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19. A PRELIMINARY REPORT OF EARLY CRETACEOUS DINOCYST FLORAS FROM SITE 765, ARGO ABYSSAL PLAIN, NORTHWEST AUSTRALIA[1]

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ABSTRACT

Results of a preliminary study of Early Cretaceous dinocyst assemblages from Site 765 on the Argo Abyssal Plain, off northwestern Australia, are presented. The palynological sequence is interpreted in terms of Australian zones and is, in descending order, the late Aptian *Diconodinium davidii* Zone (Cores 123-765C-33R to -39R), the middle to early Aptian *Odontochitina operculata* Zone (Cores 123-765C-40R to -49R), the Barremian *Muderongia australis* Zone (Cores 123-765C-50R to -54R), and the Berriasian lower *Batioladinium reticulatum* Zone (Core 123-765C-59R). The dating of the sequence as late Aptian to Berriasian on the basis of dinocysts is supported, in part, by data concerning associated foraminiferal, radiolarian, and calcareous nannofossil suites.

INTRODUCTION

Well-preserved, variably diverse, Early Cretaceous dinoflagellate cyst (dinocyst) assemblages were recovered from Site 765 of Leg 123. This site was located on marine magnetic anomaly M26 on the Argo Abyssal Plain, approximately 400 km north of Port Hedland, at 15°58.541′S, 117°34.495′E (Fig. 1), in a water depth of 5728.5 m. The sedimentary sequence at Site 765 is presented in Figure 2. Although Neogene dinocysts were recorded at higher levels (McMinn, this volume), attempts to recover dinocysts from intervening samples were unsuccessful. The dinocyst associations have been interpreted in terms of the zonation outlined by Helby et al. (1987).

Wiseman and Williams (1974), in the only published report of dinocysts from the Argo Abyssal Plain, recorded Barremian and Aptian assemblages at Site 261, referable to the interval between the lower *Muderongia australis* and lower *Odontochitina operculata* zones. Helby et al. (1987) summarized relevant Australian dinoflagellate studies prior to 1987. Backhouse (1988) published a major study of Late Jurassic to Early Cretaceous palynology of the Perth Basin, Western Australia, while Ingram and Morgan (1988) reviewed the development and status of Mesozoic palynostratigraphy of the Australian Northwest Shelf, and Islam (1988) discussed aspects of a Rhaetian to Barremian sequence in the Beagle and Dampier sub-basins, off Western Australia.

MATERIALS AND METHODS

Twenty-six samples were selected for study on the basis of relative palynomorph productivity and position, although some specimens from unreported samples are illustrated. Location details are given in Figure 2. The samples were processed by conventional techniques on board the Resolution. Preliminary interpretation of the samples was undertaken during the cruise by McMinn. Quantitative data are based on rapid counts of 200 specimens (or lesser available number; by McMinn). Helby recorded assemblage data. The strew mounts are deposited in the collections of the Geological Survey of New South Wales. Single-grain mounts have been retained (by Helby) pending further study.

BIOSTRATIGRAPHY

Diconodinium davidii Zone

Samples from Cores 123-765C-33R-1 to -39R-CC yielded extremely low to low numbers of palynomorphs. In Core 123-765C-34R, spores and pollen dominated the palynomorph suites, while microplankton dominated Cores 123-765C-33R, -765C-35R, and -765C-39R. Dinocyst diversity was variable and ranged from 9 to 48 species (Table 1). Samples were characterized by the common to abundant occurrence of *Diconodinium davidii*, with relatively common *Dingodinium cerviculum* and *Rhombodella paucispina*. Significant accessory species included *Ascodinium* sp. A, which occurs throughout and commonly constitutes a distinctive lower acme subzone of the *D. davidii* Zone in sequences elsewhere on the Australian Northwest Shelf. *Canninginopsis intermedia* has not been recorded previously at this level. *Spiniferites* content ranged from 2.5% to 4.5%. An extremely meager dinocyst association in Core-123-765C-39R-CC contained several specimens of *Diconodinium davidii* and more numerous Ascodinium sp. A. In view of the extremely low palynomorph recovery, the assignment to the *D. davidii* Zone was tentative. Jurassic reworking was evident in samples from Cores 123-765C-37R and -39R.

Odontochitina operculata Zone

Samples from Cores 123-765C-40R-4 to -49R-CC yielded low-to-moderate numbers of palynomorphs, dominated by microplankton (up to 99%). Diversity of the dinocyst suites was variable (18–73 species). Samples were characterized by the relatively consistent occurrence of the eponymous species and the apparent absence of *Ascodinium* sp. A, *Diconodinium davidii*, and *Pseudoceratium turneri*. *Muderongia macwhaei* formed a distinctive subzone in the lower part of the interval, similar to those from the Carnarvon Basin. A *Batiacasphaera subtilis* plexus is intermittently dominant, while a *Leptodinium* acme occurred in the middle-to-lower part of the zone. *Epitricysta vinckensis* and *Herendeenia postprojecta* occurred in the lower part of the zone. Late Jurassic reworking was prominent in Cores 123-765C-45R and -49R.

The *Ovoidinium cinctum* Zone (Helby et al., 1987) was not sampled.

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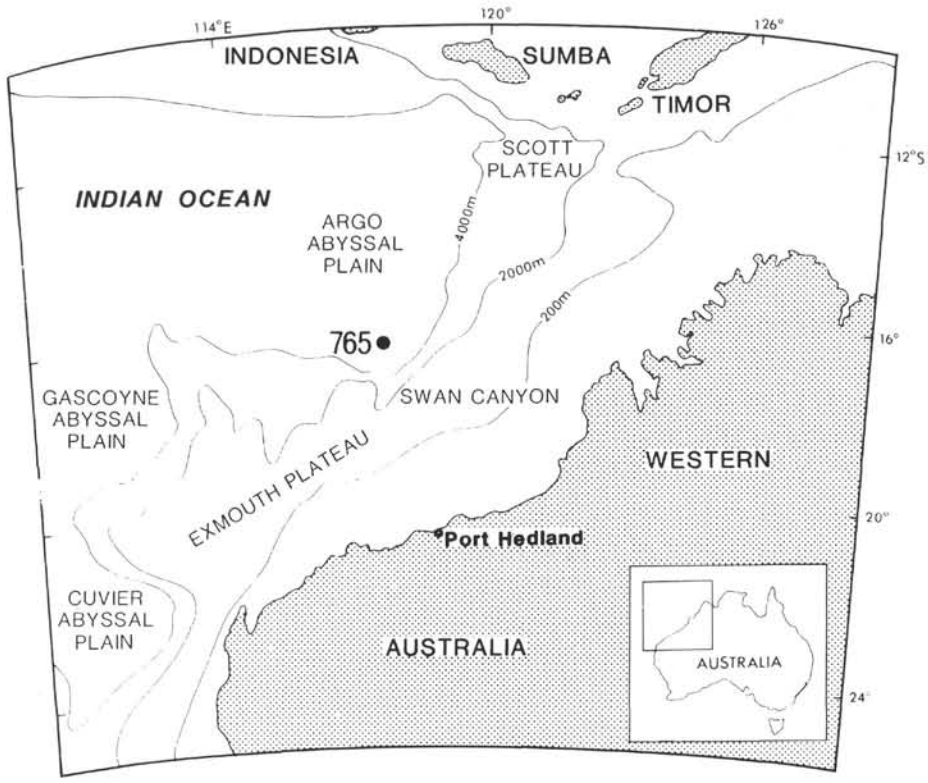

Figure 1. Location of Site 765.

Muderongia australis Zone

Samples from Cores 123-765C-50R-CC to -54R-CC yielded low-to-moderate palynomorph numbers. The palynomorph suites were completely dominated by relatively diverse microplankton associations (Table 1). The dinocyst assemblages were characterized by the occurrence of the eponymous species, with relatively consistent *Belodinium dysculum, Circulodinium deflandrei, Cribroperidinium aparsium, Dingodinium cerviculum, Dissiliodinium* sp. A, *Herendeenia postprojecta,* and *Impagidinium phlyctaena.* A *Batiacasphaera imperfecta* plexus acme and a *Cribroperidinium*(?) sp. cf. *C. asarotum* acme occurred in the upper part of the zone, while *Dissiliodinium* sp. A was abundant in the middle part of the zone. The occurrence of *Phoberocysta neocomica* in Core 123-765C-54R indicated that the associations are at least as old as the lower part of the zone. However, the apparent absence of twin-horned muderongoids, *Gardodinium lowii* and *Senoniasphaera tabulata,* suggested that these lower samples were not as old as the Hauterivian *Muderongia testudinaria* Zone. Jurassic reworking was noted in residues from Core 123-765C-54R. Core 123-765C-58R-2 yielded an extremely meager, almost monospecific, palynomorph residue of *Kaiwaradinium scrutillinum,* suggesting that it is no older than mid-Valanginian.

