

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

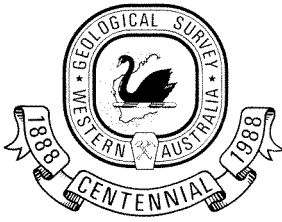
BULLETIN 135

**LATE JURASSIC AND EARLY CRETACEOUS
PALYNOLOGY OF THE PERTH BASIN,
WESTERN AUSTRALIA**

by
JOHN BACKHOUSE



**DEPARTMENT OF MINES
WESTERN AUSTRALIA**



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by

JOHN BACKHOUSE

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ABSTRACT

Detailed and systematic palynological studies have been carried out on Late Jurassic and Early Cretaceous strata that were intersected in about 200 boreholes in the Perth Basin, Western Australia.

Two major stratigraphic sequences are separated by an unconformity. Below the unconformity, miospore assemblages of the uppermost Yarragadee Formation and the Parmelia Formation are dominated by a diversity of cryptogam spores. Marine microplankton are absent; instead, the Parmelia Formation contains suites of unusual dinoflagellate cysts that possess epicystal and apical archeopyles. They are interpreted to be the cysts of non-marine dinoflagellates that flourished in an extensive interior drainage–lake system which was created in a rift valley between Australia and India in the late Tithonian and Berriasian.

Above the unconformity, in the Warnbro Group, miospore assemblages are less diverse and gymnosperm pollen are more prominent. The sediments of deltaic sands and marine shales contain the cysts of marine dinoflagellates including many species known from other Australian basins.

A total of 111 miospore species, 104 dinoflagellate-cyst species, 18 acritarch species, and 2 algal-cyst species are recognized and illustrated. Of these, 11 miospore, 17 dinoflagellate-cyst, and 4 acritarch species are new; four new dinoflagellate-cyst genera are also described.

Four miospore zones are recognized, in ascending order: the *Retitritiles watherooensis* and *Aequitriradites acusus* Zones in the Yarragadee Formation; the *Biretisporites eneabbaensis* Zone in the Parmelia Formation; and the *Balmeiopsis limbata* Zone in the Warnbro Group. Seven microplankton zones are employed, in ascending order: the *Fusiformacysta tumida* Zone, which corresponds approximately with the Parmelia Formation; and the *Gagiella mutabilis*, *Kaiwaradinium scrutillinum*, *Phoberocysta lowryi*, *Aproblocysta alata*, *Batioladinium jaegeri*, and *Fromea monilifera* Zones in the Warnbro Group. A group of microplankton species, referred to as the *Cyclonephelium attadalicum* Association, constitute a shallow-water species association in the *B. jaegeri* Zone.

From the distribution of the Warnbro Group microplankton zones in some 140 onshore boreholes in the Perth area, it is possible to trace the Valanginian–Hauterivian advance of marine deposition into the Vlaming Sub-basin and southern Dandaragan Trough. By the late Barremian, marine deposition extended over all the Vlaming Sub-basin and southern Dandaragan Trough, and had penetrated into the central Dandaragan Trough and the Bunbury Trough.

The ratio of marine to non-marine palynomorphs in Warnbro Group sections is a guide to eustatic sea-level changes in the Valanginian–Barremian. A sea-level curve for the Perth Basin based on this data is compared with curves proposed by previous authors.

CHAPTER 1

INTRODUCTION

The Perth Basin is the most southerly basin on the western margin of Australia (Fig. 1). In the Jurassic it formed the eastern part of a rift-valley system that lay between Australia and greater India (Veevers and others, 1975). During the separation of India and Australia in the Early Cretaceous, the Perth Basin evolved into a fringe

basin on the western trailing edge of the Australian Plate. To the north, separation of Australia from greater India had been in progress since the Late Jurassic, but it was not until the Valanginian that sea-floor spreading commenced west of Perth (Markl, 1974, 1978). Breakup was accompanied by a period of tectonic activity, mainly expressed by

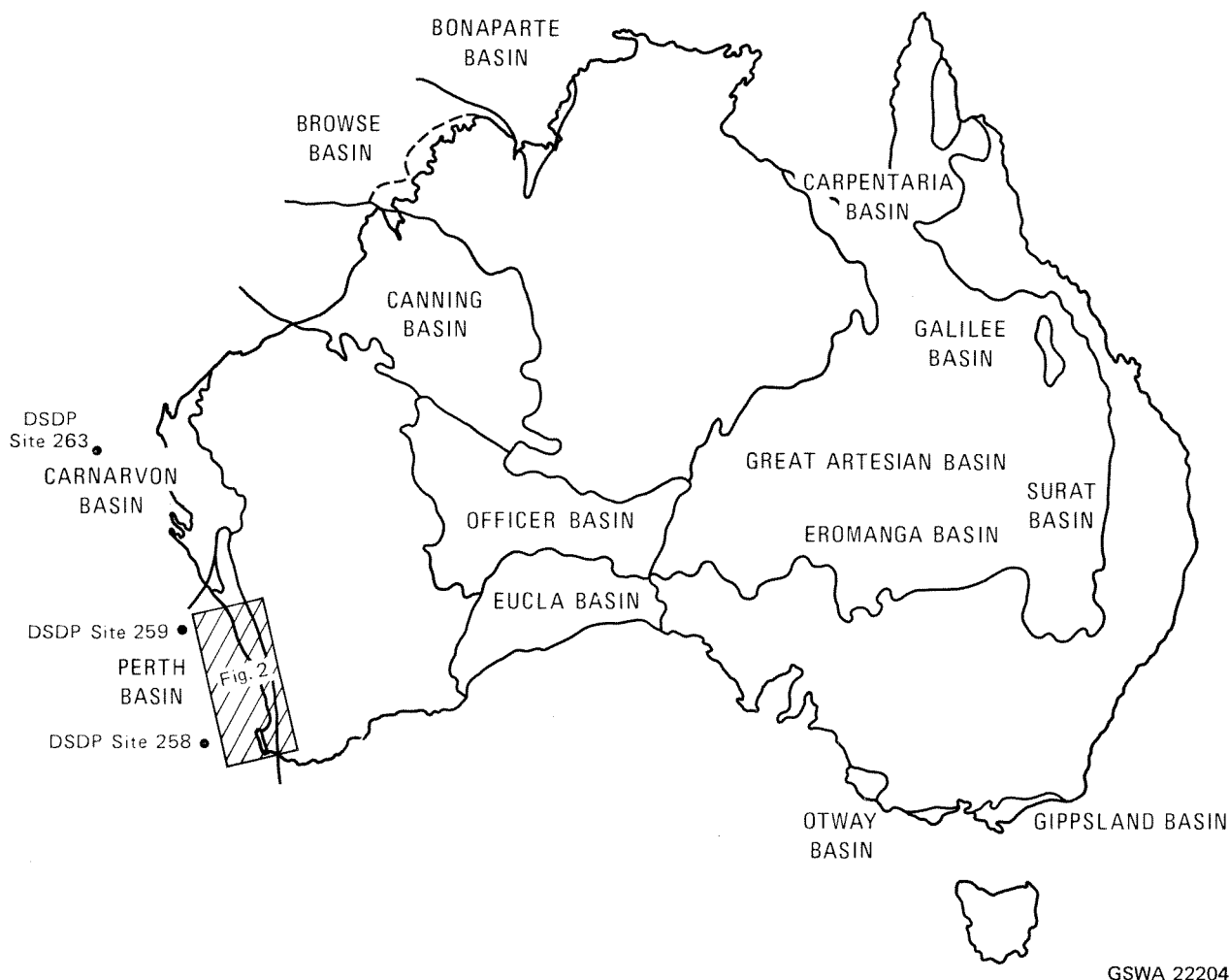


Figure 1. Location of the Perth Basin in relation to other Australian basins with significant Late Jurassic–Early Cretaceous deposits.

block faulting, and followed by a marine transgression. Marine deposition was confined initially to a small area near Perth, but later it extended over a large area of the central and southern basin. The Tithonian–Neocomian interval is therefore represented by two sedimentary cycles, a pre-breakup rift-valley succession and a largely marine sequence that was deposited after the start of sea-floor spreading. The earlier cycle is represented by the upper part of the Yarragadee Formation and the Parmelia Formation. Unconformably overlying this sequence and forming the second cycle is the Warnbro Group, which is divided into the South Perth Shale below and the Leederville Formation above.

An extensive Pliocene–Quaternary cover blankets the Mesozoic sediments and, where Mesozoic sediments crop out, deep lateritization has removed all organic material. Palynological study of the Mesozoic relies, therefore, on samples from hydrogeological and petroleum-exploration boreholes. Large numbers of such samples have only become available in recent years. Previous palynological studies of the Early Cretaceous in the Perth Basin were based on a few isolated subsurface samples, or were concerned with only a small area of the basin. Therefore, although some taxa have been described, the Late Jurassic–Early Cretaceous biostratigraphy of the basin as a whole has only been elucidated in very general terms.

In this study the palynology of the section from the upper part of the Yarragadee Formation to the top of the Warnbro Group has been examined in detail. The results enable a detailed geological history of the basin from the Tithonian to early Aptian to be constructed.

Some 2 000 samples from over 200 boreholes were studied initially, and then the most representative and best sampled sections were selected for more detailed study.

In the following account, the term *palynomorph* is used to include all forms of miospore, megaspore, and microplankton; *miospore* embraces microspores and pollen grains; and *microplankton* refers to dinoflagellate cysts and all forms of acritarchs.

Two zonations have been erected, one based on miospores and one on microplankton. Biostratigraphic correlation based on these zonal schemes has permitted palaeogeographic reconstructions to be made of the onshore area between the towns of Gingin and Mandurah, hereafter referred to as the Perth area (Fig. 6).

GEOLOGICAL BACKGROUND

The Perth Basin is a complex of subsidiary sedimentary basins which formed the eastern section of an ancient rift-valley system active since the Permian, with downthrow controlled by the Darling Fault and associated smaller faults (Jones and Pearson, 1972; Playford and others, 1976). The western section of the rift valley, attached to the Indian Plate, separated from the Perth Basin during the ?early Valanginian. This left the Perth Basin as a trailing-edge marginal basin. In its present configuration the Perth Basin is an elongate north-south basin, that is bounded on the east by the Darling Fault Zone and on the west by the continental slope (Fig. 2). Beyond the Darling Fault Zone the Yilgarn Block, an Archaean craton virtually devoid of Mesozoic sedimentary cover, extends 700 km to the east.

Late Jurassic and Early Cretaceous sediments are present in the Dandaragan Trough, Vlaming Sub-basin, and Bunbury Trough (Fig. 2). Late Jurassic sediments are represented by the Yarragadee Formation (Fairbridge, 1953; McWhae and others, 1958), a fluvatile-sandstone unit. Conformably overlying the Yarragadee Formation is the Parmelia Formation (Backhouse, 1984), a variable sandstone, siltstone, claystone, and shale unit of approximately latest Jurassic to earliest Cretaceous age. The Early Cretaceous Warnbro Group (Cockbain and Playford, 1973) unconformably overlies the block-faulted Yarragadee and Parmelia Formations, and is unconformably overlain by the Osborne Formation (Albian–Cenomanian). Stratigraphic sections for the four areas of the basin covered by this study are presented in Figure 3.

YARRAGADEE FORMATION

The name “Yarragadee Beds” was used by Fairbridge (1953) for a sandstone unit exposed some 300 km north of Perth. The name was changed to Yarragadee Formation by Playford, Willmott and McKellar (*in* McWhae and others, 1958) who provided a fuller description of the unit. More recently the upper part of the unit has been transferred to the Parmelia Formation (Backhouse, 1984).

The Yarragadee Formation is a fluvatile sandstone sequence with minor shale beds, and carbonaceous stringers in some sections. The sandstone is characteristically medium- to coarse-grained, poorly sorted, and kaolinitic. It is present in the subsurface, with little regional lithologic variation, throughout the Dandaragan Trough, Vlaming Sub-basin, and Bunbury Trough. As

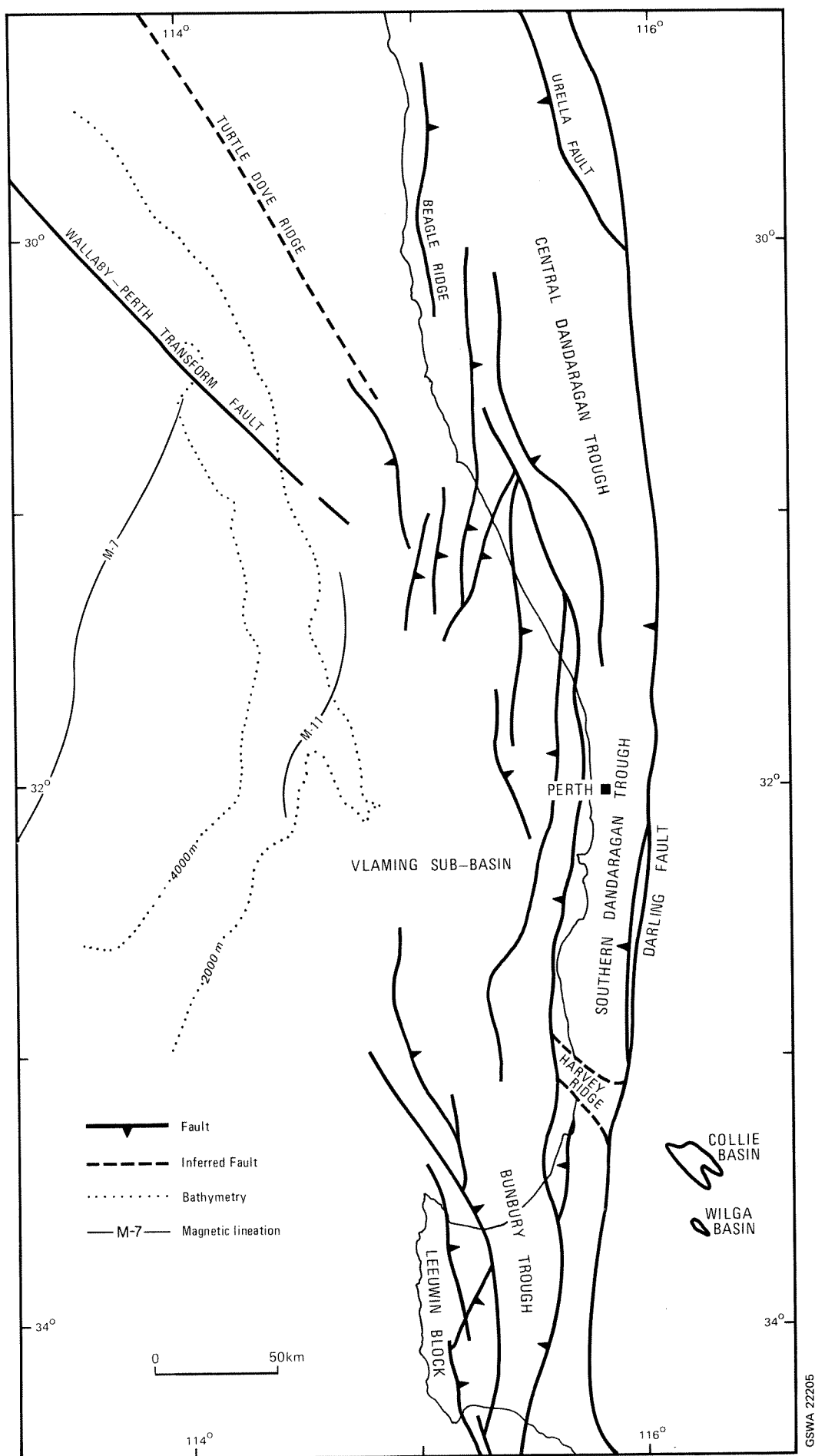


Figure 2. Structural elements, bathymetry and magnetic lineations, central and southern Perth Basin. Based mainly on Johnstone and others (1976) and Markl (1978).

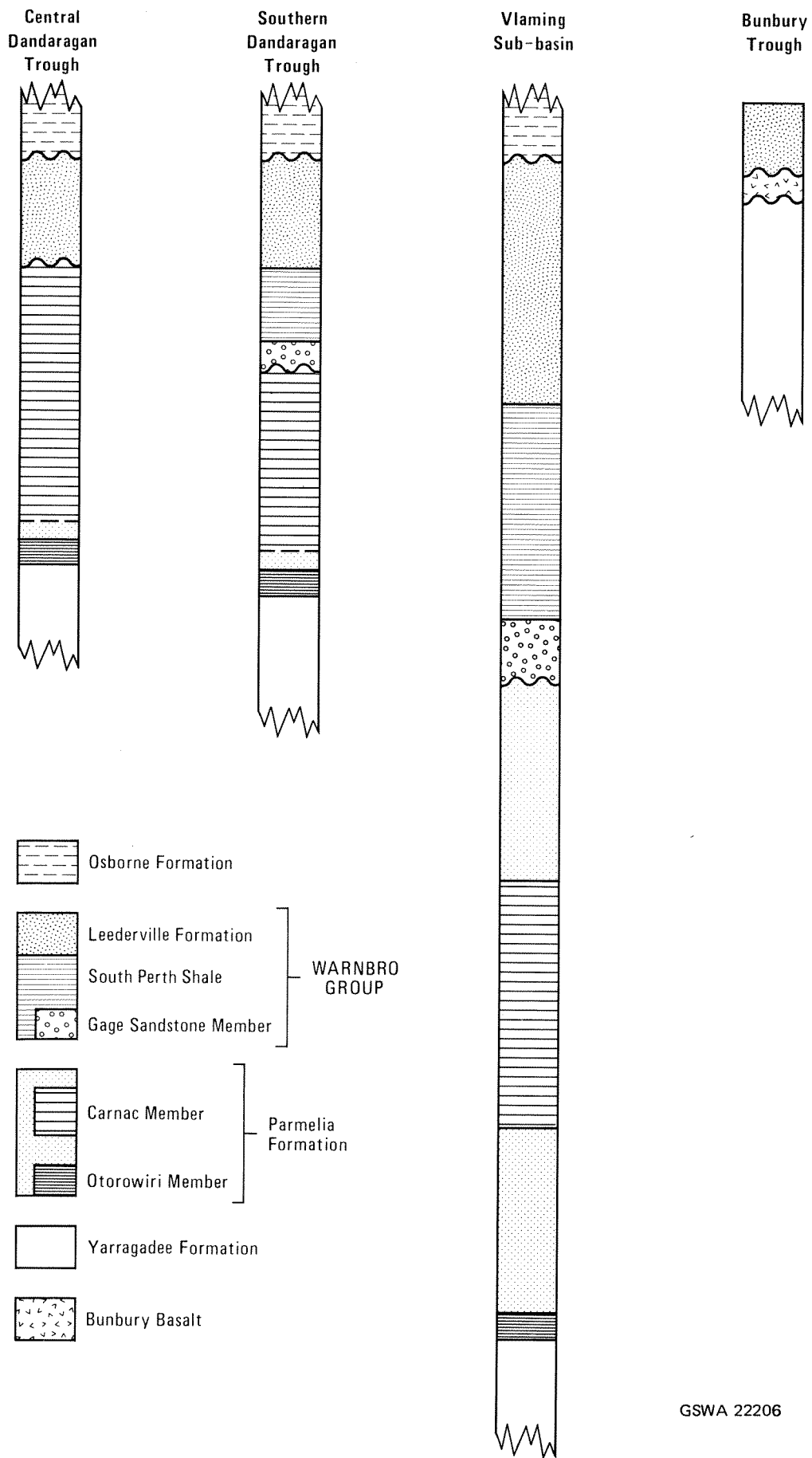


Figure 3. Late Jurassic–Early Cretaceous stratigraphic columns in four parts of the Perth Basin.

redefined by Backhouse (1984) the Yarragadee Formation is up to 3 000 m thick in the Dandaragan Trough and Vlaming Sub-basin, and up to 900 m thick in the eastern part of the Bunbury Trough.

PARMELIA FORMATION

The Parmelia Formation is known in detail only from the subsurface, although a weathered outcrop forms a north-south scarp between Arrowsmith River and Gingin. The type section in Peel 1 (Fig. 5) between 1 625 m and 3 551 m (Backhouse, 1984) is a sequence of sandstone interspersed with frequent beds of micaceous siltstone, shale, and claystone. Two predominantly siltstone, shale and claystone members are recognized, the Otorowiri Member at the base and the Carnac Member in the middle of the formation. The Otorowiri Member (Ingram, 1967b) was previously named the Otorowiri Siltstone Member and included in the Yarragadee Formation. It is recognized by its electric log characteristics and the presence of an unusually diverse assemblage of reworked palynomorphs. It is 24 m thick in its type section in Arrowsmith River 25 borehole and attains a maximum-drilled thickness of 99 m in Eneabba Line 2 borehole. The Carnac Member is lithologically similar to the Otorowiri Member, but is much thicker. The Carnac Member is 655 m thick in its type section in Peel 1, and has an incomplete section of 1 262 m in Roe 1.

In the Vlaming Sub-basin the Otorowiri and Carnac Members are separated by a sequence of fine- to coarse-grained sandstone units interspersed with thin shale beds. The Carnac Member is overlain by a sequence of thick beds of coarse-grained, kaolinitic sandstone and infrequent thin shale beds. The Parmelia Formation increases in thickness from east to west across the Vlaming Sub-basin. Seismic evidence indicates a maximum thickness of up to 8 000 m below the continental slope west of Roe 1 (Jones and Pearson, 1972; Johnstone and others, 1973; Playford and others, 1976).

In the Dandaragan Trough the Carnac Member either immediately overlies the Otorowiri Member, or is separated from it by a thin sandstone unit. The Parmelia Formation subcrops along the eastern side of the Dandaragan Trough, but has been eroded from the western side. It attains a maximum-drilled thickness of 900 m near Moora, about 150 km NNE of Perth. Erosion in the Dandaragan Trough before deposition of the succeeding Warnbro Group may have removed some of the section.

Sandstone sections in the Parmelia Formation probably represent periods of fluvio-deltaic deposition. Based on palynological evidence many of the siltstone-shale beds are recognized as open-water deposits. Palynomorphs are the only fossils known from the Parmelia Formation.

Following deposition of the Parmelia Formation large-scale block faulting on a general north-south trend produced substantial displacement of the Yarragadee and Parmelia Formations in the Vlaming Sub-basin and, to a lesser extent, affected other parts of the Perth Basin (Jones and Pearson, 1972; Johnstone and others, 1976; Playford and others, 1976). The Bunbury Basalt was extruded during or immediately following this period of tectonic activity. It subcrops an extensive area in the eastern Bunbury Trough. Two flows are present in a number of places and can be seen clearly in cores taken from the bed of Bunbury Harbour (Burgess, 1978) where siltstone and shale beds are present between the flows.

WARNBRO GROUP

The Warnbro Group (Cockbain and Playford, 1973), formerly known as the "South Perth Formation" (McWhae and others, 1958) includes all the section between the top of the Parmelia Formation and the base of the Osborne Formation. It overlies block-faulted and eroded older sediments with a strongly unconformable contact in the Vlaming Sub-basin and southern Dandaragan Trough, and with little angular unconformity in the central Dandaragan Trough and Bunbury Trough.

In the Vlaming Sub-basin and southern Dandaragan Trough the Warnbro Group is subdivisible into a lower shale-claystone unit, the South Perth Shale, and an upper mainly sandstone unit, the Leederville Formation. The South Perth Shale has at its base the Gage Sandstone Member.

In the central Dandaragan Trough the Warnbro Group is represented by a predominantly sandstone section, with numerous shale beds near the top. North of the Watheroo Line boreholes it has been removed by erosion.

In the Bunbury Trough the Warnbro Group consists of a thin sandstone and shale section, with minor coal seams, and unconformably overlies the Yarragadee Formation.

Gage Sandstone Member

The Gage Sandstone (Bozanic, 1969) has its type section in Gage Roads 1 (Fig. 5) between 1 588 m and 1 801 m. In Warnbro 1, where it at-

tains a thickness of 249 m, it is composed, at least in part, of turbidites. A cored section in this borehole passes through two complete turbidite beds, each approximately 2 m thick. Elsewhere in the Vlaming Sub-basin the member consists of fine- to coarse-grained, often well-sorted sandstone. Shale beds may be closely spaced or almost totally absent, and some sections include thick siltstone and shale intervals. In the southern Dandaragan Trough, sediments of the same age and facies as the Gage Sandstone Member in the Vlaming Sub-basin are known only in the Wanneroo area, approximately 15 km NNW of Perth.

Elsewhere in the southern Dandaragan Trough an interbedded, poorly sorted sandstone, siltstone, and shale sequence occurs at the base of the South Perth Shale in many borehole sections. These sediments are included here in the Gage Sandstone Member, although at many localities they may be younger than the type section of that unit.

The Gage Sandstone Member appears to have been deposited in structurally low areas during erosion of the newly formed fault blocks, partly in marine or restricted marine open water. The deposits in the southern Dandaragan Trough are similar in origin, but apart from those in the Wanneroo area they appear to be strictly fluvial deposits. Palynomorphs are the only fossils recorded from the Gage Sandstone Member.

South Perth Shale

The type section of the South Perth Shale (Fairbridge, 1953) is an incomplete section in South Perth 1 borehole (Fig. 6, no. 83). Excluding the Gage Sandstone Member, the formation ranges in thickness from 638 m in Peel 1 to 4 m in Artesian Monitoring 51. The contact of the shale with the underlying Gage Sandstone Member is usually sharp. Near its base it is a dark-grey pyritic claystone or shale, often containing small bivalve fragments, coarse sand grains, and small, rare glauconite grains. This lithology gives way to paler grey, silty claystone and shale, and greenish-grey siltstone. In all sections the South Perth Shale is lighter in colour and more equigranular towards the top. Bar sands can be recognized on electric logs in some boreholes and have the effect of locally increasing the total thickness of the formation.

The South Perth Shale is a shallow-water, inner-shelf marine deposit containing abundant palynomorphs, rare benthonic foraminifers

(Crespin, 1937; Coleman, 1952; Rao, 1954), and ostracods (Crespin, 1937). Bivalves were recorded from the formation by Playford and Willmott (1958), and by Cockbain (1967), who mistakenly ascribed his material from Pinjar 6 to the Yarragadee Formation.

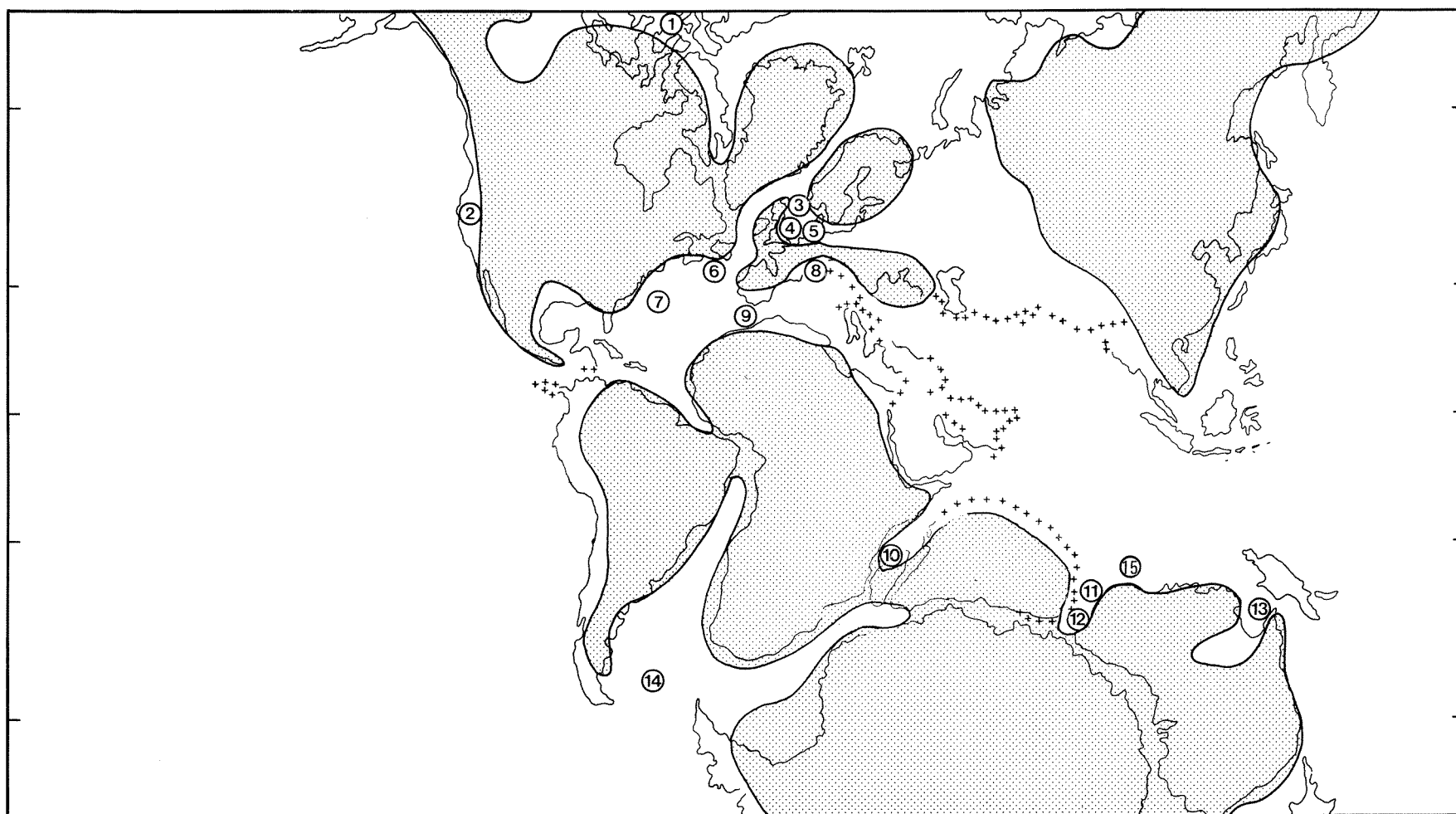
Leederville Formation

The type section of the Leederville Formation (Cockbain and Playford, 1973) is in the Leederville Valley Bore (Fig. 6, no. 75). It is predominantly sandstone with varying amounts of shale, claystone, siltstone, and rare conglomerate. The sandstone is usually poorly sorted and may be clean or contain a significant clay component. The junction with the underlying South Perth Shale tends to be sharply defined in boreholes in the central and northern Perth area and in the offshore boreholes Quinns Rock 1 and Charlotte 1. In Gage Roads 1 the South Perth Shale is overlain by a sequence of alternating sandstone and shale units representing successive minor transgressive and regressive phases. In Warnbro 1 and Peel 1 the transition from claystone and siltstone to predominantly sandstone takes place at a stratigraphically higher level. In the southern Perth area, near Mandurah, the Warnbro Group consists of siltstone and shale, with only minor sandstone, and here it is difficult to distinguish the Leederville Formation from the South Perth Shale.

Warnbro Group sections in the central Dandaragan Trough and Bunbury Trough are equated with the Leederville Formation, although the lower part of the section in the central Dandaragan Trough may correlate with the South Perth Shale in the southern Dandaragan Trough.

The Leederville Formation is a fluvio-deltaic unit, with shallow marine intervals. Palynomorphs are the only fossils recorded from the formation.

Erosion during the Aptian truncated the Leederville Formation over most of the onshore area. The overlying Osborne Formation is a marine unit which consists of dark-grey, frequently glauconitic claystone, glauconitic sandstone, and well-sorted quartz sandstone. The junction of the formations is sharp, and readily identified on geophysical borehole logs.



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Figure 4. Land and sea distribution in the Hauterivian, based on palaeocontinental maps by Smith and Briden (1977) and Smith, Hurley, and Briden (1981). Locations of previous major Neocomian microplankton studies indicated by numbers. 1, Pocock, 1976; Brideaux and Fisher, 1976; Brideaux, 1977; McIntyre and Brideaux, 1980. 2, Warren, 1967. 3, Raynaud, 1978; Davey, 1979b. 4, Neale and Sarjeant, 1962; Sarjeant, 1966; Davey, 1974, 1979b; Duxbury, 1977, 1980. 5, Gocht, 1957, 1959; Alberti, 1961; Davey, 1982a. 6, Williams, 1975; Bujak and Williams, 1978. 7, Habib, 1972, 1976, 1977. 8, Millioud 1967, 1969; Renneville and Raynaud, 1981. 9, Williams, 1978; Williams and Bujak, 1980; Below, 1981, 1982. 10, Chen, 1978. 11, Wiseman and Williams, 1974; Wiseman, 1979, 1980. 12, Edgell, 1964; this Bulletin. 13, Evans, 1966a,b; Burger 1980b, 1982. 14, Hedlund and Beju, 1977; Harris, 1977. 15, Helby and others, 1987.

PREVIOUS PALYNOLOGICAL STUDIES

WESTERN AUSTRALIA

The Perth Basin has been the subject area for a number of papers on Jurassic and Early Cretaceous palynology. Balme (1957) included several sample from the basin in his early work on Western Australian Mesozoic palynology. He followed this with a general review paper (Balme, 1964), and numerous unpublished reports for petroleum-exploration companies. Ingram (1967a, b) and Backhouse (1974, 1975, 1978) described Late Jurassic to Cretaceous assemblages from hydrogeological boreholes in the Dandaragan Trough, and Filatoff (1975) published a large systematic paper on Jurassic material from WAPET petroleum-exploration boreholes.

Cookson and Eisenack described microplankton from the Perth Basin in a number of publications, but only four papers (Cookson and Eisenack, 1958, 1962a, b; Eisenack and Cookson, 1960) concerned samples that are now considered to be from the Warnbro Group. Edgell (1964) produced a preliminary zonation of the Warnbro Group, then known as the "South Perth Formation", in Mandurah 1 borehole. This was the first biostratigraphic work in Western Australia using Mesozoic dinoflagellate cysts. Unfortunately the use of unreliable ditch cuttings samples detracts from the usefulness of this work.

In palynological studies of the Cretaceous in other Western Australian basins, Cookson and Eisenack (1958, 1960b, 1974) described pre-Albian Cretaceous microplankton that were from the Carnarvon Basin, and Wiseman and Williams (1974) listed Early Cretaceous miospores and microplankton that were identified from cores in DSDP boreholes 259, 261, and 263. Wiseman (1978, 1980) subsequently published biostratigraphic papers on dinoflagellate cysts from petroleum-exploration boreholes in the Carnarvon Basin. Kemp (1976) described a microplankton assemblage of putative Aptian age from the Samuel Formation in the Officer Basin, and Ingram (1968) listed microplankton of similar age from the Madura Shale in the Eucla Basin. A series of systematic papers, recently published in Australasian Association of Palaeontologists Memoir 4, describe dinoflagellate cysts from several offshore petroleum-exploration boreholes in Western Australia. Several species encountered during this study are described in these papers, as indicated in the systematic section of this bulletin.

EASTERN AUSTRALIA

Cookson and Dettmann (1958a, b, 1961) published early papers on Cretaceous spores from eastern Australia, principally the Otway and Gippsland Basins. Dettmann continued this work (Dettmann, 1963; Dettmann and Playford, 1968) which has been summarized in a biostratigraphic review paper (Dettmann and Playford, 1969). Burger (1968, 1973a, b, 1974, 1976, 1980a) continued the study of Early Cretaceous assemblages from eastern Australia by working on material from the Surat, Eromanga, Carpentaria, and Galilee Basins. In these papers Burger revised and elaborated the zonation of Dettmann and Playford (1969).

Evans (1966a, b, and in numerous unpublished records of the Bureau of Mineral Resources, Canberra) used miospores and dinoflagellate cysts for biostratigraphy in several sedimentary basins in eastern Australia and Papua. His Jurassic and Cretaceous microplankton zonation was for over 10 years the only published zonation for eastern Australia, until Morgan (1975, 1977, 1980a) presented the results of a major biostratigraphic study of Neocomian–Early Cenomanian microplankton from all major Australian Mesozoic basins. The results of this study formed the basis of Morgan's (1980b) paper on Cretaceous eustatic sea-level changes in Australia. Burger (1980a, b, 1982) has also published on Neocomian microplankton from north-eastern Australia.

WORLDWIDE

Owing to the large number of practising palynologists working in India and Argentina, these countries are the most extensively studied Gondwana areas outside Australia. The large number of papers published by Indian authors are principally concerned with taxonomic refinement or broad biostratigraphic review, and provide few constructive biostratigraphic details. Papers by Volkheimer and co-authors (Volkheimer and others, 1977; Volkheimer and Quattrocchio, 1975, 1977; Volkheimer and Sepulveda, 1976), and by Archangelsky (1979), and Archangelsky and Gamero (1965, 1966a, b, c, 1967) describe Tithonian and Early Cretaceous miospores from Western Argentina and Patagonia.

A largely unpublished thesis by Chen (1978) describes Tithonian–Aptian microspore and microplankton assemblages from a borehole in Madagascar. Several studies have been made of

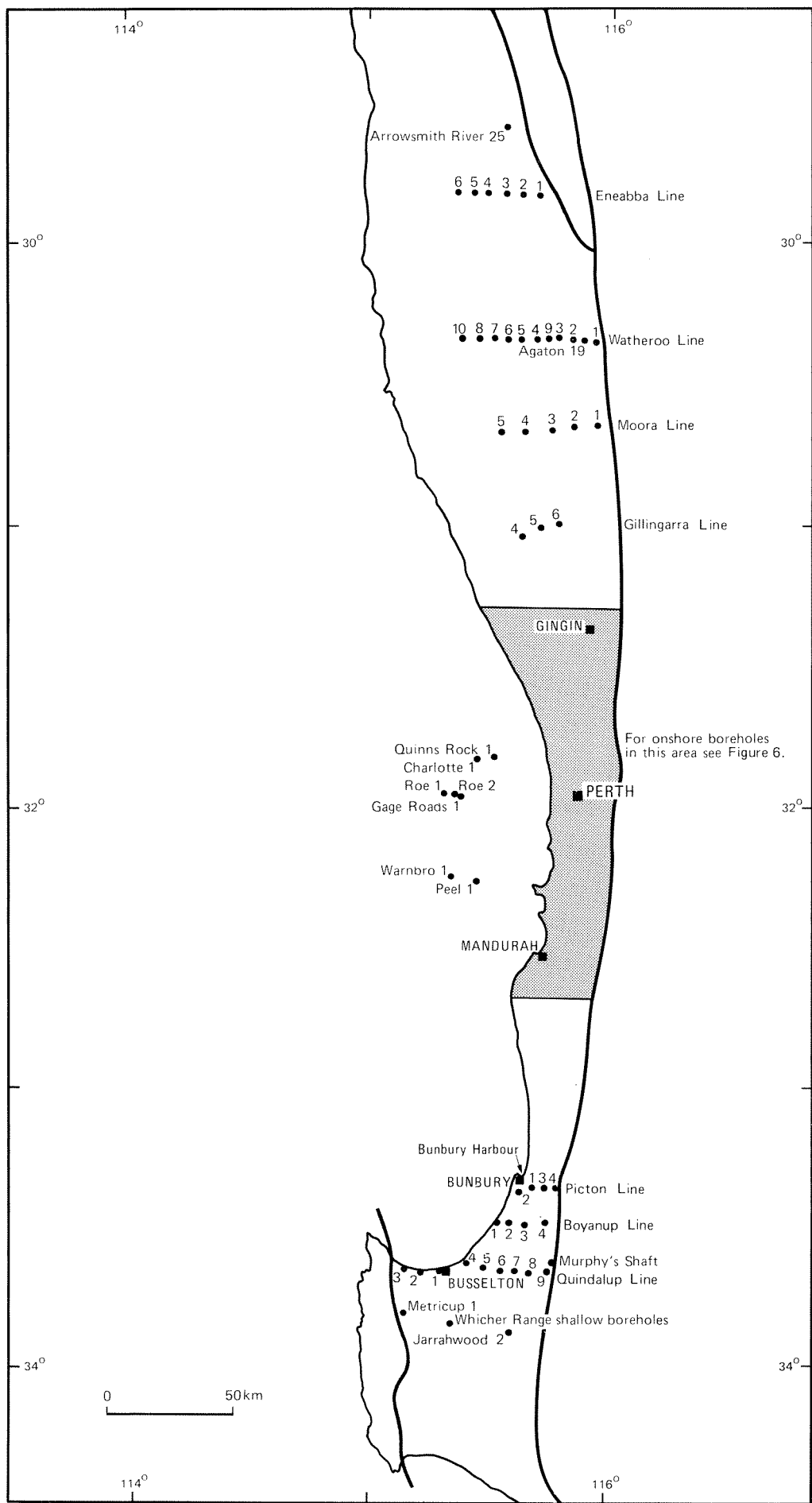


Figure 5. Borehole location map, central and southern Perth Basin.

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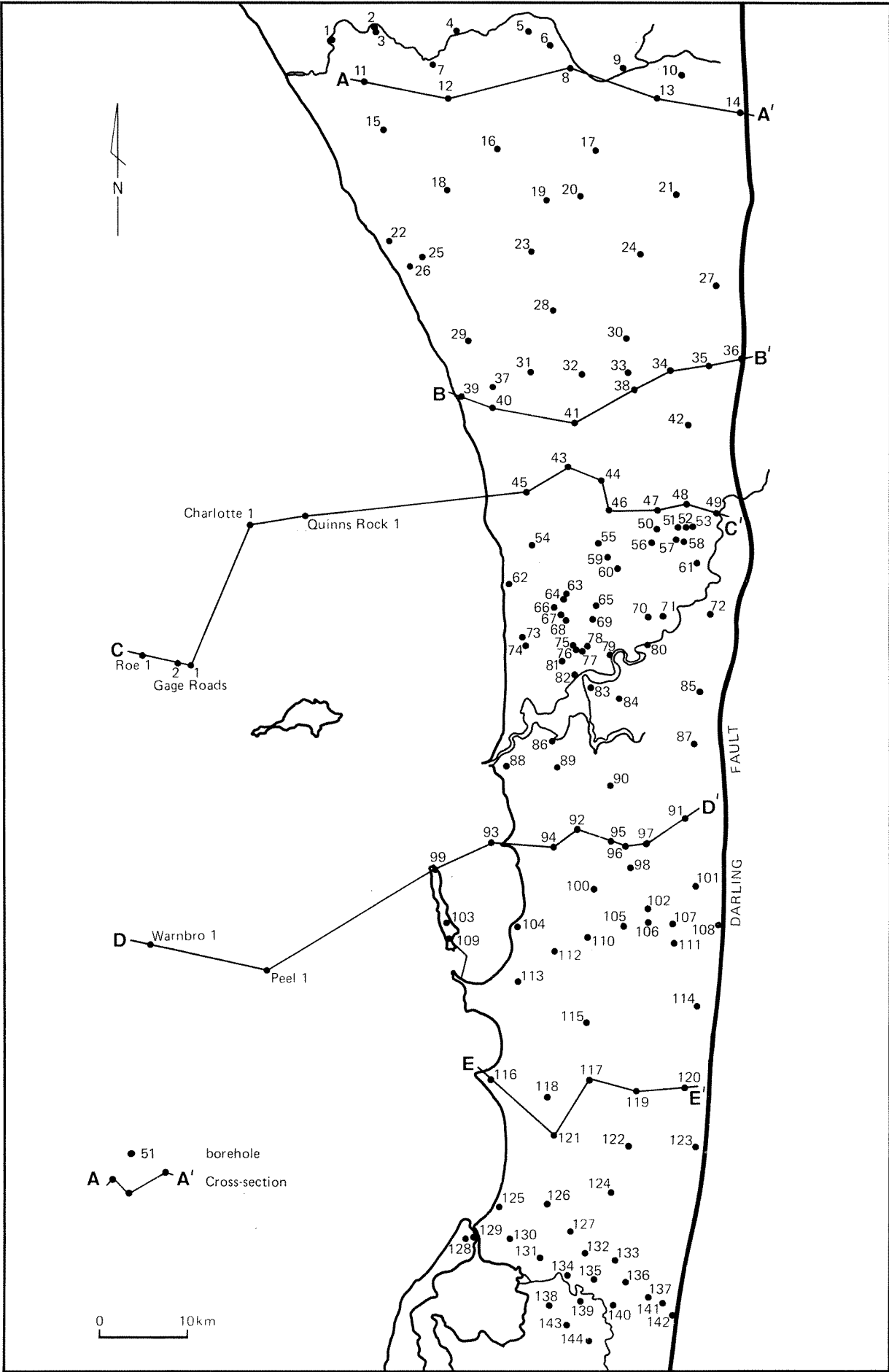


Figure 6. Borehole locations in the Perth area and locations of cross-sections A–A' to E–E'.

1	Gingin Brook Line 4	50	Mirrabooka 30Z	99	Garden Island 3
2	Gingin Brook Line 6	51	Mirrabooka 260	100	Artesian Monitoring 49
3	Artesian Monitoring 3	52	Mirrabooka 270	101	Artesian Monitoring 51
4	Gingin Brook Line 3	53	Mirrabooka 280	102	Byford Line 3
5	Artesian Monitoring 4	54	Artesian Monitoring 33A	103	Garden Island 2
6	Gingin Brook 2	55	Mirrabooka 2	104	Artesian Monitoring 52
7	Badaminna 1 (Wapet)	56	Mirrabooka 55	105	Byford Line 4
8	Artesian Monitoring 6	57	Mirrabooka 160	106	Artesian Monitoring 50
9	Gingin Brook 5	58	Mirrabooka 180	107	Byford Line 2
10	Gingin Brook 1	59	Mirrabooka 1	108	Byford Line 1
11	Barragoon 1 (Wapet)	60	Artesian Monitoring 34	109	Garden Island 1
12	Artesian Monitoring 5	61	Artesian Monitoring 35	110	Byford Line 5
13	Artesian Monitoring 7	62	Triggs 1	111	Lake Thompson 220*
14	Artesian Monitoring 11	63	Balcatta 1	112	Byford Line 6
15	Artesian Monitoring 8	64	Balcatta 2	113	Artesian Monitoring 54
16	Artesian Monitoring 9	65	Mount Yokine 1	114	Artesian Monitoring 56
17	Artesian Monitoring 10	66	Artesian Monitoring 36A	115	Artesian Monitoring 55
18	Artesian Monitoring 13	67	Hector Street Bore	116	Becher Point 1
19	Artesian Monitoring 14	68	Roberts Street Bore	117	Becher Point 3
20	Bullsbrook 1 (Wapet)	69	Mount Yokine 2	118	Becher Point 2
21	Artesian Monitoring 15	70	Artesian Monitoring 37	119	Becher Point 4
22	Artesian Monitoring 12	71	Mount Lyall Bore	120	Becher Point 5
23	Artesian Monitoring 17	72	Artesian Monitoring 38	121	Artesian Monitoring 62
24	Artesian Monitoring 18	73	Bold Park 1	122	Artesian Monitoring 63
25	Yanchep Sun City 1	74	Bold Park 2	123	Artesian Monitoring 64
26	Yanchep Sun City 2	75	Leederville Valley Bore	124	Artesian Monitoring 66
27	Artesian Monitoring 19	76	Regent Street Bore	125	Artesian Monitoring 67
28	Artesian Monitoring 21	77	Loftus Street Bore	126	Artesian Monitoring 65
29	Artesian Monitoring 20	78	Sanitary Site Bore	127	Artesian Monitoring 68
30	Artesian Monitoring 22	79	Power House Bore	128	Halls Head E.D. 2*
31	Pinjar 4	80	Ascot 5	129	Mandurah 1
32	Pinjar 3	81	Subiaco Bore	130	Mandurah 2
33	Pinjar 2	82	Kings Park 2	131	Mandurah 3
34	Pinjar 1	83	South Perth 1 and 2	132	Mandurah 7
35	Pearce Bore	84	Artesian Monitoring 40	133	Mandurah 8
36	Pinjar 7	85	Artesian Monitoring 41	134	Mandurah 4
37	Pinjar 5	86	Attadale Bore	135	Mandurah 5
38	Artesian Monitoring 25	87	Artesian Monitoring 44	136	Mandurah 13
39	Pinjar 6	88	Hampden Road Bore	137	Mandurah 14
40	Artesian Monitoring 23	89	Artesian Monitoring 42	138	Mandurah 12
41	Artesian Monitoring 24	90	Artesian Monitoring 43	139	Mandurah 6
42	Artesian Monitoring 29	91	Woodman Point 3	140	Mandurah 9
43	Wanneroo 1	92	Jandakot Woolscourers Bore	141	Mandurah 16
44	Artesian Monitoring 28	93	Cockburn 1 (Wapet)	142	Mandurah 15
45	Whitfords 1	94	Artesian Monitoring 45	143	Mandurah 10
46	Mirrabooka 305	95	Woodman Point 1	144	Mandurah 11
47	Mirrabooka 345	96	Jandakot 105		
48	Whitfords 4	97	Woodman Point 2		
49	Whitfords 5	98	Jandakot 45		

*shallow boreholes.

Tithonian–Aptian sequences in DSDP boreholes around southern Africa and South America (McLachlan and Pieterse, 1978; Davey, 1978; Harris, 1977; Hedlund and Beju, 1977).

North American and European Jurassic and Cretaceous strata are the subject of numerous palynological studies. The Neocomian microplankton studies relevant to this study are indicated in Figure 4. Details of some of these papers are discussed in a later section.

STUDY METHODS

SAMPLES

About 1 800 samples from deep boreholes in the Perth Basin were examined initially. They comprised 53 samples from 21 boreholes in the Bunbury Trough, approximately 200 samples from 26 boreholes in the central Dandaragan Trough, nearly 1 350 samples from 142 boreholes in the southern Dandaragan Trough between Gingin and Mandurah, and 200 samples from 7 petroleum-exploration boreholes in the Vlaming Sub-basin. All boreholes, except those drilled for petroleum exploration and a few coal-exploration boreholes, were drilled for groundwater exploration or production. The locations of all boreholes are shown in Figures 5 and 6. Other material from numerous shallow boreholes has been examined over a number of years and provides supporting evidence for the biostratigraphy established in the deep boreholes. Only shallow boreholes mentioned elsewhere in the text are located in Figures 5 and 6. Balme's (1957) sample from Murphy's shaft (Fig. 5) was reprocessed and re-examined.

The study concentrated on the thickest and most closely sampled sections available at, or soon after, the start of the investigation: the Yarragadee Formation and Parmelia Formation sections in the Eneabba Line, Watheroo Line, and Moora Line boreholes; the Parmelia Formation sections in Roe 1, Gage Roads 1, and Charlotte 1; and the Warnbro Group sections in Peel 1, Warnbro 1, Gage Roads 1, Whitfords 1, 4 and 5, Jandakot 105, Woodmans Point 2, and Artesian Monitoring 49. Most samples from deep boreholes are from sidewall or conventional cores. Samples from shallow boreholes are mainly ditch cuttings.

Sandstone samples were invariably barren unless they were poorly sorted and contained a significant proportion of argillaceous material. Most

productive samples consisted of siltstone, shale, or claystone. Lithological descriptions of all samples from hydrogeological boreholes are given in the relevant palaeontological reports of the Geological Survey of Western Australia. A card catalogue of palynomorph identifications from each sample and the tabulated results of species counts in the main borehole sections are held in the Palaeontology Branch of the same institution.

PREPARATION

Samples from the offshore petroleum boreholes were obtained as residues from West Australian Petroleum Pty Ltd (WAPET). Some of these were further treated with Schultze Solution and dilute ammonia solution. Over a number of years Geological Survey of Western Australia samples were prepared by standard palynological methods which included treatment with HCl, HF, Schultze Solution (or conc. HNO_3), and dilute ammonia solution (approx. 6% NH_4OH). Good results were obtained with later preparations by boiling the residue in concentrated HCl after digestion in HF. Gravity separation in zinc chloride or zinc bromide solution (S.G. 1.9) was carried out on all samples. Residues were mounted in Clearcol, Petropoxy, or glycerine jelly.

EXAMINATION PROCEDURES

Counts were made on samples from the sections studied in detail. In most assemblages 200 specimens were counted from one slide, and at least one other slide was scanned for rare species. In sparse assemblages fewer than 200 specimens were counted. Specimens not identifiable to species level were categorized as araucariacean pollen, saccate pollen, spores, or microplankton. Figures 40–46 give the distribution of these groups in six major borehole sections.

Light photomicrographs were taken on a Leitz Orthoplan microscope fitted with an Orthomat automatic camera. Scanning electron microscope (SEM) micrographs were taken on a JEOL JSM 35C scanning electron microscope located in the School of Physics and Geosciences at the Western Australian Institute of Technology. Several of the specimens photographed with the SEM were subsequently lost before the cover slips on which they were located were transferred to glass slides for permanent storage.

ACKNOWLEDGEMENTS

This bulletin is the result of a Ph.D. thesis completed at the University of Western Australia in 1984 under the joint supervision of Dr B. E. Balme and Dr A. E. Cockbain whose assistance and endurance is gratefully acknowledged.

I also thank the following institutions and their staff: Geology Department, University of Western Australia for providing facilities during part of the project; National Museum of Victoria for access to the collections of Cookson and Eisenack (1958–1968) and Dettmann (1963); Bureau of Mineral Resources, Geology and Geophysics, Canberra for access to Balme's (1957) collec-

tion; British Museum (Natural History), London for access to Duxbury's (1977, 1980) collections; West Australian Petroleum Pty Ltd (WAPET) for providing palynological slides and residues from offshore wells; Water Authority of Western Australia (WAWA), formerly Metropolitan Water Authority of Perth, for supplying sidewall cores from deep boreholes in the Perth area; and Department of Physics, Western Australian Institute of Technology, for the use of their SEM.

Robin J. Helby, Lew E. Stover, and Julie F. Wiseman provided constructive discussion on a number of occasions on aspects of dinoflagellate-cyst taxonomy and biostratigraphy.

CHAPTER 2

PALYNOLOGICAL ZONATIONS

Two parallel zonations are used, one based on miospores and the other on microplankton (principally dinoflagellate cysts). Miospore and microplankton zone boundaries coincide at the bottom of the Parmelia Formation and are nearly synchronous at the top of this formation. Within the Warnbro Group microplankton display greater vertical variation than miospores, and six microplankton zones are recognized within the range of a single miospore zone. The distribution of the pre-Warnbro Group miospore zones and the Warnbro Group microplankton zones in 6 sections across the Perth Basin are shown in Figures 19, 20, and 36–39.

MIOspore ZONATION

Filatoff's (1975) work and this study show spore diversity increasing steadily through the Late Jurassic. Species appear gradually, and are often rare in the lower part of their range. A few spore species disappear, and *Microcachryidites castellanosii* Menendez gives way to *M. antarcticus* Cookson at the same general level that araucariacean pollen cease to dominate the miospore assemblages. This is also close to the base of the *Retitriletes watherooensis* zone (Backhouse, 1978). The miospore zonation of Backhouse (1978) has been extended by the addition of one more zone to the top of the Warnbro Group. The zones are listed below in descending order:

Balmeiopsis limbata Zone (new)

Biretisporites eneabbaensis Zone (Backhouse, 1978)

Aequitriradites acusus Zone (Backhouse, 1978)

Retitriletes watherooensis Zone (Backhouse, 1978)

Below the *R. watherooensis* Zone is the *Murospora florida* Microflora, part of the *Callialasporites dampieri* Assemblage-zone (Filatoff, 1975). Miospore assemblages in the Perth Basin above the *B. limbata* Zone are assigned to the *Hoegisporis* Assemblage of Balme (1964).

The miospore zones used in this study are based on the appearance and disappearance of key species and supported by quantitative changes in the microflora. They are essentially Oppel-zones (Hedberg, 1976). The two most important zone boundaries, between the *A. acusus* and *B. eneabbaensis* Zones and between the *B. eneabbaensis* and *B. limbata* Zones, correspond with major palaeogeographic and sedimentological changes. The latter boundary also approximately corresponds with a regional unconformity.

A range chart for all miospore species encountered during this study is provided in Figure 34.

Retitriletes watherooensis Zone (Backhouse, 1978)

Filatoff's (1975) zonation of the Late Jurassic in the Perth Basin records a steady increase in spore diversity and a continuing abundance of araucariacean pollen. His highest biostratigraphic unit, the *Murospora florida* Microflora, spans a thick stratigraphic section and has an ill-defined upper limit that approximately coincides with the first appearance of *Cicatricosisporites australiensis* (Cookson) Potonié 1956. Spore diversity continued to increase in the *M. florida* Microflora, with araucariacean pollen still abundant.

The *Retitriletes watherooensis* Zone of Backhouse (1978) occupies part of the biostratigraphic section included by Filatoff in the *M. florida* Microflora. The base is marked by the first appearance of the eponymous species and

typical forms of the trisaccate pollen *Microcachryidites antarcticus* Cookson 1947.

Concavissimisporites verrucosus Delcourt and Sprumont 1955, and *Retispora triquetra* (Lantz) comb. nov. also appear within this zone. Araucariacean pollen decline in abundance within the zone, but are still abundant at some horizons. *Concavissimisporites variverrucatus* (Couper) Brenner 1963 and *Contignisporites multimuratus* Dettmann 1963 are present in the zone but are not commonly recorded.

The top of the zone is marked by the appearance of species of *Aequitriradites* Delcourt and Sprumont 1955.

***Aequitriradites acusus* Zone (Backhouse, 1978)**

In the Dandaragan Trough *Aequitriradites acusus* (Balme) Dettmann 1963 and *A. hispidus* Dettman and Playford 1968 appear at a slightly lower level than *Cicatricosisporites australiensis* and other species that mark the base of the *B. eneabbaensis* Zone. This short biostratigraphic interval was referred to as the *A. acusus* Zone by Backhouse (1978). In the Vlaming Sub-basin the part of the sequence where this zone may be expected to occur is composed almost entirely of sandstone and has yielded few productive palynological samples. Consequently, the *A. acusus* Zone has not been unequivocally recognized in the Vlaming Sub-basin.

The base of the *B. eneabbaensis* Zone marks the top of the *A. acusus* Zone.

***Biretisporites eneabbaensis* Zone (Backhouse, 1978)**

The *Biretisporites eneabbaensis* Zone includes all the section now included in the Parmelia Formation. The base is marked by the first appearance of a large number of spores including *Aequitriradites dandaraganensis* sp. nov., *Cicatricosisporites australiensis*, *C. ludbrookae* Dettmann 1963, *Laevigatosporites belfordii* Burger 1976, *Matonisporites agatonensis* Backhouse 1978, *Pilosisorites ingramii* sp. nov., *Januasporites multispinus* sp. nov., and *Polypodiidites horridus* Backhouse 1978.

Several spore species display highly variable horizontal and vertical distribution within the zone. *Aequitriradites dandaraganensis*, *Biretisporites eneabbaensis* Backhouse 1978, *Concavissimisporites variverrucatus*, *Nevesisporites undatus* sp. nov. and *P. ingramii* are common, or even abundant, at some horizons in the

Dandaragan Trough, but remain rare in the Vlaming Sub-basin.

After increasing through the Late Jurassic, spore diversity reached an acme in the *B. eneabbaensis* Zone before decreasing in the succeeding *B. limbata* Zone. Araucariacean pollen compose 5–30% of the miospore count, but never dominate the miospore assemblages as they do in the *Callialasporites dampieri* Assemblage-zone. Disaccate and trisaccate pollen are common, but *Classopollis* normally composes less than 2% of the miospore count. Reworked miospores and microplankton are common in many samples from this zone. This reworking is described in more detail in a later section.

***Balmeiopsis limbata* Zone (new zone)**

The *Balmeiopsis limbata* Zone occurs in Warnbro 1 in the interval 1 076 m to 2 181.5 m.

The base of the zone is marked by the first occurrence of the eponymous species and *Balmeiopsis robusta* sp. nov. Twelve miospore species appear at, or near, the base of the zone, but several of these are infrequently recorded species. *Krauselisporites whitfordensis* sp. nov. and *Vallizonosporites tegmentiferus* sp. nov. are not known from the upper part of the zone.

The *B. limbata* Zone corresponds with the Warnbro Group in all sections where it is recorded. Marine conditions prevailed over much of the basin during this period and this is reflected by the high percentages of *Classopollis*, disaccate pollen, and *Microcachryidites antarcticus*. Small spores such as *Stereisporites antiquasporites* (Wilson and Webster) Dettmann 1963 are more common in this zone than in lower zones, and araucariacean pollen are less frequent. Spore assemblages of greatly restricted diversity are common in parts of this zone (Figure 7); they are discussed further in Chapter 5. A large form of *B. robusta* with a broad cingular rim is a conspicuous component of many assemblages in the upper part of the zone.

The unconformity at the top of the Warnbro Group approximately corresponds with the top of the *B. limbata* Zone. A miospore microflora referable to Balme's (1964) *Hoegisporis* Assemblage is present above the unconformity.

Many species present in the *B. limbata* Zone have not been recorded from the *Hoegisporis* Assemblage, although twenty-two species recorded here are known to be present in the *Hoegisporis* Assemblage (Fig. 34).

BOREHOLE	DEPTH IN METRES	<i>Aequitriradites acutus</i>	<i>Cicatricosisporites</i> sp. cf. <i>C. hughesi</i>	<i>Cicatricosisporites ludbrookae</i>	<i>Contignisporites cooksonae</i>	<i>Cyathidites minor</i>	<i>Foveosporites canalis</i>	<i>Ischyosporites crateris</i>	<i>Leptolepidites verrucatus</i>	<i>Marattisporites scabratus</i>	<i>Matonisporites crassiangulatus</i>	<i>Dictyophyllidites equiexinus</i>	<i>Murospora florida</i>	<i>Neoraistrickia</i> spp.	<i>Osmundacidites dubius</i>	<i>Reticuloidosporites arcus</i>	<i>Staplinisporites telata</i>	<i>Stereisporites antiquasporites</i>
Artesian Monitoring 3	360				•	•		•		•	•		•					
	394				•	•					•		•				•	
Artesian Monitoring 7	105				•			•	•		•		•					
Artesian Monitoring 11	525		•		•						•				•			
	693				•						•							
Artesian Monitoring 15	302				•	•					•		•					
Gillingarra Line 4A	231					•		•			•							
	94.5			•	•	•					•		•					
Moora Line 2B	168				•	•		•			•							
	285				•			•			•							
Quindalup Line 2	110										•		•			•		
Whitfords 4	283						•				•			•				•
	454	•				•					•					•		

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Figure 7. Samples from the Warnbro Group with miospore assemblages of low diversity versus miospore species present.

MICROPLANKTON ZONATION

Microplankton are recorded in the Perth Basin in the Middle Jurassic Cadda Formation (Filatoff, 1975), but are absent from the Yarragadee Formation. They appear for the first time in Late Jurassic sediments of the Perth Basin in the Otorowiri Member of the Parmelia Formation, where they comprise a distinctive suite of non-marine dinoflagellate cysts and rare *Schizosporis*-style acritarchs. Marine species appear in the Warnbro Group, sometimes in large numbers.

The zonation used here is based on the ranges of marine and non-marine microplankton. Owing to lateral and vertical palaeoenvironmental variations within the Perth Basin during this period, some of the zones represent a particular facies and are in this sense assemblage zones. The zones are defined on the first and last appearances of species whose distribution may be facies controlled, but which display a restricted vertical range in the Perth Basin sections covered by this report. The zones are therefore regarded as Oppel-zones in the sense of Hedberg (1972, 1976).

These zones are listed below in descending order:

- Fromea monilifera* Zone (Backhouse, 1987)
- Batioladinium jaegeri* Zone (Backhouse, 1987)
- Aprobolocysta alata* Zone (Backhouse, 1987)
- Phoberocysta lowryi* Zone (Backhouse, 1987)
- Kaiwaradinium scrutillinum* Zone (Backhouse, 1987)
- Gagiella mutabilis* Zone (new)
- Fusiformacysta tumida* Zone (new)

A range chart showing the distribution of all microplankton species in these zones is given in Figure 35.

***Fusiformacysta tumida* Zone (new zone)**

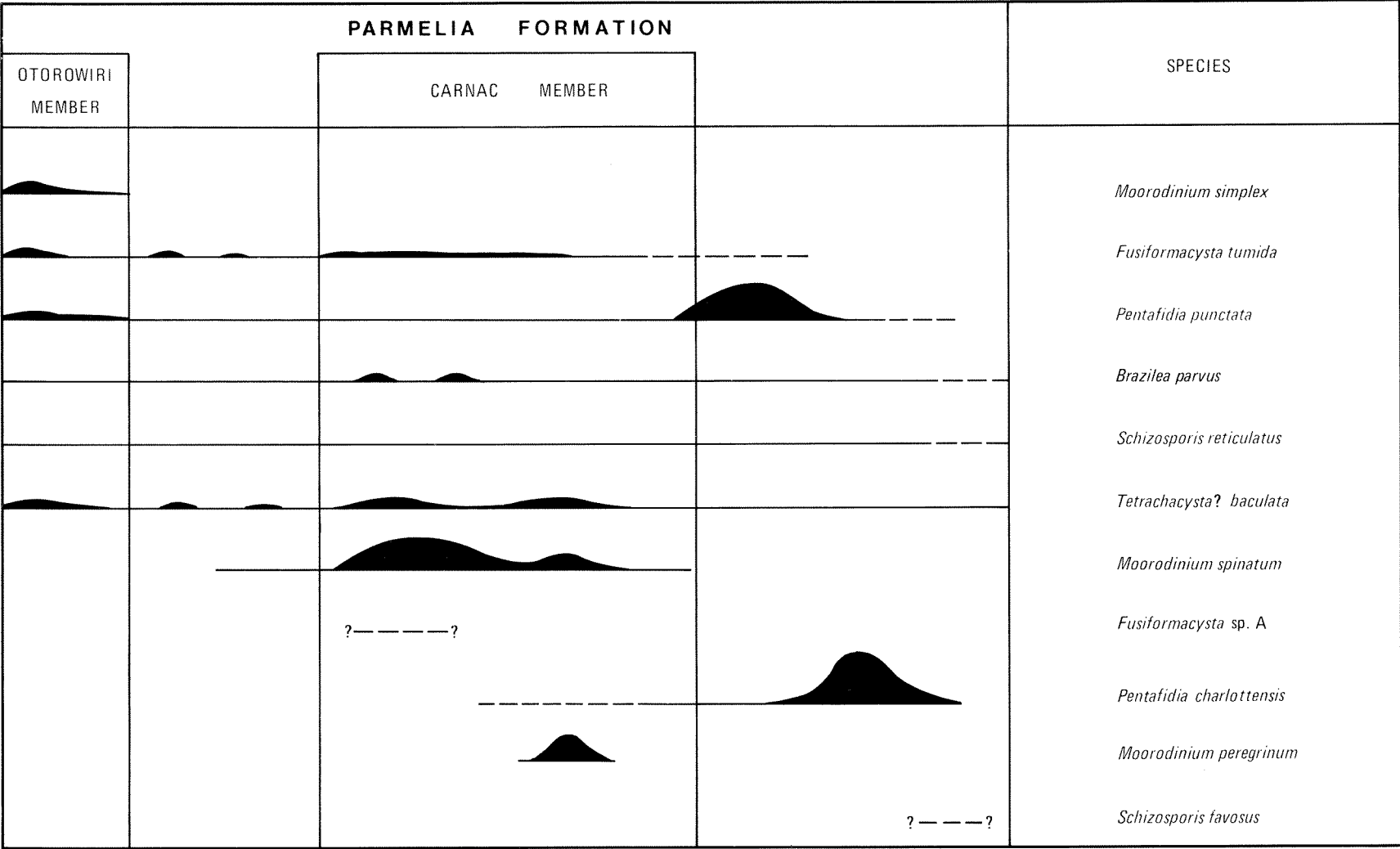
The *Fusiformacysta tumida* Zone incorporates the whole of the Parmelia Formation and is represented in the following borehole intervals, examined in detail for this study: Gage Roads 1, 1 705–2 612 m; Roe 1, 876.5–2 114.5 m; and Charlotte 1, 1 701.5–2 402 m. It is characterized by a suite of unusual cysts. These dinoflagellate cysts represent non-marine dinoflagellates which flourished in large lakes in the Perth Basin at the time of deposition of this unit. Most of them belong in two generic groups, the *Moorodinium* and *Pentafidia* lineage groups. Other dinoflagellate-cyst species present are *Fusiformacysta tumida* sp. nov., *Fusiformacysta* sp. A, and *Tetrachacysta?* *baculata* sp. nov. Four acritarch species are also

represented: *Schizosporis reticulatus* Cookson and Dettmann 1959, *S. favosus* sp. nov., *Brazilea parvus* (Cookson and Dettmann) comb. nov., and Gen. et sp. indet. A.

Figure 8 shows the generalized distribution of microplankton species, excluding reworked forms, in the Parmelia Formation. *Fusiformacysta tumida*, *Pentafidia punctata* nov., and *T.? baculata* appear at, or near, the base of the Otorowiri Member in most sections (Fig. 40). In the Eneabba boreholes, in the northern central Dandaragan Trough, *Moorodinium simplex* sp. nov. is present in the Otorowiri Member, but it has not been recorded further south. *Moorodinium spinatum* sp. nov. is the dominant species in several Carnac Member intervals in the Vlaming Sub-basin (Fig. 41) and the Dandaragan Trough. Near the top of the Carnac Member in the Watheroo Line and Moora Line boreholes, *M. spinatum* occurs in conjunction with *M. peregrinum* sp. nov. Above the Carnac Member, microplankton assemblages are dominated by species of the *Pentafidia* cyst lineage. This section is well represented in Charlotte 1 (Fig. 42) where *P. punctata* appears in large numbers (up to 40% of the total palynomorph count) in the top few metres of the Carnac Member and in thin shale beds just above the Carnac Member. It is replaced, in succeeding shale horizons, by *Pentafidia charlottensis* sp. nov., which composes up to 60% of the total palynomorph count. *Pentafidia*-type cysts do not range to the top of the Parmelia Formation in the Charlotte 1 section, but this may be due to local depositional factors.

Species of *Moorodinium* and *Pentafidia* display considerable vertical and geographical variation. For example, specimens of *M. spinatum* are more spinose in the central Dandaragan Trough than in the Vlaming Sub-basin, and specimens of *P. charlottensis* possess a relatively thinner cyst wall in the lower part of its range than in the upper part. Morphological variations of this nature, and the localized and sporadic distribution of species within the *Moorodinium* and *Pentafidia* lineage-groups preclude their use as reliable biostratigraphic indices. Other microplankton species occurring in the Parmelia Formation either range through most of the formation, or are known from only one or two samples (e.g. *Fusiformacysta* sp. A., *Schizosporis favosus*). Thus, it is not possible at the present time to biostratigraphically subdivide the thick sedimentary sequence included here in the *F. tumida* Zone.

The appearance of *Gagiella mutabilis* sp. nov., or species of marine dinoflagellate cysts associated with the overlying Warnbro Group, marks the top of the *F. tumida* Zone.



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Figure 8. Generalized distribution of non-marine microplankton in the Parmelia Formation (*Fusiformacysta tumida* Microplankton Zone).

***Gagiella mutabilis* Zone (new zone)**

The *Gagiella mutabilis* Zone is present in Gage Roads 1 in the interval 1 587–1 700 m. The base of the zone is marked by the appearance of *G. mutabilis* which is the only species consistently encountered in the zone. In some sections, for example Gage Roads 1, other dinoflagellate cysts appear in the upper part of the zone. Reworked microplankton and miospores from the Parmelia Formation are usually common and may cause confusion in poorly sampled sections.

In offshore and some onshore boreholes where the *G. mutabilis* Zone is recognized, it approximately coincides with the lithological unit, the Gage Sandstone Member of the South Perth Shale. In some sections *G. mutabilis* is absent from the lowest part of this unit. These sections are included here in the *G. mutabilis* Zone. The zone has a restricted distribution in the onshore area. It is present at the base of the Warnbro Group only in boreholes in the Wanneroo area, north-northwest of Perth.

The top of the zone is marked by the appearance of *Kaiwaradinium scrutillinum* sp. nov. at the base of the *K. scrutillinum* Zone.

***Kaiwaradinium scrutillinum* Zone (Backhouse 1987)**

The appearance of *Kaiwaradinium scrutillinum* and a large number of other marine dinoflagellate-cyst species marks the base of this zone (Fig. 34). *Cribroperidinium delicatum* sp. nov., *Scriniodinium attadalense* (Cookson and Eisenack) Eisenack 1967, *Senoniasphaera tabulata* Backhouse and Helby in Helby 1987, *Exochosphaeridium robustum* sp. nov., *Avellodinium lepidum* sp. nov., *Nummus similis* (Cookson and Eisenack) Burger 1980b, *N. parvus* sp. nov. on *Gonyaulacysta* sp. cf. *G. exsanguia* Duxbury 1977, *Batiacasphaera asperata* Backhouse 1987, and *Meiourogoniaulax bulloidea* (Cookson and Eisenack) Sarjeant 1969 are frequently encountered species. *Kaiwaradinium scrutillinum* does not range above the lower part of the zone. *Aprobolocysta galeata* Backhouse 1987, *Cleistosphaeridium* sp. A, and *Tubotuberella vlamingii* Backhouse 1987 are not recorded above this zone.

The *K. scrutillinum* Zone is the lowest zone in which apparently open-marine conditions prevailed over a substantial part of the basin. The lower part of the zone is present over a limited onshore area, but the upper part extends over a substantially wider area (Fig. 15). Where the *G. mutabilis* Zone is not represented, the zone may

immediately overlie the *F. tumida* Zone, or older biostratigraphic units.

The zone ends at the base of the *Phoberocysta lowryi* Zone.

***Phoberocysta lowryi* Zone (Backhouse 1987)**

The first appearance of *Phoberocysta lowryi* Backhouse 1987 and/or *Muderongia testudinaria* Burger 1980b marks the base of the *P. lowryi* Zone. In two sections *M. testudinaria* appears at a slightly lower level than *P. lowryi*, but *P. lowryi* is a more frequently occurring species and usually marks the base of the zone. Most species appearing in the *K. scrutillinum* Zone range through the *P. lowryi* Zone; a few of these are not known above this zone. *Batiacasphaera ovata* Backhouse 1987, *Gardodinium lowii* Backhouse 1987, and *Aprobolocysta bipartita* sp. nov. are confined to the *P. lowryi* Zone. *Cassiculosphaeridia pygmaea* Stevens 1987 is first recorded near the base of the zone and *Dingodinium cerviculum* Cookson and Eisenack 1958, near the top of the zone.

The *P. lowryi* Zone is recorded in most borehole sections in the Perth area. The top of the zone is marked by the base of the *Aprobolocysta alata* Zone.

***Aprobolocysta alata* Zone (Backhouse 1987)**

The first appearance of *Phoberocysta burgeri* Helby 1987 marks the base of this zone. *Phoberocysta burgeri* is probably a morphological successor to *P. lowryi*. The transition from one species to the other takes place over a short interval and is a widely recognizable biostratigraphic event. *Aprobolocysta alata* Backhouse 1987, *Canningia transitoria* Stover and Helby 1987, *Dingodinium cerviculum*, *Meiourogoniaulax* sp. cf. *M. bulloidea* Cookson and Eisenack 1960b, and *Cernocysta helbyi* (Morgan) Stover and Helby 1987 are species frequently recorded from this zone. *Apteodinium maculatum* Eisenack and Cookson 1960 and *Coronifera oceanica* Cookson and Eisenack 1958 appear within it, and a number of other species make their first appearance just below the top of the zone.

A number of species, including *P. burgeri*, *Canningia reticulata* Cookson and Eisenack 1960b, *Muderongia testudinaria*, *Senoniasphaera tabulata*, and *Kleithriasphaeridium fasciatum* (Davey and Williams) Davey 1974, end their ranges within, or at the top of, this zone.

During *A. alata* Zone time, a minor regression took place resulting in the retreat of marine conditions and in widespread sandstone deposition in

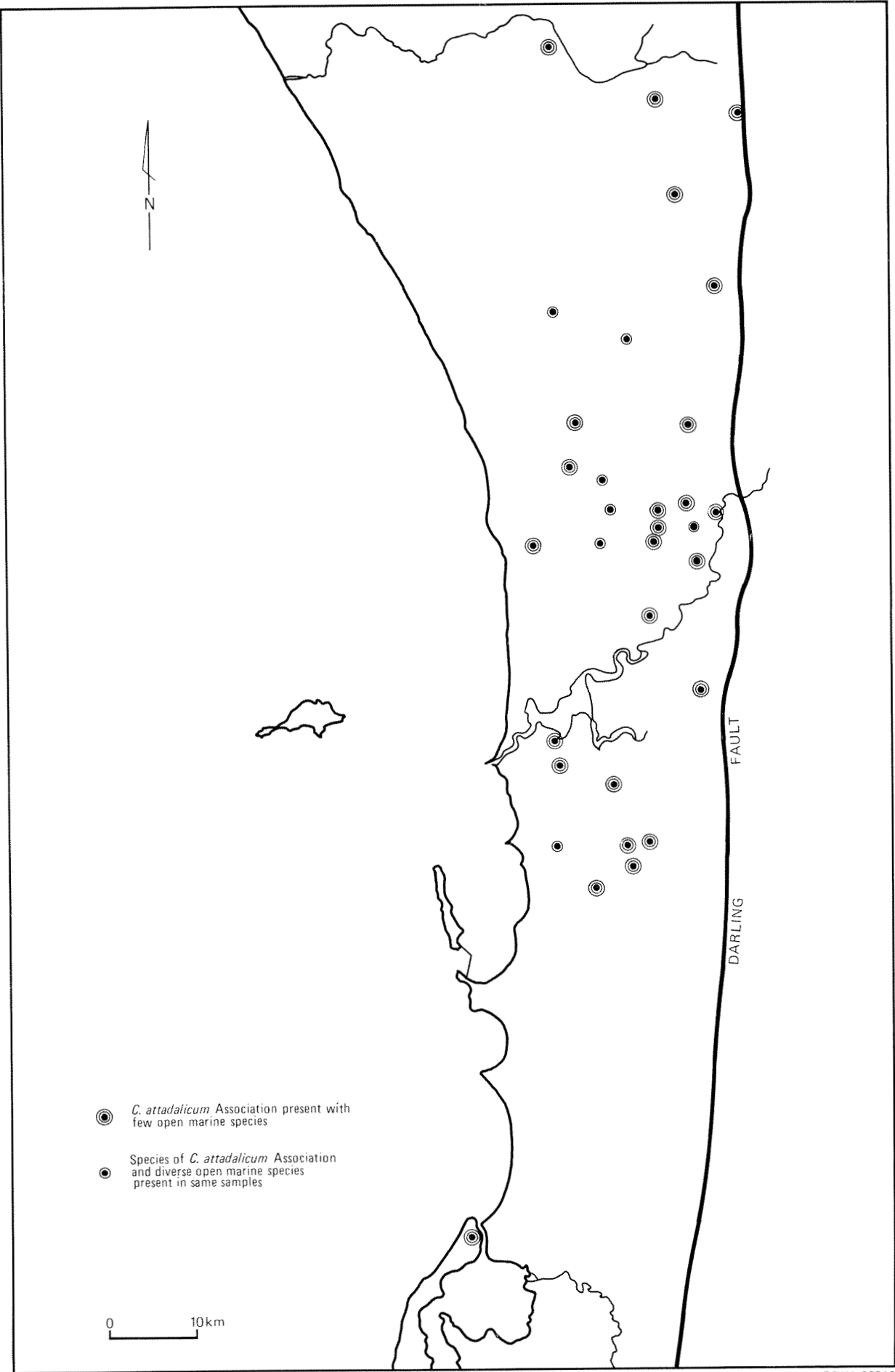


Figure 9. Distribution of the *Cyclonephelium attadalicum* Association in the Perth area.

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the onshore Perth area. Consequently, the zone is represented in many onshore boreholes by sandy sections largely devoid of microplankton. Offshore, the regression is expressed by low microplankton counts in all sections.

The appearance of *Muderongia australis* Helby 1987 and a number of other species associated with the *Batioladinium jaegeri* Zone marks the top of the *A. alata* Zone.

***Batioladinium jaegeri* Zone (Backhouse 1987)**

The base of this zone is marked by the appearance of *M. australis* and *Batioladinium jaegeri* (Alberti) Brideaux 1975. A large number of other species are first recorded at approximately this level (Fig. 35). Species of *Sentusidinium* and *Spiniferites* become common in the zone, and in all sections the microplankton count increases from the low level of the *A. alata* Zone. The base of the zone approximates the start of a major transgression, which, in this and the succeeding zone, extended over much of the basin.

Within the *B. jaegeri* Zone a small number of dinoflagellate cysts and acritarchs consistently occur together in the southern Dandaragan Trough where palaeoenvironmental reconstructions suggest that shallow-marine conditions prevailed during this period. This group of species is referred to here as the *Cyclonephelium attadalicum* Association after its most characteristic component species. Other members of the association are the dinoflagellate cysts *Meiourogonyaux maculata* sp. nov., *Tetrachacysta allenii* sp. nov. and *Horologinella lineata* Cookson and Eisenack 1962a, and the acritarchs *Nummus pentagonus* sp. nov. and

Domasiella discophora (Cookson and Eisenack) Loeblich and Loeblich 1970.

These species are rare in the offshore sections further from the edge of the basin and in onshore sections where microplankton assemblages are diverse, and represent deeper water of less restricted marine conditions. Assemblages containing the *C. attadalicum* Association have a low diversity. Frequently they contain only the species listed above. Species present in large numbers in more diverse assemblages from the *B. jaegeri* Zone, such as a species of *Cribroperidinium*, *Sentusidinium* and *Spiniferites*, are rare or absent. The *C. attadalicum* Association is correlatable with the *B. jaegeri* Zone by the occasional coincident occurrence of open-marine species, such as *Muderongia australis* and *B. jaegeri*, with members of the association. In some sections the *C. attadalicum* Association is succeeded by the *F. monilifera* Zone. Sections where *C. attadalicum* Association has been recognized are indicated in Figure 9.

***Fromea monilifera* Zone (Backhouse 1987)**

The base of the zone is marked by the first appearance of the eponymous species. A few other species make a first appearance at about this level (Fig. 35). Some distance above the base of the zone *Canninginopsis colliveri* (Cookson and Eisenack) comb. nov. appears, and at a still higher level three distinctive forms appear: *Diconodinium micropunctatum* sp. nov., *Ovoidinium cinctum* (Cookson and Eisenack) Davey 1970, and *Palaeoperidinium cretaceum* Pocock 1962. A disconformity or angular unconformity exists at the top of this zone in all sections.

CHAPTER 3

BIOSTRATIGRAPHIC CORRELATION

Bivalves are the only macrofossils known from the Warnbro Group (Cockbain, 1967; Grey and Cockbain, 1975), macrofossils have not been recovered from the Parmelia Formation; so that dating of the palynomorph assemblages in these units by extrapolation from macrofossil evidence is not possible. However, the chance recovery of an ammonite identified as *Blandfordiceras* sp. cf. *B. acuticosta* (Uhig) in WAPET's Barrow 1 bore hole in the Carnarvon Basin has provided some age control for the palynological sequence in this borehole. In an unpublished report, a Tithonian to basal Berriasian age was indicated for the ammonite (Casey in McTavish, 1965). The age is now tentatively regarded as basal Berriasian (Wiseman, 1980). The ammonite occurs in a section palynologically correlatable with the *B. eneabbaensis* Zone in the Perth Basin. The first (uphole) appearance of *Cicatricosisporites* in Barrow 1 is some distance below this level. This is tenuous evidence for dating the base of the *B. eneabbaensis* Zone, which starts with the first appearance of *Cicatricosisporites*, as late Tithonian.

Both miospores and microplankton assemblages from the Perth Basin are comparable, to a limited degree, with assemblages from other basins in Australia and overseas.

MIOAPORES

Miospores have a limited role in long-range correlation. Spores and pollen grains of terrestrial origin are principally transported by drainage systems and deposited with the finer grained sediments. Wind-carried grains may have more random distribution, but they are seldom transported greater distances than water-borne grains. Although many Late Jurassic and Early Cretaceous miospore species have a world-wide distribution, others are only known from one hemisphere, and some are only known from one sedi-

mentary basin. From a comparison of the biostratigraphic ranges of selected species in different parts of the world it is apparent that many possess different stratigraphic ranges in different areas. This is the result of palaeoclimatic and other phytogeographic factors, and this must be taken into consideration when biostratigraphic correlations are being made.

Late Jurassic and Early Cretaceous plant microfossil assemblages show broad general similarities throughout Gondwana. Despite this general similarity it has not proved possible to correlate the Perth Basin miospore zones closely with any previously described palynostratigraphic sequence outside Western Australia.

Previous Western Australian zonal schemes (Balme, 1957, 1964; Filatoff, 1975; Backhouse, 1978) have been established, at least in part, on sections from the Perth Basin. I now consider the boundary between Balme's *Microcachrydites* and *Dampieri* assemblages, which is also the top of Filatoff's *Murospora florida* Microflora, to be at the base of the *Biretisporites eneabbaensis* Zone rather than at the base of the *Retitriletes watheroensis* Zone (Backhouse, 1978). The *R. watheroensis* and *Aequitriradites acusus* Zones therefore overlap the upper part of the *M. florida* Microflora (Fig. 10).

Correlation of Western Australian and eastern Australia Cretaceous microfloras is always difficult because of the absence from Western Australia of a number of biostratigraphically useful eastern Australian species. The lowest biostratigraphic units of Dettmann (1963), Dettmann and Playford (1968), and Burger (1973b, 1974, 1980b) are placed at the base of the Cretaceous, but comparison with the Perth Basin zonation shows that they overlap only the upper part of the *B. eneabbaensis* Zone. Therefore they may not extend as low as the Jurassic-Cretaceous boundary (Fig. 10).

STAGE	PERTH BASIN			EASTERN AUSTRALIA		
	BALME, 1964	FILATOFF, 1975	BACKHOUSE, 1978 this bulletin	DETTMANN and PLAYFORD, 1969 DETTMANN and PLAYFORD, 1976		BURGER, 1973b, 1974, 1980 a.
ALBIAN	<i>Hoegisporis</i> Microflora		<i>Hoegisporis</i> Microflora	<i>Phimopollenites pannosus</i> Zone		
				<i>Coptospora paradoxa</i> Zone		<i>Coptospora paradoxa</i> Zone
				<i>Dictyosporites speciosus</i> zone	<i>Crybelosporites striatus</i> Sub-zone	<i>Crybelosporites striatus</i> Zone
<i>Cyclosporites hughesi</i> Sub-zone	<i>Osmundacidites dubius</i> Zone					
			<i>Murospora florida</i> Zone		<i>Foraminisporis asymmetricus</i> Sub-zone	
					<i>Foraminisporis wonthaggiensis</i> Sub-zone	
	<i>Cicatricosisporites australiensis</i> Sub-zone					
APTIAN	<i>Microcachryidites</i> Assemblage			<i>Balmeiopsis limbata</i> Zone		
BARREMIAN						
HAUTERIVIAN						
VALANGINIAN						
BERRIASIAN		<i>Biretisporites eneabbaensis</i> Zone	<i>Crybelosporites striatus</i> Zone		<i>?</i>	<i>?</i>
TITHONIAN	<i>Dampieri</i> Assemblage	<i>Callialasporites dampieri</i> Assemblage zone	<i>Murospora florida</i> Microflora	<i>Aequitriradites acusus</i> Zone		
KIMMERIDGIAN				<i>Retitriteles watherooensis</i> Zone		
OXFORDIAN						
CALLOVIAN			<i>Contignisporites cooksonae</i> Oppel-zone			

Figure 10. Correlation of Australian miospore biostratigraphic units.

Miospore assemblages containing a high proportion of species present in the Perth Basin are recorded from several Indian Mesozoic basins (Sukh Dev, 1961; Jain and Sah, 1966; Kumar, 1973; Saxena, 1978; Singh and others, 1964; Venkatachala, 1967, 1969a, b; Venkatachala and Kar, 1970; Venkatachala and others, 1969a, b, c). Imprecise biostratigraphy and taxonomic uncertainties preclude detailed correlation of these assemblages with the Perth Basin zonation.

Assemblages dated as Aptian and containing *Balmeiopsis limbata* (Balme) and *B. robusta* sp. nov. are recorded from southern Africa in DSDP Hole 361, cores 28–48 (McLachlan and Pieterse, 1978). An extremely high *Classopollis* count, and low microplankton and saccate pollen counts over this section suggest a somewhat different depositional situation to that existing in the Perth Basin during *B. limbata* Zone time.

Scott (1976) recorded assemblages, to which he assigned a Late Jurassic to Barremian age, from the Sundays River Beds, north of Port Elizabeth, South Africa. These assemblages contain *B. robusta* (recorded as *Inaperturopollenites* sp. I) and a few microplankton consistent with a Hauterivian to Barremian age.

Some Early Cretaceous assemblages from Argentina broadly resemble those of the Perth Basin. In particular, a microflora containing *B. limbata* was recorded in Hauterivian–Barremian sediments from the Neuquen Basin, western Argentina (Volkheimer and Sepulveda, 1976), and from Patagonia (Archangelsky, 1979). A comparable microflora was reported by Kotova (1983) from her Assemblage II in DSDP Hole 511 on the Falkland Plateau.

From the preceding discussion it is apparent that microfloras containing *B. limbata* and *B. robusta*, and tentatively correlatable with the *B. limbata* Zone of the Perth Basin, can be recognized in southern South America and southern Africa. In each case the conjectured age is within the range Hauterivian to Aptian.

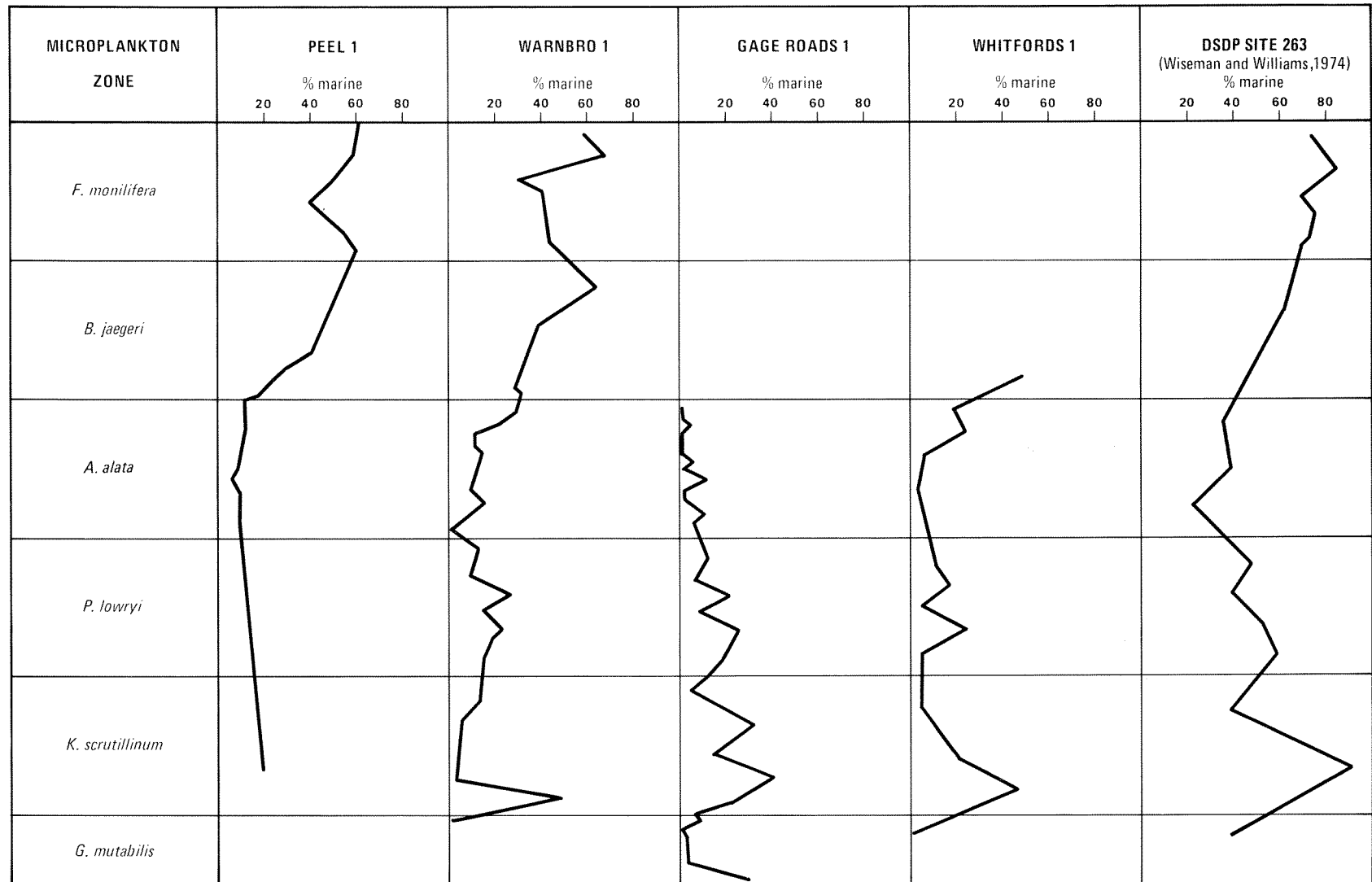
The Tithonian and Neocomian microfloral zonations of southern England and northern Germany were reassessed and correlated by Dörhöfer and Norris (1977). Tenuous correlations can be made between the north European zonations and the Perth Basin. Using the first appearance of the genus *Cicatricosisporites*, the abundance of trilete verrucate spores of the type assigned here to *Concavissimisporites* and other quantitative similarities, the *Biretisporites eneabbaensis* Zone may be correlated with

palynological Suite A of Norris (1969) and Hils 1 and 2 of Dörhöfer (1977). Suite C of Norris (1969) and Hils 3 and 4 of Dörhöfer (1977) contain many species not known from the Perth Basin, and have few points of similarity with either the *B. eneabbaensis* or *B. limbata* Zones. Dörhöfer and Norris (1977) date the strata containing Suites A and B and Hils 1 and 2 as upper Kimmeridgian to upper Berriasian. This is support for the Portlandian to late Berriasian age suggested here for the *B. eneabbaensis* Zone.

MICROPLANKTON

Early Cretaceous microplankton assemblages of the Perth Basin contain a number of species previously recorded from other southern hemisphere localities, but the number of common species decreases with increasing distance. Northern hemisphere assemblages are comparable to those of the Perth Basin at generic level but contain few of the same species. The known biostratigraphic ranges of some species appears to be different in the two areas, and taxonomic problems cause some confusion. Several northern hemisphere forms have been incorrectly assigned to Australian species described by Cookson and Eisenack. The most widespread example of this is the frequent assignment of *Cyclonephelium hystrix* (Eisenack) to *Cyclonephelium distinctum* Cookson and Eisenack. For these reasons only a small number of northern hemisphere biostratigraphic studies are compared in detail with the Perth Basin assemblages. The locations of previous biostratigraphic studies of Neocomian microplankton are indicated in Figure 4.

Marine Neocomian microplankton that were described by Wiseman and Williams (1974) from DSDP Site 263 in the Carnarvon Basin (Fig. 1) are correlatable with the Warnbro Group zonation. Based on Wiseman and Williams' distribution chart, cores 26 and 28 correlate with the *Kaiwaradinium scrutillinum* Zone and cores 18–25 are approximately equivalent to the *Phoberocysta lowryi* and *Aprobolocysta alata* Zones. The boundary between the *P. lowryi* and *A. alata* Zones is arbitrarily placed between cores 20 and 21. Cores 15 and 17 correlate with the *B. jaegeri* Zone, and core 14 to approximately core 12 correlate with the *Fromea monilifera* Zone. Wiseman's later papers (Wiseman 1979, 1980) also demonstrate the similarity between the Carnarvon and Perth Basins. The marine transgression at the base of the *K. scrutillinum* Zone correlates with correlation point 1 of Wiseman (1979), and the interval between correlation points 5 and 6 correlates with the *F. monilifera* Zone.



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Figure 11. Comparison of marine microplankton–non-marine miospore ratios in four Warnbro Group sections and DSDP Site 263.

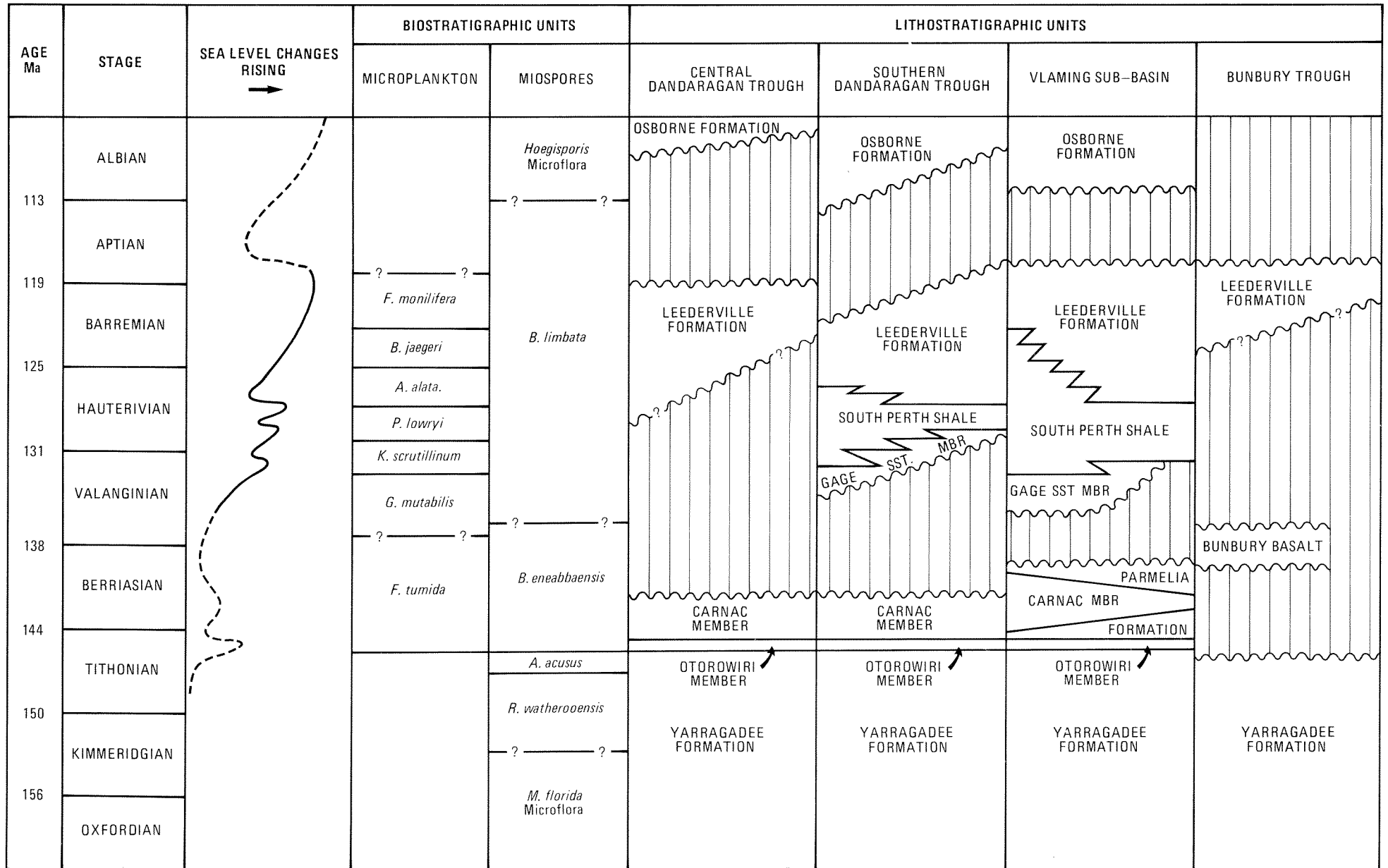


Figure 12. Correlation of Perth Basin sea-level curve, biostratigraphic units, and lithostratigraphic units.

