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8. NEOGENE DINOFLAGELLATE CYST BIOSTRATIGRAPHY FROM SITES 815 AND 823, LEG 133, NORTHEASTERN AUSTRALIAN MARGIN[1]

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ABSTRACT

Well-preserved and diverse dinoflagellate cyst assemblages were recovered from Ocean Drilling Program (ODP) Sites 815 and 823. The late middle Miocene is indicated by the presence of *Sumatradinium* spp. up to Core 133-823C-10R at Site 823 and up to Core 133-815B-47X at Site 815. *Melitasphaeridium choanophorum* appeared in the late Miocene (Cores 133-823C-19R and 133-815B-45X) and disappeared during the late Pliocene (Cores 133-823C-56X and 133-815 B-4H). Other significant biostratigraphic datums include the disappearances of *Hystrichokolpoma rigaudiae* (Cores 133-823B-22X and 133-815A-5H) and *Dapsilidinium pasteilsii* (Cores 133-823B-23X and 133-815A-5H) at the end of the Pliocene; the first appearance of *Blysmatodinium argoi* during the late Miocene (Core 133-815B-43X) and subsequent disappearance during the early Pliocene (Cores 133-823B-47X and -815B-27X); and the disappearance of *Operculodinium longispinigerum* (Sections 133-823A-3H-4 and -815A-1H-3) during the Pleistocene. These results are consistent with the ages determined by nannoplankton and foraminifers at these sites and also with the dinoflagellate biostratigraphy from Leg 123 (McMinn, 1992).

The Neogene assemblages of both sites are characterized by abundant *Spiniferites* spp., *Impagidinium* spp., and *Operculodinium* spp. Both *Tuberculodinium vancampoae* and *Lingulodinium machaerophorum* are consistently present and sometimes abundant but most other species occur only sporadically. Peridiniaceae, which is often associated with nutrient enrichment, is rare in all samples. This suggests that the environment has always been oligotrophic. *Impagidinium* spp., taxa typically associated with oceanic environments, are present throughout both cores, but are more abundant in post-Pliocene sediments.

INTRODUCTION

Site 815 is located on the northern margin of the Marion Plateau, approximately 250 km east of the Australian mainland (Fig. 1). This site was drilled in 450 m of water and contains a Pleistocene to middle Miocene sequence. Six lithostratigraphic units were recognized and these are (Unit I) Pleistocene to early late Pliocene age sequence of foraminifer nannofossil to nannofossil foraminifer ooze, (Unit II) early Pliocene age nannofossil ooze and unlithifed nannofossil mixed sediment, (Unit III) early Pliocene age chalk and lithified mixed sediment, (Unit IV) late late Miocene age foraminifer nannofossil and nannofossil foraminifer chalk, (Unit V) late middle to late Miocene age calcareous to dolomitized foraminifer packstone, and (Unit VI) latest early to early middle Miocene age dolomitized benthic foraminifer rudestone to floatstone (Davies, McKenzie, Palmer-Julson et al., 1991).

Site 823 is located in the central-western Queensland Trough (Fig. 1), in 1638 m of water and was drilled to a depth of 1011 m. The Pleistocene to late middle Miocene sequence consists of seven stratigraphic units: (Unit I) Pleistocene age nannofossil ooze interbedded with debris flows and turbidites; (Unit II) Pleistocene to late Pliocene age nannofossil ooze interbedded with debris flows and turbidites; (Unit III) early Pliocene age nannofossil ooze interbedded with debris flows and turbidites; (Unit IV) early Pliocene to latest late Miocene age foraminifer nannofossil chalk and is characterized by larger slump features (compared to III); (Unit V) late Miocene age nannofossil mixed sediment to nannofossil claystone; (Unit VI) late Miocene age bioturbated nannofossil chalk to mixed sediment; (Unit VII) late Miocene to late middle Miocene age lithoclastic rudstone with shallow-water, platform-derived pebbles and clasts (Davies, McKenzie, Palmer-Julson et al., 1991).

Comparatively few studies of Neogene dinoflagellate cysts have been done and most of these are of Northern Hemisphere, temperate and boreal assemblages. A summary of previously published Northern Hemisphere Neogene dinoflagellate data is presented in Head et al. (1989). Published accounts of Neogene assemblages from the Southern Hemisphere are limited to those of Deflandre and Cookson (1955), Truswell et al.(1985), Martin (1991) and McMinn (1992a) from Australia, and Gamerro and Archangelsky (1981) from Argentina. Similarly, there have been few published studies of Neogene tropical dinoflagellate cyst assemblages. These include the studies by Jarvis and Tocher (1985) of equatorial Pacific Ocean core samples and McMinn (1992a) from the eastern Indian Ocean. However, subtropical assemblages from the Gulf of Mexico (Duffield and Stein [1986], Lenoir and Hart [1986], and Wrenn and Kokinos [1986]), are similar to the tropical assemblages reported by McMinn (1992a).

MATERIALS AND METHODS

Thirty-eight, 10 cm^3 samples from Site 815 and 47 from Site 823 were collected for this study by Leg 133 shipboard scientists and were processed at the Palynological Laboratory of the New South Wales (N.S.W) Geological Survey. Samples were initially disaggregated in 30% HCl and then left overnight in 30% HF. After repeated washings in distilled water they were sieved on an 8 μm screen with the aid of an ultrasonic needle. The residue was then further concentrated by the use of a heavy liquid $ZnBr_2$ solution having a 2.1 specific gravity. No oxidation was used in sample preparation. Residues were mounted in Eukitt and are stored in the Palaeoecology Collection of the Institute of Antarctic and Southern Ocean Studies at the University of Tasmania, Hobart. All photography was done with a Zeiss Photomicroscope II at the N.S.W. Geological Survey, Sydney. All specimens on a measured slide were counted to obtain the number of cysts/g of sediment; if this number was less 400, an additional slide was examined. The "relative abundance" was based on a count of 200 palynomorphs and represents the number of dinoflagellate cysts in a palynomorph assemblage. Percentage distributional data are documented in Tables 1 and 2.

[1]McKenzie, J.A., Davies, P.J., Palmer-Julson, A., et al., 1993. *Proc. ODP, Sci. Results,* 133: College Station, TX (Ocean Drilling Program).

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BIOSTRATIGRAPHY

Because no widely accepted Neogene dinoflagellate zonation is currently available, the dinoflagellate cyst assemblages will be discussed with reference to age determinations based on foraminifers and nannofossils (Davies, McKenzie, Palmer-Julson, et al., 1991).

Middle Miocene

A single late middle Miocene age sample (133-823C-24R-3, 22–24 cm) was examined; this was characterized by abundant *Lingulodinium machaerophorum, Operculodinium israelianum*, and *Spiniferites bulloideus*. Although the sample contained abundant specimens, species diversity was low and no biostratigraphically significant species were present.

Late Miocene

Late Miocene age assemblages were examined from Samples 133-815B-47X-3, 100–103 cm, through -43X-3, 87–93 cm, and 133-823C-21R-4, 50–53 cm, through -823B-70X-4, 60–64 cm. Assemblages typically are dominated by *Spiniferites bulloideus* with common *Lingulodinium machaerophorum, Operculodinium israelianum, Spiniferites hyperacanthus*, and *Tuberculodinium vancampoae*. Intermittently common forms include *Batiacasphaera* spp., *Impagidinium patulum, Operculodinium longispinigerum*, and *Operculodinium echigoense*. Significant first appearances include *Blysmatodinium argoi, Dapsilidinium pasteilsii*, and *Melitasphaeridium choanophorum*. Significant last occurrences include *Sumatradinium hispidum*.

Early Pliocene

Early Pliocene age sequences occur from Samples 133-823B-68X-4, 65–68 cm, to -40X-4, 66–79 cm, at Site 823 and from Samples 133-815B-26X-3, 98–103 cm, to -41X-3, 87–93 cm, and 133-815A-9H-3, 87–89 cm, through -24H-3, 100–105 cm, at Site 815. *Spiniferites bulloideus* is the most abundant species in the majority of samples, although *Batiacasphaera* spp., *Dapsilidinium pasteilsii, Hystrichokolpoma rigaudiae, Impagidinium paradoxum, Impagidinium patulum, Lingulodinium machaerophorum, Melitasphaeridium choanophorum, Operculodinium longispinigerum, Operculodinium echigoense*, and *Tuberculodinium vancampoae* are also sometimes abundant. No significant first appearances are seen in the early Pliocene although *Batiacasphaera* spp., *Blysmatodinium argoi*, and *Spiniferites pachydermus* disappear.

