14. MIocene Dinocysts FROM DEEP Sea DRILLING PROJECT LEG 81, ROCKALL PLATEAU, EASTERN NORTH ATLANTIC OCEAN

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ABSTRACT

The biostratigraphic occurrences of dinoflagellate cysts from the Miocene sediments of DSDP Leg 81 are documented using 38 fossiliferous samples from Holes 555, 553A, 552, 552A, 554, and 554A, Rockall Plateau, eastern North Atlantic Ocean. Lower Miocene dinocysts were recovered from Hole 555, middle Miocene dinocysts from Holes 555 and 553A, and upper Miocene dinocysts from Holes 555, 552, 552A, 554, and 554A.

In the middle Miocene, important species at Leg 81 sites include: "Nematosphaeropsis" aquaeducta (lowest and highest occurrences within the middle Miocene), Tectatodinium simplex n. comb. (lowest occurrence within the middle Miocene), Daneal sp. (lowest and highest occurrences), Labyrinthodinium truncatum (lowest and highest occurrences), Batiscaspheara sp. 1 (highest occurrence), Invertocysta tabulata n. gen., n. sp. (lowest occurrence), Invertocysta lacrymosa n. gen., n. sp. (lowest occurrence), Operculodinium sp. of Jan du Chêne (lowest occurrence), Incertae sedis sp. 1 (lowest occurrence), Fibrocytis fusiforma n. sp. (lowest occurrence), and Pentadinium latincinctum (highest occurrence).

In the upper Miocene, important species from Leg 81 sites include: Incertae sedis sp. II (lowest occurrence), Fibrocytis fusiforma n. sp. (highest occurrence), and Incertae sedis sp. I (highest occurrence).

Invertocysta tabulata n. gen., n. sp. reveals a unique and well-developed paratabulation.

INTRODUCTION

Leg 81 of the Deep Sea Drilling Project drilled eight holes at four sites in the southwestern part of the Rockall Plateau in the eastern North Atlantic Ocean (Fig. 1). This chapter deals with the biostratigraphic occurrences of dinoflagellate cysts in the Miocene sediments of this leg. The Pliocene-Quaternary dinocysts are discussed by Harland (this volume) and the Paleogene dinocysts are treated by Brown and Downie (this volume).

Relatively few detailed stratigraphic studies of Miocene dinoflagellate cysts have been made. Maier (1959) and Gerlach (1961) documented ranges of selected dinoflagellate cysts in Germany and included Miocene deposits. Habib (1971) reported the occurrences of dinoflagellates across the Miocene/Pliocene boundary in northern Italy. In 1972, Habib included Miocene dinocysts in his report on the Mesozoic and Cenozoic dinoflagellates from offshore North America. Williams (1975) and Williams and Brideaux (1975) included Miocene as well as older and younger dinoflagellate material in their studies of the Grand Banks and Scotian Shelf. In his 1977 work, Williams presented a zonation of the Triassic to Pliocene, which includes three zones in the Miocene.

Manum (1976) studied the Tertiary dinocysts from the Norwegian-Greenland Sea sediments and erected a provisional zonation. Costa and Downie (1979) reported on the Cenozoic dinocysts from the Rockall Plateau and established nine informal partial-range zones. For this same leg, Harland (1979) documented the ranges of dinocysts from the Neogene and Quaternary of the Bay of Biscay. He, too, erected a different, tentative fourfold informal zonation. Piasecki (1980) erected four formal biozones based on successive first occurrences and documented the dinoflagellate cyst biostratigraphy in the Miocene of Denmark. In this chapter, the observed dinocyst ranges for the Miocene are given, but no formal or informal zonation is introduced.

METHODS

Six of the eight holes drilled on Leg 81 recovered Miocene sediments. From these, 54 samples were taken for dinoflagellates, 38 of which contained identifiable dinocysts. Samples (10–40 cm³ of sediment) were treated with hydrochloric and hydrofluoric acids, oxidized with nitric acid, separated by floating in heavy liquid (ZnCl₂, sp. gr. 1.8) if there was sufficient residue or by swirling if there was little residue, and stained with Bismark brown. All samples were observed by light microscope using Nomarski interference contrast. In addition, two samples (555-22-1, 107–109 cm and 555-21-2, 60–62 cm) were ex-
amined using the scanning electron microscope (SEM). All processed
and bulk material is housed at the U.S. Geological Survey palynology
collection in Reston, Virginia. All microscope slide coordinates used
in the text, systematic descriptions, and plate captions are given for
Olympus microscope 201526 held by a specially milled metal insert.

