

## 20. PALYNOLOGY OF MIDDLE CRETACEOUS BLACK CLAY FACIES FROM DEEP SEA DRILLING PROJECT SITES 417 AND 418 OF THE WESTERN NORTH ATLANTIC

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### ABSTRACT

A palynological study of 23 samples of black and green claystones of middle Cretaceous age recovered from DSDP Sites 417 and 418 documents the position of a subtropical flora interference belt in a climatically differentiated North Atlantic realm.

A relatively large dinoflagellate/pollen ratio and lack of significant wood cuticle suggest moderately long-distance transportation of land-derived components by surface currents. These components tend to decrease numerically upsection, but show a uniform composition. These sediments fit into the pollen-zones I, II, and III ranging from the early Aptian to early Cenomanian (Doyle and Robbins, 1977). Several new angiosperm forms are identified, including the oldest known occurrence of a monoporate form. Dinoflagellates, acritarchs, and microforaminifers dominate the palynomorph spectrum. Their occurrence is closely linked with complex lithologies interbedded on a decimeter scale. The palynomorphs are equally well preserved, but vary in abundance in the black and green claystones and are rare in nannofossil chalks, radiolarian sands, or red-brown clays to marls. The overall sedimentation rate appears to have been slow, but individual thin, carbonaceous black clay beds are commonly dominated by a single dinoflagellate species which may be evidence of high productivity following circulation events in a closed basin.

### INTRODUCTION

In the controversy concerning the origin of the black clay facies in the middle Cretaceous Atlantic basin, the type of organic matter involved plays a central role. On several DSDP legs (e.g., Legs 11, 41, 47, and 48), Cretaceous black clay samples have been taken from sites close to the continental margin which were rich in terrestrially derived organic matter. Recent organic geochemical data have also tended to emphasize influxes of terrestrially derived organic matter (e.g., Tissot et al., 1974; and Deroo et al., 1978); earlier studies of the black clay had suggested oceanic sources (e.g., Lancelot et al., 1972; and Ryan and Cita, 1977). Thus, some authors (e.g., Montadert, Roberts, et al., 1976) question the necessity of basinwide stagnation to explain the typical black clay beds from the Atlantic mid-Cretaceous, preferring instead a redistribution of land-derived carbonaceous components by turbidity currents. The purpose of this paper is to consider these questions in the light of palynological evidence, while reporting the results of palynological investigations of material recovered during Legs 51 through 53 (Figure 1).

In the course of drilling on the southern tip of the Bermuda Rise at Sites 417 and 418 during Legs 51 through 53,

we recovered continuous cores from well-developed sections of Aptian to Cenomanian black clay facies sediments. These sites are uniquely suited for palynological examination for several reasons. Both sites are located on oceanic crust from the same magnetic anomaly, *M-0*, implying equal ages. They are only 8 km apart, permitting examination of lateral variability of possible correlative sequences. The basement age was determined as early Aptian (Gartner, this volume) or about 115 million years (van Hinte, 1976). From a reconstruction of the subsidence history of this location (e.g., Sclater et al., 1977), it follows that these sites were the locus of deposition at depths between 2000 and 3000 meters on a mid-ocean ridge during times of possible euxinic events and maximum preservation of organic-matter. The ridge environment provides an opportunity to examine dominantly pelagic sedimentation, thus avoiding the problem of turbidity currents resedimenting terrestrial carbonaceous matter. The sediments should represent an actual pelagic rain.

With respect to land flora, these sites, when plotted with other black clay sites on a reconstruction of the Aptian to Albian Sea (Figure 2) (Sclater et al., 1977), are distant from land sources. Several hundred kilometers to the south, a belt of shallow reefs was flourishing. The position of the tropical flora belts (after Brenner, 1976) (Figure 2) indicates that Sites 417 and 418 lie in a transition subtropical zone midway between Sites 367 and 105. Because the Albian to Aptian period is also the time of the rise of angiosperms, new forms were expected.

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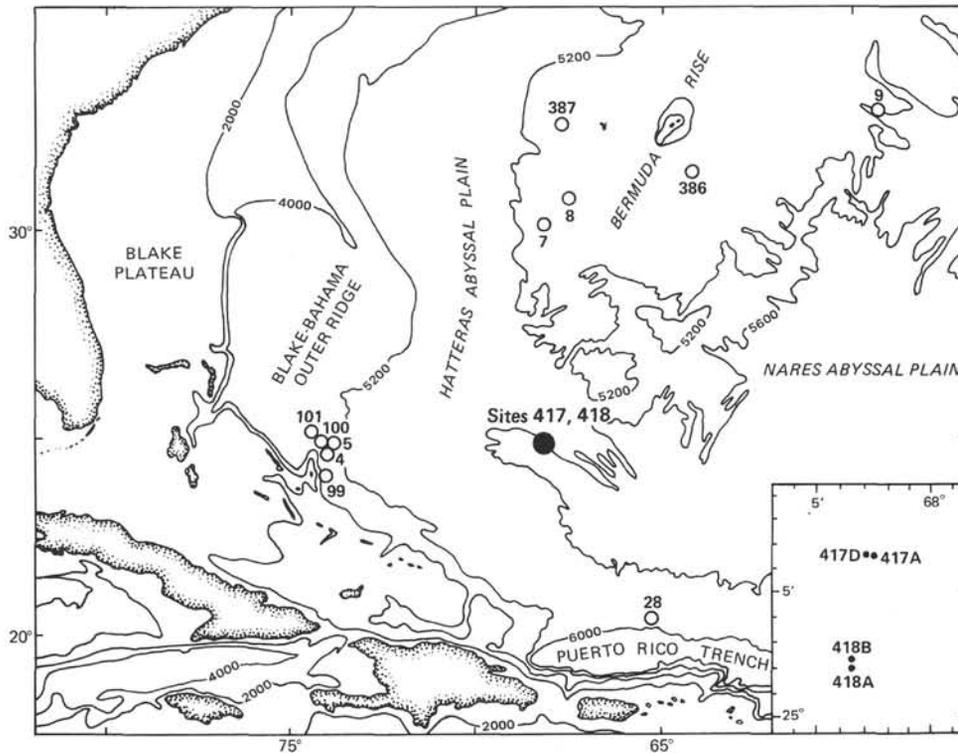


Figure 1. Index map of the locations of Sites 417 and 418 from Legs 51 through 53. Inset indicates the spatial relationships of the four holes drilled. All are on crust along the M0 magnetic anomaly with Sites 417 and 418 about 8 km apart.

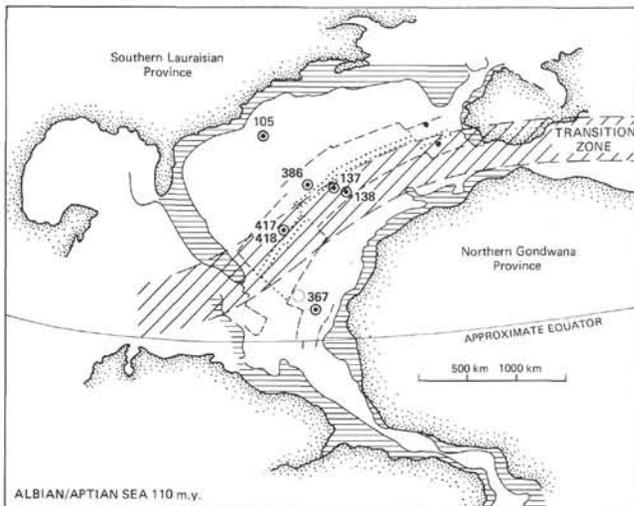


Figure 2. Reconstruction of North Atlantic paleogeography during Aptian to Albian times after Sclater et al., 1977. This shows the major physiographic features and approximate location of floral provinces (Brenner, 1976) in relation to the paleomagnetically determined equator (after van der Voo and French, 1974). Hatched areas may have been shallow during Middle Cretaceous.

In this study we have given particular consideration to the relationships between palynomorph stratigraphy and the diversified sediment types encountered on a decimeter-scale in these cores, so as to reduce the randomness of the paleontological data.

### LITHOLOGY

The total sediment section on Hole 417D is 343 meters thick and for Holes 418A, and B only 8 km to the south, it is 320 meters thick. The black clay facies from early Aptian to middle Cenomanian is about 55 meters in Hole 417D, and 65 meters in Hole 418 of this facies lies directly above the igneous basement at both sites; basement recovery in the black clay interval was about 28 to 34 per cent. Using the van Hinte (1976) time scale, the thickness indicates an overall sedimentation rate of 2 to 3 meters per million years, which is typical of pelagic sedimentation. Chert layers, which form the contact with overlying barren, oxic zeolitic multicolored clays may indicate a significant hiatus in the Cenomanian. Another hiatus may occur in Hole 417D between the early Aptian and late Aptian to early Albian.

Carbonaceous clay beds form only a minor portion of the sediment column. The black clay facies is a combination of varied — in some cases, cyclic — lithologies that change rapidly on a centimeter scale. Some contacts are abrupt, others transitional. Intercalated “black clay” beds are black to gray, and may be either laminated or burrowed, waxy or crumbly and contain from 1 to 8.6 per cent carbon (Deroo, this volume). Waxy, fine-grained black clays show essentially the same mineral composition as surrounding green clays. The green clays also show black burrow fillings (Figure 3). Disseminated pyrite is common and some pyrite nodules occur in both types of clay. Abundance of palynomorphs however, is somewhat greater in the black than in green layers. Radiolarians are common in Sections 417D-19-21 and 418B-29-34 (upper Aptian to upper Albian), and

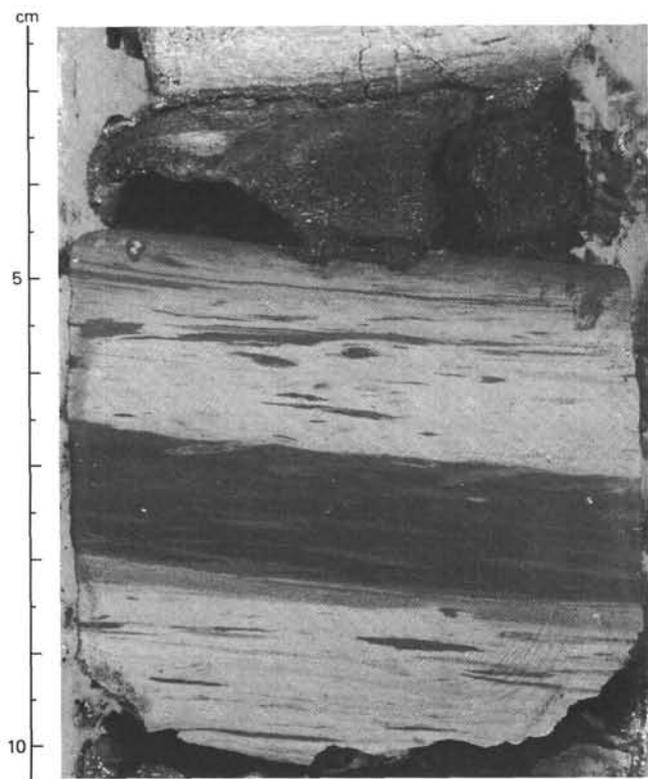


Figure 3. Typical black and green carbonaceous clay cycle.

sandy radiolarian beds may be pitch black, light green, or red. Intercalated nannofossil chalks occur in numerous sections as white, light green, olive-gray or gray beds; some are thinly laminated. Induration levels vary — a fact which may have affected the drilling recovery. Radiolarian sands may be cemented by silica-chalk and opal-CT, while some carbonaceous clay is crumbly and easily washed from the core barrel.

On a broad scale, Holes 417D and 418B are easily correlated. Zones with a high density of the black clay layers are encountered in upper Albian to the middle Cenomanian Cores 417D-17 through 19 and 418A-10 and Section 418B-29-31 as well as the basal part of the column (lower Aptian) in Sections 417D-21-3 and 418B-34-1. Between these zones, Sections 417D-20-1 to 21-1 and Cores 418B-32 and 418B-33 (upper Aptian to middle Albian) record a period of oxic conditions in which the same lithological types are dominantly reddish brown to pale-green radiolarian sands, nannofossil chalks, marls, and clays. Palynomorphs are rare in these more oxidized sediments.

Most palynomorph samples were selected from reduced sediments, particularly black layers. For comparison, samples of the green clay and dark-olive nannofossil chalk were also examined. Good preservation was not limited to the black beds. In gray beds where some calcite and a few nannofossils persist, the condition of the palynomorphs was excellent.

Table 1 lists the samples and their corresponding lithologic character. In some crumbly black clay beds, palynomorphs, and a few scattered wood cuticles dominate the bulk smear slides. In other carbonaceous layers, much of the organic matter visible in bulk smear slides collects in amorphous masses. In some of the pitch black radiolarian

sand layers, the density of pollen and dinoflagellates is very low. The black coloration of these sands may result from impregnation by immature hydrocarbons. Under only 250 meters of overburden, sediments would probably not be warmed above 50°C and diagenetic changes are minimal, as indicated by isotope studies (McKenzie and Kelts, this volume). Single samples probably represent time spans on the order of 5000 to 20,000 years, which is within the realm of variability for oceanic currents and upwelling but not broad tectonic movements.

## METHODS

All of the samples have been prepared by the standard palynological procedure using concentrated HCl and HF. The samples were dissolved with HF at room temperature for about 30 hours, without use of an oxidizer. The very finest grained organic material was removed using a sieve with a mesh of 14 microns. The residues were then mounted in glycerine jelly for optical counting. The taxonomic descriptions of the species are given immediately preceding the plate captions.

## STRATIGRAPHY AND CORRELATION

In the palynological spectrum observed in the middle Cretaceous samples from Legs 51 through 53 we can separate the flora elements into three groups. These flora types match well with the zonal scheme established by Brenner (1963) and Doyle (1969). The floral elements from the top of the sediment sequence also match well with the zonal scheme for the South American middle Cretaceous flora (Herngreen, 1975). Primitive angiosperm pollen (*Clavatipollenites*, *Retimonocolpites*, and *Tricolpites*) form the most important stratigraphic marker assemblages along with the gymnosperm groups (*Classopollis* and *Elaterosporites*). Dinoflagellate cysts and acritarchs may occur as sudden pulses in which a limited number of species dominate the spectrum. The dinoflagellate peaks have been used to establish a correlation between Sites 417D and 418B (see Figure 4 and Tables 2 and 3). The dinoflagellate-cyst assemblages do not contain the index forms that Habib (1977) used to subdivide the Aptian to Cenomanian. The relative abundance of dinoflagellate-cyst assemblages serves as a guide to monitor land-derived input.

### Leg 51B, Hole 417D

#### Sections 21-3 and 21-4

Four samples were examined from the sediments recovered from the last 2 meters above the basalt contact in Hole 417D. Two contained a well-preserved microflora, in which dinoflagellate cysts are the dominant palynomorphs. The spectrum is dominated by two, respectively three, species: *Druggidinium deflandrei* and *Dictyopysidia reticulata* in both samples, while in addition *Prolixosphaeridium granulosum* is prominent in the younger specimen (Sample 417D-21-3, 55-56 cm).

The most common pollen form in this zone is the gymnosperm, *Classopollis noeli*. Angiosperm pollen are very rare in the lowest part of the section. The only representative found in these sediments is *Clavatipollenites*; other types such as monocolpates and tricolpates are absent. The assemblage therefore best fits into the Zone I established by Brenner

TABLE 1  
Listing of Samples From Legs 51 Through 53, Sites 417 and 418<sup>a</sup>

	Sample (Interval in cm)	Description	Carbonate
Leg 51, Hole 417D	17-1, 52-54	Light gray, thinly laminated, hard mudstone	traces
	17-1, 94-95	Waxy green clay	minor
	17-3, 65-66	Olive-gray chalk	60%
	17-3, 127-128	Black clay, rich in organic matter	trace
	17, CC	Black crumbly clay with pyrite	none
	18-1, 3-4	Black crumbly clay	trace
	18-2, 16-19	Pale-green clay, pyritic radiolarians	trace
	19-2, 6-8	Dark-gray mudstone	trace
	19-2, 11-14	Black clay with thin wispy white laminations	none
	21-1, 108-110	Hard, grainy black and burrowed green clay	none
	21-3, 55-56	Black crumbly clay, pyritic radiolarians	trace
	21-4, 22-24	Light-gray laminated chalk	80%
	Leg 52, Hole 418A	10-1, 95-97	Gray and black laminated mudstone
10, CC		Black mudstone	none
Leg 53, Hole 418B	28-2, 53-55	Dark-olive gray mudstone with nannofossils	10%
	28-3, 75-77	Dark grayish brown	minor
	29-2, 91-92	Black cycle, with nannofossils	20%
	31-2, 4-6	Black clay, sub-millimeter laminations	none
	31-2, 11-13	Black, crumbly, coarse mudstone	trace
	34-1, 6-7	Transitional greenish gray clay	none
	34-1, 10-13	Coarse, greenish black clay	none
	34-1, 15-16	Black, carbonaceous, radiolarian molds, nannofossils	30%
	34-1, 30-31	Black, sandy mudstone	none

<sup>a</sup>Carbonate estimates from X-ray data.