Late Pliocene

Late Pliocene age assemblages occur in samples from 133-823A-22X-4, 60–64 cm, to -38X-4, 66–70 cm, and 133-815A-3H-3, 105–109 cm, through -8H-3, 93–97 cm. The most abundant species are *Melitasphaeridium choanophorum, Operculodinium longispinigerum*, and *Spiniferites ramosus*. Other spasmodically common taxa include *Dapsilidinium pasteilsii, Impagidinium aculeatum, Impagidinium paradoxum, Impagidinium patulum, Impagidinium* sp., *Operculodinium centrocarpum, Operculodinium israelianum, Spiniferites bulloideus*, and *Spiniferites hyperacanthus*. No significant first appearances occur but important disappearances include *Dapsilidinium pasteilsii, Hystrichokolpoma rigaudiae*, and *Melitasphaeridium choanophorum*.

Quaternary

Quaternary age assemblages were obtained from Samples 133-823A-1H-4, 65–69 cm, through -11H-4, 65–69 cm, 133-823B-13X-3, 58–60 cm, through -16X-3, 60–64 cm, and 133-815A-1H-3, 121–125 cm, through -2H-3, 121–125 cm. These assemblages are characterized by abundant *Impagidinium aculeatum, Impagidinium paradoxum*, and *Spiniferites bulloideus*. Other common forms include *Achomosphaera* sp., *Impagidinium patulum, Impagidinium sphaericum, Impagidinium strialatum, Lingulodinium machaerophorum, Operclodinium centrocarpum, Operculodinium israelianum, Spiniferites hyperacanthus, Spiniferites ramosus*, and *Tuberculodinium vancampoae*. The only significant biostratigraphic event within the Quaternary sequence is the disappearance of *Operculodinium longispinigerum*.

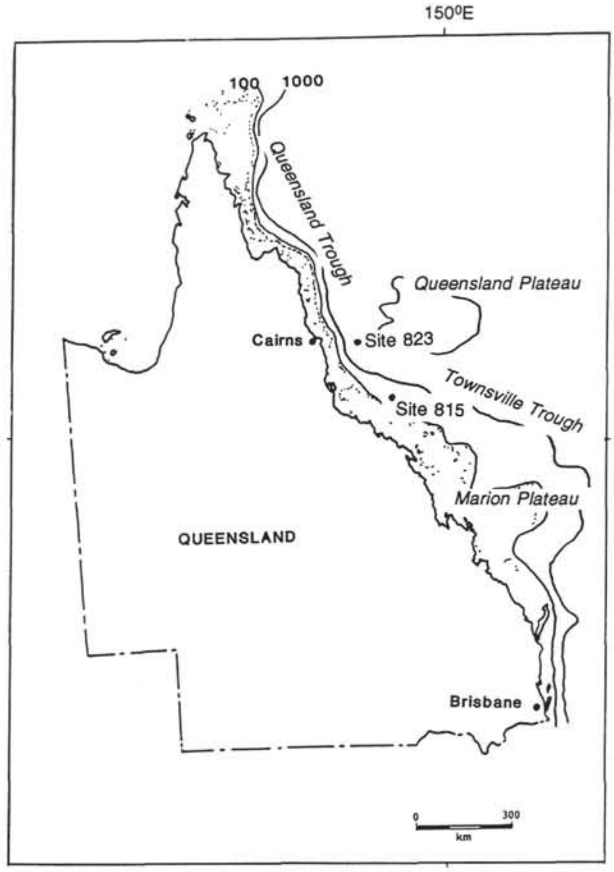

Figure 1. Location of Sites 815 and 823. Bathymetry in meters.

Most of the significant biostratigraphic datums documented by McMinn (1992a) from the Argo Abyssal Plain in the Indian Ocean off northwestern Australia occur synchronously at Sites 815 and 823, off northeastern Australia. Of those datums identified as biostratigraphically significant by McMinn (1992a) from northwestern Australia, only the middle Miocene disappearance of *Systematophora placacantha* is absent. *Sumatradinium hispidum*, however, disappears in the late Miocene sequences of Sites 815 and 823 of northeastern Australia, but is absent from similarly aged samples from northwestern Australia.

Blysmatodinium argoi appears in the late Miocene section and disappears in the early Pliocene sections of both northeastern and northwestern Australia. *Melitasphaeridium choanophorum* similarly appears simultaneously in both northeastern and northwestern Australia in the late Miocene sequence and disappears synchronously in the late Pliocene section. Both *Dapsilidinium pasteilsii* and *Hystrichokolpoma rigaudiae* appear earlier in the Tertiary, but disappear in the late Pliocene age sections of Sites 815 and 823; neither species is present in the Quaternary sequence of Site 820 (McMinn, this volume). Their later disappearance in the Pleistocene section of northwestern Australia is likely to be the result of reworking from the turbidite sequence of Site 765 (McMinn, 1992a).

Table 1. Percentage distribution of dinoflagellate taxa at Site 815.