Lower *Batioladinium reticulatum* Zone

Samples from Cores 123-765C-59R-4 and -59R-5 yielded meager palynomorph residues. High-diversity microplankton suites dominated the residues (Table 1). The dinocyst associations were assigned to the lower zonule of the *B. reticulatum* Zone on the basis of the occurrence of the eponymous species with *Dissimulidinium lobispinosum.* Significant accessory species included *Aldorfia*(?) sp. A, *Egmontodinium torynum,* and *Kleithriasphaeridium fasciatum.* The occurrence of *Wanaea* species is evidence of reworking of Kimmeridgian to Callovian sediments, while the occurrence of *Dingodinium cerviculum* and *Gardodinium attenuatum* indicated downhole contamination of the samples.

DISCUSSION

Summary details are presented in Table 1. Dating of the dinoflagellate zones (adapted from Helby et al., 1987) is outlined together with data from calcareous nannofossil, radiolarian, and foraminiferal studies. The distribution of selected taxa in the samples is presented in Table 2. The distal position of Site 765 in relation to the Early Cretaceous basins of northwestern Australia provides an opportunity for testing quantitative variations in the zones.

The late Aptian *Diconodinium davidii* Zone occurred in lithologic Unit IV (von Rad et al., 1989, Fig. 9), which was predominantly claystone with turbiditic carbonates, nannofossil chalk, and zeolitic claystone; the samples were taken from medium to dark gray claystone beds. The palynomorph suites were characterized by variable ratios of microplankton to spores and pollen (1:5 to 4:1). Reworking was evident throughout this interval. In the Timor Sea region, the major part of the Aptian is supercondensed, sedimentation recommencing with deposition of radiolarian-rich sediments characterized by the *D. davidii* Assemblage (lower Jamieson Formation of Pattillo and Nicholls, 1990). In the Carnarvon Basin, the zone is associated with the Windalia Radiolarite (Hocking et al., 1987, p. 151).

The middle to early Aptian *Odontochitina operculata* Zone occupies the upper part of lithologic Unit V, which was predominantly claystone with rhodochrosite and radiolarite; samples were collected from medium to dark gray and black claystone horizons. All samples were dominated by microplankton (Table 1). The associations were characterized by major abundances of taxa not encountered in these numbers in more proximal depositional locations (*Batiacasphaera* and *Leptodinium*). An apparent inverse relationship exists between the numbers of *Spiniferites* and the microplankton to spore/pollen ratio, which may reflect an

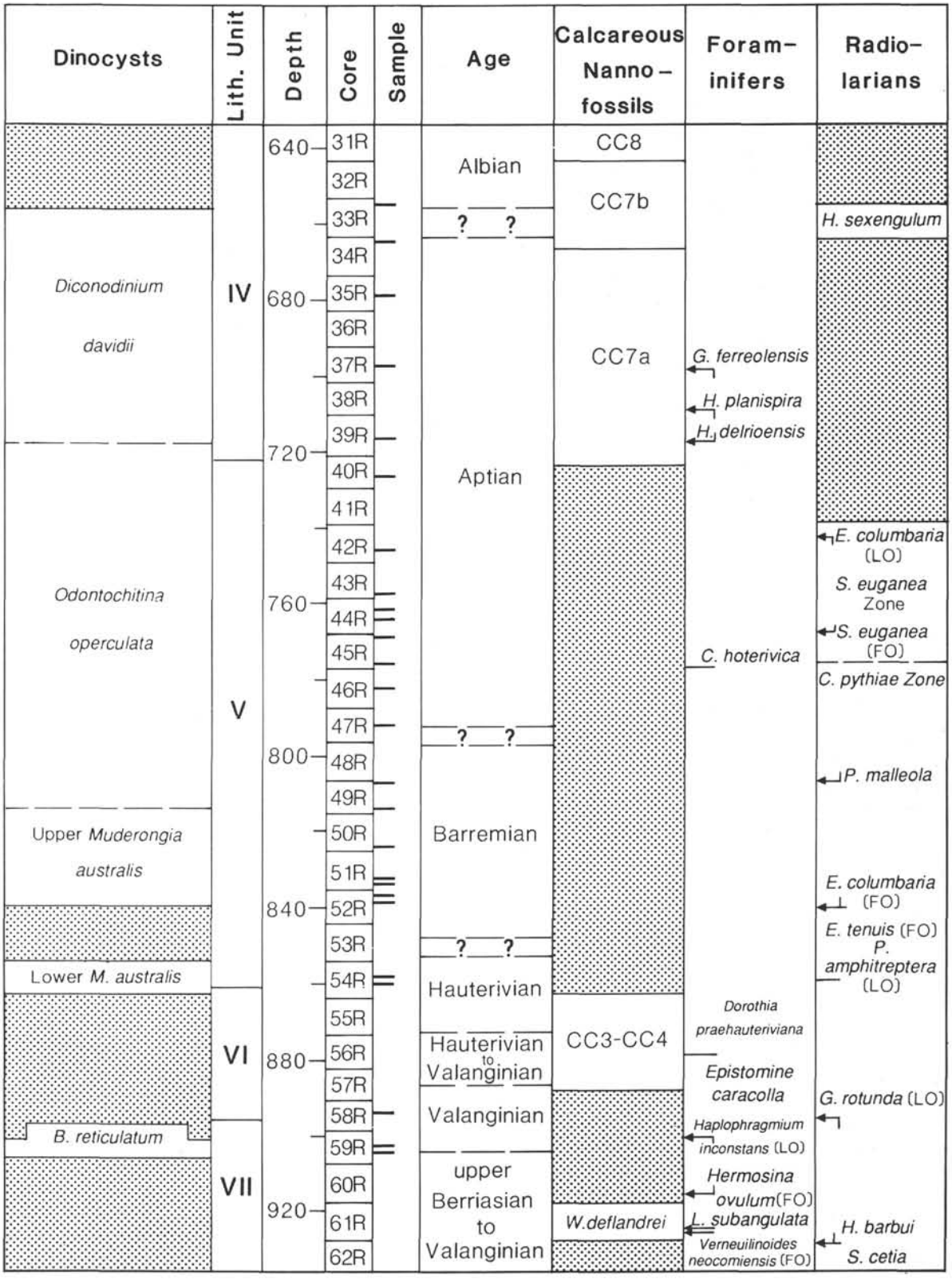

Figure 2. Early Cretaceous biostratigraphy at Site 765.

Table 1. Palynological summary.

Core, section, interval (cm)	Palynomorph yield	Counts (1)	(2)	(3)	Zone
123-765C-33R-1, 38-40	Very low	3:1	38	11%	*Diconodinium davidii*
34R-1, 130-132	Low	1:5	37	2.5%	*Diconodinium davidii*
[a]35R-CC	Moderate	4:1	48	4.5%	*Diconodinium davidii*
37R-CC	Ext. low	1:1	10	2 %	Indeterminate
39R-CC1	Ext. low	2:1	9	—	*Diconodinium davidii*
[a]40R-4, 138-140	Moderate	19:1	37	1.5%	*Odontochitina operculata*
42R-2, 117-119	Low	3:1	21	19%	*Odontochitina operculata*
43R-1, 111-112	Low	19:1	25	5%	*Odontochitina operculata*
43R-CC	Low	4:1	35	7%	*Odontochitina operculata*
44R-1, 100-102	Moderate	49:1	42	1%	*Odontochitina operculata*
44R-CC	Low	9:1	20	1%	*Odontochitina operculata*
[a]45R-1, 12-14	Moderate	19:1	31	3%	*Odontochitina operculata*
45R-CC	Very low	16:1	31	1%	*Odontochitina operculata*
47R-3, 39-40	Low	99:1	18	0.5%	*Odontochitina operculata*
49R-1, 125-126	Low	4:1	73	10.5%	*Odontochitina operculata*
49R-CC	Very low	9:1	32	2.5%	*Odontochitina operculata*
[a]50R-CC	Low	99:1	28	0.5%	*Muderongia australis*
[a]51R-5, 106-107	Low	19:1	39	2%	*Muderongia australis*
51R-CC	Moderate	99:1	23	0.5%	*Muderongia australis*
52R-1, 150-151	Moderate	6:1	37	1%	*Muderongia australis*
52R-2, 36-40	Low	9:1	43	7.5%	*Muderongia australis*
[a]54R-4, 49-50	Low	99:1	35	Tr	Lower *M. australis*
54R-CC	Low	49:1	18	—	Lower *M. australis*
58R-2, 14-19	Ext. low	NR	3	—	Indeterminate
59R-4, 105-112	Low	9:1	76	Tr	Lower *Batioladinium reticulatum*
123-765C-59R-5, 8-9	Low	4:1	47	Tr	*Batioladinium reticulatum* or older

[a] Single species mounts prepared. Counts: (1) microplankton to spores/pollen ratio; (2) microplankton diversity (s.l.); (3) *Spiniferites* as proportion of microplankton. NR = not recorded; Tr = trace.

increase in the number of taxa introduced from more proximal locations by turbidity flow. The *O. operculata* Zone is commonly obscured by a supercondensed section in the Timor Sea region. The zone occurs in the Muderong Shale in the Carnarvon Basin, where it exhibits much higher spore/pollen to microplankton ratios and is associated with substantial vascular plant debris, reflecting more proximal depositional locations.