Assemblages described by Kemp (1976) from the Officer Basin, located to the east of the Yilgarn Block (Fig. 1), compare with those of the *B. jaegeri* and *F. monilifera* Zones. The persistent presence of *Cyclonephelium attadalicum* Cookson and Eisenack in the Officer Basin assemblages suggests that they represent shallow-marine conditions comparable with those of the *C. attadalicum* Association of the Perth Basin. Microplankton of similar age are recorded by Ingram (1968) from the lower section of Madura 1 borehole in the Eucla Basin, not far above Precambrian basement. These assemblages represent the oldest marine microflora to be found in this area of the Eucla Basin.

The Neocomian microplankton sequence in the Perth Basin from the *K. scrutillinum* to the *F. monilifera* Zones is typical of the sequence in Australian west-coast marginal basins. Marine sediments equivalent in age to the upper Warnbro Group (*B. jaegeri* and *F. monilifera* Zones) are present in the intracontinental basins east of the Yilgarn Block, but older marine sediments (*K. scrutillinum*–*A. alata* Zones) are absent. The marine curve for the Perth Basin (Figs 11 and 12) shows maximum marine onlap during the *B. jaegeri* and *F. monilifera* Zones, the period when marine conditions extended into the intracontinental basins.

Correlation with eastern Australian microplankton sequences previously described by Evans (1966a, b), Burger (1980b), and Morgan (1977, 1980a) is more dubious. Evans produced a zonation based on borehole sections in northeastern Australia and the Papuan Basin. His *Cannosphaeropsis mirabilis*–*Scrutinium attadalense* Zone corresponds, at least in part, with the *A. alata* Zone. His *Dingodinium cerviculum* Zone and higher zones are difficult to place in the Perth Basin sequence, but the *D. cerviculum* Zone may correlate with the *B. jaegeri* and *F. monilifera* Zones.

Burger's DK3 Zone from northern Queensland may correlate with the uppermost *A. alata* Zone. The remainder of Burger's (1980b) zonation cannot presently be correlated with the Perth Basin sequence.

Several Early Cretaceous species recorded here from the Perth Basin are mentioned in Chen's (1978) study of palynomorphs from a borehole in northwestern Madagascar. Chen's study was based on ditch cuttings samples, and his individual species ranges must be regarded as unreliable. Nevertheless, comparisons can be made with the Perth Basin sequence. Chen tentatively subdivided

his section into palynomorph zones based on first-downhole occurrences (top of range) and acme zones. He considered his top zone, Zone II, to be late Neocomian to Aptian in age. It contains the following species known to occur consistently in the *B. jaegeri* and *F. monilifera* Zones (with Chen's assignments in parentheses):

- Apteodinium maculatum* (*Apteodinium* sp.)
- Belodinium* sp. A (*Belodinium* sp. 2)
- Dingodinium cerviculum*
- Munderongia australis* (*Munderongia mcwhaei*)
- Herendeenia postprojecta* (*Herendeenia* sp.)
- Prolixosphaeridium parvispinum*

Two species in Chen's next lower zone, Zone III, were referred by him to *Oligosphaeridium diastema* Singh 1971 and *Gonyaulacysta dangeardi* Sarjeant 1968 may be *Kaiwaradinium scrutillinum* Backhouse 1987 and *Tubotuberella vlammingii* Backhouse 1987 respectively. In which case Chen's Zone III may be provisionally correlated, in part, with the *K. scrutillinum* Zone of the Perth Basin. Chen noted the similarity of the Late Jurassic marine sequence in Madagascar to palynofloras of the same age in northwestern Australia. This similarity reflects the proximity of the two areas in the Late Jurassic (Fig. 4), a proximity that persisted until the Aptian.

Studies on DSDP boreholes at sites 327 and 330, located on the Falkland Plateau, by Harris (1977) and Hedlund and Beju (1977) describe late Neocomian to Aptian assemblages with points of similarity to Western Australian assemblages. Analysis of results from DSDP borehole 327A indicates that assemblages from cores 22–24 approximately correlate with the *B. jaegeri* and *F. monilifera* Zones and, more tenuously, core 27 correlates with the *K. scrutillinum* Zone. Similarly, DSDP borehole 330 core 3 contains an assemblage typical of the *B. jaegeri* Zone in the Perth Basin.

Because some of these assemblages from Gondwana areas are not fully described correlation between them is tentative. However, sufficient similarity exists to suggest that further work will lead to the establishment of a zonal scheme covering all the Gondwana Neocomian marine sequences.

Previous studies of northern hemisphere Neocomian microplankton sequences are concentrated in North America and western Europe (Fig. 4). The most comprehensively described sequence is from the Speeton Clay of

north-eastern England. Some 18 species listed by Duxbury (1977, 1979, 1980) in his range charts for the Speeton Clay are also present in the Perth Basin. At generic level *Druggidium* Habib and *Fromea* Cookson and Eisenack, which appear in sediments of Barremian age at Speeton, appear at a similar level in the Perth Basin in the *B. jaegeri* and *F. monilifera* Zones.

Duxbury's (1977) Zone E can be tentatively correlated with the upper *A. alata* Zone, or possible the lower *B. jaegeri* Zone, and his Zone D with the upper part of the *K. scrutillinum* Zone, the *P. lowryi* Zone, and the lower *A. alata* Zone. By extrapolation of the ages of the Speeton Clay zones, the *K. scrutillinum* Zone is late Valanginian to early Hauterivian, the *P. lowryi* and *A. alata* Zones are Hauterivian, and the *B. jaegeri* Zone and probably most of the *F. monilifera* Zone are Barremian.

Species ranges from a study of the Barremian stratotype by Renneville and Raynaud (1981) support the dating of the *B. jaegeri* and *F. monilifera* Zones as Barremian, as does the work of Millioud (1967, 1969). Millioud (1969) records the first appearance of *Coronifera oceanica* Cookson and Eisenack 1958, *Odontochitina operculata* (O. Wetzel) Deflandre and Cookson 1955, and *Prolixosphaeridium parvispinum* (Deflandre) Davey and others 1966 (= *P. deirense* Davey and others 1966) at similar levels to their first appearances in the Perth Basin.

Other northern hemisphere biostratigraphic studies contain few points for comparison and correlation, although assemblages from shelf areas bordering the North Atlantic (Williams and Bujak, 1980; Williams, 1978; Below, 1981, 1982) contain many genera present in the Perth Basin.

CHAPTER 4

REWORKED PALYNOMORPHS

Reworking of older palynomorphs into younger sediments takes place when sedimentary rocks are acted on by marine or fluviatile erosion and the palynomorphs they contain are redeposited. The Tithonian–Early Cretaceous rocks of the Perth Basin contain abundant reworked palynomorphs with ages ranging from Late Devonian to Late Jurassic. Devonian–Jurassic assemblages from Western Australia have been the subject of several publications, and are generally well documented. Consequently, reworked palynomorphs can be readily recognized when they occur in Tithonian–Early Cretaceous assemblages.

YARRAGADEE AND PARMELIA FORMATIONS

Filatoff (1975) recorded Permian miospores in consistently small numbers (approximately 0.1%) through the Late Jurassic *Callialasporites dampieri* Assemblage-zone that covers the Yarragadee Formation. It is also my experience that Permian miospores are present throughout the Yarragadee Formation, but reworked miospores of other ages are not usually represented.

At the base of the Parmelia Formation, in the lower Otorowiri Member, reworked palynomorphs of diverse ages appear suddenly. Ingram (1967b) noted the presence of Late Jurassic dinoflagellate cysts; Early Triassic acritarchs; mid-Late Triassic, Early Triassic, Late Permian, Early Permian, and Devonian miospores in the Otorowiri Member in four boreholes at Arrowsmith River. In boreholes south of Arrowsmith River reworked Devonian miospores are rare or unknown, but palynomorphs representative of the other ages listed above are recorded in the lower part of the Otorowiri Member throughout the Dandaragan Trough and

Vlaming Sub-basin. In addition to the reworked forms listed by Ingram, Early Jurassic miospores represented by *Exesipollenites tumulus* Balme 1957 are present in the Otorowiri Member towards the western limit of its subcrop in the Dandaragan Trough. Generally, reworked Early Triassic miospores predominate and Permian forms are also common. The following Late Jurassic dinoflagellate cysts occur repeatedly in low numbers: *Dingodinium jurassicum* Cookson and Eisenack 1958, *Wanaea clathrata* Cookson and Eisenack 1958, *Adnatosphaeridium aemulum* (Deflandre) Williams and Downie 1969, *Gonyaulacysta perforans* (Cookson and Eisenack) Sarjeant 1969, and *Cyclonephelium densebarbatum* Cookson and Eisenack 1960b. *Gonyaulacysta scottii* (Cookson and Eisenack) Sarjeant 1969, and *Wanaea digitata* Cookson and Eisenack 1958 are the other Late Jurassic dinoflagellate cysts recorded.

The source of the reworked palynomorphs is a matter for conjecture. Ingram (1967b) favoured a source for the Devonian miospores within the Perth Basin, or on the Archaean shield to the east. Because Devonian miospores occur regularly only in the most northerly sections of the Otorowiri Member, I favour a source to the north, in the Coolcalalaya Sub-basin east of the Urella Fault, where older Palaeozoic sediments may be present in the subsurface, or further north in the Carnarvon Basin. A microflora described by Balme (1962) from the Carnarvon Basin, from a lateral equivalent of the Gneudna Formation of Frasnian age, contains species present in the Otorowiri Member. Devonian sediments probably subcrop other areas of the Carnarvon Basin further south, and may have been exposed to erosion in the Tithonian. The Late Jurassic dinoflagellate cysts present a dilemma. Some of them (e.g. *Cyclonephelium densebarbatum* and *Dingodinium jurassicum*) may have been extant in the late Tithonian (Helby and others, 1987). The supposition that they are all reworked may not be

correct. If some of them represent an extant assemblage then the assemblage must have been of low diversity and the marine incursion which produced it of short duration. The presence of other Late Jurassic forms (*e.g.* *Wanaea* spp.), which were not extant in the late Tithonian, suggests that all the Jurassic cysts present in the Otorowiri Member are reworked.

The Carnarvon Basin is probably the source of Late Jurassic dinoflagellate cysts. These cysts have a wider reworked distribution than the Devonian miospores. This can be accounted for if the outcrop area of Late Jurassic sediments was larger than the Devonian outcrop. The recently deposited Jurassic sediments would have been uncompacted and easily eroded, probably by more than one drainage system and possibly by coastal erosion. Devonian sediments, by comparison, were probably eroded from a small area by one drainage system.

The origin of Permian, Triassic, and Early Jurassic palynomorphs is less problematical. Sediments of these ages underlie all the Dandaragan Trough and crop out below Quaternary cover east of the Urella Fault, on the flanks of the Northampton Block, and on the Beagle Ridge. In addition active erosion of Permian sediments from the Yilgarn Block may have continued into the Tithonian.

Large numbers of Triassic palynomorphs were reworked into the Carnac Member of the Parmelia Formation in the Vlaming Sub-basin. Figures 41 and 42 show the distribution of reworked forms through the Parmelia Formation in Roe 1 and Charlotte 1. The highest percentage (65%) of the reworked specimens was recorded in Roe 1 at 903.5 m. A breakdown of the total palynomorph count in this sample shows that 2% are pre-Tithonian Jurassic miospores, 7% are Early Triassic trilete spores, 10% are taeniate disaccate pollen (probably all Early Triassic), and ?Triassic acritarchs compose 46%. The sample with the highest count of reworked specimens (50%) in Charlotte 1 is at 2 402 m. In this sample 6% of the count are trilete Early Triassic spores, 7% are taeniate disaccate pollen, and 37% are ?Triassic acritarchs. These figures for reworked palynomorphs are conservative. Only firmly identified specimens were assessed as being reworked. Most Late Jurassic miospores are extant in the Tithonian and therefore reworked specimens can not be recognized.

Although Jurassic and Permian forms are present in the Carnac Member it is evident that the majority of reworked specimens are of Early

Triassic age. The Early Triassic Kockatea Shale is easily identified as the probable source of most of the spores and pollen. It contains abundant acritarchs (Balme, 1963), and is probably also the source of most of the acritarchs. The Kockatea Shale crops out round the southern margin of the Northampton Block and is present in the subsurface of the Beagle Ridge. It may subcrop post-Early Cretaceous sediments west of the present coastline in the vicinity of the Turtle Dove Ridge. Positive movement of the Beagle Ridge, Turtle Dove Ridge, and Northampton Block during the late Tithonian and/or Berriasian resulted in rapid erosion of mainly Early Triassic sediments from these areas, and re-deposition of Triassic palynomorphs in the Vlaming Sub-basin and to a lesser degree in the Dandaragan Trough.

The number of reworked specimens per sample declines in the upper part of the Parmelia Formation in the Vlaming Sub-basin (Fig. 42), thus indicating decreased erosion from areas of Kockatea Shale outcrop or depletion of the sediments which supplied the reworked palynomorphs.

GAGE SANDSTONE MEMBER

On a smaller scale, reworking of Permian, Jurassic and, rarely, Triassic miospores into the Warnbro Group took place in the Valanginian–Hauterivian. Reworked specimens are rare or absent in most samples from the South Perth Shale, but they are sometimes more common in the basal Gage Sandstone Member and compose up to 2% of the total palynomorph count. The reworking reflects local erosion taking place during deposition of this unit. In the northern Perth region assemblages include spores and certain *Moorodinium*-type dinoflagellate-cyst species thought to be restricted to the Parmelia Formation. This formation was exposed and formed a scarp in early Warnbro Group time to the northeast of the area of Gage Sandstone Member deposition (Fig. 18).

In the southern Perth region the reworked forms are from the Early Jurassic. The Early Jurassic Cockleshell Gully Formation was exposed at this time on the eastern side of the basin adjacent to the Darling Fault and also possibly in a ridge in the position of the present coastline. Erosion from these areas appears to have contributed much of the sediment to the Gage Sandstone Member in the onshore area between Perth and Mandurah (Fig. 14).

CHAPTER 5

PALAEOENVIRONMENTAL DISCUSSION

The importance of palynomorphs as palaeo-environmental indicators in the Late Jurassic and Early Cretaceous of the Perth Basin is magnified by the almost complete absence of other fossil groups. The range of palaeoenvironments indicated by the palynomorph assemblages encountered during this study is discussed below. The proportional distribution of the major spore and microplankton groups in the principal borehole sections is shown in Figures 40–46.

MIOSPORES

The dominance of Araucariaceae pollen in the Yarragadee Formation (Filatoff, 1975) gives way near the top of the formation (in the *Retitriletes watherooensis* Zone) to assemblages with a higher proportion of lycopod and filicalean spores. This is succeeded by a basin-wide change in the Otorowiri Member at the base of the Parmelia Formation. A number of spore species appear for the first time at this level, which approximates the base of the *Biretisporites eneabbaensis* Zone. The fern species producing these spores apparently colonized the Perth Basin following the formation of a large body of water in the developing rift-valley system along the south-western continental margin of Australia.

Miospore assemblages change little in general composition through the Parmelia Formation. Species of *Callialasporites* compose approximately 5% of the miospore count as compared with 10–15% in most assemblages from the Yarragadee Formation (Filatoff, 1975). *Araucariacites australis* Cookson 1947 varies from 5 to 20% of the miospore count and disaccate pollen compose up to 30% of the count. *Microcachryidites antarcticus* Cookson 1947 appears in low numbers in the upper part of the Yarragadee Formation and increases to 5–10% of the miospore count in the Parmelia Formation. *Classopollis* pollen are consistently present in low numbers throughout the

Yarragadee and Parmelia Formations. They comprise less than 3% of the miospores in all counted samples from the Parmelia Formation.

Particularly rich and well-preserved assemblages were recorded in the Eneabba Line, Watheroo Line, and Moora Line boreholes from the central Dandaragan Trough. They occur in conjunction with abundant plant cuticle, and small to moderate quantities of fibrous woody material and melanogen (Bujak and others, 1977). Some spore species such as *Aequitriradites dandaraganensis* sp. nov., *Concavissimisporites variverrucatus* (Couper) Brenner 1963, *Nevesisporites harleyi* sp. nov., *N. undatus* sp. nov. and *Pilosisporites ingramii* sp. nov., have unusually high counts in some of these samples. These features suggest that spores were deposited in the Dandaragan Trough close to their source area, with local floral variations reflected in adjacent miospore assemblages. Local variations in the quantitative composition of assemblages are less evident in the Vlaming Sub-basin, where more uniform spore assemblages persist throughout the Parmelia Formation.

Evidence from the unusual dinoflagellate-cyst assemblages indicates that the Parmelia Formation was deposited in large freshwater or brackish lakes, with minor delta development where rivers entered. Spore-producing ferns probably occupied the deltaic areas surrounding the lakes. Gymnosperms may have inhabited higher ground and hinterland areas, and their pollen was mainly carried by drainage systems entering the lakes. The consistently low *Classopollis* count suggests that members of the Cheirolepidaceae were not important components of the flora, or occurred only in areas well removed from the lakes, so that relatively few *Classopollis* pollen were incorporated in the lake sediments. The shale and finely cross-bedded siltstone lithology common in much of the Parmelia Formation is consistent with lacustrine deposition.

Miospore assemblages in the Warnbro Group are of two types. The first, and by far the most common type, contains a high (usually over 60%) proportion of gymnosperm pollen. *Microcachryidites antarcticus*, disaccate pollen, and *Classopollis* pollen are particularly abundant. *Classopollis* represents 5–15% of the miospore count, compared with less than 3% in the Parmelia Formation. Araucariaceae pollen represent 10–25% of the count in the lower two thirds of the Warnbro Group, and decrease to less than 10% near the top (Figs 43–46). Filicalean spores are usually represented by 10–30 species and the smaller lycopodialean and bryophytic spores are also common. Opaque melanogenic material and woody tissue make up the bulk of the palynological residues in this assemblage type. Cuticle material is occasionally significant, but is usually rare. All samples that contain marine microplankton are associated with this first assemblage type, which supports the frequently reported association of a high *Classopollis* count with marine deposits.

The palaeoecology of *Classopollis* occurrences has been widely discussed in the literature (Pocock and Jansonius, 1961; Hughes and Moody-Stuart, 1967; Chaloner and Muir, 1968; Vakhrameev, 1970; Batten, 1974; Filatoff, 1975; Srivastava, 1976). The more recent authors have concluded that the Cheirolepidaceae, an important producer of *Classopollis* pollen, occupied upland areas, or at least well-drained soils in climatically warm, probably arid, regions. The abundance of *Classopollis* in near-shore marine sediments is attributed to their small size, which facilitates water transport from upland areas and deposition in fine-grained marine sediments. The low *Classopollis* count in the Parmelia Formation can be partly attributed to the proliferation of spore-producing pteridophytes in areas that bordered the depositional basin. The habitat of the pteridophytes was probably largely destroyed in the succeeding period of tectonic activity. Cheirolepidaceae in the hinterland would have remained relatively undisturbed and *Classopollis* pollen are more abundant in the succeeding Warnbro Group sediments.

The second miospore-assemblage type is present in a few samples from the Leederville Formation. It is characterized by low species diversity and the near, or complete, absence of gymnosperm pollen. As few as 3 or 4 spore species may be represented. *Contignisporites cooksonae* (Balme) Dettmann 1963, *Cyathidites minor* Couper 1953, *Dictyophyllidites equiexinus* (Couper) Dettmann 1963, *Ischyosporites crateris* Balme 1957, and

Murospora florida (Balme) Pocock 1961 are nearly always present in this assemblage type. A few other species are occasionally present, usually in greater numbers than they are normally recorded in assemblages of the first type. Figure 7 lists the samples containing the second assemblage type cross-referenced against the species they contain in unusual abundance. Fibrous woody material, cuticle, or melanogen may be associated with this assemblage type, although typically they have a low total-organic content with spores as the major constituent. Similar assemblages are recorded by Batten (1969, p. 348–9; 1974, p. 449) from the Wealden of southeast England.

Marine microplankton are never associated with the second assemblage type, but strata above and below may contain microplankton. When microplankton assemblages above and below miospore assemblages of the second type can be correlated with the microplankton zonal scheme they usually fall within the *Aprobolocysta alata* Zone. The period represented by the *A. alata* Zone is associated with a minor regression and the expansion of fluvio-deltaic deposition. This second type of miospore assemblage represents swamp or small lake deposits within the expanded delta system. The low spore diversity reflects the small source area for the miospore assemblage, probably a narrow belt of vegetation within the swamp, or at the lake margin. Ferns of the Cyatheaceae–Dicksoniaceae, Matoniaceae, and Schizaeaceae were prominent in this flora. The absence of gymnosperm pollen is further evidence that gymnosperms mainly occurred in areas away from the deltaic environment.

Spores in the second assemblage type often exhibit signs of degradation by oxidation resulting in a finely pitted exine surface (Pl. 13, fig 16). In extreme cases most of the exine may be removed, to leave only a skeletal structure that represents the thickest parts of the exine, for example the muri and cingulum of *Contignisporites cooksonae* and the cingulum of *Murospora florida*.

MICROPLANKTON

PARMELIA FORMATION

The distribution of non-marine microplankton in the Parmelia Formation is summarized in Figure 7. Marine dinoflagellate cysts, some possibly extant in the mid-Tithonian (*Dingodinium jurassicum* Cookson and Eisenack 1958, *Cyclonephelium densebarbatum* Cookson and Eisenack 1960b) are present in the Otorowiri

Member at the base of the Parmelia Formation. Some, or all, of the marine cysts may be reworked from Late Jurassic marine sediments in the Carnarvon Basin (see Chapter 4). If so, the presence of marine dinoflagellate cysts in the Otorowiri Member is not conclusive evidence for marine conditions.

Non-marine cysts appear at the base of the Otorowiri Member, and are present throughout the Parmelia Formation. The most abundant forms are species of the genera *Moorodinium* and *Pentafidia*. In a typical sample containing these cysts, one cyst species usually occurs in large numbers, often 10% or more of the total palynomorph count. A freshwater or brackish-water origin for these cysts is suggested for the following reasons:

- (a) Marine dinoflagellate cysts, such as those present in rocks of this age in the Canning Basin, are entirely absent from the Parmelia Formation above the Otorowiri Member.
- (b) Most species possess thin walls, which suggest adaptation to a low-energy environment.
- (c) The cysts are substantially different morphologically from marine cysts of similar age.
- (d) The only previously described morphologically similar cyst, *Fusiformacysta salasii* Morgan 1975, from the Neocomian of the Great Artesian Basin, is considered to be a non-marine cyst (Morgan, 1975).
- (e) They occur in micaceous shales, claystones, and siltstones with fine bedding structures consistent with a low-energy environment.
- (f) Other marine fossils which may be expected to be present in borehole core and ditch cuttings samples (foraminifers, ostracods, small bivalves) have not been observed.

The evidence of these cysts suggests that semi-marine or non-marine deposition took place in lakes in which non-marine dinoflagellates flourished.

The possibility of a marine connection to the north at the start of Parmelia Formation time cannot be discounted, but if it existed it did not persist. The absence of diverse marine dinoflagellate-cyst assemblages at this level suggest that conditions never became fully marine at this or any subsequent period during deposition of the Parmelia Formation.

WARNBRO GROUP

The ratio of land-derived miospores to marine microplankton is widely used to estimate relative distance from land. This ratio in four of the best sampled Warnbro Group sections is represented in detail in Figures 43–46, and comparatively in Figure 11. Insufficient samples from the lower part of the Warnbro Group in Peel 1 is responsible for the poor correlation of the lower part of the marine graph from this borehole with the other Warnbro Group sections.

At the base of the Warnbro Group the *Gagiella mutabilis* Zone roughly coincides with the Gage Sandstone Member of the South Perth Shale. *Gagiella mutabilis* sp. nov. is consistently present in this zone, sometimes in large numbers. Dinoflagellate cysts associated with marine deposition in other parts of the Warnbro Group occur in association with *G. mutabilis* in a few sections, most notably in Gage Roads 1.

The dinoflagellate producing the cyst species *G. mutabilis* probably inhabited lagoons that formed in low-lying areas between horsts. These may have been freshwater, but more probably were subject to some marine influence. *Gagiella mutabilis* is often present in shale beds that are preceded and succeeded by sandstones including the turbidites in Warnbro 1. This attests to the continued erosion of the horst during *G. mutabilis* Zone time.

Rich and diverse marine-microplankton assemblages appear at the base of the *Kaiwaradinium scrutillinum* Zone and continue through the *Phoberocysta lowryi* Zone. Assemblages in these zones do not show repeated species associations, but several samples contain unusually large numbers of a single cyst species. They mark brief acme periods, possibly the result of dinoflagellate blooms in a particularly favourable area of shallow water. Species with local acme periods include *Senoniasphaera tabulata* Backhouse and Helby in Helby 1987, *Tanyosphaeridium boletum* Davey 1974, *Tubotuberella vlammingii* Backhouse 1987, *Phoberocysta lowryi* Backhouse 1987, and *Leptodinium sepimentum* Stevens and Helby 1987.

In the *Aprobolocysta alata* Zone microplankton decrease in abundance in all sections studied. They disappear completely from many horizons in the northern Perth area, and are often less than 2% of the total palynomorph count at other horizons. Species most frequently

represented in these sparse microplankton assemblages from the *A. alata* Zone are the dinoflagellate cysts *Cyclonephelium hystrix* (Eisenack) Davey 1978 and *Oligosphaeridium pulcherrimum* (Deflandre and Cookson) Davey and Williams 1966a, and the acritarch *Nummus similis* (Cookson and Eisenack) Burger 1980b. They are interpreted as shallow-water assemblages that occur in thin marine shales in a predominantly deltaic section. In the southern Perth area, microplankton assemblages remain more diverse, which reflects deeper water conditions, or greater distance from the sediment source.

An increase in the microplankton count at the top of the *A. alata* Zone which continues into the *Batioladinium jaegeri* Zone marks a second phase of transgression. Many new species appear at this level, which considerably alters the composition of the microplankton assemblages in samples from open-marine areas of the basin. In the central Perth and northeastern Perth areas, and in the central Dandaragan Trough, many microplankton assemblages are referable to the *Cyclonephelium*

attadalicum Association (Fig. 9). The *C. attadalicum* Association is interpreted as representing shallow-marine conditions (see Chapter 2). Marine circulation in the Perth area was probably restricted by a sub-sea ridge in the approximate position of the present coastline, which may have reduced the numbers of open-marine cysts in the shallow water east of the ridge.

Little information is available about the variation of assemblages in the *Fromea monilifera* Zone. The zone is known only from two offshore sections, some sections in the central Dandaragan Trough, sections near Mandurah in the southern Dandaragan Trough, and from a small area of the Bunbury Trough. Microplankton assemblages in this zone are rich and diverse; microplankton usually compose 30% or more of the total palynomorph count. The zone represents the greatest extent of pre-Albian Cretaceous onlap in the Perth Basin. Open-marine conditions extended into the central Dandaragan Trough, and south at least into the northern part of the Bunbury Trough (Fig. 17).

CHAPTER 6

GEOLOGICAL IMPLICATIONS

The Late Jurassic–Early Cretaceous palynomorph assemblages of the Perth Basin are reviewed here in the context of the sedimentary and tectonic history of the basin. The unconformity produced by Berriasian–Valanginian tectonism separates two quite different sedimentary sequences: an underlying block-faulted, mainly non-marine sequence; and an overlying, relatively undisturbed, predominantly marine succession. Figure 12 shows the correlation of the rock and biostratigraphic units with a proposed sea-level curve for the Perth Basin. The sequence of stages and time boundaries used here are based on Harland and others (1982).

PRE-BREAKUP SEQUENCE

The pre-tectonic sedimentary sequence consists of the Yarragadee and Parmelia Formations. This study supports the currently held view that the Late Jurassic Yarragadee Formation is a fluvatile deposit derived from older sedimentary and Archaean crystalline rocks. The consistent presence of reworked Permian miospores indicates that redeposition of Permian sediments contributed to the Yarragadee Formation. The region of the Yilgarn Block is the probable source of most of the sediments. Permian rocks are present in the Collie and Wilga Basins (Fig. 2), which are small intracratonic structures 25 km east of the Darling Fault Zone. From geological evidence (Lowry, 1976; Wilde and Walker, 1978), the Permian sequence in these basins has been preserved by down-faulting and represents part of a previously more widespread Permian cover. Erosion of this Permian cover probably contributed to the thick late Jurassic sedimentary accumulation of the Yarragadee Formation.

Subsidence in the Perth Basin in the Jurassic, up to the Tithonian, was controlled on the eastern margin by downthrow on the Darling and Urella Faults. Minor positive movement took place along

the Beagle Ridge, and the Leeuwin Block was also a positive feature during this period. Floral stability during this long period of uninterrupted fluvatile deposition is reflected in the miospore assemblages of the Yarragadee Formation. They display a slow increase in diversity, with few species disappearing (Filatoff, 1975; Backhouse, 1978).

At the base of the Parmelia Formation the Otorowiri Member is evidence for a basin-wide sedimentological change from fluvatile to lacustrine–lagoonal deposition. The Otorowiri Member is present in areas of the Dandaragan Trough and Vlaming Sub-basin where it has not been removed by erosion (Backhouse, 1984), and there is evidence to suggest it was once present in the Bunbury Trough. The palaeoenvironmental significance of the palynological characteristics of the Otorowiri Member is detailed in Chapters 4 and 5. A period of uniform deposition in a large lake or inland sea is required to account for the Otorowiri Member. A eustatic rise in sea level would effect such a widespread uniform change. A rise in sea level need not necessarily have led to marine deposition in the Perth Basin but could have reduced the erosional gradient, which would have allowed a large body of fresh or brackish water to accumulate.

An alternative mechanism is suggested by the sudden increase in the number of reworked Triassic palynomorphs. As suggested in Chapter 5, these are probably derived from the Turtle Dove Ridge and Northampton Block. Rapid upward movement of these areas may have blocked northward draining river systems, thus creating a large inland lake.

The formation of a large body of water modified the local climate sufficiently to enable new filicalean species to colonize the basin margins, which led to the microfloral changes that mark the base of the *Biretisporites eneabbaensis* Zone.

Chapter 4 includes a discussion on the origin and palaeogeographic implications of reworked palynomorphs in the remainder of the Parmelia Formation. Horizons that contain non-marine microplankton represent a lacustrine environment (see Chapter 5). These conditions persisted during the period of the Carnac Member deposition and sporadically pertained at frequent intervals before and after this period in the Vlaming Sub-basin.

EARLY CRETACEOUS TECTONISM

The period of tectonism in the Berriasian–Valanginian resulted in widespread block faulting of the Parmelia Formation and older strata. Post-tectonic miospore assemblages differ significantly from those of the Parmelia Formation and belong in the *Balmeiopsis limbata* Zone. This period of tectonism is coeval with, or immediately preceeds, the start of sea-floor spreading west of Perth. Markl (1974) recorded magnetic anomalies M-1 to M-11 in the Perth Abyssal Plain; the oldest anomaly, M-11, is situated at the foot of the continental slope (Fig. 2) and is dated at approximately 135 Ma (Harland and others, 1982). This dates the start of sea-floor spreading in the Perth Basin as no later than mid-Valanginian. This period of tectonic activity is very close in age to a European tectonic period referred to as the Late Cimmerian phase and dated as earliest Cretaceous (Ziegler, 1982). As with the Perth Basin tectonic phase, the Late Cimmerian phase was accompanied by a regional regression and succeeded by a period of sea-floor spreading.

The Bunbury Basalt, a tholeiitic basalt consisting in places of at least two separate flows, was probably extruded sometime during this episode of tectonic activity. Beds of siltstone and shale are present between two basalt flows in boreholes drilled in the bed of Bunbury Harbour (Burgess, 1978). The microflora from these sediments belong in the *Biretisporites eneabbaensis* Zone. This indicates, that the Bunbury Basalt was extruded during, or soon after, deposition of the Parmelia Formation. The flora, represented by assemblages of the *Balmeiopsis limbata* Zone was probably established throughout the basin by the mid-Valanginian. Index species of the zone are not represented in samples from between the basalt flows; this suggests that the flows are older than mid-Valanginian.

Geological evidence suggests that the basalt was extruded onto an erosional surface following the Neocomian tectonism. If so, it was extruded during, or soon after, the tectonism but before the microflora change representing the boundary between the *B. eneabbaensis* and *B. limbata* Zones.

Therefore, a late Berriasian to early Valanginian age is indicated for the Bunbury Basalt. This age is close to the radiometric age of 136 ± 3 Ma for the dolerite sill in Sue 1 well in the Bunbury Trough (Williams and Nicholls, 1966), which Playford and others (1976) suggest may be comagmatic with the Bunbury Basalt. Potassium–argon dates for the Bunbury Basalt obtained by McDougall and Wellmann (1976) ranged from 88 ± 4 Ma to 105 ± 5 Ma, but these authors suggested that argon loss largely invalidated these results. McDougall and Wellmann concluded only that the age of the Bunbury Basalt is at least 90 Ma.

POST-BREAKUP SEQUENCE

A major structural feature produced by the Berriasian–Valanginian tectonic phase is a series of north-south normal faults near the present coastline, with a downthrow to the west towards a deep graben in the Vlaming Sub-basin (Jones and Pearson, 1972; Playford and others, 1976). A structural contour map, based on borehole data, on the base of the Warnbro Group in the Perth area (Fig. 13) shows another north-south trough extending from Gingin to north of Mandurah. A particularly deep zone exists in the Wanneroo area, 20 km north of Perth. The trough is bounded to the west by a north-south ridge and to the north by a structurally positive area near Gingin.

The present configuration of the unconformity at the base of the Warnbro Group is taken to resemble closely the physiography of the erosion surface on which the Warnbro Group was deposited. Minor movement along faults, and general basin subsidence and compaction are responsible for subsequent modifications.

Erosion of the recently deposited Yarragadee and Parmelia Formations commenced at the same time as the block faulting, and continued after the cessation of major faulting wherever major relief still existed. Some blocks in the Vlaming Sub-basin may have lost over 1 000 m of sediment and considerable erosion must also have taken place in the southern Dandaragan Trough. In the relatively undisturbed central Dandaragan Trough the Warnbro Group overlies the Parmelia Formation with no obvious angular unconformity.

Considerable uplift and erosion took place in the Bunbury Trough. The Parmelia Formation may originally have been deposited in the centre of the trough but, if so, it was removed by subsequent erosion.

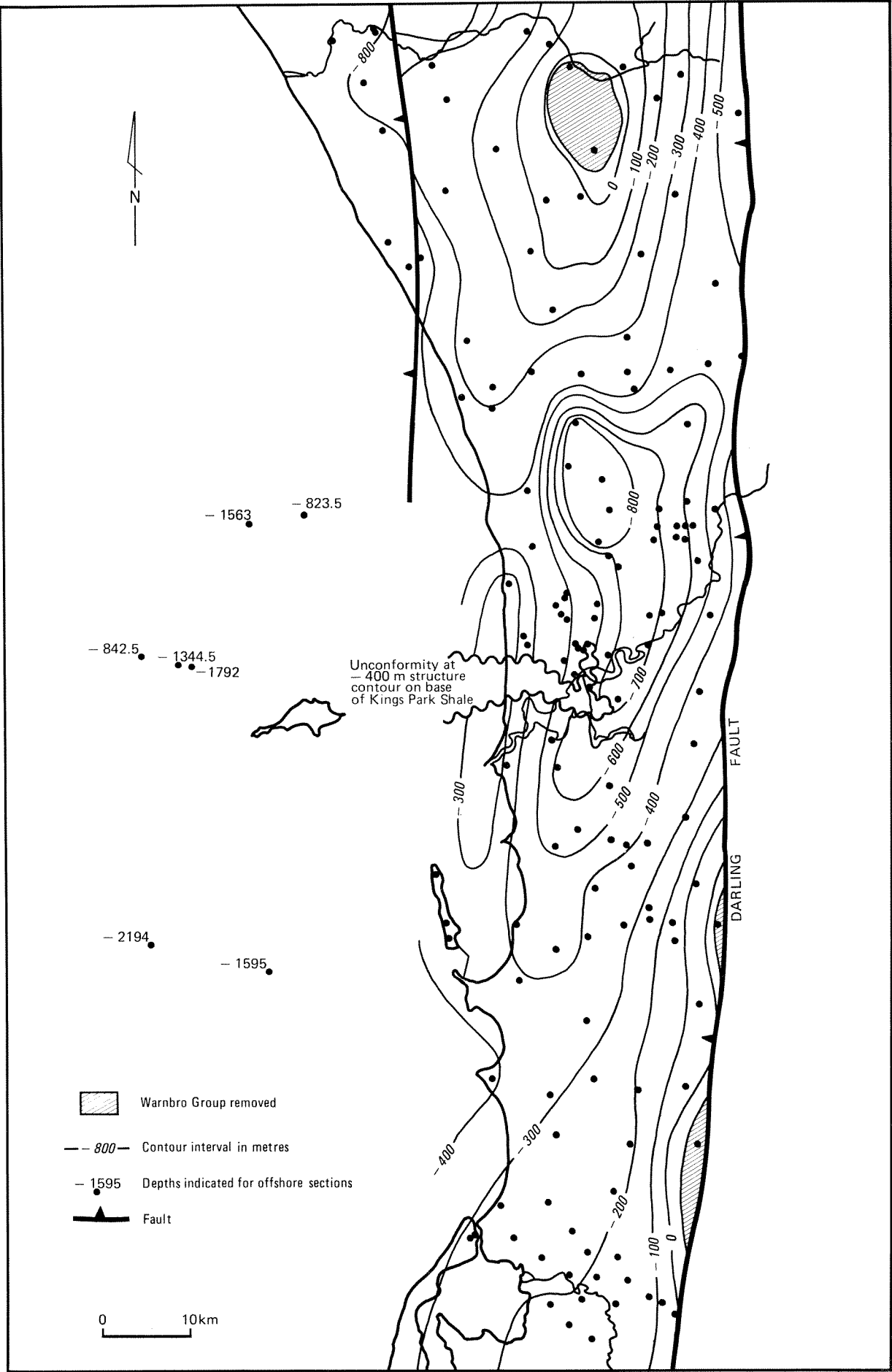


Figure 13. Structure contours on the base of the Warnbro Group, Perth onshore area.

GSWA 22216

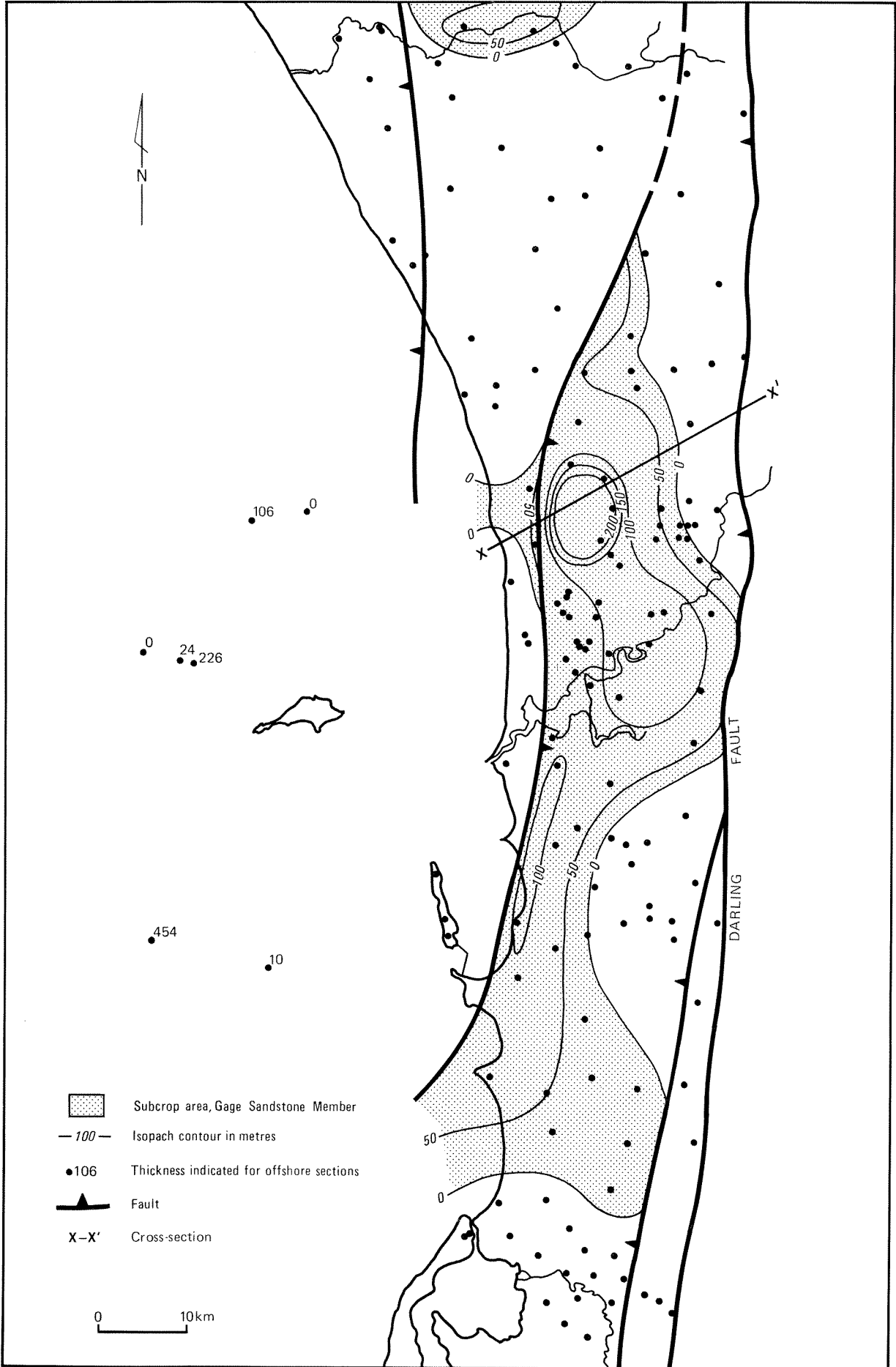


Figure 14. Isopach map, Gage Sandstone Member, Perth onshore area.

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***Gagiella mutabilis* Zone.**

The Gage Sandstone Member at the base of the South Perth Shale is probably composed largely of sediment eroded from underlying units. The greatest thicknesses of sediment were accumulated in the most deeply down-faulted areas. The best example of this is in the Wanneroo area where a thick section of over 200 m of Gage Sandstone Member was deposited on the eastern downthrown side of a large postulated fault (Fig. 14). In the offshore area the thickest section is 454 m in Warnbro I. This section includes turbidite beds and represents the infilling of a deep portion of the large offshore graben.

Gagiella mutabilis is the only microplankton species regularly present in the Gage Sandstone Member. It is present in some boreholes in the Wanneroo area, but is not recorded from the Gage Sandstone Member in onshore boreholes south of Perth. In this area the Gage Sandstone is probably slightly younger and represents a fluvialite equivalent to the marine shales of the lower part of the South Perth Shale in the Wanneroo area. The presence of *G. mutabilis* is assumed to indicate a shallow, restricted marine environment, or a lagoonal, brackish-water environment. This environment existed in several, possibly interconnected, graben areas in earliest Warnbro Group time.

***Kaiwaradinium scrutillinum*–*Aprobolocysta alata* Zones.**

The advance of open-marine deposition into the Perth Basin is marked by the appearance in large numbers of marine species at the base of the *Kaiwaradinium scrutillinum* Zone (Figs 43–46). Some 35 marine dinoflagellate-cyst species and 11 acritarch species, most of them known from marine deposits in the Carnarvon and Canning Basins, are present at the base of the *K. scrutillinum* Zone (Fig. 35).

Extensive borehole coverage of the onshore Perth area has permitted a detailed map to be drawn of marine and non-marine deposition at various stages of marine onlap from the base of the *K. scrutillinum* Zone to the top of the *Phoberocysta lowryi* Zone (Fig. 15). Initially, at the base of the *K. scrutillinum* Zone, marine deposition extended into an area approximating the structurally low areas at Wanneroo and northwest of Gingin. Towards the end of the *K. scrutillinum* Zone the area of marine deposition had expanded as far as the Darling Fault scarp; by the end of the *P. lowryi* Zone it extended over the whole Perth onshore area, with the exceptions of a narrow zone

bordering the Darling Fault east of Mandurah and a small area south of Gingin. The *K. scrutillinum* and *P. lowryi* Zones in the Gingin area are represented by the South Perth Shale. This unit thins towards the structurally positive zone south of Gingin, and may never have been deposited over the centre of this area (Fig. 37).

The *Aprobolocysta alata* Zone was a period of basin-wide regression. Fluvio-deltaic deposition represented by thick beds of poorly sorted sandstone and minor shale spread over the northern and central Perth area. To the south, towards Mandurah, sandstone deposition was less predominant, and typical sediments of this age are interbedded shale, siltstone, and thin sandstone units. Palynomorph assemblages in this zone have a low microplankton yield (see Chapter 5), and in many sections microplankton are only sporadically present (Fig. 16).

Slow basin subsidence continued from *G. mutabilis* to *A. alata* Zone time, with the rate of deposition locally controlled by fault movement. For example, the Warnbro Group, generally, and the South Perth Shale, in particular, are unusually thick in the structurally low Wanneroo area. This was a depocentre throughout the period of Warnbro Group deposition, probably owing to movement on a fault to the west (Fig. 14).

Deposition in the central Dandaragan Trough may have been almost continuous from the Parmelia Formation through to units clearly recognizable as belonging in the Warnbro Group. In sections in the central Dandaragan Trough, sandstone beds with thin shale intervals occupy the interval between the Carnac Member of the Parmelia Formation and a marine unit, which contains micropankton assemblages correlatable with the *Batioladinium jaegeri* and *Fromea monilifera* Zones. Marine assemblages correlatable with the *G. mutabilis*, *K. scrutillinum*, *P. lowryi*, and *A. alata* Zones are absent. Owing to the unsuitable lithology, few palynological samples from this interval are available for study. Those which are available contain undiagnostic miospore assemblages, or sometimes unusual miospore assemblages with elements from both the *Biretisporites eneabbaensis* and *Balmeiopsis limbata* Zones. It seems probable that this sandstone interval was deposited during the period of tectonism and during the early part of Warnbro Group time up to the Barremian

Marine deposits equivalent in age to the lower part of the Warnbro Group in the Perth area are similarly absent from the Bunbury Trough. A thin, non-marine sequence may represent this period of deposition, but the miospore assemblages it con-

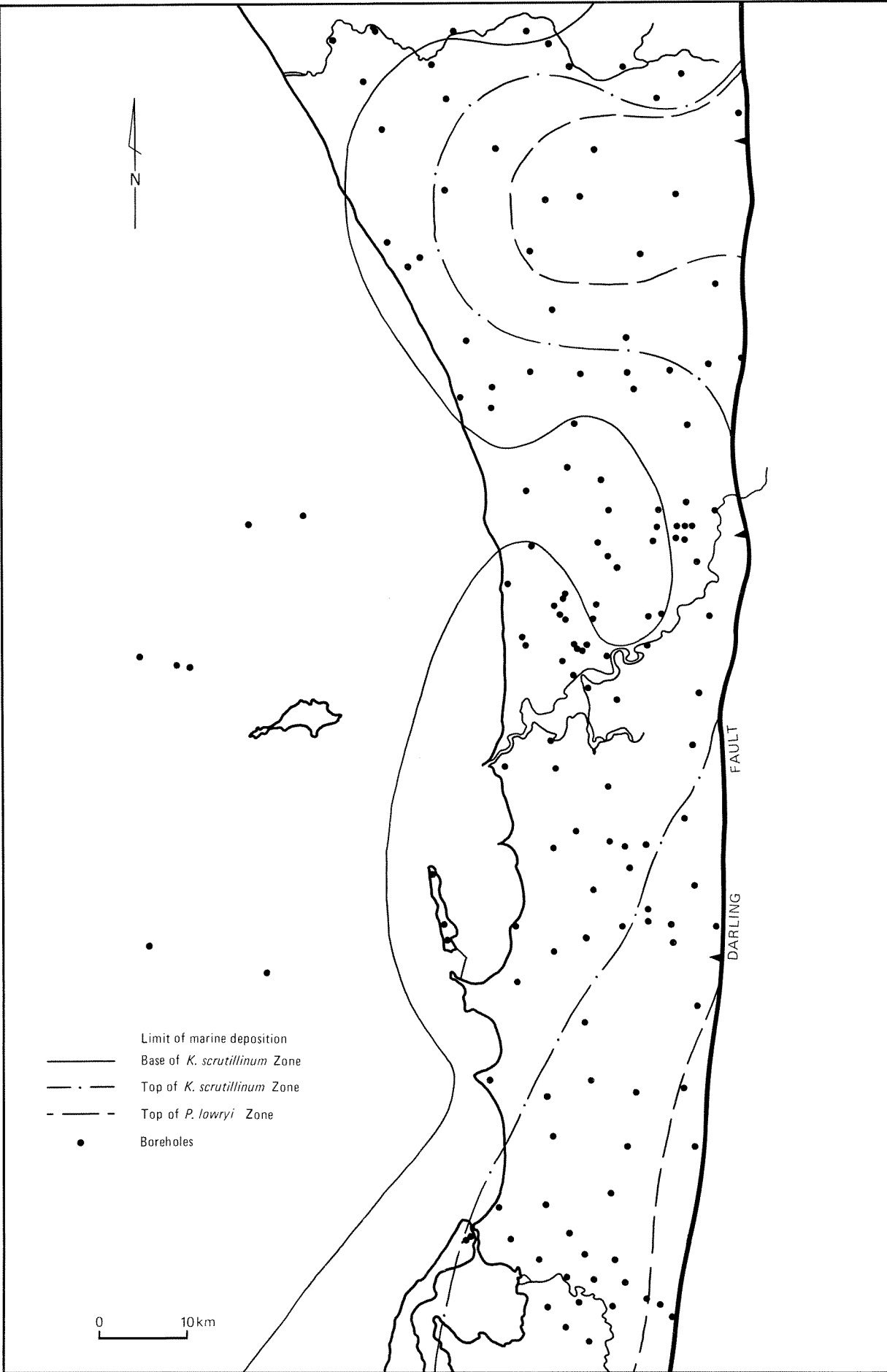


Figure 15. Marine deposition, *Kaiwaradinium scrutillinum* to *Phoberocysta lowryi* Zones, Perth area. GSWA 22218

tains show more affinity with those from the upper part of the Warnbro Group in the Perth area. It is concluded that little deposition took place in the Bunbury Trough in the Valanginian–Hauterivian.

***Batioladinium jaegeri*–*Fromea monilifera* Zones.**

Microplankton numbers increase rapidly just below the top of the *A. alata* Zone and continue to increase through the *B. jaegeri* and *F. monilifera* Zones; this increase reflects a second major transgressive phase. During this transgression marine deposition spread into the central Dandaragan Trough and into the Bunbury Trough (Fig. 17). The only evidence for deposition east of the Darling Fault at this time is in a narrow strip northeast of Bunbury where Warnbro Group sediments occur at least 1.5 km east of the fault.

The *B. jaegeri* Zone, represented by the *Cyclonephelium attadalicum* Association, is present at 712 m, near the base of the thick (569 m) Warnbro Group section in Artesian Monitoring 11, southeast of Gingin. Rapid downthrow in the order of 500 m on the Darling Fault during *B. jaegeri* Zone time is suggested to account for this section. From the shape of the structure contours on the base of the Warnbro Group (Fig. 13) this phase of movement on the Darling Fault probably extended over a short section of the fault from a point north of Gingin to a position northeast of Perth. Biostratigraphic evidence indicates that there was no movement at this time on the Darling Fault south of the latitude of Perth, and probably not at any time after the main period of Berriasian–Valanginian tectonism.

The transgression attained its zenith in the *F. monilifera* Zone. Fine- and medium-grained, sometimes glauconitic sandstone with interbedded shale predominates in the Vlaming Sub-basin. In the Dandaragan Trough this interval is represented by thin, well-sorted, sometimes glauconitic sandstone, and in the Bunbury Trough by a glauconitic sandstone interbedded with claystone. Microplankton are diverse and abundant, and compose over 50% of the palynomorph count at many horizons. This suggests that open-marine conditions prevailed over most of the basin.

Figure 18 is a series of reconstructions along the section X–X' (Fig. 14) that show the development of the Warnbro Group in the northern Perth area. Section line X–X' is close to the seismic section Yanchep Line C, and is presented (as Figure 39) in Playford and others (1976). This seismic section clearly shows the configuration of the unconformity surface, including the scarp formed by the Parmelia Formation.

Sometime during the Aptian the sea retreated from many parts of the basin. Erosion of the Leederville Formation took place in the southern Dandaragan Trough and in parts of the Vlaming Sub-basin and the Bunbury Trough. Marine conditions returned in the late Aptian or early Albian, and by the late Albian they extended over the area previously covered by the sea in the Barremian–earliest Aptian *Fromea monilifera* Zone.

SEA-LEVEL CHANGES

The synchronism of global eustatic sea-level changes has been recognized and proposed as an aid to stratigraphic correlation (Cooper, 1977; Vail, 1977). Morgan (1980b) presented a eustatic sea-level curve for the Cretaceous of the Eromanga Basin in central Australia, and suggested that some features of this curve can be recognized in other Australian basins, including the Perth Basin.

Sea-level curves based on the ratio of marine microplankton to non-marine miospores were presented by Wiseman and Williams (1974) for DSDP Sites 259, 261, and 263, offshore from Western Australia. The dinoflagellate-cyst distribution chart for Site 263 (Wiseman and Williams, 1974, Fig. 7) has been reinterpreted in terms of the zonation presented in this study (see Chapter 3). When the marine curve for Site 263 is redrawn on the same time scale as the curves for Peel 1, Warnbro 1, Gage Roads 1 and Whitfords 1, it compares closely with the Perth Basin sections (Fig. 11). DSDP Site 263 is situated on the edge of the Cuvier Abyssal Plain, west of the Carnarvon Basin, in an area probably unaffected by local tectonic activity in the Perth Basin. The similarity of the curves suggests that eustasy, rather than local tectonic movement, was the major cause of sea-level changes from the Valanginian to Aptian in the Perth Basin.

The microplankton to miospore ratio, although possibly a useful tool for recognizing sea-level changes, is probably inaccurate as a measure of the geographical extent of transgressive phases. In all Perth Basin sections the microplankton count is higher as a ratio of the total palynomorph count at the base of the *Kaiwaradinium scrutillinum* Zone than later in the transgressive phase in the *Phoberocysta lowryi* Zone. However, the distribution of marine sediments indicate that marine onlap was further advanced by the close of the *P. lowryi* Zone than it was at the base of the *K. scrutillinum* Zone. Several factors may explain this. The miospore count may be suddenly reduced at the beginning of a transgression by inundation of the densely vegetated low-lying areas.

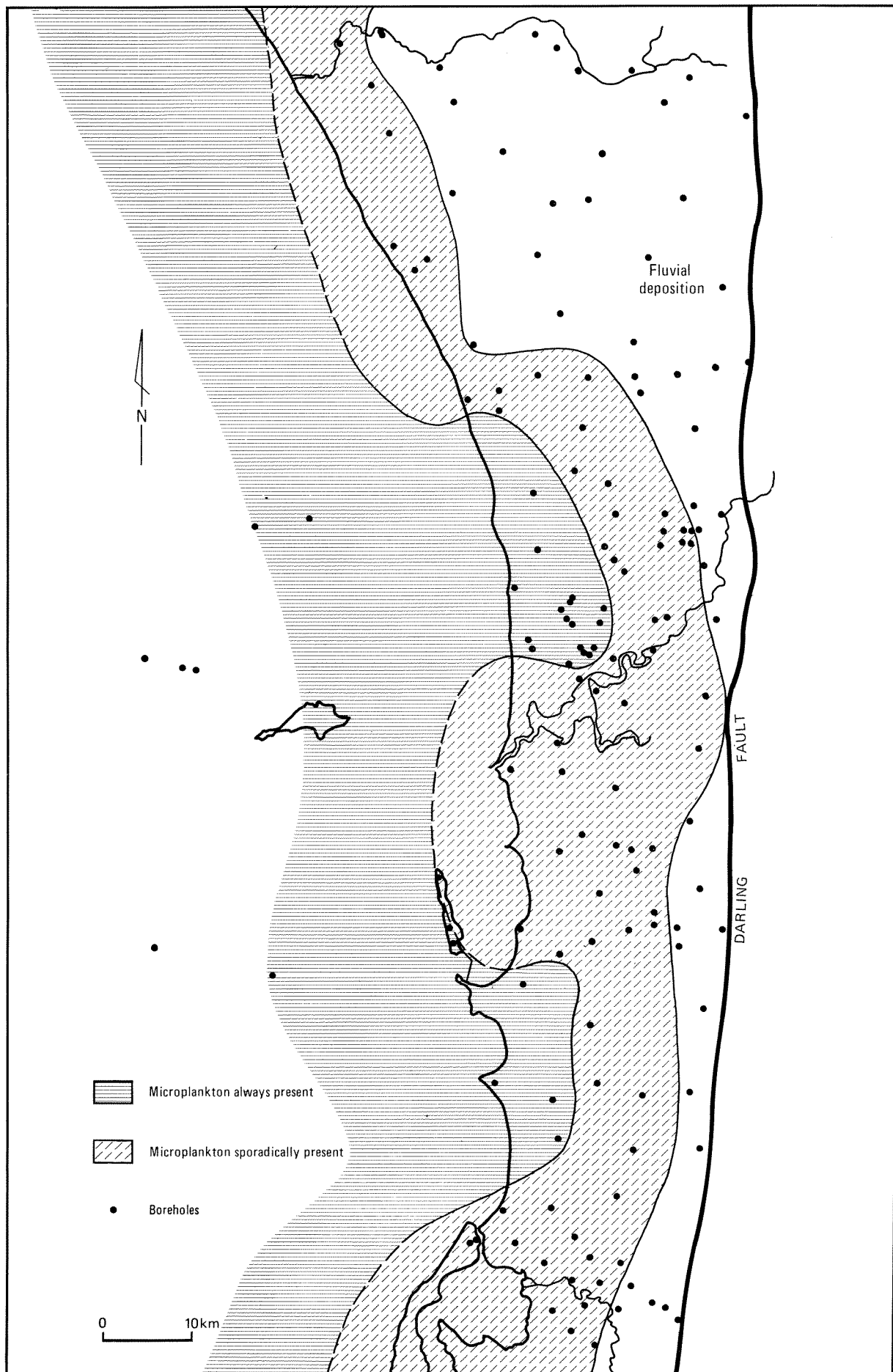


Figure 16. Microplankton distribution in *Aprobolocysta alata* Zone, Perth area.

GSWA 22219

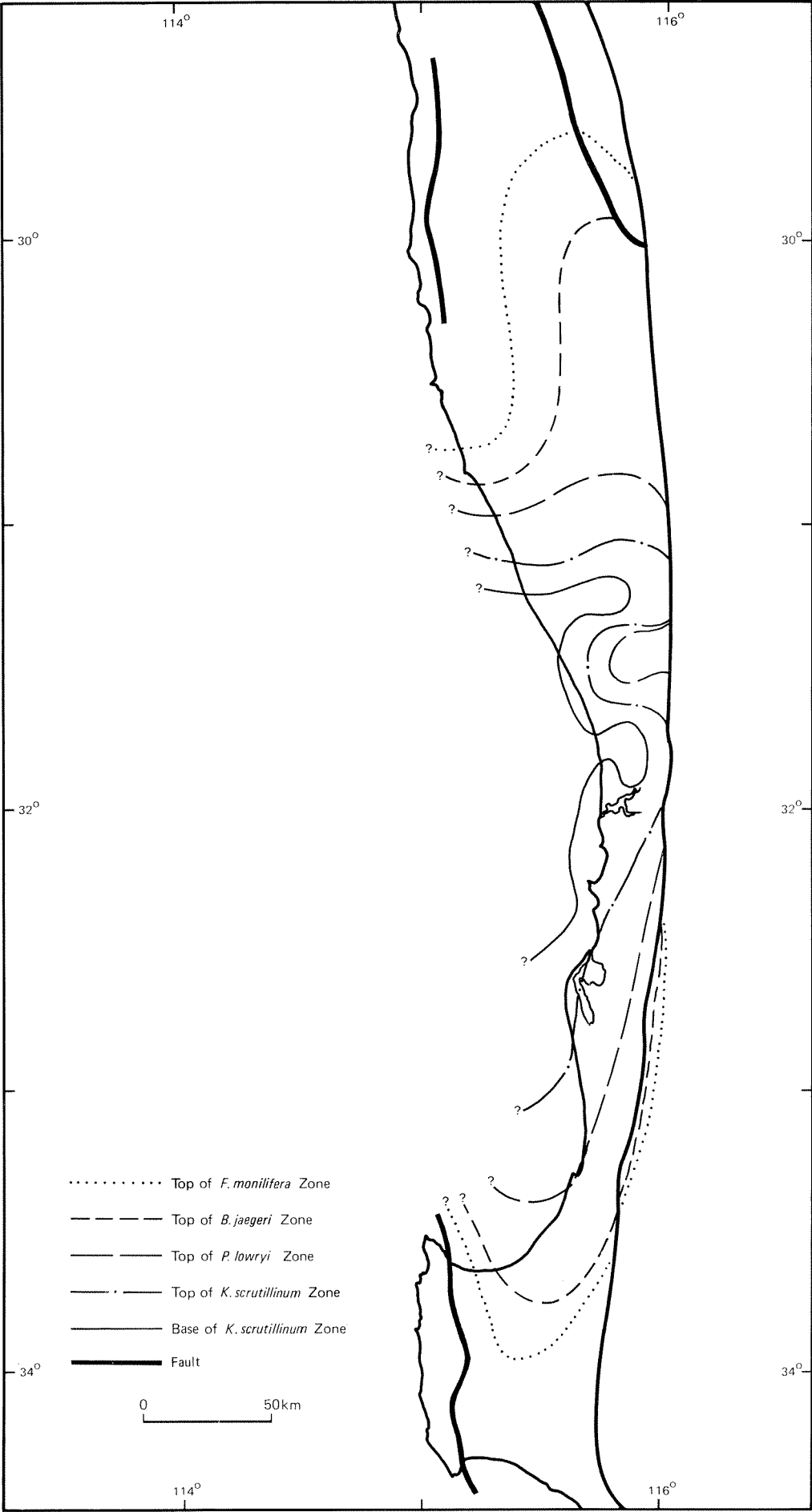


Figure 17. Marine deposition *Kaiwaradinium scrutillinum* to *Fromea monilifera* Zones.

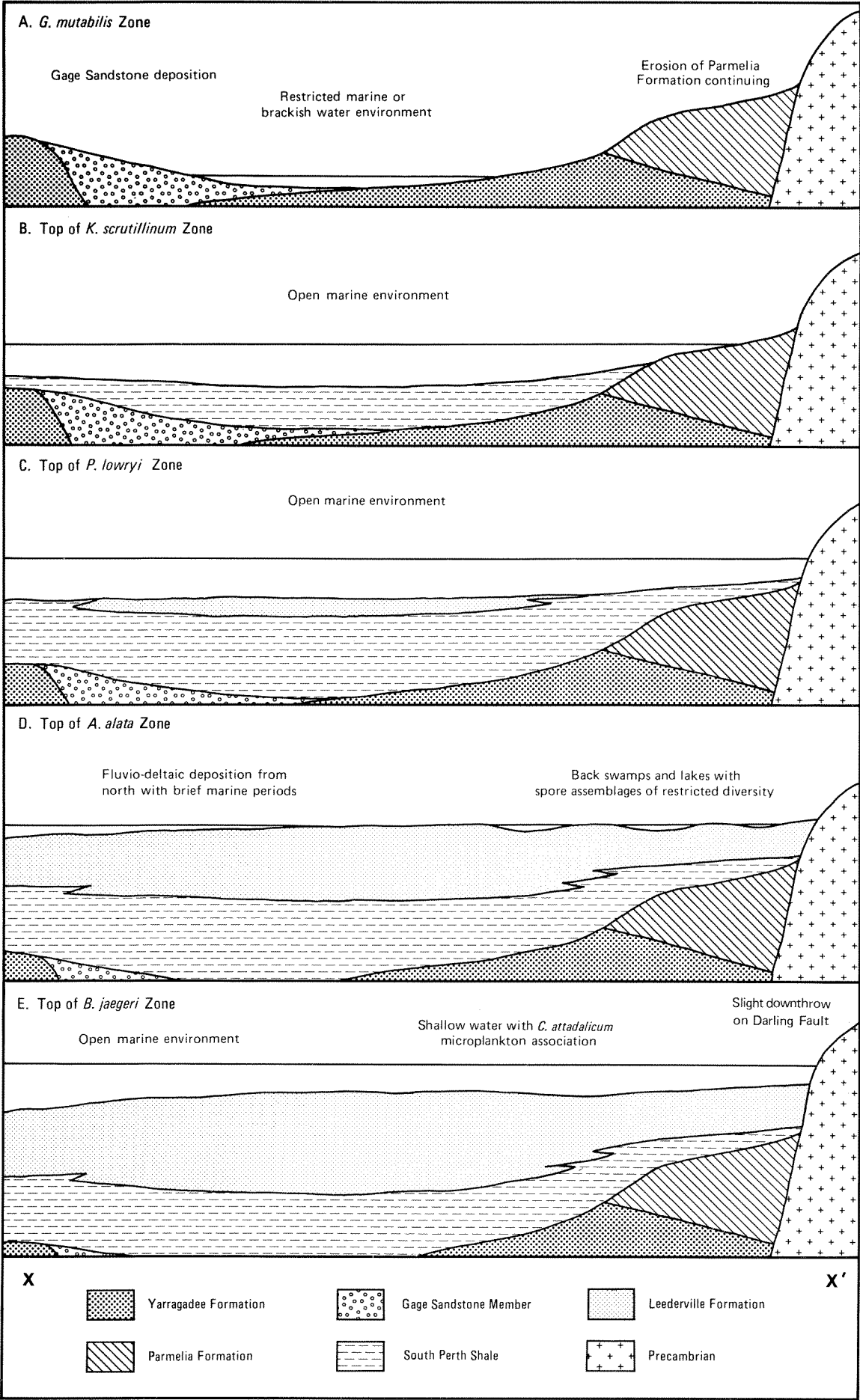


Figure 18. Palaeoenvironmental reconstructions along cross-section X–X', for location see Figure 14.

GSWA 22221

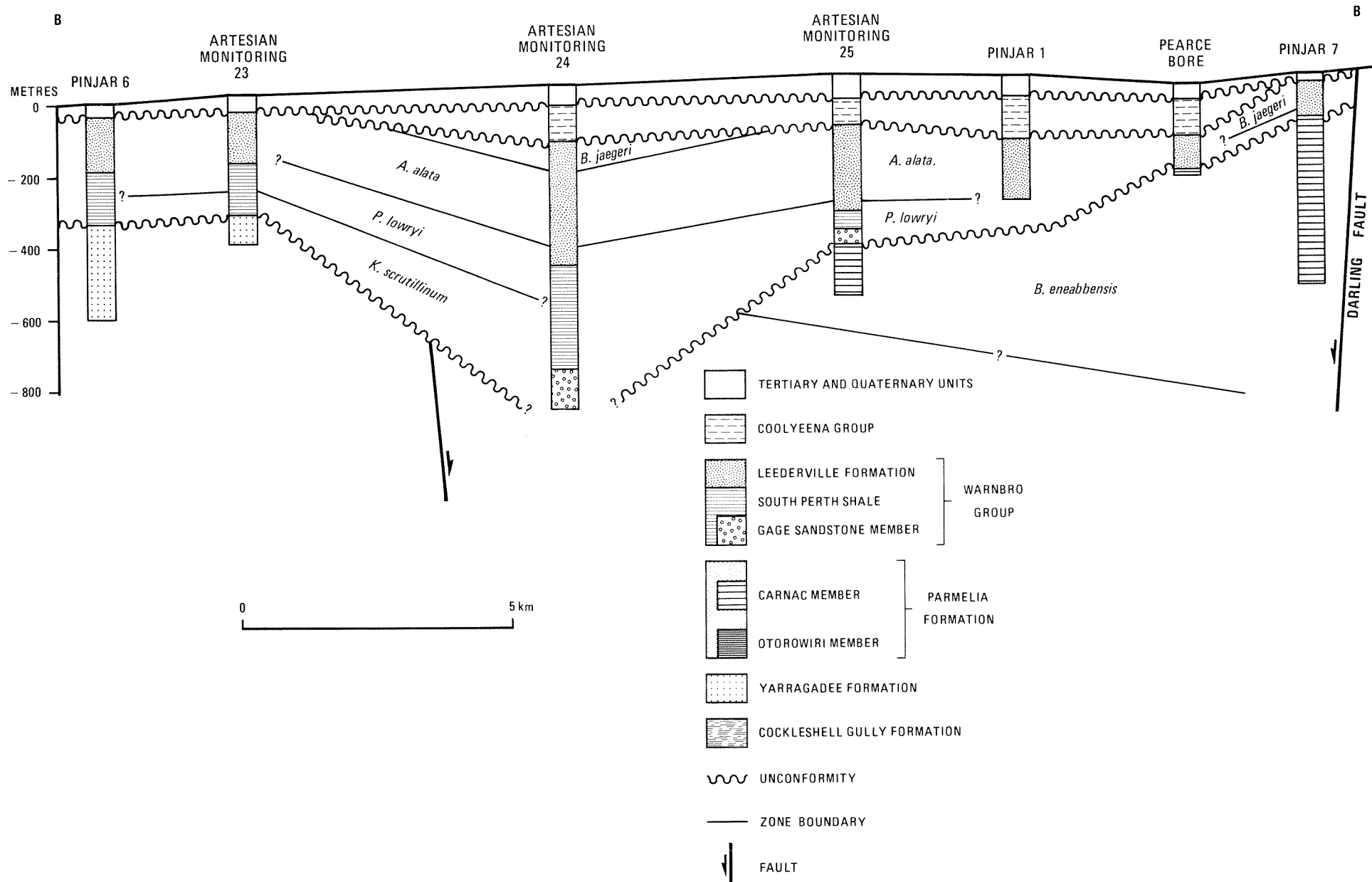


Figure 19. Cross-section B-B', for location see Figure 6.

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The water may be richer in nutrients for a short period after the initial inundation and thus increase the microplankton yield. Many species of microplankton may be more abundant in shallow water, and decrease in total numbers as water depth increases. Finally, the transgression may change the local climate by increasing precipitation and the vegetation density in the hinterland of local river systems, and lead to an increase in the miospore yield.

Notwithstanding this limitation on the microplankton-miospore ratio as a basis for a marine curve, the generalized curve in Figure 12 is presented as a reasonable representation of sea-level fluctuations in the Perth Basin for the Tithonian-Albian period. The curve above the mid-Valanginian largely represents eustatic sea-level changes, whereas local tectonic activity may have influenced sea-level changes below this level.

Cooper's (1977) representation of eustatic fluctuations shows a sea-level rise starting in the

late Valanginian, but reversing in the late Hauterivian and Barremian. Other smaller, transgressive phases are indicated in the late Barremian and Aptian. The Valanginian-Hauterivian transgression corresponds with the transgression commencing in the *K. scrutillum* zone, but the later transgressions are not easily correlated with sea-level fluctuations in the Perth Basin.

A better correlation can be made with the sea-level changes presented by Vail and others (1977). These authors indicate a steady rise in sea level which started in the Valanginian and carried through to the early Aptian, before a substantial fall in the mid-Aptian; a pattern approximated by the Perth Basin sea-level curve. This is followed by a further sea-level rise that commenced in the Albian and ended in the early Cenomanian; this rise corresponds with the transgressive cycle represented by the Osborne Formation in the Perth Basin.

CHAPTER 7

SYSTEMATIC PALYNOLOGY

The nomenclature of miospores, dinoflagellate cysts, and acritarchs at generic and lower levels is determined by rules laid down by the International Code of Botanical Nomenclature. Suprageneric classification of each group is discussed below.

Synonymy lists provided for some species are not intended to be exhaustive. They are provided where taxonomic revision is undertaken, or where they assist to circumscribe a species. Rare, undescribed species are identified only to generic level and, if justified, a brief description is provided. Question marks with the names of taxa are used in the manner adopted by the Museum of Natural History, Washington (Kornicker, 1979). Maximum and minimum dimensions are given for most species, with the arithmetic mean in parenthesis.

Miospores: Artificial morphological suprageneric classification schemes have not been adopted and a simple phyletic scheme of three basic categories has been used: spores, cycadophyte pollen, and coniferalean pollen. Coniferalean pollen are further subdivided into three types. Within each category, genera and species are arranged in alphabetic order.

Dinoflagellate cysts: Several authors have presented suprageneric classification schemes for fossil dinoflagellate cysts. Early workers favoured a classification based on extant dinoflagellate families (e.g. Eisenack, 1961). Sarjeant and Downie (1966, 1974) presented familial classifications independent of extant families. Wall and Dale (1968) proposed a series of broad lineages, a system which leaves many cyst species inadequately classified. More recent papers use schemes based on the archeopyle type (e.g. Stover and Evitt, 1978), or based on cyst affinity with gonyaulacacean, peridineacean, or ceratiacean dinoflagellates (e.g. Duxbury, 1980; Below, 1981).

Schemes based on cyst affinity have much to commend them but for long taxonomic works such as this a simple alphabetic arrangement is more practicable. The dinoflagellate cyst species in this section are therefore arranged in alphabetic order.

Descriptive terminology of dinoflagellate cysts follows Evitt and others (1977). Generic descriptions are arranged in the style of Stover and Evitt (1978).

Acritarchs: The diverse group of organic microfossils included in the Acritarcha Evitt 1963 was subdivided by Downie and others (1963) on gross homeomorphic criteria into a number of subgroups. Included in each subgroup are form genera of widely differing phylogeny, and consequently the subgroups have little biological significance. In this study the acritarchs are divided into two broad groups: small spinose forms such as *Veryhachium* and *Micrhystridium*, and a group for all other acritarch genera.

MIOSPORES

CRYPTOGAM SPORES

Genus *Aequitriradites* Delcourt and Sprumont 1955 emend. Cookson and Dettmann 1961

Type species: *Aequitriradites dubius* Delcourt and Sprumont 1955.

Aequitriradites acusus (Balme) Dettmann 1963
Pl. 1, figs 1, 2

1957 *Zonalsporites acusus* Balme, p. 27, Pl. 5, figs 64, 65; Pl. 6, fig. 66.

1978 *Aequitriradites acusus* (Balme) Backhouse, p. 33, Pl. 4, figs 8, 9.

Redescription of holotype: Holotype located on slide TS 136, now lodged with the Bureau of Mineral Resources, Canberra. Hilate biconvex spores with a subtriangular amb. Zona $12\mu\text{m}$ wide at apices, slightly narrower interradially, and dark in colour. Zona surface roughened, but not heavily spinose; distal margin ragged and irregular. Distal spore body surface composed of closely spaced verrucae, many surmounted by short blunt spines up to $3\mu\text{m}$ high. Much of the distal surface removed by hilate opening. Spines, 1 to $2.5\mu\text{m}$ long, spaced 0.5 to $2.5\mu\text{m}$ apart, cover proximal surface; a few spines are located on zona. Trilete mark represented by low ridges on the zona, and does not extend onto spore body.

Dimensions: Diameter of holotype $60\mu\text{m}$. Range of diameter (25 specimens) $44(57)75\mu\text{m}$.

Remarks: I have examined the holotype of *Aequitriradites spinulosus* (Cookson and Dettmann) Cookson and Dettmann 1961 (slide P17632 in the National Museum of Victoria), the species most closely comparable to *A. acusus*. Unfortunately, the slide bearing the holotype is badly desiccated, but other specimens assigned to *A. spinulosus* by Cookson and Dettmann (1958, Pl. 19, fig. 1, and unfigured specimens on slides P17828–9 and P17836) exhibit closely spaced distal verrucae with a smaller basal diameter than is usual in *A. acusus*. This and differences in the relative width of the zona are sufficient reason to retain both species. Most unpublished records of *A. spinulosus* from Western Australia are probably *A. acusus*.

Range: *Aequitriradites acusus* to *Balmeiopsis limbata* Zones

***Aequitriradites dandaraganensis* sp. nov.**

Pl. 1, figs 3–5

1978 *Aequitriradites verrucosus* (Cookson and Dettmann); Backhouse, p. 34, Pl. 5, figs 9, 10.

Derivation of name: After the Dandaragan Trough where it is a common species in the *Balmeiopsis eneabbaensis* Zone.

Holotype: F8528/1 (–41.9, –101.5), Eneabba Line 3B, 151 m, Parmelia Formation, Pl. 1, fig. 3.

Description: Spores biconvex, zonate with a convexly subtriangular amb. Zona 10 to $18\mu\text{m}$ wide; thickest at the proximal margin, with a roughened surface and an irregular distal margin. Proximal spore body surface slightly roughened rather than granular, and bears a few isolated grana. Distal surface composed of polygonal-based verrucae which separate at the pole to form a hilum. Proximal trilete mark formed by raised ridges and extends to the

equator. Similar, but shorter ridges radiate across the zona in interradiial positions.

Dimensions: Diameter of holotype $75\mu\text{m}$, diameter of spore cavity $48\mu\text{m}$. Range of diameter (22 specimens) $62(79)93\mu\text{m}$, spore cavity $38(49)56\mu\text{m}$.

Remarks: The well-developed trilete ridges and wide granulose zona with radial ridges distinguish *Aequitriradites dandaraganensis* from *A. verrucosus* (Cookson and Dettmann) Cookson and Dettmann 1961. The absence of spinose sculpture distinguishes it from *A. hispidus* Dettmann and Playford 1968, *A. spinulosus* (Cookson and Dettmann) Cookson and Dettmann 1961, and *A. acusus* (Balme) Dettmann 1963.

Range: *Biretisporites eneabbaensis* Zone.

***Aequitriradites hispidus* Dettmann and Playford 1968**

Pl. 1, fig. 6; Pl. 12, fig. 1

Dimensions: Diameter (20 specimens) $45(58)71\mu\text{m}$.

Range: *Aequitriradites acusus* and *Biretisporites eneabbaensis* Zones. Rare specimens recorded from the base of the *B. limbata* Zone (in the Gage Sandstone Member) are considered to be reworked.

***Aequitriradites inornamentus* sp. nov.**

Pl. 1, figs 7–10

Derivation of name: Latin, *inornamentus*, unornamented.

Holotype: F9422/2 (–59.6, –103.6), Moora Line 3A, 166.5 m, ?Parmelia Formation, Pl. 1, fig. 8.

Description: Spores zonate, amb subtriangular with rounded or protruding apices and convex sides. Proximal surface finely scabrate, and lacks spines; tetrad mark indicated only by low radial ridges at the apices, or not at all. Distal surface of spore body composed of small, low, closely spaced verrucae which separate at the distal pole to form a hilum. Zona thick, frequently very dark, scabrate, and thinning to a smooth or ragged distal margin; 10 to $17\mu\text{m}$ in maximum width.

Dimensions: Diameter of holotype $64\mu\text{m}$, spore cavity $42\mu\text{m}$. Range of diameter (25 specimens) $46(60)83\mu\text{m}$, spore cavity $32(40)49\mu\text{m}$.

Remarks: *Aequitriradites inornamentus* is distinguished from *A. acusus* (Balme) by the absence

of spines and by possessing a broader, darker zona, and from *Cooksonites variabilis* Pocock 1962 by the thick dark zona and distinctly verrucate distal surface. A few specimens bear short spines on the spore body suggesting a morphological gradation to *A. acusus*.

Range: ?Uppermost *Biretisporites eneabbaensis* to *Balmeiopsis limbata* Zones.

***Aequitriradites norrisii* sp. nov.**

Pl. 2, figs 1–4

1969 *Couperisporites complexus* (Couper) Norris, Pl. 108, fig. 13; Pl. 109, fig. 1.

1970 *Couperisporites complexus* (Couper) Norris, Pl. 2, fig. 10

1975 cf. *Krauselisporites majus* (Cookson and Dettmann); Filatoff, p. 88, Pl. 20, fig. 6.

Derivation of name: After Geoff Norris who illustrated the species in 1969 from the Tithonian–Berriasian of southern England.

Holotype: F8460/3 (–33.0, –103.5), Eneabba Line 4B, 156.5 m, Parmelia Formation, Pl. 2, fig. 3.

Description: Hilate spores, biconvex and zonate, with a subtriangular to subcircular amb. Intexine subcircular in polar view, 1.5 to 2 μm thick. Exoexine forms a thin zona, 7 to 18 μm in maximum width; distal surface of exoexine covering the spore body bears blunt spines 3 to 9 μm long, some with expanded bases. Spines longest on equatorial zone of spore body, sometimes interconnected by low ridges. Spines much reduced on, or absent from, distal surface of zona; at distal pole spines are superimposed on polygonal-based verrucae. Hilum produced by removal of verrucae in a small area at the distal pole. Proximal surface of spore body sculptured by widely spaced short spines which do not protrude onto zona. Trilete mark prominent, formed by three high (4 to 8 μm), narrow (1 to 2 μm), membranous ridges running from equator towards proximal pole. At approximately two-thirds of distance from equator to pole, each ridge is divided to join the other two ridges and form a subtriangular or circular structure surrounding the proximal pole; ridges never extend over unsculptured proximal pole.

Dimensions: Diameter of holotype 97 μm , spore cavity 60 μm . Range of diameter (20 specimens) 55(67)97 μm , spore cavity 39(47)59 μm .

Remarks: *Couperisporites complexus* (Couper) Pocock 1962 is significantly larger than *Aequitriradites norrisii* (90 to 105 μm according to Couper, 1958), and has shorter spines. Illustrations of *C. complexus* in Couper (1958) show a greater number of clearly defined polygonal

verrucae on the distal surface of the spore body. The distinctive trilete mark also distinguishes *A. norrisii* from *C. complexus* and from all other species of *Aequitriradites*.

Range: *Retitriteles watherooensis* to *Biretisporites eneabbaensis* Zones. Previously recorded from the Tithonian–Berriasian of southern England (Norris, 1969) and the Late Jurassic of the Perth Basin (Filatoff, 1975).

***Aequitriradites* sp. A**

Pl. 2, fig. 5

Dimensions: Diameter (5 specimens) 64(71)79 μm .

Remarks: Insufficient specimens are available to erect a new species. *Aequitriradites* sp. A possesses a wide zona that bears a radial sculpture of broad verrucae and rugulae. Combined with the verrucose spore body this imparts a strongly verrucate appearance to the spore.

Range: *Biretisporites eneabbaensis* Zone.

Genus *Antulsporites* Archangelsky and Gamero 1966

Type species: *Antulsporites baculatus* (Archangelsky and Gamero) Archangelsky and Gamero 1966.

***Antulsporites saevus* (Balme) Archangelsky and Gamero 1966**
Pl. 2, fig. 8

Dimensions: Diameter (10 specimens) 34(39)55 μm .

Range: *Retitriteles watherooensis* to lower *Biretisporites eneabbaensis* Zones. Recorded below this level by Filatoff (1975).

Genus *Baculatisporites* Thomson and Pflug 1953

Type species: *Baculatisporites primarius* (Wolff) Thomson and Pflug 1953.

***Baculatisporites comaumensis* (Cookson) Potonić 1956**
Pl. 2, figs 9–11

1953 *Triletes comaumensis* Cookson, p. 470, Pl. 2, figs 27, 28.

1957 *Osmundacidites comaumensis* (Cookson) Balme (*pars*), p. 25, Pl. 4, figs 54, 56.

1963 *Baculatisporites comaumensis* (Cookson); Dettmann, p. 35, Pl. 3, figs 22, 34.

1975 *Osmundacidites wellmanii* Couper; Filatoff, p. 58, Pl. 9, figs 2–5.

1975 *Baculatisporites comaumensis* (Cookson); Filatoff, p. 59, Pl. 9, figs 6, 7.

1975 *Verrucosisporites varians* Volkheimer; Filatoff, p. 59, Pl. 9, figs 8–11.

1980a *Baculatisporites comaumensis* (Cookson); Burger, p. 50, Pl. 4, figs 6, 8, 9.

Dimensions: Diameter (20 specimens) 26(39)51 μm .

Remarks: The sculpture of *B. comaumensis* varies with the diameter of the specimen. Small specimens bear clavae and bacula, often closely spaced up to 3 μm high. Larger specimens bear dispersed bacula or grana, 1 μm or less in height. *Osmundacidites wellmanii* Couper 1953 may fall within this morphological range and is possibly synonymous with *B. comaumensis*.

Range: *Retitriletes watherooensis* to *Balmeiopsis limbata* Zones. *Baculatisporites comaumensis* is the most abundant species in most samples from the *R. watherooensis*, *Aequitriradites acusus*, and *Biretisporites eneabbaensis* Zones.

Genus **Biretisporites** Delcourt and Sprumont emend. Delcourt Dettmann and Hughes 1963

Type species: *Biretisporites potoniaei* Delcourt, Dettmann and Sprumont 1955.

Biretisporites eneabbaensis Backhouse 1978
Pl. 2, fig. 12

Dimensions: Diameter of 21 specimens from samples other than the topotype material 55(74)103 μm .

Remarks: The original description (Backhouse, 1978) is based largely on specimens from a single sample (Eneabba Line 3, 151 m). Specimens from other samples, particularly those from the Vlaming Sub-basin and the Bunbury Trough, are often significantly smaller, but since they are similar in other respects to the holotype they are included here in *B. eneabbaensis*.

Range: *Biretisporites eneabbaensis* Zone. Usually a rare species, but locally abundant in the Dandaragan Trough.

Genus **Calamospora** Schopf, Wilson and Bentall 1944

Type species: *Calamospora hartungiana* Schopf, Wilson and Bentall 1944.

Calamospora mesozoica Couper 1958
Pl. 3, fig. 1

Dimensions: Diameter (5 specimens) 34(43)50 μm .

Remarks: The fine sculpturing of the contact faces mentioned by Filatoff (1975) was not observed on any of the present specimens of *Calamospora mesozoica*; the exine is merely darker in the vicinity of the suturae.

Range: *Biretisporites eneabbaensis* and *Balmeiopsis limbata* Zones, rare. Previous records suggest that *Calamospora mesozoica* occurs through most of the Jurassic section in the Perth Basin (Filatoff, 1975).

Genus **Cibotiumspora** Chang 1965

Type species: *Cibotiumspora paradoxa* (Maljavkina) Chang 1965.

Cibotiumspora jurienensis (Balme) Filatoff 1975
Pl. 3, figs 2, 3

Dimensions: Diameter (7 specimens) 24(29)32 μm .

Remarks: For a description and comments on *C. jurienensis* and comparable spores see Filatoff (1975).

Range: *Retitriletes watherooensis* to *Balmeiopsis limbata* Zones.

Genus **Cicatricosisporites** Potonié and Gelletich 1933

Type species: *Cicatricosisporites dorogensis* Potonié and Gelletich 1933.

Cicatricosisporites australiensis (Cookson)
Potonié 1956
Pl. 3, figs 4, 5; Pl. 12, figs 2, 3

Dimensions: Diameter (30 specimens) 43(54)70 μm .

Range: *Biretisporites eneabbaensis* and *Balmeiopsis limbata* Zones. Previously recorded from the Early Cretaceous of Australia, Europe, and North America. In the Perth Basin *C. australiensis* first appears in the Otorowiri Siltstone Member of the Parmelia Formation at the base of the *B. eneabbaensis* Zone. It is rare through most of its range in the Perth Basin, but becomes abundant in a few samples from the *B. limbata* Zone.

Cicatricosisporites sp. cf. *C. hughesii*

Dettmann 1963

Pl. 3, figs 6, 7

Description: Trilete spores, radially symmetrical, amb triangular; sides straight or convex; proximal surface pyramidal, distal surface strongly convex. Suturæ, three-quarters radius, in length, bordered by narrow labra 2 to 8 μm high; contact faces smooth. Spore sculptured distally and equatorially with elongate muri arranged parallel to interradian sides of amb, 3 to 5 muri along each side. Muri, 1 to 2 μm wide, usually uneven in height with an undulating distal edge; separated by lumina of irregular width, 0.5 to 6 μm wide. Muri closest to distal pole may coalesce on distal surface; outer muri always extend onto proximal surface at apices.

Dimensions: Diameter (14 specimens) 39(50)61 μm .

Remarks: *Cicatricosisporites* sp. cf. *C. hughesii* is more convex distally than *C. hughesii* and the distal muri coalesce to a greater degree, but in other respects it is morphologically close to this species. The muri of *C. purbeckensis* Norris 1969 are discontinuous and more numerous than those of *C. sp. cf. C. hughesii*.

Range: Uppermost *Biretisporites eneabbaensis* Zone to the *Balmeiopsis limbata* Zone, but only common in the *B. limbata* Zone

Cicatricosisporites ludbrookae Dettmann 1963

Pl. 3, fig 8

Dimensions: Diameter (28 specimens) 48(59)74 μm .

Range: *Biretisporites eneabbaensis* and *Balmeiopsis limbata* Zones. In the Perth Basin *C. ludbrookae* has a range and frequency similar to that of *C. australiensis* (Cookson).

Cicatricosisporites sp. cf. *C. ludbrookae*

Dettman 1963

Pl. 3, fig 9

Description: Trilete spores, biconvex; amb triangular; sides straight, convex or concave. Suturæ three-quarters radius in length with narrow labra, up to 6 μm high. Distal muri arranged in three series parallel to interradian sides of amb; muri uneven in height (up to 3 μm high) with an undulating appearance. Inner muri of each series coalesce on distal surface; remaining muri extend on to proximal surface, protruding as ridges at

apices. Individual muri, 1.5 to 2.5 μm wide, separated by lumina of variable width, 1 to 6 μm wide.

Dimensions: Diameter (12 specimens) 47(57)79 μm .

Remarks: Only the irregularity in shape and arrangement of the muri distinguish this form from *C. ludbrookae*. *Cicatricosisporites* sp. cf. *C. hughesii* Dettmann is more convex distally.

Range: Mid *Biretisporites eneabbaensis* zone.

Cicatricosisporites pseudotripartitus

(Bolkhovitina) Dettmann 1963

Pl. 3, fig. 10

Dimensions: Diameter (1 specimen) 49 μm .

Range: *Balmeiopsis limbata* Zone, rare.

Cicatricosisporites sp. A Burger 1976b

Pl. 3, fig. 11

1976b *Cicatricosisporites* sp. A Burger, p. 6, Pl. 2, fig. 4; Pl. 3, fig. 2.

Dimensions: Diameter (7 specimens) 45(58)66 μm .

Range: Upper *Biretisporites eneabbaensis* and *Balmeiopsis limbata* Zones. Recorded from the late Neocomian of the Eromanga and Surat Basins by Burger (1976b).

Genus **Concavissimisporites** Delcourt and Sprumont 1955 emend. Delcourt, Dettmann and Hughes 1963.

Type species: *Concavissimisporites verrucosus* Delcourt and Sprumont 1955.

Concavissimisporites crassatus (Delcourt and Sprumont) Delcourt, Dettmann and Hughes 1963

Pl. 4, fig. 1

Dimensions: Diameter (5 specimens) 51(68)87 μm .

Range: *Balmeiopsis limbata* Zone.

Concavissimisporites infirmus (Balme 1957)
comb. nov.

Pl. 3, figs. 12-14; Pl. 12, figs. 4, 5

1957 *Concavisorites infirmus* Balme, p. 21, Pl. 2, figs. 32-33

Expanded description: Small trilete spores, slightly biconvex; amb triangular; sides straight or slightly concave. Slight arcuate folds developed on each contact face. Suturæ three-quarters radius in

length with extremely low labra, or none at all. Exine less than 1 μm thick, evenly sculptured proximally and distally with small sinuous inter-connected rugulae. Rugulae 0.5 μm or less in height, 1 μm or less in basal width; along the sutural margins the rugulae fuse to form a continuous ridge.

Dimensions: Diameter (18 specimens) 30(36)41 μm .

Remarks: This species is assigned to *Concavissimisorites* because the original generic assignment *Concavisporites* is for smooth spores. *C. infirmus* is distinguished from similar small spores by the nature of the sculpture and the arcuate folds on the contact faces.

Range: *Biretisporites eneabbaensis* and *Balmiopsis limbata* Zones. *Concavissimisorites infirmus* is extremely rare through most of the section, and is common only in a few samples from the Leederville Formation. For example in the topotype material from Murphy's shaft.

***Concavissimisorites irregularis* (Pocock 1970)**
comb. nov.

Pl. 3, figs. 15, 16; Pl. 12, fig. 8

1970 *Manumia irregularis* Pocock, p. 40, Pl. 7, figs 3–5

1975 *Converrucosisporites* sp. Filatoff, p. 71, Pl. 17, fig 7.

Description: Trilete spores, biconvex; amb triangular with rounded angles and straight or concave sides. Suturae three-quarters radius in length, bordered by low membranous labra. Exine, 1.0 to 1.5 μm thick, sparsely sculptured distally and proximally by small verrucae, 0.5 to 3.0 μm high and 2 to 5 μm in basal diameter, slightly concentrated on the apices.

Dimensions: Diameter (26 specimens) 33(42)51 μm .

Remarks: This species lacks the distinctively broad raised labra of the type species of *Manumia* Pocock 1970, *M. verrucata* Pocock 1970. It is therefore assigned to the genus *Concavissimisorites* (Delcourt and Sprumont). *Concavissimisorites irregularis* is smaller and has smaller verrucae than *C. variverrucatus* (Couper) Brenner 1963.

Range: *Retitriletes watherooensis* to *Biretisporites eneabbaensis* Zone. Previously recorded by Pocock (1970) from the Callovian of Canada and by Filatoff (1975), as *Converrucosisporites* sp., from the Middle Jurassic of the Perth Basin.

***Concavissimisorites variverrucatus* (Couper)**

Brenner 1963

Pl. 4, figs. 3–5; Pl. 12, fig. 9

Dimensions: Diameter (90 specimens) 49(70)98 μm .

Remarks: Observations on a large number of specimens show that a gradation exists between lightly and heavily sculptured forms. At one morphological extreme the sculpture is restricted to low (less than 2 μm), broad verrucae restricted to, or best developed on, the apices. At the other extreme the entire surface of the spore is covered with closely spaced hemispherical verrucae, up to 5 μm in height. All the forms have in common a triangular amb with straight to concave sides and an exine 2 to 3 μm thick excluding sculpture. Some previous authors (e.g. Dörhöfer, 1977; Pocock, 1970) have recognized several species within this morphological range. However, in this study no biostratigraphic significance could be attributed to the various so-called species, and observation of a large number of specimens in a number of samples suggests that all forms occur in consistently similar ratios. The whole group is treated here as a single, variable species.

Range: *Retitriletes watherooensis* to *Biretisporites eneabbaensis* Zones. The same or similar spores are widely recorded in Europe and North America from the Late Jurassic and Early Cretaceous.

***Concavissimisorites verrucosus* Delcourt and**
Sprumont 1955

Pl. 4, fig. 2; Pl. 12, fig. 10

Dimensions: Diameter (17 specimens) 61(76)87 μm .

Range: *Retitriletes watherooensis* to *Biretisporites eneabbaensis* Zones.

Genus *Contignisorites* Dettmann 1963

Type species: *Contignisorites glebulentus* Dettmann 1963.

***Contignisorites cooksonae* (Balme)**

Dettmann 1963

Pl. 4, fig. 6; Pl. 12, fig. 7

Dimensions: Diameter (20 specimens) 28(42)55 μm .

Remarks: Included here in *Contignisorites cooksonae* are a group of spores ranging from forms without discernible proximal verrucae to larger examples with distinct proximal verrucae. Many larger forms with prominent verrucae are

similar to forms referred by some authors to *C. glebulentus* Dettmann 1963. A complete morphological gradation exists between the two extremes, with most specimens exhibiting some development of proximal verrucae. Indeed, the development of the verrucae is apparently directly proportional to the overall size of the spore. No biostratigraphic significance is attached to the morphological variation.

Range: *Retitriteles watherooensis* to *Balmeiopsis limbata* Zones. In the Perth Basin the species has previously been recorded as low as the *Contignisporites cooksonae* Zone (Filatoff, 1975).

Contignisporites multimuratus Dettmann 1963
Pl. 4, figs 7, 8

1963 *Contignisporites multimuratus* Dettmann, p. 76, Pl. 16, figs 6–13.