Age	Depth (mbsf)	Sample	Relative abundance	*Achomosphaera sp*	*Batiacasphaera spp*	*Blysmatodinium argoi*	*Dapsilidinium pastielsii*	*Hystrichokolpoma rigaudiae*	*Impagidinium aculeatum*	*Impagidinium paradoxum*	*Impagidinium patulum*	*Impagidinium sphaericum*	*Impagidinium strialatum*	*Impagidinium sp.*	*Lingulodinium machaerophorum*	*Melitasphaeridium choanophorum*	*Nematosphaeropsis lemniscata*	*Operculodinium centrocarpum*	*Operculodinium echigoense*	*Operculodinium israelianum*	*Operculodinium janduchenei*	*Operculodinium longispinigerum*	*Multispinula quanta*	*Polysphaeridium zoharyi*	*Reticulosphaera sp.*	*Selenopemphix nephroides*	*Spiniferites bulloideus*	*Spiniferites hyperacanthus*	*Spiniferites membranaceus*	*Spiniferites mirabilis*	*Spiniferites pachydermus*	*Spiniferites ramosus*	*Steladinium reidii*	*Sumatradinium hispidum*	*Tuberculodinium vancampoae*	Cyst Type A	Count
Pleistocene	0	1H-3, 121-125	59	0.0	0.0	0.0	0.0	0.0	11.5	11.1	13.8	3.4	8.1	0.0	1.1	0.0	0.0	8.0	0.0	2.3	1.2	1.2	0.0	0.0	0.0	0.0	17.2	14.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.3	87
Pliocene, late		2H-3, 105-107	71	0.0	0.0	0.0	0.0	0.0	23.2	7.3	18.3	7.3	4.9	0.0	3.7	0.0	0.0	0.0	0.0	6.1	0.0	1.2	0.0	1.2	0.0	0.0	9.8	8.5	1.2	0.0	0.0	7.3	0.0	0.0	0.0	0.0	82
		3H-3, 105-109	38	1.6	0.0	0.0	0.0	0.0	10.9	10.9	34.4	4.7	4.7	0.0	0.0	0.0	0.0	3.1	0.0	4.7	0.0	9.4	0.0	0.0	0.0	0.0	0.0	6.3	0.0	0.0	0.0	6.3	0.0	0.0	1.6	1.6	64
		4H-3, 93-97	35	0.0	0.0	0.0	0.0	0.0	1.4	11.3	9.2	0.0	0.0	0.0	0.7	0.7	0.0	19.7	2.1	1.4	0.0	17.6	0.0	0.0	0.0	0.0	10.6	0.0	0.0	0.0	0.0	4.9	0.0	0.0	0.0	0.0	142
		5H-3, 93-97	46	1.6	0.0	0.0	1.6	0.5	2.1	12.8	9.6	4.3	1.6	0.0	5.3	3.7	0.0	3.2	0.0	0.0	0.0	17.6	0.0	0.0	0.0	0.0	3.2	9.0	1.1	0.0	0.0	8.5	0.0	0.0	1.6	5.9	188
		6H-3, 93-97	49	0.4	0.0	0.0	7.4	0.4	0.0	1.1	2.6	2.6	0.7	3.3	2.2	27.1	0.0	1.9	0.4	1.9	0.0	5.6	0.0	0.0	0.0	0.0	9.3	8.2	0.4	0.0	0.0	20.4	0.0	0.0	0.4	1.5	269
		8H-3, 93-97	6	0.0	0.0	0.0	10.3	0.0	5.1	0.0	2.6	2.6	0.0	12.8	0.0	0.0	0.0	2.6	0.0	5.1	0.0	35.9	0.0	0.0	0.0	0.0	5.1	2.6	0.0	0.0	0.0	10.3	0.0	0.0	0.0	5.1	39
		9H-3, 87-89	27	1.9	0.0	0.0	8.4	9.3	0.0	0.0	3.8	1.9	0.0	12.1	0.0	0.9	0.0	5.6	0.0	6.5	1.9	20.6	0.0	0.0	0.0	0.0	1.9	4.7	0.0	0.0	0.0	15.9	0.0	0.0	1.9	1.9	107
		10H-3, 60-65	39	0.4	0.0	0.0	6.7	7.5	1.2	2.0	0.4	0.4	1.2	6.3	1.2	2.8	0.4	3.6	3.2	3.6	1.2	26.5	0.0	2.0	0.0	0.0	14.2	4.3	0.0	0.0	0.0	7.5	0.0	0.0	2.0	2.0	253
Pliocene, early		11H-3, 100-105	70	0.3	0.0	0.0	18.1	1.5	0.8	0.3	1.8	2.8	0.3	1.8	2.5	14.3	0.3	0.0	0.8	0.8	0.0	18.1	0.0	0.0	0.0	0.0	6.6	6.1	0.0	0.0	0.0	21.4	0.0	0.0	0.8	1.5	393
	100	12H-3, 100-105	22	0.0	0.0	0.0	2.9	6.5	2.5	2.5	1.8	0.7	0.0	4.3	5.8	0.0	0.0	2.2	4.7	4.3	0.0	27.3	0.0	0.7	0.0	0.0	11.5	6.5	0.4	0.0	0.0	8.6	0.0	0.0	4.3	2.5	278
		13H-3, 100-105	66	2.0	0.0	0.0	5.8	2.0	0.0	0.7	0.2	0.2	0.2	0.2	4.3	0.0	0.0	2.0	11.9	7.6	0.0	2.9	0.7	0.2	0.0	0.0	31.5	4.0	0.0	0.0	0.0	16.0	0.0	0.0	6.5	1.3	445
		14H-3, 100-105	53	0.7	0.0	0.0	13.7	6.2	0.2	0.5	2.5	1.4	0.2	0.0	3.7	0.0	0.0	5.9	24.0	3.0	0.0	2.1	0.2	0.0	0.0	0.0	8.2	6.9	0.0	0.0	0.0	13.5	0.0	0.0	5.9	1.4	437
		15H-3, 100-102	47	3.5	0.0	0.0	14.5	8.6	0.0	0.0	5.5	2.7	0.0	2.2	1.6	0.0	0.0	1.6	0.4	5.5	0.0	13.3	0.0	3.9	0.0	0.0	16.8	4.7	0.4	0.0	0.0	9.0	0.0	0.0	4.7	1.2	256
		18H-3, 100-104	42	1.2	0.0	0.0	2.1	6.5	0.9	1.8	3.9	0.5	0.5	1.3	1.2	0.0	0.2	0.2	0.0	0.9	0.0	10.2	0.0	54.3	0.0	0.0	5.5	2.5	0.0	0.0	0.0	1.4	0.0	0.0	3.2	0.9	433
		19H-3, 100-104	16	11.2	0.0	0.0	4.5	6.7	3.0	1.2	5.2	1.2	0.0	9.0	0.0	0.0	0.0	3.0	1.2	1.2	0.0	9.7	0.0	0.0	0.0	0.0	9.0	5.2	0.0	0.0	0.0	9.7	0.0	0.0	8.2	9.7	134
		20H-3, 100-104	18	1.7	0.0	0.0	11.0	0.0	0.0	0.6	2.9	0.0	0.0	2.3	0.6	0.0	0.0	0.0	0.0	19.7	0.0	25.4	0.0	0.0	0.0	0.0	12.1	4.6	0.0	0.0	0.0	8.1	0.0	0.0	4.6	5.2	173
		21H-3, 96-100	28	4.5	0.0	0.0	4.6	6.0	0.0	0.4	1.3	0.2	0.0	0.2	1.9	0.0	0.0	2.3	4.8	2.3	0.0	1.0	0.2	1.4	0.0	0.4	54.5	2.5	0.0	0.0	0.0	3.9	0.0	0.0	4.3	2.5	484
	200	22H-3, 98-104	82	0.5	0.0	0.0	0.2	0.5	0.3	0.2	0.6	0.0	0.2	0.8	0.6	0.0	0.0	0.9	1.1	18.3	0.0	1.4	0.0	0.0	0.0	0.0	65.5	2.7	0.0	0.0	0.0	1.5	0.0	0.0	3.2	0.8	656
		23H-3, 98-104	69	0.0	0.0	0.0	7.6	0.5	0.0	0.3	0.3	0.0	0.0	1.4	0.5	0.3	0.0	0.3	0.0	6.6	0.0	14.7	0.0	0.0	0.0	0.2	56.7	1.2	0.0	0.0	0.6	1.7	0.0	0.0	4.6	1.6	661
		24H-3, 100-105	54	0.4	0.0	0.0	0.0	1.0	0.8	0.2	1.9	0.0	0.0	0.8	0.8	0.4	0.0	4.0	0.2	10.2	0.0	35.6	0.0	0.0	0.2	0.0	27.9	2.3	0.0	0.0	0.0	1.7	0.0	0.0	10.2	1.5	520
		26X-3, 98-103	15	0.8	0.0	0.0	0.0	10.9	3.9	0.8	3.1	0.0	1.6	3.1	1.6	0.8	0.0	2.3	0.8	0.8	3.1	0.0	0.8	1.6	0.0	0.0	30.2	0.8	0.0	0.0	0.0	0.8	0.0	0.0	25.6	5.4	129
		27X-3, 98-102	18	0.0	0.0	0.4	0.4	6.1	1.6	2.4	4.9	0.0	0.0	4.5	3.7	3.3	0.0	2.0	0.0	3.3	9.8	9.8	0.0	0.0	0.0	0.0	40.8	0.0	0.0	0.0	0.0	1.2	0.0	0.0	4.9	0.0	245
		28X-3, 98-102	15	1.0	1.0	0.0	0.0	20.4	1.9	3.8	3.8	0.0	3.0	1.9	1.0	0.0	0.0	1.9	1.9	1.0	0.0	8.7	0.0	0.0	0.0	0.0	21.4	3.0	0.0	0.0	0.0	5.8	0.0	0.0	13.6	3.0	103
		29X-3, 98-102	48	0.3	2.0	0.0	0.3	13.8	0.0	0.3	0.5	0.0	0.3	0.9	2.0	0.0	0.3	5.6	0.0	8.2	0.0	0.8	0.6	0.1	0.0	0.9	47.0	4.5	0.0	0.0	0.0	0.0	0.0	0.0	5.9	6.5	781
		30X-3, 97-102	12	0.0	0.0	0.0	0.0	4.4	1.1	6.7	12.2	0.0	1.1	12.2	0.0	0.0	2.2	0.0	0.0	0.0	0.0	22.2	0.0	0.0	0.0	0.0	30.0	2.2	0.0	0.0	0.0	1.1	0.0	0.0	4.4	0.0	90
		31X-3, 98-102	61	0.1	1.6	0.1	0.0	0.2	0.7	0.7	0.8	0.0	0.0	0.3	1.9	0.1	0.0	10.4	0.0	4.2	0.0	8.3	0.1	0.0	0.0	0.5	65.8	1.1	0.1	0.0	0.0	0.1	0.0	0.0	2.1	0.5	876
		32X-3, 100-105	12	1.3	0.0	2.6	0.0	0.0	10.3	0.0	16.7	1.3	1.3	2.6	2.6	0.0	0.0	0.0	0.0	1.3	1.3	6.4	0.0	0.0	0.0	2.6	21.8	3.9	0.0	0.0	0.0	5.1	0.0	0.0	9.0	3.8	78
	300	33X-3, 100-105	23	0.0	3.0	0.0	0.0	0.0	3.0	5.0	7.0	0.0	1.0	7.0	7.0	0.0	0.0	0.0	2.0	1.0	3.0	33.0	0.0	0.0	0.0	3.0	16.0	2.0	0.0	0.0	0.0	4.0	1.0	0.0	6.0	1.0	101
		34X-3, 100-105	13	1.9	1.0	0.0	0.0	5.7	7.6	10.5	11.4	0.0	1.9	0.0	1.0	0.0	0.0	0.0	0.0	5.7	1.0	14.3	0.0	0.0	0.0	1.9	18.1	7.6	0.0	0.0	0.0	4.8	0.0	0.0	1.0	1.0	105
		35X-3, 100-105	42	0.0	13.5	2.3	0.0	2.3	0.8	8.3	15.0	0.0	3.0	1.5	1.5	1.5	0.0	0.0	1.5	0.0	3.1	24.1	0.0	0.0	0.0	0.0	13.5	3.8	0.0	0.0	0.0	1.5	0.0	0.0	1.5	0.8	133
		36X-3, 95-100	27	0.0	12.0	0.0	0.0	0.6	0.0	9.5	4.4	0.0	0.6	0.0	0.6	27.3	0.0	0.0	1.9	0.0	3.2	20.0	0.0	0.0	0.0	0.6	19.0	1.9	0.0	0.0	0.0	4.4	0.0	0.0	0.6	1.3	158
		37X-3, 90-94	29	0.0	12.3	0.0	2.9	0.0	1.0	7.6	20.0	0.0	2.9	1.0	2.9	0.0	0.0	0.0	0.0	0.0	7.6	20.0	0.0	0.0	0.0	0.0	5.5	1.0	0.0	0.0	0.0	7.6	0.0	0.0	2.9	0.0	105
		38X-3, 100-104	16	0.0	0.0	7.0	2.3	0.0	0.0	18.6	20.9	0.0	4.7	0.0	2.3	0.0	0.0	0.0	4.7	0.0	0.0	14.0	0.0	0.0	0.0	0.0	9.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	11.6	4.7	43
Miocene, late		39X-3, 90-95	9	0.0	20.9	0.0	0.0	0.0	0.0	4.7	7.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.0	55.8	0.0	0.0	0.0	0.0	2.3	0.0	0.0	0.0	0.0	2.3	0.0	0.0	0.0	0.0	43
		40X-3, 92-97	21	0.0	23.4	0.0	0.0	0.0	0.6	0.7	3.2	0.0	0.7	0.7	0.0	0.0	0.0	0.0	1.9	0.7	5.8	44.8	0.0	0.0	0.0	0.0	7.8	0.7	0.0	0.0	0.0	2.6	0.0	0.0	1.3	1.3	154
		41X-3, 87-93	19	0.0	26.6	0.0	0.0	0.6	0.6	1.7	2.9	0.0	1.2	0.6	0.0	0.0	0.0	0.0	0.0	2.3	9.2	45.1	0.6	0.0	0.0	0.0	1.7	0.0	0.0	0.0	0.0	4.6	0.0	0.0	0.6	0.6	173
		43X-3, 87-93	38	1.1	3.7	1.6	0.0	0.5	0.0	5.3	5.8	0.0	2.6	1.1	0.0	20.1	0.0	0.0	0.5	0.5	1.6	19.6	0.0	0.0	0.0	0.5	15.3	2.7	0.0	5.3	0.0	9.0	0.0	0.0	1.1	2.1	189
	400	44X-3,105-110	21	0.5	4.1	0.0	0.0	0.0	0.0	3.6	4.1	2.1	2.1	1.0	0.0	38.5	0.0	0.0	0.5	0.0	3.1	5.1	0.5	0.0	0.0	0.0	29.7	0.5	0.0	0.0	0.0	1.0	0.0	0.0	1.0	5.1	195
		45X-2, 114-119	31	0.0	64.3	0.0	0.0	0.0	0.0	5.4	1.0	0.3	0.0	0.0	1.2	8.7	0.2	0.0	2.4	1.1	1.7	3.3	0.2	0.0	0.0	0.2	3.8	1.7	0.0	0.2	0.2	2.1	0.0	0.0	1.4	0.5	574
		47X-3, 100-103	41	0.2	3.3	0.0	0.0	2.1	0.0	1.5	1.5	0.8	0.3	1.8	5.2	0.0	0.9	0.9	2.0	15.3	0.0	5.2	0.0	0.0	0.0	0.5	30.4	3.5	0.5	0.5	1.1	7.9	0.0	0.6	0.2	7.8	658

