Barker, P. F., Kennett, J. P., et al., 1990
Proceedings of the Ocean Drilling Program, Scientific Results, Vol. 113

29. EARLY CRETACEOUS PALYNOMORPHS FROM ODP SITES 692 AND 693, THE WEDDELL SEA, ANTARCTICA[1]

Barbara A. R. Mohr[2]

ABSTRACT

Detailed descriptions of *in situ* ?Valanginian to Albian Antarctic palynofloras are presented from Weddell Sea claystones with high percentages of organic matter ("black shales") and intercalated volcanic ash layers. The claystones were recovered from two sites (ODP Leg 113, Sites 692 and 693) on the continental margin of Dronning Maud Land. Palynological investigations of these Cretaceous sediments revealed a ?Valanginian-Hauterivian age for the Site 692 sediments and an Aptian-Albian age for Site 693. This paper is focused on the palynomorphs of Site 692. Miospores, dinoflagellate cysts, and acritarchs are listed and compared with early Cretaceous microfloras from the Antarctic Peninsula, Australia, and South America. The dinocyst assemblage of Site 692 seems to be very similar in composition to an assemblage from the South Shetlands (?Valanginian-Hauterivian-Barremian). It also agrees well with associations described from early Early Cretaceous sequences from the Perth Basin, southwestern Australia. According to the Australian miospore zonation schemes, the sporomorph flora from Site 692 belongs to the South Australian *Foraminisporis wonthaggiensis* Zone (early Valanginian to Hauterivian) or the lower part of the dinocyst *Muderongia* Superzone (Valanginian to Hauterivian).

INTRODUCTION

ODP Leg 113 drilled two Sites (692 and 693) in the Weddell Sea area, near the continental margin of Dronning Maud Land (~70°S, 13°W; Fig. 1) which contain in their lower cores Early Cretaceous mudstones with high percentages of organic matter (black shales), intercalated with volcanic ash and limestone layers.

These black shales seem to be facies equivalent with black shales found in the South Atlantic on the Falkland Plateau and off South Africa. Those sequences were drilled at Sites 327, and 330, on DSDP Leg 36 (Barker, Dalziel, et al., 1977) and at Site 511 on Leg 71 (Ludwig, Krasheninnikov, et al., 1983) and are of Neocomian to Aptian-Albian age. Herbin and Deroo (1979) noted that the black shale facies changed to a calcareous facies with lower organic matter content in the Albian. In contrast to the black shales drilled at more northerly DSDP sites, the black shales from the Falkland Plateau area are considered to be deposited at shallow depth, probably no greater than 400 m (Parker et al., 1983), and consist mainly of dark mudstones with only thin intercalated light limestone layers.

The black shale sequence, drilled at Site 692 contains a high nannoplankton content (Mutterlose and Wise, this volume) in contrast to the Hole 693A sequence, where nannoplankton was found rarely. Benthic foraminifers (Thomas, this volume) and palynomorphs were recognized at both sites. Important concerns about these black shales include the palynomorph content, the depositional environment, and the timing of black shale sedimentation in the high latitudes near Antarctica. This publication is focused on palynological investigations of the Hole 692B Cretaceous sequence and adds information about the Hole 693A palynomorph content.

MATERIAL AND METHODS

At Site 692 (Fig. 1) two holes were drilled (692A and 692B). The uppermost core of Hole 692B (Core 113-692B-1R) which was rotary drilled, contains Quaternary/Pliocene sediments based on siliceous microfossils. Cores 113-692B-2R and -3R were determined to be of Pliocene/Miocene age, while Cores 113-692B-4R to -6R yield material of unidentifiable age based on shipboard analysis (Barker, Kennett, et al., 1988). From Core 113-692B-7R (~54 mbsf) to the bottom of the hole (Core 113-692B-13W; 97.9 mbsf) organic rich claystones of Early Cretaceous age were drilled, (see Fig. 2).

Hole 693A (Fig. 2) was rotary drilled. At Hole 693B the sequence was partly redrilled with the advanced hydraulic piston corer (APC) and extended core barrel techniques (XCB) to get better recovery of Cenozoic sediments. The two uppermost cores 113-693A-1R to -2R, contain Pleistocene sediments based on shipboard analysis of siliceous microfossils (Barker, Kennett, et al., 1988). A Pliocene/Miocene sequence with high sedimentation rates was then drilled from Cores 113-693A-3R to -33R. Late early Oligocene siliceous sediments were recovered in Cores 113-693A-34R to -43R. The Cretaceous sequence was recovered from Core 113-693A-44R (~406 mbsf) until the bottom of the hole (Core 113-693A-51R; ~484 mbsf).

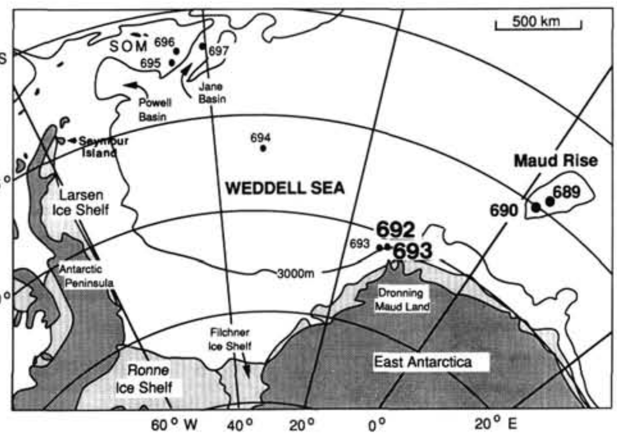

Figure 1. Map showing location of Sites 692 and 693 and other Leg 113 sites in the Weddell Sea. SOM = South Orkney microcontinent.

---

[1] Barker, P. F., Kennett, J. P., et al., 1990. *Proc. ODP, Sci. Results*. 113: College Station, TX (Ocean Drilling Program).

[2] Geological Institute, Federal Institute of Technology (ETH), 8092 Zürich, Switzerland.

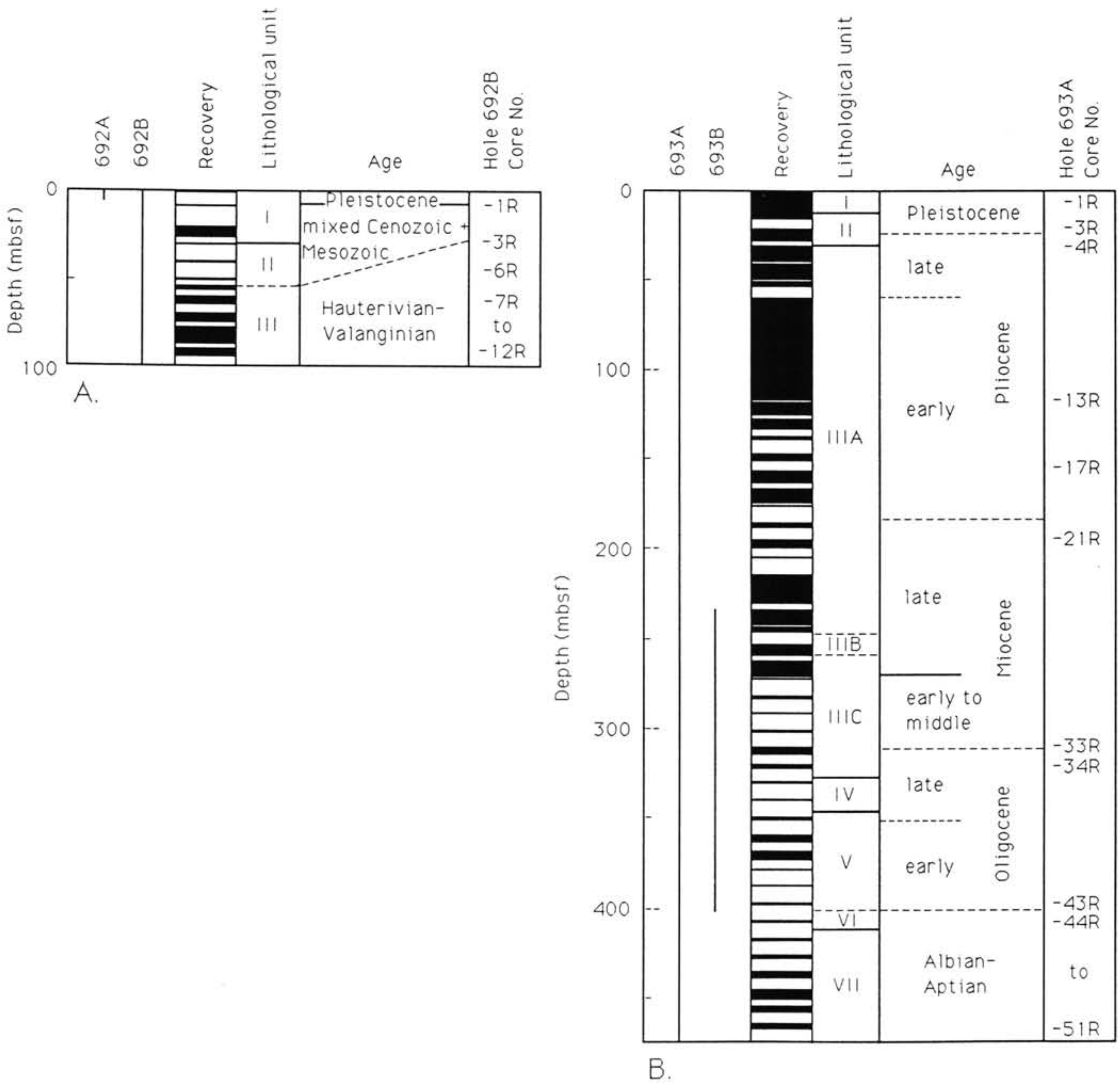

Figure 2. Summary columns of Sites 692 **(A)** and 693 **(B)**. Cored interval for each hole, core recovery (white = no recovery), lithostratigraphic units, age, and core numbers for some of the samples which are mentioned in the text. mbsf = meters below seafloor.

The sediments recovered in Cores 113-692B-7R to -12R at Hole 692B are composed of organic rich, nannofossil-bearing claystones, intercalated with medium grey ash-layers. The dark layers average 8.6% organic carbon, and contain the clay minerals chlorite, kaolinite, illite, and smectite (Barker, Kennett, et al., 1988).

The samples of Hole 692B (and samples of Hole 693A) were processed using standard centrifuge preparation techniques, in addition to sieving with a 15 μm sieve. Because of the abundance of coagulated fine organic particles (size 0.5–5 μm), which are closely attached to the palynomorphs and complicate identification, some of the samples were oxidized. After oxidation, the palynomorphs were light yellow. To increase the contrast, some samples were stained with Fuchsin. Smear slides, mounted with glycerine jelly were made to examine the kerogen and palynomorph content. For purposes of taxonomic determination and photographic documentation additional single grain slides were made. ODP localities and slide numbers of the figured specimens are given in the plate captions. If the sporomorphs were found in smear slides, coordinates are mentioned in addition, referring to the Nikkon Microscope "Microphot FX" No. 1020-1219. The slides are deposited at the Geological Institute of the ETH (Federal Institute of Technology) in Zürich.

RESULTS

Kerogen of Site 692

Most of the organic debris (80%-90%) from the black shale sediments of Hole 692B consist of fine particles (0.5-3 μm) of probable marine origin. Identifiable plant remains and palynomorphs are relatively rare (Pl. 1, Figs. 1, 2). This microscopic view is in accordance with the chemical analyses, which indicates that the origin of the organic matter is mainly marine (Barker, Kennett, et al., 1988). The palynofloras are estimated to be about 10% land derived sporomorphs and 90% marine palynomorphs (20% dinoflagellate cysts, and 70% acritarchs; Pl. 6, Fig. 2). Well preserved spores/pollen and dinocysts are therefore rare, even after oxidation of the samples and removal of the small organic debris. Among the acritarchs, the Leiospherids make up about 80%-90%. Different morphotypes of *Pterospermella* (Pl. 6, Figs. 3, 7), as described by Weiler (1988), and *Cymatiosphaera* (Pl. 7, Figs. 2, 6) are also common.