1978 *Contignisporites multimuratus* Dettmann; Backhouse, p. 27, Pl. 4, fig. 1.

non 1971 *Contignisporites multimuratus* Dettmann; Singh, p. 86, Pl. 11, figs 7, 8.

non 1974 *Contignisporites multimuratus* Dettmann; Burger, Pl. 15, figs 3, 4.

non 1980a *Contignisporites multimuratus* Dettmann; Burger, p. 59, Pl. 13, fig. 11.

Dimensions: Diameter in longest plane (14 specimens) 54(67)74 μm .

Remarks: *Contignisporites multimuratus* is a large form of *Contignisporites* possessing an oval amb, and almost bilaterally symmetrical proximal and distal sculpture. The cingulum is wide and even in width or, more often, partitioned into smoothly rounded segments.

The specimens illustrated by Singh (1971) and Burger (1974, 1980a) do not display broad cingulums, and lack bilateral symmetry. They are similar to the larger, proximally verrucate forms of *C. cooksonae* (Balme) encountered in this study.

Range: *Retitriteles watherooensis* to *Biretisporites eneabbaensis* Zones. Rare occurrences of *C. multimuratus* in the *Balmeiopsis limbata* Zone are attributed to reworking. Most eastern Australian records of this species are from the *Dictyotosporites speciosus* Zone (Dettmann, 1963) of Neocomian to Aptian age.

Genus **Cooksonites** Pocock 1962 emend.
Dettmann 1963

Type species: *Cooksonites variabilis* Pocock 1962

Cooksonites variabilis Pocock 1962

Pl. 4, fig. 9

Dimensions: Diameter (5 specimens) 54(67)75 μm .

Range: Lower *Balmeiopsis limbata* Zone. Previously recorded from the Neocomian of Canada (Pocock, 1962) and southeastern Australia (Dettmann, 1963; Dettmann and Playford, 1968).

Genus **Crybelosporites** Dettmann 1963

Type species: *Crybelosporites stylosus* (Cookson and Dettmann) Dettmann 1963.

Crybelosporites stylosus Dettmann 1963
Pl. 4, fig. 10; Pl. 12, figs 11, 12

Dimensions: Diameter (30 specimens) 45(59)92 μm , intexinal spore body 34(46)56 μm .

Range: *Biretisporites eneabbaensis* and *Balmeiopsis limbata* Zones. Previously recorded from the Neocomian and Early Aptian of Australia (Dettmann, 1963; Dettmann and Playford, 1968; Burger, 1973b; Morgan, 1980).

Genus **Cyathidites** Couper 1953

Type species: *Cyathidites australis* Couper 1953

Cyathidites concavus (Bolkhovitina)
Dettmann 1963
Pl. 12, fig. 6

Dimensions: Diameter (30 specimens) 35(41)47 μm .

Remarks: *Cyathidites concavus* is distinguished from *C. minor* by the development of gabled apices and slight arcuate folds on the contact faces. It is also slightly larger than *C. minor*. Some specimens bear distal folds across the apices in the style of *Cibotium jurienensis* (Balme).

Range: *Biretisporites eneabbaensis* and *Balmeiopsis limbata* Zones.

Cyathidites minor Couper 1953
Pl. 5, fig. 1

Dimensions: Diameter (32 specimens) 27(34)45 μm .

Remarks: In addition to forms clearly belonging to *C. minor*, as figured by Couper (1953) and Dettmann (1963), a number of small smooth triangular spores not agreeing so closely with the type were included in this species in sample counts.

Range: *Retitriteles watherooensis* to *Balmeiopsis limbata* Zones.

Genus **Densoisporites** Weyland and Krieger 1953

Type species: *Densoisporites velatus* Weyland and Krieger 1953.

Densoisporites velatus Weyland and Krieger 1953
Pl. 5, fig. 2; Pl. 13, fig. 5

Dimensions: Diameter (32 specimens) 34(54)73 μm .

Range: *Retitriteles watherooensis* to *Balmeiopsis limbata* Zones.

Genus **Dictyophyllidites** Couper 1958 emend.
Dettmann 1963

Type species: *Dictyophyllidites harrisii* Couper 1958.

Dictyophyllidites equixinus (Couper)
Dettmann 1963
Pl. 4, fig. 11; Pl. 5, fig. 5.

Dimensions: Diameter (34 specimens) 36(52)62 μm .

Remarks: Included here in *Dictyophyllidites equixinus* are microfoveolate forms of the type previously assigned to *Foveotriteles parviretis* (Balme) Dettmann 1963.

Balme's original material from Murphy's shaft was reprocessed as part of this study. It yielded numerous rather small specimens of *D. equixinus* and a few microfoveolate forms corresponding with specimens assigned by Balme to *F. parviretis*. I have interpreted these to be specimens of *D. equixinus* that were degraded subaerially at the time of deposition. Microfoveolate specimens of other species are also known from samples apparently affected by oxidation at the time of deposition.

Range: *Retitriteles watherooensis* to *Balmeiopsis limbata* Zones.

Genus **Dictyotosporites** Cookson and Dettmann 1958a

Type species: *Dictyotosporites speciosus* Cookson and Dettmann 1958a.

Dictyotosporites complex Cookson and Dettmann 1958a
Pl. 5, figs 3, 4

Dimensions: Diameter (14 specimens) 36(47)61 μm , intexinal body 29(35)46 μm .

Range: *Retitriteles watherooensis* to *Balmeiopsis limbata* Zones.

Dictyotosporites speciosus Cookson and Dettmann 1958a
Pl. 5, figs 6, 7

Dimensions: Diameter (23 specimens) 35(40)45 μm , intexinal body 31(34)41 μm .

Range: *Biretisporites eneabbaensis* and *Balmeiopsis limbata* Zones.

Genus **Foveosporites** Balme 1957

Type species: *Foveosporites canalis* Balme 1957.

Foveosporites canalis Balme 1957
Pl. 5, figs 8–10; Pl. 13, figs 1–3

1957 *Foveosporites canalis* Balme, p. 17, Pl. 1, figs 15–17.

1980a *Foveosporites canalis* Balme; Burger (*pars*), p. 54, Pl. 8, fig. 6.

non 1978 *Foveosporites canalis* Balme; Backhouse, p. 20, Pl. 2, fig. 6.

Description: Small trilete spores, distally convex, proximally pyramidal; amb subtriangular with convex sides. Suturae three-quarters radius in length, with low, narrow, membranous labra. Exine 1.0 to 1.5 μm thick, thicker (up to 3 μm) interradially where slight crassitudes are developed. Proximal exine finely granular to nearly smooth, without foveolae. Distal and equatorial sculpture consists of numerous, closely spaced, shallow, oval foveolae arranged in a crudely radial pattern. A circular area at the distal pole may be devoid of foveolae.

Dimensions: Diameter (32 specimens) 31(36)41 μm .

Remarks: The exine is slightly paler over the smooth area at the distal pole; this suggests that it may be thinner at this point due to erosion of the exine. *Foveosporites canalis* is smaller than *F. subtriangularis* Brenner 1963, and possesses a thinner exine with shallower distal foveolae.

Range: *Balmeiopsis limbata* Zone. *Foveosporites canalis* is usually rare, but it is common in a small number of samples from the upper part of the Leederville Formation.

Foveosporites moretonensis de Jersey 1964

Pl. 5, fig. 11; Pl. 13, fig. 4

Dimensions: Diameter (21 specimens) 23(31)41 μm .

Range: *Retitriletes watherooensis* to *Balmeiopsis limbata* Zones.

Foveosporites subtriangularis (Brenner)

Döring 1966

Pl. 5, fig. 12; Pl. 13, fig. 6

1977 *Foveosporites subtriangularis* (Brenner); Dörhöfer, p. 42, Pl. 8, fig. 4 (with synonymy)

1978 *Foveosporites canalis* Balme; Backhouse, p. 20, Pl. 2, fig. 6.

Dimensions: Diameter (17 specimens) 35(41)47 μm .

Range: *Biretisporites eneabbaensis* and *Balmeiopsis limbata* Zone.

Genus Gleicheniidites Ross 1949

Type species: *Gleicheniidites senonicus* Ross 1949.

Gleicheniidites senonicus Ross 1949.

Pl. 6, fig. 2

Range: *Retitriletes watherooensis* to *Balmeiopsis limbata* Zones.

Genus Ischyosporites Balme 1957

Type species: *Ischyosporites crateris* Balme 1957

Remarks: The synonymy of *Klukisporites* with *Ischyosporites* is extensively discussed by Guy (1971) and Van Konijnenburg-van Cittert (1981). These authors concluded that the two genera are identical. The absence of a margo and the development of radial crassitudes in *Ischyosporites*, the criteria by which Dettmann (1963) and Filatoff (1975) distinguish the genera, are inconsistent and variable morphological features in the type species *I. crateris*. Consequently I concur with the view that *Klukisporites* is a junior synonym of *Ischyosporites*.

Ischyosporites crateris Balme 1957

Pl. 5, fig. 14

Dimensions: Diameter (20 specimens) 41(48)56 μm .

Range: *Retitriletes watherooensis* to *Balmeiopsis limbata* Zones.

Ischyosporites scaberis Cookson and

Dettmann 1958

Pl. 5, fig. 14

Dimensions: Diameter (22 specimens) 42(49)60 μm .

Remarks: The broader lumina of this species readily distinguish it from *Ischyosporites variegatus* (Couper) Schulz 1967. All specimens of *I. scaberis* have a secondary sculpture of small closely spaced verrucae over the entire exine, a feature variably developed on *I. variegatus*. This species was assigned to *Klukisporites* by Dettmann (1963) and numerous subsequent authors.

Range: *Retitriletes watherooensis* to *Balmeiopsis limbata* Zones.

Ischyosporites variegatus (Couper) Schulz 1967

Pl. 5, fig. 15

1971 *Ischyosporites variegatus* (Couper); Guy, p. 35, Pl. 3, figs 3–16 (with synonymy).

1975 *Klukisporites variegatus* Couper; Filatoff, p. 68, Pl. 15, figs 1–5.

1975 *Klukisporites neovariegatus* Filatoff, p. 69, Pl. 15, figs 6–8.

Dimensions: Diameter (17 specimens) 40(50)66 μm .

Remarks: In this study no criteria could be established, other than size and scale of the sculptural elements, to distinguish the larger heavily ornamented specimens of the type assigned by Filatoff (1975) to *Klukisporites neovariegatus* from *I. variegatus*.

Range: *Retitriletes watherooensis* to *Balmeiopsis limbata* Zones.

Genus Januasporites Pocock 1962

Type species: *Januasporites reticularis* Pocock 1962.

Januasporites multispinus sp. nov.

Pl. 5, figs 16–19; Pl. 6, fig. 1; Pl. 13, fig. 8

Derivation of name: Latin, *multi*, many, *spinus*, a spine, referring to the distal sculpture.

Holotype: F9425/2 (–22.5, –106.0) Moora Line 3A, 724 m, Parmelia Formation, Pl. 5, fig. 18.

Description: Trilete spores, slightly biconvex or flat; amb subtriangular to quadrangular. Suturae formed in both exinal layers, extending to equator, never gaping; suturae bordered by low membranous labra formed by exoexine. Intexine 1.5 to 2

μm thick, usually unfolded. Exoexine thin and membranous, finely wrinkled on the proximal surface, sometimes in a pattern radiating from the suturae, but distally drawn into short acicular spines 1 to 2 μm high, spaced 1 to 3 μm apart. Exoexine sometimes separated from intexine at the equator, but appressed to the intexine on the distal and/or proximal surfaces, except where spines are formed.

Dimensions: Diameter of holotype 52 μm . Range of diameter (25 specimens) 41(53)58 μm .

Remarks: The exine structure of *J. multispinus* is comparable to that of *J. reticularis* Pocock 1962 and *J. spinulosus* Dettmann 1963. In all three species a membranous exoexine is narrowly separated from a thicker intexine and drawn into distal and equatorial spines. In contrast to the other species of *Januasporites* the spines of *J. multispinus* are short and do not develop an observable reticulum. Singh (1964) in his emendation of the genus refers to a non-functional tetrad scar on the type species. On *J. multispinus* the suturae do not open, but an alternative point of rupture is not evident.

Range: *Biretisporites eneabbaensis* Zone.

Januasporites spinulosus Dettmann 1963

Pl. 6, fig. 3

Dimensions: Total diameter (20 specimens) 55(69)92 μm .

Range: *Biretisporites eneabbaensis* and *Balmeiopsis limbata* Zones.

Genus **Kraeuselisporites** Leschik 1956

Type species: *Kraeuselisporites dentatus* Leschick 1956.

Kraeuselisporites whitfordensis sp. nov.

Pl. 6, figs. 4–6; Pl. 13, fig. 7

Derivation of name: After the type locality, Whitfords 1 borehole.

Holotype: F8351/3 (–24.4, –94.2), Whitfords 1, 288 m, South Perth Shale, Pl. 6, fig. 5.

Description: Trilete, zonate spores; amb subtriangular, sides convex, angles rounded. Suturae extend onto zona, bordered by low narrow labra. Intexinal body subtriangular, unsculptured intexine less than 1 μm thick. Membranous exoexine appressed to intexine proximally and distally, but equatorially forms a thin zona of even thickness. Proximal surface unsculptured. Distal surface, including zona, sculptured with acicular or truncate tapered spines, 2 to 6 μm high, spaced

4 to 6 μm apart: sometimes connected basally by low ridges. Spines developed along distal margin of zona produce a strongly denticulate amb.

Dimensions: Diameter of holotype 78 μm . Range of diameter (14 specimens) 52(63)78 μm , diameter of intexine 27(42)49 μm .

Remarks: The large number of narrow, closely spaced spines and the thin readily folded exine distinguish *Krauselisporites whitfordensis* from other species of *Krauselisporites*

Range: *Balmeiopsis limbata* Zone.

Genus **Laevigatosporites** Ibrahim 1933

Type species: *Laevigatosporites vulgaris* Ibrahim 1933

Laevigatosporites belfordii Burger 1976.

Pl. 6, fig. 7; Pl. 13, fig. 15

Dimensions: Length (15 specimens) 62(89)115 μm , polar diameter (7 specimens) 45(68)79 μm .

Range: *Biretisporites eneabbaensis* and *Balmeiopsis limbata* Zones. The first appearance of this species is a useful marker for the base of the *B. eneabbaensis* Zone.

Genus **Leptolepidites** Couper 1953

Type species: *Leptolepidites verrucatus* Couper 1953.

Leptolepidites major Couper 1953

Pl. 6, fig. 8

Dimensions: Diameter (23 specimens) 32(44)58 μm .

Remarks: *Leptolepidites major* has a subcircular amb, and proximal and distal verrucae of comparable size. Norris (1969) transferred *L. major* to *Rubinella* Maljavkina 1949 emend. Potonié 1960, but the species is no more easily included in the poorly circumscribed genus *Rubinella* than it is in *Leptolepidites*. Some specimens of the type species, *L. verrucatus* Couper 1953, possess well-developed proximal sculpture, and species with proximal verrucae should be included in this genus. Consequently, I prefer to follow Burger (1980a), and retain this species in *Leptolepidites*.

Range: *Retitritletes watherooensis* to *Balmeiopsis limbata* zones.

Leptolepidites pudens (Balme 1957)

comb. nov.

Pl. 6, fig. 9; Pl. 13, figs 9–11

1957 *Reticulatisporites pudens* Balme, p. 17, Pl. 1, figs 12–14.

1983 *Reticulatisporites pudens* Balme; Dettmann, p. 47, Pl. 7, figs 23–26

1980a *Reticulatisporites pudens* Balme; Burger, p. 54, Pl. 8, fig. 3.

Description: Small trilete spores, slightly convex distally, flat proximally; amb, subcircular to convexly subtriangular. Suturae one-half to two-thirds radius in length, bordered by narrow labra, 0.5 μm or less in height. Exine approximately 1 μm thick, sculptured distally with interconnected, strongly sinuous rugulae. Rugulae 2 to 3 μm wide, approximately 2 μm high at the distal pole, lower towards amb, separated by elongate lumina, 0.5 to 1.5 μm wide. Proximal sculpture consists of low, broad, closely spaced rugulae arranged in an approximately radial pattern, fused into a continuous structure abutting the labra.

Dimensions: Diameter of 12 specimens from Murphy's shaft 20(24)28 μm .

Remarks: *Leptolepidites pudens* is transferred from *Reticulatisporites* because it lacks a cingulum. *Leptolepidites pudens* possesses sculpture similar in style to *L. verrucatus* Couper 1953, but it bears distal rugulae rather than verrucae and is considerably smaller than that species. It is also smaller than *L. psarosus* Norris 1969 and *Leptolepidites* sp. A, species characterized by distal verrucae rather than rugulae

Range: Upper *Balmeiopsis limbata* Zone. *Leptolepidites pudens* is only common in the topotype material from Murphy's shaft.

Leptolepidites verrucatus Couper 1953

Pl. 6, figs 10–12

Dimensions: Diameter (20 specimens) 27(34)40 μm .

Range: *Retitriletes watherooensis* to *Balmeiopsis limbata* Zones.

Leptolepidites sp. A

Pl. 6, fig. 14

Dimensions: Diameter (16 specimens) 33(39)47 μm .

Remarks: *Leptolepidites* sp. A is smaller than *L. major* Couper 1953, and bears fewer but larger verrucae than that species. *Leptolepidites psarosus* Norris 1969 and *Conv verrucosporites proxigranulatus* Brenner 1963 are comparable forms but both, apparently, lack proximal verrucae.

Range: *Biretisporites eneabbaensis* Zone.

Genus **Lycopodiacidites** Couper 1953 emend.
Potonić 1956

Type species: *Lycopodiacidites bullerensis* Couper 1953.

Lycopodiacidites asperatus Dettmann 1963

Pl. 6, fig. 13

Dimensions: Diameter (20 specimens) 43(53)62 μm .

Range: *Retitriletes watherooensis* to *Balmeiopsis limbata* Zones.

Genus **Marattisporites** Couper 1958.

Type species: *Marattisporites scabratus* Couper 1958.

Marattisporites scabratus Couper 1958.

Pl. 7, fig. 6

Dimensions: Length (20 specimens) 18(24)30 μm , width (10 specimens) 12(17)22 μm , polar diameter (8 specimens) 12(18)23 μm .

Remarks: Norris (1965) transferred this species to *Punctatosporites* Ibrahim 1933. However, Krutzsch (1959) described the sculpture of *P. minutus* Ibrahim 1933, the type species of *Punctatosporites*, as scattered small and very small grana. *Marattisporites* is retained for monoete spores with a sculpture of small closely spaced grana.

Range: *Retitriletes watherooensis* to *Balmeiopsis limbata* Zones.

Genus **Matonisporites** Couper 1958

Type species: *Matonisporites phlebopteroides* Couper 1958.

Matonisporites agatonensis Backhouse 1978

Pl. 6, figs 15, 16

Dimensions: Diameter (26 specimens) 87(101)127 μm .

Occurrence: Lower *Biretisporites eneabbaensis* Zone.

Matonisporites crassiangulatus (Balme)

Dettmann 1963

Pl. 7, figs 1–3; Pl. 13, fig. 16

1957 *Cyathidites crassiangulatus* Balme, p. 22, Pl. 3, figs 39–41.

1963 *Cyathidites crassiangulatus* Balme; Brenner, p. 60, Pl. 15, fig. 4.

1963 *Matonisporites cooksoni* Dettmann, p. 59, Pl. 11, figs 1–8.

1964 *Matonisporites crassiangulatus* (Balme) Levet-Carette, p. 94.

1971 *Matonisporites crassiangulatus* (Balme); Singh, p. 103, Pl. 14, fig. 12.

1971 *Matonisporites crassiangulatus* (Balme); Guy, p. 32, Pl. 2, fig. 21.

1971 *Matonisporites scabratus* Guy, p. 33, Pl. 3, fig. 1.

1973 *Matonisporites dubius* Kumar, p. 103, Pl. 3, figs 58–59.

1973 *Matonisporites discoidalis* Kumar, p. 103, Pl. 3, figs 60–61.

1973 *Lametriletes tenuis* Kumar, p. 103, Pl. 3, figs 62–63.

1974 *Matonisporites cooksonae* Dettmann; Burger, Pl. 14, fig. 9.

1975 *Matonisporites crassiangulatus* (Balme); Filatoff, p. 62, Pl. 11, figs 12, 13.

1980a *Matonisporites cooksonae* Dettmann; Burger, p. 56, Pl. 11, figs 2, 3.

non 1967 *Matonisporites crassiangulatus* (Balme); Schulz, p. 557, Pl. 1, figs 5–7.

Description: Trilete spores, biconvex; amb triangular with straight or concave sides. Suturae extend almost to radial crassititudes, bordered by membranous labra about 5 μm high at proximal pole. Exine, 1.5 to 2.5 μm thick, smooth or irregularly punctate when affected by corrosion, thickened at apices to form smooth rounded or squared crassititudes 3 to 6 μm wide.

Dimensions: Diameter (21 specimens) 40(52)66 μm .

Remarks: All late Mesozoic Australian records of *Matonisporites* which fall within this general size range can be assigned to *M. crassiangulatus*. *Matonisporites phlebopteroides* Couper 1958 and the forms assigned to *M. crassiangulatus* by Schulz (1967) have a thicker exine and substantially thicker radial crassititudes. Forms of *M. crassiangulatus* with less distinct crassititudes grade into *Dictyophyllidites equixinus* (Couper). The specimens described by Balme (1957) as *Foveosporites parviretus* are probably degraded specimens of *M. crassiangulatus*, or *D. equixinus*. *Matonisporites crassiangulatus* is susceptible to degradation of the distal and proximal exine (Pl. 13, fig. 6); often only the radial crassititudes remain apparently unaffected.

Range: *Retitriletes watherooensis* to *Balmeiopsis limbata* Zones.

Genus *Murospora* Somers 1952

Type species: *Murospora kosankei* Somers 1952.

Murospora florida (Balme) Pocock 1961
Pl. 7, figs 4, 5

Dimensions: Diameter (24 specimens) 50(67)83 μm .

Remarks: Like *Dictyophyllidites equixinus* (Couper) and *Matonisporites crassiangulatus* (Balme), *Murospora florida* is susceptible to degradation resulting in an irregular punctate proximal and distal exine. The cingulum of *M. florida*, like the radial crassititudes of *M. crassiangulatus*, remains relatively unaffected by the degradation. In extreme cases all the distal and proximal exine is removed and leaves the cingulum as an empty rim. In this respect the similarity of *M. florida* to *D. equixinus* is a clue to the botanical affinities of *M. florida*. Spores of the genus *Dictyophyllidites* are considered to have matoniacean affinities (Couper, 1958), as probably does *M. florida*.

Range: *Retitriletes watherooensis* to *Balmeiopsis limbata* Zones.

Genus *Neoraistrickia* Potonié 1956

1956 *Neoraistrickia* Potonié, p. 34.

1958a *Ceratosporites* Cookson and Dettmann, p. 101.

Type species: *Neoraistrickia truncata* (Cookson) Potonié 1956.

Remarks: Sculptural elements on the type species, *Neoraistrickia truncata*, are normally restricted to the equatorial and distal areas. This is the basis for the proposal by Bharadwaj and Kumar (1972) in which *Ceratosporites* becomes a junior synonym of *Neoraistrickia*.

The only species presently assigned to the genus *Ceratosporites* is the type species *C. equalis* Cookson and Dettmann 1958a, which differs from the type species of *Neoraistrickia* only by possessing longer truncate sculptural elements. The transfer of *C. equalis* to *Neoraistrickia* places all Mesozoic species of this general type with truncate distal bacula or short spines and largely unsculptured proximal surfaces in a single comprehensive genus.

The suggestion by Schulz (1967) that *Cepulina* Maljavkina 1949 is the senior synonym of *Neoraistrickia* is rejected because *Cepulina* is a *nomen nudum* (Jansonius and Hills, 1976).

Neoraistrickia equalis (Cookson and Dettmann)
comb. nov.

Pl. 7, fig. 7; Pl. 13, fig. 14

1958a *Ceratosporites equalis* Cookson and Dettmann,
p. 101, Pl. 14, figs 17–20.

1963 *Ceratosporites equalis* Cookson and Dettmann;
Dettmann, p. 36, Pl. 6–8.

non 1980a *Ceratosporites equalis* Cookson and Dettmann;
Burger, p. 51, Pl. 5, figs 1–3.

Description: Small trilete spores, convex distally, pyramidal proximally; amb subtriangular to subcircular with convex sides. Contact faces flat and unsculptured; suturae three-quarters radius in length with low membranous labra. Exine 1.5 to 2.0 μm thick; distally and equatorially sculptured with simple or, rarely, branching spines 3 to 6 μm long, 1.5 to 2.5 μm in basal diameter, tapered to a slightly expanded truncate tip.

Dimensions: Overall diameter (20 specimens) 36(41)49 μm .

Remarks: For a comparison with *Neoraistrickia trichosa* see below.

Range: *Biretisporites eneabbaensis* and *Balmeiopsis limbata* Zones.

Neoraistrickia levidensis (Balme 1957) comb. nov.
Pl. 7, figs 9, 10; Pl. 13, figs 12, 13

1957 *Acanthotriletes levidensis* Balme, p. 18, Pl. 1, figs 18, 19.

Redescription of holotype: Holotype located on slide TS200 of Balme's collection, now lodged at the Bureau of Mineral Resources, Canberra. Small trilete spores, convex distally, pointed proximally; amb subcircular. Suturae three-quarters radius in length with low, narrow labra. Exine, 1 μm thick, sculptured distally and equatorially with narrow spines, 2 to 3 μm long, 1.0 to 1.5 μm in basal diameter, tapered to truncate tips less than 0.5 μm wide. Spines regularly spaced 2 to 4 μm apart.

Dimensions: Diameter of holotype 35 μm . Range of overall diameter (11 specimens from Murphy's shaft) 27(30)35 μm .

Remarks: This species was originally assigned to *Acanthotriletes* Naumova ex Potonié and Kremp 1954, a genus probably based on a Palaeozoic acritarch (Jansonius and Hills, 1976). The truncate tips to the spines justify the assignment to *Neoraistrickia*. *Neoraistrickia levidensis* is smaller, with shorter spines than *N. trichosa* Filatoff 1975.

Range: *Balmeiopsis limbata* Zone, rare. Balme (1957) recorded *Neoraistrickia levidensis* as a common species at Murphy's shaft, but noted that elsewhere it was rare.

Neoraistrickia trichosa Filatoff 1975

Pl. 7, fig. 8

1975 *Neoraistrickia trichosa* Filatoff, p. 51, Pl. 6, figs 1–4.

1980a *Ceratosporites equalis* Cookson and Dettmann; Burger,
p. 51, Pl. 5, figs 1–3.

Dimensions: Overall diameter (21 specimens) 30(38)45 μm .

Remarks: The presence of spines on the contact face, mentioned by Filatoff (1975), is not a regular feature of this species. *Neoraistrickia trichosa* is retained for spores of approximately the same size, or slightly smaller than *N. equalis*, but possessing shorter and more slender truncate spines. A morphological gradation exists between *N. trichosa* and *N. equalis*, but most specimens can be confidently assigned to one of the two species. For this reason both species are retained.

Range: *Retitriletes watherooensis* to *Balmeiopsis limbata* Zones.

Neoraistrickia truncata (Cookson)

Potonié 1956

Pl. 7, fig. 11; Pl. 14, figs 1, 2

Dimensions: Overall diameter (20 specimens) 27(32)41 μm .

Remarks: Rare examples of *Neoraistrickia truncata* from the *Biretisporites eneabbaensis* Zone have spines with oval rather than circular bases that, on some specimens, link up to form an incomplete reticulum. These forms were referred to *Neoraistrickia* sp. A by Filatoff (1975).

Range: *Retitriletes watherooensis* to *Balmeiopsis limbata* Zones.

Genus **Nevesisporites** de Jersey and Paten 1964

Type species: *Nevesisporites vallatus* de Jersey and Paten 1964.

Remarks: The type species, *Nevesisporites vallatus*, is strongly sculptured on the proximal surface, but is unsculptured on the distal surface. Morbey (1975) extended the generic concept to include forms with distal verrucae arranged in circum-polar rows. I see no reason to restrict the genus to such a narrow range of distal sculpture. To circumscribe a usefully distinct group of spores, the genus should include spores with distal and/or proximal sculpture arranged in a regular pattern, a subquadrangular amb, long suturae bordered by grana rather than labra, and a narrow unsculptured cingulum. The absence of strong proximal and distal convexity demonstrated by the invariable polar compression and the absence of exinal folds further characterize the genus

Nevesisporites dailyi (Cookson and Dettmann)
comb. nov.

Pl. 7, figs 12, 13; Pl. 14, fig. 3

- 1958a *Granulatisporites dailyi* Cookson and Dettmann, p. 99, Pl. 14, figs 2–4.
- 1963 *Foraminisporis dailyi* (Cookson and Dettmann) Dettmann, p. 72, Pl. 14, figs 15–18.
- 1963 *Granulatisporites dailyi* Cookson; Brenner, p. 62, Pl. 16, fig. 4.
- 1964 *Foraminisporis dailyi* (Cookson and Dettman); Burger, Pl. 14, fig. 10.
- 1971 *Foraminisporites dailyi* (Cookson and Dettman); Singh, p. 35, Pl. 1, fig. 8.
- 1978 *Foraminisporis dailyi* (Cookson and Dettman); Backhouse, p. 28, Pl. 4, fig. 2.
- 1980a *Foraminisporis dailyi* (Cookson and Dettman); Burger, p. 59, Pl. 13, figs 5–7.

Dimensions: Diameter (22 specimens) 36(46)55 μm .

Remarks: The previous generic assignments of this species to *Granulatisporites* Ibrahim 1933 and *Foraminisporis* Krutzsch 1959 are rejected because *Nevesisporites dailyi* is clearly cingulate. *Nevesisporites dailyi* belongs in the morphologically distinctive group of spores included here in *Nevesisporites*. It is distinguished from other species of *Nevesisporites* by a small cluster of grana at the centre of each contact face.

Range: *Aequitriradites acus* to *Balmeiopsis limbata* Zones.

Nevesisporites harleyi sp. nov.

Pl. 7, figs 14–17; Pl. 4, figs 4, 5

- 1973 *Nevesisporites vallatus* de Jersey and Paten; Burger, Pl. 1, fig. 12.
- 1974 *Nevesisporites vallatus* de Jersey and Paten; Backhouse, Fig. 65.
- 1978 *Nevesisporites* sp. cf. *N. vallatus* de Jersey and Paten; Backhouse, p. 29, Pl. 4, fig. 3.

Derivation of name: After Alan Harley, hydrogeologist for the Watheroo Line drilling programme.

Holotype: F6669/2 (–36.0, –107.8), Watheroo Line 1, 477.5 m, Parmelia Formation, Pl. 7, fig. 15.

Description: Trilete, cingulate spores; amb subtriangular to quadrangular. Cingulum 2 to 5 μm wide, thinning towards a ragged distal margin. Suturæ extend to inner margin of cingulum, bordered by small grana and rugulae associated with the proximal sculpture. Each contact face is sculptured by low rugulae arranged in a radial pattern; the distal surface is unsculptured or bears low, broad verrucae.

Dimensions: Diameter of holotype 56 μm . Range of diameter (20 specimens) 42(49)60 μm .

Remarks: *Nevesisporites harleyi* possesses similar proximal sculpture to *N. vallatus* de Jersey and Paten 1964, but is distinguished from that species by its larger size, wider cingulum, and more quadrangular amb. A substantial biostratigraphic gap separates the two species. *Nevesisporites vallatus* is recorded from the Early Jurassic, including the Early Jurassic of the Perth Basin (Filatoff, 1975), and *Nevesisporites harleyi* first appears in the Tithonian. *N. harleyi* is similar to *N. undatus* in size and structure, but is distinguished from it by possessing radial sculpture on the contact faces. *Taurocusporites? chlonovae* Döring 1966 is smaller than *N. harleyi*.

Range: *Biretisporites eneabbaensis* Zone. *Nevesisporites harleyi* has been recorded by Burger (1973) (as *N. vallatus*) from the Early Cretaceous of Queensland.

Nevesisporites undatus sp. nov.

Pl. 8, figs 1–3; Pl. 14, figs 6–10

Derivation of name: Latin *undatus*, wavy, referring to the distal surface of the spore.

Holotype: F6684/4 (44.0, –110.9), Watheroo Line 3, 124 m, Parmelia Formation, Pl. 8, fig. 1.

Description: Trilete cingulate spores, always preserved in polar compression; amb subtriangular to quadrangular. Cingulum 3 to 8 μm wide, regular in width on one specimen, distal margin slightly ragged. Suturæ extend to inner margin of cingulum, labra not developed; each suture bordered by small grana. Remainder of proximal face smooth, or bearing scattered grana. Distal surface sculptured by low, broad smooth verrucae with elongate or circular bases. Verrucae arranged in a radial pattern about the distal pole, or randomly distributed (Pl. 14, fig. 8).

Dimensions: Diameter of holotype 72 μm . Range of diameter (22 specimens) 53(63)75 μm .

Remarks: The absence of proximal sculpture arranged in a regular pattern and the presence of broad verrucae on the distal surface distinguish *N. undatus* from other species of *Nevesisporites*.

Range: *Biretisporites eneabbaensis* Zone. Notably common in some samples from the lower part of this zone in the Dandaragan Trough.

Genus **Obtusisporis** Krutzsch 1959

Type species: *Obtusisporis obtusangulus* (Potonié) Krutzsch 1959.

Obtusisporis canadensis Pocock 1970
Pl. 8, figs 4, 5

Dimensions: Diameter (20 specimens) 30(38)49 μm .

Remarks: These spores are possibly abortive forms of *Dictyophyllidites* spp. and *Matonisporites crassiangulatus* (Balme). However, they are recorded only occasionally above the *Biretisporites eneabbaensis* Zone, although spores of the genera *Dictyophyllidites* and *Matonisporites* are quite abundant above this zone.

Range: *Retitriteles watherooensis* to *Balmeiopsis limbata* Zones.

Obtusisporis yarragadensis Filatoff 1975
Pl. 8, figs 6, 7

Dimensions: Diameter (20 specimens) 30(38)49 μm .

Remarks: Spores assigned to *O. yarragadensis* are possibly abortive forms of *Ischyosporites crateris*.

Occurrence: *Retitriteles watherooensis* to *Balmeiopsis limbata* Zones.

Genus **Osmundacidites** Couper 1953

Type species: *Osmundacidites wellmanii* Couper 1953.

Osmundacidites sp. cf. **O. dubius** Burger 1980a
Pl. 8, figs. 9–12; Pl. 14, fig. 11; Pl. 15, fig. 3

1957 *Osmundacidites comaumensis* (Cookson) Balme (pars), p. 25, Pl. 4, fig. 55.

Description: Trilete spore, subspherical to lenticular, amb subcircular. Suturae of two-thirds to three-quarters radius in length, bordered by low narrow labra, sometimes sinuous near the pole. Exine, 1.5 to 2.0 μm thick, ornamented by closely packed low sculptural elements to form a granular surface, and irregularly distributed clavi and bacula. Bacula and clavi usually concentrated near the proximal and distal poles, often in clusters, but always absent from the equatorial zone.

Dimensions: Diameter (25 specimens) 35(48)63 μm .

Remarks: Although Burger (1980a) does not mention clavi and bacula as sculptural elements, one of the isotypes appears to possess them (Burger 1980a, Pl. 4 fig. 5). In specimens from the Perth Basin the number of clavi and bacula varies from specimen to specimen they may be completely absent or, rarely, they may dominate one surface of the spore (Pl. 15, fig. 3).

Range: *Retitriteles watherooensis* to *Balmeiopsis limbata* Zones, common only in the *Biretisporites eneabbaensis* Zone.

Genus **Perinopollenites** Couper 1958

Type species: *Perinopollenites elatoides* Couper 1958.

Perinopollenites elatoides Couper 1958
Pl. 8, fig. 8

Dimensions: Diameter (10 specimens) 27(35)44 μm .

Range: *Biretisporites eneabbaensis* and *Balmeiopsis limbata* Zones.

Genus **Perotrilites** Couper 1958 emend.
Evans 1968

Type species: *Perotrilites granulatus* Couper 1953.

Perotrilites linearis (Cookson and Dettmann)
Evans 1970
Pl. 8, fig. 13

Dimensions: Diameter (6 specimens) 49(55)66 μm , intexinal diameter 34(42)47 μm .

Range: *Balmeiopsis limbata* Zone. *Perotrilites linearis* has been recorded previously from the early Aptian (Dettmann, 1964; Dettmann and Playford, 1968; Burger, 1973, 1974, 1980a). Burger's record of *P. linearis* from the Cenomanian of Bathurst Island is extremely doubtful (Burger in Norvick and Burger, 1976). The illustrated specimens (Burger and Norvick, 1976, Pl. 25, figs 1–3) do not display a convincing zona, and possess shorter distal spines than those normally borne by *P. linearis*.

Genus **Pilosisorites** Delcourt and Sprumont 1955

Type species: *Pilosisorites trichopapillosus* (Thiergart) Delcourt and Sprumont 1955.

Pilosisorites ingramii sp. nov.

Pl. 8, fig. 14; Pl. 9, fig. 1; Pl. 15, fig. 1

1967b *Pilosisorites* sp. cf. *P. notensis* Cookson and Dettmann; Ingram, Pl. 37, fig. 4.

1978 *Pilosisorites notensis* Cookson and Dettmann; Backhouse, p. 18, Pl. 2, fig. 1.

Derivation of name: After Barry S. Ingram, who illustrated the species from the Perth Basin in 1967.

Holotype: F6284/3 (–36.6, –102.2) Arrowsmith River 25, 70–73 m, Parmelia Formation, Pl. 8, fig. 14

Description: Trilete spore; amb triangular with concave sides and broadly rounded angles. Suturae two-thirds to three-quarters radius in length, bordered by narrow labra 8 μm high at the pole, decreasing in height towards the apices. Exine, 2.5 to 5.0 μm thick, with a distal and proximal sculpture of echinate or bluntly rounded, tapered spines. Spines variable in length, maximum length 5 to 9 μm , spaced 1 to 5 μm apart; spines concentrated on the apices where the largest spines are located. A single, irregular row of small spines borders the suturae.

Dimensions: Diameter of holotype spore body 90 μm . Range of spore body diameter (12 specimens) 72(87)99 μm .

Remarks: *Pilosisorites ingramii* is distinguished from *P. trichopapillosus* (Thiergart) by its larger size, larger spines, and concave sides. *Pilosisorites notensis* Cookson and Dettmann 1958a possesses shorter, regularly shaped spines including a double row of smaller spines bordering the suturae. A specimen of *P. notensis* from the Inverlock Shore Platform Victoria (southeastern Australia) is illustrated for comparison (Pl. 15, fig. 2).

Range: Lower *Biretisporites eneabbaensis* Zone.

Genus **Polycingulatisporites** Simoncsics and Kedves 1961 emend. Playford and Dettmann 1965

Type species: *Polycingulatisporites circulus* Simoncsics and Kedves 1961.

Polycingulatisporites clavus (Balme) Burger 1980a
Pl. 2, figs 6, 7

Dimensions: Diameter (14 specimens) 25(31)43 μm .

Range: *Balmeiopsis limbata* Zone, rare. In the Perth Basin, Filatoff (1975) records the species (as *Antulsporites clavus*) from as low as the upper part of the *Callialasporites dampieri* Assemblage-zone. Its apparent absence in the intervening zones (*Retitriteles watherooensis* to *Biretisporites eneabbaensis*) is rather puzzling. The type material from Murphy's shaft is in the upper *B. limbata* Zone, but in the Carnarvon and Canning Basins Balme recorded *P. clavus* from the Callovian to Oxfordian. Elsewhere, it is recorded (as *Stereisporites clavus*) from the Callovian to Kimmeridgian of Canada (Pocock, 1970), and

from the Late Jurassic to Albian of the Great Artesian Basin (Burger, 1980a). Other records of this species are dubious (see Burger's 1980a synonymy list).

Polycingulatisporites reduncus (Bolkhovitina)
Playford and Dettmann 1965
Pl. 1, figs 11, 12

Dimensions: Total diameter (9 specimens) 35(39)43 μm .

Range: *Biretisporites eneabbaensis* Zone to ?*Balmeiopsis limbata* Zone. *Polycingulatisporites reduncus* is recorded from only a few samples in the Perth Basin; worldwide it has a recorded range of Jurassic to Late Cretaceous (Bolkhovitina, 1953; Stover, 1962).

Genus **Polypodiidites** Ross 1949 amend.
Potonić 1966

Type species: *Polypodiidites senonicus* Ross 1949.

Polypodiidites horridus Backhouse 1978
Pl. 9, figs 2, 3

Dimensions: Range of length (20 specimens) 27(36)45 μm , polar diameter (10 specimens) 21(22)24 μm .

Range: *Biretisporites eneabbaensis* Zone. A few specimens occur in the lower part of the *Balmeiopsis limbata* Zone where they are probably reworked.

Genus **Reticuloidosporites** Pflug 1953

Type species: *Reticuloidosporites dentatus* Pflug 1953.

Reticuloidosporites arcus (Balme) Dettmann 1963
Pl. 9, figs 3–6; Pl. 15, fig. 7

Dimensions: Range of length (35 specimens) 28(39)46 μm , breadth (10 specimens) 22(28)35 μm , polar diameter (5 specimens) 18(25)32 μm .

Remarks: *Reticuloidosporites arcus* is frequently preserved in polar compression. It is significantly larger than *Marattisporites scabratus* Couper 1958 and possesses larger sculptural elements (up to 2.5 μm in height).

Range: *Biretisporites eneabbaensis* and *Balmeiopsis limbata* Zones. *Reticuloidosporites arcus* was recorded by Balme (1957) in several samples now assigned to the Warnbro Group and from the Jarlemai Siltstone, of suggested Oxfordian age, in the Canning Basin. This latter

record is considerably older than its known range in the Perth Basin. Dettmann (1963) and Burger (1973) recorded *R. arcus* from the Neocomian and Aptian of eastern Australia.

Genus **Retispora** Staplin 1960

Type species: *Retispora florida* Staplin 1960.

Retispora triquetra (Lantz 1958) comb. nov.
Pl. 9, fig. 7; Pl. 15, fig. 4

1958 *Laricoidites triquetrus* Lantz, p. 926, Pl. 5, figs 51–54.

1963 *Velosporites triquetrus* (Lantz) Dettmann, p. 82, Pl. 19, figs 1–3.

1978 *Velosporites triquetrus* (Lantz); Backhouse, p. 31, Pl. 4, fig. 4.

1980a *Velosporites triquetrus* (Lantz); Burger, p. 61, Pl. 15, figs 10, 16.

Dimensions: Diameter (26 specimens) 40(51)61 μm , diameter of intexine 29(36)43 μm .

Remarks: The distinctive features of this species are an unsculptured rigid intexinal body enveloped by a punctate exoexine which forms a wide, rigid pseudosaccate equatorial zone. Sometimes a fine rugose sculpture is developed on the exoexine over the distal intexinal body. These features are more characteristic of *Retispora* than *Velosporites* Hughes and Playford 1961, or *Laricoidites* Potonié 1958; the species is consequently transferred to this genus.

Range: *Retitriletes watherooensis* to *Balmeiopsis limbata* Zones.

Genus **Retitriletes** Pierce 1961 emend. Döring and others in Krutzsch 1963

Type species: *Retitriletes globosus* Pierce 1961.

Retitriletes austroclavatidites (Cookson) Döring and others in Krutzsch 1963
Pl. 9, fig. 10; Pl. 15, fig. 5

Dimensions: Diameter (22 specimens) 32(44)51 μm .

Remarks: *Retitriletes austroclavatidites* possesses a distal reticulum, 2 to 5 μm high, with wide polygonal lumina, 5 to 12 μm in maximum diameter. The reticulum frequently extends onto the proximal surface at the apices. A few specimens, otherwise indistinguishable from this species, possess a distinct proximal reticulum and are included here in *R. austroclavatidites*.

Range: *Retitriletes watherooensis* to *Balmeiopsis limbata* Zones.

Retitriletes circolumenus (Cookson and Dettmann) Backhouse 1978
Pl. 8, fig. 8; Pl. 15, fig. 6

Dimensions: Diameter (26 specimens) 36(46)55 μm .

Range: *Retitriletes watherooensis* to *Balmeiopsis limbata* Zones.

Retitriletes clavatoides (Couper) Döring and others in Krutzsch 1963
Pl. 9, fig. 9; Pl. 15, fig. 8

Dimensions: Diameter (26 specimens) 32(37)41 μm .

Range: *Retitriletes watherooensis* to *Balmeiopsis limbata* Zones.

Retitriletes eminulus (Dettmann) Srivastava 1977
Pl. 9, figs 13, 14

Dimensions: Diameter (19 specimens) 26(33)37 μm .

Range: *Retitriletes watherooensis* to *Balmeiopsis limbata* Zones.

Retitriletes facetus (Dettmann) Srivastava 1977
Pl. 9, fig. 11

Dimensions: Diameter (8 specimens) 41(50)63 μm .

Range: *Biretisporites eneabbaensis* Zone, extremely rare.

Retitriletes nodosus (Dettmann) Srivastava 1977
Pl. 9, fig. 12

Dimension: Total diameter (25 specimens) 46(52)63 μm .

Remarks: *Retitriletes nodosus* has proximal sculpture which ranges from a few isolated muri to a complete reticulum. Each distal and proximal lumina may enclose a few small grana or a greater number of closely packed grana, of which some may be up to 2 μm in diameter.

Range: *Biretisporites eneabbaensis* and *Balmeiopsis limbata* Zones.

Retitriletes parvireticulatus sp. nov.
Pl. 9, figs 15, 16

1980a *Lycopodiumsporites eminulus* Dettmann; Burger, p. 53, Pl. 7, fig. 6.

Derivation of name: Latin, *parvus*, small, *reticulum*, net, referring to the extremely fine distal reticulum.

Holotype: F8528/3 (–42.3, –97.5), Eneabba Line 3B, 151 m, Parmelia Formation. Pl. 9, fig. 16.

Description: Small, trilete biconvex spores; amb subcircular. Suturae, two-thirds radius in length, bordered by narrow membranous labra less than $2.0\ \mu\text{m}$ high. Exine, $1.0\ \mu\text{m}$ thick; distal surface completely reticulate. Muri, $1.0\ \mu\text{m}$ high, less than $0.5\ \mu\text{m}$ wide, enclosing polygonal to subcircular lumina 1.0 to $3.5\ \mu\text{m}$ in maximum width. Reticulum extending onto proximal surface at apices; contact faces unsculptured.

Dimensions: Diameter of holotype $24\ \mu\text{m}$. Range of diameter (21 specimens) $22(27)30\ \mu\text{m}$.

Remarks: *Retitriletes parvireticulatus* is distinguished from *R. eminulus* by its finer reticulum and smaller size.

Range: *Biretisporites eneabbaensis* and *Balmeiopsis limbata* Zones.

***Retitriletes reticulumsporites* (Rouse) Döring**
and others in Krutzsch 1963
Pl. 9, fig. 17

Dimensions: Diameter (23 specimens) $26(33)36\ \mu\text{m}$.

Remarks: Forms placed in *R. reticulumsporites* possess a low proximal and distal reticulum. The proximal muri exhibit a slight radial orientation.

Range: *Retitriletes watherooensis* to *Balmeiopsis limbata* Zones.

***Retitriletes tenuis* (Balme 1957) comb. nov.**
Pl. 9, figs 18, 19; Pl. 15, figs 9, 10

1957 *Lycopodiumsporites austroclavatidites tenuis* Balme: p. 16, Pl. 1, figs 9–11.

Description: Small trilete spore, biconvex; amb subcircular. Suturae one-half to two-thirds radius in length, enclosed by low membranous labra. Distal surface and most of proximal surface reticulate; muri, 1 to $3\ \mu\text{m}$ high, less than $1\ \mu\text{m}$ wide enclosing polygonal lumina 2 to $6\ \mu\text{m}$ wide. Proximal lumina often irregular in size and smaller than distal lumina. The reticulum diminishes towards the suturae.

Dimensions: Diameter (19 specimens) $18(22)24\ \mu\text{m}$.

Remarks: Balme's subspecies is elevated here to species status on the grounds that it is considerably smaller than, and easily distinguished from, *R. austroclavatidites* (Cookson). It is also considerably smaller than other species of *Retitriletes* reported from the Mesozoic of Australia, with the exception of *R. parvireticulatus* which has a much

finer reticulum. The species is transferred to *Retitriletes* because the sculpture is reticulate rather than foveoreticulate.

Range: Upper *Balmeiopsis limbata* Zone. Balme (1957) recorded this species from Murphy's shaft and a number of other localities in the Perth Basin, but noted that it was common at the Murphy's shaft locality. In this study *R. tenuis* is common in two samples, the topotype material from Murphy's shaft and a sample from Quindalup 9A borehole at 45–85 m. Both samples are from the eastern side of the Bunbury Trough, which suggests that *R. tenuis* originated in a geographically restricted area. Only one other occurrence of *R. tenuis* is recorded in this study, a single specimen from Warnbro 1 at 1 035 m.

***Retitriletes watherooensis* Backhouse 1978**
Pl. 10, figs 1, 3; Pl. 15, fig. 11

Dimensions: Diameter (31 specimens) $32(37)43\ \mu\text{m}$.

Range: *Retitriletes watherooensis* to *Balmeiopsis limbata* Zones.

***Retitriletes* sp. A**
Pl. 10, fig. 2

Description: Trilete biconvex spore; amb subcircular to subtriangular. Suturae, threequarters radius in length, bordered by low labra. Distally and equatorially sculptured with a high reticulum; muri 5 to $9\ \mu\text{m}$ high, less than $1\ \mu\text{m}$ wide, enclosing polygonal lumina 3 to $11\ \mu\text{m}$ in maximum width (usually 4 to $6\ \mu\text{m}$). Contact faces unsculptured.

Dimensions: Diameter (20 specimens) $32(42)52\ \mu\text{m}$.

Remarks: *Retitriletes* sp. A is smaller and has lower muri than *Retitriletes singhii* (Singh) Srivastava 1972. It is a rare form which intergrades with *R. austroclavatidites* (Cookson).

Range: *Biretisporites eneabbaensis* Zone.

***Retitriletes* sp. B**
Pl. 10, fig. 4

Description: Trilete spores, biconvex; amb subtriangular. Suturae two-thirds radius in length, without distinct labra. Exine $1\ \mu\text{m}$ thick, proximal and distal surfaces sculptured with a fine reticulum. Muri about $1\ \mu\text{m}$ high, enclosing lumina 0.5 to $1.5\ \mu\text{m}$ wide; lumina becoming radially elongate and smaller near the suturae.

Dimensions: Diameter (15 specimens) $29(35)40\ \mu\text{m}$.

Remarks: A rare form which may be a morphological variant of *R. watherooensis* Backhouse 1978.

Range: *Retitriteles watherooensis* to *Balmeiopsis limbata* Zones.

Retitriteles sp. C

Pl. 10, fig. 5

Description: Trilete spores, biconvex; amb subcircular. Suturae two-thirds to three-quarters radius in length, with low labra. Exine 1 to 2 μm thick distal and proximal surfaces reticulate. Muri 3 to 4 μm high at equator, 1 μm wide, enclosing lumina of highly irregular size and shape, up to 10 μm in maximum width, often radially elongated on the contact faces.

Dimensions: Diameter (10 specimens) 35(47)57 μm .

Remarks: This species differs from other Australian Mesozoic species of *Retitriteles* by the irregular nature of the reticulum.

Range: *Balmeiopsis limbata* Zone, extremely rare.

Genus **Rogalskaisporites** Danze-Corsin and Laveine 1963

Type species: *Rogalskaisporites cicatricosus* (Rogalska) Danze-Corsin and Laveine 1963.

Rogalskaisporites canaliculus Filatoff 1975
Pl. 10, fig. 6

Dimensions: Diameter (19 specimens) 26(32)36 μm .

Range: *Retitriteles watherooensis* to *Balmeiopsis limbata* Zones.

Genus **Rouseisporites** Pocock 1962

Type species: *Rouseisporites reticulatus* Pocock 1962.

Rouseisporites reticulatus Pocock 1962
Pl. 10, fig. 20

Dimensions: Diameter (9 specimens) 55(66)76 μm .

Range: *Biretisporites encabbaensis* and *Balmeiopsis limbata* Zones.

Genus **Sestrosporites** Dettmann 1963

Type species: *Sestrosporites irregulatus* (Couper) Dettmann 1963.

Sestrosporites pseudoalveolatus (Couper)
Dettmann 1963
Pl. 10, fig. 7

Dimensions: Diameter (11 specimens) 30(40)55 μm .

Range: *Retitriteles watherooensis* to *Balmeiopsis limbata* Zones.

Genus **Staplinisporites** Pocock 1962

Type species: *Staplinisporites caminus* (Balme) Pocock 1962.

Staplinisporites caminus (Balme) Pocock 1962
Pl. 10, fig. 8

Dimensions: Diameter (14 specimens) 34(40)47 μm .

Range: *Retitriteles watherooensis* to *Balmeiopsis limbata* Zones.

Staplinisporites perforatus (Dettmann)
Filatoff 1975
Pl. 10, fig. 10

Dimensions: Diameter (21 specimens) 34(45)53 μm .

Remarks: *Staplinisporites perforatus* is distinguished from *Sestrosporites pseudoalveolatus* (Couper) by possessing a distal circumpolar ridge. The interradian crassitudes of *S. perforatus* are often wide and thin. By contrast, the crassitudes of *Staplinisporites telatus* (Balme) are thicker and narrower and, as noted by Filatoff (1975), are sometimes barely developed.

Range: *Retitriteles watherooensis* to *Balmeiopsis limbata* Zones.

Staplinisporites telatus (Balme) Döring 1965
Pl. 10, figs 9,14; Pl. 15, fig. 12

Dimensions: Diameter (25 specimens) 32(41)51 μm .

Range: *Retitriteles watherooensis* to *Balmeiopsis limbata* Zones.

Genus **Stereisporites** Pflug in Thomson and Pflug 1953

Type species: *Stereisporites steroideus* (Potonié and Venitz) Pflug in Thomson and Pflug 1953.

Stereisporites antiquasporites (Wilson and Webster) Dettmann 1963
Pl. 10, fig. 13

Dimensions: Diameter (15 specimens) 20(24)29 μm .

Range: *Retitrites watherooensis* to *Balmeiopsis limbata* Zones. *Stereisporites antiquasporites* is a rare but widely distributed species in the *R. watherooensis* to *Biretisporites eneabbaensis* Zones. In the *B. limbata* Zone it is occasionally prominent in the spore component of marine assemblages.

Genus **Trilites** Cookson ex Couper 1953

Type species: *Trilites tuberculiformis* Cookson ex Couper 1953.

Trilites sp. cf. **T. tuberculiformis** Cookson 1947
ex Couper 1953
Pl. 10, figs 15, 16

1963 *Trilites* cf. *T. tuberculiformis* Cookson; Dettmann p. 63, Pl. 11, figs 16, 19.

1980a *Triletes* cf. *T. tuberculiformis* Cookson; Burger, p. 56, Pl. 10, figs 3, 4.

Dimensions: Diameter (10 specimens) 35(50)60 μm .

Range: *Biretisporites eneabbaensis* Zone. Previously recorded from the Early Cretaceous of eastern Australia (Dettmann, 1963; Burger, 1980a).

Genus **Undulatisporites** Pflug in Thompson and Pflug 1953

Type species: *Undulatisporites microcutis* Pflug in Thompson and Pflug 1953.

Undulatisporites? pflugii Pocock 1970
Pl. 10, figs 17, 18; Pl. 15, fig. 13

Description: Trilete spores, biconvex; amb subtriangular to subquadrangular. Suturæ tortuously sinuous, particularly near the pole, bordered by low, thick labra. Exine, 1.0 to 1.5 μm thick, coarsely to finely granular, bearing narrow sinuous distal folds resembling suturæ in appearance.

Dimensions: Diameter (19 specimens) 25(33)41 μm .

Range: *Biretisporites eneabbaensis* and *Balmeiopsis limbata* Zones. Previously recorded from the Jurassic of Canada (Pocock, 1970).

Genus **Uvaesporites** Döring 1965

Type species: *Uvaesporites glomeratus* Döring 1965.

Uvaesporites crassibalteus (Filatoff 1975)
comb. nov.
Pl. 10, figs 19, 21

1975 *Leptolepidites crassibalteus* Filatoff, p. 49, Pl. 5, figs 4-6.

1978 *Leptolepidites crassibalteus* Filatoff; Backhouse, p. 17, Pl. 1, figs 8, 9

Dimensions: Diameter (10 specimens) 20(26)32 μm .

Remarks: The development of a cingulum by fusion of the equatorial verrucae justifies the transfer of this species to *Uvaesporites*.

Range: *Retitrites watherooensis* to *Biretisporites eneabbaensis* Zones. In the Perth Basin *U. crassibalteus* has been recorded from the *Klukisporites scaberis* and lower *Contignisporites cooksonae* Zones (Filatoff, 1975), and from the base of the *B. eneabbaensis* Zone (Backhouse, 1978). In the stratigraphic interval between these recorded occurrences I have observed only one specimen.

Genus **Vallizonosporites** Döring 1965

Type species: *Vallizonosporites vallifoveatus* Döring 1965.

Vallizonosporites tegmentus sp. nov.
Pl. 11, figs 1, 2

Derivation of name: Latin, *tegmentus*, covered, referring to the nature of the exoexine.

Holotype: F8356/2 (-26.2, -107.8) Whitfords 1, 387.5 m, South Perth Shale, Pl. 11, fig. 1.

Description: Trilete, biconvex, zonate spore; amb subtriangular to subcircular. Intexinal body rigid and subtriangular with narrow interrædial crassitudes. Exoexine appressed distally and proximally to the intexine, equatorially forming a smooth hyaline zona 3 to 6 μm wide. Suturæ extend to intexinal equator, and bordered by low, narrow labra. Deep foveoreticulate sculpture developed in both exine layers over the proximal and distal intexinal body. Foveolæ separated by sinuous interconnected rugulæ, 0.5 to 1.5 μm in diameter. Sculptural elements decrease in size and disappear at inner margin of the zona.

Dimensions: Diameter of holotype, 51 μm ; intexinal body, 40 μm . Range of diameter (11 specimens) 38(51)64 μm ; intexinal body 34(43)57 μm .

Remarks: The extensive foveoreticulate sculpture distinguishes *V. tegmentus* from other species of *Vallizonosporites* and from species of *Perotrilites*.

Range: *Balmeiopsis limbata* Zone. Most specimens are recorded from the lowest part of this zone.

POLLEN OF THE CYCADOPHYTA

Genus *Alisporites* Daugherty 1941

Type species: *Alisporites opii* Daugherty 1941.

Alisporites grandis (Cookson) Dettmann 1963
Pl. 11, fig. 6

Dimensions: Breadth (20 specimens) 63(79)103 μm ; corpus breadth 34(44)61 μm , corpus length 46(56)65 μm ; saccus breadth 21(28)38 μm , saccus length 45(58)75 μm .

Range: *Retitriletes watherooensis* to *Balmeiopsis limbata* Zones. *Alisporites grandis* constitutes a major part of the microflora in the *R. watherooensis* to *Biretisporites eneabbaensis* Zones, but is rarer in the *B. limbata* Zone.

Alisporites similis (Balme) Dettmann 1963
Pl. 11, figs 3, 4

Dimensions: Breadth (21 specimens) 37(53)65 μm ; corpus breadth 22(31)36 μm , corpus length 29(33)40 μm ; saccus breadth 15(20)25 μm , saccus length 30(35)39 μm .

Range: *Retitriletes watherooensis* to *Balmeiopsis limbata* Zones.

Genus *Cycadopites* Wodehouse 1933 *ex* Wilson and Webster 1946

Type species: *Cycadopites follicularis* Wilson and Webster 1946.

Cycadopites follicularis Wilson and Webster 1946
Pl. 11, fig. 7

Dimensions: Length (12 specimens) 23(32)39 μm .

Range: *Retitriletes watherooensis* to *Balmeiopsis limbata* Zones.

Genus *Vitreisporites* Leschik 1956

Type species: *Vitreisporites signatus* Leschik 1956.

Vitreisporites signatus Leschik 1955

Pl. 11, fig. 5

Dimensions: Breadth (10 specimens) 30(34)39 μm ; corpus breadth 11(14)17 μm , corpus length 14(19)23 μm ; saccus breadth 13(16)20 μm , saccus length 17(19)23 μm .

Range: *Retitriletes watherooensis* to *Balmeiopsis limbata* Zones.

POLLEN OF THE PODOCARPACEAE

Genus *Microcachryidites* Cookson 1947
ex Couper 1953

Type species: *Microcachryidites antarcticus* Cookson 1947.

Microcachryidites antarcticus Cookson 1947
Pl. 16, figs 1, 2

Remarks: Filatoff (1975) gave a comprehensive assessment of the relative size and proportion of *Microcachryidites antarcticus* and *M. castellanosii* Menendez 1968. The specimens assigned to *M. antarcticus* in this study fall within the limits prescribed by Filatoff. The sacchi of *M. antarcticus* are inflated to a varying degree and when not inflated they appear as compressed folded structures. The thickness of the cappa and its surface texture also vary. No biostratigraphic significance is attached to these variations and consequently all forms have been included in *M. antarcticus*.

Range: *Retitriletes watherooensis* to *Balmeiopsis limbata* Zones. *Microcachryidites antarcticus* appears in small numbers in the *R. watherooensis* Zone and becomes more common in the *B. eneabbaensis* Zone. In the *B. limbata* Zone it dominates the miospore assemblage in many samples.

Genus *Podocarpidites* Cookson *ex* Couper 1953

Type species: *Podocarpidites ellipticus* Cookson 1947.

Podocarpidites ellipticus Cookson 1947
Pl. 11, fig. 10

Dimensions: Breadth (14 specimens) 39(56)74 μm ; corpus breadth 26(37)50 μm , corpus length 26(36)55 μm .

Remarks: *Podocarpidites ellipticus* from the Perth Basin has a slightly greater size range than

indicated by Cookson (1947) for the type material. This may be because it is used here as a broad comprehensive taxon. Although it is desirable to subdivide this broad group, it has proved impossible to distinguish different forms on the basis of some consistent morphological difference. The whole group is therefore retained as a single species.

Range: *Retitriletes watheroensis* to *Balmeiopsis limbata* Zones. *Podocarpidites ellipticus* is most abundant in the *B. limbata* Zone.

Podocarpidites sp. cf. P. multesimus
(Bolkhovitina) Pocock 1962
Pl. 11, fig. 8

Dimensions: Total breadth (8 specimens) 63(71)83 μm ; corpus breadth 31(35)42 μm , corpus length 31(33)39 μm ; saccus breadth 27(35)40 μm , saccus length 41(47)51 μm .

Range: *Retitriletes watheroensis* to *Balmeiopsis limbata* Zones.

Podocarpidites sp. A
Pl. 11, fig. 9

Description: Bisaccate, moderately diploxylonoid; corpus subcircular or subelliptical in polar view. Cappa thin, finely granular. Sacci rather narrow, but considerably longer than corpus, joined laterally, sometimes with a substantial lateral width, and virtually monosaccate.

Dimensions: Breadth (7 specimens) 74(84)104 μm ; corpus length 40(44)47 μm , corpus breadth 33(43)55 μm ; saccus length 48(60)75 μm , saccus breadth 28(34)38 μm .

Range: *Biretisporites eneabbaensis* and *Balmeiopsis limbata* Zones, rare.

POLLEN OF THE ARAUCARIACEAE

Genus Araucariacites Cookson 1947
ex Couper 1953

Type species: *Araucariacites australis* Cookson 1947.

Araucariacites australis Cookson 1947
Pl. 11, fig. 17

Range: *Retitriletes watheroensis* to *Balmeiopsis limbata* Zones. Extremely abundant through most of the section studies; *Araucariacites australis* declines in abundance through the *B. limbata* Zone.

Genus Balmeiopsis Archangelsky 1979

Type species: *Balmeiopsis limbata* (Balme) Archangelsky 1979.

Discussion: Archangelsky (1979) proposed the genus *Balmeiopsis* for subspherical pollen with an equatorial thickening, and at one pole a thinned or aperturate exine. The type species *B. limbata* (Balme) was originally described from the Early Cretaceous of the Perth Basin. From my observation of numerous examples of *B. limbata*, ruptures may occur on both distal and proximal surfaces, on only one surface, or the exine may be intact. Since the proximal and distal surfaces are similar in appearance it is impossible to determine which surface is ruptured. It is doubtful that the rupture constitutes a true aperture and is more probably a response to pressure during diagenesis or maceration on the thinnest part of the exine. *Hoegisporis* Cookson 1961 exhibits similar thinning and rupturing in the polar areas and possesses an equatorial rim which consists of discrete nodes rather than a band of regular thickness and width. Rare specimens (Pl. 11, fig. 18) are morphologically intermediate between *Balmeiopsis robusta* sp. nov. and *Hoegisporis uniforma* Cookson. The group of conifers that produced *Balmeiopsis* pollen probably also produced *Hoegisporis*.

Balmeiopsis limbata (Balme) Archangelsky 1979
Pl. 11, figs 11–13; Pl. 16, figs 3–6

- 1957 *Inaperturopollenites limbatus* Balme, p. 31, Pl. 7, figs 83, 84.
- 1964 *Araucariacites cooksonii* Singh and others, p. 300, Pl. 9, figs 117, 118.
- 1967 *Inaperturopollenites limbatus* Balme; Archangelsky and Gamera, Pl. 2, fig. E.
- 1969 *Araucariacites limbatus* (Balme) Habib, p. 91, Pl. 4, fig. 6.
- 1971 *Inaperturopollenites limbatus* Balme; Playford, Pl. 107, fig. 8.
- 1976 *Inaperturopollenites limbatus* Balme; Burger in Norvick and Burger, p. 142, Pl. 29, figs 1–4.
- 1977 *Inaperturopollenites limbatus* Balme; Volkheimer and others, Pl. 2, fig. 6.
- 1979 *Balmeiopsis limbatus* (Balme) Archangelsky, p. 123, Pl. 1, figs 1, 2.

Description: Lenticular pollen grains with a circular amb; always preserved in polar compression. Exine thickened equatorially into a rigid rim (or cingulum), 2.5 to 4.0 μm wide; regular in width on one specimen. Folds arranged parallel to equator, usually located along inner margin of rim. Exine of proximal and distal surfaces thinner and often

ruptured at poles; ruptured exine pulled back towards equator. Under the SEM the exine surface consists of closely spaced perpendicular elements; this produces a finely granular appearance under a light microscope.

Dimensions: Diameter (22 specimens) 60(76)97 μm .

Remarks: The equatorial rim distinguishes *B. limbata* from *Araucariacites australis* Cookson. *Balmeiopsis robusta* sp. nov. is smaller and possesses a wider, slightly lobed rim.

Range: *Balmeiopsis limbata* Zone. Balme (1957) recorded it in the Perth Basin from horizons that are now placed within the Warnbro Group and can be correlated biostratigraphically with the *B. limbata* Zone.

***Balmeiopsis robusta* sp. nov.**

Pl. 11, figs 14–16; Pl. 16, figs 7–9

1979 *Inaperturopollenites* sp. VI McLachlan and Pieterse, Pl. 3, fig. 29.

Derivation of name: Latin, *robustus*, strong.

Holotype: F8551/2 (–28.0, –102.3), Whitfords 4, 503 m, Leederville Formation, Pl. 11, fig. 16.

Description: Lenticular pollen grains preserved in polar compression with a circular, subtriangular, or subquadrangular amb. Equatorial margin thickened to form a broad equatorial rim (or cingulum) of regular or, more usually, irregular width 3 to 12 μm wide; exine often folded along inner margin of equatorial rim. Exine less than 1 μm thick distally and proximally. One, or both, proximal and distal exinal surfaces may be ruptured and folded back. Under the SEM the exine surface consists of small closely spaced elements, as on *B. limbata*.

Dimensions: Diameter of holotype 60 μm . Range of diameter (30 specimens) 39(55)74 μm .

Remarks: *Balmeiopsis robusta* is smaller than *B. limbata* and possesses a thicker equatorial rim. Because of these differences *B. robusta* is less prone to distortion and rupture of the exine. Several forms recorded as *Cychusphaera* spp. by Volkheimer and others (1977) and Archangelsky (1979) are similar to *B. robusta* and may belong to this species. A large form of this species with a broad rim of even width appears in the upper part of the *B. limbata* Zone. This form is included here in *B. robusta*, but its apparent stratigraphic significance may justify the erection of a new species at a later stage.

Range: *Balmeiopsis limbata* Zone.

Genus *Callialasporites* Sukh Dev 1961

Type species: *Callialasporites trilobatus*.

***Callialasporites dampieri* (Balme) Sukh Dev 1961**

Range: *Retitriletes watherooensis* to *Balmeiopsis limbata* Zones.

***Callialasporites segmentatus* (Balme)
Srivastava 1963**

Range: *Retitriletes watherooensis* to *Balmeiopsis limbata* Zones.

***Callialasporites trilobatus* (Balme) Sukh Dev 1961**

Range: *Retitriletes watherooensis* to *Balmeiopsis limbata* Zones.

***Callialasporites turbatus* (Balme) Schulz 1967**

Range: *Retitriletes watherooensis* to lower *Balmeiopsis limbata* Zones. Rare throughout the sequence, except in occasional samples in the *R. watherooensis* Zone and in the lower *B. limbata* Zone where it may be reworked.

POLLEN OF THE CHEIROLEPIDACEAE

Genus *Classopollis* Pflug 1953

Type species: *Classopollis classoides* Pflug 1953

***Classopollis chateaunovi* Reyre 1970
Pl. 16, fig. 10**

Remarks: Most if not all *Classopollis* pollen in the Upper Jurassic and Early Cretaceous of the Perth Basin belong to this species. The environmental factors controlling the distribution of *Classopollis* pollen have been demonstrated by previous workers (Médus and Pons, 1967; Batten, 1974; Srivastava, 1976; Filatoff, 1975). Briefly, *Classopollis* is more abundant in near-shore marine sediments than in deltaic, lagoonal, or fluvial sequences. In the Perth Basin *C. chateaunovi* usually constitutes less than 2% of the total palynomorph count in the non-marine Yarragadee and Parmelia Formations. Its frequency increases in the Warnbro Group, where it may comprise 40% of the total palynomorph count in some marine samples.

Range: *Retitriletes watherooensis* to *Balmeiopsis limbata* Zones.

MICROPLANKTON

DINOFLAGELLATE CYSTS

Genus *Achomosphaera* Evitt 1963

Type species: *Achomosphaera ramulifera* (Deflandre) Evitt 1963

Achomosphaera sp. A

Pl. 17, figs 10, 11

Description: Cyst skolechorate, body subspherical to ovoid, bearing trifurcate and occasionally bifurcate processes, usually gonal in position, but probably including a few intergonal processes. Processes finely fibrous, some with a narrow hollow core, 9 to 20 μm in length to the point of furcation; bases connected by low septa. Processes connected across paracingulum by high septa. Paratabulation indicated by processes, septa, and archeopyle; formula not elucidated. Archeopyle apparently precingular, type P, operculum free.

Dimensions: Range of cyst body length (6 specimens) 56(64)72 μm , width 38(50)57 μm .

Remarks: Gocht (1959), Davey and Williams (1966a), Davey (1974), and Duxbury (1977, 1980) have referred similar forms to *Achomosphaera neptuni* (Eisenack) Davey and Williams 1966a or to *A. sp. cf. A. neptuni*. *Achomosphaera* sp. A possesses narrower processes than *A. neptuni*, and the processes are shorter in relation to cyst body size.

Range: *Kaiwaradinium scrutillinum* to basal *Aprobolocysta alata* Zones.

Genus *Aprobolocysta* Duxbury 1977

Type species: *Aprobolocysta eilema* Duxbury 1977.

Aprobolocysta alata Backhouse 1987

Pl. 17, figs 1–3

Range: *Phoberocysta lowryi* to *Batioladinium jaegeri* Zones.

Aprobolocysta bipartita Backhouse 1987

Pl. 17, figs 4–6

Range: *Phoberocysta lowryi* Zone.

Aprobolocysta galeata Backhouse 1987

Pl. 17, figs 7–9

Range: *Kaiwaradinium scrutillinum* Zone.

Genus *Apteodinium* Eisenack 1958b

Type species: *Apteodinium granulatum* Eisenack 1958b.

Apteodinium maculatum Eisenack and

Cookson 1960

Pl. 18, figs 1–3

1960 *Apteodinium maculatum* Eisenack and Cookson, p. 4, Pl. 2, figs 1–3.

1960 *Apteodinium conjunctum* Eisenack and Cookson, p. 5, Pl. 1, figs 7, 8.

1966b *Apteodinium maculatum* Eisenack and Cookson; Sarjeant, p. 205, Pl. 22, fig. 1.

1968 *Apteodinium maculatum* Eisenack and Cookson; Cookson and Eisenack 1968, p. 117, fig. 3F.

1976 *Apteodinium maculatum* Eisenack and Cookson; Norvick, p. 38, Pl. 2, fig. 9.

1980a *Apteodinium maculatum* Eisenack and Cookson; Burger, p. 80, Pl. 36, figs 2, 3.

1980a *Apteodinium maculatum* Eisenack and Cookson; Morgan, p. 16, Pl. 2, fig. 5.

non 1970 *Apteodinium maculatum* Eisenack and Cookson; Habib, p. 370, Pl. 8, fig. 7.

non 1980a *Apteodinium conjunctum* Eisenack and Cookson; Burger, p. 80, Pl. 36, fig. 1.

Dimensions: Length including apical horn (10 specimens) 61(74)87 μm , width 51(61)78 μm , length of apical horn 3–9 μm .

Remarks: The only difference between *Apteodinium maculatum* and *A. conjunctum* is the presence on the surface of *A. maculatum* of small circular areas with lighter surrounding zones. I consider these to be secondary features resulting from prolonged maceration. Similar structures can be seen on *Cribroperidinium delicatum* sp. nov. which possesses a granular autophragm similar in composition to that of *A. maculatum*. *Apteodinium conjunctum* is therefore placed in synonymy with *A. maculatum*.

Range: *Aprobolocysta alata* to *Fromea monilifera* Zones.

Apteodinium sp. A

Pl. 18, figs 4–6

Description: Cysts medium-sized, proximate and ovoid. Autophragm 2 to 3 μm thick, rigid and only rarely folded; surface finely granular. Apical horn bluntly rounded, 3 to 5 μm long. Paracingulum barely discernible, expressed by low transverse ridges; precingular and postcingular septa sometimes weakly developed. Archeopyle precingular, type P, operculum free.

Dimensions: Length including apical horn (6 specimens) 74(77)88 μm , width 59(66)72 μm .

Remarks: *Apteodinium* sp. A possesses a substantially thicker, more rigid autophragm than

A. maculatum Eisenack and Cookson. *Apteodinium grande* Cookson and Hughes 1964 is considerably larger than *Apteodinium* sp. A.

Range: Upper *Kaiwaradinium scrutillinum* Zone. Recorded from only one sample, Gage Roads 1 at 1 477 m.

Genus *Areosphaeridium* Eaton 1971

Type species: *Areosphaeridium diktyoplokus* (Klump) Eaton 1971

Areosphaeridium? sp. A

Description: Cyst skolochorate, body subspherical to ovoid, bearing 19 to 23 intratabular processes. Cyst body thin and easily folded. Processes solid, 13 to 19 μm long, rising from bases approximately 3 μm in diameter tapering to less than 1 μm diameter. Tips of processes flared and denticulate, with individual spines up to 5 μm long. Paratabulation indicated by archeopyle suture and process distribution. Tentative process formula, based largely on one well-oriented specimen, 4', 6'', 0c, 6''', 1p, 1''', 1-4s. Archeopyle apical, type [tA], operculum free on most specimens.

Dimensions: Width of cyst body (8 specimens) 26(30)39 μm .

Remarks: Too few well-preserved specimens of this species have been located to justify the erection of a new species. *Hystichosphaeridium? phoenix* Duxbury 1980 bears longer spines on the distal tips of the processes than the present species.

Range: *Kaiwaradinium scrutillinum* to *Aprobolocysta alata* Zones

Genus *Avellodinium* Duxbury 1977 emend.

Type species: *Avellodinium falsificum* Duxbury 1977.

Remarks: *Avellodinium* is herein emended to include species with long, dichotomously branched intergonal processes similar in size and shape to the trifurcate gonial processes. The number of paraplates in the apical series is emended from 3 to 3 or 4.

The long processes and essentially chorate form distinguish *Avellodinium* from *Ctenidodinium* Deflandre 1938. As Lentin and Williams (1981) point out, *Avellodinium* is distinguished from *Callaiosphaeridium* Davey and Williams 1966a by the nature of its processes.

Avellodinium lepidum sp. nov

Pl. 19, figs 3-7; Pl. 47, fig. 1

Derivation of name: Latin, *lepidus*, graceful, referring to the nature of the processes.

Holotype: F8357/16 (-36.4, -103.6) Whitfords 1, 405 m, South Perth Shale, Pl. 19, fig. 6.

Description: Chorate cysts, body ovoid to subspherical Endophragm smooth, 1 μm thick, periphragm appressed to endophragm except where it forms trifurcate gonial processes or parasutural features. Gonial processes sometimes connected by low parasutural septa. One or two bifurcate intergonal parasutural processes situated on longer parasutures whether parasutural septa are evident or not. Processes 12 to 25 μm long, similar in length on one specimen, 1 to 2 μm thick near the base, bifurcating one-half to two-thirds of the distance from the base into slender spines which bifurcate again near the tip. Paratabulation indicated by low parasutural septa, and by position of gonial and intergonal processes, formula: 4', 6'', Xc, 5''', 1p, 1''', paraplates 1''' to 5''' in the 2''' to 6''' paraplate positions. Paracingulum 5 μm wide indicated by low septa and sometimes by fused gonial processes, offset approximately one cingulum width. Archeopyle combination epicystal, type [tAtP], often attached at parasulcal tab.

Dimensions: Cyst body length of holotype approximately 54 μm , width approximately 57 μm . Range of cyst body length (15 specimens) 42(50)61 μm , width 37(44)57 μm .

Remarks: *Ctenidodinium panneum* (Norris) Lentin and Williams 1973, *C. tenellum* Deflandre 1938b, *C. cumulum* (Norris) Lentin and Williams 1973, and *C. elegantulum* Millioud 1969 all possess spinose parasutural septa, but in each case the spines are more numerous than those of *A. lepidum* and are not furcate.

Avellodinium lepidum is distinguished from *A. falsificum* Duxbury 1977 by possessing intergonal processes and lower parasutural septa.

Range: *Kaiwaradinium scrutillinum* to *Fromea monilifera* Zones.

Genus *Batiacasphaera* Drugg 1970

Type species: *Batiacasphaera compta* Drugg 1970

Batiacasphaera asperata Backhouse 1987

Pl. 19, figs 8, 9; Pl. 47, fig. 6

Range: *Kaiwaradinium scrutillinum* and *Phoberocysta lowryi* Zones.

Batiacasphaera ovata Backhouse 1987

Pl. 18, figs 7–9

Range: Mid *Phoberocysta lowryi* Zone.

Batiacasphaera sp. A

Pl. 20, figs 1–4

Description: Cysts ovoid to subspherical; autophragm 2 to 4 μm thick, usually unfolded, evenly sculptured with low, closely spaced rugulae; sculptural elements fused along margin of archeopyle suture. Archeopyle apical, type [tA], operculum free; archeopyle width considerably less than maximum cyst width. Archeopyle suture and poorly developed accessory sutures indicate six precingular paraplates. Autophragm sometimes fractured along accessory sutures.

Dimensions: Length with archeopyle formed (4 specimens) 76(82)97 μm , width 76(84)89 μm .

Remarks: The small archeopyle and the thick, rigid, finely sculptured autophragm are unlike any previously described species of *Batiacasphaera*.

Range: *Fromea monilifera* Zone.

Genus **Batioladinium** Brideaux 1975

Type species: *Batioladinium jaegeri* (Alberti) Brideaux 1975.

Discussion. In the original concept of Brideaux (1975) *Batioladinium* incorporates cysts with an autophragm, one apical and two antapical horns, and an apical archeopyle with a deep sulcal notch. Paratabulation is absent except as expressed by the archeopyle suture. *Batioladinium* was regarded as a junior synonym of *Imbatodinium* Vozzhenikova 1967 emended Dörhöfer and Davies 1980 by Dörhöfer and Davies (1980). From the illustrations in Vozzhenikova (1967) the type of *Imbatodinium*, *I. kondratjevi* Vozzhenikova 1967, appears to possess an intercalary rather than an apical archeopyle. The placing of *Batioladinium* into synonymy with *Imbatodinium* is therefore rejected.

Batioladinium jaegeri (Alberti) Brideaux 1975

Pl. 21, figs 1–3

Dimensions: Length with archeopyle formed (8 specimens) 60(73)89 μm , width 24(29)34 μm .

Range: *Batioladinium jaegeri* and *Fromea monilifera* Zones.

Originally recorded from the late Barremian (Alberti, 1961) and subsequently from the Berriasian (Bujak and Williams, 1978) to Albian

(Cookson and Hughes, 1964; Davey and Verdier, 1973; Morgan, 1980).

Batioladinium longicornutum (Alberti)

Brideaux 1975

Pl. 21, fig. 7

Dimensions: Length of one specimen 139 μm , width 21 μm .

Remarks: *Batioladinium longicornutum* represents the limit of the morphological range of the cyst lineage which starts with the short-horned *B. micropodum* and ranges through *B. jaegeri* to *B. longicornutum*. The three species are distinguished by the lengths of their horns and by the elongation of the cyst body.

Range: *Fromea monilifera* Zone (one specimen). *Batioladinium longicornutum* has a previously recorded range of late Hauterivian to late Barremian (Alberti, 1961; Brideaux, 1975).

Batioladinium micropodum (Eisenack and

Cookson) Brideaux 1975

Pl. 21, figs 4–6

Dimensions: Total length (8 specimens) 61(74)101 μm , length with archeopyle formed (7 specimens) 48(53)58 μm , width 25(33)38 μm .

Range: *Kaiwaradinium scrutillinum* to *Fromea monilifera* Zones.

Genus **Belodinium** Cookson and Eisenack 1960b

Type species: *Belodinium dysculum* Cookson and Eisenack 1960b.

Belodinium sp. A

Pl. 21, figs 8, 9

Dimensions: Total length (1 specimen) 92 μm , length without operculum (6 specimens) 47(53)57 μm , width 28(34)37 μm .

Remarks: Both specimens of *Belodinium dysculum* illustrated by Cookson and Eisenack (1960b) show antapical pericoels which are broader than that of *Belodinium* sp. A. The apical horn of *Belodinium* sp. A is also larger than that on the holotype of *B. dysculum* (Cookson and Eisenack, 1960b, Pl. 37, fig. 14). *Belodinium* sp. A is further differentiated from *B. dysculum* by possessing a less distinct paracingulum.

The ranges of the two species of *Belodinium* appear to be widely disparate. *Belodinium dysculum* is not recorded above the Tithonian, whereas *Belodinium* sp. A is recorded in the Perth

Basin only from the late Neocomian and early Aptian.

Range: *Batiolodinium jaegeri* Zone. Other examples of *Belodinium* sp. A are recorded at a similar stratigraphic level from north-western Australia in unpublished oil company reports (B.S. Ingram and J. Wiseman pers. comm.).

Genus **Canningia** Cookson and Eisenack 1960b

Type species: *Canningia reticulata* Cookson and Eisenack 1960b.

Canningia transitoria Stover and Helby 1987
Pl. 21, figs. 10, 11; Pl. 22, figs. 1, 2

Description: Medium-sized lenticular cysts, parasulcal notch offset. Asymmetrical outline showing a low apical horn and two low broad antapical horns or bulges. Autophragm smooth, 0.5 to 1 μm thick; autocyst with an apical horn, a left antapical horn, and sometimes a rudimentary right antapical horn. Ectophragm membranous, bearing round or oval perforations, supported by widely spaced non-tabular membranous spines and septa. Ectocoel widest at horns and in lateral paracingular area; autophragm and ectophragm appressed over mid-dorsal and mid-ventral surfaces. Ectophragmal right and left antapical horns well developed. Paratabulation incompletely expressed by low indistinct pandastural ridges on the ectophragm and closely spaced ectophragm-supporting septa. Paratabulation formula 4', Oa, 6'', Xc, 6''', 1p, 1'''. Parasulcus narrow and poorly expressed. Paracingulum, 3 to 4 μm wide, offset approximately twice its width. Archeopyle apical, type [tA], operculum free.

Dimensions: Range of length without operculum (15 specimens) 57(70)83 μm , width 62(78)101 μm .

Remarks: *Canningia transitoria* is comparable to *C. reticulata* Cookson and Eisenack 1960b in the relationship of the wall layers and in overall shape. It is distinguished from *C. reticulata* by possessing a well-developed ectophragm supported by membranous structures and bearing large perforations. In this respect *C. transitoria* is comparable to species of *Endoceratium* Vozzhenikova 1965. For a comparison with *C. grandis* Helby 1987, see Stover and Helby, 1987.

Range: *Aprobolocysta alata* and *Batiolodinium jaegeri* Zones. Stover and Helby record this species from a similar biostratigraphic level in Houtman I well in the Abrolhos Sub-basin of the northern Perth Basin.

Canningia reticulata Cookson and Eisenack 1960b
Pl. 22, figs. 3–6

1960b *Canningia reticulata* Cookson and Eisenack, p. 251, Pl. 38, figs. 1, 2.

1977 *Canningia* cf. *reticulata* Cookson and Eisenack; Duxbury, p. 26, Pl. 8, fig. 6, Pl. 9, fig. 1.

Description: Proximate cyst, lenticular, with an offset parasulcal notch. Autophragm bears numerous fine intratabular spines joined distally to form an ectophragm. Autocyst with short rounded apical horn and two low antapical horns or bulges. Ectophragm appressed to autophragm in mid-dorsal and mid-ventral areas, peripherally raised on numerous fine spines, and attaining a maximum separation from the autophragm at the horns and lateral paracingular areas. Narrow strips devoid of spines and bordered by higher spines delineate a variably developed paratabulation. Paratabulation formula: ?4', 6'', ?6c, 6''', 1p, 1'''. Paraplates of apical series not distinguished with certainty. Parasulcus indicated only by archeopyle suture. Archeopyle apical, type [tA], operculum free.

Dimensions: Range of length without operculum (17 specimens) 52(64)80 μm , width 64(77)101 μm .

Remarks: *Canningia palliata* Brideaux 1977 is similar to *C. reticulata* but, according to Brideaux (1977), it is not tabulate. The overall shape and distribution of surface features on *C. reticulata* is similar to species of *Cyclonephelium*, and in particular to *C. hystrix* (Eisenack) Davey 1978.

Range: *Gagiella mutabilis* to *Aprobolocysta alata* Zones. Previously recorded from the Tithonian of Western Australia (Cookson and Eisenack, 1960b), the Cretaceous of northwestern Australia (Helby, 1987), and the Hauterivian section of the Speeton Clay in England (Duxbury, 1977).

Genus **Canninginopsis** Cookson and Eisenack 1962b

Type species: *Canninginopsis denticulata* Cookson and Eisenack 1962b.

Canninginopsis colliveri (Cookson and Eisenack 1960b) comb. nov.
Pl. 22, figs 7–9

1960b *Canningia colliveri* Cookson and Eisenack, p. 251, Pl. 38, figs 3, 4.

1980a *Canningia colliveri* Cookson and Eisenack; Burger, p. 71, Pl. 21, figs 1–3.

1980a *Canningia* sp. A Burger, p. 71, Pl. 21, fig. 4.

1980a *Canningia* sp. A Morgan, p. 17, Pl. 2, figs 17, 18; Pl. 3, figs 1–3.

Dimensions: Range of length without operculum (10 specimens) 62(68)72 μm , width 72(80)89 μm .

Remarks: The genus *Canninginopsis* currently contains two species, the type *C. denticulata* Cookson and Eisenack 1960b and *C. intermedia* Morgan 1980a. *Canninginopsis denticulata* is a lenticular cyst whose outline displays an apical bulge and two low antapical bulges or horns as well as slight lateral bulges. It possesses complete paratabulation that is indicated by parasutural rows of grana. *Canninginopsis intermedia* is identical in shape to *C. denticulata*, and displays an incomplete paratabulation indicated by rows of penitabular grana. *Canninginopsis colliveri* also belongs in this group of cysts; it is the same shape as *C. denticulata* and *C. intermedia*, but can be differentiated from these species by the absence of paratabular features. Faint, partial paratabulation is expressed on a few specimens by narrow strips devoid of the normal, fine surface granulation. These specimens occur in the same samples as completely non-tabulate examples, which suggests that the presence of paratabulation is a variable feature. Forms with paratabulation are probably the precursors of *C. intermedia*. The granular forms assigned to *Canningia* sp. A. by Morgan (1980a) and Burger (1980a) are a variety of *C. colliveri*.

Range: *Fromea monilifera* Zone. Australian records of *C. colliveri* are from the Late Neocomian to Cenomanian (Cookson and Eisenack, 1960b; Burger, 1980a; Morgan, 1980a).

Genus *Cassiculosphaeridia* Davey 1969.

Type species: *Cassiculosphaeridia reticulata* Davey 1969

Cassiculosphaeridia magna Davey 1974

Pl. 20, figs 5–7

Dimensions: Range of length without operculum (16 specimens) 64(82)97 μm , width 74(93)115 μm .

Remarks: Most specimens of *Cassiculosphaeridia magna* encountered in this study conform with the type description in possessing a coarse reticulum (individual lumina 2 to 12 μm in maximum diameter). In the *Phoberocysta lowryi* Zone a form which is smaller and also possesses smaller lumina (2 to 5 μm in maximum diameter) appears, and becomes common in the *Fromea monilifera* Zone. This form occurs with, and intergrades with, the larger form.

Range: *Gagiella mutabilis* to *Fromea monilifera* Zones.

Cassiculosphaeridia pygmaea Stevens 1987

Pl. 20, figs 8–11

1976 *Dictyopyxidina* aff. *circulata* Clarke and Cerdier; Kemp, Pl. 1, figs 7, 8.

1980a *Cassiculosphaeridia* cf. *C. reticulata* Davey; Burger; p. 72, Pl. 27, figs 7–6.

1980a *Cassiculosphaeridia reticulata* Davey; Morgan, p. 144, Pl. 5, figs 14–17.

1981 *Cassiculosphaeridia reticulata* Davey; Beloe, p. 33, Pl. 10, fig. 7.

1987 *Cassiculosphaeridia pygmaea* Stevens, p. 186, Fig. 4L–Q.

Description: Small proximate cysts, subspherical to ovoid without protruberances. Autophragm, approximately 0.5 μm thick, bearing a fine, non-tabulate, complete or slightly incomplete reticulum. Muri of reticulum, 0.5 to 2.0 μm high, 0.5 to 2.0 μm in basal width, enclosing polygonal lumina 1.5 to 5.0 μm in maximum diameter. Paratabulation not indicated by surface features. Paracingulum and parasulcus not indicated. Archeopyle apical, type [tA], operculum often attached by parasulcal tab. Six precingular paraplates indicated by archeopyle suture and accessory sutures. No other evidence of paratabulation.

Dimensions: Range of length without operculum (19 specimens) 34(41)55 μm total length (5 specimens) 43(51)57 μm , width 36(47)57 μm .

Remarks: The surface reticulum of *Cassiculosphaeridia pygmaea* is composed of considerably finer muri and lumina than the reticulum of *C. reticulata* Davey 1969 and *C. magna* Davey 1974. *Cassiculosphaeridia pygmaea* is also considerably smaller than *C. magna*.

Range: *Phoberocysta lowryi* to *Fromea monilifera* Zones. Morgan (1980a) records this species (as *C. reticulata*) as high as the Cenomanian, and Stevens (1987) records it from the Berriasian.

Genus *Cernocysta* Stover and Helby 1987

Type species: *Cernocysta helbyi* (Morgan) Stover and Helby 1987.

Cernocysta helbyi (Morgan) Stover and

Helby 1987

Pl. 32, figs 6, 7

1980a *Lithodinia helbyi* Morgan, p. 26, Pl. 18, figs 4–7.

Dimensions: Range of length without operculum (13 specimens) 31(38)43 μm , width 34(37)45 μm .

Remarks: All the measured specimens possess low parasutural septa (less than 4 μm high). A single specimen with high parasutural septa is recorded from the *Fromea monilifera* Zone.

Range: *Aprobolocysta alata* to *Fromea monilifera* Zones.

Genus *Cleistosphaeridium* Davey and others 1966

Type species: *Cleistosphaeridium diversispinosum* Davey and others 1966.

Cleistosphaeridium ancoriferum (Cookson and Eisenack) Davey and others 1966
Pl. 22, fig. 10

Dimensions: Range of cyst body diameter (17 specimens) 30(38)46 μm , length of processes 3–7 μm .

Remarks: Cysts of this type are widely recorded and have usually been assigned to *Cleistosphaeridium huguoniotii* (Valensi) Davey 1969 or *C. ancoriferum*, species which Clarke and Verdier (1967) considered to be synonymous. They are assigned here to *C. ancoriferum* because the mode of preservation of the holotype of *C. huguoniotii* renders close examination impossible (Stover and Evitt, 1978, p. 32). The processes of the present examples are more numerous and shorter than those of the holotype. Forms identical to the holotype are common in Albian–Cenomanian sediments in the Perth Basin, but in the absence of other distinguishing features all forms are herein retained in *C. ancoriferum*. Despite Cookson and Eisenack's (1968) opinion an apical archeopyle is formed in this species.

Range: *Kaiwaradinium scrutillinum* to *Fromea monilifera* Zones. All previous records of *C. ancoriferum* and *C. huguoniotii* are from the Albian or Cenomanian, with the exception of those of Davey (1974) and Morgan (1980a) who reported it from the Barremian and Aptian respectively.

***Cleistosphaeridium?* sp. A**
Pl. 22, figs 11–13; Pl. 23, fig. 5

Description: Cyst proximochorate, body subspherical, bearing 150 to 200 non-tabular processes. Autophragm fibrous, evenly and finely punctate; fibres from autophragm forming processes. Processes fibrous, 7 to 10 μm long, 1 to 6 μm in basal diameter, tapered, sometimes branched, distally slightly flared and truncated. Paracingulum weakly expressed by alignment of processes along transverse parasutures, and absence of processes from some central intracingular

areas. Parasulcus indicated only by parasulcal notch. Archeopyle apical, probably type [tA]; archeopyle suture indicates 6 precingular paraplates.

Dimensions: Range of cyst body length without operculum (6 specimens) 38(45)49 μm , width 46(48)51 μm .

Remarks: On gross morphology this species is provisionally assigned to *Cleistosphaeridium*. the fibrous structure of the autophragm and spines distinguish it from other species of *Cleistosphaeridium*. Other Early Cretaceous cysts with fibrous wall structures possess precingular archeopyles and are assigned to *Exochosphaeridium* Davey and others 1966. The apical archeopyle of this species excludes it from *Exochosphaeridium*, but the wall structure can be taken to indicate a genetic affinity with *E. robustum* sp. nov. and *E. truncatum* (Davey) Stover and Evitt 1978.

Range: *Kaiwaradinium scrutillinum* Zone.

Genus *Coronifera* Cookson and Eisenack 1958

Type species: *Coronifera oceanica* Cookson and Eisenack 1958.

Coronifera oceanica Cookson and Eisenack 1958
Pl. 23, fig. 6

Dimensions: Cyst body width (6 specimens) 37(44)47 μm .

Range: Upper *Aprobolocysta alata* to *Fromea monilifera* Zones. Previous records of *Coronifera oceanica* range from the late Hauterivian (Millioud, 1969; Davey, 1974; Duxbury, 1977) into the Late Cretaceous.

Genus *Cribroperidinium* Neale and Sarjeant 1962

Type species: *Cribroperidinium sepimentum* Neale and Sarjeant 1962.

Remarks: Representatives of this genus in the Warnbro Group all possess a granular, almost spongy cyst wall, which under high magnification is usually seen to be micropunctate. Many specimens are poorly preserved, and broken specimens are common. The numerous septa and accessory ridges, the unfavourable orientation of many specimens, and the general interspecific similarity of wall structure and paratabulation further hinder identification. In addition to the six species described below other species may be present and represented by some of the many unidentifiable specimens encountered during this study.

Cribroperidinium delicatum sp. nov.

Pl. 23, figs 1–4

Derivation of name: Latin, *delicatus*, delicate.

Holotype: F11493/1 (–54.2, –95.6), Artesian Monitoring 41, 413 m, South Perth Shale, Pl. 23, fig. 4.

Description: Cyst proximate, ovoid, with a short apical horn and a rounded antapex. Autophragm $1\mu\text{m}$ thick, finely granular. Paratabulation expressed by low granular parasutural septa, usually less than $1\mu\text{m}$ high, sometimes high and membranous at the paracingulum and antapex. Precingular and postcingular intratabular areas bear low accessory ridges. Paratabulation formula: $4', 6'', 6c, 6''', 1p, 1'''$. Paracingulum clearly expressed, 3 to $5\mu\text{m}$ wide, offset approximately $8\mu\text{m}$. Parasulcus, including an indeterminate number of parasulcal paraplates, expressed by low septa. Apical horn solid, granular, 6 to $15\mu\text{m}$ long, bearing a small preapical tip. Archeopyle precingular, type P, operculum free.

Dimensions: Length of holotype $68\mu\text{m}$, width $56\mu\text{m}$. Range of length including apical horn (14 specimens) $64(80)97\mu\text{m}$, width $51(61)74\mu\text{m}$.

Remarks: *Cribroperidinium delicatum* is significantly smaller than previously described species of *Cribroperidinium*. It is distinguished from *C. muderongense* (Cookson and Eisenack) Davey 1969 by possessing lower surface features and a shorter apical horn.

Range: *Kaiwaradinium scrutillinum* to *Batioladinium jaegeri* Zones, rare above the *Phoberocysta lowryi* Zone.