(1963), or into the *Clavatipollenites*-Zone of Habib (1977). The range of this zone encompasses the entire Barremian and Aptian, and possibly the lowest Albian. There are also a few gymnosperm index forms which would indicate an age not younger than late Aptian. The one exception is *Classopollis brasiliensis*; this species was described by Herngreen (1975) as first appearing in the middle Albian. It is, however, present in all of the samples from Holes 417D and 418B.

#### Cores 417D-21 to 417D-19

The flora from these cores is characterized by the appearance of several new angiosperms. *Clavatipollenites* is still present. The pollen spectrum contains additional monocolpate forms including *Retimonocolpites dividius*, *R. reticulatus*, and *R. peroreticulatus*. Furthermore, the first tricolpate forms (*Tricolpites crassimurus* and *T. parvulus*) also appear in these samples. Zone II (Brenner, 1963; and Doyle and Robbins, 1977) matches best with this microflora assemblage. Any division into subzones is merely speculative, and is hindered by the lack of good index forms. The flora of Zone II begins in early to middle Albian and ranges up to late Albian. Here the gymnosperm pollen, *Welwitschiapollenites*, appears. We are yet uncertain whether a stratigraphic significance can be attached to the appearance of this genus. Several other forms provide clues to the age designation, including scattered spores such as *Cicatricosisporites mohrioides*, *Aequitriradites* sp., and *Klukiasporites areolatus*. The occurrence of these species is confined to the middle Albian.

The dinoflagellate flora of this section is characterized by the initial appearance of *Gingiodinium spinulosum* and the

extreme dominance of this species in the samples from Core 417D-19.

*Lithosphaeridium conispinum* and *Cribroperidinium* sp. 1 also occur for the first time. According to available studies, *Gingiodinium spinulosum* is limited to Albian and Cenomanian, while *Lithosphaeridium conispinum* can be traced back to the late Albian (Harker and Sarjeant, 1975).

#### Cores 417D-18 and 417D-17

The appearance of other tricolpate angiosperm pollen characterize the sediment section in Cores 18 and 17. Common forms include *Tricolpites barrandei* and *T. nemejci*. The appearance of both these species is characteristic of Zone III (Doyle and Robbins, 1977). Other index forms are also present; although scarce, we could observe *Striatopollenites dubius* and *Tricolpopollenites macroreticulatus*. The former begins in Albian (Jardiné and Magloire, 1962; Morgan, in press), while the second ranges from late Albian to Cenomanian. Further evidence for the assignment of this section to Zone III (Doyle and Robbins, 1977) includes the diverse variety of tricolpate angiosperm pollen and the complete absence of triporate types (Normapolles). This zone spans the interval from late Albian possibly through to early Cenomanian. The zonation of Habib (1977) differs slightly from this scheme. Zones II and III are combined into the *Retitricolpites georgensis*-Zone. The subzones IIA and IIB of Brenner (1976) correspond approximately to the *Tricolpites minutus*-Subzone of Habib (1977). The subzones IIC and Zone III are equivalent to the *Psilatricolporites*-Subzone, whereas Zone IV is called the *Complexiopollis*-Zone based on the occurrence of *Complexiopollis*.

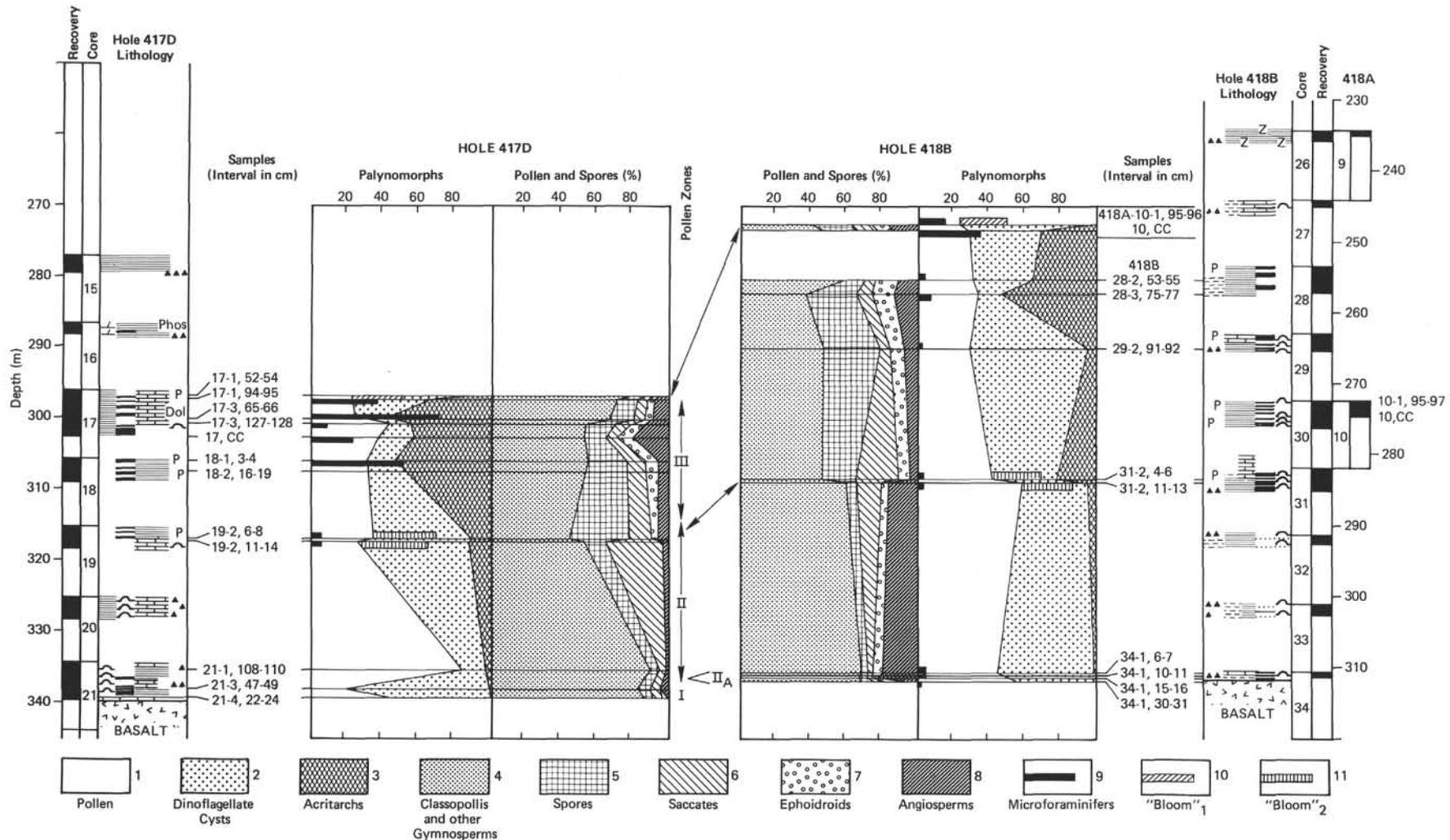


Figure 4. Compilation of palynomorph frequency and the stratigraphic position of palynology samples from Sites 417 and 418. Lithologic symbols are as defined in the site chapters. Dinoflagellate zonation I, II, and III (Doyle, 1969) is given in the center column with tentative correlation markers. Samples from the Wash-Core 418A-10 (right column) have been repositioned by the flora to fall above Hole 418B. Relative frequencies are given for: 1) pollen, 2) dinoflagellates, 3) acritarchs, 4) Classopollis and other gymnosperms, 5) spores, 6) saccate pollen, 7) ephedroide grains, 8) angiosperms, 9) microforaminifers, 10) dinoflagellate bloom *Cunningia rotunda*, and 11) dinoflagellate bloom *Ginginodinium spinulosum*. In the lithology column, black carbonaceous clay beds are marked by bars; Z = zeolite, P = pyrite.



*Canningia rotunda*. *H. arrundum* first appears in the Albian whilst as yet *Ch. discreta* is only known from Cenomanian sediments (Harker and Sarjeant, 1975). *Lithosphaeridium siphoniphorum* and *Canningia rotunda* become particularly common in the upper part of the section.

#### Core 34

Recovery was poor in the lowest core of Hole 418B. This would explain why the last meter of light-gray lower Aptian nannofossil chalks found in Section 417D-21-4 are absent here. The flora from the lowest samples from Site 418 (Section 34-1) is confidently assigned to Zone II based on the relatively common occurrences of monocolpate angiosperm pollen as well as sporadic occurrences of tricolpate types. A more refined positioning into Subzone IIA is indicated by the relatively common occurrence of *Clavatipollenites* compared with scarcer tricolpate forms, namely *Tricolpites crassimurus*, *T. parvulus*, and *T. albiensis*.

The dinoflagellate assemblage is dominated by *Drugidium deflandrei* and *Dictyopyxidid reticulata* which is very similar to the spectrum at the base of Hole 417D (Sections 21-4 and 3). The appearance of *Gingiodinium spinulosum*, on the other hand, is more suggestive of a slightly younger age placement within the early Albian. *Welwitschiapollenites* also occurs in these samples. Another indication of Albian age is the presence of *Klukisporites areolatus*.

#### Core 31

Core 418B-31 samples are dominated by the single species, *Gingiodinium spinulosum*. The unique character of this "bloom" can be directly correlated with Section 19-2 from the Hole 417D sequence. *Lithosphaeridium siphoniphorum* and *Cribroperidinium* sp. 1 also appear for the first time in the assemblage. In comparison with Core 418B-34, the angiosperm pollen spectrum shows a greater abundance of the tricolpate types: *Tricolpites crassimurus*, *T. parvulus*, and *T. albiensis*. It follows that this section belongs in the upper part of Zone II. The presence of the gymnosperm pollen, *Inaperturopollenites hiatus*, also has stratigraphic implications. According to Singh (1971), these forms range in the middle Albian.

#### Cores 418B-29 and 28 and 418A-10

Late Albian or early Cenomanian (Zone II, Doyle and Robbins, 1977, or *Classopollis spinosus*-Zone, Hergreen, 1975) ages are indicated by the flora from the uppermost part of the sequence examined from Cores 418B-29 and 28 and 418A-10. These samples correspond to the youngest occurrences of black clay beds. Evidence includes the angiosperm assemblage as well as the occurrence of *Classopollis spinosus*. The dinoflagellate assemblage is characterized by *Hystrichosphaeridium arrundum*, *Chlamydo-phorella discreta*, *Palaeohystrichophora infusorioides*, and *Canningia rotunda*.

The obvious similarity between these samples and Core 17 from Hole 417D can be used to solve a drilling problem. Core 418A-10 was taken at 272 to 282 meters below the sediment surface. The black clay lithology of the 1.5 meters of recovered sediment is most similar to sediments at 250 meters sub-bottom from Core 28 in Hole 418B, drilled only 40 meters away. The excellent floral match indicates that

during the 27 meter wash-down for Core 418A-9, sediments from the upper black clay sequence were jammed into the core barrel while sediments from the nominally cored interval were excluded (see Figure 4).

#### ASPECTS OF ANGIOSPERM EVOLUTION

Samples from Legs 51 through 53 document a time span during which angiosperms underwent rapid development. The relatively detailed palynological stratigraphy in the Aptian to Cenomanian section reflects the rapid evolution of this group. Samples from pollen Zone I from Site 417D, Sections 21-3 and 4 record an initial phase of angiosperm development. Only the most primitive monocolpate types from the genus *Clavatipollenites* occur. In particular, this includes the forms *Clavatipollenites hughesi* and *C. tenellis*. From a taxonomic point of view, this form-group appears to be related to modern forms of the Magnoliales. None of the other monocolpate forms which might be expected in this pollen Zone I (e.g., *Retimonocolpites* and *Stellatopollis*) was found in these samples. Monocolpate pollen forms dominate a considerable time span in the phases of early angiosperm evolution. They range with certainty from Barremian into the early Albian, encompassing at least 10 million years.

The succeeding evolutionary phase is manifested in the lowest samples from the section in Hole 418B, where forms are much more diversified. *Clavatipollenites* continues while, in addition, several forms of the genus *Retimonocolpites* occur along with other monocolpate types. The first few tricolpate forms appear. This, more differentiated spectrum of pollen morphologies corresponds stratigraphically to the lower parts of pollen Zone II, probably equivalent to Subzone IIA or early Albian.

Morphologically, the genus *Retimonocolpites* represents a special evolutionary trend. It is commonly compared with the *Liliacidite*-form group although it differs by having a longer colpus, which generally encircles more than 180° of the pollen grain. *Retimonocolpites* also differ by the type of connection between the endexine and the reticulum. In *Retimonocolpites*, the reticulum is moderately thick and only loosely connected with the endexine. For this reason the reticulum is commonly found separated from the inner layer (see Plate 5, Figures 32 through 34 and Plate 6, Figures 7 and 8). We interpret this genus as an isolated angiosperm group which flourished briefly in Aptian and Albian times before fading in the Cenomanian. There should be a clear taxonomic separation between this form and the relatives of the Liliaceae s. which show fossil lineage through forms such as *Liliacidites* and *Arecipites*.

Two other noteworthy pollen types with distinct angiosperm affinity occur in this interval, although they are not numerous. The first is a monocolpate form (Monocolpate sp. A, Plate 5, Figures 25 through 27) with foveolate sculpture. The sculpturing and form of the colpus indicate a relationship with pollen morphology of recent monocotyledons, in particular *Restionaceae* and *Centrolepideaceae*. The second form ("*Trichotomosulcites*" sp. 2, Plate 5, Figures 35 through 37) is trichotomosulcate and displays irregularly intergrown structural elements. According to the evolutionary concept of Muller (1970), trichotomonocolpate types represent a transitional stage between monocolpate

and tricolpate forms. Modern analogies include similar pollen grains from monocotyledons, for example palm trees.

The next phase is documented by pollen from the intervals 417D-21-1, 108 to 110 cm, 19-2, 11 to 14 cm, 19-2, 6 to 8 cm, and in the intervals 418B-31-2, 11 to 13 cm and 31-2, 4 to 6 cm. Tricolpate pollen grains become more prominent than monocolpate types. Increased differentiation is manifested by differences in surface structures and sculpturing. The spectrum corresponds to angiosperm from the upper part of pollen Zone II (B and C zones of Doyle and Robbins, 1977). Both of these subzones approximate the middle and the lower part of the late Albian. Monocolpate forms show greater diversification. *Clavatipollenites* is still common, while *Retimonocolpites* groups attain their maximum development. Along with the forms given in Table 1, *R. textus* and *R. echinatus* appear. Single pollen grains from other monocolpate forms were observed as well. We classified two types with fine reticulum and thick columellate structures with the genus *Arecipites* (*Arecipites* sp. 1 and *Arecipites* sp. 2, see Plate 5, Figures 3 through 7). Another form designated as *Magnolipollis* sp. 1 shows morphological similarities with recent magnolia pollen. A fourth type was compared with *Monocolpopollenites tranquillis verrucatus* which is comparable with recent palm varieties. Similar forms such as the reticulate- and columellate-structured "*Trichotomosulcites*" sp. (Plate 5, Figures 29 through 31) also occur in recent palms. The botanical affinity of one syncolpate form with foveolate sculpture (monocolpate sp. B, Plate 5, Figures 23 and 24) remains unclear.

A single grain was found in the same interval which has an irregular, restricted pore and scorbiculate sculpture (*Milfordia* sp. 1, Plate 5, Figures 21 and 22). A morphological comparison suggests this pollen type is related to the recent *Restionaceae*. This is the oldest reported instance of a monoporate form. Previously, its first appearance was known only from upper parts of the Late Cretaceous (Jardine and Magloire, 1965).

The next phase includes pollen associations of the pollen Zone III. It is documented by Samples 418B-29-2, 91-92 cm, 28-3, 75-77 cm, and 28-3, 53-55 cm; 418A-10, CC, 10-1, 95-97 cm, and 417D-18-1, 3-4 cm, as well as all samples from Core 417D-17. They are characterized by the increasing prominence of the angiosperm types and in particular by greater differentiation within the tricolpate types. In several species there are indications of the beginning of pore formation. In the uppermost interval of this zone we expected to find tricolporate forms with highly differentiated ornate sculpturing. Such types are, however, absent in our samples. This is an indication that our profile extends upward to include only the lower part of the pollen Zone III, or early Cenomanian.

The rich and well-preserved flora in the samples from Sites 417 and 418 underlines the diversity already attained by angiosperm populations in the middle Cretaceous. Monocolpate, syncolpate and trichotomosulcate types, which have been considered primitive forms, show various (and some advanced) degrees of differentiation. Many show morphological similarities that can be closely linked with the recent Monocotyledons.

## PALEOBIOGEOGRAPHY AND CLIMATE

The palynomorph spectrum of the land-derived components in the samples examined from Legs 51 through 53 do not show major variations that could be related to a significant climatic trend. It is thus possible to treat the results as a whole in the following discussion. The placement of the Aptian to Cenomanian flora from Sites 417 and 418 into a climatic framework was attempted by a relative comparison with those spectra available from the European and North American Cretaceous on the one hand and profiles from equatorial provinces on the other. An approximate reconstruction (Sclater et al., 1977) has been presented in Figure 2. Note that a paleolatitude determined from underlying basalts at Site 417A was 11.6°N (Bleil and Smith, this volume). This seems rather low because the middle Cretaceous (Aptian to Cenomanian) is considered a time of general worldwide climatic amelioration and this latitude would imply a more tropical flora regime. The pollen spectrum in a midbasin marine environment is, of course, a secondary phenomenon. It is dependent on factors other than primary production including direction of currents and wind transport, river drainage, arid zones, and continental mass distribution. If the paleolatitude from magnetics is correct, it is somewhat surprising to find subtropical and tropical elements combined in the flora spectrum of Sites 417 and 418, indicating a transitional position between the northerly, subtropical Southern Laurasian Province and the more southerly and tropical Northern Gondwana Province. These results have been combined with information from the Lower Cretaceous of the Southern Alps (Hochuli, in preparation) to define a floral transition zone (Figure 2).