Palynoflora of Site 692

Until recently only a few descriptions of Early Cretaceous palynomorph assemblages from Antarctica were published. Reworked Cretaceous spores/pollen and dinocysts were first reported from Quaternary/Pliocene sediments around the Antarctic Continent, usually mixed with late Paleozoic, Late Cretaceous, and early Tertiary palynomorphs (Kemp, 1972; Domack et al., 1980; Truswell, 1982, 1983; Truswell and Anderson, 1984; Truswell and Drewry, 1984). Early Cretaceous palynomorph associations from *in situ* sediments were described by Askin (1981, 1983) from Livingston and Snow Island (South Shetland Islands) and Dettmann and Thomson (1987) from James Ross Island. A short note about late Mesozoic dinocyst floras from the Antarctic Peninsula was published by Riding (1988).

Publications describing Late Jurassic-Early Cretaceous palynomorphs from former DSDP cruises in high latitudes also gave hints on the palynofloras from Antarctica. In the South Atlantic Ocean, miospores from Leg 36, Sites 330 and 327, and Leg 71, Site 511 on the Falkland Plateau (Hedlund and Beju, 1976; Kotova, 1983) were published. Dinoflagellate cysts were described from the same sites (327, 328, and 330) by Harris (1976). Bair and Hart (1984) published on Early Cretaceous palynomorph assemblages from the Malvinas (Falkland) area. Off South Africa, on Leg 40 Aptian/Albian sediments were encountered which contained *Corollina* dominated diverse miospore and dinocyst assemblages (McLachlan and Pieterse, 1978; Davey, 1978) with several species of *Ephedripites* (*Equisetosporites* in McLachlan and Pieterse, 1978; Gnetophyta). DSDP Leg 27 drilled south of Australia and recovered Early Cretaceous sediments, containing sporomorphs and dinocysts (Wiseman and Williams, 1974).

The palynoflora of Leg 113, Hole 692B is composed of spores (19 taxa), pollen grains (more than 13 taxa), dinocysts (27 taxa) and acritarchs as well as Chlorophyceae (more than six taxa).

The flora seems to be similar in composition to Early Cretaceous microfloras of Australia and South America. For taxonomic purposes mainly Australian literature was used. Comprehensive studies of miospore floras are from Couper (1953), Dettmann (1963), Dettmann and Playford (1969), Filatoff (1975), and Backhouse (1988). Descriptions of dinocyst assemblages were published by Cookson and Eisenack (1958), Burger (1980, 1982), Morgan (1980), Helby et al. (1987), and Backhouse (1988). Dinocyst taxonomy in this paper generally follows the Index of Lentin and Williams (1989). The papers in which the palynomorphs, cited in this publication, were erected, are listed in the papers mentioned above, and thus not repeated in the references.

Spores

Antulsporites sp.; Pl. 1, Fig. 7
Baculatisporites comaumensis (Cookson) Potonié, 1956; Pl. 2, Fig. 13
Cicatricosisporites ludbrookiae Dettmann, 1963; Pl. 2, Fig. 3
Concavissimisporites crassatus (Delcourt and Sprumont) Delcourt et al., 1963; Pl. 2, Fig. 4
Contignisporites sp.; Pl. 1, Fig. 8
Cyathidites australis Couper, 1953; Pl. 2, Fig. 2
Cyathidites minor Couper, 1953
Deltoidospora sp.
Dictyotosporites speciosus Cookson and Dettmann, 1958a; Pl. 2, Fig. 7
Foraminisporis wonthaggiensis (Cookson and Dettmann) Dettmann, 1963; Pl. 1, Fig. 4
Foveosporites canalis Balme, 1957; Pl. 2, Fig. 12
Foveosporites subtriangularis (Brenner) Döring, 1966; Pl. 2, Fig. 14
Gleicheniidites senonicus Ross, 1949
Ischyosporites sp.; Pl. 3, Fig. 4
Leptolepidites sp.; Pl. 3, Fig. 11
Neoraistrickia levidensis (Balme) Backhouse, 1988; Pl. 3, Figs. 6, 7A, 7B
Polycingulatisporites striatus Filatoff, 1975; Pl. 2, Fig. 1
Retitriletes sp.
Staplinisporites telatus (Balme) Döring, 1965; Pl. 2, Figs. 5, 6

Pollen

Alisporites grandis (Cookson) Dettmann, 1963, Pl. 3, Fig. 2
Alisporites sp.
Araucariacites australis Cookson, 1947; Pl. 2, Fig. 8
Callialasporites dampieri (Balme) Sukh Dev, 1961; Pl. 2, Fig. 11
Callialasporites spp.
Corollina sp., Pl. 3, Fig. 12
Cycadopites nitidus (Balme) De Jersey, 1964; Pl. 2, Fig. 9
Cycadopites sp.; Pl. 2, Fig. 10
Exesipollenites sp.; Pl. 1, Fig. 6
Microcachryidites antarcticus Cookson, 1947
Podocarpidites sp.; Pl. 3, Fig. 8
Trichotomosulcites subgranulatus Couper, 1953
Vitreisporites signatus Leschik, 1955; Pl. 3, Fig. 5

Dinoflagellate cysts

Apteodinium sp.
Batiacasphaera asperata Backhouse, 1987; Pl. 5, Fig. 7
Broomea sp.; Pl. 4, Figs. 1 and 2
Batioladinium sp.; Pl. 4, Figs. 3, 4, 5, 6, 7
Belodinium cf. *dysculum* Cookson and Eisenack, 1960
Canningia reticulata (Cookson and Eisenack) Helby, 1987; Pl. 3, Fig. 10
Canninginopsis colliveri (Cookson and Eisenack) Backhouse, 1988; Pl. 3, Fig. 9
Cassiculosphaeridia cf. *pygmaea* Stevens, 1987; Pl. 4, Fig. 10
Cometodinium comatum Srivastava, 1984
Cribroperidinium muderongense (Cookson and Eisenack) Davey, 1969; Pl. 5, Fig. 9
Cyclonephelium attadalicum Cookson and Eisenack, 1962b; Pl. 4, Figs. 8, 9
Cyclonephelium hystrix (Eisenack) Davey, 1978
Egmontodinium torynum (Cookson and Eisenack) Davey, 1969; Pl. 5, Fig. 4
Gardodinium lowii Backhouse, 1987; Pl. 6, Fig. 1
?*Gonyaulacysta* sp.; Pl. 5, Figs. 3A, 3B, 5
Kleithriasphaeridium sp.; Pl. 4, Fig. 13
Oligosphaeridium complex (White) Davey and Williams, 1966; Pl. 1, Fig. 3
Pareodinia robusta Wiggins, 1975; Pl. 4, Fig. 12
Prolixosphaeridium parvispinum (Deflandre) Davey et al., 1969; Pl. 6, Fig. 5
?*Pterodinium* sp.; Pl. 5, Fig. 8
Senoniasphaera ptomatis Helby, May and Partridge, 1987; Pl. 5, Fig. 2
Sentusidinium aptiense (Burger) Burger, 1980
Sentusidinium sp.; Pl. 6, Fig. 4
Sentusidinium sp. A, in Backhouse, 1988; Pl. 4, Fig. 11

Sirmiodiniopsis cf. *orbis* Drugg, 1978; Pl. 5, Fig. 1
?*Systematophora* sp.
Tubotuberella vlamingii Backhouse, 1987; Pl. 5, Fig. 6

Acritarchs and Chlorophyceae

Cymatiosphaera pachytheca sp.; Pl. 7, Figs. 2 and 6
Leiosphaeridia spp.; Pl. 1, Fig. 9
Micrhystridium spp.
Pterospermella aureolata (Cookson and Eisenack) Eisenack, 1972; Pl. 6, Figs. 3, 7
Tasmanites spp.
Wallodinium krutzschi (Alberti) Habib, 1972; Pl. 6, Fig. 10

Biostratigraphy of Site 692

In Sections 113-692B-10R-1 and -2 serpulid worm tubes, a poorly preserved belemnite, and buchiid bivalves were found, none of which indicate a precise age. An inoceramid is similar to Berriasian-Valanginian forms from the Antarctic Peninsula (Barker, Kennett, et al., 1988). An ammonite was determined by Doyle et al. (this volume) from Core 113-692B-10R as being of a spiticeratid type. This group has a known range of Tithonian to early Valanginian, with greatest diversity in the Berriasian.

According to nannoplankton studies by Mutterlose and Wise (this volume), the age of the Leg 113, Hole 692B section is probably Valanginian.

The pollen grains found in Hole 692B cores range from Late Jurassic through Barremian/Aptian in western Australia. The most abundant miospores are *Callialasporites*, together with bisaccate pollen and *Corollina*, (Table 1). In the Northern Hemisphere *Callialasporites* is very common in the Late Jurassic and lowermost Cretaceous. From the Aptian/Albian on, however, this genus is less frequently observed.

Some of the spores encountered at Site 692, such as *Concavissimisporites crassatus, Foveosporites canalis,* and *Neoraistrickia levidensis*, have a range of middle Valanginian to Aptian according to Backhouse (1988), but some such as *F. canalis* extend well into the Albian in eastern Australia. The presence of *Foraminisporis wonthaggiensis* in Section 113-692B-7R-01 is indicative of a Valanginian to Hauterivian age (*F. wonthaggiensis* miospore Zone; Helby et al., 1987). Thus, based on spore-taxa alone the age of the upper part of the black shale is interpreted to be not older than mid-Valanginian (see Table 2).

Some of the dinocysts encountered in the Hole 692B samples were used by Helby (1987), Helby et al. (1987), and Backhouse (1987, 1988) as zonational marker forms. The ranges of those dinocysts, which were found in Hole 692B samples, are plotted in Table 1. According to the above authors, only *Egmontodinium torynum* does not extend upward into the Valanginian. *Sirmiodiniopsis orbis* was first described by Drugg (1978) from Callovian-Oxfordian of northwestern Europe. An almost identical species was reported by Jain and Taugourdeau-Lantz (1973) under the name *Ovoidinium indicum* from Early Cretaceous sequences in southern India. Askin (1983) also mentioned a spe-

Table 1. Age ranges of selected spores and dinoflagellate cysts in Hole 692B. Time scale and spore/pollen and dinocyst zones are used in accordance with Dettmann (1986) and Helby et al. (1987).