RESULTS

The dinocysts from Leg 81 are discussed by site, in
order of decreasing age of recovered dinocysts. Site 555
(Fig. 2) is by far the most complete and contains assem-
bilages of early, middle, and late Miocene age. Site 553
(Fig. 3) yielded middle Miocene dinoflagellates and one
sample of late Miocene/early Pliocene age. Site 552
(Fig. 4) and Site 554 (Fig. 5) yielded late Miocene dinoc-
stysts. In the discussions and the accompanying charts,
the ages given are those determined by Leg 81 micropa-
leontologists (see Backman et al., this volume). Dinocyst
preservation ranges from good to poor. In many samples,
dinocyst recovery was sparse; usually less than 100 spec-
imens were observed per slide.

Site 555

The most complete Miocene section in this study comes
from Hole 555, drilled at 56°33.70′N, 20°46.93′W, at a
water depth of 1659 m in the southwestern part of the
Rockall Plateau. This site was the most landward and
the shallowest of the four Leg 81 sites. Twenty-one sam-
ple were taken and all included dinocysts. The highest
sample (555-3-7, 40-42 cm) contained only rare reworked
Paleogene specimens. The dinocyst occurrences from Hole
555 are shown in Figure 2.

Only two samples (555-26-3, 50–52 cm and 555-25-4,
70-72 cm) are from the early Miocene, and these con-
tain species such as Lingulodinium machaerophorum (De-
fandre and Cookson) Wall, Nematosphaeropsis laby-
rinthea (Ostenfeld) Reid, Batiacasphaera sp. (Plate 1, Fig.
2), B. spheraica Stover, Hystrichosphaeropsis obscura
Habib, Operculodinium sp. of Piasecki, 1980 (Plate 5, Fig.
3) and Hystrichosphaeropsis sp. b of Shima-

Site 553

Site 553 lies on the western margin of the Rockall
Plateau (Fig. 1), 56°05.32′N, 23°20.61′W, at a water
depth of 2329 m. Three holes were drilled at this site,
but Miocene sediments were recovered from only one,
Hole 553A. Seven samples within the Miocene interval
were processed for dinoflagellates. Three samples con-
tain dinocysts, but two of these have very sparse floras.
The forms found and their stratigraphic occurrences are
shown in Figure 3.

In Hole 553A, Sample 553A-8-3, 32-36 cm contains the
middle Miocene species “Nematosphaeropsis” aquae-
ducta. Sample 553A-7-3, 130-134 cm contains a rep-
resentative middle Miocene flora including Batiacaspha-
era sp. I, Pentadinium latincinctum, Palaeocystodinium
golzowense, and Hystrichostrogiyn sp. The flora is
thus approximately correlative with the middle part of
the middle Miocene in Hole 555. Sample 553A-3-2, 80-82 cm contains Operculodinium sp. of Piasecki,
1980, which in Hole 555 does not range above the lower
part of the upper Miocene.

Site 552

Site 552 lies on the western margin of the Rockall
Plateau, 56°02.56′N, 23°13.88′W, at a water depth of
2301 m, in proximity of Site 404 from Leg 48. Two holes
were cored at Site 552: Hole 552, which was rotary cored,
and Hole 552A, which was hydraulically piston cored.
Seven samples in the Miocene interval were taken from
Hole 552, three of which contained dinocysts; twelve
samples were taken from Hole 552A, seven of which
contained dinocysts. Dinocysts are not abundant at Site
552, and the lower part of the Miocene section in both
Holes 552 and 552A (middle Miocene) did not yield di-
noflagellate cysts. Figure 4 is the combined occurrence
chart for this site.

Samples that contain dinocysts from Site 552 contain
a late Miocene assemblage comparable to that found on
Site 555. Important forms include: Invertocysta tabula-

5 Any use of trade names in this chapter is for descriptive purposes only and does not
constitute endorsement by the U.S. Geological Survey.
MIOCENE DINOCYSTS

Figure 2. Range and distribution chart of dinoflagellate cysts recovered from Miocene sediments of Hole 555. Preservation: P = poor; F = fair; G = good. Age determinations from Leg 81 micropaleontologists.

Figure 3. Range and distribution chart of dinoflagellate cysts recovered from Miocene sediments in Hole 553A. Preservation: P = poor; F = fair; G = good. Age determinations from Leg 81 micropaleontologists.

ta n. gen., n. sp., Invertocysta lacrymosa n. gen., n. sp., Fibrocysta fusiforma n. sp., Polykrikos?, and Incertae sedis sp. II. Reworked Paleogene material was found in Sample 552A-32-1, 80-84 cm.

