Early Jurassic (Toarcian) dinoflagellate cysts from the Timor Sea, Australia

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An Early Jurassic (Toarcian) dinoflagellate cyst association is recorded as a rare component (normally <1%) of abundant and diverse palynoflora from the lower Plower Formation in the Jabiru and Skua Fields, Timor Sea, offshore north-western Australia. This represents the first detailed report of dinoflagellate cysts from the Toarcian in Australia. One genus, Skuadinium, and nine species of dinoflagellate cysts are described as new. The new species are: Luoehdea septata, Mendicodinium echinatum, Mendicodinium scabratum, Moorodinium tessellatum, Nanoceratopsis spinosa, Skuahdinium asymmetricum, Skuahdinium hirturinatum, Skuahdinium reticulatum and Susadinium? australis. The dinoflagellate cyst association is termed the Luoehdea Assemblage. Within this association, it is possible to delineate a lower Susadinium? Suite and an overlying Skuahdinium Suite. Correlations with Europe are indicative of an early Toarcian age for the Luoehdea Assemblage, and the occurrence of this association may be associated with a global eustatic base level rise at this time. The Luoehdea Assemblage is, however, markedly different to coeval marine palynoflora from the Northern Hemisphere and is interpreted as being marginal marine.

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THE PALYNOLOGICAL zonation of the Australian Mesozoic published by Helby et al. (1987) was the first attempt to provide an integrated, pan-Australian microplankton and spore-pollen zonation. Only the basic zonal framework was given in anticipation that further contributions, particularly documentation of new taxa, would occur as the zonation scheme evolved. This paper is one of a series providing the taxonomic foundation necessary to formalise the widely used unpublished subdivisions of these zones. These subzones have widespread currency within the hydrocarbon industry due to the legislative requirement for the release of technical data under the Petroleum (Submerged Lands) Act 1967. The informal subdivisions of the Helby et al. (1987) zonation have been entered into the Australian Geological Survey Organisation (AGSO) STRADTAT database. A diagrammatic update of the Helby et al. (1987) zonal scheme is presented by Foster (this volume), and will be fully described by Helby & Partridge (in prep.). This taxonomic project is an initiative of the Petroleum and Marine Division of AGSO.

This paper provides taxonomic descriptions of previously undescribed taxa from Early Jurassic (Toarcian) dinoflagellate cyst assemblages recorded in samples from the Skua and Jabiru fields and other areas in the Timor Sea (Figure 1; Appendices 1, 2; Foster, this volume). The dinoflagellate cyst associations are normally extremely sparse, with more than three quarters of samples in which they occur yielding less than 0.5% dinoflagellates as a proportion of total palynomorphs (Appendix 1). The dinoflagellate cyst associations are grouped as the Luoehdea Assemblage. Helby et al. (1987, figs. 95-X) illustrated Susadinium? australis sp. nov. one of the species described here, as Susadinium sp. A, from Enderby-1 well in the Carnarvon Basin, Western Australia. It was suggested that Susadinium sp. A is confined to the uppermost part of the Dapcodinium priscum dinoflagellate cyst Opell Zone and is associated with the basal part of the Callialasporites turbatus spore-pollen Opell Zone and the uppermost part of the Corollina torosa spore-pollen Opell Zone (Helby et al., 1987, p. 17, figs 8, 12). However, there is no
and assigned a Pliensbachian-Toarcian age.

The geology of the Skua Field was discussed by Osborne (1990). The reservoir sands in this field are located in the truncated Plover Formation, with the top of the unit becoming younger, from Toarcian in the south-west to Bathonian in the north-east (Fig. 2; see also Mory, 1988; Osborne, 1990, figs 8, 9). MacDaniel (1988a,b) outlined the geology of the Jabiru Field. The reservoir in this field includes the basal Oxfordian Wantaea spectabilis sand, overlying the truncated surface of the lower Plover Formation which was termed the Corollina torosa sand (MacDaniel, 1988a,b).

The figured specimens herein are from the lower Plover Formation in Jabiru-10, Skua-4, Skua-5, Skua-6 and Skua-7A wells (Figs 1, 2), although the assemblage has also been recorded in 23 other wells in the Timor Sea region (Appendices 1, 2; Foster, this volume). These data were collected by one of us (RH) between 1983-1998, and most recorded in open file well completion reports. The assemblage has also been recorded in wells in the Carnarvon Basin. Apart from Coojing-1 and Enderby-1 wells, these are not discussed.

**SYSTEMATIC PALYNOLOGY**

One genus and nine species of dinoflagellate cysts from the lower Plover Formation of the Timor Sea are described as new. The genera are in alphabetical order; the suprageneric classification of Fensome et al. (1993) is not used. Dimensions are in micrometres (μm). For descriptive purposes, the cyst sizes, small, intermediate and large, follow Stover & Evitt (1978, p. 5), with intermediate sized cysts having a maximum dimension of 50 to 100μm. Small and large forms are less than 50μm and over 100μm respectively. Most of the morphological terminology for dinoflagellate cysts is as used by Evitt (1985). Where appropriate, the cyst paraplate notation system used is Kofoidian, rather than the ‘Taylor-Evitt’ scheme of Evitt (1985).

References to author citations of taxa discussed may be found in Williams et al. (1998, p. 747-817). All figured specimens are housed in the Commonwealth Palaeontological Collection (CPC) of the Australian Geological Survey Organisation (AGSO), Canberra (see Appendix 3).

This study has used, almost exclusively, single and multiple grain mounts and most figured specimens are from these single species slides. All the samples are from sidewall cores. The photomicrographs in Figs 3-11 were taken using an Olympus DP10 digital camera system coupled to a Zeiss Axioskop photomicroscope, housed at AGSO. Some extraneous palynodebris, not
adherent to the figured specimens has been digitally removed in selected images.

The images in Figs 3-11 are stored in a digital database. Many more digital images exist than have been figured. Sample details, morphological data and measurements of each imaged specimen are on open file spreadsheets. The image database is accessible on the AGSO website (http://www.agso.gov.au).

Many of these new taxa have been used in unpublished reports, which are now on open file. To maximise their utility, these informal names are listed separate from the formal synonymy under ‘Previous Australian usage’. For continuity, where practical, these informal names have been retained.

**Dinoflagellate cysts**

**Luehndea** Morgenroth 1970 emend.

Palliani et al., p. 114, 115.

Type species: *Luehndea spinosa* Morgenroth 1970
Fig. 3. *Luchnidae septata* sp. nov. All specimens from sidewall cores in Skua-6 well at 2385.00m (Figs 3A-G K-N) and Skua-7A well at 2440.00m (Figs 3H-J O-P). All photomicrographs taken using plain transmitted light. The scale bar in Fig. 3P refers to all photomicrographs and is 26μm. Fig. 3O is the holotype, the remainder are paratypes. Note the septa connecting the processes, the prominent parcingular area and the epiectal archaeopyle. A, B - CPC 35107, paratype; ventral view, high and low focus respectively. C - CPC 35108, paratype; ventral view, median focus. D - CPC 35109, paratype; dorsal view, median focus. E, F - CPC 35110, paratype; ventral view, median and low focus respectively. Note the clear epiectal archaeopyle and the relatively low processes and septa. G - CPC 35111, paratype; ventral view, median focus. H - CPC 35112, paratype; dorsal view, low focus. I, J - CPC 35113, paratype; dorsal view, high and median focus respectively. K, L - CPC 35114, paratype; dorsal view, median and low focus respectively. Note the relatively low processes and septa. M, N - CPC 35115, paratype; ventral view, median and low focus respectively. O - CPC 35116, holotype; dorsal view, median focus. P - CPC 35117, paratype; ventral view, low focus.
Emended diagnosis. As emended here, the generic diagnosis incorporates the diagnosis of Bucefalo Pallianni et al. (1997a, p. 115), and is further extended to include species that have parasutural septa which connect the gonal and intergonal processes and cysts that are intermediate in size.

Comments. Luehndea is emended to accommodate forms intermediate in size and with parasutural septa. Previously, it was restricted to small forms with low, smooth parasutural ridges or crests (Bucefalo Pallianni et al., 1997a, fig. 3).

Luehndea septata sp. nov. (Figs 3A-P)

Previous Australian usage
“Epicrystal species” - Helby.

Description. A species of Luehndea which is subquadrangular to ellipsoidal in outline, and intermediate in size. Apparently two-layered, the periphraegm is extended into solid, slender, distally-pointed gonal and intergonal processes which are normally connected by thin septa. The paracingular processes, however, appear to lack vertical parasutural septa. The absence of spine and septa in the broad paracingular region imparts a characteristic indented outline or waist. The processes are straight or slightly curved. Gonal spines are present at all major parate process boundaries and may be separated by up to two, slightly shorter, intergonal spines. No intratabular processes, or other positive ornamentation, have been observed. The septa are smooth and the distal extremities are commonly concave. The autophraegm is smooth or microcubrate. The archaenype is epicrystal with the operculum typically attached ventrally.

Dimensions (μm, n=31): Min. (Mean) Max.
Overall length (incl. processes): 62 (80) 94
Length of cyst body (excl. processes): 40 (54) 67
Overall width (incl. processes): 55 (67) 77
Width of cyst body (excl. processes): 36 (44) 50
Length of processes: 7 (15) 27

The measured specimens are from sidewall core samples in Skua-5 (2646.00m), Skua-6 (2385.00m) and Skua-7A (2440.00m) wells.

Notes. This distinctive species of Luehndea is distinguished by its relatively large size compared to the other species within the genus and the prominent thin parasutural septa. These septa connect the gonal and intergonal processes, except at the paracingular (Fig. 3). Each septum is concave and smooth distally. There are no vertical paracingular septa, therefore the equatorial area is devoid of ornamentation. The septa define the paratabulation pattern, which is consistent with that determined for the genus (Below, 1990, fig. 10; Bucefalo Pallianni et al., 1997a). In a few samples the septa are suppressed; more commonly they may be reduced. The processes in Luehndea septata exhibit significant variety in length and those gonal spines associated with the two antapical paratablates are consistently the longest, often exceeding 20μm in length. These relatively long antapical processes can frequently be used as an orientational criterion. The processes close to the equatorial region are normally the smallest and these may be as short as 10μm in length. Furthermore, the intergonal spines are normally shorter than the gonal spines.

Comparison. Luehndea septata is distinguished by the high parasutural septa between the processes (see Morgenroth, 1970, pl. 9; Below, 1990, pl. 8). Luehndea cirvillae Bucefalo Pallianni et al. 1997, L. spinosa Morgenroth 1970 and L. microreticulata Bucefalo Pallianni et al. 1997 all have low, smooth parasutural crests or ridges (Bucefalo Pallianni et al., 1997a, fig. 3). Furthermore, Luehndea septata is about twice the average size of the European species (see Dimensions, above). The latter have average lengths of 36-39μm and average widths of 28-34μm (Bucefalo Pallianni et al., 1997, fig. 3).

Derivation of name. From the Latin septum, meaning wall or partition.

Holotype and type locality. Fig. 3Q, CPC 35116, Skua-7A well, sidewall core at 2440.00m.

Stratigraphical distribution. See Appendix 1 and Fig. 12.

Type species. Mendicodinium reticulatum Morgenroth, 1970

Mendicodinium echinatum sp. nov. (Figs 4A-L)

Previous Australian usage
Mendicodinium spinosum - Helby.
Hemicystodinium sp. - Morgan.

Description. A proximochorate Mendicodinium
Fig. 4. Mendicodinium echinatum sp. nov. Specimens are all from sidewall cores in Skua-6 well at 2385.00m (Figs 3A-B, F-J, L) and 2391.50m (Figs 3C-E, G-I, K). All photomicrographs were taken using plain transmitted light. The scale bar in photomicrograph 4L refers to all the photomicrographs and represents 25μm. The holotype is Fig.4H; the remainder are paratypes. Note the relatively short processes, the variable density of the spines and the epicystal archaeopyle of this species. A - CPC 35118, paratype; ventral view. (continued opposite)
of intermediate size, subcircular to ellipsoidal in dorsoventral outline. Hypocyst equal in size to, or slightly larger than, the epicyst. The hypocyst is frequently subangular in the antapical area (paraplate 1'''), and is often somewhat flattened. The cyst is normally slightly wider than long. The autophragm is moderately thick, scabrate to rugulate, bearing up to 150 nontubular, short, slender, solid, straight to recurved, distally-pointed spines. In the rarer, rugulate forms, the low-relief ornamentation is often present as short, smooth, randomly oriented ridges and scattered grana.

Dimensions (μm, n=31): Min. (Mean) Max.
Length of cyst body (excl. spines): 47 (60) 75
Width of cyst body (excl. spines): 54 (65) 78
Length of spines: 3 (6) 12

The measured specimens are from sidewall core samples in Skua-5 (2646.00m) and Skua-6 (2385.00m and 2391.50m) wells.

Comments. The wide range in the measured cyst body length of this genus is due to the compactional style, which varies markedly. Where the epicyst and the hypocyst are attached in open-lid mode, the measured height of the cyst is exaggerated (Fig. 4G). In contrast, the epicyst may be compressed into the hypocyst, giving a relatively low cyst length.

Comparison. Mendicodinium echinatum is similar to the early Toarcian Mendicodinium spinosum Bucefalo Palliani et al. 1997 in being proximochorate, bearing solid, distally-pointed, nontubular spines. No other validly described species of Mendicodinium are spine-bearing. Mendicodinium spinosum ranges from 16μm to 27μm in cyst body length (Bucefalo Palliani et al., 1997b, fig. 2) and therefore is considerably smaller than M. echinatum. The length of the cyst body in M. echinatum varies from 47μm to 75μm, hence the size difference between the two species is mutually exclusive and there appears to be no possibility of an overlap. Furthermore, the autophragm of M. echinatum is of average thickness (c. 1μm) and is rugulate to scabrate. The wall of M. spinosum is markedly thicker and,

in M. spinosum subsp. spinosum is psilate. The autophragm of M. spinosum subsp. perforatum is perforate. Mendicodinium echinatum also has a denser cover of spines than M. spinosum.

Derivation of name. From the Latin echinatus, meaning prickly.

Holotype and type locality. Fig. 4H, CPC 35125, Skua-6 well, sidewall core sample at 2391.50m.

Stratigraphical distribution. See Appendix 1 and Fig. 12.

Mendicodinium scabratum sp. nov. (Figs 5A–I)


Previous Australian usage
Mendicodinium sp. – Helby.

