10. DINOFLAGELLATE STRATIGRAPHY LEG 11, DEEP SEA DRILLING PROJECT

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Dinoflagellate cysts, acritarchs, pollen grains and spores were recovered from both Mesozoic and Cenozoic sections cored during Leg 11. For this report the distribution of dinoflagellates is emphasized. Broad changes of the spore and pollen assemblages are discussed only as they relate to the dinoflagellate stratigraphy. Acritarchs were not studied, although this group is numerically important in local portions of the Mesozoic.

Preservation of the dinoflagellates varies from good to excellent, especially in Mesozoic coccolith oozes where relatively uncompressed cysts occur. They are generally well-preserved, also, in those samples where only a few specimens were found. Cysts are most abundant in the coccolith oozes and carbonaceous clays of Mesozoic age cored at Holes 99A, 100, 101A, and 105. Very few specimens were recovered from the foraminiferal oozes cored at Site 98, and the recrystallized limestones cored at Sites 100 and 105.

MESOZOIC DINOFLAGELLATES

Dinoflagellates were recovered from most samples of Holes 99A, 100, 101A and 105. They are rare or absent in various samples from Cores 13 and 14 at Hole 99A, Cores 2, 3, 5 and 6 at Hole 100, and Cores 30 through 35 at Hole 105.

The distribution of dinoflagellates was examined in greater detail at Site 105, because of the larger Mesozoic section available there, and the relatively close spacing of the core intervals. One hundred and eleven samples were examined from the Mesozoic cores at this site. These form the basis for describing eight informal or tentative associations defined by the co-occurrence of species marked with an asterisk. Additional species are included in each association in support of the age suggested by dinoflagellates. These species cannot presently be considered characteristic of the association as they are either rare or do not occur in every sample. A ninth association is described from Site 100, which was not found at Site 105. Based on dinoflagellates, this association is believed to be the oldest recovered during Leg 11. A preliminary stratigraphic range chart showing the distribution of 49 species at Site 105 is proposed here, based on the lowest stratigraphic occurrences observed to date (Figure 1). These species were selected on the basis of their abundance, ease of identification, documentation in the literature, and/or comparatively restricted stratigraphic ranges.

The preliminary nature of the dinoflagellate associations and the stratigraphic ranges must be emphasized. For many samples only one or two slides could be examined. There appear to be many more species of potential stratigraphic value which require further study. There is an excellent opportunity provided in the cores at Site 105 for the eventual proposal of formal dinoflagellate stratigraphic zones.

Description Of Tentative Associations At Site 105

I. **Association A. Cores 9 and 10**

1. Diagnostic Species:

   **Deflandrea acuminata*[1]

   **Palaeohystrichophora infusorioides* (abundant)

   **Litosphaeridium siphoniphorum*

   **Cyclonephelium vannophorum*

   Epelidosphaeridia spinosa

2. Age Suggested by Dinoflagellates:

   Late Cretaceous: Cenomanian.

3. Comments:

   P. infusorioides is characteristic of Cenomanian and younger Cretaceous assemblages (Cookson and Hughes, 1964; Clarke and Verdier, 1967; Davey, 1970), although Cookson and Eisenack (1960a) and Alberti (1961) have reported it from the Albian. This species is abundant in all samples comprising this association. *D. acuminata* has a stratigraphic range of Cenomanian-Turonian. It is rare in Core 10.

4. Samples:

   105-9-5 (9-11 cm) 105-10-2 (58-60 cm)
   105-9, Core Catcher 105-10, Core Catcher

II. **Association B. Cores 11 through 15.**

1. Diagnostic Species:

[1] Asterisks denote species used for distinguishing associations. Other species included for age determination.

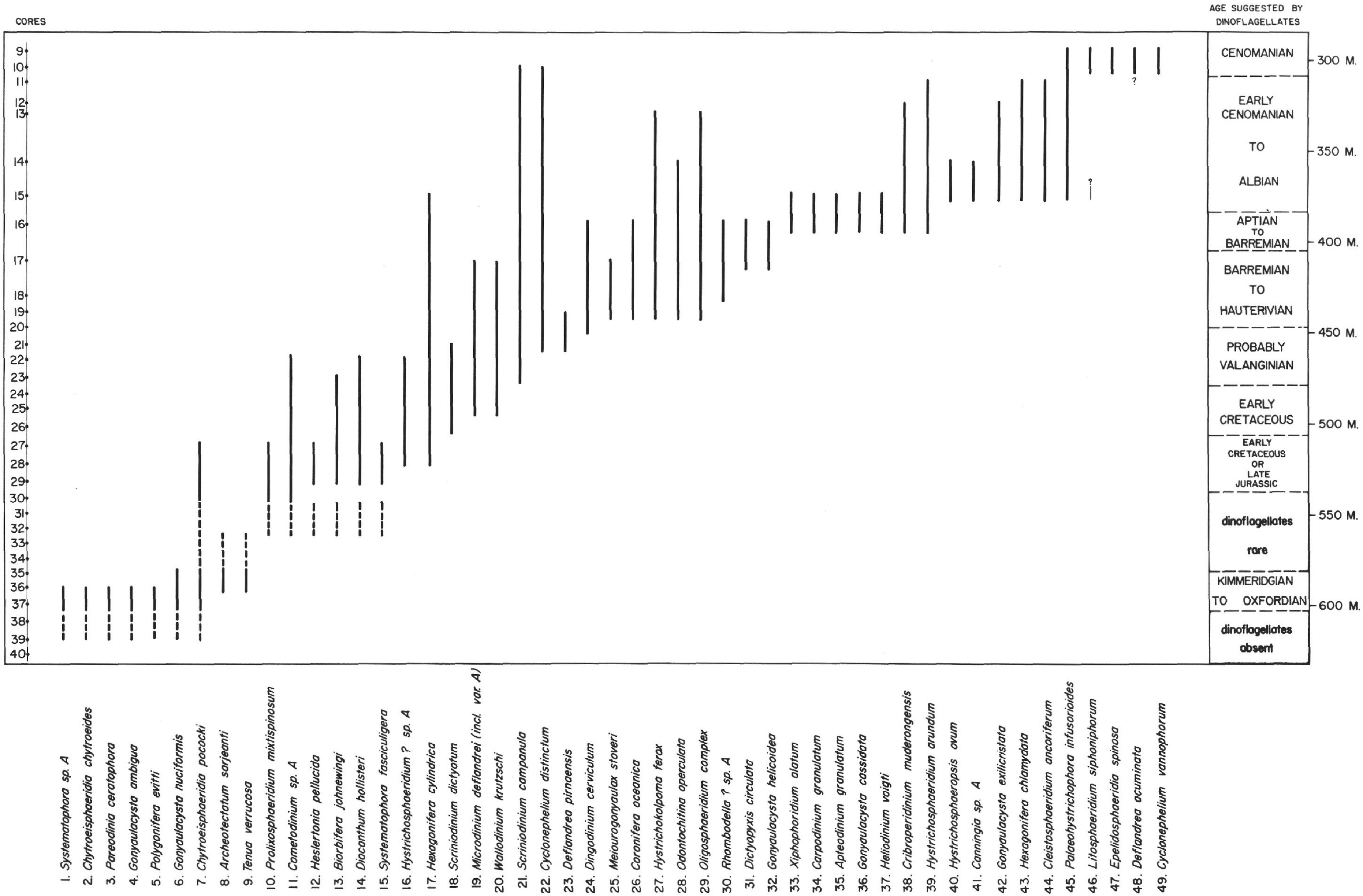

Figure 1. *Dinoflaggellate Stratigraphic Range Chart, Site 105.*

**Hystrichosphaeridium arundum*

**Cleistosphaeridium ancoriferum*

**Hexagonifera chlamydata*

**Palaeohystrichophora infusorioides*

Ovoidinium scabrosum

Oligosphaeridium complex

Odontochitina operculata

Hystrichosphaeropsis ovum

Dinogymnium sp. A
(Plate 17, Figure 5)

Gonyaulacysta exilicristata

Xiphophoridium alatum

Hystrichokolpoma ferox

Heliodinium voigti

Cribroperidinium edwardsi

Canningia sp. A
(Plate 16, Figures 3, 4 and 6)

2. Age Suggested by Dinoflagellates:

   Cretaceous: Albian - early Cenomanian.

3. Comments:

   The occurrence of *H. chlamydata* and *C. ancoriferum* suggests that the association is no older than Albian. *P. infusorioides* is also present, but its distribution in Cores 14 and 15 is erratic; it is apparently absent or rare in half the samples. A single specimen of *Litosphaeridium siphoniphorum* was observed in Sample 105-15-3 (100 to 102 centimeters). The composition of the assemblages forming Association B is close to that reported for the Cambridge Greensand by Cookson and Hughes (1964).

   The presence of retipilate dicotyledonous pollen and lack of structurally advanced types, for example, oblate triporates, indicate an age no younger than early Cenomanian (Habib, 1968; 1970). Several species of *Retitricolpites* were reported from the Albian Patapsco Formation of Maryland (Brenner, 1963). The late Albian-Late Cretaceous gymnosperm pollen species, *Rugubivesiculites reductus* Pierce is also present (Brenner, 1963; Muller, 1968).

4. Samples:

   105-11-4 (130-132 cm)
   105-11, Core Catcher
   105-12-2 (20-22 cm)
   105-12-4 (22-24 cm)
   105-12, Core Catcher
   105-13-1 (60-62 cm)
   105-13-2 (24-26 cm)
   105-13-3 (100-102 cm)
   105-15-4 (133-135 cm)
   105-15-5 (81-83 cm)
   105-13-4 (24-26 cm)
   105-13-6 (134-136 cm)
   105-13, Core Catcher
   105-14-1 (135-137 cm)
   105-14, Core Catcher
   105-15-1 (130-132 cm)
   105-15-2 (70-72 cm)
   105-15-3 (133-135 cm)
   105-15-6 (40-42 cm)
   105-15, Core Catcher

III. **Association C. Core 16.**

1. Diagnostic Species:

   **Gonyaulacysta helicoidea*

   **Gonyaulacysta cassidata*

   **Hystrichosphaeridium arundum*

   Oligosphaeridium complex

   **Dingodinium cerviculum*

   **Apteodinium granulatum*

   Dictyopyxis circulata

   Carpodinium granulatum

   Cribroperidinium muderongensis

   Heliodinium voigti

   Coronifera oceanica

   Odontochitina operculata

   Rhombodella ? sp. A
   (Plate 13, Figure 5)

2. Age Suggested by Dinoflagellates:

   Early Cretaceous: Aptian- Barremian.

3. Comments

   Dicotyledonous pollen have not been observed thus far. A few specimens of *H. arundum* were observed in Sample 105-16-2 (20-22 cm).

4. Samples:

   105-16-2 (20-22 cm)
   105-16-2 (70-73 cm)
   105-16-2 (110-112 cm)
   105-16, Core Catcher

IV. **Association D. Cores 17, 18 and 19.**

1. *Diagnostic Species:*

   **Microdinium deflandrei*

   **Dingodinium cerviculum*

   **Wallodinium krutzschi*

   Meiourogonyaulax stoveri

   Oligosphaeridium complex

   Hystrichokolpoma ferox

   Odontochitina operculata

   Deflandrea pirnaensis

   Paranetrelytron strongylum

   Dictyopyxis circulata

   Rhombodella ? sp. A.
   (Plate 13, Figure 5)

   Coronifera oceanica

2. Age Suggested by Dinoflagellates:

   Early Cretaceous: Barremian-Hauterivian

3. Comments:

   O. operculata, H. ferox, C. oceanica, and *O. complex* have their lowest stratigraphic occurrences in this association. *M. deflandrei* was described from the Barremian stratotype section (Millioud, 1969).

   The sporomorph assemblage is typically Lower Cretaceous, containing genera such as *Classopollis, Exesipollenites, Eucommiidites, Cicatricosisporites, Appendicisporites* and *Abietineaepollenites.*

   Core 19 consists to a large extent of hole cavings, and includes species characteristic of Association B (Albian-early Cenomanian).

4. Samples:

   105-17-1 (47-49 cm)
   105-17-1 (70-72 cm)
   105-17-2 (40-42 cm)
   105-17-2 (120-122 cm)
   105-17-3 (24-27 cm)
   105-17-3 (29-31 cm)
   105-17-3 (134-136 cm)
   105-17, Core Catcher
   105-18-1 (95-97 cm)
   105-18-2 (6-9) cm)
   105-18-2 (71-73 cm)
   105-18-3 (10-12 cm)
   105-18-3 (76-78 cm)
   105-18-4 (138-140 cm)
   105-18-5 (67-71 cm)
   105-18-6 (14-16 cm)
   105-18-6 (67-71 cm)
   105-18-6 (128-130 cm)
   105-18, Core Catcher
   105-19-1 (105-107 cm)
   105-19-2 (24-16 cm)
   105-19-2 (78-80 cm)
   105-19-2 (129-131 cm)
   105-19-3 (29-31 cm)
   105-19-3 (129-131 cm)
   105-19-4 (6-8 cm)
   105-19-4 (79-81 cm)

V. **Association E. Cores 20, 21 and 22**

1. Diagnostic Species:

   **Microdinium deflandrei*
   (variety A abundant)

   **Wallodinium krutzschi*

   Deflandrea pirnaensis

   Scriniodinium (Endoscrinium) campanula

   Scriniodinium (Endoscrinium) dictyotum

2. Age Suggested by Dinoflagellates:

   Early Cretaceous: Valanginian?

3. Comments:

   The assemblages forming this association are characterized by high percentages of *M. deflandrei* and *M. deflandrei* variety A, as well as the consistent occurrence of *W. krutzschi, M. deflandrei* and *W. krutzschi* make their first (lowest) stratigraphic appearance in the Lower Cretaceous. *S. campanula* has not been reported from sediments older than Valanginian. A single specimen of *D. cerviculum* was observed in Sample 20-1 (63-65 cm).

   The commonly occurring sporomorphs are the same as those of Association D.

4. Samples:

   105-20-1 (63-65 cm)
   105-20-1 (101-103 cm)
   105-21-1 (45-47 cm)
   105-21-1 (81-83 cm)
   105-21-1 (134-136 cm)
   105-21-2 (125-127 cm)
   105-22-1 (136-139 cm)
   105-22-2 (43-45 cm)
   105-22-2 (64-66 cm)
   105-22-2 (147-149 cm)

VI. **Association F. Cores 23 through 26.**

1. Diagnostic Species:

**Biorbifera johnewingi* new genus, new species

**Diacanthum hollisteri* new genus, new species

**Microdinium deflandrei* (variety A abundant)

**Wallodinium krutzschi*

Chlamydophorella wallala

Cometodinium sp. A (Plate 10, Figure 4)

Hystrichosphaeridium sp. A (Plate 9, Figure 4)

Scriniodinium (Endoscrinium) dictyotum

2. Age Suggested by Dinoflagellates:

Early Cretaceous or Late Jurassic.

3. Comments:

This association is characterized by the co-occurrence of *B. johnewingi, M. deflandrei, W. krutzschi* and *D. hollisteri.* The last species occurs consistently but is never abundant. *M. deflandrei* and *W. krutzschi* are present but rare. Their occurrence suggests an Early Cretaceous age.

4. Samples:

105-23-1 (139-141 cm)
105-23-2 (94-96 cm)
105-23-2 (122-124 cm)
105-23, Core Catcher
105-24-1 (40-42 cm)
105-24-1 (70-73 cm)
105-24-2 (82-84 cm)
105-24, Core Catcher
105-25-1 (77-79 cm)
105-25-2 (2-4 cm)
105-25-3 (1-3 cm)
105-25, Core Catcher
105-26-1 (146-148 cm)
105-26-2 (7-9 cm)
105-26, Core Catcher

VII. **Association G. Cores 27, 28 and 29.**

1. Diagnostic Species:

**Systematophora fasciculigera*

**Heslertonia pellucida*

Prolixosphaeridium mixtispinosum

Prolixosphaeridium granulosum

Chytroeisphaeridia pococki

Diacanthum hollisteri new genus, new species

Biorbifera johnewingi new genus, new species

Hystrichosphaeridium sp. A (Plate 9, Figure 4)

Cometodinium sp. A (Plate 10, Figure 4

2. Age Suggested by Dinoflagellates:

Early Cretaceous or Late Jurassic.

3. Comments:

Many of the species that constitute this association, including the two which distinguish it, *S. fasciculigera* and *H. pellucida,* were described from Upper Jurassic sediments of Europe and Great Britain (Klement, 1960; Gitmez, 1970). Several of these species have their first (lowest) stratigraphic appearance in the Kimmeridgian, although their upper limits are not known: thus far they have not been reported from the Lower Cretaceous. However, John S. Warren, in an unpublished Ph.D. dissertation (Stanford University, 1967) on Upper Jurassic and Lower Cretaceous rocks of California, illustrated specimens which appear indistinguishable from *B. johnewingi* new genus, new species. His specimens have a range of Berriansian-Valanginian; they were not found in his Tithonian material, although the dinoflagellate assemblage is varied and equally well-preserved (W.R. Evitt, Stanford University, personal communication).

It must be noted that the dinoflagellate stratigraphy near the Jurassic-Cretaceous boundary is not well established in the literature.

4. Samples

105-27-1 (11-13 cm)
105-27, Core Catcher
105-28-1 (6-8 cm)
105-28-3 (51-53 cm)
105-28-4 (97-100 cm)
105-28-5 (111-113 cm)
105-28, Core Catcher
105-29-3 (34-36 cm)
105-29-3 (103-105 cm)
105-29, Core Catcher

VIII. **Cores 30 through 35-1 (124-126 cm).**

1. Comments:

   Cores 30, 31, 32, 33, 34 and 35 are largely devoid of dinoflagellates. A few specimens of *Prolixosphaeridium mixtispinosum* were observed in Sample 105-30-2 (90-92 cm). No age determination can be made.

2. Samples:

   105-30-2 (90-92 cm)
   105-31-2 (127-129 cm)
   105-31, Core Catcher
   105-32-2 (31-33 cm)
   105-32, Core Catcher
   105-33-1 (78-80 cm)
   105-33-2 (10-12 cm)
   105-33, Core Catcher
   105-34-5 (31-33 cm).
   105-34, Core Catcher
   105-35-1 (124-126 cm)

IX. **Association H. Core 35, Core Catcher through Core 37, Core Catcher.**

1. Diagnostic Species:

   **Gonyaulacysta nuciformis*

   **Gonyaulacysta ambigua*

   **Chytroeisphaeridia chytroeides*

   **Tenua verrucosa*

   Pareodinia ceratophora

   Chytroeisphaeridia pococki

   Gonyaulacysta scarburghensis

   Tenua pilosa

   Cyclonephelium densebarbatum

   Polygonifera evitti new genus, new species

   Archeotectatum sarjeanti new genus, new species

   Cometodinium sp. A
   (Plate 10, Figure 4)

2. Age Suggested by Dinoflagellates

   Late Jurassic: Kimmeridgian-Oxfordian.

3. Comments:

   The assemblages forming Association H are composed mainly of non-tabulated cysts with apical archeopyles referable to *Chytroeisphaeridia* and *Tenua*. Several of the species above, for example, *G. nuciformis, Ch. chytroeides, Ch. pococki, P. ceratophora*, range into lower Kimmeridgian assemblages, such as *"P. baylei* Zone" studied by Gitmez (1970). The association is otherwise typical of Oxfordian assemblages.

4. Samples:

   105-35, Core Catcher
   105-36-2 (17-19 cm)
   105-36, Core Catcher
   105-37-5 (119-121 cm)
   105-37, Core Catcher

X. **Cores 38, 39 and 40.**

1. Comments:

   Barren of dinoflagellates.

2. Samples:

   105-38-4 (122-124 cm)
   105-38, Core Catcher
   105-39-1 (137-139 cm)
   105-39, Core Catcher
   105-40-1 (73-75 cm)

Site 100 (Association I)

At Site 100, a ninth association was distinguished which covered the interval of Cores 7 through 10 (100-10-2 (125-127 cm). This association is believed to be the oldest recovered during Leg 11.

I. **Association I.**

1. Diagnostic Species:

   **Meiourogonyaulax valensii*

   Gonyaulacysta ambigua

   **Pareodinia ceratophora*

   **Gonyaulacysta nuciformis*

   Gonyaulacysta scarburghensis

   Scriniodinium (Endoscrinium) galeritum

   Chytroeisphaeridia chytroeides

   Chytroeisphaeridia pococki

   Tenua verrucosa

   Gonyaulacysta dangeardi

   The following *additional* species were observed in Core 10:

   Dictyopyxis reticulata

   Tenua villersense

   aff. *Eisenackia* sp. (Plate 6, Figure 3)

Scriniodinium luridum

Stephanelytron ? sp. A (Plate 1, Figure 3)

2. Comments:

Association I is distinguished by the consistent occurrence of *M. valensii*, which heretofore was restricted to the Bathonian Stage. The Leg 11 specimens agree in every respect, including identical tabulation, with the species first described by Valensi (1953) and later formally proposed and figured as *M. valensii* by Sarjeant (1966). The assemblages are otherwise similar to those forming Association H, and are considered to be Oxfordian.

Core 10 may be Oxfordian or Callovian. This possibility is suggested on the basis of the following published stratigraphic occurrences (Sarjeant, 1968; Gitmez, 1970; Gocht, 1970).

Dictyopyxis reticulata
Bajocian-Bathonian

Pareodinia ceratophora
Bajocian-lower Kimmeridgian (*P. baylei* Zone)

Meiourogonyaulax valensii
Bathonian

Chytroeisphaeridia chytroeides
Bathonian-lower Kimmeridgian (*P. baylei* Zone)

Tenua villersense
lower Callovian (*S. calloviense* Zone-lower Oxfordian (*Q. mariae* Zone)

Gonyaulacysta ambigua
lower Callovian-Kimmeridgian

Chytroeisphaeridia pococki
lower Callovian-lower Kimmeridgian (*P. baylei* Zone)

Scriniodinium galeritum
Callovian-Kimmeridgian

Gonyaulacysta dangeardi
upper Callovian-lower Oxfordian

Tenua verrucosa
upper Callovian-Oxfordian

Gonyaulacysta nuciformis
lower Oxfordian (*Q. mariae* Zone) - lower Kimmeridgian (*P. baylei* Zone)

The following samples are considered to be correlative with the dinoflagellate associations proposed for Site 105 (A-H).

Association B. (early Cenomanian to Albian)

101A-4-1 (20-22 cm)
101A-4-1 (136-139 cm)
101A-4, Core Catcher
101A-5-1 (31-33 cm)
101A-5-1 (61-64 cm)
101A-5-1 (75-78 cm)
101A-5-1 (96-99 cm)
101A-5-2 (49-52 cm)
101A-5-2 (64-66 cm)
101A-5, Core Catcher (Association C?)

Association C (Aptian to Barremian)

101A-6-1 (65-67 cm)
101A-6-1 (116-119 cm)
101A-6-1 (132-134 cm)
101A-6, Core Catcher
101A-7-1 (105-108 cm)
101A-7-1 (130-133 cm)
101A-7, Core Catcher

Association D (Barremian to Hauterivian)

99A-3, Core Catcher
101A-8-1 (65-67 cm)
101A-8-1 (144-147 cm)
101A-8-2 (2-5 cm)
101A-8-2 (19-21 cm)
101A-8-2 (50-53 cm)
101A-8-2 (116-119 cm)
101A-8-2 (146-149 cm)
101A-8, Core Catcher

Association E. (Valanginian?)

99A-8-1 (145-147 cm)
99A-8, Core Catcher
99A-9-1 (145-147 cm)
99A-9-6 (147-149 cm)
99A-9, Core Catcher
99A-10, Core Catcher
101A-9-1 (55-58 cm)
101A-9-1 (63-66 cm)
101A-9-1 (102-104 cm)
101A-9-1 (132-135 cm)
101A-9-1 (147-150 cm)
101A-10-1 (117-119 cm)
101A-10-1 (128-130 cm)

Association E or F. (Early Cretaceous or Late Jurassic)

99A-11, Core Catcher

Association H. (Kimmeridgian to Oxfordian)

99A-14-2 (24-26 cm)
99A-14-2 (112-114 cm)
100-4, Core Catcher

CENOZOIC DINOFLAGELLATES

The following species have been identified thus far in the Cenozoic cores recovered at Sites 101 (Holes 101, 101A), 102, 103, 104, 105, 106 (Holes 106, 106B) and 108.