Site 554

Site 554 is on the outer high on the western edge of the Rockall Plateau, 56°17.41' N, 23°31.69' W, at a water depth of 2574 m. Two holes were cored at this site, Holes 554 and 554A. Three samples from the late Miocene were examined from Hole 554; all contained dinocysts. From Hole 554A, four samples were examined but only the upper sample, also late Miocene, contained dinocysts. Figure 5 is the combined occurrence chart for Holes 554 and 554A.

The samples from Site 554 contain a late Miocene assemblage comparable with that found in upper Miocene sediments at Sites 555 and 552. Important forms include:
Invertocysta tabulata n. gen., n. sp., Invertocysta lacrymosa n. gen., n. sp., Fibrocysta fusiforma n. sp., and Incertae sedis sp. I.

**ZONAL COMPARISONS**

Comparison of the Rockall Plateau material with other Miocene material is difficult because so little is known about the ranges of Miocene dinocysts. The middle Miocene at Sites 555 and 553 is within the Nematosphaeropsis aquaeducta Zone of Piacecki (1980) recognized from the Hodde Formation in Denmark. Piacecki’s upper Miocene zones, his Achosmosphaera andalousiensis and Dinopterygium verriculum Zones, were not recognized in the Rockall Plateau material. Costa and Downie (1979) used an informal partial-range zone, their Zone VIII, for the middle and late Miocene and the Pliocene. The base of this zone corresponds to the base of Impagidinium patulum (= Leptodinium patulum) and “Nematosphaeropsis” aquaeducta (= Leptodinium sp. V). Jan du Chêne (1977) used the highest occurrence of Hystrichosphaeropsis obscura to mark the top of the Miocene. For an unknown reason, this species has its last appearance somewhat lower in the Rockall material. Study of additional Miocene material may better establish dinocyst ranges.

**CONCLUSIONS**

For the documentation of the ranges of important dinocysts in the North Atlantic, Site 555 provides a nearly complete middle and upper Miocene section, as well as a short lower Miocene part. The occurrence data from Sites 552, 553, and 554 supplement Site 555 for the middle and upper Miocene.

In the middle Miocene, important species at Leg 81 sites include: “Nematosphaeropsis” aquaeducta (lowest and highest occurrences within the middle Miocene), Teiatalodinium simplex n. comb. (lowest occurrence within the middle Miocene), Danaea? sp. (lowest and highest occurrences), Labyrinthodinium truncatum (lowest and highest occurrences), Hystrichosstroglyion sp. (lowest occurrence), Batiacasphaera sp. I (highest occurrence), Operculodinium sp. of Jan du Chêne, 1977 (lowest occurrence), Invertocysta tabulata n. gen., n. sp. (lowest occurrence), Invertocysta lacrymosa n. gen., n. sp. (lowest occurrence), Incertae sedis sp. I (lowest occurrence), Fibrocysta fusiforma n. sp. (lowest occurrence), and Pentadinium latidactylum (highest occurrence).

In the upper Miocene, important species from Leg 81 sites include: Fibrocysta fusiforma n. sp. (highest occurrence), Incertae sedis sp. I (highest occurrence), and Incertae sedis sp. II (lowest occurrence).

**SYSTEMATIC DESCRIPTIONS**

Division PYRROPHYTA Pascher, 1914
Class DINOPHYCEAE Fritsch, 1935
Order PERIDINIALES Haeckel, 1894
Genus BATIACASPHAERA Drugg, 1970

**Batiacasphaera sphaerica Stover, 1977**
(Plate 1, Fig. 1)

Remarks. This form has an apical archeopyle, accessory sutures suggesting five precingular paraplates, and a surface ornamented with raised bumps and irregular discontinuous ridges. Diameter ranges from about 40 to 70 µm. Deep in Hole 555, the specimens are larger than average and ornament is more irregular. A typical specimen is shown in Plate 1, Figure 2.

**Cannosphaeropsis sp. I**
(Plate 1, Figs. 8A,B)

Remarks. This form has an apical archeopyle. The wall consists of a single spongy layer, often covered with numerous nontubular bumps 1–3 µm in height. Specimens average 37 µm in diameter (range 27–52 µm) and the wall thickness ranges from 1.5 to 4.5 µm. The form is very abundant in Sample 555-19-2, 45–47 cm.

Genus CANNOSPHAEROPSIS O. Wetzel, 1933

**Cannosphaeropsis sp. I**
(Plate 1, Figs. 5A,B,C)

Remarks. Although only three specimens of this form were observed, the nature of the trabeculae warrants discussion. Here, the trabeculae do not represent extensions of the triradiate tips of gonal processes as in the typical Nematosphaeropsis; rather, they appear to represent normal parasutural septa that are incomplete or excavated to give the appearance of trabeculae. Pending reevaluation of the genera Nematosphaeropsis and Cannosphaeropsis, this form is questionable placed in Cannosphaeropsis.