The Barremian *Muderongia australis* Zone occupies the lower part of lithologic Unit V (Fig. 2, see also von Rad et al., 1989, Fig. 9). The lithology is predominantly claystone with minor radiolarite; samples were collected from green-gray, medium to dark gray and black claystone intervals. The palynomorph suites were totally dominated by moderately diverse microplankton associations (Table 1). Acmes of *Batiacasphaera* and *Cribroperidinium* sp. cf. *C. asarotum* occurred in the upper part of the zone. The *Muderongia australis* Zone occurs in the upper part of the lower member of the Darwin Formation (Hughes, 1978) and in the Echuca Shoals Formation (Pattillo and Nicholls, 1990) in the Timor Sea region, as well as the lower part of the Muderong Shale in the Carnarvon Basin.

The Berriasian lower part of the *Batioladinium reticulatum* Zone was encountered in Cores 123-765C-59R-4 and -59R-5, which are located in the upper part of lithologic Unit VII. The lithology is predominantly brown-red silty claystone, and samples were taken from thin intercalations of dark gray claystone. The palynomorph residues were dominated by diverse microplankton suites, with evidence of Jurassic reworking. Rare specimens of taxa, not known to extend below the middle to late Valanginian *Senoniasphaera tabulata* Zone (not recorded in Hole 765C), were encountered in the samples. These are considered to represent downhole contamination. The alternative proposition, that the relatively abundant representation from the *B. reticulatum* Zone is reworked, is considered unlikely. The *B. reticulatum* Zone occurs only rarely in the Timor Sea region, where it was not deposited, has been removed, or is obscured by a supercondensed sequence. This zone has been identified recently in a well in the Arafura Sea. Over much of the Carnarvon Basin, the zone occurs in the upper Barrow Group and exceeds 650 m in some wells.

CONCLUSIONS

The Early Cretaceous palynological sequence in Hole 765C resembles sequences in the coastal margin basins of the Australian Northwest Shelf. The sequence is, in descending order, the late Aptian *Diconodinium davidii* Zone (Cores 123-765C-33R to -39R), the middle to early Aptian *Odontochitina operculata* Zone (Cores 123-765C-40R to -49R), the Barremian *Muderongia australis* Zone (Cores 123-765C-50R to -54R), and the Berriasian lower *Batioladinium reticulatum* Zone (Core 123-765C-59R). Only a few dinocyst species have not been recorded previously on the Northwest Shelf. The quantitative distribution of taxa in Hole 765C, particularly below the late Aptian, was not encountered in the marginal basins and possibly reflects the extreme distal locus of deposition. The ages assigned to the dinocyst zones by Helby et al. (1987) are essentially supported by dating from other fossil groups (Fig. 2).

ACKNOWLEDGMENTS

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APPENDIX
Species List

Achomosphaera? neptuni (Eisenack, 1954) Davey and Williams, 1966
Adnatosphaeridium tutulosum (Cookson and Eisenack, 1960) Morgan, 1980
Aldorfia deflandrei (Clark and Verdier, 1967) Stover and Evitt, 1978
Angustidinium acribes (Davey and Verdier, 1971) Goodman and Evitt, 1981
Aprobolocysta galeata Backhouse, 1987
Apteodinium granulatum Eisenack, 1958
Apteodinium maculatum Eisenack and Cookson, 1960
Batiacasphaera imperfecta Stover and Helby, 1987
Batiacasphaera scrobiculata (Deflandre and Cookson, 1955) Burger, 1980
Batiacasphaera subtilis Stover and Helby, 1987
Batioladinium jaegeri (Alberti, 1961) Brideaux, 1975
Batioladinium longicornutum (Alberti, 1961) Brideaux, 1975
Batioladinium micropodum (Eisenack and Cookson, 1960) Brideaux, 1975
Batioladinium reticulatum Stover and Helby, 1987
Belodinium dysculum Cookson and Eisenack, 1960
Broomea simplex Cookson and Eisenack, 1958
Callaiosphaeridium asymmetricum Davey and Williams, 1966
Canningia reticulata Cookson and Eisenack, 1960 emend. Helby, 1987
Canninginopsis intermedia Morgan, 1980
Canninginopsis tabulata (Davey and Verdier, 1974) Duxbury, 1977
Carpodinium granulatum Cookson and Eisenack, 1962
Cassiculosphaeridia magna Davey, 1974
Cassiculosphaeridia reticulata Davey, 1969
Cernicysta helbyi (Morgan, 1980) Stover and Helby, 1987
Chichaouadinium boydii (Morgan, 1980) Bujak and Davies, 1983
Chlamydophorella nyei Cookson and Eisenack, 1958
Chytroeisphaeridia chytroeides (Sarjeant, 1962) Downie and Sarjeant, 1965 emend. Davey, 1979
Circulodinium colliveri (Cookson and Eisenack, 1960) Helby, 1987
Circulodinium deflandrei Alberti, 1961
Circulodinium hirtellum Alberti, 1961
Cleistosphaeridium ancoriferum (Cookson and Eisenack, 1960) Davey et al., 1966 emend, Cookson and Eisenack, 1968
Codoniella campanulata (Cookson and Eisenack, 1960) Downie and Sarjeant, 1965
Cometodinium? whitei (Deflandre and Courteville, 1939) Stover and Evitt, 1978
Coronifera oceanica Cookson and Eisenack, 1958
Cribroperidinium aparsium Stover and Helby, 1987
Cribroperidinium asarotum Stevens, 1987
Cribroperidinium edwardsii (Cookson and Eisenack, 1958) Davey, 1969
Cribroperidinium leedervillense Backhouse, 1988
Cribroperidinium muderongense (Cookson and Eisenack, 1958) Davey, 1969
Dapsilidinium warrenii (Habib, 1976) Lentin and Williams, 1981
Diconodinium davidii Morgan, 1975
Diconodinium pusillum Singh, 1971
Dingodinium cerviculum Cookson and Eisenack, 1958
Dingodinium jurassicum Cookson and Eisenack, 1958
Dissimulidinium lobispinosum May et al., 1987
Dollidinium sinuosum (Cookson and Eisenack, 1960) Helby and Stover, 1987
Egmontodinium torynum (Cookson and Eisenack, 1960) Davey, 1979
Elytrocysta circulata (Clarke and Verdier, 1967) Stover and Helby, 1987
Epelidosphaeridia colligata (Morgan, 1980) Lentin and Williams, 1985
Epitricysta vinckensis Stover and Helby, 1987
Exiguisphaera phragma Duxbury, 1979
Exochosphaeridium arnace Davey and Verdier, 1973
Exochosphaeridium phragmites Davey et al., 1966
Exochosphaeridium robustum Backhouse, 1988
Eyrea nebulosa Cookson and Eisenack, 1971
Fibradinium variculum Stover and Helby, 1987
Florentinia mantellii (Davey and Williams, 1966) Davey and Verdier, 1973
Fromea amphora Cookson and Eisenack, 1958
Fromea monilifera Backhouse, 1987
Gardodinium attenuatum Stover and Helby, 1987
Gardodinium lowii Backhouse, 1987
Gonyaulacysta helicoidea (Eisenack and Cookson, 1960) Sarjeant, 1960
Gonyaulacysta jurassica (Deflandre, 1938) Norris and Sarjeant, 1965
Hapsocysta peridictya (Eisenack and Cookson, 1960) Davey, 1979
Herendeenia postprojecta Stover and Helby, 1987
Heslertonia striata (Cookson and Eisenack, 1960) Norvick, 1976
Hystrichosphaeridium pachydermum Cookson and Eisenack, 1960
Hystrichosphaeridium petilum Gitmez, 1970
Impagidinium phlyctaena Stover and Helby, 1987
Kaiwaradinium scrutillinum Backhouse, 1987
Kallosphaeridium norvickii Burger, 1980
Kiokansium polypes (Cookson and Eisenack, 1962) Below, 1982
Kleithriasphaeridium fasciatum (Davey and Williams, 1966) Davey, 1974
Kleithriasphaeridium simplicispinum (Davey and Williams, 1966) Davey, 1974
Leptodinium asymmetricum Morgan, 1980
Leptodinium eumorphum (Cookson and Eisenack, 1960) Sarjeant *in* Davey et al., 1969
Leptodinium pinnosum Davey, 1988
Leptodinium simplex Burger, 1980
Leptodinium tunellum Stover and Helby, 1987
Meiourogonyaulax maculata Backhouse, 1988
Meiourogonyaulax stoveri Millioud, 1969
Meiourogonyaulax sp. B - Helby et al., 1987
Muderongia australis Helby, 1987
Muderongia macwhaei Cookson and Eisenack, 1958
Muderongia tetracantha (Gocht, 1957) Alberti, 1961
Occisucysta tenuiceras (Eisenack, 1958) Below, 1981
Odontochitina operculata (Wetzel, 1933) Deflandre and Cookson, 1955
Oligosphaeridium anthophorum (Cookson and Eisenack, 1958) Davey, 1969
Oligosphaeridium asterigerum (Gocht, 1959) Davey and Williams, 1966
Oligosphaeridium complex (White, 1842) Davey and Williams, 1966
Oligosphaeridium poculum Jain, 1977
Oligosphaeridium pulcherrimum (Deflandre and Cookson, 1955) Davey and Williams, 1966
Palaeoperidinium cretaceum Pocock, 1962
Phoberocysta neocomica (Gocht, 1957) Millioud, 1969 emend. Helby, 1987
Platycystidia eisenackii (Mehrotra and Sarjeant, 1984) Backhouse, 1988
Prolixosphaeridium inequiornatum Stover and Helby, 1987
Prolixosphaeridium parvispinum (Deflandre, 1937) Davey et al., 1969
Protoellipsodinium densispinum Morgan, 1980
Pseudoceratium turneri Cookson and Eisenack, 1958
Pterospermella aureolata (Cookson and Eisenack, 1958) Eisenack, 1972
Pterospermella australiensis (Deflandre and Cookson, 1955) Eisenack and Cramer, 1973
Pyxidiella tumida Stover and Helby, 1987