Cribroperidinium leedervillense sp. nov.

Pl. 23, figs 7–9; Pl. 24, fig. 1; Pl. 47, fig. 2

Derivation of name: After the Leederville Formation.

Holotype: F8356/9 (–36.4, –104.1), Whitfords 1, 387.5 m, South Perth Shale, Pl. 23, fig. 7.

Description: Cyst proximate, subspherical to ovoidal, with a long apical horn. Autophragm finely granular, micropunctate, $1\mu\text{m}$ thick. Paratabulation expressed by low, fibrous, parasutural septa up to $4\mu\text{m}$ high, and associated small spines. Paratabulation formula: $?4', 6''', Xc, 6''', ?1p, 1'''$. Intratabular areas bear occasional small spines, and on precingular and postcingular paraplates low, poorly defined accessory ridges. Paracingulum narrow and prominent, 2 to $4\mu\text{m}$ wide, offset approximately $15\mu\text{m}$, bordered by high fibrous septa up to $9\mu\text{m}$ high. Parasulcus expressed by low septa. Apical horn rises from a

conical base formed by the autophragm, and continues as a fibrous, punctate extension of the parasutural septa, and ends in a small preapical tip. Total length of horn 36 to $60\mu\text{m}$. Archeopyle precingular, type P, operculum free.

Dimensions: Length of holotype $157\mu\text{m}$, width $111\mu\text{m}$. Range of length including apical horn (12 specimens) $133(147)172\mu\text{m}$, width $93(104)115\mu\text{m}$.

Remarks: The large size, narrow paracingulum, absence of prominent intratabular features, and long fibrous apical horn distinguish *C. leedervillense* from other Early Cretaceous species of *Cribroperidinium*.

Range: *Kaiwaradinium scrutillinum* to *Batioladinium jaegeri* Zones. Notably common in some samples from the lower part of the Leederville Formation in the Perth area.

Cribroperidinium muderongense (Cookson and

Eisenack) Davey 1969

Pl. 24, figs 2–6

1958 *Gonyaulax muderongensis* Cookson and Eisenack, p. 32, Pl. 3, figs 3, 4.

1958 *Gonyaulax diaphanis* Cookson and Eisenack, p. 36, Pl. 3, figs 13, 14.

1969 *Cribroperidinium muderongense* (Cookson and Eisenack), Davey, p. 128.

Description: Cyst proximate, body ovoidal, with a prominent apical horn. Autophragm finely granular, $1\mu\text{m}$ or less thick. Paratabulation fully expressed by parasutural septa, formula: $4', 6'', 1p, 1'''$, ?5s. Septa membranous, supported by spines up to $4\mu\text{m}$ high. Spines are numerous along the paracingular septa. Intratabular areas of the precingular and postcingular plate series bear truncate spines up to $4\mu\text{m}$ high and spinose accessory ridges, usually one well-developed ridge on each paraplate. Paracingulum 4 to $5\mu\text{m}$ wide, offset 10 to $15\mu\text{m}$. Parasulcus and parasulcal paraplates clearly indicated by low non-spinose septa. Apical horn 12 to $26\mu\text{m}$ long, distally solid, with a well-developed preapical tip. Archeopyle precingular, type P, operculum free.

Dimensions: Range of length including apical horn (19 specimens) $76(96)134\mu\text{m}$, width $50(72)101\mu\text{m}$.

Remarks: Specimens of *C. muderongense* from the *F. monilifera* Zone bear a slightly shorter untipped apical horn (Pl. 24, fig. 5; Morgan 1980a, Pl. 7, figs 6–8), but are otherwise similar to the stratigraphically lower forms. *Cribroperidinium edwardsii* (Cookson and Eisenack) Davey 1969 possesses a long, smooth, generally untipped apical

horn, less spinose parasutural septa, fewer intratabular spines, and a more spherical cyst body.

I consider the holotype of *Cribroperidinium diaphanis* (Cookson and Eisenack) Stover and Evitt 1978 to be indistinguishable from *C. muderongense* in the style of the surface features and in the length and shape of the apical horn. The spinose nature of the parasutural septa has been rather exaggerated in the illustrations by Cookson and Eisenack (1958, Figs 10, 11)

Specimens assigned by Norvick *in* Norvick and Burger (1976) to *C. muderongense* are probably *C. edwardsii*.

Range: *Phoberocysta lowryi* to *Fromea monilifera* Zones.

Cribroperidinium sp. A

Pl. 24, figs 7, 8

Description: Cyst proximate, ovoidal with a long apical horn. Autophragm 1 μm or less thick, finely granular. Paratabulation expressed by low parasutural septa, less than 2 μm high, sometimes with small denticulate spines sparsely distributed along crests. Paratabulation formula not elucidated. Intratabular areas bear low accessory ridges and sometimes a few spines. Paracingulum narrow (4 μm or less), offset an indeterminate distance, and bordered by slightly higher septa. Parasulcus weakly expressed. Apical horn long (45 to 54 μm on 6 measured specimens), formed by autophragm with low denticulate septa extending along its full length, and capped by a small preapical tip. Archeopyle precingular, type P, operculum free.

Dimensions: Range of length including apical horn (6 specimens) 121(131)144 μm , width 75(86)97 μm .

Remarks: *Cribroperidinium* sp. A is distinguished from *C. leedervillense* sp. nov. by the extension of the autophragm for the full length of the apical horn, and by the low denticulate nature of the parasutural septa.

Range: *Phoberocysta lowryi* Zone.

Cribroperidinium sp. B

Pl. 24, figs 9, 10

Description: Large proximate cyst, ovoid, with a long apical horn. Autophragm 1 μm or more thick, finely granular and micropunctate. Paratabulation expressed by smooth, sometimes perforate parasutural septa, 1 to 6 μm high. Paratabulation formula not determined. Intratabular areas bear

low accessory ridges, but no spines. Paracingulum clearly expressed, approximately 4 μm wide, offset an undetermined amount. Parasulcus indicated by low parasutural septa. Apical horn solid, 30 to 55 μm long, with a rounded tip and solid spur-like projections on the flanks. Archeopyle precingular, type P, operculum free.

Dimensions: Range of length including apical horn (8 specimens) 146(161)192 μm width 90(109)120 μm .

Remarks: *Cribroperidinium* sp. B is distinguished from *C. muderongense*, *C. edwardsii* (Cookson and Eisenack) Davey 1969, and *C. orthoceras* (Eisenack) Davey 1969 by its large size and the absence of intratabular and parasutural spines.

Range: *Batioladinium jaegeri* and lower *Fromea monilifera* Zone.

Cribroperidinium? sp. C

Pl. 25, figs 1, 2

Description: Cyst proximate, subspherical with a short apical horn. Autophragm granular, punctate and 1 to 1.5 μm thick. Paratabulation expressed by low parasutural septa bearing short truncate spines. Paratabulation formula: ?4', 6'', ?6c, 6''', 1p, 1'''. Intratabular areas covered by short truncate spines connected by low ridges to form a pattern of squares, some of which may represent accessory ridges. Paracingulum 5 to 6 μm wide, offset approximately 13 μm . Parasulcus poorly expressed. Apical horn, 8 to 12 μm long, with a rounded tip. Archeopyle precingular, type P, operculum free.

Dimensions: Length (2 specimens) 89 and 101 μm , width (one specimen) 87 μm .

Remarks: Only a few specimens of this species have been located, all at a similar biostratigraphic level. The distinctive intratabular pattern distinguishes this species from other species of *Cribroperidinium*.

The intratabular features of this species may exclude it from *Cribroperidinium*.

Range: *Fromea monilifera* Zone.

Genus **Cyclonephelium** Deflandre and Cookson 1955 emend. Stover and Evitt 1978

Type species: *Cyclonephelium compactum* Deflandre and Cookson 1955.

Remarks: The circumscription of the genus provided by Sarjeant and Stover (1978) and Stover and Evitt (1978) is accepted here. The type species, *C. compactum*, is common in the Osborne Formation in the Perth Basin. It is consistently asymmetrical in outline with a flattened antapex or, more usually, a shallow antapical indentation.

***Cyclonephelium attadalicum* Cookson and**

Eisenack 1962b.

Pl. 25, figs 3–6; Fig. 21

1962b *Cyclonephelium?* *attadalicum* Cookson and Eisenack p. 495, Pl. 5, figs 12–15.

1962b *Tenua?* sp. Cookson and Eisenack, p. 495, Pl. 5, figs 16–17.

1976 *Cyclonephelium attadalicum* Cookson and Eisenack; Kemp, Pl. 2, figs 7, 8.

1978 *Canningia attadalina* (Cookson and Eisenack) Stover and Evitt, p. 24.

1980a *Aptea attadalina* (Cookson and Eisenack) Davey and Verdier; Morgan, p. 14, Pl. 1, figs 1–6.

1982 *Aptea attadalina* (Cookson and Eisenack); Burger, Pl. 1, figs 1, 2.

1982 *Cyclonephelium* cf. *C. distinctum* Deflandre and Cookson; Burger, Pl. 1, figs 3, 6.

1982 *Cyclonephelium distinctum* Deflandre and Cookson; Burger, Pl. 2, fig. 16.

non 1978 *Cyclonephelium ?attadalicum* Cookson and Eisenack; Davey, Pl. 3, figs 1, 2.

Description: Cyst lenticular, parasulcal notch offset, outline suboval to asymmetric fusiform. Apical outline drawn to a pointed protrusion, antapex with two unequal protrusions, left one substantially larger than right. Autophragm sculptured with truncate, or rarely bifid spines, 3 to 9 μm long. Spines on apical and antapical protrusions, along flanks of cyst, and along

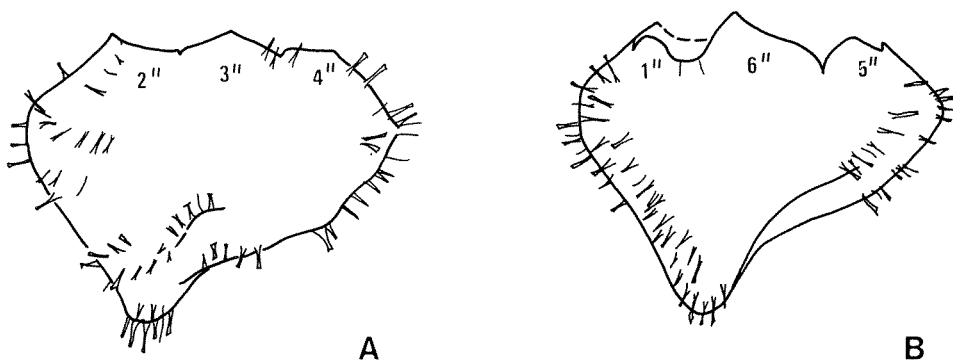
antapical margin of dorsal primary archeopyle suture; longest spines on apical and antapical protrusions. Incomplete rows of spines may delineate paracingulum on dorsal surface. Mid-dorsal and mid-ventral areas and ventral antapical margin devoid of spines. Archeopyle apical, type [tA], operculum free; archeopyle suture indicates 6 precingular paraplates including a high 6" paraplate and a sulcal notch, 3.5 to 5.0 μm wide (Fig. 21).

Dimensions: Range of cyst body length without operculum (14 specimens) 41(55)67 μm , width 50(64)84 μm .

Remarks: *Cyclonephelium attadalicum* represents a morphological variation of *C. hystrix* (Eisenack) Davey 1978 in which the cyst becomes shorter and broader, the apical and antapical protrusions longer, and the spines fewer, longer and more restricted to the peripheral areas of the cyst. In some extreme forms, such as the holotype (Cookson and Eisenack, 1962b, Pl. 5, fig. 13), rows of spines weakly delineate the paracingulum on the dorsal surface. Because of the morphological similarity to *C. hystrix* and the absence of paracingular features on most specimens, this species is reassigned to *Cyclonephelium*.

Aptea anaphrissa (Sarjeant) Sarjeant and Stover 1978, and *Aptea securigera* Davey and Verdier 1974 are more uniformly spinose than *C. attadalicum*. *Cyclonephelium attadalicum* is common only in assemblages interpreted here as indicative of shallow-water, near-shore environments. This suggests that the morphological differences from *C. hystrix* are, at least partly, the result of environmental factors.

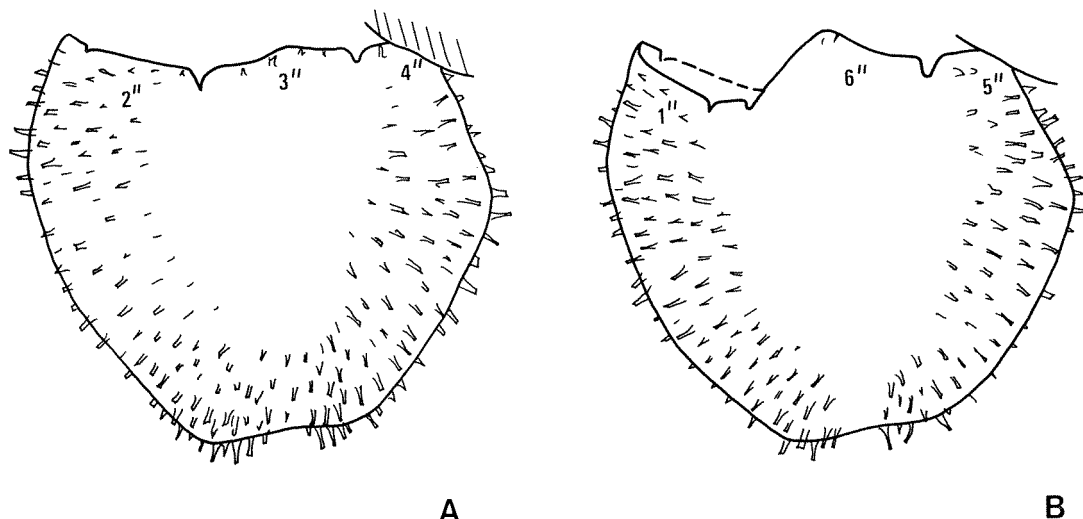
Range: Uppermost *Aprobolocysta alata* to *Fromea monilifera* Zones.



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Figure 21. *Cyclonephelium attadalicum* Cookson and Eisenack 1962b. Dorsal view, x800. Drawings based on photomicrographs.

A, dorsal surface; B, ventral surface. Pl. 25, fig. 3.



GSWA 22225

Figure 22. *Cyclonephelium hystrix* (Eisenack) Davey 1978. Dorsal view, x800. Drawings based on photomicrographs. A, dorsal surface; B, ventral surface. Pl. 25, fig. 7.

***Cyclonephelium hystrix* (Eisenack) Davey 1978**
Pl. 25, figs 7–9; Pl. 47, figs 3–5; Fig. 22

- 1958 *Tenua hystrix* Eisenack, p. 410, Pl. 23, figs 1–4.
1961 *Circulodinium deflandrei* Alberti, p. 29, Pl. 4, figs 7–13.
1969 *Cyclonephelium distinctum* Deflandre and Cookson; Millioud, p. 427, Pl. 1, fig. 7.
1969 *Cyclonephelium distinctum* var. *brevispinatum* Millioud, p. 427, Pl. 1, figs 8, 9.
1978 *Cyclonephelium hystrix* (Eisenack) Davey, p. 894, Pl. 3, figs 10, 11.
1978 *Cyclonephelium distinctum* subsp. *brevispinatum* Millioud; Davey, p. 894, Pl. 3, figs 13–15.

Description: Cyst lenticular, parasulcal notch offset; outline subcircular to sub-oval, with a low apical protrusion and an asymmetrical, indented antapical outline. Autophragm sculptured with low (2 to 7 μm), truncate, or occasionally bifid spines; spines longest on apical and antapical protrusions. Mid-dorsal and mid-ventral areas, and ventral antapical margin devoid of spines. A single row of spines on the dorsal precingular paraplates borders the primary archeopyle suture. Archeopyle apical, type [tA], operculum free; primary archeopyle suture indicates 6 precingular paraplates.

Dimensions: Range of cyst body length without operculum (28 specimens) 44(55)66 μm , width 48(65)75 μm .

Remarks: The outline of *C. hystrix* is somewhat variable. Most specimens possess an antapical indentation slightly to the right of centre, but in the *Batioladinium jaegeri* and *Fromea monilifera* Zones forms appear which display only slight antapical asymmetry (Pl. 47, fig. 5). Other forms with strongly indented antapical margins are probably transitional to *C. attadalicum*. *Cyclonephelium hystrix* and the type species of *Cyclonephelium*, *C. compactum*, are essentially similar in shape, and both possess peripheral surface features, membranous septa on *C. compactum* and short truncate spines on *C. hystrix*.

Cysts of this species have frequently been referred to *Cyclonephelium distinctum* Deflandre and Cookson 1955. However, *C. distinctum* bears long narrow spines and possesses a symmetrically rounded antapex. In the Perth Basin *C. distinctum* is not recorded below the Albian.

Canningia hirtella (Alberti) Millioud 1969 and forms assigned to *C. distinctum* by Gocht (1979) may be conspecific with *C. hystrix*.

Range: *Gagiella mutabilis* to *Fromea monilifera* Zones. Previously recorded from the Valanginian to Aptian.

Genus **Diconodinium** Eisenack and Cookson 1960 emend. Morgan 1977

Type species: *Diconodinium multispinum* (Deflandre and Cookson) Eisenack and Cookson 1960.

Diconodinium micropunctatum sp. nov.

Pl. 25, figs 10,11; Pl. 26, fig. 1

Derivation of name: Latin, *Micro*, small, *punctatus*, covered in punctures, alluding to the numerous foveolae on the autophragm.

Holotype: F33850/4 (–36.6, –110.4) Peel 1, 994 m, Leederville Formation, Pl. 26, fig. 1.

Description: Cyst small, proximate, subovoid to biconical; epicyst and hypocyst approximately equal in size. Apical horn short (3 μm) solid and truncate; antapical horn usually a short acicular process offset slightly to the left. Autophragm 0.5 μm thick, entirely covered by continuous longitudinal grooves and ridges. Distance between ridges approximately 1 μm . Grooves lined by rows of closely spaced shallow foveolae, that impart a finely punctate appearance to the autophragm. Paratabulation expressed only by archeopyle and paracingulum. Paracingulum, 4 to 6 μm wide, indicated by transverse ridges 0.5 μm high, offset approximately 3 μm . Parasulus not indicated. Archeopyle intercalary, type Ia (2a only), standard hexa, seldom clearly observed; operculum free.

Dimensions: Length of holotype 44 μm , width 37 μm . Range of length (17 specimens) 34(42)51 μm , width 25(33)38 μm .

Remarks: *Diconodinium micropunctatum* is distinguished from other species of *Diconodinium* by its small size and finely grooved foveolate surface. *Laciniadinium? tenuistriatum* (Eisenack and Cookson) Morgan 1977 is larger than *D. micropunctatum* and lacks foveolae.

Range: Upper part of the *Fromea monilifera* Zone.

Genus **Dingodinium** Cookson and Eisenack 1958

Type species: *Dingodinium jurassicum* Cookson and Eisenack 1958.

Dingodinium cerviculum Cookson and Eisenack 1958

Pl. 26, figs 2, 3; Pl. 47, fig. 7

Dimensions: Range of length (15 specimens) 62(88)104 μm , width 40(48)61 μm .

Remarks: The length of the apical horn formed by the periphragm varies from 18 to 36 μm , thus contributing considerably to the variation in length displayed by this species. The endophragm bears numerous, closely spaced, apparently non-tabular spines, up to 1.5 μm long, which support the periphragm over the lateral and dorsal surfaces. The periphragm is perforate in the parasulcal area, but non-perforate elsewhere. The

archeopyle suture frequently gapes open on the dorsal side while remaining attached over a large portion of the caveate ventral side. No clear evidence for an intercalary series of paraplates was observed on any specimen from the Perth Basin. *Dingodinium albertii* Sarjeant 1966b and *D. cerviculum* may be northern and southern hemisphere representatives of the same cyst species. Many illustrated specimens of *D. albertii*, and specimens from the northern hemisphere assigned to *D. cerviculum* are less elongate and possess shorter apical horns than southern hemisphere forms of *D. cerviculum*.

Range: Upper *Phoberocysta lowryi* to *Fromea monilifera* Zones. Most records of *Dingodinium cerviculum* in the Australasian region date the first appearance as Hauterivian–Barremian (Cookson and Eisenack, 1958; Evans, 1966; Morgan, 1980a), but Burger (1982) records it from his DK2 Zone of putative Valanginian age. The top of the range is in the Early Albian (Morgan 1980a). In the Perth Basin *D. cerviculum* appears in the upper part of the *P. lowryi* Zone, but only becomes a commonly recorded species in the *Aprobolocysta alata* Zone.

Genus **Discorsia** Duxbury 1977

Type species: *Discorsia nanna* (Davey) Duxbury 1977.

Discorsia nanna (Davey) Duxbury 1977

Pl. 26, figs 4,5

Dimensions: Cyst body length (5 specimens) 22(30)36 μm , length of processes 9–15 μm .

Range: *Kaiwaradinium scrutillinum* to *Fromea monilifera* Zones. Previously recorded from the Valanginian to Albian (Davey, 1974; Duxbury, 1977; Morgan, 1980a)

Genus **Druggidium** Habib 1973.

Type species: *Druggidium apicopaucicum* Habib 1973.

Druggidium rhabdoreticulatum Habib 1973

Pl. 26, figs 6,7

Dimensions: Range of length (10 specimens) 20(26)31 μm width 18(21)25 μm .

Range: *Batioladinium jaegeri* and *Fromea monilifera* Zones. Previously recorded from the Valanginian to Albian of North America (Habib, 1973) and the Late Neocomian of Australia (Morgan, 1980a).

Genus *Endoscrinium* (Klement 1960)
Vozzhennikova 1967 emend. Gocht 1970

Type species: *Endoscrinium galeritum* (Deflandre)
Vozzhennikova 1967.

Endoscrinium campanulum (Gocht)
Vozzhennikova 1967
Pl. 26, fig. 8

Description: Proximate cyst, subovoid, with a prominent apical horn. Cyst wall two-layered, cavate only at apical horn. Endophragm 0.5 μm thick, smooth, drawn into conical distally closed apical horn. Periphragm membranous, forming tubular distally open apical horn. Paratabulation incomplete, expressed by parasutural septa 3 to 5 μm high. Paratabulation formula: 4', 6'', ?6c, 5''', 1''''; parasuture between paraplates 3''' and 4''', mid dorsal in position. Archeopyle precingular, type P, operculum free.

Dimensions: Range of length (13 specimens) 70(91)112 μm , width 53(68)78 μm , length of periphragmal apical horn 11 to 19 μm .

Remarks: The present specimens are cavate only on the vicinity of the apical horn, but a high parasutural septum at the antapex gives the appearance of antapical cavation. As noted by Below (1981), other examples of this species appear to display varying degrees of cavation; however, it is difficult to distinguish from the illustrations between antapical cavation and high antapical parasutural septa. The paratabulation of the Perth Basin specimens corresponds with that given by Below (1981).

Range: *Kaiwaradinium scrutillinum* to *Aprobolocysta alata* Zones. For previous reported occurrences see Below (1981).

Genus *Epitricysta* Stover and Helby 1987

Type species: *Epitricysta vinckensis* Stover and Helby 1987.

Epitricysta vinckensis Stover and Helby 1987
Pl. 28, figs 13–15

Dimensions: Diameter of cyst body (11 specimens) 49(55) 60 μm , diameter including cingular septum 58(66)72 μm .

Range: *Aprobolocysta alata* to *Fromea monilifera* Zones, rare below the *Batioladinium jaegeri* Zone. This unusual cyst is reported by Stover and Helby (1987) from the *Muderongia australis* Zone (Helby and others, 1987) in Vinck 1 well on the Exmouth Plateau, off Western Australia.

Genus *Exochosphaeridium* Davey and others 1966

Type species: *Exochosphaeridium phragmites*
Davey and others 1966.

Exochosphaeridium robustum sp. nov.
Pl. 26, figs 9, 10; Pl. 28, fig. 7; Pl. 48, fig. 1

Derivation of name: Latin, *robustus*, strong, robust.

Holotype: F8351/4 (–48.5, –111.3) Whitfords 1, 288 m, South Perth Shale, Pl. 26, fig. 10.

Description: Chorate cyst, body subspherical bearing at least 70 and up to 100 processes. Autophragm composed of interlocking fibres; each fibre less than 0.5 μm or less in maximum diameter; fibres drawn upwards and fused at a number of points to form fibrous processes. Processes rod-shaped, 8 to 19 μm long, 1 to 3 μm in minimum diameter, occasionally branching and distally truncate. Process distribution non-tabular, but small areas devoid of processes may indicate central intratabular areas. Paracingulum and parasulcus not indicated. Multibranched processes usually present at apex. Archeopyle precingular, type P, operculum free.

Dimensions: Cyst body width of holotype 70 μm . Range of body width (16 specimens) 41(56)70 μm .

Remarks: *Exochosphaeridium robustum* is distinguished from *E. truncatum* by possessing thicker less tapered processes. In the *Batioladinium jaegeri* Zone it is replaced by *E. truncatum*; all specimens of *Exochosphaeridium* recorded above this level possess slender, tapered processes and are referred to *E. truncatum*.

Range: *Kaiwaradinium scrutillinum* to *Batioladinium jaegeri* Zones.

Exochosphaeridium truncatum (Davey) Stover and Evitt 1978
Pl. 28, figs 8, 9

Dimensions: Length of cyst body (7 specimens) 49(54)61 μm , width 39(43)49 μm .

Remarks: This species bears the typical fibrous processes of *Exochosphaeridium*, which in this case are long and evenly tapered with truncate tips. The archeopyle appears to be formed by the loss of a single precingular paraplate rather than the two specified for *E. truncatum*. Forms described as *Hystrichosphaeridium* cf. *hirsutum* (Ehrenberg) by Cookson and Eisenack (1958) belong in *E. truncatum*.

Range: Upper *Aprobolocysta alata* to *Fromea monilifera* zones.

Genus *Fusiformacysta* Morgan 1975

Type species: *Fusiformacysta salasii* Morgan 1975.

***Fusiformacysta tumida* sp. nov.**

Pl. 29, figs 1–6

Derivation of name: Latin, *tumidus*, inflated, referring to the shape of the cyst.

Holotype: F8534/5 (–37.8, –106.3) Eneabba Line 3, 490 m, *Parmelia* Formation, Pl. 29, fig. 5.

Description: Medium-sized proximate cysts, inflated fusiform in shape, drawn into a broad rounded apical horn of varying length and a shorter antapical horn. Autophragm less than 0.5 μm thick, completely covered by evenly spaced grana less than 0.5 μm high and less than 1 μm in diameter. Paratabulation indicated only by archeopyle. Paracingulum and parasulcus not expressed. Archeopyle precingular, formed by loss of 3" paraplate and usually one other paraplate; operculum often in position.

Dimensions: Length of holotype 90 μm , width 57 μm . Range of length (22 specimens) 79(87)99 μm , width 46(54)60 μm .

Remarks: *Fusiformacysta tumida* is shorter and more inflated in shape than *F. salasii* Morgan 1975. All occurrences are in sediments of probable restricted-marine or non-marine origin. This supports the observations of Morgan (1975) who noted that a similar species, *F. salasii*, occurs in poorly diversified dinoflagellate-cyst assemblages of possibly non-marine origin.

Range: *Fusiformacysta tumida* Zone.

***Fusiformacysta* sp. A**

Pl. 29, figs 7, 8

Dimensions: Range of length (6 specimens) 99(104)108 μm , width 46(51)55 μm .

Remarks: This species is more elongate than *F. tumida*, and shorter than *F. salasii* Morgan. It is characterized by fine granulation towards the apical and antapical extremities, and coarser granulation around the middle of the cyst.

Range: *Fusiformacysta tumida* Zone. Only observed in one sample from Gingin Brook 5 at 82 m.

Genus *Gagiella* gen. nov.

Type species: *Gagiella mutabilis* sp. nov.

Derivation of name: After the type locality, Gage Roads 1 borehole.

Synopsis: Cyst quadrilobate, trilobate or ovoid; paratabulation not indicated by surface features; autophragm bearing grana or rugulae; archeopyle apical, type [tA], archeopyle suture indicating 5 or 6 precingular paraplates, paraplates 3" and 4" sometimes represented by a single paraplate.

Description:

Shape: Quadrilobate, trilobate or ovoidal, outline rounded.

Wall Relationships: Autophragm only.

Paratabulation: Indicated only by archeopyle, 5 to 6 precingular paraplates including a wide 3" paraplate in the position of the 3" and 4" paraplates, or narrow 3" and 4" paraplates with a short accessory suture between. Apical series always consists of 4 fused paraplates.

Archeopyle: Apical, type [tA], operculum free, constituent paraplates undifferentiated.

Paracingulum: Sometimes expressed by narrow groove devoid of surface features, slightly offset.

Parasulcus: Not expressed.

Size: Medium.

Comparison: The type species, *Gagiella mutabilis*, is an unusually variable dinoflagellate cyst. Cysts which precede and succeed *Gagiella* in a morphological lineage are assigned here to *Pentafidia* gen. nov. and *Batiacasphaera* Drugg 1970 respectively. *Pentafidia* and *Batiacasphaera* do not include lobate cysts; *Pentafidia* possesses 5 precingular paraplates, and *Batiacasphaera*, 6 precingular paraplates. *Tetrachacysta* gen. nov. is symmetrically quadrilobate and possesses a 6 precingular paraplate primary archeopyle suture.

***Gagiella mutabilis* sp. nov.**

Pl. 27, figs 1–15; Pl. 28, figs 1–6; figs 23–25

Derivation of name: Latin, *mutabilis*, variable, referring to the shape and surface features of the cyst.

Holotype: F22416/6 (–46.8, –103.5), Gage Roads 1, 1700 m, Gage Sandstone Member of South Perth Shale, Pl. 27, fig 1.

Description: Cyst asymmetrically quadrilobate, trilobate, or ovoid, usually laterally compressed with the parasulcal notch close to the lateral margin. Strongly lobate forms bear a lobe in the posterior parasulcal position and some also bear a lobe in the 4" paraplate position (Fig. 23). Autophragm 1.0 to 1.5 μm thick, bearing rugulate,

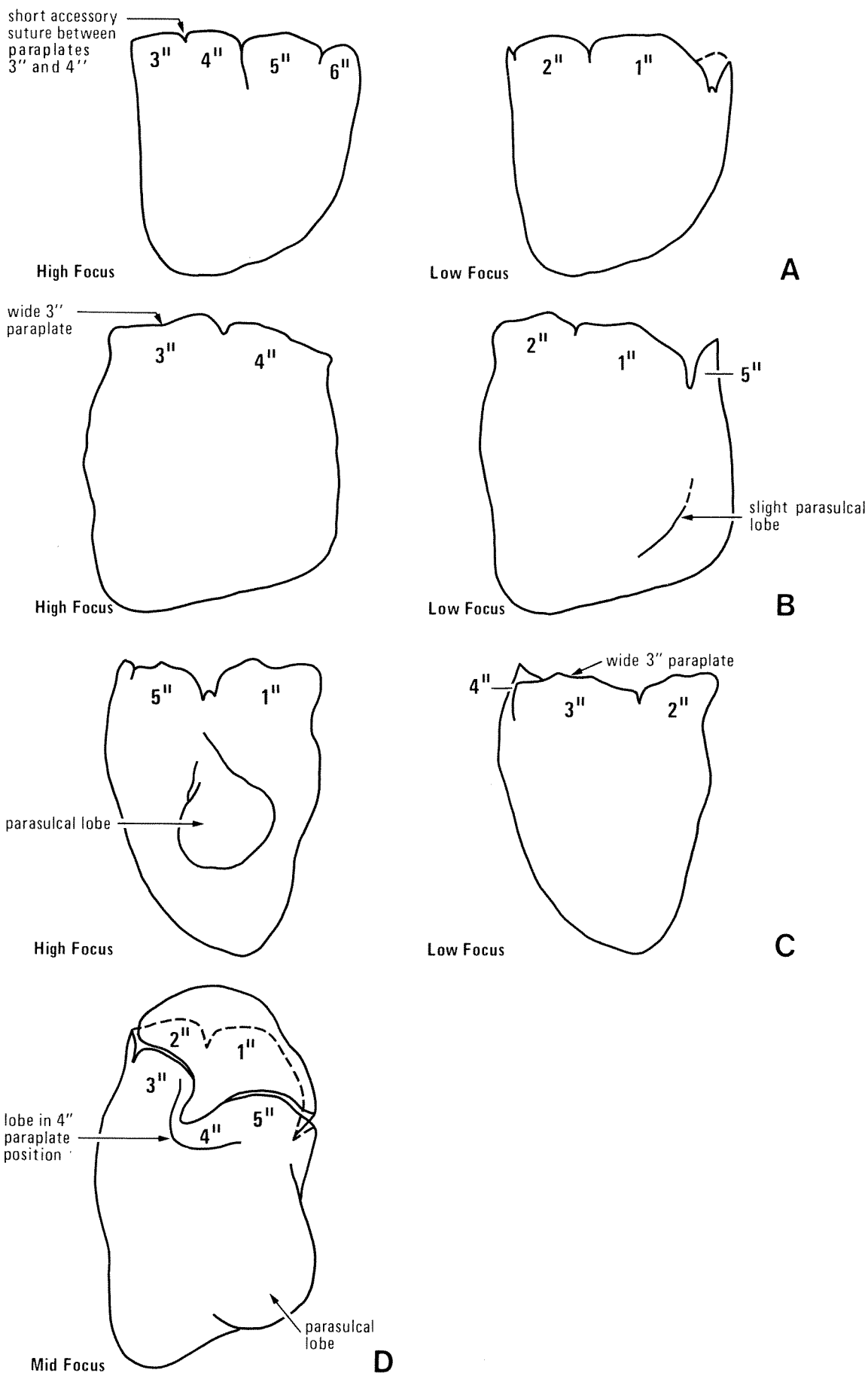


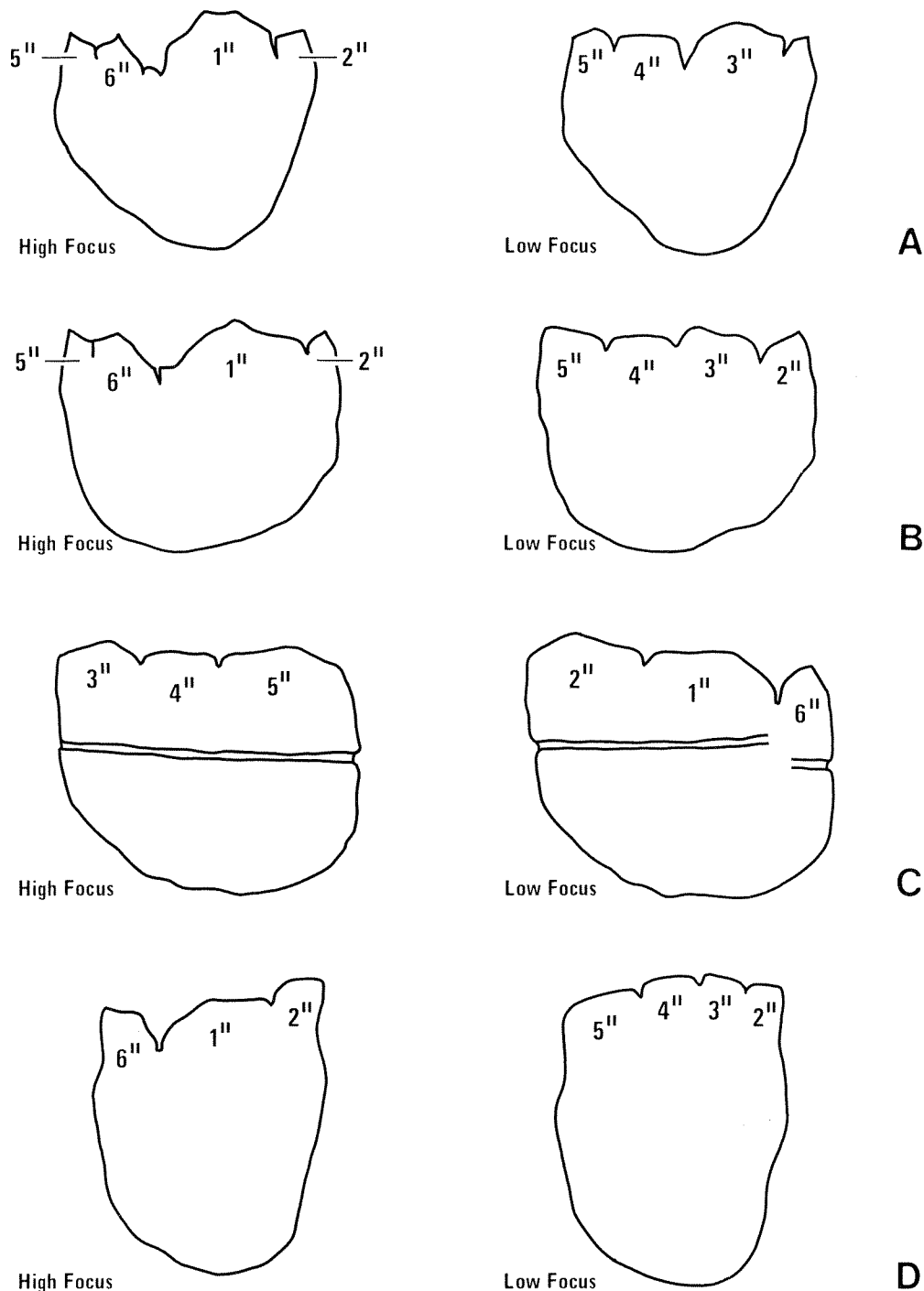
Figure 23, *Gagiella mutabilis* sp. nov. x800. Drawings based on photomicrographs.

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A, right lateral view, Pl. 27, fig. 4; B, right lateral view, Pl. 27, fig. 2; C, ventral view, Pl. 27, fig. 3; D, holotype, right lateral view, Pl. 27, fig. 1.

reticulate, spinose or granular surface features. Lobate forms rugulate (rugulae less than $1\mu\text{m}$ high); ovoid forms reticulate, granulate or, rarely, spinose, with individual elements up to $2\mu\text{m}$ high. Paratabulation indicated only by archeopyle suture. Paracingulum indicated on some ovoid forms by a narrow groove $2\text{--}3\mu\text{m}$ wide, offset

approximately $4\mu\text{m}$. Some large lobate forms display a broad bulge in paracingular zone. Archeopyle apical, type [tA], operculum free; constituent paraplates not differentiated. Sulcal notch deep and narrow; primary archeopyle suture and accessory sutures indicate 5 or 6 precingular paraplates and 4 apical paraplates (Fig. 25).



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Figure 24, *Batiacasphaera* sp. and *Gagiella mutabilis* sp. nov. $\times 800$. Drawings based on photomicrographs. A-C, *Batiacasphaera* sp. A, ventral view, Pl. 27, fig. 18; B, ventral view, Pl. 28, fig. 3; C, right lateral view, Pl. 27, fig. 13. D, *Gagiella mutabilis*, ventral view, Pl. 28, fig. 2.

Lobate forms possess an archeopyle suture indicating 5 precingular paraplates including a wide 3" paraplate. Transition to a subovoid shape accompanied by splitting of the 3" paraplate into two narrow paraplates by development of a short accessory suture (Figs 23 to 25). Ovoid forms lack any expression of lateral or antapical lobes and possess archeopyle sutures indicating 6 distinct precingular paraplates.

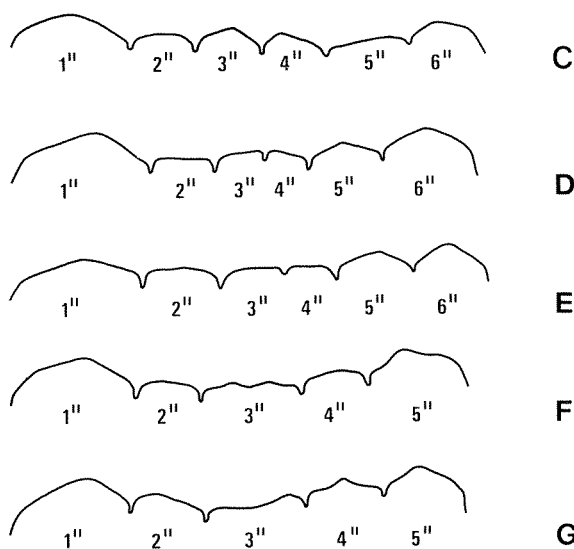
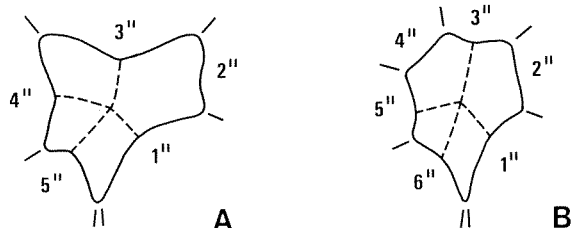
Dimensions: Length of holotype 85 μm , width 49 μm . Range of length without operculum (58 specimens) 41(59)84 μm , width 38(53)63 μm .

Remarks: *Gagiella mutabilis* displays considerable variation in shape and surface sculpture. Attempts to subdivide the species have proved impracticable. Forms intermediate between the various morphological types are common, and the whole group spans a relatively thin stratigraphic section

of the Perth Basin. The morphological lineage represented by these cysts is continued by the appearance of smooth subspherical cysts at the same level as the paracingulate forms of *G. mutabilis* (Pl. 27, figs 16–18). These smooth cysts possess a thick autophragm and 6 precingular paraplates (figs 24, 25), and are referable to the genus *Batiacasphaera*. They may be the precursor of subspherical Early Cretaceous cysts with 6 precingular paraplate archeopyle sutures such as *Batiacasphaera asperata* sp. nov. *Gagiella mutabilis* may have derived from cysts of the *Pentafidia* type during the period of Neocomian tectonism in the Perth Basin.

Gagiella mutabilis is the cyst of a dinoflagellate species which inhabited a restricted-marine, or possibly non-marine environment. It is recorded in large numbers in the Gage Sandstone Member in sections devoid of Late Jurassic and Early Cretaceous marine cysts.

Range: *Gagiella mutabilis* Zone. Occasional specimens, which are thought to be reworked, are recorded above this level.



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Figure 25. *Batiacasphaera* sp. and *Gagiella mutabilis* sp. nov. Diagrammatic representation of paratabulation.

A, operculum configuration on lobate form, Pl. 28, fig. 4. B, operculum configuration on ovoid form, Pl. 28, fig. 5. C–G, archeopyle suture configurations. C, Pl. 27, fig. 18; D, Pl. 28, fig. 2; E, Pl. 27, Fig 4; F, Pl. 27, fig. 3; G, Pl. 27, fig. 1.

Genus *Gardodinium* Alberti 1961

Type species: *Gardodinium trabeculosum* (Gocht) Alberti 1961.

Gardodinium attenuatum Stover and Helby 1987
Pl. 29, figs 13, 14

Dimensions: Range of length (9 specimens) 60(74)(98) μm , width 29(38)43 μm .

Remarks: This species resembles *Gardodinium lowii* sp. nov. in general shape and structure but is distinguished from it by its slightly smaller size and shorter apical horn. The length of the horn developed on the autophragm is 5 to 12 μm , and on the ectophragm 18 to 32 μm .

Range: *Kaiwaradinium scrutillinum* and *Phoberocysta lowryi* Zones.

Gardodinium lowii Backhouse 1987
Pl. 29, figs 9–12

Range: Uppermost *Kaiwaradinium scrutillinum* and *Phoberocysta lowryi* Zones.

Genus *Gonyaulacysta* Deflandre 1964 emend.
Stover and Evitt 1978

Type species: *Gonyaulacysta jurassica* (Deflandre) Norris and Sarjeant 1965.

Gonyaulacysta sp. cf. *G. exsanguia* Duxbury 1977
Pl. 28, figs 10–12; Pl. 47, fig 8

Range: *Kaiwaradinium scrutillinum* Zone to lower part of *Phoberocysta lowryi* Zone.

Gonyaulacysta helicoidea (Eisenack and Cookson)
Sarjeant 1966a
Pl. 28, fig. 16

Description: Proximate ovoidal cyst with a short blunt apical horn. Endophragm approximately $1\mu\text{m}$ thick, enveloped by, and appressed to, a smooth thin periphragm, except where periphragm forms an apical horn and parasutural septa. Apical horn hollow, 12 to $15\mu\text{m}$ long, apparently closed distally. Parasutural septa, 1 to $3\mu\text{m}$ high, surmounted by truncate spines up to $3\mu\text{m}$ long. Paratabulation formula: $4', 6'', 6c, 6''', 1p, 1'''$. Paracingulum 3 to $5\mu\text{m}$ wide, offset approximately $15\mu\text{m}$. Parasulcus strongly sinuous. Septa on apical horn low, bearing extremely small spines, or none at all. Small spines or grana sparsely distributed over intratabular areas. Archeopyle precingular, type P, operculum free.

Dimensions: Range of length (4 specimens) $52(59)71\mu\text{m}$, width $46(47)49\mu\text{m}$.

Remarks: The resemblance between *Gonyaulacysta helicoidea* and *G. cretacea* (Neale and Sarjeant) Sarjeant 1969 has been remarked on by Davy and Verdier (1971) and Duxbury (1977). Re-examination of the holotype of *G. cretacea* may reveal no systematically significant differences from *G. helicoidea*.

Range: *Kaiwaradinium scrutillinum* to *Fromea monilifera* Zones.

Genus **Herendeenia** Wiggins 1969

Type species: *Herendeenia pisciformis* (Cookson and Eisenack) Wiggins 1969.

Herendeenia postprojecta Stover and
Helby 1987
Pl. 37, fig. 3

Dimensions: Range of endophragm length (3 specimens) $72(74)75\mu\text{m}$, width $43(45)47\mu\text{m}$. Length of periphragm (2 specimens) 97 and $99\mu\text{m}$.

Range: Upper *Batioladinium jaegeri* to *Fromea monilifera* Zones, rare. Stover and Helby (1987) suggest a range of Hauterivian–Barremian for this species in Vinck 1, Exmouth Plateau.

Genus **Horologinella** Cookson and Eisenack 1962a
emend.

Type species: *Horologinella lineata* Cookson and Eisenack 1962a.

Synopsis: Cysts small, proximate quadrate to subquadrate with an equatorial constriction. Paratabulation expressed by low surface features; paratabulation formula: $6', 7'', 6c, 7'', 2''', Xs$; archeopyle apical, subcircular, operculum free.

Description:

Shape: Dorso-ventrally compressed, outline quadrate to subquadrate with rounded corners, lateral margins constricted.

Wall relationships: Autophragm only.

Wall features: Low parasutural ridges, non-tabular ridges, grana, and fine punctae.

Archeopyle: Apical, atypical, opening subcircular occupying most of plate $4'$ and parts of adjoining paraplates. Paratabulation indicated by parasutural features; formula: $6', Oa, 7'', ?6c, 7''', Op, 2''', Xs$.

Paracingulum: Indicated by parasutural features and lateral constrictions.

Parasulcus: Indicated by parasutural features; several paraplates may be expressed.

Size: Small.

Comparison: *Dollidinium sinuosum* (Cookson and Eisenack) Helby and Stover 1987 is hexalobate and is interpreted as possessing only 6 precingular and 6 postcingular paraplates, although the overall distribution of paraplates is fairly similar to *Horologinella*. *Tetrachacysta* gen. nov. lacks parasutural features and possesses 6 precingular paraplates.

Remarks: The genus *Horologinella* is emended to accommodate detailed knowledge of the type species gained by SEM work on specimens from the Perth Basin. The unusual nature of the paratabulation displayed by *Horologinella lineata* confirms the view of Stover and Evitt (1978) that most other species assigned to this genus, and which lack paratabulation are acritarchs. The exception is *H. spinosigibberosa* Brideaux and Fisher 1976 which is transferred herein to *Tetrachacysta* gen. nov.

Horologinella lineata Cookson and Eisenack 1962a
Pl. 29, figs 15–17; Pl. 30, figs 1, 2; Pl. 48,
figs 2–4; Fig. 26

Description: Cysts small, dorso-ventrally compressed, subquadrate with deep lateral paracingular constrictions; apical angles bevelled or squared, antapical angles squared; apical ventral outline with a central indented projection, antapical outline straight. Hypocyst and epicyst

approximately equidimensional. Autophragm $0.5\mu\text{m}$ thick, under SEM seen to be smooth, finely punctate, or bearing small widely spaced grana. Non-tabular ridges present on some ventral paraplates. Paratabulation expressed by low parasutural ridges approximately $0.25\mu\text{m}$ wide and high; formula: $6', \text{Oa}, 7'', ?6c, 7'', \text{Op}, 2''', ?4s$. Apical series consists of a narrow elongate $1'$ paraplate and five paraplates of approximately equal size, two on the ventral surface and three on the dorsal surface. Precingular series arranged with paraplates $2''$ and $6''$ in lateral positions and a narrow $4''$ paraplate slightly right of the dorsal midline. Postcingular series with paraplates $3'''$ and $6'''$ in lateral positions, and the parasuture between paraplates $4'''$ and $5'''$ in the mid-dorsal position. Paraplate $1'''$ corresponds with a posterior intercalary paraplate. Paracingulum divided into at least 6 paraplates, indicated by parasutural ridges, poorly expressed ventrally, and occupying the area of deep lateral constriction, 3 to $5\mu\text{m}$ wide, offset 2 to $3\mu\text{m}$. Parasulcus composed of at least 3 poorly defined paraplates and a well-defined posterior sulcal paraplate. Archeopyle apical, subcircular, approximately $6\mu\text{m}$ wide, formed by most of paraplate $4'$ and possibly the edges of paraplates $3'$ and $5'$. Operculum free, details not known.

Dimensions: Range of length (26 specimens) $18(22)25.5\mu\text{m}$, epicystal width $18(21.5)26\mu\text{m}$, hypocystal width $18.5(21.5)25.5\mu\text{m}$.

Remarks: The small size, deeply constricted outline, and unusual paratabulation distinguish *H. lineata* from other dinoflagellate cyst species.

Dollidinium sinuosum (Cookson and Eisenack) Helby and Stover 1987, possesses a similar paratabulation and archeopyle, but it is larger than *H. lineata* and is hexalobate rather than quadrilobate.

Range: *Batioladinium jaegeri* Zone. *Horologinella lineata* is known from only three localities:

- Attadale Bore at 188.5 m (Cookson and Eisenack (1962a) — a ditch cuttings sample, also containing *Cyclonephelium attadalicum*, considered to be from the Osborne Formation by Cookson and Eisenack (1962b) but now placed in the Leederville Formation.
- Woodmans Point 2 at 87 m — a sidewall core sample from the Leederville Formation containing dinoflagellate cysts and acritarchs that belong in the *Cyclonephelium attadalicum* Association.
- Borehole E.D. 2, Halls Head, Mandurah at 20 m — a conventional core in the Leederville Formation. *Horologinella lineata* is the only microplankton species recorded in this sample.

Horologinella sp. A

Pl. 30, fig. 3

Dimensions: Length of two specimens 22 and $24\mu\text{m}$, width 22 and $23\mu\text{m}$.

Remarks: *Horologinella* sp. A is dorso-ventrally compressed rounded quadrate in outline with a slight lateral construction. The full paratabulation cannot be determined using an optical microscope.

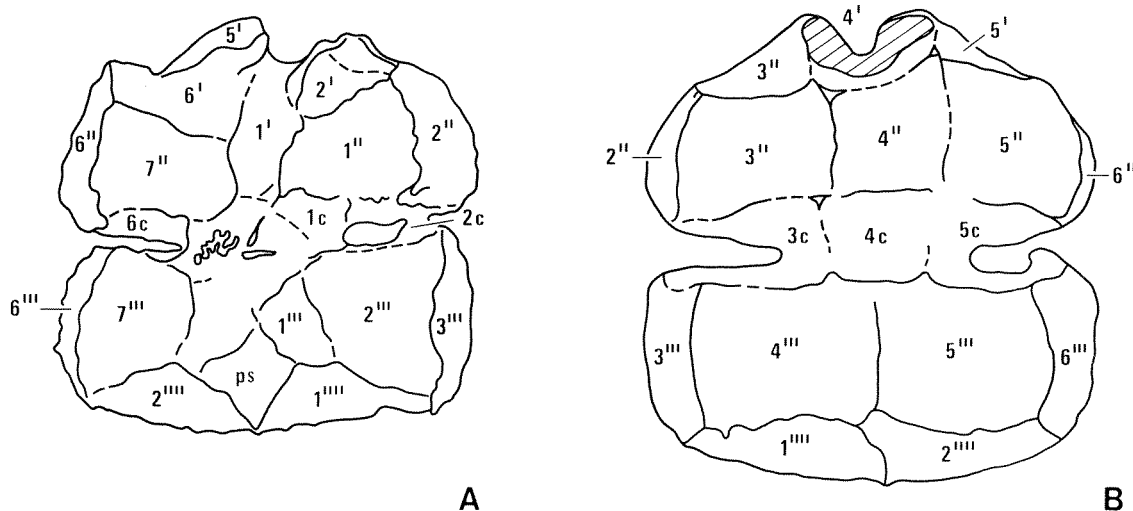


Figure 26. *Horologinella lineata* Cookson and Eisenack 1962a. x800. Drawings based on scanning electron micrographs.

A, ventral view, Pl. 48, fig. 3; B, dorsal view, Pl. 48, fig. 4.

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Some parts of the dorsal paratabulation resemble the paratabulation of *H. lineata* Cookson and Eisenack 1962a. Only one specimen displays an archeopyle, a subcircular structure on the central apical surface. From its general morphology and stratigraphic position *Horologinella* sp. A is probably a precursor to *H. lineata*.

Range: ?*Phoberocysta lowryi* Zone. One specimen is from a marine assemblage in Artesian Monitoring 30Z in the *P. lowryi* Zone. The other specimen is from Agaton 19 at 305 m, in a sample otherwise devoid of microplankton.

Genus **Hystrichodinium** Deflandre 1935 emend.
Clark and Verdier 1967

Type species: *Hystrichodinium pulchrum*
Deflandre 1935.

Hystrichodinium compactum Alberti 1961
Pl. 30, figs 4, 5; Pl. 47, fig. 10

Dimensions: Range of cyst body length (9 specimens) 48(56)69 μm , width 38(46)58 μm ; length of parasutural spines 5–23 μm .

Remarks: The Perth Basin specimens correspond with the German examples of Alberti (1961) in the number and length of the parasutural spines. The greater number of spines and their brevity distinguishes *H. compactum* from *H. oligacanthum* Deflandre and Cookson 1955, *H. pulchrum* Deflandre 1935, *H. voigtii* (Alberti) Davey 1974 and *H. patriciae* (Neale and Sarjeant) Lentin and Williams 1975, and other species of *Hystrichodinium* with unbranched spines.

Range: *Gagiella mutabilis* to *Fromea monilifera* Zones.

Hystrichodinium oligacanthum Deflandre
and Cookson 1955
Pl. 30, figs 6, 7

Dimensions: Range of cyst body length (10 specimens) 49(53)63 μm , width 38(49)59 μm ; length of parasutural spines 15–39 μm .

Remarks: *Hystrichodinium voigtii* (Alberti) Davey 1974, and *H. patriciae* (Neale and Sarjeant) Lentin and Williams 1975 possess a similar number of parasutural spines of comparable length to those of *H. oligacanthum*, and are possible junior synonyms of this species. *Hystrichodinium pulchrum* Deflandre 1935 exhibits an evenly patterned cyst body, whereas *H. oligacanthum* is usually unsculptured.

Range: *Batioladinium jaegeri* and *Fromea monilifera* Zones. *Hystrichodinium voigtii*, a form possibly conspecific with *H. oligacanthum*, was originally reported from the early Barremian to early Aptian of Germany (Alberti, 1961), but subsequent records range from the Berriasian (Duxbury, 1977) to Cenomanian (Sarjeant, 1966a).

Genus **Hystrichosphaerina** Alberti 1961

Type species: *Hystrichosphaerina schindewolfii*
Alberti 1961

Hystrichosphaerina schindewolfii Alberti 1961
Pl. 30, figs 8, 9

Dimensions: Range of cyst body length (10 specimens) 45(59)67 μm .

Remarks: *Hystrichosphaerina schindewolfii* possesses slender unbranched paracingular processes (Alberti, 1961). Of the cysts tentatively included here in *H. schindewolfii* only one has been found with paracingular processes. The precingular and postcingular processes correspond in style and position with those of *H. schindewolfii*. Duxbury (1980) illustrated a form he assigned to *H. schindewolfii* on which the paracingular processes appear to be rudimentary, therefore the absence of these processes from most of the present specimens is probably not taxonomically significant.

Range: *Kaiwaradinium scrutillinum* and *Phoberocysta lowryi* Zones. Previously recorded from the late Hauterivian to Barremian (Alberti, 1961; Davy, 1974; Duxbury, 1977, 1980).

Genus **Impagidinium** Stover and Evitt 1978

Type species: *Impagidinium dispertitum* (Cookson and Eisenack) Stover and Evitt 1978.

Impagidinium phlyctaena Stover and
Helby 1987
Pl. 39, figs 12, 13

Dimensions: Cyst body length (8 specimens) 43(47)50 μm , width 36(43)50 μm .

Remarks: The present specimens are less well preserved than those illustrated by Stover and Helby (1987); nevertheless, there is little doubt that they are the same cysts. There is some resemblance between this species and *Pteridinium aliferum* Eisenack 1958, but until the latter species is redescribed in detail it is impossible to determine whether the two are conspecific.

Range: *Batioladinium jaegeri* and *Fromea monilifera* Zones.

Genus **Kaiwaradinium** Wilson 1978

Type species: *Kaiwaradinium buccinatum* Wilson 1978.

Kaiwaradinium scrutillinum Backhouse 1987
Pl. 31, figs 1–3; Pl. 49, fig. 3

Range: Lower *Kaiwaradinium scrutillinum* Zone.

Genus **Kalyptea** Cookson and Eisenack 1960b

1960b *Kalyptea* Cookson and Eisenack, p. 257.

Type species: *Kalyptea diceras* Cookson and Eisenack 1960b.

Remarks: The original generic description by Cookson and Eisenack (1960b) is retained here in preference to the emended description by Wiggins (1975). The original description differs from the modified descriptions of Wiggins (1975), and Stover and Evitt (1978) by only including species with a kalyptra, and by including species without an antapical horn. The transfer of *Komewuia glabra* Cookson and Eisenack 1960b to *Kalyptea* by Wiggins (1975) is rejected because of the absence of a kalyptra on *K. glabra*. The presence of an inner body in species of *Netrelytron* Sarjeant 1961 and *Paranetrelytron* Sargeant 1966 (Sarjeant, 1976) is the basis for distinguishing these genera from *Kalyptea*.

Other species accepted in *Kalyptea*:

K. jurassica Alberti 1961

K. monoceras Cookson and Eisenack 1960b.

Kalyptea monoceras Cookson and Eisenack 1960b
Pl. 30, figs 10–12

1960b *Kalyptea monoceras* Cookson and Eisenack, p. 257, Pl. 39, figs 2, 3.

1975 *Pareodinia ceratophora* subsp. *scopaeus* (Sarjeant) Lentin and Williams; Wiggins, p. 103, Pl. 1, figs 8, 9.

1978 *Pareodinia ceratophora* Deflandre; Davey, Pl. 8, fig. 12.

1980a *Pareodinia ceratophora* Deflandre; Burger, p. 85, Pl. 45, figs 4, 5.

Description: Proximate cysts, ovoid, with a short apical horn. Autophragm smooth, or finely granular. Apical horn short and narrow, or short and broad, 2 to 9 μm long. Intercalary archeopyle poorly defined, formed by removal of one or more paraplates. Paratabulation not expressed. Cyst always surrounded by a kalyptra. Kalyptra regular in width on undamaged specimens, from 2 to 15 μm wide, but usually about 10 μm wide.

Dimensions: Length excluding kalyptra (17 specimens) 41(57)69 μm , width 26(39)43 μm .

Remarks: Gocht (1970b) and Wiggins (1975) both considered this species to be a junior synonym of *Pareodinia ceratophora* Deflandre 1947c. The presence of a kalyptra on all specimens examined during this study has convinced this author of the wisdom of retaining it as an item of generic significance, at least until it can be unequivocally shown to be a variable feature.

Range: *Kaiwaradinium scrutillinum* to *Fromea monilifera* Zones. Previous records are from the Aptian (Davey, 1978) and the Late Jurassic (Cookson and Eisenack, 1960b; Wiggins, 1975).

Genus **Kleithriasphaeridium** Davey 1974

Type species: *Kleithriasphaeridium corrugatum* Davey 1974.

Kleithriasphaeridium eoinodes (Eisenack)
Davey 1974
Pl. 31, figs 7, 8

Dimensions: Cyst body length (6 specimens) 41(46)52 μm , width 45(50)54 μm , length of processes 16–29 μm .

Remarks: The present specimens are slightly larger than the type material from the Aptian of Germany (Eisenack, 1958). *Kleithriasphaeridium simplicispinum* (Davey and Williams) Davey 1974 from the Barremian of England may be synonymous.

Range: Uppermost *Aprobolocysta alata* to *Fromea monilifera* Zones.

Kleithriasphaeridium fasciatum (Davey and Williams) Davey 1974
Pl. 31, figs 4–6; Pl. 49, figs 1, 2

Dimensions: Range of cyst body length (16 specimens) 37(46)55 μm , width 35(52)65 μm , length of processes 8–22 μm .

Range: *Kaiwaradinium scrutillinum* to lower *Aprobolocysta alata* Zones. Previously recorded from the Berriasian to Barremian of north-east England (Davey and Williams 1966b; Davey, 1974; Duxbury, 1977) and the Neocomian of the Indian Ocean DSDP Hole 263 (Wiseman and Williams, 1974).

Genus **Leptodinium** Klement 1960 emended.
Stover and Evitt 1978

Type species: *Leptodinium subtile* Klement 1960.

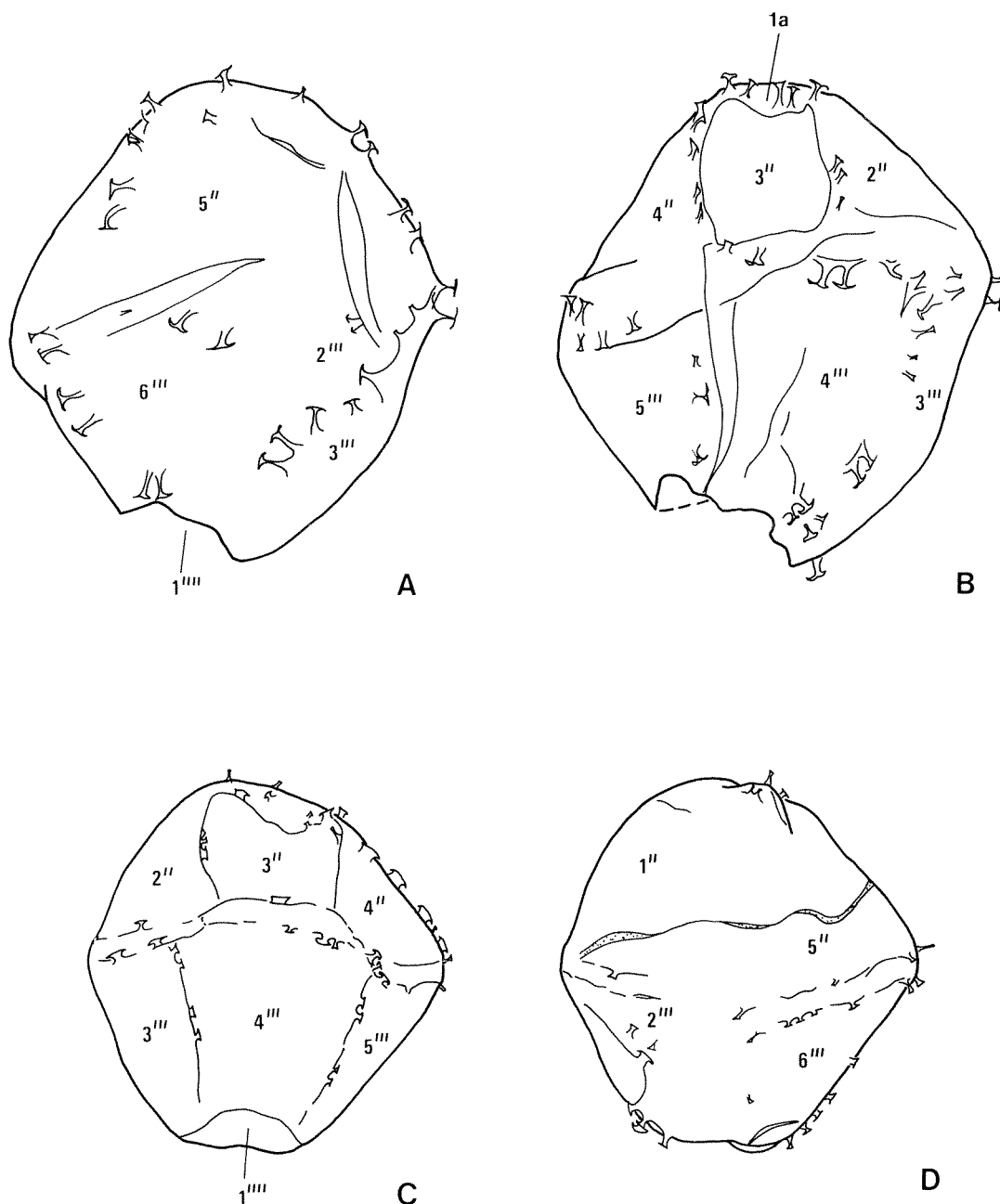
Leptodinium? hyalodermopsis (Cookson and Eisenack) Stover and Evitt 1978
Pl. 32, fig. 1; Pl. 49, figs 4, 5

Dimensions: Range of length (18 specimens) 47(60)72 μm , width 34(41)47 μm .

Range: *Kaiwaradinium scrutillinum* to *Fromea monilifera* Zones. Widely recorded previously from the Early Cretaceous, including the late Neocomian and ?Aptian of Western Australia (Cookson and Eisenack, 1958).

Leptodinium sepimentum Stevens and Helby 1987
Pl. 42, figs 9, 10; Fig. 27

Description: Proximochorate cyst, lenticular, dorsoventrally compressed; amb subpolygonal to oval. Autophragm 0.5 μm or less in thickness, smooth, and frequently folded. Paratabulation poorly expressed by discontinuous low septa 0.5 to 1.0 μm high. Small anchor-shaped processes elongated along line of parasuture may surmount parasutural septa, or isolated processes may



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Figure 27. *Leptodinium sepimentum* Stevens and Helby sp. nov. x800. Drawings based on photomicrographs. A, B, holotype, ventral view, A, ventral surface; B, dorsal surface, Pl. 42, fig. 10. C, D, dorsal view. C, dorsal surface; D, ventral surface, Pl. 42, fig. 9.

protrude directly from autocyst in parasutural positions. Paratabulation weakly expressed, provisional formula: X', 1a, ?5'', Xc, 5 or 6''', ?p, 1'''. Paracingulum usually well-expressed, offset approximately 10 μ m. Parasulcus not indicated. Archeopyle precingular, type P, operculum free. Antapical plate removed on approximately half the specimens observed.

Dimensions: Range of length (11 specimens) 63(77)88 μ m, width 59(69)77 μ m.

Remarks: Stevens and Helby (1987) provide a more detailed paratabulation formula based on the more completely paratabulate holotype from the Carnarvon Basin. The distinctive anchor-shaped parasutural processes facilitate easy identification of even poorly preserved specimens of this species.

Range: *Kaiwaradinium scrutillinum* to lower *Phoberocysta lowryi* Zones.

Genus *Meiourogonyaulax* Sarjeant 1966a

Type species: *Meiourogonyaulax valensii* Sarjeant 1966a.

Meiourogonyaulax bulloidea (Cookson and Eisenack) Sarjeant 1969
Pl. 32, fig. 2; Pl. 49, fig. 6; Fig. 28

Description: Medium-sized proximate lenticular cysts, with an oval outline, and preferred dorso-ventral orientation. Autophragm finely and evenly granular; bearing rounded, granular, rarely perforate parasutural septa approximately 2 μ m high. Septum between antapical paraplate and posterior parasulcal paraplate usually significantly higher (up to 9 μ m) and more perforate than other septa. Paratabulation complete, but paracingular cross septa usually poorly defined; formula: 4', 6'', 6c,

1p, 6''', 1''', ps. Paracingulum laevo-rotary, 4 to 5 μ m wide, offset one paracingulum width. Parasulcus broad, slightly sinuous, cyst wall sometimes split down one side of parasulcus. Most specimens preserved with antapical paraplate on dorsal surface and parasulcus extending to antapex. Archeopyle apical, type [tA], operculum free.

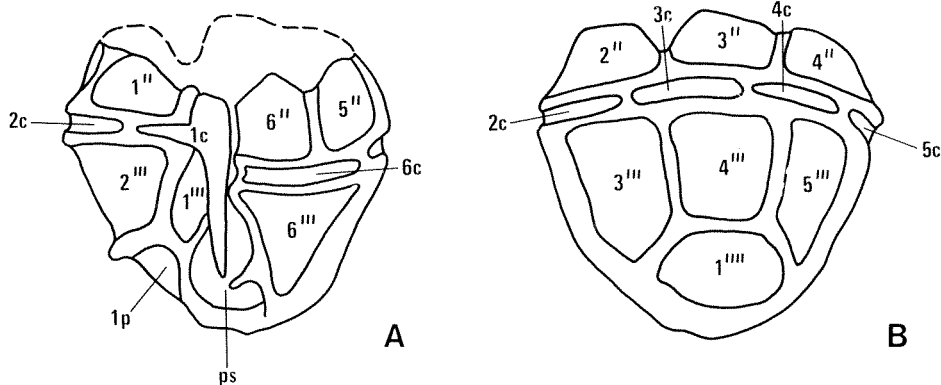
Dimensions: Range of length without operculum (17 specimens) 54(62)75 μ m, width 59(70)83 μ m.

Remarks: The specimens recorded in this study bear broader and often higher parasutural septa than the holotype from the Jarlemai Siltstone (Cookson and Eisenack, 1960b). The development of a high antapical septum is part of the transition to *Meiourogonyaulax* sp. cf. *M. bulloidea*. *Merourogonyaulax stoveri* Millioud 1969 is possibly a morphological variant of *M. bulloidea*.

Range: *Kaiwaradinium scrutillinum* to *Aprobolocysta alata* Zones.

Meiourogonyaulax* sp. cf. *M. bulloidea (Cookson and Eisenack) Sarjeant 1969
Pl. 32, figs 3–5

Description: Proximochorate cysts, lenticular, dorso-ventrally compressed, parasulcal notch central or slightly offset. Autophragm finely granular to almost spongy, bearing rounded parasutural septa laterally and antapically. Parasutural features not developed over central ventral and central dorsal areas. Paratabulation, where expressed, is identical with paratabulation of *M. bulloidea*. Paracingulum indicated by parasutural septa, 4 to 5 μ m wide, offset 5 to 10 μ m, sometimes developed across the mid-dorsal surface. Parasulcus rarely indicated; sometimes a split develops in the cyst wall below the parasulcal notch. Archeopyle apical, type [tA], operculum free.



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Figure 28. *Meiourogonyaulax bulloidea* (Cookson and Eisenack) Sarjeant 1969. Dorsal view, x800. Drawings based on photomicrographs.

A, ventral surface; B, dorsal surface. Pl. 32, fig. 2.

Dimensions: Range of length without operculum. (14 specimens) 38(60)97 μm , width 42(66)104 μm

Remarks: At one morphological extreme *M. sp. cf. M. bulloidea* approaches *Yalkalpodinium scutum* Morgan 1980a, but is distinguished by its weak paratabulation and the absence of cavation. The antapical parasulcal septum is high and perforate on some specimens of *M. sp. cf. M. bulloidea*, and resembles antapical cavation. *Meiourogonyaualax bulloidea* bears a comprehensive and clearly expressed paratabulation.

Range: *Phoberocysta lowryi* to *Batioladinium jaegeri* Zones.

***Meiourogonyaualax maculata* sp. nov.**

Pl. 32, figs 8–11; Fig. 29

Derivation of name: Latin, *maculatus*, spotted.

Holotype: F9081/5 (–50.0, –95.7), Whitfords 5, 92 m, Leederville Formation, Pl. 32, fig. 9.

Description: Small to medium proximate cyst, ovoid to lenticular, compressed laterally. Autophragm, less than 0.5 μm thick, usually entirely covered with small round dark grana of no discernible height, up to 1 μm in basal diameter; grana imparting a spotted appearance to the cyst. Some populations lack visible grana. Paracingulum approximately 5 μm wide, clearly expressed by low (less than 1 μm) narrow septa, offset 2 paracingulum widths. Details of parasulcus not usually observed because of lateral compression. Paratabulation on remainder of cyst weakly expressed by low septa; formula: ?4', 6'', Xc, 6''', 1p, 1'''. Archeopyle apical, type [tA], operculum free. Operculum bears a small truncate apical spine, 2 μm long.

Dimensions: Length of holotype without operculum 50 μm , width 51 μm . Range of length without operculum (31 specimens) 33(43)52 μm , width 41(40)60 μm . Length of one complete specimen 57 μm .

Remarks: The spotted appearance, thin autophragm, and lateral compression distinguish *Meiourogonyaualax maculata* from other species of the genus.

Range: *Batioladinium jaegeri* Zone. *Meiourogonyaualax maculata* is a member of the *Cyclonephelium attadalicum* Association.

***Meiourogonyaualax?* sp. A**

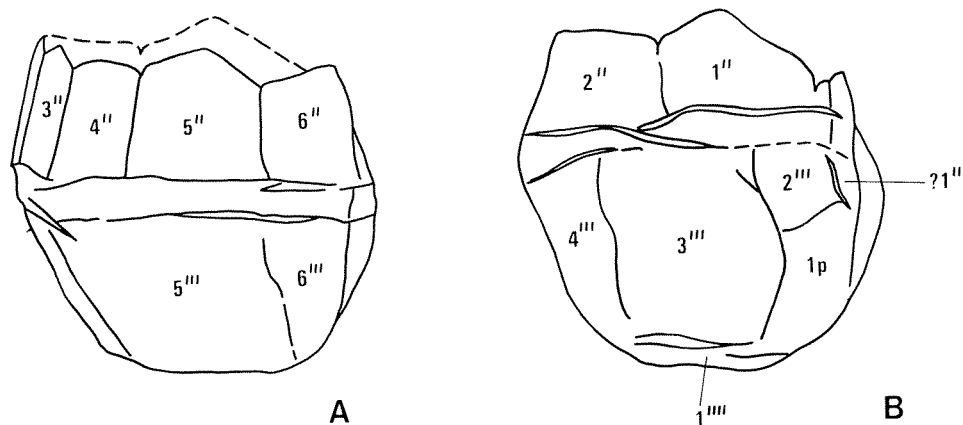
Pl. 34, figs 16, 17

Description: Small subspherical proximochorate cysts. Autophragm, less than 1 μm thick, bearing a variably developed reticulate surface pattern. Paratabulation expressed by membranous septa supported by fine vertical elements. Paratabulation formula not decipherable on specimens available. Paracingulum approximately 4 μm wide, offset 6 μm . Parasulcus narrow, poorly expressed. Archeopyle apparently apical; precingular paraplates very short, or foreshortened during archeopyle formation.

Dimensions: Range of length without operculum (3 specimens) 35(37)40 μm , width 37(40)46 μm .

Remarks: This species is only provisionally assigned to *Meiourogonyaualax* because the type of archeopyle and the nature of the paratabulation are not fully determined.

Range: *Fromea monilifera* Zone, rare.



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Figure 29. *Meiourogonyaualax maculata* sp. nov. Right lateral view, x800. Drawings of holotype based on photomicrographs.

A, right surface; B, left surface. Pl. 32, fig. 9.

Meiourogonyaulax? sp. B

Pl. 32, figs 12–15; Pl. 34, fig. 15

Description: Small lenticular proximochorate cysts, outline ovoid or rounded rectangular, dorso-ventrally flattened: parasulcal notch offset slightly left of centre. Hypocyst larger than epicyst. Wall two-layered, endophragm and periphragm separated where the latter forms smooth raised ridges up to 5 μm high. Surface of periphragm finely granular. Paratabulation fully expressed by periphragmal ridges; formula: ?4', 7'', 6c, 6''', 1p, 1'''. Paraplate 7'', small, triangular, tapered towards deep parasulcal notch. Paraplates 1''' and 6''', and parasulcus occupy almost entire ventral surface of hypocyst. Posterior intercalary quadrangular, postero-lateral in position. Antapical paraplate large, forming a broad flat antapex. Paraplate 4''' relatively small. Paracingulum prominent, 7 to 8 μm wide, offset 4 to 5 μm . Parasulcus prominent, represented by a large undivided oval area on hypocyst. Archeopyle apical, probably type [tA], operculum free. One complete specimen possesses a small flat operculum of probably 4 paraplates.

Dimensions: Range of length without operculum (10 specimens) 26(32)38 μm , width 25(32)37 μm .

Remarks: *Cernocysta helbyi* (Morgan) is comparable with *Meiourogonyaulax?* sp. B in wall structure and in the nature of the parasutural ridges, but *Meiourogonyaulax?* sp. B is smaller than *C. helbyi*, dorso-ventrally flattened, and possesses a slightly different paratabulation. Several criteria suggest that *Meiourogonyaulax?* sp. B may not belong in *Meiourogonyaulax*, but in the absence of specimens which better illustrate the paratabulation it is provisionally assigned to this genus.

Range: *Fromea monilifera* Zone.

Genus **Moorodinium** gen. nov.

Type species: *Moorodinium spinatum* sp. nov.

Derivation of name: After the town of Moora, near the type locality of the type species.

Synopsis: Cysts small to medium, ovoid to trilobate; autophragm smooth or granular, thin and membranous. Paratabulation indicated by fine septa or not expressed; paracingulum always indicated, parasulcus usually not indicated. Archeopyle combination epicystal, type [tA, tP], operculum free or attached.

Description:

Shape: Ovoid or trilobate, epicyst and hypocyst usually differing in shape.

Wall Relationships: Autophragm only, always thin, membranous and usually finely folded.

Wall Features: Autophragm may bear membranous septa and spines. Surface finely granular or smooth under SEM. Some surface features pass dorso-ventrally over the apex of the cyst.

Paratabulation: May be expressed by septa or by patterns in the surface granulation. Formula not known, 6 postcingular paraplates, and an antapical paraplate indicated on type species.

Archeopyle: Combination epicystal, type [tA, tP], epicyst and hypocyst similar in size so that archeopyle formation splits cyst in half. Operculum frequently attached.

Paracingulum: Usually clearly expressed by transverse septa, slightly offset, not subdivided into paracingular paraplates.

Parasulcus: Usually not indicated.

Size: Small to medium.

Comparison: *Isthmocystis* Duxbury 1979 is similar in general structure to *Moorodinium* but possesses a 6P rather than an epicystal archeopyle.

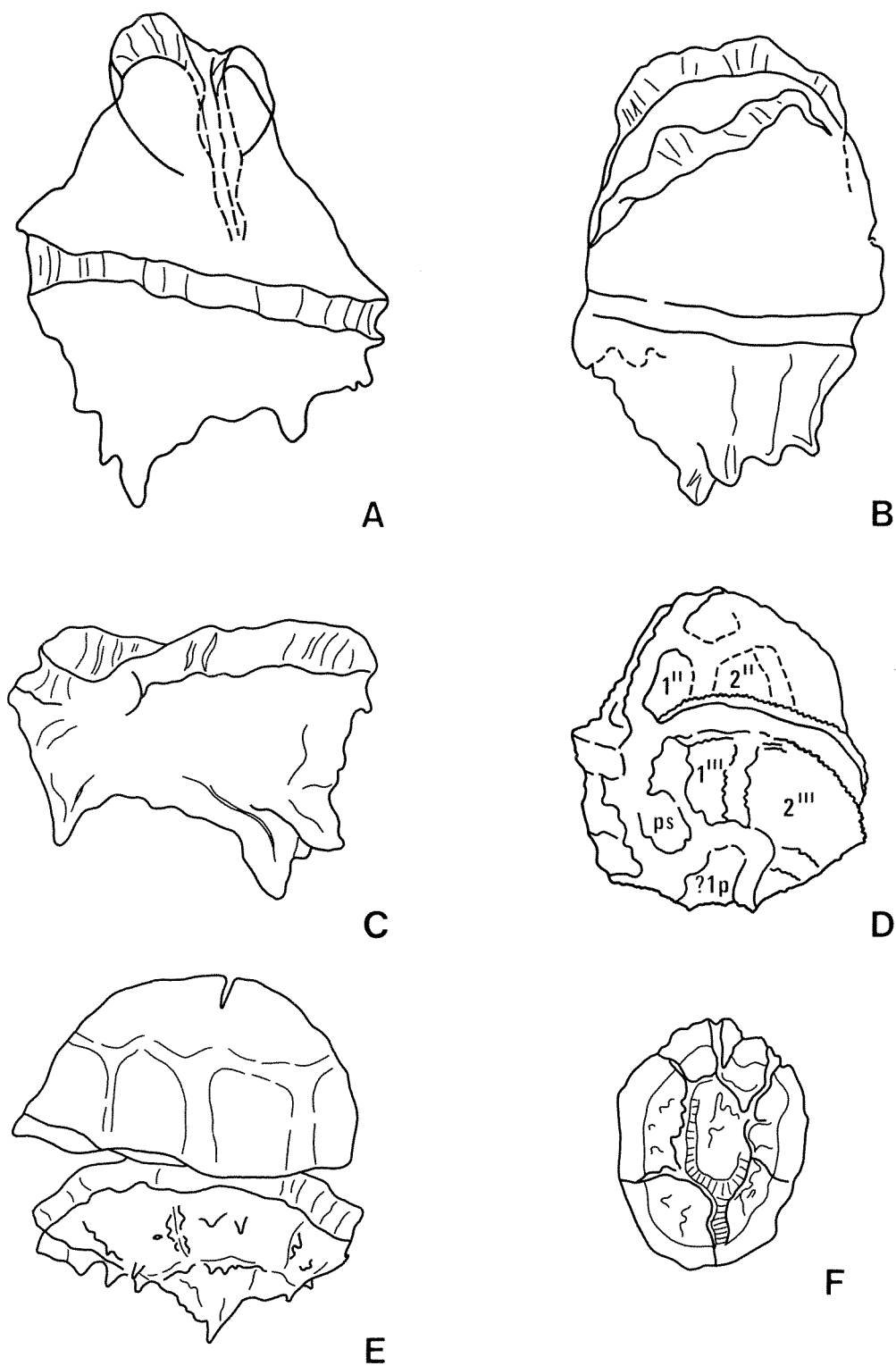
Remarks: Species assigned to *Moorodinium* all possess thin autophragms bearing fine folds, epicystal archeopyles, and dorso-ventral apical structures. The cysts represent a homogeneous and rapidly evolving group of dinoflagellates which occupied a series of fresh or brackish aqueous environments in the Perth Basin through the ?late Tithonian and Early Cretaceous. Large numbers of *Moorodinium* cysts are present at some shale horizons in the Parmelia Formation, and reach an acme of abundance and diversity in the Carnac Member. In addition to the four species described below, small numbers of some other forms have been observed, which suggests that the diversity of this genus in the Early Cretaceous was greater than the four species described in this bulletin.

Moorodinium peregrinum sp. nov.

Pl. 33, figs 1–5; Pl. 48, figs 5, 6; Fig. 30A–C

Derivation of name: Latin, *peregrinus*, *strange*.

Holotype: F6685/3 (–50.1, –102.8), Watheroo Line 3, 124.5 m, Carnac Member of Parmelia Formation, Pl. 33, fig. 1.



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Figure 30. *Moorodinium peregrinum* sp. nov. and *M. spinatum* sp. nov. Drawings based on photomicrographs and scanning electron micrographs.

A–C, *M. peregrinum*. x1000. A, holotype, dorsal view, Pl. 33, fig. 1; B, left lateral view, Pl. 33, fig. 3; C, detached hypocyst, ventral view, Pl. 33, fig. 5.

D–F, *M. spinatum*. D, ventral view showing partial paratabulation, x1200, Pl. 48, fig. 7; E, holotype, left lateral view, x1000, Pl. 34, fig. 8; F, detached hypocyst, antapical view, x1000, Pl. 34, fig. 6.

Description: Medium-sized proximochorate cysts, subovoid to lobate; epicyst an inflated cone with a rounded apex; hypocyst with two multibranched lobes: in a left antapical position, and in a lateral position, slightly right of the parasulcal zone. Autophragm finely folded, and on rare specimens appears to bear low parasutural septa. Paratabulation otherwise not indicated. Paracingulum indicated by raised ridges and numerous fine cross striae, approximately 5 μm wide, offset only 2 or 3 μm . Position of parasulcus indicated at paracingulum, otherwise not expressed. Two sub-parallel, non-tabular septa, up to 6 μm high, pass dorso-ventrally over apex of cyst. Archeopyle combination epicystal, type [tA, tP]; operculum attached for a considerable part of cyst circumference, only at parasulcus, or free. Primary archeopyle suture formed immediately above anterior paracingular transverse septum.

Dimensions: Length of holotype 77 μm , width 56 μm . Range of length (23 specimens) 58(69)85 μm , width 42(50)63 μm .

Remarks: As in other species of *Moorodinium* the apical ventro-dorsal septa of *M. peregrinum* confer a strong preferred lateral orientation to the epicyst. The lobes of the hypocyst confer a preferred dorso-ventral orientation to the lower half of the cyst. In most cases detached epicysts and hypocysts are found in lateral and dorso-ventral orientations respectively. When the epicyst is still attached to the hypocyst at the parasulcus the cyst is usually twisted so that the epicyst is laterally oriented and the hypocyst dorso-ventrally oriented. Whole specimens may be oriented either way, or twisted across the centre (Pl. 33, fig. 4). *Moorodinium peregrinum* is distinguished from other species of *Moorodinium* by its lobate hypocyst, large epicyst, and high apical septa. It is the largest species of *Moorodinium* encountered in this study.

Range: *Fusiformacysta tumida* Zone. Recorded only from the upper part of the Carnac Member in the Dandaragan Trough.

***Moorodinium quindalupense* sp. nov.**

Pl. 33, figs 6–10; Pl. 34, fig. 1

Derivation of name: After the type locality, Quindalup Line 7A borehole.

Holotype: F10291/2 (–24.4, –110.6), Quindalup 7A, 141 m, Leederville Formation, Pl. 33, fig. 9.

Description: Medium-sized ovoid proximochorate cysts bearing a single broad, antapical spine. Epicyst not paratabulate under a light microscope, finely granular, bearing two membranous septa passing dorso-ventrally over apex of cyst. Septa up

to 3 μm high, usually lower. Paratabulation on hypocyst indicated by low features in penitabular positions, number of paraplates not determined, but paratabulation appears similar to that of *M. spinatum*. Parasulcus weakly indicated by low surface features. Paracingulum indicated by low transverse septa, cross septa absent. Antapical spine up to 10 μm long, broadly based, asymmetrical and pointed, positioned in centre of antapical paraplate. Archeopyle combination epicystal, type [tA, tP], operculum usually attached on ventral surface. Principal archeopyle suture positioned immediately above paracingulum.

Dimensions: Length of holotype including antapical spine 67 μm , width 48 μm . Range of length (20 specimens) 52(61)71 μm , width 37(44)57 μm .

Remarks: *Moorodinium quindalupense* is larger, possesses a larger antapical spine and less prominent paracingular transverse septa than *M. spinatum*. It is the only species of *Moorodinium* unequivocally known to occur in the Warnbro Group. It was recorded from two apparently non-marine sections of the Leederville Formation in the Bunbury Trough (Quindalup Line 7A at 141 m and Boyanup Line 1C at 72–73 m). *Nummus pentagonus* sp. nov. is recorded at a similar level in Boyanup 1C. Other *Moorodinium*-type cysts are occasionally recorded in the Warnbro Group in the Perth area, but these cysts may be reworked from the Parmelia Formation, which outcropped north of Perth during the Early Cretaceous.

Range: ?*Batioladinium jaegeri* Zone.

***Moorodinium simplex* sp. nov.**

Pl. 34, figs 2–5

Derivation of name: Latin, *simplex*, simple, referring to the simple shape and absence of large surface features.

Holotype: F8463/2 (–38.8, –98.0), Eneabba Line 4, 267 m, Otorowiri Member of Parmelia Formation, Pl. 34, fig. 4.

Description: Small, ovoid, proximate cysts with a preferred lateral orientation. Wall very thin, may be single-layered or composed of two thin layers appressed over most of cyst surface. Slight cavation may be developed in antapical area. Epicyst bears low, narrow, dorso-ventral septa less than 2 μm high. Hypocyst without discernible paratabulation, lacking spines. Paracingulum indicated by low transverse ridges, 3 to 4 μm wide, not visibly offset. Parasulcus not indicated, or obscured by orientation. Archeopyle combination

epicystal, type [tA, tP], operculum usually attached for part of circumference. Primary archeopyle suture situated along anterior margin of paracingulum.

Dimensions: Length of holotype 35 μm , width 29 μm . Range of length (21 specimens) 30(35)39 μm , width 24(29)33 μm .

Remarks: *Mooradinium simplex* is distinguished from other species of *Moorodinium* by its small size and lack of discernible hypocystal surface features. The paracingulum is the only evidence of paratabulation on most specimens. Because of its small size and the difficulties of observation, the morphology of this species is less well-known than other members of the *Moorodinium* cyst-lineage.

Range: Base of *Fusiformacysta tumida* Zone in the Eneabba Line boreholes, Dandaragan Trough.

***Moorodinium spinatum* sp. nov.**

Pl. 34, figs 6–14; Pl. 47, fig. 9; Pl. 48, figs 7–10; Fig. 30D–F

Derivation of name: Latin, *spinatus*, bearing spines, referring to surface features on the hypocyst.

Holotype: F9120/5 (–36.4, –99.8), Moora Line 3, 220 m, Carnac Member of Parmelia Formation, Pl. 34, fig. 8.

Description: Small proximate cysts, ovoid, with a slight preferred lateral orientation. Autophragm membranous, finely granular under SEM. Hypocyst bears narrow spinose parasutural septa, up to 3 μm high, and intratabular spines, up to 2 μm high. Observed with SEM, some septa are penitabular in position with a less prominent row of grana in the parallel adjacent penitabular position. Antapical plate bears central cluster of 2 or 3 connected spines; largest up to 5 μm long. Spines reduced in size in some populations. Septum bordering right side of parasulcus high and prominent. Under SEM, epicystal paratabulation indicated by penitabular rows of discrete or fused grana which enclose pandasutural areas of smaller grana. Epicystal intratabular areas bear isolated grana and rugulae. Epicystal paratabulation arranged around two dorso-ventral ridges which, on some specimens, develop into low narrow septa. These dorso-ventral structures impart a preferred lateral orientation to the cyst. Paratabulation formula not determined, at least 5 and possibly 6 postcingular paraplates and one antapical paraplate indicated by parasutural features on suitably oriented detached hypocysts (Fig. 30F). Paracingulum indicated by prominent transverse septa, not subdivided, 3 to 4 μm wide, offset 2 to 3 μm . Parasulcus not usually observed

owing to lateral compression; distinguishable on one specimen under SEM (Fig. 30D). Archeopyle combination epicystal, type [tA, tP], operculum often only partly separated; primarily archeopyle suture immediately above anterior transverse paracingular septum.

Dimensions: Length of holotype 54 μm , width 49 μm . Range of length of 20 specimens with prominent spines from Dandaragan Trough 36(43)54 μm , width 32(37)49 μm . Range of length of 13 specimens with reduced spines from Roe 1 44(50)59 μm , width 37(40)49 μm .

Remarks: Specimens of *M. spinatum* with reduced spines possess a longer, more inflated hypocyst than more spinose forms. The two forms are recorded from different sets of samples. The form with reduced spines is present in the Carnac Member in Roe 1, Peel 1, and Artesian Monitoring 7; the spinose form is present in the Carnac Member in Moora Line 3C and 2B, and in Watheroo Line 3. Correlation between all these sections is not possible, but the positions of the two forms within the Carnac Member suggests that the less spinose form occurs stratigraphically below the more spinose form. *Moorodinium spinatum* is larger than *M. simplex* sp. nov. and smaller than *M. quindalupense* sp. nov. It is further distinguished from *M. simplex* by possessing paratabulation and from *M. quindalupense* by possessing spinose septa and a multibranching antapical spine rather than a single long antapical spine.

Range: *Fusiformacysta tumida* Zone.

Genus ***Muderongia*** Cookson and Eisenack 1958

Type species: *Muderongi mcwhaei* Cookson and Eisenack 1958.

***Muderongia australis* Helby 1987**

Pl. 35, figs 1–3

Description: Cyst proximate, cornucavate, dorso-ventrally flattened. Body rhomboid in outline, bearing prominent apical, antapical and two lateral horns. Endophragm 0.5 to 1.0 μm thick, unfolded; periphragm thinner, sometimes folded, often bearing small subcircular perforations on the horns. Apical horn, simple, straight, rounded at tip; antapical horn offset to left with a short protruberance on right at base of horn. Lateral horns of variable length, notched near base and angled towards antapex, sometimes bearing short spines. Paratabulation not clearly evident; paracingulum often indicated on dorsal surface, passing on to lateral horns and ending at notches. Archeopyle apical, type [tA], operculum almost

always removed. Primary archeopyle suture indicates 6 precingular and 4 apical paraplates.

Dimensions: Range of length without operculum (12 specimens) 74(89)110 μm , width 73(88)116 μm ; length of endophragm without operculum 43(50)56 μm , width 50(55)62 μm .

Remarks: *Muderongia mcwhaei* Cookson and Eisenack 1958 possesses lateral horns which are longer below the paracingular notch. Rare forms intermediate between *M. australis* and *M. mcwhaei* have been observed in the *Fromea monilifera* Zone.

Range: *Batioladinium jaegeri* and *Fromea monilifera* Zones.

***Muderongia testudinaria* Burger 1980b**

Pl. 35, figs 5, 6; Pl. 51, fig. 1

1964 *Muderongia mcwhaei* Cookson and Eisenack; Edgell, Pl. 31, fig. 4.

1980b *Muderongia testudinaria* Burger, p. 274, figs 9B, 20A–E.

1980 *Muderongia* sp. Wiseman, p. 345, Pl. 1, fig. 6.

Dimensions: Range of length without operculum (4 specimens) 70(83)100 μm , width 95(98)103 μm ; endophragm length without operculum (9 specimens) 43(57)66 μm , width 38(60)74 μm . Length of antapical horns 11 to 41 μm ; length of lateral horns 15 to 36 μm .

Range: *Phoberocysta lowryi* and *Aprobolocysta alata* Zones. Previously recorded from the Neocomian of the Perth Basin (Edgell, 1964), northern Queensland (Evans, 1966; Burger, 1980b), DSDP site 263 (Wiseman and Williams, 1974), and the Carnarvon Basin (Wiseman, 1980).

***Muderongia tetracantha* (Gocht) Alberti 1961**

Pl. 35, fig. 4; Pl. 49, figs 7, 8

1957 *Pseudoceratium tetracanthum* Gocht 1957, p. 168, Pl. 18, figs 7–9.

1961 *Muderongia tetracantha* (Gocht) Alberti, p. 14.

1962 *Muderongia crucis* Neale and Sarjeant, p. 449, Pl. 20, figs 2, 6.

1964 *Pseudoceratium tetracanthum* Gocht; Edgell, Pl. 31, fig. 5.

1974 *Muderongia tetracantha* (Gocht) Davey, p. 67, Pl. 8, fig. 3.

1974 *Muderongia crucis* Neale and Sarjeant; Davey, p. 66, Pl. 8, fig. 6.

1975 *Muderongia tetracantha* (Gocht); Wall and Evitt, Pl. 3, figs. 6–8.

1977 *Muderongia crucis* Neale and Sarjeant; Duxbury, p. 54, Pl. 25, fig. 8.

1977 *Muderongia tetracantha* (Gocht); Duxbury, p. 55, Pl. 15, fig. 5.

non 1980a *Muderongia tetracantha* (Gocht); Morgan, p. 28, Pl. 20, figs 2–5, 8.

Dimensions: Range of cyst body length (13 specimens) 48(50)65 μm , width 44(62)70 μm . Length of lateral horns 36–81 μm ; length of antapical horns 43–69 μm .

Remarks: Forms included in *M. tetracantha* possess two long lateral horns and one broad-based antapical horn. The lateral horns are broad based and most are angled backwards at an elbow near the cyst body. In this respect, they correspond to the specimens illustrated by Gocht (1957). The long apical horn of Gocht's specimens has not been observed on the Perth Basin specimens. Rows of perforations are evident on the antapical horns of many specimens about one-third of the way down the horn from the base, at the point where the horn is most strongly tapered. Perforations are sometimes also present on the lateral horns. The species with narrow horns recorded by Morgan (1980a) from the Aptian of Australia is referred here to *Muderongia* sp. A.

Range: *Kaiwardinium scrutillinum* to *Aprobolocysta alata* Zones. Previous records of *M. tetracantha* give a range starting in the late Hauterivian. The specimens assigned to *Muderongia* sp. cf. *M. staurota* Sarjeant by Morgan (1980a) may belong in *M. tetracantha*. If so, the range of this species extends into the Aptian.

***Muderongia* sp. A**

Pl. 35, figs 7, 8

1978 *Muderongia tetracantha* (Gocht); Davey, Pl. 6, fig. 3.

1980 *Muderongia tetracantha* (Gocht); Wiseman, Pl. 1, fig. 4.

1980a *Muderongia tetracantha* (Gocht); Morgan, p. 18, Pl. 30, figs 2, 5, 8; non Pl. 20, figs 3, 4.

Dimensions: Range of cyst body length without operculum (6 specimens) 58(60)61 μm , width 61(64)67 μm . Length of antapical horn 51 to 75 μm ; length of lateral horns 41 to 78 μm .