Description. A proximate Mendicodinium of intermediate size and ellipsoidal dorsoventral outline. The hypocyst is frequently larger than the epicyst. Paraplate 1'''' is normally slightly concave or flattened. The cyst is normally slightly wider than long. The autophragm is of moderate thickness and scabrate, microscabrate or granulate. The paracingulum may be faintly indicated on the hypocyst by a low parasutural ridge or a lineation of ornamentation. There may also be a slight inset or concavity at the paracingulum.

Dimensions (μm, n=30): Min. (Mean) Max.
Length: 41 (52) 67
Width: 43 (54) 62

The measured specimens are from sidewall core samples in Skua-5 (2646.00m) and Skua-6 (2385.00m and 2391.50m) wells.

Comments. Mendicodinium scabratum typically has a scabrate autophragm (Figs 5A–F), but microscabrate (Figs 5G–I) or granulate individuals have been recorded. The type and density of ornamentation in this species is somewhat

median focus. B - CPC 35119, paratype; ventral view, median focus. Note that the archaeopyle has not fully formed. C - CPC 35120, paratype; ventral view, low focus. D - CPC 35121, paratype; ventral view, median focus. E - CPC 35122, paratype; ventral view, high/median focus. F - CPC 35123, paratype; ventral view, low focus. G - CPC 35124, paratype; dorsal view, median focus. Note the almost completely detached epicyst (epipalea). H - CPC 35125, holotype; ventral view, high focus. I - CPC 35126, paratype; dorsal view, high focus. J - CPC 35127, paratype; ventral view, low focus. K - CPC 35128, paratype; ventral view, median focus. Note the flat antapical area. L - CPC 35129, paratype; ventral view, median focus.
Fig. 5. *Mendicodinium scabratum* sp. nov. Specimens are all from sidewall cores in Skua-5 well at 2646.00m (Figs 5A-E) and Skua-6 well at 2391.50m (Figs 5G-I). All photomicrographs were taken using plain transmitted light. The scale bar in Fig. 5I refers to all the photomicrographs and represents 25μm. The holotype is Figs 5D-F; the remainder are paratypes. Note the variably scabrate/microscabrate nature of the autophragm and the epicystal archaeopyle. A-C - CPC 35130, paratype; dorsal view, high, median and low focus respectively. A densely scabrate specimen in ‘open-lid’ preservational mode; the paracingulum is faintly indicated on the hypocyst. Note the slight concavity in the antapical region. D-F - CPC 35131, holotype; oblique ventral view, high, median and low focus respectively. A scabrate individual. G - CPC 35132, paratype; dorsal view, median focus. An elongate, microscabrate form. H - CPC 35133, paratype; ventral view, median focus. Note the microscabrate autophragm. The epicyst is significantly more cone-shaped than the hypocyst, which has a somewhat flattened antapex. I - CPC 35134, paratype; dorsal view, median focus. A biconical specimen with microscabrate autophragm.
variable (Fig. 5). Occasionally, the paracingulum is faintly indicated on the hypocyst by a low parasutural ridge or lineation of ornament (Fig. 5B) and may also be marked by a slight indentation or concavity. The relatively high size range in the cyst body dimensions is due to the occurrence of 'open-lid' preservational style (Figs 5A-C).

Comparison. Mendicodinium scabratum is similar to several members of the plexus of small Mendicodinium described from the Toarcian of central Italy by Bucciarelli Palliani et al. (1997b). These are M. bruneum, M. microscabratum and M. umbriense, none of which exceeds 38 μm in width (Bucciarelli Palliani et al., 1997b, fig. 2); they are all significantly smaller than M. scabratum. Mendicodinium bruneum has a thick autophragm and is granulate. The cyst wall of M. microscabratum Bucciarelli Palliani et al. 1997 varies from smooth to microscabrate, and the autophragm of Mendicodinium umbriense is characterised by relatively large granules. Mendicodinium reticulatum Morgenroth 1970, the genotype, is also small but it differs from M. scabratum in having a coarsely reticulate autophragm. The seven remaining validly described species of Mendicodinium listed by Williams et al. (1998, p. 397, 398) are all significantly larger in size and, incidentally, younger than M. scabratum. Mendicodinium coeruleum Bideaux 1977 and M. granulatum Kumar 1986 are both scabrate/granulate. Two Mid to Late Jurassic species Mendicodinium groenlandicum (Pocock & Sarjeant 1970b) Davey 1979 and M. quadratum Kumar 1987 have characteristically pilate autophragms. The autophragm of M. kemperi Heilmann-Clausen (in Heilmann-Clausen & Thomsen 1995) is ornamented by thin discontinuous ridges, rugole and granules. Mendicodinium microreticulatum Kumar 1986 and Mendicodinium morgenrothii Butler 1995 have micoreticulate and verrucate autophragms respectively.

Derivation of name. From the Latin scabra, meaning rough.

Holotype and type locality. Figs 5D-F, CPC 35131, Skua-5 well, sidewall core sample at 2646.00m.

Stratigraphical distribution. See Appendix 1 and Fig. 12. Mendicodinium scabratum also ranges into Aalenian/Bajocian strata which are referable to the upper Callialasporites turbatus Oppel Zone equivalent of Helby et al. (1987) (Oliver-

well at 3057.00m, see Appendix 1).

Moorodinium Backhouse 1988

Type species. Moorodinium spinatum Backhouse 1988

Moorodinium tessellatum sp. nov. (Figs 6A-P)

Description. Proximate, acavate, longitudinally elongetae dinoflagellate cysts belonging to the genus Moorodinium which are intermediate in size. The outline in dorsoventral view is highly variable around a broad subpentagonal theme. There are two basic varieties; firstly, forms with a broad, bulbous epicyst and a subconical hypocyst normally with a single antapical horn (Figs 6I-P). Secondly, individuals with rounded subangular epicysts with an apical horn or protuberance and three-sided hypocysts with a straight or concave antapex (Figs 6A-H). The latter variety may have up to four antapical horns or protuberances (Fig. 6G). Rarely, one or more lateral protuberances may also occur. The epicyst is normally longer than the hypocyst. A reticulum is formed by low smooth ridges which normally define hexagonal and quadrat fenestrae; the autophragm is otherwise smooth. Paratabulation presumably gonyaulaclean, indicated only by the paracingulum, archaeopyle and the presumed gonal position of the antapical horns or protuberances, where developed. The paracingular parasutures are marked by smooth ridges or low crests. Parasutural indented. Archaeopyle probably epicystal.

Dimensions (μm, n=33); Min. (Mean) Max.
Length of autocyst: 63 (82) 102
Width of autocyst: 46 (59) 75
Length of epicyst: 26 (47) 62
Length of hypocyst: 25 (36) 52
Epicyst as % of overall length: 37 (56) 69
Length of apical horns: 3 (6) 10
Length of antapical horns: 3 (8) 18
Diameter of fenestrae: 4 (8) 12

The measured specimens are all from a sidewall core sample in Skua-6 well at 2385.00m.

Comments. Moorodinium tessellatum is a relatively large cyst (see Dimensions, above), however using the criteria of Stover & Evitt (1978, p. 5), it is mainly within the intermediate range. The species has an extremely variable outline around a broad, subpentagonal theme (Fig. 6). The highly variable number of horns or
Fig. 6. *Mozosolimum tessellatum* sp. nov. Specimens are all from a sidewall core at 2385.00m in Skua-6 well. All photomicrographs were taken using Nomarski Interference Contrast. The scale bar in Fig. 6P refers to all the photomicrographs and represents 25μm. Fig. 6J is the holotype and the remainder are paratypes; Figs 6K, L, O are composite photomicrographs. Figs 6A-H are 'deltoid' morphotypes and Figs 6I-P are 'bulbous' morphotypes. Note the highly variable cyst outline, the prominent paracingulum, the reticulate nature of the autophragm and the apparently epicystal archaeopyle in Fig. 6M. A, B = CPC 35135, paratype; ventral view, median and low focus respectively. C = CPC 35136, paratype; dorsal view, median focus. (continued opposite)
protuberances are of similar variable sizes and shapes. They are normally subconical with distally rounded terminations but may have bluntly pointed extremities. The epicyst is commonly bulbous but may be subconical and these latter forms, which comprise the minority, are informally termed 'deltoid morphotypes' (Figs 6A-H). Most have a bulbous epicyst and typically have a single antapical horn which is assumed to be inserted at, or close to, the centre of the antapical (1‴) paraplate. These are informally referred to as 'bulbous morphotypes' (Figs 6I-P). Dinoflagellate cysts with a single horn present on the hypocozyct are extremely rare, another Jurassic example being Wannsee Cookson & Eisenack 1958. Up to four antapical horns/protuberances may be present (Fig. 6G). When four are present, they are presumably inserted at the gonial points on the 1‴ paraplate. Rarely, lateral horns or protuberances may also be present (Figs 6L, K). The horns or protuberances may be broken off in poorly-preserved material. The autophagium is relatively thin and readily folded. A relatively large, brown, subcircular accumulation body is present close to the paracingulum in many specimens. Commonly, the only indication of paratubulation is the paracingulum, which is low in height and is weakly laevorotatory; it is indicated by prominent, distally smooth ridges or crests. The paracingulum is typically low in position on the cyst and normally appears to offset or cut the mosaic-like reticulate pattern which is developed over all the autophagium. Rarely, the paracingulum is either not developed or suppressed. In one specimen (Fig. 6N), the fields forming the reticulum are rectangular to square on either side of a split which may be the principal archaephyse suture. These four-sided fields may be paracingular paraplates. The lack of a consistently developed epicystal archaephyse is intriguing. However, some specimens have a split apparently immediately anterior to, or within, the paracingulum (Fig. 6M).

The reticular units of Moorodinium tesselatum are overwhelmingly six-sided. The effect of the superpositioning of the ventral and dorsal surfaces often tends to obscure this feature. The species is assumed to have a gonyaulacalean paratabulation. The characteristic regular reticulum is reminiscent of gymnodimoid and suessiid forms. If Moorodinium tesselatum was gymnodimoid, each polygonal field defined by the reticulum would represent an amphiasial vesicle in the parent theca (Fensome et al., 1993, fig. 41). The species is not considered likely to have a suessiid affinity because paraplates arranged in latitudinal series are generally lacking and the paracingulum in Moorodinium tesselatum is relatively narrow. This may indicate that the reticulum is a feature of ornamentation, perhaps to give strength to the cyst wall, and that the fields do not necessarily represent paraplates. However, in Fig 6M, there appears to be a paracingulum indicated by two equatorial rows of four-sided fields, which may represent paraplates. This broadly resembles Suesia Morby 1975 (see Morby 1975, figs 12-15), which has an equatorial paracingulum comprising many paraplates, most of which are four-sided. However, both Below (1987, figs 43, 53) and Stover & Helby (1987, figs 21A, B) illustrated suessiid paratabulation patterns in which the paracingular paraplates are square areas represent the paracingulum, it would mean that the surrounding hexagonal fields are also reflected thecal plates. As this phenomenon in M. tesselatum is only observed on a single specimen, its suessiid affinity must be deemed equivocal at present. When first described by Backhouse (1988), the genus was deemed to be an index for lacustrine or estuarine deposition.

Comparison. Moorodinium tesselatum is superficially similar to suessiid dinoflagellate cysts in having an autophagium which is subdivided into numerous fields. Moorodinium, however, is significantly longer than the five suessiid genera, apparently has an epicystal archaephyse and the fields are more numerous and possibly do not reflect paratabulation (Bassetfalo Palliani & Riding, 1997, fig. 7). Moorodinium

D - CPC 35137, paratype; ventral view, median focus. An elongate specimen. E - CPC 35138, paratype; ventral view. A large, 'deltoid' specimen. F - CPC 35139, paratype; ventral view; median focus. G - CPC 35140, paratype; ventral view; median focus. Note the small, regular antapical horns at gonial points around the antapical (1‴) paraplate. H - CPC 35141, paratype; dorsal view; low focus. I - CPC 35142, paratype; dorsal view, low focus. Note the hexagonal reticulum. J - CPC 35143, holotype; dorsal view, low focus. Note the regular, hexagonal reticulum. K - CPC 35144, paratype; dorsal view. Note the lateral horns or protuberances. L - CPC 35145, paratype; ventral view. Note the mid lateral horn/protuberance on the epicyst. M - CPC 35146, paratype; right lateral view, median focus. Note the distinctly quadrilateral fields along the possibly epicystal archaephyse. N - CPC 35147, paratype; dorsal view, low focus. O - CPC 35148, paratype; ventral view. A bilaterally symmetrical specimen. P - CPC 35149, paratype; ventral view, low focus. Note the elongate, subrectangular outline.
rassellatum has some similarities with representatives of Cassidulosaeraeida Davey 1969 and Valensiella Eisenack 1963, which may have fine and irregularly reticulate autophaguls, are ovoidal and have apical archaephyles. Scintillacassis Gocht 1964 emend. Preuss 1989 also has a reticulate autophagul, yet is ovoidal, has much thicker autophagul and has a combination apical/precingular archaephyile.

Derivation of name. From the Latin tessellatum, meaning mosaic.

Holotype and type locality. Fig. 6I, CPC 35143, Skua-6 well, sidewall core sample at 2385.00m.

Stratigraphical distribution. See Appendix I and Fig. 12.

Nannoceratopsis Deflandre 1939 emend.

1939 Nannoceratopsis Deflandre, p. 183.
1992 Nannoceratopsis Deflandre 1939 emend. Poulsen, p. 44.

Type species. Nannoceratopsis pellucida Deflandre 1939.

Emended diagnosis. The emended generic diagnoses of Piel & Evitt (1980) and Poulsen (1992) are accepted but the genus is further emended here to include species which are proxiomorphic and/or have parasutural crests.

Comments. The genus Nannoceratopsis is emended here to accommodate proxiomorphic forms which have parasutural crests. This is due to the discovery of Nannoceratopsis spinulosus sp. nov. (see below), which bears numerous short processes, most specimens being proxiomorphic and having parasutural crests. Previously, the genus was restricted to proximate forms (see Preuss, 1989, fig. 3; Buceta-Pallí & Riding, 1998, fig. 9). The processes in Nannoceratopsis spinulosus sp. nov. exhibit significant variation in length. Most are less than 10% of the minimum diameter of the cyst body. However the processes frequently exceed 10%, especially the antapical spines close to the paired dorsal and ventral horns, therefore the diagnosis of Nannoceratopsis needed to be formally emended to include proximate horns (Sarjeant, 1982, p. 392).

