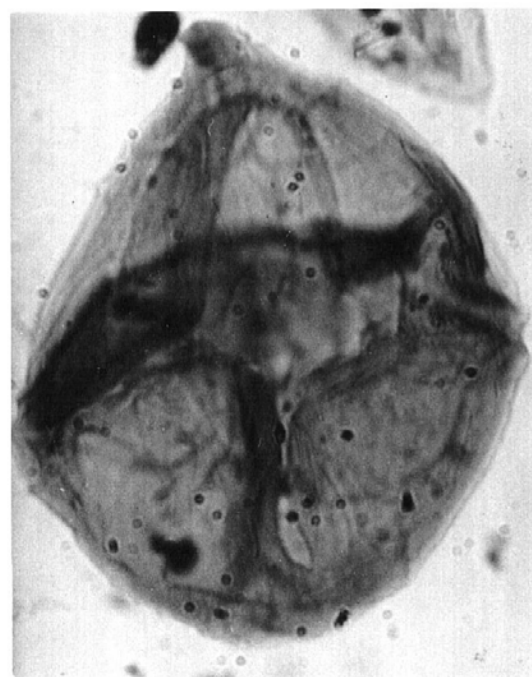
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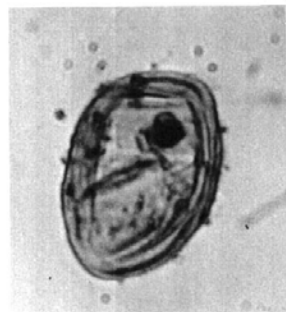
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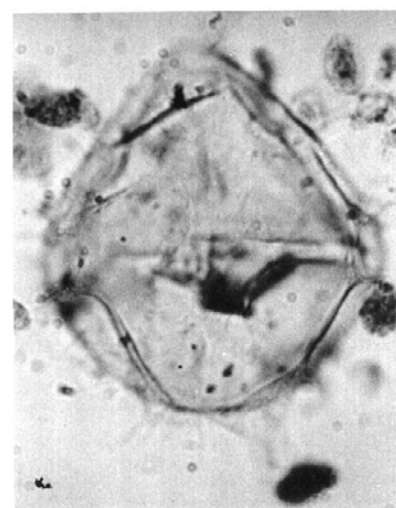
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longitudinal plane. Most processes are as long as half the diameter of the periphragm, and may be longer. The equatorial split in the periphragm extends approximately two-thirds of the equatorial diameter.

Fifteen measured specimens range in size from 15 to 50 microns.

*Holotype*: Plate 10, figure 6. 25×19 microns (excluding spines). Slide V228B16.

*Remarks*: Leopold and Pakiser (1964) figured a specimen that they identified as *Sporites echinosporus* Potonié, which is here placed in *Baltisphaeridium stellatum*.

*Occurrence*: *B. stellatum* was observed in every core but RC10–284. It is most common in core V22–8, where it forms 5.5% of all dinoflagellates and acritarchs. It also occurs in lower Upper Cretaceous deposits in the Coastal Plain of Alabama (Leopold and Pakiser, 1964).

Subgroup DINETROMORPHITAE  
Genus PRISMATOCYSTIS Habib, 1969

*Prismatocystis ewingii* Habib  
Plate 9, figure 9

*Description*: Prismatic acritarch with pentagonal outline; one apex pyramidal; opposite apex truncated. Endophragm thin (approximately one micron in thickness), subcircular in outline, and situated at truncated apical end.Periphragm psilate; endophragm psilate or scabrate.

*Occurrence*: Observed only in the sample from core RC10–284.

*Prismatocystis cylindrica* Habib, n. sp.  
Plate 10, figure 2

*Description*: Prismatic acritarch, with a broadly rounded to subpyramidal closed apex opposite an open truncated apex.Periphragm sides straight or slightly convex. Endophragm circular in outline, frequently open and folded, its diameter approximately half the length of the periphragm, located near closed apex, thinner

(less than one micron in thickness) than periphragm.Periphragm and endophragm psilate.

Six specimens range in size from 27 to 36 microns.

*Holotype*: Plate 10, figure 3. 36×28 microns. Slide RC10282B12.

*Remarks*: *P. cylindrica* is distinguished by its rounded apex and size. The endophragm is missing in two of the six specimens.