**Cannosphaeropsis sp. b of Shimakura, Nishida, and Matsuoka, 1971**
(Plate 1, Fig. 4)

Remarks. This distinctive form has been reported from several high latitude locations in the North Atlantic, North Pacific, and Arctic oceans. Morphologic details have not been determined but this form is probably more closely related to Melitasphaeridium than to Cannosphaeropsis.
Genus **DANEA** Morgenroth, 1968

*Danea?* sp.  
(Plate 4, Figs. 1A, B; C; Plate 5, Figs. 4–6)

**Remarks.** This form has a gonyaulacacean paratabulature and a 3′ archeopyle. Paratabulature is expressed by pentagonal ridges that are incomplete bordering the paracingulum. This form is questionable placed in *Danea* because of its spherical rather than elongate shape and because it lacks any sort of apical projection.

**Genus **DAPSIDILINIUM** Bujak et al., 1980**

*Dapsidilinium pseudocolügerum* (Stover, 1977) Bujak et al., 1980  
(Plate 1, Fig. 6)

**Genus FIBROCYSTA** Stover and Evitt, 1978

*Fibrocysta fusiformis* n. sp.  
(Plate 4, Figs. 2, A, B)

**Holotype.** Plate 4, Figure 2, slide R 2712 BJ (2), 33.7 × 77.4, Sample 555-7, 44–48 cm.

**Derivation of name.** Latin, spindle shaped.

**Diagnosis.** Cyst fusiform, autophragm only; surface rough with many (15–40) smooth nontubular processes; paratabulature presumably gonyaulacacean, indicated by pentagonal 3′ precingular archeopyle and faint alignment of processes in paracingulum region; operculum free; dimensions of holotype, length 75 µm, width 47.4 µm, processes 10–13 µm.

**Description.** Cyst fusiform, with elongate rounded protrusion at apex, pointed nubbin, with or without additional spine at antapex; wall thin, autophragm only, surface rough with smooth 15–40 (typically 20–30) smooth nontubular processes; processes are typically acuminate, may be bifid, especially at paracingulum; processes hollow at bases, probably solid distally, paratabulation presumably gonyaulacacean, indicated by archeopyle and faint alignment of processes at paracingulum region; archeopyle five-sided, type P, 3′ only, operculum free.

**Dimensions.** Length, average 73 µm, range 65–81 µm; width, average 41 µm, range 35–52 µm; length of spines, 7–13 µm; 16 specimens measured.

**Remarks.** This species is provisionally placed in *Fibrocysta* because the processes and the autophragm are smooth rather than fibrous.

**Occurrence.** Lower part of upper Miocene in Holes 555, 552A, and 554A.

**Genus **HYSTRICHOKOLPOMA** Klumpp, 1953**

*Hystrichokolpoma sp.*  
(Plate 1, Fig. 3)

**Remarks.** A few specimens of a small delicate *Hystrichokolpoma* were found in the material from the Rockall Plateau.

**Genus **HYSTRICHOSPHAEROPSIS** Deflandre, 1935**

*Hystrichosphaeropsis obscura* Habib, 1972  
(Plate 1, Fig. 10)

**Genus **HYSTRICHOSTROGYLON** Agelopoulos, 1964**

*Hystrichostrogylon sp.*  
(Plate 1, Figs. 7A, B, C)

**Remarks.** Specimens from the Rockall Plateau show large ventral pericoels, often have spines on the periphragm wall, and may or may not have intergonal processes in addition to the typical gonal processes.

**Genus **IMPAJIDINUM** Stover and Evitt, 1978**

(Plate 1, Figs. 11A, B)

**Remarks.** In the Rockall material, the size of this species is highly variable (length ranges from 40 to 110 µm). A typical specimen is shown in Plate 1, Figures 11A, B.

**Impagidinium sp.**  
(Plate 1, Figs. 12A, B)

**Remarks.** Small specimens of *Impagidinium* (probably several species) were found in the Rockall material, typically 30 µm or less. Septa are high relative to cyst body size. No attempt was made in the present study to differentiate them. A typical specimen is illustrated in Plate 1, Figures 12A, B.

**Genus **INVERTOCYSTA** n. gen.**

**Derivation of name.** Latin, *invertere*, to turn inside out or upside down.

**Diagnosis.** Cyst cavate; endocyst ovoidal to ellipsoid, often with a short apical boss; pericyst discoidal or bowl-shaped, meridionally placed, open towards dorsal side; endophragm and periphragm appressed midventrally, periphragm extended outward elsewhere; wall surfaces smooth except for parasutural ridges or thickenings of the periphragm indicating paratabulature; paratabulature gonyaulacacean, 4′, 6′, 4-6c, 5-6′, 1′, 1′′, 3′-5′ for *Invertocysta tabulata*; probably similar formula for *I. lacrymosa* but incompletely expressed; archeopyle precingular, type P, 3′ only; distribution of periphragmal paraplates asymmetrical such that most or all of the dorsal surface represents 3′ and is absent, and the dorsal part of the paracingulum is displaced towards the antapex; up to five small paraplates may be distinguished in the parasulcal region.