Achomosphaera ramulifera (Deflandre)

A. alcicornu Eisenack

Achomosphaera sp. aff. *A. triangulata* (Gerlach)

Chiropteridium sp. A

Cymatiosphaera sp.

Hystrichosphaeropsis obscurum new species

Hystrichokolpoma cinctum Klumpp

H. rigaudae Deflandre and Cookson

Leptodinium aculeatum Wall

L. patulum Wall

L. paradoxum Wall

Leptodinium ? sp. A

Leptodinium sp. aff. *L. victorianum* Cookson and Eisenack

Lingulodinium machaerophorum (Deflandre and Cookson)

Nematosphaeropsis balcombiana Deflandre and Cookson

Operculodinium centrocarpum (Deflandre and Cookson)

O. israelianum (Rossignol)

Pentadinium taeniagerum Gerlach

Spiniferites ramosus (Ehrenberg)

S. crassipellis (Deflandre and Cookson)

Svalbardella sp. A

Tectatodinium pellitum Wall

Thalassiphora sp.

Tuberculodinium vancampoae (Rossignol)

Wetzeliella sp. aff. *W. echinosuturata* Wilson

This list contains the more commonly occurring species in the cores ranging in age from Eocene (Site 108) to Pleistocene, although it represents less than fifty per cent of the species which occur.

Pleistocene-Pliocene

The distribution of palynomorphs is erratic in the hemipelagic muds dated as Pleistocene and Pliocene by calcareous nannoplankton and foraminifera. The dinoflagellate flora consists entirely of long-ranging species, many of which are related to modern motile thecae (Wall and Dale, 1968a, 1968b; 1970). The more commonly occurring cysts include *Operculodinium centrocarpum* (Deflandre and Cookson), *Tectatodinium pellitum* Wall, species of *Leptodinium*, and *Spiniferites ramosus* (Ehrenberg). *O. centrocarpum* and *T. pellitum* are abundant in Pleistocene samples. *Achomosphaera ramulifera* (Deflandre) is a potentially useful stratigraphic guide fossil, as it was not observed in samples dated younger than Pliocene or early Pleistocene. This species ranges into the Cretaceous (Davey, 1969).

Pine (*Pinus*) is the most common pollen type found in the investigated samples, although fern spores (Polypodiaceae), *Lycopodium* spores, and spruce pollen (*Picea*) occur as well. Spruce grains are most frequent in the Pleistocene samples at Site 106, although a few specimens also were found in the cores at Site 102. Their occurrence in these sediments suggests transportation by marine currents. Reworked palynomorphs occur in most samples as well, although they are always rare. Spores and pollen of Cretaceous affinity include the genera *Rugubivesiculites, Gleicheniidites, Camarozonosporis, Retitricolpites, Abietineaepollenites* and *Parvisaccites*. Genera of Carboniferous affinity include *Densosporites, Lycospora, Punctatisporites* and *Laevigatosporites*. The Cretaceous palynomorphs are more frequent than the Carboniferous, and are surprisingly well-preserved. They may represent erosion of the continental margin, including the Atlantic Coastal Plain, and/or erosion of deep-sea sediments. The presence of Carboniferous spores in sediments as far south as Site 101 suggests transportation from a northern source (Needham, Habib and Heezen, 1969).

Miocene - Oligocene

The dinoflagellate flora of the independently dated Miocene cores at Sites 103, 104, and Hole 106B is characterized by a number of species which apparently do not range into the Pliocene, and by long-ranging species found in the Pliocene and Pleistocene. Of potential stratigraphic value is *Hystrichosphaeropsis obscurum* new species, which has not been found thus far in cores dated younger than late Miocene (*Ceratolithus tricorniculatus* calcareous nannoplankton zone). This species was used to date the otherwise unfossiliferous samples from 105-4-6 (40-42 centimeters) and 105-4, Core Catcher at Site 105 as Miocene. It was not found, however, in late Miocene cores at Hole 101A. *Pentadinium taeniagerum* Gerlach occurs in the core catcher samples of Core 10 at Site 104 and Core 5B at Site 106, which suggests that these samples are

correlative. This conclusion is supported by the occurrence of *Chiropteridium* sp. A (Plate 22, Figure 5) in these samples. The upper-most stratigraphic occurrence of *P. taeniagerum* at Sites 104 and 106 apparently is immediately below the lowest observed occurrence of *H. obscurum.*

The pollen and spores of the Miocene cores are also diversified when compared to the Pliocene and Pleistocene. Oak pollen (*Quercus*) is common, and in several samples occurs in percentages as high as those for pine. Other pollen representatives of a temperate forest include *Carya* (hickory) and *Juglans* (walnut). Spruce pollen was not observed, although pteridophyte spores and the pollen of the nonarboreal Gramineae, Compositae, and Cyperaceae are common.

Reworked palynomorphs occur in most samples, and are of similar frequency and distribution as in the Pliocene-Pleistocene.

Eocene

The palynomorphs contained in the calcareous sediment cored at Site 108 are represented by a large and varied dinoflagellate flora and relatively few pollen grains and spores. *Hystrichokolpoma cinctum* Klummp and *Wetzeliella* aff. *W. echinosuturata* Wilson are common. Many species have not been identified.

SYSTEMATIC PALEONTOLOGY

Only those taxa which pertain directly to stratigraphic problems are treated.

Sixteen species are discussed, including six which are proposed as new. For the most part informal specific epithets, such as "sp. A", are presented, because of the need for additional study. Four genera, *Archeotectatum, Polygonifera, Diacanthum* and *Biorbifera*, are proposed as new.

For the purpose of future reference, 128 specimens are illustrated in 22 plates.

Genus **Stephanelytron** Sarjeant

Stephanelytron? sp. A (Plate 1, Figure 3).

Remarks: A number of well-preserved specimens recovered from Site 100 are provisionally attributed to *Stephanelytron*. The species shares with *Stephanelytron* its everted tubular processes and a circular field located at the "antapex". It differs by the absence of a true corona (Sarjeant, 1961, p. 109) and by the possession of a number of circular fields, rather than one or a few. The latter feature places it closer to *Systematophora* Klement, although in that genus the processes are closed distally.

Occurrence: In Core 10 at Site 100. It is most frequent in Sample 100-10-2 (125-127 cm).

Genus **Tenua** Eisenack amended Sarjeant

Tenua atlantica new species (Plate 4, Figures 2 and 5).

Holotype: Sample 100-10-2 (125-127) Slide 1. Plate 4, Figure 2.30 X 20 microns.

Description: Relatively small untabulated proximate cysts. Outline of hypotract rectangular, epitract triangular. Hypotract same size or slightly larger than epitract. Cyst longer than wide; it is widest in the region of the cingulum, although a distinctive cingulum is not evident. Apical archeopyle small; its margin is zig-zag suggesting six precingular plates and a sulcus below; operculum triangular but well-rounded. Wall is thin and densely granulate. Maximum size of seven measured specimens 24 to 35 microns.

Remarks: This species of *Tenua* is distinguished by its form and small apical archeopyle. In several specimens, including the holotype, there is evidence of faint sutures reflecting a minimum of six precingular plates and five or six postcingular plates. Further detailed examination of additional specimens is necessary before it can be determined if a tabulation is present.

Occurrence: At Site 100, Core 10.

Genus **Meiourogonyaulax** Sarjeant 1966

Meiourogonyaulax valensii Sarjeant (Plate 3, Figures 1 and 3).

Occurrence: Numerous excellently preserved specimens corresponding identically in tabulation and structure of the sulcus to *M. valensii*—e.g., Plate 3, Figure 1—were recovered at Site 100, Cores 7 through 10 (Association I). The occurrence of *M. valensii* marks its highest stratigraphic position published to date. Its previously published stratigraphic range is Bathonian (Sarjeant, 1966; 1967).

Genus **Archeotectatum** new genus

Type Species. Archeotectatum sarjeanti new species.

Diagnosis: Proximate dinoflagellate cysts. Outline polygonal in lateral view, with an apical horn and two

rounded antapical horns; essentially oval in dorso-ventral compression. Wall is thick and spongy. Archeopyle precingular. Untabulated. Ornamentation variable.

Remarks: *Archeotectatum* is similar to *Tectatodinium* Wall with respect to the thick wall and precingular archeopyle. It is distinguished by the occurrence of apical and antapical horns. The genus closely resembles *Apteodinium* Eisenack but is distinguished by its thick tectum-like wall.

Archeotectatum sarjeanti new species (Plate 5, Figures 3 and 4

Holotype: Sample 105-35, Core Catcher, Slide 1. Plate 5, Figure 3. 44 X 36 microns.

Description: Untabulated proximate cysts. Polygonal in lateral view with broadly rounded apical horn and two closely set well-rounded antapical horns; cyst is widest in cingular region, although a distinctive cingulum is not established. Wall is thick and spongy. Precingular archeopyle is large and pentagonal, suggesting in the theca the existence of apical and precingular tabulation. Ornamentation densely granulate. Range is maximum size of nine measured specimens from 40 to 48 microns.

Occurrence: At Site 105, Cores 35 and 36; at Site 100, Core 7.

Genus **Polygonifera** new genus

Type Species. Polygonifera evitti new species.

Diagnosis: Cavate cysts of polygonal to oval shape; archeopyle apical, six-sided, and with a sulcal notch. Tabulation not evident. Capsule more-or-less oval. It is appressed to one surface of the outer membrane. Antapical pericoel well developed. Cingulum distinct and invariably represents greatest width of cyst.

Remarks: *Polygonifera* most closely resembles species of *Hexagonifera* and *Wallodinium* from which it is distinguished by its distinctive cingulum.

Polygonifera evitti new species (Plate 5, Figures 1 and 2).

Holotype. Sample 100-10-2 (125-127 cm.). Plate 5, Figure 1.48 X 53 microns.

Description. Cavate cysts formed by a thick-walled subspherical, ellipsoidal, or ovoidal central capsule, and thin outer membrane which appears polygonal to oval in dorso-ventral compression and oval in lateral. Capsule displaced eccentrically near membrane. Pericoel best developed in antapical area. Distinct cingulum formed at maximum width of membrane. Archeopyle apical in position, defined by zig-zag margin which reflects the upper margins of a distinct sulcus (sulcal notch) and six precingular plates below. Otherwise cysts appear untabulated. Apical operculum has not been observed. Ornamentation of cysts variable, ranging from scabrate to granulate. Maximum size of ten measured specimens ranges from 42 to 62 microns.

Remarks: *Polygonifera evitti* n. sp. is characterized by the presence of a distinct cingulum, the eccentric displacement of the central capsule near the outer membrane, and the polygonal to oval outline as seen in dorso-ventral view. This species resembles the lower Kimmeridgian "*Hexagonifera* sp." illustrated by Gitmez (1970). It is similar also to the Bathonian specimen described and illustrated by Gocht (1970) as "Gen. et. sp. indet. 1".

Occurrence: At Site 99A, Core 14; Site 100, Core 10; Hole 105, Cores 36 and 37.

Genus **Diacanthum** new genus

Type Species. Diacanthum hollisteri new species.

Diagnosis: Spherical to subspherical proximate cysts without pronounced apical extensions. Tabulation obscured in many specimens, but appears to consist of the following minimum tabulation: $4'-5$ or $6''-6c-6'''-1?''''$. Plate boundaries delimited in well-preserved specimens by raised perforate crests. Archeopyle relatively large, precingular, and formed by two plates (2P). Ornamentation variable, in the form of spines, grana, and alveolae.

Remarks: *Diacanthum* is intermediate in taxonomic position between *Acanthaulax* Sarjeant and *Occisucysta* Gitmez. It is similar to the former genus in the basic tabulation, absence of apical horns and possession of spines, but differs in the nature of the archeopyle. It is similar to *Occisucysta* in the two-plate archeopyle, but lacks the pronounced apical horn characteristic of this genus.

Diacanthum hollisteri new species (Plate 9, Figures 1 and 3; Plate 10, Figure 1; Text-Figure 2).

Holotype: Plate 9, Figure 1. Sample 100-1, Core Catcher, 80 X 85 microns.

Description: Proximate cysts compressed to a subcircular outline. Apical polar areas always well-rounded, and without horns. Periphragm and endophragm closely appressed. Cingulum is narrow, and

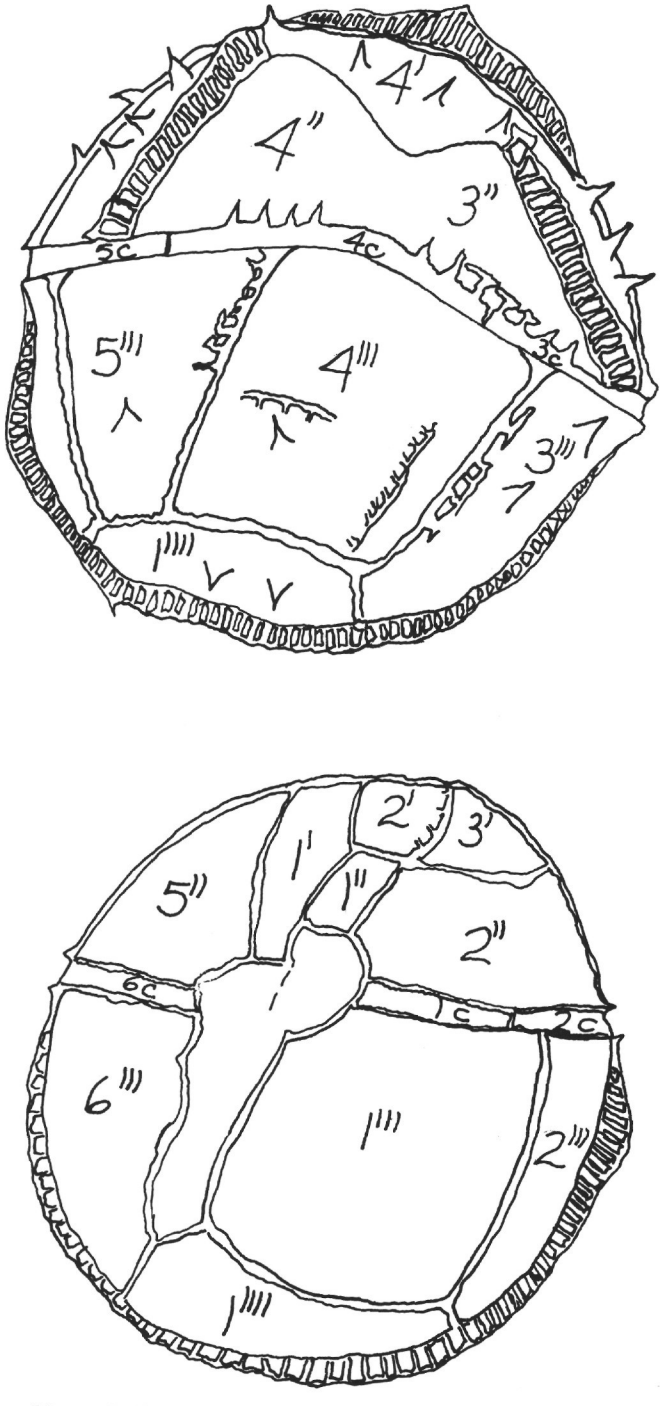

Figure 2. Diacanthum hollisteri *new genus, new species. Schematic illustration of tabulation.*

only weakly helicoid, it divides the epitract and hypotract into more-or-less equal halves. Sulcus extends deeply into hypotract. Tabulation is that for the genus. Precingular archeopyle apparently formed by plates 3" and 4". Plate boundaries formed by raised crests which for the most part are perforate; the perforate crests do not appear to be entirely restricted to plate margins, as they extend over the periphragm, to varying degrees, as alveolae. Periphragm covered with dense grana, and by isolated broadly tapering sharp spines.

Size of twenty measured specimens from 75 to 104 microns, maximum length.

Remarks: The tabulation of this species, and the genus, is not firmly established, primarily because the surface ornamentation tends to obscure plate boundaries. Consequently, the formula given for the genus is provisional and is offered as minimum tabulation.

Occurrence: At Site 100, Core 1; Site 105, Cores 30 through 24, and 22; Site 99A, Core 11.

Genus **Biorbifera** new genus

Type Species. Biorbifera johnewingi new species.

Diagnosis: Proximate dinoflagellate cysts. Outline of both epitract and hypotract essentially semi-circular. Cingulum present and indented. Untabulated. Archeopyle epitractal. Ornamentation variable.

Remarks: This genus resembles *Tenua* as emended by Sarjeant (1968), but differs in the form of the archeopyle. The archeopyle is apical in *Tenua*, and is characterized by a notched zig-zag outline reflecting precingular plates below. The archeopyle forms immediately anterior to the cingulum in *Biorbifera* and is more-or-less smooth at this margin.

Biorbifera johnewingi new species (Plate 10, Figures 2 and 3).

Holotype: Sample 105-24-1 (40–42 cm). Plate 10, Figure 3. 28 X 19 microns.

Description: Relatively small untabulated proximate cysts with indented relatively wide cingulum. Both epitract and hypotract essentially semi-circular in outline. Polar areas always broadly rounded and, with the indented cingulum, tend to give the cyst a dumb-bell or peanut shape. Hypotract larger than epitract. The operculum dehisces immediately anterior to the cingulum (epitractal archeopyle, AP); in the majority of specimens the operculum remains partially attached. Periphragm covered with numerous broadly tapering sharp spines; only very few appear blunt at the tip; spines number from 150 to 250 at the outline; their distribution is less dense in the larger specimens (for example, holotype) and more dense in the smaller. Range in maximum size of twenty measured specimens is 24 to 38 microns.

Remarks: This species resembles *Tenua pilosa* (Ehrenberg) but is clearly distinguished in the archeopyle formation.

Occurrence: At Site 105, Cores 29 through 23. The species is rare in Cores 29, 28 and 23.

Genus **Hexagonifera** Cookson and Eisenack

Hexagonifera cylindrica (Habib) new combination (Plate 10, Figure 5).

Prismatocystis cylindrica Habib, 1970. *Micropaleontology*, vol. 16, p. 374.

Remarks: Examination of numerous well-preserved specimens recovered during Leg 11, and consequently re-examination of the holotype, have revealed that the "truncated apex" of Habib (1970) is an apical archeopyle with a six-sided margin. Its dinoflagellate affinities established, the species is transferred to *Hexagonifera*.

Occurrence: The species is long-ranging, occurring in Cores 15 through 28 at Site 105.

Genus **Microdinium** Cookson and Eisenack

Microdinium deflandrei Millioud variety A (Plate 12, Figures 3 and 4 Text-Figure 3).

Remarks: A large number of well-preserved specimens very closely resemble *Microdinium deflandrei* Millioud (Plate 12, Figures 5 through 8), with which they occur together at Holes 99A, 101A and 105? They are presently given the informal designation of *M. deflandrei* variety A, on the basis of the following characters: Variety A is slightly larger and more angular in outline, with well-defined tabulation, crenulate sutures, and perforate sutural crests. The tabulation is ?′, 6″, 6c, 6‴, 1⁗ and is illustrated in Text-Figure 2. The single antapical plate is inclined towards the ventral surface and gives the antapex its flattened appearance. In the postcingular series, plate 1‴ is the smallest and is nearly square. The remaining plates are essentially rectangular. In the cingular series, plate 1c is consistently smallest. In the precingular series the six plates are triangular in outline, and all but one or two have tongue-like protusions which extend towards the apex (apical plates?). An apical series could not be firmly established, as sutures were not observed between the triangular precingular plates and the apical extensions.

Excystment is interpreted to have occurred by splitting of the apical (?) and precingular plates at their lateral margins, thereby involving all the plates of the epitract. The apical (?) plates remain attached to the precingular. This method of archeopyle formation appears to be unique, and is distinct from that of the type species of *Microdinium, M. ornatum* Cookson and Eisenack.

In accordance with the diagnosis given by Millioud (1969), specimens assigned in this study to *M. deflandrei* possess an obscured tabulation. However, where plates could be distinguished, they appear to have the same arrangement as in *M. deflandrei* variety A. Also, the form of the archeopyle appears identical.

Formal taxonomic revision of this species, and possibly the genus *Microdinium*, must await additional study.

Genus **Wallodinium** Loeblich and Loeblich

Wallodinium Loeblich and Loeblich, 1968. *J. Paleontology*, vol. 42, p. 212.

Diplotesta Cookson and Eisenack, 1960. *Palaeontology*, vol. 2, p. 256 (*non* Brongniart, 1874).

Wallodinium krutzschi (Alberti) new combination (Plate 12, Figure 9; Plate 13, Figure 2).

Diplotesta krutzschi Alberti, 1961. *Palaeontographica*, vol. 116, p. 21.

Remarks: Morphological varieties close to *W. glaessneri*, were observed, together with typical *W. krutzschi*, but they were not considered sufficiently different to constitute a separate species.

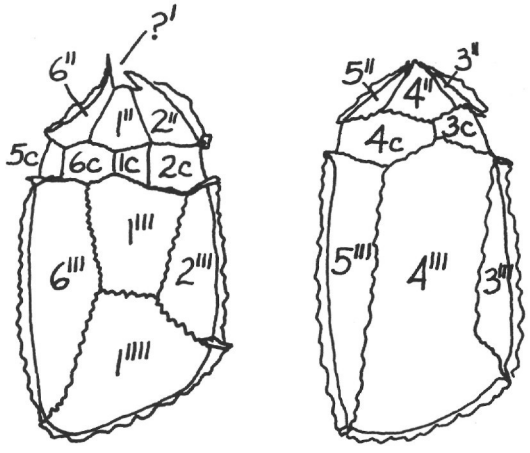

Figure 3. Microdinium deflandrei *Millioud Variety A. Schematic illustration of tabulation.*

Wallodinium glaessneri (Cookson and Eisenack) new combination.

Diplotesta glaessneri Cookson and Eisenack, 1960. *Palaeontology*, vol. 2, p. 256.

Genus **Dingodinium** Cookson and Eisenack

Dingodinium cerviculum Cookson and Eisenack (Plate 12, Figures 1 and 2).

Remarks: Many very well-preserved specimens of *D. cerviculum* were found at all sites which cored Lower Cretaceous. The majority of specimens show evidence of partial detachment of the apical horn (Plate 12, Figure 1), similar to the situation described by Alberti (1961). However, in several specimens a distinctive intercalary archeopyle is evident (Plate 12, Figure 2b), indicating that the species' correct position of excystment was intercalary. The rupturing at the base of the apical horn is considered to be secondary in nature, possibly the result of splitting due to compaction. This phenomenon was not observed in relatively uncompressed specimens.

The presence of an intercalary archeopyle in this species indicates a close relationship with species of *Deflandrea*. Splitting at the base of the apical horn has been observed in species of *Deflandrea* recovered from Upper Cretaceous sediments of New Jersey.

Genus **Rhombodella** Cookson and Eisenack

Rhombodella? sp. A (Plate 13, Figure 5).

Remarks: Specimens similar to *Rhombodella* were found at Holes 101A and 105 to have restricted stratigraphic ranges (Associations C and D), and therefore are considered potentially valuable stratigraphic guides. The Leg 11 specimens differ from the type species of *Rhombodella, R. natans* Cookson and Eisenack, in the lack of appendages at the corners.

Occurrence: At Site 105, Cores 16–2 (70–73 cm) through 18–4 (138–140 cm); at Site 101A, Core 6–1 (65–67 cm).

Genus **Canningia** Cookson and Eisenack

Canningia sp. A (Plate 16, Figures 3, 4 and 6).

Remarks: This species closely resembles the species described as *Chytroeisphaeridia euteiches* by Davey (1969), and the two may be conspecific. *Canningia* sp. A shares with *Ch. euteiches* the subspherical form, thick periphragm, and densely granular texture comprised apparently of "minute cellular elements". It differs from the genus *Chytroeisphaeridia*, and *Ch. euteiches*, by the possession of a short but prominent apical horn. Because of the very close similarity of the two species, especially when the operculum is detached, this species cannot presently be given a formal specific epithet.

Occurrence: Cores 14 and 15 at Hole 105; Core 5 at Hole 101A.

Genus **Pentadinium** Gerlach

Pentadinium taeniagerum Gerlach (Plate 20, Figure 4; Plate 21, Figures 5 and 6).

Remarks: Specimens assigned to *P. taeniagerum* have the tabulation 1′, 5″, ?c, 5‴, ?p, 1⁗, which is characteristic of the genus. The ventral area is vague, and a distinct sulcus could not be distinguished. A cingulum is clearly evident and tabulated, although the plate boundaries are obscured. In several specimens, the tabulation of the entire epitract could not be distinguished. The internal capsule is densely granulated, and in most specimens lies close to the outer membrane.