Remarks: *Muderongia* sp. A is distinguished from *M. tetracantha* (Gocht) by the shape of the horns and the more subspherical cyst body. The horns are narrower, particularly near the base and the lateral horns possess less prominent elbows than *M. tetracantha*.

Range: *Batioladinium jaegeri* and *Fromea monilifera* Zones. Recorded by Morgan (1980a) from the Late Neocomian to Early Albian of Australia.

Muderongia sp. B
Pl. 35, fig. 9; Pl. 36, fig. 1

1980a *Muderongia tomaszowensis* Alberti; Morgan, p. 28, Pl. 19, figs 12–14.

1980a *Muderongia tetracantha* (Gocht); Burger, p. 75, Pl. 35, Figs 1, 3.

Dimensions: Length without operculum (1 specimen) 121 μm , width (5 specimens) 57(65)78 μm .

Remarks: Insufficient well-preserved specimens have been recorded to allow a full description of this species. It possesses two short broad lateral horns, and a single antapical horn offset to one side. The antapical horn is damaged or missing on most specimens. The only evidence of paratabulation is the archeopyle suture and, in some specimens, a faintly expressed dorsal paracingulum. The nearest species are *Muderongia staurota* Sarjeant 1966 and *Muderongia simplex* Alberti 1961. *Muderongia staurota* possesses longer lateral horns which clearly extend well beyond the elbowed bend and a larger antapical pericoel than *Muderongia* sp. B. *Muderongia simplex* possesses a short second antapical horn. *Muderongia* sp. B is most frequently observed in the upper part of the *Aprobolocysta alata* Zone, just below the first appearance of *M. australis* sp. nov.

Range: *Aprobolocysta alata* to ?*Fromea monilifera* Zones. The full range of *Muderongia* sp. B is uncertain because poorly preserved specimens are easily overlooked. Morgan gives it a tentative range of Barremian to early Albian.

Genus **Occisucysta** Gitmez 1970

Type species: *Occisucysta balia* Gitmez 1970.

Occisucysta tenuiceras (Eisenack) Below 1981
Pl. 36, fig. 2

Description: Cyst proximochorate, subspherical, bearing a short apical horn. Autophragm less than 1 μm thick, finely granular to finely perforate. Paratabulation completely expressed by membranous septa, 3 to 5 μm high, supported by spines of similar length. Paratabulation formula: 4', Oa, 6'', ?6c, 6'', 1p, 1''', 5s. Intratabular areas sculptured with acicular spines, 1 to 2 μm long. Paracingulum 5 μm wide, offset approximately 12 μm . Parasulcus clearly expressed, parasulcal paraplates usually prominent. Archeopyle precingular, type 2P, composed of paraplates 2'' and 3'', operculum free.

Dimensions: Range of length (6 specimens) 64(72)83 μm , width 58(67)78 μm .

Range: *Phoberocysta lowryi* to *Fromea monilifera* Zones.

Genus **Odontochitina** Deflandre 1935 emend.
Davey 1970

Type species: *Odontochitina operculata* (O. Wetzel) Deflandre and Cookson 1955.

Odontochitina operculata (O. Wetzel)
Deflandre and Cookson 1955
Pl. 36, figs 3, 4

Dimensions: Range of cyst body length (5 specimens) 46(56)69 μm , width 48(56)68 μm . Length of antapical horn 55(64)79 μm , length of lateral horn 45(53)75 μm .

Remarks: The present specimens possess shorter lateral and antapical horns than specimens from the Albian. One specimen bears a second short (6 μm) lateral horn (Pl. 36, fig. 4), but is otherwise identical with other specimens from the same sample. *Odontochitina operculata* probably evolved from *Muderongia*-style cysts by losing the left lateral horn.

Range: *Batioladinium jaegeri* to *Fromea monilifera* Zones.

Genus **Oligosphaeridium** Davey and
Williams 1966a

Type species: *Oligosphaeridium complex* (White) Davey and Williams 1966b.

Oligosphaeridium complex (White) Davey
and Williams 1966b.
Pl. 36, figs 6, 7

Range: *Kaiwaradinium scrutillinum* to *Fromea monilifera* Zones, common in the *F. monilifera* Zone.

Oligosphaeridium pulcherrimum (Deflandre and Cookson) Davey and Williams 1966b
Pl. 36, fig. 8; Pl. 51, fig. 4

Dimensions: Range of cyst body length without operculum 42(56)68 μm , width 45(51)57 μm .

Remarks: The processes of *Oligosphaeridium pulcherrimum* are slightly fibrous, particularly near the base. Distally, the processes are deeply flared and sometimes perforate. *Oligosphaeridium pulcherrimum* is slightly larger than *O. complex* (White).

Range: *Kaiwaradinium scrutillinum* to *Fromea monilifera* Zones. *Oligosphaeridium pulcherrimum*

is common in most microplankton assemblages from the Warnbro Group and is consistently present in near-shore marine assemblages.

Oligospheridium sp. A
Pl. 37, fig. 1

Dimensions: Range of cyst body length (4 specimens) 41(53)71 μm , width 35(47)58 μm .

Remarks: Few specimens of this species have been located. It is distinguished by its short, funnel-shaped, distally spinose, fibrous processes.

Range: *Phoberocysta lowryi* to *Fromea monilifera* Zones.

Genus **Ovoidinium** Davey 1970 emend. Lentin and Williams 1976

Type species: *Ovoidinium verrucosum* (Cookson and Hughes) Davey 1970.

Ovoidinium cinctum (Cookson and Eisenack)
Davey 1970
Pl. 37, fig. 2

Dimensions: Range of length (10 specimens) 71(78)86 μm , width 46(52)58 μm .

Range: Upper *Fromea monilifera* Zone. Originally recorded from the Birdrong Formation of the Carnarvon Basin (Cookson and Eisenack, 1958), Wiseman (1978) dated the first appearance of this species in the Carnarvon Basin as late Barremian. Morgan (1980a) recorded it from the late Neocomian and early Aptian of Australia.

Genus **Palaeoperidinium** Deflandre 1935 emend. Lentin and Williams 1976

Type species: *Palaeoperidinium pyrophorum* (Ehrenberg) Sarjeant 1967.

Palaeoperidinium cretaceum Pocock 1962
Pl. 37, fig. 4

Range: Upper *Fromea monilifera* Zone. Several examples of this widely recorded species are present in one sample (Warnbro 1, 1 102 m).

Genus **Pareodinia** Deflandre 1947 emend. Stover and Evitt 1978

Type species: *Pareodinia ceratophora* Deflandre 1947.

Pareodinia sp. cf. *P. arctica* Wiggins 1975
Pl. 37, figs 5, 6

Dimensions: Range of length (8 specimens) 74(93)99 μm , width 37(44)49 μm .

Remarks: The present specimens compare closely in size and shape with the type material of *P. arctica* from Alaska, but they lack the faintly expressed paracingulum described by Wiggins (1975).

Range: *Kaiwaradinium scrutillinum* to *Fromea monilifera* Zones.

Pareodinia ceratophora Deflandre 1947
Pl. 37, fig. 7

Dimensions: Range of length (4 specimens) 52(66)77 μm , width 31(40)43 μm .

Range: *Kaiwaradinium scrutillinum* to *Aprobolocysta alata* Zones.

Genus **Pentafidia** gen. nov.

Type species: *Pentafidia charlottensis* sp. nov.

Derivation of name: Greek, *pentafid*, divided or cleft into five parts, alluding to the five precingular paraplates indicated by the archeopyle suture.

Synopsis: Cysts subcircular to ovoid, paratabulation indicated only by archeopyle. Autophragm smooth, punctate, or bearing fine non-tabular surface features. Archeopyle apical, type [tA], primary and accessory archeopyle sutures indicating 5 precingular and 4 apical paraplates.

Description:

Shape: Subspherical, ovoid, or slightly lenticular.

Wall Relationships: Autophragm only.

Wall Features: No parasutural features, surface smooth, finely punctate or bearing fine evenly distributed features.

Paratabulation: Indicated only by archeopyle and accessory sutures. Principal archeopyle suture indicates 5 precingular and 4 apical paraplates.

Archeopyle: Apical, type [tA], operculum free, constituent paraplates undifferentiated.

Paracingulum: Not expressed.

Parasulcus: Not expressed.

Size: Small to medium.

Comparison: *Pentafidia* differs from *Chytroeisphaeridia* Sarjeant 1962 emend. Davey 1979c by possessing an apical rather than a precingular archeopyle. *Batiacasphaera* Drugg 1970b, *Kallosphaeridium* De Coninck 1969, and *Cassiculosphaeridia* Davey 1969 all possess 6 precingular paraplates.

Remarks: The two species recognized in the Perth Basin are not found in association with marine dinoflagellate cysts. The dinoflagellates that produced cysts of the genus *Pentafidia* apparently occupied a restricted marine, brackish or fresh-water environment.

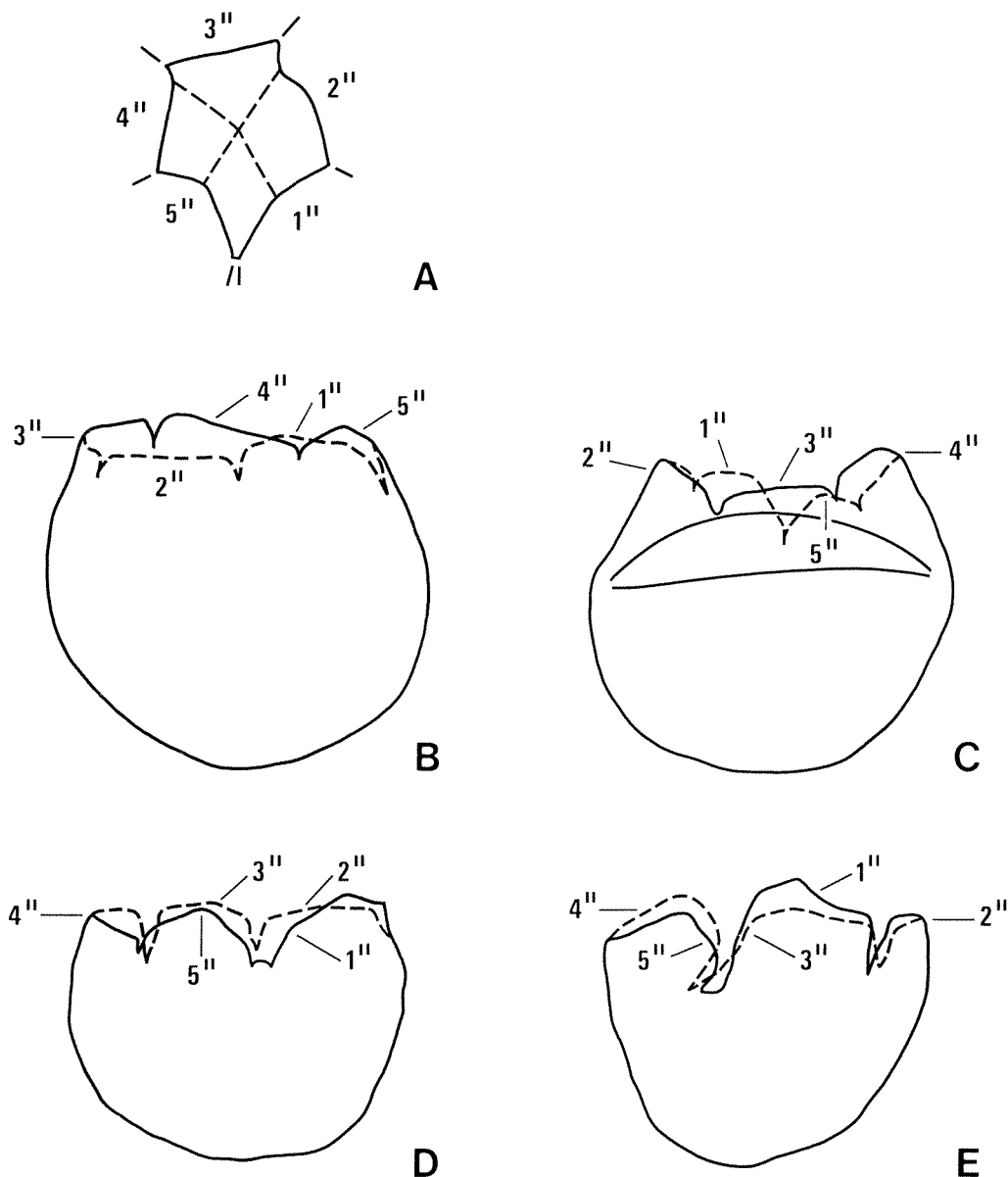
***Pentafidia charlottensis* sp. nov.**

Pl. 37, figs 8–16; Pl. 50, figs 1–3; Fig. 31A–C

Derivation of name: After the type locality, Charlotte 1 borehole.

Holotype: F15062/9 (–34.9, –103.2), Charlotte 1, 1932 m, Parmelia Formation, Pl. 37, fig. 8.

Description: Cysts medium-sized, subspherical, ovoid, lenticular or flask-shaped. Autophragm 1.5 μm thick, rigid, and perfectly smooth. One or more large transverse folds developed across centre. Paratabulation indicated only by primary archeopyle suture and short accessory sutures.



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Figure 31. *Pentafidia charlottensis* sp. nov. and *P. punctata* sp. nov. x800. Drawings based on photomicrographs.

A–C, *P. charlottensis*. A, operculum configuration, Pl. 37, fig. 11; B, holotype, right lateral view, Pl. 37, fig. 8; C, dorsal view, Pl. 37, fig. 10.

D–E, *P. punctata*. D, holotype, ventral view, Pl. 38, fig. 1; E, ventral view, Pl. 38, fig. 5.

Paracingulum and parasulcus not expressed. Archeopyle apical, type [tA], operculum free. Primary archeopyle suture indicates 5 precingular paraplates. Paraplates 1" and 5" are gabled, paraplates 2" and 4" may be asymmetrically gabled, paraplates 3" is always straight. Parasulcal notch deep and narrow. Principal archeopyle suture rather variable in relief, reflecting variable cyst shape. Operculum small, lacking accessory sutures, apparently composed of 4 fused apical paraplates.

Dimensions: Length of holotype without operculum 61 μm , width 70 μm . Range of length without operculum (30 specimens from type material) 51(57)63 μm , width 48(54)70 μm .

Remarks: *Pentafidia charlottensis* is distinguished from *P. punctata* sp. nov. by possessing an autophragm completely devoid of surface features, even with the aid of the SEM. Specimens referable to *P. charlottensis* from stratigraphically lower levels than the type material possess thinner, more readily folded autophragms. These forms may occur in association with *P. punctata*, which they closely resemble, this suggests a close phyletic relationship between the two species.

Range: Middle and upper parts of the *Fusiformacysta tumida* Zone. In the type material and other samples from the uppermost part of the Parmelia Formation *P. charlottensis* dominates the microplankton assemblages. It is found in association with *Tetrachacysta? baculata* sp. nov. and at lower levels with *Pentafidia punctata* sp. nov. Rare occurrences in the *Gagiella mutabilis* Zone are probably reworked specimens.

***Pentafidia punctata* sp. nov.**

Pl. 38, figs 1–7; Pl. 50, figs 3, 4; Fig. 31D, E

Derivation of name: Latin, *punctatus*, covered in punctures.

Holotype: F15079/8 (–40.0, –102.3), Charlotte 1, 2 179.5 m, Parmelia Formation, Pl. 38, fig. 1.

Description: Medium to small subspherical cysts. Autophragm less than 0.5 μm thick, usually irregularly folded, bearing numerous fine evenly spaced punctae. Paratabulation indicated only by archeopyle. Paracingulum and parasulcus not indicated. Archeopyle apical, type [tA], operculum free. Primary archeopyle suture and deep gaping accessory sutures delimit 5 precingular paraplates, configuration as for *P. charlottensis*. Sulcal notch moderately deep, 1 to 3 μm wide. Operculum probably composed of 4 fused paraplates.

Dimensions: Length of holotype without operculum 46 μm , width 58 μm . Range of length without operculum (39 specimens) 38(47)55 μm , width 48(58)64 μm .

Remarks: *Pentafidia punctata* is distinguished from *P. charlottensis* by its thin punctate autophragm, more spherical shape, and gaping accessory sutures.

Range: *Fusiformacysta tumida* Zone. *Pentafidia punctata* first appears at the base of the *F. tumida* zone and is abundant towards the middle and upper parts of the zone, slightly below the acme zone of *P. charlottensis*.

Genus *Phoberocysta* Millioud 1969

Type species: *Phoberocysta neocomica* (Gocht) Millioud 1969.

***Phoberocysta burgeri* Helby 1987**

Pl. 38, figs 8–10

Description: Cyst cornucavate, dorso-ventrally flattened, outline rhomboid to pentagonal with an apical, two antapical, and two lateral horns. Endophragm approximately 0.5 μm thick, rarely folded; periphragm thinner, forming long horns, appressed to endophragm over central dorsal and ventral areas and frequently folded or torn. Cyst cavate where horns are formed and in antapical region. Apical and antapical horns broad, lightly spinose or non-spinose. Lateral horns with long broad lateral extensions and narrower antapically directed lower sections below a notched elbow. Small spines developed on most specimens along lateral horns or on cyst body near base of horns. Paratabulation poorly developed; where observable it corresponds with the paratabulation of *P. lowryi* Backhouse 1987. Paracingulum extends across the lateral horns to the notch. Archeopyle apical, type [tA], operculum usually free.

Dimensions: Length of holotype (tip of apical horn missing) 124 μm , width 146 μm . Range of length without operculum (11 specimens) 87(106) 124 μm , width 100(127)149 μm ; length with operculum (6 specimens) 140(158)175 μm .

Remarks: *Phoberocysta burgeri* is larger, more cavate about the antapical area, and possesses longer and broader lateral horns than *P. lowryi* Backhouse 1987. Examples from the upper part of its range tend to be less spinose. In this study the name *P. burgeri* has been restricted to forms displaying well-developed cavation and wide horns. Helby and others (1987) have included in *P. burgeri* forms which are here referred to *P. lowryi*.

Range: *Aprobolocysta alata* Zone.

***Phoberocysta lowryi* Backhouse 1987**

Pl. 38, fig. 11; Pl. 39, figs 1–4

Range: *Phoberocysta lowryi* Zone to basal *Aprobolocysta alata* Zone.

Phoberocysta sp. A

Pl. 39, figs 5, 6

Dimensions: Range of endocyst length without operculum (8 specimens) 42(55)63 μm , width 43(54)72 μm . Range of periphragm length without operculum (5 specimens) 70(88)100 μm , width 63(77)93 μm .

Remarks: A few specimens of *Phoberocysta* present in the lower part of the Warnbro Group are referred here to *Phoberocysta* sp. A. They differ from *P. lowryi* Backhouse 1987 by possessing an endocyst with an oval outline. The antapical horns are narrow, one usually considerably longer than the other, and the lateral horns are short. Some specimens exhibit a poorly developed paratabulation.

Range: *Kaiwaradinium scrutillinum* and *Phoberocysta lowryi* Zones.

Phoberocysta sp. B.

Pl. 39, figs 10, 11

Dimensions: Range of endocyst length without operculum (5 specimens) 41(43)47 μm , width 38(44)55 μm . Range of pericyst length without operculum (5 specimens) 55(68)78 μm , width 55(66)77 μm .

Remarks: *Phoberocysta* sp. B resembles *Phoberocysta* sp. A in shape, but is distinguished by being circumcavate. The lateral horns are sometimes reduced to lateral bulges of the paracingulum and only the left antapical horn is well developed.

Range: Upper *Aprobolocysta alata* to lowermost *Batioladinium jaegeri* Zones.

Genus Polysphaeridium Davey and Williams 1966b

Type species: *Polysphaeridium subtile* Davey and Williams 1966b.

Polysphaeridium? sp. A

Pl. 39, fig. 9

Dimensions: Diameter of cyst body (11 specimens) 31(37)42 μm .

Remarks: No well-preserved specimens of this species showing the archeopyle have been found. On a few specimens there are suggestions of an apical archeopyle. The species is recognized by the subspherical shape of the cyst body and the nature of the processes which appear as simple parallel sided or slightly tapered tubes (7 to 12 μm long)

similar in length on each specimen and open distally at a simple unflared tip. They number over 100.

Range: Upper *Phoberocysta lowryi* to lower *Batioladinium jaegeri* Zones.

Genus Prolixosphaeridium Davey 1966 emend. Davey 1969

Type species: *Prolixosphaeridium deirense* Davey 1966.

Prolixosphaeridium parvispinum (Deflandre)

Davey and others 1969

Pl. 39, figs 7, 8

Dimensions: Range of cyst body length without operculum (7 specimens) 45(51)55 μm , width 24(27)29 μm . Length of processes 6–8 μm .

Range: *Batioldinium jaegeri* and *Fromea monilifera* Zones. Previously recorded from the lower Barremian to earliest Cenomanian (Cookson and Eisenack, 1958; Davey, 1974; Davey and Verdier 1971, 1973, 1974; Morgan, 1980a).

Genus Scriniodinium Klement 1957

Type species: *Scriniodinium crystallinum* (Deflandre) Klement 1960.

Scriniodinium attadalense Cookson and Eisenack
Eisenack 1967

Pl. 40, figs 1–3; Pl. 50, figs 7, 8

1958 *Gymnodinium luridum* Deflandre; Cookson and Eisenack p. 24, Pl. 1, figs 3, 4.

1958 *Gymnodinium attadalense* Cookson and Eisenack, p. 25, Pl. 1, fig. 7.

1960b *Scriniodinium luridum* (Deflandre); Cookson and Eisenack, p. 247, Pl. 37, fig. 10.

1973 *Scriniodinium attadalense* (Cookson and Eisenack) Eisenack, p. 193.

non 1976 *Scriniodinium attadalense* (Cookson and Eisenack) Habib, Pl. 2, fig. 8.

Description: Cyst proximate, convexly lenticular and evenly circumcavate. Endophragm 0.5 to 1.0 μm thick, rigid and subcircular in dorso-ventral view. Endophragm surrounded by a thin, less rigid periphragm. Periphragm in some specimens bears a low rounded apical projection. Wall layers appressed over mid-ventral and mid-dorsal areas, evenly circumcavate at periphery. Small and large circular to oval periphragmal perforations in peripheral intratabular areas. Paratabulation weakly indicated by low ridges on dorsal periphragm, paratabulation formula not

elucidated, Paracingulum, approximately 5 μm wide, indicated by low ridges on dorsal surface and near lateral margins on ventral surface; constituent paraplates usually indicated on dorsal surface. Paracingulum indicated at lateral margin by shallow indentation of ambitus. Paratabulation not expressed on most of ventral surface. Archeopyle precingular, type P, developed in both wall layers, operculum free. Archeopyle position suggests apical paraplates small and positioned largely on ventral side.

Dimensions: Range of length (14 specimens) 71(77)85 μm , width 69(80)92 μm ; length of endophragm 54(61)71 μm , width 54(60)68 μm .

Remarks: As described by Gocht (1970) and Klement (1960) the European Jurassic species *Scriniodinium luridum* (Deflandre) possesses a complete paratabulation, and is thus distinguishable from *S. attadalense*.

Range: *Kaiwaradinium scrutillinum* to lower *Batioladinium jaegeri* Zones. Recorded by Cookson and Eisenack (1958, 1960b) from the Leederville Formation in the Attadale Bore, and from the Late Jurassic in the Canning Basin.

Genus **Senoniasphaera** Clarke and Verdier 1967

Type species: *Senoniasphaera protrusa* Clarke and Verdier 1967.

Senoniasphaera tabulata Backhouse and Helby in Helby 1987

Pl. 40, figs 4–7; Pl. 50, fig. 9; Pl. 51, fig. 1

Dimensions: Range of length without operculum (22 specimens) 65(84)113 μm , width 67(84)102 μm .

Range: *Gagiella mutabilis* to lower part of *Aprobolocysta alata* Zone.

Genus **Sentusidinium** Sargeant and Stover 1978

Type species: *Sentusidinium rioulti* (Sarjeant) Sarjeant and Stover 1978.

Remarks: Davey (1978) proposed to conserve the name *Tenua* by erecting a new type species, *T. rioulti* Sarjeant 1968, for the genus *Tenua* Eisenack 1958. The original type, *T. hystrix* Eisenack 1958, he transferred to *Cyclonephelium* Deflandre and Cookson 1955. The name *Tenua* Davey 1978 is rejected as a homonym under article 64 of the International Code of Botanical Nomenclature (Stafleu, 1978).

Sentusidinium aptiense (Burger) Burger 1980b
Pl. 41, figs 1, 2

1980a *Tenua aptiense* Burger, p. 76, Pl. 23, figs 1, 5, Pl. 24, fig. 1.

1980a *Tenua microrobusta* Morgan, p. 33, Pl. 29, figs 15, 16.

1980b *Sentusidinium aptiense* (Burger) Burger, p. 277.

Description: Proximochorate cyst, body subspherical, bearing 100–150 non-tabular spines. Autophragm 0.5 μm thick, finely granular. Spines spaced 1 to 4 μm apart, 3 to 5 μm long, hollow, tapered from a base approximately 1 μm in diameter to a closed, flared tip. Archeopyle apical, type [tA], operculum free, archeopyle suture indicates 6 precingular paraplates.

Dimensions: Length of cyst body without operculum (20 specimens) 30(44)55 μm .

Range: *Kaiwaradinium scrutillinum* to *Fromea monilifera* Zones, only common in the *Aprobolocysta alata* and higher zones. Recorded by Burger (1980a) and Morgan (1980a) from the late Neocomian and Aptian of Australia.

Sentusidinium? fibrillosum sp. nov.
Pl. 41, figs 3–6

Derivation of name: Latin, *fibrillosus*, having fibres, alluding to the composition of the autophragm.

Holotype: F22400/6 (–46.9, –101.5) Gage Roads 1. 1 505 m, South Perth Shale, Pl. 41, fig. 4.

Description: Small, ovoid, proximochorate cysts, without a preferred orientation. Small, offset antapical horn on some specimens. Autophragm less than 1 μm thick, composed of numerous fine interlocking fibres, bearing numerous fine, fibrous, truncate processes up to 3 μm high. Fibres of processes continuous with fibres of cyst wall. Paracingulum 4 to 6 μm wide, offset approximately 5 μm , expressed by transverse ridges, not subdivided. Other parasutural features absent. Archeopyle apical, type [tA], operculum free. Six precingular paraplates delineated by primary archeopyle suture and accessory sutures.

Dimensions: Length of holotype without operculum 39 μm , width 46 μm . Range of length without operculum (10 specimens) 29(35)39 μm , width 29(39)46 μm . Total length of 2 specimens 46 and 47 μm .

Remarks: Because it is a subspherical cyst bearing evenly distributed nontabular processes this species is provisionally assigned to *Sentusidinium*, although the development of paracingular ridges strictly excludes it from this genus. Other species of *Sentusidinium* do not possess a fibrous

autophragm, or fibrous spines; this suggests that *S. ? fibrillosum* belongs in a different cyst lineage from other cysts currently included in *Sentusidinium*.

Range: *Kaiwaradinium scrutillinum* to *Phoberocysta lowryi* Zones, rare.

***Sentusidinium* sp. A**

Pl. 41, figs 7, 8

Description: Cyst proximochorate, subspherical to ovoid, bearing over 200 spines. Autophragm less than 0.5 μm thick, finely granular. Spines small (1 to 3 μm high) and closely spaced (1 to 2 μm). Archeopyle apical, type [tA], operculum free; archeopyle suture indicating 6 precingular paraplates.

Dimensions: Cyst body length without operculum (12 specimens) 31(37)34 μm , width 35(41)49 μm .

Remarks: The closest species to *Sentusidinium* sp. A is *S. pilosum* (Ehrenberg) Sarjeant and Stover 1978. Sarjeant (1968, p. 231) recorded over 500 spines on *S. pilosum*, far more than the number present on *Sentusidinium* sp. A.

Range: *Aprobolocysta alata* to *Fromea monilifera* Zones, often abundant in the *Batioladinium jaegeri* and *F. monilifera* Zones.

Genus ***Spiniferites*** Mantell 1850 emend.
Sarjeant 1970

Type species: *Spiniferites ramosus* (Ehrenberg) Loeblich and Loeblich 1966.

Spiniferites* sp. cf. *S. dentatus (Gocht) Lentin
and Williams 1973
Pl. 41, figs 9, 10

Description: Cyst proximochorate, body ovoid, periphragm appressed to endophragm except where periphragm forms processes and septa. Endophragm smooth, less than 0.5 μm thick. Periphragm thin, forming trifurcate gonol processes (6 to 10 μm high) and parasutural septa with high denticulate crests bearing a variable number of truncate or bifurcate spines. Paratabulation fully expressed; formula: 4', Oa, 6'', 6c, 1''', 1p, 1''', Xs. Archeopyle precingular, type P, operculum free.

Dimensions: Range of cyst body length (13 specimens) 42(47)52 μm , width 35(40)47 μm .

Range: *Phoberocysta lowryi* to *Fromea monilifera* Zones.

***Spiniferites* sp. A**

Pl. 41, fig. 11

Description: Cyst proximochorate, body ovoid, endophragm and periphragm appressed except where periphragm forms processes and septa. Processes, 5 to 12 μm long, connected by low parasutural septa bearing rare bifurcate intergonal processes. Paratabulation complete; formula: 4', Oa, 6'', 6c, 6''', 1p, 1''', Xs. Archeopyle precingular, type P, operculum free.

Dimensions: Range of cyst body length (6 specimens), 40(46)48 μm , width 41(44)46 μm .

Remarks: *Spiniferites ramosus multibrevis* (Davey and Williams 1966a) Lentin and Williams 1973 possesses slightly longer processes than *S. sp. A*. Specimens assigned to *Spiniferites ramosus multibrevis* by Duxbury (1977) may be conspecific with this species.

Range: *Gagiella mutabilis* to *Fromea monilifera* Zones.

***Spiniferites* sp. B**

Pl. 41, figs 12, 13

Description: Cyst proximochorate, body ovoid. Endophragm 0.5 μm thick; finely granular or, rarely, smooth. Periphragm thin and membranous, sometimes finely punctate, appressed to endophragm except where it forms gonol processes and parasutural septa. Trifurcate gonol processes, 9 to 15 μm high, connecting septa 2 to 5 μm high at lowest point. Intergonal processes absent. Paratabulation complete; formula: 4', Oa, 6'', 6c, 6''', 1p, 1''', Xs. Archeopyle precingular, type P.

Dimensions: Range of cyst body length (9 specimens) 45(50)54 μm , width 37(42)47 μm .

Remarks: The fine punctation of the periphragm on some specimens is assumed to be secondary. Similar cysts have previously been assigned to *Spiniferites ramosus granomembranaceous* (Davey and Williams 1966a) Lentin and Williams 1973 (Morgan, 1980a). I hesitate to assign these specimens to a European Early Tertiary species in the absence of comparative material.

Range: *Batioladinium jaegeri* and *Fromea monilifera* Zones.

Genus ***Stiphrosphaeridium*** Davey 1982a

Type species: *Stiphrosphaeridium dictyophorum* (Cookson and Eisenack 1958) Davey 1982a.

Stiphrosphaeridium anthophorum (Cookson and Eisenack) Davey 1982a

Pl. 36, fig. 5

1958 *Hystrichosphaeridium anthophorum* Cookson and Eisenack, p. 43, Pl. 11, figs 12, 13.

?1961 *Hystrichosphaeridium anthophorum* Cookson and Eisenack; Alberti, p. 34, Pl. 9, fig. 16.

1969a *Oligosphaeridium anthophorum* (Cookson and Eisenack) Davey, p. 147, Pl. 5, figs 1–3.

1980 *Oligosphaeridium anthophorum* (Cookson and Eisenack); Wiseman, Pl. 1, fig. 22.

1980a *Oligosphaeridium pulcherrimum* (Deflandre and Cookson) Davey and Williams; Burger, p. 78, Pl. 28, fig. 1, Pl. 29, figs 1, 2.

1982 *Oligosphaeridium anthophorum* (Cookson and Eisenack); Burger, Pl. 5, figs. 7, 10.

1982a *Stiphrosphaeridium anthophorum* (Cookson and Eisenack) Davey, p. 18.

1982b *Stiphrosphaeridium anthophorum* (Cookson and Eisenack); Davey, Pl. 6.3–6.5, fig. 5, Pl. 6.3–6.6, fig. 6.

non 1958 *Hystrichosphaeridium anthophorum* (Cookson and Eisenack); Eisenack, p. 40, Pl. 26, figs 1, 2.

non 1979a *Polystephanephorus anthophorum* (Cookson and Eisenack) Davey, p. 147, Pl. 5, figs 1–3.

Dimensions: Length of cyst body (6 specimens) 55(62)66 μm , width 45(54)65 μm , length of processes 30 to 40 μm .

Remarks: The processes of *Stiphrosphaeridium anthophorum* are proximally narrow, fibrous and imperforate, becoming widely flared and perforate distally. The round and oval perforations are variable in size, usually with a mixture of large and small perforations on each process. The distal rim of each process is entire and sometimes finely denticulate. The specimens assigned to this species by Eisenack (1958) and Davey (1979a) bear broad processes, which are perforate along their full length, and they should not be included in *S. anthophorum*. Duxbury's (1980) reassignment of *S. anthophorum* to *Hystrichosphaerina* Alberti 1961 is rejected because *S. anthophorum* lacks paracingular processes, and because the processes on *S. anthophorum* are imperforate for half of their length.

Range: *Kaiwaradinium scrutillinum* to *Fromea monilifera* Zones. Previously recorded from the late Jurassic to Albian (Cookson and Eisenack, 1958; Alberti, 1961; Morgan, 1980a; Davey 1982b)

Genus **Tanyosphaeridium** Davey and Williams 1966b

Type species: *Tanyosphaeridium variecalamum* Davey and Williams, 1966b

Tanyosphaeridium boletum Davey 1974
Pl. 41, figs 14, 15

Description: Small chorate cysts, body elongate, circular in cross-section, apex and antapex broadly rounded. Endophragm and periphragm appressed over granular cyst body, except where periphragm forms delicate, tubular, non-tabular processes. Processes 8 to 17 μm long, usually slightly flared distally but sometimes unflared, 30 to 60 in number, usually concentrated towards apex and antapex; paracingular area occasionally devoid of processes. Paratabulation indicated only by operculum and archeopyle suture; archeopyle suture delineating 6 precingular paraplates. Archeopyle apical, type [tA], operculum free.

Dimensions: Range of cyst body length without operculum (27 specimens) 30(27)51 μm , width 15(23)26 μm .

Remarks: The distal flaring of the processes is less marked on the present specimens than on the type material described by Davey (1974). Specimens from the *Fromea monilifera* Zone are usually small and have processes evenly distributed over the whole cyst, but these minor differences can be attributed to intraspecific variation.

Range: *Kaiwaradinium scrutillinum* to *Fromea monilifera* Zones. *Tanyosphaeridium boletum* has a particularly patchy distribution. It is present in large numbers in a few samples from the *K. scrutillinum* and *Phoberocysta lowryi* Zones, but it is not consistently common in these zones, or elsewhere in the section.

Genus **Tetrachacysta** gen. nov.

Type species: *Tetrachacysta allenii* sp. nov.

Derivation of name: Greek, *tetracha*, in four parts, referring to the quadrilobate shape.

Synopsis: Cysts small, quadrilobate with a waisted paracingular zone. Surface features low, usually evenly distributed; paratabulation not indicated, or poorly expressed by surface features. Archeopyle apical, type [tA].

Description:

Shape: Quadrilobate, rounded sub-quadrangular in outline.

Wall Relationships: Autophragm only.

Wall Features: Generally no parasutural features. Surface features low, usually evenly distributed and regular in size, or slightly larger on the extremities of the cyst.

Paratabulation: Generally indicated only by the archeopyle and the archeopyle suture which indicates 6 precingular paraplates. Paratabulation may be poorly expressed by surface features.

Archeopyle: Apical, type [tA], operculum free.

Paracingulum: Generally not expressed; cyst constricted in the paracingular zone.

Parasulcus: Not expressed.

Size: Small.

Comparison: *Stenopyxinium* Deflandre 1968 is trilobate and bears spines on the extremities of the cyst. *Horologinella* Cookson and Eisenack 1962a exhibits an unusual paratabulation (see this manuscript), whereas *Tetrachacysta* appears to possess a normal gonyaulacacean paratabulation. *Gagiella* gen. nov. is only rarely quadrilobate and lacks a waisted paracingulum.

Other Species: *Tetrachacysta? baculata* sp. nov., *Tetrachacysta spinosigibberosa* (Brideaux and Fisher 1976) comb. nov. = *Horologinella spinosigibberosa* Brideaux and Fisher 1976, p. 22, Pl. 4, fig. 9, Pl. 5, figs 1–16.

***Tetrachacysta allenii* sp. nov.**

Pl. 42, figs 1–3; Fig. 32

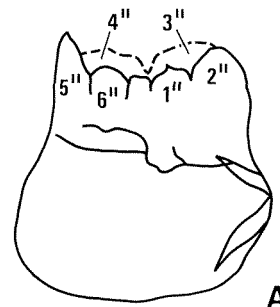
1962a *Horologinella* sp. indet. Cookson and Eisenack, p. 273, Pl. 37, fig. 15.

1976 *Horologinella* sp. Kemp. Pl. 1, fig. 3, non figs 1, 2.

Derivation of name: Named after Dr A. D. Allen who initiated the sidewall coring programme for boreholes in the Perth area.

Holotype: F8543/3 (–39.0, –110.8), Whitfords 4, 211 m, Leederville Formation, Pl. 42, fig. 1.

Description: Cysts small, trilobate, sub-quadrangular in outline with a paracingular constriction; slightly compressed dorso-ventrally. Hypocyst sometimes wider than epicyst, producing a flask-shaped outline. Autophragm thin, covered by small, regularly spaced truncate or rounded grana, or acicular spines less than $1\ \mu\text{m}$ high and usually less than $0.5\ \mu\text{m}$ wide. Surface features subdued in paracingular zone and sometimes in mid-dorsal and mid-ventral areas. Paratabulation expressed only by archeopyle suture. Archeopyle apical, type [tA], operculum flat, usually free. Archeopyle suture indicating 6 precingular paraplates.



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Figure 32. *Tetrachacysta allenii* sp. nov. x800. Drawings based on photomicrographs.

A, ventral view, Pl. 42, fig. 3. B, C, holotype, ventral view. B, ventral surface; C, dorsal surface, Pl. 42, fig. 2.

Dimensions: Length of holotype without operculum $35\ \mu\text{m}$, width of epicyst $31\ \mu\text{m}$, width of hypocyst $33\ \mu\text{m}$. Range of length without operculum (22 specimens) $29(37)41\ \mu\text{m}$, width of epicyst $27(32)34\ \mu\text{m}$, width of hypocyst $33(38)51\ \mu\text{m}$.

Remarks: *Tetrachacysta allenii* is usually more angular in outline and possesses finer surface features than *T. spinosigibberosa* and *T. baculata*; it also lacks the paratabulate clustering of the surface features shown by *T. spinosigibberosa*. In addition, the difference in width between epicyst and hypocyst displayed by most specimens of *T. allenii* does not occur in *T. spinosigibberosa* or *T. baculata*.

Range: *Gagiella mutabilis* and *Batioladinium jaegeri* Zones. Normally only found in near-shore environments as part of the *Cyclonephelium attadalicum* Association, but a single specimen is recorded from the *G. mutabilis* Zone. Kemp's (1976) record of this species from the Samuel Formation in the Officer Basin is consistent with its known range in the Perth Basin.

***Tetrachacysta? baculata* sp. nov.**

Pl. 42, figs 4, 5; Pl. 51, figs 2, 3

Derivation of name: Latin, *baculus*, a rod, alluding to the surface elements.

Holotype: F8354/1 (–42.1, –96.6) Eneabba Line 3B, 490 m, Parmelia Formation, Pl. 42, fig. 5.

Description: Cysts small, strongly quadrilobate, slightly dorso-ventrally flattened, epicyst and hypocyst similar in width. Autophragm 0.5 to 1.0 μm thick; bearing bacula, verrucae, or rarely clavae to 1 μm high. Surface elements subdued in cingular area and in slight apical and antapical indentations. Paratabulation expressed only at archeopyle suture, but precise number of precingular paraplates not determined on any specimen observed. Archeopyle apical, type [tA], operculum flat and often in position. Archeopyle usually difficult to detect.

Dimensions: Length of holotype 55, width 55 μm . Range of length (17 specimens) 30(42)56 μm , width 30(40)55 μm .

Remarks: *Tetrachacysta? baculata* is more strongly lobate, more angular in outline, possesses a less prominent archeopyle, and bears coarser surface elements than *T. allenii*. It differs from *T. spinosigibberosa* by being approximately equidimensional, bearing predominantly baculate surface features, and lacking paratabulation. Until more is known about the archeopyle, this species is only provisionally assigned to *Tetrachacysta*.

Range: *Fusiformacysta tumida* and *Gagiella mutabilis* Zones. The distribution of *Tetrachacysta baculata* suggests a freshwater, or brackish water, or restricted marine origin for the species.

Genus **Tubotuberella** Vozzhennikova 1967

Type species: *Tubotuberella rhombiformis* Vozzhennikova 1967 ex Stover and Evitt 1978.

Tubotuberella vlamingii Backhouse 1987
Pl. 42, figs 6–8; Pl. 51, fig. 5

Range: *Kaiwaradinium scrutillinum* Zone, particularly common in the middle of this zone.

NON-SPINOSE ACRITARCHS

Genus **Brazilea** Tiwari and Navale 1967

Type species: *Brazilea punctata* Tiwari and Navale 1967.

Brazilea parvus (Cookson and Dettmann)
comb. nov. Pierce 1976
Pl. 45, fig. 7

1959 *Schizosporis parvus* Cookson and Dettmann, p. 216
Pl. 1, figs 15–20.

Dimensions: Equatorial diameter (15 specimens) 54(68)81 μm , polar diameter 22(30)45 μm .

Remarks: As pointed out by Foster (1979, p. 111), laevigate acritarchs exhibiting an equatorial split belong in the genus *Brazilea*.

Range: *Fusiformacysta tumida* to *Fromea monilifera* Zones. Previously recorded from the Berriasian (Norris, 1969) to Cenomanian, and possibly Danian (Drugg, 1967).

Genus **Fromea** Cookson and Eisenack 1958

Type species: *Fromea amphora* Cookson and Eisenack 1958.

Fromea monilifera Backhouse 1987
Pl. 43, figs 1, 2

Range: *Fromea monilifera* Zone.

Genus **Leiosphaeridia** Eisenack 1958a

Type species: *Leiosphaeridia baltica* Eisenack 1958a.

Leiosphaeridia? perthensis sp. nov.
Pl. 43, figs 4–9

Derivation of name: After the city of Perth, W.A.

Holotype: F8342/2 (–46.7, –103.6) Whitfords 1, 110 m, Leederville Formation, Pl. 43, fig. 6.

Description: Subspherical palynomorph usually folded and fractured. Wall 0.5 μm thick; completely covered by small regularly spaced rugulae, bacula or, rarely, spines 0.5 μm high and 0.5 μm or less in minimum basal diameter. Wall brittle, always fractured, usually with a portion of wall removed at an irregular opening.

Dimensions: Maximum diameter of holotype 83 μm . Range of maximum diameter (16 specimens) 50(71)97 μm .

Remarks: Incomplete broken specimens of this species, readily recognized by the characteristic surface pattern and absence of paratabulation, are common in many samples in the upper part of the Warnbro Group. Angular fractures in the wall of the test sometimes suggest a zig-zag apical archeopyle, but an archeopyle suture can never be traced for more than the width of one possible paraplate. The species is therefore regarded as an acritarch and is tentatively assigned to *Leiosphaeridia*.

Range: *Batioladinium jaegeri* and *Fromea monilifera* Zones.

Genus **Nummus** Morgan 1975 emend.

Type species: *Nummus monoculatus* Morgan 1975.

Emended description: Lenticular palynomorph, always compressed in polar direction; polar outline oval or subquadrangular. Wall one-layered, considerably thicker on one side (dorsal). Ventral wall usually removed, possibly never present on some species. Dorsal wall encircled equatorially by a flat rim. Subcircular pylome present on some species, situated near equatorial margin at one end (apical) of dorsal wall. Folds in dorsal wall consistent in position for each species.

Remarks: *Nummus*-type acritarchs are frequently occurring, often abundant, components of marine Early Cretaceous microplankton assemblages in the Perth Basin. They all display the same basic structure as *N. monoculatus*. Differences in size and details of the dorsal folds and pylome differentiate the four species recognized in this report. The generic description of Morgan (1975) is emended to include this expanded range of *Nummus*-type acritarchs. The terms dorsal and ventral are retained as an aid to description and do not imply any known affinity to dinoflagellate cysts.

Abundant specimens of *N. monoculatus* in a sample from the Leederville Formation in Cockburn 1 (90 m) are joined by overlapping of a marginal section of the dorsal wall; this suggest a flat, continuously attached colony of acritarchs (Pl. 43, fig. 12). An encrusting habit is suggested by the flat equatorial rim common to all species of *Nummus*, and the shallow convex shape of the dorsal wall. In most specimens the ventral wall apparently remained attached to the substrate and is not evident on detached specimens.

Nummus monoculatus Morgan 1975

Pl. 43, figs 10–12; Fig. 33D

Range: *Batioladium jaegeri*–*Fromea monilifera* Zones. Usually rare, but common in one sample (Cockburn 1, 90 m).

Nummus parvus sp. nov.

Pl. 43, figs 13–16, Fig. 33C

Derivation of name: Latin, *parvus*, small.

Holotype: F8357/8 (–44.2, –96.6) Whitfords 1, 405 m, South Perth Shale, Pl. 43, fig. 14.

Description: Small lenticular palynomorphs, oval to subquadrangular in polar outline, sometimes slightly constricted in middle of lateral margins. Dorsal wall smooth, less than 0.5 μm thick, almost flat, surrounded by a narrow (1 to 2 μm) rim.

Pylome small, subcircular, positioned near apical end. A shallow groove passes across dorsal surface between lateral constrictions on most specimens. Ventral wall thin, seldom retained.

Dimensions: Length of holotype 31 μm , width 26 μm . Range of length (24 specimens) 26(32)45 μm , width 22(27)36 μm .

Remarks: The small size and the median lateral constrictions distinguish *N. parvus* from other species of *Nummus*.

Range: *Kaiwaradinium scrutillinum* to *Fromea monilifera* Zones. Common in the *K. scrutillinum* and *Phoberocysta lowryi* Zones.

Nummus pentagonus sp. nov.

Pl. 44, figs 1–7; Fig. 33E

Derivation of name: Greek, *pentagon*, with five angles, alluding to the dorsal pattern of folds.

Holotype: F12436/1 (–31.6, –109.0), Artesian Monitoring 35A, 162 m, Leederville Formation, Pl. 44, fig. 5.

Description: One (dorsal) wall preserved as a flat to saucer-shaped palynomorph with an oval to subspherical outline. Wall single-layered, usually finely granular. Perimeter bears a narrow 2 to 3 μm , dark rim. Five straight or arcuate folds form a pentagon on dorsal wall; four folds approximately equal in length, fifth shorter and always positioned nearer rim at one end (?apical). An unopened split or low ridge passes over centre of dorsal wall, and bisects two angles of pentagon. Pylome never developed.

Dimensions: Length of holotype 46 μm , width 45 μm . Range of length (25 specimens) 44(53)61 μm , width 41(50)57 μm .

Remarks: The absence of a pylome and the distinctive arrangement of dorsal folds distinguishes *N. pentagonus* from *N. monoculatus* and other species of *Nummus*.

Range: *Batioladinium jaegeri* and *Fromea monilifera* Zones. *Nummus pentagonus* is most abundant in near-shore marine assemblages of the *Cyclonephelium attadalicum* Association.

Nummus similis (Cookson and Eisenack)
Burger 1980b

Pl. 44, figs 8, 9; Pl. 51, fig. 6; Fig. 33A, B

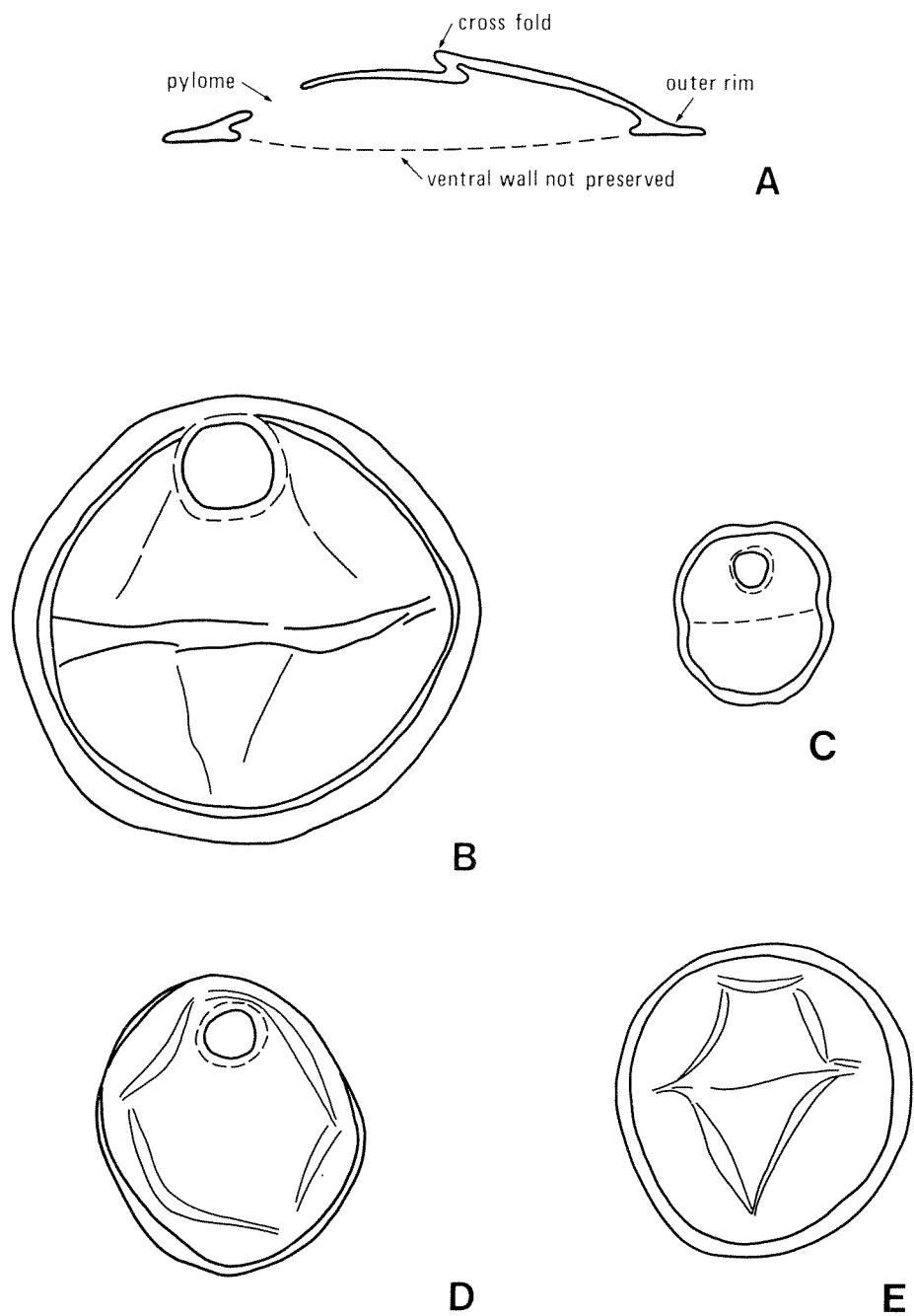
Description: Subcircular to oval palynomorph, flat or slightly convex dorsal wall; surface finely granular. Thin ventral wall sometimes preserved, but usually missing. Dorsal wall encircled by smooth

rim of even width, up to 7 μm wide, sometimes folded back over dorsal wall to which it is attached (Fig. 33A). Pylome, subcircular to sub-quadrangular, surrounded by narrow zone of thicker wall and positioned near apical margin. A large fold crosses centre of dorsal surface, always oriented normal to line bisecting pylome and dorsal surface. Rarely, small folds developed normal to this large cross fold.

Dimensions: Range of length measured through the pylome (8 specimens) 64(80)89 μm , width 64(79)90 μm .

Remarks: *Nummus similis* is common in some samples with low microplankton counts which suggests that it has a shallow-water origin.

Range: *Kaiwaradinium scrutillinum* to *Fromea monilifera* Zones.



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Figure 33. *Nummus*-type acritarchs. A, diagrammatic longitudinal section of *N. similis*. B–E, drawings based on photomicrographs. x700. B, *N. similis* (Cookson and Eisenack) Burger 1980b, Pl. 44, fig. 8; C, *N. parvus* sp. nov., Pl. 43, fig. 14; D, *N. monoculatus* Morgan 1975, Pl. 43, fig. 10; E, *N. pentagonus* sp. nov., Pl. 44, fig. 5.

Genus **Platycystidia** Cookson and Eisenack 1960a

Type species: *Platycystidia diptera* Cookson and Eisenack 1960a.

Platycystidia eisenackii (Mehrotra and Sarjeant)
comb. nov.

Pl. 46, figs 1–3

1984 *Polygonifera eisenackii* Mehrotra and Sarjeant, p. 46, Pl. 1, figs 1–7, Pl. 2, figs 1–7.

Description: Lenticular palynomorph, oval in outline. Wall two-layered, finely granular inner wall forming an elongate ovoidal inner body. Outer wall thin and punctate; separated from inner body by 5 to 15 μm , although appressed in one plane, possibly due to compaction; two wall layers closer together near pylome. Small transverse folds sometimes developed across centre of outer wall. A simple slanted pylome always present at one end, pylome suture lacking evidence of paratabulation.

Dimensions: Range of inner body length (12 specimens) 42(56)68 μm , width 32(37)42 μm .

Remarks: Mehrotra and Sarjeant (1984) assigned the species to *Polygonifera* Habib 1972. However, the genotype of *Polygonifera* (Habib, 1972, Pl. 5, fig. 1) displays unmistakable dinoflagellate characteristics including an apical archeopyle. I see no evidence in Mehrotra and Sarjeant's illustrations and line drawings to support their contention that the opening is an archeopyle, nor that the transverse structure is necessarily a cingulum. Some acritarch genera (e.g. *Fromea* Cookson and Eisenack) display pseudo-cingular structures. Therefore, until the dinoflagellate affinity of this species is more convincingly demonstrated I prefer to retain it as an acritarch. The same palynomorph is figured as *Platycystidia* sp. A by Stover and Helby (1987) from Houtman 1 well in the Perth Basin. The assignment to *Platycystidia* appears to be appropriate given the morphological similarity to *P. diptera*.

Range: *Batioladinium jaegeri* and *Fromea monilifera* Zones. The record by Mehrotra and Sarjeant (1984) is from the Aptian of India, and by Stover and Helby (1987) from the Barremian (*Muderongia australis* Zone of Helby and others, 1987).

Genus **Pterospermella** Eisenack 1972

Type species: *Pterospermella aureolata* (Cookson and Eisenack) Eisenack 1972.

Pterospermella aureolata (Cookson and Eisenack) Eisenack 1972
Pl. 44, figs 10, 11

Dimensions: Range of diameter (19 specimens) 47(102)153 μm , central body 28(61)99 μm .

Remarks: Size is the only significant difference between *P. aureolata* and *P. australiensis* (Deflandre and Cookson) Eisenack and Cramer 1973. In this study a central body diameter of 25 μm is arbitrarily selected as the boundary between the two species. When a wider data base is available it will probably be possible to demonstrate a continuous morphological gradation from *P. australiensis* through *P. eurypyteris* (Cookson and Eisenack) Eisenack and Cramer 1973 to *P. aureolata*.

Range: *Kaiwaradinium scrutillium* to *Batiolodinium jaegeri* Zones.

Pterospermella australiensis (Deflandre and Cookson) Eisenack and Cramer 1973
Pl. 44, figs 12, 13

Dimensions: Range of diameter (8 specimens) 22(41)53 μm , central body 9(17)24 μm .

Range: *Gagiella mutabilis* to *Fromea monilifera* Zones.

Genus **Rhombodella** Cookson and Eisenack 1962b

Type species: *Rhombodella paucispina* (Alberti) Duxbury 1980.

Remarks: In this report I have followed Duxbury (1980) in regarding *Rhombodella* as a valid acritarch genus.

Rhombodella paucispina (Alberti) Duxbury 1980
Pl. 45, figs 1, 2

1961 *Palaeohystrichophora paucispina* Alberti, p. 19, Pl. 3, fig. 25.

1962b *Rhombodella natans* Cookson and Eisenack, p. 496, Pl. 7, figs 12, 13.

1980a *Rhombodella natans* Cookson and Eisenack; Morgan, p. 31, Pl. 26, fig. 3.

1980 *Rhombodella paucispina* (Alberti) Duxbury, p. 136.

1980a *Rhombodella natans* Cookson and Eisenack; Burger, p. 87, Pl. 46, figs 3, 5, 6.

1982 *Palaeotetradinium paucispinum* (Alberti) Stover and Evitt; Burger, Pl. 8, fig. 16.

Dimensions: Range of body length (6 specimens) 47(55)69 μm , width 35(37)46 μm .

Remarks: The species originally described as *Palaeohystrichophora paucispina* by Alberti (1961) is the senior synonym of *Rhombodella natans* Cookson and Eisenack 1962b (Stover and Evitt, 1978, p. 71). In this case the type of *R. paucispina* becomes the genotype of *Rhombodella* in place of the type of *R. natans*.

Range: *Kaiwaradinium scrutillinum* to *Fromea monilifera* Zones; common in Gage Roads 1 at 1 505 m, rare elsewhere. Previously recorded from the Late Aptian to Cenomanian (Alberti, 1961; Cookson and Eisenack, 1962b; Morgan, 1980a).

Genus **Schizocystia** Cookson and Eisenack 1962a

Type species: *Schizocystia rugosa* Cookson and Eisenack 1962a.

Schizocystia rugosa Cookson and Eisenack 1962a
Pl. 45, figs 3–5

1962a *Schizocystia rugosa* Cookson and Eisenack, p. 270, Pl. 37, figs 11, 12.

1962a *Schizocystia laevigata* Cookson and Eisenack, p. 270, Pl. 37, figs 13, 14.

1971 *Schizocystia laevigata* Cookson and Eisenack; Singh, p. 430, Pl. 80, figs 7–9.

Description: Palynomorph flattened quadrilobate in shape, outline weakly or strongly indented, lenticular in cross-section. Wall 1 to 2 μm thick, smooth to finely rugulate. Rugulae approximately 0.5 μm high, rounded in cross-section, sometimes arranged in subparallel bands. Test always divided into two symmetrical halves by a longitudinal split; two halves frequently separated.

Dimensions: Range of equatorial diameter measured parallel to the longitudinal split (24 specimens) 52(63)80 μm ; maximum diameter of half test measured perpendicular to split 23(36)45 μm ; total diameter of complete test measured perpendicular to split (6 specimens) 54(59)70 μm .

Remarks: Few specimens bear such pronounced rugulae and are as deeply indented as the holotype (Cookson and Eisenack, 1962a, Pl. 37, fig. 11). A graduation exists between strongly rugulate and smooth forms. I therefore follow Elsik (1968) in regarding *S. laevigata* as synonymous with *A. rugosa*, but reject his assignment of the species to *Tetraporina* Naumova 1950. *Schizocystia rugosa* is abundant in two samples, Moora Line 2B at 77 m and Gillingarra Line 4A at 231 m. In the latter sample, separated halves of *S. rugosa* constitute 30% of the total palynomorph count. Marine microplankton are not recorded in either sample, and *S. rugosa* is infrequent in marine assemblages. This suggests that *S. rugosa* originated in a restricted marine, brackish-water, or freshwater environment.

Range: *Kaiwaradinium scrutillinum* to *Batioladinium jaegeri* Zones. *Schizocystia rugosa* is not recorded from the *Fromea monilifera* Zone in this study, although earlier records indicate that

it ranges into the Albian-Cenomanian (Cookson and Eisenack, 1962a; Singh, 1971) and the Late Cretaceous (Manum and Cookson, 1964).

Schizocystia sp. A

Pl. 45, fig. 6; Pl. 51, fig. 8

Description: Test flattened, subtrilobate in equatorial outline. Wall 1 μm thick, sculptured by small evenly spaced rounded grana less than 0.5 μm high. Longitudinal slit divides test into two asymmetrical sections; separated halves not observed.

Dimensions: Equatorial diameter perpendicular to split (3 specimens) 35 μm , 35 μm , and 50 μm .

Remarks: *Schizocystia* sp. A is distinguished from *S. rugosa* by its smaller size and asymmetry. The split does not completely encircle the test and the apparent absence of separated halves suggests that unlike *S. rugosa* the two parts of the test do not completely separate.

Range: *Batioladinium jaegeri* Zone, rare. *Schizocystia* sp. A is associated with near-shore marine assemblages.

Genus **Schizosporis** Cookson and Dettmann 1959
emend. Pierce 1976

Type species: *Schizosporis reticulatus* Cookson and Dettmann 1959.

Remarks: Pierce (1976) emended this genus to only include species with walls composed of a solid continuous inner layer and an outer layer of cell-like units.

Schizosporis favosus sp. nov.

Pl. 45, figs 8–11

Derivation of name: Latin, *favosus*, like a honeycomb, referring to the external appearance of the test.

Holotype: F9422/4 (–57.7, –101.0) Moora Line 3A, 166.5 m, Leederville Formation, Pl. 45, fig. 9.

Description: Large, slightly convex, discoidal palynomorph, subcircular to subquadrangular in polar view. Wall composed of a continuous layer, 2 to 3 μm thick, surmounted by interconnected muri. Muri narrow, up to 4 μm high, and expanded distally to enclose polygonal cells, as in *S. reticulatus*, or lower rounded structures which form an incomplete reticulum with irregular

elongate lumina; cells 2 to 8 μm in maximum diameter, usually about 4 μm . Wall often fragmented, separated equatorially into two saucer-shaped halves. No structured openings observed.

Dimensions: Equatorial diameter of holotype 143 μm . Range of equatorial diameter (17 specimens) 87(125)166 μm .

Remarks: *Schizosporis favosus* is distinguished from *S. reticulatus* by its smaller surface cells and generally thinner wall. *Schizophacus rugulatus* (Cookson and Dettmann) Pierce 1976 resembles the forms of *S. favosus* with low muri, but from the illustrations by Cookson and Dettmann (1959) it possesses a finer surface sculpture. *Schizosporis favosus* has been found in only one sample. *Schizosporis reticulatus* and *Brazilea parvus* (Cookson and Dettmann) were also present in this sample. The palynological assemblage from the sample (Moora Line 3A, 166.5 m) suggests that it represents a lacustrine deposit in a generally fluviatile sequence that was laid down in the Dandaragan Trough during, or immediately before, the period of tectonism in the Perth Basin.

Range: ?Uppermost part of the *Fusifformacysta tumida* Zone.

Schizosporis reticulatus Cookson and Dettmann 1959
Pl. 45, fig. 12; Pl. 51, fig. 7

Dimensions: Range of equatorial diameter (11 specimens) 90(126)151 μm .

Remarks: The extensive reports of *S. reticulatus* in the literature are listed in a comprehensive synonymy by Pierce (1976). In the Perth Basin it is a rare but long-ranging species which is associated with non-marine deposits in the Parmelia Formation. Infrequent specimens have been recorded from marine deposits in the Warnbro Group. The organism producing the palynomorph appears to have flourished in freshwater lakes, and occasionally specimens were transported into marine environments.

Range: *Fusifformacysta tumida* to *Fromea monilifera* Zones. Previously recorded from the Berriasian (Norris, 1969) to Cenomanian (numerous authors).

Genus **Wallodinium** Loeblich and Leoblich 1968

Type species: *Wallodinium glaessneri* (Cookson and Eisenack) Loeblich and Leoblich 1968.

Wallodinium krutzschi (Alberti) Habib 1972
Pl. 45, figs 13–15

- 1960b *Diplotesta glaessneri* Cookson and Eisenack, *pars*, p. 256, Pl. 39, fig. 5.
- 1961 *Diplotesta krutzschi* Alberti, p. 21, Pl. 7, figs 19–21, Pl. 12, figs 6, 7.
- 1972 *Wallodinium krutzschi* (Alberti) Habib, p. 378, Pl. 12, fig. 9, Pl. 13, fig. 2.
- 1976 *Wallodinium luna* (Cookson and Eisenack); Kemp, Pl. 1, fig. 9.
- 1977 *Wallodinium krutzschi* (Alberti); Duxbury, p. 58, Pl. 13, fig. 3.
- 1977 *Wallodinium luna* (Cookson and Eisenack); Duxbury, p. 58, Pl. 15, fig. 7.
- 1980 *Wallodinium elongatum* (Beju) Duxbury, p. 136, Pl. 11, fig. 11.
- 1980 *Wallodinium krutzschi* (Alberti); Duxbury, Pl. 4, fig. 3, Pl. 12, fig. 8.
- 1980 *Wallodinium lunum* (Cookson and Eisenack); Duxbury, Pl. 11, fig. 8.

Dimensions: Range of length with cap missing (13 specimens) 55(65)82 μm , width 29(31)33 μm .

Remarks: *Wallodinium glaessneri* (Cookson and Eisenack) Loeblich and Leoblich 1968, *W. krutzschi*, and *W. lunum* (Cookson and Eisenack) Lentin and Williams 1973 can be distinguished on the basis of minor but consistent differences in morphology. *Wallodinium glaessneri* is relatively long, tends to be striated, and, from the illustrations by Cookson and Eisenack (1960b), is only slightly curved. *Wallodinium krutzschi* is shorter than *W. glaessneri*, unstriated, and is straight or broadly curved towards the closed end. *Wallodinium lunum* is sharply curved at each end, and both the outer and inner bodies are sharply tapered. The specimen figured by Duxbury (1980, Pl. 11, fig. 11) as *W. elongatum* (Beju) I consider to be a folded specimen of *W. krutzschi*. All the specimens encountered in this study are referable to *W. krutzschi*. Straight and curved forms frequently occur in the same sample.

Range: *Kaiwaradinium scrutillinum* to *Fromea monilifera* Zones. Previously recorded from the Berriasian to Aptian (see synonymy list).

Gen. et sp. indet. A
Pl. 45, figs 16, 17

Description: Small subspherical or ovoid palynomorph. Wall two layered; inner layer 0.5 to 1.0 μm thick, smooth; outer layer thin and membranous, bearing short narrow spines up to 2 μm long. Wall layers sometimes partly separated. Pylome not observed.

Dimensions: Range of total diameter (15 specimens) 42(49)64 μm .

Range: Lower *Fusiformacysta tumida* Zone. Recorded only in the Dandaragan Trough.

SPINOSE ACRITARCHS

Small spinose acritarchs occur throughout the Parmelia Formation and Warnbro Group. Those in the Parmelia Formation are probably reworked from Late Permian and Triassic sediments (see Chapter 8), but there is no evidence for extensive reworking of Permian and Triassic palynomorphs into the Warnbro Group. Consequently, spinose acritarchs in the Warnbro Group are considered to be Early Cretaceous forms. Of these, one species is treated systematically, the remainder are identified to generic level and illustrated on Plate 46, figures 7–17.

Genus *Domasiella* Eisenack 1969

Type species: *Domasiella discophora* (Cookson and Eisenack) Eisenack 1969.

Domasiella discophora (Cookson and Eisenack)
Loeblich and Loeblich 1970
Pl. 46, figs 4–6

Dimensions: Range of body length (16 specimens) 24(34)40 μm , width 13(20)29 μm .

Remarks: The specimens encountered during this study conform with Cookson and Eisenack's (1962b) description. Well-preserved specimens possess two long solid spines of almost equal length at one end and a short conical spine at the other. The disc-shaped endings of the long spines are often missing. Small slits in the body wall are evident on some specimens which suggests an affinity with other small spinose acritarchs such as *Veryhachium* Deunff 1954.

Range: *Batioladinium jaegeri* Zone. Cookson and Eisenack (1962b) recorded *D. discophora* in two ditch cuttings samples from the Attadale Bore, which they believed to be from the Osborne Formation. In this study it is recorded in several sections, always in the upper part of the Leederville Formation, in assemblages assigned to the *Cyclonephelium attadalicum* Association. Cookson and Eisenack's samples were probably contaminated by down-hole material from the overlying Osborne Formation, which caused these authors to assign their samples mistakenly to that unit.

ALGAL CYSTS

Class Chlorophyceae

Family Tasmanaceae

Genus *Crassosphaera* Cookson and Manum 1960

Type species: *Crassosphaera concinna* Cookson and Manum 1960.

Crassosphaera sp. A

Pl. 46, fig. 18

Dimensions: Diameter of 2 specimens, 84 and 92 μm .

Remarks: Both recorded specimens are from the same part of the section and occur in marine sediments. In the number of papillae they resemble *C. papillata* Singh 1971, but the papillae are lower than those of *C. papillata*.

Range: *Kaiwaradinium scrutillinum* Zone, rare.

Genus *Tasmanites* Newton 1875 emend.

Eisenack 1958a

Pl. 46, figs 19, 20

Remarks: A small number of tasmanitid-type palynomorphs were recorded from the section studied. No attempt is made to classify them below generic level.

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PLATE 1

All figures x700.

HF, high focus; MF, median focus; LF, low focus.

Figure

1, 2 *Aequitriradites acusus* (Balme).

1. Distal view, a, HF; b, LF. F10291/3 (–31.0, –101.3).
2. Proximal view, a, HF; b, LF. F15078/5 (–38.2, –100.3).

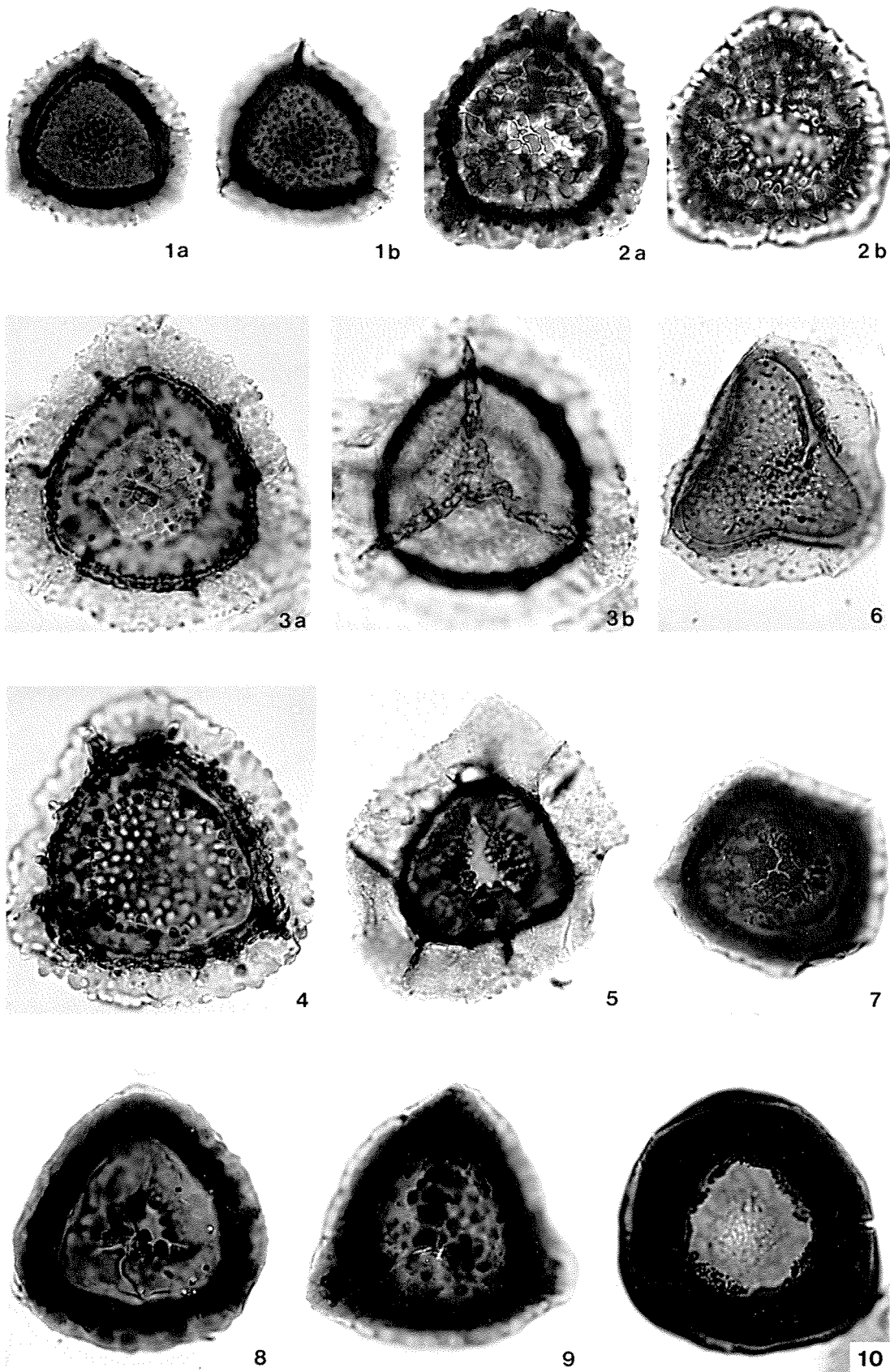
3–5 *Aequitriradites dandaraganensis* sp. nov.

3. Holotype, distal view, a, HF; b, LF. F8528/1 (–41.9, –101.5).
4. Proximal view, HF. F8528/1 (–41.3, –100.5).
5. Proximal view, LF. F9422/1 (–33.5, –96.8).

6 *Aequitriradites hispidus* Dettmann and Playford.
Dorsal view, MF. F8606/2 (–49.6, –94.2).

7–10 *Aequitriradites inornatus* sp. nov.

7. Dorsal view, HF. F9422/2 (–52.8, –104.9).
8. Holotype, dorsal view, HF. F9422/2 (–59.6, –103.6).
9. Proximal view, HF. F9422/2 (–57.1, –104.7).
10. Dorsal view, HF. F6660/2 (–29.0, –101.5).



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PLATE 2

All figures x700 unless otherwise indicated.
HF, high focus; MF, median focus; LF, low focus.

Figure

1–4 *Aequitriradites norrissii* sp. nov.

1. Proximal view, HF. F8187/2 (–43.6, –103.0).
2. Distal view, a, LF; b, HF; F8460/3 (33.0, –103.5).
3. Holotype, proximal view, a, HF; b, LF. F8359/3 (–44.4, –93.3).
4. Distal view, HF. F6685/4 (–38.5, –106.4).

5 *Aequitriradites* sp. A.

Distal view, HF. F8534/2 (–29.5, –104.8).

6, 7 *Polycingulatisporites clavus* (Balme).

6. Proximal view, x800, a, HF; b, LF. F12403/1 (–44.4, –104.5).
7. Distal view, x800, HF. F12403/1 (–36.2, –106.0).

8 *Antulsporites saevus* (Balme).

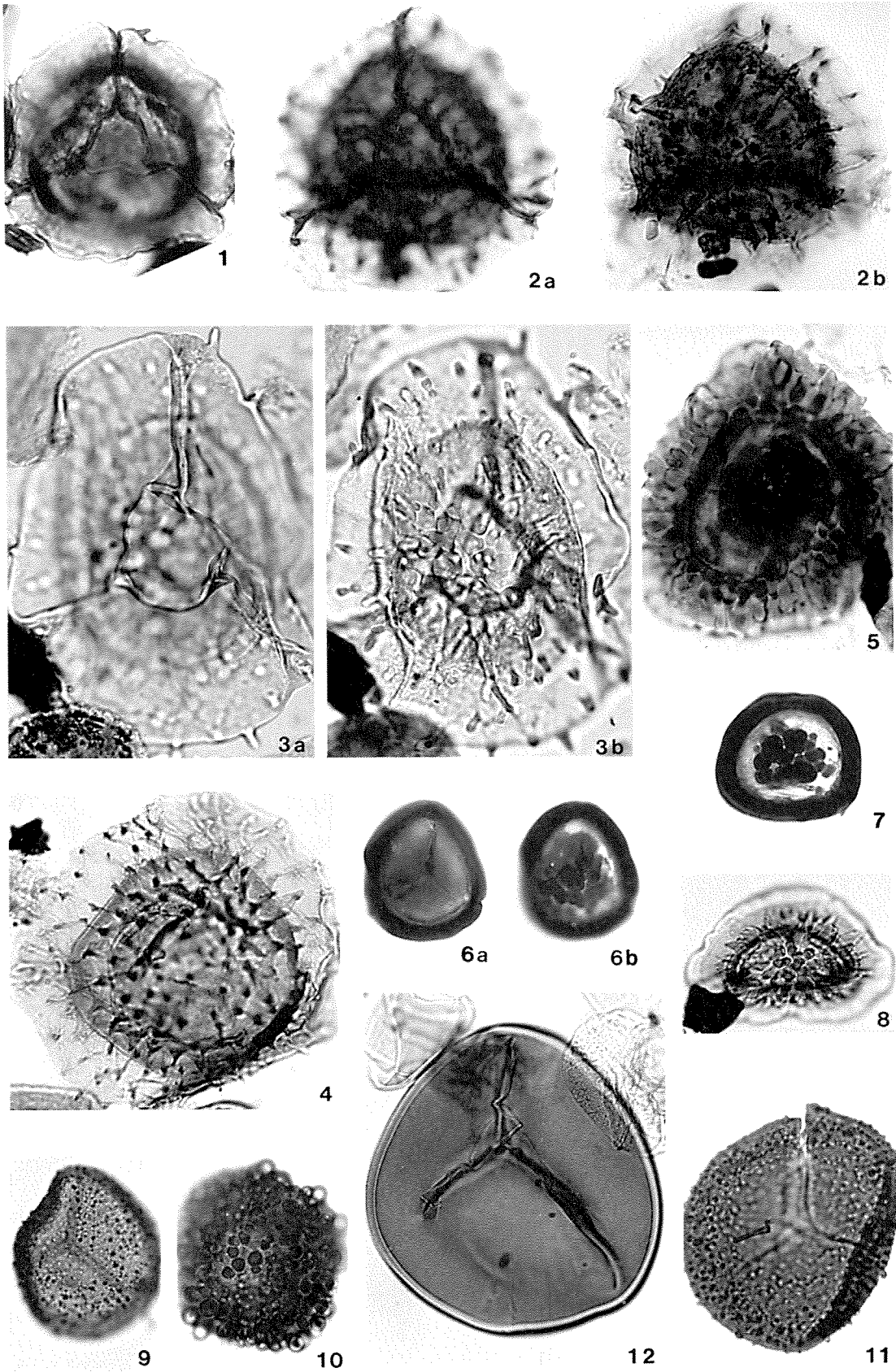
Distal view, HF. F9339/1 (–36.9, –112.5).

9–11 *Baculatisporites comaumensis* (Cookson).

9. Distal view, HF., F12442/1 (–56.0, –108.3).
10. Distal view, HF. F6595/3 (–37.3, –102.0).
11. Proximal view, HF. F11500/4 (–40.8, –111.8).

12 *Biretisporites encabbaensis* Backhouse.

Holotype, proximal view, x500. HF. F8528/2 (–38.8, –103.8).



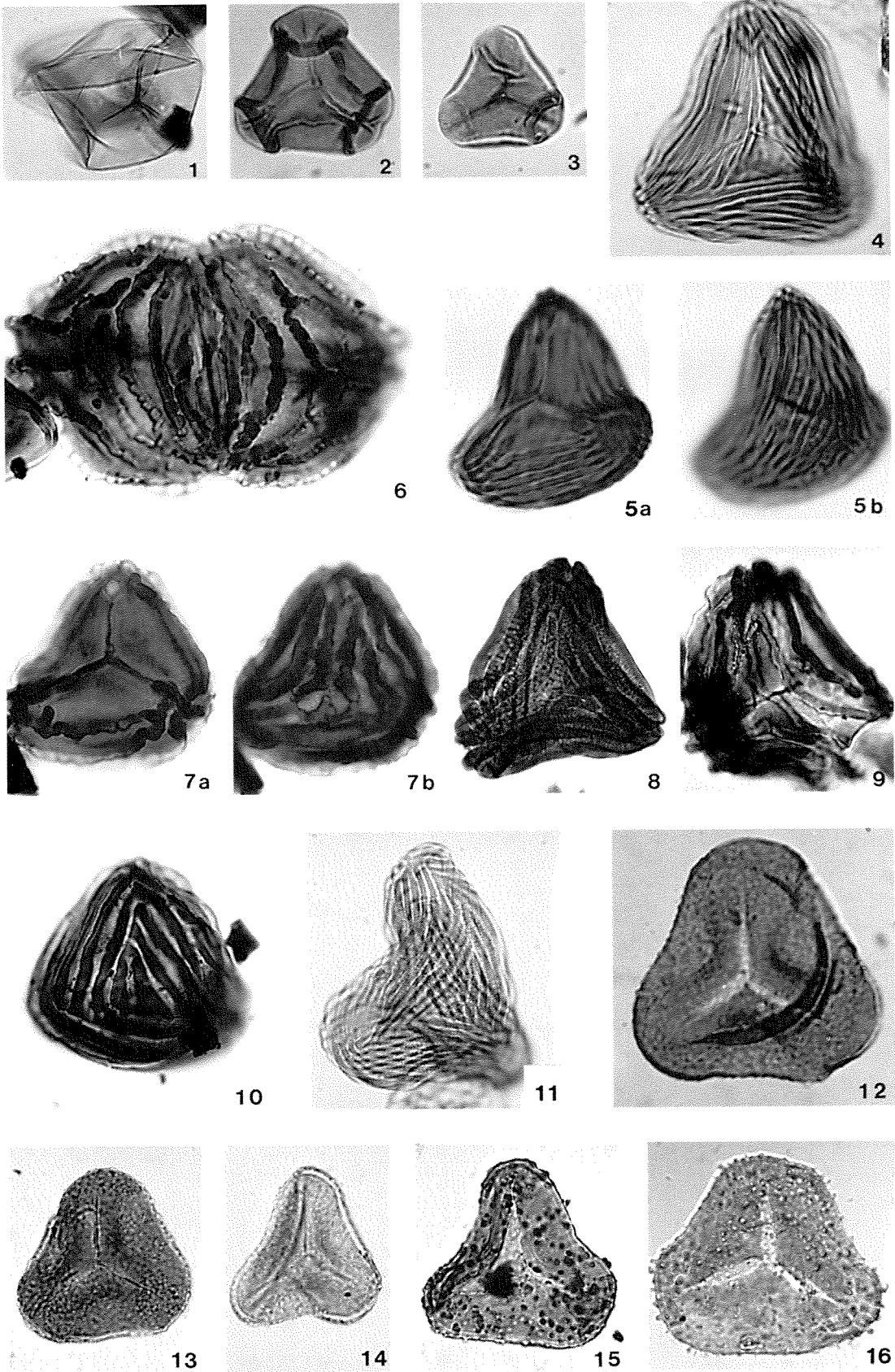
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PLATE 3

All figures x700 unless otherwise indicated.
HF, high focus; MF, median focus; LF, low focus.

Figure

- 1** *Calamospora mesozoica* Couper.
Proximal view, HF. F8350/4 (−47.0, −108.6).
- 2, 3** *Cibotiumspora jurienensis* (Balme).
2. Holotype, Balme T. S. 155.
3. Proximal view, HF. F9115/2 (−47.8, −99.4).
- 4, 5** *Cicatricosisporites australiensis* (Cookson).
4. Distal view, HF. F6685/4 (−59.6, −103.9).
5. Distal view, a, LF; b, HF. F6595/3 (−44.0, −108.0).
- 6, 7** *Cicatricosisporites* sp. cf. *C. hughesii* Dettman.
6. Two attached specimens in lateral view, HF. F8549/3 (−40.4, −100.3).
7. Proximal view, a, HF; b, LF. F8549/3 (−33.0, −98.4).
- 8** *Cicatricosisporites ludbrookae* Dettmann.
Distal view, HF. F11500/4 (−28.9, −109.8).
- 9** *Cicatricosisporites* sp. cf. *C. ludbrookae* Dettmann.
Proximal view, LF. F15078/1 (−28.2, −107.2).
- 10** *Cicatricosisporites pseudotripartitus* (Bolkhovitina).
Distal view, HF. F6660/3 (−47.0, −104.4).
- 11** *Cicatricosisporites* sp. A Burger.
Distal view, MF. F8355/4 (−32.8, −108.4).
- 12–14** *Concavissimisporites infirmus* (Balme).
12. Holotype, proximal view, HF, x1000. Balme T. S. 350.
13. Proximal view, HF. F46236/4 (−51.7, −104.0).
14. Proximal view, HF. F10118/1 (−20.8 –106.0).
- 15, 16** *Concavissimisporites irregularis* (Pocock).
15. Proximal view, HF. F8613/1 (−32.3, −107.6).
16. Proximal view, LF. F8606/2 (−56.9, −109.8).



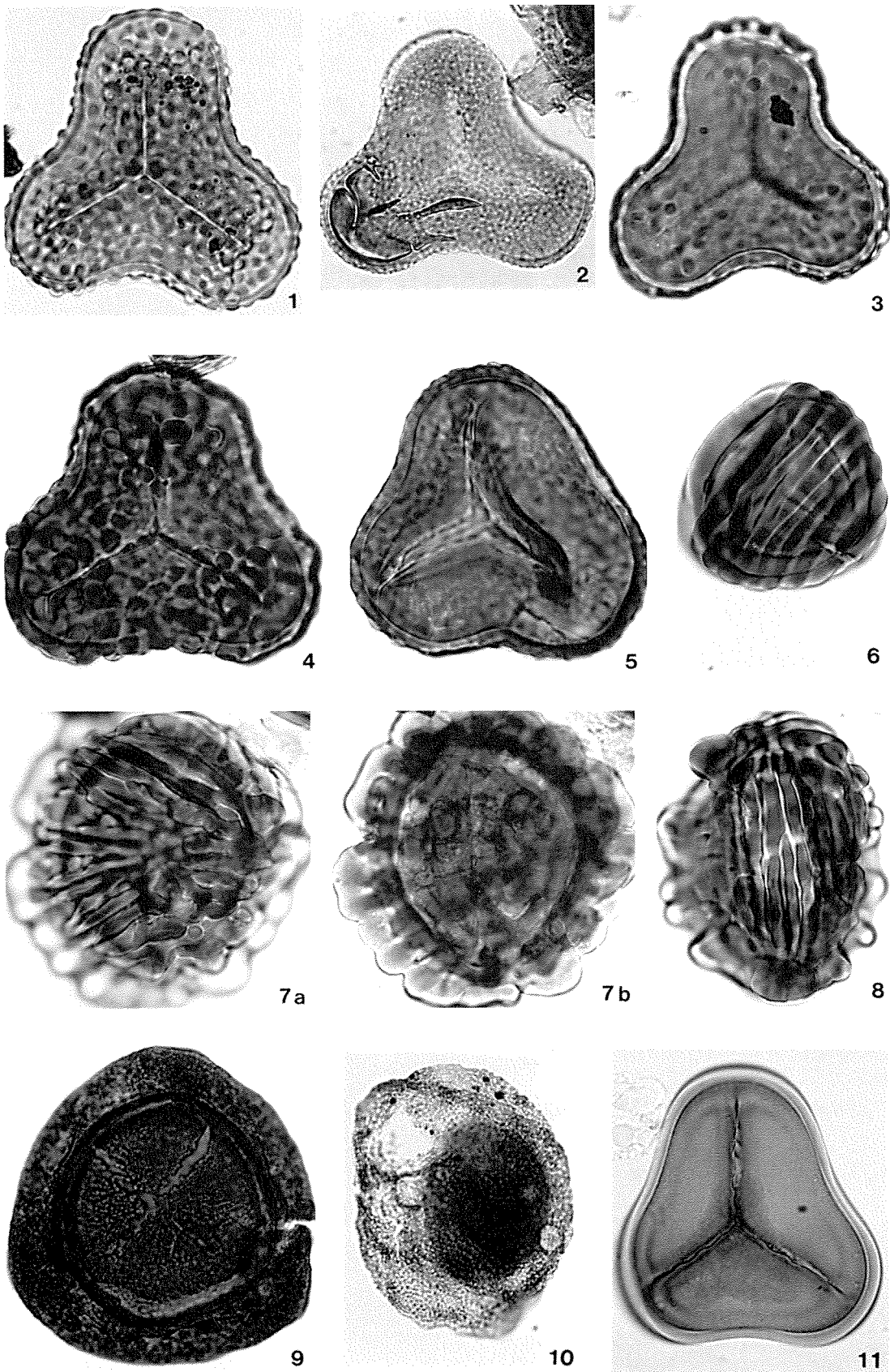
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PLATE 4

All figures x700 unless otherwise indicated.
HF, high focus; MF, median focus; LF, low focus.

Figure

- 1 *Concavissimisporites crassatus* (Delcourt and Sprumont).
Proximal view, HF. F10119/1 (–28.8, –105.8).
- 2 *Concavissimisporites verrucosus* Delcourt and Sprumont.
Distal view, MF. F8606/1 (–56.5, –102.7).
- 3–5 *Concavissimisporites variverrucatus* (Couper).
 3. Distal view, HF. F6669/1 (–40.4, –95.9).
 4. Distal view, MF. F6669/1 (–34.6, –96.3).
 5. Proximal view, HF. F6669/1 (–37.3, –103.7).
- 6 *Contignisporites cooksonae* (Balme).
Distal view, HF. F8549/1 (–33.0, –109.7).
- 7, 8 *Contignisporites multimuratus* Dettmann.
 7. Distal view, a, HF; b, LF. F6669/1 (–46.3, –104.0).
 8. Distal view, HF. F6669/1 (–35.8, –111.7).
- 9 *Cooksonites variabilis* Pocock.
Distal view, HF. F10291/4 (–58.1, –110.0).
- 10 *Crybelosporites stylosus* Dettmann.
Lateral view, x500, MF. F10210/2 (–32.6, –93.1).
- 11 *Dictyophyllidites equiexinus* (Couper).
Proximal view, HF. F8528/2 (–24.3, –106.1).



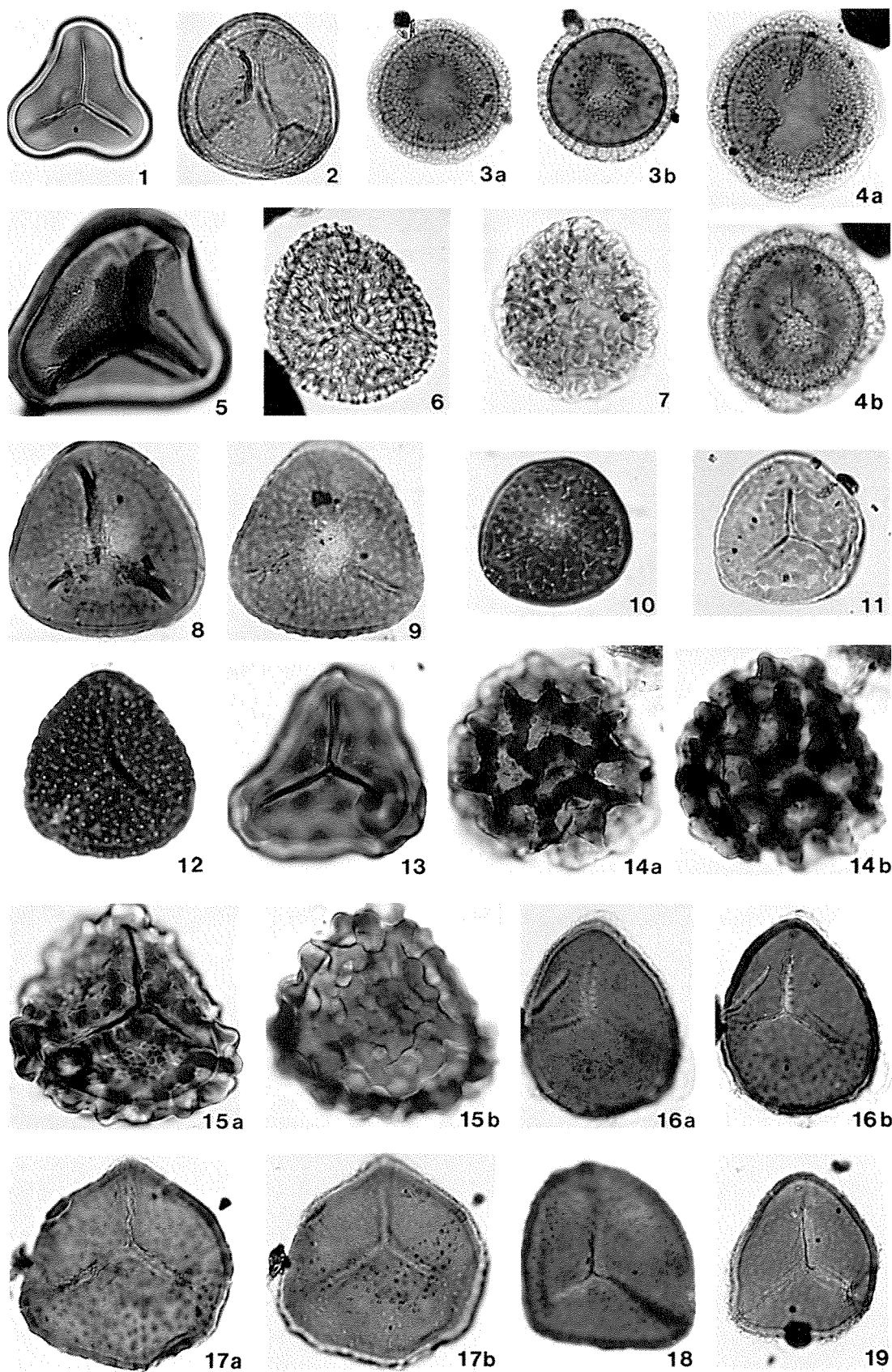
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PLATE 5

All figures x700 unless otherwise indicated.
HF, high focus; MF, median focus; LF, low focus.

Figure

- 1** *Cyathidites minor* Couper.
Proximal view, HF. F6661/1 (–34.1, –109.3).
- 2** *Densoisporites velatus* Weyland and Krieger.
Distal view, MF. F9422/3 (–56.3, –99.0).
- 3, 4** *Dictyotosporites complex* Cookson and Dettmann.
3. Distal view, a, HF; b, MF. F46273/1 (–40.2, –98.7).
4. Proximal view, a, HF; b, MF. F8357/1 (–36.5, –106.7).
- 5** *Dictyophyllidites equiexinus* (Couper).
Proximal view, HF. F6669/1 (–29.0, –100.4).
- 6, 7** *Dictyotosporites speciosus* Cookson and Dettmann.
6. Proximal view, HF. F8355/5 (–27.1, –96.5).
7. Proximal view, HF. F6086/4 (–34.7, –106.6).
- 8–10** *Foveosporites canalis* Balme.
8. Proximal view, x1000, HF. F46236/3 (–18.6, –100.3).
9. Distal view, x1000, MF. F46236/3 (–32.4, –101.7).
10. Holotype, ?distal view, MF. Balme TS 330.
- 11** *Foveosporites moretonensis* de Jersey.
Proximal view, LF. F7860/3 (–32.0, –102.9).
- 12** *Foveosporites subtriangularis* Brenner.
Proximal view, LF. F11500/4 (–33.8, –110.0).
- 13** *Ischyosporites crateris* Balme.
Proximal view, HF. F6661/1 (–41.1, –109.1).
- 14** *Ischyosporites scaberis* Cookson and Dettmann.
Distal view, a, HF; b, LF. F8200/5 (–31.4, –104.2).
- 15** *Ischyosporites variegatus* (Couper).
Proximal view, a, HF; b, LF. F6665/1 (–33.1, –105.7).
- 16–19** *Januasporites multispinus* sp. nov.
16. Distal view, a, HF; b, LF. F9430/2 (–28.2, –101.0).
17. Distal view, a, HF; b, LF. F9115/2 (–40.0, –107.7).
18. Holotype, proximal view, LF. F9425/2 (–28.2, –101.0).
19. Proximal view, HF. F8582/1 (–37.2, –109.5).