Table 2. Percentage distribution of dinoflagellate taxa at Site 823.

Age		Depth (mbsf)	Sample	Relative abundance	*Achomosphaera sp.*	*Bataicasphaera spp.*	*Blysmatodinium argoi*	*Dapsilidinium pastielsii*	*Hystrichokolpoma rigaudiae*	*Impagidinium aculeatum*	*Impagidinium paradoxum*	*Impagidinium sphaericum*	*Impagidinium patulum*	*Impagidinium striatum*	*Impagidinium sp cf paradoxum*	*Lingulodinium machaerophorum*	*Melitasphaeridium choanophorum*	*Nematosphaeropsis lemniscata*	*Operculodinium centrcarpum*	*Operculodinium echigoense*	*Operculodinium israelianum*	*Opeculodinium janduchenei*	*Operculodinium longispinigerum*	*Multispinula quanta*	*Quinquecuspis concretum*	*Polysphaeridium zoharyi*	*Selenopemphix nephroides*	*Spiniferites bulloideus*	*Spiniferites hyperacanthus*	*Spiniferites pachydermus*	*Spiniferites ramosus*	*Sumatradinium hispidum*	*Tectatodinium pellitum*	*Tuberculodinium vancampoae*	Cyst Type A	Count
Pleistocene		0	1H-4, 65-69	24	0.0	0.0	0.0	0.0	0.0	53.0	10.7	3.4	20.1	6.7	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.7	0.0	0.0	0.0	0.0	0.0	2.0	0.0	149
			3H-4, 64-69	18	0.0	0.0	0.0	0.0	0.0	9.4	6.3	0.0	12.5	0.0	0.0	6.3	0.0	0.0	3.1	3.1	6.3	0.0	3.1	0.0	0.0	0.0	0.0	34.4	9.4	0.0	0.0	0.0	0.0	6.3	0.0	32
			5H-4, 65-69	19	0.0	0.0	0.0	0.0	0.0	45.8	12.5	2.1	16.7	16.7	0.0	0.0	0.0	0.0	2.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.1	0.0	0.0	0.0	0.0	0.0	2.1	0.0	48
			7H-4, 65-69	8	0.0	0.0	0.0	0.0	0.0	18.2	40.9	0.0	9.1	9.1	0.0	0.0	0.0	0.0	0.0	4.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.6	4.6	0.0	0.0	0.0	0.0	0.0	0.0	22
			9H-4, 63-67	35	0.8	0.0	0.0	0.0	0.0	2.3	7.9	0.0	3.2	0.0	1.0	7.1	0.0	1.6	7.9	4.8	7.9	0.0	1.6	0.0	0.0	0.0	0.0	42.9	7.1	0.0	0.0	0.0	0.0	1.6	2.3	126
		100	11H-4, 65-69	31	0.9	0.0	0.0	0.0	0.0	4.1	13.0	0.5	5.9	1.4	0.0	2.7	0.0	0.0	2.7	2.7	7.7	0.0	2.7	0.0	0.0	0.0	0.0	59.3	2.3	0.0	0.0	0.0	0.0	2.7	0.5	221
			13X-3, 58-60	13	10.4	0.0	0.0	0.0	0.0	3.5	5.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.6	3.5	12.1	0.0	5.2	0.0	0.0	0.0	0.0	36.2	8.6	0.0	2.0	0.0	0.0	1.7	1.7	58
			15X-3, 60-64	25	2.7	0.0	0.0	0.0	0.0	2.7	1.8	2.7	0.9	2.7	0.0	0.0	0.0	0.0	8.1	3.6	6.3	0.0	3.6	0.0	0.0	0.0	0.9	49.5	2.7	0.0	1.8	0.0	0.0	4.5	1.8	111
			16X-3, 60-64	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2
Pliocene	late	200	22X-4, 60-64	22	0.0	0.0	0.0	0.0	1.0	13.8	17.2	0.0	13.8	10.3	0.0	0.0	0.0	0.0	3.4	0.0	0.0	0.0	10.3	0.0	0.0	6.9	0.0	10.3	6.9	0.0	0.0	0.0	0.0	3.4	0.0	29
			25X-3, 60-64	8	0.0	0.0	0.0	0.0	0.0	0.0	4.4	0.0	0.0	4.4	0.0	0.0	0.0	0.0	8.7	13.0	13.0	0.0	0.0	0.0	0.0	0.0	0.0	17.4	21.7	0.0	4.4	0.0	0.0	8.7	4.4	23
			27X-4, 68-72	55	2.0	0.0	0.0	2.0	12.0	3.0	5.0	0.0	5.0	0.0	1.0	12.0	0.0	0.0	4.0	1.0	7.0	0.0	1.0	0.0	0.0	0.0	0.0	34.0	1.0	0.0	0.0	0.0	0.0	4.0	2.0	97
			29X-4,65-70	51	0.0	0.0	0.0	2.6	2.0	0.5	1.0	0.5	0.0	0.0	0.5	4.6	0.0	0.0	7.7	0.0	5.6	0.0	2.6	0.5	0.0	0.0	0.0	67.2	2.1	0.0	0.0	0.0	0.0	2.1	1.5	195
			31X-4, 86-90	32	0.0	0.0	0.0	0.9	5.1	6.8	6.0	0.0	10.0	3.0	0.9	0.0	0.0	0.0	8.6	0.9	5.0	0.0	4.3	0.0	0.0	0.0	0.0	46.2	0.0	0.0	0.0	0.0	0.0	0.9	2.6	117
		300	34X-4, 87-91	68	0.0	0.0	0.0	3.5	22.3	8.1	5.0	0.7	3.9	1.8	1.4	2.5	0.0	1.1	0.7	0.0	1.4	0.0	3.5	0.0	0.0	2.1	0.0	41.3	1.1	0.0	0.0	0.0	0.0	0.4	0.4	283
			36X-4, 65-69	83	0.0	0.0	0.0	0.0	1.2	0.4	1.8	1.0	1.0	0.0	0.2	5.1	0.0	0.2	0.0	4.9	4.8	0.0	2.7	0.2	0.0	25.8	0.0	48.8	0.4	0.0	0.0	0.0	0.0	0.4	0.2	512
			38X-4, 66-70	51	0.0	0.0	0.0	0.0	13.3	1.7	5.0	1.3	4.2	0.0	0.8	0.4	0.0	0.0	0.0	5.4	2.1	0.0	2.1	0.0	0.0	54.2	0.0	7.5	0.8	0.0	0.0	0.0	0.0	1.3	0.0	240
	early		40X-4, 66-70	70	0.0	0.0	0.0	0.0	1.4	0.0	0.0	0.0	0.3	0.0	0.3	0.0	0.0	0.5	0.0	0.5	1.0	0.0	0.3	0.0	0.0	93.3	0.3	1.2	0.5	0.0	0.3	0.0	0.0	0.5	0.0	418
		400	43X-4, 64-68	30	0.0	0.0	0.0	0.9	0.9	0.3	1.2	0.0	1.2	0.0	0.6	6.6	0.0	0.0	0.0	8.7	12.6	0.0	7.2	0.3	0.0	1.5	0.9	48.9	3.3	0.0	0.6	0.0	0.0	2.7	1.5	333
			45X-4, 65-69	39	1.4	0.0	0.0	0.0	3.6	3.6	2.9	0.0	2.2	0.0	2.2	7.9	0.0	0.0	0.0	0.7	3.6	0.0	4.3	0.0	0.0	0.0	0.0	54.0	2.9	0.0	1.4	0.0	0.0	8.6	0.7	139
			47X-4, 57-60	33	0.0	0.0	3.9	0.0	3.9	2.6	6.4	0.0	3.9	1.3	1.3	2.6	0.0	0.0	0.0	1.3	9.0	0.0	11.6	0.0	0.0	0.0	0.0	39.7	1.3	0.0	0.0	0.0	0.0	2.6	9.0	78