Occurrence: Sample 104-10; Core Catcher at Hole 104; Sample 106B-5, Core Catcher at Hole 106B.

Genus **Hystrichosphaeropsis** Deflandre

Hystrichosphaeropsis obscurum new species (Plate 21, Figures 1, 2 and 3).

Holotype: Sample 104-3-3 (40–43 cm). Plate 21, Figure 1. 76 X 55 microns.

Description: Bicavate dinoflagellate cysts. Outline of compressed specimens essentially rectangular, and longer than wide; hypotract is rectangular, and is the same size or slightly larger than epitract; epitract rectangular or broadly triangular, always with a short rounded horn appearing arched at the apex. Internal capsule oval and commonly closely appressed to outer membrane in the area of the cingulum. Antapical pericoel and apical pericoel well-developed; the former is usually larger than the latter. Tabulation of cysts imperfect, varying from distinguishing only a cingular series and several plates of the hypotract, for example, Plate 21, Figure 3, to the formula 3?′, 5 or 6″, 5 or 6c, 5‴, ?P, 1⁗, such as, Plate 21, Figure 1. Tabulation of the cingulum is usually best expressed; it is difficult to

determine the formula for the ventral surface because of the very poor definition of the sulcus. The apical series is vague, and varies from a single "plate area" in the poorly tabulated specimens to 3?′ in the well tabulated. Precingular archeopyle (3″) is large and rectangular. Surface of internal capsule is densely granular; the outer membrane is smooth or scabrate. Twenty measured specimens range in maximum length from 70 to 95 microns.

Remarks: This species is distinguished from *Hystrichosphaeropsis borussica* (Cookson and Eisenack) and *H. ovum* Deflandre by its lack of furcate processes arising from the cingulum and elsewhere on the periphragm. It is the same species as that described as *Hystrichosphaeropsis* sp. cf. *H. ovum* by Habib (MS) from late Miocene sediments near Tabiano, Italy (Tabianian stratotype). Gerlach (1961) illustrated a Miocene-?Oligocene species as *H. ovum*, which is similar to *H. obscurum*. Graham Williams reported specimens which are considered to be conspecific in Late Miocene to Late Eocene assemblages from shallow cores recovered from the Grand Banks, Newfoundland (personal communication).

Occurrence: *H. obscurum* was observed in the following samples:

103-3, Core Catcher
103-4-3 (50-42 cm)
103-4, Core Catcher
103-5-1 (138-140 cm)
103-5-2 (110-112 cm)
103-5-3 (43-45 cm)
103-5, Core Catcher
103-6-1 (110-112 cm)
106B-3, Core Catcher
103-6, Core Catcher
103-7, Core Catcher
104-2-2 (97-99 cm)
104-2, Core Catcher
104-3-3 (40-43 cm)
104-3, Core Catcher
106B-4, Core Catcher
104-4, Core Catcher
104-6, Core Catcher
104-7, Core Catcher
104-8, Core Catcher
104-9, Core Catcher
105-4-6 (40-42 cm)
105-4, Core Catcher

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PLATE 1
Mesozoic Dinoflagellates (Magnification approximately X870)

Figures 1, 2 *Dictyopyxis reticulata* (Valensi).
1. Obliquely compressed specimen. 1a. Focus on apical archeopyle. Note presence of cingulum and evidence of tabulation. 1b. Focus on surface reticulation. Note the occurrence of spines rising from reticulate pattern, both within the margin and at the outline.
Sample 100-10-2 (125-127 cm).
2. Cingulum and plate boundaries are evident.
Sample 100-10-2 (125-127 cm).

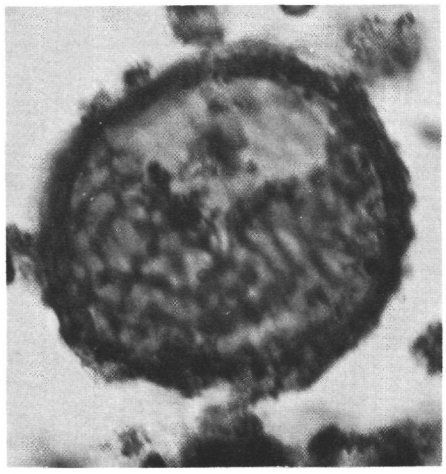
Figure 3 *Stephanelytron*? sp. A.
3a. Antapical circular field is in focus, but note also other circular fields (tabulation?) from which arise everted tubular processes.
3b. Focus on distally flaring tubular processes.
Sample 100-10-2 (125-127 cm).

Figure 4 *Tenua villersense* Sarjeant.
Sample 100-10-2 (125-127 cm).

Figure 5 *Gonyaulacysta dangeardi* Sarjeant.
This specimen resembles *Leptodinium egemenii* Gitmez, but possesses a short apical horn. Compare with Plate 2, Figure 2.
Sample 100-10-2 (125-127 cm).

Figure 6 *Leptodinium Sp.*
Sample 105-27, Core Catcher

PLATE 1



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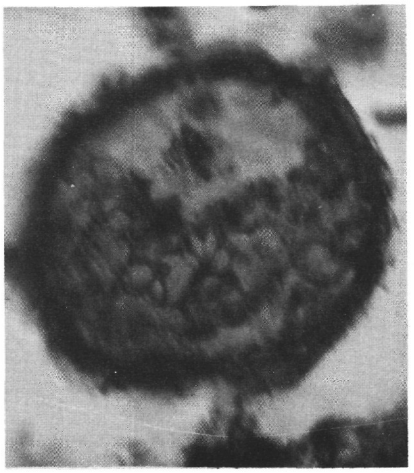

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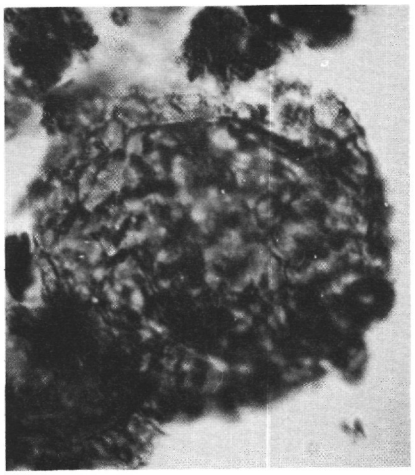
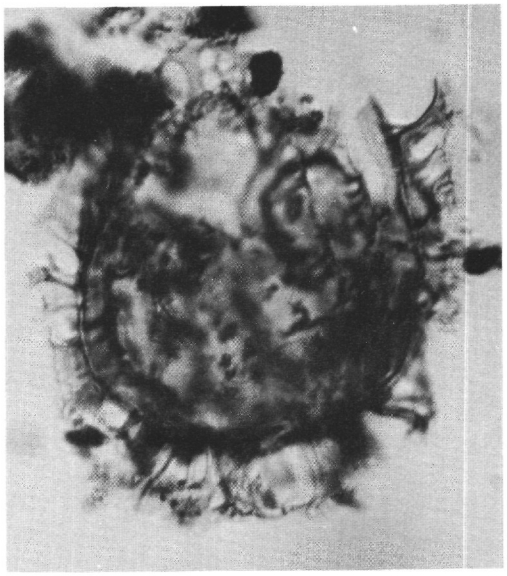


2

3a



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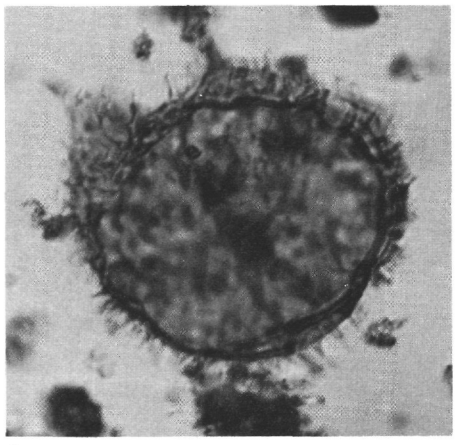

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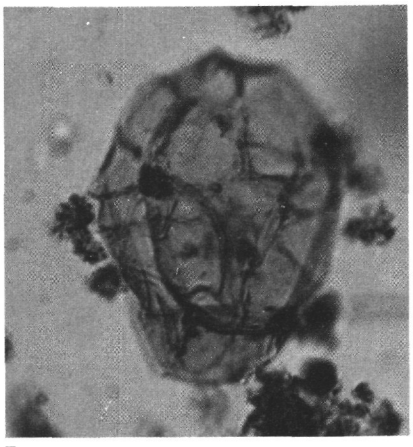

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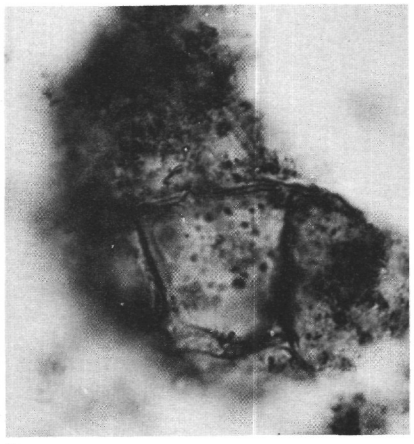

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PLATE 2
Mesozoic Dinoflagellates (Magnification approximately ×870)

Figure 1 *Chytroeisphaeridia pococki* Sarjeant.
1a. Focus on archeopyle.
1b. Focus on surface granulation.
Sample 100-10-2 (125-127 cm).

Figure 2 *Gonyaulacysta dangeardi* Sarjeant.
Sample 100-9, Core Catcher.

Figure 3 *Cyclonephelium densebarbatum* Cookson and Eisenack.
Sample 105-35, Core Catcher.

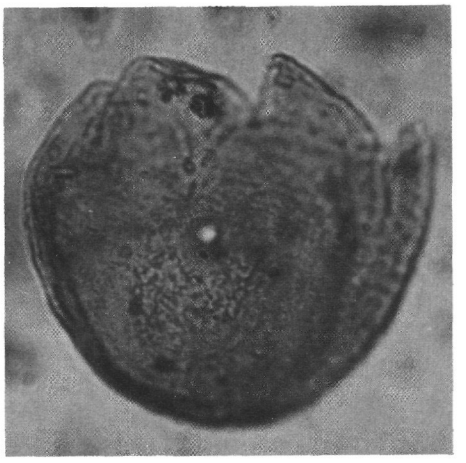
Figure 4 *Tenua* sp.
Sample 105-27, Core Catcher.

Figure 5 *Leptodinium* sp.
Sample 100-10-2 (125-127 cm).

Figure 6 *Gonyaulacysta ambigua* (Deflandre).
6a. Focus on ventral tabulation.
6b. Focus on precingular archeopyle.
Sample 100-10-2 (125-127 cm).

PLATE 2

1a



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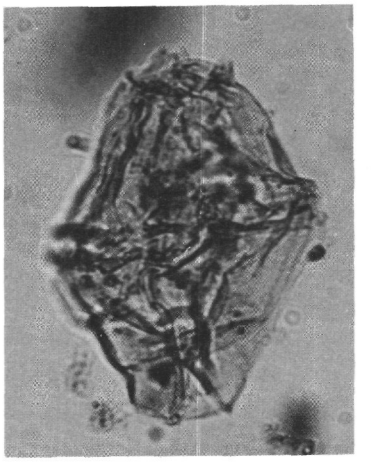

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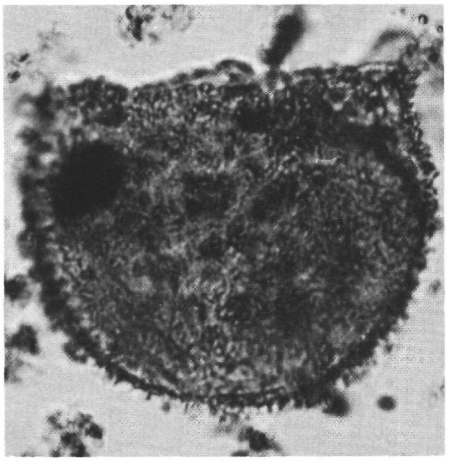

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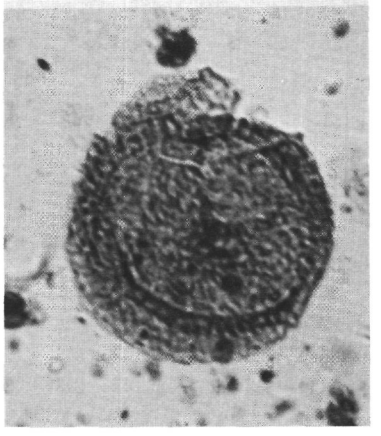

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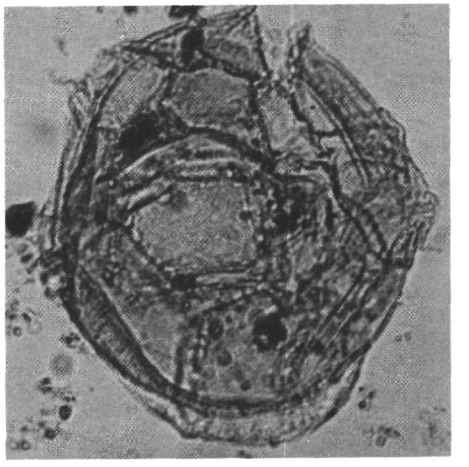

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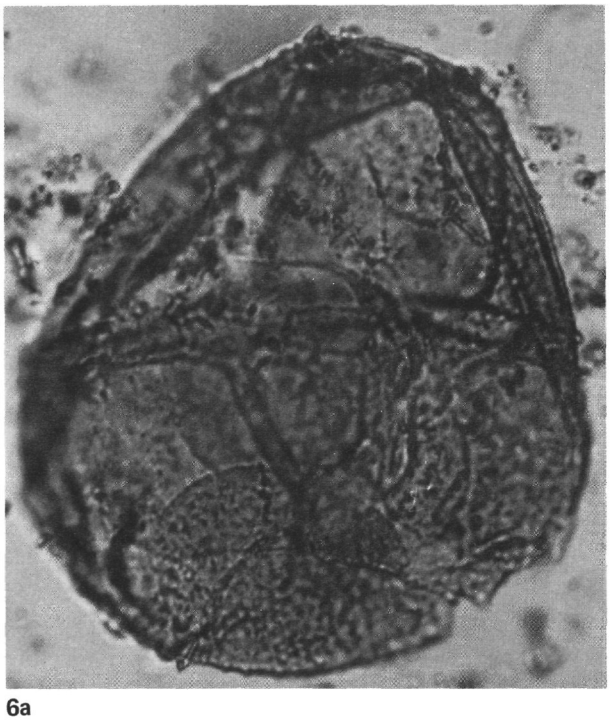

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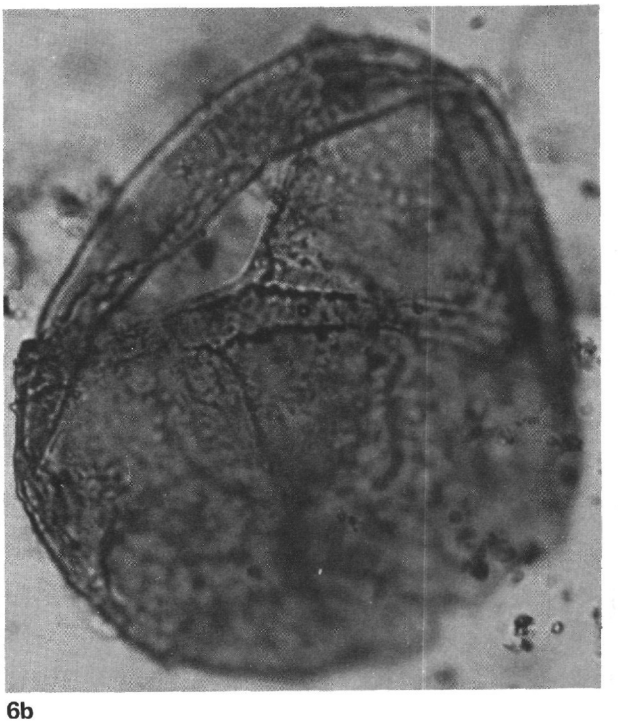


6b

PLATE 3
Mesozoic Dinoflagellates (Magnification approximately X870)

Figure 1, 3 *Meiourogonyaulax valensii* Sarjeant.

1. Well tabulated, excellently preserved specimen. Focus on apical archeopyle (note sulcal notch), structure of sulcus, and crestal development of sutures. Alveolate specimens were also observed. This species was previously restricted to Bathonian sediments.
   Sample 100-7, Core Catcher.
3. Lateral compression. 3a. Plate boundaries of epitract and of cingulum shown. 3b. Postcingular plates and antapical plate.
   Sample 100-7-1 (140-143 cm).

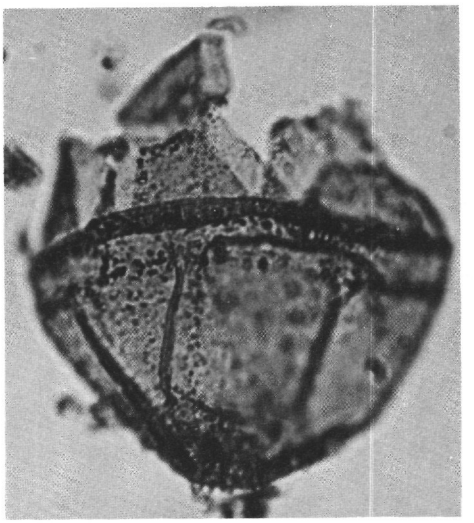
Figure 2 *Chytroeisphaeridia pococki* Sarjeant.
Note evidence of faint tabulation reflected in granulation pattern.
Sample 100-10-2 (125-127 cm).

Figure 4 *Gonyaulacysta nuciformis* (Deflandre).
Sample 100-9, Core Catcher.

Figure 5 *Systematophora* sp. A.
Sample 100-9, Core Catcher.

PLATE 3

1



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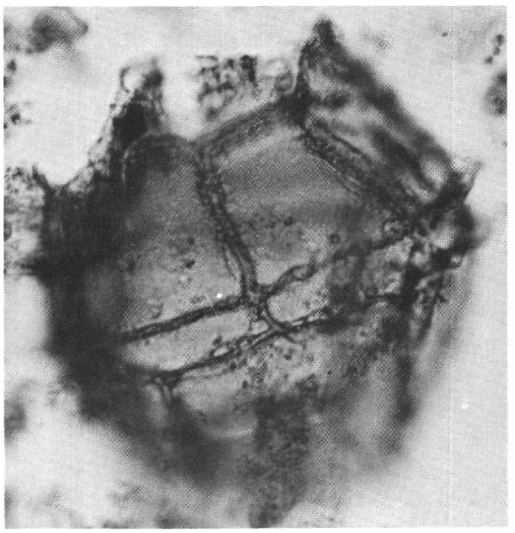

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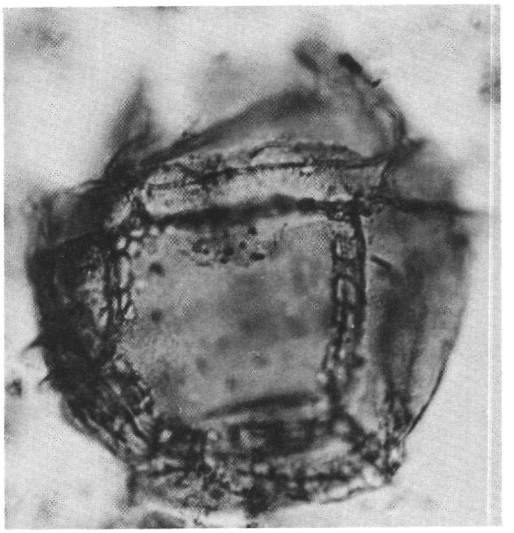

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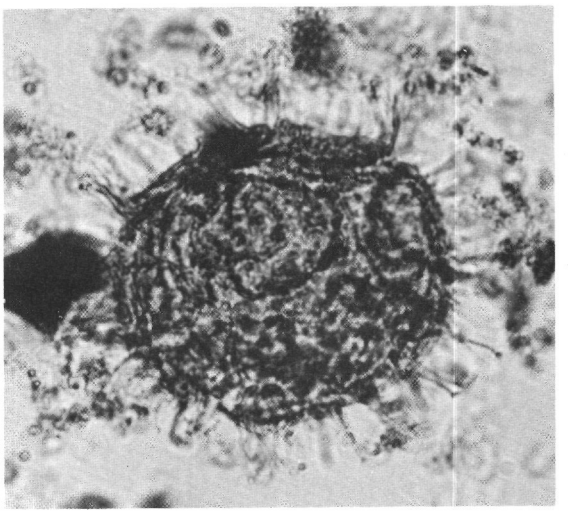


5

PLATE 4
Mesozoic Dinoflagellates (Magnification approximately X870)

Figure 1 — *Gonyaulacysta* sp. aff. *G. nuciformis* (Deflandre).
1a. Optical cross-section. Note surface ornamentation and apical horn.
1b. Ventral focus.
Sample 100-9, Core Catcher.

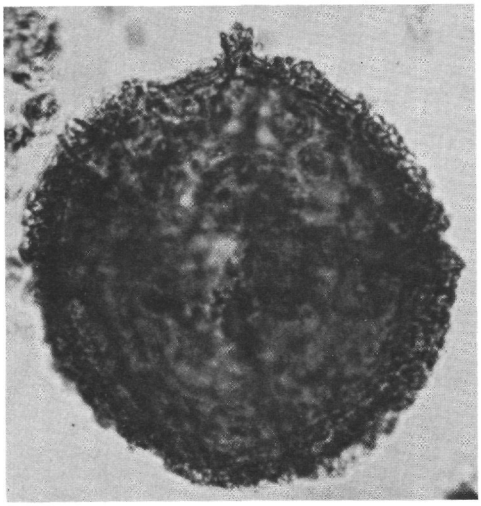
Figures 2, 5 — *Tenua atlantica* new species.
2. Holotype. Note typically triangular epitract and rectangular hypotract.
Sample 100-10-2 (125-127 cm).
5. Specimen with a more rounded hypotract.
Sample 100-10-2 (125-127 cm).

Figure 3 — *Tenua verrucosa* Sarjeant.
Sample 105-37, Core Catcher.

Figure 4 — *Chytroeisphaeridia chytroeides* Sarjeant.
Sample 100-10-2 (125-127 cm).

Figure 6 — *Gonyaulacysta ambigua* (Deflandre).
6a. Dorsal view. Note tabulation and large precingular archeopyle.
6b. Ventral view, showing structure of the sulcus.
Sample 100-4, Core Catcher.