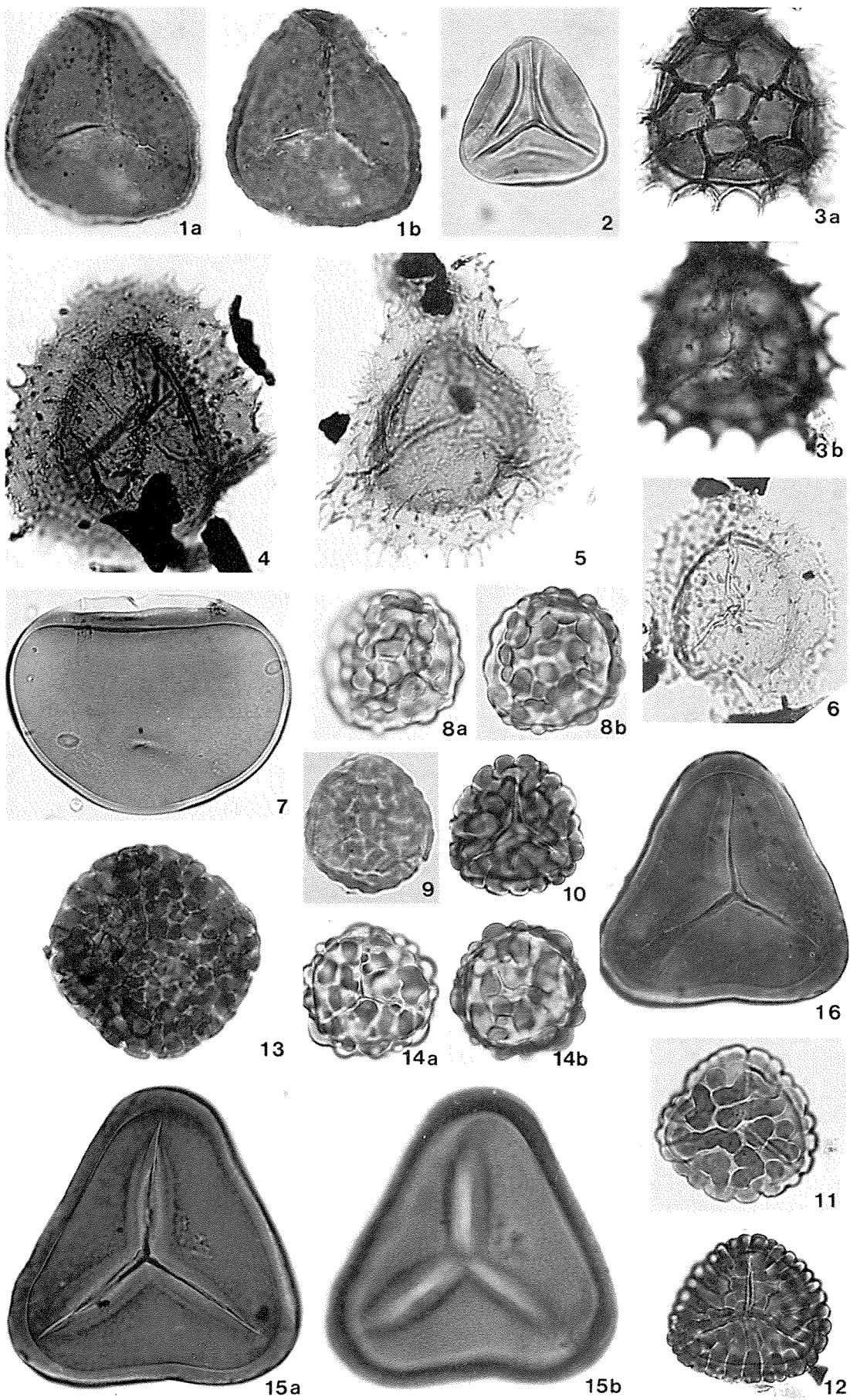
GSWA 22254

PLATE 6

All figures x700 unless otherwise indicated.
HF, high focus; MF, median focus; LF, low focus.

Figure

- 1 *Januasporites multispinus* sp. nov.
Dorsal view a, HF; b, LF. F6087/3 (–34.5, –108.8).
- 2 *Gleicheniidites senonicus* Ross.
Proximal view, HF. F6666/2 (–29.9, –96.6).
- 3 *Januasporites spinulosus* Dettmann.
Distal view, x500, a, HF; b, LF. F8608/1 (–59.2, –101.9).
- 4–6 *Krauselisporites whitfordensis* sp. nov.
 4. Distal view, HF. F8551/2 (–41.9, –106.4).
 5. Holotype, distal view, HF. F8351/3 (–24.4, –94.2).
 6. Distal view, MF. F9422/2 (–32.7, –110.5).
- 7 *Laevigatosporites belfordii* Burger.
Lateral view, x500, MF. F6595/37 (–36.0, –104.2).
- 8 *Leptolepidites major* Couper.
Proximal view, a, HF; b, LF. F6669/1 (–28.7, –100.9).
- 9 *Leptolepidites pudens* (Balme).
Proximal view, x1000, LF. F46236/3 (–49.2, –98.3).
- 10–12 *Leptolepidites verrucatus* Couper.
 10. Proximal view, HF. F8187/4 (–46.0, –104.6).
 11. Distal view, HF. F8606/1 (–46.7, –109.4).
 12. Proximal view, HF. F8608/1 (–47.3, –108.9).
- 13 *Lycopodiacidites asperatus* Dettmann.
Dorsal view LF. F22389/6 (–30.2, –101.0).
- 14 *Leptolepidites* sp. A.
Proximal view, a, HF; b, LF. F6668/1 (–35.5, –96.4).
- 15, 16 *Matonisporites agatonensis* Backhouse.
 15. Holotype, proximal view, x500, a, HF; b, LF. F6669/1 (–45.9, –97.1).
 16. Proximal view, x500, HF. F6666/2 (–33.7, –104.9).



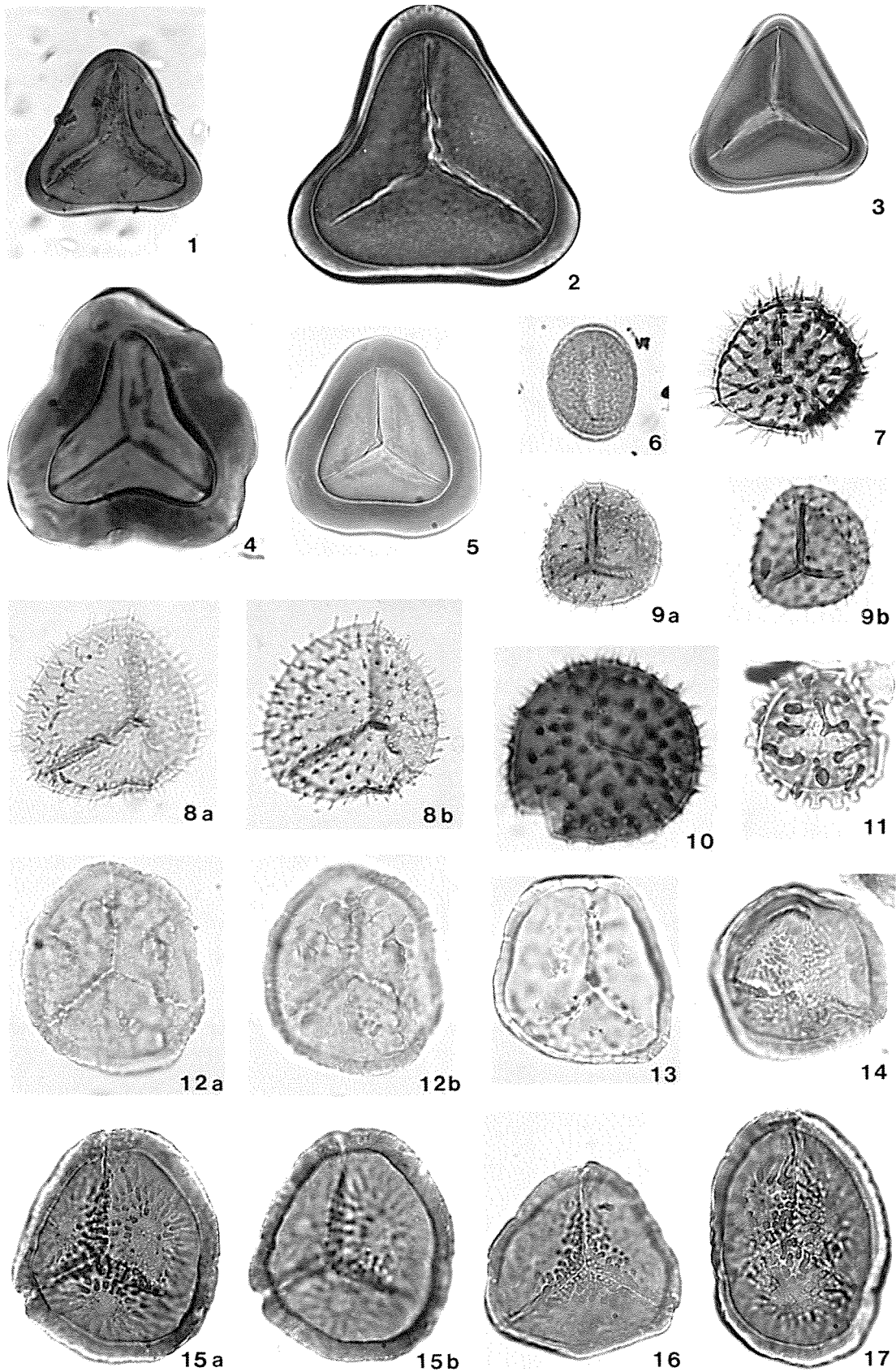
GSWA 22255

PLATE 7

All figures x700 unless otherwise indicated.
HF, high focus; MF, median focus; LF, low focus.

Figure

- 1–3** *Matonisporites crassiangulatus* (Balme).
1. Holotype, proximal view, x500. Balme T. S. 226.
2. Proximal view, MF. F9728/1 (–41.4, –109.0).
3. Proximal view, HF, F10119/1 (–31.9, –103.7).
- 4, 5** *Murospora florida* (Balme).
4. Distal view, MF. F6669/1 (–29.6, –96.2).
5. Proximal view, HF. F10119/1 (–31.9, –103.7).
- 6** *Marattisporites scabratus* Couper.
Distal view, MF. F22305/6 (–41.6, –104.2).
- 7** *Neoraistrickia equalis* (Cookson and Dettmann).
Distal view, MF. F10199/1 (–44.0, –106.0).
- 8** *Neoraistrickia trichosa* Filatoff.
Proximal view, a, HF; b, LF. F8352/4 (–37.0, –109.0).
- 9, 10** *Neoraistrickia levidensis* (Balme).
9. Distal view, a, HF; b, LF. F46236/3 (–54.0, –105.2).
10. Holotype, ?proximal view, x1000, MF. Balme T. S. 200.
- 11** *Neoraistrickia truncata* (Cookson).
Distal view, HF. F6087/3 (–29.3, –94.1).
- 12, 13** *Nevesisporites dailyi* (Cookson and Dettmann).
12. Proximal view, a, HF; b, LF. F6595/8 (–51.7, –103.3).
13. Distal view, LF. F6595/41 (–41.9, –102.7).
- 14–17** *Nevesisporites harleyi* sp. nov.
14. Proximal view, HF. F8609/1 (–35.5, –98.0).
15. Holotype, proximal view, a, HF; b, LF. F6669/2 (–36.0 –107.8).
16. Proximal view, HF. F6669/1 (–35.4, –96.4).
17. Proximal view, HF. F6669/2 (–41.7, –103.3).



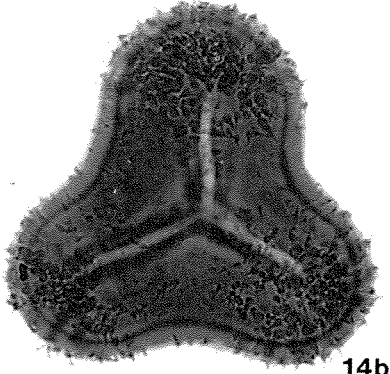
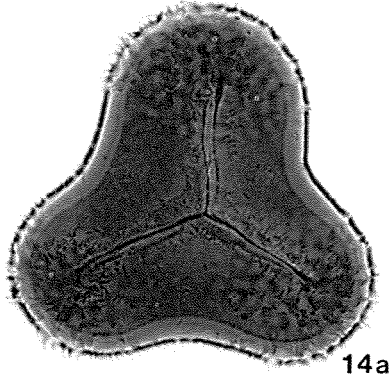
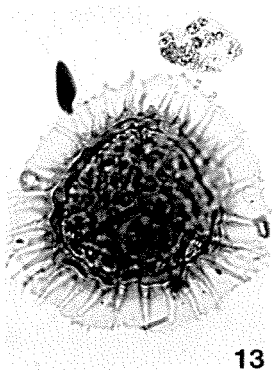
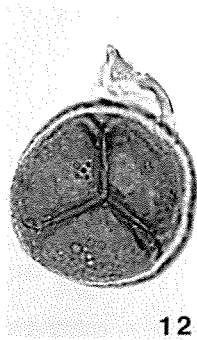
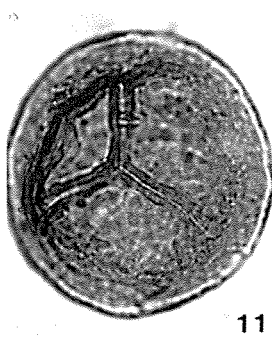
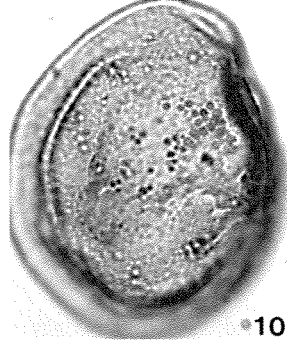
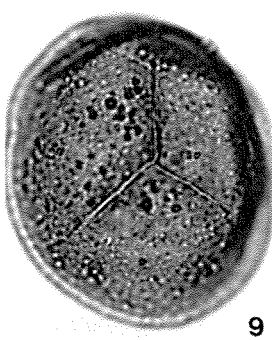
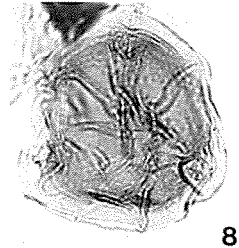
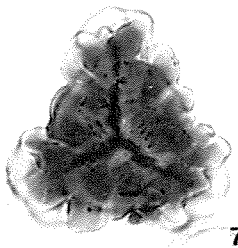
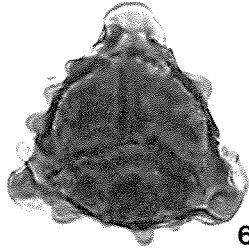
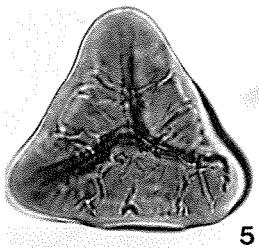
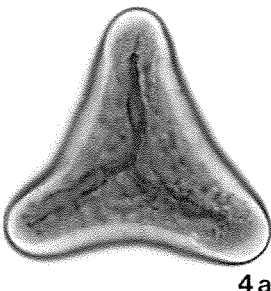
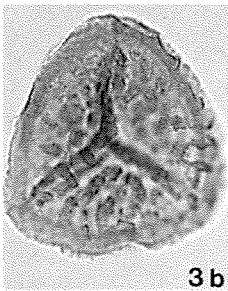
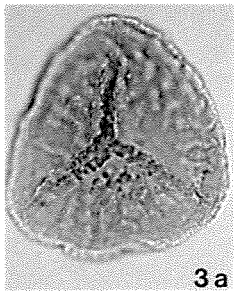
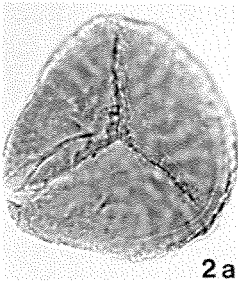
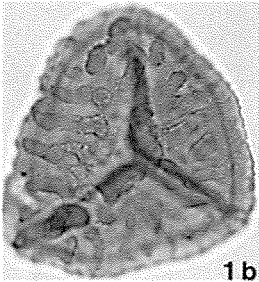
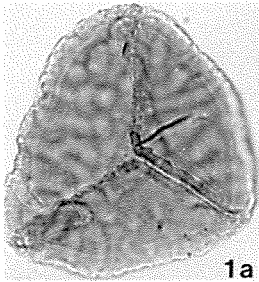
GSWA 22256

PLATE 8

All figures x700 unless otherwise indicated.
HF, high focus; MF, median focus; LF, low focus.

Figure

- 1–3** *Nevesisporites undatus* sp. nov.
1. Holotype, proximal view, x500, a, HF; b, LF, F6684/4 (–44.0, –110.9).
2. Proximal view, x500, a, HF; b, LF, F6684/4 (36.0, –102.8).
3. Proximal view, x500, a, HF; b, LF, F6684/4 (–35.8, –105.4).
- 4, 5** *Obtusisporites canadensis* Pocock.
4. Proximal view, a, HF; b, LF, F6669/1 (–39.9, –95.5).
5. Proximal view, LF, F6669/1 (–29.1, –94.2).
- 6, 7** *Obtusisporites yarragadensis* Filatoff.
6. Distal view, MF, F6668/2 (–30.6, –112.1).
7. Distal view, HF, F8610/2 (–33.1, –112.2).
- 8** *Perinopollenites elatoides* Couper.
?Distal view, HF, F6595/6 (–50.8, 101.5).
- 9–12** *Osmundacidites* sp. cf. *O. dubius* Burger.
9. Proximal view, HF, F6595/8 (–48.2, –102.0).
10. Proximal view, HF, F6595/3 (–41.6, –104.6).
11. Distal view, HF, F6595/3 (–45.5, –107.2).
12. Proximal view, HF, F6689/1 (–42.1, –105.0).
- 13** *Perotrilites linearis* (Cookson and Dettmann).
Proximal view, HF, F10065/1 (–22.3, –102.3).
- 14** *Pilosisporites ingramii* sp. nov.
Holotype, proximal view, x500, a, HF; b, LF, F6284/3 (–36.6, –102.2).



GSWA 22257

PLATE 9

All figures x700 unless otherwise indicated.
HF, high focus; MF, median focus; LF, low focus.

Figure

- 1 *Pilosisorites ingramii* sp. nov.
Proximal view, x500, HF. F6686/1 (–31.2, –105.9).
- 2, 3 *Polypodioidites horridus* Backhouse.
2. Holotype, lateral view, a, HF; b, LF. F8606/2 (–33.9, –110.4).
3. Lateral view, HF. F6665/1 (–40.5, –106.5).
- 4–6 *Reticuloidosporites arcus* (Balme).
4. Lateral view, MF. F8350/3 (42.6, –105.0).
5. Proximal view, HF. F8347/1 (–28.9, –95.7).
6. Distal view, HF. F9121/2 (–41.1, –105.7).
- 7 *Retispora triquetra* (Lantz).
Proximal view, a, HF; b, LF. F11799/1 (–35.8, –97.9).
- 8 *Retitriletes circolumenus* (Cookson and Dettmann)
Distal view, HF. F8347/2 (–42.8, –107.0).
- 9 *Retitriletes clavatoides* (Couper).
Distal view, LF. F6595/8 (–40.7, –102.7).
- 10 *Retitriletes austroclavatidites* (Cookson).
Proximal view, a, HF; b, LF. F8528/3 (–54.7, –100.6).
- 11 *Retitriletes facetus* (Dettmann)
Proximal view, a, HF; b, LF. F6087/3 (–36.9, –94.9).
- 12 *Retitriletes nodosus* (Dettman)
Distal view, HF. F8187/2 (–29.3, –98.1)
- 13, 14 *Retitriletes eminulus* (Dettmann).
13. Distal view, HF. F12788/6 (–30.6, –98.4).
14. Distal view, HF. F12442/1 (–38.8, –106.0).
- 15, 16 *Retitriletes parvireticulatus* sp. nov.
15. Proximal view, a, HF; b, LF. F6087/3 (–37.2, –104.5).
16. Holotype, distal view, x1000, a, HF; b, LF. F8528/3 (–42.3, –97.5).
- 17 *Retitriletes reticulumsporites* (Rouse).
Proximal view, a, HF; b, LF. F12436/1 (–53.7, –92.0).
- 18, 19 *Retitriletes tenuis* (Balme).
18. Paratype, x1000. Balme T.S. 196.
19. Distal view, x1000, HF. F46236/3 (–31.5, –98.6).

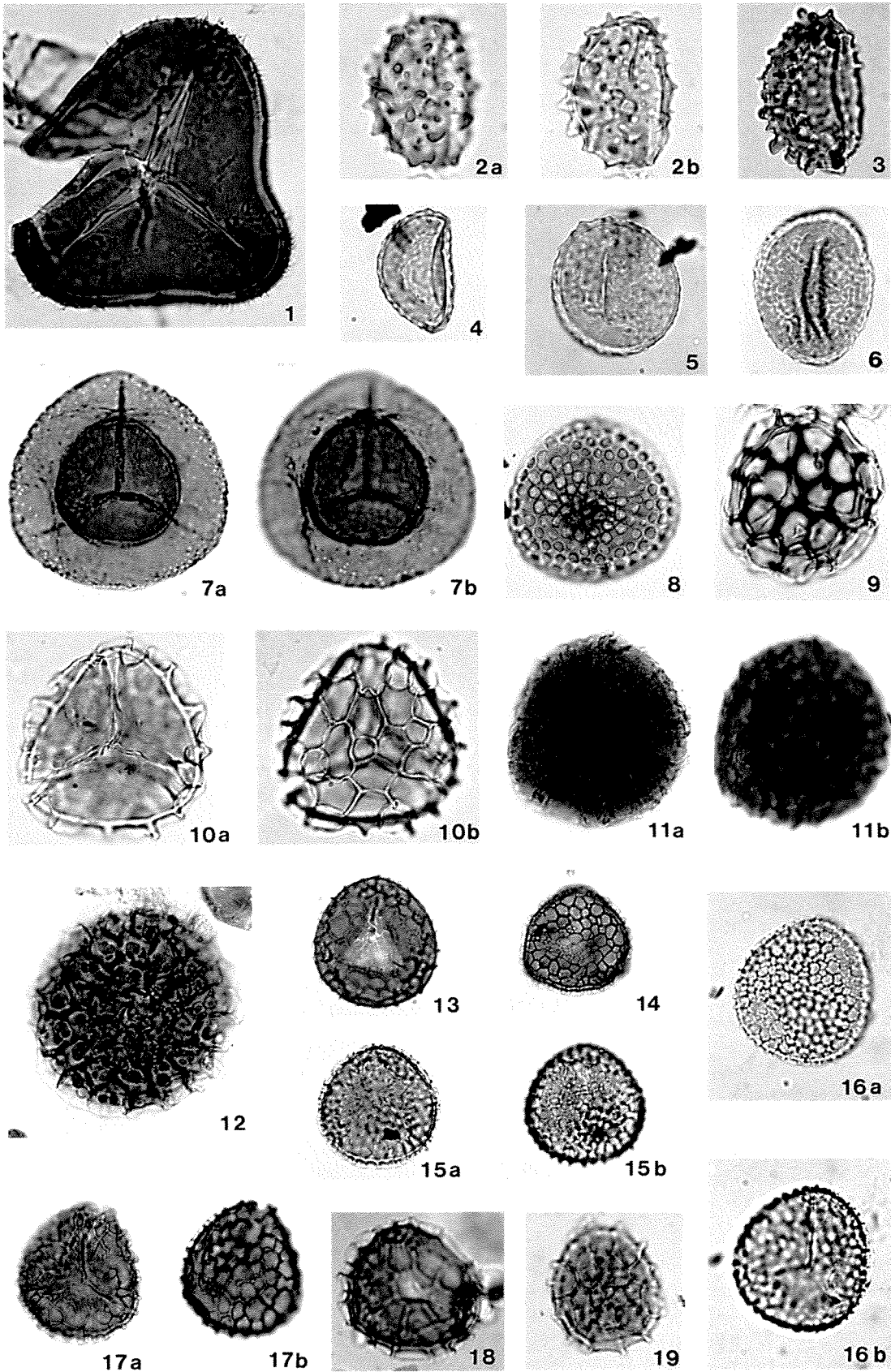
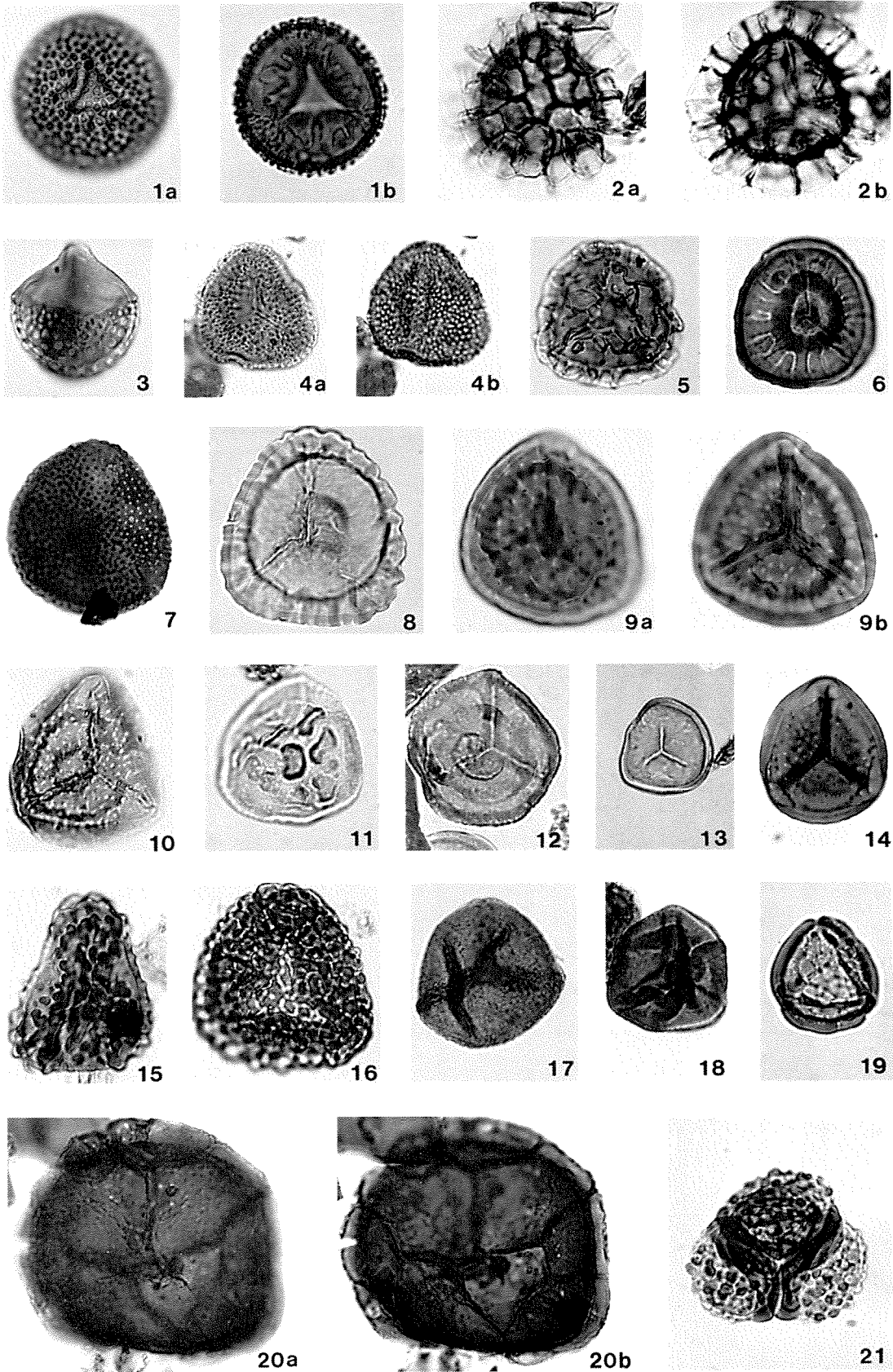


PLATE 10

All figures x700 unless otherwise indicated.
HF, high focus; MF, median focus; LF, low focus.

Figure

- 1, 3** *Retitriteles watheroonensis* Backhouse.
 1. Distal view, a, HF; b, LF. F6595/3 (–43.7, –94.1).
 3. Lateral view, HF. F8528/3 (–34.2, –97.9).
- 2** *Retitriteles* sp. A.
 - Distal view, a, HF; b, LF. F9996/1 (–27.7, –105.4).
- 4** *Retitriteles* sp. B.
 - Proximal view, a, HF; b, LF. F8338/1 (–41.4, –104.3).
- 5** *Retitriteles* sp. C.
 - Proximal view, HF. F9045/3 (–39.7, –111.6).
- 6** *Rogalskaisporites canaliculus* Filatoff.
 - Distal view, HF. F6595/3 (–39.8, –105.8).
- 7** *Sestrosporites pseudoalveolatus* (Couper).
 - Proximal view, HF. F12451/1 (–52.0, –109.0).
- 8** *Staplinisporites caminus* (Balme).
 - Distal view, LF. F6684/4 (–29.2, –106.2).
- 9, 14** *Staplinisporites telatus* (Balme).
 9. Distal view, a, HF; b, LF. F6669/1 (–28.3, –101.0).
 14. Proximal view, MF. F9422/1 (–34.0, –99.4).
- 10** *Staplinisporites perforatus* (Dettmann).
 - Distal view, MF. F6088/5 (–28.3, –112.9).
- 11, 12** *Polycingulatisporites reduncus* (Bolk-hovitina).
 11. Distal view, HF. F9422/3 (–46.8, –107.2).
 12. Proximal view, MF. F23899/2 (–30.6, –105.5).
- 13** *Stereisporites antiquasporites* (Wilson and Webster).
 - Proximal view, HF. F9038/2 (–48.8, –92.3).
- 15, 16** *Trilites tuberculiformis* Cookson.
 15. Distal view, HF. F9428/1 (–44.9, –106.7).
 16. Distal view, HF. F6667/4 (–48.0, –105.9).
- 17, 18** *Undulatisporites? pflugii* Pocock.
 17. Proximal view, MF. F9422/2 (–22.3, –106.6).
 18. Distal view, MF. F6595/3 (–32.2, –99.3).
- 19, 21** *Uvaesporites crassibalteus* (Filatoff).
 19. Proximal view, LF. F8528/3 (–34.1, –95.5).
 21. Lateral view of a tetrad. F8528/3 (–48.0, –94.6).
- 20** *Rouseisporites reticulatus* Pocock.
 - Proximal view, a, HF; b, LF. F46213/1 (–40.8, –101.5).



GSWA 22259

PLATE 11

All figures x700 unless otherwise indicated.
HF, high focus; MF, median focus; LF, low focus.

Figure

- 1, 2** *Vallizonosporites tegmentus* sp. nov.
 1. Holotype, distal view, a, HF; b, LF. F8356/2 (–26.2, –107.8).
 2. Distal view, a, HF; b, LF. F8347/2 (–39.3, –110.0).
- 3, 4** *Alisporites similis* (Balme).
 3. Distal view, x500, MF. F8187/3 (–57.0, –96.1).
 4. Proximal view, x500, MF. F9422/3 (–47.3, –93.7).
- 5** *Vitreisporites signatus* Leschik.

Distal view, MF. F9115/2 (–39.4, –107.3).
- 6** *Alisporites grandis* (Cookson).

Distal view, x500, MF. F6666/2 (–44.8, –102.7).
- 7** *Cycadopites follicularis* Wilson and Webster.

Proximal view, HF. F7928/1 (–40.5, –97.4).
- 8** *Podocarpidites* sp. cf. *P. multesimus* (Bolkhovitina).

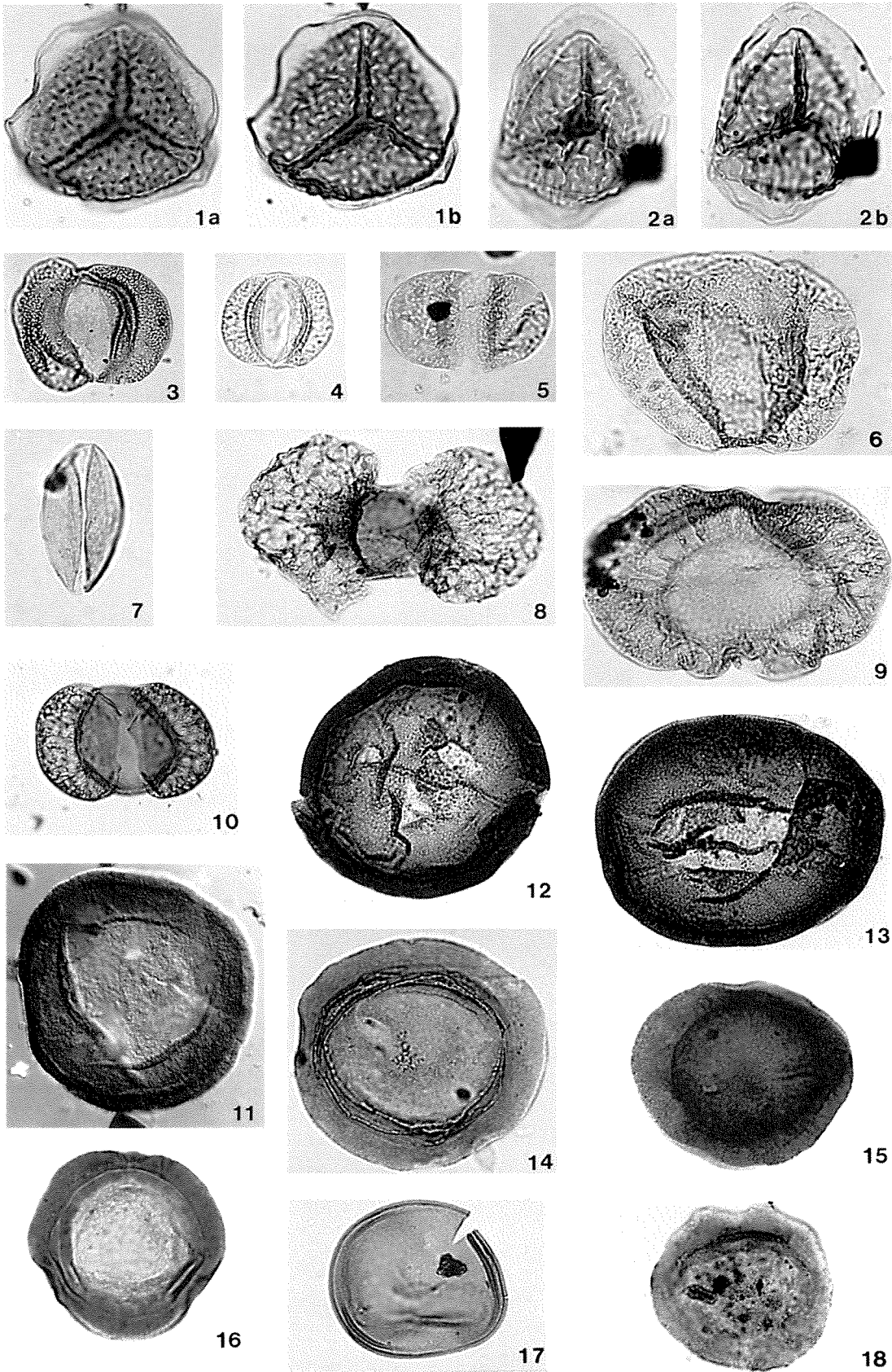
Proximal view, x500, MF. F12437/1 (–49.6, –107.0).
- 9** *Podocarpidites* sp. A.

Proximal view, x500, HF. F6595/4 (–40.6, –109.0).
- 10** *Podocarpidites ellipticus* Cookson.

Proximal view, x500, MF. F8357/8 (–42.5, –106.0).
- 11–13** *Balmeiopsis limbata* (Balme).
 11. Holotype, interference contrast, x500, Balme T. S. 356.
 12. Polar view, x500, MF. F7926/12 (–36.8, –101.6).
 13. Polar view, x500, MF. F7926/11 (–37.6, –103.7).
- 14–16** *Balmeiopsis robusta* sp. nov.
 14. Polar view, MF. F8544/2 (–38.0, –107.5).
 15. Polar view, x600, MF. F33871/5 (–57.4, –101.5).
 16. Holotype, polar view, MF. F8551/2 (–28.0, –102.3).
- 17** *Araucariacites australis* Cookson.

Polar view, MF, x500. F9422/2 (–24.5, –104.4).
- 18** *Hoegisporis uniforma* Cookson.

Specimen from Osborne Formation showing indistinct nodes, morphologically transitional to *B. robusta*. Polar view, MF. F8763/1 (–35.7, –112.1).



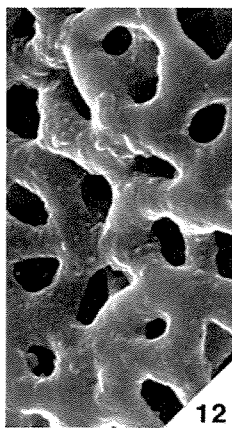
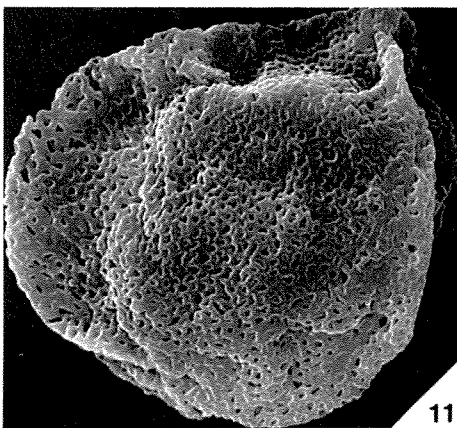
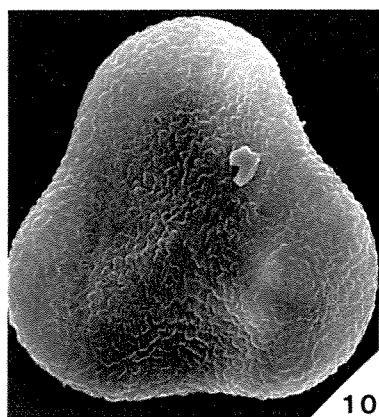
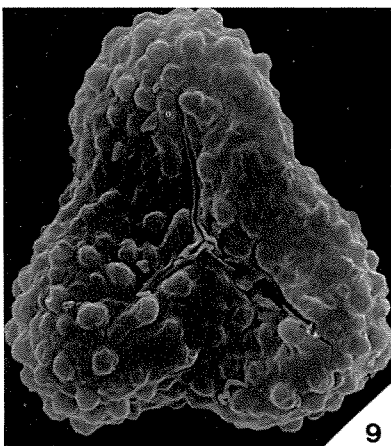
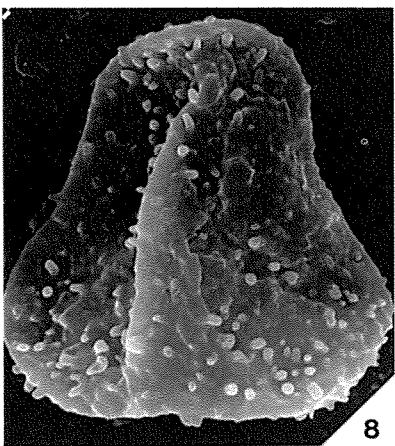
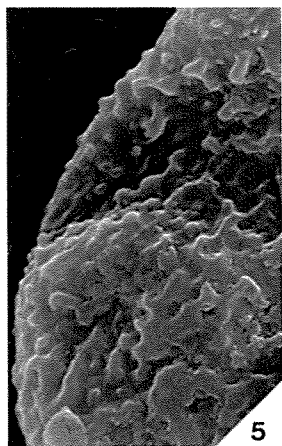
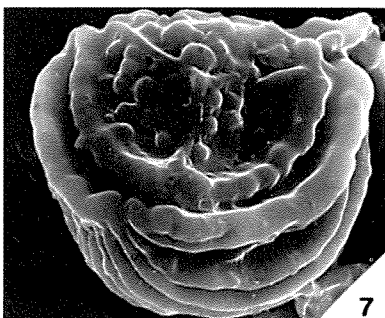
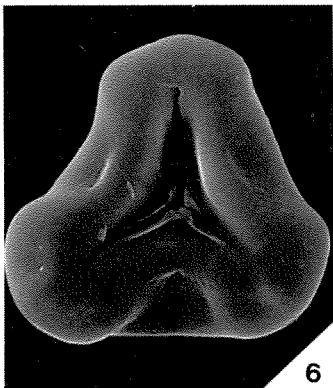
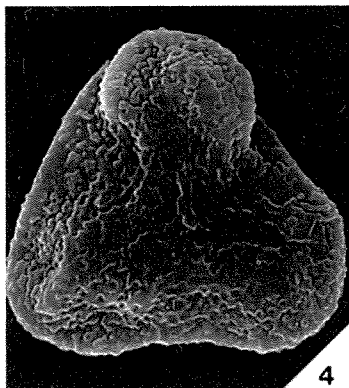
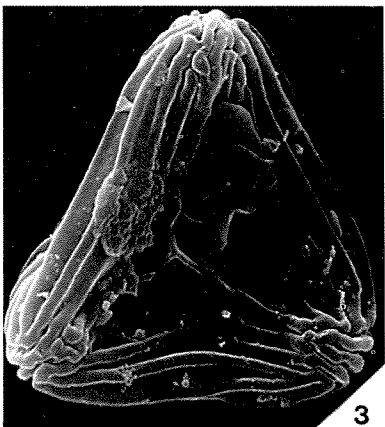
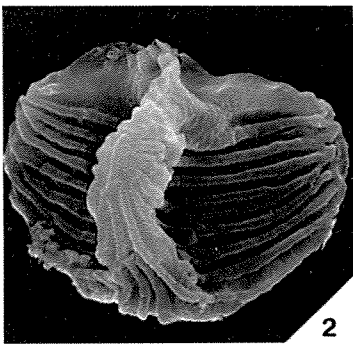
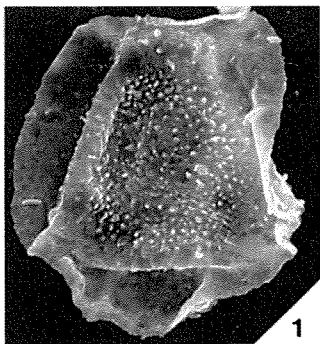
GSWA 22260

PLATE 12

All figures SEM micrographs.

Figure

- 1** *Aequitriradites hispidus* Dettmann and Playford.
Proximal surface, x650. F6685/12 (–35.7, –103.0).
- 2, 3** *Cicatricosisporites australiensis* (Cookson).
 2. Lateral view, x1000. F7817/3 (–39.5, –100.9).
 3. Proximal view, x1000. F7817/3 (–37.6, –103.1).
- 4, 5** *Concavissimisporites infirmus* (Balme).
 4. Proximal surface, x1200. F46236/5 (–31.3, –101.6).
 5. Same specimen, surface detail, x3000.
- 6** *Cyathidites concavus* (Bolkhovitina).
Proximal surface, x1000. F7817/3 (–37.8, –102.1).
- 7** *Contignisporites cooksonae* (Balme).
Proximal surface, x1000. F6595/10 (–36.9, –105.0).
- 8** *Concavissimisporites irregularis* (Pocock).
Distal surface, x1000. F11499/6 (–35.2, –103.2).
- 9** *Concavissimisporites variverrucatus* (Couper).
Proximal surface, x1000. F7817/3 (–37.0, –98.6).
- 10** *Concavissimisporites verrucosus* Delcourt and Sprumont.
Distal surface, x750. Specimen lost.
- 11, 12** *Crybelosporites stylosus* Dettmann.
 11. ?Distal surface, x1000. F6595/10 (–35.7, –106.7).
 12. Surface detail of same specimen, x7000.



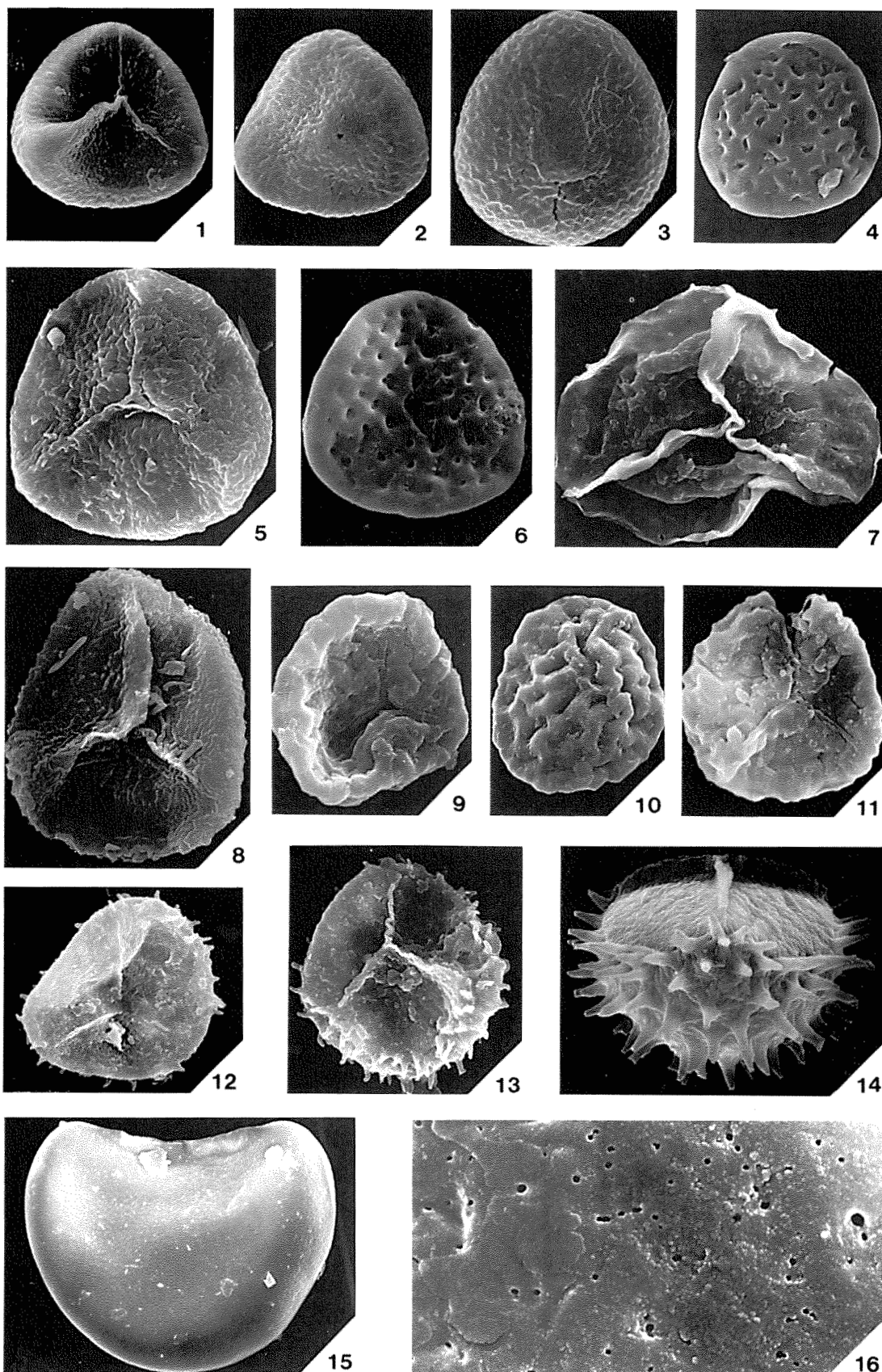
GSWA 22261

PLATE 13

All figures SEM micrographs.

Figure

- 1–3** *Foveosporites canalis* Balme.
1. Proximal surface, x1200. F46236/5 (–29.5, –95.7).
2. Distal surface, x1000. F46236/6 (–30.7, –108.3).
3. Distal surface, x1200. F9327/3 (–36.1, –100.1).
- 4** *Foveosporites moretonensis* de Jersey.
Distal surface, x1000. F11499/7. Specimen lost.
- 5** *Densoisporites velatus* Weyland and Krieger.
Proximal surface, x1000. Specimen lost.
- 6** *Foveosporites subtriangularis* (Brenner).
Distal surface, x1000. Specimen lost.
- 7** *Krauselisporites whitfordensis* sp. nov.
Proximal surface, x700. F11499/6 (–35.5, –106.6).
- 8** *Januasporites multispinus* sp. nov.
Proximal surface, x1000. F7817/3 (–31.9, –98.2).
- 9–11** *Leptolepidites pudens* (Balme).
9. Proximal surface, x1500. Specimen lost
10. Distal surface, x1500. F46236/6 (–37.0, –104.1).
11. Proximal surface, x1500. F46236/6 (–34.6, –100.2).
- 12, 13** *Neoraistrickia levidensis* (Balme).
12. Proximal surface, x1200. F46236/6 (–39.6, –100.8).
13. Proximal surface, x1200. F46236/6 (–35.5, –105.7).
- 14** *Neoraistrickia equalis* (Cookson and Dettmann).
Lateral view, x1500. Specimen lost.
- 15** *Laevigatosporites belfordii* Burger.
Lateral view, x600. F46350/3 (–49.2, –101.6).
- 16** *Matonisporites crassiangulatus* (Balme).
Surface detail of corroded specimen showing irregular pitting of the exine, x9000. F7817/3 (–38.8, –105.5).



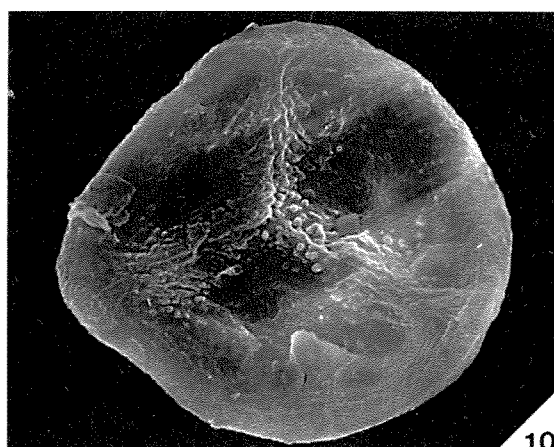
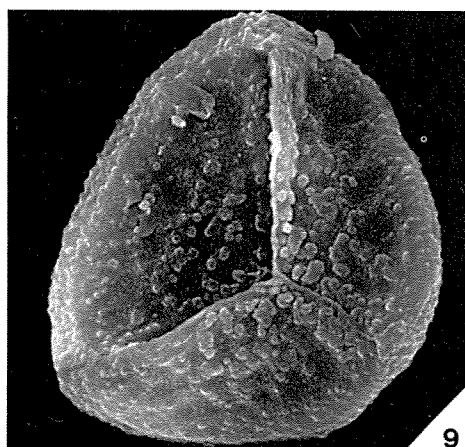
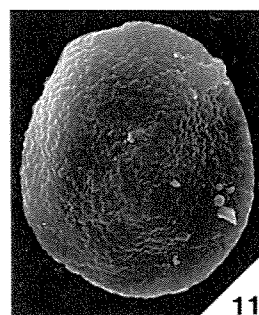
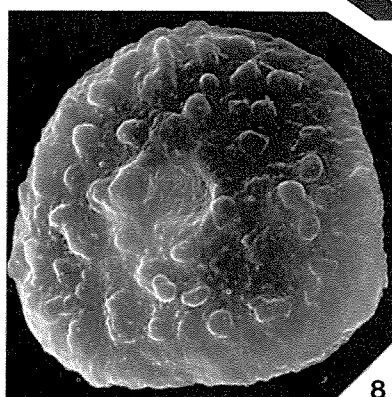
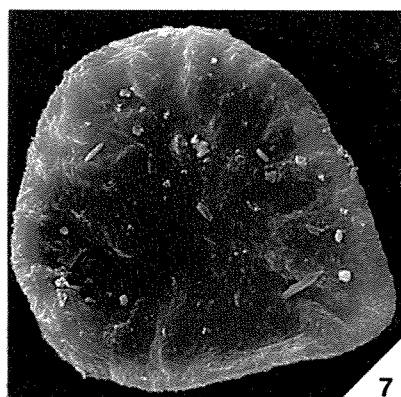
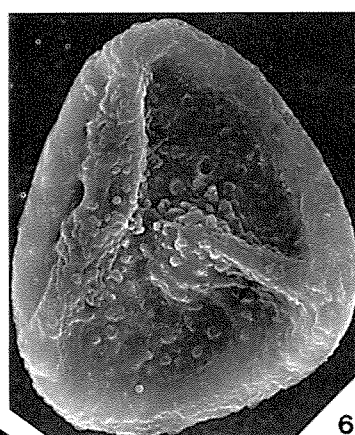
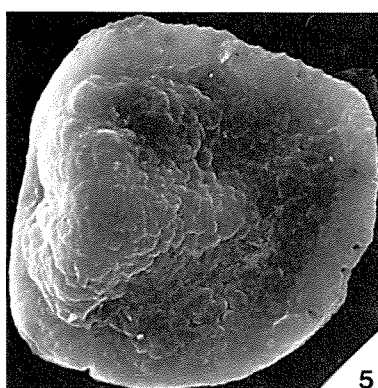
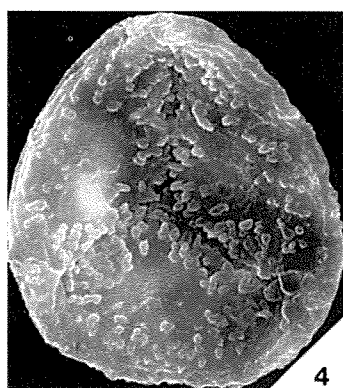
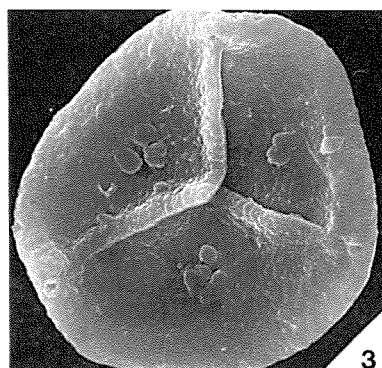
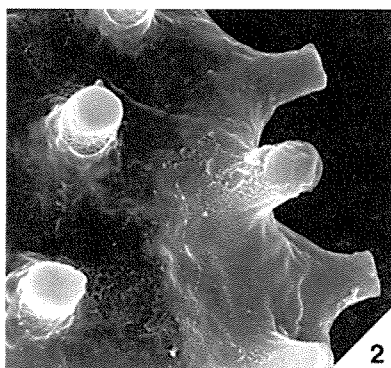
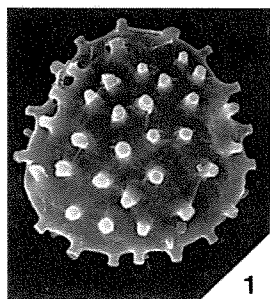
GSWA 22262

PLATE 14

All figures SEM micrographs.

Figure

- 1, 2** *Neoraistrickia truncata* (Cookson)
1. Distal surface, x1000. F6685/13 (–37.9, –105.5).
2. Surface detail of same specimen, x5000.
- 3** *Nevesisporites dailyi* (Cookson and Dettmann).
Proximal surface, x1000. F6685/14 (–36.3, –102.2).
- 4, 5** *Nevesisporites harleyi* sp. nov.
4. Proximal surface, x1000. Specimen lost.
5. Distal surface, x1000. F46350/3 (–36.6, –103.3).
- 6–10** *Nevesisporites undatus* sp. nov.
6. Proximal surface, x1000. F6685/13 (–42.1, –97.0).
7. Distal surface, x1000. F7817/3 (–31.9, –98.2).
8. Distal surface, x1000. Specimen lost.
9. Proximal surface, x1000. Specimen lost.
10. Proximal surface, x1000. F6685/12 (–30.8, –97.6).
- 11** *Osmundacidites* sp. cf. *O. dubius* Burger.
Distal surface, x1000. Specimen lost.



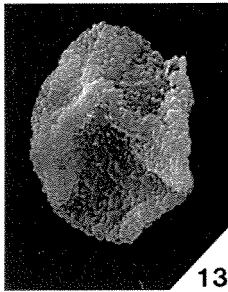
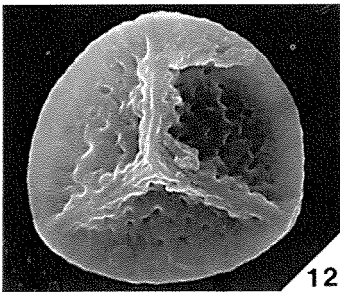
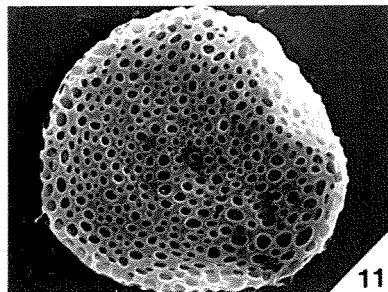
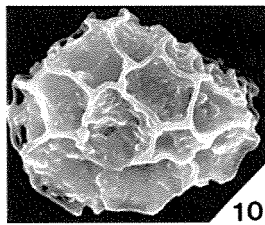
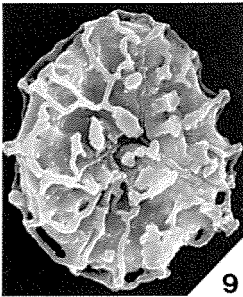
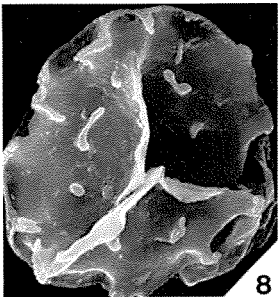
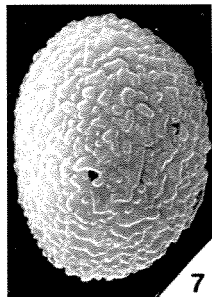
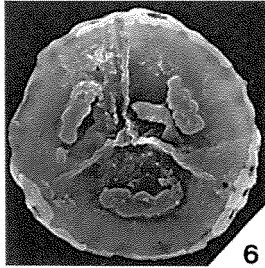
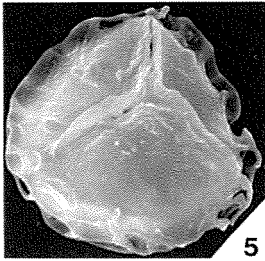
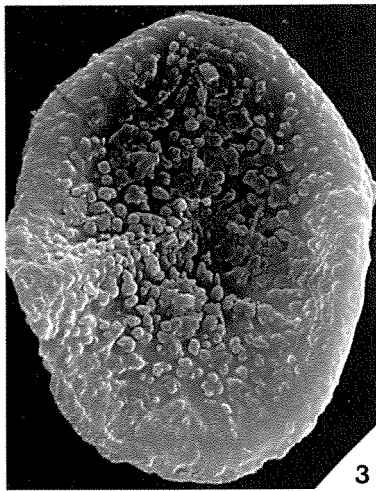
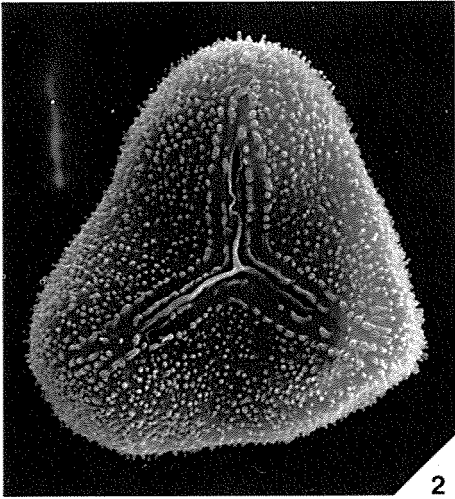
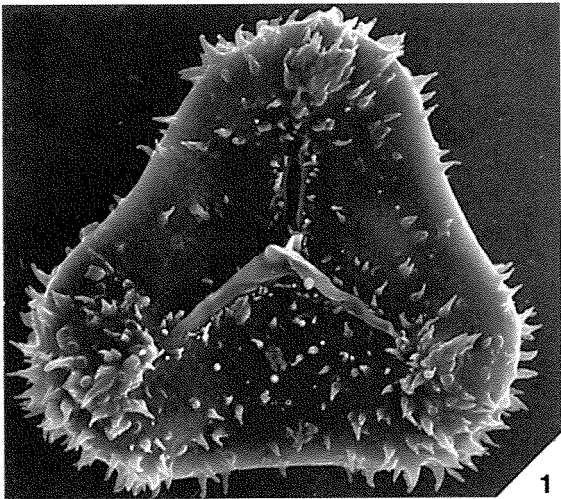
GSWA 22263

PLATE 15

All figures SEM micrographs

Figure

- 1 *Pilosisporites ingramii* sp. nov.
Proximal surface, x600. F7817/3 (–32.3, –103.2).
- 2 *Pilosisporites notensis* Cookson and Dettmann.
Specimen from SE Australia, illustrated for comparison with *P. ingramii*. Proximal surface, x600. F46351/1 (–35.5, –98.7).
- 3 *Osmundacidites* sp. cf. *O. dubius* Burger.
Distal surface, x1000. F6685/14 (–41.3, –100.6).
- 4 *Retispora triquetra* (Lantz).
Distal surface, x1000. F8358/6 (–38.8, –98.8).
- 5 *Retitriletes austroclavatidites* (Cookson).
Proximal surface, x850. F46350/2 (–29.9, –100.8).
- 6 *Retitriletes circolumenus* (Cookson and Dettmann).
Proximal surface, x850. F11499/7 (–31.0, –105.2).
- 7 *Reticuloidosporites arcus* (Balme).
Distal surface, x1200. F8342/3 (–36.1, –106.0).
- 8 *Retitriletes clavatoides* (Couper).
Proximal surface, x1000. F6595/10 (–34.4, –104.3).
- 9, 10 *Retitriletes tenuis* (Balme).
9. Proximal surface, x1500. F46236/6 (–32.9, –104.0).
10. Distal surface, x1500. F46236/6 (–36.0, –100.0).
- 11 *Retitriletes watherooensis* Backhouse.
Distal surface x1000. F8353/11 (–38.8, –100.4).
- 12 *Staplinisporites telatus* (Balme).
Proximal surface, x1000. F6595/10 (–35.0, –101.0).
- 13 *Undulatisporites? pflugii* Pocock.
Proximal surface, x1000. F11499/7 (–33.2, –103.1).



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PLATE 16

All figures SEM micrographs.

Figure

1, 2 *Microcachryidites antarcticus* Cookson.

1. Distal surface, x1000. F8356/10 (–25.8, –100.5).
2. Lateral surface, x1000. Specimen lost.

3–6 *Balmeiopsis limbata* (Balme).

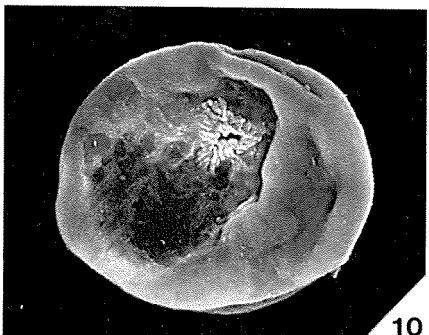
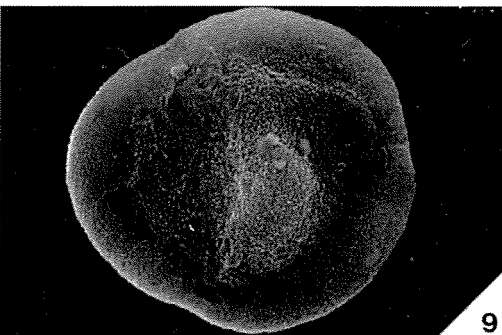
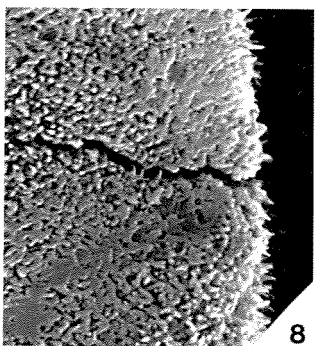
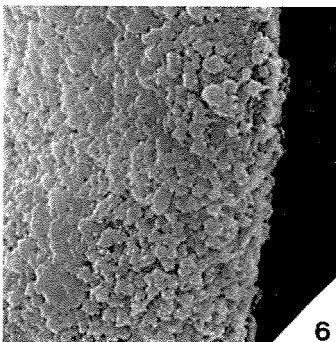
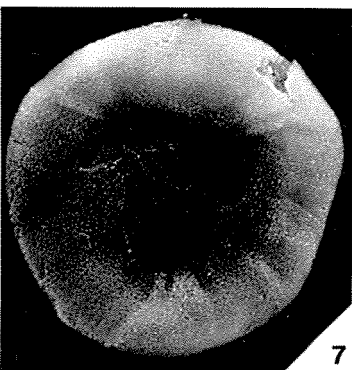
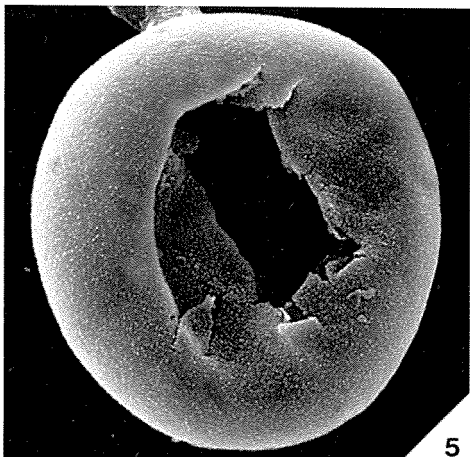
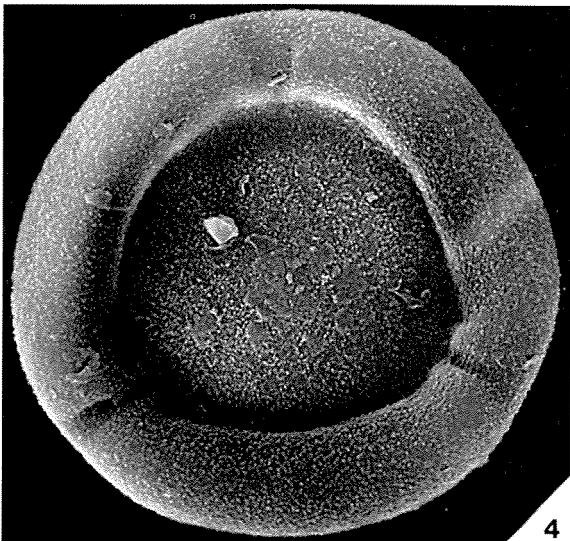
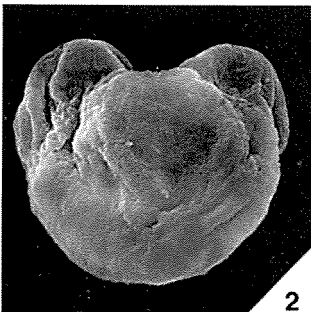
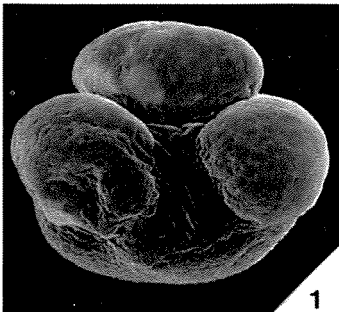
3. Polar view, x1000. F8353/11 (–35.6, –103.3).
4. Polar view of specimen morphologically transitional to *B. robusta*, x1500. F9327/4 (–34.2, –103.2).
5. Polar view of specimen with both polar areas ruptured, x700. F9327/3 (–33.1, –100.2).
6. Detail of exine, x5000. F8353/11 (–35.6, –103.3).

7–9 *Balmeiopsis robusta* sp. nov.

7. Polar view, x1000. F8351/5 (–33.8, –99.7).
8. Detail of exine surface, x5000. Same specimen as above.
9. Polar view, x1200. F9327/4 (–37.1, –104.7).

10 *Classopollis chateaunovi* Reyre.

- Distal surface, x1000. F8358/6 (–33.9, –97.3).



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PLATE 17

All figures x800 unless otherwise indicated.
HF, high focus; MF, median focus; LF, low focus.

Figure

1–3 *Aprobolocysta alata* Backhouse.

1. Dorso-left lateral view. HF. F9199/2 (–42.0, –95.4).
2. Dorsal view, HF. F9199/1 (–40.0, –105.3).
3. Dorsal view, a, LF; b, HF. F9199/1 (–39.0, –108.8)

4–6 *Aprobolocysta bipartita* Backhouse.

4. Left lateral view, a, HF; b, LF. F8551/1 (–35.7, –102.3).
5. Ventro-left lateral view, a, HF; b, LF. F8551/2 (–51.0, –97.3).
6. Ventral view, a, HF; b, LF. F8551/1 (–35.9, –100.2).

7–9 *Aprobolocysta galeata* Backhouse.

7. Ventral view, HF. F11259/1 (–29.1, –95.8).
8. Dorsal view, MF. F11533/1 (–55.3, –109.3).
9. Dorsal view, MF. F9843/2 (–60.8, –105.8).

10, 11 *Achomosphaera* sp. A.

10. Lateral view, x600, MF. F10228/2 (–43.5, –111.3).
11. Right lateral view, x600, MF. F10228/1 (–46.7, –100.4).

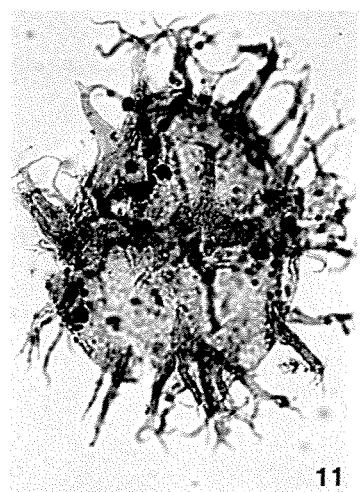
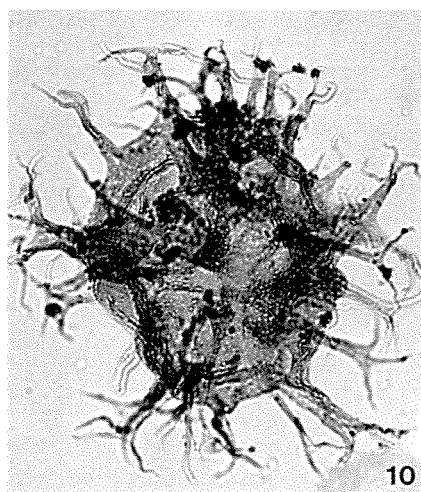
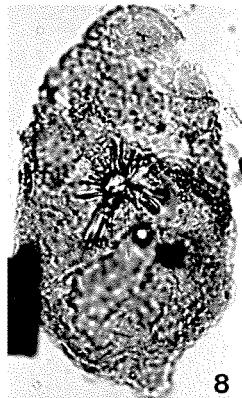
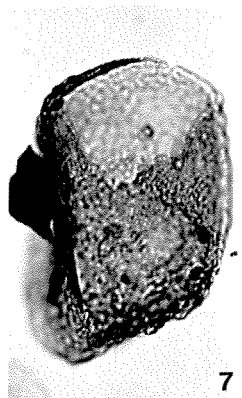
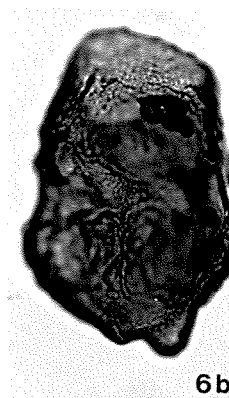
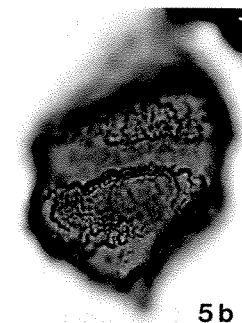
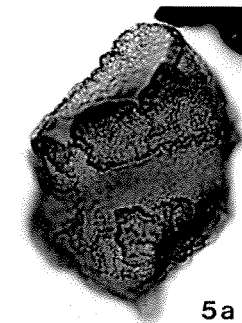
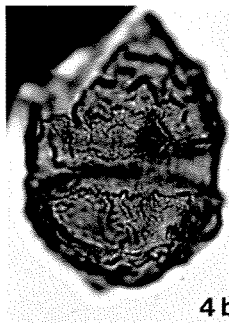
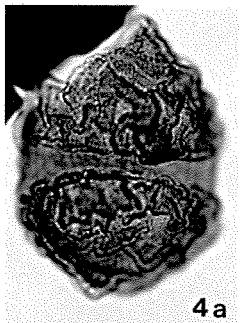
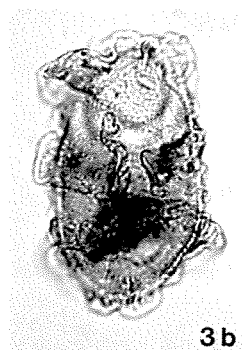


PLATE 18

All figures x600.

HF, high focus; MF, mid focus; LF, low focus.

Figure

1–3 *Apteodinium maculatum* Eisenack and Cookson.

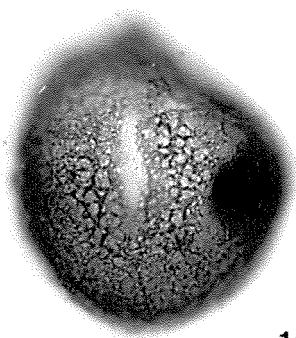
1. Ventral view, a, HF; b, LF. F33871/5 (–41.8, –97.7).
2. Dorsal view, MF. F33871/5 (–39.2, –107.9).
3. Right lateral view, MF. F10209/1 (–37.4, –105.9).

4–6 *Apteodinium* sp. A.

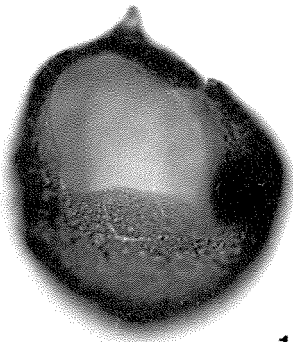
4. Left lateral view, a, HF; b, LF. F22387/6 (–20.5, –102.1).
5. Right lateral view, a, HF; b, LF. F22387/6 (–41.3, –103.1).
6. Ventral view, LF. F22387/6 (–41.7, –103.1).

7–9 *Batiacasphaera ovata* Backhouse.

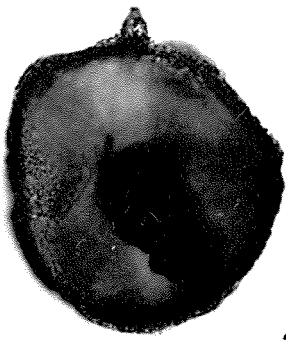
7. Dorsal view, a, HF; b, LF. F14876/2 (–28.5, –98.2).
8. Ventral view, MF. F14876/1 (–39.7, –112.0).
9. ?Right lateral view, HF. F14876/3 (–29.5, –111.4).



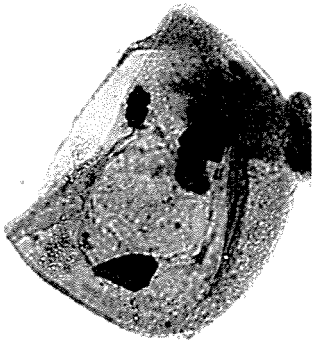
1a



1b



2



3



4a



4b



5a



5b



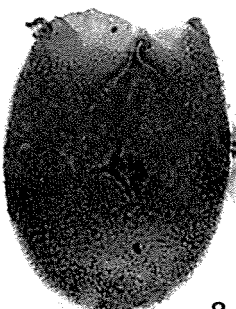
6



7a



7b



8



9

GSWA 22267

PLATE 19

All figures x600 unless otherwise indicated.
HF, high focus; MF, mid focus; LF, low focus.

Figure

1, 2 *Areosphaeridium?* sp. A.

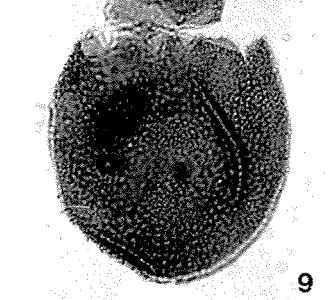
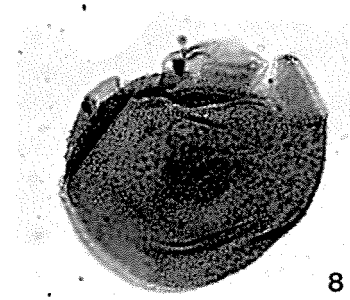
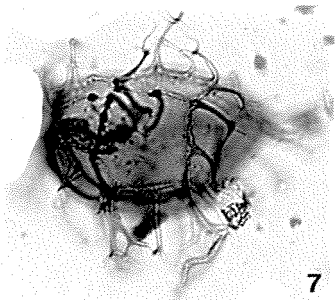
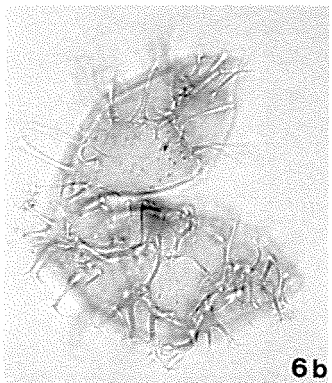
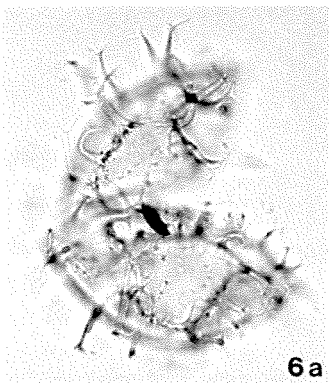
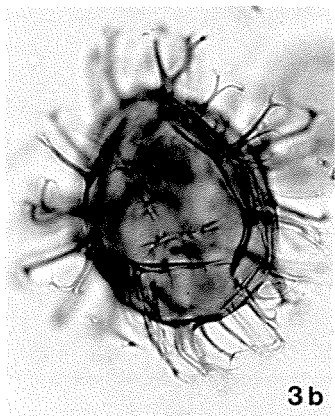
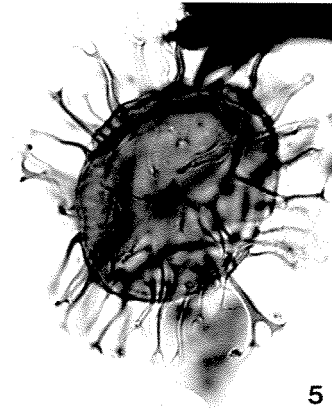
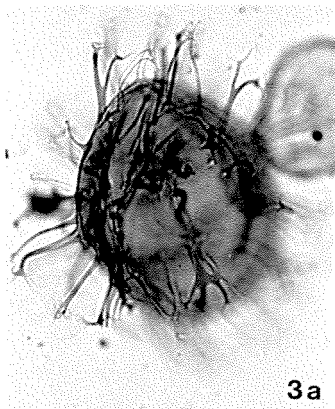
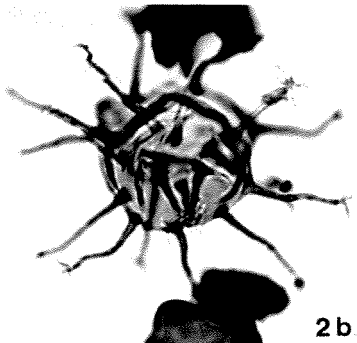
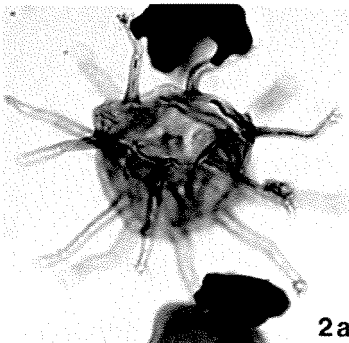
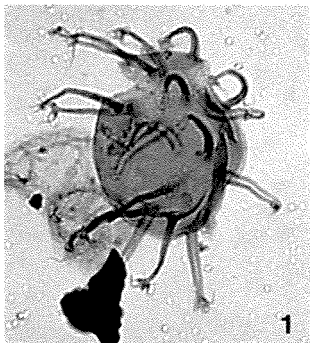
1. Ventral view, x800, HF. F11367/3 (–63.7, 112.1).
2. Dorsal view, x800, a, HF; b, LF. F22400/6 (–35.1, –96.1).

3–7 *Avellodinium lepidum* sp. nov.

3. ?Apical view, a, HF; b, LF. F8357/7 (–47.0, –102.8).
4. Lateral view, MF. F8353/3 (–29.8, –99.5).
5. ?Ventral view, MF. F8357/8 (–45.6, –104.2).
6. Holotype, lateral view, a, HF; b, LF. F8357/16 (–36.4, –103.6).
7. Dorsal view of separate hypocyst, HF. F8357/7 (–34.2, –103.4).

8, 9 *Batiacasphaera asperata* Backhouse.

8. ?View, MF. F8356/2 (–36.6, –96.6).
9. ?Left lateral view, HF. F8356/2 (–29.9, –103.6).



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PLATE 20

All figures x600 unless otherwise indicated.
HF, high focus; MF, mid focus; LF low focus.

Figure

1–4 *Batiacasphaera* sp. A.

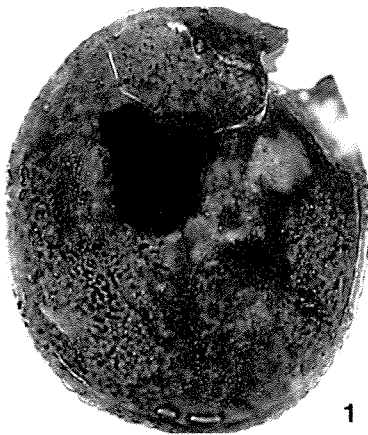
1. Dorsal view, MF. F10198/2 (–56.7, –105.3).
2. Ventral view, a, HF; b, LF. F11527/1 (–50.2, –112.0).
3. Dorsal view, HF. F33871/4 (–56.7, –105.3).
4. Apical view, HF. F33871/5 (–44.5, –98.3).

5–7 *Cassiculosphaeridia magna* Davey.

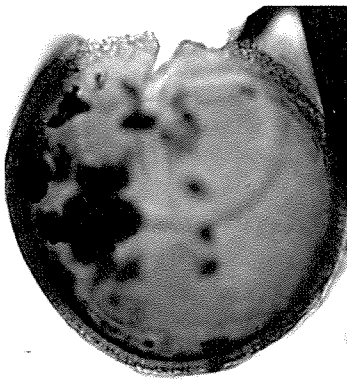
5. Detached operculum. F8551/2 (–55.1, –106.3).
6. Dorsal view, LF. F8357/6 (–40.9, –96.3).
7. Left lateral view, HF. F46265/1 (–51.4, –112.1).

8–11 *Cassiculosphaeridia pygmaea* Stevens.

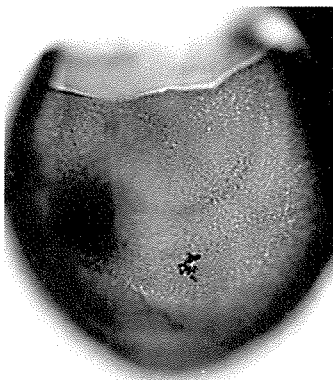
8. Ventral view, a, HF; b, LF. F10196/2 (–42.3, –103.6).
9. Dorsal view, a, HF; b, LF. F33871/5 (–26.0, –93.7).
10. Right lateral view, HF. F10198/3 (–26.0, –93.7).
11. Lateral view, HF. F10199/2 (–54.2, –107.3).



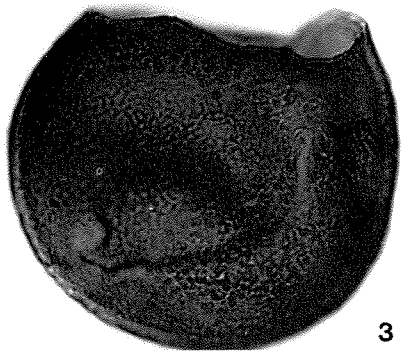
1



2 a



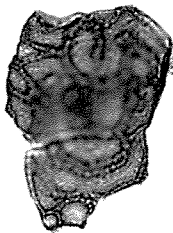
2 b



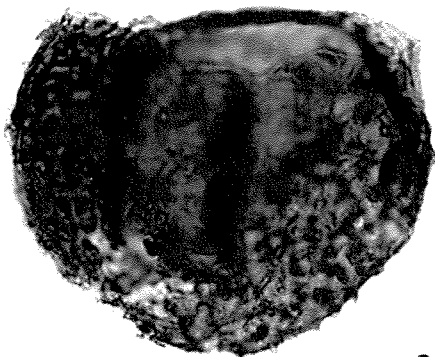
3



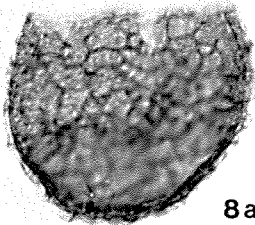
4



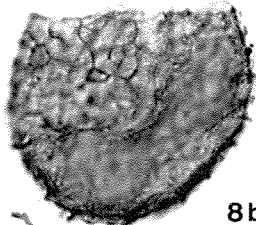
5



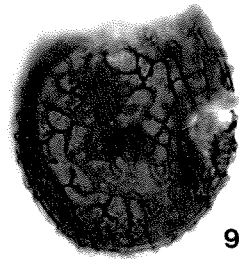
6



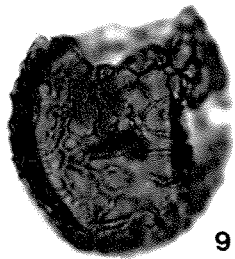
8 a



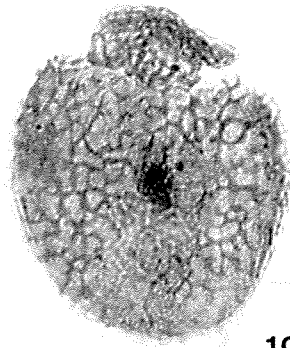
8 b



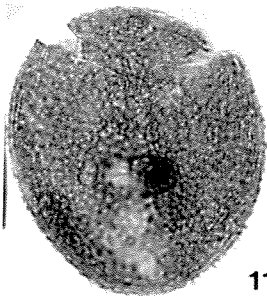
9 a



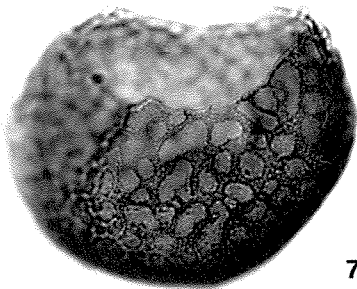
9 b



10



11



7

PLATE 21

All figures x600.

HF, high focus; MF, mid focus; LF, low focus.

Figure

1–3 *Batioladinium jaegeri* (Alberti).

1. Detached operculum, MF. F33850/5 (–45.6, –104.3).
2. Lateral view, MF. F10199/1 (–53.3, –101.5).
3. Left lateral view, MF. F10199/2 (–52.1, –109.7).

4–6 *Batioladinium micropodum* (Eisenack and Cookson).

4. Ventral view, MF. F8356/2 (–26.8, –94.1).
5. Ventro-lateral view, LF. F10324/1 (–35.0, –106.6).
6. Ventro-lateral view, MF. F9702/1 (–44.7, –100.5).

7 *Batioladinium longicornutum* (Alberti).

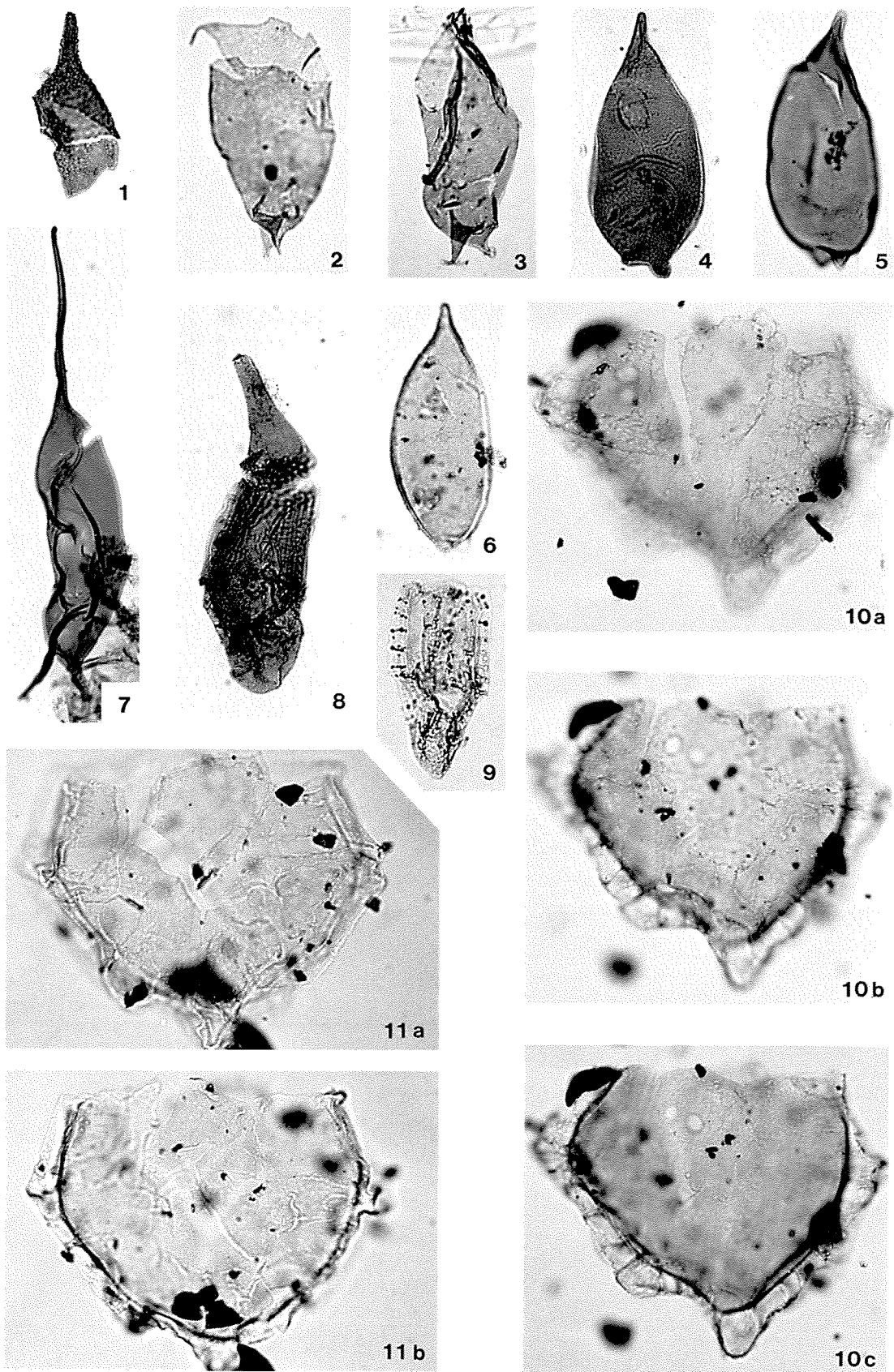
Left lateral view, MF. F33854/5 (–29.8, –99.2).

8, 9 *Belodinium* sp. A.

8. Ventral view, HF. F33865/4 (–32.7, –102.9).
9. ?Dorsal view, MF. F10198/2 (–54.4, –107.6).

10, 11 *Canningia transitoria* Stover and Helby.

10. Ventral view, a, HF; b, MF; c, LF. F10324/1 (–22.5, –100.8).
11. Ventral view, a, HF; b, LF. F8342/1 (–43.6, –103.0).



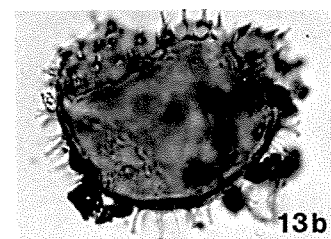
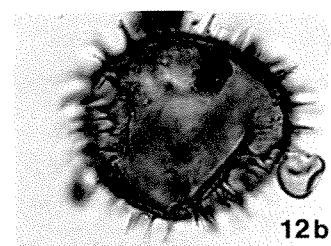
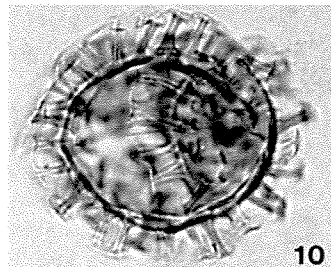
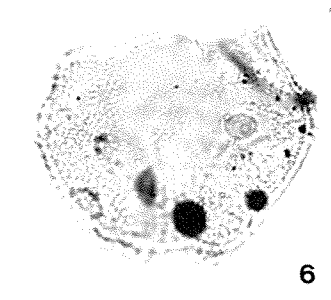
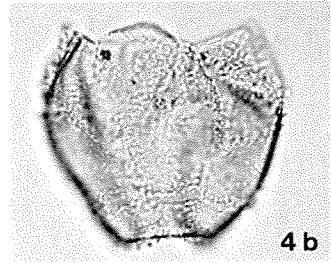
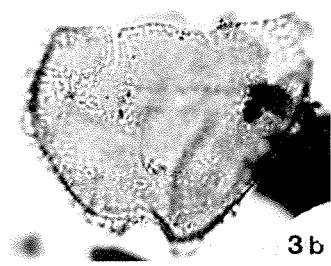
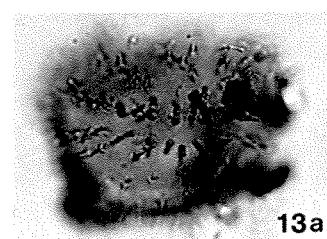
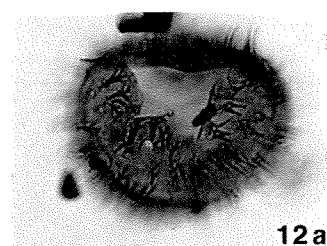
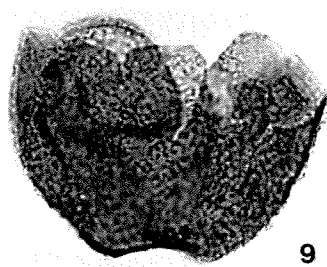
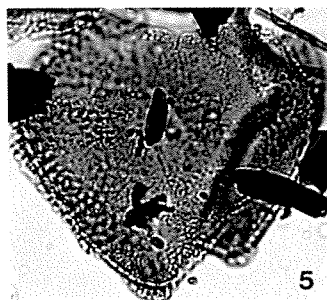
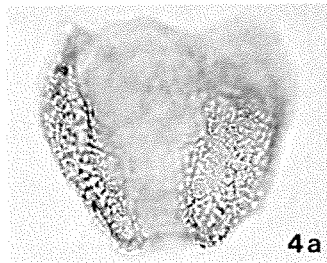
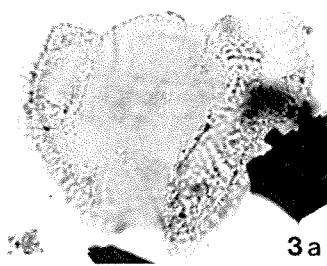
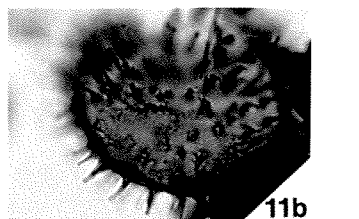
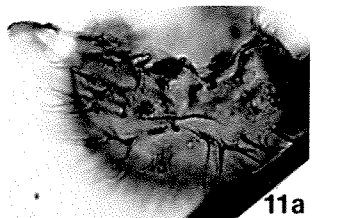
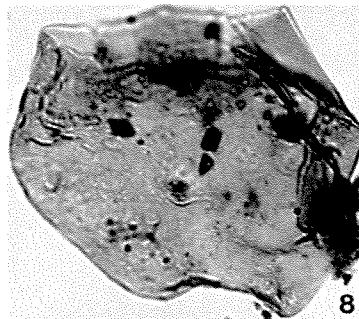
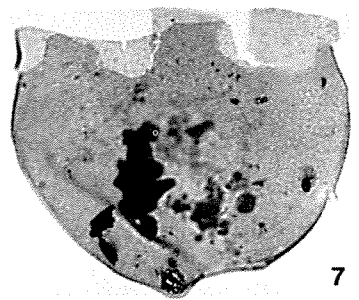
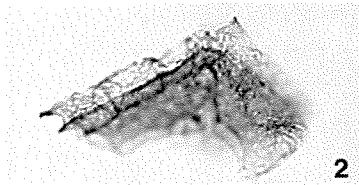
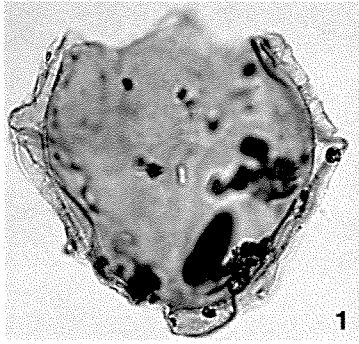
GSWA 22270

PLATE 22

All figures x600 unless otherwise indicated
HF, high focus; MF, median focus; LF, low focus.

Figure

- 1, 2** *Canningia transitoria* Stover and Helby.
1. Ventral view, MF. F10319/1 (–32.3, –109.3).
2. Detached operculum. F8546/3 (–43.5, –108.1).
- 3–6** *Canningia reticulata* Cookson and Eisenack.
3. Ventral view, a, HF; b, LF. F8357/2 (–38.6, –98.0).
4. Ventral view, a, HF; b, LF. F8357/17 (–42.2, –99.4).
5. Dorsal view, HF. F8357/8 (–41.8, –101.2).
6. Ventral view, HF. F8357/1 (–44.3, –108.9).
- 7–9** *Canninginopsis colliveri* (Cookson and Eisenack).
7. Dorsal view, MF. F12421/1 (–28.5, –107.6).
8. Ventral view, HF. F10197/1 (–36.0, –110.6).
9. Ventral view, x700, MF. F7926/10 (–37.2, –100.4).
- 10** *Cleistosphaeridium ancoriferum* (Cookson and Eisenack).
?View, x800, MF. F10198/2 (–30.1, –103.3).
- 11–13** *Cleistosphaeridium* sp. A.
11. Lateral view, a, HF; b, LF. F8357/5 (–34.7, –106.7).
12. Apical view, a, HF; b, LF. F8357/6 (–42.5, –99.4).
13. Left lateral view, a, HF; b, LF. F8357/5 (–36.4, –94.0).



GSWA 22271

PLATE 23

HF, high focus; MF, median focus; LF, low focus.

Figure

1–4 *Cribroperidinium delicatum* sp. nov.

1. Right lateral view, x500, a, HF; b, MF; c, LF. F9049/2 (–50.7, –93.8).
2. Dorso-left lateral view, x500, MF. F9843/9 (–43.5, –107.7).
3. Dorsal view, x500, a, HF; b, LF. F9843/9 (–57.5, –107.8).
4. Holotype, left lateral view, x500, a, HF; b, LF. F11493/1 (–54.2, –95.6).

5 *Cleistosphaeridium* sp. A.