			49X-4, 61-64	81	0.0	0.0	0.0	0.0	1.4	2.9	4.3	0.0	0.0	0.7	0.0	2.1	0.0	0.0	0.0	0.0	6.4	0.0	11.4	0.0	0.0	16.4	0.0	48.6	5.0	0.0	0.0	0.0	0.0	3.6	0.7	140
			52X-4, 58-60	33	0.0	0.0	0.0	0.0	0.7	0.7	0.7	0.0	5.5	0.7	0.0	13.2	0.0	0.0	0.0	0.0	6.3	0.0	10.4	0.0	0.0	0.0	0.0	58.3	2.1	0.0	0.7	0.0	0.0	2.8	0.0	144
		500	54X-4, 75-77	39	0.6	0.0	0.0	0.0	0.3	0.9	1.2	0.0	2.2	0.3	0.0	12.9	0.0	0.0	0.0	0.0	4.3	0.0	8.6	0.6	0.0	0.0	0.0	51.4	1.2	0.0	0.0	0.0	0.0	13.9	1.2	325
			56X-4, 87-90	48	0.0	0.0	0.0	0.0	1.8	0.5	1.8	0.0	1.0	0.0	0.0	5.9	0.5	0.0	0.0	0.5	6.4	0.0	5.4	0.5	0.0	0.0	0.0	69.0	3.2	0.0	0.5	0.0	0.0	1.4	1.4	219
			58X-4, 84-88	27	0.0	0.0	0.0	0.0	2.6	0.0	7.9	0.0	1.3	4.0	0.0	4.0	0.0	0.0	0.0	0.0	1.3	0.0	17.1	0.0	0.0	0.0	1.3	40.8	4.0	1.3	0.0	0.0	0.0	2.6	11.8	76
			60X-4, 60-64	14	0.0	0.0	0.0	0.0	1.1	0.0	0.0	0.0	1.1	0.0	0.0	2.2	0.0	0.0	0.0	2.2	4.4	0.0	26.7	0.0	0.0	0.0	0.0	44.4	2.2	1.1	0.0	0.0	0.0	2.2	12.2	90
			62X-4, 60-62	26	0.0	0.0	0.0	0.0	0.5	0.5	3.4	0.0	7.7	0.5	0.0	2.9	0.0	0.0	0.0	0.0	5.8	0.5	7.8	0.0	0.0	0.0	0.5	58.3	4.9	0.5	1.5	0.0	0.0	2.9	1.9	206
		600	64X-4, 60-64	39	0.0	0.0	0.0	0.0	14.1	0.0	11.3	0.0	2.8	0.0	0.0	2.8	0.0	0.0	0.0	0.0	12.7	0.0	5.6	0.0	0.0	1.4	0.5	36.6	1.4	0.0	1.4	0.0	0.0	7.0	2.8	71
			66X-4, 58-64	68	0.0	0.0	0.0	0.0	1.6	1.2	0.4	0.0	2.3	0.0	0.0	3.2	0.0	0.0	0.4	0.4	9.1	0.0	2.8	0.0	0.0	0.0	0.0	71.8	1.6	0.8	0.8	0.0	0.0	3.2	0.4	252
			68X-4, 65-68	69	0.0	0.0	0.0	5.2	0.2	0.0	0.2	0.0	0.0	0.0	0.0	7.6	0.2	0.7	0.0	1.2	6.4	0.0	11.4	0.2	0.0	0.2	0.2	61.7	0.7	0.2	1.2	0.0	0.0	1.4	0.7	421
Miocene	late		70X-4, 60-64	46	0.0	0.0	0.0	0.0	1.0	3.3	3.3	0.0	5.2	0.0	1.0	1.4	0.0	0.0	0.0	1.0	9.0	0.5	32.2	0.0	0.0	0.0	0.5	21.3	4.7	1.9	3.8	0.0	0.0	9.0	1.4	211
			73X-4, 63-67	52	0.0	0.0	0.0	0.0	0.0	1.5	1.9	0.8	2.3	0.3	0.0	7.2	0.8	3.0	0.0	3.8	7.6	0.0	3.8	0.0	0.0	0.0	0.0	63.5	3.0	0.0	0.3	0.0	0.0	1.5	0.3	263
		700	75X-4, 66-70	44	0.0	0.0	0.0	0.0	0.9	3.1	1.8	0.0	1.3	0.0	0.4	3.5	11.4	0.4	0.0	2.2	8.3	0.4	8.3	0.0	0.0	0.4	0.4	44.3	0.0	0.4	2.2	0.0	0.0	7.9	2.2	228
			77X-4, 67-71	28	0.0	0.0	0.0	0.0	0.3	0.3	0.0	0.0	0.3	0.0	0.0	3.7	0.0	0.0	0.0	1.7	3.4	0.0	10.7	0.3	0.0	0.9	2.0	67.2	2.8	0.3	1.1	0.0	0.0	3.1	1.4	354
			79X-5, 72-79	28	0.0	0.0	0.0	0.0	0.7	0.0	0.0	0.0	0.7	0.0	0.0	2.1	0.0	0.0	0.0	0.7	3.8	0.0	3.8	0.3	0.0	0.3	1.4	80.3	4.5	1.7	1.0	0.0	0.0	1.0	0.7	290
			81X-4, 64-66	57	1.0	0.0	0.0	0.0	0.5	1.0	0.8	0.0	0.8	0.3	0.5	2.8	0.8	0.5	0.0	1.3	5.1	0.0	2.5	0.3	0.0	0.8	2.0	74.4	2.5	0.5	0.8	0.0	0.0	8.0	0.5	395
			1R-1, 75-79	30	0.0	0.0	0.0	0.0	0.0	0.0	1.8	0.0	0.6	0.0	0.0	10.7	1.2	0.6	0.0	0.6	5.9	0.0	1.2	0.6	0.6	9.5	0.0	58.6	4.1	0.6	0.6	0.0	0.0	2.9	0.0	169
		800	3R-3, 59-61	70	0.0	0.0	0.0	0.0	0.0	0.0	0.9	0.0	0.4	0.2	0.0	5.9	2.6	0.2	0.0	0.2	1.3	0.0	3.3	0.2	0.0	0.2	0.2	78.1	0.7	1.1	0.9	0.0	0.2	0.4	2.6	461
			5R-4, 47-50	66	0.2	0.0	0.0	0.0	0.0	0.2	1.8	0.2	1.3	0.0	0.0	6.4	8.3	0.2	0.2	0.9	5.3	0.0	1.2	0.0	0.0	0.2	0.0	69.0	2.8	0.2	0.0	0.0	0.0	0.7	0.7	435
			10R-6, 69-73	27	3.4	0.0	0.0	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.3	3.4	0.0	0.0	1.5	19.1	0.0	2.3	0.0	0.0	2.3	0.8	84.7	4.6	0.0	0.0	2.3	0.0	1.5	6.1	131
			12R-4, 64-68	67	3.0	0.0	0.0	0.0	1.3	0.0	1.1	0.0	0.0	0.0	0.0	2.4	0.0	0.2	0.0	4.7	8.0	0.0	0.0	0.0	0.0	0.0	0.4	75.4	0.4	0.0	0.0	0.4	0.0	1.3	1.3	464
		900	14R-4, 58-62	58	2.1	0.0	0.0	0.0	1.4	0.0	3.0	0.0	1.6	0.0	0.0	0.7	4.4	0.0	0.0	2.1	7.6	0.2	2.3	0.0	0.0	1.6	0.7	67.8	1.2	0.0	0.0	0.0	0.0	1.2	2.1	435
			17R-6, 83-88	58	0.4	0.0	0.0	0.0	3.5	0.0	1.3	0.0	1.1	0.0	0.0	4.6	0.7	0.2	0.2	1.1	6.3	0.0	0.7	0.0	0.0	0.0	0.2	72.7	0.4	0.0	0.4	2.2	0.0	1.3	0.9	461
			19R-3, 62-67	19	0.0	0.0	0.0	0.0	11.4	0.0	1.0	0.0	0.0	0.0	0.0	5.7	2.4	0.0	0.0	0.0	12.4	0.0	4.3	0.0	0.0	0.0	1.0	43.3	10.5	0.0	0.5	2.9	0.0	2.4	1.9	210
	m.		21R-4, 50-53	23	0.0	0.0	0.0	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.6	0.0	0.0	0.0	0.7	0.7	0.0	0.0	0.0	0.0	1.4	0.0	70.4	4.9	0.0	1.4	2.8	0.0	2.1	0.7	142
		1000	24R-3, 22-24	73	0.0	0.0	0.0	0.0	0.9	0.0	0.0	0.0	0.0	0.0	0.4	33.3	0.0	0.0	0.0	4.3	10.0	0.0	1.4	0.0	0.0	0.0	0.0	43.1	4.6	0.0	0.5	0.0	0.0	1.8	0.2	439