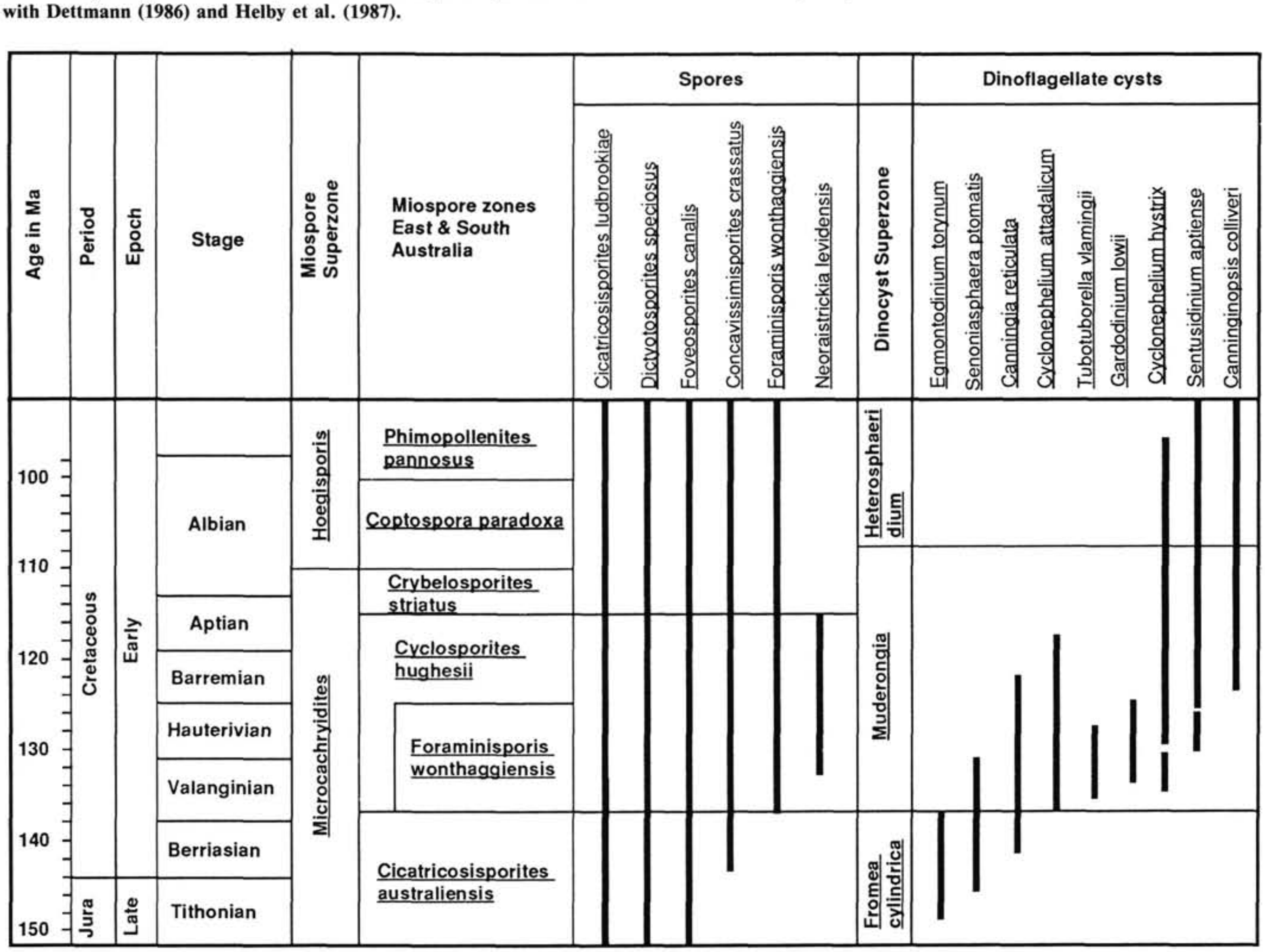

Table 2. Occurrence of spore/pollen species in Hole 692B samples. mbsf = meters below seafloor.

Depth (mbsf)	Hole 692B (Core-section interval in cm)	Alisporites spp.	Antulsporites sp.	Araucariacites australis	Baculatisporites sp.	Callialasporites spp.	Cicatricosisporites sp.	Concavissimisporites sp.	Contignisporites sp.	Corollina sp.	Cycadopites sp.	Deltoidospora sp.	Exesipollenites sp.	Foraminisporis wonthaggiensis	Foveosporites sp.	Gleicheniidites sp.	Leptolepidites sp.	Microcachryidites sp.	Neoraistrickia sp.	Podocarpidites spp.	Polycingulatisporites striatus	Staplinisporites telatus	Vitreisporites sp.
53.58	692B-07R-01, 38-39 cm	x		x	x	x		x		x	x	x		x	x		x	x		x		x	x
54.65	692B-07R-02, 10-12 cm	x		x	x	x				x	x	x					x		x		x		x
55.75	692B-07R-02, 111-112 cm																						
59.63	692B-08R-01, 33-36 cm		x		x	x	x			x		x				x	x						
60.20	692B-08R-01, 90-92 cm																						
61.50	692B-08R-02, 70-72 cm	x			x	x											x						
68.80	692B-08R-CC					x	x			x							x						x
69.08	692B-09R-01, 28-29 cm											x			x								
70.68	692B-09R-02, 42-43 cm																						
72.59	692B-09R-03, 95-97 cm					x				x													
72.84	692B-09R-03, 122-123 cm																						
78.50	692B-09R-CC					x				x													
79.20	692B-10R-01, 70-74 cm	x				x				x	x									x			
80.57	692B-10R-02, 73-77 cm					x				x		x				x							
81.94	692B-10R-03, 77-81 cm					x				x													x
82.93	692B-10R-04, 41-44 cm						x			x								x					
84.95	692B-10R-05, 113-118 cm				x	x			x	x		x					x		x	x			x
86.23	692B-10R-06, 91-95 cm																						
88.20	692B-10R-CC	x			x	x				x		x				x		x					x
55.80	692B-11W-01, 100-102 cm	x				x															x		
56.55	692B-11W-02, 27-29 cm	x								x													
57.54	692B-11W-02, 126-128 cm									x													
88.02	692B-11W-CC	x			x	x				x													
88.53	692B-12R-01, 25-27 cm	x			x	x	x			x													
89.87	692B-12R-02, 17-19 cm																						
91.33	692B-12R-03, 13-15 cm					x				x													x
97.70	692B-12R-CC	x		x		x	x			x		x	x			x				x			x

cies of *Sirmiodiniopsis* in her Assemblage B from the South Shetland Islands (age: ?Valanginian-Hauterivian-Barremian) as cf. *Sirmiodiniopsis* sp. A. *Senoniasphaera ptomatis* ranges, according to Helby et al. (1987), into the late Valanginian. Two short ranging forms, *Tubotuberella vlamingii* and *Gardodinium lowii* were first described from Valanginian to Hauterivian sediments in West Australia (Backhouse, 1987; 1988). *Canninginopsis colliveri* is the only species which is not reported from pre-Barremian sediments (Backhouse, 1988).

If we consider the ranges of the dinocysts mentioned above, it is most likely that *Egmontodinium torynum* and *Senoniasphaera ptomatis* have slightly extended ranges into younger strata in the Weddell Sea area, compared to Australia. *C. colliveri* is found here probably slightly earlier than in Australia. Thus an overlap of the ranges is seen in the Hauterivian, which is about equivalent with Burger's zone DK3 (1982, 1986, 1988).

A ?Valanginian/Hauterivian age of the sequence drilled at Site 692 is also in accordance with the fact that marker forms indicative of the late *Muderongia* Superzone (Helby et al., 1987), such as *Dingodinium cerviculum, Odontochitina operculata,* and *Muderongia* spp. are missing. It must be admitted, however, that the flora is not very diverse and the absence of marker forms is not a convincing argument.

The miospore and dinocyst range charts (Tables 2, 3) for the Cores 113-692B-7R to -12R show the following distribution pattern: common species generally range throughout; rare forms occur sporadically, but seem to show random distribution. This makes it difficult to zone the section. The genus *Batioladinium* is observed only in the lowermost part of the drilled section (Cores 113-692B-10R to -12R). This pattern fits the provisional zonation scheme proposed by Helby et al. (in Williams and Bujak, 1985), where a *Batioladinium* Zone (uppermost Berriasian to middle Valanginian) is proposed. *Batioladinium* specimens, however, very similar to those found in the Hole 692B samples, were also reported by Burger (1982) from the Australian Barremian to Aptian.

Biostratigraphy of Site 693

The Site 693 sediments contain a rich assemblage of miospores and dinocysts. In particular, Cores 113-693A-44R and -45R yield well preserved dinocysts. Of biostratigraphic importance in Core 113-693A-44R is, among others, the dinoflagellate cysts *Codoniella campanulata* (Pl. 7, Fig. 7), first described from the Australian Turonian and Santonian (Cookson and Eisenack, 1960). This taxon also occurs in Albian sediments in the northern Bay of Biscay (Davey, 1979) and in Cenomanian strata

Table 3. Occurrence of dinocyst species in Hole 692B samples. mbsf = meters below seafloor.

Depth (mbsf)	Hole 692B (Core-section, interval in cm)	Batioladinium sp.	Canningia reticulata	Canninginopsis colliveri	Cribroperidinium muderongense	Cyclonephelium attadalicum	Cyclonephelium hystrix	Egmontodinium torynum	Gardodinium lowii	Gonyaulacysta sp.	Oligosphaeridium complex	Pareodinia robusta	Prolixosphaeridium parvispinum	Senoniasphaera ptomatis	Sentusidinium aptiense	Sirmidiniopsis cf. orbis	Tubotuberella sp.
53.58	692B-07R-01, 38-39 cm				x	x				x		x			x		x
54.65	692B-07R-02, 10-12 cm			x	x	x									x		
55.75	692B-07R-02, 111-112 cm				x	x	x										
59.63	692B-08R-01, 33-36 cm				x	x		x	x			x	x			x	
60.20	692B-08R-01, 90-92 cm				x												
61.50	692B-08R-02, 70-72 cm		x	x	x	x					x		x		x		
68.80	692B-08R-CC			x		x	x				x			x			
69.08	692B-09R-01, 28-29 cm		x								x		x		x		
70.68	692B-09R-02, 42-43 cm					x					x						
72.59	692B-09R-03, 95-97 cm																
72.84	692B-09R-03, 122-123 cm																
78.50	692B-09R-CC																
79.20	692B-10R-01, 70-74 cm	x	x	x		x	x								x		
80.57	692B-10R-02, 73-77 cm			x		x						x					
81.94	692B-10R-03, 77-81 cm											x	x				
82.93	692B-10R-04, 41-44 cm	x			x												
84.95	692B-10R-05, 113-118 cm			x		x					x			x	x		
86.23	692B-10R-06, 91-95 cm																
88.20	692B-10R-CC			x		x					x		x		x		
55.80	692B-11W-01, 100-102 cm					x									x		
56.55	692B-11W-02, 27-29 cm	x			x	x					x	x					
57.54	692B-11W-02, 126-128 cm			x		x	x				x		x				
88.02	692B-11W-CC			x											x		
88.53	692B-12R-01, 25-27 cm			x							x						
89.87	692B-12R-02, 17-19 cm	x		x							x	x			x		
91.33	692B-12R-03, 13-15 cm						x				x						
97.70	692B-12R-CC	x		x	x	x	x				x	x	x			x	

off the Moroccan coast (Below, 1984). *Hapsocysta peridictya* (Pl. 7, Fig. 4) occurs in Australian Aptian and lower Albian strata (Morgan, 1980). Given the known ranges of these two species, the age of Core 113-693A-44R sediments is most likely Albian. Lower in the section, in Cores 113-693A-45R to -51R, several stratigraphically important species were found. These include *Odontochitina operculata, Muderongia tetracantha* (Pl. 7, Fig. 5), *Dingodinium cerviculum* (Pl. 7, Fig. 1), and *Diconodinium davidii* (Pl. 7, Fig. 3). The last species is the index species for the "*Diconodinium davidii* Zone" of Australia (Helby et al.,1987), which is late Aptian. Detailed results on material from Site 693 will be published later (Mohr and Gee, in prep.).

Vegetational Cover and Paleoclimate

The miospores of the Hole 692B samples indicate a luxurious vegetation on the continent. Plants represented by spores include Bryophyta such as the Anthoceralean moss spore *Foraminisporis* sp. (Dettmann, 1986), and *Staplinisporites* sp. (see Table 4). Lycophytes (*Neoraistrickia* sp. and *Leptolepidites* sp.) and several fern families were represented on the southern continents, especially Gleicheniaceae (*Gleicheniidites* sp.), Osmundaceae (*Baculatisporites* sp.) and ?Lygodiaceae (*Concavissimisporites* sp., *Klukisporites* sp.). The spore genus *Cicatricosisporites* sp. can be assigned to either the Schizaeaceae, Parkeriaceae, or Lygodiaceae.

