

20. DINOFLAGELLATE CYST STRATIGRAPHY OF PALEOCENE TO MIOCENE SEDIMENTS FROM THE GOBAN SPUR (SITES 548-550, LEG 80)¹

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ABSTRACT

Cyst assemblages from Sites 548, 549, and 550 were examined and gave evidence of early Eocene to late Miocene age. These assemblages were compared with other North Atlantic DSDP sites and with onshore sections in Denmark, southern England, Spain, and Italy. Some environmental interpretation is attempted for the Miocene assemblages; pollen, spores, and dinoflagellate cyst species were used to interpret the proximity of the shoreline. Key species are illustrated, along with some forms that are not discussed.

INTRODUCTION

During IPOD Leg 80, four sites were drilled along a transect across the sediment-starved Goban Spur. The transect is 250 km southwest of Ireland in the northern part of the Bay of Biscay and crosses the continent/ocean boundary. The post-rift sedimentary cover there is much thinner than on the American margin, since the Goban Spur has remained structurally higher. The principal objectives of Leg 80 were to determine the nature, age, and subsidence history of the continental and oceanic basement near their juncture and to document the age and paleoenvironments of the syn-rift and post-rift sedimentary rocks. The objective of this study is to date the Cenozoic post-rift sediments and to infer their depositional environments.

Samples of Paleocene to Miocene age were processed from Sites 548, 549, and 550, which are at the locations shown in Table 1. All the samples were prepared by using standard palynological techniques and were handled beyond the hydrofluoric acid stage by using the method described by Neves and Dale (1963). The samples processed are listed in Table 2.

Only Hole 548A provided samples that contained a good sequence of dinoflagellate cysts; only 10 of the

samples from the other holes contained dinoflagellates. The remaining samples were barren of palynomorphs. However, most of the samples that contained palynomorphs yielded rich assemblages of dinoflagellate cysts, pollen, and spores. Our ability to use dinocysts to correlate the holes is very limited, unfortunately, since the first appearances of species cannot be defined in the sequences from Holes 549 and 550.

No attempt was made to zone the range chart (Fig. 1), since no Tertiary dinoflagellate zonation scheme is widely accepted. Rather than construct another zonation, we referred to those of Costa and Downie (1979), Harland (1979), Bujak et al. (1980), and Manum (1976). The large amount of information published on Neogene dinoflagellate cysts in recent years (e.g., Harland, 1977, 1979; Jan du Chêne, 1977; and Piasecki, 1980) has made regional comparison and correlation possible. Species found by these authors to have some stratigraphic significance were used for the relative dating of the samples, and these dates are discussed below in association with the relative dates obtained from the study of the Leg 80 nannoplankton assemblages (Müller, this volume).

The results from Hole 548A are discussed in chronological order. The results from the other, less productive holes are summarized.

Table 1. Location of studied sites.

Hole	Latitude (N)	Longitude (W)	Water depth (m)
548A	48°54.93'	12°09.87'	1251
549	49°05.28'	13°05.88'	2515
549A	49°05.28'	13°05.88'	2513
550	48°30.91'	13°26.37'	4420
550B	48°30.96'	13°26.32'	4420

HOLE 548A

Early Eocene

The early Eocene from Hole 548A is represented by four samples from Sections 26-6 (69-72 cm) to 23-1 (84-85 cm). The assemblages present in these samples contain a few diagnostic early Eocene species as well as several with longer ranges. In the presence of *Apectodinium quinquelatum*, *Melitasphaeridium asterium*, the *Areoligera senonensis* complex, *Eatonicysta ursulae*, *Dracodinium condylos*, *Adnatosphaeridium robustum*, and *Rhombodinium* spp., the assemblage is similar to Ypresian assemblages found in Belgium (De Coninck, 1980) and Zone LC-2 from the London Clay of south-

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Table 2. Samples processed.