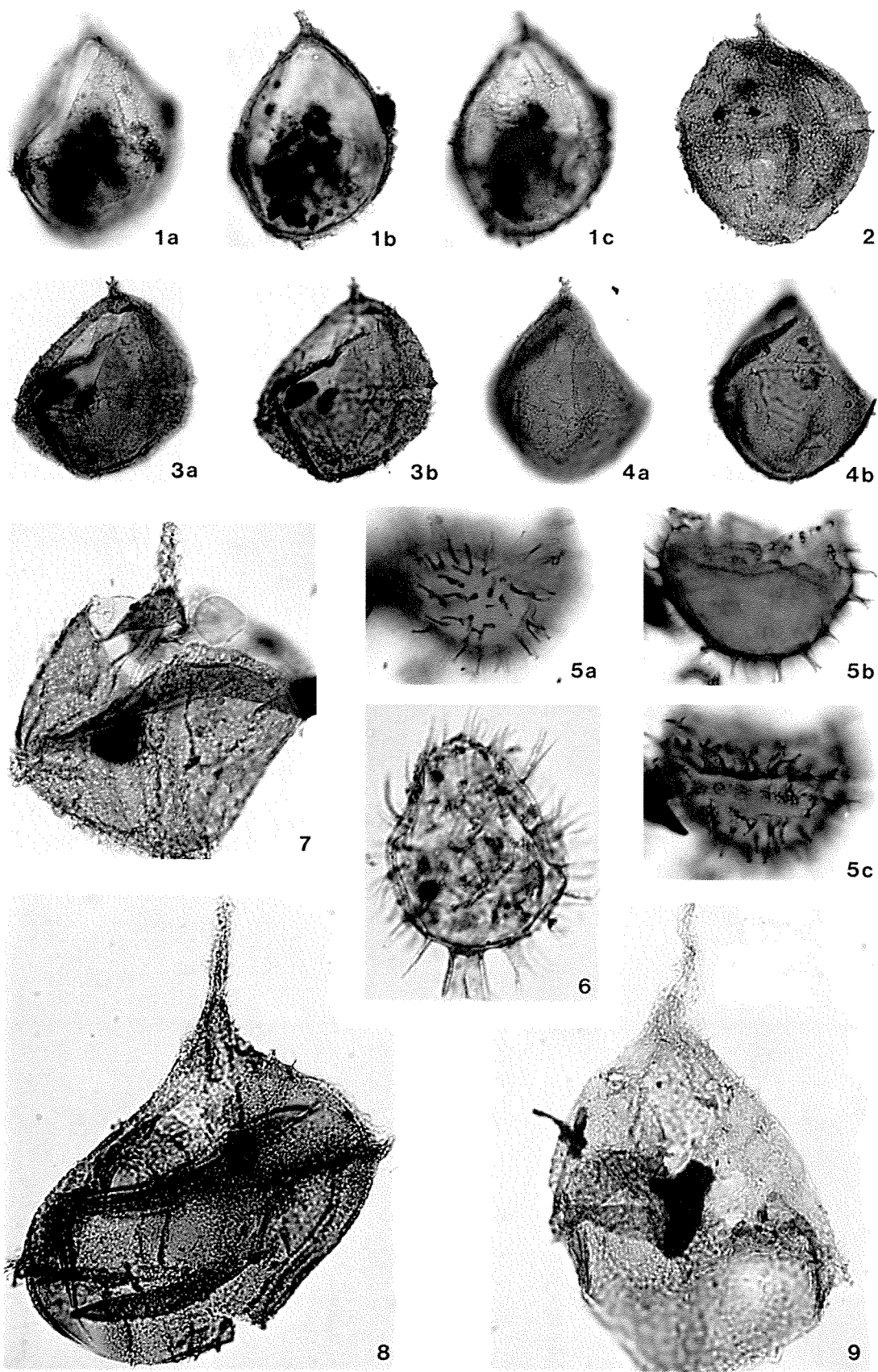
Ventral view, x600, a, HF; b, MF; c, LF. F8357/7 (–40.8, –94.7).

6 *Coronifera oceanica* Cookson and Eisenack.

?View, x800, MF. F10196/2 (–55.3, –99.7).

7–9 *Cribroperidinium leedervillense* sp. nov.

7. Ventral view, x500, HF. F8347/2 (–37.2, –97.7).
8. Holotype, ventral view, x500, MF. F8356/9 (–36.5, –103.7).
9. ?Ventral view, x500, MF. F8347/1 (–46.1, –96.7).



GSWA 22272

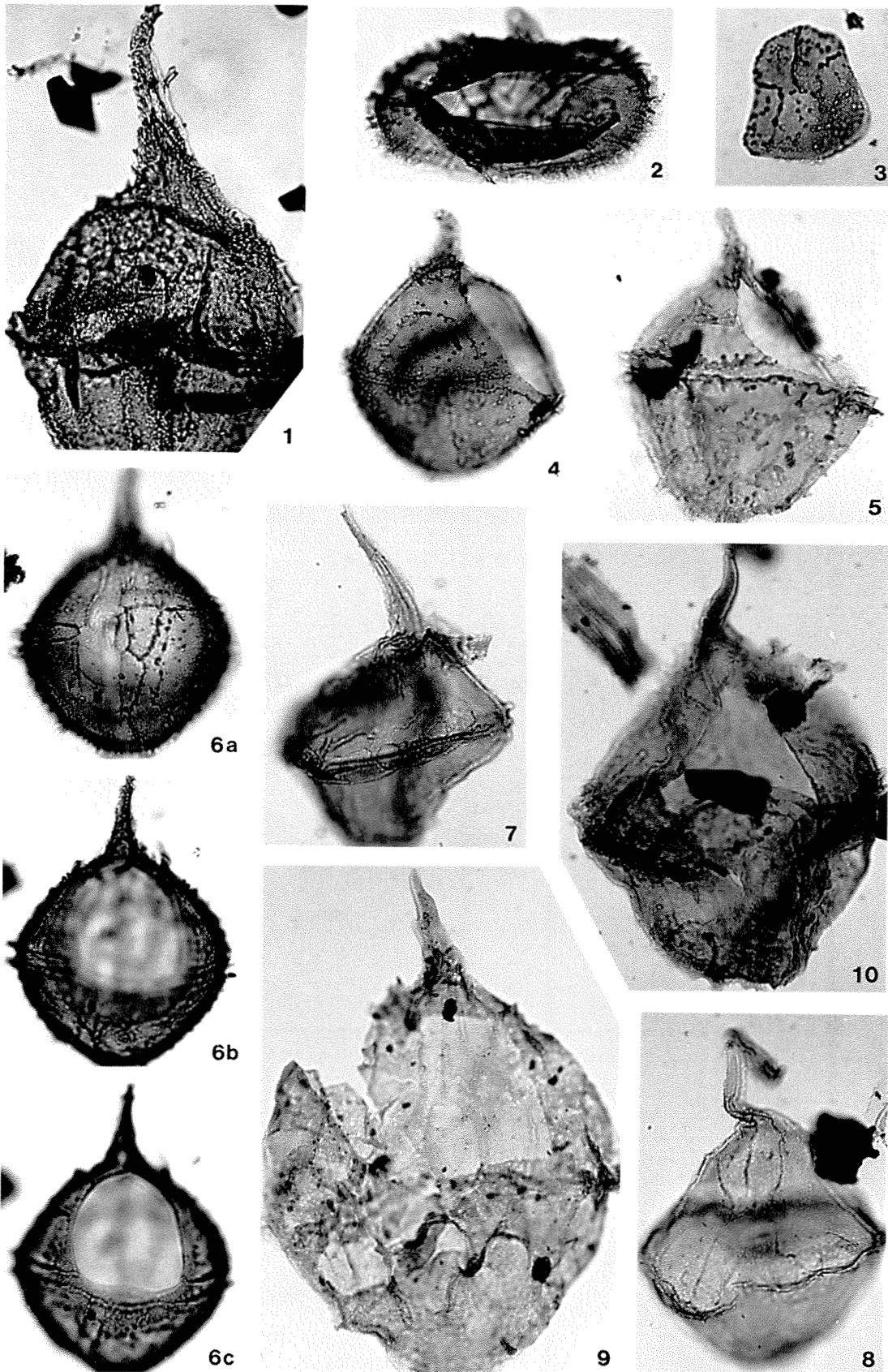
PLATE 24

All figures x500

HF, high focus; MF, median focus; LF, low focus.

Figure

- 1** *Cribroperidinium leedervillense* sp. nov.
Dorsal view, MF. F8347/1 (–32.1, –102.1).
- 2–6** *Cribroperidinium muderongense* (Cookson and Eisenack).
 2. Antapical view, MF. F10199/1 (–39.5, –92.6).
 3. Detached operculum. F8551/2 (–38.2, –104.2).
 4. Left lateral view, HF. F46265/1 (–46.8, –92.3).
 5. Left lateral view, HF. F33873/5 (–35.0, –109.7).
 6. Ventral view, a, HF; b, MF; c, LF. F46265/1 (–54.3, –104.2).
- 7, 8** *Cribroperidinium* sp. A.
 7. ?Dorsal view, HF. F8350/3 (–31.5, –109.1).
 8. Ventral view, HF. F8351/4 (–41.1, –107.5).
- 9, 10** *Cribroperidinium* sp. B.
 9. Dorsal view, MF. F33877/5 (–22.3, –101.7).
 10. Dorsal view, HF. F33877/5 (–44.5, –103.9).



GSWA 22273

PLATE 25

All figures x600 unless otherwise indicated.
HF, high focus; MF, median focus; LF, low focus.

Figure

1, 2 *Cribroperidinium* sp. C.

1. Ventral view, x500, a, HF; b, LF. F10198/2 (–30.9, –106.6).
2. Left lateral view, x500, HF. F10198/2 (–41.2, –103.2).

3–6 *Cyclonephelium attadalicum* Cookson and Eisenack.

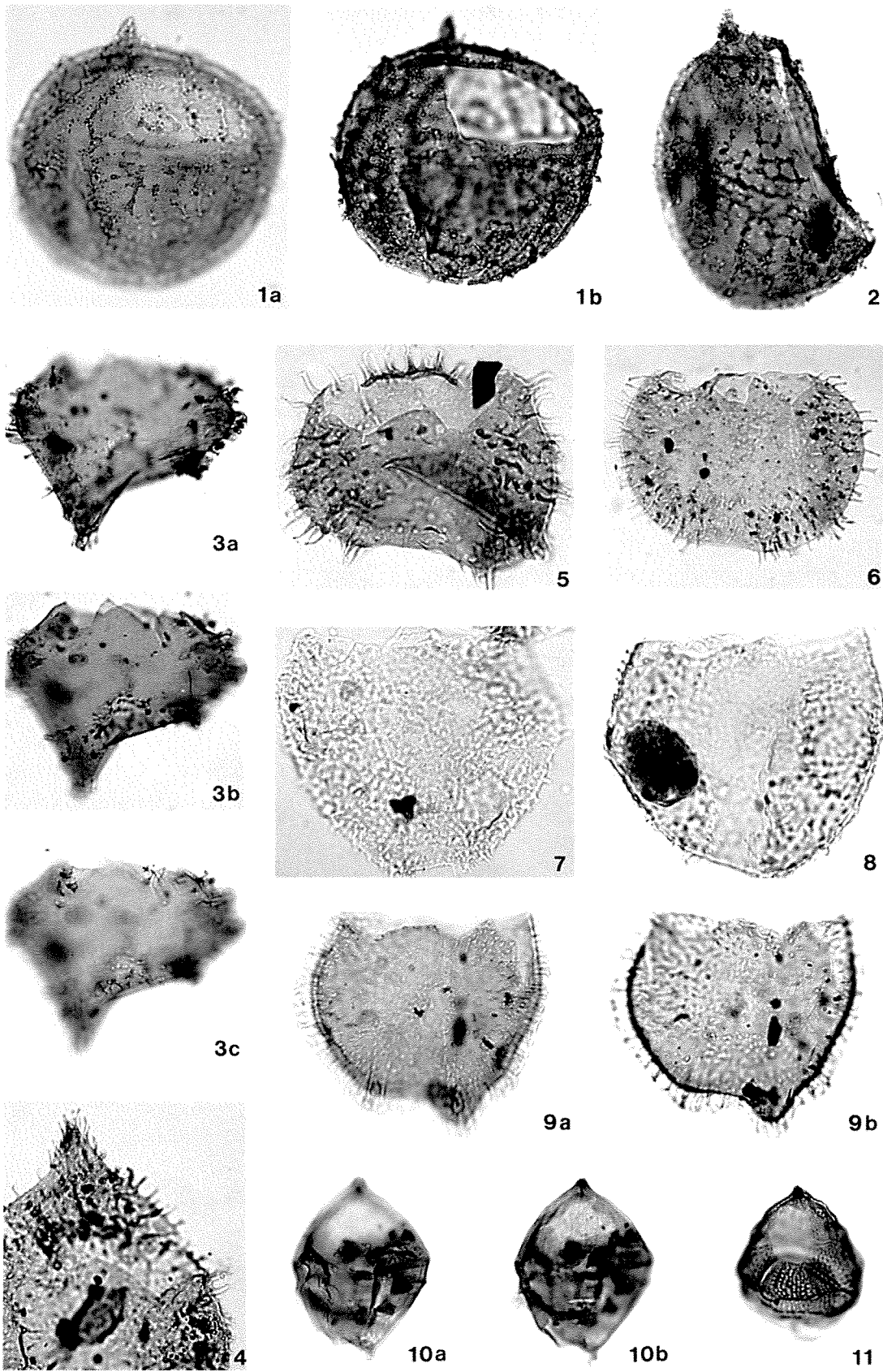
3. Dorsal view, a, LF; b, MF; c, HF. F8766/4 (–62.0, –105.2).
4. Epicyst with operculum attached, dorsal view, MF. F10311/1 (–43.5, –94.3).
5. Ventral view, MF. F8544/2 (–39.0, –108.7).
6. Ventral view, MF. 10199/2 (–47.6, –103.5).

7–9 *Cyclonephelium hystrix* (Eisenack).

7. Dorsal view, HF. F8353/4 (–20.0, –107.7).
8. Ventral view, HF. F8353/9 (–37.6, –104.5).
9. Ventral view, a, HF; b, LF. F46265/2 (–51.8, –96.0).

10, 11 *Diconodinium micropunctatum* sp. nov.

10. Ventral view, x800, a, HF; b, LF. F10197/2 (–36.8, –108.7).
11. Dorsal view, x800, HF. F33854/1 (–39.0, –102.0).



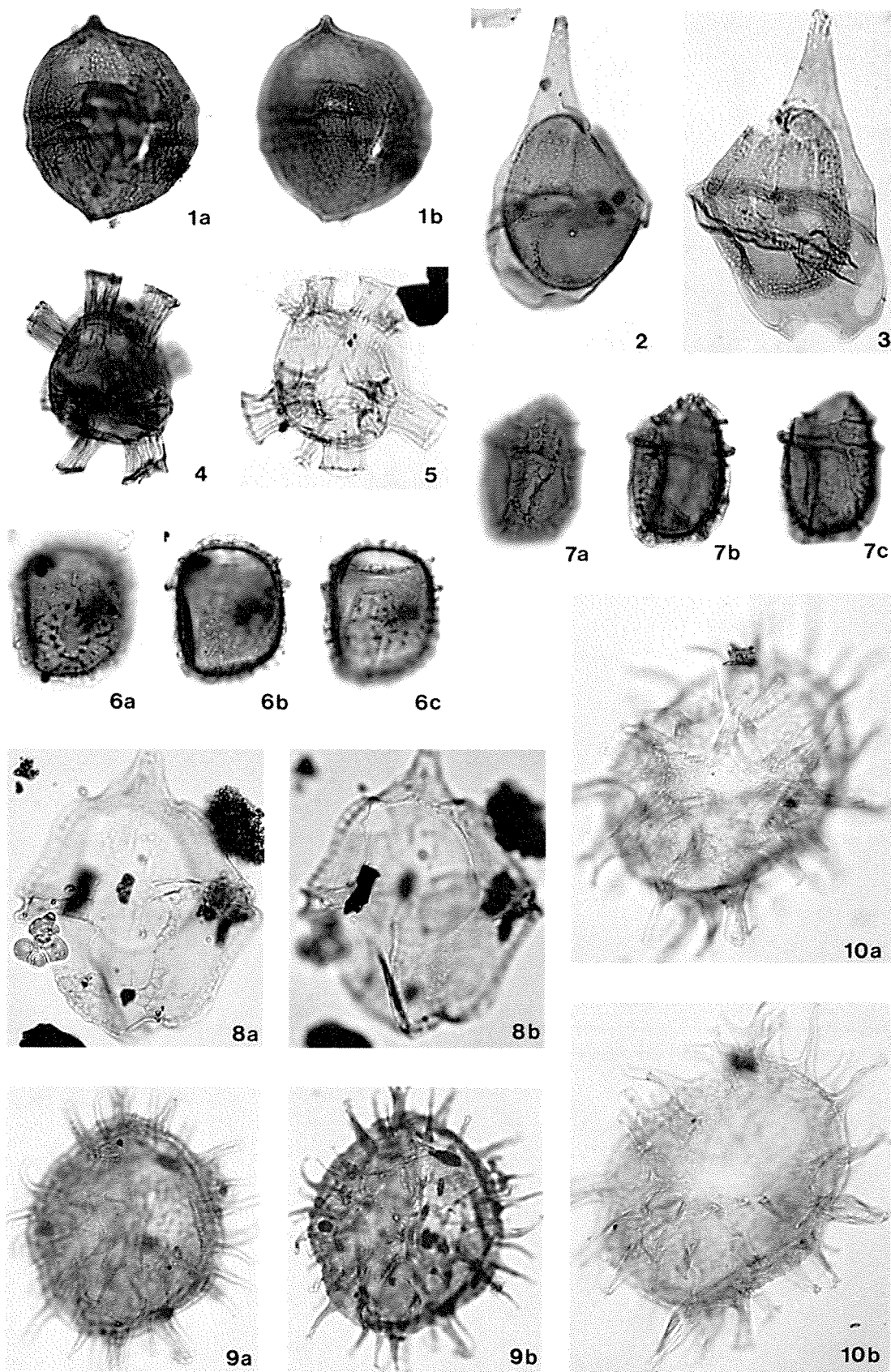
GSWA 22274

PLATE 26

All figures x600 unless otherwise indicated.
HF, high focus; MF, median focus; LF, low focus.

Figure

- 1 *Diconodinium micropunctatum* sp. nov.
Holotype, dorsal view, x800, a, LF; b, HF. F33850/4 (–36.7, –110.4).
- 2, 3 *Dingodinium cerviculum* Cookson and Eisenack.
 2. Left lateral view, LF. F12421/1 (–34.4, –93.8).
 3. Right lateral view, MF. F10198/3 (–42.3, –108.8).
- 4, 5 *Discorsia nanna* (Davey).
 4. ?View, x800, HF. F33850/5 (–26.9, –111.0).
 5. ?Dorsal view, x800, MF. F22394/6 (–23.1, –94.9).
- 6, 7 *Druggidium rhabdoreticulatum* Habib.
 6. Ventral view, x1000, a, HF; b, MF; c, LF. F10197/3 (–56.0, –99.5).
 7. Right lateral view, x1000, a, HF; b, MF; c, LF. F33850/5 (–60.1, –110.0).
- 8 *Endoscrinium campanulum* Gocht.
Ventral view, a, HF; b, LF. F11386/2 (–52.5, –105.2).
- 9, 10 *Exochosphaeridium robustum* sp. nov.
 9. Left lateral view of specimen transitional to *E. truncatum*, a, HF; b, MF. F33886/4 (–39.0, –111.0).
 10. Holotype, dorsal view, a, LF; b, HF.



GSWA 22275

PLATE 27

All figures x600 unless otherwise indicated.
HF, high focus; MF, median focus; LF, low focus.

Figure

1–10 *Gagiella mutabilis* sp. nov.

Specimens from sample at 1 700m in Gage Roads 1.

1. Holotype, right lateral view, x800, a, HF; b, LF. F22416/6 (–46.3, –103.4).
2. Right lateral view, MF. F22416/6 (–38.4, –102.7).
3. Ventral view, MF. F22416/6 (–26.6, –111.7).
4. Right lateral view, LF. F22416/6 (–54.0, –110.0).
5. Dorsal view, HF. F22416/6 (–24.0, –97.1).
6. Dorsal view, LF. F22416/5 (–47.3, –97.8).
7. Left lateral view, MF. F22416/5 (–35.6, –95.9).
8. Left lateral view, HF. F22416/6 (–29.9, –100.7).
9. Right lateral view, MF. F22416/6 (–27.0, –95.5).
10. Dorsal view, HF. F22416/6 (–20.0, –111.2).

11–15 *Gagiella mutabilis* sp. nov.

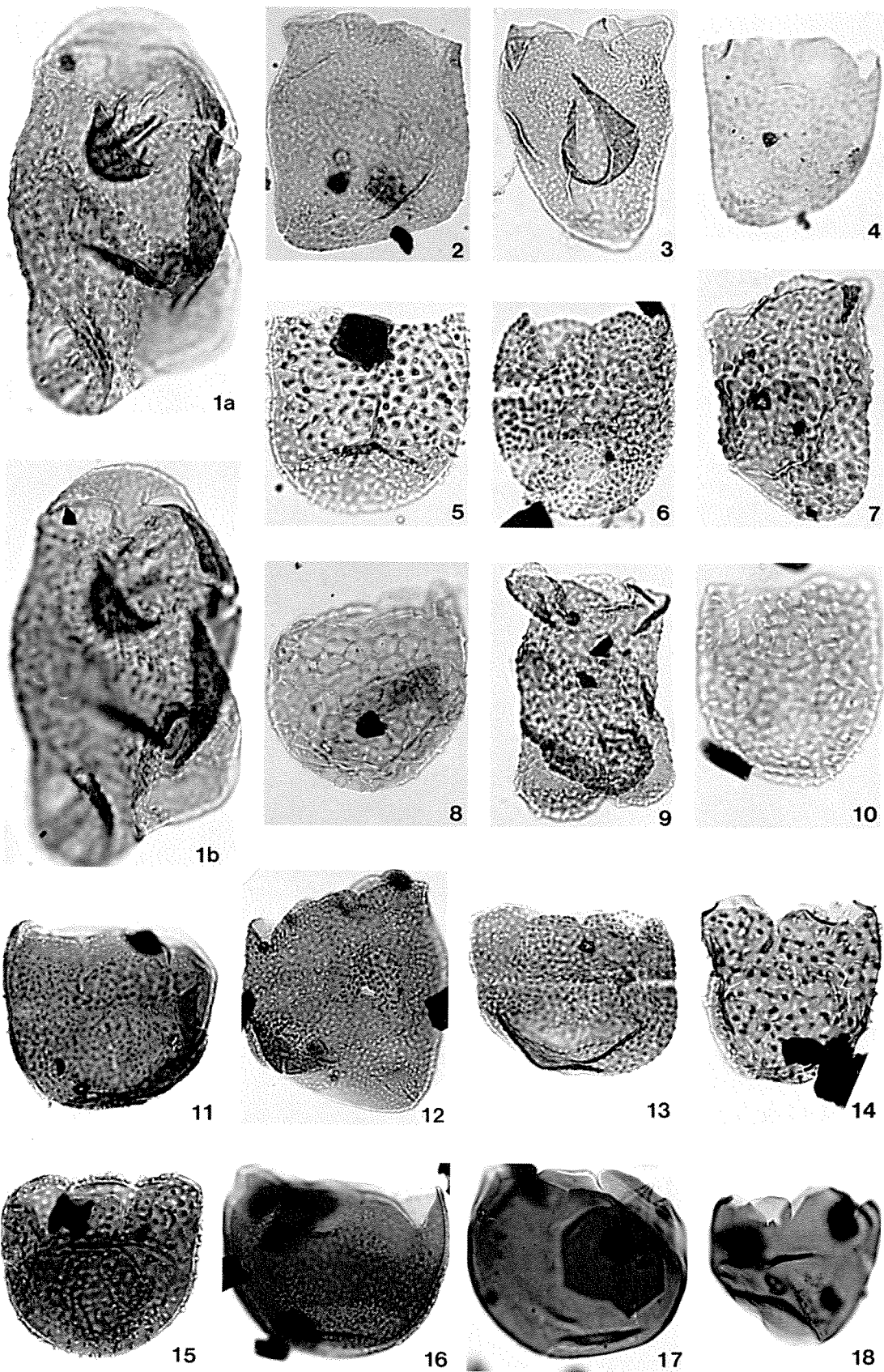
Specimens from sample at 1 690m in Gage Roads 1.

11. Right lateral view, HF. F22414/7 (–29.6, –111.5).
12. Left lateral view, MF. F22414/7 (–50.6, –105.1).
13. Right lateral view, MF. F22414/7 (–49.2, –92.8).
14. Dorsal view, HF. F22414/5 (–49.3, –106.8).
15. Left lateral view, MF. F22414/5 (–49.3, –106.8).

16–18 *Batiacasphaera* sp.

Specimens from sample at 1 690 m in Gage Roads 1.

16. Right lateral view, HF. F22414/7 (–22.1, –101.6).
17. Right lateral view, MF. F22414/5 (–35.5, –101.6).
18. Ventral view, HF. F22414/7 (–30.0, –108.8).



GSWA 22276

PLATE 28

All figures x600.

HF, high focus; MF, median focus; LF, low focus.

Figure

1–6 *Gagiella mutabilis* sp. nov.

1. Ventral view, HF. F22412/6 (–29.6, –111.4)
2. Ventral view, LF. F12788/6 (–43.0, –101.8)
3. Ventral view, HF. F12788/6 (–39.1, –100.0).
4. Detached operculum, internal view. F22416/5 (–34.0, –104.0).
5. Detached operculum, internal view. F12788/6 (–37.4, –109.1).
6. Detached operculum, ventral view, MF. F22416/6 (–19.0, –107.4).

7 *Exochosphaeridium robustum* sp. nov.

- ?Lateral view, MF. F8356/7 (–41.0, –104.3).

8, 9 *Exochosphaeridium truncatum* (Davey).

8. Apical view, HF. F10199/2 (–60.2, –103.1)
9. Ventral view, LF. F10199/1 (–49.6, –105.9)

10–12 *Gonyaulacysta* sp. cf. *G. exsanguia* Duxbury.

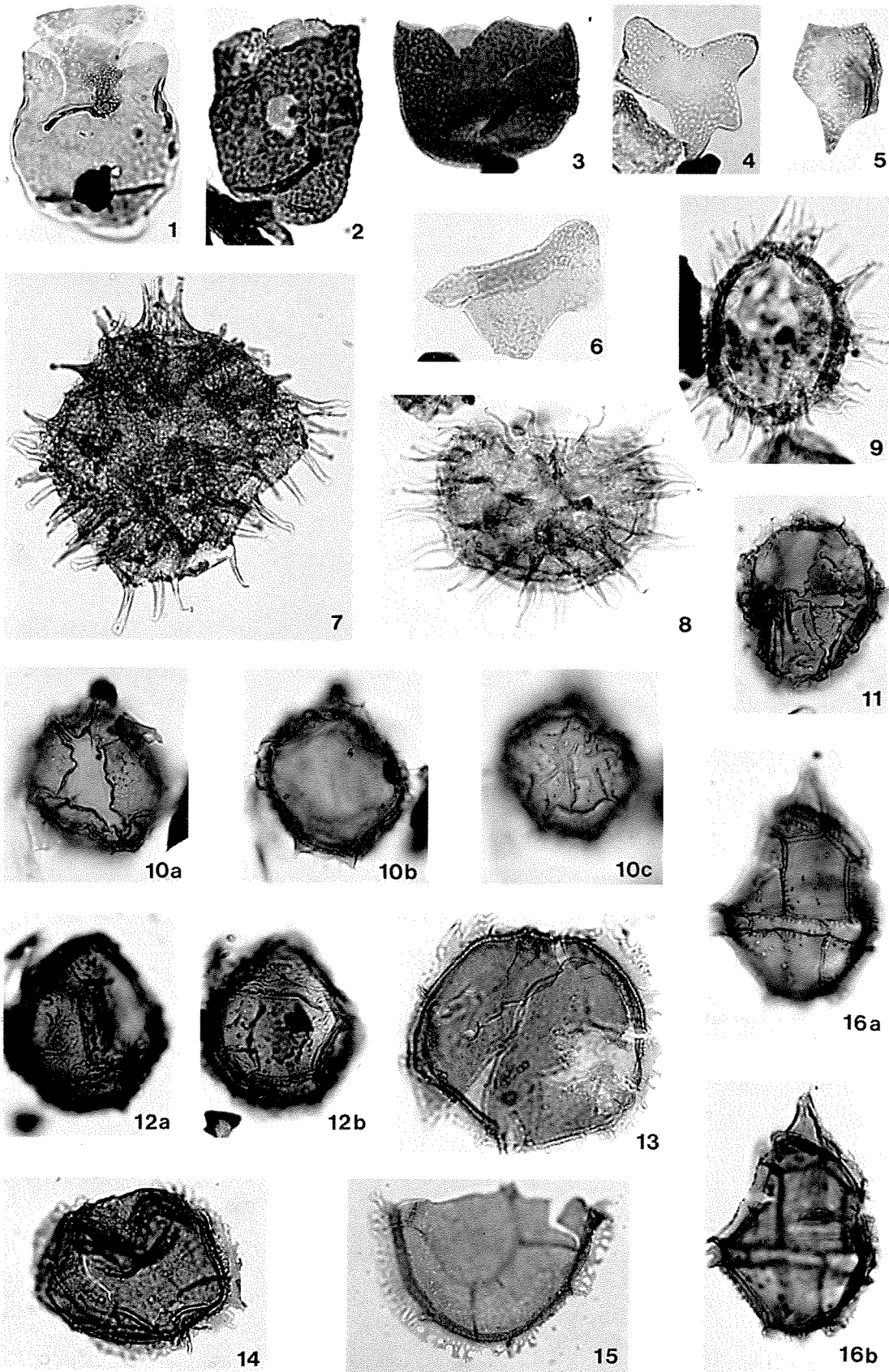
10. Dorsal view, a, HF; b, MF; c, LF. F8357/7 (–37.0, –103.2).
11. Dorsal view, HF. F8357/7 (–31.7, –101.3).
12. Left lateral view, a, HF; b, LF. F8357/7 (–32.7, –94.0).

13–15 *Epitricysta vinckensis* Stover and Helby.

13. Apical view, HF. F33871/5 (–37.1, –103.0).
14. ?Antapical view, HF. F33871/5 (–51.5, –95.0).
15. Antapical view, MF. F33871/4 (–29.0, –104.3)

16 *Gonyaulacysta helicoidea* (Eisenack and Cookson).

- Right lateral view, a, HF; b, LF. F33871/5 (–45.3, –109.8)



GSWA 22277

PLATE 29

All figures x600 unless otherwise indicated.
HF, high focus; MF, median focus; LF, low focus.

Figure

1–6 *Fusiformacysta tumida* sp. nov.

1. ?View, LF. F8534/5 (–37.1, –105.8).
2. ?Dorsal view, MF. F8534/3 (–47.2, –95.6).
3. Right lateral view, MF. F22505/2 (–22.8, –92.4).
4. ?Left lateral view, MF. F12793/2 (–34.3, –93.8)
5. Holotype, left lateral view, HF. F8534/2 (–35.8, –96.0).
6. Right lateral view, MF. F12793/2 (–42.5, –101.9)

7, 8 *Fusiformacysta* sp. A

7. ?Right lateral view, MF. F6086/3 (–54.4, –95.0).
8. Left lateral view, MF. F6086/3 (–42.5, –103.0).

9–12. *Gardodinium lowii* Backhouse.

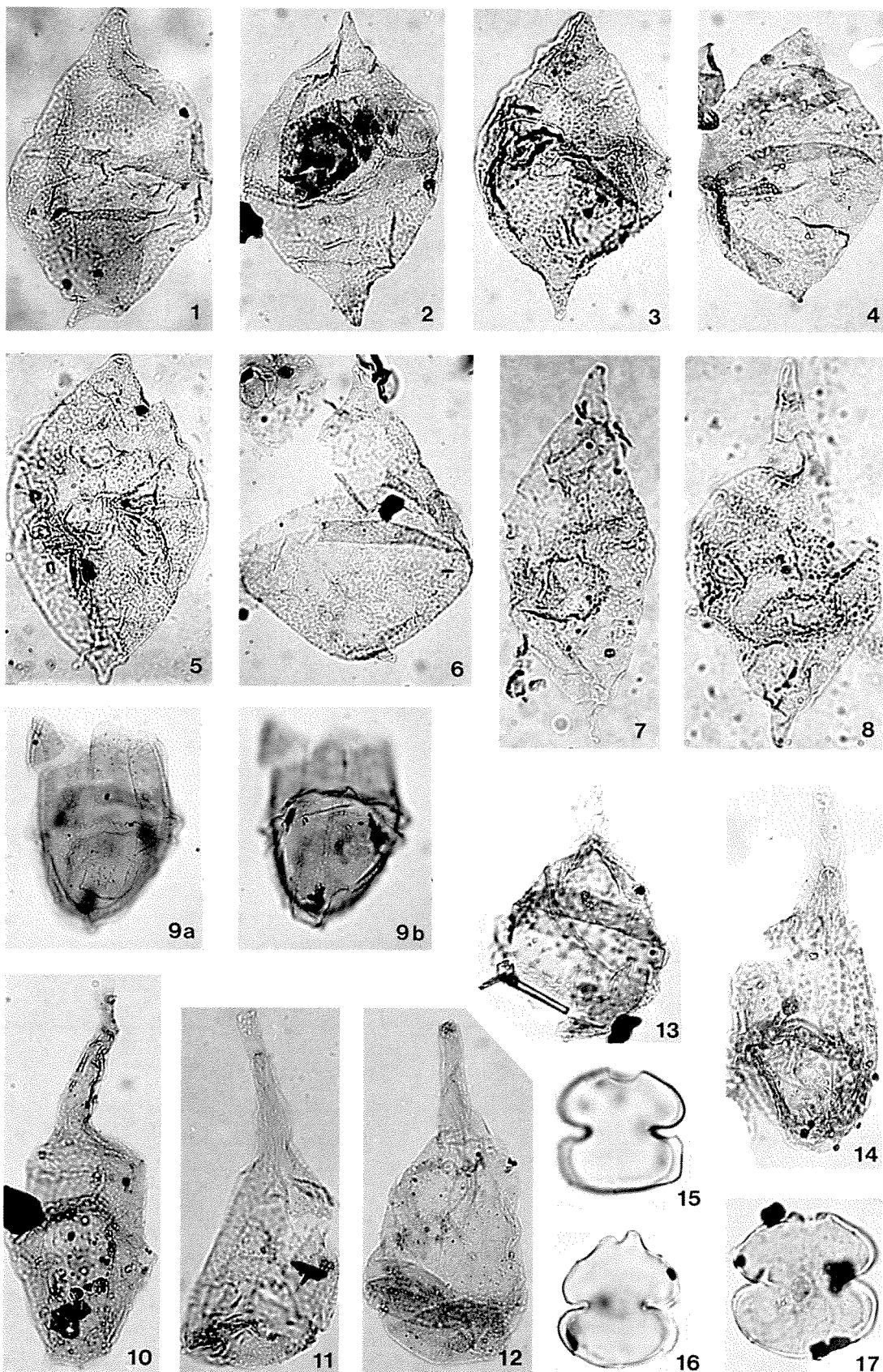
9. Left lateral view, a, HF; b, LF. F46265/1 (–36.3, –92.0).
10. ?View, MF. F46228/1 (–28.6, –94.7).
11. ?Left lateral view, MF. F8351/3 (–40.6, –111.5).
12. ?View, MF. F11533/4 (–24.7, –95.8).

13, 14 *Gardodinium attenuatum* Stover and Helby.

13. View, MF. F22394/5 (–21.0, –108.0).
14. Right lateral view, MF. F22406/6 (–15.4, –101.7).

15–17 *Horologinella lineata* Cookson and Eisenack.

15. Ventral view, x1000, MF. F9327/1 (–47.1, –92.4).
16. Ventral view, x1000, LF. F9327/1 (–37.6, –107.6).
17. Ventral view, x1000, HF. F9327/1 (–36.4, –101.5).



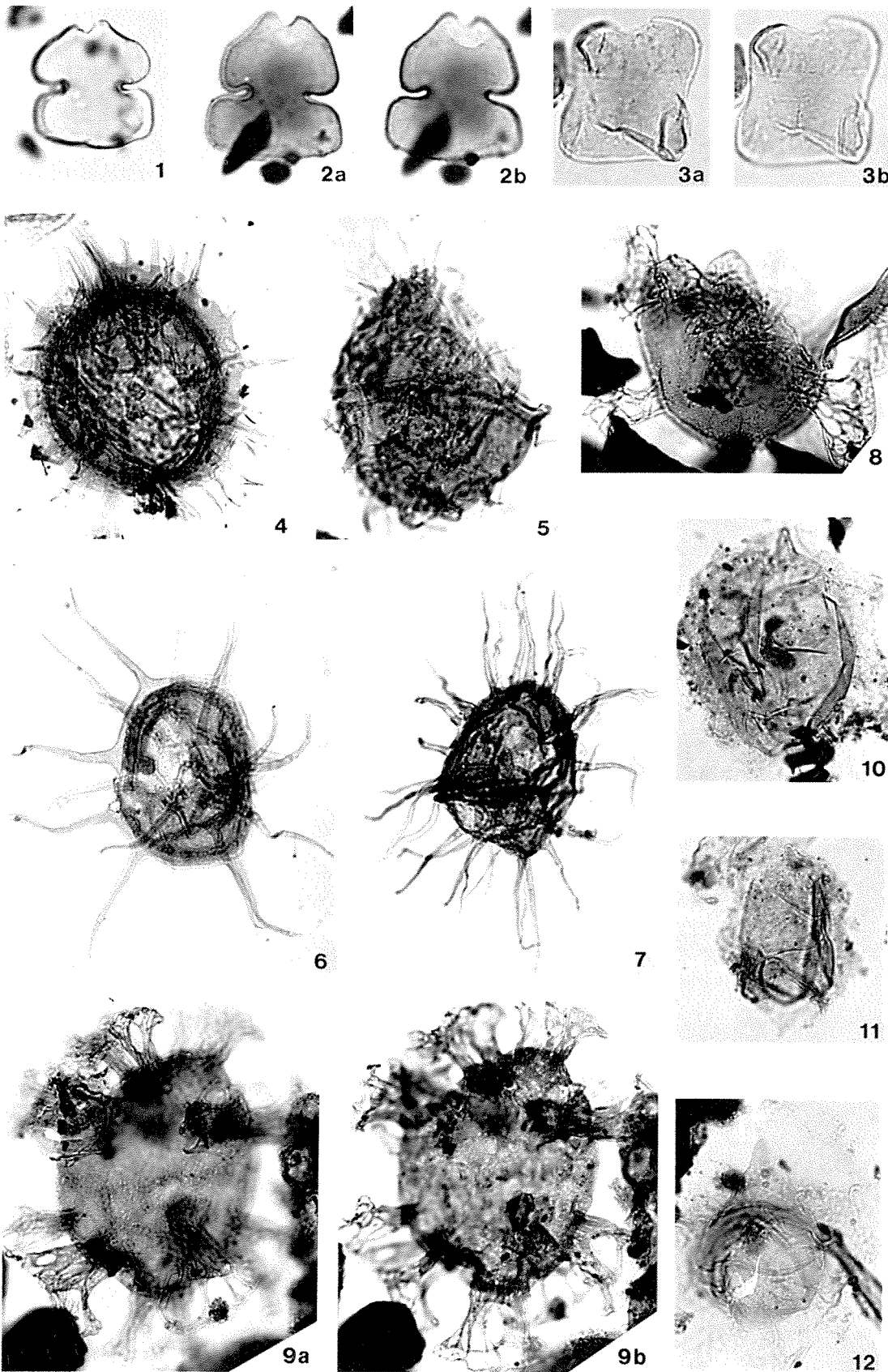
GSWA 22278

PLATE 30

All figures x600 unless otherwise indicated.
HF, high focus; MF, median focus; LF, low focus.

Figure

- 1, 2** *Horologinella lineata* Cookson and Eisenack.
1. Dorsal view, x1000, LF. F9327/2 (–45.4, –102.8).
2. Ventral view, x1000, a, HF; b, LF. F11815/2 (–31.8, –111.8).
- 3** *Horologinella* sp. A.
?Dorsal view, x1000, a, LF; b, HF. F7928/1 (–44.2, –95.8)
- 4, 5** *Hystrichodinium compactum* Alberti.
4. Antapical view, MF. F8356/1 (–26.4, –111.0).
5. Left lateral view, HF. F8356/4 (–27.0, –110.4).
- 6, 7** *Hystrichodinium oligacanthum* Deflandre and Cookson.
6. Apical view, HF. F10198/2 (–55.6, –100.0).
7. Left lateral view, MF. F10198/2 (–53.0, –94.7).
- 8, 9** *Hystrichosphaerina schindewolfii* Alberti.
8. Dorsal view, MF. F8551/1 (–43.5, –107.0).
9. Ventral view, a, HF; b, LF. F10226/2 (–21.3, –105.0)
- 10–12** *Kalypteia monoceras* Cookson and Eisenack.
10. ?View, MF. F8344/1 (–56.1, –110.7).
11. ?View, MF. F8344/1 (–41.0, –108.7).
12. ?View, MF. F8344/1 (–45.2, –109.0).



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PLATE 31

All figures x600.

HF, high focus; MF, median focus; LF, low focus.

Figure

1–3 *Kaiwaradinium scrutillinum* Backhouse.

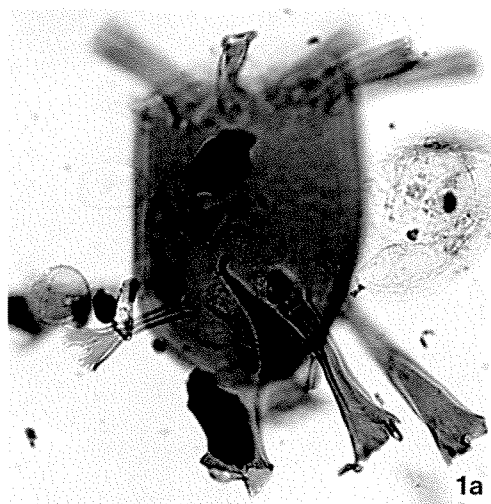
1. Ventral view, a, HF; b, LF. F8357/7 (–33.8, –101.1).
2. Ventral view, HF. F8357/6 (–22.9, –100.2).
3. Right lateral view, HF. F8357/17 (–46.7, –102.1).

4–6 *Kleithriasphaeridium fasciatum* (Davey and Williams).

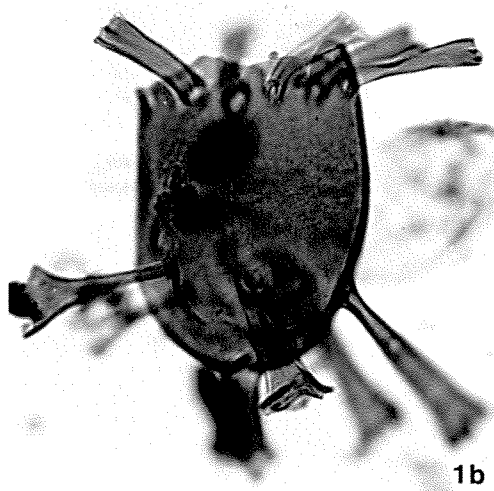
4. Ventral view, a, HF; b, LF. F8356/2 (–40.1, –95.5).
5. Dorsal view, HF. F8356/2 (–40.0, –93.2).
6. Right lateral view, MF. F8356/3 (–30.6, –104.6).

7, 8 *Kleithriasphaeridium coinodes* (Eisenack).

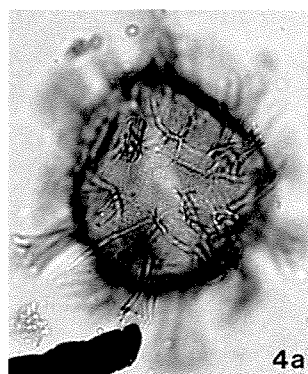
7. Antapical view, a, MF; b, HF. F10198/3 (–33.8, –104.5).
8. ?Apical view, MF. F10198/2 (–42.4, –106.7).



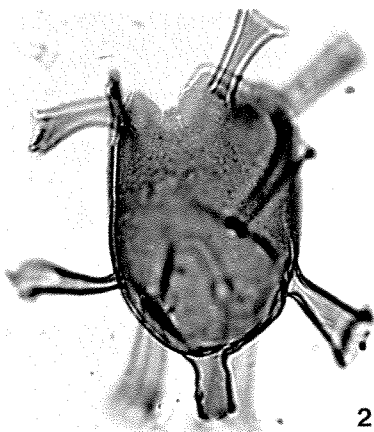
1a



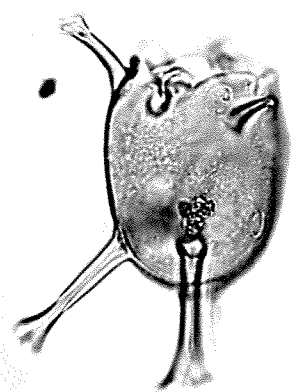
1b



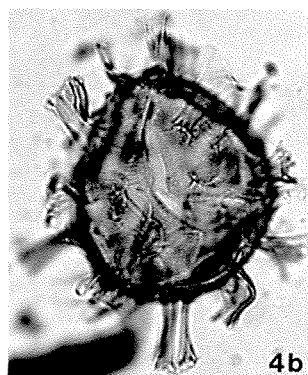
4a



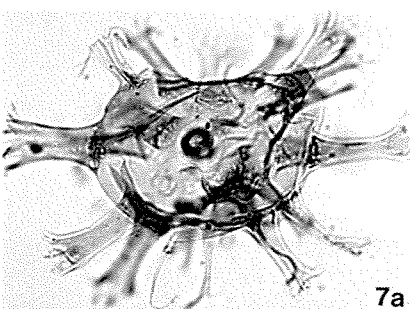
2



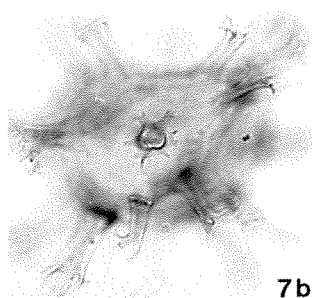
3



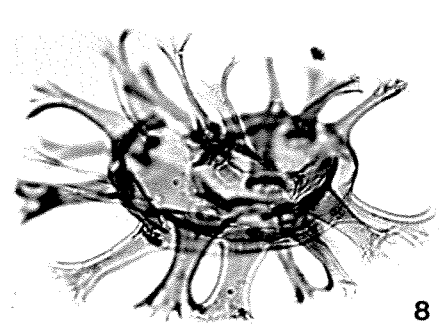
4b



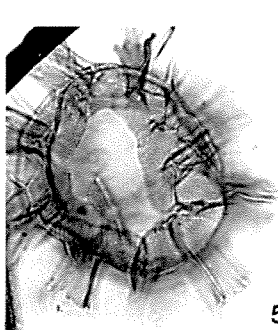
7a



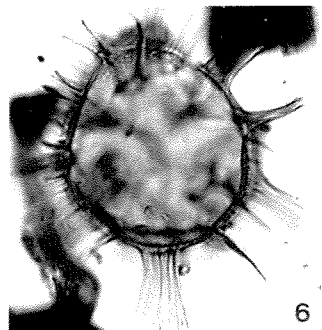
7b



8



5



6

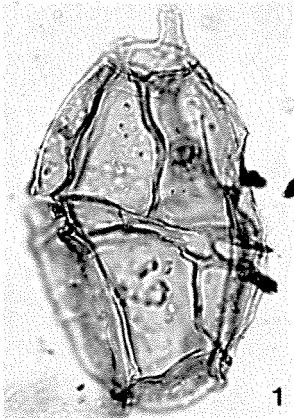
GSWA 22280

PLATE 32

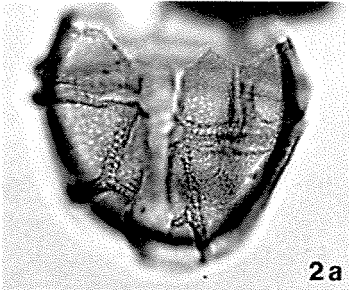
All figures x600 unless otherwise indicated.
HF, high focus; MF, median focus; LF, low focus.

Figure

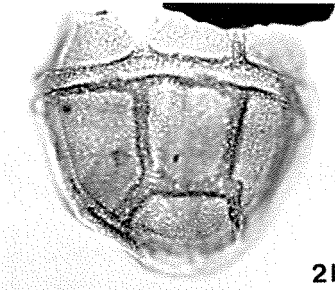
- 1** *Leptodinium hyalodermopsis* (Cookson and Eisenack).
Left lateral view, x800, LF. F8356/2 (–39.7, –106.0).
- 2** *Meiourogonyaulax bulloidea* (Cookson and Eisenack).
Dorsal view, a, LF; b, HF. F8357/2 (–42.0, –108.1).
- 3–5** *Meiourogonyaulax* sp. cf. *M. bulloidea* (Cookson and Eisenack).
 3. Ventral view, HF. F9197/1 (–33.4, –108.4).
 4. Dorsal view, HF. F9199/1 (–25.6, –107.3).
 5. Dorsal view, HF. F46265/1 (–39.0, –103.8).
- 6, 7** *Cernocysta helbyi* (Morgan).
 6. Ventral view, x800, a, HF; b, LF. F9199/2 (–27.1, –96.6).
 7. Right lateral view, x800, HF. F9199/1 (–31.4, –98.7).
- 8–11** *Meiourogonyaulax maculata* sp. nov.
 8. Right lateral view, x800, MF. F10012/1 (–58.3, –102.0).
 9. Holotype, right lateral view, x800, a, HF; b, LF. F9081/5 (–50.9, –95.7).
 10. Right lateral view, x800, LF. F6063/1 (–55.1, –96.7).
 11. Left lateral view, x800, MF. F8543/3 (–31.5, –108.8).
- 12–15** *Meiourogonyaulax* sp. B.
 12. Dorsal view, x800, a, LF; b, HF. F33850/5 (–42.5, –110.3).
 13. Dorsal view, x800, HF. F10196/2 (–31.4, –105.1).
 14. Dorsal view, x800, a, LF; b, HF. F10196/2 (–49.8, –105.2).
 15. Dorsal view, x800, HF. F10197/1 (–24.6, –96.6).



1



2a



2b



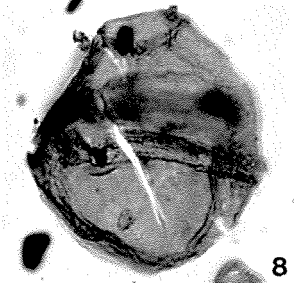
3



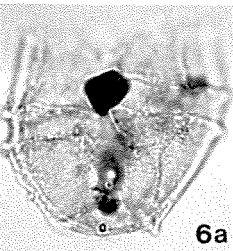
4



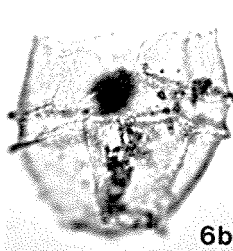
5



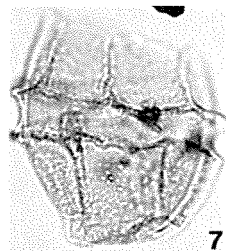
8



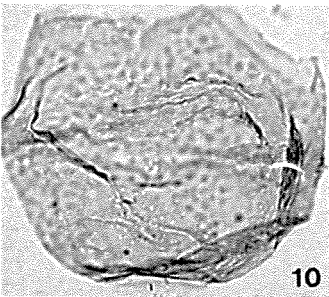
6a



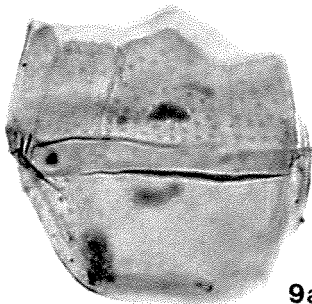
6b



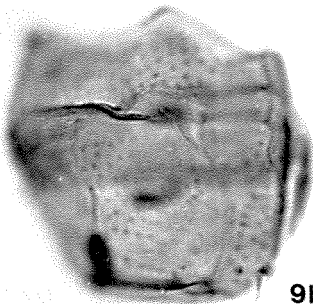
7



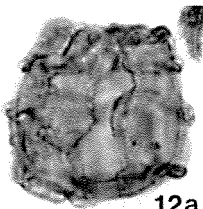
10



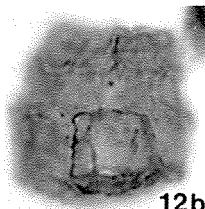
9a



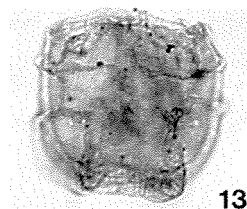
9b



12a



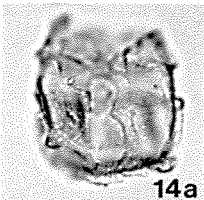
12b



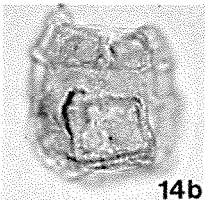
13



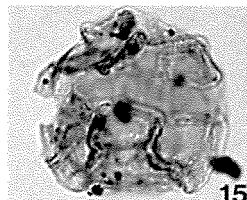
11



14a



14b



15

PLATE 33

All figures x800.

HF, high focus; MF, median focus; LF, low focus.

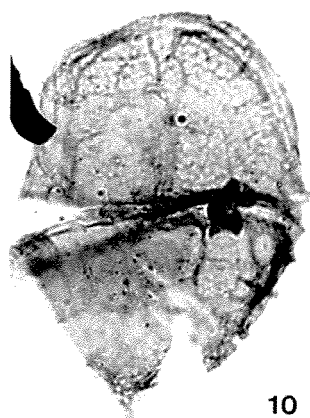
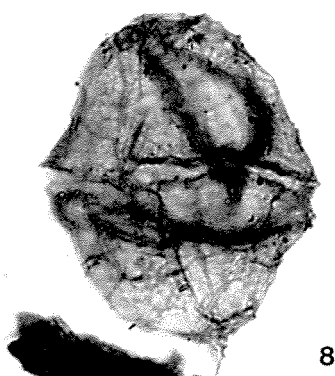
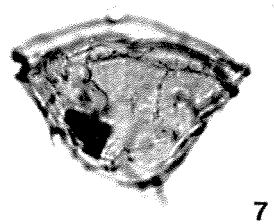
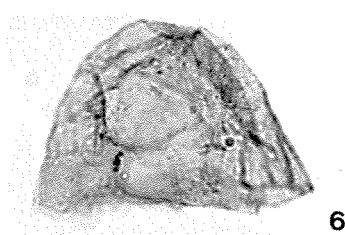
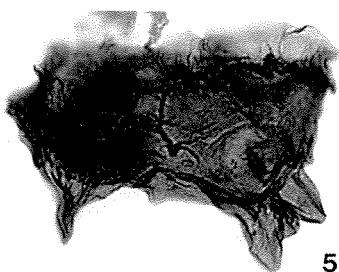
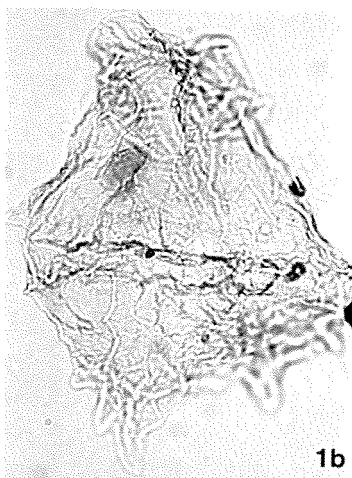
Figure

1–5 *Moorodinium peregrinum* sp. nov.

1. Holotype, dorsal view, a, LF; b, HF. F6685/3 (–50.0, –102.4).
2. Dorsal view, MF. F9120/7 (–57.3, –110.8).
3. Right lateral view, a, HF; b, LF. F9120/2 (–27.7, –100.8).
4. Right lateral view of epicyst, hypocyst twisted into dorsal view, MF. F9120/2 (–59.9, –102.5).
5. Ventral view of detached hypocyst, HF. F9120/5 (–63.6, –103.5).

6–10 *Moorodinium quindalupense* sp. nov.

6. Lateral view of detached epicyst, MF. F12455/1 (–46.1, –109.5).
7. ?Dorsal view of detached hypocyst, HF. F12455/1 (–39.1, –109.4).
8. Ventral view, HF. F12455/1 (–31.2, –109.1).
9. Holotype, left lateral view, MF. F10291/2 (–24.4, –110.6).
10. Right lateral view, MF. F12455/1 (–50.3, –111.9).



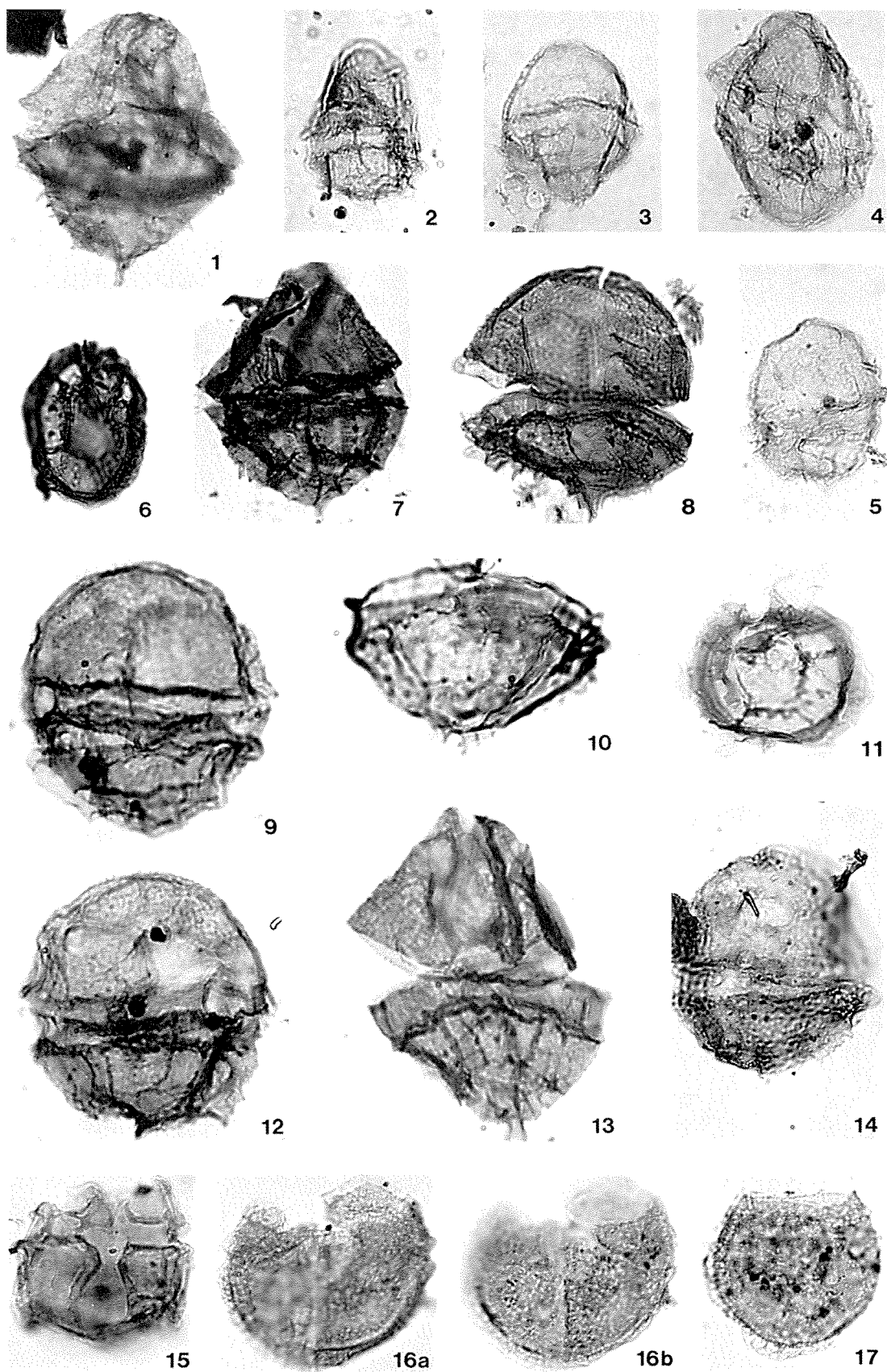
GSWA 22282

PLATE 34

All figures x800 unless otherwise indicated
HF, high focus; MF, Median focus; LF, low focus.

Figure

- 1** *Moorodinium quindalupense* sp. nov.
?View, MF. F12454/1 (–33.6, –109.5).
- 2–5** *Moorodinium simplex* sp. nov.
 2. ?Lateral view, MF. F8463/1 (–40.0, –94.8).
 3. Lateral view, MF. F8463/2 (–54.6, –97.5).
 4. Holotype, ?right lateral view, MF. F8463/2 (–38.8, –98.3).
 5. Lateral view, MF. F8463/2 (–39.0, –98.0).
- 6–14** *Moorodinium spinatum* sp. nov.
 6. Apical view of detached hypocyst, MF. F9120/5 (–41.7, –105.5).
 7. ?Dorsal view, MF. F9120/2 (–35.0, –107.3)
 8. Holotype, left lateral view, MF. F9120/5 (–36.0, –99.4).
 9. Left lateral view, x1000, MF. F11499/5 (–58.2, –111.5).
 10. Right lateral view of detached hypocyst, x1000, MF. F9121/2 (–30.3, –110.9).
 11. Antapical view of detached hypocyst, MF. F9120/2 (–49.0, –108.3).
 12. Right lateral view, x1000, MF. F11499/5 (–25.1, –103.2).
 13. ?Dorsal view, x1000, MF. F9120/1 (–28.7, –92.5).
 14. Right lateral view, HF, F23936/1 (–25.6, –112.2).
- 15** *Meiourogonyaulax* sp. B.
Ventral view, HF. F10197/3 (–44.3, –95.5).
- 16, 17** *Meiourogonyaulax* sp. A.
 16. Dorsal view, a, LF: b, HF. F10198/2 (–23.2, –108.7).
 17. Ventral view, HF. F10198/3 (–49.8, –110.9).



GSWA 22283

PLATE 35

All figures x600 unless otherwise indicated.
HF, high focus; MF, median focus; LF, low focus.

Figure

1–3 *Muderongia australis* Helby.

1. ?Dorsal view, MF. F10199/1 (–49.4, –105.0)
2. Holotype, dorsal view, HF. F33871/4 (–27.0, –106.6).
3. Dorsal view, LF. F9684/1 (–49.9, –109.5).

4 *Muderongia tetracantha* (Gocht).

?Dorsal view, MF. F8352/2 (–33.6, –102.9).

5, 6 *Muderongia testudinaria* Burger.

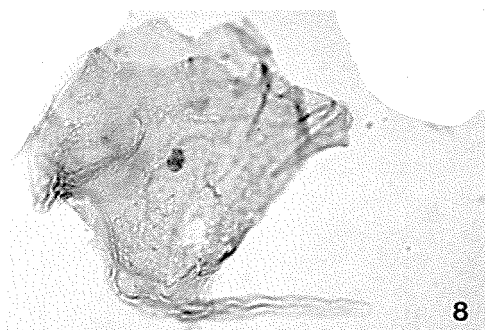
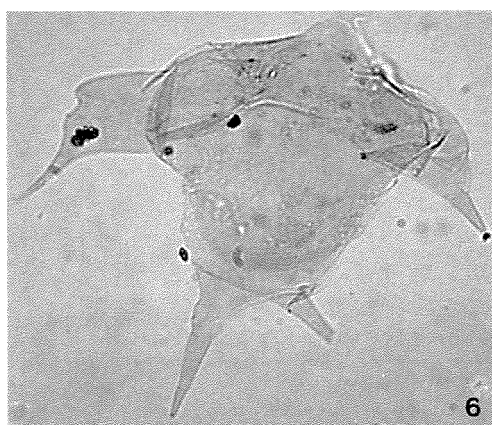
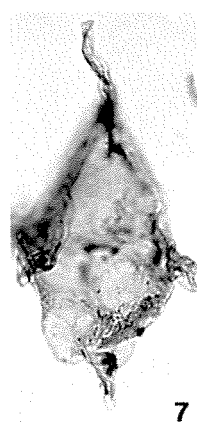
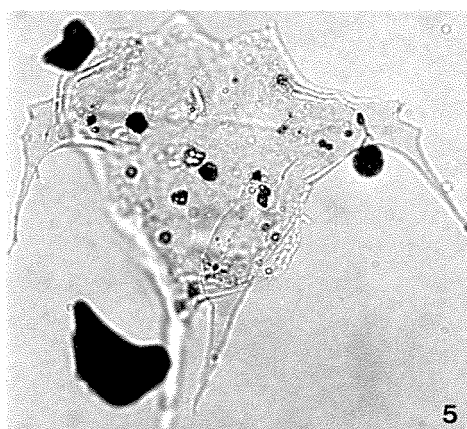
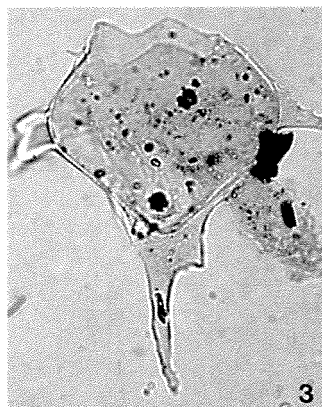
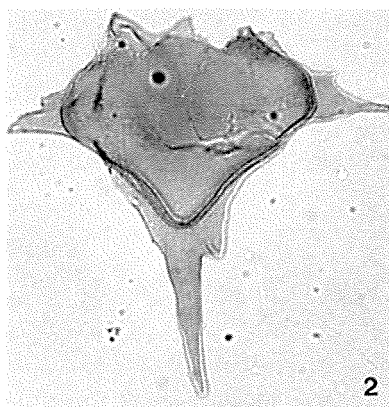
5. Ventral view, HF. F9199/1 (–18.4, –105.0).
6. ?Dorsal view, x700, MF. F9199/2 (–20.5, –108.6).

7, 8 *Muderongia* sp. A.

7. ?Ventral view, HF. F10210/1 (–54.5, –104.5).
8. Ventral view, HF. F33861/4 (–57.3, –111.0).

9. *Muderongia* sp. B.

Dorsal view, x500, HF. F7926/4 (–24.6, –101.0).



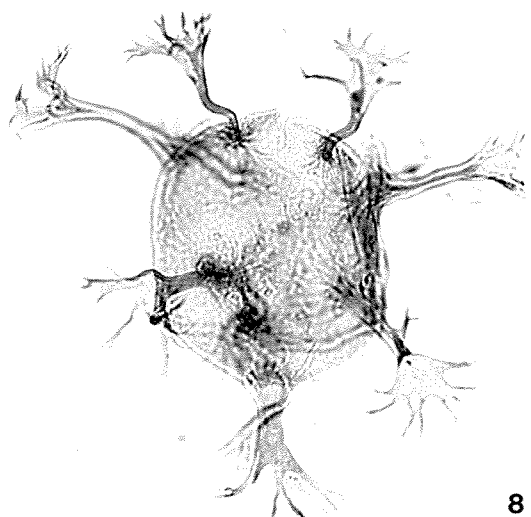
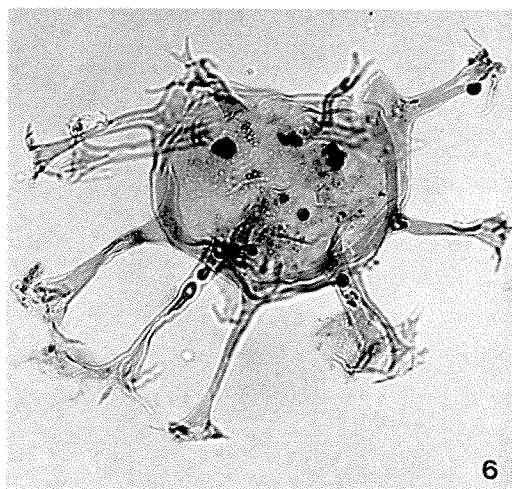
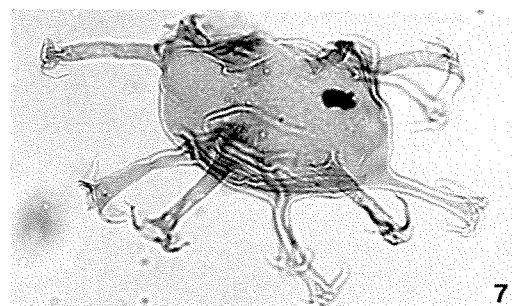
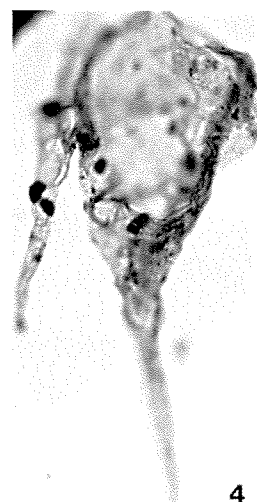
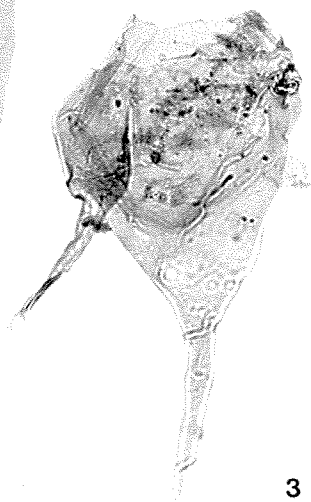
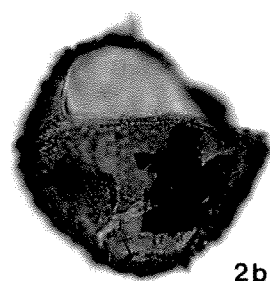
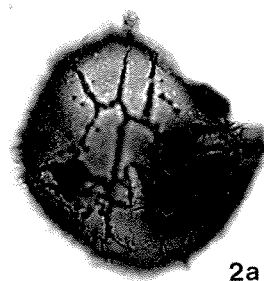
GSWA 22284

PLATE 36

All figures x600 unless otherwise indicated.
HF, high focus; MF, median focus; LF, low focus.

Figure

- 1 *Muderongia* sp. B.
Dorsal view, x500, HF. F7926/3 (–51.4, –92.3).
- 2 *Occisucysta tenuiceras* (Eisenack).
Ventral view, x500, a, HF; b, LF. F10396/1 (–48.7, –100.2).
- 3, 4 *Odontochitina operculata* (O. Wetzel).
3. ?Dorsal view. MF. F10199/2 (–34.4, –95.5).
4. ?Dorsal view, MF. F33872/5 (–26.4, –106.0).
- 5 *Stiphrosphaeridium anthophorum* (Cookson and Eisenack).
?Ventral view, MF. F14896/2 (–67.0, –95.0).
- 6, 7 *Oligosphaeridium complex* (White).
6. Dorsal view, MF. F10199/3 (–47.0, –108.0).
7. Dorsal view, MF. F10199/1 (–47.0, –105.4).
8. *Oligosphaeridium pulcherrimum* (Deflandre and Cookson)
Dorsal view, HF. F10199/1 (–46.7, –105.2).



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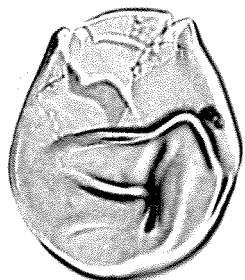
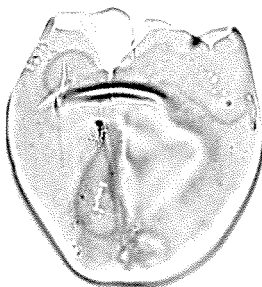
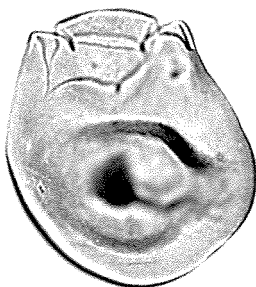
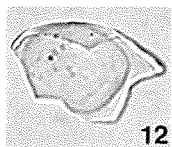
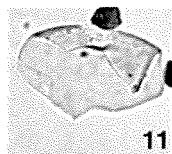
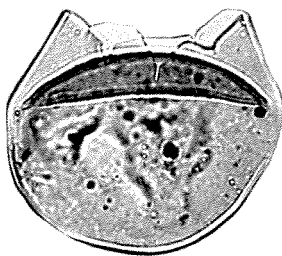
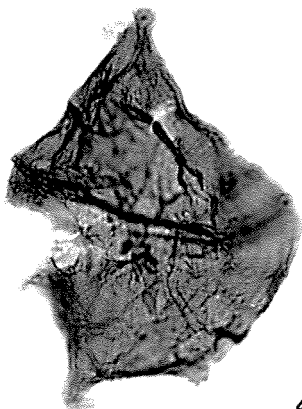
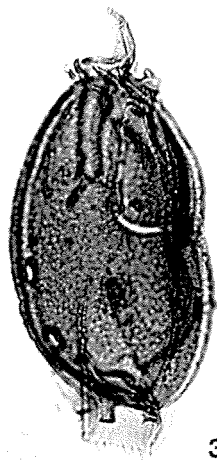
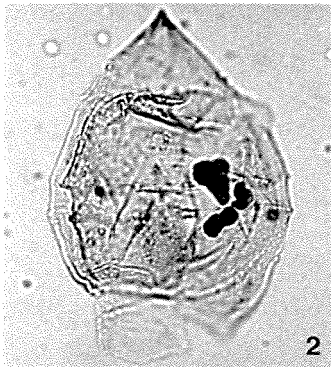
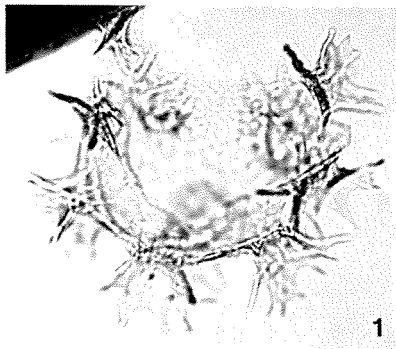
PLATE 37

All figures x600.

HF, high focus; MF, median focus; LF, low focus.

Figure

- 1** *Oligosphaeridium* sp. A.
Dorsal view, MF. F8355/3 (–44.7, –98.7).
- 2** *Ovoidinium cinctum* (Cookson and Eisenack).
Ventral view, LF. F10196/1 (–38.0, –95.1).
- 3** *Herendeenia postprojecta* Stover and Helby.
Left lateral view, MF. F10199/1 (–37.0, –104.0).
- 4** *Palaeoperidinium cretaceum* Pocock.
Dorsal view, MF. F33850/5 (–27.0, –111.2).
- 5, 6** *Pareodinia* sp. cf. *P. arctica* Wiggins.
5. ?Ventral view, HF. F12443/1 (–22.5, –105.7).
6. Right lateral view, MF. F12553/1 (–48.5, –96.4).
- 7** *Pareodinia ceratophora* Deflandre.
?View, MF. F22387/6 (–15.8, –103.7).
- 8–16** *Pentafidia charlottensis* sp. nov.
8. Holotype, right lateral view, MF. F15062/9 (–34.9, –103.2).
9. Dorsal view, MF. F15062/10 (–40.9, –103.5).
10. Dorsal view, LF. F15062/6 (–33.3, –101.9).
11. Detached operculum, right lateral view, MF. F15062/2 (–48.5, –93.7).
12. Detached operculum, ventral view, MF. F15062/2 (–33.3, –99.0).
13. ?Dorsal view, MF. F15062/8 (–35.5, –103.6).
14. Dorsal view, MF. F15062/1 (–39.4, –97.8).
15. Ventral view, MF. F15062/1 (–39.4, –97.8).
16. Ventral view, MF. F15062/5 (–38.2, –96.8).



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PLATE 38

All figures x600 unless otherwise indicated.
HF, high focus; MF, median focus; LF, low focus.

Figure

1–7 *Pentafidia punctata* sp. nov.

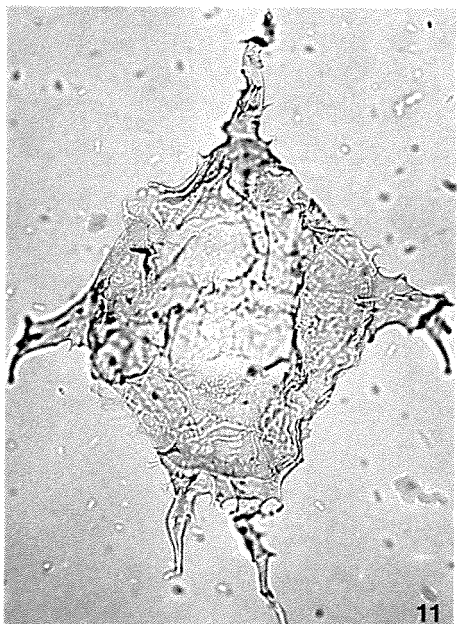
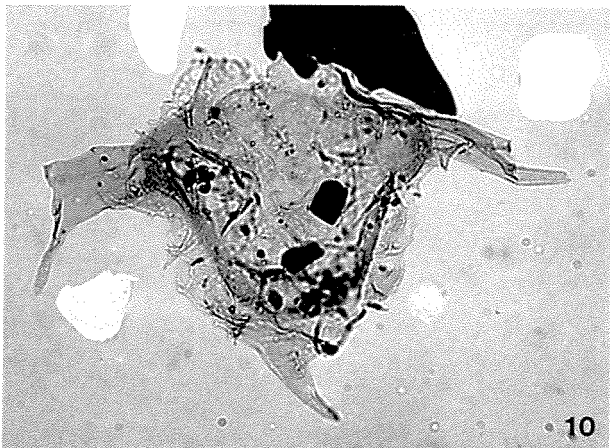
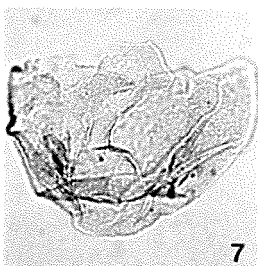
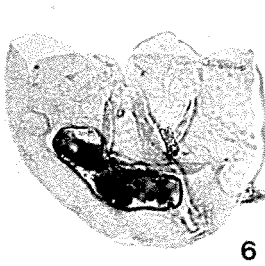
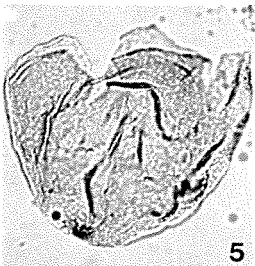
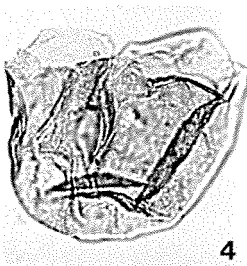
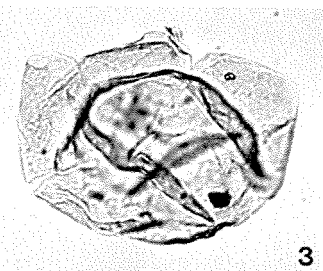
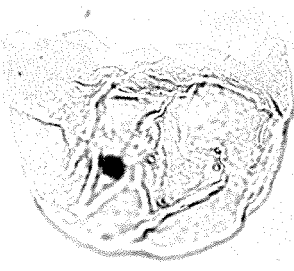
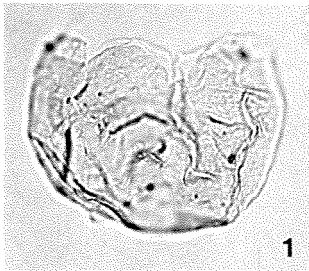
1. Holotype, ventral view, HF. F15079/8 (–40.0, –102.3).
2. Ventral view, MF. F15079/2 (–49.8, –109.8).
3. Left lateral view, MF. F15079/9 (–39.1, –103.3).
4. ?View, MF. F15079/7 (–34.7, –104.2).
5. Lateral view, MF. F15079/5 (–37.6, –101.0).
6. Dorsal view, MF. F15078/2 (–30.0, –107.6).
7. Ventral view, HF. F15079/6 (–38.2, –103.3).

8–10 *Phoberocysta burgeri* Helby.

8. Dorsal view, x500, MF. F22378/12 (–39.5, –102.7).
9. Dorsal view, x500, MF. F22378/11 (–35.4, –104.0).
10. Dorsal view, x500, MF. F11565/3 (–37.3, –93.3).

11 *Phoberocysta lowryi* Backhouse.

- Ventral view, x500, MF. F8051/6 (–37.5, –102.3).



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PLATE 39

All figures x600 unless otherwise indicated.
HF, high focus; MF, median focus; LF, low focus.

Figure

1–4 *Phoberocysta lowryi* Backhouse.

1. Dorsal view, x500, a, HF; b, LF. F11375/10 (–43.5, –111.0).
2. Dorsal view, x500, LF. F11375/7 (–45.2, –101.0).
3. Ventral view, MF. F14876/2 (–38.4, –112.0).
4. Dorsal view, HF. F14876/2 (–50.0, –101.5).

5, 6 *Phoberocysta* sp. A.

5. Left lateral view of detached operculum, HF. F8357/7 (–46.0, –103.5).
6. Ventral view, MF. F8357/6 (–37.7, –103.8).

7, 8 *Prolixosphaeridium parvispinum* (Deflandre).

7. ?Dorsal view, HF. F10199/1 (–54.5, –110.2).
8. ?Left lateral view, HF. F33850/5 (–49.2, –104.4).

9 *Polysphaeridium?* sp. A.

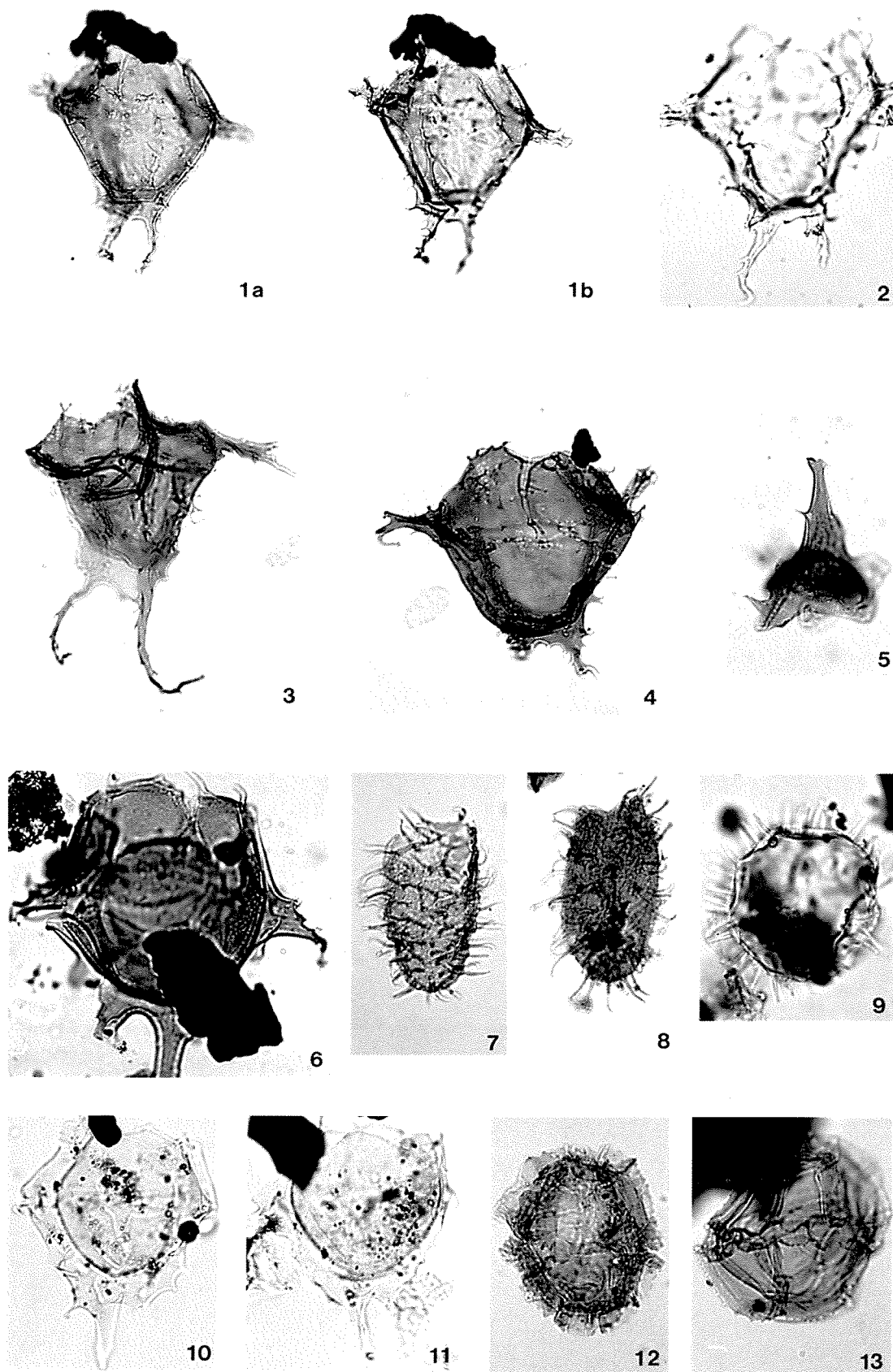
- ?View, MF. F9045/3 (–34.2, –100.0).

10, 11 *Phoberocysta* sp. B.

10. Dorsal view, MF. F9199/1 (–35.7, –107.8).
11. Dorsal view, MF. F9199/1 (–19.1, –104.4).

12, 13 *Impagidinium phlyctaena* Stover and Helby.

12. Dorsal view, MF. F10210/1 (–27.9, –100.0).
13. Dorsal view, HF. F10199/2 (–55.5, –93.6).



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PLATE 40

All figures x600.

HF, high focus; MF, median focus; LF, low focus.

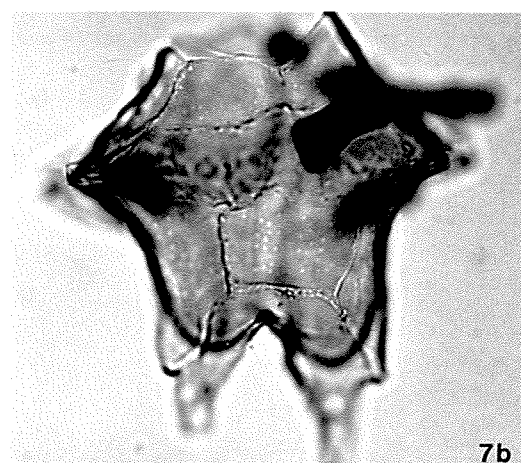
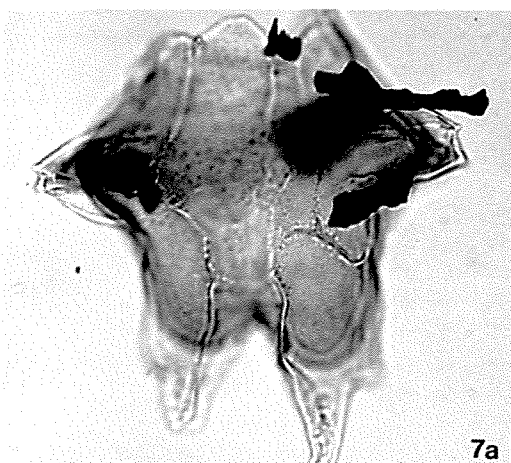
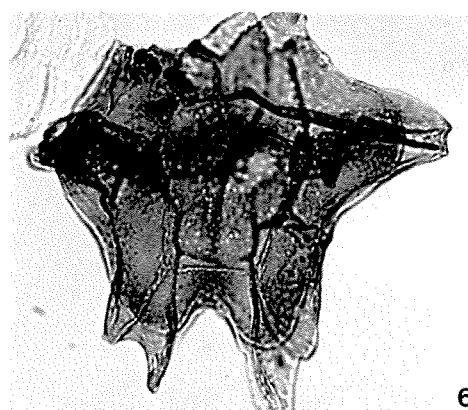
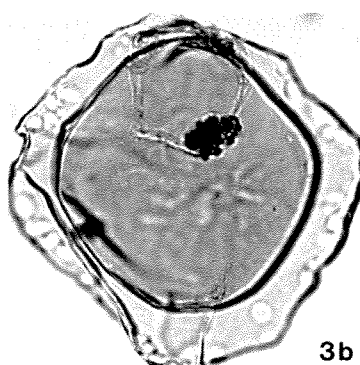
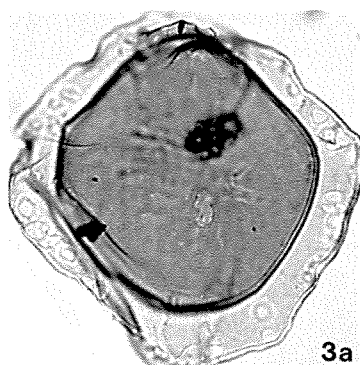
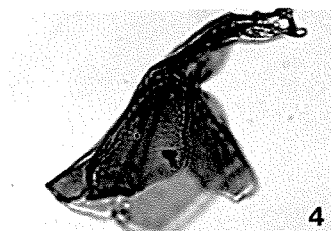
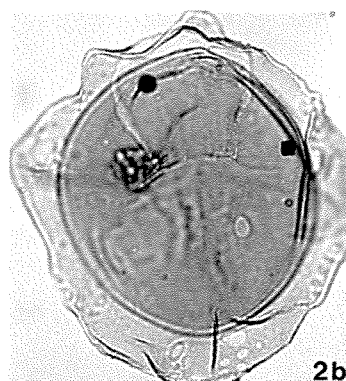
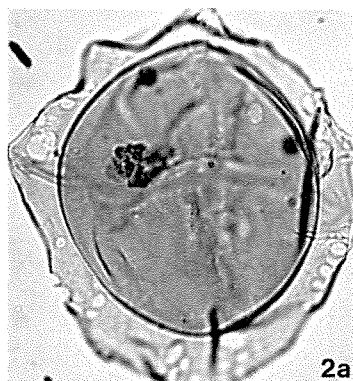
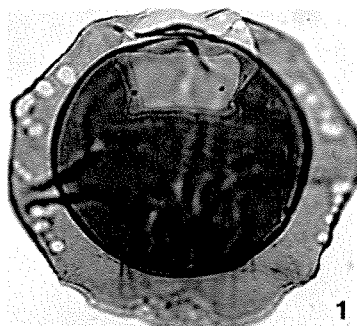
Figure

1–3 *Scriniodinium attadalense* (Cookson and Eisenack).

1. Ventral view, LF. F8357/6 (–29.2, –108.5).
2. Dorsal view, a, LF; b, HF. F8357/9 (–30.5, –101.7).
3. Ventral view, a, HF; b, LF. F8356/8 (–39.0, –103.6).

4–7 *Senoniasphaera tabulata* Backhouse and Helby.

4. Detached operculum, ventral view, LF. F8551/2 (–29.4, –98.8).
5. Ventral view, MF. F33902/4 (–63.9, –102.8).
6. Ventral view, MF. F8356/6 (–35.8, –102.3).
7. Ventral view, a, HF; b, LF. F8551/1 (–45.1, –108.1).



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PLATE 41

All figures x600 unless otherwise indicated.
HF, high focus; MF, median focus; LF, low focus,

Figure

1, 2 *Sentusidinium aptiense* (Burger).

1. Ventral view, x800, HF. F10199/1 (–31.0, –102.8).
2. Dorsal view, x800, HF. F10200/3 (–35.5, –102.4).

3–6 *Sentusidinium? fibrillosum* sp. nov.

3. Right lateral view, x800, a, HF; b, LF. F11493/2 (–57.0, –94.3).
4. Holotype, right lateral view, x800, a, HF; b, LF. F22400/6 (–46.9, –101.5).
5. Dorsal view, x800, a, LF; b, HF. F12442/1 (–35.0, –100.7).
6. Dorsal view, x800, HF. F22400/5 (32.3, –111.4).

7, 8 *Sentusidinium* sp. A.

7. ?View, x800, MF F10200/3 (–56.2, –98.4).
8. Dorsal view, x800, MF. F10198/4 (–30.6, –102.9).

9, 10 *Spiniferites* sp. cf. *S. dentatus* (Gocht)

9. Right lateral view, HF. F33891/5 (–56.5, –93.1).
10. Dorsal view, a, LF; b, HF. F10198/2 (–51.5, –103.2).

11 *Spiniferites* sp. A.

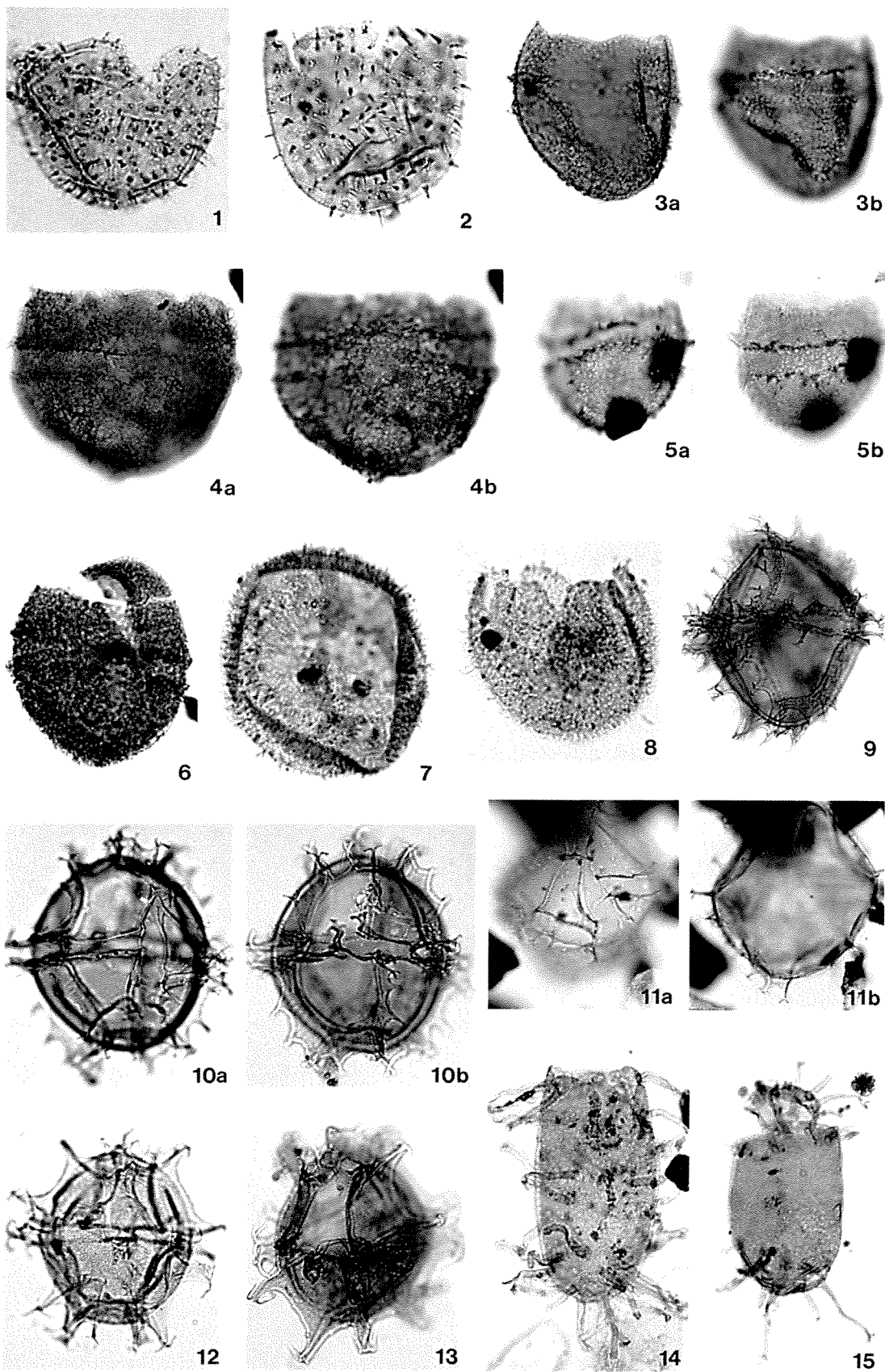
Ventral view, a, HF; b, LF. F8551/2 (–35.4, –100.7).

12, 13 *Spiniferites* sp. B.

12. Dorsal view, MF. F10199/1 (–32.3, –102.8).
13. Dorsal view, HF. F10199/1 (–50.4, –96.0).

14, 15 *Tanyosphaeridium boletum* Davey.

14. Ventral view. x800, HF. F22500/2 (–53.2, –108.3).
15. ?Dorsal view, x800, MF. F22400/6 (–28.4, –104.5).



GSWA 22290

PLATE 42

All figures x600 unless otherwise indicated.
HF, high focus; MF, medium focus; LF, low focus.

Figure

1–3 *Tetrachacysta allenii* sp. nov.

1. Holotype, ?ventral view, x800, a, HF; b, LF. F8543/3 (–39.0, 110.8).
2. ?Ventral view, x800, a, HF; b, LF. F12436/1 (–53.5, –91.9).
3. Ventral view, x800, HF. F11180/2 (–47.5, –103.7).

4, 5 *Tetrachacysta? baculata* sp. nov.