Seed ferns (Caytonyales) are represented by *Vitreisporites* sp. (Van Konijnenburg-Van Cittert, 1971). The genus *Alisporites* incorporates seed ferns as well as conifers. *Alisporites similis* might be synonymous with *Pteruchus* cf. *dubius,* described by Melendi and Scafati (1987), which can be assigned to the family Corystospermaceae (Townrow, 1962). The pollen taxon *Cycadopites* sp. might have affinities to the cycadophytes, ginkgophytes, or even to the Pentoxylales (Dettmann, 1986).

Gymnosperms are also well documented by bisaccate pollen grains and pollen of the "Classopollis"-type (*Corollina* sp.), which indicate the presence of the family Cheirolepidiaceae. Podocarps, represented by *Microcachryidites* sp. (*Microcachrys* sp.) and *Podocarpidites* sp. (*Podocarpus* sp.), and Araucariaceae represented by *Araucariacites* sp. respectively (Table 4).

The relative abundance of Conifer pollen in the Site 692 samples and of Early Cretaceous microfloras from James Ross Island (Dettmann and Thomson, 1987) agrees with observations on megafloras, especially on fossil wood found in the Antarctic Peninsula area. According to Francis (1986) the forests there were mainly composed of podocarp and araucarian conifers. Well developed and relatively wide growth rings in fossil wood

Table 4. Botanical affinities of some of the sporae dispersae, found in Hole 692B samples.

Botanical affinities				Miospores of Site 692
Division	**Order**	**Family**	**Genus**	
Bryophyta	Anthocerales			Foraminisporis Staplinisporites
Lycopodophyta	Lycopo- diales			Neoraistrickia Leptolepidites
Pterophyta	Filicales	Gleicheniaceae	Gleichenia	Gleicheniidites
		Osmundaceae (Hymenophyllaceae)		Baculatisporites
		Lygodiaceae	Lygodium	Concavissimisporites Klukisporites
		Parkeriaceae or Schizaeaceae		Cicatricosisporites
Pterido- spermophyta	Caytoniales Corysto- spermales			Vitreisporites Alisporites similis
Cycadophyta Ginkgophyta	Cycadales Ginkgoales			Cycadopites
Coniferophyta	Coniferales	Cheirolepidiaceae		Corollina
		Podocarpaceae	Microcachrys Podocarpus	Microcachryidites Podocarpidites
		Araucariacae	Araucaria	Araucariacites Callialasporites

from Lower Cretaceous strata of Alexander Island (Jefferson, 1983) and from ?Valanginian to Barremian strata from Byers Peninsula, South Shetland Islands (Francis, 1986), indicate strong seasonality in climate, but favorable growth conditions.

All the palynomorphs found in Site 692 samples are also a consistent element of Australian floras, such as the floras of the Perth Basin (Backhouse, 1988) and the Koonwarra Fossil Bed, South Victoria (Dettmann, 1986), where also a megaflora was found (Drinnan and Chambers, 1986). This megaflora is dated by fission track analysis (see in Rich et al., 1988) as Barremian to Aptian (118 $\pm$ 5 to 115 $\pm$ 6 Ma) and is dominated by several conifers and Ginkgo, over an understory of pentoxylaleans, ferns, sphenophytes, and bryophytes. This flora is considered to be indicative of a cool, possibly montane environment. Temperatures during the winter probably dropped below freezing, according to recent geochemical studies of carbonate concretions in the Otway and Strzelecki groups of Aptian/Albian age (Gregory et al., 1989).

The Hole 692B flora also shows South Australian and South American affinities (Volkheimer et al., 1977; Volkheimer, 1978; Baldoni and Archangelsky, 1983) and affinities to South Atlantic floras (Kotova, 1983; Harris, 1976). The main difference is the lack of *Ephedripites* pollen and *Cyclusphaera psilata* in Hole 692B samples, of which the latter one is, according to Volkheimer and Sepulveda (1976), a marker form of the Argentinian Early Cretaceous (Hauterivian to Albian). In all these more northerly floras, *Corollina* strongly dominates the assemblages. High percentages and diversity of *Ephedripites*, seen in a miospore assemblage offshore South Africa (McLachlan and Pieterse, 1978) might indicate a relatively dry climate, in contrast to the hypothesized cool temperate climate with high humidities of the Australian and Antarctic Early Cretaceous (Douglas and Williams, 1982; Rich et al., 1988), located at this time in very high latitudes (70°–85°S).

Sedimentation

The black shales drilled at Leg 113 Sites 692 and 693 are part of the early "South Atlantic" (Late Jurassic to Albian) anoxic basin, from which sediments were previously known from the Antarctic Peninsula, the Falkland Plateau, offshore South Africa, and offshore southern Madagascar (Farquharson, 1983). The depositional environment of the Dronning Maud land margin localities (Sites 692 and 693) is thought to be well offshore (probably $\geq$100 km), based on the low percentage of organic terrestrial debris. This is presumably from the Antarctic continent, since it lacks some floral elements of the "South American/Falkland Plateau" Early Cretaceous assemblage (see above under "Flora").

In the anoxic basin, the sediments were depleted of oxygen, so that bacterial decomposition of organic matter did not take place (Habib, 1982) and there were high amounts of pyrite, which is frequently found in the palynomorphs. The high percentage of algal cysts in the Hole 692B samples, especially leiospherids, indicates that the upper water column was well oxygenated, with only the lower parts lacking O_2. This is in accordance with the poor benthic foraminiferal fauna found in these samples (Thomas, this volume). Bernier and Courtinat (1979), found similar high amounts of acritarchs in laminated organic rich limestones of a (restricted) backreef environment in the Kimmeridgian from the southern Jura. Restricted circulation is also the most likely explanation for these dark organic rich claystones of the Sites 693 and 692.

CONCLUSIONS

The age of the sequence in Site 692 has been determined using Australian sporomorph and dinocyst zonations of Dettmann (1986), Helby et al. (1987) and Burger (1982, 1986) as Valanginian/Hauterivian to Hauterivian. The Early Cretaceous sequence of Site 693 is dated as Aptian to Albian.

Kerogen characteristics indicate that Lower Cretaceous sedimentation at Site 692 and 693 occurred offshore, in a basin with restricted circulation and deoxygenated bottom layers.

Early Cretaceous of the Weddell Sea palynofloras show the strongest affinities with those of the Antarctic Peninsula and South Australia. On the Antarctic continent a cool temperate rain forest, mainly composed of podocarps and araucarian conifers, is reconstructed by the miospore evidence. Coeval megafloras from the Antarctic Peninsula and southern Australia indicate strong seasonality, with prolonged dark winters and temperatures below freezing. High humidities are postulated for the Weddell Sea region.

ACKNOWLEDGMENTS

The Swiss National Fonds supported this study by providing the financial support for participation in the ODP Leg 113, technical help and laboratory supplies. The samples were processed with care by C. Gee and N. Harley Wyss (Zürich). N. Harley Wyss also helped in producing the tables and plates. The art work was meticulously undertaken by K. Meyer (Zürich). U. Gerber (Zürich) did the photographic work to the usual high standards. C. Gee, and D. Lazarus (Zürich) critically read the manuscript. Two anonymous reviewers greatly improved the manuscript with helpful comments. To all my warmest thanks.

REFERENCES

Askin, R. A., 1981. Jurassic-Cretaceous palynology of Byers Peninsula, Livingston Island, Antarctica. *U.S. Antarct. J.,* 16:11-13.

_______, 1983. Tithonian (uppermost Jurassic)-Barremian (Lower Cretaceous) spores, pollen and microplankton from the South Shetland Islands, Antarctica. *In* Oliver, R. L., James, P. R. and Jago, J. B. (Eds.), *Antarctic Earth Science: Fourth Int. Symp. Adelaide:* Cambridge, (Cambridge Univ. Press), 295-297.

Backhouse, J., 1987. Microplankton zonation of the Lower Cretaceous Warnbro Group, Perth Basin, Western Australia. *Mem. Ass. Australas. Palaeontols.,* 4:205-225.

Backhouse, J., 1988. Late Jurassic and Early Cretaceous palynology of the Perth Basin, Western Australia. *Geol. Surv. West. Austr. Bull.,* 135:1-233.

Bair, J., and Hart, G. F., 1984. Palynology of some Lower Cretaceous sediments from the Malvinas area. South Atlantic. *In* Perrilliat, M. de C. (Ed.), *Mem. III congreso Latinoamericano de Paleontologia,* 1984, Mexico City, 280-288.

Baldoni, A. M., and Archangelsky, S., 1983. Palinologia de la Formacion Springhill (Cretacico inferior), subsuelo de Argentina y Chile Austral. *Rev. Esp. Micropaleontol.,* 15:47-101.

Barker, P. F., Dalziel, I.W.D. et al., 1977. *Init. Repts. DSDP,* 36: Washington (U.S. Govt. Printing Office).

Barker, P. F., Kennett, J. P., et al., 1988. *Proc. ODP, Init. Repts.,* 113, College Station, TX (Ocean Drilling Program).

Below, R., 1984. Aptian to Cenomanian dinoflagellate cysts from the Mazagan Plateau, northwest Africa (Sites 545 and 547, Deep Sea Drilling Project Leg 79). *In* Hinz, K., Winterer, E. L., et al., *Init. Repts. DSDP,* 79: Washington (U.S. Govt. Printing Office), 621-649.

Bernier, P., and Courtinat, B., 1979. Le microplancton (Leiosphaeridae) et la matière organique des calcaires d' arrière-recif du Kimmeridgien supérieur dans le Jura méridional. Systematique, conditions de genèse et d' environment. *Doc. Lab. Géol. Fac. Sci. Lyon,* 75:95-117.

Burger, D., 1980. Palynological studies in the Lower Cretaceous of the Surat Basin, Australia. *BMR Bull.,* 189:1-106.

_______, 1982. A basal Cretaceous dinoflagellate suite from northeastern Australia. *Palynology,* 6:161-192.

_______, 1986. Palynology, cyclic sedimentation, and palaeoenvironments in the Late Mesozoic of the Eromanga Basin. *Geol. Soc. Austr., Spec. Publ.* 12:53-70.

_______, 1988. Early Cretaceous environments in the Eromanga Basin; palynological evidence from GSQ Wyandra-1 corehole. *Mem. Ass. Australas. Palaeontols.* 5:173-186.

Cookson, I. C., and Eisenack, A., 1958. Microplankton from Australian and New Guinea Upper Mesozoic sediments. *Proc. R. Soc. Victoria,* 70:19-79.

_______, 1960. Microplankton from Australian Cretaceous sediments. *Micropaleontology,* 6:1-18.

Couper, R. A., 1953. Upper Mesozoic and Cainozoic spores and pollen grains from New Zealand. *N. Z. Geol. Surv. Pal. Bull.,* 22:1-77.

Davey, R. J., 1978. Marine Cretaceous palynology of Site 361, DSDP Leg 40, off southwestern Africa. *In* Bolli, H. M., Ryan, W.B.F., et al., *Init. Repts. DSDP,* 40: Washington (U.S. Govt. Printing Office), 883-913.

_______, 1979. Marine Apto-Albian palynomorphs from Holes 400A and 402A, IPOD Leg 48, northern Bay of Biscay. *In* Montadert, L., Roberts, D. G., et al., *Init. Repts. DSDP,* 48: Washington (U.S. Govt. Printing Office), 547-577.

Dettmann, M. E., 1963. Upper Mesozoic microfloras from southeastern Australia. *Proc. R. Soc. Victoria,* 77:1-148.

_______, 1986. Early Cretaceous palynoflora of subsurface strata correlative with the Koonwarra Fossil Bed, Victoria. *Mem. Ass. Australas. Palaeontols.,* 3:79-110.