The sporomorphs which dominate the samples from the western North Atlantic are almost exclusively *Classopollis*. There is a conspicuous lack of saccate pollen as compared with sections from Northern Europe and North America. Only rare examples, such as *Alisporites*, *Cedripites*, *Parvisaccites*, and *Podocarpidites* occur. One exception is *Vitreisporites pallidus*, which is common in several samples. In contrast, saccate pollen comprise the major group in the corresponding stratigraphic intervals for the boreal realm. These types are almost entirely excluded from equatorial regions (Herngreen, 1975; Brenner, 1976). Another example is the relatively common occurrence of ephedroid pollen-grains in samples from Sites 417 and 418. Here these forms are almost as common as the saccate pollen, while extremely rare in European spectra. Thus, floras from Site 417 and 418 resemble closely floras from the equatorial South American/African Province. This has been referred to as the AAS-Province by Herngreen (1974) or the Northern Gondwana Province by Brenner (1976).

There is a problem with this comparison. The main characteristic of these tropical-province floras is the occurrence of forms from the *Elaterosporites* group. No modern plant group is known which can be related to these elater-bearing pollen forms. Yet, they show a tremendous development in equatorial regions ranging from the latter part of the Early Cretaceous to the early part of the Late Cretaceous. On the other hand, they have a very limited distribution. In samples from Hole 417D, only a few rare examples

of *Elaterosporites klaszi* could be identified. By comparison with the distribution charts of Herngreen, 1975 (Fig. 7), the rare appearance of *E. klaszi* at Site 417 constitutes the northernmost reported occurrence of this species to date.

In summary, the pollen spectrum of Sites 417 and 418 lies in a transitional flora belt. The occurrence of *Elaterosporites* and the abundance of ephedroid pollen grains shows distinct affinities with an equatorial flora from the Northern Gondwana province. The presence of saccate pollen points to a relationship with boreal belts of the Southern Laurasia Province. Both the saccate pollen and the elater-bearing forms are scarce, which indicates that these samples derive from a region peripheral to both these major flora zones. There appears to have been a significant regional floral gradient. Bisaccate forms are well-adapted to current transport, and further investigation of other Albian to Aptian deep-sea and land sites may define paleocurrent patterns.

Any climatic interpretation of Cretaceous flora is made with great reservation. This applies particularly to the equatorial regions. The botanical affinities of the main floral elements are completely unknown. We can assume that the characteristic floral elements of the boreal regions, Pinaceae and Podocarpaceae types, derive from a relatively humid, temperate climate and would tolerate a broad temperature range. Fern spores are also common along with the saccate pollen, in boreal regions. Some of these, for example Schizaeaceae, show affinities to present-day families that are exclusively tropical or subtropical. For this reason Brenner (1976) designated this association as the Southern Laurasia Province. The corresponding climate is considered warm temperate to subtropical. Brenner (1976) used several criteria to conclude that the climate in the North Gondwana Province of the Middle Cretaceous, while tropical, had some strong semi-arid overprints. Pinaceae and Podocarpaceae pollen are scarce, as are the Pteridophyte spores which resemble the Schizaeaceae. Pollen grains from forms related to Ephedra along with *Welwitschia* and *Classopollis* suggest tropical, but semi-arid conditions.

## PALEOENVIRONMENT

### Terrestrial Influence

The Aptian to Albian central North Atlantic Sea was about 1500 km wide (Sclater et al., 1977), although land may have been present about 500 km to the south of Site 417 (see Figure 2). Land-derived organic components form a minor fraction of the flora examined in this study. Some fragments of wood cuticles and tissues occur in the prepared slides, but none of the particles exceeds 120 microns. As this is near the average size of pollen and spores, it follows that normal surface currents and winds were probably responsible for the distribution of terrestrial material fragments. The spectrum and size ranges are some evidence for a relatively long distance from Site 417 to the nearest major landmasses. Further supporting evidence is the lack of thick-walled spores. In flysch-like sediments and marine deposits with a heavy terrestrial overprint, such forms are particularly common along with coarse wood and tissue fragments. Turbidity-current distribution of land-derived

components, particularly at the ridge Sites 417 and 418, seems unlikely. Very little, however, is known about the amount of land-derived organic matter or the pollen/dinoflagellate ratios in the present-day Mid-Atlantic Ridge sediments (Farrington, personal communication). A qualitative evaluation of the palynomorphs suggests that organic particles of terrestrial origin may have been fractionated by relatively long-distance transport by surface currents.

In general, the percentage of pollen and spores in the palynological profiles tends to decrease in upward direction in the sediment column, indicating decreasing terrestrial influences. Possibly this represents a faint echo of late Albian transgressions onto the continents. A maximum in the quantity of land-derived components is observed at the base of Zone II (late Aptian to early Albian). The peak content of up to 8 to 10 per cent  $C_{org}$  in the top of the section does not appear to correspond with the maximum indication of land-derived organic matter, but rather to dinoflagellate species "blooms." Along with a decrease in pollen and spores the upward onset and increase of microforaminifers document pelagic, open marine conditions. The delicate chitinous remnants of microforaminifers are rarely found in sediments along the continental margins. In contrast, dinoflagellates as yet give little indication of coastal distances. These microfossils may be abundant in nearshore sediments. Dinoflagellates are the dominant representative of marine phytoplankton in the lower parts of the sediment column from Legs 51 through 53. Very little is known about the systematic relationship or ecology of the other plankton forms recorded, such as *Tythodiscus*, *Monogemmites*, and *Pleurozonaria*. It is noteworthy that they first appear along with the microforaminifers at the base of the pollen Zone II. In some samples they form a major portion of the phytoplankton assemblage. In the younger part of the section, these forms diminish in importance. The palynomorphs in the sediment column from late Aptian to early Cenomanian at both Sites 417 and 418 are clearly dominated by an open marine phytoplankton flora. A decrease in the pollen/dinoflagellate ratio and corresponding increase in microforaminifers from late Aptian to early Cenomanian are interpreted as signs of further decline of terrestrial influences. Several mechanisms could lead to this situation including 1) a shift in the predominant oceanic current patterns, 2) parallel development to the inward migration of source areas due to mid-Cretaceous transgression and regression factors, 3) reductions in the outpourings of organic matter by the large delta complexes around the Aptian to Albian sea, 4) phytoplankton evolutionary trends, and 5) changes in the preservation of organic matter due to fluctuations in an anoxic boundary layer. More anoxic conditions would increase preservation of marine-derived organic matter with respect to more robust, refractory land-derived organic matter.

### "Blooms"

One of the most conspicuous and puzzling observations is the rapid fluctuations and dominance of individual species in the phytoplankton spectrum. In the lower part of the section we see a dominance of *Druggidium deflandrei* and *Dictyopyxidia reticulata* (Sections 417D-21-4 and 21-3; and Section 418B-34-1). Subsequently, this phase wanes and is replaced by another low-diversity, limited-individual as-

semblage. There follows a flora with predominance of *Gingiodinium spinulosum*. In the Hole 418B section, this bloom follows directly the *Druggidium-Dictyopyxidiella* maximum. The maximum development of the *Gingiodinium* also corresponds to a marked increase in the number of cysts from *Tythodiscus*, *Monogemmites*, and *Pleurozonaria*, as well as the expansion of microforaminifers. The *Gingiodinium* "bloom" preserved in Hole 418B, Section 31-2, is followed by the first clearly polyspecific, rich dinoflagellate flora in Sample 418B-29-2, 91-93 cm. Shortly thereafter, in the next specimen, Sample 418B-28-3, 75-77 cm, we find the same assemblage considerably diminished, overwhelmed by a quantitative dominance of *Tythodiscus* and *Monogemmites*. The next specimen, Sample 28-2, 53-55 cm, again shows a well-developed dinoflagellate spectrum. Here again a single species, *Cleistosphaeridium huguonoti*, plays the major role.

Samples from Core 418A-10 also contain a rich dinoflagellate spectrum, but here the most common species is *Chlamydothorella discreta* and, in addition, *Canningia rotunda* in the youngest specimen (Sample 418A-10-1, 95-97 cm).

The *Gingiodinium* maximum in Hole 417D is followed by a high-diversity dinoflagellate population. The number of individuals is low, however. This situation prevails in Samples 417D-18-1, 3-4 cm, 17, CC, 17-3, 127-128 cm, and 17-3, 65-66 cm. The cysts, *Tythodiscus* and *Monogemmites*, dominate the flora. Dinoflagellates once again regain dominance towards the top of the sediment section, particularly by an increase in *Canningia rotunda*. The conspicuous abundance of this species suggests a direct correlation with specimens from Hole 418A (Sample 10-1, 95-97 cm).

In summary, we note that the phytoplankton spectrum in the stratigraphic interval from early Aptian to middle Cenomanian in Sites 417 and 418 shows signs of rapid change in both quantitative and qualitative composition. Some variations could be attributed to preservation effects, but the conspicuous dominance of individual species, their rapid expansion, and short-time spans all suggest a phasal or bloom-like development of the planktonic flora. The paleoenvironment and depositional regime control the composition of the phytoplankton spectrum. It follows that the mechanisms of distribution, reproduction, and cyst formation are all governed by complex variables in the surface waters of the ocean at that time. We attribute the rapid, and fundamental fluctuations in assemblage character to primary, short-term changes in the paleoceanography. Near continents, such fluctuations could be the result of changes in upwelling patterns and in the input of land-derived organic matter. We have seen that the terrestrial spectrum, except for a quantitative decrease in upward direction, has a fairly uniform composition and texture indicating a more or less homogenized input. This would be expected if a site some distance from coastal areas was the locus of a pelagic rain that included land-derived components transported by surface currents.

It is possible that the rapid changes are a result of extreme variations in the nutrient budget. We recall that the samples examined for palynomorphs are about 1 to 3 cm<sup>3</sup> and represent a likely interval on the order of 10,000 to 20,000 years.

This is the time scale on which climate-induced changes in oceanic circulation, such as the overturn of an euxinic basin, could be expected.

The ecology of ancient dinoflagellate forms is poorly known. From the study of recent lakes we know, however, that dinoflagellates (e.g., *Peridinium*) can be strong competitors during periods of low nutrient input. In many meromictic lacustrine systems, with annual stratification and stagnation, diatom blooms occur commonly during spring circulation when surface waters are recharged with nutrients from anoxic bottom waters. Under these conditions, *Peridinium* may bloom, with a biomass larger than warranted by nutrient conditions, and they may replace diatoms as the dominant species during the summer stagnation when nutrient levels are low. If we apply this generalized model to an euxinic Albian sea, the following salient features emerge. The rapid fluctuations in phytoplankton populations could result from alternating periods of basinwide stagnation and periods of partial to full circulation. After long periods of stagnation, overturn and mixing of nutrient-rich waters cause phytoplankton blooms. Possibly during initial phases of surplus nutrients, coccolith or radiolarian assemblages may be favored depending on the local levels and types of nutrient supply. If some dinoflagellate blooms are more closely associated with episodes of stagnation, they may be preferentially preserved in sediments because of the higher pycnocline at those times. Dinoflagellates, although more sparse, are also well-preserved in some green clays with low organic content. Perhaps these are also times with widespread anoxia but overall low productivity. Because currents and oxygenation continue in surface waters, the distribution of refractory land-derived components would be less affected by the episodic stagnation. Some dinoflagellate blooms possibly even caused widespread red tides as in the modern ocean. Naturally, oceans are a complex biological and chemical system, and the rapid sediment variations may only indicate subtle changes in the balance of populations at the surface and their survival as particles falling through the water column.

## SYSTEMATICS

Only a few remarks are made concerning the morphology, systematics, and taxonomy of the palynomorphs. Except for one new species, formal descriptions are not given for several palynomorphs which are probably new for the middle Cretaceous. Most of these forms are very rare and only a few isolated examples of these species have been found. Informal designations are used in this publication. These species will be the subject of a later paper.

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## APPENDIX

## List of Spores and Pollens

## Spores

- Aequitriradites* sp.  
(Plate 1, Figure 1)  
A similar form named (but not formally described) *Aequitriradites* sp. is known from the Albian of Africa (Jardiné and Magloire, 1965).
- Appendicisporites problematicus* (Burger) Singh, 1971.  
(Plate 1, Figures 2, 3)  
Stratigraphic distribution: Berriasian-Albian.
- Appendicisporites tricornitatus* Weil. and Greif., 1953  
(Plate 1, Figures 4, 5)
- Baculatisporites* sp.  
(Plate 1, Figures 6, 7)  
Trilete spore, rounded triangular or round in outline. Ornamented with more or less isodiametric gemmae, baculae or blunt echinae. The sculpture is the same on the proximal and distal face. Trilete laesura simple, reaching the equator.
- Biretisporites potoniaei* Delc. and Sprum., 1955  
(Plate 1, Figure 8)
- Cicatricosisporites hallei* Delc. and Sprum., 1955  
(Plate 1, Figure 9)  
Stratigraphic distribution: Early Cretaceous and Cenomanian.
- Cicatricosisporites minutaestriatus* (Bolikh.) Pocock, 1964  
(Plate 1, Figures 12, 13)
- Cicatricosisporites mohrioides* Delc. and Sprum., 1955  
(Plate 1, Figures 10, 11)  
Stratigraphic distribution: Purbeckian-Albian.
- Cicatricosisporites* cf. *patapscoensis* Brenner, 1963  
(Plate 1, Figures 14, 15)  
The spores compared with *C. patapscoensis* found in our material are smaller than the typus. The typical *C. patapscoensis* is stratigraphically restricted to Zone II (Brenner, 1963).
- Cicatricosisporites subrotundus* Brenner, 1963  
(Plate 1, Figures 16, 17)  
Stratigraphic distribution: restricted to Zone II (Brenner, 1963).

*Cicatricosisporites venustus* Deak, 1963

(Plate 1, Figures 21, 22)

Stratigraphic distribution: Barremian–Cenomanian/Turonian (Singh, 1971).

*Concavisporites juriensis* Balme, 1957

(Plate 2, Figures 9, 10)

Stratigraphic distribution: Late Jurassic–Early Cretaceous

*Converrucosisporites platyverrucosus* Brenner, 1963

(Plate 1, Figures 19, 20)

In contrast to *Baculatisporites* (see forementioned), the sculpture-elements are anisodiametric and the trilete laesura is bordered by an undulating crest. Stratigraphic distribution: Zones I and II (Brenner, 1963).*Converrucosisporites proxigranulatus* Brenner, 1963

(Plate 1, Figure 18)

*Costato perforosporites foveolatus* Deak, 1962

(Plate 1, Figures 29, 30)

Stratigraphic distribution: Late Aptian–Albian (Singh, 1971)

*Cyathidites australis* Couper, 1953*Cyathidites minor* Couper, 1953*Gleicheniidites circinidites* (Cooks.) Dettm., 1963

(Plate 1, Figure 23)

*Gleicheniidites confossus* Hedlund, 1966

(Plate 1, Figures 24, 25)

Stratigraphic distribution: To date, has only been found in the Cenomanian.

*Gleicheniidites echinatus* (Bolikh.) W.Kr., 1959

(Plate 1, Figures 26–28)

*Gleicheniidites* sp. 1

(Plate 2, Figures 1, 2)

This species differs from the similar *G. circinidites* by the thick wall (about 5  $\mu\text{m}$ ) along the margin.*Klkisporites areolatus* Singh, 1971

(Plate 2, Figures 4, 5)

Stratigraphic distribution: Albian (Singh, 1971)

*Klukisporites foveolatus* Pocock, 1971

(Plate 2, Figure 3)

Stratigraphic distribution: Barremian–Albian (Singh, 1971)

*Psilatrilletes circumundulatus* Brenner, 1963

(Plate 2, Figures 6, 7)

Stratigraphic distribution: Zones I–II (Brenner, 1963).

*Stereisporites antiquasporites* (Wils. and Webst.) Dettm., 1963

(Plate 2, Figures 11–13)

*Triplanosporites* sp. 1

(Plate 2, Figures 18, 19)

This type of spore is very often found in different grain sizes.

*Triplanosporites* sp. 2

(Plate 2, Figure 8)

A species of the form-genus *Triplanosporites* with a flat coarse verrucate sculpture.*Undulatisporites* cf. *fossulatus* Singh, 1971

(Plate 2, Figures 16, 17)

In contrast to the type *U. fossulatus*, the sides of the spores are not straight, but convex. The amb is rounded triangular. Stratigraphic distribution of the typical *U. fossulatus*: middle and late Albian (Singh, 1971).*Undulatisporites undulapolus* Brenner, 1963

(Plate 2, Figures 14, 15)

Stratigraphic distribution: Barremian–Albian (Singh, 1971).