Nannoceratopsis spinulosus sp. nov. (Figs 7A-F, I)

Previous Australian usage
Nannoceratopsis spinulosus - Helby.

Description. An acavate, relatively elongate species of Nannoceratopsis, intermediate in size and having two prominent, distally tapering, antapical horns of essentially similar size. The horns are distally pointed or rounded. The antapex is consistently markedly concave due to the presence of the large, subequall antapical horns. Paratulangium is well developed and is devoid of ornamentation on the paratulangium surfaces, although high crests, surmounted by spines, are developed on, or close to, the anterior and posterior parasutures. The autophagul varies in thickness. Numerous short, solid, distally-pointed, thorn-shaped processes arise from the parasutures bordering the sagittal band, surmounting parasutural crests in the dorsal, ventral and antapical areas of the hypostulangium, on the paracircular parasutures and on the hypostulangium. The processes at and close to the distal parts of the antapical horns are frequently significantly longer than the spines elsewhere on the cyst. Spines may also be scattered in nonstulangular positions on

Fig. 7. Nannoceratopsis spp. All specimens are from a sidewall core at 1790.00m in Jabiru-10 well. The photomicrographs were all taken using plane transmitted light. The scale bar in Fig. 7I refers to all the photomicrographs and represents 25μm. 7A-F, I - Nannoceratopsis spinulosus sp. nov. Fig. 7I is the holotype, the remainder are paratypes. Figs. 7A, E are composite photomicrographs. Note the prominent paratulangium and the spinose nature of the cyst. A - CPC 35150, paratype; left lateral view. A form with a particularly prominent paratulangium. B - CPC 35151, paratype; right lateral view, median focus. C - CPC 35152, paratype; right lateral view, low focus. A damaged specimen, lacking the relatively small hypostulangium. D - CPC 35153, paratype; right lateral view, low focus. A relatively broad specimen. E - CPC 35154, paratype; oblique ventral view. Note the prominent paratulangium and the spinose nature of the cyst. F - CPC 35155, paratype; right lateral view, median focus. G - CPC 35156, holotype; right lateral view, median focus. Note the prominent, regular spines in the sagittal areas. G, H - Nannoceratopsis sp. A. Note the relatively small antapical horns and the weakly concave antapical margin. G - CPC 35157, left lateral view, high focus. H - CPC 35158, left lateral view, high focus. Note that the entire hypostulangium has broken off, presumably due to mechanical damage.
the lateral parts of the hypocyst.

**Dimensions (μm, n=35):** Min. (Mean) Max.
Length of cyst body (excl. processes): 54 (67) 82
Width of cyst body (excl. processes): 30 (46) 65
Height of paracingulum: 7 (8) 12
Length of processes: 1 (3) 15

The measured specimens are all from a sidewall core sample in Jabiru-10 well at 1790.00m.

**Comments.** *Nannoceratopsis spinosus* is the only species of this genus which is proximochorate. The small, relatively densely packed processes around the sagittal band and the prominent paracingulum, distinguish this taxon. The majority of the processes are parasutural and are typically centred around the sagittal band on the hypocyst, on or close to the paracingular parasutures and on the epicyst (Fig. 7). Because of the extremely small size of the epicyst, resolution of the precise location of the epicystal spines is difficult. The processes at the distal tips of the antapical horns are frequently up to 15μm, which is three times as long as the remaining spines. The majority of the processes are normally 2-4μm long. The parasutural crests developed on the hypocyst adjacent to the sagittal band are surmounted by processes. The processes surrounding the anterior paracingular parasuture in the epicyst have a radiating pattern and often appear to form a corona (Fig. 7E). The nontubular processes on the hypocyst vary in density but are normally sparse. The surfaces of the singular paraplates may be devoid of processes but are commonly microgranulate, scabrate or smooth. The paracingulum is consistently prominent, broad and slopes antapically from dorsal to ventral in lateral view (Fig. 7A).

**Comparison.** *Nannoceratopsis spinosus* differs from all other species of the genus in having parasutural and nontubular processes.

**Derivation of name.** From the Latin *spinosus*, meaning thorny.

**Holotype and type locality.** Fig. 7I, CPC 35156, Jabiru-10 well, sidewall core sample at 1790.00m.

**Stratigraphical distribution.** See Appendix 1.

**Nannoceratopsis sp. A (Figs 7G-H)**

**Description.** A relatively elongate form of *Nannoceratopsis* which is characterised by small antapical horns which engender a weakly concave antapical margin. The dorsal and ventral sides are straight to weakly convex. These almost straight antapical, dorsal and ventral sides of the hypocyst, together with the apical side of the hypocyst, give this morphotype a characteristic rounded triangular outline in lateral view. The autophragm is scabrate or microscabrate.

**Dimensions (μm, n=3):** Min. (Mean) Max.
Length: 65 (70) 79
Width: 55 (56) 57

The measured specimens are all from sidewall core 2 in Jabiru-10 well at 1790.00m.

**Comments.** Insufficient material of this species has been recovered for a formal description.

**Comparison.** This morphotype is most similar to *Nannoceratopsis symmetrica* Buccefalo Palliani & Riding 2000. However, the latter is significantly smaller and has a more robust autophragm.

*Nannoceratopsis* sp. A is similar to *Nannoceratopsis raunsgaardii* Poulsen 1996, however the latter is not longitudinally elongate and thus is much wider in lateral view than *Nannoceratopsis* sp. A. *Nannoceratopsis raunsgaardii* is also characterised by sharply distally pointed antapical horns; *Nannoceratopsis* sp. A, by contrast, has blunt, rounded terminations to the antapical horns. The relatively small, rounded *Nannoceratopsis evae* Prauss 1989 also has reduced antapical horns engendering a subrectangular lateral hypocystal outline. However, *N. evae* is characterised by a differentiated or coarsely reticulate autophragm.

*Nannoceratopsis triangulata* Prauss 1987 is also similar in overall shape to *Nannoceratopsis* sp. A, but has pointed antapical horns and the ventral horn is reduced. Furthermore, *Nannoceratopsis* sp. A is markedly smaller than *Nannoceratopsis triangulata* and has significantly thicker autophragm.

**Stratigraphical Distribution.** See Appendix 1.

**Skuadinium** gen. nov.

**Type species.** *Skuadinium bturbinatum* sp. nov.

**Diagnosis.** Acuate, proximate, biconical or sub-biconical dinoflagellate cysts, intermediate in size with single apical and antapical horns. Sub-biconical forms may be distorted by two hypocystal protuberances at and below the

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**Appendix 1.**

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**References.**

paracingulum on the ventral side. Autophragm smooth, or with low-relief ornamentation; entire or reticulate. Ornamentation nontabular to occasionally partially tabular. Dark, subcircular accumulation bodies are generally present in the paracingulum region. Paratabulation generally indicated by the paracingulum and parasulcus. Archaeopyle type uncertain, possibly epicystal.

Comparison. In outline, Skuadinium resembles several Triassic and Jurassic genera. *Kalyptea* Cookson & Eisenack 1960 has an anterior intercalary archaeopyle and is normally kalyptate. The Early Jurassic *Liasidium* Drugg 1978 has a large single parasulc plate anterior intercalary archaeopyle and prominent shoulders on the epicyst and hypocyst. The archaeopyle of *Rhactogonyaulax* Sarjeant 1966 emend. Harland et al. 1975 is a distinctive combination (apical/anterior intercalary type and *Sverdrupiella* Bujak & Fisher 1976 is cavit.

Derivation of name. The genus Skuadinium is named after the Skua oilfield in the Timor Sea.

*Skuadinium biturbinatum* sp. nov. (Figs 8A-P)

Previous Australian usage
*Skuadinium* sp. – Helby.

Description. A species of *Skuadinium* which is longitudinally elongate and largely symmetrical about the paracingulum and parasulcus. Apical and antapical horns relatively short and broad with blunt or rounded distal terminations. Autophragm thin, smooth, microscabrate or microgranulate. The markedly low to low-relief ornamentation of this form is indented. Discontinuous lines of low-relief ornamentation sometimes present, generally on the apical and antapical horns. Archaeopyle type unknown, possibly epicystal.

Dimensions (μm, n=28): Min. (Mean) Max.
Length: 55 (74) 86
Width: 39 (54) 63

The measured specimens are from sidewall core samples in Jabiru: 10 (17900.00m), Skua-5 (2646.00m), Skua-6 (2385.00m) and Skua-7A (2440.00m) wells.

Comments. The outline is variable because the thin autophragm readily folds and tears. Additionally, the cyst is not always dorsoventrally flattened and may present in different orientations.

The paracingulum and parasulcus are usually the only indications of paratabulation, but short lineations, which may be paratabular, often occur close to the distal parts of the horns. A definite archaeopyle has not been observed; however, vague indications of an epicystal excavation are present.

Comparison. *Skuadinium biturbinatum* differs from *S. asymmetrical* sp. nov. in being biconical and lacking reticulate surface features, and from *S. reticulum* sp. nov. in lacking a reticulate autophragm.

Derivation of name. From the Latin prefix bi-, meaning two or double, and *turbinatus*, meaning conical or top-shaped.

Holotype and type locality. Fig. 8M, CPC 35177, Skua-6 well, sidewall core sample at 2385.00m.

Stratigraphical distribution. See Appendix I and Fig. 12.

*Skuadinium asymmetrical* sp. nov. (Figs 9A-I)

Previous Australian usage
Skuaceratops – Helby.

Description. Representatives of *Skuadinium* which have a reticulate to occasionally scabrate autophragm. The horns are highly variable; they range from relatively short to markedly elongate and may be pointed or rounded distally. In lateral view, the dorsal sides of the epicyst and hypocyst are convex. The ventral side of the epicyst is, however, generally highly concave, while the ventral side of the hypocyst is normally straight to convex, although concave close to the antapical horn. The main reason for the asymmetrical nature of this form in lateral view is that the ventral side of the cyst is inflated. The ventral precingular, and particularly the postcingular paraplates, are markedly inflated close to the paracingulum, resulting in the parasulcus being deeply indented. Most specimens have a relatively large, subcircular brown accumulation body within the cyst. The paracingulum may sometimes be faintly indicated by autophragmal folds. An epicystal archaeopyle is suggested by relatively consistent tearing along the anterior margin of the paracingulum.

Dimensions (μm, n=25): Min. (Mean) Max.
Length: 56 (72) 95
Width: 36 (50) 62
Fig. 8. *Skuadinium biturbinatum* sp. nov. The specimens are from sidewall cores in Jabiru-10 well at 1790.00m (Figs 8I-L), Skua-5 well at 2646.00m (Fig. 8P) and Skua-6 well at 2385.00m (Figs 8A-H, M-O). All photomicrographs were taken using Nomarski Interference Contrast. The scale bar in Fig. 8P refers to all the photomicrographs and represents 25μm. The holotype is Fig. 8M; the remainder are paratypes. Note the biconical shape, the blunt, rounded distal terminations of the apical and apical horns, the relatively thin, smooth autosphragm and the apparent lack of a consistent archaeopyle. A - CPC 35167, paratype; dorsal view, high focus. B - CPC 35168, paratype; dorsal view, low focus. C - CPC 35169, paratype; (continued opposite)
Width of fenestrae: 1 (2) 5
The measured specimens are from sidewall core samples in Skua-6 (2385.00m) and Skua-7A (2440.00m) wells.

Comments. The asymmetry of the epicyst in lateral view, caused by extension of the ventral side is diagnostic of this species (Fig. 9). The shape of the epicyst, and often the hypocyct, in lateral view may impart a lateral outline superficially similar to a lateral view of *Namoceratopsis* (see Piel & Evitt, 1980). However, the profound differences in paratabulation distinguish *Skuadinium asymmetricum* from species of *Namoceratopsis*. A definite archaeopyle has not been observed, but incomplete splits immediately anterior of the paracingulum strongly suggest that the archaeopyle type is epicystal (Fig. 9F).

Comparison. *Skuadinium asymmetricum* differs from the other species of the genus in its distinctively asymmetrical outline in lateral view and its reticulate autophagm. It is most similar to *S. reticulatum* sp. nov., but lacks its symmetrical biconical shape, and has more variable ornament and commonly rounded horn extremities.

Derivation of name. From the marked asymmetry of the cyst in lateral view.

Holotype and type locality. Figs 9H-I, CPC 35166, Skua-6 well, sidewall core sample at 2385.00m.

Stratigraphical distribution. See Appendix 1 and Fig. 12.

*Skuadinium reticulatum* sp. nov. (Figs 10A-I)

Previous Australian usage
*Skuadinium reticulatum* – Helby.

Description. *Skuadinium* with a strongly reticulate autophagm. The apical and antapical horns are subequally developed and have pointed distal terminations. The fenestrae are frequently longitudinally elongate and appear to be arranged in apical-antapical lineations. A prominent accumulation body is normally present in the vicinity of the paracingulum. Paratabulation indicated only by the paracingulum and paralocular. The former is marked in most specimens by prominent smooth ridges. A consistently developed archaeopyle has not been observed, but consistent tearing along the anterior surface of the paracingulum suggests that it is possibly epicystal.

Dimensions (μm, n=25): Min. (Mean) Max.
Length: 59 (81) 99
Width: 32 (50) 63
Diameter of fenestrae: 1 (3) 8
The measured specimens are from sidewall core samples at 2385.00m and 2391.50m in Skua-6 well.

Comments. The apical and antapical horns are sometimes slightly recurved (Fig. 10A).

Comparison. The prominent reticulation characterises *Skuadinium reticulatum*. It differs from *S. asymmetricum* in its spindle shape, and in lacking ventral inflations in the region of the paracingulum. It is similar to *Scrinicocasis weberi* Gocht 1964 in its strongly reticulate autophagm. However, *S. weberi* is ovoid in outline, has a thicker, differentiated autophagm and a consistently developed polyplacoid combination (apical/precingular) archaeopyle (Below, 1990).

Derivation of name. From the Latin reticulatus meaning netted or net-like.

Holotype and type locality. Figs 10G-H, CPC 35187, Skua-6 well, sidewall core sample at 2391.50m.

Stratigraphical distribution. See Appendix 1 and Fig. 12.