PLATE 4



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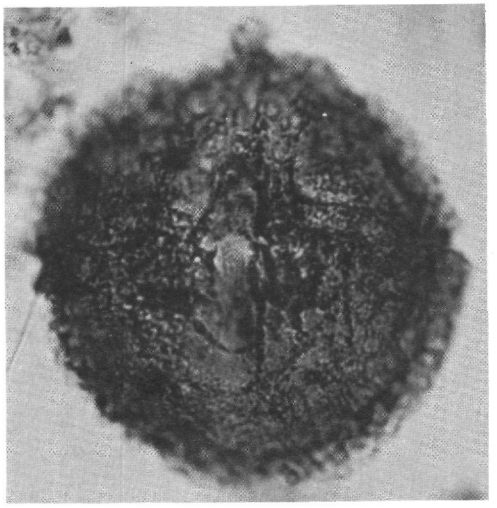

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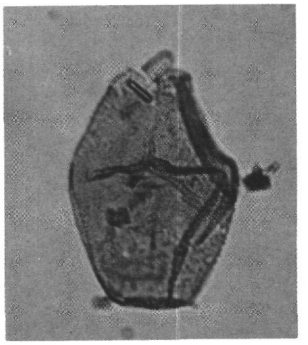

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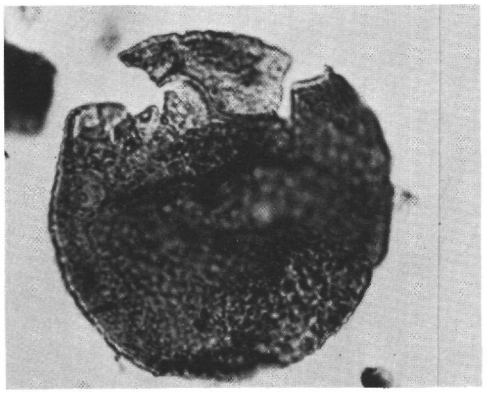

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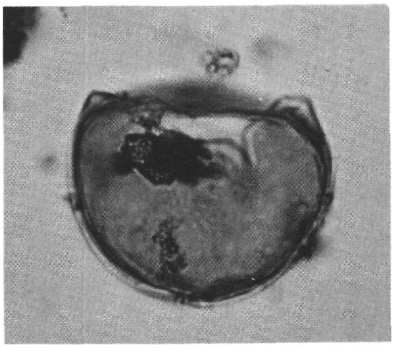

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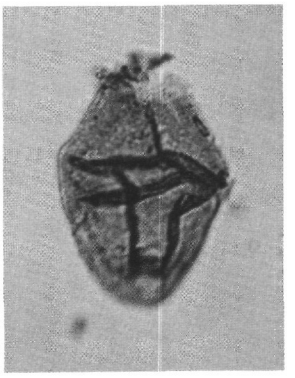

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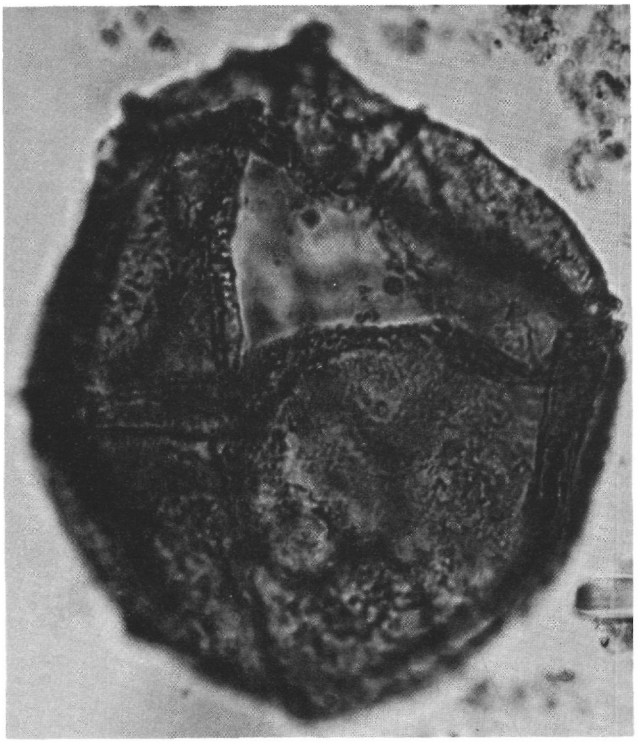

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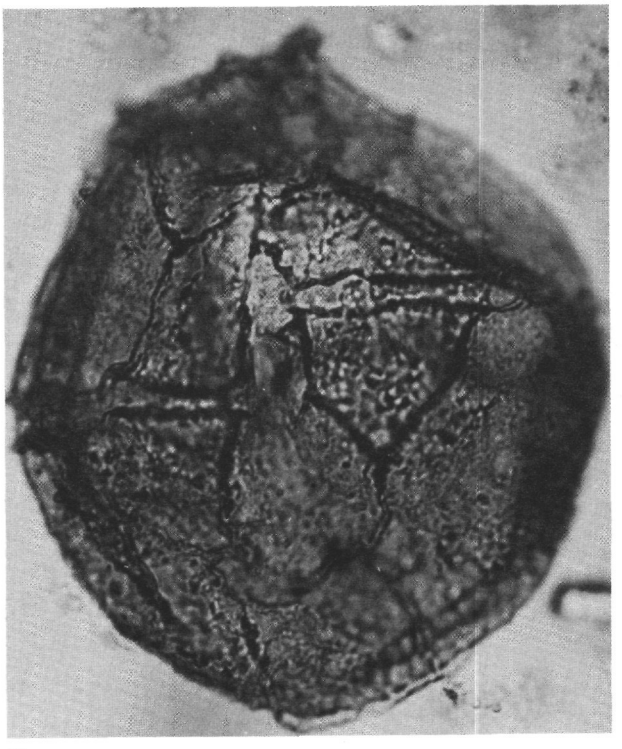


6b

PLATE 5
Mesozoic Dinoflagellates (Magnification approximately X870)

Figures 1, 2 *Polygonifera evitti* new genus, new species.

1. Holotype. Dorso-ventral compression. 1a. Focus on internal capsule and apical archeopyle. 1b. Focus on polygonal outline. Note wide cingulum and sulcal notch.
   Sample 100-10-2 (125-127 cm).
2. Lateral view. Note eccentric disposition of capsule. Cingulum can be seen to be folded over.
   Sample 105-36, Core Catcher.

Figures 3, 4 *Archeotectatum sarjeanti* new genus, new species.

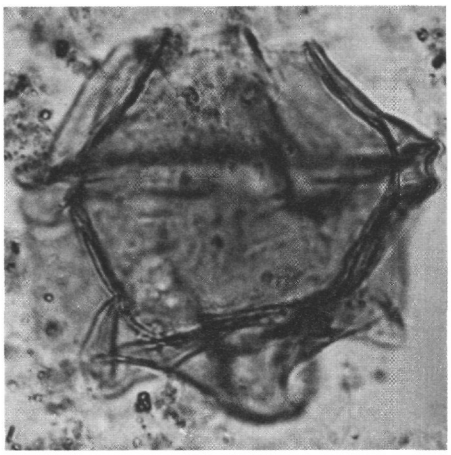
3. Holotype. Lateral view, showing large precingular archeopyle, outline of cyst, and tectum-like wall.
   Sample 105-35, Core Catcher.
4. Dorso-ventral compression. Focus on apical horn, large precingular archeopyle, and structure of wall.
   Sample 105-35, Core Catcher.

Figure 5 *Tenua verrucosa* Sarjeant.
Note apical archeopyle and evidence of six precingular plates below. There is faint indication of a cingulum below these plates.
Sample 105-35, Core Catcher.

Figure 6 *Gonyaulacysta scarburghensis* Sarjeant.
Sample 105-35, Core Catcher.

Figure 7 Dinoflagellate type A.
Note sutural tabulation and occurrence of circular fields formed *within* plate boundaries. Archeopyle is precingular.
Sample 100-8 Core Catcher.

PLATE 5



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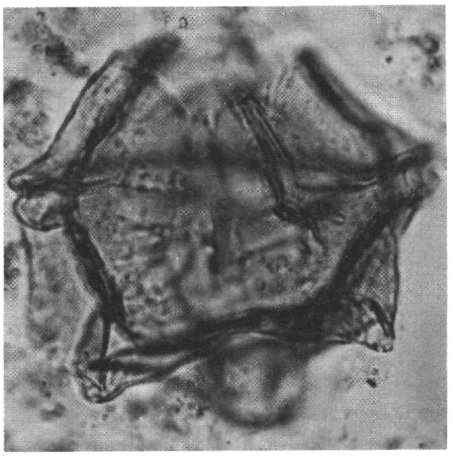

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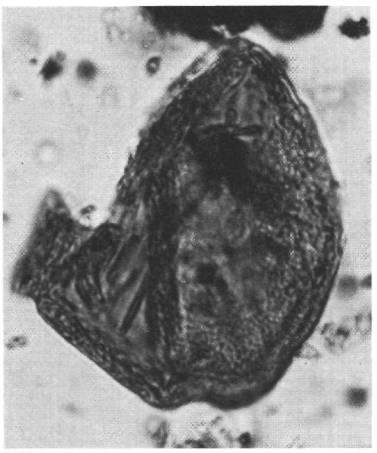

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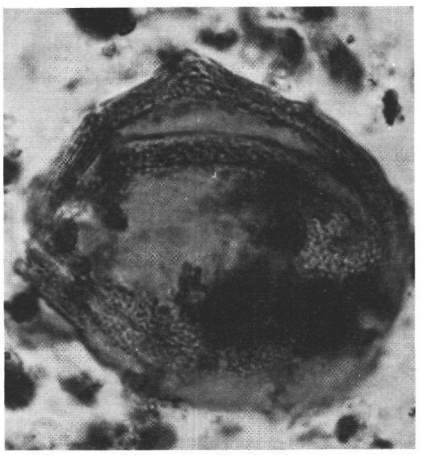

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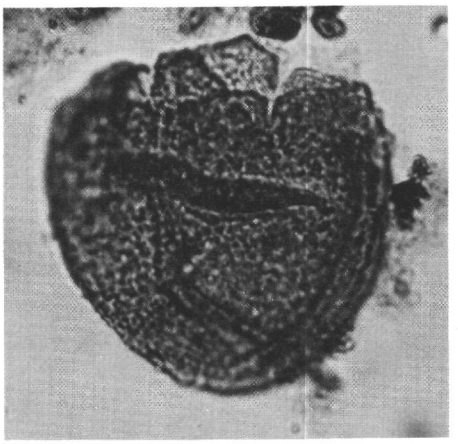

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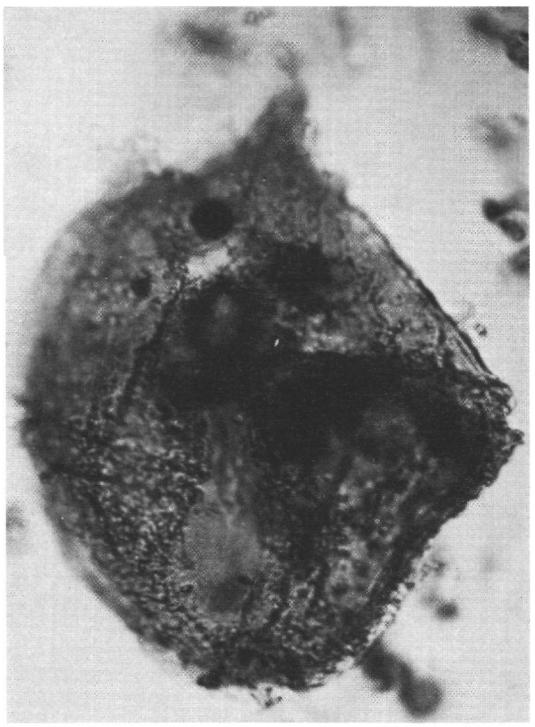

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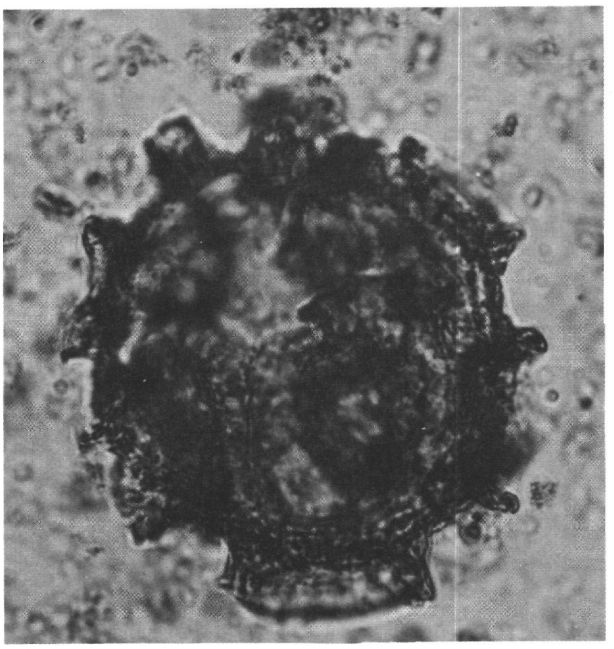


7

PLATE 6
Mesozoic Dinoflagellates (Magnification approximately X870)

Figure 1 *Gonyaulacysta nuciformis* (Deflandre)
Sample 100-9, Core Catcher.

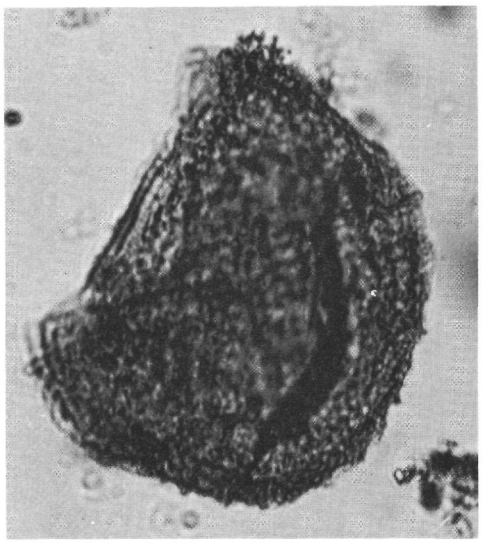
Figure 2 *Pareodinia ceratophora* Sarjeant.
Sample 100-9, Core Catcher.

Figure 3 *Scriniodinium (Endoscrinium) galeritum* (Deflandre)
Sample 100-9-1 (79-81 cm).

Figure 4 aff. *Eisenackia* sp.
4a. Dorsal focus, showing cingulum and fossate tabulation.
4b. Optical cross-section. Focus on apical archeopyle.
4c. Ventral focus.
Sample 100-10-2 (125-127 cm).

Figure 5 *Systematophora* sp. aff. *S. fasciculigera* Klement.
5a. Focus on processes.
5b. Note circular field formed at the base of each cluster of processes.
Sample 105-27, Core Catcher.

PLATE 6



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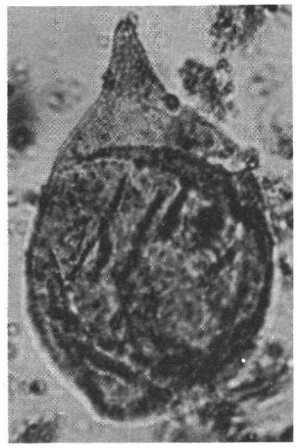

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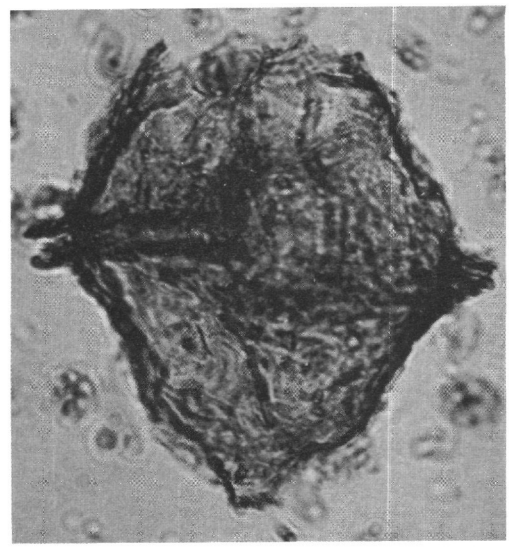

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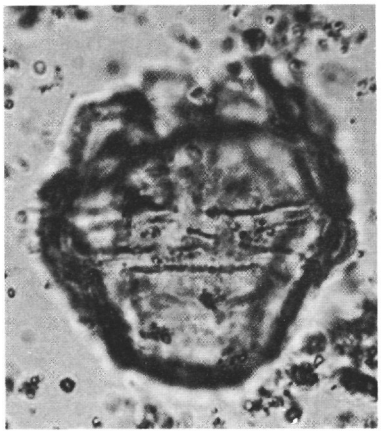

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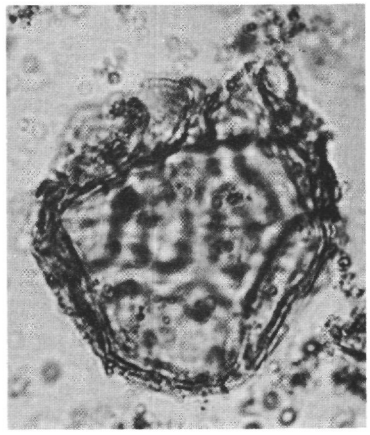

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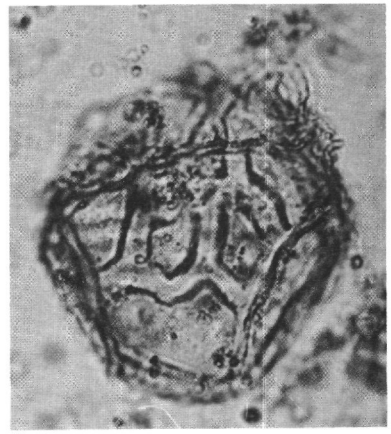

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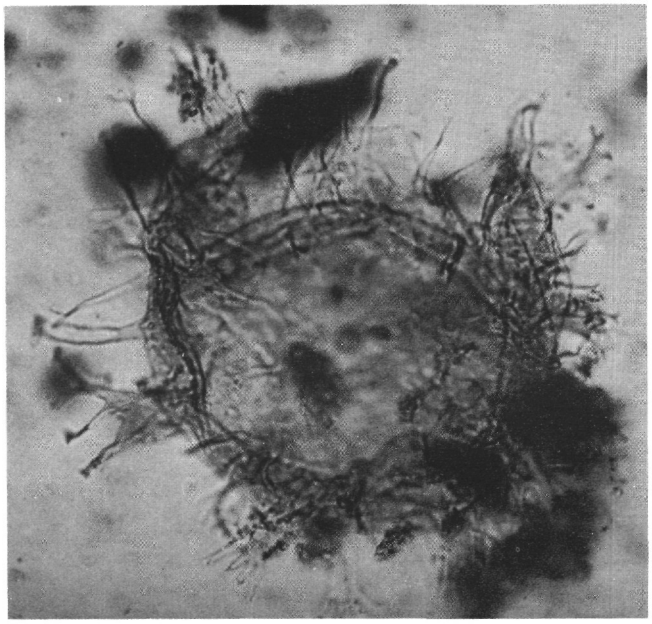

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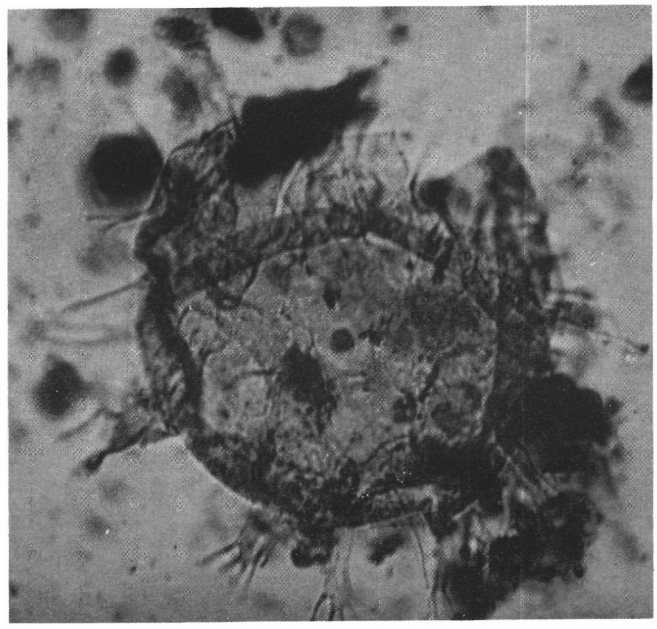


5b

PLATE 7
Mesozoic Dinoflagellates (Magnification approximately X870)

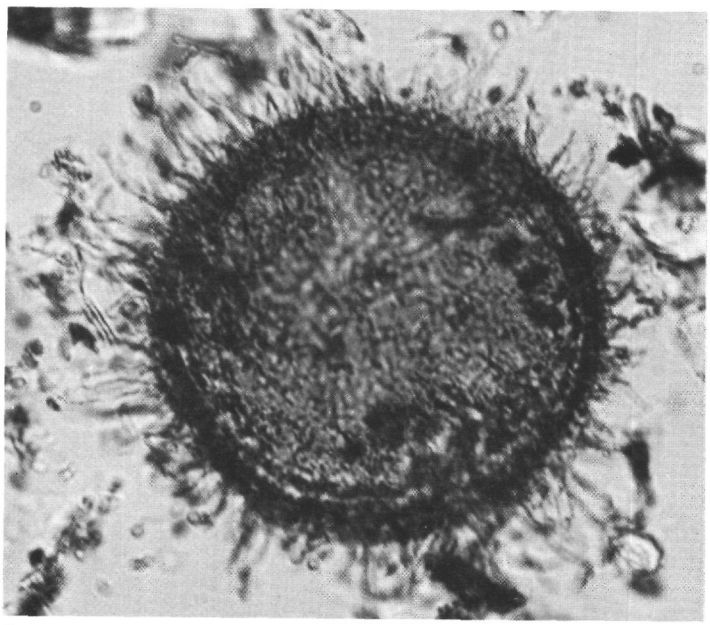
Figure 1 *Cometodinium* sp. A
Sample 105-28, Core Catcher.

Figure 2 *Prolixosphaeridium granulosum* (Deflandre)
Sample 105-26, Core Catcher.

Figure 3 *Systematophora*? sp.
Sample 105-27, Core Catcher.

Figures 4, 5 *Gonyaulacysta* sp. A.
4. Note large precingular archeopyle.
Sample 105-27, Core Catcher.
5a. Ventral view, showing structure of sulcus.
5b. Dorsal view.
Sample 100-1, Core Catcher.

PLATE 7



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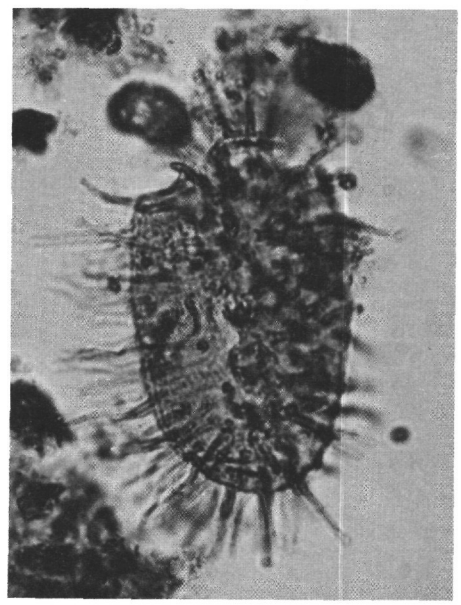

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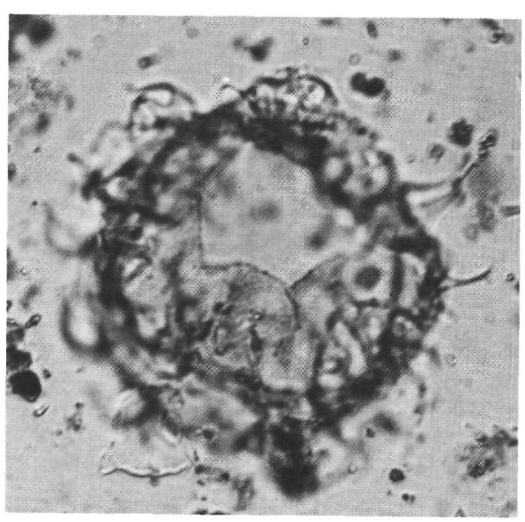

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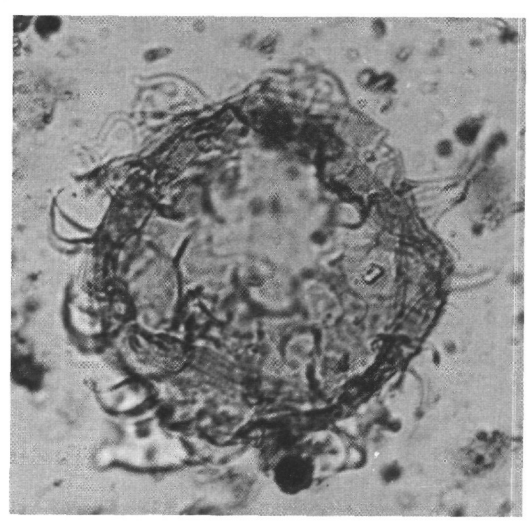

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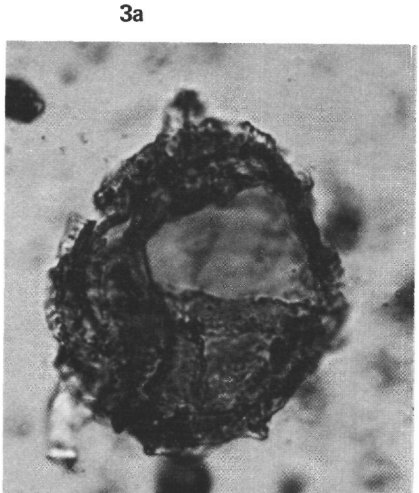

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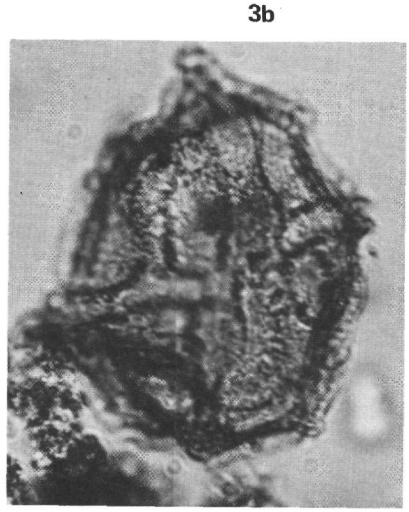

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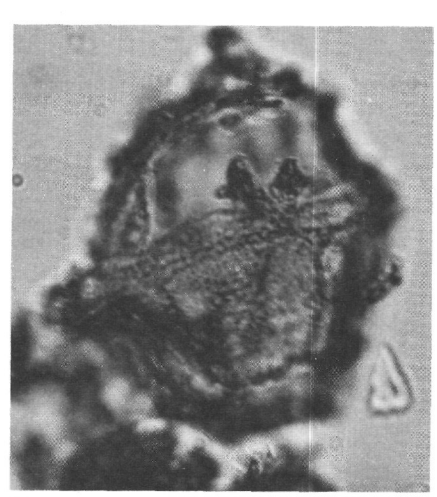


5b

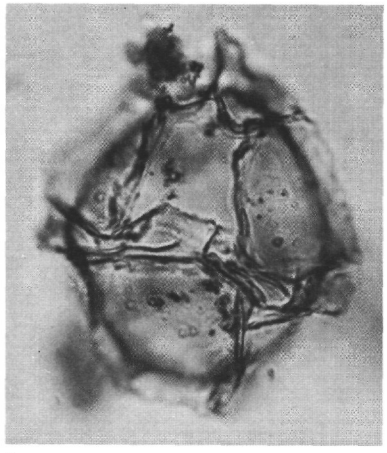
PLATE 8
Mesozoic Dinoflagellates (Magnification approximately X870)

Figure 1 *Gonyaulacysta* sp. B
1a. Dorsal view, showing precingular archeopyle. Note that specimen appears uncompressed.
1b. Ventral view. Note sigmoidal sulcus.
Sample 101A-9-1 (132-135 cm).