Pyxidinopsis challengerensis Habib, 1976
Rhombodella paucispina (Alberti, 1961) Duxbury, 1980
Rigaudella aemula (Deflandre, 1938) Below, 1982
Schizocystia laevigata Cookson and Eisenack, 1962
Scriniodinium attadalense (Cookson and Eisenack, 1958) Eisenack, 1967
Scriniodinium? *campanula* Gocht, 1959
Senoniasphaera ptomatis Helby, May and Partridge *in* Helby, 1987
Senoniasphaera tabulata Backhouse and Helby *in* Helby, 1987
Sirmiodinium grossii Alberti, 1961
Systematophora areolata Klement, 1960
Systematophora palmula Davey, 1982
Tanyosphaeridium boletus Davey, 1974
Trichodinium castanea (Deflandre, 1935) Clarke and Verdier, 1967
Tubotuberella vlamingii Backhouse, 1987
Wallodinium krutzschii (Alberti, 1961) Habib, 1972
Wallodinium luna (Cookson and Eisenack, 1960) Lentin and Williams, 1973
Yalkalpodinium scutum Morgan, 1980

Full details of the citations can be found in Lentin and Williams (1989).

Table 2. Distribution of selected taxa at Hole 765C/D.

Core no.:	33R	34R	35R	37R	39R	40R	42R	42R	43R	44R	44R	45R	45R	47R	49R	49R	50R	51R	51R	52R	52R	54R	54R	58R	59R	59R
Section:	1	1	CC	CC	CC	4	2	CC	1	CC	1	CC	1	CC	3	1	CC	CC	5	CC	1	2	4	CC	2	4	5
Species																											
Achomosphaera(?) *neptuni*								X			X						X									X	X
Adnatosphaeridium tutulosum			X																								
Aldorfia deflandrei						X										X										X	X
Aldorfia(?) sp. A																X			X							F	X
Angustidinium acribes		X					X																				
Aprobolocysta(?) *galeata*																X	X		X		X	X				X	
Apteodinium granulatum	X	X	R			F		R		X	X		X			F		X		X		X	X			A	A
Apteodinium maculatum			X													R	X	X				X	X				
Ascodinium sp. A	X	R	X		F																						
Ascodinium(?) sp. A			X																								
Avellodinium spp.												X					X									F	R
Batiacasphaera imperfecta plexus						R	R	R	X	X	F	F	R	F	X	X	A	A	R	F	F	R	X	C			
Batiacasphaera scrobiculata								R																			
Batiacasphaera subtilis plexus						A	C	A	F	X	C	C	R	R	A	X	C	F		X	R	R	C	C		F	R
Batiacasphaera sp.A																										X	
Batiacasphaera spp.		X		F	R	X	X	X	X	X			X	X	X		X	X	X	X	X	X	X			X	X
Batioladinium jaegeri						X					X					X											
Batioladinium longicornutum						X					X																
Batioladinium micropodum			X			X					X					X	X				X					X	
Batioladinium reticulatum																										X	
Belodinium dysculum																X		X	X		R	X				X	
Broomea simplex																										X	
Callaoisphaeridium asymmetricum	X		R																								
Canningia reticulata																							X			X	
Canninginopsis intermedia	C		F																								
Canninginopsis tabulata																										X	
Carpodinium granulatum	X		X								R	X	X	R			X	X	X		F	R					
Cassiculosphaeridia magna						R					X	X		F	R	X	X	C	X	R	X	R	C	F		F	
Cassiculosphaeridia reticulata			R		R	F	R	F	X		F	R	X			X	R										
Cassiculosphaeridia sp. A						R	X	X	X		X				X												
Cernicysta helbyi			X										X			X											
Chichaouadinium boydii	X	R	R																								
Chlamydophorella nyei	X	F	R		X		C			R	X	R	X			X			X	X	R	X			R	X	
Chytroeisphaeridia chytroeides																										X	X
Circulodinium colliveri	X		C	R			F	R	X	R	X					X							X	R		R	X
Circulodinium deflandrei	X			C	F					R	X			F		X	F	R	R	R	X	R	A	A		X	
Circulodinium hirtellum																X											
Cleistosphaeridium ancoriferum				X				X				X				X			X								
Cleistosphaeridium spp.	X	F	X	X	X			X		X		X					X	X	X		X	R				X	X
Codoniella campanulata	X	X	X																								
Cometodinium(?) *whitei*	X	R	X			R	X	R			R	X				X			X			X				X	X
Coronifera oceanica		X	X								X			X		X	X		R								
Cribroperidinium aparsium								X								X	R	X	X			A	F	F			
Cribroperidinium sp. cf. *C. asarotum*																		A	A	A	A						
Cribroperidinium edwardsii	X		X																								
Cribroperidinium leedervillense	X		R					R		X			X		X	X		X					X				
Cribroperidinium muderongense						X										X	X			X			R				
Cribroperidinium sp. A																				X							
Cribroperidinium sp. B												R	X														
Cymatiosphaera spp.																					X						
Dapsilidinium warrenii						X		X	X		X		X				X									X	
Diconodinium davidii	F	A	A		X																						
Diconodinium pusillum	X																										
Dingodinium cerviculum	X	C	R		C	X	F			F	X	R		X		X		X	X	X	X	X					
Dingodinium jurassicum																										X	
Dissiliodinium spp.		X	X	R		F				X	X					X	X	R	R	F	A	F				X	R
Dissimulidinium lobispinosum																										X	
Dollidinium sinuosum																										X	
Druggidium spp.														X						X	X	?				X	
Egmontodinium torynum																										R	R
Elytrocysta circulata						X																					
Epelidosphaeridia colligata																							X				
Epitricysta vinckensis														X		X			X	X	X		X				
Epitricysta sp. A																							R	X			
Escharisphaeridia sp. A						X						X	A	F	X												
Exiguisphaera phragma																X		X									
Exochosphaeridium arnace																					X		X				
Exochosphaeridium phragmites	X		X			R		R	X		R		X			X	X	X	X	X		R	X				
Exochosphaeridium robustum																					X		X	X		R	
Exochosphaeridium sp. A						X	X	X	X					X			X										
Eyrea nebulosa	R		X					R	X							X	X		X								X
Fibradinium variculum			X							X		X		X	X			X									
Florentinia mantellii	X	X	X			X																					

Table 2 (continued).