*Susadinium* Dörhöfer & Davies 1980

Type species. *Susadinium scroboides* Dörhöfer & Davies 1980

Comments. The paratabulation pattern of *Facetadinium* Bjaerke (1980) and *Susadinium* by oblique dorsal view, low focus. D - CPC 35170, paratype; ventral view, median focus. A relatively broad specimen. E, F - CPC 35171, paratype; dorsal view, high and low focus respectively. An almost perfectly biconical form. G - CPC 35172, paratype; ventral view, high focus. Note the prominent laevorotatory paracingulum. H - CPC 35173, paratype; oblique ventral view, median focus. I, J - CPC 35174, paratype; left lateral view, median and low focus respectively. An elongate example. K - CPC 35175, paratype; ventral view, low focus. This specimen is unusually squat. L - CPC 35176, paratype; oblique ventral view, median/low focus. M - CPC 35177, holotype; dorsal view, low focus. N - CPC 35178, paratype; oblique ventral view, median focus. O - CPC 35179, paratype; dorsal view, median focus. P - CPC 35180, paratype; left lateral view, median focus. Note the curved antapical horn and the prominent paracingulum.
Fig. 9. *Skuadrinium asymmetricum* sp. nov. Specimens are all from sidewall cores in Skua-6 well at 2385.00m (Figs 9A, D-I) and Skua-7A well at 2440.00m (Figs 9B-C). All photomicrographs were taken using plain transmitted light. The scale bar in Fig. 9I refers to all the photomicrographs and represents 25μm. Figs 9H-I are of the holotype; the remainder are paratypes. Note the asymmetrically biconical shape, the pointed distal terminations of the apical and apical horns, the finely reticulate autophragm, the prominent accumulation body within the cyst and the lack of a consistent archaeopyle. A - CPC 35159, paratype; right lateral view, low focus. B - CPC 35160, paratype; right lateral view, high focus. C - CPC 35161, paratype; left lateral view, low focus. D - CPC 35162, paratype; right lateral view; median focus. E - CPC 35163, paratype; left lateral view; median focus. F - CPC 35164, paratype; left lateral view, median focus. G - CPC 35165, paratype; right lateral view, median focus. H, I - CPC 35166, holotype; right lateral view, median and low focus respectively.
Below (1987) is accepted. However, the synonymy of *Susadinium* with *Dodekovaia* proposed by Below (1987) is not followed here. The holotype of *Dodekovaia syzygia* Dörfler & Davies 1980 is referable to *Aptodinium* (see Stover & Williams, 1987, p. 87).

**Susadinium? australis** sp. nov. (Figs 11A-P)

1987 *Susadinium* sp. A; Helby *et al.*, figs 9S-X.
1996 *Susadinium* sp. A of Helby *et al*. 1987;
Burger, pl. 9, figs S-U.

Previous Australian usage

*Susadinium* sp. – Helby.

**Description.** Small, with a rounded pentagonal to subovoidal outline. Autophragm relatively thick, smooth, scabrate to microreticulate, frequently with low, smooth, anastomosing ridges. Prominent intratabular, rounded, commonly inflated protuberances are present in the precingular, postcingular and antapical paraplate series. These protuberances are surmounted by rounded to quadrate/rectangular periphragmal extensions which may be low ridges or relatively high and septate in form. The distal edges of the ridges are smooth to echinate and their height varies between specimens and also within individuals. There is a marked tendency for the protuberances and ridges/septa to be better developed in the precingular and postcingular paraplate series. Furthermore, they are typically located close to the paracingulum. Occasionally, low relief or negative ornamentation in the paracingulum partially indicate the paracingular paraplate boundaries. Parasulcus apparently not subdivided. Archaeocyte combination, apparently involving the apical and anterior intercalary paraplate series; compound operculum.

**Dimensions (µm, n=31);** Min. (Mean) Max.
Length incl. operculum: 38 (45) 53
Length excl. operculum: 31 (44) 53
Width: 31 (42) 56
Maximum height of protuberances: 2 (4) 7

The measured specimens are from sideway core samples in Skua-3 (2402.50m) and Skua-4 (2366.00m) wells.

**Comments.** The most striking morphological feature of this species is the rounded, intratabular protuberances surmounted by ridges or septate periphragmal extensions. These are best developed in the precingular and postcingular paraplate series. However, low, reduced protuberances and ridges/septa may be present in the antapical series. These vary markedly in shape according to the size of the paraplate. In smaller paraplates, such as 1", the protuberances may be suppressed. The apparent separation of the periphragm and endophragm where the ridges and/or septa emerge on the protuberances means that the protuberances are floored by autophragm proximally. Normally, the ridges/septa are echinate (and open) distally. However, they may also be distally smooth (Fig. 11). In the precingular and postcingular paraplate series, the protuberances and ridges/septa are present immediately adjacent to the paracingulum (Fig. 11). This leaves up to 50% of the paraplate entirely free of major ornamentation. Such eccentricity of intratabular features is extremely unusual among dinoflagellate cysts; normally features like these are located in the centres of paraplates. In the precingular paraplate series, the periphragmal extensions may be inserted close together, forming a row (Figs 11A-C). The ridges/septa vary in height within assemblages, specimens and in single paraplates, giving a dissected and incomplete appearance (Figs 11G-J). Frequently the side of the ridge/septal complex is reduced in height toward the paracingulum (Figs 11H-I, M). This feature is comparable to the septa which are open toward the paracingulum in *Amphorula* Dodekovaia 1969. However, this ridge/septal variability in *S? australis* is not as regular as in *Amphorula*. In some specimens of *S? australis*, the periphragmal extensions may be highest toward the paracingulum. The protuberance on the 2" paraplate may be significantly larger and more bulbous than the 1" paraplate, engendering an asymmetrical outline in dorsoventral view (Fastone *et al.*, 1993, fig 123). This prominent feature can often be a useful orientational criterion. Furthermore, a crack close to the 1"/2" parasutur is often present (Figs 11H, L-O); this may be a result of mechanical damage along a line of weakness. The intratabular protuberances are largely parallel-sided in the Timor Sea specimens (Fig. 11) but are more rounded in the Carnarvon Basin specimens (Helby *et al.*, 1987, figs 95-X). Also, the latter appear to have aligned, coalescing low relief elements rather than complete ridges/septa.

**Susadinium? australis** is tentatively attributed to *Susadinium* because the archaeocyte is a combination, apparently involving the apical and anterior intercalary paraplate series. Unequivocal representatives of *Susadinium* have single
Fig. 10. *Skuadinium reticulatum* sp. nov. Specimens are all from sidewall cores in Skua-6 well at 2385.00m (Fig. 10f) and 2391.50m (Figs 10a-h). All photomicrographs were taken using plain transmitted light. The scale bar in Fig. 10f refers to all photomicrographs and represents 25μm. Figs 10g, h are the holotype; the remainder are paratypes. Note pointed terminations of apical and antapical horns, strongly reticulate autophragm and large accumulation bodies in the cysts. This species possibly has an epicystal archaeopyle (Figs 10c, e). A - CPC 35181, paratype; left lateral view, low focus. Note recurved nature of apical and antapical horns. B - CPC 35182, elongate paratype; ?ventral view, high focus. C - CPC 35183, unusually squat paratype; (continued opposite)
Fig. 11. *Susadinium? australis* sp. nov. All specimens from a sidewall core at 2366.00m in Skua-4 well. The photomicrographs were all taken using plain transmitted light. The scale bar in Fig. 11P refers to all the photomicrographs and represents 25 μm. Figs 11M-O are the holotype; the remainder are paratypes. Note apparently apical intercalary archaeopyle and prominent intratabular protuberances in precingular and postcingular paraplate series. A, B - CPC 35189, paratype; dorsal view, median and low focus respectively. Unusually, this lacks an equatorial constriction and low intratabular protuberances. C - CPC 35190, paratype; ventral view, low focus. Subcircular form with low protuberances. D - CPC 35191, relatively elongate paratype; ventral view, median focus. E - CPC 35192, paratype; ventral view, low focus. Note prominent equatorial constriction. F - CPC 35193, paratype; ventral view, low focus. Elongate individual; note the antapical asymmetry. G - CPC 35317, paratype; dorsal view, median focus. This lacks clear antapical asymmetry. H - CPC 35318, paratype; ventral view, median focus. I, J - CPC 35319, paratype; dorsal view, high and low focus respectively. K - CPC 35320, paratype; ventral view, low focus. L - CPC 35321, paratype; ventral view, median focus. M, N, O - CPC 35322, holotype; dorsal view, high, median and low focus respectively. Well-preserved, with prominent protuberances and a strong paracingular concavity. Note the mid antapical crack in the autophragm. P - CPC 35323, relatively broad paratype; ventral view, median focus.

(continued from opposite) Oblique dorsal view, median focus. D - CPC 35184, typical regularly biconical paratype; left lateral view, high focus. E - CPC 35185, paratype; left lateral view, median focus. F - CPC 35186, paratype; ventral view, median focus. G, H - CPC 35187, holotype; left lateral view, median and low focus respectively. Large, relatively broad, with a slightly recurved antapical horn. I - CPC 35188, paratype, dorsal view, low focus. Regularly biconical, with a sharply pointed apical horn.
paraplate anterior intercalary archaeopyle (type 1) (Fensome et al., 1993, fig. 123). Individuals of S? australis where the operculum is missing are typically round quadrangular (Figs 11A-C). The outline is normally slightly longitudinally elongate, but may be equant or, rarely, wider than long (Fig. 11; see Dimensions, above). A detailed analysis of the principal archaeopyle suture is problematic as the autophragm in this part of the cyst is thin and easily folded (Fig. 11). The paratabulation formula is 3"5, 3a, 7", Xc, 5"5, 2"5, Xs.

Comparison. Susadinium? australis differs from other species of Susadinium in its combination archaeopyle and the rounded quadrangular/rectangular intratabular protuberances in the precingular and postcingular areas which are open distally. The antapical paraplates bear only slightly inflated protuberances, unlike Susadinium scrofoideus. The six previously described species of the genus do not have protuberances surmounted by ridges or crests. They all have rounded, distally closed intratabular features except Susadinium? piuna (Below 1987) Lentin & Williams 1989 and S? tabulatum (Below 1987) Lentin & Williams 1989, which have parasutural crests and negative penitabular ornamentation respectively. Susadinium delinense (Below 1987) Lentin & Williams 1989 and S. fascium (Bjaerke 1980) Lentin & Williams 1985 have granulate and baculate autophragm respectively. The thick-walled Susadinium incertense (Below 1987) Lentin & Williams 1989 is relatively elongate and subangular in outline. The Late Jurassic Tringadinium Riding & Helby (this volume) is similar in outline and general morphology to S? australis. However, Tringadinium has an apical archaeopyle with a simple operculum and a different paratabulation pattern, with four apical, six precingular and six postcingular paraplates. Horologinella Cookson & Eisenack 1962 is similar to S? australis in shape and apparent archaeopyle style. However, Horologinella is much more deeply incised equatorially, its principal archaeopyle suture is circular, not angular (Backhouse, 1988, pl. 48, figs 2, 4) and it lacks intratabular protrusions.

Derivation of name. The specific name refers to the Southern Hemisphere location.

Holotype and type locality. Figs 11M-O, CPC 35322, Skua-4 well, sidwall core at 2366.00m.

Stratigraphical distribution. Susadinium? australis is recorded from the Tororian of the Timor Sea (Appendix 1 and Fig. 12.) and from Endersby-1 well in the Carnarvon Basin (Helby et al., 1987).

BIOSTRATIGRAPHY

These distinctive, low diversity, dinoflagellate cyst associations in the Timor Sea constitute a biostratigraphical marker of regional significance. They also appear to represent a base level rise. Dinoflagellate cysts are generally absent from the overlying and underlying successions, and this restricted microplankton flora is designated the Luwhindea Assemblage (Fig. 12). Two dinoflagellate cyst suites are recognised within this assemblage. The lower Susadinium? Suite is distinguished by the presence of Luwhindea septata and Susadinium? australis and the absence of Skuadinium spp. (Fig. 12). The overlying Skuadinium Suite is characterized by the occurrence of Moorodinium tessellatum, Skuadinium spp. and S? australis. Moorodinium and Skuadinium are considered to reflect marginal marine to lacustrine depositional environments (see below). However, most Skuadinium Suite samples also exhibit more cosmopolitan genera such as Luwhindea, Mendicodium etc., suggesting they may have been washed into more open marine palaeoenvironments. Luwhindea septata and Mendicodium spp. range below the Susadinium? Suite, while Mendicodium scabrum and Namoceratopsis spp. are present above the Skuadinium Suite (Fig. 12; Appendix 1).

These distinctive dinoflagellate cyst assemblages are normally minor components of abundant and diverse palynofloras (Appendix 1). Within the microplankton category, acanthomorph acritarchs are usually more prominent (up to 15% of total palynomorphs), with rare prasinophytes and relatively consistent occurrences of the freshwater alga Botryococcus. The Luwhindea Assemblage is associated with the Kekryphalospora disticta (spore-pollen) Oppel Zone (Helby & Partridge, in prep). Kekryphalospora disticta Fenton & Riding 1987 is a locally stratigraphically diagnostic taxon and occurs most consistently in the Susadinium? Suite. The spore-pollen associations are dominated by Corollina spp., which increases in prominence down sequence (21.5%-86% of total palynomorphs). Dictyophyllidites spp. are also prominent and generally decrease in prominence down section; 66%-7%. However, there are several anomalous high counts of Dictyophyllidites spp. approximately corresponding with the top of the
Bucefalo Palliani et al. (1997b) reviewed the occurrence of *Mendicodinium* and Bucefalo Palliani & Mattioli (1998, fig.5) indicated that *Mendicodinium* is an important element in early Toarcian assemblages from the Tethyan Realm. Therefore, by comparison with northern and southern Europe, the overlapping ranges of the genera *Luehndeia* (key range top) and *Susadinium*? (key range base), the *Luehndeia* Assemblage is of early Toarcian age. It seems likely that the eustatic rise represented by this marine association reflects the early Toarcian global eustatic increase (Haq et al., 1987). The records of *Susadinium* sp. A by Helby et al. (1987) from Enderby-1 well and by Burger (1996) from offshore Western Australia represent the only other published records of Toarcian to Aalenian dinoflagellate cysts from Australia.