**Type species.** *Invertocysta tabulata* n. sp.

**Comparisons.** In the genus *Invertocysta*, the bowl- or saucer-shaped periphragm opens towards the dorsal side and is appressed to the endophragm midventrally. In *Thalassiphora*, the “bowl” of the periphragm opens ventrally and it is attached middorsally. *Stephodinium* has a periphragmal extension which is positioned equatorially, rather than meridionally as in *Invertocysta*. *Hystrichostrogylon* has gonal processes and the wall layers are appressed middorsally. *Invertocysta* is probably related to *Amiculosphaera*, although in *Amiculosphaera*, the periphragm is appressed to the endophragm over most of the hypo-cyst.

**Invertocysta tabulata** n. sp.  
(Plate 3, Figs. 3A, B; Text-Fig. 6)

**Form A (= *Thalassiphora delicata*)** Costa and Downie, 1979, pl. 3, fig. 9–13, 15–17, 20–23, 25–26, 29, 30, 31, 32

**Holotype.** Plate 3, Figures 3A, B, slide R 2712 BC (2), 35.5 × 103.3, sample 555-15-1, 50–52 cm.

**Derivation of name.** Latin, *tabulatus*, boarded, plated.

**Diagnosis.** Cyst cavate; endocyst ovoidal to ellipsoid with apical boss; pericyst discoidal, meridionally placed, with endophragm and periphragm in contact midventrally; wall surface smooth or nearly smooth with well-developed parasutural ridges; paratabulature gonyaulacacean, 4′, 6′, 4-6c, 5-6′, 1′, 1′′, 3′-5′; archeopyle precingular, type P, 3′ only; distribution of paraplates such that nearly all of the dorsal area of the periphragm represents 3′ and is missing (see Fig. 6) and the dorsal part of the paracingulum is displaced to form the antapical margin of the pericyct; up to five small paraplates may be distinguished in the parasulcal region; dimensions of holotype, pericyct length 90 µm, pericyct width 92 µm, endocyst length 54 µm, endocyst width 37 µm.

**Description.** Cyst cavate; endocyst ovoidal to ellipsoid with small but prominent apical protrusion; pericyct discoidal, meridionally located with endocyst centered within pericyct, and endophragm and periphragm in contact in the midventral region and separated elsewhere; wall surfaces smooth to shagreenate; paratabulature indicated by low parasutural ridges, gonyaulacean, 4′, 6′, 4-6c, 5-6′, 1′, 1′′, 3′-5′; well expressed where periphragm extends out from endophragm, well to poorly expressed midventrally (with younger specimens showing less definition in the midventral area than older specimens); paratabulature asymmetrical such that all of the pericyct tabulature is expressed on the ventral surface and what would be the dorsal side is missing; paracingulum displaced antapically so that what would normally be in the middorsal portion lies along the antapical margin and the paracingulum forms a characteristic eccentric circle on the ventral hypocyst; archeopyle precingular, type P, 3′ only in endocyst, presumably the missing dorsal side of the pericyct also represents 3′; up to five small paraplates may be distinguished in the parasulcal region.

**Dimensions.** Outer diameter, average 89 µm, range 63–113 µm; endocyst length, average 46 µm, range 37–58 µm; endocyst width, average 37 µm, range 31–60 µm; 25 specimens measured.

**Remarks.** The discoidal shape, the prominent paratabulature, and the eccentric circle formed by the paracingulum distinguish this species from *I. lacrymosa*. This species only superficially resembles *Thalassiphora delicata* Williams and Downie, 1966, as emended by Eaton,
Invertocysta lacrymosa n. sp.

(Plate 3, Figs. 4A,B, 5)

Thalassiphora sp. cf. T. pelagica Habib, 1971, pl. 4, fig. 2.

"Thalassiphora delicata" Williams and Downie emend. Eaton, 1976, Harland, 1979, pl. 2, fig. 15.

Holotype. Plate 3, Figures 4 A,B, slide R 2712 BH (2), 19.0 × 79.1, Sample 555-9-1, 28–30 cm.

Derivation of name. Latin, lacrimosus, tearful.