Hole 548A	Hole 549A (cont.)
2-2, 10-12	8-1, 60-61 ^a
2-4, 10-12	9-1, 80-81 ^a
3-1, 74-76	10-1, 70-71
4-2, 80-82	14-1, 39-40 ^a
5-1, 70-72	16-1, 39-40 ^a
6-2, 30-34	18-1, 39-40 ^a
7-1, 50-52	22, CC, 7-8 ^a
8-1, 75-77	24-1, 39-40 ^a
9-1, 87-88	26-1, 80-81 ^a
10-3, 82-83	27-1, 60-61
11-1, 8-9	28-1, 60-61 ^a
11-3, 8-9	32-1, 80-81 ^a
11-5, 8-9	33-1, 70-71 ^a
12-1, 77-78	34-1, 79-80 ^a
13-1, 90-92	35-1, 32-33 ^a
14-1, 52-54	36-1, 8-9 ^a
15-1, 118-119	37, CC 14-15 ^a
16-1, 41-42	38-1, 55-56 ^a
17-1, 60-62 ^a	39-1, 100-101 ^a
18-1, 42-43 ^a	40-1, 80-81 ^a
19-1, 34-36 ^a	41-1, 1-2 ^a
19-5, 36-38 ^a	42-1, 16-18 ^a
20-4, 3-5 ^a	
21-1, 95-96	Hole 550
22-2, 97-99 ^a	13-1, 75-7 ^a
23-1, 83-85	14-1, 103-104 ^a
24-3, 27-29	15-1, 64-66
25-1, 42-43	16-1, 87-89 ^a
26-6, 69-72	17-3, 66-68 ^a
28-7, 34-35 ^a	18-3, 86-88 ^a
29-1, 72-73 ^a	19-1, 120-122 ^a
	20, CC, 18-19 ^a
Hole 549	21-1, 66-67 ^a
2-1, 36-38	22-1, 79-80 ^a
3-1, 8-10	23-1, 24-25 ^a
4-1, 52-54	24-1, 40-44 ^a
5-1, 72-73	24-5, 28-29 ^a
6-1, 69-70 ^a	25-5, 63-65 ^a
7-1, 39-40 ^a	26-1, 52-54
8-1, 80-82 ^a	27-3, 53-55 ^a
9-1, 41-42 ^a	28-3, 57-59 ^a
10-1, 75-76 ^a	29-3, 58-59 ^a
11-1, 102-104 ^a	30-3, 58-59 ^a
12-1, 46-48 ^a	31-1, 60-61 ^a
13-1, 59-61 ^a	32-3, 80-81
14-1, 60-62 ^a	33-3, 66-67 ^a
15-1, 62-63 ^a	34-3, 68-70 ^a
16-1, 60-61 ^a	35-3, 68-70 ^a
17-1, 70-71 ^a	36-1, 57-58 ^a
18-1, 69-70 ^a	37-1, 68-69 ^a
19-1, 35-36 ^a	38-1, 62-63 ^a
20-1, 72-73 ^a	39-1, 82-84 ^a
21-2, 16-17 ^a	39-3, 85-87 ^a
Hole 549A	Hole 550B
4-4, 34-35	2-1, 80-81 ^a
5-1, 130-131	2-2, 77-78 ^a
6-1, 125-126	2-3, 77-78 ^a
7-1, 120-121 ^a	

^a Barren of palynomorphs.

ern England (Bujak et al., 1980). The assemblage is impoverished but similar in some respects to the early Eocene Zone II and III assemblages of Costa and Downie (1979) from the Rockall Plateau. Since so few short-ranging species are present, it is impossible to give a more accurate correlation with onshore sections. It was

assumed that the boundary between the early and middle Eocene occurred in a barren core.

Middle Eocene

Only one sample of probable middle Eocene age (from Section 21-1, 95-96 cm) produced dinocysts. The nannoplankton in this core are the only evidence that allow the core to be dated (NP15; Müller, this volume), since the dinoflagellate cysts were predominantly *Spiniferites ramosus* complex, along with *Hystrichosphaeropsis obscurum* and *Impagidinium* sp., all species with local ranges that extend beyond this particular sample.

All samples taken from Cores 20 to 17 inclusive were found to be barren.

Late Oligocene

The late Oligocene is represented by just one sample from Core 16, Section 1. The few dinoflagellates present showed similarities to the late Oligocene Zone VIIa of Costa and Downie (1979) and Zone IIb of Manum (1976); the latter is thought to be of late Oligocene/early Miocene age. The assemblage from the Goban Spur includes *Impletosphaeridium* sp. I (Manum), *Cannosphaeropsis* sp. A (Costa and Downie), *Operculodinium centrocarpum*, and *Batiacasphaera baculata*.

Early Miocene

Dinocysts from Cores 15 to 13 inclusive are of early Miocene age. The assemblage from Core 15 contains two typical Oligocene forms that die out in the early Miocene, *Distatodinium paradoxum* and *Apteodinium spiridoides*. Several species make their first appearance in Core 15 and continue into the middle and late Miocene. They include *Hystrichokolpoma* sp. A, *Pentadinium latincinctum*, *Spiniferites mirabilis*, cf. *Cordosphaeridium minimum*, and *Achomosphaera crassipellis*.

Comparison with other regions is difficult because of the differences in assemblages. The extinction of *Distatodinium* spp. in the Rockall area (Costa and Downie, 1979) appears to be the only correlatable dinocyst event for the early Miocene. *Nematosphaeropsis* sp. A occurs with a very restricted range at the end of the early Miocene.

Middle Miocene

The first appearance of *Nematosphaeropsis aquaeducta* is considered to be a reliable marker for the early/middle Miocene boundary (Piasecki, 1980). In Hole 548A it appears in Core 12, Section 1, along with "*Thalassiphora delicata*" (Forma A of Costa and Downie). *N. aquaeducta* was found by Piasecki (1980) in the Hodde Formation of Denmark, where it was dated as middle Miocene, and also by Costa and Downie in the Rockall area, where it marked the base of their Zone VIII. Manum (1976) figured it as *Leptodinium* sp. V and gave its age as middle Miocene; it marked the base of his Zone Ia. Other species that appear for the first time in the middle Miocene of the Goban Spur are *Tuberculodinium vancampoae*, *Melitasphaeridium choanophorum*, *Tectatodinium psilatium*, cf. *Pyxidiella scrobiculata*, and *Polysphaeridium* sp. A. (A specimen similar to *Polysphaeridium* sp. A was figured by Piasecki

[1980] as cf. *Cleistosphaeridium ancoriferum*, which had a range throughout the middle and upper Miocene.) The middle Miocene assemblage from the Goban Spur correlates very well with the Danish sequence, and it shows distinct similarities to both the Rockall assemblages from Zone VIII and the Norwegian Sea assemblages from Zone Ia (Manum, 1976). Some similarity exists with the impoverished middle Miocene assemblage described by Harland (1979) from the Bay of Biscay (DSDP Leg 48).