*Occurrence*: Rare in all cores but RC10–284. Most common in core RC10–282.

Genus WALLODINIUM Cookson and Eisenack, emend. Loeblich and Loeblich, 1968

*Wallodinium inflatum* (Habib) Habib, n. comb.  
Plate 10, figures 4, 13

*Diplostea inflata* HABIB, 1969, p. 98, pl. 3, figs. 14–15; pl. 4, fig. 2.

*Remarks*: This species is similar to *Wallodinium krutzschii* (Alberti) but can be distinguished by its relatively larger endophragm.

*Occurrence*: Species of *Wallodinium* have usually been reported from Upper Jurassic and Lower Cretaceous sediments. However, Cookson and Eisenack (1960) reported a species, *Wallodinium luna*, from Cenomanian deposits in Australia.

*W. inflatum* was found only in core CR10–284, where it is the commonest species of phytoplankton.

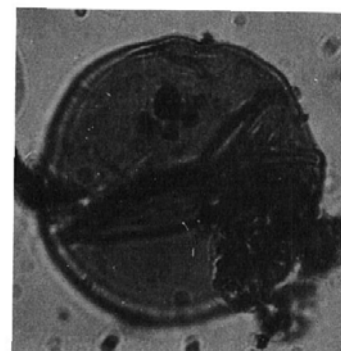
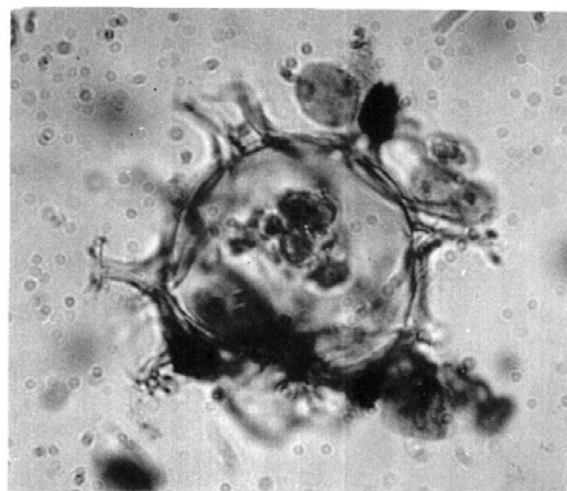
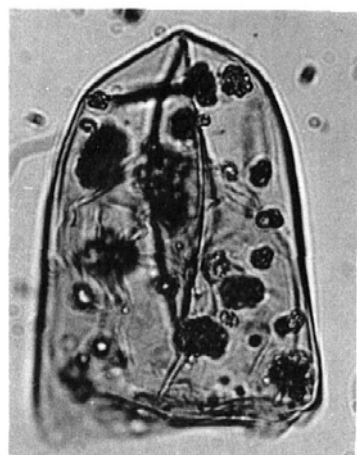
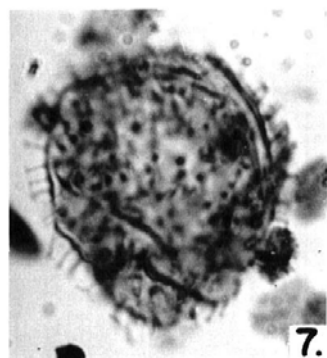
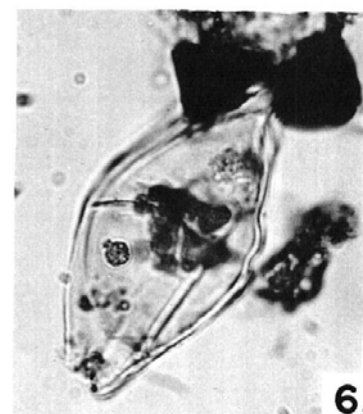
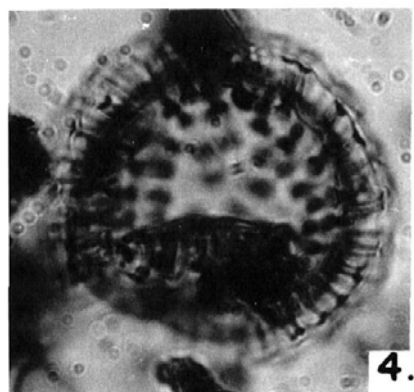
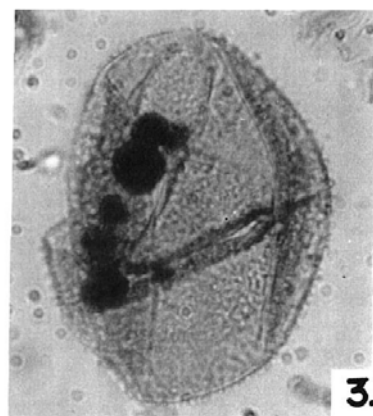
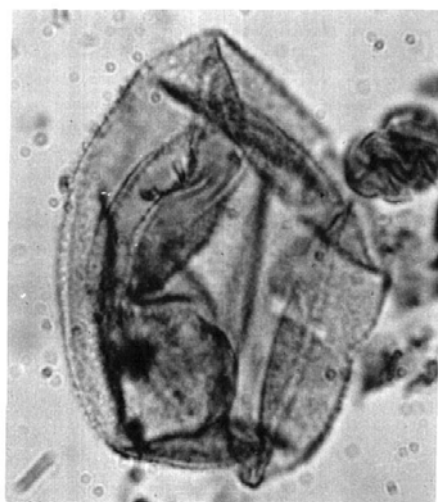
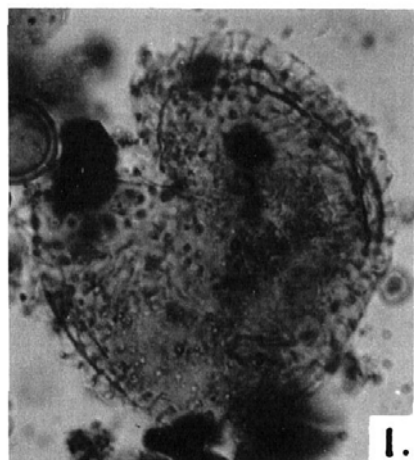
Acritarch type A  
Plate 10, figure 3