The presence of *Operculodinium longispinigerum* in middle Miocene through late Quaternary sections of Sites 815 and 823 and in the late Pleistocene age deposits of Site 820 (McMinn, this volume) from northeastern Australia extends the total known range of this species from the early late Miocene to early Pleistocene range previously documented at Site 765. However, this species has still not been reported from Holocene samples, surface sediment samples, or living assemblages.

With the exception of *Blysmatodinium argoi,* which has only previously been reported by McMinn (1992a), all of the above species have similar biostratigraphic ranges in areas outside the Australian region. These were reviewed by McMinn (1992a). The biostratigraphic ranges of these species (Fig. 2) will form the basis of a future tropical Neogene dinoflagellate cyst zonation. Other dinoflagellate cysts with consistent range tops and/or bottoms within the Neogene, such as *Achomosphaera ramulifera, Spiniferites rubinus* and so forth, are apparently restricted to temperate or boreal environments and were not recorded here, but are discussed elsewhere (McMinn, 1992b; Bujak and Matsuoka, 1986).

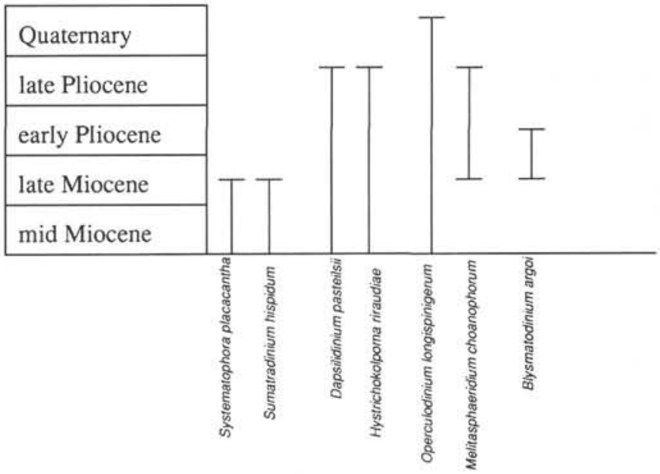

Figure 2. Distribution of selected dinoflagellate cysts that have restricted biostratigraphic ranges within the Neogene sequences of ODP Sites 765, 815, and 823 from northern Australia.

COMPARISON OF ASSEMBLAGES FROM SITES 815 AND 823

The paleogeographic settings of Sites 823 and 815 have several dissimilarities. Site 823, located ~200 km from shore, is currently at a depth of 1638 m in the central western Queensland Trough. Benthic foraminifers imply that deposition has occurred at lower bathyal paleodepths (1000–2000 m) since the late Miocene. However, Site 815 is located ~250 km from shore, at a depth of only 450 m on the northern margin of the Marion Plateau. Here, benthic foraminifers indicate outer neritic water depths (100–200 m) during the latest Miocene, deepening to upper bathyal paleodepths (200–600 m) during the Pliocene.

Most dinoflagellates are planktonic and, therefore, their distribution in the water column is controlled not so much by the depth of water beneath them, but by factors related to availability of nutrients, turbidity, salinity, and temperature (McMinn, 1991; Wall et al., 1977). In shallow waters, particularly those shoreward of the shelf-break, bathymetry is likely to significantly effect the distribution of surface currents and upwelling zones and hence the nutrient supply. However, at oceanic sites the effects of deeper topographic features are less likely to be significant and dinoflagellate cyst distribution patterns are more likely to reflect the presence of the predominantly oligotrophic, mid-oceanic waters. Water depths above the submerged margin plateaus off the northern Queensland coast are considerably less than those of the surrounding ocean basins, but these changes in benthic topography are apparently insufficient to significantly effect either local surface currents or upwelling and consequently have not been reflected in the distribution of dinoflagellate cyst assemblages. Assemblages from Sites 815 and 823 are similar and apparently show few indications of their differing positions and bathymetric histories.

Wall et al. (1977), Harland (1983), Wrenn and Kokinus (1986) and McMinn (1992a, 1992c) have described a distinctive oceanic dinoflagellate cyst assemblage that is dominated by *Impagidinium* spp. and *Nematosphaeropsis lemniscata.* This assemblage is well represented throughout the Neogene section at Sites 815 and 823 but became significantly more abundant after the late Pliocene. McMinn (1992c) used the changing abundance of this assemblage in a Quaternary sequence from southeastern Australia to indicate changes in sea level. However, at Sites 815 and 823, the correlation between the abundance of this assemblage and the relative dinoflagellate percentage (the proportion of dinoflagellates in a palynomorph assemblage), another factor that usually increases with distance from shore, is poor, and other data reflecting sea-level change are unavailable. Therefore, as it is not possible to independently establish the validity of the oceanic assemblage/sea-level change correlation at these sites, an interpretation in terms of sea-level change would be unwarranted.

COMPARISON WITH OTHER SITES

McMinn (1992a) reviewed the composition of Neogene, tropical, and subtropical dinoflagellate cyst assemblages and compared them with those recovered from Site 765, off the northwestern coast of Australia. The assemblages documented from Sites 815 and 823 most closely resemble those from Site 765, which were also obtained from a tropical, outer-shelf, abyssal-plain environment. The most consistently abundant taxa seen were *Spiniferites bulloideus* and *Operculodinium israelianum.* Other taxa that achieve scattered dominance include *Polysphaeridium zoharyi, Lingulodinium machaerophorum, Impagidinium* spp., and *Operculodinium longispinigerum.* This composition is consistent with other tropical and subtropical locations, particularly those from deeper water settings such as the equatorial Pacific Ocean (Jarvis and Tocher 1985) and the Gulf of Mexico (Wrenn and Kokinos 1986).

SYSTEMATIC PALYNOLOGY

Division DINOPHYTA Pascher, 1914
Class DINOPHYCEAE Fritsch, 1935
Order PERIDINIALES Haeckel, 1894

Achomosphaera sp. (Pl. 2, Fig. 16).
Batiacasphaera micropapillata Stover, 1977 (Pl. 2, Fig. 15).
Blysmatodinium argoi McMinn, 1992 (Pl. 2, Figs. 4, 5).
Dapsilidinium pasteilsii (Davey and Williams, 1966) Bujak et al., 1980 (Pl. 3, Figs. 1, 2).
Hystrichokolpoma rigaudiae Deflandre and Cookson, 1955 (Pl. 3, Fig. 8).
Impagidinium aculeatum (Wall, 1967) Lentin and Williams, 1981 (Pl. 1, Figs. 1, 3).
Impagidinium paradoxum (Wall, 1967) Stover and Evitt, 1978.
Impagidinium patulum (Wall, 1967) Stover and Evitt, 1978 (Pl. 1, Figs. 11, 14).
Impagidinium sphaericum (Wall, 1967) Lentin and Williams, 1981 (Pl. 1, Figs. 2, 6, 9, 10, 13).
Impagidinium strialatum (Wall, 1967) Stover and Evitt, 1978 (Pl. 1, Fig. 12).
Impagidinium sp. cf. *I. paradoxum* (Wall, 1967) Stover and Evitt, 1978 (Pl. 1, Figs. 3, 4, 7, 8).
Impletosphaeridium spp. (Pl. 2, Fig. 10).
Lingulodinium machaerophorum (Deflandre and Cookson, 1955) Wall, 1967 (Pl. 3, Fig. 3).
Melitasphaeridium choanophorum (Deflandre and Cookson, 1955) Harland and Hill, 1979 (Pl. 2, Figs. 6, 7).
Multispinula quanta Bradford, 1975 (Pl. 3, Fig. 5).
Nematosphaeropsis lemniscata Bujak, 1984 emend. Wrenn, 1988. (Pl. 2, Fig. 19).
Operculodinium centrocarpum (Deflandre and Cookson, 1955) Wall, 1967 (Pl. 2, Fig. 14).