*Trilete* sp. 1

(Plate 2, Figures 20, 21)

Trilete spore with a rounded amb. Trilete laesurae straight, short, not reaching the equator. Sculpture irregular reticulate, lumen 1 to 3  $\mu\text{m}$  in diameter. Muri inhomogeneous, composed of small elements. Occurrence: single spore found in Sample 418B-31-2, 11–13 cm.*Trilete* sp. 2

(Plate 2, Figures 22, 23)

Trilete spore, amb round to rounded triangular. Sculpture verrucate. The high verrucae are interconnected by low irregular bridges forming an indistinct reticulum. Trilete laesurae straight, not reaching the equator. Occurrence: single spore found in Sample 417D-21-1, 108–110 cm.

**Gymnosperms****Vesiculate Grains***Alisporites thomasi* Couper, 1958

(Plate 2, Figures 24, 25)

*Cedripites admirabilis* (Bolikh.) W.Kr., 1971

(Plate 3, Figures 3–5)

*Parvisaccites radiatus* Couper, 1958

(Plate 2, Figures 31, 32)

*Parvisaccites rugulatus* Brenner, 1963

(Plate 2, Figure 29)

*Podocarpidites multesimus* (Bolikh.) Pocock, 1962

(Plate 3, Figures 1, 2)

*Rugubivesiculites minimus* Burger, 1966

(Plate 2, Figure 30)

*Vitreisporites pallidus* (Reiss.) Nilss., 1958

(Plate 2, Figures 26–28)

In our material the grains of *V. pallidus* are highly variable in size (20 to 40  $\mu\text{m}$ ).**Classopollis-Exesipollenites-Form Group***Classopollis brasiliensis* Herngreen, 1975

(Plate 3, Figures 10, 11)

*Classopollis noeli* Reyre, 1970

(Plate 3, Figures 6–9)

The most frequent species of *Classopollis* can be compared best with *C. noeli*. The grains found in our material are highly variable in size (20 to 40  $\mu\text{m}$ ). The ornamentation is, in contrast to *C. brasiliensis*, isodiametric verrucate.*Classopollis spinosus* Herngreen, 1973

(Plate 3, Figures 18, 19)

*Exesipollenites tumulus* Balme, 1957

(Plate 3, Figures 12, 13)

Besides the distal "pore," several specimens show a very fine trilete scar. Tetrads of *E. tumulus* are found very rarely (compare Plate 3, Figure 13).*Exesipollenites* sp. 1

(Plate 3, Figure 14)

In contrast to *E. tumulus*, this species is smaller and shows a very small depression (diameter about 2  $\mu\text{m}$ ) within the thickened area of the distal pole.**Inaperturate and Colpate Gymnosperms***Araucariacites australis* Cooks., 1947

(Plate 3, Figure 33)

*Araucariacites* cf. *hungaricus* Deak, 1965(Plate 3, Figures 21, 22) from *A. australis*This form can be distinguished by its coarser sculpture. *A. hungaricus* is known from the Cenomanian.*Callialasporites dampieri* (Balme) Sukh Dev, 1961

(Plate 3, Figure 17)

*Cerebropollenites mesozoicus* (Couper) Nilsson, 1958

(Plate 3, Figure 20)

*Cycadopites minimus* (Cooks., 1947)

(Plate 3, Figure 15)

The species has been described as *Monosulcites minimus*. The genus *Monosulcites* is a synonym of *Cycadopites* Wdh., 1933 (ex Webster and Webster, 1946).*Cycadopites carpentieri* (Del. and Sprum.)

(Plate 3, Figure 16)

*C. carpentieri* differ from *C. minimus* by the size (about 70  $\mu\text{m}$ ) and the coarser structure.

*Cycadopites* sp. 1

(Plate 3, Figures 24, 25)

This pollen grain, with a relatively thick structured (granulate) wall and a wide colpus, can be compared with the specimen of Jardiné and Magloire (1965; Pl. 9, fig. 14) named *Monosulcites* sp. from the Albian–Aptian.

*Eucommiidites troedssonii* (Erdtm.) R. Pot., 1958

(Plate 3, Figures 31, 32)

*Eucommiidites* ? *glottus* (Brenner, 1963)

(Plate 3, Figure 23)

Brenner described a similar form as *Monosulcites glottus*. It is possible that the two folds beside the main sulcus of the holotypus correspond to the reduced colpi of *Eucommiidites*.

*Eucommiidites* sp. 1

(Plate 3, Figures 27, 28)

Tricolpate grain with one big and two smaller colpi. In contrast to the typical *E. troedssonii*, this grain is considerably larger (52  $\mu\text{m}$ ). The ectexine is about 2  $\mu\text{m}$  thick at the equator with a thickening trend toward the pole. The endexine is thin. The structure shows the typical granulation of the gymnosperms.

*Inaperturopollenites hiatus* (R.Pot.) Th. and Pf., 1953

(Plate 3, Figure 26)

The first occurrence of this form lies in the middle Albian.

*Sciadopityspollenites* sp. 1

(Plate 3, Figures 29, 30)

The structure and sculpture of this inaperturate grain correspond to the genus *Sciadopityspollenites*, for example to *S. crassus* from European Tertiary. According to W. Krutzsch (1970), *Sciadopityspollenites* first occurs in the Late Cretaceous. *Cerebropollenites mesozoicus*, resembling *Sciadopityspollenites*, has a coarser sculpture and a different structure. *C. mesozoicus* is very frequent in the Jurassic and in the Early Cretaceous.

**Ephedroide Pollen Grains***Aucmancisporites* cf. *cretaceous* (Pocock) Pocock, 1964

(Plate 4, Figure 1)

The single grain found in the material of Hole 418A is smaller than the holotype. Distinctive for the genus is the transverse colpus.

*Ephedripites* (*Distachyapites*) cf. *markovii* (Pocock, 1964)

(Plate 4, Figures 4, 5)

*Ephedripites* (*Distachyapites*) cf. *mediolobatus* Bolkh., 1953

(Plate 4, Figures 14, 15)

*Ephedripites* (*Distachyapites*) *multistriatus* (Pocock, 1964)

(Plate 4, Figure 2)

*Ephedripites* (*Distachyapites*) sp. 2 — Herengreen (1973)

(Plate 4, Figures 8, 9)

Small grains (about 40  $\mu\text{m}$ ) with numerous fine ribs separated by fine grooves. It is possible that they have a sulcus-like area without sculpture. Stratigraphic distribution: Albian–Cenomanian (Herengreen, 1973)

*Ephedripites* (*Distachyapites*) sp. 4 — Herengreen (1973)

(Plate 4, Figure 13)

Relatively large grain with about 15 coarse ribs separated by wide grooves. Stratigraphic distribution: as *E. sp. 2*.

*Ephedripites* (*Distachyapites*) sp. 5 — Herengreen (1973)

(Plate 4, Figure 3)

Small grain with numerous (15) about 2  $\mu\text{m}$  broad ribs. The grooves in between are very fine. Stratigraphic distribution: as *E. sp. 2* and 5.

*Ephedripites* (*Spiralipites*) *barghoornii* (Pocock, 1964)

(Plate 4, Figures 6, 7)

Stratigraphic distribution: In the material from the mid-Cretaceous of South America (Herengreen, 1975) *E. barghoornianum*, *staplinii* and *E. jansonii* are frequent in the Albian and disappear in the Cenomanian.

*Ephedripites* (*Spiralipites*) *jansonii* (Pocock, 1964) Müller, 1968

(Plate 4, Figure 12)

*Ephedripites* (*Spiralipites*) *staplinii* (Pocock, 1964)

(Plate 4, Figures 10, 11)

*Steevesipollenites binodosus* Stover, 1964

(Plate 4, Figures 29, 30)

Stratigraphic distribution: Albian–Turonian (Stover, 1964)

*Steevesipollenites* cf. *binodosus* Stover, 1964

(Plate 4, Figures 16; 22, 23)

The distal ends of these grains are also thickened but less prominent than in the type *St. binodosus*. Ribs numerous (15 to 20); grooves narrow.

*Steevesipollenites multilineatus* Stover, 1964

(Plate 4, Figures 18 through 21)

Stratigraphic distribution: Albian–Turonian (Stover, 1964; Herengreen, 1973).

*Steevesipollenites* sp. 1

(Plate 4, Figure 17)

Large grain (about 100  $\mu\text{m}$ ) with thickened ends and numerous coarse ribs (about 24). Grooves between them are rather wide and flat. This form can be compared with *Ephedripites* sp. 7 — Herengreen (1973), which is about 130  $\mu\text{m}$  in diameter.

*Steevesipollenites* sp. 2

(Plate 4, Figure 28)

Small grain with thick end and more than 30 fine ribs. Grooves as broad as the ribs.

*Welwitschiapites* sp. 1

(Plate 4, Figures 24, 27)

The grains assigned to *Welwitschiapites* sp. have numerous ribs (15 to 20) and one longitudinal furrow accompanied by two more solid ribs. Under the other ribs the endexine seems to be folded, producing a cross-striated ornamentation on the ribs. The ribs merge at the distal ends. The ectexine is thickened but, in contrast to *Steevesipollenites*, the two layers are still recognizable. *W. sp. 1* is comparable in general features with *W. virgatus* Deak 1964, but this species is larger and shows no ornamentation of the ribs.

**Elaters-Bearing Species***Elaterosporites klaszi* (Jard. and Magl.) Jard., 1967

(Plate 5, Figures 1, 2)

Stratigraphic distribution: Albian–Cenomanian (Herengreen, 1975).

**Angiosperms***Arecipites* sp. 1

(Plate 5, Figures 3–5)

Slightly asymmetric monocolpate grain. Sculpture fine reticulate, homobrochate, lumen about 1  $\mu\text{m}$  in diameter. Structure densely columellate. *Arecipites* can be distinguished from *Liliacidites* by its smaller size and by the density of the reticulum. A similar form has been described as *Liliacidites* sp. B by Doyle and Robbins, 1977.

*Arecipites* sp. 2

(Plate 5, Figures 6, 7)

This form can be distinguished from *A. sp. 1* by the narrow colpus, very fine reticulum, and extremely dense structure.

*Clavatipollenites hughesii* Couper, 1958

(Plate 5, Figures 10–12; 19, 20)

Stratigraphic distribution: Zones I–III (Doyle and Robbins, 1977).

*Clavatipollenites tenellis* Phillips and Felix, 1971

(Plate 5, Figures 15, 16)

Stratigraphic distribution: as *C. hughesii*.

*Magnolipollis* sp. 1

(Plate 5, Figures 13, 14)

Monocolpate grain with a narrow colpus. Wall about 1  $\mu\text{m}$  thick, two-layered, endexine very thin. Structure columellate, sculpture punctate or very fine reticulate. This form can be compared with *Magnolipollis magnolioides* W.Kr., 1970 known from the European Tertiary.

*Monocolpopollenites* cf. *tranquillus* *tranquillus* (R.Pot.) Th. and Pf., 1953

(Plate 5, Figures 8, 9)

Monocolpate grain with smooth to fine punctate surface. Structure fine columellate. This form can best be compared with *M. tranquillus*, a species related to the *Palmae* occurring in the Paleogene.

*Monocolpopollenites* cf. *tranquillus verrucatus* W.Kr., 1962a

(Plate 5, Figures 17, 18)

This type can be distinguished from the former species by the characteristic verrucate sculpture. A very similar subspecies of *M. tranquillus* occurs in the European Tertiary.

*Milfordia* sp. 1

(Plate 5, Figures 21, 22)

Monoporate grain; pore of irregular shape. Wall thin (about 1.5  $\mu\text{m}$ ), two-layered, structure hardly visible. Sculpture scorbiculate (tectum perforate), surface smooth. This pollen grain can best be compared with the fossil genera *Milfordia* Erdtm., 1960 and with the pollen of recent Restionaceae.

*Monocolpate* sp. A

(Plate 5, Figures 25–27)

Monocolpate grain with a distinct colpus surrounded by an anulus-like zone without sculpture. Wall about 2  $\mu\text{m}$  thick, ectexine thicker than endexine. Sculpture scorbiculate (tectum perforate), distance between the scorbiculae 1 to 2  $\mu\text{m}$ . Structure columellate, elements grown together forming an irregular intrareticulum. The grain can be compared with the pollen grains of the recent monocots families Restionaceae and Centrolepidaceae.

*Monocolpate* sp. B

(Plate 5, Figures 23, 24)

Monocolpate grain with a long colpus which extends over more than 180° of the pollen grain. Wall thin (about 1  $\mu\text{m}$  thick), two-layered ( $r \sim 1:1$ ). Structure not visible. Sculpture scorbiculate (tectum perforate), distribution of the scorbiculae irregular.

## "Trichotomosulcites" Erdtm., 1945 sp. 1

(Plate 5, Figures 28–31)

Trichotomocolpate grain. Sculpture reticulate, homobrochate, lumen about 2  $\mu\text{m}$  in diameter, muri 1  $\mu\text{m}$ , monobaculate, baculae thicken toward the top (diameter at the top 1  $\mu\text{m}$ ). Endexine very thin, less than 1  $\mu\text{m}$ . This form can be compared with the pollen grains of recent palms (for example *Acanthorhiza*, Erdtmann [1971, fig. 177 C]).

## "Trichotomosulcites" sp. 2

(Plate 5, Figures 35–37)

Trichotomocolpate grain. Colpus accompanied by a folding of the wall. Wall two-layered ( $r \sim 1:1$ ). Elements of structure grown together, forming an irregular network. Surface smooth.

*Retimonocolpites* Pierce

This genus can be distinguished from similar forms of the genus *Liliacidites* by the long colpus encircling the grain and by the reticulum which is connected with the endexine by scattered columellae. The reticulum is very often partly separated from the grain. *Retimonocolpites* has been regarded as synonymous with *Liliacidites* by Kemp (1968).

*Retimonocolpites dividuus* Pierce, 1961

(Plate 5; 6 Figures 32–34; 1–3)

Reticulum fine, more or less regular (hombrochate), lumen 1 to 2  $\mu\text{m}$  in diameter. The reticulum is attached to the endexine with about one columella per brochus. In our material this form can be observed relatively often in different grain sizes (20 to 35  $\mu\text{m}$ ). Stratigraphic distribution: Zones IIA–III (Doyle and Robbins, 1977).

*Retimonocolpites clavatus* (Singh, 1971)

(Plate 6, Figures 4–6; 7, 8)

In contrast to *R. dividuus*, the reticulum of *R. clavatus* is heterobrochate and there are several distally thickened columellae per brochus. Stratigraphic distribution: late Albian (Singh, 1971).

*Retimonocolpites echinatus* n.sp.

(Plate 6, Figures 9–11)

*R. echinatus* differ from other forms of the genus by its echinate ornamentation of the reticulum. The latter is held by about one columella per brochus. The columellae are distally thickened. The echinate ornamentation is not in connection with the columellae. About 10 echinae of 1  $\mu\text{m}$  length can be observed on one brochus.

*Retimonocolpites peroreticulatus* (Brenner) Doyle, 1975

(Plate 6, Figures 14, 15)

In this species the reticulum is heterobrochate (diameter of the lumen 1 to 4  $\mu\text{m}$ ). The muri of the reticulum are relatively broad (1  $\mu\text{m}$  or more) and inhomogeneous in structure. Stratigraphic distribution: Zones I–III (Doyle and Robbins, 1977).

*Retimonocolpites* cf. *peroreticulatus* (Brenner) Doyle, 1975

(Plate 6, Figures 12, 13)

This form can be distinguished from the typical *R. peroreticulatus* by the size (40 to 50  $\mu\text{m}$ ), by the coarse irregular reticulum (lumen diameter about 5  $\mu\text{m}$ ) and the large distance between the endexine and the reticulum. A

similar grain has been described by Brenner (1968) as *Reticulatisporites jordanus*.

*Retimonocolpites reticulatus* (Brenner, 1963)

(Plate 6, Figures 16, 17; 18–20)

In this species the muri are very narrow and the reticulum is attached by several (4 to 6) pilae per brochus. The lumina of the reticulum are of irregular form and size. Stratigraphic distribution: Barremian–Albian (Singh, 1971).

*Striatopollis dubius* (Jard. and Magl.) Morgan, 1978

(Plate 6, Figures 27–29)

Stratigraphic distribution: Albian (Morgan, 1978).

*Tricolpites albiensis* Kemp, 1968

(Plate 6, Figures 32, 33)

Stratigraphic distribution: Zones IIA–IIC (Doyle and Robbins, 1977)

*Tricolpites* cf. *barrandei* Paclt., 1971

(Plate 6, Figures 30, 31)

Stratigraphic distribution: Zone III (Doyle and Robbins, 1977).

*Tricolpites crassimurus* (Groot and Penny) Singh, 1971

(Plate 6, Figures 21–24)

First occurrence: Zone II (Doyle and Robbins, 1977).

*Tricolpites nemejci* Paclt., 1971

(Plate 6, Figures 38, 39)

Stratigraphic distribution: Zone III (Doyle and Robbins, 1977)

*Tricolpites parvulus* (Groot and Penny, 1960)

(Plate 6, Figures 34, 35)

First occurrence: Zones IIA–III (Doyle and Robbins, 1977).

*Tricolpites* cf. *parvulus* (Groot and Penny, 1960)

(Plate 6, Figures 25, 26)

Tricolpate grain, colpae narrow, somewhat larger in the equatorial region. Cavernae well-developed. Wall thin (about 1  $\mu\text{m}$ ), endexine thinner than ectexine. These grains are larger than the typical *T. parvulus* (about 30  $\mu\text{m}$  instead of 20 to 25  $\mu\text{m}$ ).