Diagnosis. Cyst cavate; ovoidal endocyst connected at apical boss to lip of bowl-shaped pericyst; periphragm and endophragm appressed midventrally; periphragm turned inward on dorsal side around opening representing 3; wall surfaces smooth to shagreenate with poorly to moderately well-developed parasutural ridges; paratabulation gonyaulacacean, exact formula undetermined; archeopyle precingular, type P, 3" only; dimensions of holotype, pericyst length 79 µm, pericyst width 85 µm, endocyst length 52 µm, endocyst width 44 µm.

Description. Cyst cavate; endocyst ovoidal to ellipsoidal with apical boss connecting endocyst to inner lip of pericyst; pericyst boss-shaped with inward-turning lip at opening of bowl on dorsal side; periphragm and endophragm appressed midventrally; opening on dorsal side variable in size, shape, and position, ranging from a small opening on the dorsal epicyst to an opening of approximately the same size and shape as the endocyst to an opening that is considerably larger and broader than the endocyst; wall surfaces smooth to shagreenate with faint to moderately well-developed parasutural ridges; paracingulum displaced antapically on dorsal side, outline of paracingulum is in the shape of a hemicircle with the flat side centered across the ventral side; paratabulation gonyaulacacean, exact formula undetermined but presumably similar to that of I. tabulata, paraplates analogous to 3", 4", 5", and 1" on I. tabulata are clearly visible on some specimens of I. lacrymosa; archeopyle precingular, type P, 3" only on endocyst, large opening corresponding to 3" on pericyst.

Dimensions. Pericyst length, average 76 µm, range 60–92 µm; pericyst width, average 77 µm, range 62–90 µm; endocyst length, average 44 µm, range 33–60 µm; endocyst width, average 36 µm, range 29–46 µm; dorsal opening length, average 58 µm, range 13–90 µm; dorsal opening width, average 56 µm, range 23–77 µm; 31 specimens measured.

Remarks. This form shows a wide range of variation in size, shape, degree of definition of paratabulation, and size, shape, and position of the dorsal opening. As a rough trend, the middle Miocene specimens have smaller openings than late Miocene specimens. The specimens illustrated here are typical of the Rockall material. The specimens illustrated by Habib (1971) and Harland (1979) are end members in the limits of variation.

I. lacrymosa differs from I. tabulata in possessing a bowl-shaped, as opposed to disc-shaped, pericyst, in having less definition of paratabulation and in having a less "droopy" paracingulum. It differs from Thalassiphora delicata Williams and Downie, 1966, as emended by Eaton, 1976, in that the wall layers of I. lacrymosa are appressed midventrally and the large dorsal opening represents 3". In T. delicata, the wall layers are appressed mddorsally and the large ventral opening represents 1". I. lacrymosa is distinguished from Amiculosphaera umbracula Harland, 1979, by the appression of periphragm and endophragm in the hypocyst of the latter.

Occurrence. Upper part of middle Miocene to upper Miocene in Hole 555, upper Miocene in Holes 552A and 554.

Genus LABYRINTHODINIUM Piasecki, 1980

Labyrinthodinium truncatum Piasecki, 1980

(Plate 1, Fig. 9)


Lingulodinium machaerophorum (Deflandre and Cookson, 1955) Wall, 1967

(Plate 2, Fig. 2)

Remarks. Specimens of L. machaerophorum were encountered with 3P, 5P, and epitractal archeopyles. Those with epitractal archeopyles, as shown in Plate 2, Figure 2, are by far the most common.

Genus MELITASPHAERIDIUM Harland and Hill, 1979

Melitasphaeridium choanophorum (Deflandre and Cookson, 1955)

Harland and Hill, 1979

(Plate 2, Fig. 8)

Genus NEMATOSPHAEROPSIS Deflandre and Cookson, 1955

Nematosphaeropsis labyrinthae (Ostenfeld, 1903) Reid, 1974

(Plate 2, Figs. 7A,B)

"Nematosphaeropsis" aquaeducta Piasecki, 1980

(Plate 5, Fig. 1)

Remarks. In their comparison of the genera Cannosphaeropsis and Nematosphaeropsis, Stover and Evitt (1978, p. 143) stated that Cannosphaeropsis differs from Nematosphaeropsis in having single parasutural trabeculae between gonal positions. In Nematosphaeropsis, ectophragmal trabeculae represent extensions of the triradiate tips of the gonial processes so that at least two trabeculae connect adjacent processes. Other workers (e.g., Williams and Downie, 1966; May, 1980) have come to different conclusions about the two genera. Pending resolutions of these differences, "N." aquaeducta, which has single trabeculae between gonal positions, is considered a problematical species in "Nematosphaeropsis."
Remarks. This species is highly variable in size (60–135 µm including processes) and in degree of development of the processes. A typical specimen is shown in Plate 5, Figure 2.