Operculodinium israelianum (Rossignol, 1962) Wall, 1967 (Pl. 2, Figs. 11, 12).
Operculodinium janduchenei Head et al., 1989 (Pl. 2, Figs. 1, 2, 3).
Operculodinium longispinigerum Matsuoka, 1983 (Pl. 2, Fig. 13).
Operculodinium echigoense Matsuoka, 1983 (Pl. 2, Figs. 20, 21, 22).
Operculodinium sp. cf. *O. janduchenei* Head et al., 1989.
Polysphaeridium zoharyi (Rossignol, 1962) Bujak et al., 1980.
Pyxidinopsis sp. (Pl. 2, Figs. 8, 9).
Quinquecuspis concretum (Reid 1977) Harland 1982.
Reticulosphaera sp.
Selenopemphix nephroides Benedek, 1972 (Pl. 3, Fig. 4).
Spiniferites bulloideus (Deflandre and Cookson, 1955) Sarjeant, 1970.
Spiniferites hyperacanthus (Deflandre and Cookson, 1955) Cookson and Eisenack, 1974.
Spiniferites membranaceus (Rossignol, 1964) Sarjeant, 1970.
Spiniferites mirabilis (Rossignol, 1964) Sarjeant, 1970.
Spiniferites pachydermus (Rossignol, 1964) Sarjeant, 1970 (Pl. 2, Fig. 17).
Spiniferites ramosus (Ehrenberg, 1838) Loeblich and Loeblich, 1966 (Pl. 2, Fig. 18).
Stelladinium reidii Bradford, 1975.
Sumatradinium hispidum (Drugg, 1970) Lentin and Williams, 1976 (Pl. 3, Fig. 7).
Tectatodinium pellitum Wall, 1967.
Tuberculodinium vancampoae Wall, 1967 (Pl. 3, Fig. 6).
Votadinium calvum Reid, 1977.

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* Abbreviations for names of organizations and publication titles in ODP reference lists follow the style given in *Chemical Abstracts Service Source Index* (published by American Chemical Society).

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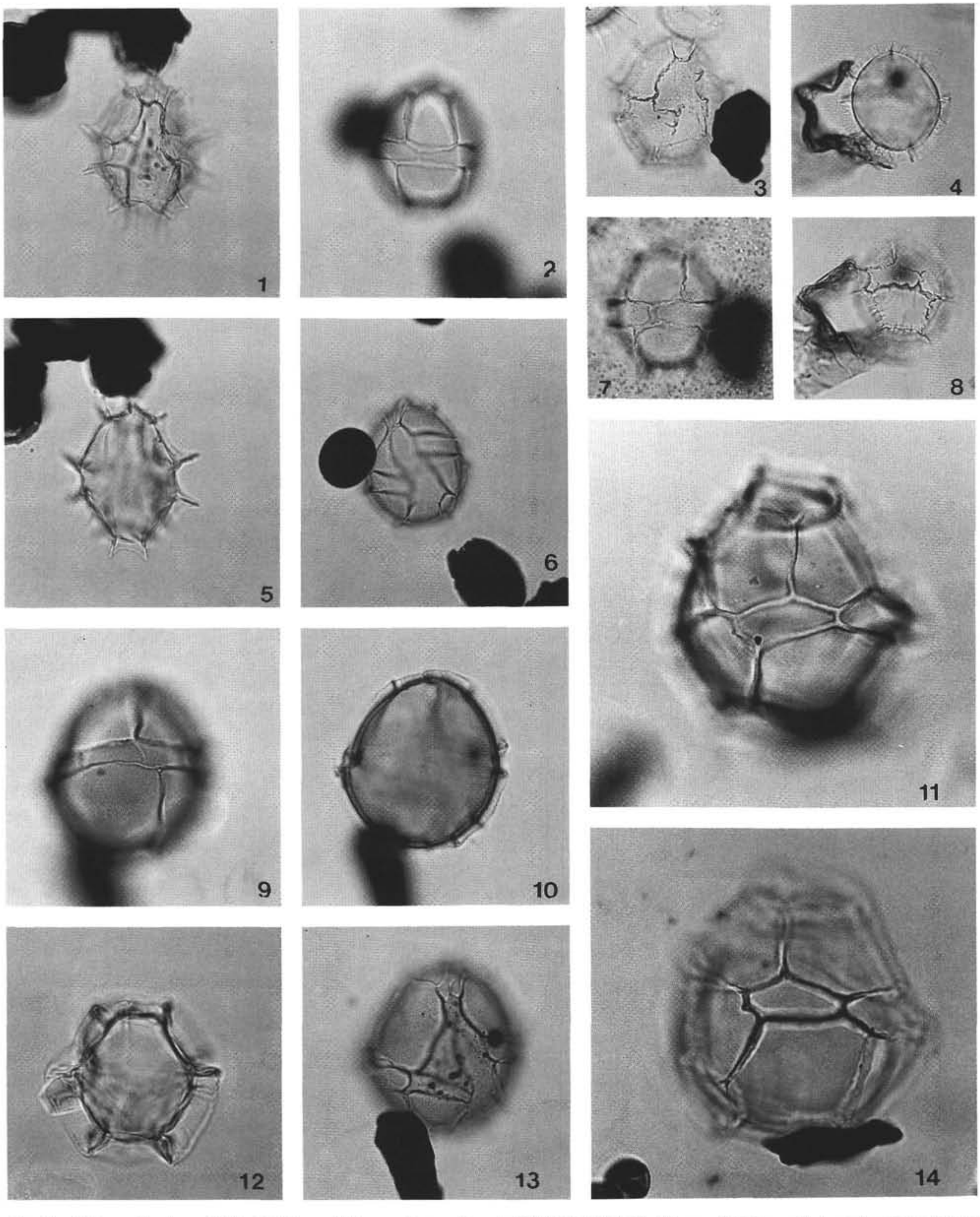

Plate 1. (All magnifications ×650.) **1, 5.** *Impagidinium aculeatum*, Sample 133-815B-26X-3, 98–103 cm. **2, 6.** *Impagidinium sphaericum*, Sample 133-815A-14H-3, 100–105 cm. **3, 7.** *Impagidinium* sp. cf. *paradoxum*, Sample 133-815A-6H-3, 105–109 cm. **4, 8.** *Impagidinium* sp. cf. *paradoxum*, Sample 133-815B-23H-3, 98–104 cm. **9, 10, 13.** *Impagidinium sphaericum*, Sample 133-815A-14H-3, 100–105 cm. **11, 14.** *Impagidinium patulum*, Sample 133-815B-44X-3, 105–110 cm. **12.** *Impagidinium strialatum*, Sample 133-815B-44X-3, 105–110 cm.