Late Miocene

The middle/late Miocene boundary is marked by the first appearance in Section 11-3 (8-9 cm) of *Amiculasphaera umbracula*, *Achomosphaera andalousiense*, *Lejeunecysta fallax*, and *Selenopemphix nephroides*. Harland (1979) gave the range of *Amiculasphaera umbracula* as late Miocene to early Pleistocene. His quoted range for "*Spiniferites septentrionalis*" (a junior synonym of *Achomosphaera andalousiense*) was from middle late Miocene to Pleistocene. *A. andalousiense* was first described by Jan du Chêne (1977) from the upper Miocene (Andalusian) of southern Spain in an assemblage that has many species in common with the late Miocene assemblages of the present study.

The species composition of the Gram Formation assemblages from Denmark (Piasecki, 1980) is also similar in many ways to that of the late Miocene from the Goban Spur. The first occurrence of *A. andalousiense* at the middle/late Miocene boundary is particularly useful in that it can be correlated with both the present study and that of Harland (1979) from the Bay of Biscay. Harland's late Miocene assemblages are similar in many ways to those of the Goban Spur, but some species that occur in one area are absent from the other.

Other species that occur for the first time in the late Miocene assemblages at Hole 548A are *Impadiginium paradoxum*, *I. striatum*, *I. aculeatum*, *Selenopemphix* spp., *Bitectadodinium tepikiense*, cf. *Quinquecuspis concretum*, cf. *Trinovantedinium capitatum*, and *Achomosphaera* sp. A.

In general, the Miocene sequence from Hole 548A correlates very well with other published data for the European region.

HOLE 549

Only three samples from Hole 549 contained palynomorphs (those from Sections 2-1, 36-38 cm; 4-1, 52-54 cm; and 5-1, 72-73 cm). The assemblages are dominated by the *Spiniferites ramosus* complex and contain no species of diagnostic value in dating.

HOLE 549A

Five samples from Hole 549A produced dinoflagellate cysts. The presence of *Nematosphaeropsis aquaeducta*, *Achomosphaera andalousiense*, and *Amiculasphaera umbracula* suggests that the three productive samples at the top of the hole (in Sections 4-4, 34-35 cm; 5-1, 130-131 cm; and 6-1, 125-126 cm) are of late Miocene age.

Core 10, Section 1, contains a few specimens of an unidentified species of *Michrystridium*. These are the only palynomorphs present, so they do not allow an age to be given.

Core 27, Section 1, is the only other sample that contains dinocysts. However, no diagnostic species were present; only *Spiniferites ramosus* occurs in this sample.

HOLE 550

Hole 550 produced two samples that contained dinocysts. The sample from Section 15-1 (64-66 cm) gave an assemblage that contained *Nematosphaeropsis aqueducta*, *Impadiginium* spp., *Lingulodinium machaerophorum*, *Operculodinium centrocarpum*, and others that indicated a middle Miocene age. Diagnostic late Miocene species were absent.

The other productive sample was in Section 32-3 (80-81 cm). This sample contained a number of species that indicated an early to middle Eocene age: *Dracodinium* sp., *Lentinia wetzeli*, *Deflandrea phosphoritica*, and *Achomosphaera alcornu*.

HOLE 548A: EVIDENCE FROM POLLEN AND SPORES

The pollen, spores, and dinoflagellates in each sample were counted, and the proximity of land was estimated by comparing the percentage of pollen and spores with the percentage of dinoflagellates. Within the total number of pollen and spores for each sample, the relative percentages of three broad groups (gymnosperm pollen, angiosperm pollen, and pteridophyte spores) were also examined.

The samples from the early Eocene are characterized by high percentages of dinoflagellates; the pollen present is mainly gymnosperm pollen. The percentage of angiosperm pollen and pteridophyte spores is very small. The dominance of windborne gymnosperm pollen indicates a distant shoreline.

The record of pollen and spores from the late Oligocene and Miocene shows that the shoreline was generally quite distant. All the samples contain 80% or more dinoflagellates, and there are two peaks in the dinocyst values, one in the middle Miocene and one in the late Miocene. These peaks probably represent major marine transgressions when the shoreline became even more distant. This hypothesis is supported by a drop in the percentage of angiosperm pollen and pteridophyte spores and a rise in the percentage of windborne gymnosperm pollen in the same samples (those from Sections 12-1, 77-78 cm [middle Miocene] and 6-2, 30-34 cm [upper Miocene]).

ENVIRONMENTAL INDICATIONS FROM MIOCENE DINOCYSTS

As a result of work by Reid (1974, 1977), Harland (1977), and Wall et al. (1977), it has become clear that dominant species in a fossil dinocyst assemblage may be used to infer paleoenvironmental conditions. In the present study only the Miocene dinocyst assemblages are considered, because few modern species are found in Paleogene sediments.