Species	Core no.:	33R	34R	35R	37R	39R	40R	42R	42R	43R	43R	44R	44R	45R	45R	47R	49R	49R	50R	51R	51R	52R	52R	54R	54R	58R	59R	59R
	Section:	1	1	CC	CC	CC	4	2	CC	1	CC	1	CC	1	CC	3	1	CC	CC	5	CC	1	2	4	CC	2	4	5
Fromea amphora		X	X	X				X			X						X											
Fromea monilifera								X									X										?	
Gardodinium sp. cf. *G. attenuatum*																											X	
Gen. et sp. indet. A							X																					
Gen. et sp. indet. B																											X	
Gen. et sp. indet. C																											X	
Gen. et sp. nov. A																											X	X
Gonyaulacysta helicoidea			R	R			F	R																			X	
Gonyaulacysta jurassica																											F	R
Hapsocysta peridictya				X																								
Herendeenia postprojecta																	X	R	R	R	X	R	R					
Heslertonia striata		X																										
Hystrichodinium spp.																	X			R		X	X				X	
Hystrichosphaeridium pachydermum																											X	F
Hystrichosphaeridium petilum																	X						R				X	
Hystrichosphaeropsis sp. A				X																								
Impagidinium phlyctaena																				X		X	X	X				
Kaiwaradinium scrutillinum																								F	C	F		
Kallosphaeridium norvickii		X	X	X	X	X	X	R			X						X	X		X		X					X	X
Kallosphaeridium sp. A														X														
Kiokansium polypes		X	R	X								X		R	X		X	X				X						
Kleithriasphaeridium fasciatum																											X	X
Kleithriasphaeridium simplicispinum																	X	X										
Lanterna(?) sp. A							R				X	X	X	R														
Leptodinium asymmetricum							X					X							X			X						
Leptodinium eumorphum																											X	
Leptodinium pinnosum																											X	
Leptodinium simplex																	X	R			R	F	R					
Leptodinium tunellum												X	X															
Leptodinium spp.		F	R	R		X	X	R	C	C	A	A	A	F	R	R	X	X	X	X	X	X	X	R			X	X
Leptodinium(?) sp. A							X																					
Leptodinium(?) sp. B																											X	
Meiourogonyaulax maculata																												X
Meiourogonyaulax stoveri							X		X	X	X				X		X							X			X	
Meiourogonyaulax sp. B																											R	X
Meiourogonyaulax(?) sp. A									X	X	A	R		X	X	X				X		X	X					
Micrhystridium spp.			X												X		X										X	
Muderongia australis															X		X	X	X	X	X	X	R	R	X			
Muderongia macwhaei											X	X		X	X	X	X											
Muderongia tetracantha				X				F	X	X				X	X		X	R	F	R	X	R	X	X	X			
Nummus spp.			X								X						X											
Occisucysta tenuiceras				X			R		X	X	A	X	R	R	X	R	X		X	X	X	X	X				X	
Odontochitina operculata		R		R			F	R	F	X		F	R	R	X	X	X	X										
Oligosphaeridium anthophorum								X			X				X	X												
Oligosphaeridium cf. *O. asterigerum*																	X	X	R	R			X	R	X		F	F
Oligosphaeridium complex		X		R	F			R	R	X				R	R													
Oligosphaeridium sp. cf. *O. poculum*				X																				X			X	
Oligosphaeridium pulcherrimum				R			X							X														
Palaeoperidinium cretaceum				X																								
Pareodinia spp.																	X										X	R
Phoberocysta neocomica																						?		R	R			
Platycystidia eisenackii												X					X											
Prolixosphaeridium inequiornatum							X	X	X	X														F	R		X	
Prolixosphaeridium parvispinum		X	X				X	F	F	X		R		X	X	X	X	R		X	X	X	X	X	X		X	X
Prolixosphaeridium spp.			X		X																							
Protoellipsodinium densispinum		?																										
Pseudoceratium turneri		X		X																								
Pterospermella aureolata																	X											
Pterospermella australiensis																								X				
Pyxidiella tumida																				X								
Pyxidinopsis challengerensis							X				X																	
Reworking —Jurassic					X										X		X							X	X		X	
—Permian			X	X																								
Rhombodella paucispina			C	R													X			X								
Rigaudella aemula																											X	X
Schizocystia laevigata			X																									
Scriniodinium attadalense											X					X											R	R
Scriniodinium(?) *campanula*																	X										X	R
Senoniasphaera sp. cf. *S. ptomatis*																											X	X
Sentusidinium spp.		X	F	R	C	F	R	C		X	R	R	R	R	R	X	X	R		X	R	R		R			A	F

Table 2 (continued).

Species	Core no.:	33R	34R	35R	37R	39R	40R	42R	42R	43R	44R	44R	45R	45R	47R	49R	49R	50R	51R	51R	52R	52R	54R	54R	58R	59R	59R
	Section:	1	1	CC	CC	CC	4	2	CC	1	CC	1	CC	1	CC	3	1	CC	CC	5	CC	1	2	4	CC	2	4	5
Sirmiodinium grossii																	X							X	X			
Spiniferites spp.		F	R	F			R	A	F	X	F	R	R	R	X	X	X	R	X	R	X	R	F	X			X	X
Systematophora areolata					X										X												X	R
Systematophora palmula																											R	F
Tanyosphaeridium boletus							X	X	F	X							X	X					X				X	X
Tanyosphaeridium sp. A																											X	X
Trichodinium castanea				R																								
Tubotuberella vlamingii																								X			X	
Veryhachium spp.			F	X			X		X	X		X					X											
Wallodinium krutzschii			X																									
Wallodinium luna			X														X											
Yalkalpodinium scutum				X			X	X	X	X		X		X	X			X		X	R	X	X	X	X		X	