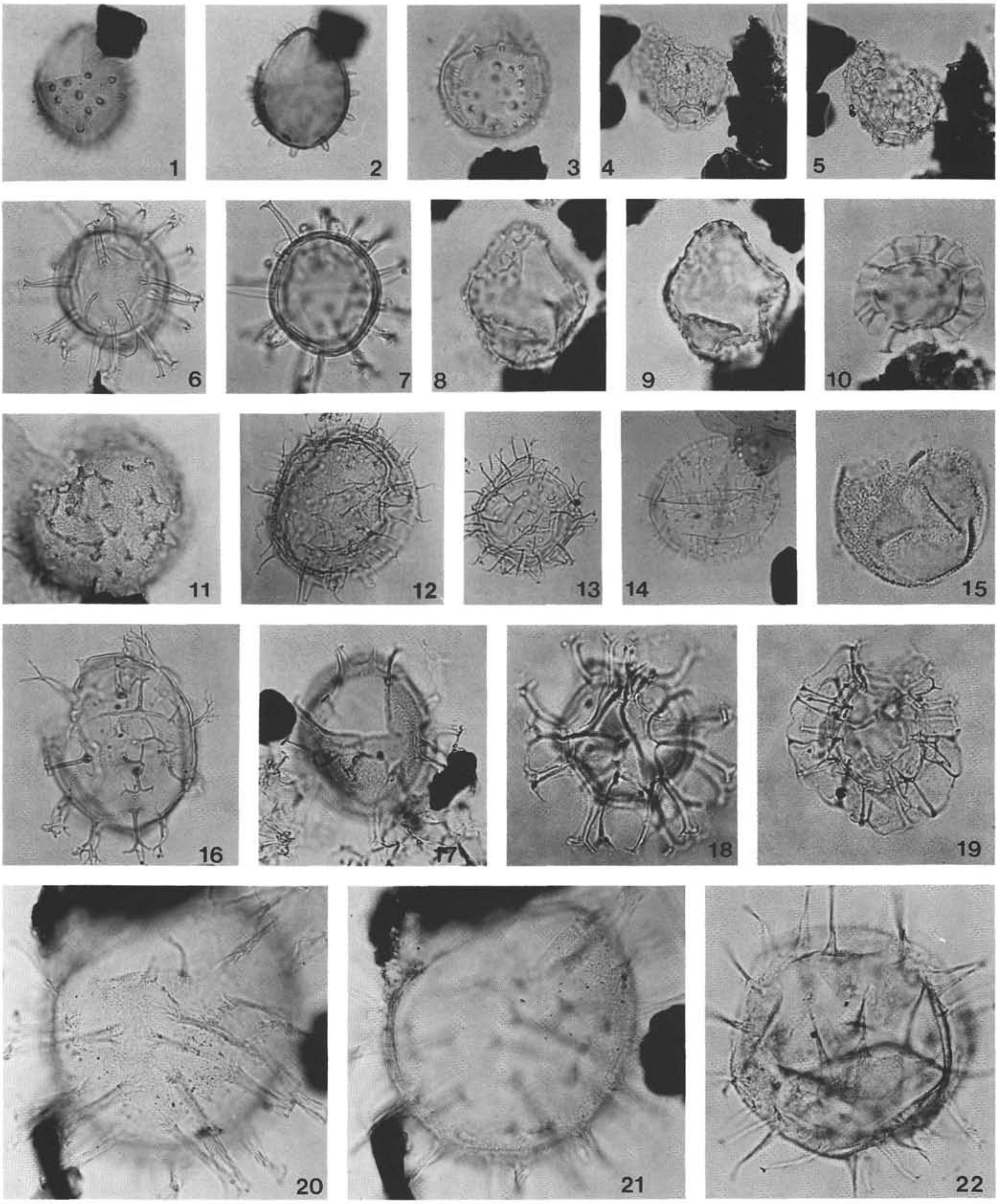

Plate 2. (All magnifications ×650.) **1, 2.** *Operculodinium janduchenei,* Sample 133-815B-26X-3, 98–103 cm. **3.** *Operculodinium janduchenei,* Sample 133-815A-22X-3, 98–102 cm. **4, 5.** *Blysmatodinium argoi,* Sample 133-815B-27X-3, 98–102 cm. **6, 7.** *Melitasphaeridium choanophorum,* Sample 133-815B-44X-3, 105–110 cm. **8, 9.** *Pyxidinopsis* sp., Sample 133-815B-44X-3, 105–110 cm. **10.** *Reticulosphaera* sp., Sample 133-815B-47X-3, 100–103 cm. **11, 12.** *Operculodinium israelianum,* Sample 133-815B-27X-3, 98–102 cm. **13.** *Operculodinium longispinigerum,* Sample 133-815B-31X-3, 98–102 cm. **14.** *Operculodinium centrocarpum,* Sample 133-815B-31X-3, 98–102 cm. **15.** *Batiacasphaera* sp., Sample 133-815B-47X-3, 100–103 cm. **16.** *Achomosphaera* sp., Sample 133-815B-28X-3, 98–102 cm. **17.** *Spiniferites pachydermus,* Sample 133-815A-23H-3, 98–104 cm. **18.** *Spiniferites ramosus,* Sample 133-815B-47X-3, 100–103 cm. **19.** *Nematosphaeropsis lemniscata,* Sample 133-815B-28X-3, 98–102 cm. **20, 21.** *Operculodinium echigoense,* Sample 133-815A-14H-3, 100–105 cm. **22.** *Operculodinium echigoense,* Sample 133-815B-47X-3, 100–103 cm.

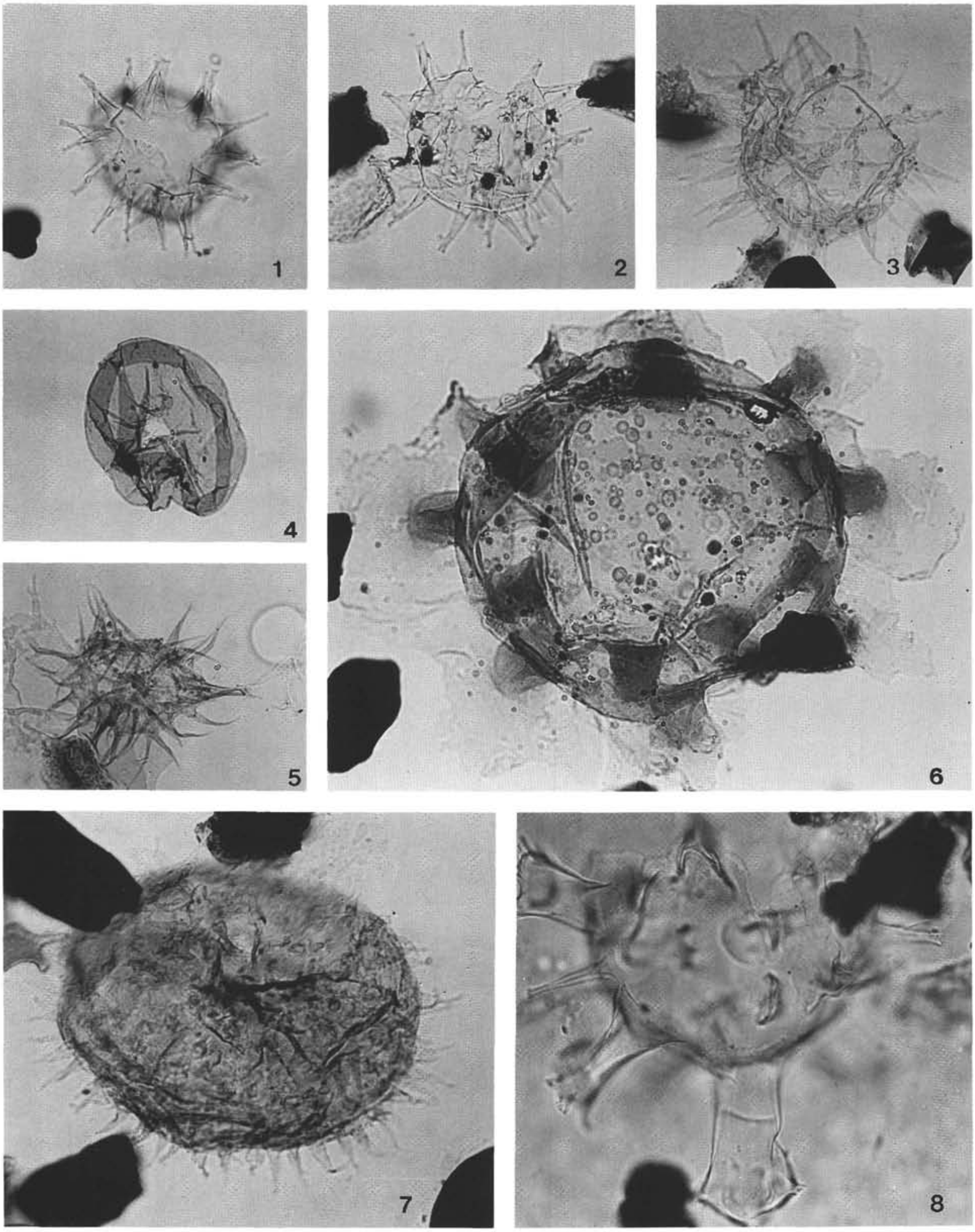

Plate 3. (All magnifications ×650) **1.** *Dapsilidinium pasteilsii*, Sample 133-815A-21H-3, 96–100 cm. **2.** *Dapsilidinium pasteilsii*, Sample 133-815A-10H-3, 60–65 cm. **3.** *Lingulodinium machaerophorum*, Sample 133-815A-27X-3, 98–102 cm. **4.** *Selenopemphix nephroides*, Sample 133-815B-28X-3, 98–102 cm. **5.** *Multispinula quanta*, Sample 133-815A-13H-3, 100–105 cm. **6.** *Tuberculodinium vancampoae*, Sample 133-815A-19H-3, 100–104 cm. **7.** *Sumatradinium hispidum*, Sample 133-815B-47X-3, 100–103 cm. **8.** *Hystrichokolpoma rigaudiae*, Sample 133-815B-47X-3, 100–103 cm.