*Tricolpites sagax* Norris, 1967

(Plate 6, Figures 45, 46)

Stratigraphic distribution: Zones IIA–III (Doyle and Robbins, 1977).

*Tricolpites* sp. 1

(Plate 6, Figures 36, 37)

Tricolpate grain with distinct cavernae. Wall thin (about 1  $\mu\text{m}$ ). Structure densely baculate, sculpture punctate.

"Tricolpopollenites" *macroreticulatus* Groot and Groot, 1962

(Plate 6, Figures 40, 41)

Stratigraphic distribution: upper Albian–lower Cenomanian.

"Tricolpopollenites" *pumilis* Groot, Penny, and Groot, 1961

(Plate 6, Figures 42–44)

## Proximate Dinoflagellate Cysts

*Canningia colliveri* Cooks. and Eisenack, 1960

(Plate 7, Figure 1)

First occurrence: upper Barremian (Harker and Sarjeant, 1975).

*Canningia rotunda* Cooks. and Eisenack, 1961

(Plate 7, Figure 2)

A similar form has been described as *Archeotectatum sarjeantii* Habib (1972) from the Late Jurassic of Leg 11.

*Canningia circularis* Cooks. and Eisenack, 1971

(Plate 7, Figures 3, 5)

Stratigraphic distribution: this species is known from mid-Cretaceous of Australia.

*Cribroperidinium muderongensis* (Cooks. and Eisenack) Davey, 1969

(Plate 7, Figure 4)

Stratigraphic distribution: Berriasian–Aptian.

*Cribroperidinium orthoceras* (Eisenack) Davey, 1969*Cribroperidinium* sp. 1

(Plate 7, Figures 6, 7; 9, 10)

The arrangement and the number of the plates correspond with those of the genus *Cribroperidinium*. Theca oval or rounded with one apical and one more or less, prominent antapical horn. Tabulation reflected by irregular vermiculate ridges. Cingulum slightly helicoid.

*Diacanthum hollisteri* Habib, 1972

(Plate 7, Figure 8)

Stratigraphic distribution: After Habib (1977), this species is restricted to the Neocomian. In our material it occurs regularly in the entire profile.

*Dictyopyxidida reticulata* (Valensi) Lentin and Williams, 1973

(Plate 7, Figure 11)

*Druggidium deflandrei* (Millioud) Habib, 1973

(Plate 7, Figure 18)

*Fromea amphora* Cooks. and Eisenack, 1958

(Plate 7, Figures 22, 23)

Stratigraphic distribution: Barremian–Cenomanian.

*Gingodinium spinulosum* Cooks. and Eisenack, 1960

(Plate 7, Figures 14–17)

Stratigraphic distribution: Albian–Cenomanian (Harker and Sarjeant, 1975).

*Gonyaulacysta helicoidea* (Eisenack and Cooks.) Sarjeant, 1966b

*Gonyaulacysta ordovaca* Duxbury, 1977

(Plate 8, Figures 5, 6)

*Leptodinium* cf. *aculeatum* Wall, 1967

(Plate 7, Figures 20, 21)

*Leptodinium alectrophum* Sarjeant, 1966

(Plate 8, Figures 11, 12)

*Leptodinium* cf. *margariferum* (Cooks. and Eisenack) Sarjeant, 1969

(Plate 8, Figure 3)

*Meiourgonyaulax psoros* Davey and Verdier, 1974

(Plate 7, Figure 19)

Stratigraphic distribution: Hauterivian–Albian (Harker and Sarjeant, 1975).

*Palaeoperidinium* sp.

(Plate 8, Figure 4)

This form can be assigned to the genus *Palaeoperidinium*. The theca is rounded pentagonal with one prominent apical horn. The cingulum is helicoid. A tabulation is hardly visible. Dorsal archeopyle polygonal; ornamentation punctate. First occurrence of the genus: Albian (Harker and Sarjeant, 1975).

cf. *Pyxidiella* sp.

(Plate 7; 8, Figures 12, 13; 1, 2)

Ovoidal or spherical body with a subapical archeopyle, which is more or less rectangular. The thin wall is ornamented with blunt echinae which are of different sizes from one specimen to another (2 to 5  $\mu\text{m}$ ). Cingulum or tabulation not visible.

"*Scriniodinium attadalense*" (Cooks. and Eisenack) Eisenack, 1967

(Plate 8, Figures 7, 8)

Similar forms from the Lower Cretaceous of Leg 11 have been assigned to *S. attadalense* by Habib (1975). Stratigraphic distribution: Valanginian–Cenomanian (Habib, 1977).

#### Proximo-Chorate Dinoflagellate Cysts

*Hystrichosphaeropsis ovum* Defl., 1935

*Spiniferites cingulatus* (Wetzel, 1935) Sarjeant, 1970

First occurrence: upper Aptian (Harker and Sarjeant, 1975).

*Spiniferites ramosus* (Ehrenb.) Loeblich and Loeblich, 1966

#### Chorate Dinoflagellate Cysts

*Cannosphaeropsis peridicta* Eisenack and Cooks., 1960

(Plate 8, Figure 15)

Stratigraphic distribution: Aptian–Albian.

*Chlamydothorella discreta* Clarke and Verdier, 1967

(Plate 8, Figures 9, 10; 18)

First occurrence: Cenomanian.

*Cleistosphaeridium huguonoti* (Valensi) Davey, 1969

(Plate 8, Figures 13, 14)

Stratigraphic distribution: occur regularly in the Albian and in the lower part of the Late Cretaceous.

*Cometodinium* sp.

(Plate 8, Figure 17)

*Cyclonephelium distictum* subsp. *brevispinatum* (Millioud) Lentin and Williams, 1973

(Plate 8, Figure 16)

Stratigraphic distribution: Berriasian–early Aptian (Harker and Sarjeant, 1975)

In our material the species occurs in the profile of Hole 417D.

*Gardodinium deflandrei* Clarke and Verdier, 1967

(Plate 8, Figure 23)

Stratigraphic distribution: Albian (Harker and Sarjeant, 1975).

*Hystrichosphaeridium arundum* Eisenack and Cooks., 1960

(Plate 8, Figure 22)

Stratigraphic distribution: Albian (Harker and Sarjeant, 1975).

*Lithosphaeridium conispinum* Davey and Verdier, 1973

(Plate 8, Figures 19, 20)

First occurrence: late Aptian.

*Lithosphaeridium siphoniphorum* (Cooks. and Eisenack) Davey and Williams, 1966

(Plate 8, Figure 26)

First occurrence: late Aptian.

*Oligosphaeridium complex* (White) Davey and Williams, 1966

*Prolixosphaeridium granulosum* (Defl. 1937) Davey et al., 1966

(Plate 8; 9, Figures 24, 25; 15)

A similar type has been described as *Polysphaeridium warrenii* by Habib (1975).

*Prolixosphaeridium deirense* Davey et al., 1966

(Plate 9, Figure 5)

*Systematophora fasciculigera* Klement, 1960

(Plate 9, Figure 6)

#### Cavate Dinoflagellate Cysts

*Actinotheca aphroditae* Cooks. and Eisenack, 1960

(Plate 8, Figure 21)

Stratigraphic distribution: To date this form has only been found in the Turonian of Australia.

*Odontochitina operculata* (Wetz.) Defl. and Cooks., 1955

(Plate 9, Figures 1, 2)

*Palaeohystrichophora infusorioides* Defl., 1935

(Plate 9, Figure 3)

First occurrence: middle Albian (Harker and Sarjeant).

*Subtilisphaera perlucida* (Alberti) Jain and Millepied, 1973

(Plate 9, Figure 7)

Stratigraphic distribution: After Habib (1977), this species is restricted to the *Odontochitina operculata* Zone (Barremian–early Albian). In our material it also occurs in the lower part of the floral Zone III (late Albian–early Cenomanian).

*Xenikoon australis* Cooks. and Eisenack, 1960

(Plate 9, Figures 4, 8)

A similar form has been registered as *Pyxidiella* sp. A by Habib (1972) from the Barremian and Aptian of DSDP Leg 11. *X. australis* is known from the Late Cretaceous of Australia.

#### Acritarchs, Tasmanaceae, and Cysts of Uncertain Affinity

*Micrhystridium fragile* Defl., 1947

(Plate 9, Figure 23)

*Pterospermopsis helios* Sarjeant, 1974

(Plate 9, Figure 20)

This species has been observed in highly variable sizes (40 to 85  $\mu\text{m}$ ).

*Pleurozonaria* sp. 1

(Plate 9, Figures 16, 17; 18, 19)

In our material the size of *Pleurozonaria* varies from 20 to 50  $\mu\text{m}$ .

*Tythyodiscus* sp. 1

(Plate 9, Figures 9, 10)

We can distinguish two types of *Tythyodiscus* by their different sizes. *T.* sp. 1 is of about 35  $\mu\text{m}$  in diameter; the large form *T.* sp. 2 of about 80  $\mu\text{m}$ .

*Tythyodiscus* sp. 2

(Plate 9, Figure 21)

*Tythodiscus* sp. 3  
(Plate 9, Figures 11, 12)

A spheroid body with a thick homogeneous wall, very similar to *Tythodiscus*, has been found ornamented with scattered echinae of about 4  $\mu\text{m}$  length.

*Monogemmites* cf. *pseudosetarius* (Weyl. and Pf.) W.Kr., 1970  
(Plate 9, Figures 13, 14; 24, 25)

A probable algal cyst very similar to *Tythodiscus* shows a regular gemmate to echinate ornamentation. It can be compared with *Monogemmites pseudosetarius* known from lacustrine sediments of the European Tertiary. Krutzsch (1970) attributes this form to a resting cyst of a freshwater algae. The same form can also be found in marine sediments of the Central Paratethys.

#### **Incertae Sedis**

*Spermatites* sp.  
(Plate 9, Figure 22)

Our form from the Albian of Hole 417D looks similar to the material from the Cenomanian of Oklahoma (Hedlund, 1966) named *Spermatites* or the "lenticular bodies" from the Late Albian of Alberta (Singh, 1971). Another type resembling *Spermatites* has been described as *Lancettopsis lanceolata* by Mädler (1969) from the Jurassic.

#### **Microforaminifers**

(Plate 9, Figure 26)

Besides the planispiral microforaminifers found very frequently in our material, several forms with uni- or biserial arrangement of the chambers could be observed.



## APPENDIX Aiii

Sample (Interval in cm)	Angiosperms														Angiosperms (sum)	%	Pollen sum	Acritarchs and Tasmanaceae	Monogermmites cf. pseudostetarius					(Sum)	Microforaminifer		BF- or uniserial	(Sum)
	<i>Clavatipollenites</i> sp.	<i>Retimonocolpites clavatus</i>	<i>R. dividius</i>	<i>R. peroreticulatus</i>	<i>R. cf. peroreticulatus</i>	<i>R. reticulatus</i>	<i>Retimonocolpites</i> indet.	<i>Sriatopollis dubius</i>	<i>Tricolpites albiensis</i>	<i>T. barrandei</i>	<i>T. crassimurus</i>	<i>T. macroreticulatus</i>	<i>T. nemejci</i>	<i>T. parvulus</i>					<i>Tricolpites</i> div. sp.	<i>Angiosperms</i> div. sp.	<i>Pteropemopsis helios</i>	<i>Pleurosonaria</i> sp.	<i>Microhystridium</i> sp.		<i>Tyrthodiscus</i> sp.	<i>Microforaminifer</i>		
418A-10-1, 95-97 10, CC	5 3	1 1	1 1		6 3	3 1									6	16 13	16 13	100 100						2 101		59 125	4	63 125
418B-28-2, 53-55	3	1	1	1	5								1	1	1	13	10.	126						139		17	17	
28-3, 75-77	7	8	1	1	2											23	23.	99					164		21	21		
29-2, 91-92	1	1	1	1	3							1		1	1	9	9.	100					15		4	4		
31-2, 4-6	1	1														6	5.	123					68		12	12		
31-2, 11-13	4	3	2	2	5	1		1		2			1	1	1	32	17.5	183					9					
34-1, 6-7	18			1	1										1	22	20.	107					1		10	10		
34-1, 10-11	25	1			4										31	24.5	126					1		10	10	10		
34-1, 15-16 barren	19	1	1	1	5									2	4	33	12.	270					5		1	1		

## APPENDIX Aiv

Sample (Interval in cm)	Dinoflagellates																				Dinoflagellates (sum)										
	<i>Canningia collyeri</i>	<i>C. rotunda</i>	<i>C. circularis</i>	<i>Cribroperridium</i> sp. 1	<i>Diacanthum hollisteri</i>	<i>Dicropyxidia reticulata</i>	<i>Druggidium deflandrei</i>	<i>Gingnodinium spinulosum</i>	<i>Gonyaulacysta hellicoides</i>	<i>G. ordoyaca</i>	<i>cf. Pyxidiella</i> sp.	" <i>Scriniotidium attadalense</i> "	<i>Spiniferites cingulatus</i>	<i>Sp. ramosus</i>	<i>Subtilisphaera perlucida</i>	<i>Chlamydomphorella discreta</i>	<i>Cometodinium</i> sp.	<i>Cleistosphaeridium huguonotii</i>	<i>Cyclonephelium distinctum brevispinatum</i>	<i>Gardobinium deflandrei</i>		<i>Lithosphaeridium contispinum/siphoniphorum</i>	<i>Hystrichosphaeridium arandum</i>	<i>Prolixosphaeridium granulosum</i>	<i>P. deivense</i>	<i>Systematophora fasciculigera</i>	<i>Odontochitina operculata</i>	<i>Palaehystrichophora infusorioides</i>	<i>Xenikoon australis</i>	Dinoflagellates div. sp. and indet.	
418A-10-1, 95-97 10, CC	4 2	101 2	18 2	12 4		1		1	45 17	11 1		8 2	2 5	6 5	40 75					1	26 25							1	1	14 3	296 136
418B-28-2, 53-55	2				4	12		1	3			3	2	2		6	64				26									3	129
28-3, 75-77					1				1			6	1	1		4	4				8								5	40	
29-2, 91-92			5	6	10	3	3	1	16	7	6	41	9	5	1	21			8		24	6							31	218	
31-2, 4-6			1		1				82			1	1		1	2			1				1					4	6	105	
31-2, 11-13			3	2		2			87			4	2		2													3	2	113	
34-1, 6-7						67	36	2				6	1	7					2	1								1	11	139	
34-1, 10-11			2		1	52	39	2	1			8	7	7									2	1	2			3	2	113	
34-1, 15-16 barren	1		1			36	145		1			4	10			2						1						6	127		
34-1, 30-31																													6	207	





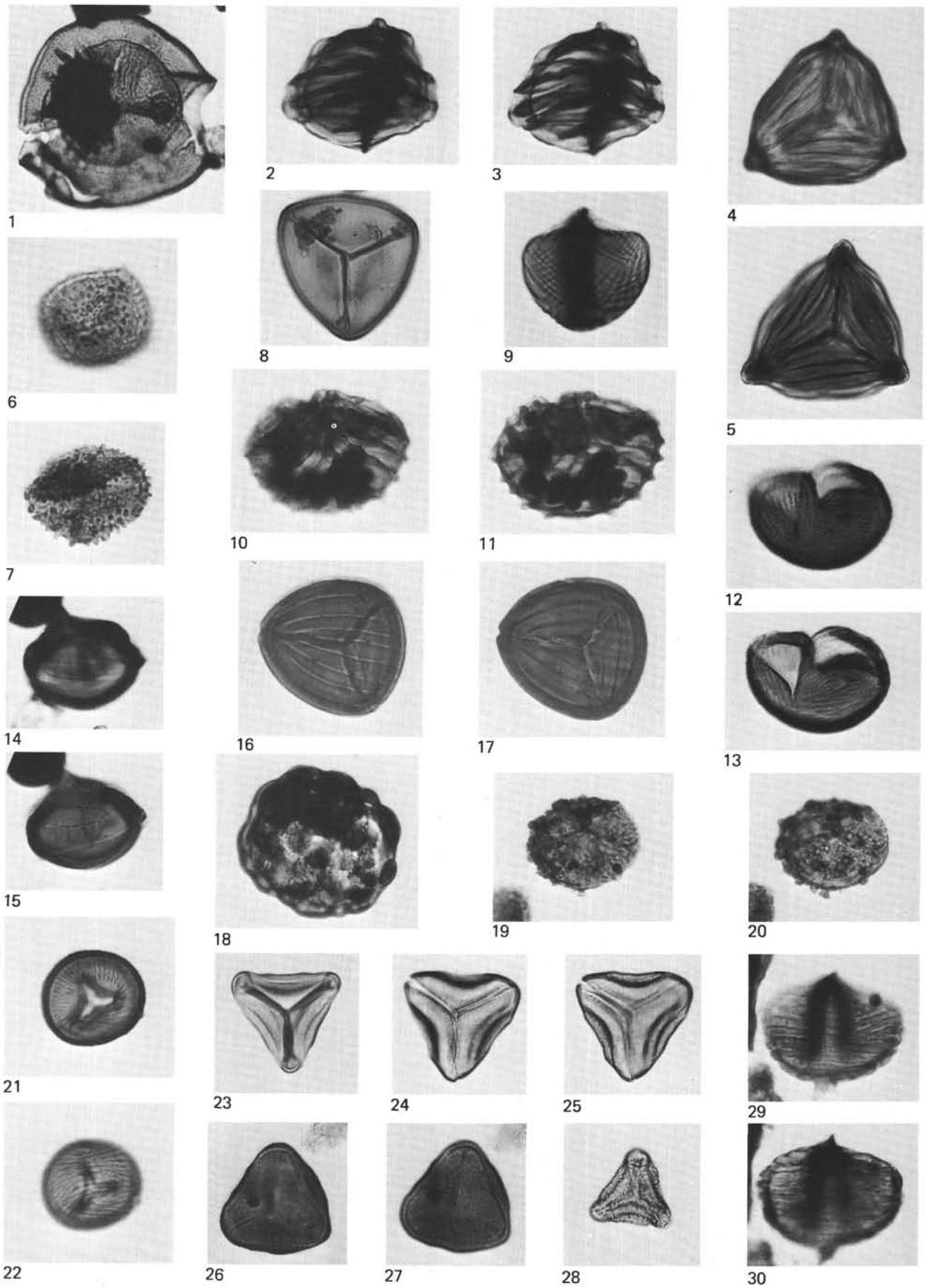


## PLATE 4

All figures  $\times 750$  unless otherwise indicated.