The dominant groups through most of the Miocene at Hole 548A are *Spiniferites* spp. and *Achomosphaera* spp. However, during the two transgressive phases inferred from the pollen and spore data outlined above, *Operculodinium centrocarpum* becomes the dominant

component of the assemblage. Reid and Harland (1977) indicated that *Spiniferites* spp. suggested temperate neritic conditions and that *O. centrocarpum* was ubiquitous. However, more recent evidence (R. Harland, pers. comm., 1982) shows that the highest percentages of *O. centrocarpum* in recent sediments are found in the central North Atlantic and Norwegian seas. In the two transgressive phases identified in the present study, *O. centrocarpum* occurs in numbers well above 50% of the total dinoflagellate cyst population. At the same time, *Impagidinium* spp. and *Nematosphaeropsis aquaeducta*, species that have been taken in the past to be indicative of oceanic conditions (Wall et al., 1977), increase in importance.

In the light of this evidence there seems to be little doubt that there were two transgressive phases, one during the early part of the middle Miocene and one in the middle of the late Miocene.

Other genera and species known from modern sediments were recorded from the Miocene of the Goban Spur. For the most part they are considered to be ubiquitous in terms of latitudinal distribution; an exception is *Tuberculodinium vancampoae*, which is known today only from estuaries in tropical and subtropical areas (Wall et al., 1977). Many estuarine species occurred in small numbers in the assemblages, probably as a result of their being flushed from estuaries during floods.

CONCLUSIONS

The dinoflagellate cyst assemblages recovered from the Goban Spur show a close similarity, in terms of species composition, to assemblages previously reported from on- and offshore sites in northwestern Europe (i.e., the Rockall Plateau [Costa and Downie, 1979]; the Norwegian Sea [Manum, 1976]; Denmark [Piasecki, 1980]; Belgium [De Coninck, 1980]; southern England [Bujak et al., 1980], the Bay of Biscay [Harland, 1979], and Spain [Jan du Chêne, 1977]). The Miocene of northern Italy also has many species in common with the Miocene of the Goban Spur (Powell, in press). Of particular interest is a new species of *Nematosphaeropsis* (sp. A in this chapter), which occurs in both areas and becomes extinct at the early/middle Miocene boundary. This species appears to be a good marker for the early Miocene and may have stratigraphic significance in a broader context. Several other new species were found in the present study but occurred in insufficient numbers to warrant description.

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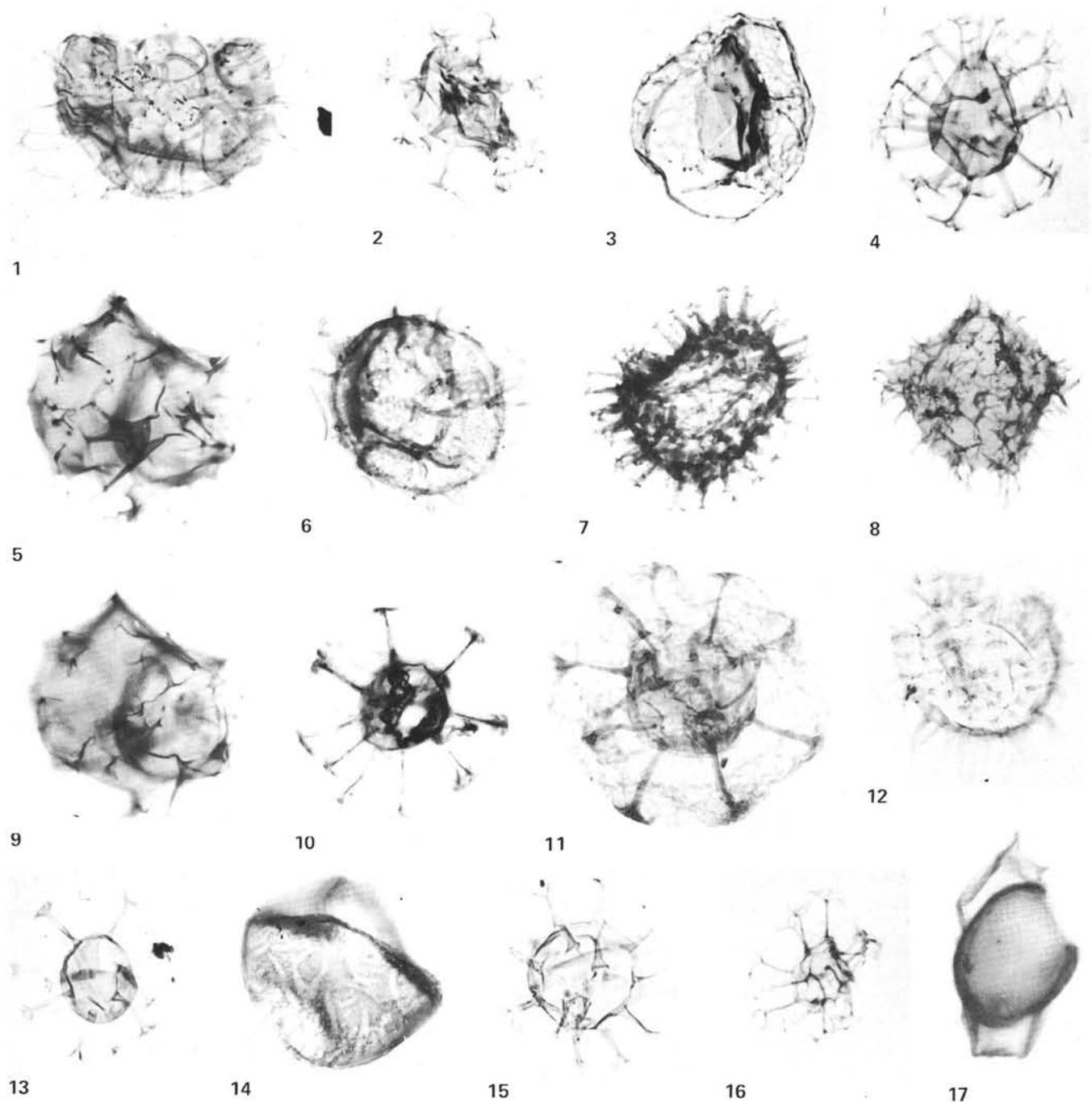