Dettmann, M. E., and Playford, G., 1969. Palynology of the Australian Cretaceous: a review. *In* Campbell, K.S.W. (Ed.), *Stratigraphy and Palaeontology, Essays in Honour of Dorothy Hill.* Canberra (A.N.U. Press), 174-210.

Dettmann, M. E., and Thomson, M.R.A., 1987. Cretaceous palynomorphs from the James Ross Island area, Antarctica—a pilot study. *Br. Antarct. Surv. Bull.,* 77:13-59.

Douglas, J. G., and Williams, G. E., 1982. Southern polar forests: the Early Cretaceous floras of Victoria, Australia and their palaeoclimatic significance. *Palaeogeogr., Palaeoclimatol., Palaeoecol.,* 39: 171-185.

Domack, E. W., Fairchild, W. W., and Anderson, J. B., 1980. Lower Cretaceous sediment from the East Antarctic continental shelf. *Nature,* 287:625-626.

Drinnan, A. N., and Chambers, T. C., 1986. Flora of the Lower Cretaceous Koonwarra Fossil Bed (Koruburra Group), South Gippsland, Victoria. *Mem. Ass. Australas. Palaeontols.,* 3:1-77.

Drugg, W. S., 1978. Some Jurassic dinoflagellate cysts from England, France and Germany. *Palaeontographica* B, 168:61-79.

Farquharson, G. W., 1983. Evolution of late Mesozoic sedimentary basins in the Northern Antarctic Peninsula. *In* Oliver, R. L., James, P. R., and Jago, J. B. (Eds.), *Antarctic Earth Science: Fourth Int. Symp. Adelaide:* Cambridge (Cambridge Univ. Press), 323-327.

Filatoff, J., 1975. Jurassic palynology of the Perth Basin, Western Australia. *Palaeontographica* B, 154:1-113.

Francis, J., 1986. Growth rings in Cretaceous and Tertiary wood from Antarctica and their palaeoclimatic implications. *Palaeontology,* 29: 665-684.

Gregory, R. T., Douthitt, C. B., Duddy, I. R., Rich, P. V., and Rich, T. H., 1989. Oxygen isotopic composition of carbonate concretions from the lower Cretaceous of Victoria, Australia: implications for the evolution of meteoric waters on the Australian continent in a paleopolar environment. *Earth Planet. Sci. Lett.*, 92:27–47.

Habib, D., 1982. Sedimentary supply origin of Cretaceous black shales. *In* Schlanger, S. O., and Cita, M. B. (Eds.), *Nature and origin of Cretaceous Carbon-rich facies:* London (Academic Press), 113–117.

Harris, W. K., 1976. Palynology of Cores from Deep Sea Drilling Sites 327, 328, and 330, South Atlantic Ocean. *In* Barker, P. F., Dalziel, I.W.D., et al., *Init. Repts. DSDP,* 36: Washington (U.S. Govt. Printing Office), 761–815.

Hedlund, R. W., and Beju, D., 1976. Stratigraphic palynology of selected Mesozoic samples, DSDP Hole 327A and Site 330. *In* Barker, P. F., Dalziel, I.W.D., et al., *Init. Repts. DSDP,* 36: Washington (U.S. Govt. Printing Office), 817–827.

Helby, R., 1987. *Muderongia* and related dinoflagellates of the latest Jurassic to Early Cretaceous of Australasia. *Mem. Ass. Australas. Palaeontols.*, 4:297–336.

Helby, R., Morgan, R., and Partridge, A. D., 1987. A palynological zonation of the Australian Mesozoic. *Mem. Ass. Australas. Palaeontols.*, 4:1–94.

Herbin, J. P., and Deroo, G., 1979. Etude sedimentologique de la matière organique dans les argiles noires cretacées de l'Atlantique Sud. *Doc. Lab. Géol. Fac. Sci. Lyon,* 75:71–87.

Jain, K. P., and Taugourdeau-Lantz, J., 1973. Palynology of Dalmiapuram Grey Shale, Dalmiapuram Formation, District Trichinopoly, South India-. 1. Taxonomy. *Geophytology,* 3:52–68.

Jefferson, T. H., 1983. Palaeoclimatic significance of some Mesozoic Antarctic fossil forests. *In* Oliver, R. L., James, P. R., and Jago, J. B. (Eds.), *Antarctic Earth Science,* Canberra, Australian Academy of Science, 593–598.

Kemp, E. M., 1972. Reworked palynomorphs from the West Ice Shelf area, and their possible geological and palaeoclimatological significance. *Mar. Geol.* 13:145–157.

Kotova, I. Z., 1983. Palynological study of Upper Jurassic and Lower Cretaceous sediments, Site 511, Deep Sea Drilling Project Leg 71 (Falkland Plateau). *In* Ludwig, W. J., Krasheninnikov, V. A., et al., *Init. Repts. DSDP,* 71: Washington (U.S. Govt. Printing Office), 879–906.

Lentin, J. K., and Williams, G. L., 1989. Fossil dinoflagellates. Index to genera and species. *AASP Contrib. Ser.*, 20:1–473.

Ludwig, W. J., Krasheninnikov, V. A., et al., 1983. *Init. Repts. DSDP,* 71: Washington (U.S. Govt. Printing Office).

McLachlan, I. R., and Pieterse, R. E., 1978. Preliminary palynological results: Site 361 Leg 40, Deep Sea Drilling Project. *In* Bolli, H., Ryan, W.B.F., et al., *Init. Repts. DSDP,* 40: Washington (U.S. Govt. Printing Office), 857–881.

Melendi, D. L., and Scafati, L. H., 1987. Estudio de variabilidad en una poblacion de granos de polen del genero *Pteruchus* Thomas. *VII. Symp. Argentino Paleobot. Palinol.*, 1987, 97–100.

Morgan, R., 1980. Palynostratigraphy of the Australian Early and Middle Cretaceous. *Geol. Surv., New South Wales, Palaeontol., Mem.*, 18:1–153.

Parker, M. E., Arthur, M. A., and Wise, S. W., 1983. Carbonate cycles in Aptian-Albian "black shales" of the Falkland Plateau. *U.S. Antarct. J.,* 18:153–154.

Rich, P. V., Rich, T. H., Wagstaff, B. E., McEwen Mason, J., Douthitt, C. B., Gregory, R. T., and Felton, E. A., 1988. Evidence for low temperatures and biologic diversity in Cretaceous high latitudes of Australia. *Science,* 242:1403–1406.

Riding, J. B., 1988. Preliminary palynological investigation of the Mesozoic from the Antarctic Peninsula. *Palynology,* 12:246.

Townrow, J. A., 1962. On *Pteruchus,* a microsporophyll of the Corystospermaceae. *Bull. Br. Mus. (Nat. Hist.), Geol.*, 6:289–320.

Truswell, E. M., 1982. Palynology of seafloor samples collected by the 1911–14 Australasian Antarctic expedition: implications for the geology of coastal East Antarctica. *J. Geol. Soc. Aust.*, 29:343–356.

———, 1983. Recycled Cretaceous and Tertiary pollen and spores in Antarctic marine sediments: a catalogue. *Palaeontographica* B, 186: 121–174.

Truswell, E. M., and Anderson, J. B., 1984. Recycled palynomorphs and the age of sedimentary sequences in the eastern Weddell Sea. *U.S. Antarct J.,* 19:90–92.

Truswell, E. M., and Drewry, D. J., 1984. Distribution and provenance of recycled palynomorphs in surficial sediments of the Ross Sea, Antarctica. *Mar. Geol.*, 59:187–214.

Van Konijnenburg-Van Cittert, J.H.A., 1971. In situ gymnosperm pollen from the Middle Jurassic of Yorkshire. *Acta Bot. Neerl.*, 20:1–96.

Volkheimer, W., 1978. Microfloras fosiles. *In* VII. Congr. Geol. Arg., Buenos Aires, *Asoc. Geol. Arg.*, 193–207.

Volkheimer, W., Caccavari de Filice, M. A., and Sepulveda, E., 1977. Datos palinologicos de la Formacion Ortiz (Grupo La Marga), Cretacico inferior de la Cuenca Neuquina (Republica Argentina). *Ameghiniana,* 14:59–74.

Volkheimer, W., and Sepulveda, E., 1976. Biostratigraphische Bedeutung und mikrofloristische Assoziation von *Cyclusphaera psilata* n. sp., einer Leitform aus der Unterkreide des Neuquen-Beckens (Argentinien). *N. Jahrb. Geol. Palaeontol., Mh.,* 1976:97–108.

Weiler, H., 1988. *Pterospermella* Eisenack (1972) (Prasinophyceae). Morphotypen aus mitteloligozänen Sedimenten Südwestdeutschlands. *Mainzer geowiss. Mitt.*, 17:283–312.

Williams, G. L., and Bujak, J. P., 1985. Mesozoic and Cenozoic dinoflagellates. *In* Bolli, H. M., Saunders, J. B., and Perch-Nielsen, K. (Eds.) *Plankton Stratigraphy:* Cambridge (Cambridge Univ. Press), 847–964.

Wiseman, J. F., and Williams, A. J., 1974. Palynological investigation of samples from Sites 259, 261, and 263, Leg 27, Deep Sea Drilling Project. *In* Veevers, J. J., Heirtzler, I. R., et al., *Init. Repts. DSDP,* 27: Washington (U.S. Govt. Printing Office), 915–924.

Date of initial receipt: 7 March 1989.
Date of acceptance: 17 July 1989.
Ms 113B-207.