- Figure 1 *Aequitriradites* sp.  
Sample 417D-21-1, 108-110 cm (No. 1)
- Figures 2, 3 *Appendicisporites problematicus* (Burger) Singh  
1971.  
Sample 418A-10-1, 95-97 cm (No. 4)
- Figures 4, 5 *Appendicisporites tricornitatus* Weil & Greif 1953.  
Sample 418A-10-1, 95-97 cm (No. 6)
- Figures 6, 7 *Baculatisporites* sp.  
Sample 418B-31-2, 11-13 cm. (No. 4)
- Figure 8 *Biretisporites potoniaei* Delc. & Sprum. 1955.  
Sample 418B-31-4, 4-6 cm. (No. 8)
- Figure 9 *Cicatricosisporites hallei* Delc. & Sprum. 1955.  
Sample 417D-19-2, 6-8 cm. (No. 7)
- Figures 10, 11 *Cicatricosisporites mohrioides* Delc. & Sprum. 1955.  
Sample 418A-10, CC, (No. 4)
- Figures 12, 13 *Cicatricosisporites minutaestriatus* (Bolikh.) Pocock  
1964.  
Sample 417D-21-1, 108-110 cm (No. 2)
- Figures 14, 15 *Cicatricosisporites* cf. *patapscoensis* Brenner 1963.  
Sample 417D-17-3, 127-128 cm (No. 10)
- Figures 16, 17 *Cicatricosisporites subrotundus* Brenner 1963.  
Sample 418B-29-2, 91-92 cm (No. 10)
- Figure 18 *Converrucosisporites proxigranulatus* Brenner (1963)  
Sample 417D-21-1, 108-110 cm (No. 1)
- Figures 19, 20 *Converrucosisporites platyverrucosus* Brenner 1963.  
Sample 418B-34-1, 30-31 cm (No. 3)
- Figures 21, 22 *Cicatricosisporites venustus* Deak 1963.  
Sample 418B-31-2, 11-13 cm (No. 1)
- Figure 23 *Gleicheniidites circinidites* (Cooks.) Dettm. 1963.  
Sample 418B-34-1, 30-31 cm (No. 3)
- Figures 24, 25 *Gleicheniidites confossus* Hedlund 1966.  
Sample 418A-10-1, 95-97 cm (No. 3)
- Figures 26-28 *Gleicheniidites echinatus* (Bolikh.) W.Kr. 1959.  
Sample 418B-29-2, 91-92 cm (No. 10)
- Figures 29, 30 *Costatoperforosporites foveolatus* Deak 1962.  
Sample 417D-17-1, 94-95 cm (No. 1)

PLATE 1

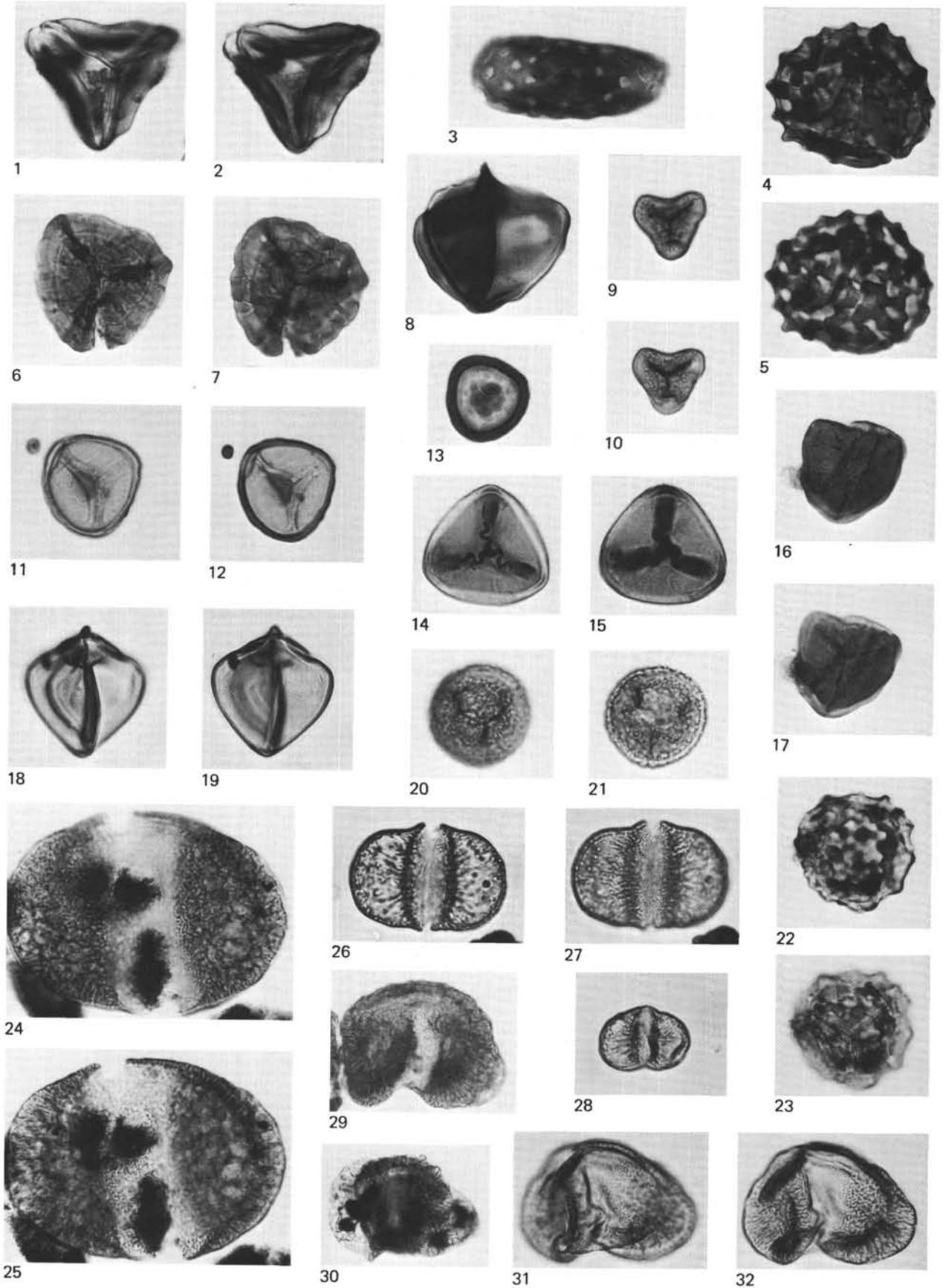


## PLATE 2

(All figures  $\times 750$  unless otherwise indicated)

- Figures 1, 2 *Gleicheniidites* sp. 1  
Sample 418A, 10, CC (No. 9)
- Figure 3 *Klukisporites foveolatus* Pocock 1971.  
Sample 418B-34-1, 30-31 cm (No. 4)
- Figures 4,5 *Klukisporites areolatus* Singh 1971.  
Sample 417D-21-1, 108-110 cm (No. 1)
- Figures 6, 7 *Psilatriteles circumundulatus* Brenner 1963.  
Sample 417D, 17, CC (No. 5)
- Figure 8 *Triplanosporites* sp. 2.  
Sample 417D, 17, CC (No. 9)
- Figures 9, 10 *Concavisporites juriensis* Balme 1957.  
Sample 418B-34-1, 30-31 cm (No. 3)
- Figures 11-13 *Stereisporites antiquasporites* (Wils. & Webst.)  
Dettm. 1963.  
Sample 418B-31-2, 11-13 cm (Nos. 4 and 1)
- Figures 14, 15 *Undulatisporites undulapolus* Brenner 1963.  
Sample 418B-34-1, 30-31 cm (No. 2)
- Figures 16, 17 *Undulatisporites* cf. *fossulatus* Singh 1971.  
Sample 417D-17-3, 127-128 cm (No. 10)
- Figures 18, 19 *Triplanosporites* sp. 1.  
Sample 418B-31-2, 11-13 cm (No. 2)
- Figures 20, 21 Trilete sp. 1.  
Sample 418B-31-2, 11-13 cm (No. 3)
- Figures 22, 23 Trilete sp. 2.  
Sample 417D-21-1, 108-110 cm (No. 2)
- Figures 24, 25 *Alisporites thomasi* Couper 1958.  
Sample 418B-34-1, 30-31 cm (No. 3)
- Figures 26-28 *Vitreisporites pallidus* (Reiss.) Nilss. 1958.  
Sample 418B-31-2, 11-13 cm (No. 1)
- Figure 29 *Parvisaccites rugulatus* Brenner 1963.  
Sample 417D, 17cc (No. 7)
- Figure 30 *Rugubivesiculites minimus* Burger 1966.  
Sample 418A-10-1, 95-97 cm (No. 3)
- Figures 31, 32 *Parvisaccites radiatus* Couper 1958.  
Sample 417D-17-1, 94-95 cm (No. 1)

PLATE 2

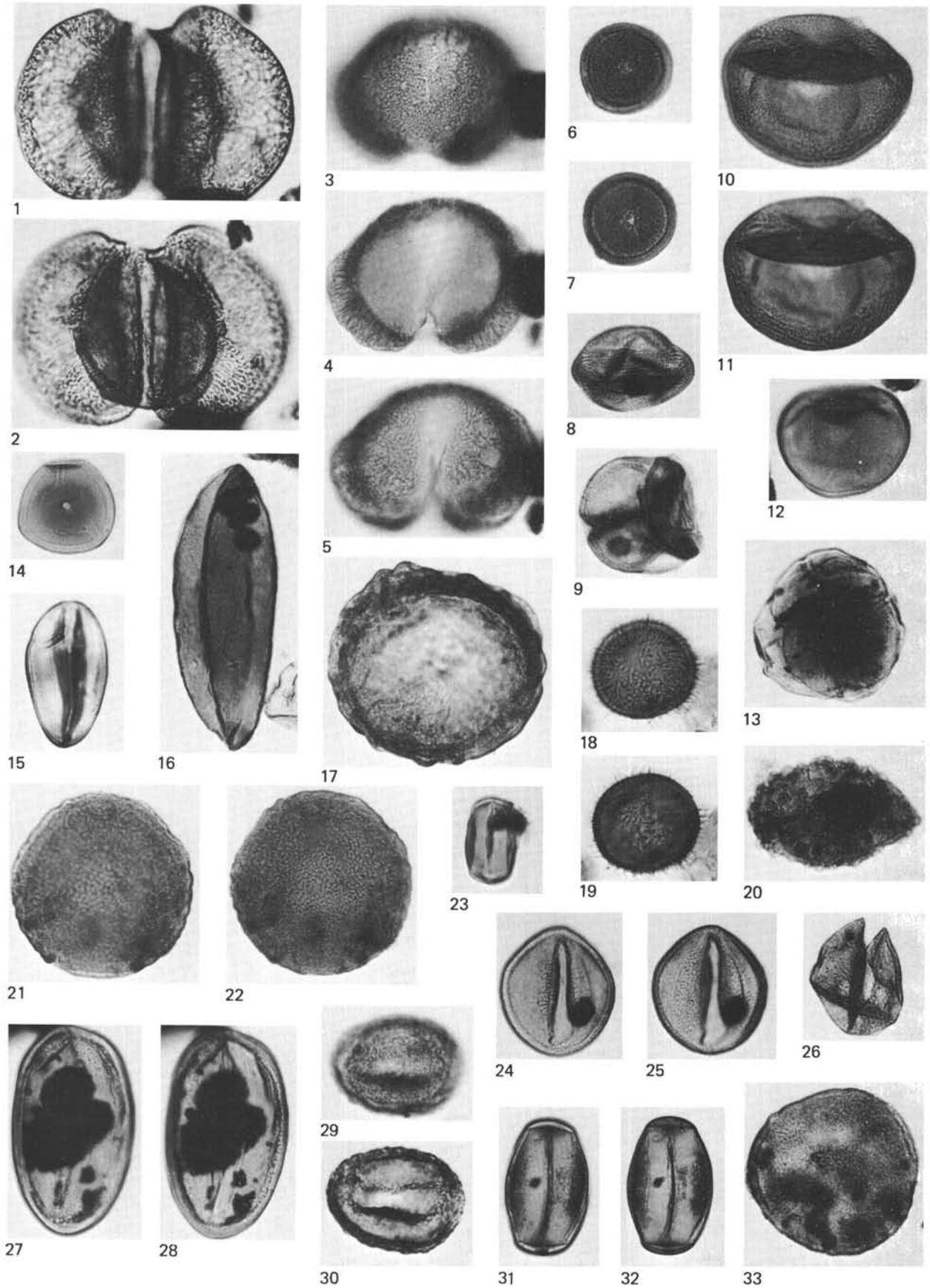


## PLATE 3

(All figures  $\times 750$  unless otherwise indicated)

- Figures 1, 2 *Podocarpidites multesimus* (Bolikh.) Pocock 1962.  
Sample 418A, 10, CC (No. 8)
- Figures 3-5 *Cedripites admirabilis* (Bolikh.) W.Kr. 1971.  
Sample 418B-31-2, 11-13 cm (No. 1)
- Figures 6-9 *Classopollis noeli* Reyre 1970.  
Sample 417D-17-3, 65-66 cm (No. 1)  
Sample 417D-21-1, 108-110 cm (No. 3)
- Figures 10, 11 *Classopollis brasiliensis* Hengreen 1975.  
Sample 417D-17-1, 94-95 cm (No. 3)
- Figures 12, 13 *Exesipollenites tumulus* Balme 1957.  
Sample 418B-31-2, 11-13 cm (No. 1)  
Sample 417D-21-1, 108-110 cm (No. 1)
- Figure 14 *Exesipollenites* sp. 1  
Sample 418B-31-2, 11-13 cm (No. 4)
- Figure 15 *Cycadopites minimus* (Cooks. 1947).  
Sample 418B-34-1, 30-31 cm (No. 2)
- Figure 16 *Cycadopites carpentieri* (Delc. & Sprum. 1955).  
Sample 418B-34-1, 30-31 cm (No. 4)
- Figure 17 *Callialasporites damperi* (Balme) Sukh Dev 1961.  
Sample 418B-28-2, 53-55 cm (No. 1)
- Figures 18, 19 *Classopollis spinosus* Hengreen 1973.  
Sample 418B-28-2, 53-55 cm (No. 1)
- Figure 20 *Cerebropollenites mesozoicus* (Couper) Nilsson 1958.  
Sample 417D-19-2, 11-14 cm (No. 9)
- Figures 21, 22 *Araucariacites cf. hungaricus* Deak 1965.  
Sample 417D-19-2, 6-8 cm (No. 8)
- Figure 23 *Eucommidites ? glottus* (Brenner 1963).  
Sample 418B-31-2, 11-13 cm (No. 3)
- Figures 24, 25 *Cycadopites* sp. 1  
Sample 417D-17-1, 94-95 cm (No. 3)
- Figure 26 *Inaperturopollenites hiatus* (R.Pot.) Th. & Pf. 1953.  
Sample 418A-10-1, 95-97 cm (No. 3)
- Figures 27, 28 *Eucommidites* sp. 1  
Sample 417D-21-4, 22-24 cm (No. 3)
- Figures 29, 30 *Scidopityspollenites* (sp. 1)  
Sample 418B-31-2, 11-13 cm (No. 3)
- Figures 31, 32 *Eucommidites troedssonii* (Erdtm.) R.Pot. 1958.  
Sample 418B-31-2, 11-13 cm (No. 2)
- Figure 33 *Araucariacites australis* Cooks. 1947.  
Sample 417D-21-1, 108-110 cm (No. 1)