Plate 1. All specimens are from Hole 548A and are magnified $\times 500$. Slide numbers and other identifiers are for the England Finder Reference.

1. *Areoligera senonensis* complex Lejeune-Carpentier; Section 24-3, 27-29 cm; S1, G31/0. 2. *Distatodinium paradoxum* (Brosius) Eaton; Section 15-1, 118-119 cm; S2, S48/4. 3. *Thalassiphora reticulata* Morgenroth; Section 11-1, 8-9 cm; S1, Z34/3. 4. *Achomosphaera andalou-siense* Jan du Chêne; Section 9-1, 87-88 cm; S2, F37/1. 5, 9. *Hystrichostrogylon membraniphorum* Agelopoulos; Section 13-1, 90-92 cm; S3, P29/0. 6. *Dinopterygium cladoideis* Deflandre; Section 23-1, 83-85 cm; S2, Q41/4. 7. *Polysphaeridium* sp. A; Section 2-2, 10-12 cm; SB, M48/1. 8. *Apectodinium quinquelatum* (Williams and Downie) Lentin and Williams; Section 26-6, 69-71 cm; S1, U35/2. 10. *Melitasphaeridium asterium* Eaton; Section 26-6, 69-71 cm; P39/0. 11. *Eatonicysta ursulae* (Morgenroth) Stover and Evitt; Section 25-1, 42-43 cm; S2, F37/0. 12. *Lingulodinium machaerophorum* (Deflandre and Cookson) Wall; Section 2-2, 10-12 cm; SB, V35/4. 13. *Melitasphaeridium choanophorum* (Deflandre and Cookson) Harland and Hill; Section 9-1, 87-88 cm; S4, M35/0. 14. *Apteodinium spiridoides* Benedek; Section 15-1, 118-119 cm; S1, V46/4. 15. *Achomosphaera ramulifera* (Deflandre) Evitt; Section 11-3, 8-9 cm; S2, L43/4. 16. *Impletosphaeridium* sp. I (Manum); Section 15-1, 118-119 cm; S2, T38/3. 17. *Hystrichosphaeropsis ovum* Deflandre; Section 23-1, 83-85 cm; S2, V39/0.