A = >30%; C = >10%–<30%; F = >3.5%–<10%; R = >1%–<3.5%; X = <1%

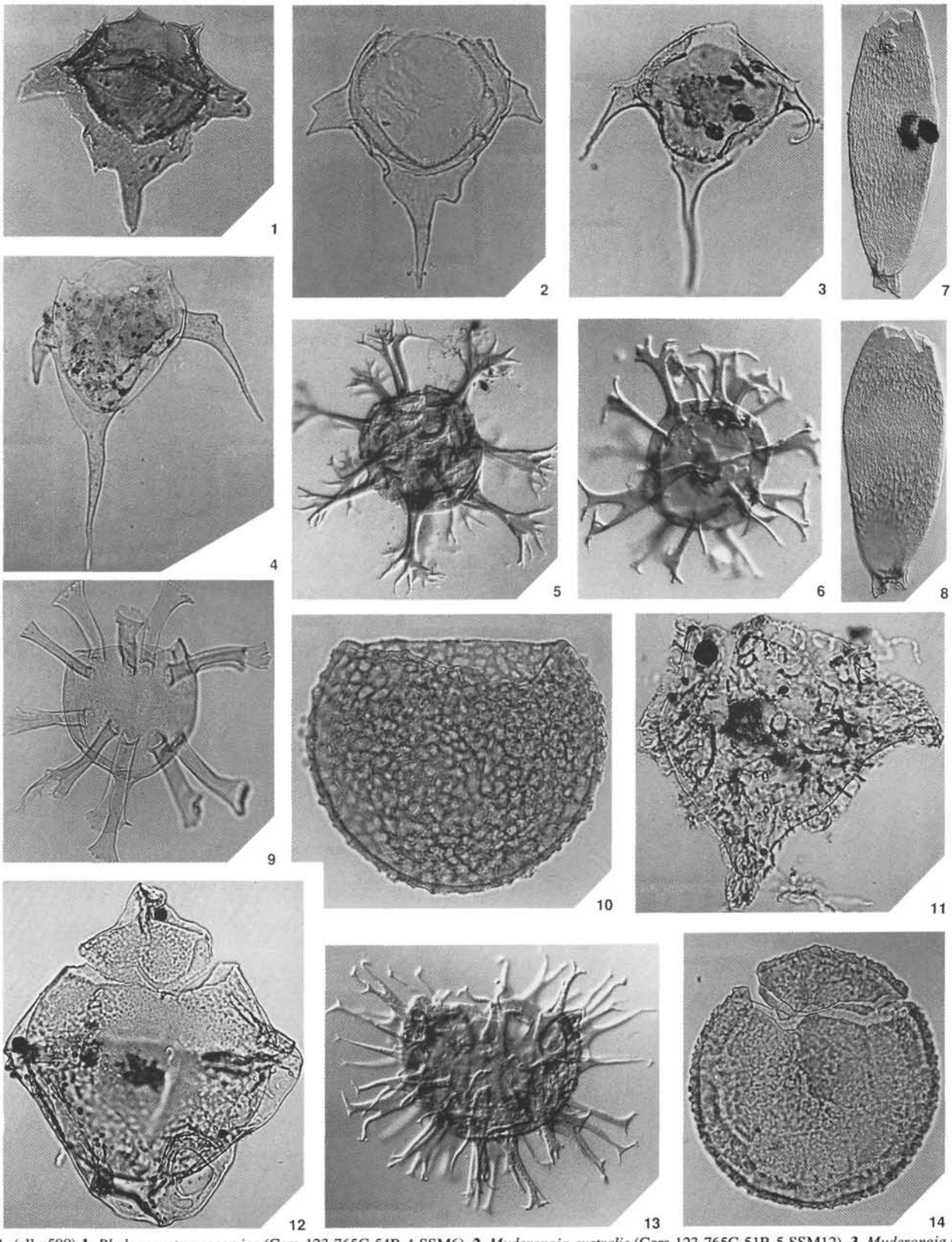

Plate 1. (all x500) **1.** *Phoberocysta neocomica* (Core 123-765C-54R-4 SSM6). **2.** *Muderongia australis* (Core 123-765C-51R-5 SSM12). **3.** *Muderongia* sp. cf. *M. tetracantha* (Core 123-765C-35R-CC SSM35). **4.** *Muderongia tetracantha* (Core 123-765C-50R-CC SSM11). **5.** *Oligosphaeridium asterigerum* (Core 123-765C-59R-4 SSM26). **6.** *Systematophora palmula* (Core 123-765C-59R-4 SSM20). **7.** Gen. et sp. nov. A (Core 123-765C-59R-4 SSM5). **8.** Gen. et sp. nov. A (Core 123-765C-59R-4 SSM6). **9.** *Kaiwaradinium scrutillinum* (Core 123-765C-54R-4 SSM1). **10**. *Cassiculosphaeridia* magna (Core 123-765C-54R-4 SSM8). **11.** *Pseudoceratium turneri* (Core 123-765C-35R-CC SSM8). **12.** *Yalkalpodinum scutum* (Core 123-765C-35R-CC SSM10). **13.** *Systematophora areolata* (Core 123-765C-59R-4 SSM15). **14.** *Meiourogonyaulax*? sp. A (Core 123-765C-40R4 SSM1).

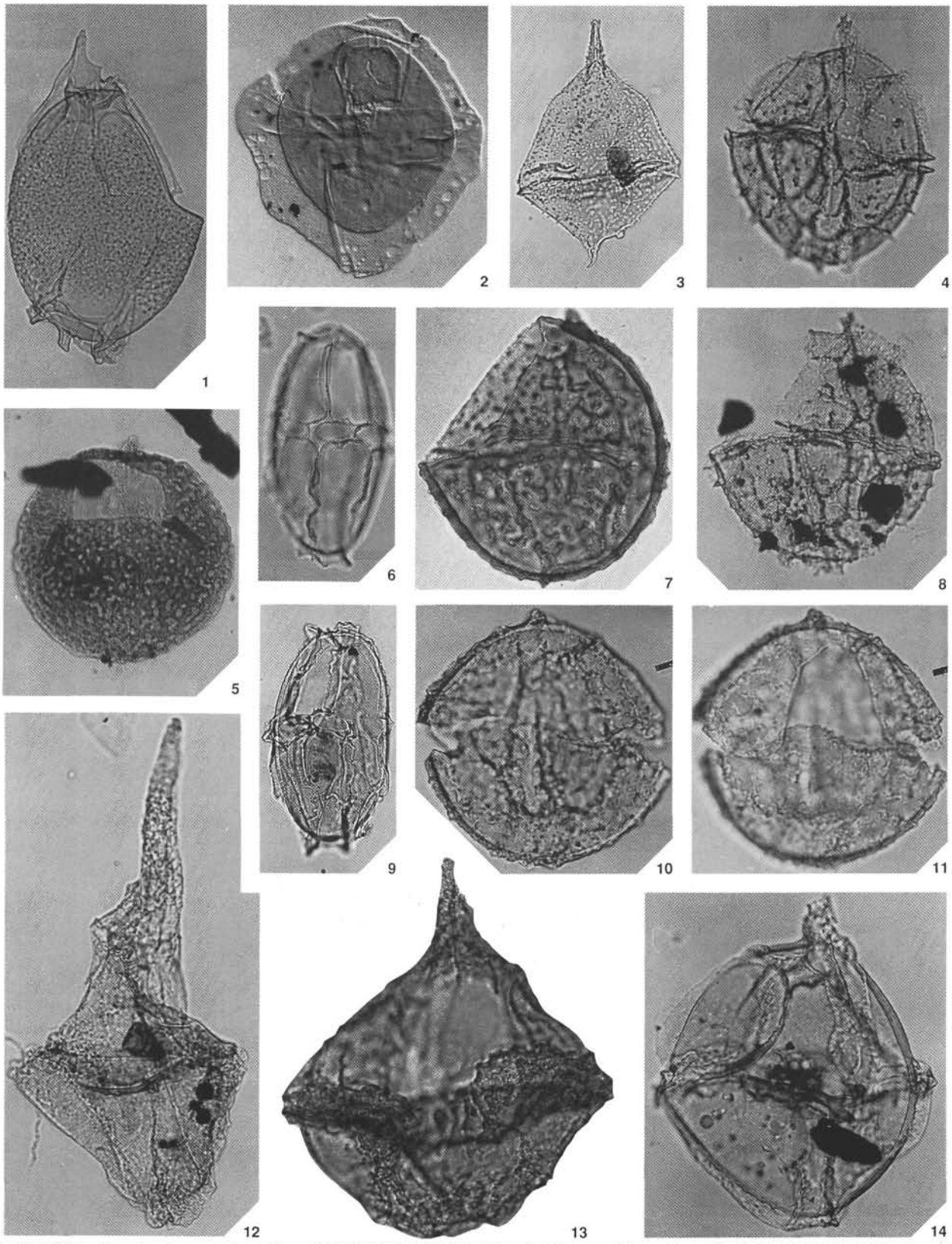

Plate 2. (all x500) **1.** *Herendeenia postprojecta* (Core 123-765C-51R-5 SSM1). **2.** *Scriniodinium attadalense* (Core 123-765C-59R-4 SSM31). **3.** *Diconodinium davidii* (Core 123-765C-35R-CC SSM2). **4.** *Occisucysta tenuiceras* (Core 123-765C-40R-4 SSM2). **5.** *Aldorfia*? sp. A (Core 123-765C-59R-4 2/922 199). **6.** *Carpodinium granulatum* (Core 123-765C-51R-5 SSM4). **7.** *Cribroperidinium* sp. cf. *C. asarotum* (Core 123-765C-54R-4 SSM25). **8.** *Occisucysta tenuiceras* (Core 123-765C-40R-4 SSM2). **9.** *Carpodinium granulatum* (Core 123-765C-50R-CC SSM9). **10,11.** *Cribroperidinium*? sp. cf. *C. asarotum* (Core 123-765C-51R-5 SSM9). **12.** *Cribroperidinium* sp. cf. *C. leedervillense* (Core 123-765C-35R-CC SSM25). **13.** *Cribroperidinium* sp. A (Core 123-765C-54R-4 SSM27). **14.** *Cribroperidium* sp. B (Core 123-765C-45R-1 SSM15).