PLATE 3

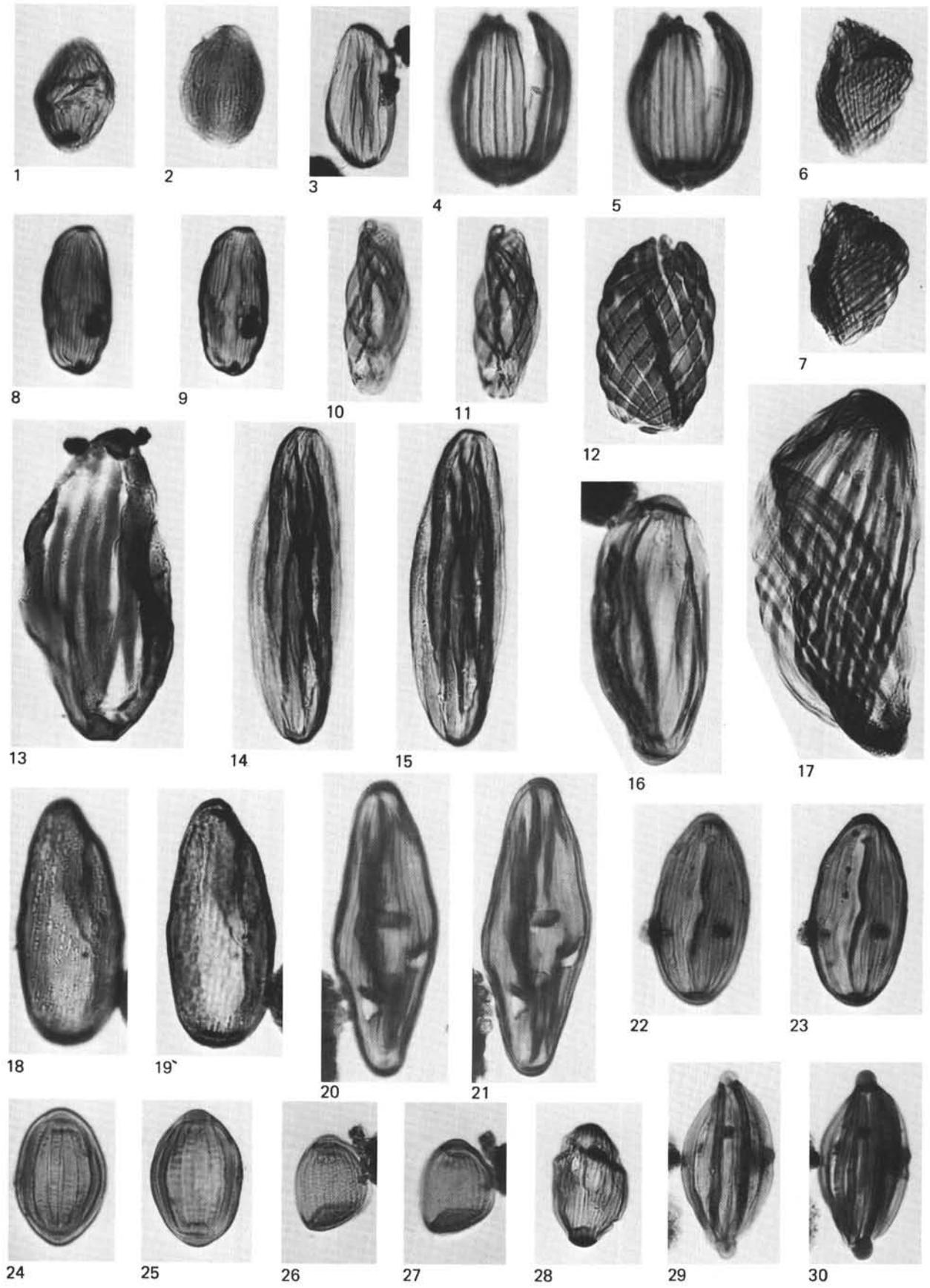


## PLATE 4

(All figures  $\times 750$  unless otherwise indicated)

- Figure 1 *Aumancisporites* cf. *cretaceous* (Pocock) Pocock 1964  
Sample 418A-10-1, 95-97 cm (No. 3)
- Figure 2 *Ephedripites* (*Distachyapites*) *multistriatus* (Pocock 1964)  
Sample 418B-34-1, 30-31 cm (No. 3)
- Figure 3 *Ephedripites* (*Distachyapites*) sp. 5 — Herngreen (1973)  
Sample 418B-31-2, 11-13 cm (No. 4)
- Figures 4, 5 *Ephedripites* (*Distachyapites*) cf. *markovii* (Pocock 1964)  
Sample 418B-34-1, 30-31 cm (No. 3)
- Figures 6, 7 *Ephedripites* (*Spiralipites*) *barghoornii* (Pocock 1964)  
Sample 418A-10-1, 95-97 cm (No. 3)
- Figures 8, 9 *Ephedripites* (*Distachyapites*) sp. 2 — Herngreen (1973)  
Sample 418B-31-2, 11-13 cm (No. 2)
- Figures 10, 11 *Ephedripites* (*Spiralipites*) *staplinii* (Pocock 1964)  
Sample 418B-34-1, 30-31 cm (No. 3)
- Figure 12 *Ephedripites* (*Spiralipites*) *jansonii* (Pocock) Muller 1968  
Sample 417D, 17, CC (No. 3)
- Figure 13 *Ephedripites* (*Distachyapites*) sp. 4 — Herngreen (1973)  
Sample 418A-10-1, 95-97 cm (No. 4)
- Figures 14, 15 *Ephedripites* (*Distachyapites*) cf. *mediolobatus* Bolkh. 1953  
Sample 418B-31-2, 11-13 cm (No. 3)
- Figure 16 *Steevesipollenites* cf. *binodosus* Stover 1964  
Sample 418B-34-1, 30-31 cm (No. 4)
- Figure 17 *Steevesipollenites* sp. 1  
Sample 418B-28-2, 53-55 cm (No. 1)
- Figures 18-21 *Steevesipollenites* *multilineatus* Stover 1964  
Sample 418B-34-1, 30-31 cm (No. 2)/Sample 417D-19-2,  
11-14 cm (No. 10)
- Figures 22, 23 *Steevesipollenites* cf. *binodosus* Stover 1964  
Sample 418B-31-2, 4-6 cm (No. 7)
- Figures 24-27 *Welwitschiapites* sp. 1  
Sample 417D-19-2, 6-8 cm (No. 8) / Sample 418B-31-2, 11-  
13 cm (No. 4)
- Figure 28 *Steevesipollenites* sp. 2  
Sample 418B-34-1, 30-31 cm (No. 4)
- Figures 29, 30 *Steevesipollenites* *binodosus* Stover 1964  
Sample 417D, 17, CC (No. 9)

PLATE 4

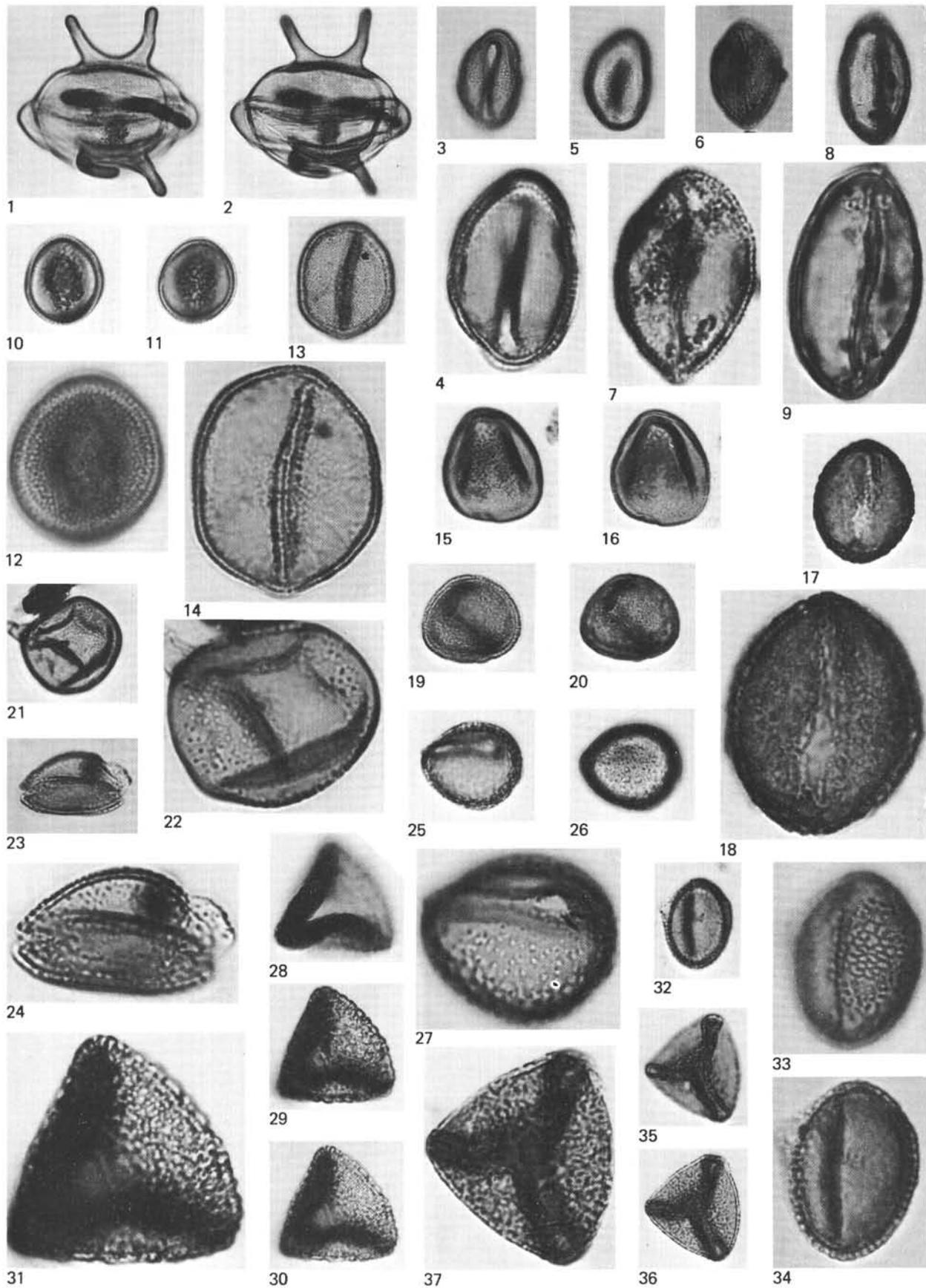


## PLATE 5

(All figures  $\times 750$  unless otherwise indicated)

- Figures 1, 2 *Elaterosporites klaszi* (Jard. & Magl.) Jard. 1967  
Sample 417D-17-1, 94-95 cm (No. 1)
- Figures 3-5 *Arecipites* sp. 1  
(Figure 4:  $\times 1500$ )  
Sample 418-31-2, 11-13 cm (No. 1)
- Figures 6, 7 *Arecipites* sp. 2  
(Figure 7:  $\times 1500$ )  
Sample 418B-31-2, 11-13 cm (No. 1)
- Figures 8, 9 *Monocolpopollenites* cf. *tranquillus tranquillus* (R. Pot.) Th. & Pf. 1958  
(Figure 9:  $\times 1500$ )  
Sample 418A, 10 cc (No. 9)
- Figures 10-12 *Clavatipollenites hughesii* Couper 1958  
(Figure 12:  $\times 1500$ )  
Sample 418B-31-2, 11-13 cm (No. 3)
- Figures 13, 14 *Magnolipollis* sp. 1  
(Figure 14:  $\times 1500$ )  
Sample 418B-31-2, 11-13 cm (No. 2)
- Figures 15, 16 *Clavatipollenites tenellis* Phillips & Felix 1971  
Sample 418B-34-1, 30-31 cm (No. 3)
- Figures 17, 18 *Monocolpopollenites* cf. *tranquillus verrucatus* W. Kr. 1962a  
(Figure 18:  $\times 1500$ )  
Sample 418B-31-2, 11-13 cm (No. 2)
- Figures 19, 20 *Clavatipollenites hughesii* Couper 1958  
Sample 418B-31-2, 11-13 cm (No. 1)
- Figures 21, 22 *Milfordia* sp. 1  
(Figure 22:  $\times 1500$ )  
Sample 418B-31-2, 11-13 cm (No. 2)
- Figures 23, 24 *Monocolpate* sp. B  
(Figure 24:  $\times 1500$ )  
Sample 418B-31-2, 11-13 cm (No. 1)
- Figures 25-27 *Monocolpate* sp. A  
(Figure 27:  $\times 1500$ )  
Sample 418B-34-1, 30-31 cm (No. 4)
- Figures 28-31 "*Trichotomosulcites*" Erdtm. 1945 sp. 1  
(Figure 31:  $\times 1500$ )  
Sample 418B-31-2, 11-13 cm (No. 1)
- Figures 32-34 *Retimonocolpites dividuus* Pierce 1961  
(Figures 33, 34:  $\times 1500$ )  
Sample 418B-31-2, 11-13 cm (No. 2)
- Figures 35-37 "*Trichotomosulcites*" sp. 2  
(Figure 37:  $\times 1500$ )  
Sample 418B-34-1, 30-31 cm (No. 3)

PLATE 5



## PLATE 6

(All figures  $\times 750$  unless otherwise indicated)

- Figures 1-3 *Retimonocolpites dividius* Pierce 1961  
(Figure 3:  $\times 1500$ )  
Sample 418B-28-2, 53-55 cm (No. 1)
- Figures 4-8 *Retimonocolpites clavatus* (Singh 1971)  
Sample 418B-34-1, 30-31 cm (No. 4)
- Figures 9-11 *Retimonocolpites echinatus* n. sp.  
(Figure 9:  $\times 1500$ )  
Sample 418B-31-2, 4-6 cm (No. 7)
- Figures 12, 13 *Retimonocolpites* cf. *peroreticulatus* (Brenner) Doyle 1975  
Sample 418B-31-2, 11-13 cm (No. 1)
- Figures 14, 15 *Retimonocolpites peroreticulatus* (Brenner) Doyle 1975  
(Figure 14:  $\times 1500$ )  
Sample 418B-34-1, 30-31 cm (No. 2)
- Figures 16-20 *Retimonocolpites reticulatus* (Brenner 1963)  
(Figure 18:  $\times 1500$ )  
Sample 418B-31-2, 11-13 cm (No. 4)
- Figures 21-24 *Tricolpites crassimurus* (Groot & Penny) Singh 1971  
Sample 418B-31-2, 11-13 cm (No. 3)  
Sample 418B-31-2, 11-13 cm (No. 1)
- Figures 25, 26 *Tricolpites* cf. *parvulus* (Groot & Penny 1960)  
Sample 418B-34-1, 30-31 cm (No. 3)
- Figures 27-29 *Striatopollis dubius* (Jard. & Magl.) Morgan 1978  
Sample 417D-17-3, 65-66 cm (No. 2)
- Figures 30, 31 *Tricolpites* cf. *barrandei* Paclt. 1971  
Sample 417D, 17, CC (No. 6)
- Figures 32, 33 *Tricolpites albiensis* Kemp 1968  
Sample 418B-31-2, 11-13 cm (No. 1)
- Figures 34, 35 *Tricolpites parvulus* (Groot & Penny 1960)  
Sample 418B-31-2, 11-13 cm (No. 4)
- Figures 36, 37 *Tricolpites* sp. 1  
Sample 418B-31-2, 11-13 cm (No. 1)
- Figures 38, 39 *Tricolpites nemejci* Paclt. 1971  
Sample 417D, 17, CC (No. 7)
- Figures 40, 41 "*Tricolpopollenites*" *macroreticulatus* Groot & Groot 1962  
Sample 417D, 17, CC (No. 10)
- Figures 42-44 "*Tricolpopollenites*" *pumilis* Groot, Penny & Groot 1961  
Sample 418B-31-2, 11-13 cm (Nos. 1 and 3)
- Figures 45, 46 *Tricolpites sagax* Norris 1967  
(Figure 45:  $\times 1500$ )  
Sample 418B-31-2, 11-13 cm (No. 3)