Figure 2 *Systematophora fasciculigera* Klement.
Sample 105-27, Core Catcher.

Figures 3, 4 *Scriniodinium (Endoscrinium) dictyotum* Cookson and Eisenack
These specimens are of somewhat more angular outline, but agree in all other respects to the species. Compare this species with *S. campanula.*
3. Sample 105-24-1 (40-42 cm).
4. Sample 105-22-1 (136-139 cm).

PLATE 8



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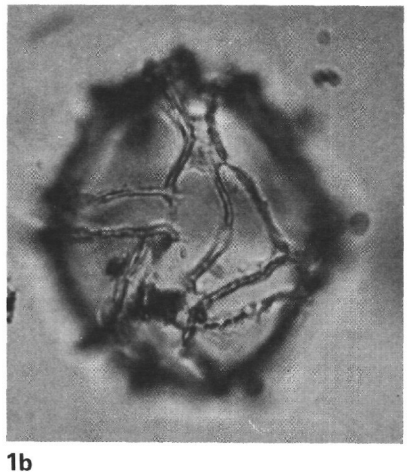

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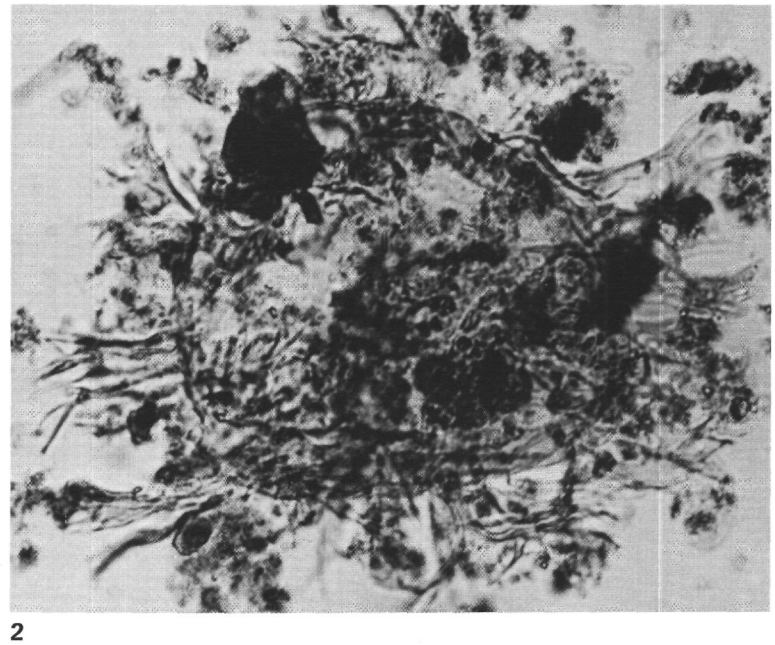

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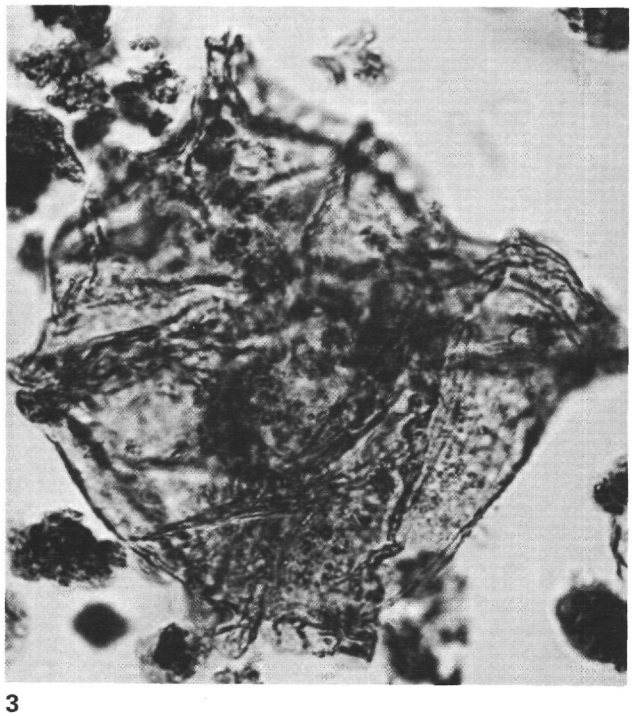

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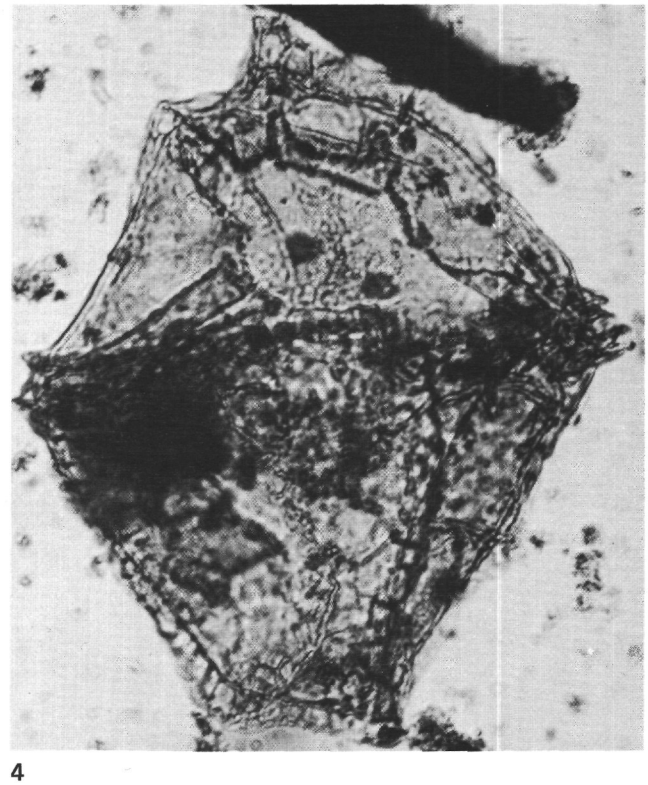


4

PLATE 9
Mesozoic Dinoflagellates (Magnification approximately X870)

Figures 1, 3 *Diacanthum hollisteri* new genus, new species.

1. Holotype. Dorso-ventral compression. Note two-plate archeopyle and tabulation.
   Sample 100-1, Core Catcher.

3. Oblique lateral compression. Archeopyle opens to upper left.
   Sample 105-24, Core Catcher.

Figure 2 *Gonyaulacysta* sp. C.
Sample 105-22-2 (147-149 cm).

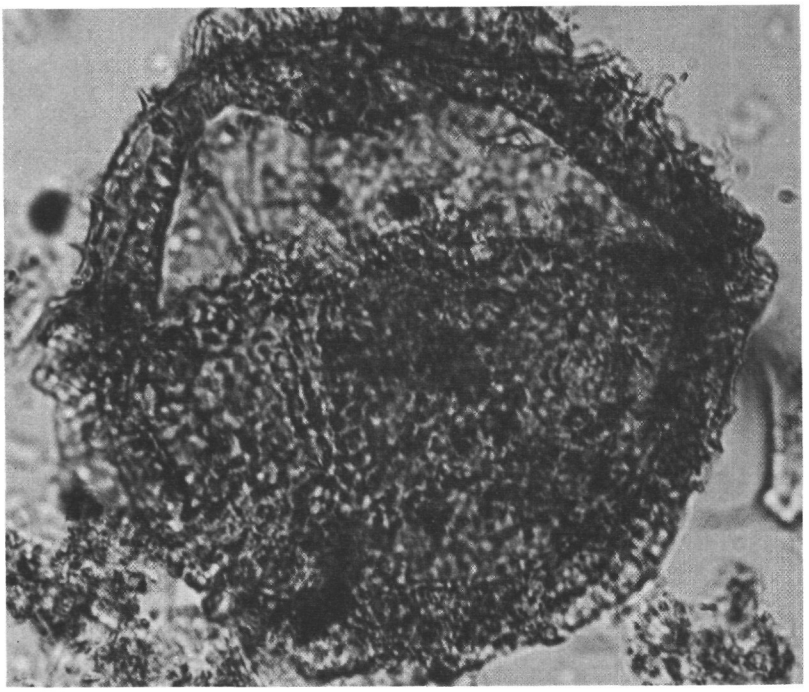
Figure 4 *Hystrichosphaeridium*? sp. A.

4a. Focus on six-sided apical archeopyle.

4b. Focus on parallel-sided tubular processes, which are open at both proximal and distal ends. Note that all processes are of similar form and length.

Sample 105-26, Core Catcher.

PLATE 9



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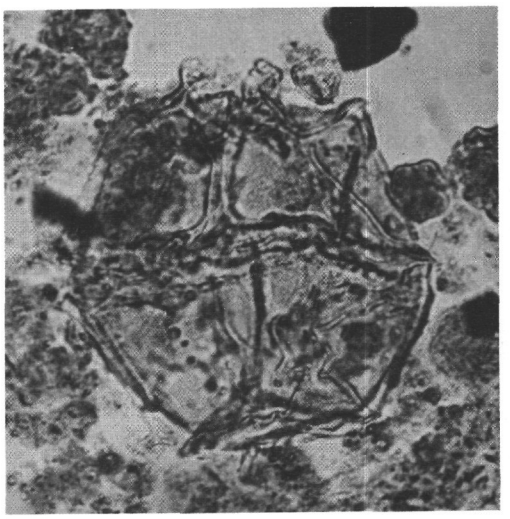

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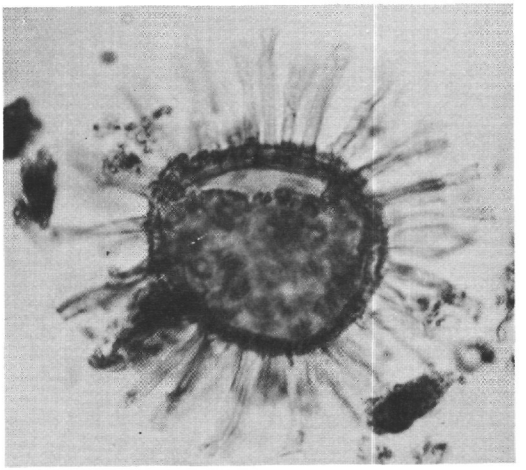

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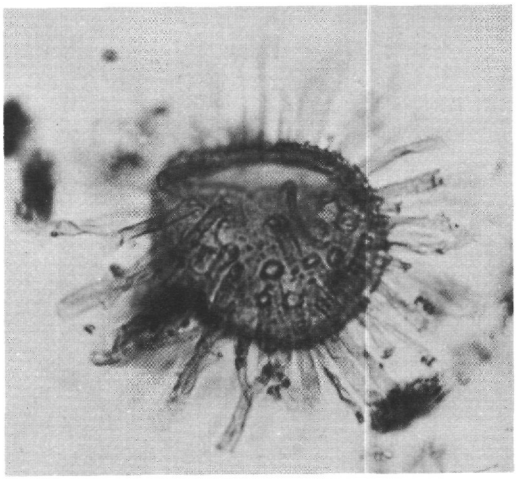


4b

PLATE 10
Mesozoic Dinoflagellates (Magnification approximately X870)

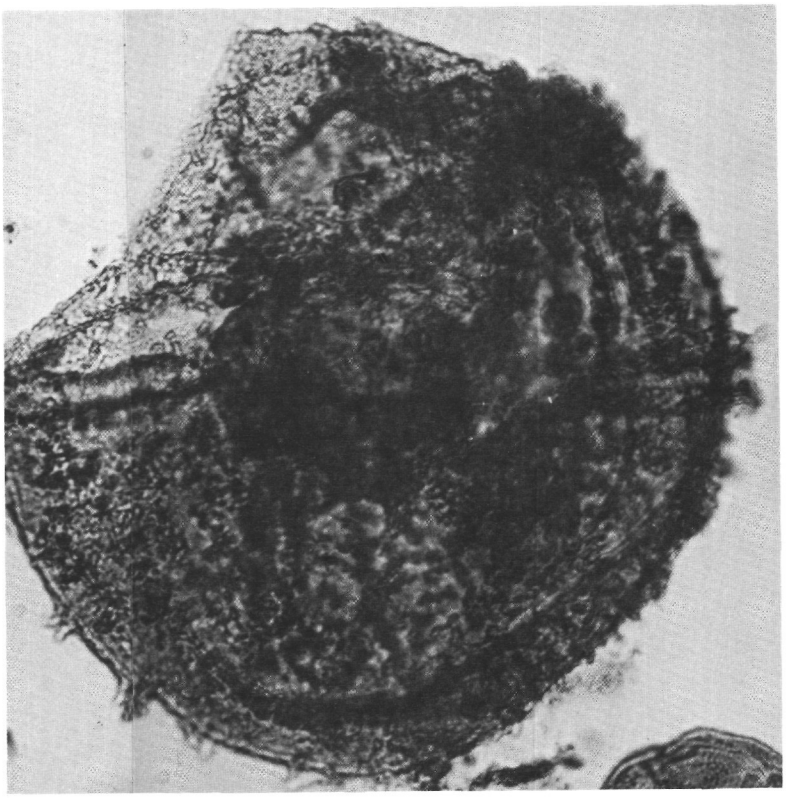
Figure 1 *Diacanthum hollisteri* new genus, new species.
Good lateral compression. Note broad-based tapering spines arising from the periphragm.
Sample 105-24, Core Catcher.

Figures 2, 3 *Biorbifera johnewingi* new genus, new species.
2. Specimen showing partial detachment of the operculum to form the archeopyle. Note that the archeopyle lies adjacent the cingulum in this genus.
Sample 105-24-1 (40-42 cm).
3. Holotype.
Sample 105-24-1 (40-42 cm).

Figure 4 *Cometodinium* sp. A.
Sample 99A-11, Core Catcher.

Figure 5 *Hexagonifera cylindrica* (Habib) new combination.
Note occurrence of six-sided apical archeopyle.
Sample 105-23-2 (94-96 cm).

PLATE 10



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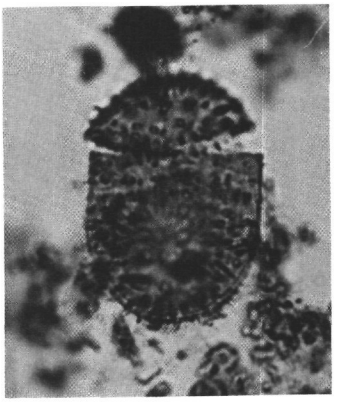

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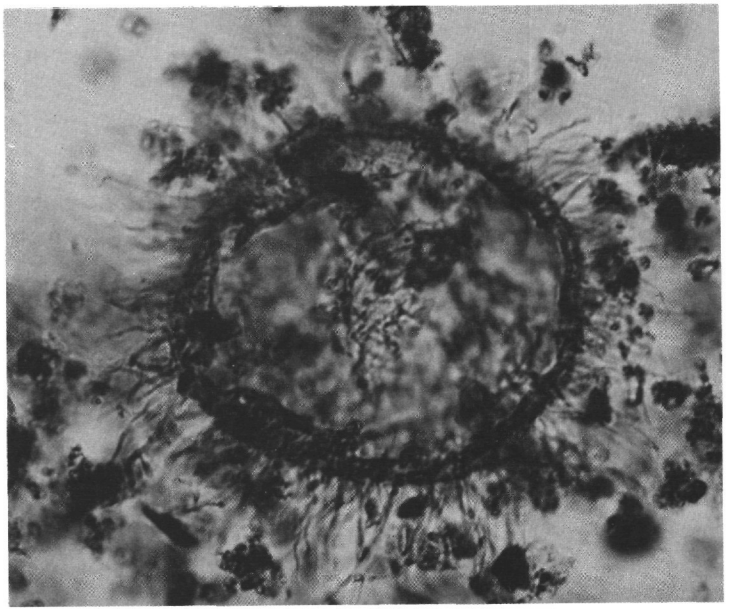

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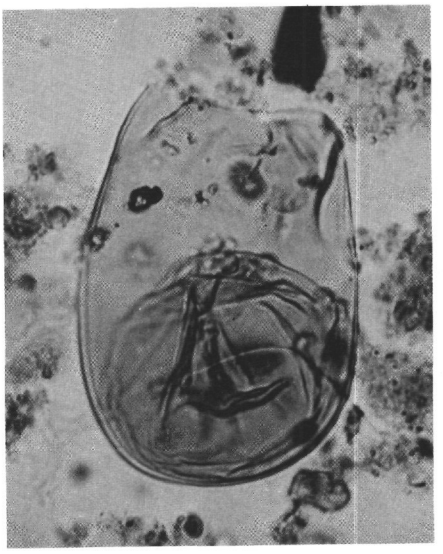

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PLATE 11
Mesozoic Dinoflagellates (Magnification approximately X870)

Figure 1 *Deflandrea acuminata* Cookson and Eisenack.
Note acuminate form of internal capsule. This was not observed in all specimens.
Sample 105-9-5 (9-11 cm).

Figure 2 *Ovoidinium scabrosum* (Cookson and Hughes).
Sample 101A-5-1 (95-97 cm).

Figure 3 *Dictyopyxis circulata* Clarke and Verdier.
Note apical archeopyle, cingulum, and several plate boundaries.
Sample 105-17-2 (120-122 cm).

Figure 4 *Epiplosphaera* sp.
Note vaguely defined circular areas.
Sample 105-27, Core Catcher.

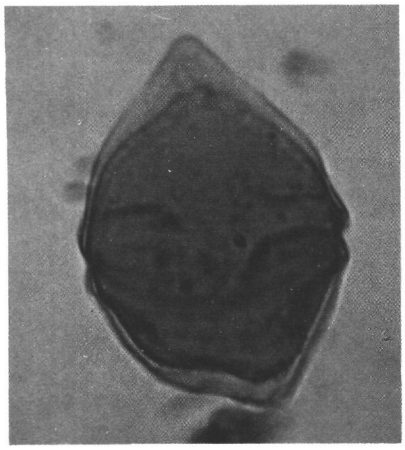
Figure 5 *Prolixosphaeridium mixtispinosum* (Klement).
Sample 105-27, Core Catcher.

Figure 6 *Occisucysta* sp.
Sample 105-27, Core Catcher.

Figure 7 *Systematophora fasciculigera* Klement.
Sample 105-28, Core Catcher.

Figure 8 *Heslertonia pellucida* Gitmez.
A thin, transparent specimen.
Sample 105-29-3 (34-36 cm).

PLATE 11



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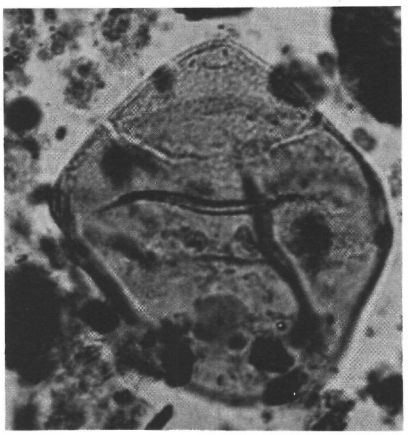

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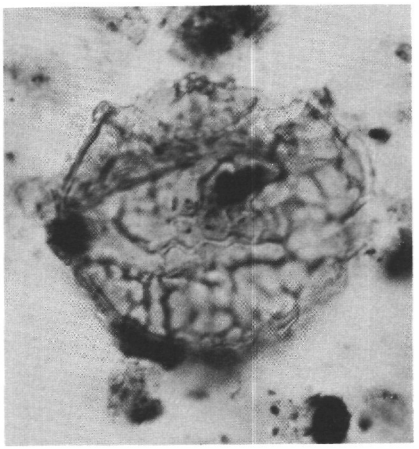

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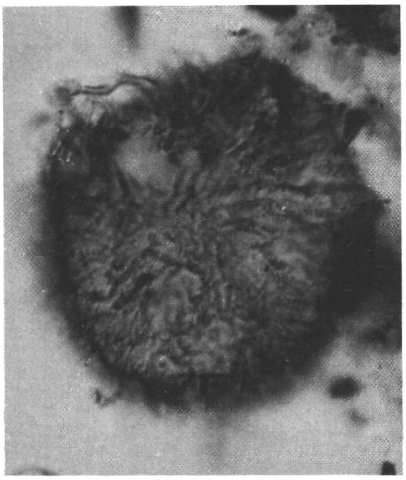

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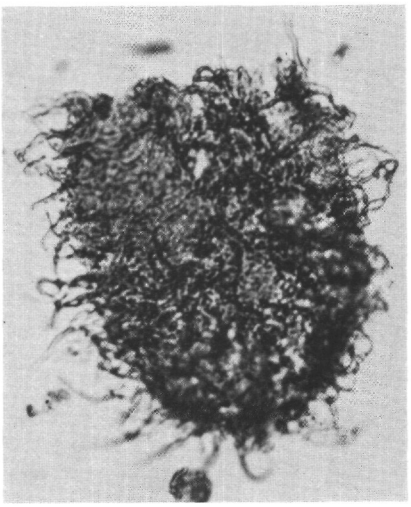

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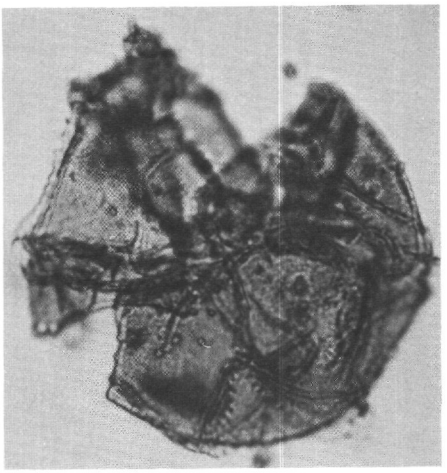

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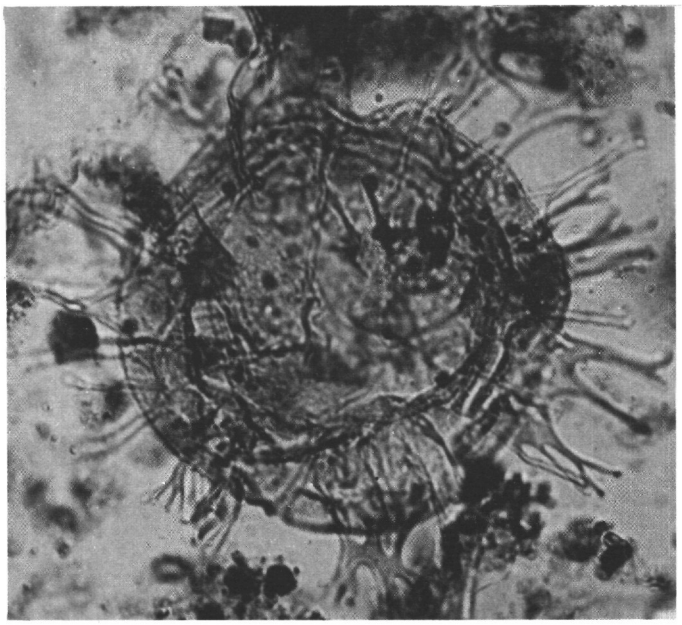

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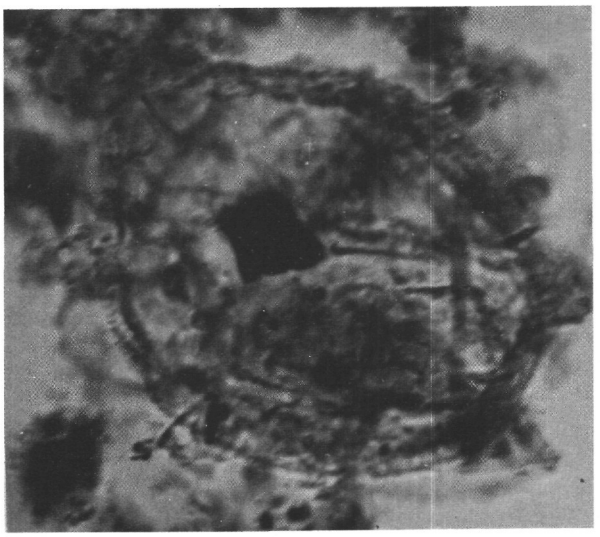

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PLATE 12
Mesozoic Dinoflagellates (Magnification approximately X870)

Figures 1, 2

Dingodinium cerviculum Cookson and Eisenack.