The *Luehndeia* Assemblage has been recorded from Coojong-1 well in the Carnarvon Basin at 1663.40m and 1652.50m. Howe (2000) interpreted the calcareous nannofossil assemblages from these samples as NJ5b/NJ6 and NJ6 respectively. He assigned an early Toarcian age on the basis of correlation with the Boreal nannofossil zonation of Bown et al. (1988).

Helby et al. (1987, p. 17, fig. 12) indicated that the boundary of the associated *Corollina torosa* and *Callialasporites turbatus* spore-pollen Oppel Zones (interval now represented by the *Kekryphalospora distincta* spore-pollen Oppel Zone) occurs within the Toarcian *Reinholdeella cf. crenata* foraminiferal zone of Aptorpe & Heath (1981). The *Kekryphalospora distincta* Zone is distinguished by the occurrence of the index species and by a marked down-sequence increase in the proportion of *Corollina* spp. (Helby & Partridge, in prep.). In Europe, the range of *Kekryphalospora distincta* is late Pliensbachian to early Bajocian (Fenton & Riding, 1987). However, late Pliensbachian records of this spore are sparse, and its co-occurrences with *Luehndeia* and *Susadinium*? support a correlation with the early Toarcian.

**COMPARISONS WITH NORTHERN HEMISPHERE TOARCIAN PALYNOFLORAS**

The *Luehndeia* Assemblage differs fundamentally in species spectra from both the northwest European and North American provinces of Riding (1984b). The genera *Luehndeia*, *Nannoceratopsis* and unequivocal *Susadinium* are all known from the Toarcian worldwide (Johnson & Hills, 1973; Morley, 1978; Davies, 1983; 1985; Riding, 1984a, b; 1987; De
Vains, 1988; Feist-Burkhardt & Wille, 1992; Fauconnier, 1995; Riding et al., 1999). The lower Triassic strata of northwest Europe and Siberia are dominated by Nanoceratopsis; in upper Toarcian successions, the latter genus and Parvocysta and its relatives, the including Susadinium are predominant (Bjørnker, 1980; Riding, 1984b; Riding et al., 1991; Riding & Thomas, 1992; Ilyina et al., 1994). The lower Toarcian of southern Europe, by contrast, is dominated by Meliodinium (Bucefalo Palliani & Riding, 1999). The Parvocysta complex of Riding (1984b) in the Northern Hemisphere becomes more diverse with increasing latitude (Thuiss, 1978; Riding, 1984b; Riding et al., 1991; 1999). It thus is possible that this association has a bipolar distribution. It is clear that Susadinium appears to be the most widely distributed member of this closely related plexus of genera. The Toarcian of Arctic Canada is relatively diverse (Dörfler & Davies, 1980; Davies, 1983, fig. 4). However, the only genera in common with the Australian assemblages are Nanoceratopsis and Susadinium in Zone B of Davies (1983).

PALAEOECOLOGY

The reason the Timor Sea assemblages are so unlike any other reported Toarcian dinoflagellate cyst associations may be due to the marginal marine depositional setting of the Lower Plover Formation. MacDaniel (1988a), Mory (1988) and Osborne (1990) reported that the Plover Formation is a heterolithic unit representing a fluvial regime. The formation passes upstream into deltaic and shallow marine depositional conditions, possibly with interbedded lacustrine sediments. This is supported by the consistently overwhelming dominance of spores and pollen, the presence of Botryococcus and the relatively rare and sporadic occurrence of dinoflagellate cysts (Appendix 1). The species Skuaamam hitiburinatum and Moorodinium tessellatum, in particular, are relatively thin-walled. Both these taxa also have archaeocytes which are difficult to observe and to relate to paraplate equivalence. These are characteristic species from freshwater, brackish or marginal marine regimes (e.g. Batten, 1985; Hunt et al., 1985; Batten & Lister, 1988a,b). Furthermore, Moorodinium is a freshwater/brackish genus, originally described from near the Jurassic-Cretaceous boundary in the Perth Basin, Western Australia (Backhouse, 1988).

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REFERENCES

APTHORPE, M. C. & HEATH, R. S., 1981. Late Triassic and Early to Middle Jurassic foraminifera from the North West Shelf, Australia. Fifth Australian Geological Convention. Abstracts 3, 66.


BUCEFALO PALLIANI, R. & MATTIOLI, E., 1998. High resolution integrated microbiostratigraphy of
the Lower Jurassic (late Pliensbachian-early Toarcian) of central Italy. *Journal of Micropaleontology* 17, 153-172.


FOSTER, C.B., this volume. Introduction.


CENTURY AUSTRALIAN PETROLEUM EXPLORATION ASSOCIATION PUBLICATION. 270-284.


OSBORNE, M. O., 1990. The exploration and appraisal history of Skua Field, AC/P2 – Timor Sea. APEA Journal 30, 197-211.


### APPENDIX 1: THE DISTRIBUTION OF LUEHNDEA ASSEMBLAGE TAXA AND OTHER POLYFORMS IN SELECTED TIMOR SEA WELLS

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Above and overleaf: Occurrence of Luehndea Assemblage taxa and other polynomorphs in selected Timor Sea wells. Abbreviations are: D (m), depth (metres); Ms, Mendicodinium scabrum; Ls, Luehndea septata; Me, Mendicodinium echinatum; Su, Sudauidiaceae? australis; Nu, Nannoceratopsis spinosus; Nu, undifferentiated species of Nannoceratopsis; Sb, Sudauidiaceae? bicornatum; Mt, Moerodinum tessellatum; Sa, Sudauidiaceae? asymmetricum; Sr, Sudauidiaceae? reticulatum; Ot, unidentified dinoflagellate cysts; Ph, Pareodiorma halosa (Filato 1975) Prauss 1999; Kd, Kocksophora distincta (pteridophyte spore); Ac, Total acritarchs (largely Micrhystridium and Verynachium); Din, Total dinoflagellate cysts; Ara, Acratisporites spp.; Ct, Callulaspores turbatus; Cor, Corollina spp.; Dicr, Dictyophylloides spp.; X, present; ?, questionable identification; ...., absent; NC, not counted. The numbers refer to percentages of the respective group/taxon.
<p>| Well    | D (m)  | Ms | Ls | Me | Su | Ts | Ne | Nu | Sb | Mt | Sa | Sr | Ot | Ph | Kd | Ac | Din | Ara | Ct | Cor | Dict |
|---------|--------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| JABRU-12 | 1732.5 | X  |    |    |    |    |    |    |    |    |    |    |    |    | X  | 0.5 | 4   |    | 7  | 37 | 24 |
| JABRU-12 | 1740   | X  |    |    |    |    |    |    |    |    |    |    |    |    | X  | 1.5 | 1.5 | 45 | 16 |
| LORKEET-1 | 1779   |    |    |    |    |    |    |    |    |    |    |    |    |    | X  | 2   | 0.5 | 32 | 54 |
| LORKEET-1 | 1811   |    |    |    |    |    |    |    |    |    |    |    |    |    | X  | 41  | 0.5 | 37 | X  |
| LORKEET-1 | 1849   |    |    |    |    |    |    |    |    |    |    |    |    |    | X  | 3.5 | 1   | 2  | 61.5 | 14 |
| OLIVER-1  | 3057   | X  |    |    |    |    |    |    |    |    |    |    |    |    | X  |    |    | 15 | 31 | 30 |
| OLIVER-1  | 3094   |    |    |    |    |    |    |    |    |    |    |    |    |    | X  | 0.5 | 1   | 3  | 49 | 15 |
| OLIVER-1  | 3106   |    |    |    |    |    |    |    |    |    |    |    |    |    | X  | 1   | 0.5 | 78 | 9  |
| OLIVER-1  | 3123   |    |    |    |    |    |    |    |    |    |    |    |    |    | X  | 1   | 0.5 | 78 | 9  |
| OLIVER-1  | 3127   |    |    |    |    |    |    |    |    |    |    |    |    |    | X  | 7.5 |    |    | 64 | 9  |
| OLIVER-1  | 3134   |    |    |    |    |    |    |    |    |    |    |    |    |    | X  | 0.5 |    |    | 74 | 10 |
| SKUA-1    | 2786   |    |    |    |    |    |    |    |    |    |    |    |    |    |    | NC | NC | NC | NC | NC |
| SKUA-2    | 2342   |    |    |    |    |    |    |    |    |    |    |    |    |    | X  | NC | NC | NC | NC | NC |
| SKUA-2    | 2349   |    |    |    |    |    |    |    |    |    |    |    |    |    | X  | NC | NC | NC | NC | NC |
| SKUA-3    | 2394   |    |    |    |    |    |    |    |    |    |    |    |    |    | X  | 5.5 | 0.5 | 1  | 65 | 8  |
| SKUA-3    | 2395   |    |    |    |    |    |    |    |    |    |    |    |    |    | X  | 1   |    | 69 | 11 |
| SKUA-3    | 2395.9 |    |    |    |    |    |    |    |    |    |    |    |    |    | X  | 5   | 0.5 | 76 | 9  |
| SKUA-3    | 2397.1 |    |    |    |    |    |    |    |    |    |    |    |    |    | X  | 12  | 0.5 | 69 | 13 |
| SKUA-3    | 2401.9 |    |    |    |    |    |    |    |    |    |    |    |    |    | X  | 3   |    | 75 | 11.5 |
| SKUA-3    | 2402.5 |    |    |    |    |    |    |    |    |    |    |    |    |    | X  | 8.5 | 1   | 66 | 17 |
| SKUA-4    | 2302   |    |    |    |    |    |    |    |    |    |    |    |    |    | X  |    |    |    |    |
| SKUA-4    | 2304   |    |    |    |    |    |    |    |    |    |    |    |    |    | X  |    |    | 2  | 80 | 11 |
| SKUA-4    | 2321   |    |    |    |    |    |    |    |    |    |    |    |    |    | X  | 1.5 | 0.5 | 78 | 11.5 |
| SKUA-4    | 2322   |    |    |    |    |    |    |    |    |    |    |    |    |    | X  | 1.5 | 1   | 68 | 23 |
| SKUA-4    | 2323   |    |    |    |    |    |    |    |    |    |    |    |    |    | X  | 5   | 0.5 | X  | 71 | 23 |
| SKUA-4    | 2324   |    |    |    |    |    |    |    |    |    |    |    |    |    | X  | 1   |    | 74 | 10 |
| SKUA-4    | 2336   |    |    |    |    |    |    |    |    |    |    |    |    |    | X  | 4   | 0.5 | X  | 76 | 14 |
| SKUA-4    | 2375   |    |    |    |    |    |    |    |    |    |    |    |    |    | X  | X   | X  | 84 | 9  |
| SKUA-5    | 2612   | X  |    |    |    |    |    |    |    |    |    |    |    |    | X  | 6   | 2   | 6  | 7.5 | 43.5 | 22 |
| SKUA-5    | 2624   |    |    |    |    |    |    |    |    |    |    |    |    |    | X  | 1   |    | 28 | 66 |
| SKUA-5    | 2633   |    |    |    |    |    |    |    |    |    |    |    |    |    | X  | 7   | 3   | 2.5 | 64 | 9  |
| SKUA-5    | 2646   |    |    |    |    |    |    |    |    |    |    |    |    |    | X  | 11.5 | 1   | X  | 45 | 15 |
| SKUA-5    | 2654   |    |    |    |    |    |    |    |    |    |    |    |    |    | X  | 4.5 |    |    | 47 | 38 |
| SKUA-5    | 2659   |    |    |    |    |    |    |    |    |    |    |    |    |    | X  |    |    |    |    |
| SKUA-6    | 2335   | X  | X  |    | X  |    | X  | X  | X  | X  | X  |    |    | X  | 7   | 3   | 1   | 0.5 | 48 | 18 |
| SKUA-6    | 2391.5 | X  | X  | X  |    | X  | X  | X  | X  | X  |    |    |    | X  | 0.5 | 32.5 | X  | 40 | 8  |
| SKUA-6    | 2412   |    |    |    |    |    |    |    |    |    |    |    |    |    |    | 11.5 | 1   | X  | 45 | 15 |
| SKUA-6    | 2440.5 |    |    |    |    |    |    |    |    |    |    |    |    |    |    | 2.5  | 1   | X  | 47 | 17.5 |
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### APPENDIX 3: REGISTER OF FIGURED SPECIMENS

All palynomorph specimens figured in this paper are listed here. The specimens are all curated in the Commonwealth Palaeontological Collection (CPC) of the Australian Geological Survey Organisation, Canberra. The dinoflagellate cyst genera and species are listed alphabetically and the location of the specimens on the microscope slides are all 'England-Finder' co-ordinates (EF). These were taken with the slide label to the left of the observer. The coding for types is as follows: $H$ = holotype; $P$ = paratype; $T$ = topotype. All specimens of new taxa examined during this study contributed to the specific concepts, therefore all the figured specimens which are not holotypes are paratypes. $SGM$ = single grain mount. The single grain mounts do not have unique numbers; they are numbered sequentially for each species within a particular sample. The specimens are all from sidewall core samples.
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A selective reappraisal of *Wanaea* Cookson & Eisenack 1958 (Dinophyceae)

**JAMES B. RIDING and ROBIN HELBY**


Selected species of the dinoflagellate cyst genus *Wanaea* from Australasia and Europe have been restudied. The new species *Wanaea lacuna* from the late Bathanian of Australia demonstrates that the genus may be extensively cavate and the generic diagnosis has been emended. Other new species from the Bathanian and earliest Callovian of Australia include *Wanaea enoda* and *W. verrucosa*. *Wanaea enoda, W. lacuna* and *W. verrucosa* are all energyniod forms which lack a prominent posterior paracingular flange. The European and sub-Mediterranean energyniod species *Wanaea acollaris* Dodekova 1975 and *W. zharenensis* Conway 1978 have been redescribed and emended. *Wanaea zharenensis* may have a solid extension to the antapical horn or protuberance and the term antapical structure is proposed for this feature. In Australia, the form originally described as *Epicephalopyxis spectabilis* Deflandre & Cookson 1955 has been subsequently misidentified. The species has a complex paracingular flange comprising three distinct zones; it is also stratigraphically important, being confined to the mid Oxfordian. It was transferred to *Wanaea* in 1958, however the figured specimen accompanying this transfer is not conspecific with the type. This specimen has a narrower flange comprising short, regular processes which are connected distally by a trabeculum. Subsequent identifications of *Wanaea spectabilis* have followed the latter specimen. The new species *Wanaea talea* is erected to accommodate these latter forms.