*Description*: Oblate fusiform acritarch specimen.Periphragm widest at the equator tapering broadly and convexly towards the apices. A transverse fold at the equator simulates a cingulum. Light lines in parts of both halves of the specimen form a polygonal pattern, which may reflect plates.

The specimen measures 48×27 microns.

# PLATE 9 Magnification approximately ×850

- |         |   |    |  |
|---------|---|----|--|
| 1, 4, 7 | <i>Cleistosphaeridium huguonioti</i> (Valensi)<br>Davey | 8  | <i>Palaeostomocystis fragilis</i> Cookson and Eisenack |
| 2–3     | Cf. <i>Tenua hystricella</i> Eisenack                   | 9  | <i>Prismatocystis ewingii</i> Habib                    |
| 5       | <i>Palaeohystrichophora infusorioides</i> Deflandre     | 10 | <i>Spiniferites ramosus</i> (Ehrenberg) Mantell        |
| 6       | <i>Scriniodinium</i> sp. A                              | 11 | <i>Canningia minor</i> Cookson and Hughes              |



11.

*Remarks:* A single specimen was found. Additional specimens are necessary to determine if the transverse fold and polygonal lines are significant.

*Occurrence:* Core RC10-282.

#### ACKNOWLEDGMENTS

I thank Jim Hays, Lloyd Burckle, John Ewing, Harold Cousminer, David Wall and Gilbert Brenner for reviewing various drafts of the manuscript. Anne Riley typed the final manuscript.