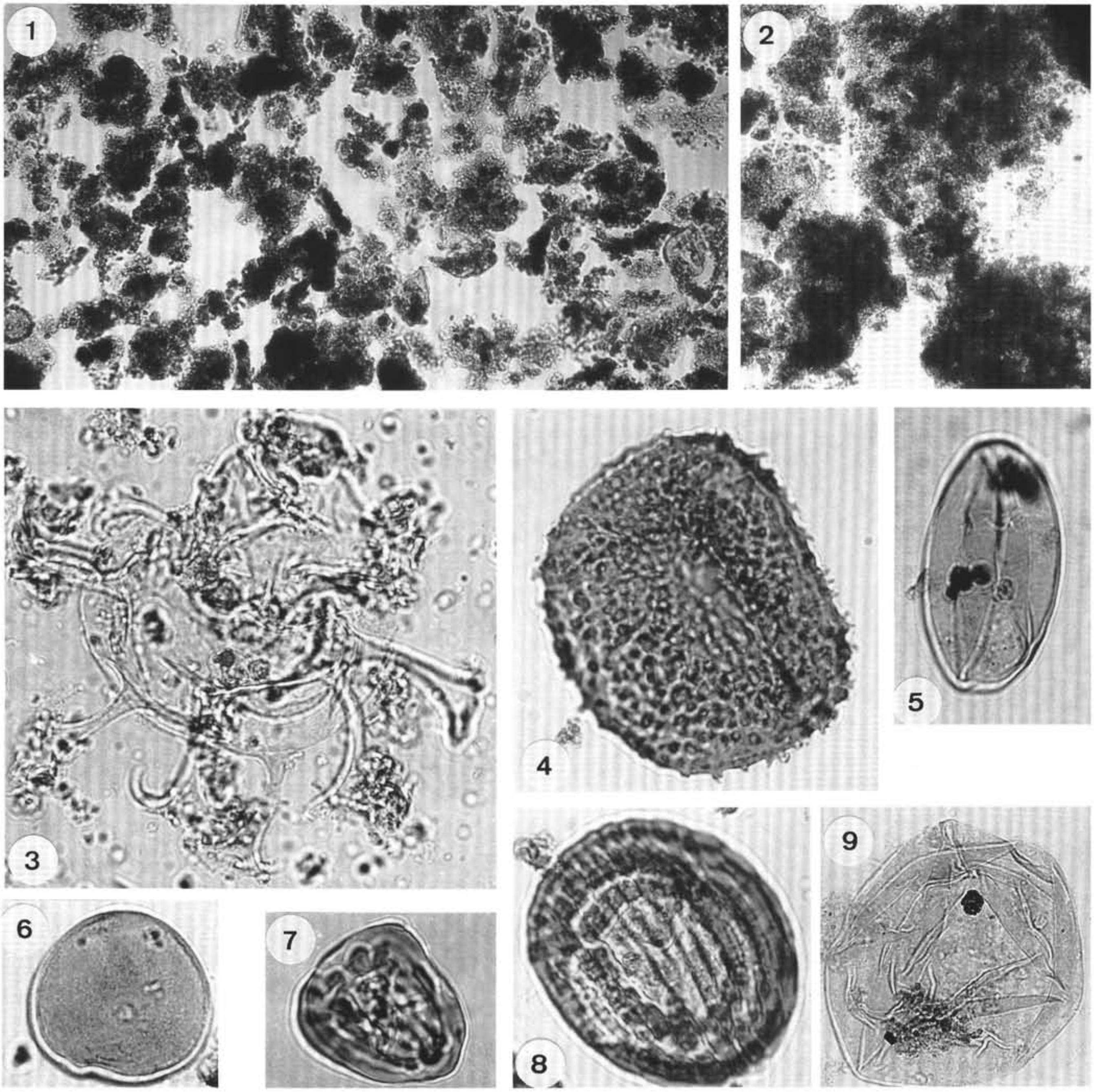

Plate 1. **1.** Kerogen. Sample 113-692B-7R-01, 38–39 cm; sl. S1; ×300. **2.** Kerogen. Sample 113-692B-7R-01, 38–39 cm; sl. S1; ×300. **3.** *Oligosphaeridium complex* (White) Davey and Williams, 1966. Sample 113-692B-12R-02, 17–19 cm; sl. A; ×1000. **4.** *Foraminisporis wonthaggiensis* (Cookson and Dettmann) Dettmann, 1963. Sample 113-692B-7R-01, 38–39 cm; sl. 24; ×1000. **5.** *Cycadopites* sp. Sample 113-692B-7R-01, 38–39 cm; sl. 33; ×1000. **6.** *Exesipollenites* sp. Section 113-692B-12R, CC; sl. 9; ×1000. **7.** *Antulsporites* sp. Sample 113-692B-8R-01, 33–35 cm; sl. A, 31.3/86.2; ×1000. **8.** *Contignisporites* sp. Sample 113-692B-10R-05, 113–115 cm; sl. 3; ×1000. **9.** *Leiosphaera* sp. Sample 113-692B-9R-02, 42–43 cm; sl. 3; ×500.

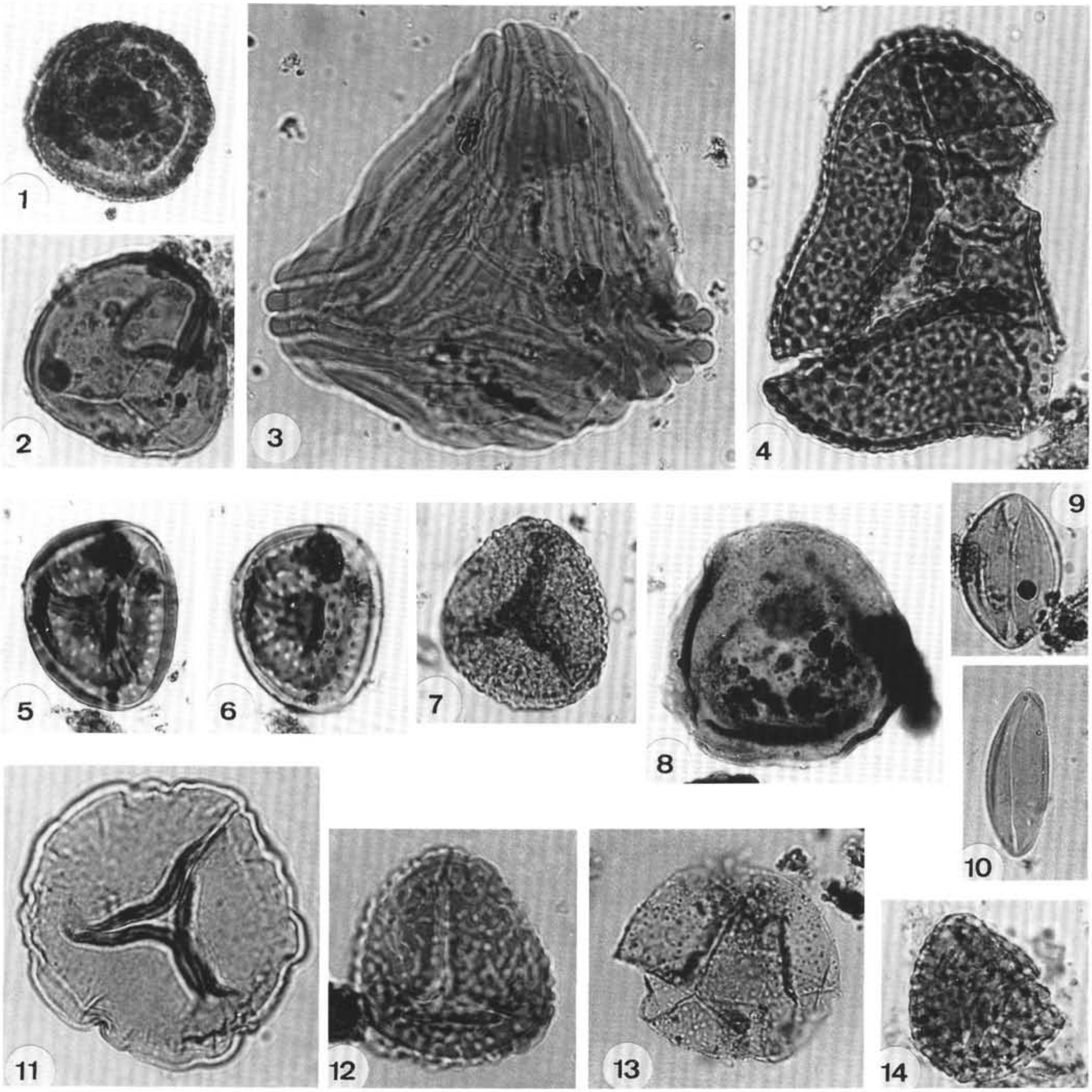

Plate 2. All magnifications ×850, unless specified. **1.** *Polycingulatisporites striatus* Filatoff, 1975. Sample 113-692B-7R-02, 10–12 cm; sl. 7. **2.** *Cyathidites australis* Couper, 1953. Sample 113-692B-7R-01, 38–39 cm; sl. 15; ×1000. **3.** *Cicatricosisporites ludbrookiae* Dettmann, 1963. Sample 113-692B-7R-04, 41–44 cm; sl. 11. **4.** *Concavissimisporites crassatus* (Delcourt and Sprumont) Delcourt et al., 1963. Sample 113-692B-7R-01, 38–39 cm; sl. D. **5–6.** *Staplinisporites telatus* (Balme) Döring, 1965. Sample 113-692B-7R-01, 38–39 cm; sl. G, 37.2/93.5. **7.** *Dictyotosporites speciosus* Cookson and Dettmann, 1958a. Sample 113-692B-10R-05, 113–115 cm; sl. S, 35/95.5. **8.** *Araucariacites* sp. Sample 113-692B-7R-02, 10–12 cm; sl. S, 39.2/90.5. **9.** *Cycadopites nitidus* (Balme) De Jersey, 1964. Sample 113-692B-7R-01, 38–39 cm; sl. J, 37/94.2. **10.** *Cycadopites* sp. (Balme) De Jersey, 1964. Sample 113-692B-8R-01, 33–35 cm; sl. D. **11.** *Callialasporites dampieri* (Balme) Sukh Dev, 1961. Sample 113-692B-7R-01, 38–39; sl. 8. **12.** *Foveosporites canalis* Balme, 1957. Sample 113-692B-7R-01, 38–39 cm; sl. F2; 45.9/82.8. **13.** *Baculatisporites comaumensis* (Cookson) Potonié, 1956. Sample 113-692B-10R-05, 113–115 cm; sl. 11. **14.** *Foveosporites subtriangularis* (Brenner) Döring, 1966. Sample 113-692B-9R-01, 28–29 cm; sl.1, 42.7/95.