The more flamboyant species of this genus with lace-like paracingular flanges are consistently younger than the energyniod species. Energyniod species are largely confined to the Middle Jurassic (late Bajocian-Callovian) worldwide, and are most prominent in the Bathanian. However the presumably more evolved, flanged forms are confined to the mid Callovian to early Oxfordian in Europe and the mid Callovian to earliest Kimmeridgian in Australasia. Most species of *Wanaea* exhibit marked North-South provincialism and are currently known only from Europe and surrounding areas or the Indo-Pacific region. The exception to this is *Wanaea indotata* which is cosmpolitan and may be an intermediate between the energyniod and flanged species.

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Keywords: dinoflagellate cysts, Middle and Late Jurassic, Australia, Europe, biostratigraphy, evolution, taxonomy.

*THE JURASSIC* dinoflagellate cyst genus *Wanaea* Cookson & Eisenack 1958 comprises a conical hypocyst with an antapical horn and a flattened to slightly apically convex epicyst. It has an epicystal archaeopyle and, while the epicyst is commonly paratabulate (Figs 1C, 1D), the hypocyst rarely exhibits more than a partial paratabulation. Many representatives bear distinctive posterior paracingular flanges which are interrupted at the paraculus. Some Bajocian-Bathonian representatives may exhibit minor, restricted and commonly delicate, crest development on the posterior paracingular suture but lack the prominent and relatively robust flange development of the mid Callovian and younger species. The Bajocian-Bathonian forms also commonly display convex epicysts. We refer, informally, to this group as the energyniod species. In the flanged forms, the hypocyst is almost invariably smooth. *Wanaea indotata* Druge 1978 is regarded as transitional between the two groups. Where present, the paratabulation is gonyaulacolean and is assumed to be a standard sexiform configuration (Sarjeant, 1966; Stover & Evitt, 1978). The epicystal archaeopyle style of the genus was first noted by Norris (1965).

*Wanaea* was proposed by Cookson & Eisenack (1958, p. 57), to accommodate forms originally described as *Epicephalopyxis spectabilis* Deflandre & Cookson 1955 and two new species,
Wanaea clathrata and *W. digitata*, from the Upper Jurassic of Australia and Papua New Guinea, Cookson & Eisenack (1958) were unsure as to the affinity of the genus and classified it as *Incertae Sedis*. Three years later, Evitt (1961) recognised that *Wanaea* is of unequivocal dinoflagellate affinity. Subsequently, Evitt (1963) stated that fossil dinoflagellates are dominantly of the cyst stage and this hypothesis was confirmed by experiments using modern dinoflagellates (for example, Wall & Dale, 1968). The type, *Wanaea spectabilis* from Papua New Guinea, was transferred to *Wanaea* from *Epicephalopyxys* Deflandre 1937 by Cookson & Eisenack (1958). However, in doing this Cookson & Eisenack (1958, pl. 9, fig. 1) illustrated a morphotype, which is different from the type specimen. This new form is named *Wanaea taka* sp. nov. herein. The first European species, *Wanaea fimbrilata* was described by Sarjeant (1961), from the Lower Oxfordian of Yorkshire, northern England.

In 1975, Dodekova described *Wanaea acollaris* from the late Bajocian of north-east Bulgaria. This species lacks a posterior paracingular flange and is weakly paratabulate. Hence Dodekova (1975) informally modified the generic concept to include such forms. Shortly after, Sarjeant (1976) published *Energlynia kyrbasia* from the late Bajocian of the English Midlands. Sarjeant (1976) proposed a gonystealcalcean paratabulation pattern for this species which, like *W. acollaris*, lacks a paracingular flange. By establishing *Energlynia*, Sarjeant (1976) considered that the non-flanged forms should be distinguished from *Wanaea*. Sarjeant (1978) later stressed this by transferring *Wanaea acollaris* to *Energlynia*. However, in the same year, *Energlynia kyrbasia* was deemed to be a junior synonym of *Wanaea acollaris* by Fenton & Fisher (1978). This situation was effectively resolved by Riley & Fenton (1982) and Lentin & Williams (1993), who, in a broad consensus, listed *Energlynia* as a junior synonym of *Wanaea* (see also Drugg, 1978, p. 74).

In 1978 two further species of *Wanaea* were proposed. These were *Wanaea indotata*, a form with a variable posterior paracingular flange, from the late Bajocian and mid Callovian of England and an energyloid species, *Wanaea zoharensis* Conway 1978, from the late Bajocian of southern Israel. An energyloid species with minor cavoation, *Wanaea cornucavata* Feist Burkhardt & Pross 1998, was recently described from the early Bajocian of England, France and Germany.

A generic synopsis and modified description of *Wanaea* were given by Stover & Evitt (1978, p. 223) and this treatment was a de facto emendation. It stressed the possible paratabulation, archaepolyte style and the presence of accessory archaepolyte sutures on the ecypt.

Woollam (1980, p. 250) proposed that *Energlynia kyrbasia*, *Wanaea indotata* and *Wanaea zoharensis* are all junior synonyms of *Energlynia acollaris*. Subsequently, two papers on the genera *Energlynia* and *Wanaea* were published in the early 1980s. Fensome (1981) and Woollam (1982) reviewed the two genera and these authors chose to retain both *Energlynia* and *Wanaea*. These reviews agreed that *Energlynia* is difficult to speciate and Fensome (1981) followed Woollam (1980) in synonymising *Energlynia acollaris*, *E. kyrbasia* and *Wanaea zoharensis*. Fensome (1981, p. 51) also transferred *Wanaea indotata* to *Energlynia*, and inferred that the latter species may be conspecific with *E. acollaris*. Woollam (1982) did not formally describe species of *Energlynia*, however he illustrated *E. acollaris*, *"E. kyrbasia" and E. indotata*. A possible phylogenetic succession from the late Bajocian to mid Callovian genus *Energlynia* to the several Callovian-Kimmeridgian *Wanaea* species with their complex posterior paracingular flanges was presented by Fensome (1981, fig. 3). This approach was criticised by Woollam (1982) because of the clear provincialism between Europe and Australasia. Further, Woollam (1982) argued that the form which had been assigned to *Wanaea digitata* in the Northern Hemisphere (e.g. by Sarjeant, 1968, 1972; Fensome, 1979; Woollam, 1980) was significantly different from the Australasian form, and proposed *Wanaea thyssanoa* Woollam 1982.

This paper is one of a series designed to provide the taxonomic foundation that will allow the formal definition of some unpublished subdivisions of the Australian Mesozoic palynological zonation of Helby et al. (1987). That publication was the first attempt at an integrated, pan-Australian microplankton and spore-pollen zonation. Only the basic framework of the zonation was provided in anticipation that further contributions, particularly the documentation of new taxa, would be necessary as the zonation scheme evolved. Indeed, informal subdivisions of these zones have been recorded in Helby’s unpublished reports to industry for over 20 years. These subzones have widespread currency within the hydrocarbon industry due to the legislative requirement for the release of technical data under the Petroleum (Submerged Lands) Act 1967. The informal subdivisions of the Helby et al. (1987) zonation...
have been entered into the Australian Geological Survey Organisation (AGSO) STRATDAT database. A diagrammatic update of the Helby et al. (1987) zonal scheme is presented by Foster (this volume), and will be described fully by Helby & Partridge (in prep.). This taxonomic project is an initiative of the Petroleum and Marine Division of AGSO.

**SYSTEMATIC PALYNOLGY**

In this section, the genus *Wanarea* and the species *W. acollaris*, *W. spectabilis* and *W. zoharensis* are emended. Four new species of *Wanarea*, *W. enoda*, *W. lactana*, *W. talea* and *W. verrucosa*, are described from the Bathonian and Oxfordian of Australia. The locations of the offshore Australian wells are given by Foster (this volume). The dimensions quoted are all given in micrometres (μm). Herein, intermediate forms have a maximum dimension of between 50μm and 100μm and large cysts are over 100μm in size (Stover & Evitt, 1978, p. 5). Most of the morphological terminology for dinoflagellate cysts is that of Evitt (1985). References to author citations of taxa discussed may be found in the bibliography of Williamson et al. (1998, p. 747-817). The synonymy lists are selective and mainly confined to illustrated specimens. Most figured specimens are deposited in the Commonwealth Palaeontological Collection (CPC) of AGSO, Canberra (Appendix 2).

This study has been conducted largely using single grain mounts (or mounts with multiple specimens) and the majority of the figured specimens are from these single species slides. Most samples are from outcrop, sidewall core or normal core material, however a small number of ditch cuttings samples were also used. The photomicrographs in Figs. 1-10 were all taken at AGSO using an Olympus DP10 digital camera system coupled to a Zeiss Axioskop photomicroscope. Some extraneous palynodebris, not adherent to the figured specimens, has been digitally removed in selected images.

The photomicrographs in this paper are from a database that contains many digital images. Sample details, key morphological data and measurements of each imaged specimen are held on open file spreadsheets. The image database may be accessed on the AGSO website (http://www.agso.gov.au).

The new taxa have been extensively used in unpublished reports, which are now in the public domain (open file). In order to maximise the utility of the species, the informal names and/or codes are listed, separate from any formal synonymy listing, under the heading 'Previous Australian usage'. To provide continuity, wherever practical, the informal name has been retained.

**Dinoflagellate cysts**

*Wanarea* Cookson & Eisenack 1958 emend.

1958 *Wanarea* Cookson & Eisenack, p. 57.
1976 *Energiynia* Sarjeant, p. 164-166.
1990 *Energiynia* Sarjeant; Dodekova, p. 43.

**Type species.** *Wanarea spectabilis* (Deffandre & Cookson 1955) Cookson & Eisenack 1958

**Emended diagnosis.** Proximate to proximochorate dinoflagellate cysts which may be cavate. Large or intermediate in size and subcircular in polar view. The hypocyst is relatively large and is strongly conical in subcircular in outline, with a prominent antapical horn being blunt, rounded distal extremity. The antapical horn may be parallel to the polar axis or it may be slightly inclined; it may have a solid distal extension. By contrast, the epicyst is smaller and may be slightly to markedly apically convex. Endophragm and/or periphragm are smooth or may be ornamented with low-relief features, typically granules or spinules. Paratabulation is standard gonyaulacallean and is partially to fully indicated by parasutural elements. The posterior paracingular crest or flange can be prominent and may comprise radially arranged, solid, elements which may be interconnected radially. Alternatively, the flange may comprise a reticulate mesh lacking radial elements. Archaeopyle epicystal, the simple operculum is normally attached ventrally. The principal archaeopyle suture is immediately anterior of the paracingulum. The operculum may exhibit accessory archaeopyle sutures and may be detached mechanically. Paracingulum normally indicated by paired equatorial ridges or crests; the posterior one may be prominent. The parasulcus is marked by a midventral depression on the hypocyst, which may be flanked by parasutural ridges, and an interruption of the paracingulum.

**Comments.** The genus *Wanarea* is emended here to encompass cavate species and forms lacking a paracingulum. Feist-Burkhardt & Pross (1998) previously described *Wanarea cornucavata*, which is cornucavate to holocavate. However, these authors did not expand the generic diagnosis to
Fig. 1. *Wanaea acollaris* Dodekova 1975 emend. All specimens from Upper Bathonian Blisworth Limestone, Ketton Grange Quarry, Ketton, Lincolnshire, England U.K. (British Geological Survey micropalaeontological palynological sample MPA 15438). All photomicrographs taken using plain transmitted light. The scale bar is 25μm in Fig. 11 and refers to all the photomicrographs. All specimens are topotypes of *Enerygia kyrhasia* Sarjeant 1976, a junior synonym of *Wanaea acollaris*. Note acavate organisation, relatively short antapical horn, flattened epicyst which may have accessory archaeopyle sutures, the smooth, scabrate, microgranulate to sparsely spinose autophragm and parasutural or penitabular nature of the spines (where developed), which may be trabeculate. A - hypocyst, right lateral view, high focus. Note short, slender spines in antapical region, highly incomplete hypocyst paratabulation, posterior paracingular ridge/crest. B - hypocyst, oblique lateral view, high focus. Note prominent nature of antapical horn. C - isolated epicyst, apical view, high focus. Note accessory archaeopyle sutures, consistent presence of low parasutural ridges. D - hypocyst with adherent epicyst, oblique left lateral view, high focus. Note disparity in paratabulation expression on the epicyst and hypocyst. E - entire cyst, left lateral view, high focus. Note slightly domed epicyst, trabeculate spinose ornamentation on the right side of hypocyst. F - relatively short, wide hypocyst with adherent operculum, lateral view, high/median focus. Note short antapical horn. G - large hypocyst with adherent epicyst, left lateral view, high/median focus. Note partial nature of hypocyst paratabulation. H - hypocyst and adjacent operculum, left lateral view, high/median focus. Note highly folded autophragm. I - hypocyst with adjacent, damaged operculum in oblique left lateral view, high/median focus. Specimen has relatively little ornamentation.
include cavate species. Species which lack a prominent posterior paracingular flange (energynoidiform forms) are considered to be proximate, but species with a wide equatorial flange such as "Wanaja clathrata" Cookson & Eisenack 1958 are interpreted as proximochorate.

The synonymy of "Wanaja" and "Energynia" was first validly accomplished by Dodekova (1990, p. 43). Operating at the species level, Riley & Fenton (1982, p. 200) had earlier relegated the genotype of "Energynia. E. kyrkastia", to "W. acollaris". They suggested that "Energynia" was therefore superfluous, but this was not supported by formal taxonomic procedures.

**Wanaja acollaris** Dodekova 1975 emend. (Figs 1A-I)

1975 *Wanaja acollaris*: Dodekova, p. 20-21, pl. 2, figs 9, 10, pl. 3, figs 1-7, 9.
1976 *Energynia kyrkastia*: Sarjeant, p. 166-172, figs 1-16.