**Opcerculodinium sp. of Piasecki, 1980**
(Plate 5, Fig. 3)

Opcerculodinium sp. Piasecki, 1980, p. 70, pl. 3, fig. 6.

Remarks. As stated by Piasecki (1980), this species is small, ovoid, and covered with short massive processes. The archeopyle is precingular, 3° only. Processes may be cylindrical to truncated conical and may be interconnected at the bases to varying degrees. A typical specimen is shown in Plate 5, Figure 3. Harland's specimen is somewhat atypical in having poorly delimited processes.

**Opcerculodinium sp. of Jan du Chêne, 1977**
(Plate 2, Figs. 3A,B)


Remarks. As noted by Jan du Chêne (1977), this species is subspherical to ovoid, has a simple precingular archeopyle and has short hollow spines, which are truncated and open at the ends.

**Genus PALAEOCYSTODINIUM** Alberti, 1961

Palaecystodinium golczowense Alberti, 1961 sensu lato
(Plate 2, Figs. 1,6)

Remarks. Several of Piasecki's (1980, p. 70–71) comments are applicable here. The size is variable, and specimens are often shorter than Alberti's holotype; horns may be faintly granular.

**Genus PENTADINIUM** Gerlach, 1961

Pentadinium laticinctum Gerlach, 1961
(Plate 2, Fig. 4)

Remarks. As noted by Benedek et al. (1982) and Edwards (1982), there is no consistent criterion for separating Pentadinium laticinctum and *P. taeniogerum*; the latter is restricted to its holotype. The Rockall specimens are faintly granular and some show pericoel development in the apical region.

**Genus SPINIFERITES** Mantell, 1850

Spiniferites mirabilis (Rossignol, 1963) Sarjeant, 1970
(Plate 2, Fig. 5)

Remarks. In the Rockall material, this species ranges in length from 60 to 120 µm. A typical specimen is shown in Plate 2, Figure 5.

**Spiniferites spp.**
(Plate 2, Figs. 9,10,11)

Remarks. Numerous specimens of Spiniferites spp. were found in the Rockall material. Because of their variability and often poor preservation, no attempt was made to identify them at the species level. Three typical forms are shown in Plate 2, Figures 9,10,11.

**Spiniferites-group sp. I**
(Plate 5, Fig. 9)

Remarks. This small equant form with high septa is common in several samples in the Rockall Plateau material. It lacks typical Spiniferites-type processes and appears intermediate between Spiniferites and Impagidinium.

**Spiniferites-group sp. II**
(Plate 2, Fig. 12)

Remarks. This form is thin-walled and appears very faint. The truncated-tipped processes are atypical in Spiniferites.

**Genus SYSTEMATOPHORA** Klement, 1960

Systematophora placacantha (Deflandre and Cookson, 1955) Davey et al., 1969
(Plate 3, Fig. 1)

**Genus TECTATODINIUM** Wall, 1967

Tectatodinium pellitum Wall, 1967
(Plate 3, Fig. 2)

Remarks. This species shows varying thickness (1–4 µm) of the wall.

Tectatodinium simplex (Harland, 1979) n. comb.
(Plate 5, Figs. 8A,B, 10A,B)

Remarks. This form resembles *Tectatodinium pellitum* Wall and Dale, 1973, from which it differs in lateral profile and in the generally coarser ornament. The specimen figured by Piasecki as *T. psilatum* is most probably *T. simplex* n. comb.

**Genus TUBERCULODINIUM** Wall, 1967

Tuberculodinium vancampoae (Rossignol, 1962) Wall, 1967
(Plate 5, Fig. 11)

Remarks. These forms are spherical with a precingular archeopyle, a "fuzzy" outline, and varying amounts of paratabulation expressed. More work, and more specimens, are required on this group.

**Incertae sedis sp. I**
(Plate 3, Figs. 7A,B, 7A,B,C, 8)

Remarks. This form has a five-sided archeopyle, which is therefore presumably 3°, and has six long blunt-tipped processes, which are triradiate in cross section. Eleven specimens were well-enough preserved to be measurable. For the cyst body, length averages 60 µm (range 52–79 µm), width averages 43 µm (range 31–56 µm). Processes range in length from 27 to 60 µm, with the average at 45 µm, but this may be too low because the processes often lie at an angle to the plane of the slide. The processes are consistently arranged: two on the epicyst, four on the hypocyst. On the epicyst, one process is on the dorsal surface, one is on the ventral surface, towards the right-lateral side; one is on the ventral surface, towards the left-lateral side. On the hypocyst, two processes are closely spaced and nearly symmetrical about the middorsal surface, and two processes are nearly symmetrical, more widely spaced about the ventral surface. A single, atypical specimen (Plate 3, Fig. 8) showed well-developed gonyaulacean paratabulation and prominent apical projection.