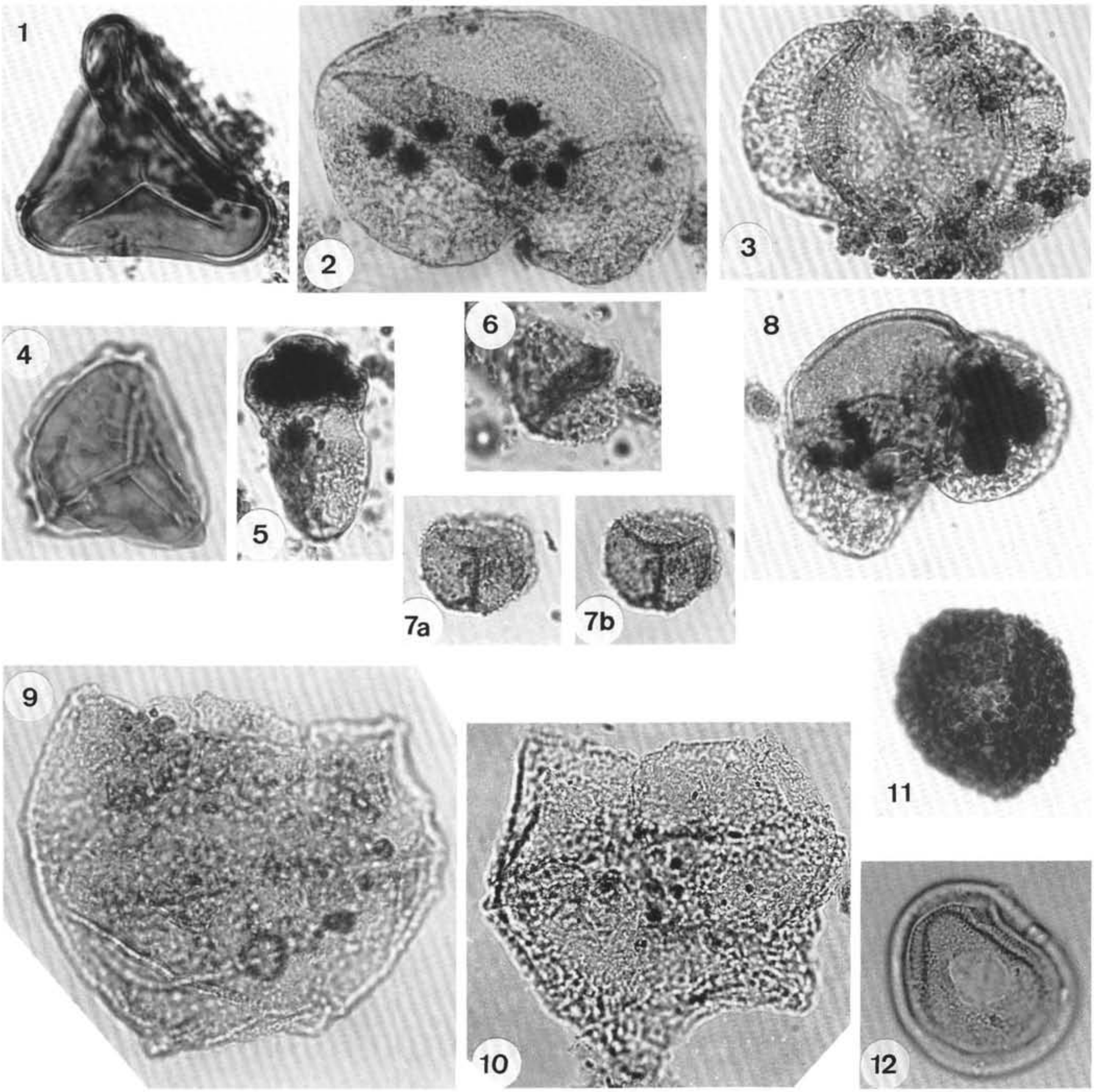

Plate 3. **1.** *Cyathidites* sp. Couper, 1953. Sample 113-692B-7R-01, 38–39 cm; sl. 10; ×1000. **2.** *Alisporites grandis* (Cookson) Dettmann, 1963. Sample 113-692B-7R-01, 38–39 cm; sl. 1; ×850. **3.** *Alisporites similis* (Balme) Dettmann, 1963. Sample 113-692B-7R-01, 38–39 cm; sl. 28; ×850. **4.** *Ischyosporites* sp. Sample 113-692B-8R-01, 33–35 cm; sl. F10; ×850. **5.** *Vitreisporites* sp. Sample 113-692B-7R-01, 38–39 cm; sl. E; 35/94; ×850. **6.** *Neoraistrickia levidensis* (Balme) Backhouse, 1988. Sample 113-692B-10R-05, 113–115 cm; S1; ×850. **7A–7B.** *Neoraistrickia levidensis* (Balme) Backhouse, 1988. Sample 113-692B-7R-01, 38–39 cm; sl. 37; ×850. **8.** *Podocarpidites* sp. Sample 113-692B-7R-01, 38–39 cm; sl. 28; ×850. **9.** *Canninginopsis colliveri* (Cookson and Eisenack) Backhouse, 1988. Sample 113-692-10R-05, 113–115 cm; sl. 2; ×850. **10.** *Canningia reticulata* (Cookson and Eisenack) Helby, 1987. Sample 113-692B-9R-02, 42–43 cm; sl. 2; ×500. **11.** *Leptolepidites* sp. Sample 113-692B-7R-02, 10–12 cm; sl. 2; ×850. **12.** *Corollina* sp. Sample 113-692B-8R-01, 33–35 cm; sl. B, 36/97.2; ×850.

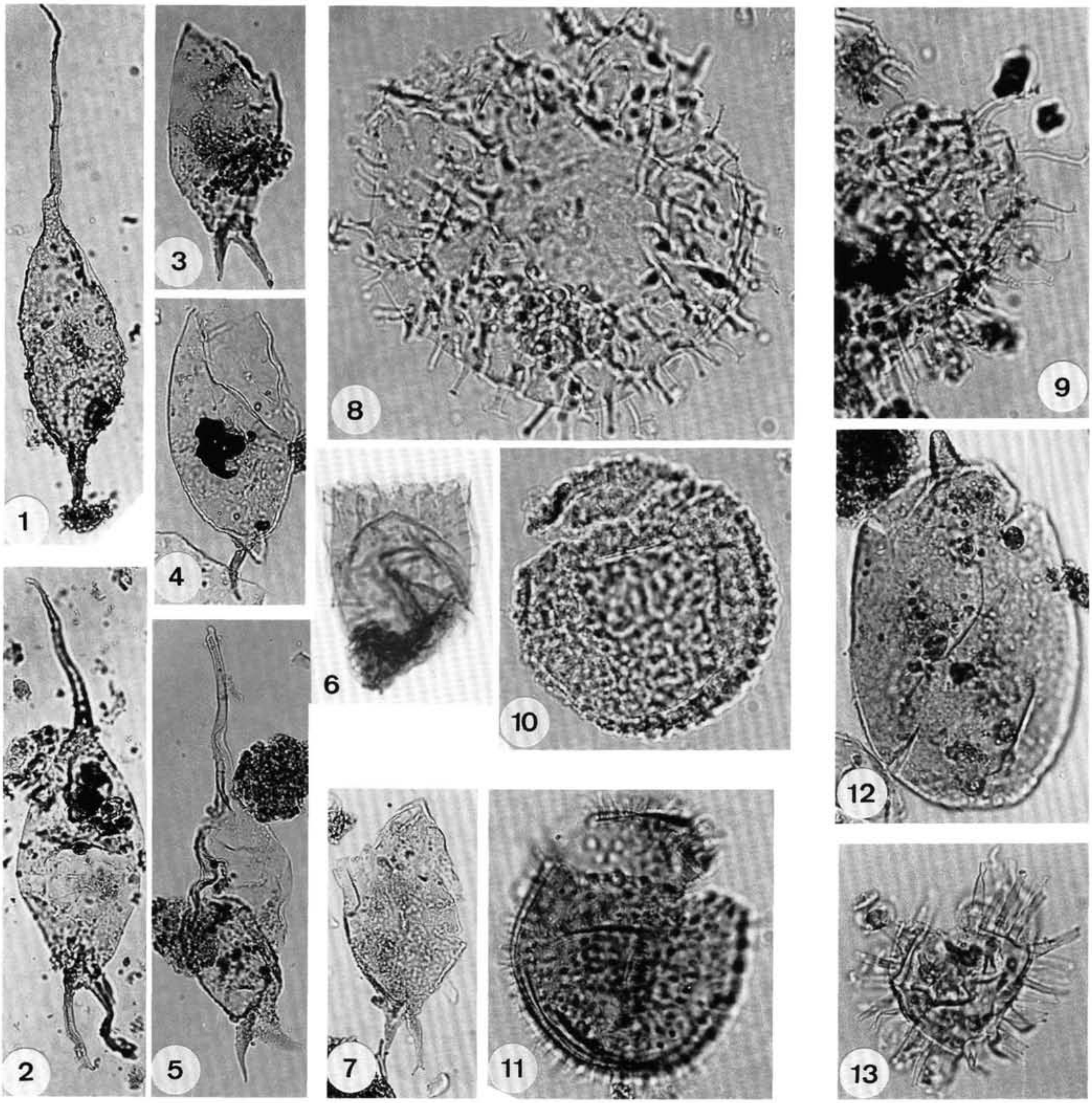

Plate 4. **1.** *Broomea* sp. Section 113-692B-12R, CC; sl. 22; ×450. **2.** *Broomea* sp. Sample 113-692B-12R-02, 17–19 cm; sl. 5; ×450. **3.** *Batioladinium* sp. Sample 113-692B-12R-02, 17–19 cm; sl. 12; ×450. **4.** *Batioladinium* sp. Sample 113-692B-12R-02, 17–19 cm; Sl. 10; ×450. **5.** *Batioladinium* sp. Sample 113-692B-12R-02, 17–19 cm; sl. 8; ×450. **6.** *Gardodinium lowii* Backhouse, 1987. Sample 113-692B-8R-01, 33–35 cm; sl. F3, 34.5/96. **7.** *Batioladinium* sp. Sample 113-692B-12R-02, 17–19 cm; sl. 7; ×450. **8.** *Cyclonephelium attadalicum* (Cookson and Eisenack) Stover and Evitt, 1978. Sample 113-692B-8R-01, 33–36 cm; sl. B, 27/88.5; ×450. **9.** *Cyclonophelium attadalicum* (Cookson and Eisenack) Stover and Evitt, 1978. Sample 113-692B-7R-01, 38–39 cm; sl. 31; ×450. **10.** *Cassiculosphaeridia* cf. *pygmaea* Stevens, 1987. Sample 113-692B-7R-01, 33–36 cm; sl. B 29/88; ×450. **11.** *Sentusidinium* sp. A, in Backhouse, 1988. Sample 113-692B-8R-01, 33–36 cm; sl. F2, 33.3/85.5. **12.** *Pareodinia robusta* Wiggins, 1975. Sample 113-692B-10R-03, 77–81 cm; sl. 1, 34.2/82. 5; ×450. **13.** *Kleithriasphaeridium* sp. Sample 113-692B-8R-01, 33–36 cm; sl. F2, 33.3/85.5.

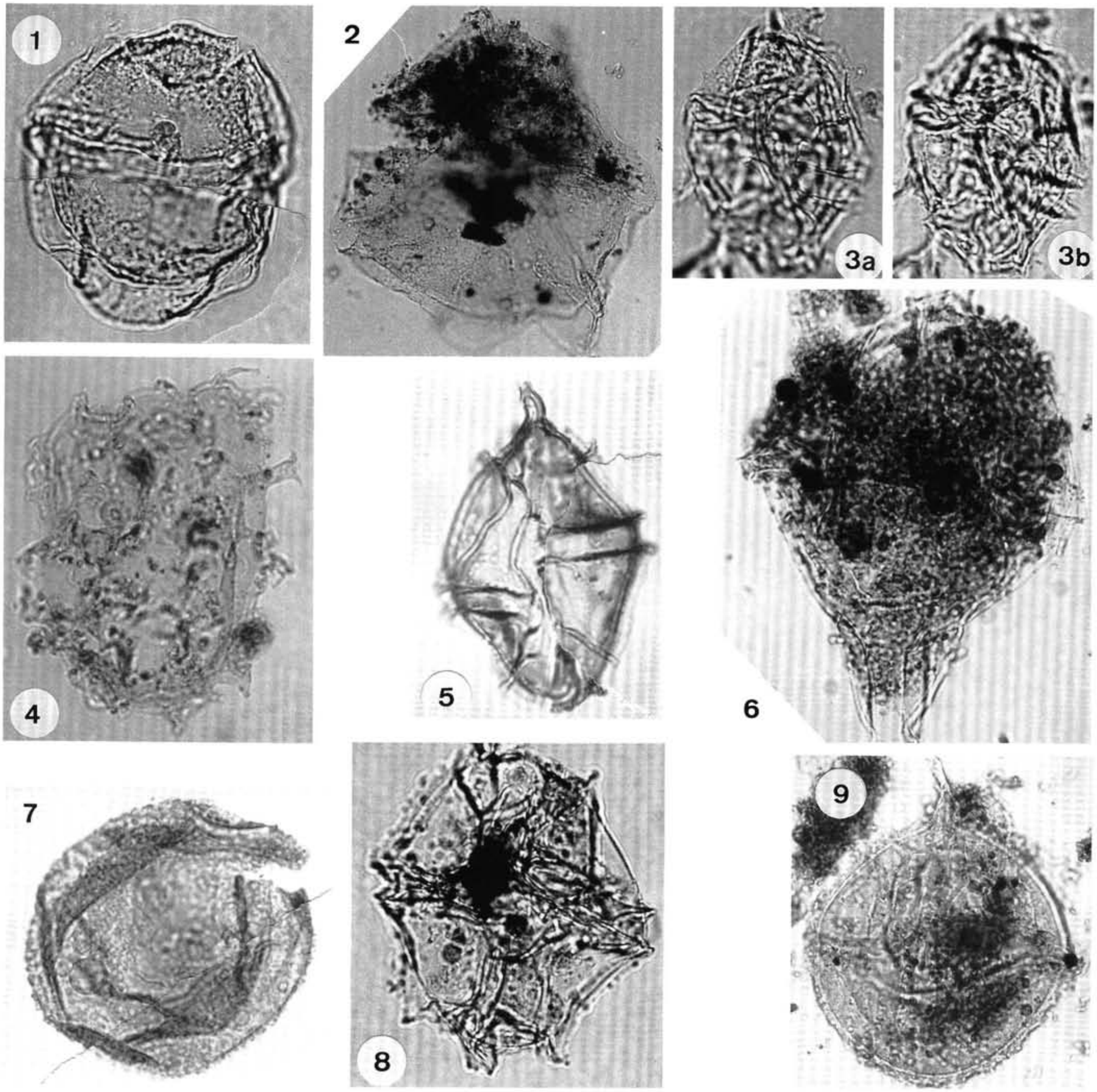

Plate 5. **1.** *Sirmiodiniopsis* cf. *orbis* Drugg, 1978. Sample 113-692B-8R-01, 33-36 cm; sl. B, 32.2/90.2; ×850. **2.** *Senoniasphaera ptomatis* Helby et al., 1987. Section 113-692B-8R, CC; sl. 20; ×450. **3A-3B.** ?*Gonyaulacysta* sp. Sample 113-692B-8R-01, 33-36 cm; sl. B, 28/94, ×850. **4.** *Egmontodinium torynum* (Cookson and Eisenack) Davey, 1979. Sample 113-692B-8R-01, 33-35 cm; sl. F3, 44.7/95; ×850. **5.** ?*Gonyaulacysta* sp. Sample 113-692B-8R-01, 33-35 cm; Sl. F3, 44.7/95; ×850. **6.** *Tubotuberella vlamingii* Backhouse, 1987. Sample 113-692B-7R-01, 38-39 cm; sl. 2; ×850. **7.** *Batiacasphaera asperata* Backhouse, 1987. Sample 113-692B-8R-01, 33-35 cm; sl. F3, 47.5/90.5; ×850. **8.** ?*Pterodinium* sp. Sample 113-692B-7R-01, 38-39 cm; sl. 26; ×850. **9.** *Cribroperidinium muderongense* (Cookson and Eisenack) Davey, 1969. Sample 113-692B-7R-01, 38-39 cm; sl. 11; ×500.