*Emended description.* An acavate, intermediate sized species of *Wanaja* with a subconical hypocyst which bears an antapical horn. The epicyst is domed and varies in convexity from flat to slightly rounded. Accessory archaeopyle sutures are frequently developed on the epicyst. The antapical protuberance is closed, distally rounded and slightly variable in size; the horn may be relatively slender to somewhat squat and is straight or may be slightly inclined. The autophymn is moderately thick (0.5-1 μm), smooth, scabrate, microgranulate to sparsely spinose. The low relief ornamentation, where developed, is extremely variable even within individual specimens. The scabrae and microgranae are nontubular, however the spines may be parasutural or penitubular. The spines are extremely slender (<0.5 μm) and vary between 1 and 2 μm in height. Occasionally parasutural spines may be joined distally by trabeculae, forming low, discontinuous crests, which are most common in the antapical and paracingular areas. Paratabulation may also be partially indicated by low (<0.5 μm), smooth, irregular ridges, which may be surmounted by occasional spines, and are either parasutural or penitubular. The paratabulation is best expressed on the epicyst, where it is dominantly parasutural;

typically the hypocyst has an incomplete paratabulation. Parasutural and penitubular ridges may occur on the hypocyst; both styles may rarely occur on the same specimen. The paracingular parasutures are marked by low ridges with occasional spines, which may be trabeculate or relatively long (c. 2 μm), solid, simple processes which coalesce into crests. The paraculeus is indicated by a shallow concavity and the simple operculum is generally attached ventrally.

*Dimensions* (μm; n=17): Min. (Mean) Max.
- Length of entire cyst: 65 (67) 71
- Length of epicyst: 13 (17) 21
- Length of hypocyst: 43 (55) 67
- Equatorial width of hypocyst (in lateral view): 53 (62) 78
- Length of antapical horn: 5 (7) 10
- Width of antapical horn (at midpoint): 3 (5) 7

A single epicyst was observed in apical view, which measured 43 μm x 42 μm (Fig. 1C). These dimensions are similar to those of Dodekova (1975) except the width, which is significantly less than in the type material. The measured specimens are from the bitsworth limestone (Upper Bathonian) of Ketton Grange Quarry, Ketton, Lincolnshire, U.K., the type locality of *Energynia kyrkastia* Sarjeant 1976. The British Geological Survey (BGS) slides MPA 15438/1 and 2 were used in this study. These slides are in the palynological collections of the BGS, Nottingham, U.K.

*Comments.* This emendation of *Wanaja acollaris* is based upon the acceptance of the proposition by Fenton & Fisher (1978, p. 236), that it is a senior synonym of *Energynia kyrkastia*. The original description of Dodekova (1975, p. 21) stressed the relative shortness of the epicyst to the hypocyst, i.e. that the epicyst is around 20% of the entire cyst length. However, fig. 2 of Dodekova (1975) is a line drawing of an idealised specimen which has a markedly inflated or 'domed' epicyst. Dodekova (1975) described the species as being 'proximo-chorate'; in fact it is prolate. The hypocysts of the Ketton Grange specimens are relatively narrow compared to other members of the genus and generally subtriangular in outline (Fig. 1). The paratabulation interpretations of Dodekova (1975, fig. 2) and Sarjeant (1976, figs 1-5) cannot be confirmed here because of the irregular and incomplete nature of the hypocyst paratabulation.

*Comparison.* *Wanaja acollaris* is most similar to *W. zoharensis* Conway 1978, distinguished mainly
by the denser, more variably distributed ornament of the latter, Wanaea verrucosa sp. nov. resembles W. ucollaris in having granulate to verrucose ornament, but the former lacks parsutural ridges, crests and parasutural aligned ornament. The latter also displays more strongly domed epicysts. Wanaea cornucavata is very similar but is distinguished by the cornucavate to holecavate cyst organization. Wanaea enoda sp. nov. is smooth, lacks a demonstrable paracingulum and
has a highly domed epicyst. The smooth hypocyst and the prominent 'fuzzy' posterior paracingular
structure of *Wanaea indotata* Drugg 1978
distinguish it from *W. acollaris*. All remaining
*Wanaea* species are distinguished by prominent
posterior paracingular flanges.

**Holotype and type locality.** Slide 870-6 from
745.50m in Borehole C-32, Dolina, north-east
Bulgaria (Dodekova, 1975). This horizon is within
the Dobrich Formation and is Upper Bathonian.
Material housed in the collections of the
Geological Institute 'Str. Dimitrov', Sofia, Bulgaria.

**Stratigraphical distribution.** *Wanaea acollaris*
extends from the latest early Bajocian to the early
Oxfordian of north-west Europe (Fig. 12, Wooliam &
Riding, 1983; Riding, 1984; Gowland & Riding,
1991; Feist-Burkhardt & Wille, 1992; Riding &
Thomas, 1992; 1997), but it is most prominent in
the Bathonian (Riding et al., 1985).

*Wanaea enoda* sp. nov. (Figs 2A-I)

**Previous Australian usage**
M.P. 491 – Helby.

*Wanaea enoda* – Helby.

**Description.** An intermediate sized, acavate
species of *Wanaea* lacking demonstrable
paracingular differentiation. Hypocyst subconical,
subtringular in dorsoventral and lateral views;
sometimes with a rounded antapical horn which is
sometimes slightly inclined. The epicyst is
domed; the degree of convexity variable (see
**Dimensions**, below). The autophagun is thin (c.
0.5μm thick) and generally smooth to irregularly
sebrate. Ventrally, the paracyst is marked by a
narrow, shallow concavity. Simple operculum
normally attached ventrally.

**Dimensions** (μm; n=26): Min. (Mean) Max.
Length of entire cyst: 61 (72) 82
Length of epicyst: 12 (22) 40
Length of hypocyst: 40 (59) 75
Equatorial width of hypocyst (in lateral view): 60
(75) 94
Length of antapical horn: 5 (8) 13
Width of antapical horn (at midpoint): 4 (7) 12

The measured specimens are from a
conventional core sample at 2066.02m in Magobu
Island-1 well.

**Comments.** The description above is based on a
single sample (see above). Despite this limitation,
the general morphology is accurately covered with
the single exception that in other material the cyst
wall may be slightly thicker (up to 1μm). The shape
of the hypocyst is somewhat variable. Some
specimens are relatively wide (Fig. 2I), whereas
others are markedly elongate (Fig. 2B). In the
Magobu Island-1 well specimens, the autophagum
is thin and flimsy, however this species is
surprisingly not especially susceptible to
mechanical distortion. The development of an
antapical horn is variable. Some individuals have
a relatively distinct, short horn (Fig. 2D) and others
have subtringular hypochysts which lack a well
differentiated antapical protrusion (Figs 2E, I). No
accessory archaeopyle sutures have been
observed on the epicyst.

**Comparison.** This distinctive species of *Wanaea*
is characterised by its acavate organisation, the
domed nature of the epicyst and its thin, smooth
autophagum. *Wanaea enoda* differs from younger
species of the genus by lacking a posterior
paracingular flange. It is most similar to *Wanaea
lacuna* sp. nov. in size, shape and autophagum
morphology, however *W. enoda* is acavate. It
differs from other acavate *Wanaea* species such as
*W. verrucosa* sp. nov. and *W. zoharensis* in
possessing a smooth autophagum. The lack of a
paracingular crest and partial paratabulation
together with a domed epicyst differentiates
*Wanaea enoda* from *W. acollaris*.

**Derivation of name.** From the Latin *enoda*,
meaning free of knots and referring to the lack of
ornamentation on the autophagum.

**Holotype and type locality.** Fig. 2H, CPC 35848,
from a conventional core sample in Magobu
Island-1 well at 2066.02m.

**Stratigraphical distribution.** *Wanaea enoda*
ranges from the Bathonian base of the *Wanaea
verrucosa* Zone (7ciiaii) to the Callovian basal
*Wanaea digitata* Zone (7bi) (Figs 11, 12; Foster,
this volume; Helby & Partridge, in prep.).

*Wanaea lacuna* sp. nov. (Figs 3A-L)

**Previous Australian usage**
M.P. 1016 – Helby.

**Description.** A smooth, caved species of *Wanaea*
intermediate in size and lacking a posterior
paracingular flange and with a subconical
hypocyst which has an antapical horn or
Fig. 3. *Wanaea lacuna* sp. nov. All from core in the Sunrise-2 well at 2122.33m (Figs 3B, D-F, H-I, K), 2122.25m (Figs 3E, G, J) and 2122.05m (Figs 3A, C, L). All photomicrographs taken using plain transmitted light. The scale bar of 25μm in Fig. 3L refers to all photomicrographs. Figures 3A, G-I are composite photomicrographs. Figure 3J is the holotype, the remainder are paratypes. Note subconical hypocrust lacking a posterior paracircular flange, hemispherical epicyst, antapical horn or protuberance, cavate cyst organisation and relatively thin endophragm and periphragm. A - CPC 35850, left lateral view, median focus (continued opposite)
protuberance. The short, broad antapical horn is slightly inclined and is blunt and rounded distally. A hemispherical epicyst is present. The endophragm is approximately 0.5 μm thick; the periphragm is markedly thinner; both the cyst layers are irregularly smooth to microscabrate. This species is hypocavate to circumcavate; the two wall layers are consistently separated in the antapical region (Fig. 3). There is a distinct periphragmal antapical horn developed but no corresponding protuberance on the endocyst. Most specimens are cornucavate. Occasionally, the endophragm and periphragm are slightly separated in the lateral and apical areas, therefore ranging to bicaucate and circumcavate organization. No unequivocal parasutural features are present. On the ventral side, the parasulus is marked by a narrow, shallow concavity or depression. The smooth principal endoarchaeopyle and periarachaeopyle sutures are interpreted as being immediately anterior of the anterior paracingular parasuture; the simple operculum is generally attached ventrally.

**Dimensions (μm; n=45); Min. (Mean) Max.**

Length of entire cyst: 65 (60) 96
Length of epicyst: 12 (21) 40
Length of hypocyst (including paracingulum): 35 (61) 75
Equatorial width of hypocyst (in lateral view): 56 (70) 99
Length of antapical horn: 5 (9) 15
Width of antapical horn (at midpoint): 5 (9) 13
Length of pericoel at antapex: 5 (15) 23
Length of pericoel excluding at antapex: 1 (4) 13

The measured specimens are from conventional core samples in Sunrise-2 well at 2122.33m, 2122.25m, and 2122.05m.

**Comments.** This species of *Wonaea* is distinguished by being cavate. The principal area where the endophragm is separated from the periphragm is at, and adjacent to, the antapical horn (Fig. 3). Most specimens are therefore hypocavate, however the cavation style is somewhat variable and bicavate. Circumcavate and cornucavate forms have also been observed (Fig. 3). Wall separation in the lateral regions and in the epicyst is minor (see fine drawing of a similar scenario in Sarjeant, 1982, fig. 4e).

No definite indications of parasutural waves were observed, however occasional discontinuous low ridges which may represent parasutures are present. The fact that there is no ridge, crest or flange at the paracingulum is unusual for *Wonaea*, even the 'energynoid' species such as *Wonaea acollaris* Dodekova 1975 have paracingular ridges or rims (Woollam, 1982, p. 47). The endophragm and periphragm are both susceptible to folding as a result of compression and this leads to the formation of arcuate folds (Figs 3G-L). The epicyst is distinctly hemispherical and lacks horns or protrusions (Figs 3B-C, J). Few specimens were observed where the epicyst is absent and many opercula were only slightly displaced. The lack of paracingular features and the frequent retention of the operculum in this species may make the differentation of the epicyst and hypocyst difficult in some specimens.

**Comparison.** The only other species of this genus which is cavate is *Wonaea cornucavata*. However, that species is ornamented, has a trabeculate paracingular flange, is partially paratubate and has a flat, lid-like epicyst (Feist-Burkhardt & Pros, 1998). *Wonaea enoda* is a closely similar, smooth-walled, acingulate, epicystally domed *Wonaea* but lacks cavate wall organization. *Wonaea indotata*, like *W. lacuna*, lacks parasutural features, however the former is acavate and has a prominent paracingular rim.

**Derivation of name.** From the Latin *lacuna*, meaning cavity or hollow and referring to the cavate cyst organisation of this species.

**Holotype and type locality.** Figure 43, CPC 35859, from conventional core, Sunrise-2 well at 2122.25m.

**Stratigraphical distribution.** *Wonaea lacuna* is Bathonian, from the middle subzone (7cii) of the *Wonaea verrucosa* Zone (Figs 11, 12; Foster, this volume; Helby & Partridge, in prep).

Fig. 4. *Wanaca spectabilis* (Deflandre & Cookson 1955) Cookson & Eisenack 1958 emend. All from Eclipse-2 well, sidewall core at 2477.00m. All photomicrographs taken using plain transmitted light. The scale bar of 18μm in Fig. 4F refers to all photomicrographs. Note broad, conical hypocyst with single antapical horn and broad, lace-like posterior paracingular flange. Flange complex and variable with long, radial processes arising from thin, largely entire, proximal area. Radial processes coalesce and branch distally, often distal to a distinct trabeulum. A - CPC 35862, hypocyst, oblique right lateral view, low focus. B - CPC 35863, right lateral view, low focus. Note epicyst within hypocyst. C - CPC 35864, hypocyst, oblique antapical view, low focus. D - CPC 35865, antapical view, median focus. Ventral side down. E - CPC 35866, hypocyst, apical view, median/low focus. Ventral side down. F - CPC 35867, antapical view, median/low focus. Ventral side down.
**Wanaea spectabilis** (Deflandre & Cookson 1955) Cookson & Eisenack 1958 emend.

(Figs 4A-F, 5, 6A-C, 7B)


1958 *Wanaea spectabilis* (Deflandre & Cookson 1955); Cookson & Eisenack, p. 57, non. pl. 9, fig 1.

1987 *Wanaea spectabilis* *nec. non* (Deflandre & Cookson 1955) Cookson & Eisenack; Davey, pl. 12, fig. 13.

**Previous Australian usage**

*Wanaea clathrata* - Helby.