1. A well-compressed specimen, showing almost entire cyst in focus. Note rupturing at base of apical horn. Intercalary archeopyle faces to upper right.
   Sample 105-18-2 (6-9 cm).
2. A relatively uncompressed cyst recovered from calcareous nannoplankton ooze. 2a. Focus on internal capsule and apical horn. Note alignment of granulation pattern. 2b. Focus on well-developed intercalary archeopyle.
   Sample 99A-3, Core Catcher.

Figures 3, 4

Microdinium deflandrei Millioud variety A.

3a. Focus on apical archeopyle. 3b. Focus on ventral (?) tabulation.
Sample 99A-10, Core Catcher.

4. Note excellent preservation of relatively uncompressed specimen. 4a. Ventral (?) view. Note rectangular outline of hypotract. 4b. Optical cross-section. Note structure of apical archeopyle, and nature of crenulated sutural crests. 4c. Dorsal (?) view. 4d. Same specimen rotated in glycerine mounting medium to illustrate nature of epitract and archeopyle.
   Sample 99A-10, Core Catcher.

Figures 5, 6, 7, 8

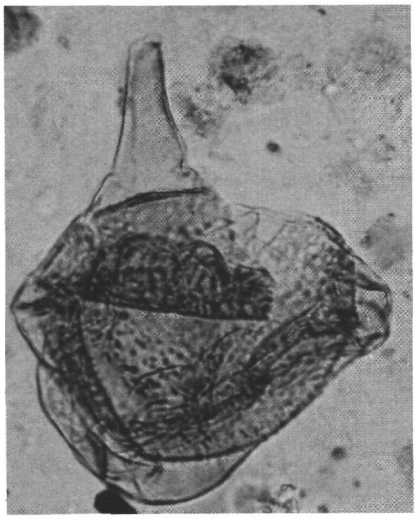
Microdinium deflandrei Millioud.
Compare with *M. deflandrei* variety A.

5. A strongly alveolate specimen.
   Sample 105-17, Core Catcher.
6. Sample 105-17, Core Catcher.
7. Specimen with open apical archeopyle.
   Sample 105-24, Core Catcher.
8. Sample 105-20-1 (63-65 cm).

Figure 9

Wallodinium krutzschi (Alberti) new combination.
A specimen which resembles *W. glaessneri* (Cookson and Eisenack) new combination.
Sample 105-20-1 (63-65 cm).

PLATE 12



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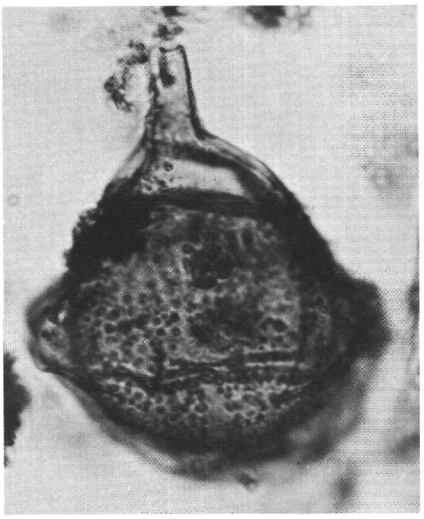

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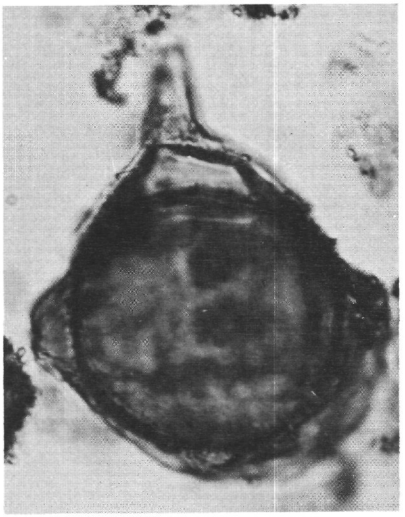

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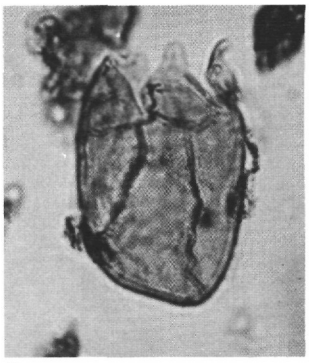

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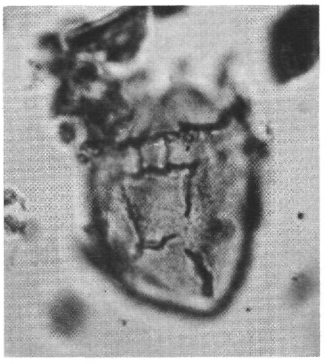

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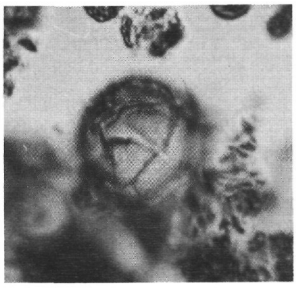

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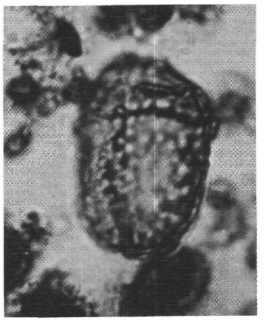

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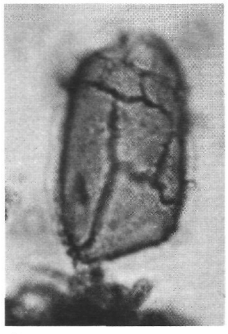

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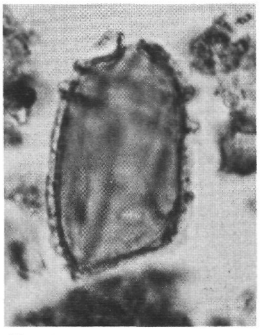

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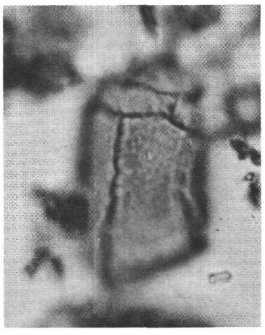

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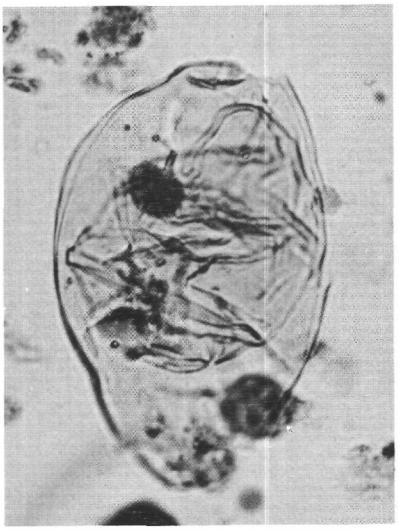

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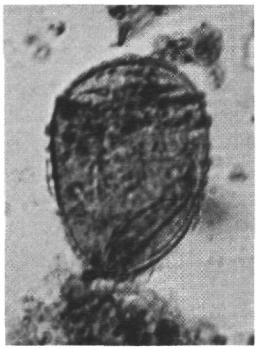

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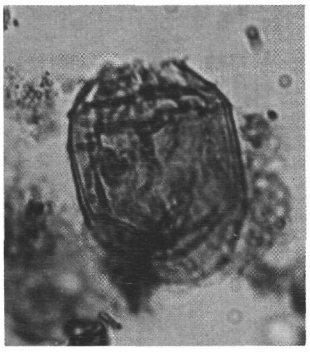

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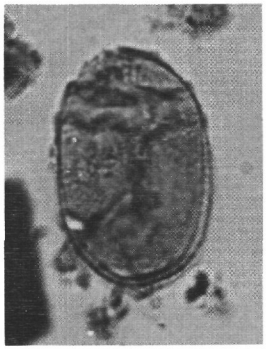

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PLATE 13
Mesozoic Dinoflagellates (Magnification approximately X870)

Figures 1, 3 *Meiourogonyaulax stoveri* Millioud
1a. Focus on cingulum. 1b. Focus on apical archeopyle. Note nature of crests along plate boundaries. Sample 105-18, Core Catcher.
3. A slightly larger specimen. Sample 101A-8, Core Catcher.

Figure 2 *Wallodinium krutzschi* (Alberti) new combination. Sample 105-20-1 (63-65 cm).

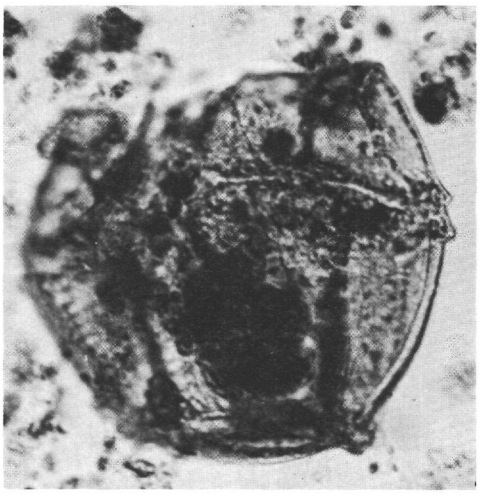
Figure 4 *Hexagonifera chlamydata* Cookson and Eisenack Sample 105-13-3 (100-102 cm).

Figure 5 *Rhombodella*? sp. A. Sample 105-16-2 (70-73 cm).

Figure 6 *Deflandrea pirnaensis* Alberti Sample 101A-7, Core Catcher.

Figure 7 *Carpodinium granulatum* Cookson and Eisenack Sample 101A-6-1 (132-134 cm).

PLATE 13



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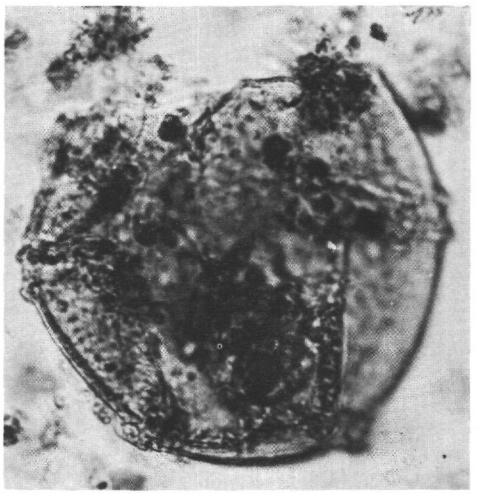

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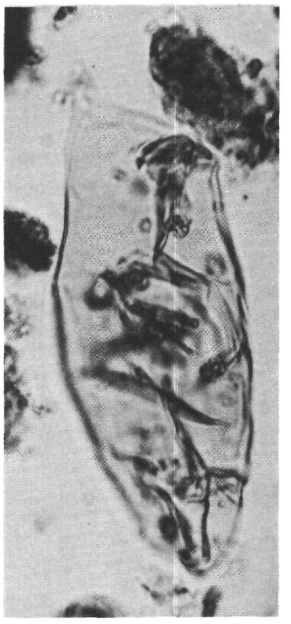

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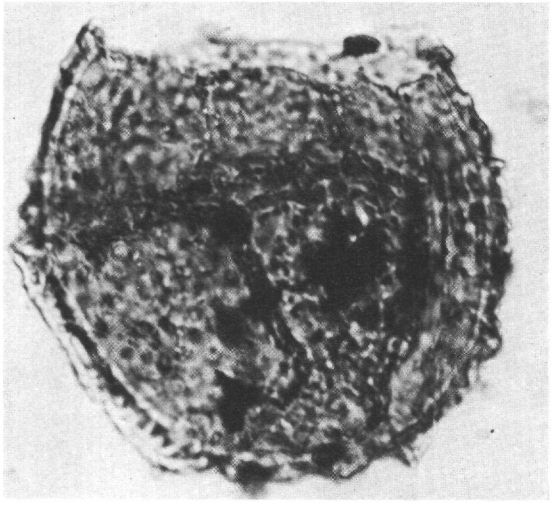

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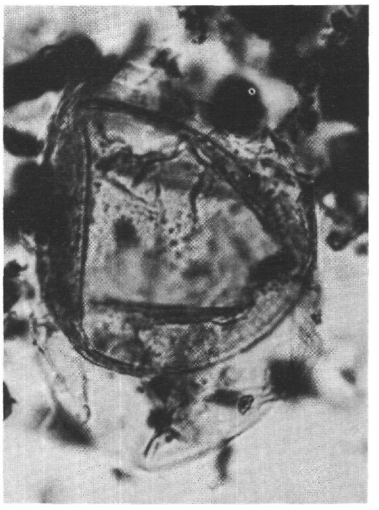

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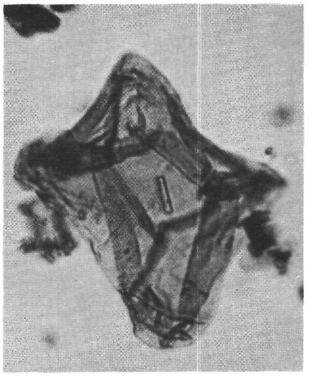

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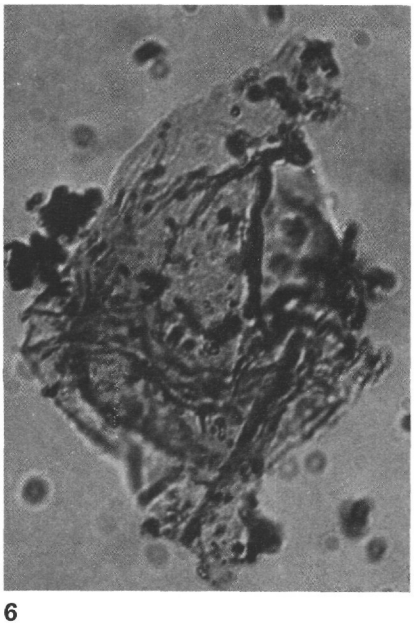

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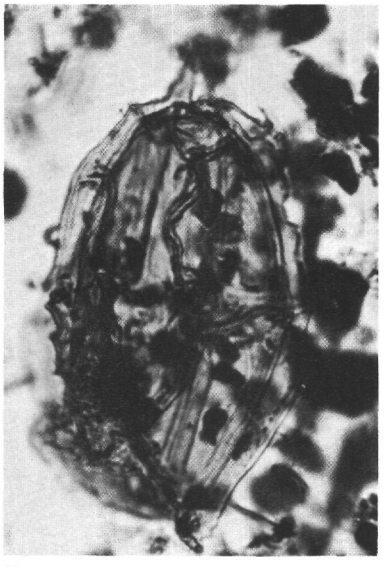


7a

7b

PLATE 14
(Mesozoic Dinoflagellates (Magnification approximately X870)

Figure 1 *Heliodinium voigti* Alberti
Sample 105-15-4 (133-135 cm).

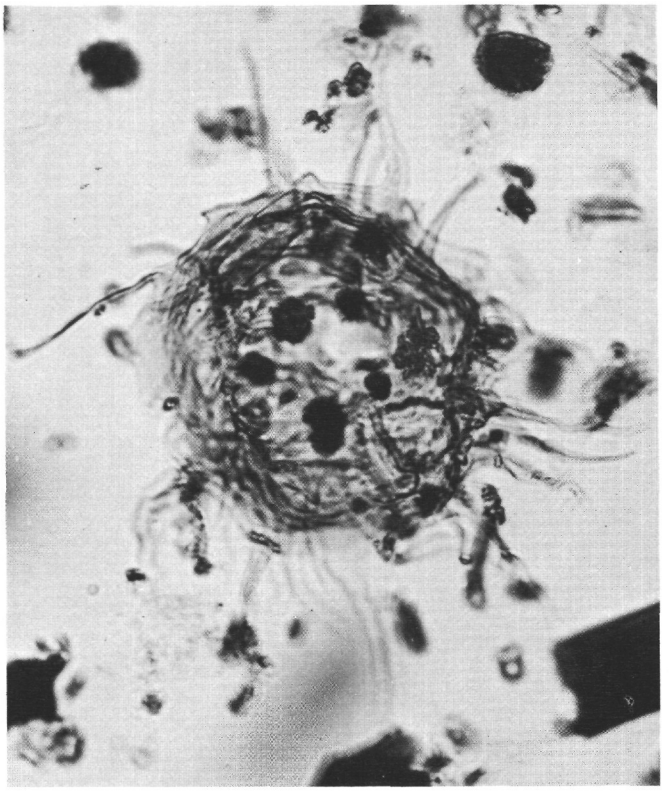
Figure 2 *Cyclonephelium distinctum* Deflandre and Cookson
Operculum retained on cyst, although archeopyle sutures are evident.
Sample 101A-6-1 (65-67 cm).

Figure 3 *Xiphophoridium alatum* (Cookson and Eisenack)
Sample 105-16-2 (110-112 cm).

Figure 4. *Oligosphaeridium complex* (White)
Sample 101A-6-1 (132-134 cm).

Figure 5 *Apteodinium granulatum* Eisenack
Sample 101A-6-1 (132-134 cm).

PLATE 14



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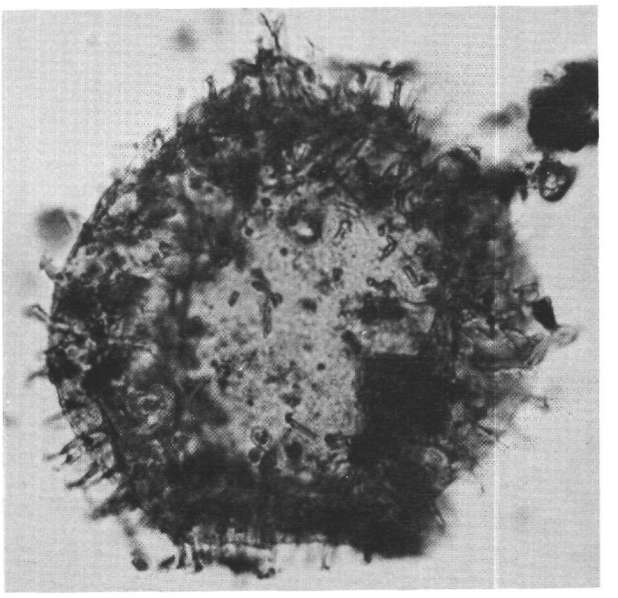

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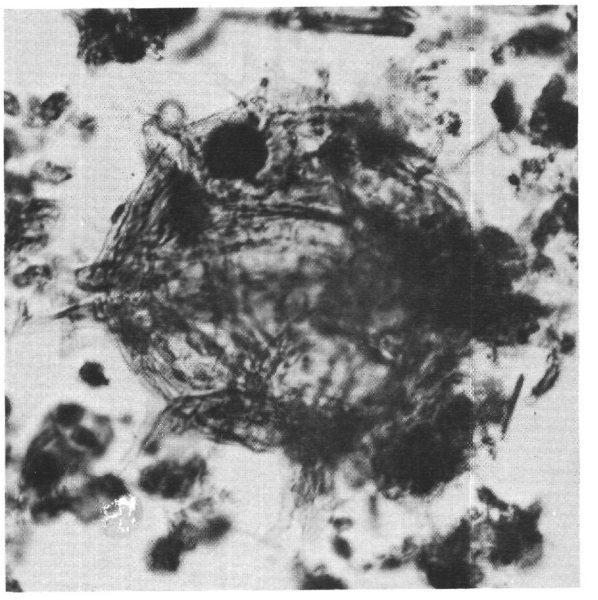

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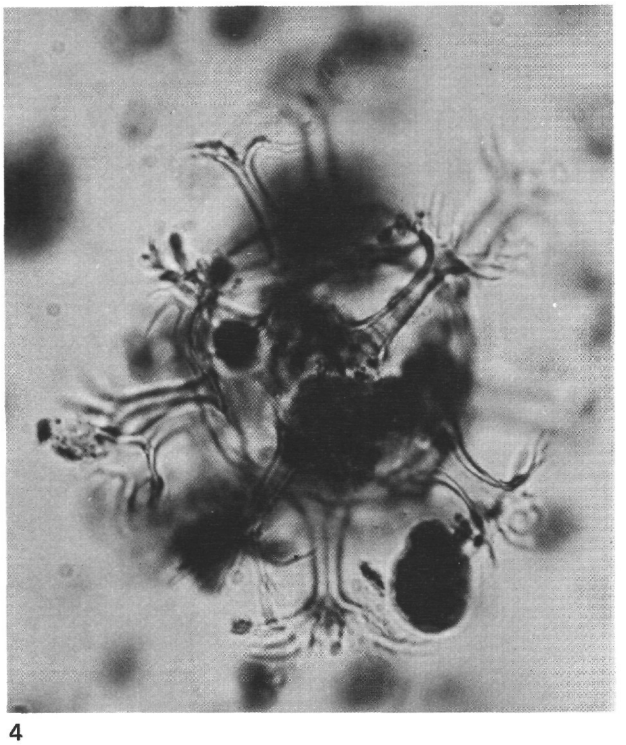

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PLATE 15
Mesozoic Dinoflagellates (Magnification approximately X870)

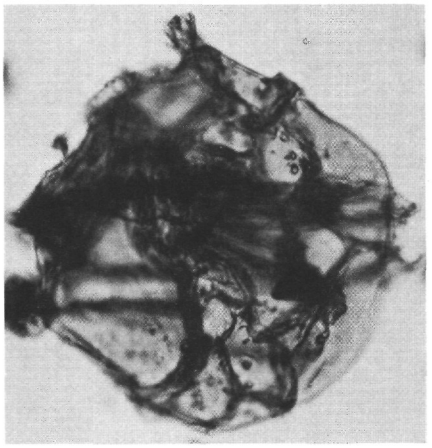
Figure 1 *Gonyaulacysta heliocoidea* (Eisenack and Cookson)
Sample 105-16-2 (70-73 cm).

Figure 2 *Gonyaulacysta cassidata* (Eisenack and Cookson)
Sample 105-16-2 (70-73 cm).

Figure 3 *Hystrichosphaeropsis ovum* Deflandre
Note furcate processes arising from the cingulum.
Sample 101A-6-1 (132-134 cm).

Figure 4, 5 *Cribroperidinium muderongensis* Cookson and Eisenack
4. Sample 105-16-2 (110-112 cm).
5. Sample 101A-7-1 (130-133 cm).