PLATE 6

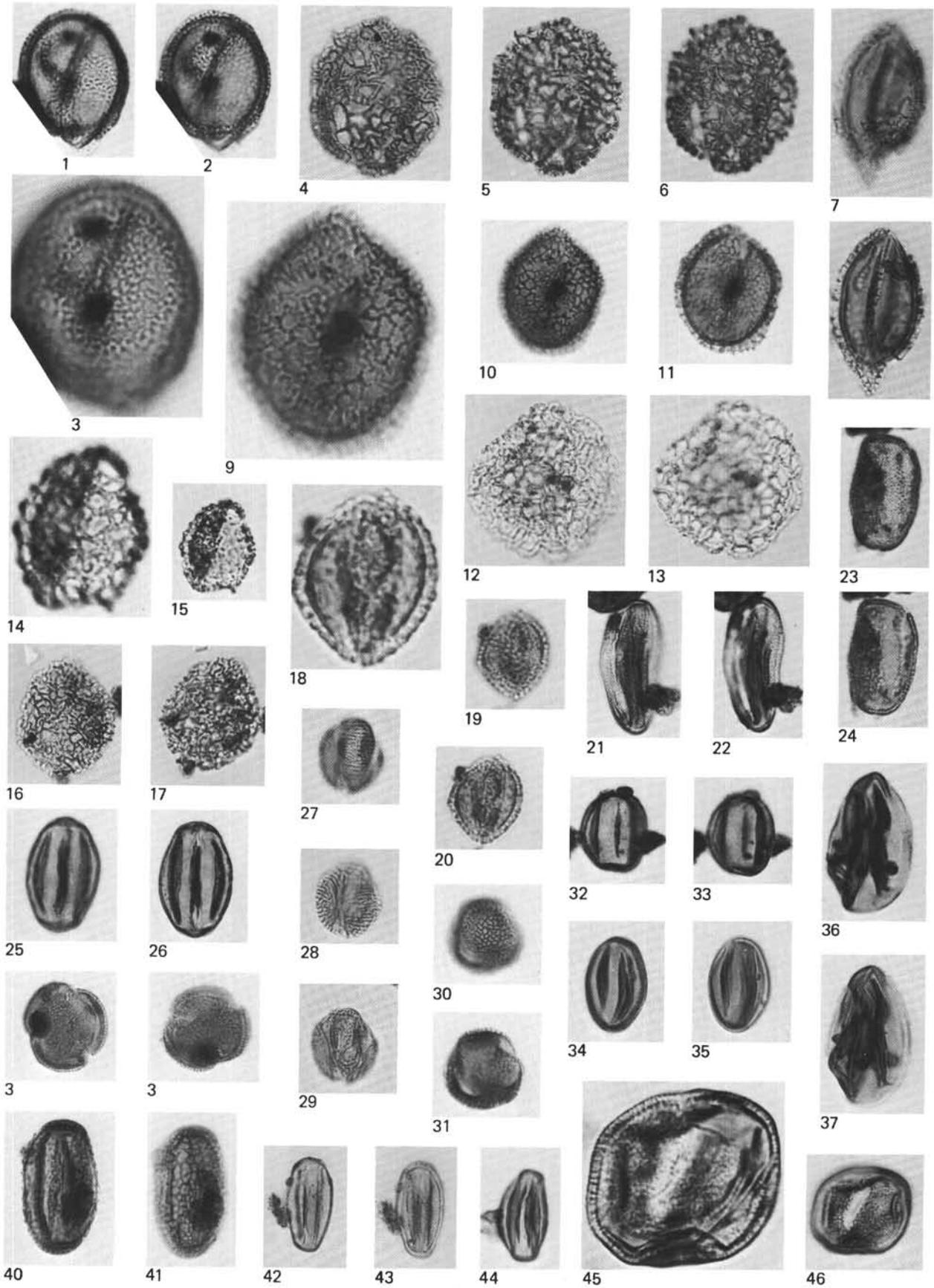
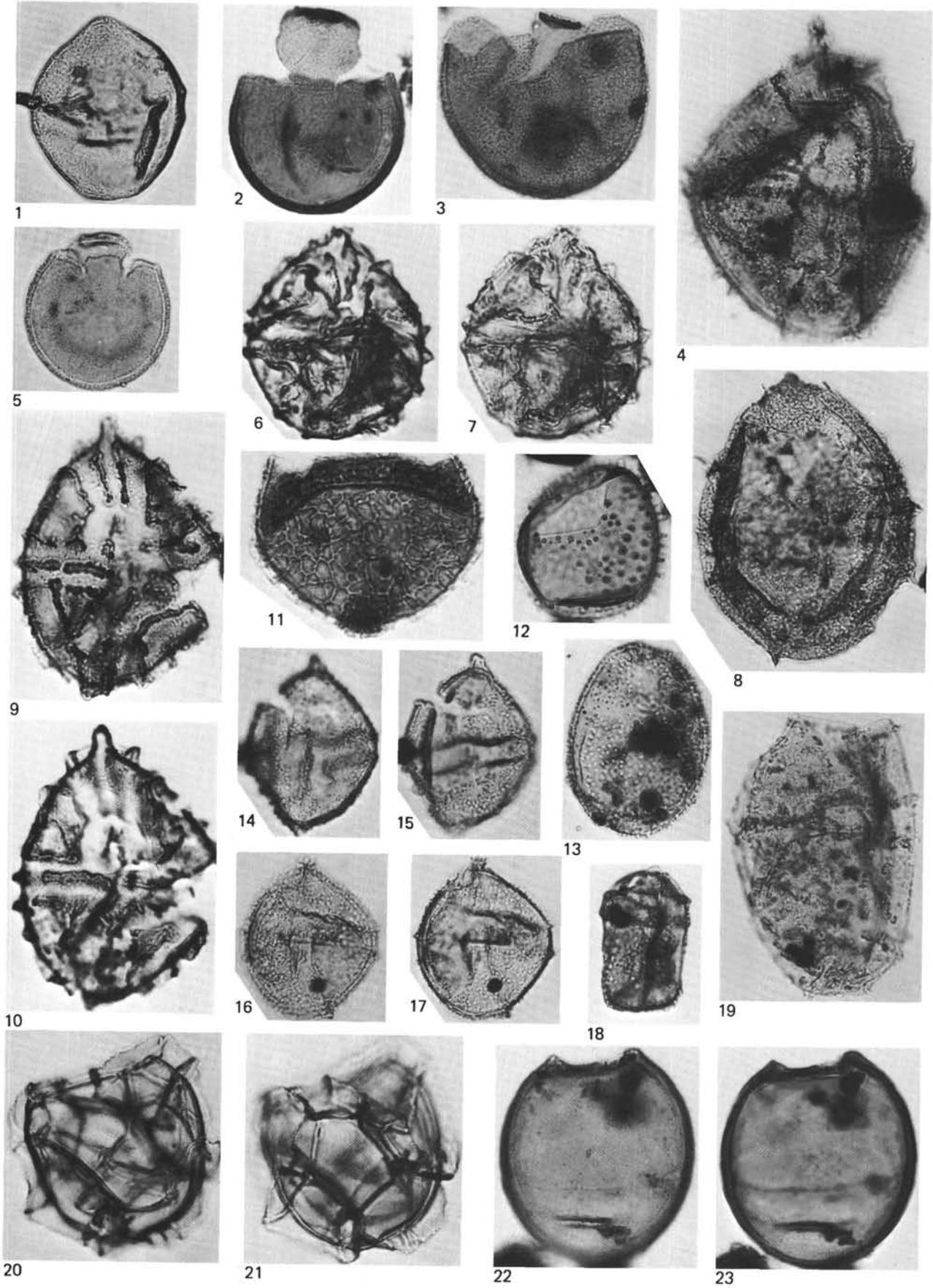


PLATE 7

(All figures  $\times 740$  unless otherwise indicated)

- Figure 1 *Canningia colliveri* Cooks. & Eisenack 1960  
Sample 417D-17-1, 94-95 cm (No. 2)
- Figure 2 *Canningia rotunda* Cooks. & Eisenack 1961  
Sample 418A-10-1, 95-97 cm (No. 6)
- Figures 3, 5 *Canningia circularis* Cooks. & Eisenack 1971  
Sample 418B-31-2, 11-13 cm (No. 3)  
Sample 417D-17-1, 94-95 cm (No. 1)
- Figure 4 *Cribroperidinium muderongensis* (Cooks. & Eisenack) Davey 1969  
Sample 417D-21-1, 108-110 cm (No. 2)
- Figures 6, 7, 9, 10 *Cribroperidinium* sp. 1  
Sample 418A-10-1, 96-97 cm (No. 4)  
Sample 418A-31-2, 11-13 cm (No. 3)
- Figure 8 *Diacanthum hollisteri* Habib 1972  
Sample 418B-29-2, 91-92 cm (No. 10)
- Figure 11 *Dictyopyxidia reticulata* (Valensi) Lentin & Williams 1973  
Sample 418B-34-1, 30-31 cm (No. 2)
- Figures 12, 13 cf. *Pyxidiella* sp.  
Sample 417D-19-2, 6-8 cm (No. 8)
- Figures 14-17 *Ginginodinium spinulosum* Cooks. & Eisenack 1960  
Sample 418B-31-2, 11-13 cm (Nos. 1 and 2)
- Figure 18 *Druggidium deflandrei* (Millioud) Habib 1973  
Sample 418B-34-1, 30-31 cm (No. 3)
- Figure 19 *Neiourogonyaulax psoros* Davey & Verdier 1974  
Sample 417D-21-1, 108-110 cm (No. 1)
- Figures 20, 21 *Leptodinium* cf. *aculeatum* Wall 1967  
Sample 417D-17-1, 94-95 cm (No. 1)
- Figures 22, 23 *Fromea amphora* Cooks. & Eisenack 1958  
Sample 417D-21-1, 108-110 cm (No. 2)

PLATE 7

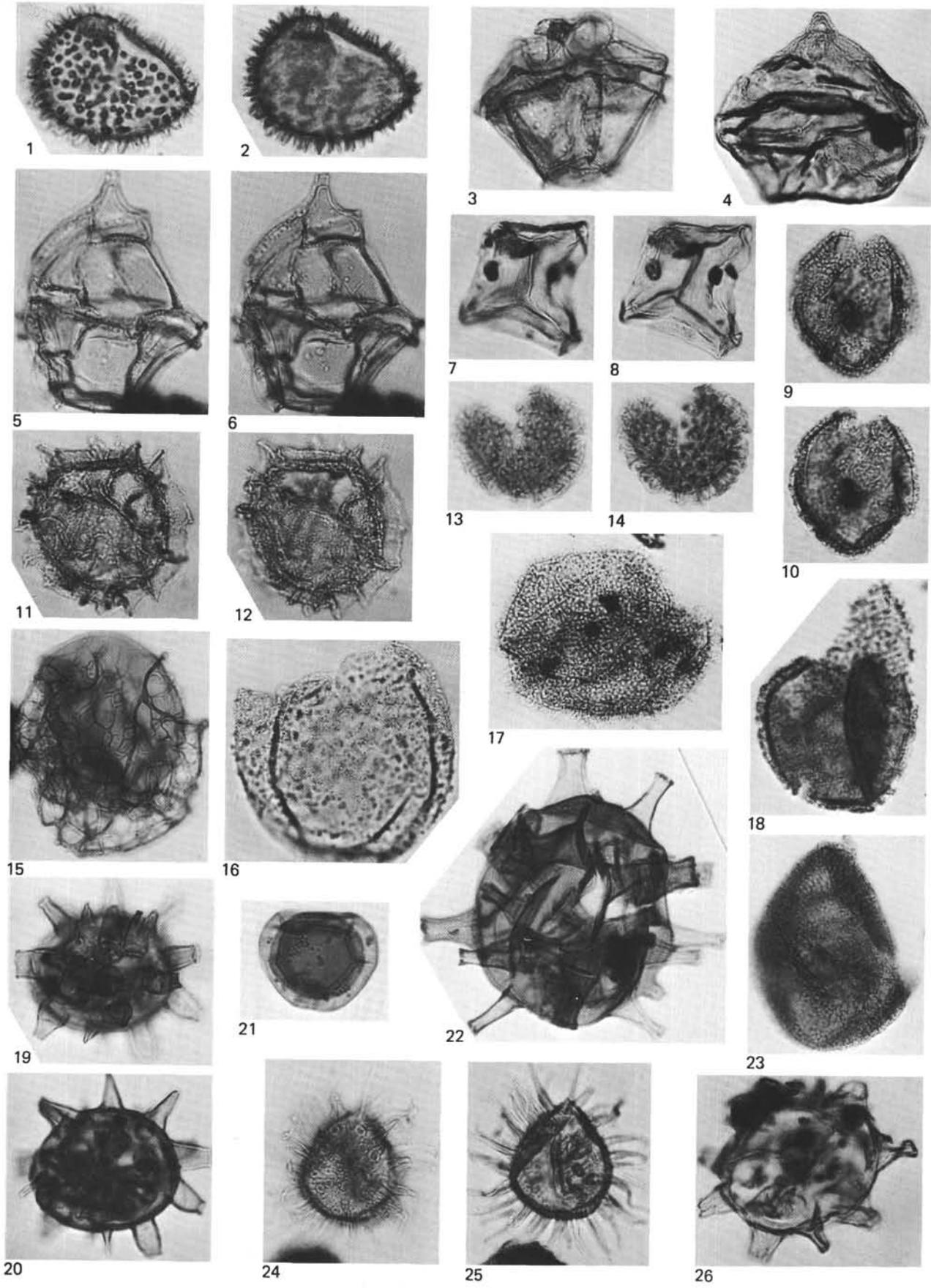


## PLATE 8

(All figures  $\times 750$  unless otherwise indicated)

- Figures 1, 2    *cf. Pyxidiella* sp.  
Sample 418B-34-1, 30-31 cm (No. 3)
- Figure 3        *Leptodinium cf. margaritiferum* (Cooks. & Eisenack)  
Sarjeant 1969  
Sample 418A-10-1, 95-97 cm (No. 6)
- Figure 4        *Palaeoperidinium* sp.  
Sample 418B-34-1, 30-31 cm (No. 3)
- Figures 5, 6    *Gonyaulacysta ordovaca* Duxbury 1977  
Sample 417D-17-1, 94-95 cm (No. 3)
- Figures 7, 8    "*Scriniodinium attadalense*" (Cooks. Eisenack)  
Eisenack 1967  
Sample 418B-3-12, 11-13 cm (No. 1)
- Figures 9, 10   *Chlamydotheca discreta* Clarke & Verdier 1967  
Sample 418A, 10, CC (No. 2)
- Figures 11, 12 *Leptodinium alectrolophum* Sarjeant 1966  
Sample 417D-17-1, 94-95 cm (No. 2)
- Figures 13, 14 *Cleistosphaeridium huguonioti* (Valensi) Davey 1969  
Sample 418B-28-2, 53-55 cm (No. 8)
- Figure 15       *Cannosphaeropsis peridicta* Eisenack & Cooks. 1960  
Sample 418B-29-2, 91-92 cm (No. 9)
- Figure 16       *Cyclonephelium distictum* subsp. *brevispinatum* (Mil-  
lioud) Lentin & Williams 1973  
Sample 417D-17-1, 94-95 cm (No. 1)
- Figure 17       *Cometodinium* sp.  
Sample 417D-17-1, 94-95 cm (No. 2)
- Figure 18       *Chlamydotheca discreta* Clarke & Verdier 1967  
Sample 418A, 10, CC (No. 2)
- Figures 19, 20 *Lithosphaeridium conispinum* Davey & Verdier 1973  
Sample 417D-17-1, 94-95 cm (No. 3)
- Figure 21       *Actinotheca aphroditae* Cooks. & Eisenack 1960  
Sample 418B-28-2, 53-55 cm (No. 8)
- Figure 22       *Hystrichosphaeridium arrundum* Eisenack & Cooks.  
1960  
Sample 418B-29-2, 91-92 cm (No. 9)
- Figure 23       *Gardodinium deflandrei* Clarke & Verdier 1967  
417D, 17 cc (No. 5)
- Figures 24, 25 *Prolixosphaeridium granulosum* (Defl. 1937) Davey  
et al. 1966  
Sample 417D-21-1, 108-110 cm (No. 2)
- Figure 26       *Lithosphaeridium siphoniphorum* (Cooks. & Eisenack)  
Davey & Williams, 1966  
Sample 418B-31-2, 11-13 cm (No. 1)

PLATE 8



## PLATE 9

(All figures  $\times 750$  unless otherwise indicated)

- Figures 1,2 *Odontochitina operculata* (Wetz.) Defl. & Cooks.  
1955  
Sample 417D-21-1, 108-110 cm (No. 1)
- Figure 3 *Palaeohystrichophora infusorioides* Defl. 1935  
Sample 418B-29-2, 91-92 cm (No. 9)
- Figure 4 *Xenikoon australis* Cooks. & Eisenack 1960  
Sample 418B-31-2, 11-13 cm (No. 3)
- Figure 5 *Prolixosphaeridium deirense* Davey et al. 1966  
Sample 417D-21-1, 108-110 cm (No. 3)
- Figure 6 *Systematophora fasciculigera* Klement 1960  
Sample 417D, 17, CC (No. 4)
- Figure 7 *Subtilisphaera perlucida* (Alberti) Jain & Millepied  
1973  
Sample 417D-18-1, 3-4 cm (No. 9)
- Figure 8 *Xenikoon australis* Cooks. & Eisenack 1960  
Sample 418B-31-2, 11-13 cm (No. 1)
- Figures 9, 10 *Tythodiscus* sp. 1  
Sample 417D-17-1, 94-95 cm (No. 3)
- Figures 11, 12 ? *Tythodiscus* sp. 3  
Sample 417D-21-1, 108-110 cm (No. 2)
- Figures 13, 14 *Monogemmites* cf. *pseudosetarius* (Weyl. & Pf.) W.  
Kr. 1970  
Sample 417D, 17, CC (No. 9)
- Figure 15 *Prolixosphaeridium granulosum* (Defl. 1937) Davey  
et al. 1966  
Sample 417D-19-2, 6-8 cm (No. 8)
- Figures 16-19 *Pleurozonaria* sp. 1  
Sample 418B-31-2, 11-13 cm (No. 2)
- Figure 20 *Pterospermopsis helios* Sarjeant 1974  
Sample 417D-19-2, 11-14 cm (No. 7)
- Figure 21 *Tythodiscus* sp. 2  
Sample 417D-18-1, 3-4 cm (No. 9)
- Figure 22 *Spermatites* sp.  
Sample 417D-19-2, 11-14 cm (No. 9)
- Figure 23 *Micrhystridium fragile* Defl. 1947  
Sample 418B-31-2, 11-13 cm (No. 2)
- Figures 24, 25 *Monogemmites* cf. *pseudosetarius* (Weyl. & Pf.) W.  
Kr. 1970  
Sample 417D, 17, CC (No. 9)
- Figure 26 Microforaminifers (biserial)  
Sample 418A-10-1, 95-97 cm (No. 4)

PLATE 9