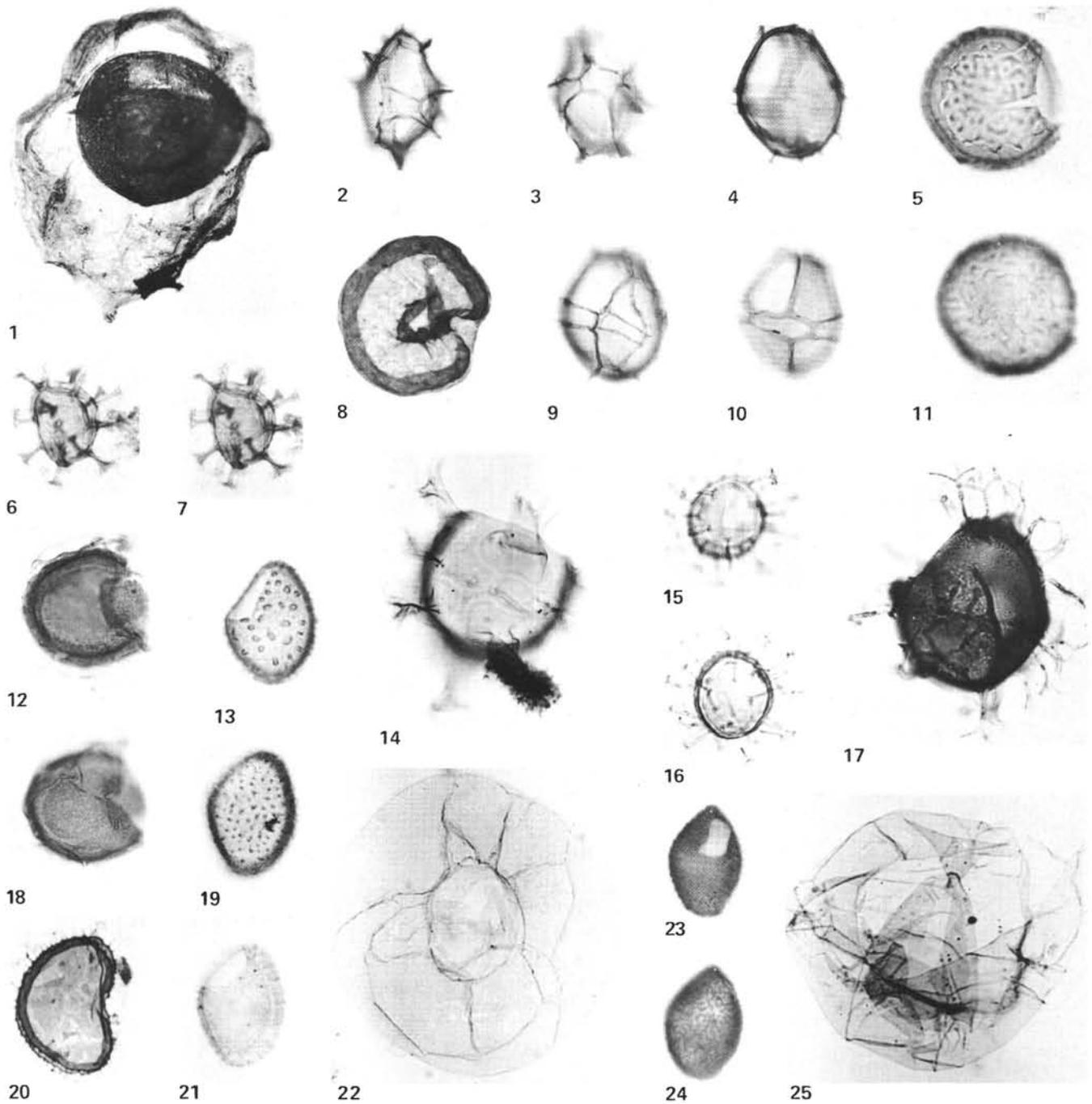


Plate 2. All specimens are from Hole 548A and are magnified $\times 500$ unless stated otherwise. Slide numbers and other identifiers are for the England Finder Reference. 1. *Thalassiphora pelagica* (Eisenack) Eisenack and Gocht ($\times 350$); Section 25-1, 42-43 cm; S2, N29/2. 2, 3. *Impagidinium aculeatum* (Wall) Stover and Evitt; Section 4-2, 80-82 cm; S2, L31/0. 4, 9, 10. *Impagidinium* cf. *paradoxum* (Wall) Stover and Evitt; Section 15-1, 118-119 cm; S4, L37/2. 5, 11. *Cerebrocysta bartonensis* Bujak et al.; Section 24-3, 27-29 cm; S1, U47/0. 6, 7. cf. *Cordosphaeridium minimum* (Morgenroth) Benedek; Section 15-1, 118-119 cm. 8. Cyst of *Protoperidinium* sp. indet.; Section 2-2, 10-12 cm; S1, H34/0. 12, 18. *Pentadinium laticinctum* Gerlach; Section 15-1, 118-119 cm; S3, E42/2. 13. cf. *Pyxidiella* sp.; Section 2-2, 10-12 cm; SB, T49/4. 14. *Hystrichokolpoma* sp.; Section 15-1, 118-119 cm; S4, E39/0. 15, 16. *Melitasphaeridium* cf. *pseudorecurvatum*; Section 2-2, 10-12 cm; SB, T56/3. 17. *Achomosphaera sagena* Davey and Williams; Section 2-2, 10-12 cm; SC, P38/3. 19, 21. *Pyxidiella* cf. *scrobiculata* (Deflandre and Cookson) Cookson and Eisenack; Section 7-1, 50-52 cm; S1, P35/0. 20. *Selenopemphix* sp. A; Section 2-2, 10-12 cm; E50/1. 22. "*Thalassiphora delicata*" Williams and Downie; Section 2-2, 10-12 cm; SB, L46/4. 23, 24. cf. *Pyxidiella* sp.; Section 2-2, 10-12 cm; S3, E55/2. 25. *Amiculosphaera umbracula* Harland; Section 2-2, 10-12 cm; SC, P57/3.