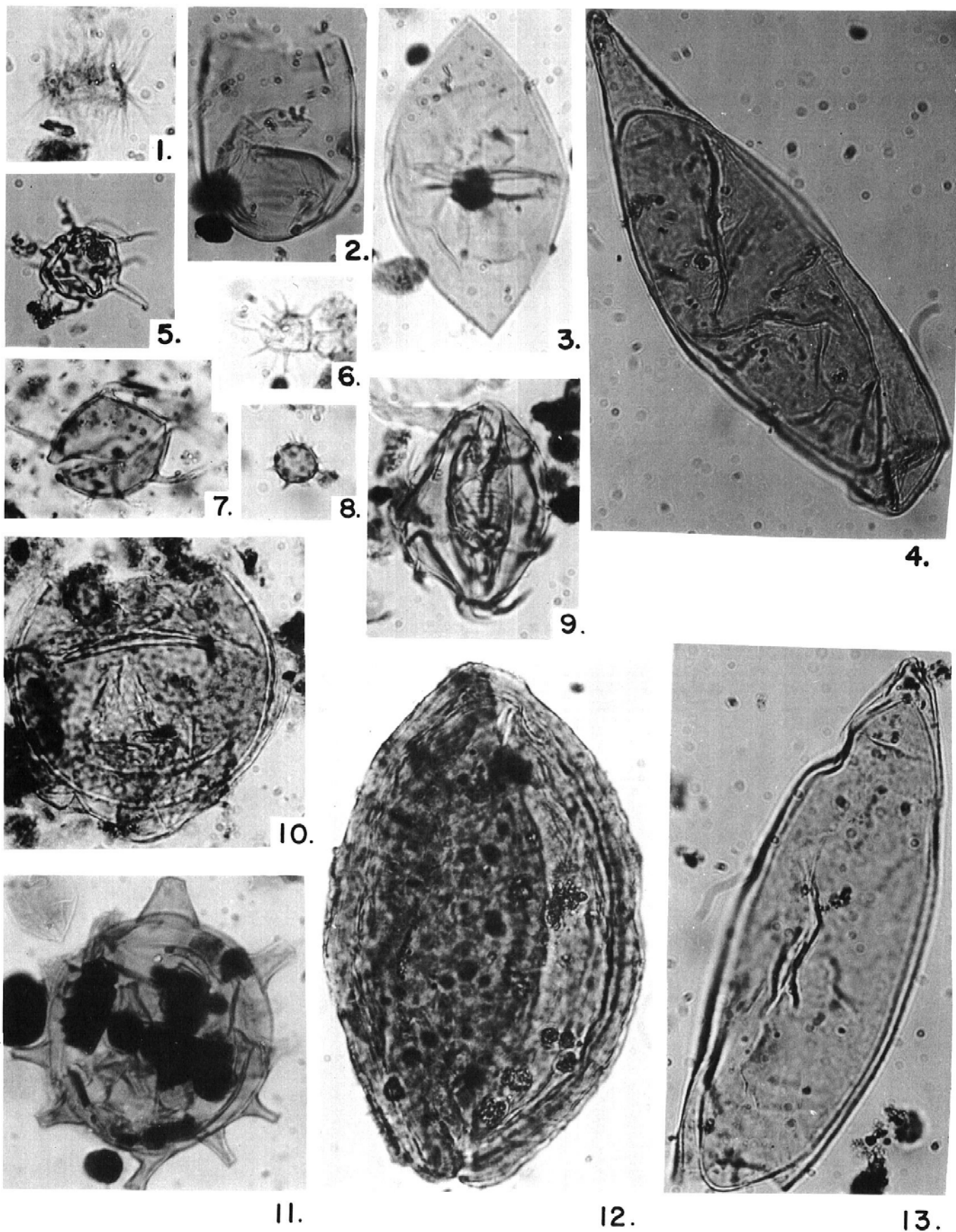
This study was supported by the National Science Foundation (NSF-GA1193 and NSF-GA10635) and the Office of Naval Research (N-0014-67-A-0108-0004). This paper is Lamont-Doherty Geological Observatory Contribution No. 1437.

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#### PLATE 10 Magnification approximately $\times 850$

- |  |   |
|--|---|
| 1 Cf. <i>Baltisphaeridium pilosum</i> (Ehrenberg) var. <i>longispinosum</i> Sarjeant | 7 <i>Baltisphaeridium stellatum</i> Habib, n. sp. Holotype.                     |
| 2 <i>Prismatocystis cylindrica</i> Habib, n. sp. Holotype.                           | 8 <i>Michrystidium inconspicuum</i> Deflandre                                   |
| 3 Acritarch type A   | 9 <i>Baltisphaeridium pseudohystrichodinium</i> (Deflandre) Downie and Sarjeant |
| 4, 13 <i>Wallodinium inflatum</i> (Habib) Habib, n. comb.                            | 10 <i>Xenikoon americanus</i> Habib, n. sp. Holotype.                           |
| 5 Cf. <i>Baltisphaeridium stimulierum</i> (Deflandre) Sarjeant                       | 11 <i>Hystrichosphaeridium arundum</i> Eisenack and Cookson                     |
| 6 <i>Michrystidium fragile</i> Deflandre   | 12 <i>Schizosporis burcklei</i> Habib   |





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