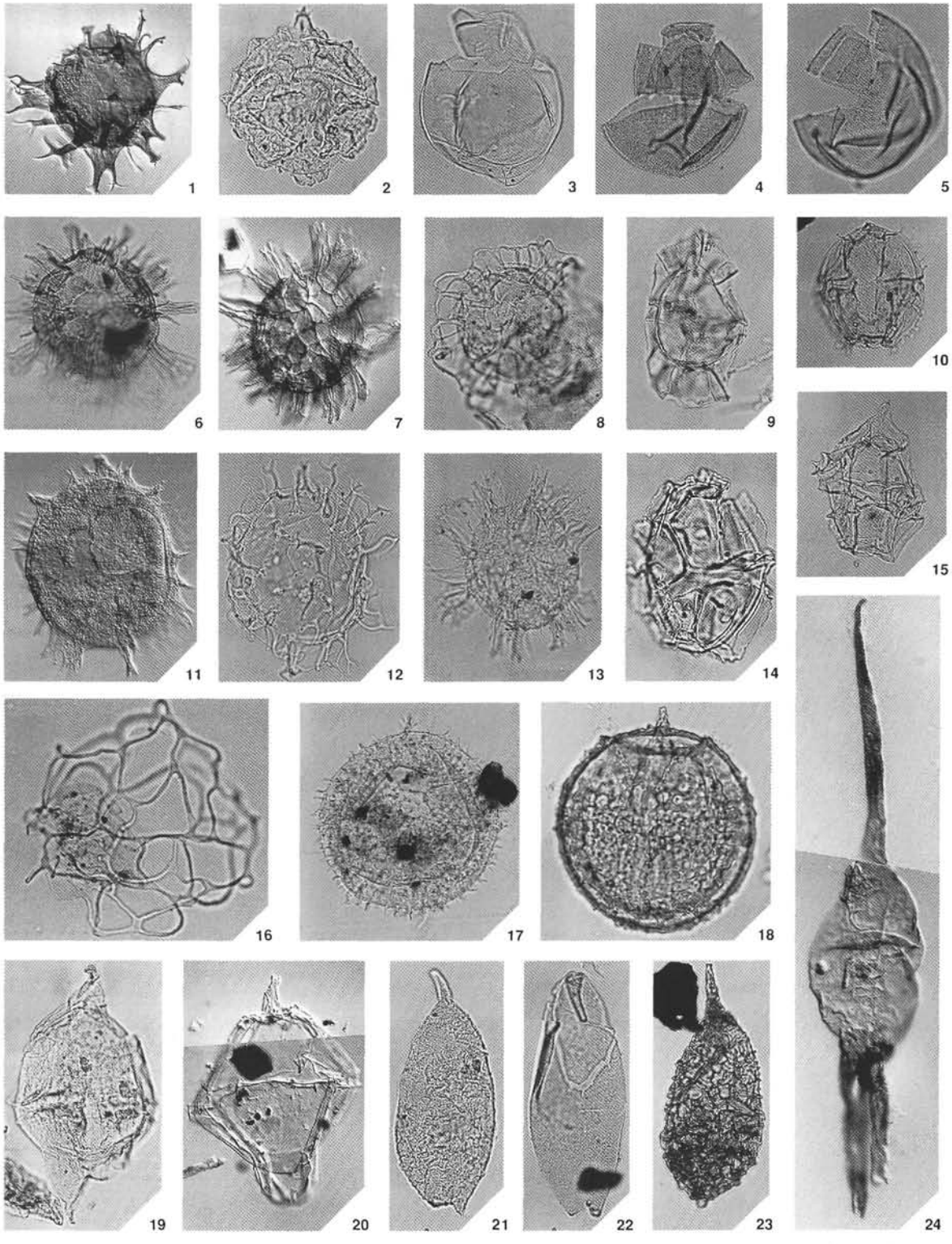

Plate 3. (all x500) **1.** *Achomosphaera? neptuni* (Core 123-765C-59R-4 SSM36). **2.** *Leptodinium*? sp. (Core 123-765C-40R-4 SSM7). **3.** *Ascodinium*? sp. A (Core 123-765C-35R-CC SSM33). **4.** *Dissiliodinium* sp. A (Core 123-765C-40R-4 SSM19). **5.** *Dissiliodinium* sp. A (Core 123-765C-4OR-4 SSM20). **6.** *Kleithriasphaeridium fasciatum* (Core 123-765C-59R- SSM34). **7.** *Kleithriaspbaeridium fasciatum* (Core 123-765C-59R-4 1/1100 110). **8.** *Adnatosphaeridium tutulosum* (Core 123-765C-35R-CC SSM31). **9.** *Hystrichosphaeropsis* sp. A (Core 123-765C-35R-CC SSM22). **10.** *Leptodinium*? sp. (Core 123-765C-59R-4/956 040). **11.** *Exochosphaeridium arnace* (Core 123-765C-54R SSM25). **12.** *Avellodinium* sp. A (Core 123765C-51R-5 SSM6). **13.** *Exochosphaeridium* sp. A. (Core 123-765C-40R-4 SSM18). **14.** *Impagidinium phlyctaena* (Core 123-765C-51R-4 SSM4). **15.** *Gonyaulacysta* sp. cf. *G. helicoidea* (Core 123-765C-40R-4 SSM17). **16.** *Hapsocysta perdictya* (Core 123-765C-35R-CC SSM30). **17.** *Trinchodinium castanea* (Core 123-765C-35R-CC SSM24). **18.** *Cribroperidinium* sp. cf. *C. asarotum* (Core 123-765C-50R-CC SSM4). **19.** *Ascodinium* sp. A (Core 123765C-35R-CC 1/1160 180). **20.** *Tubotuberella vlamingii* (Core 123-765C-59R-4 SSM33). **21.** *Batioladinium micropodum* (Core 123-765C-35R-CC SSM14). **22.** *Batioladinium micropodum* (Core 123-765C-40R-4 SSM30). **23.** *Batioladinium reticulatum* (Core 123-765C-59R-4 1/1092 218). **24.** *Broomea simplex* - reworked (Core 123-765C-59R-4 SSM28).