**Incertae sedis sp. II**
(Plate 3, Figs. 6A,B,C)

Remarks. This form resembles *Impagidinium striatum* (Wall, 1967) Stover and Evitt, 1978, in size and in having weakly striate septa, but
differs in having septa outlining the archeopyle. The paratabulation is incompletely known.

**Polykrikos? Bütschli, 1873**

**Remarks.** Specimens such as illustrated in Plate 4, Figure 4 are common in some samples of the Rockall material. They are probably cysts of Polykrikos.

**Reworded Paleogene material**

**Remarks.** Specimens of *Apectodinium homomorphum* (Deflandre and Cookson, 1955) Lentin and Williams, 1977; *Wilkinsonium tabulatum* (Wilson, 1967) Lentin and Williams, 1976 (Plate 4, Fig. 6); and *Wetzelielia* spp. were occasionally found in the Rockall material. These specimens presumably have been reworked from the Paleogene.

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**REFERENCES**


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Plate 3. 1. Systematophora placacantha (Deflandre and Cookson, 1955) Davey et al., 1969. Sample 555-24-3, 70-72 cm, R 2712 AU (1), 36.4 x 96.1, length 67 µm, apical view of antapical surface.  2. Tectatodinium pellitum Wall, 1967. Sample 552A-26-2, 120-124 cm, R 2869 L (1), 23.6 x 98.6, diameter 28 µm, dorsal view of dorsal surface.  3. Invertocysta tabulata n. gen., n. sp. Holotype. Sample 555-15-1, 50-52 cm, R 2712 BC (2), 35.5 x 103.3, length 90 µm, dorsal views, (A) dorsal surface, (B) ventral surface.  4. Invertocysta lacrymosa n. gen., n. sp. Holotype. Sample 555-9-1, 28-30 cm, R 2712 BH (2), 19.0 x 79.1, length 80 µm, ventral views, (A) ventral surface, (B) dorsal surface.  5. Invertocysta lacrymosa n. gen., n. sp. Paratype. Sample 555-5-6, 45-47 cm, R 2712 BL (2), 25.0 x 91.1, length 67 µm, ventral view of dorsal surface.  6. Incertae sedis sp. II. Sample 552A-29-2, 124-128 cm, R 2869 I (1), 29.6 x 93.1, length 47 µm, ventral7 views through specimen.  7. Incertae sedis sp. I. Sample 555-10-5, 70-72 cm, R 2712 BG (1), 29.0 x 87.8, width from tips of spines 125 µm, dorsal views, (A) dorsal surface, (B) ventral surface.  8. Incertae sedis sp. I. Sample 555-15-1, 50-52 cm, R 2712 BC (2), 29.1 x 99.4, length excluding spines 79 µm, ventral view of ventral surface.
Plate 4. 1. *Danea*? sp. Sample 555-21-2, 60-62 cm, R 2712 AW (1), 30.1 × 86.8, length 96 µm, ventral views, (A) ventral surface, high focus, (B) ventral surface, lower focus, (C) dorsal surface. 2. *Fibrocysta? fusiforma* n. sp. Holotype. Sample 555-7-6, 44-48 cm, R 2712 BJ (2), 33.7 × 77.4, length 75 µm, ventral view of dorsal surface. 3. *Fibrocysta? fusiforma* n. sp. Paratype. Sample 555-9-1, 28-30 cm, R 2712 BH (2), 30.9 × 103.5, length 71 µm, right lateral views, (A) upper surface, (B) lower surface. 4. *Polykrikos?* Sample 555-15-1, 50-52 cm, R 2712 BC (2), 18.7 × 87.6, length 64 µm. 5. Gonyaulacacean cyst group. Sample 555-16-5, 50-52 cm, R 2712 BB (2), 30.5 × 108.3, max. diam. 92 µm, dorsal views, (A) dorsal surface, (B) optical section. 6. *Wilsonidium tabulatum* (Wilson, 1967) Lentin and Williams, 1976. Sample 555-3-7, 40-42 cm, R 2712 BN (1), 21.4 × 74.2, length 102 µm, dorsal view of dorsal surface, reworked. 7. Gonyaulacacean cyst group. Sample 555-14-1, 20-22 cm, R 2712 BD (2), 33.3 × 78.7, max. diam. 81 µm, dorsal views, (A) dorsal surface, (B) optical section, (C) ventral surface. 8. Gonyaulacacean cyst group. Sample 555-14-1, 20-22 cm, R 2712 BD (2), 16.9 × 103.7, length 47 µm, interior view of operculum.