PLATE 15



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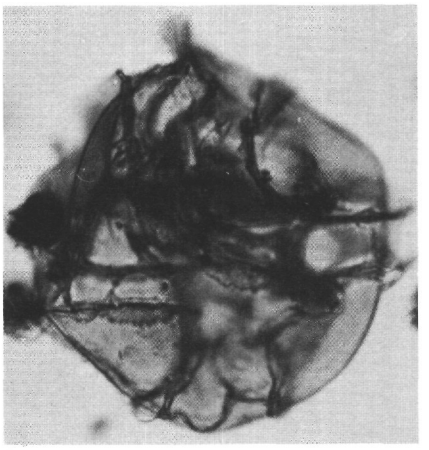
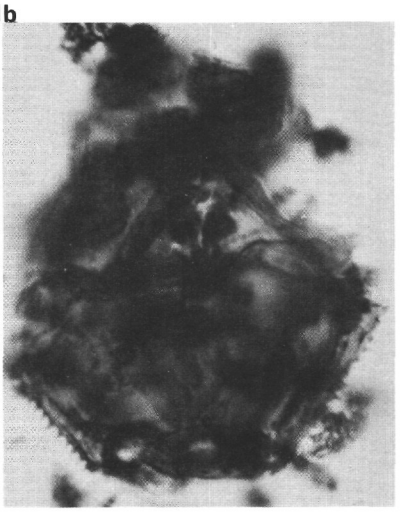


1b

2a



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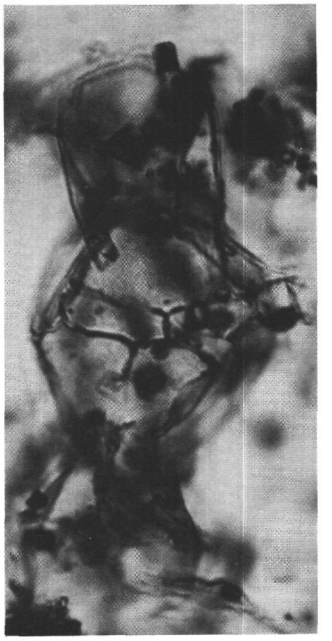

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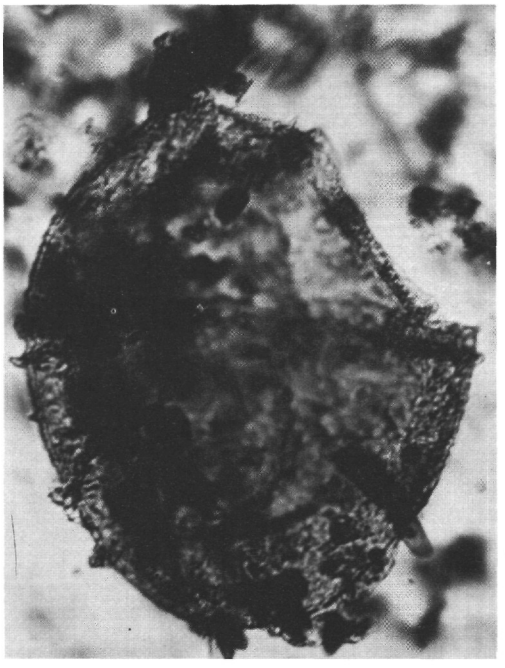

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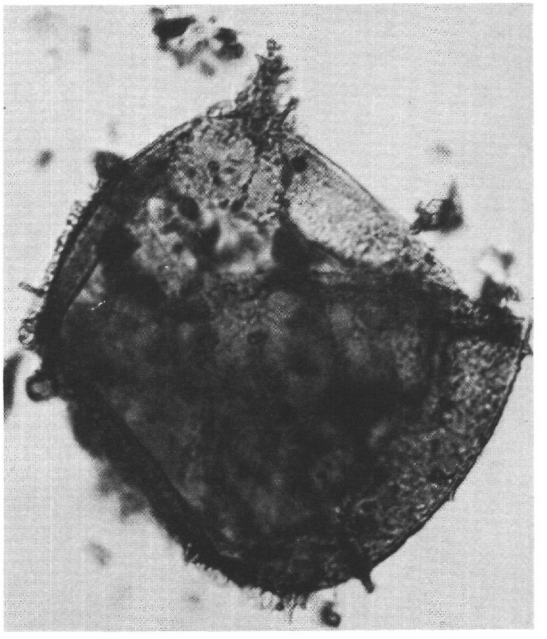

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PLATE 16
Mesozoic Dinoflagellates (Magnification approximately X870)

Figure 1 — *Scriniodinium (Endoscrinium) campanula* Gocht.
Sample 101A-4, Core Catcher.

Figure 2 — *Pyxidiella* sp. A
Sample 101A-6-1 (116-119 cm).

Figures 3, 4, 6 — *Canningia* sp. A.

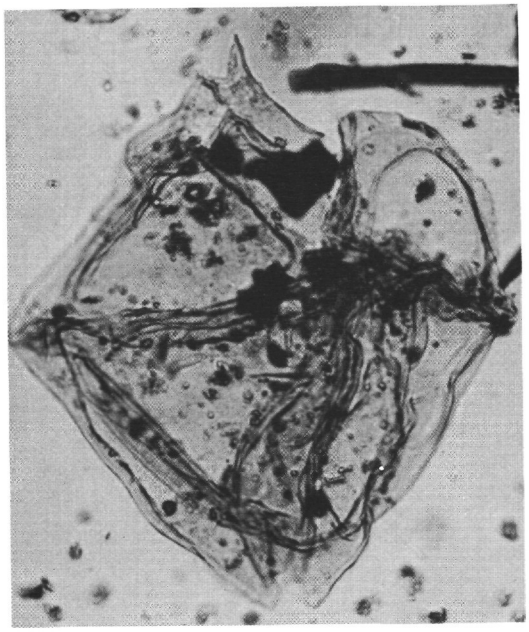
3. Note thick granulated wall and short apical horn arising from partially dehisced operculum.
   Sample 105-15, Core Catcher.
4. A more circular specimen which still shows flattening in the antapical area. An apical horn is present on this specimen as well, but is out of focus.
   Sample 105-15, Core Catcher.
6. A specimen showing the nature of the apical archeopyle.
   Sample 105-14-1 (135-137 cm).

Figure 5 — *Cyclonephelium vannophorum* Davey.
Sample 101A-4-1 (20-22 cm).

Figure 7 — *Hystrichosphaeridium arundum* Eisenack and Cookson.
Sample 105-13-6 (134-136 cm).

Figure 8 — *Litosphaeridium siphoniphorum* (Cookson and Eisenack).
Sample 101A-4-1 (136-139 cm).

PLATE 16



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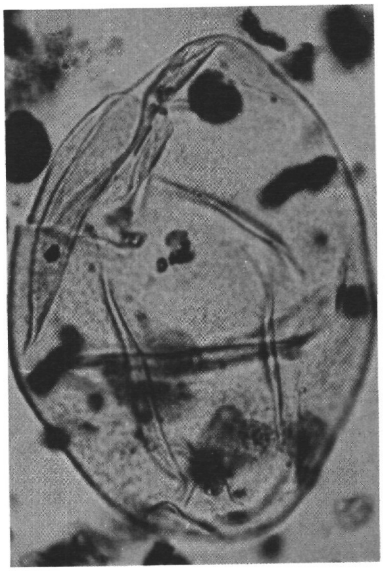

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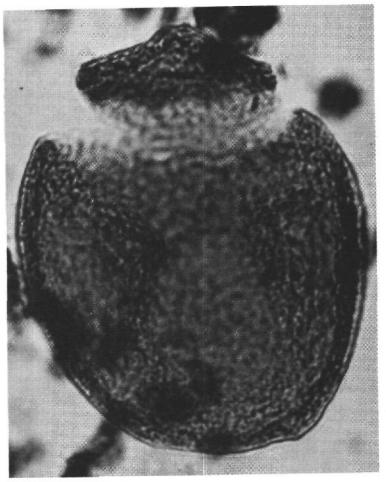

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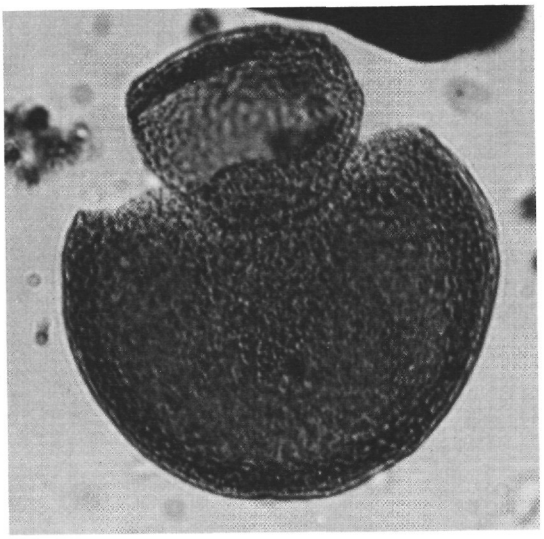

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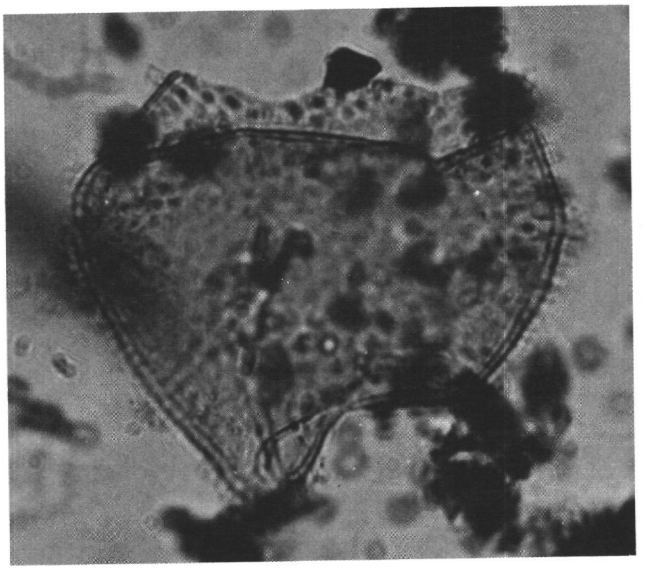

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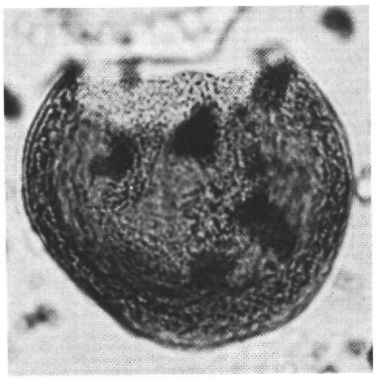

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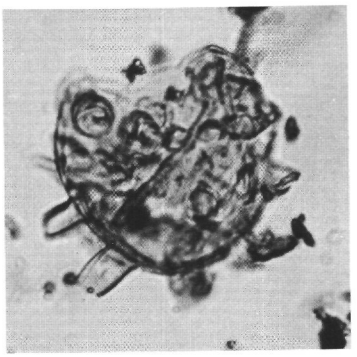

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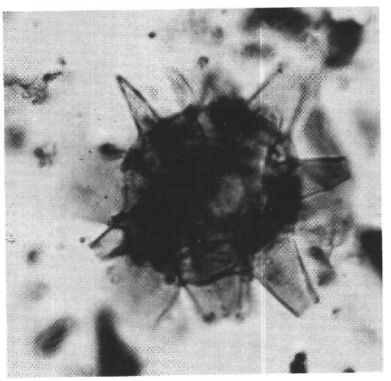

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PLATE 17
Mesozoic Dinoflagellates (Magnification approximately ×870)

Figures 1, 3 *Odontochitina operculata* (Wetzel).
1. Operculum. Note striated performations. Striate ridges were not observed.
Sample 105-16-2 (110-112 cm).
3. Cyst showing nature of the archeopyle.
Sample 105-16-2 (110-112 cm).

Figure 2 *Gonyaulacysta exilicristata* Davey.
Sample 101A-4, Core Catcher.

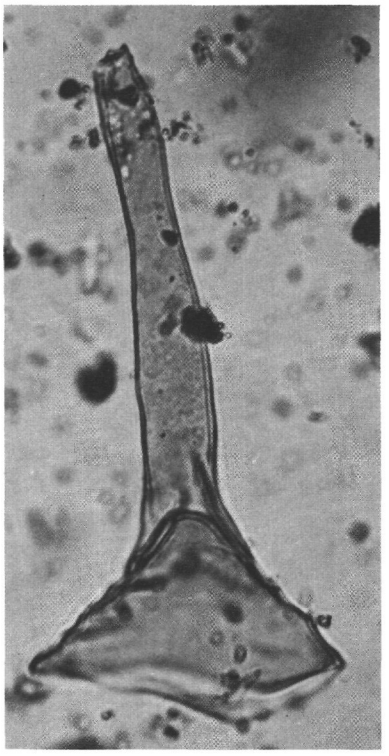
Figure 4 *Palaeohystrichophora infusorioides* Deflandre.
Sample 105-9-5 (9-11 cm).

Figure 5 *Dinogymnium* sp. A.
Sample 101A-4-1 (136-139 cm).

Figure 6 *Hystrichosphaeridium* sp. B.
Sample 105-16-2 (70-73 cm).

Figure 7 *Epelidosphaeridia spinosa* Davey.
Sample 105-10, Core Catcher.

PLATE 17



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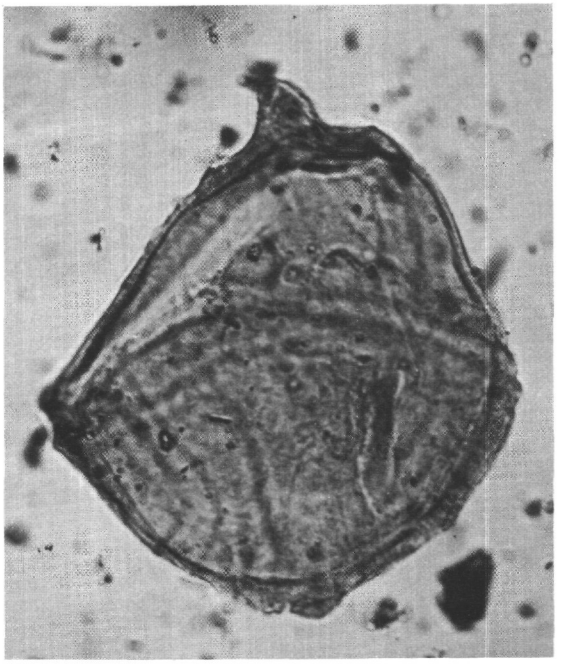

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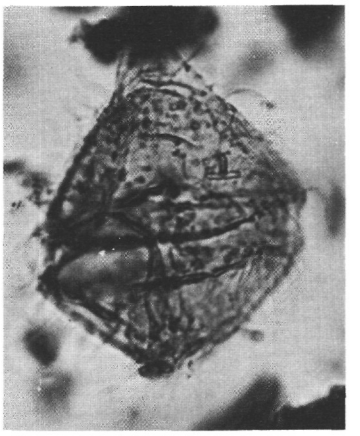

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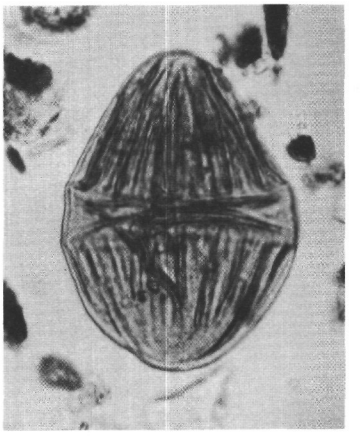

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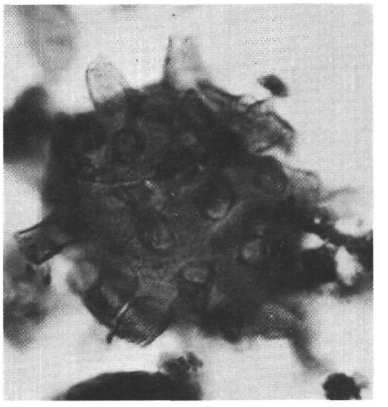

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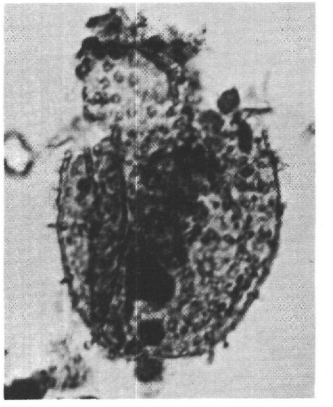

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PLATE 18
Cenozoic Dinoflagellates (Magnification approximately X870)

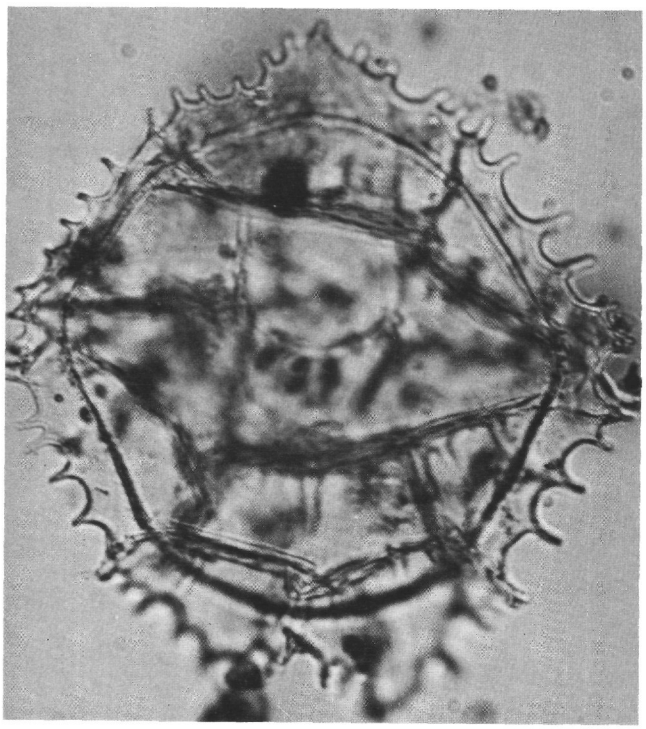
Figure 1 *Wetzeliella echinosuturata* Wilson
1a. Focus on well-serrated outline. 1b. Intercalary archeopyle.
Sample 108-1, Core Catcher.

Figure 2 *Hystrichokolpoma cinctum* Klumpp.
Sample 108-1, Core Catcher.

Figure 3 *Tectatodinium pellitum* Wall.
Sample 106B-2, Core Catcher.

Figure 4 *Leptodinium* sp. aff. *L. victorianum* Cookson and Eisenack.
A relatively large cyst with high granulated sutural crests.
Sample 108-2, Core Catcher.

PLATE 18



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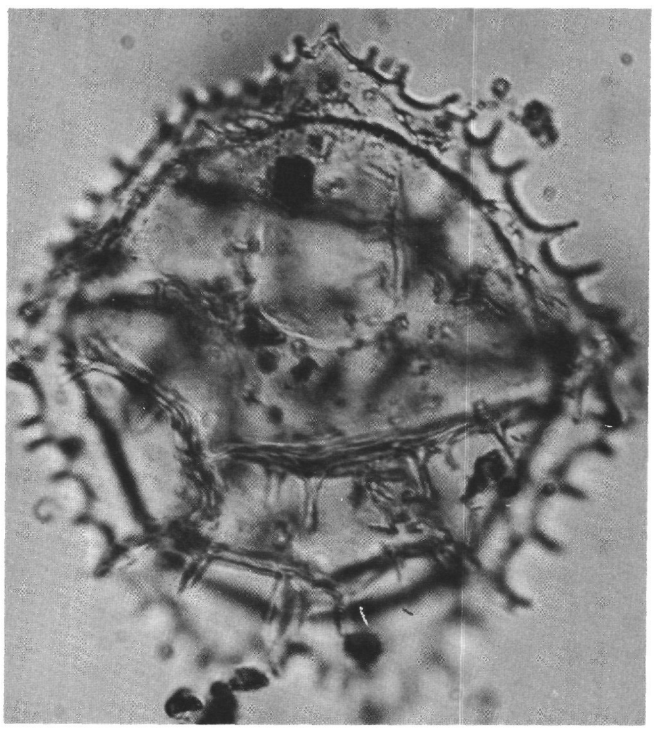

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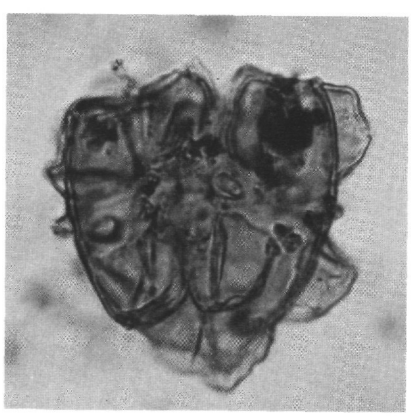

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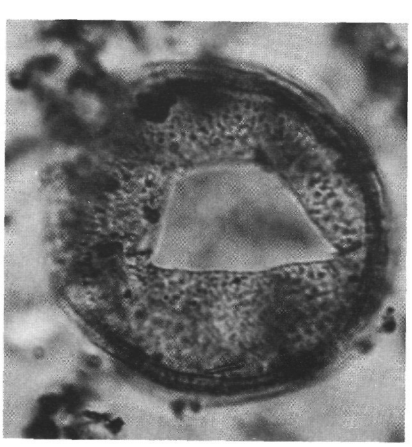

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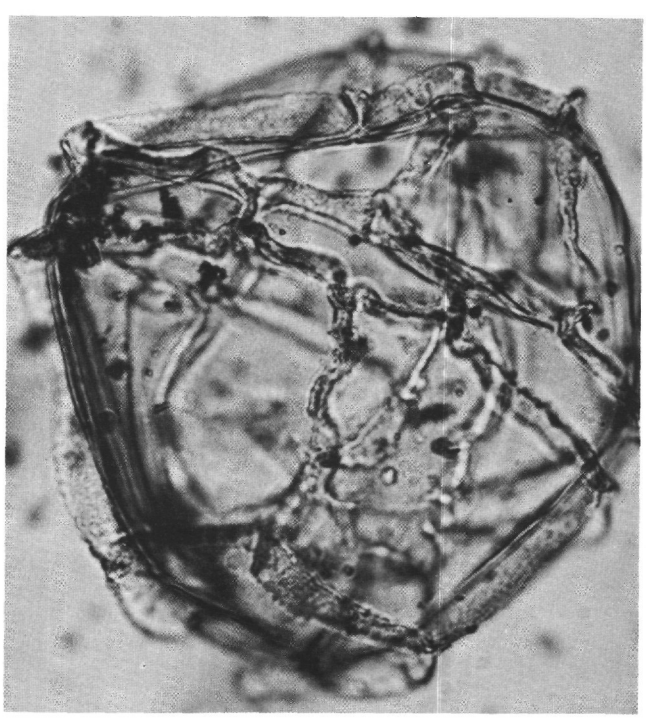

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PLATE 19
Cenzoic Dinoflagellates (Magnification approximately X870)

Figure 1 *Operculodinium centrocarpum* (Deflandre and Cookson). Sample 103-1, Core Catcher.

Figure 2 *Achomosphaera ramulifera* (Deflandre). Sample 102-19, Core Catcher.

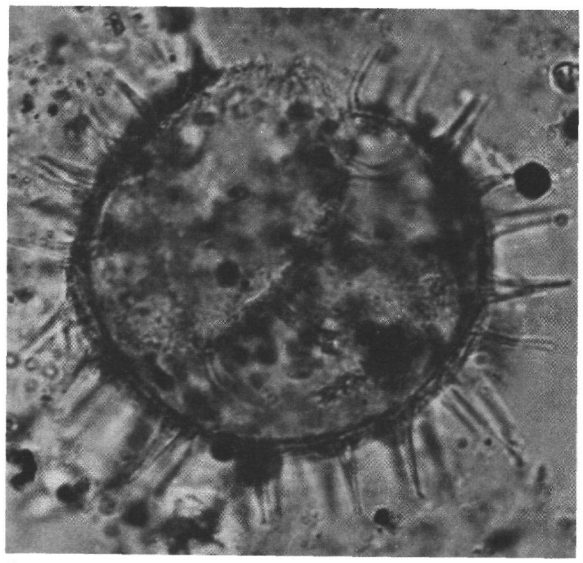
Figure 3 *Leptodinium patulum* Wall. Sample 105-4, Core Catcher.

Figure 4 *Leptodinium aculeatum* Wall. Sample 106-1, Core Catcher.

Figure 5 *Nematosphaeropsis balcombiana* Deflandre and Cookson. Sample 106-1, Core Catcher.