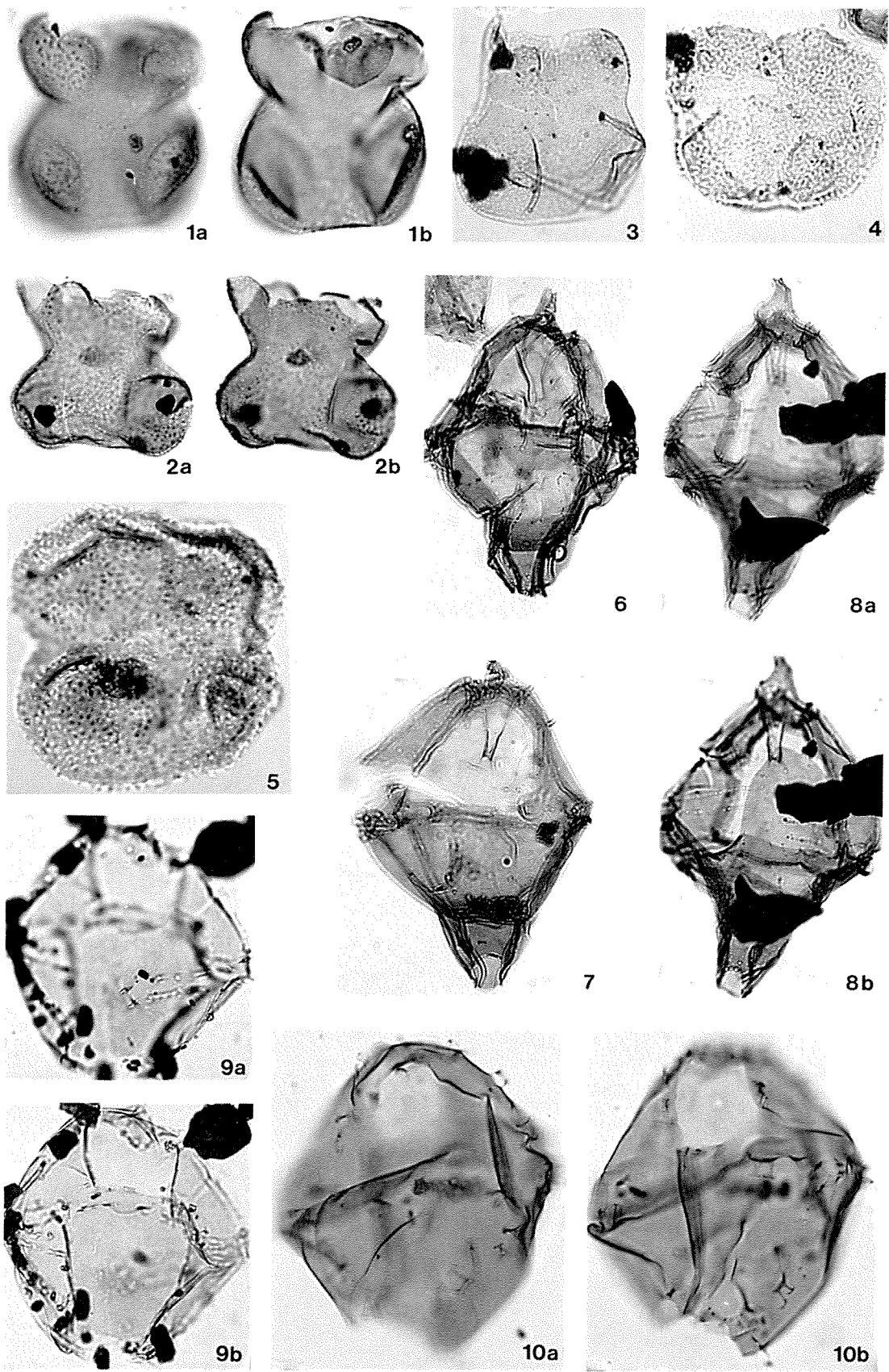
4. ?Dorsal view, x800, MF. F8535/1 (–52.9, –106.7).
5. Holotype, ?view, x800, MF. F8534/1 (–42.1, –96.6).

6–8 *Tubotuberella vlamingii* Backhouse.

6. Dorsal view, HF. F9843/10 (–53.8, –109.3).
7. Ventral view, HF. F9843/10 (–58.0, –106.1).
8. Dorsal view, a, HF; b, LF. F9843/10 (–42.2, –99.5).

9, 10 *Leptodinium sepimentum* Stevens and Helby.

9. Dorsal view, a, LF; b, HF. F11372/1 (–32.4, –98.4).
10. Ventral view, a, HF; b, LF. F8357/6 (–36.8, –103.6).



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PLATE 43

All figures x600 unless otherwise indicated.
HF, high focus; MF, median focus; LF, low focus.

Figure

1, 2 *Fromea monilifera* Backhouse.

1. MF. F33871/5 (–57.4, –104.5).
2. MF. F33863/4 (–48.3, –94.9).

3–9 *Leiosphaeridia? perthensis* sp. nov.

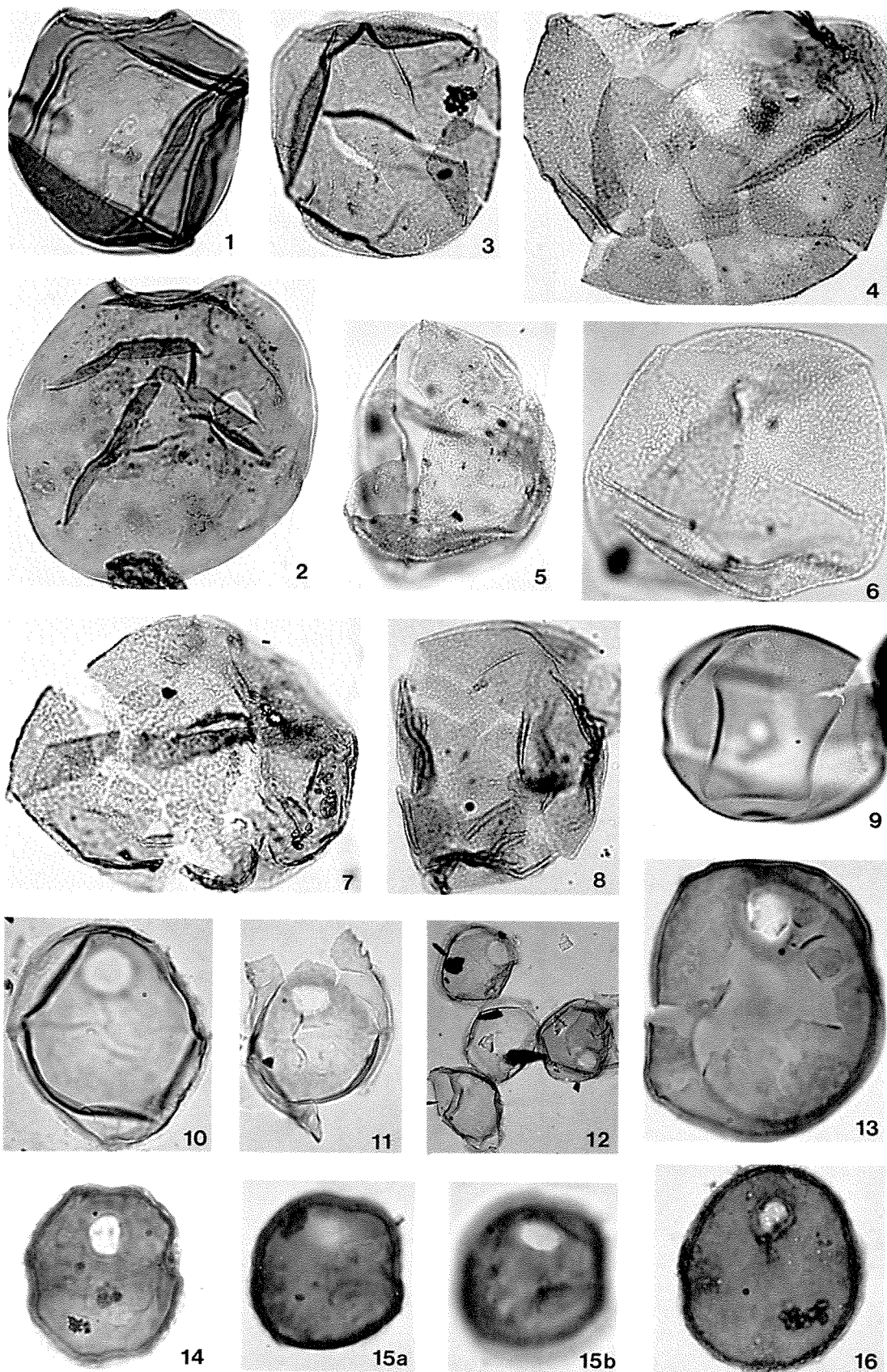
3. HF. F33871/5 (–54.5, –92.8).
4. MF. F33871/5 (–29.1, –100.1).
5. HF. F10206/2 (–22.0, –95.4).
6. Holotype, HF. F8342/2 (–46.7, –103.6).
7. MF. F10200/1 (–43.8, –110.4).
8. MF. F33871/4 (–29.2, –112.2).
9. MF. F33871/5 (–47.8, –100.0).

10–12 *Nummus monoculatus* Morgan.

10. Dorsal view, HF. F20538/1 (–53.3, –102.2).
11. Dorsal view, MF. F20538/1 (–48.7, –100.6).
12. Group of attached specimens, x350. F20538/1 (–44.0, –100.3).

13–16 *Nummus parvus* sp. nov.

13. Ventral view, x1000, HF. F20538/1 (–46.2, –99.6).
14. Holotype, ventral view, x1000, MF. F8357/8 (–43.4, –96.7).
15. Ventral view, x1000, a, HF; b, LF. F8357/8 (–43.1, –96.8).
16. ?View, x1000, MF. F8357/14 (–38.7, –101.0).



GSWA 22292

PLATE 44

All figures x600 unless otherwise indicated.
HF, high focus; MF, median focus; LF, low focus.

Figure

1–7 *Nummus pentagonus* sp. nov.

1. View, HF. F9038.2 (–27.1, –106.0).
2. Ventral view, MF. F12436/1 (–24.3, –103.0).
3. Ventral view, HF. F12436/1 (–50.9, –107.5).
4. Dorsal view, MF. F8544/2 (–42.4, –94.3).
5. Holotype, ventral view, x800, a, HF; b, LF. F12436/1 (–31.6, –108.0).
6. Ventral view, MF. F12436/1 (–29.8, –94.7).
7. Dorsal view, MF. F8543/3 (–39.0, –110.8).

8, 9 *Nummus similis* (Cookson and Eisenack).

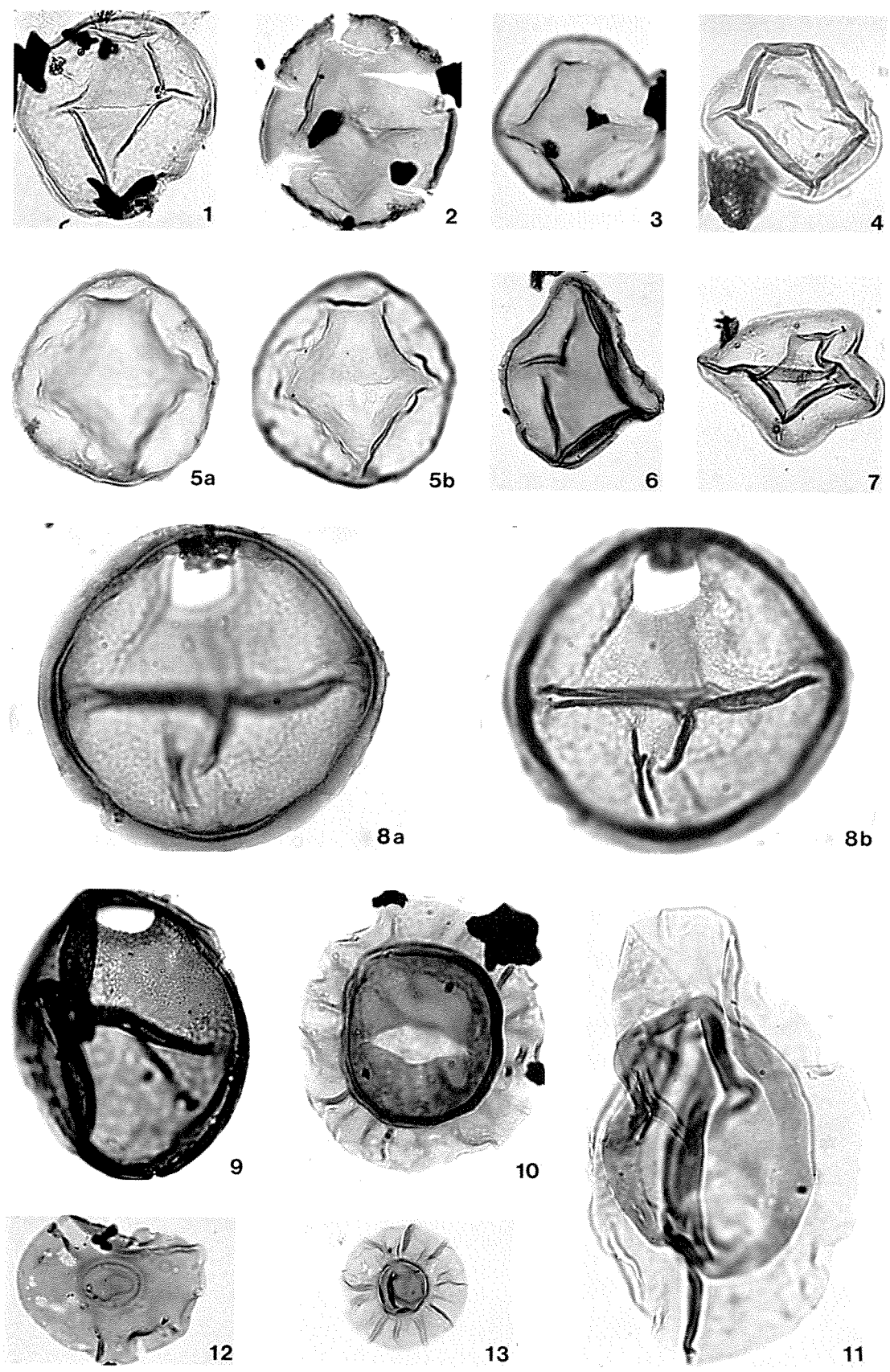
8. Ventral view, a, HF; b, LF. F8357/5 (–45.9, –107.4).
9. Dorsal view, MF. F46265/1 (–39.6, –105.4).

10, 11 *Pterospermella aureolata* (Cookson and Eisenack)

10. MF. F33883/4 (–56.8, –96.8).
11. MF. F8353/1 (–46.1, –99.1).

12, 13 *Pterospermella australiensis* (Deflandre and Cookson).

12. MF. F10200/1 (–43.0, –107.8).
13. MF. F12788/6 (–26.4, –97.9).



GSWA 22293

PLATE 45

All figures x600 unless otherwise indicated.
HF, high focus; MF, median focus; LF, low focus.

Figure

- 1, 2** *Rhombodella paucispina* (Alberti).
 1. HF. F12421/1 (−30.1, −108.6).
 2. MF. F22400/6 (−40.0, −100.4).
- 3–5** *Schizocystia rugosa* (Cookson and Eisenack).
 3. HF. F12758/1 (−31.3, −106.6).
 4. HF. F12758/1 (−32.9, −102.2).
 5. Separated half, MF. F9404/1 (−38.3, −108.8).
- 6** *Schizocystia* sp. A.
 - MF. F9083/1 (−42.0, −100.4).
- 7** *Brazilea parvus* (Cookson and Dettmann).
 - MF. F9422/1 (−33.9, −101.4).
- 8–11** *Schizosporis favosus* sp. nov.
 8. Separated half, x300, a, HF; b, LF. F9422/1 (−49.8, −96.0).
 9. Holotype separated half, x300, a HF; b, LF. F9422/4 (−57.7, −101.0).
 10. Separated half, x300, MF. F9422/4 (−30.6, −96.4).
 11. Detail of holotype, x800. F9422/4 (−57.7, −101.0).
- 12.** *Schizosporis reticulatus* (Cookson and Dettmann).
 - Fragment of a separated half, x300, MF. F9422/1 (−47.0, −109.8).
- 13–15** *Wallodinium krutzschi* (Alberti).
 13. MF. F22410/6 (−49.3, −96.2).
 14. MF. F10230/1 (−48.2, −103.4).
 15. MF. F22400/6 (−35.0, −94.6).
- 16, 17** Gen. et sp. indet. A.
 16. MF. F8528/3 (−54.9 –96.3).
 17. MF. F8528/3 (−45.2, −101.6).

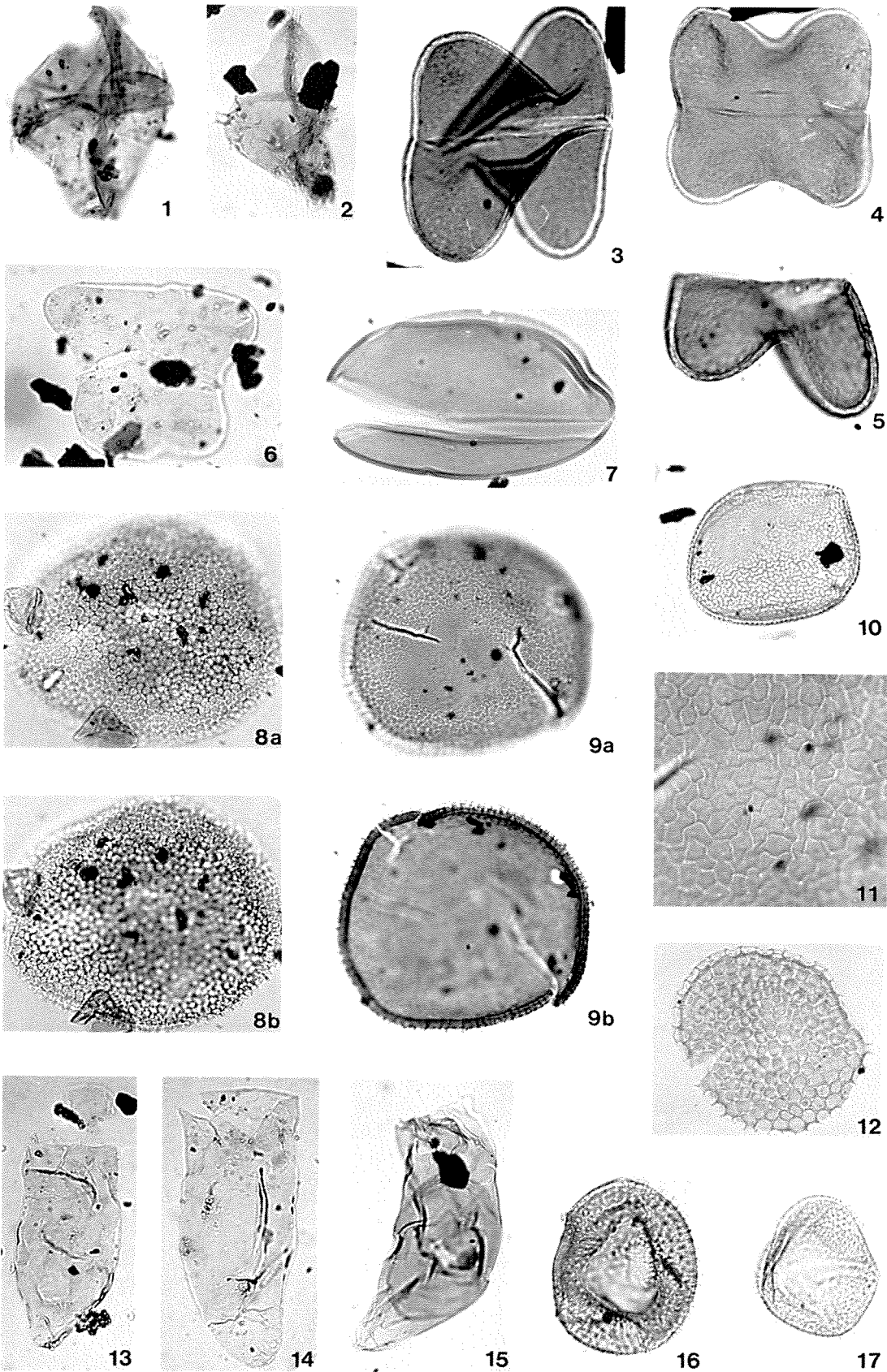


PLATE 46

All figures x600 unless otherwise indicated.
HF, high focus; MF, median focus; LF, low focus.

Figure

1–3 *Platycystidia eisenackii* (Mehrotra and Sarjeant).

1. MF. F11558/1 (–56.4, –109.8).
2. MF. F33865/5 (–56.5, 97.2).
3. MF. F10198/3 (–38.2, –100.3).

4–6 *Domasiella discophora* (Cookson and Eisenack).

4. Complete specimen, x800. F10389/1 (–20.0, –109.9).
5. Specimen with truncated spines, x800. F11179/1 (–34.0, –103.3).
6. Specimen with truncated spines, x800. F11180/1 (–38.4, –100.1).

7–17 Spinose acritarchs from the Warnbro Group.

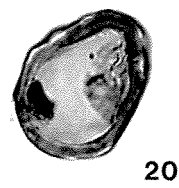
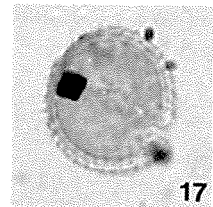
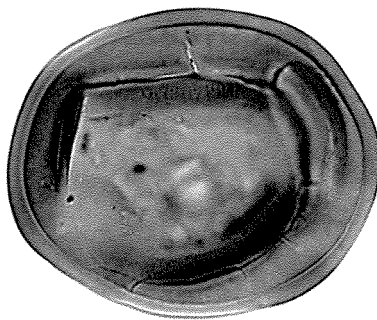
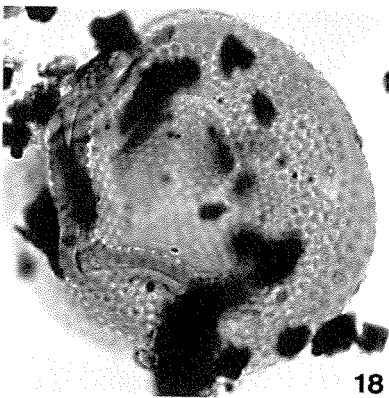
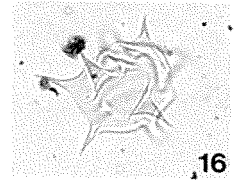
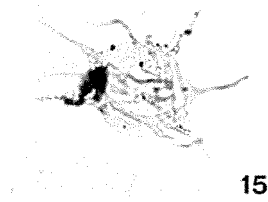
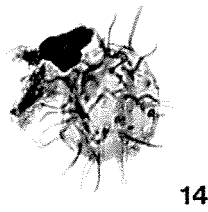
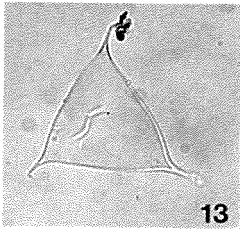
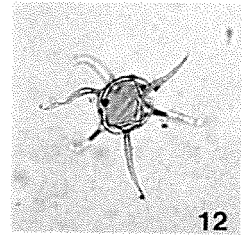
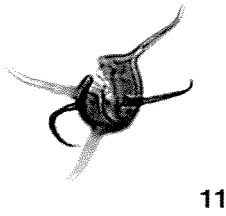
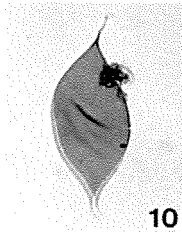
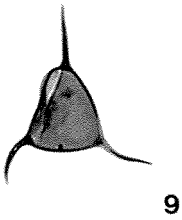
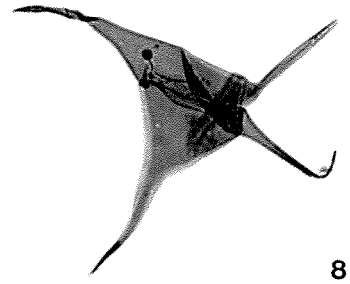
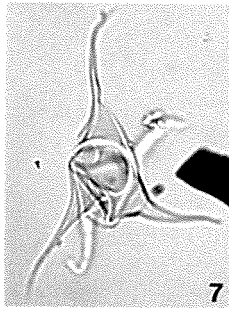
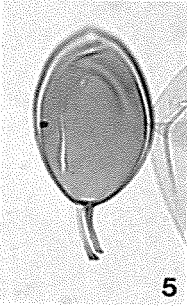
7. *Veryhachium* sp. F22369/6 (–34.6, –113.4).
8. *Veryhachium* sp. F33850/5 (–62.6, –112.8).
9. *Veryhachium* sp. F33854/4 (–42.4, –97.7).
10. *Leiofusa* sp. F22400/5 (–29.3, –111.2).
11. *Veryhachium* sp. F33850/5 (–39.5, –113.0).
12. *Veryhachium* sp. F10197/2 (–60.0, –105.6).
13. *Veryhachium* sp. F8342/2 (–27.0, –96.5).
14. *Baltisphaeridium* sp. F22400/6 (–25.5, –106.0).
15. *Baltisphaeridium* sp. F10210/2 (–34.8, –104.8).
16. *Micrhystridium* sp. F8546/2 (–37.7, –111.5).
17. *Baltisphaeridium* sp., x1200. F8357/10 (–36.0, –109.1).

18 *Crassosphaera* sp. A

- HF. F24022/1 (–37.2, –93.3).

19, 20 *Tasmanites* spp.

19. HF. F8605/1 (–30.3, –101.0).
20. MF. F15084/2 (–44.1, –95.4).



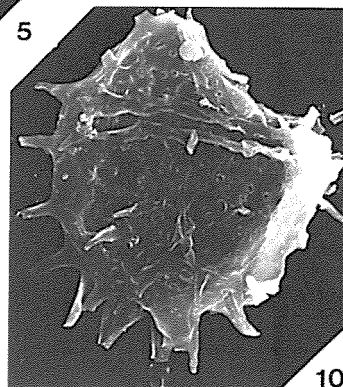
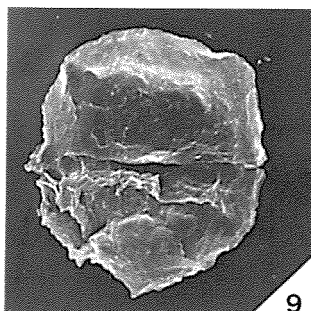
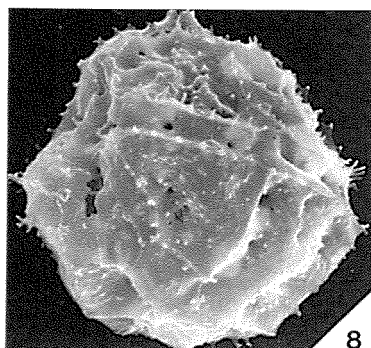
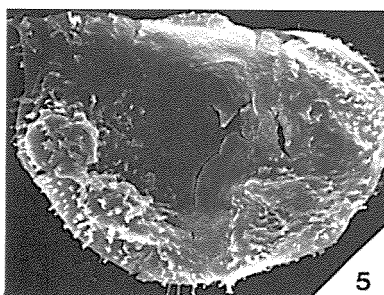
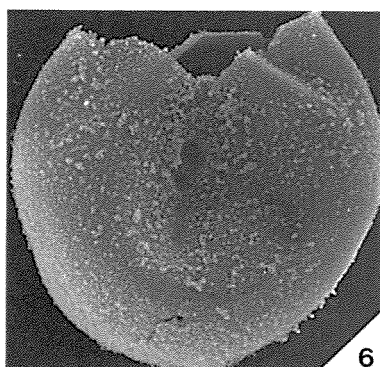
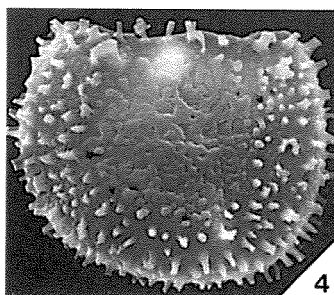
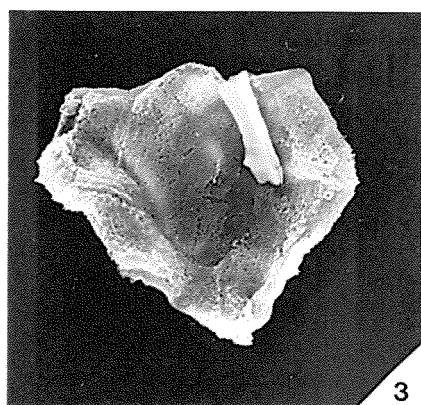
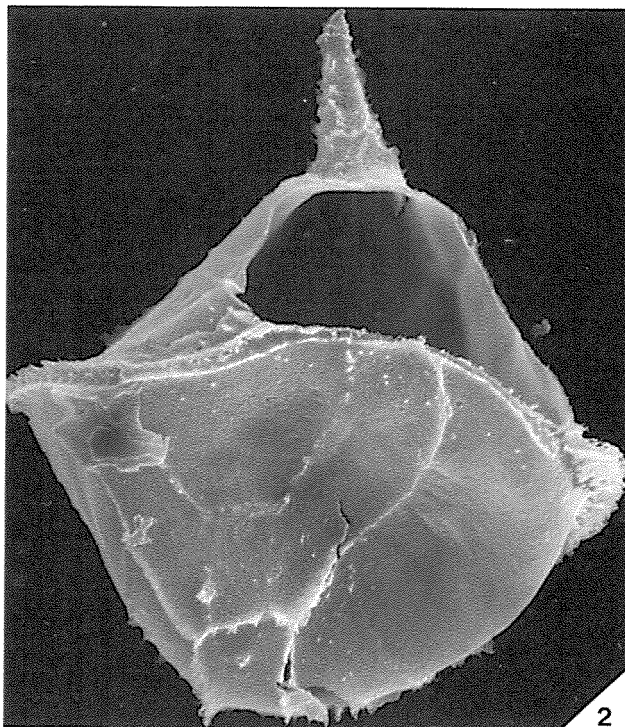
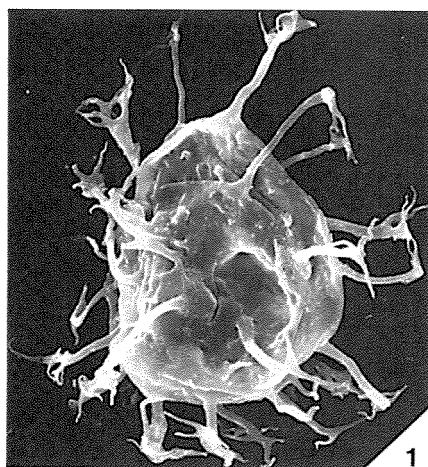
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PLATE 47

All figures SEM micrographs.

Figure

- 1 *Avellodinium lepidum* sp. nov.
?Antapical view, x700. F8353/11 (–37.3, –99.5).
- 2 *Cribroperidinium leedervillense* sp. nov.
Dorsal view, x700. Specimen lost.
- 3–5 *Cyclonephelium hystrix* (Eisenack)
 3. Ventral view, x700. Specimen lost.
 4. Dorsal view, x700. F8342/3 (–38.5, –101.7).
 5. Ventral view, x700. F8353/11 (–32.0, –105.5).
- 6 *Batiacasphaera asperata* Backhouse.
Ventral view, x1000. Specimen lost.
- 7 *Dingodinium cerviculum* Cookson and Eisenack.
Right lateral view, x700. F8342/3 (–35.4, –100.2).
- 8 *Gonyaulacysta* sp. cf. *G. exsanguia* Duxbury.
Left lateral view, x1000. F8357/25 (–37.9, –102.6).
- 9 *Moorodinium spinatum* sp. nov.
Left lateral view, x1000. F11499/8 (–39.0, –104.0).
- 10 *Hystrihodinium compactum* Alberti.
Left lateral view, x700. F8356/11 (–38.8, –102.4).



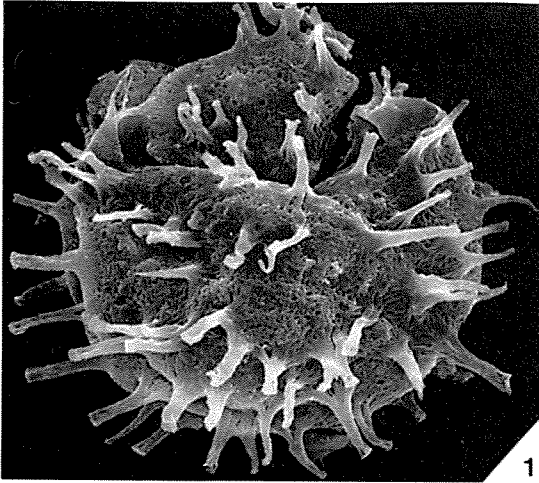
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PLATE 48

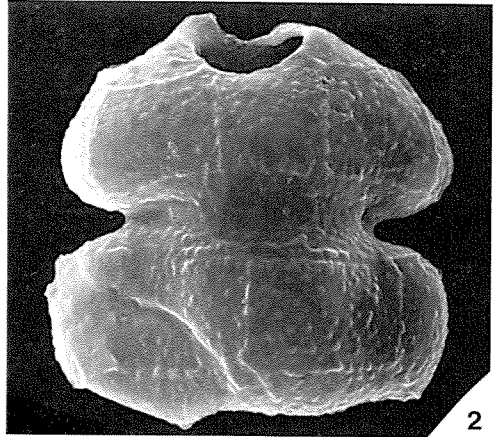
All figures SEM micrographs.

Figure

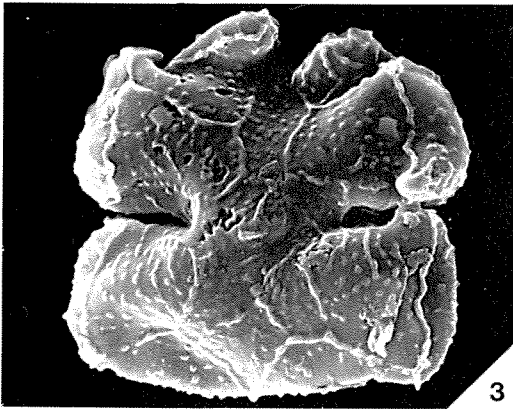
- 1** *Exochosphaeridium robustum* sp. nov.
Dorsal view, x800. F8356/10 (–27.6, –104.6).
- 2–4** *Horologinella lineata* Cookson and Eisenack.
 2. Dorsal view, x2500. F9327/4 (–28.4, –100.8).
 3. Ventral view, x2500. F9327/4 (–28.3, –100.0)
 4. Dorsal view, x2500. F9327/4 (–36.5, –100.0).
- 5, 6** *Moorodinium peregrinum* sp. nov.
 5. Lateral view, x1000. F9120/9 (–34.4, –107.8).
 6. ?Dorsal view, x1000. F9120/10 (–37.2, –101.8).
- 7–10** *Moorodinium spinatum* sp. nov.
 7. Ventral view, x1200. F11499/7 (–29.7, –105.7).
 8. Lateral view, x1000. F11499/8 (–30.6, –102.8).
 9. Antapical view, x1000. F11499/8 (–38.0, –103.2).
 10. Lateral view, x1200. F9120/10 (–31.9, –102.8).



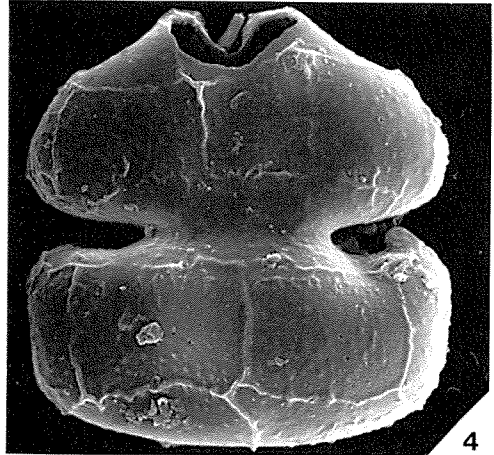
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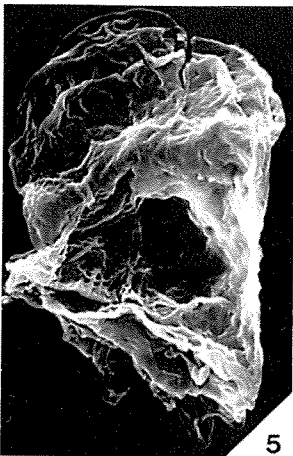
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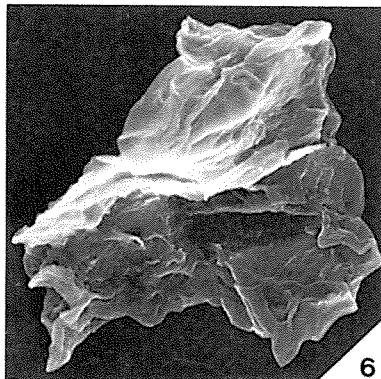
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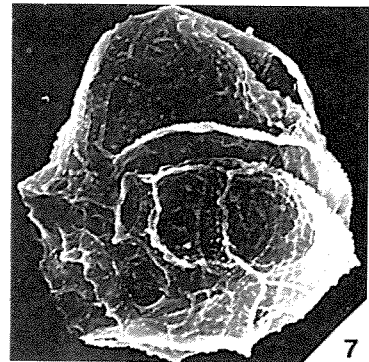
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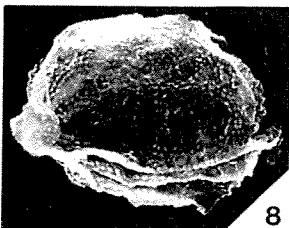
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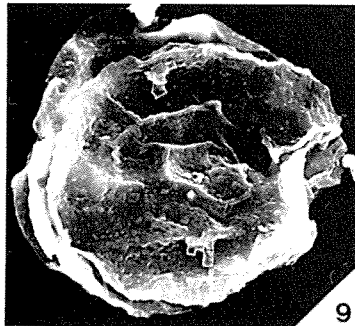
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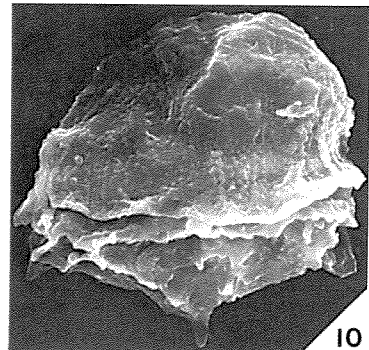
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PLATE 49

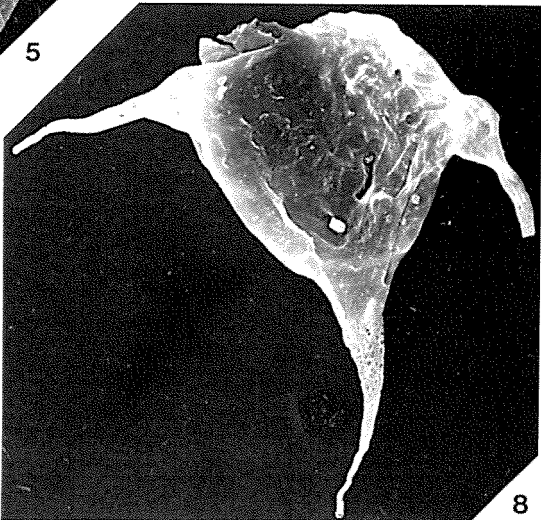
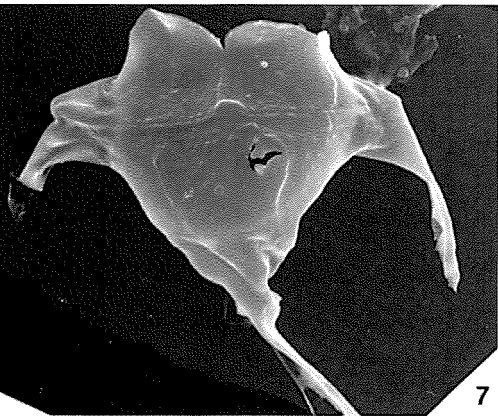
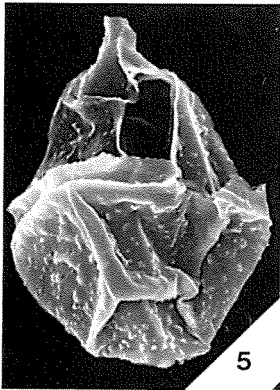
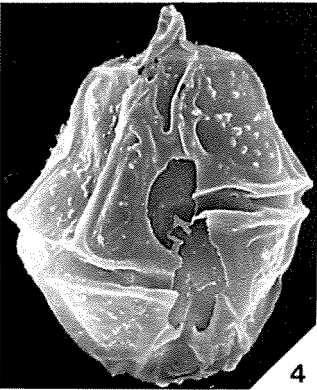
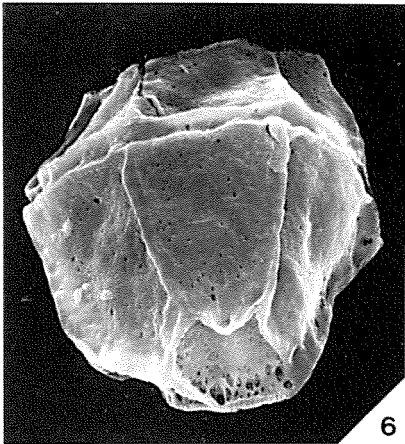
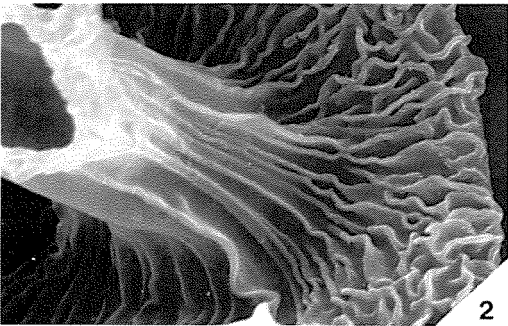
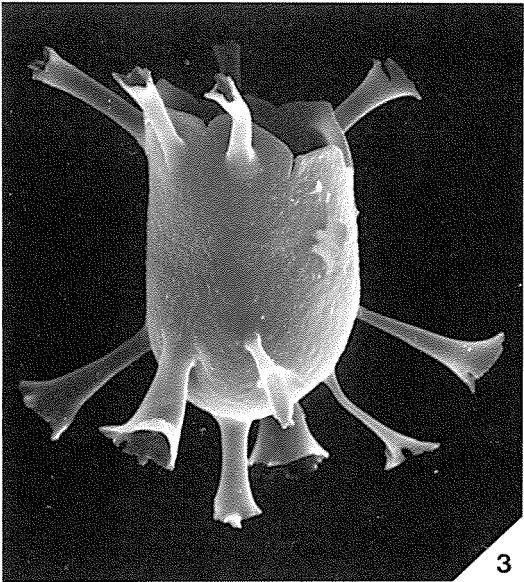
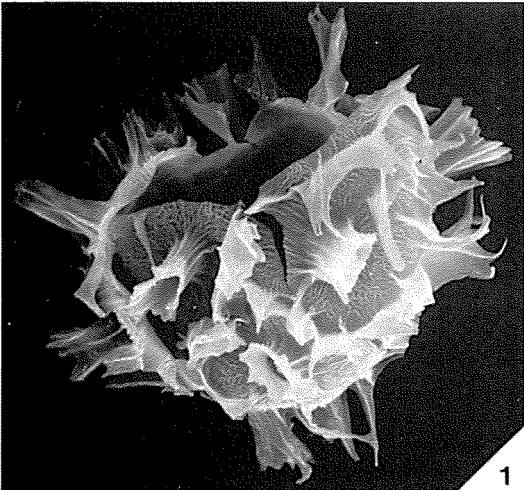
All figures SEM micrographs.

Figure

- 1, 2** *Kleithriasphaeridium fasciatum* (Davey and Williams).
 1. ?Lateral view, x800. F8356/12 (–34.8, –99.9).
 2. Same specimen, surface detail, x4500.
- 3** *Kaiwaradinium scrutillinum* Backhouse.

Right lateral view, x800. Specimen lost.
- 4, 5** *Leptodinium? hyalodermopsis* (Cookson and Eisenack).
 4. Ventral view, x10000. F8357/25 (–34.4, –106.7).
 5. Dorsal view, x1000. F8357/25 (–38.2, –107.2).
- 6** *Meiourogonyaulax bulloidea* (Cookson and Eisenack).

Dorsal view, x700. F8356/11 (–33.4, –104.1).
- 7, 8** *Muderongia tetracantha* (Gocht).
 7. Dorsal view, x700. F8356/12 (–33.9, –103.4).
 8. ?Dorsal view, x700. F8351/5 (–39.4, –102.0).



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PLATE 50

All figures SEM micrographs.

Figure

1–3 *Pentafidia charlottensis* sp. nov.

1. Dorsal view, x1000. F15062/7 (–32.5, –97.5).
2. Dorsal view, x1000. F15062/7 (–37.3, –101.0).
3. Dorsal view, x1000. Specimen lost.

4–6 *Pentafidia punctata* sp. nov.

4. Dorsal view, x1000. F15078/5 (–36.5, –98.3).
5. Dorsal view, x1000. Specimen lost.
6. Surface detail, x7000. F15078/5 (–36.5, –98.3).

7, 8 *Scriniodinium attadalense* (Cookson and Eisenack).

7. Ventral view, x700. Specimen lost.
8. Dorsal view, x700. F8357/26 (–36.0, –109.0).

9 *Senoniasphaera tabulata* Backhouse and Helby.

9. Dorsal view, x600. Specimen lost.

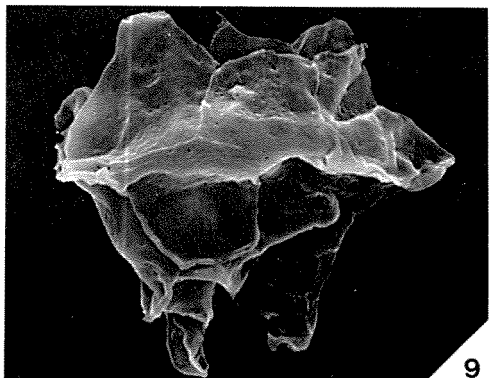
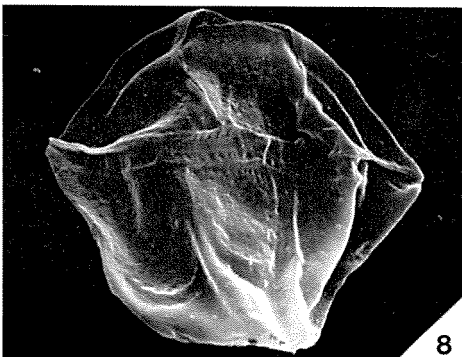
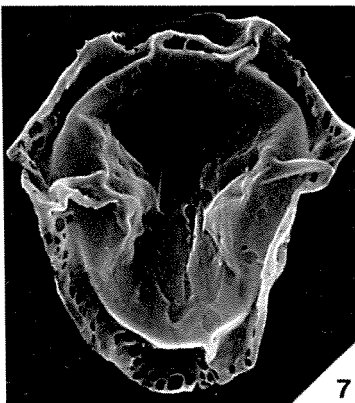
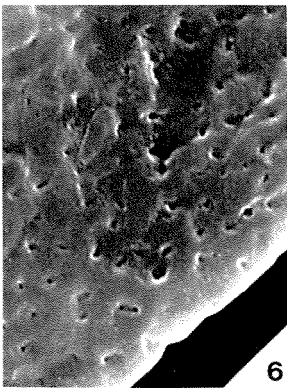
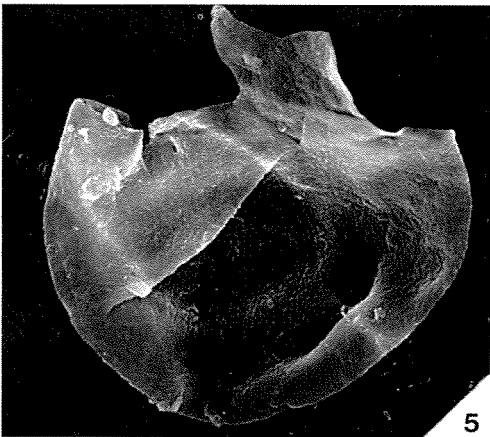
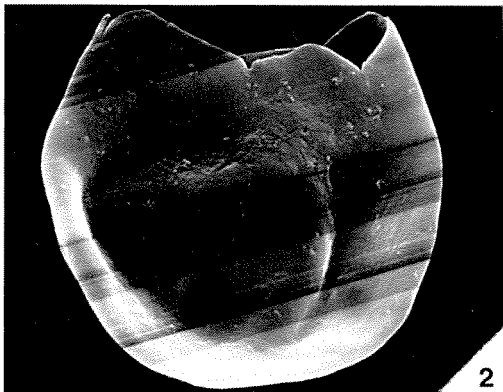
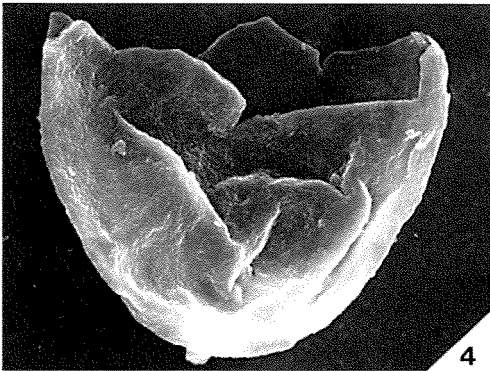
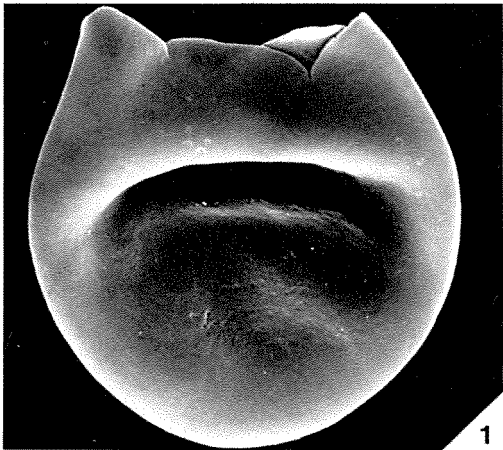
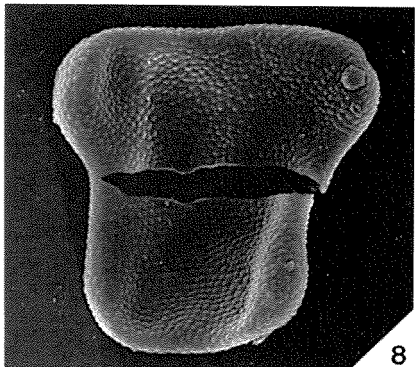
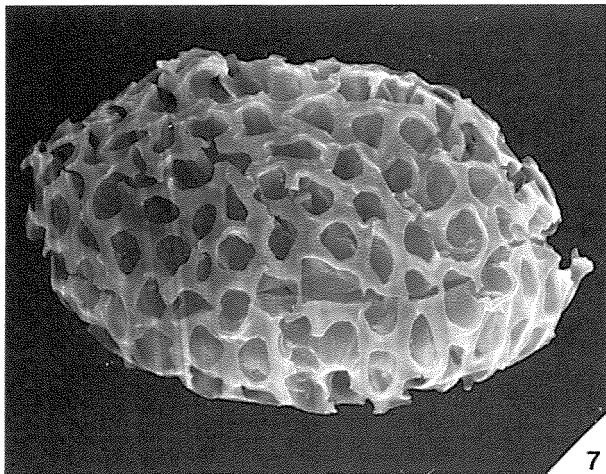
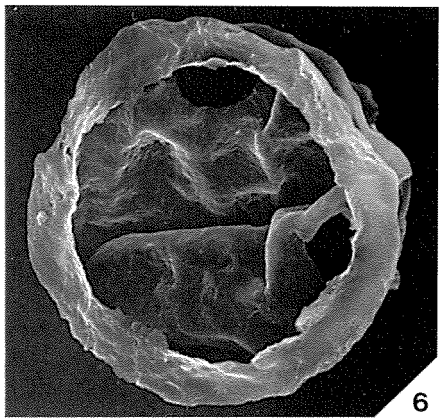
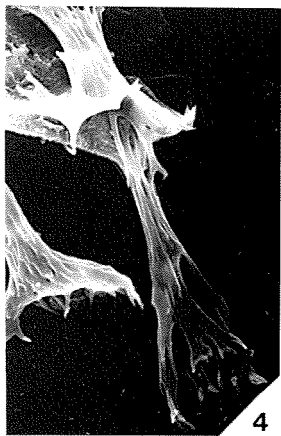
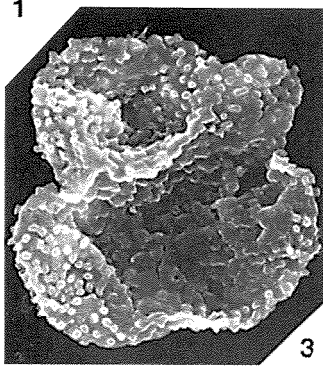
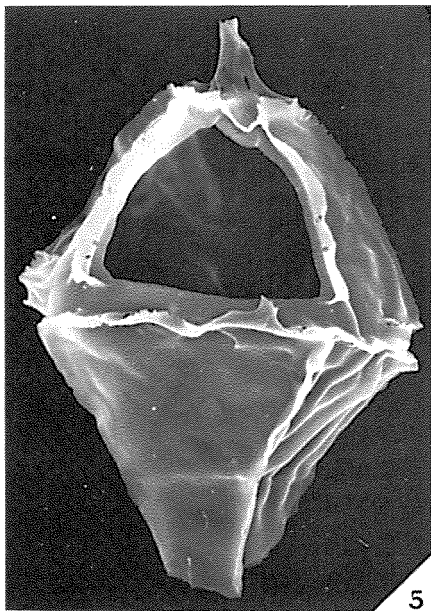
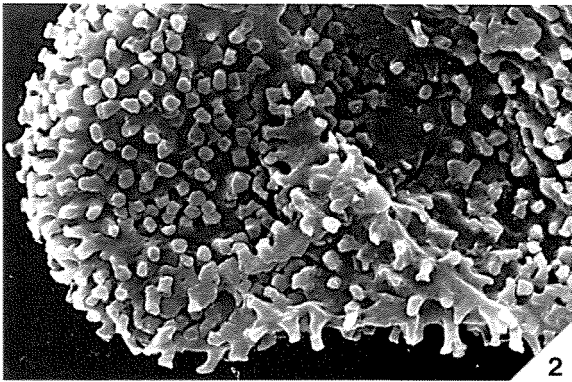
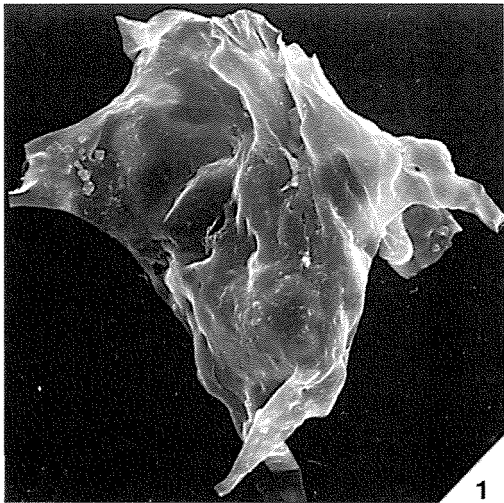


PLATE 51

All figures SEM micrographs.

Figure

- 1** *Muderongia testudinaria* Burger.
?Dorsal view, x700. F8353/11 (–41.6, –105.7).
- 2, 3** *Tetrachacysta? baculata* sp. nov.
 2. Surface detail, x2500. F15062/7 (–30.4, –102.0).
 3. ?Dorsal view, X1200. F15078/5 (–32.4, –105.8).
- 4** *Oligosphaeridium pulcherrimum* (Deflandre and Cookson).
Process detail, x1200. F8357/25 (–37.4, –101.1).
- 5** *Tubotuberella vlamingii* Backhouse.
Dorsal view, x1000. Specimen lost.
- 6** *Nummus similis* (Cookson and Eisenack).
x700. F8356/12 (–36.8, –97.8).
- 7** *Schizosporis reticulatus* Cookson and Dettmann.
x700. F46236/6 (–38.5, –98.0).
- 8** *Schizocystia* sp. A.
x1200. F9327/4 (–33.3, –105.2).



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reticulatus, *Schizosporis* 116
Reticuloidosporites 66
reticulumsporites, *Retitriletes* 67
Retispora 67
Retitriletes 67
rhabdoreticulatum, *Druggidium* 84
Rhombodella 114
robusta, *Balmeiopsis* 73
robustum, *Exochosphaeridium* 85
Rogalskaisporites 69
Rouseisporites 69
rugosa, *Schizocystia* 115

saevus, *Antulsporites* 53
scaberis, *Ischyosporites* 59
scabratus, *Marattisporites* 61
schindewolfii, *Hystrichosphaerina* 92
Schizocystia 115
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Scrinioidinium 106
scrutillinum, *Kaiwaradinium* 93
segmentatus, *Callialasporites* 73
Senoniasphaera 107
senonicus, *Gleicheniidites* 59
Sentusidinium 107
sepimintum, *Leptodinium* 94
Sestrosporites 69
signatus, *Vitreisporites* 71
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similis, *Nummus* 112
simplex, *Moorodinium* 99
sp. A, *Achomosphaera* 74

sp. A, *Aequitriradites* 53
 sp. A, *Apteodinium* 74
 sp. A, *Areosphaeridium*? 75
 sp. A, *Batiacasphaera* 76
 sp. A, *Belodinium* 76
 sp. A, *Cicatricosisporites* 55
 sp. A, *Cleistosphaeridium*? 79
 sp. A, *Crassosphaera* 117
 sp. A, *Cribrroperidinium* 81
 sp. A, *Fusiformacysta* 86
 sp. A, *Horologinella* 91
 sp. A, *Leptolepidites* 61
 sp. A, *Meiourugonyaulax*? 97
 sp. A, *Muderongia* 101
 sp. A, *Oligospheridium* 103
 sp. A, *Phoberocysta* 106
 sp. A, *Podocarpidites* 72
 sp. A, *Polysphaeridium*? 106
 sp. A, *Retitriteles* 68
 sp. A, *Schizocystia* 115
 sp. A, *Sentusidinium* 108
 sp. A, *Spiniferites* 108
 sp. B, *Cribrroperidinium* 81
 sp. B, *Meiourugonyaulax*? 97
 sp. B, *Muderongia* 102
 sp. B, *Phoberocysta* 106
 sp. B, *Retitriteles* 68
 sp. B, *Spiniferites* 108
 sp. C, *Cribrroperidinium* 81
 sp. C, *Retitriteles* 69
speciosus, *Dictyotosporites* 58
spinatum, *Moorodinium* 100
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spinulosus, *Januasporites* 60
Staplinisporites 69
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Stiphrosphaeridium 108
stylosus, *Crybelosporites* 67
subtriangularis, *Foveosporites* 59
tabulata, *Senoniasphaera* 107
Tanyosphaeridium 109
Tasmanites 117
tegmentosus, *Vallizonosporites* 70
telatus, *Staplinisporites* 69
tenuiceras, *Occisucysta* 102
tenuis, *Retitriteles* 67
testudinaria, *Muderongia* 101
tetracantha, *Muderongia* 101
Tetrachacysta 109
transitoria, *Canningia* 76
trichosa, *Neoraistrickia* 63
Trilites 70
trilobatus, *Callialasporites* 73
triquetra, *Retispora* 67
truncata, *Neoraistrickia* 63
truncatum, *Exochosphaeridium* 85
Tubotuberella 111
tuberculiformia, *Trilites* sp. cf. *T.* 70
tumida, *Fusiformacysta* 86
turbatus, *Callialasporites* 73

undatus, *Nevesisporites* 64
Undulatisporites 70
Uvasporites 70

Vallizonosporites 70
variabilis, *Cooksonites* 57
variegatus, *Ischyosporites* 59
variverrucatus, *Concavisimisporites* 56
velatus, *Densoisporites* 58
verrucatus, *Leptolepidites* 61
verrucosus, *Concavisimisporites* 56
vinckensis, *Epitricysta* 85
Vitreisporites 71
vlamingii, *Tubotuberella* 111

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watheroensis, *Retitriteles* 67
whitfordensis, *Krauselisporites* 60
yarragadensis, *Obtusisporis* 65

Figure 34. Miospore range chart

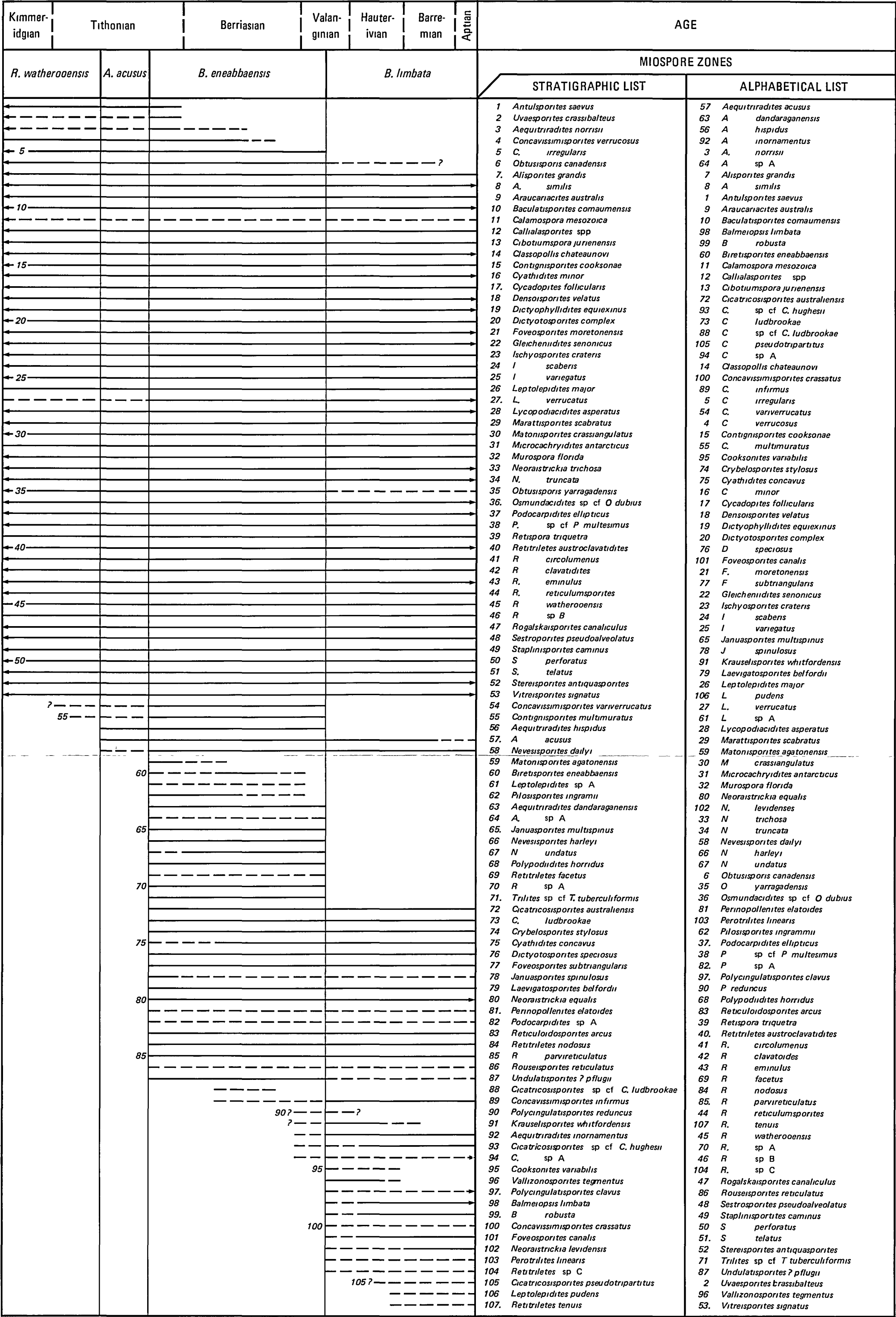
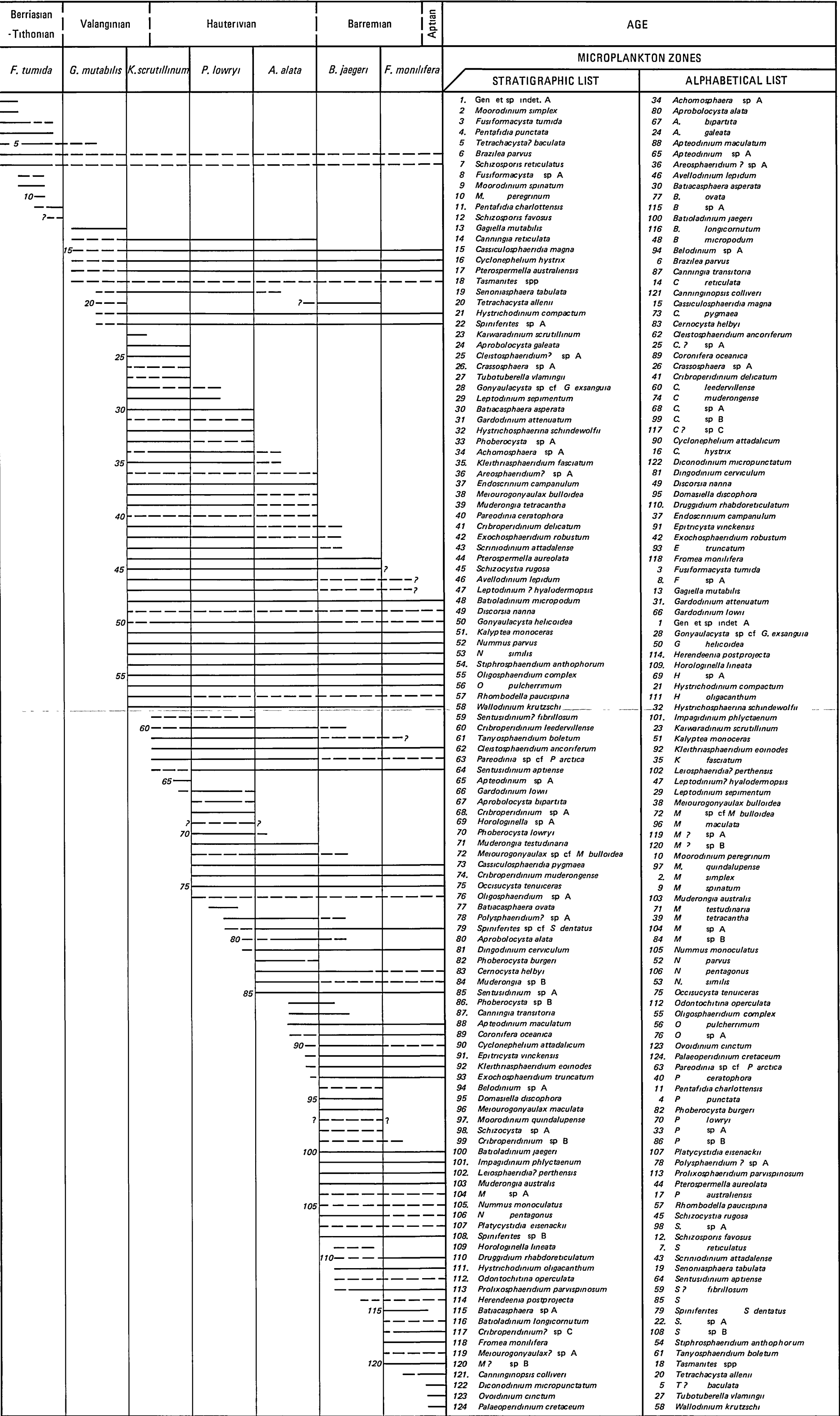


Figure 35. Microplankton range chart



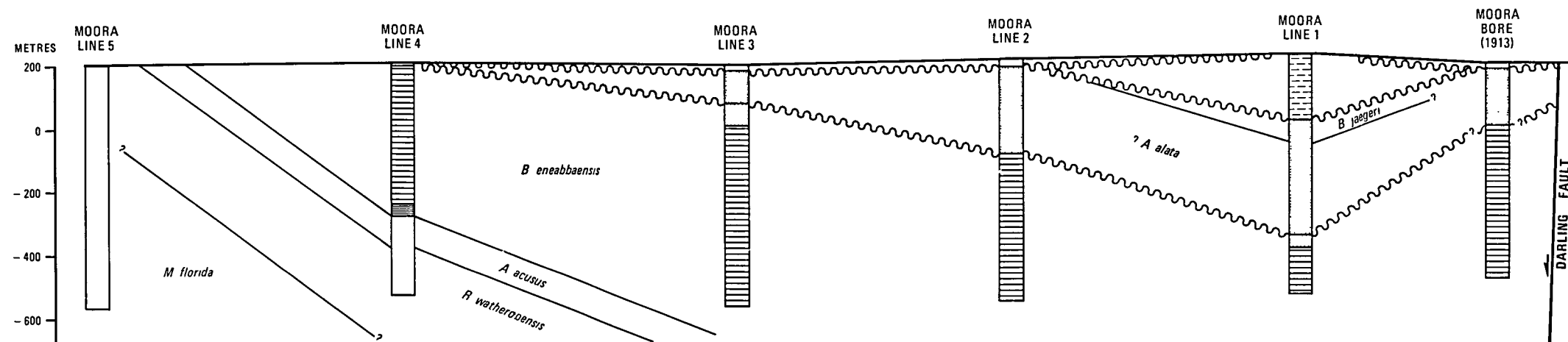


Figure 36 Cross-section through the Moora Line, for location see Figure 5
GSMA 22239

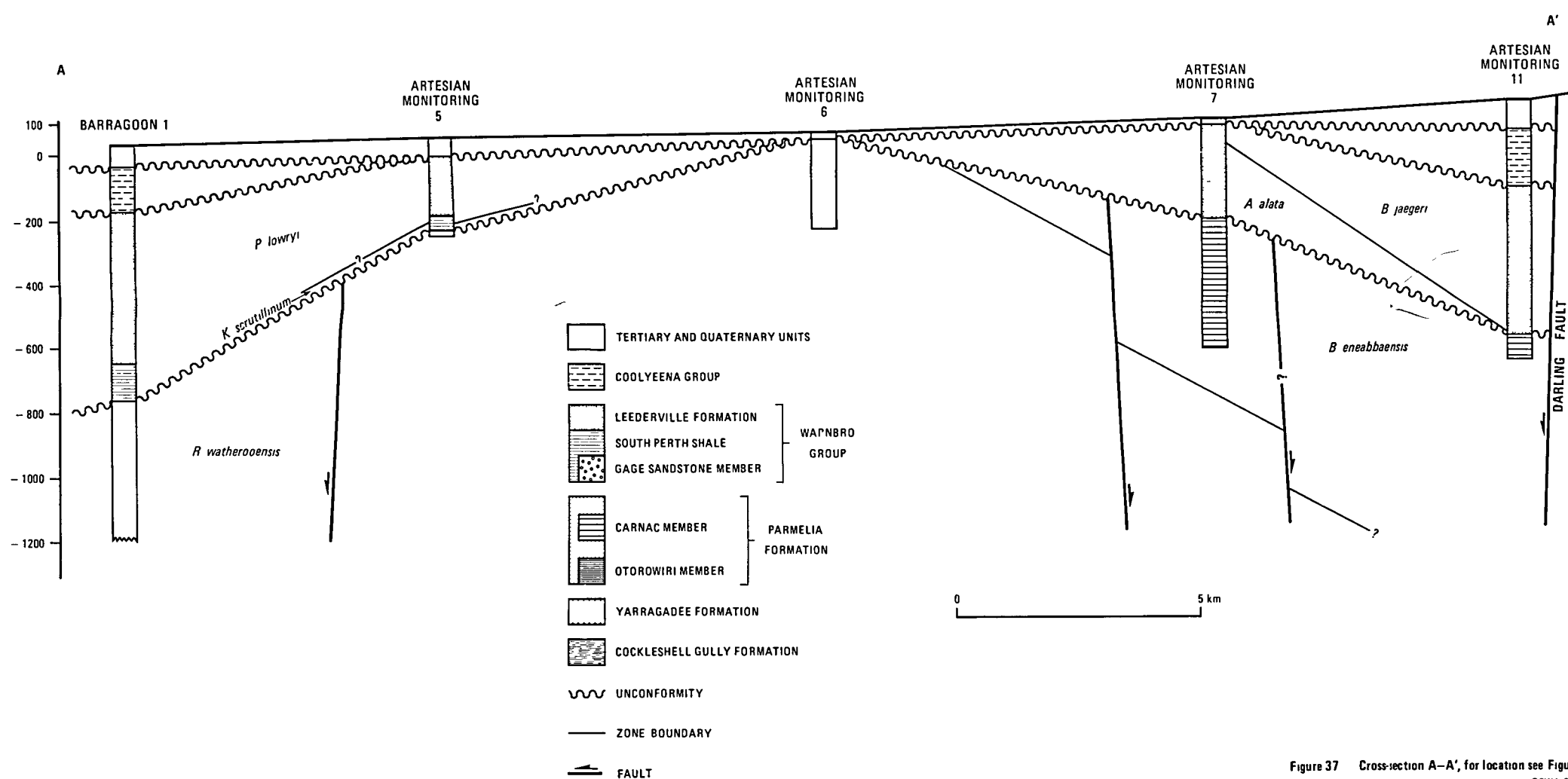


Figure 37 Cross-section A-A', for location see Figure 5
GSMA 22240

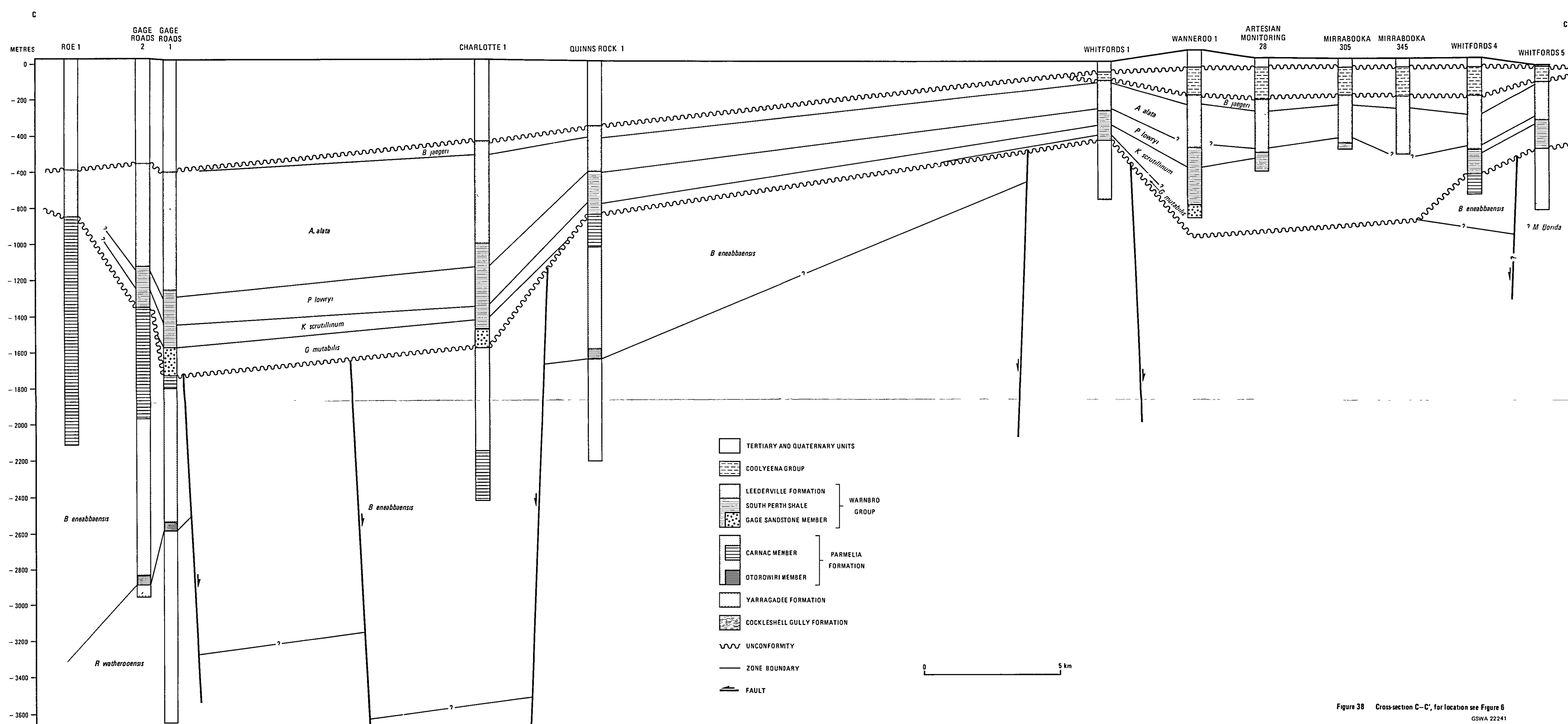


Figure 38 Cross-section C-C', for location see Figure 6
GSMA 22241

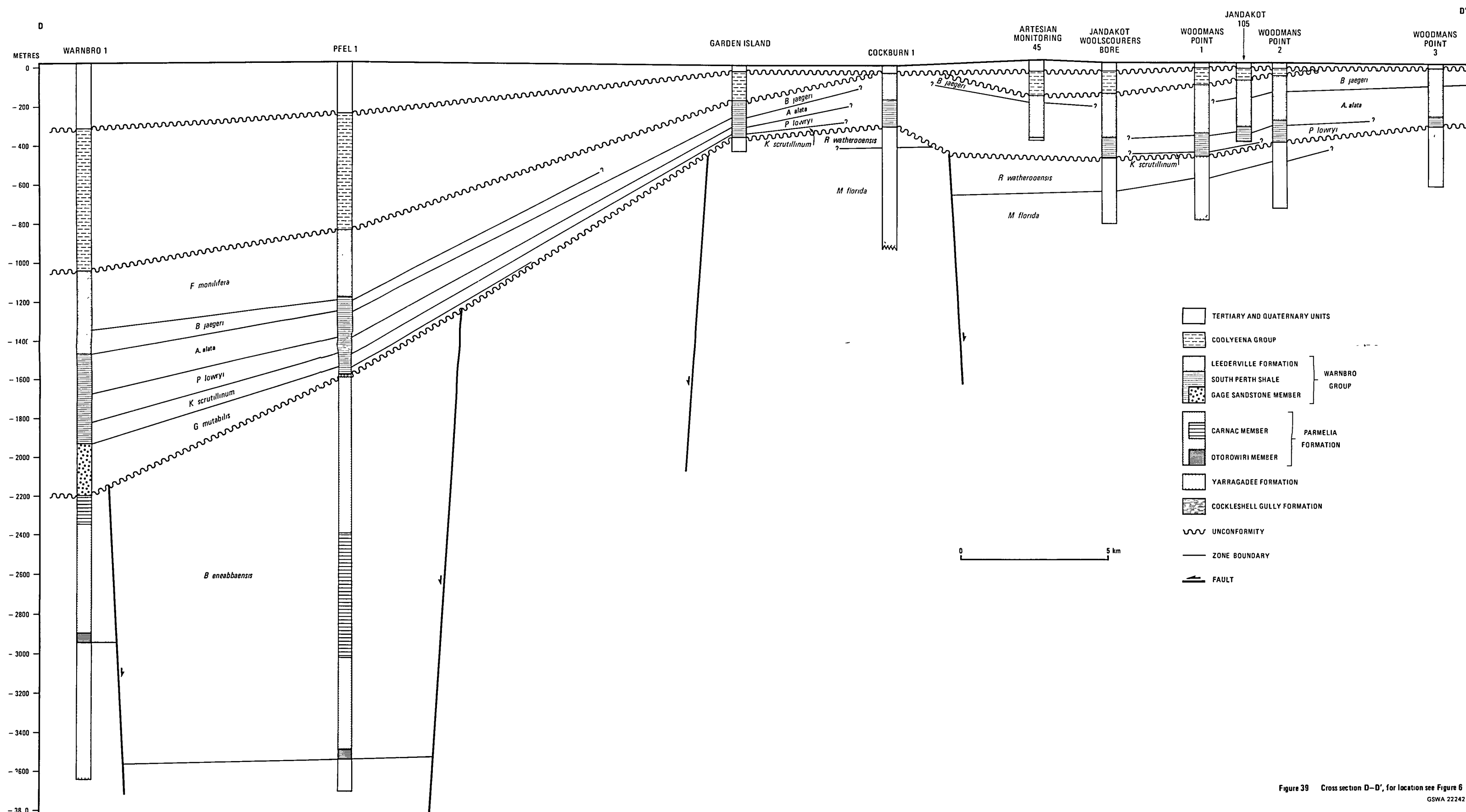


Figure 39 Cross-section D-D', for location see Figure 6
GSMA 22242

Figure 40 Gage Roads 1 (WAPET), Pamella Formation section, for location see Figure 5

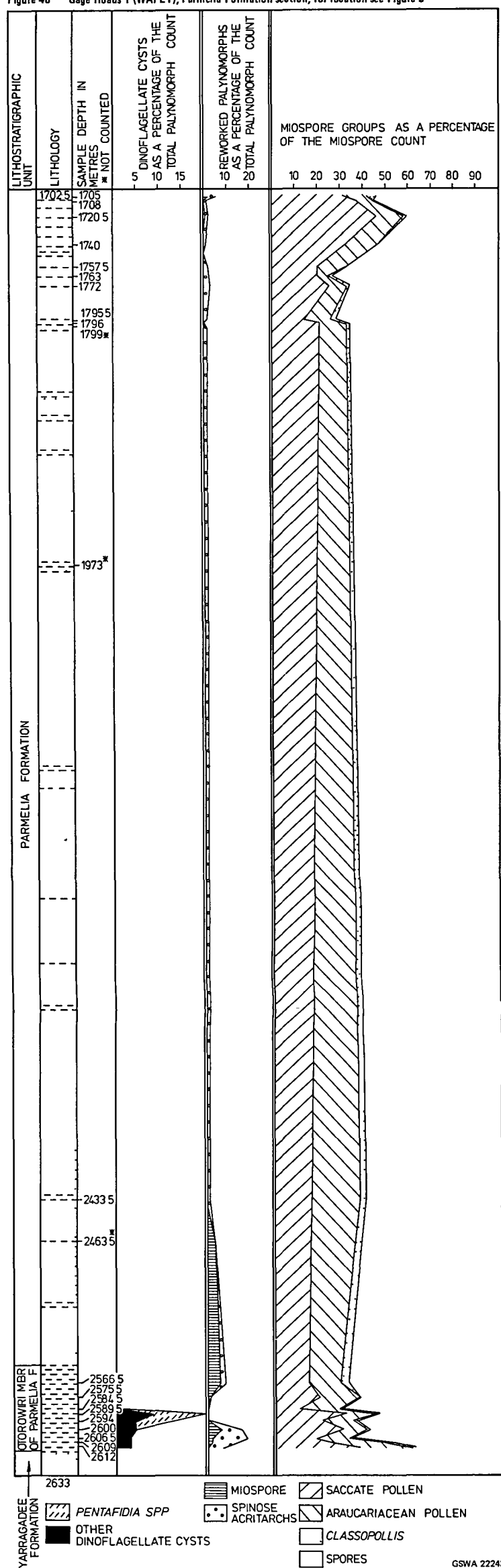


Figure 41 Rite 1 (WAPET), Pamella Formation section, for location see Figure 5

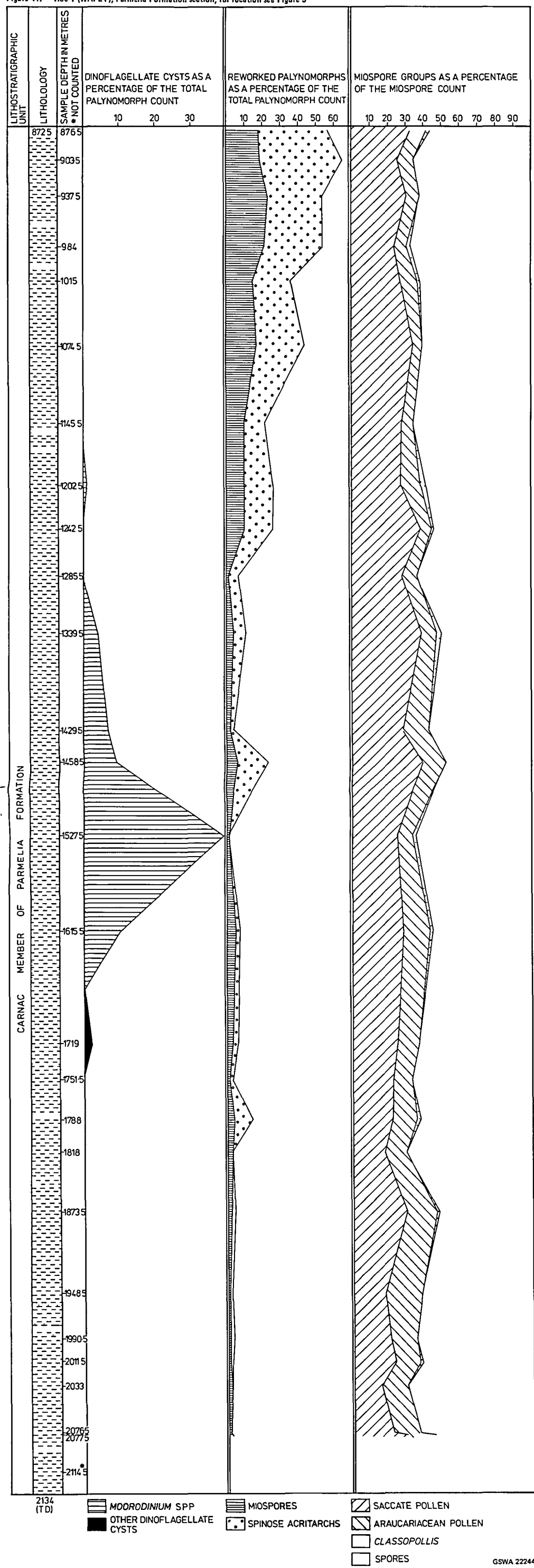


Figure 42 Charlotte 1 (WAPET), Pamella Formation section, for location see Figure 5

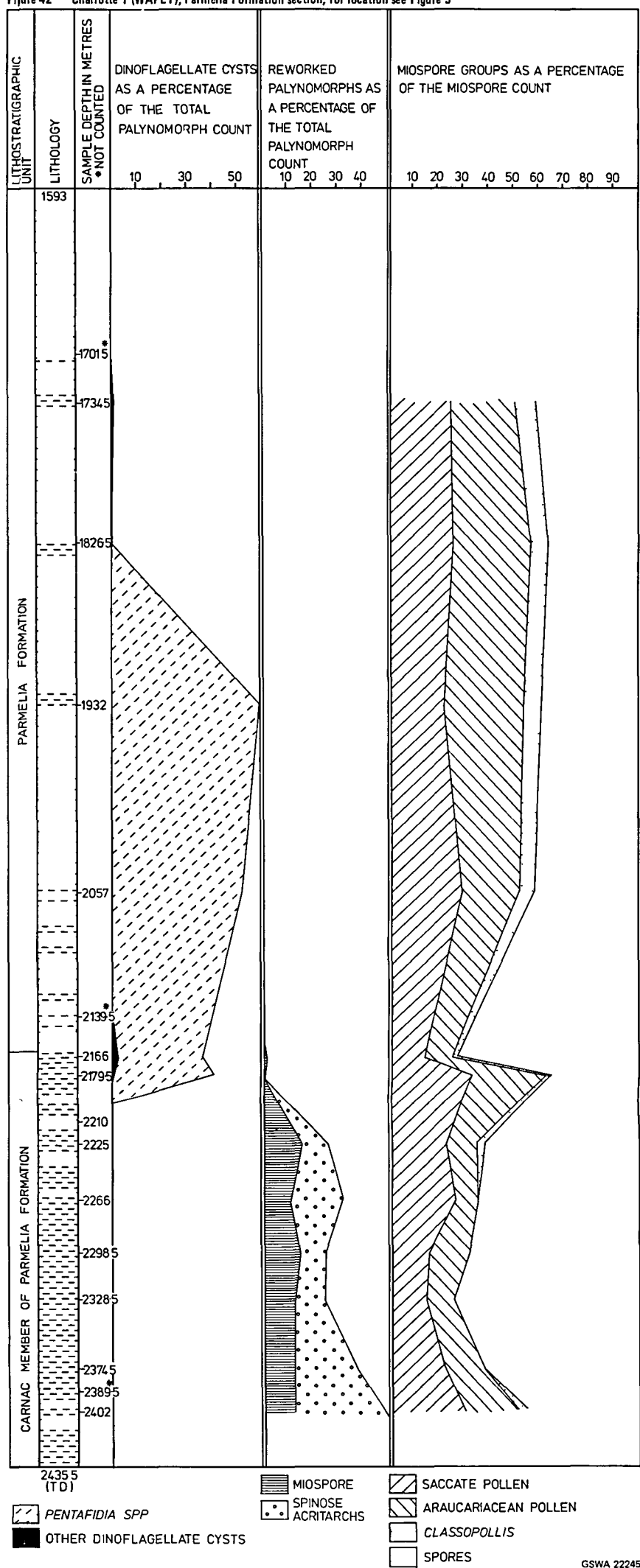


Figure 43 Peel 1 (PHILLIPS AUSTRALIA OIL CO.) Warrbro Group section, for location see Figure 5

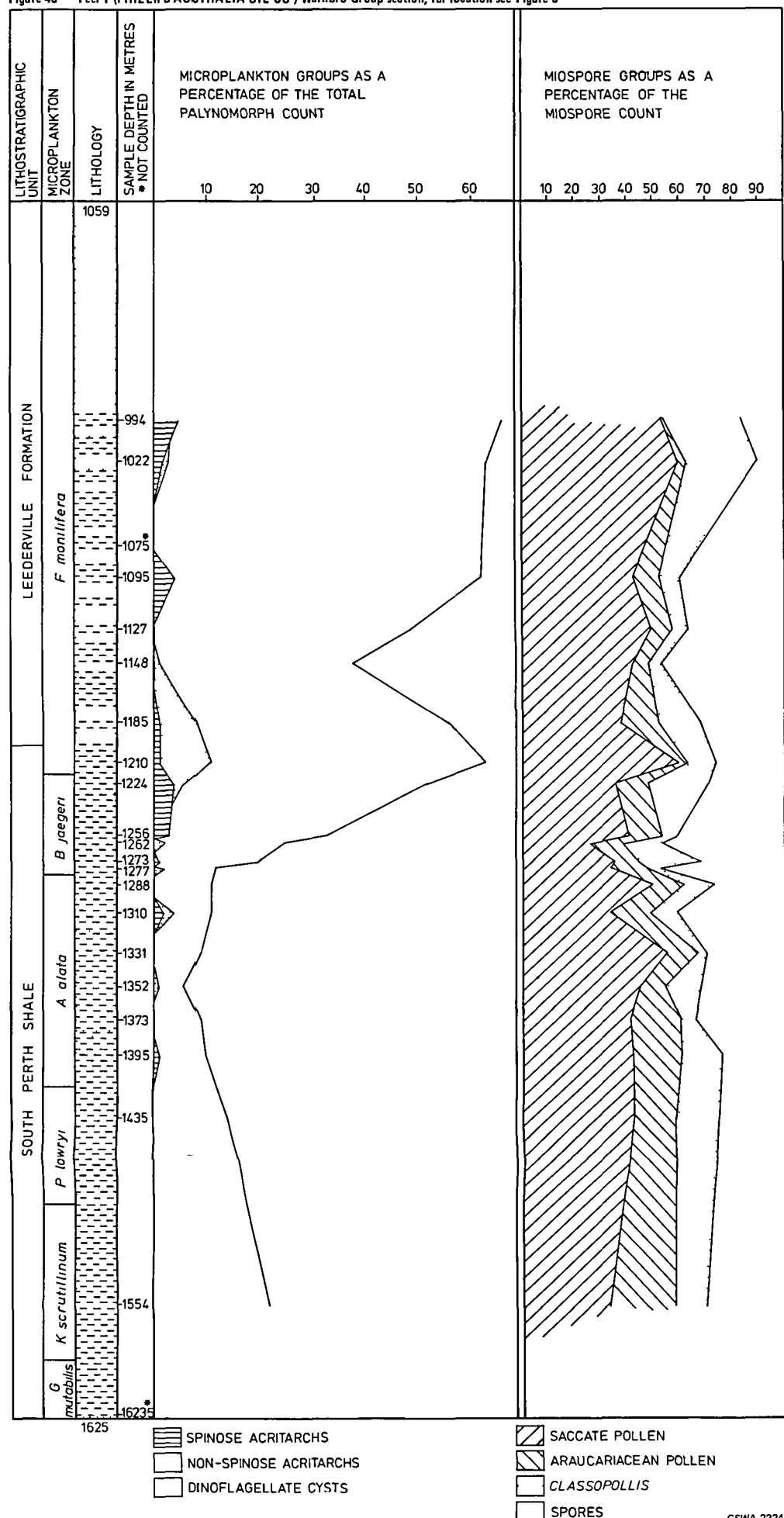


Figure 44 Warrbro 1 (WAPET), Warrbro Group section, for location see Figure 5

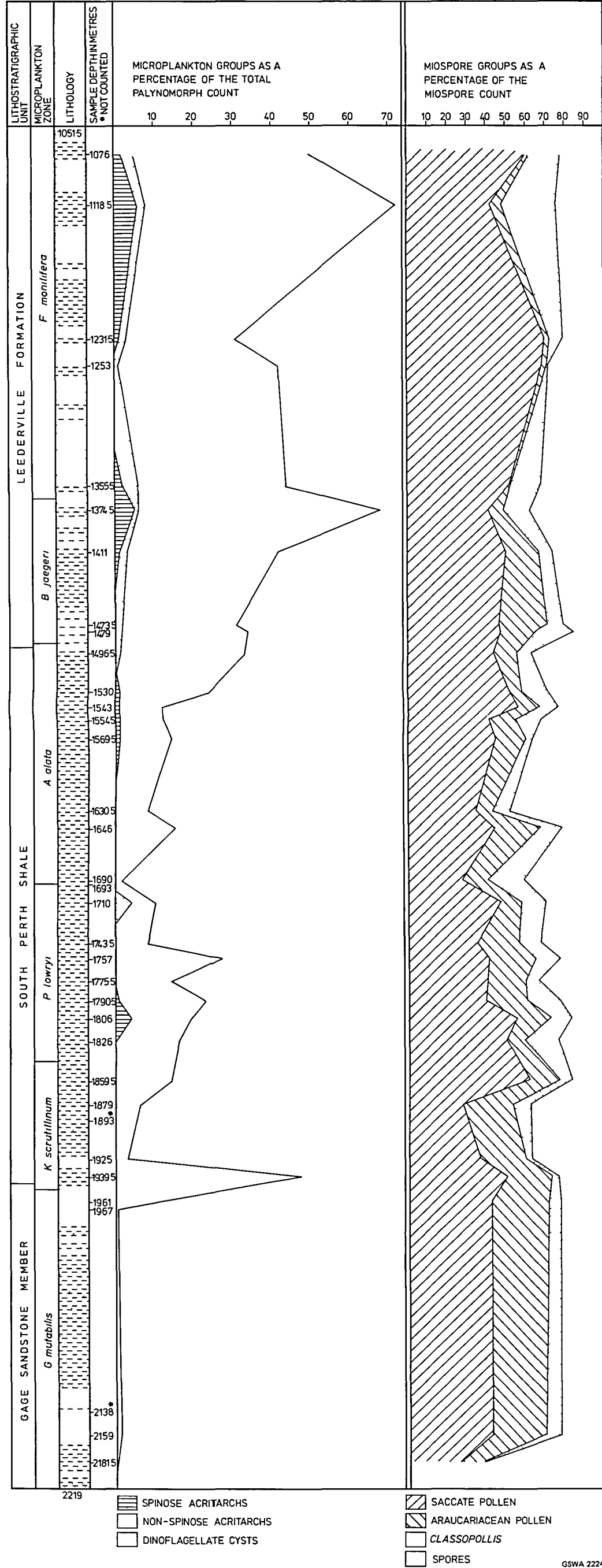


Figure 45 Gage Roads 1 (WAPET), Warrbro Group section, for location see Figure 5

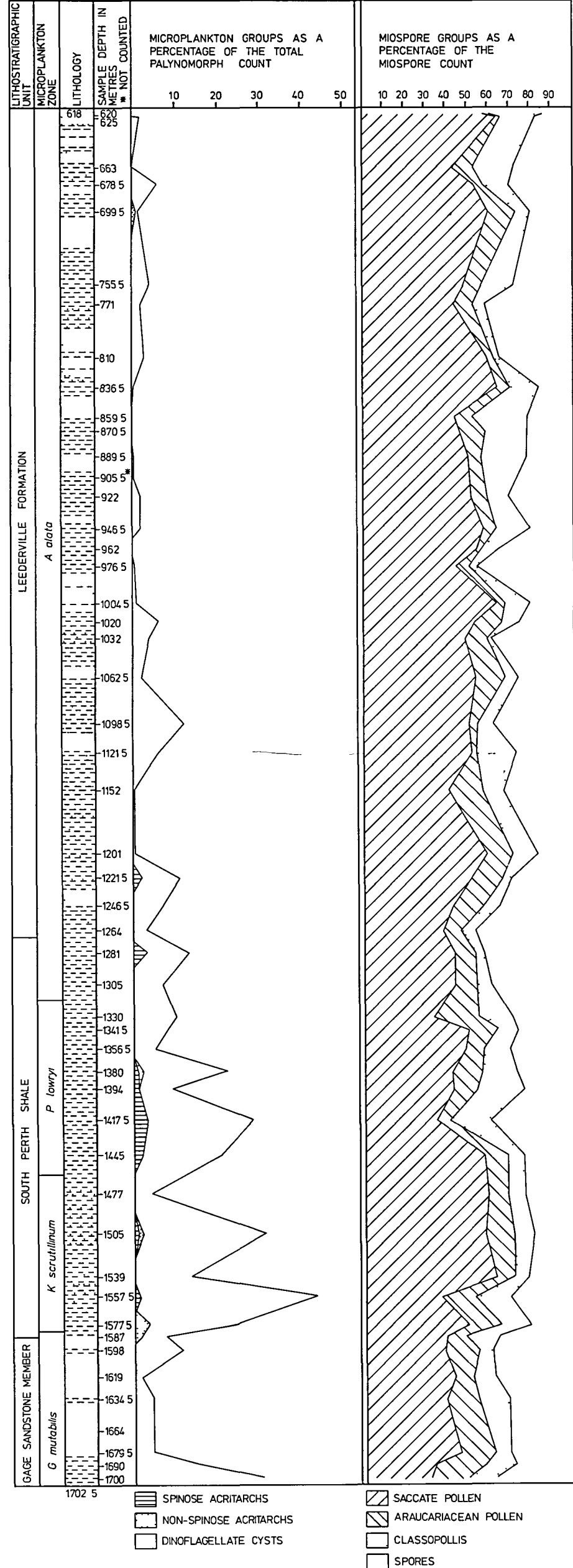


Figure 46 Withford 1, Warrbro Group section, for location see Figure 5