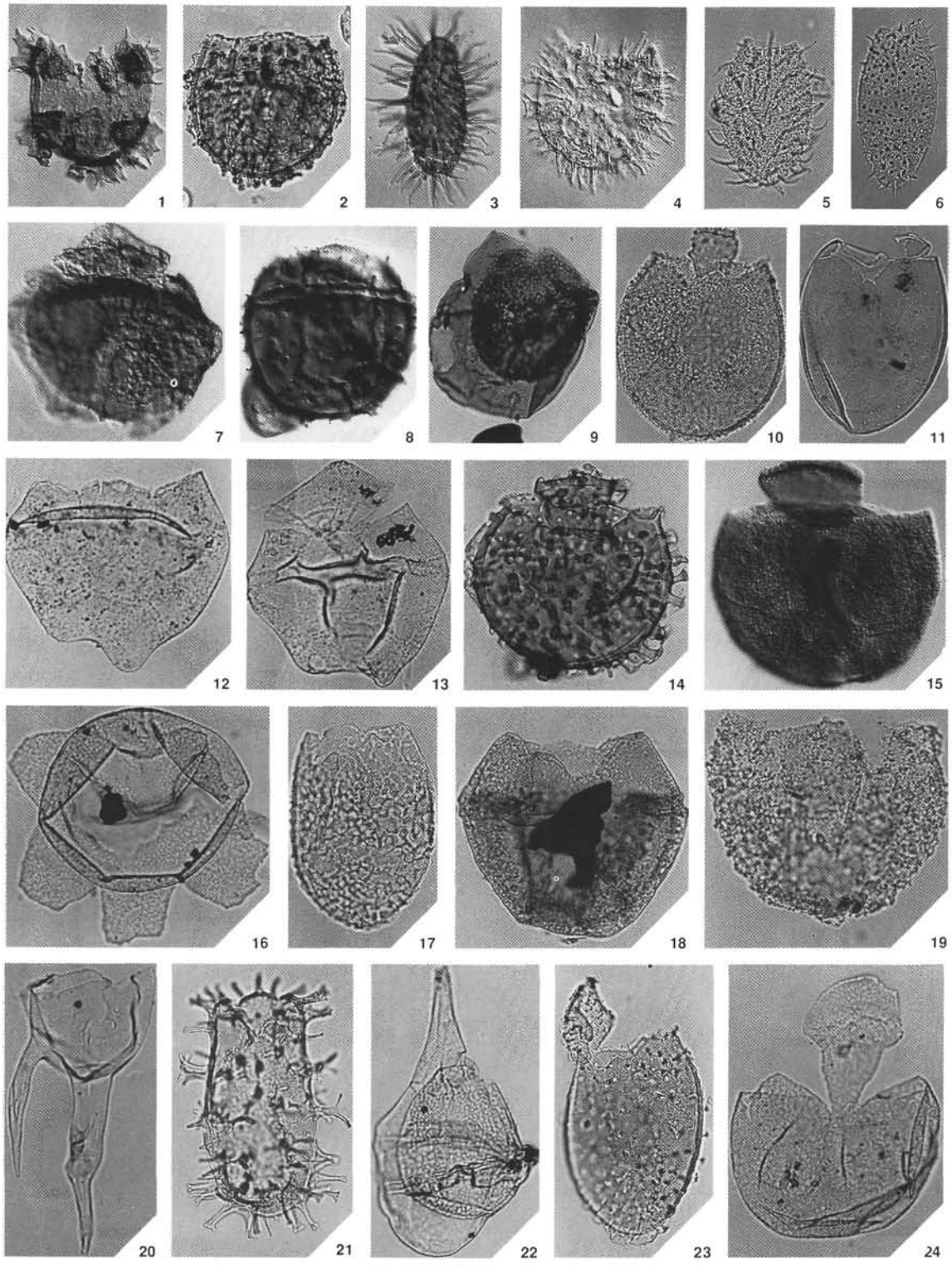

Plate 4. (all x500) **1.** *Oligosphaeridium* sp. cf. *O. poculum* (Core 123-765C-59R-4 SSM24). **2.** *Meiourogonyaulax*? sp. A (Core 123-765C-50R-CC SSM5). **3.** *Tanyosphaeridium* sp. A (Core 123-765C-59R-4 SSM16). **4.** *Epelidosphaeridia colligata* (Core 123-765C-54R SS13). **5.** *Prolixosphaeridium parvispinum* (Core 123-765C-40R-4 SSM46). **6.** *Prolixosphaeridium inequiornatum* (Core 123-765C-54R-5 SSM11). **7.** Senoniasphaera sp. cf. *S. ptomatis* (Core 123-765C-59R-4 SSM23). **8.** *Meiourogonyaulax* sp. B (Core 123-765C-59R-4 SSM10). **9.** *Dingodinium jurassicum* (Core 123-765C-59R-4 2/911 130). **10.** *Batiacasphaera* sp. (Core 123-765C-40R-4 SSM46). **11.** *Batiacasphaera*? sp. (Core 123-765C-4OR-4 SSM51). **12.** *Canninginopsis intermedia* (Core 123-765C-35R-CC SSM6). **13.** *Canninginopsis intermedia* (Core 123-765C-35R-CC SSM6). **14.** *Meiourogonyaulax*? sp. A (Core 123-765C-45R-1 SSM10). **15.** *Batiacasphaera* sp. A–*imperfecta* plexus (Core 123-765C-59R-4 1/995 210). **16.** *Escharisphaeridia* sp. A (Core 123-765C-45R-1 SSM4). **17.** *Batiacasphaera* sp.–*imperfecta* plexus (Core 123-765C-51R-5 SSM6). **18.** *Meiourogonyaulax stoveri* (Core 123-765C-40R-1 SSM33). **19.** Gen et sp. indet. A (Core 123-765C-40R-4 SSM37). **20.** *Odontochitina operculata* (Core 123-765C-40R-4 SSM31). **21.** *Egmontodinium torynum* (Core 123-765C-59R-4 SSM12). **22.** *Dingodinium cerviculum* (Core 123-765C-35R-CC SSM17). **23.** *Batiacasphaera*? sp. *imperfecta* plexus (Core 123-765C-45R-1 SSM8). **24.** *Kallosphaeridium* sp. A (Core 123-765C-45R-1 SSM14).

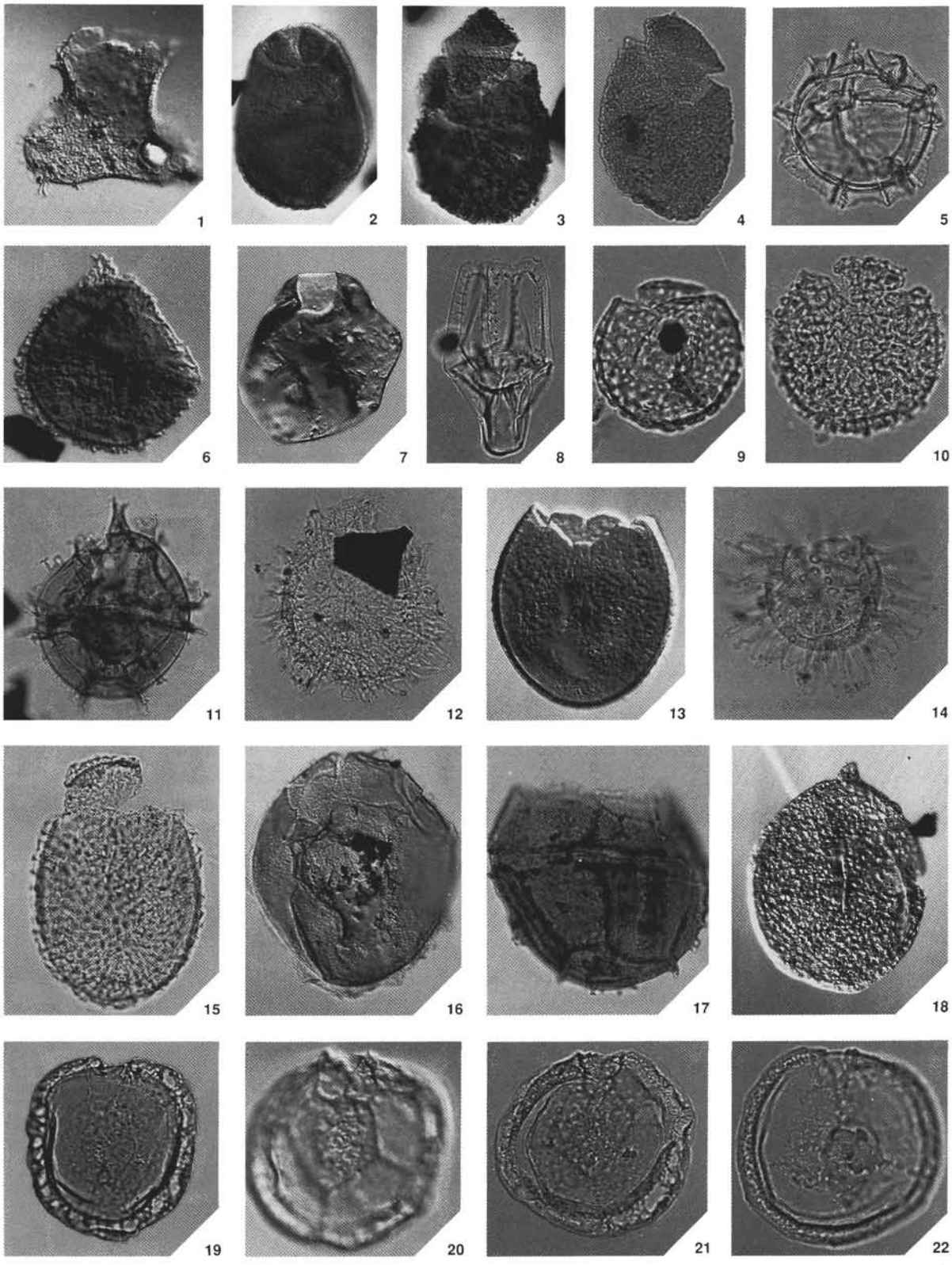

Plate 5. (all x750) **1.** *Dissimulidinium lobispinosum* (Core 123-765C-59R-4 SSM17). **2.** Gen. et sp. indet. B (Core 123-765C-59R-4 1/1084 190). **3.** *Aprobolocysta*? *galeata* (Core 123-765C-59R-4 2/1030 150). **4.** *Aprobolocysta*? *galeata* (Core 123-765C-59R-4 2/955 225). **5.** *Leptodinium* sp. (Core 123-76SC-35R-CC SSM15). **6.** *Aldorfia deflandrei* (Core 123-765C-59R-4 SSM20). **7.** *Dollidinium sinuosum* (Core 123-765C-59R-4 SSM41). **8.** *Belodinium dysculum* (Core 123-765C-51R-6 SSM3). **9.** *Cassiculosphaeridia* sp. A (Core 123-765C-40R-4 SSM50). **10.** *Batiacasphaera* sp.–*imperfecta* plexus (Core 123-765C-40R-4 SSM48). **11.** *Spiniferites*? sp A (Core 123-765C-59R-4 1/1113 040). **12.** *Cometodinium*? *whitei* (Core 123-765C-40R-4 SSM28). **13.** *Batiacasphaera* sp.–*subtilis* plexus (Core 123-765C-54R-4 SSM13). **14.** *Dapsilidinium warrenii* (Core 123-765C-40R-4 SSM44). **15.** *Batiacasphaera* sp.–*imperfecta* plexus (Core 123-765C-50R-CC SSM5). **16.** Gen. et sp. indet. C (Core 123-765C-59R-4 1/900 145). **17.** *Meiourogonyaulax* sp. B (Core 123-765C-59R-4 1090 210). **18.** *Aldorfia*? sp. A (Core 123-765C-59R-4 SSM29). **19–22.** *Epitricysta* sp. A (all Core 123-765C-54R-4 SSM19).