Figure 6 *Achomosphaera* sp. aff. *A. triangulata* (Gerlach). Sample 105-6, Core Catcher.

PLATE 19



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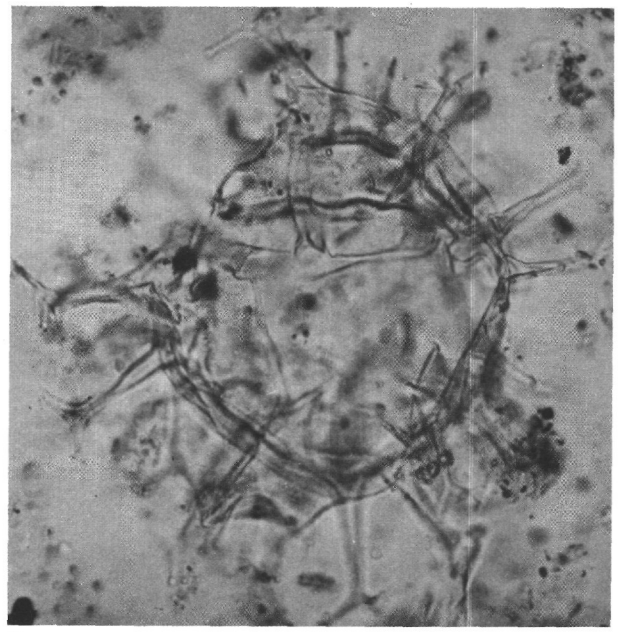

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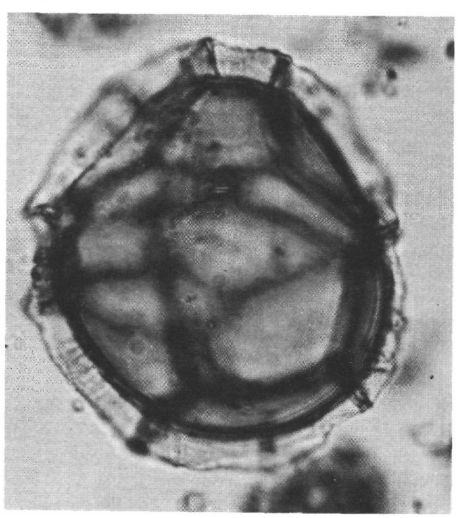

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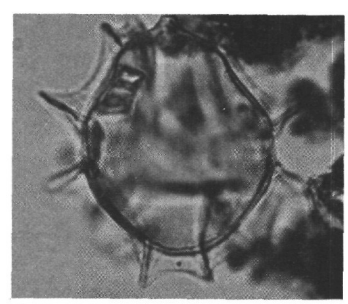

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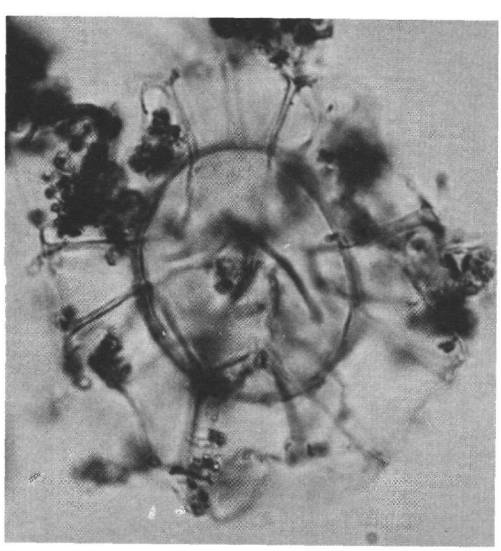

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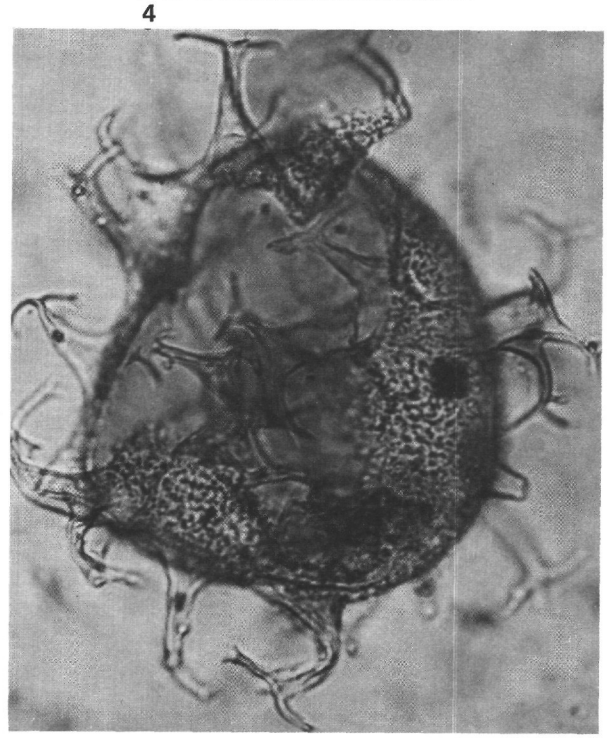

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PLATE 20
Cenozoic Dinoflagellates (Magnification approximately X870)

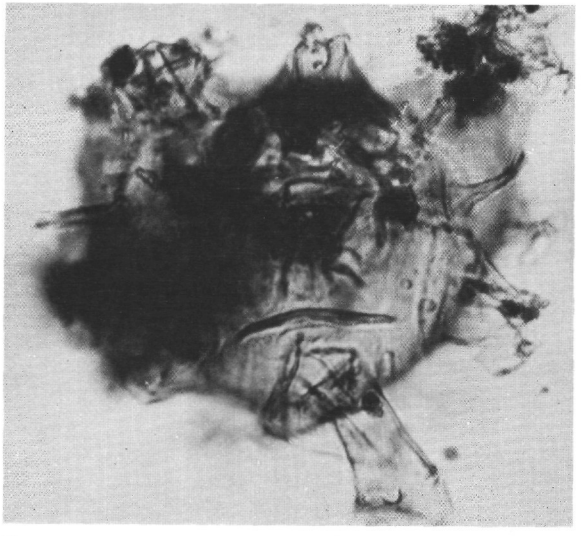
Figure 1 *Hystrichokolpoma rigaudae* Deflandre and Cookson.
Sample 106-1, Core Catcher.

Figure 2 *Achomosphaera alcicornu* (Eisenack).
Sample 108-1, Core Catcher.

Figure 3 *Leptodinium*? sp. A.
Note tabulation and precingular archeopyle. The specimen is damaged, but is characterized by many slender echinate processes.
Sample 106B-8, Core Catcher.

Figure 4 *Pentadinium taeniagerum* Gerlach.
A specimen which closely resembles the holotype illustrated by Gerlach (1961). Note loose fitting of membrane around capsule, leaving a poorly defined pericoel. Tabulation is lacking in the epitract, but a precingular archeopyle is evident.
Sample 106B-5 Core Catcher.

PLATE 20



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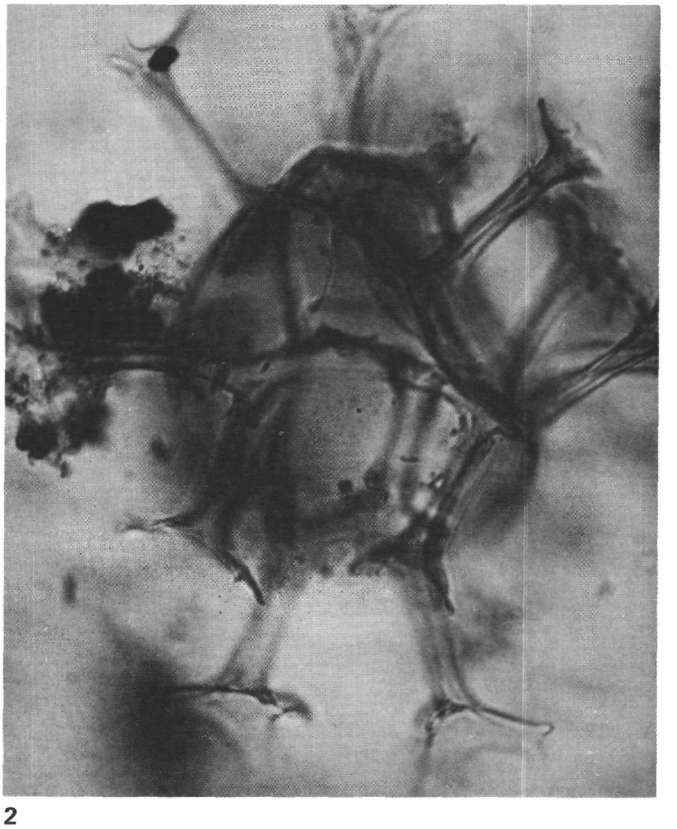

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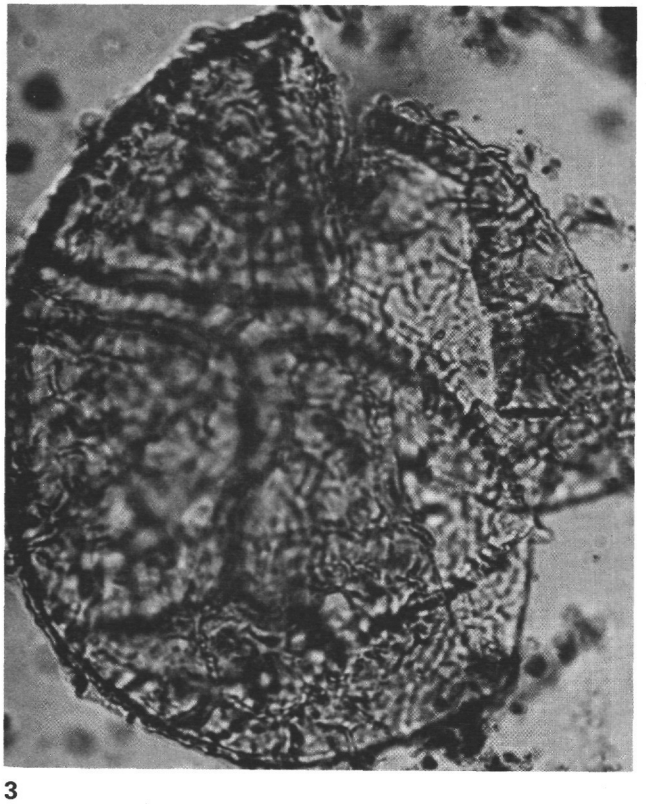

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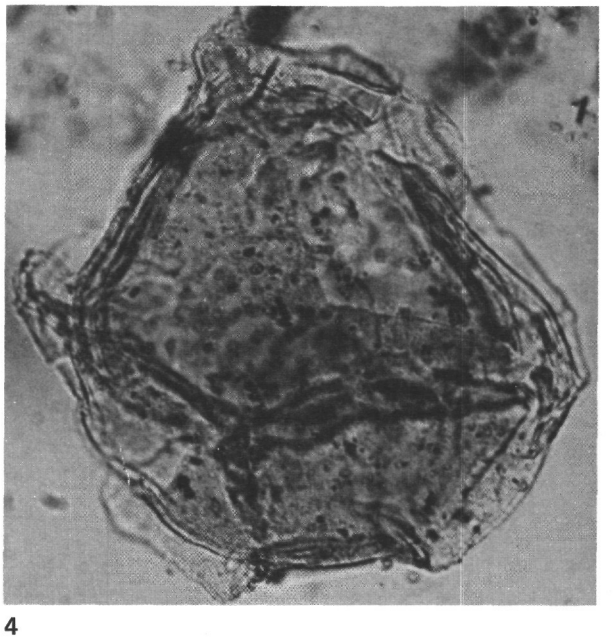

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PLATE 21
Cenzoic Dinoflagellates (Magnification approximately X870)

Figures 1, 2, 3 *Hystrichosphaeropsis obscurum* new species.

1. Holotype. The reflected tabulation in this species is imperfect. Note the absence of furcate processes. Sample 104-3-3 (40-43 cm).
2. A very poorly tabulated specimen. The folding of the hypotract may or may not reflect a sulcus. 3. The epitract is untabulated in this specimen, although the arched apical horn and large precingular archeopyle (facing upper left) are evident. Sample 103-4-3 (50-52 cm).

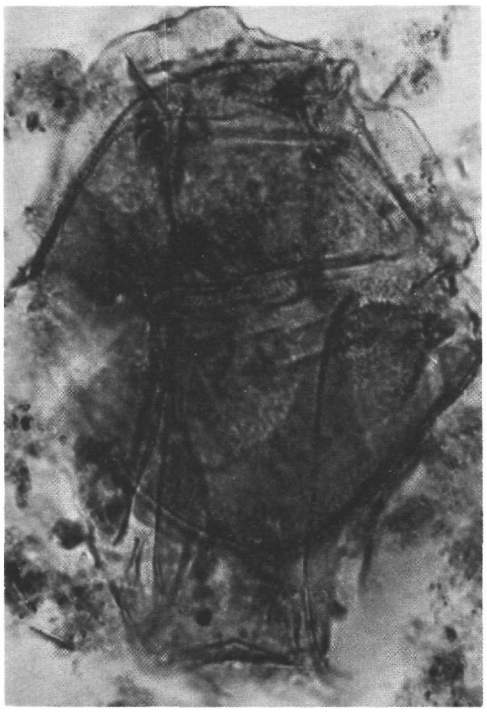
Figure 4 *Densosporites* sp.
A reworked Carboniferous spore. Most Carboniferous palynomorphs were found to be poorly preserved. Sample 103-6-1 (110-112 cm).

Figures 5, 6 *Pentadinium taeniagerum* Gerlach.

5. A relatively well-tabulated specimen, with the formula 1′, 5″, ?c, 5‴, 1″ ″. A well-defined sulcus could not be distinguished. The cingulum is distinctive and tabulated, but plate boundaries are difficult to discern. Note the similarity in tabulation, nature of sutural crests, structure of capsule, surface ornamentation, and arched apical horn with *Hystrichosphaeropsis obscurum* (Figure 1). A relatively large precingular archeopyle faces upper left.
6. A specimen which closely resembles the holotype illustrated by Gerlach (1961). Note the absence of tabulation in the epitract. A pericoel is developed but is not distinct. A large precingular archeopyle faces the upper left. Compare this specimen with the distinctively bicavate specimen of *Hystrichosphaeropsis obscurum* illustrated in Figure 3.

Sample 104-10, Core Catcher.

PLATE 21



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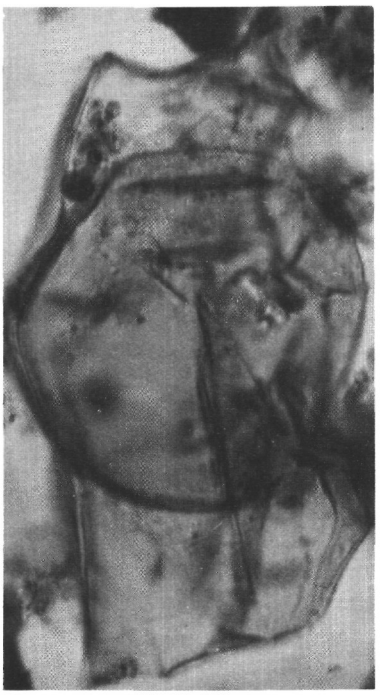

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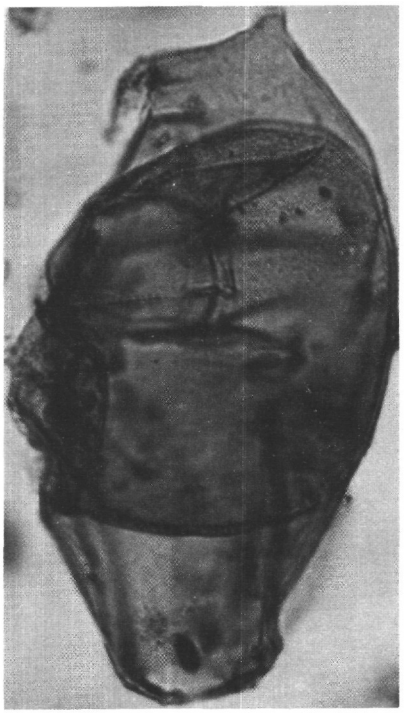

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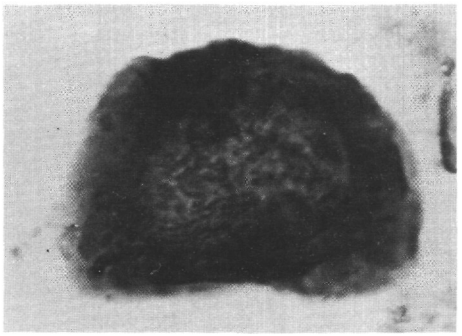

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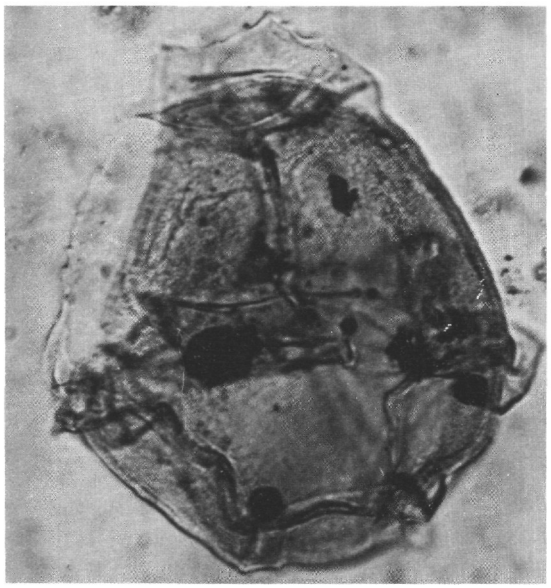

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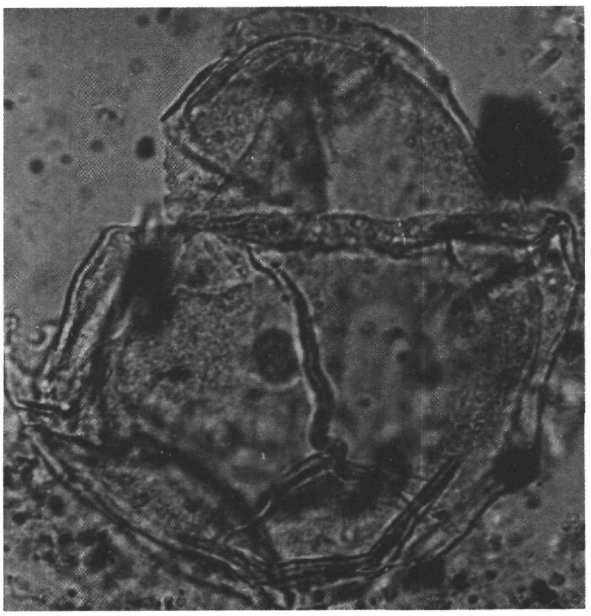

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PLATE 22
Cenozoic Dinoflagellates and Pollen
(Magnification approximately X870)

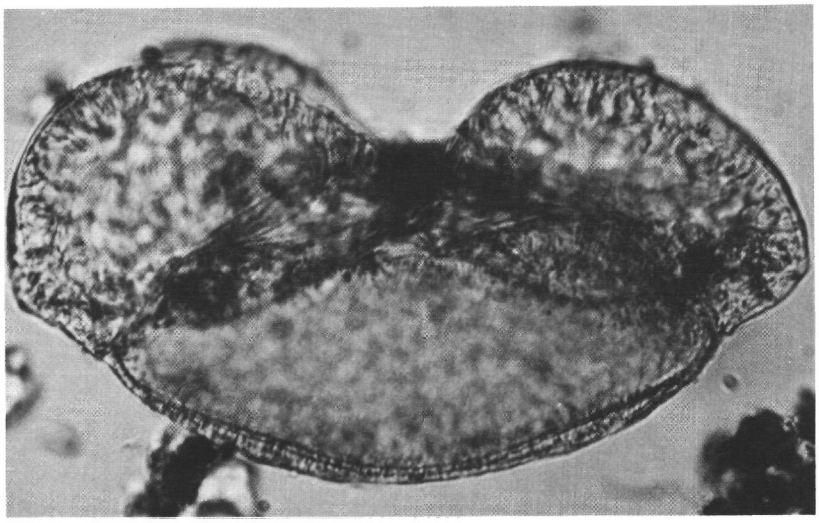
Figures 1, 2 Spruce pollen (*Picea* sp.).
Pollen grains attributed to *Picea* were observed at most sites which cored Pleistocene; they were not observed at Site 98.
1. Equatorial view.
   Sample 106-1, Core Catcher.
2. Polar view, with bladders folded over central body.
   Sample 102-2, Core Catcher.

Figure 3 *Spiniferites crassipellis* (Deflandre and Cookson).
Sample 104-3-3 (40-42 cm).

Figure 4 *Svalbardella* sp. A.
Note circular internal capsule and well-defined intercalary archeopyle. Both the apical horn and antapical horns have a crenulated surface pattern.
Sample 104-10-1 (77-79 cm).

Figure 5 *Chiropteridium* sp. A.
Sample 106B-5, Core Catcher.

PLATE 22



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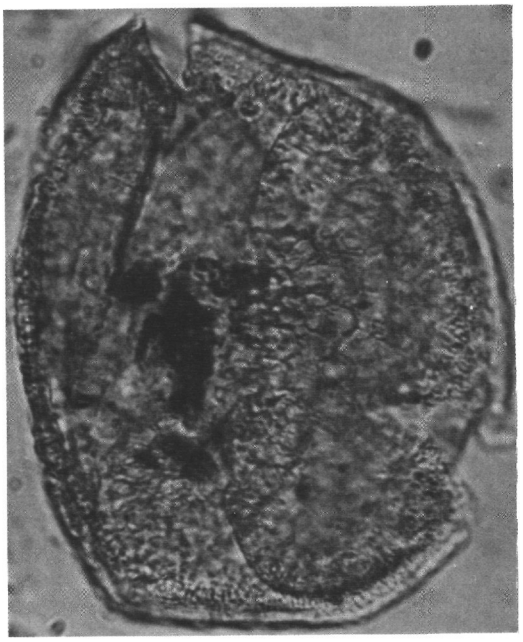

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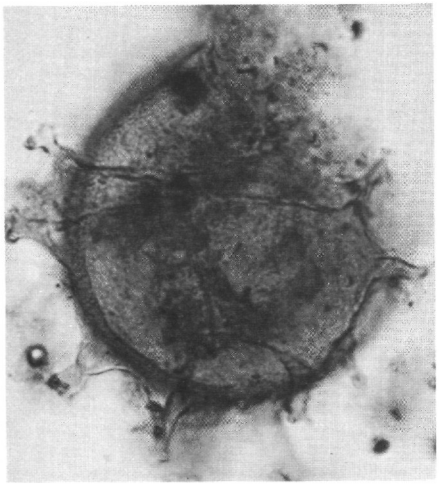

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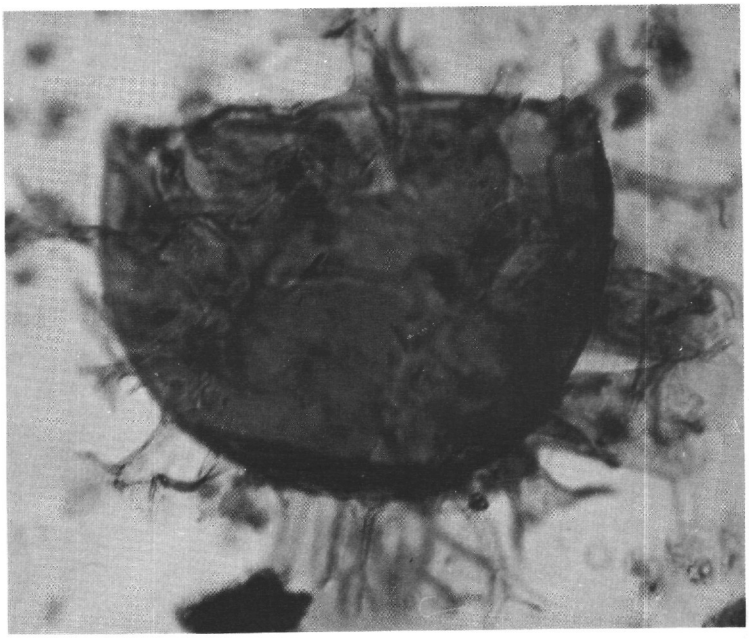

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