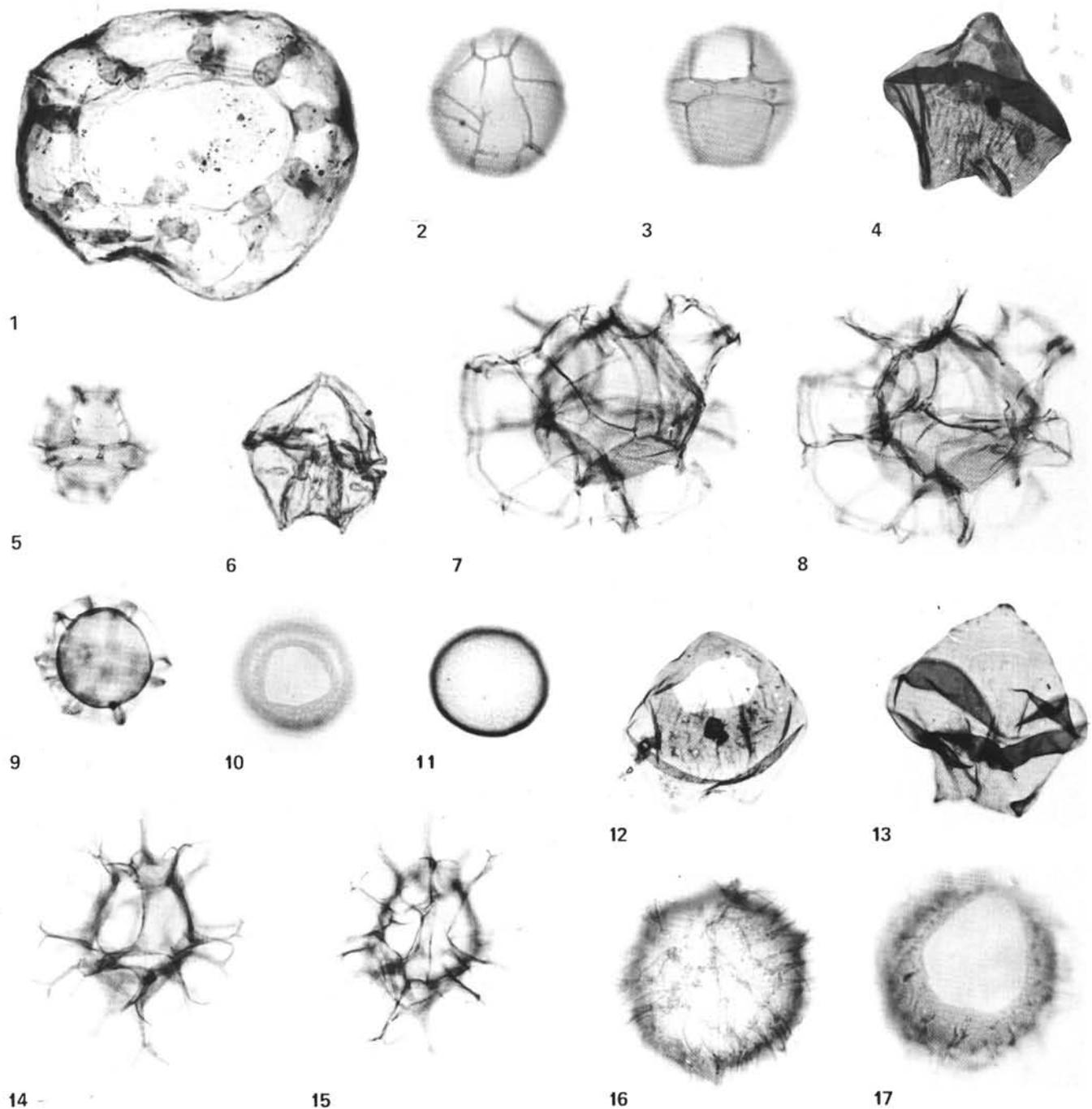


Plate 3. All specimens are from Hole 548A (unless stated otherwise) and are magnified $\times 500$. Slide numbers and other identifiers are for the England Finder Reference. 1. *Tuberculodinium vancampoae* (Rosignol) Wall emend. Wall and Dale; Section 11-3, 8-9 cm; S2, P35/1. 2, 3. *Impagidinium patulum* (Wall) Stover and Evitt; Section 4-2, 80-82 cm; S3, T37/1. 4. cf. *Quinquecuspid concretionum* Harland; Section 9-1, 87-88 cm; S4, J41/0. 5, 9. *Nemosphaeropsis aquaeducta* Piasecki; Hole 549A; Section 6-1, 125-126 cm; S1, P47/0. 6. *Lejeunia fallax* Morgenroth; Section 9-1, 87-88 cm; S4, E42/0. 7, 8. *Nemosphaeropsis* sp. A; Section 14-1, 52-54 cm; S2, U32/1. 10, 11. *Tectatodinium pellitum* Wall; Section 2-2, 10-12 cm; SB, X42/0. 12. cf. *Quinquecuspid concretionum* Harland, Section 9-1, 87-88 cm; S2, J36/2. 13. Protoperidinoid cyst gen. et sp. indet.; Section 11-3, 8-9 cm; S2, N40/0. 14, 15. *Spiniferites ramosus* (Ehrenberg) Loeblich and Loeblich; Section 14-1, 52-54 cm; S1, N30/0. 16, 17. *Operculodinium centrocarpum* (Deflandre and Cookson) Wall; Section 2-2, 10-12 cm; SB, N56/2.