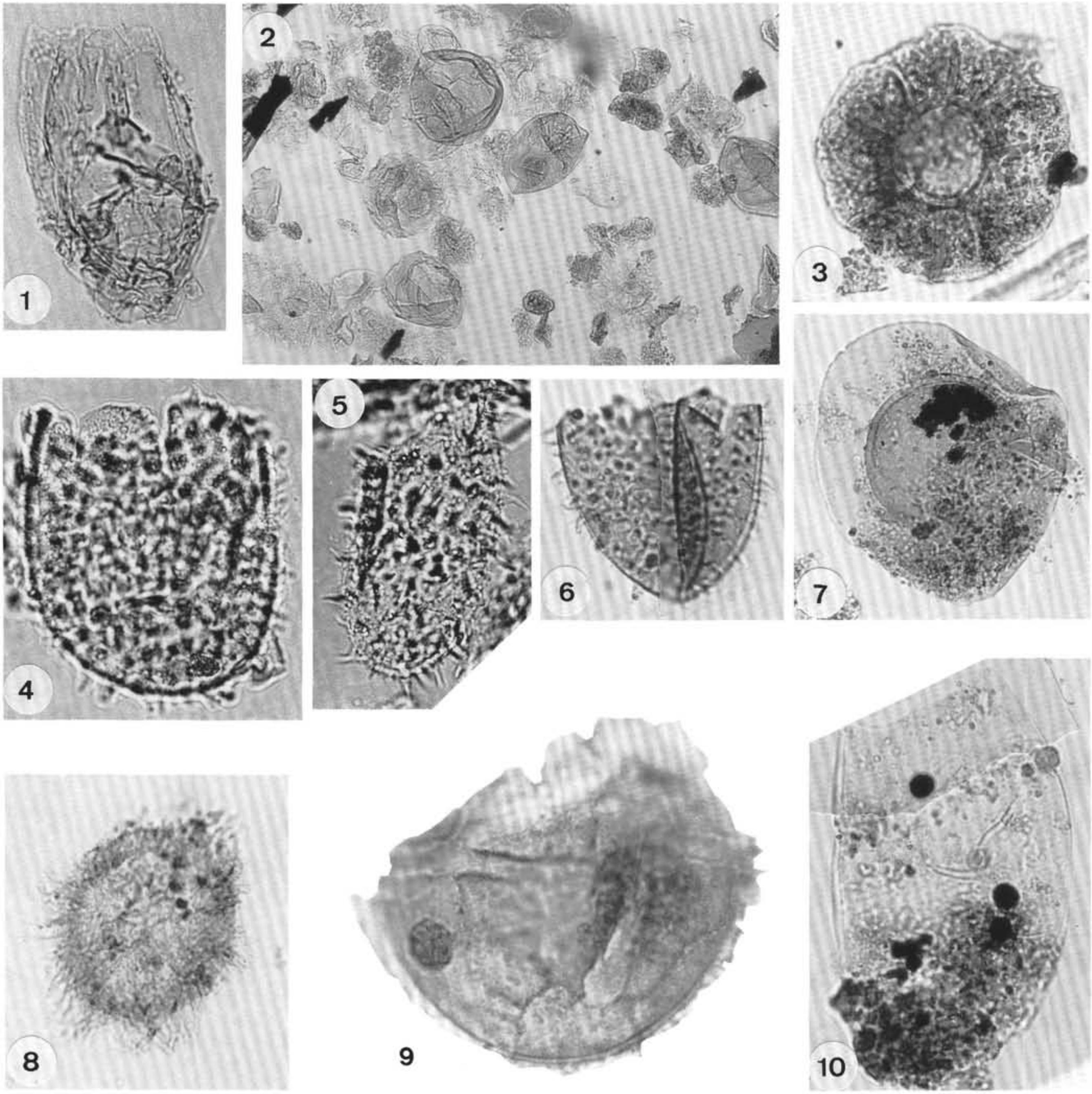

Plate 6. **1.** *Belodinium* cf. *dysculum* Cookson and Eisenack, 1960b. Sample 113-692-8R-01, 33–35 cm; sl. B, 30/95.3; ×850. **2.** Kerogen, mainly composed of Leiospherids. Sample 113-692B-8R-01, 33–36 cm; sl. B, 38.5/95.7; ×150. **3.** *Pterospermella aureolata* (Cookson and Eisenack) Eisenack, 1972. Section 113-692B-9R, CC; sl. 1; ×450. **4.** *Sentusidinium* sp. Section 113-692B-12R, CC; sl. X; ×850. **5.** *Prolixosphaeridium parvispinum* (Deflandre) Davey et al., 1969. Sample 113-692B-8R-01; 33–36 cm; sl. B, 32.2/94; ×850. **6.** *Sentusidinium aptiense* (Burger) Burger, 1980b. Sample 113-692B-8R-01, 33–35 cm; sl. F6, 31.5/93.2; ×850. **7.** *Pterospermella aureolata* (Cookson and Eisenack) Eisenack, 1972. Section 113-692B-09, CC; sl. 4; ×450. **8.** *Cometodinium comatum* Srivastava, 1984. Sample 113-692B-8R-01, 33–35 cm; sl. F6; ×850. **9.** *Cribroperidinium* sp. Sample 113-692B-8R-01, 33–35 cm; sl. F6, 40/86.5; ×850. **10.** *Wallodinium krutzschi* (Alberti) Habib, 1972. Section 113-692B-8R, CC; sl. 6; ×850.

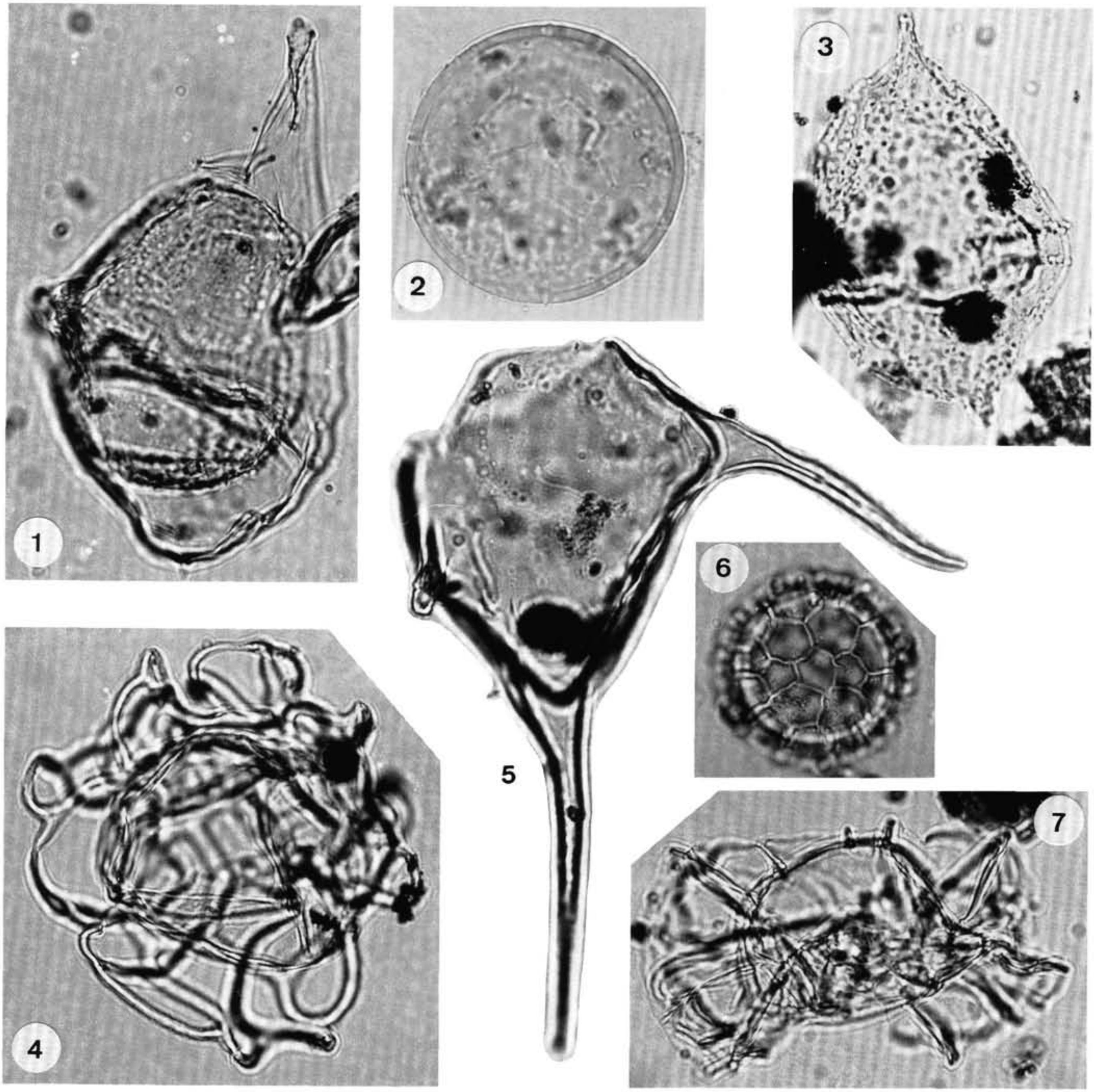

Plate 7. **1.** *Dingodinium cerviculum* Cookson and Eisenack, 1958. Section 113-693A-44R, CC; sl. A, 32.2/87.5; ×1000. **2.** *Cymatiosphaera* sp. Section 113-692B-9R, CC; sl. 13; ×850. **3.** *Diconodinium davidii* Morgan, 1975. Section 113-693A-44R, CC; Sl. A, 25.7/96; ×1000. **4.** *Hapsocysta peridictya* (Eisenack and Cookson) Stover and Evitt, 1978. Section 113-693A-44R, CC; sl. C; ×1000. **5.** *Muderongia tetracantha* (Gocht) Alberti, 1961. Section 113-693A-44R, CC; Sl. A, 28/91.5; ×1000. **6.** *Cymatiosphaera* sp. Sample 113-692B-7R-01, 38–39 cm; Sl. 23; ×850. **7.** *Codoniella campanulata* (Cookson and Eisenack) Downie and Sarjeant, 1965. Section 113-693A-44R, CC; sl. C, 47/84.2; ×1000.