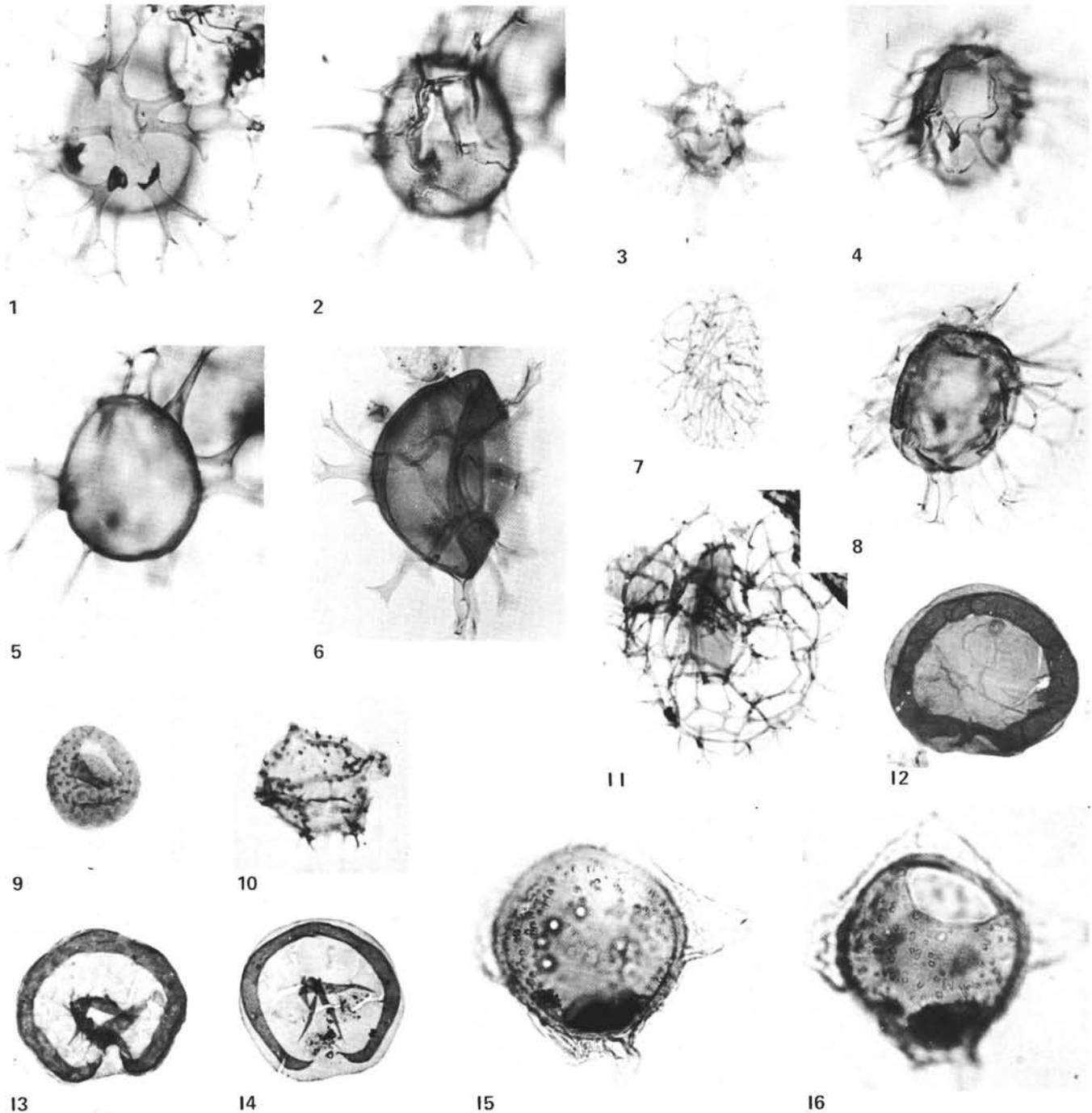


Plate 4. All specimens are from Hole 548A and are magnified $\times 500$. Slide numbers and other identifiers are for the England Finder Reference. 1, 2, 5. *Achomosphaera* sp. A; Section 2-2, 10-12 cm; SB, M54/0. 3. *Hystrichokolpoma* sp. A; Section 14-1, 52-54 cm; S1, N33/0. 4, 8. *Spiniferites mirabilis* (Rossignol) Sarjeant; Section 2-2, 10-12 cm; SB, M40/3. 6. *Spiniferites pseudofurcatus* (Klumpp) Sarjeant; Section 14-1, 52-54 cm; S1, L30/0. 7. *Cannosphaeropsis* sp. A (Costa and Downie); Section 15-1, 118-119 cm; S3, 033/1. 9. Gen. et sp. indet.; Section 14-1, 52-54 cm; S1, H34/0. 10. Gen. et sp. indet.; Section 11-3, 8-9 cm; S1, L44/0. 11. *Cannosphaeropsis utinensis* Wetzel; Section 5-1, 70-72 cm; S1, J32/0. 12. *Selenopemphix nephroides* Benedek; Section 5-1, 70-72 cm; S1, M32/3. 13. Cyst of *Protoperidium* sp. indet.; Section 11-3, 8-9 cm; S2, H35/4. 14. *Selenopemphix nephroides* Benedek; Section 2-2, 10-12 cm; SB, L45/1. 15, 16. *Dracodinium condylos* (Williams and Downie) Bujak et al.; Section 25-1, 42-43 cm; S3, H47/1.