**Emended description.** A large, acutate species of *Wanaea*, with a conical hypostom and a short, distally rounded antapical horn which may point toward the ventral side. Autophragm smooth to sebaceous. The epicyst is slightly apically convex to flattened and may show parasutural traces and re-entrants along the principal archaeopyle suture. Paratabulation is normally absent on the hypostoma, apart from a prominent, lace-like posterior paracingular flange, which is equatorial in position and interrupted at the indented parasulcus. This flange morphology comprises three distinct zones (Deflandre & Cookson, 1955, pl. 3, fig. 13; Figs 4, 5 and 7B). Zone 1 is a solid proximal area, which may be irregularly vacuolate or fenestrate. Zone 2 is the central, main body comprising radial processes. Zone 3 is the distal part of the flange which is irregularly reticulate and is bounded distally by a continuous trabeculum, whereas the inner boundary may be marked by a generally discontinuous trabeculum. The median zone 2 comprises long, radially arranged processes which may occasionally coalesce and branch. They are 10-16μm in length and 1-2μm wide. Generally, the processes are connected by a normally incomplete distal trabeculum, beyond which the zone 3 reticulation is developed. Principal archaeopyle suture generally smooth, located immediately...
Fig. 6. Wanaea spectabilis (Deflandre & Cookson 1955) Cookson & Eisenack 1958 emend. Photomicrographs of the holotype (6A, B) and a topotype (6C) from the Museum of Victoria, Melbourne. Material from the Era River district, south-east Papua New Guinea, Australasian Petroleum Co. Wana Well sample W.451. This sample was considered Lower Cretaceous by Deflandre & Cookson (1955), but revised to Upper Jurassic by Cookson & Eisenack (1958). Both photographed using plain transmitted light. Scale bar in C represents 25 µm. Note distinctive, broad, complex, variable, lace-like posterior paracingular flange with long, radial processes which coalesce and branch distally and arise from an entire proximal area. A-B - P.16235, polar view, high and low focus respectively. Note interruption of posterior paracingular flange ventrally. C - P.16234, lateral view, high focus. Note epicyst within hypocyst.

anterior of the anterior paracingular parastaurhe. Operculum generally attached ventrally.

Dimensions (µm; n=35): Min. (Mean) Max. Length of hypocyst (excl. paracingular flange): 67 (73) 86
Length of antapical horn: 7 (13) 17
Width of cyst (incl. paracingular flange): 102 (120) 143
Width of cyst (excl. paracingular flange): 86 (96) 114
Width of paracingular flange: 10 (15) 20

The measured specimens are from sidewall core samples in Arunta-1 well at 1919.00m, Eclipse-2 well at 2477.00m and Krill-1 well at 3458.00m, 3470.00m and 3474.00m. Dimensions for holotype provided by Deflandre & Cookson (1955): 110µm x 84µm; paracingular flange c. 8µm.

Comments. Deflandre & Cookson (1955) figured three specimens of their new species Epistephalophyxis spectabilis. In their transfer of E. spectabilis to Wanaea, Cookson & Eisenack (1958) illustrated a morphotype which we consider to be a separate taxon (Cookson & Eisenack, 1958, pl. 9, fig. 1). Since then, the latter form has been widely, but erroneously, accepted as defining the concept of W. spectabilis (for example, Fensome, 1981, fig. 3; Helby et al., 1987, fig. 18A). Therefore, the specific description of Wanaea spectabilis is emended (see above), and the morphotype illustrated by Cookson & Eisenack (1958) is described separately as Wanaea talea sp. nov.

Wanaea spectabilis has a wide posterior paracingular flange, characterised by a thin outer reticulate rim, surmounting the long, radially inserted, slender, solid processes of the central area. Generally, the proximal part of the flange is largely entire and is sporadically interrupted by small, subcircular vacuoles which are normally inserted irregularly (Figs 4, 5, 7B). A trabeculum may occur 3 to 5 µm from the distal rim connecting most of the radial processes (Figs 4A, E, 7B). This trabeculum is typically more slender than the radial elements of zone 2, which it deflects proximally. The trabeculum merges into the outer reticulate rim (Figs 4, 7B). In poorly preserved material, the outer rim of the flange (zone 3) may be absent due to mechanical damage. These damaged specimens appear similar to Wanaea digitata Cookson & Eisenack 1958. However, damaged forms of W. spectabilis have long, irregular, anastomosing processes and not the regular spines which characterise the outer flange of W. digitata.

The posterior paracingular flange of Wanaea spectabilis is considered to be intermediate in morphology between Wanaea clathrata Cookson & Eisenack 1958 and W. talea. It is similar to the flange in W. talea, however the latter is significantly narrower and has a smooth, trabeculate, distal rim (Figs 7C, 8). The flange in Wanaea spectabilis is most similar to that in W. clathrata in that it is wide and there is extensive coalescing of the lace-like elements, particularly in the distal region (Fig. 4). The paracingular flange in W. clathrata, despite the presence of some elongate fenestrae, is characterised by complex anastomosing elements throughout the flange.
often giving a relatively even reticulation pattern (Cookson & Eisenack, 1958, pl. 9, figs 7, 8; Helby et al., 1987, fig. 18E; Fig. 7A). Furthermore, the distal edge of the flange in *W. clathrata* is relatively smooth (Fig. 7A).

**Comparison.** *Wanacea spectabilis* differs from other species of this genus due to the characteristic posterior paracingular flange (Fig. 7). It is most similar to *Wanacea clathrata* and *W. talea*. The other Australian species, *Wanacea digitata* has a posterior paracingular flange, which is two-layered. The inner layer is generally fenestrate, but may be less regular, defaulting to vacuolate. The outer layer comprises regular spines, although the length of the spines may vary considerably between specimens. *Wanacea spectabilis* also resembles the two European taxa *Wanacea thyrsanota* Woollam 1982 and *W. fimbriata* Sarjeant 1961. Indeed, damaged specimens with the outer rim entirely removed would be virtually indistinguishable from *W. thyrsanota*. Similarly, *W. fimbriata* resembles *W. spectabilis* from which the outer trabeculate rim has been stripped, although there is a greater tendency in the latter towards vacuolation than in the former.

**Holotype and type locality.** Figs 6A, B, Museum of Victoria specimen P.16235, Era River district, south-east Papua New Guinea, Australasian Petroleum Company Wana Well sample W.451. Sample originally considered Lower Cretaceous by Deflandre & Cookson (1955); this was revised to Upper Jurassic by Cookson & Eisenack (1958).

**Stratigraphical distribution.** *Wanacea spectabilis* occurs consistently through the Oxfordian, lower part of the upper *Wanacea spectabilis* Zone (subzones 6ci/a/6ci/b) (Figs 11, 12; Foster, this volume; Helby & Partridge, in prep.). It ranges as an extremely rare component into the Oxfordian, lower *Wanacea clathrata* Zone (6bii) in the Timor Sea region but is slightly more prominent at this level in samples from the Sula Islands, Indonesia (from localities 8B & 9B in Sato et al., 1978, fig. 8).

**Wanacea talea** sp. nov. (Figs 7C, 8A-1)

1958 *Wanacea spectabilis* (Deflandre & Cookson 1955); Cookson & Eisenack, p. 57, pl. 9, fig. 1.

1981 *Wanacea spectabilis* (Deflandre & Cookson 1955) Cookson & Eisenack 1958; Fensome, fig. 3.

1987 *Wanacea spectabilis* (Deflandre & Cookson 1955) Cookson & Eisenack 1958; Fensome, fig. 3.
Fig. 8. Wangeia talea sp. nov. Specimens from sidewall cores from Buang-1 well at 3518.50m (Fig. 8A), Circinus-1 ST1 well at 3517.50m (Figs 8C-G-H), Crux-1 well at 3266.60m (Figs 8B, D-F) and ditch cuttings from Omati-1 well from 4285.54-4288.59m (Fig. 8I). All photomicrographs taken using plain transmitted light. The scale bar of 25μm in Fig. 8I refers to all photomicrographs. Figure 8I is the holotype, the remainder paratypes. Note conical hypocyst, presence or absence of short, rounded antapical horn, flattened epicyst, smooth autophragm and prominent posterior paracircular flange comprising a narrow proximal zone surmounted by slender trabeculate processes. A - CPC 35869, hypocyst, right lateral view, high focus. Relatively short, wide specimen. Note short antapical horn and smooth distal edge to posterior paracircular flange. B - CPC 35870, hypocyst, lateral view, median focus. Note susceptibility of the posterior paracircular flange to mechanical damage. C - CPC 35871, damaged hypocyst, lateral view, high/medium focus. Note regular insertion of processes on the posterior paracircular flange. D, E - CPC 35872, hypocyst with adherent operculum, right lateral view, median and low focus respectively. Note relatively narrow posterior paracircular flange which may readily fold. F - CPC 35873, hypocyst with attached operculum, left lateral view, low focus. Specimen lacks antapical horn; small antapical protuberance barely differentiated from the hypocyst. G, H - CPC 35874, hypocyst with attached operculum, oblique right lateral view, high and low focus respectively. Note relatively prominent posterior paracircular flange. I - P17297, hypocyst with adherent operculum, right lateral view, high focus. Well preserved specimen, note flattened epicyst and relatively narrow, regular posterior paracircular flange.
Previous Australian usage
Wanaea spectabilis – Ott (1970, pl. 8, figs 19, 20).
Wanaea spectabilis – Parker (1986, pl. 41, fig. 9).
Wanaea spectabilis – Helby.

Description. An acinate, intermediate to large species of Wanaea with a conical, hypocyst and with or without a short, distally blunt and rounded antapical horn which may be slightly inclined. The hypocyst is essentially flat. Autophagous smooth. Paratabulation is absent on the hypocyst, apart from a prominent posterior paracircular flange; although accessory archaeopyle sutures are not uncommon on the hypocyst. The paracircular flange is 5-11 µm wide, equatorial in position and interrupted at the indented parasacculus. The flange comprises a short (1-4 µm) proximal zone, which is entire to rarely irregularly vacuolate. This is surmounted by a simple, slender (1-2 µm wide), solid, processes which are linked distally by a continuous trabeculum. The processes vary from 3-9 µm in length, however most are between 5 and 7 µm. The trabeculum is c. 1 µm in width, parallel sided and imparts a smooth distal margin to the flange. The processes are inserted densely and regularly at approximately every 1 to 2 µm along the flange. The flange is not always perfectly regular and small, irregular areas where the processes appear to coalesce may occur. In these areas, the flange is usually solid or sparsely and irregularly vacuolate. Rarely, some processes bifurcate distally or are connected medially. Principal archaeopyle suture generally smooth, located immediately anterior of the anterior paracircular parasuture. The operculum is frequently attached ventrally.

Dimensions (µm, n=23): Min. (Mean) Max.
Length of hypocyst: 49 (62) 73
Width of cyst (incl. paracircular flange): 90 (107) 134
Width of cyst (excl. paracircular flange): 73 (92) 115
Width of paracircular flange: 5 (7) 11
Length of processes in paracircular flange: 3 (5) 9
Length of antapical horn: 5 (9) 18

The hypocyst of this species is profoundly flattened and no epicysts were observed in lateral view. Therefore the length of the entire cyst is approximately equal to the length of the hypocyst. It proved difficult to accurately and consistently measure the antapical horn because a distinct protuberance on the hypocyst is not always developed.

The measured specimens are from sidewall cores in Circinus-1 ST1 well at 3517.50m, Crux-1 well at 3266.60m and Buang-1 well at 3518.50m and sample 40, ditch cuttings between 4285.54m and 4288.59m from Island Exploration Company Omati-1 well, south-east Papua New Guinea (Cookson & Eisenack, 1958, figs 1, 2).

Comments. The most characteristic feature of this species is the trabeculum which forms a distinct, regular, outer rim to the paracircular flange (Figs 7C, 8). The epicyst of Wanaea talea is flat (Fig. 81), which is consistent with other species of Wanaea with prominent posterior paracircular flanges. Typically, the hypocyst is relatively low and wide, has a subtriangular outline, typically with a clearly differentiated antapical horn (Figs 8A, D-F). The postcircular flange is extremely characteristic, having a narrow, largely solid proximal zone surmounted by prominent parallel to subparallel, simple processes which are distally trabeculate (Figs 7C, 8). The proximal zone of the flange is normally 2-3 µm across, it is rarely reduced to 1 µm. Restricted, irregularly vacuolate areas may occur in the flange (Fig. 8I). Rarely, some processes are distally bifurcate or medial connections are developed (Figs 8D, G-H).

Comparison. Wanaea talea is similar to other members of the genus with prominent posterior paracircular flanges. Of these, it is most similar to Wanaea spectabilis, with which it intergrades. However, the flange of W. talea is much more simple than that of W. spectabilis, having a short, entire proximal zone which is surmounted by simple processes which are distally connected at a single trabeculate strand. The flange of W. spectabilis is much wider, has longer, more complex processes and a thin outer reticulate to vacuolate rim (Figs 4, 5, 7B). The posterior paracircular flange of W. clylindra resembles that of W. talea in having a smooth distal margin. However, the flange of W. clylindra can be extremely wide and is vacuolate, comprising elements which form a relatively regular, complex pattern (Cookson & Eisenack, 1958, pl. 9, figs 7, 8; Fig. 7A). Wanaea digitata has a two-layered posterior paracircular flange, which lacks a distal trabeculum. The inner zone is fenestrate to vacuolate and is surmounted by spines (Cookson & Eisenack, 1958, pl. 9, figs 4, 5; Woollam, 1982, fig. 1B). Wanaea talea is also similar to Wanaea thyrsanota and W. fimbrata. The resemblance is
Fig. 9. *Wanacea verrucosa* sp. nov. From ditch cuttings at 800.00m in Stag-1 well (Fig. 9A) and AGSO dredge sample 96-DR01/4/5 from Rowley Terrace, offshore Western Australia (Figs 9B-L). All taken using plain transmitted light. The scale bar of 25μm in Fig. 9L refers to all images. Holotype is Fig. 9A, remainder paratypes. Note acervate cyst organisation, prominent antapical horn, broadly hemispherical nature of epicyst, robust autophragm ornamented by seabrae, grana, verrucae, baculae and occasionally pilae and virtual absence of paratabulation. A - CPC 35875, hypocyst and operculum, right lateral view, high focus. Note prominent antapical horn, dense, low-relief ornamentation. B - CPC 35876, entire specimen, right lateral view, high focus. Note domed nature of epicyst. C - CPC 35877, hypocyst and operculum, right lateral view, high focus. Note slightly angular nature of epicyst. D-F - CPC 35878, entire, elongate specimen, right lateral view, high to low focus sequence. G-I - CPC 35879, hypocyst and operculum, right lateral view, high to low focus sequence. Note dense, low-relief ornamentation and domed operculum. J-L - CPC 35880, wide hypocyst and adjacent operculum, right lateral view, high to low focus sequence.
closest in *W. thysonota*, which has simple, solid distal processes which are occasionally connected. However, the posterior paracingular flanges of both these species are irregular, and there is no consistent distal trabeculum (Woollam, 1982, figs 1Bi, 1Biv).

**Derivation of name.** From the Latin *talea*, meaning slender staff, rod or stick and referring to the distinctive, simple, rod-like trabeculum at the distal side of the posterior paracingular flange.

**Holotype and type locality.** Figures 7C, 81, Museum of Victoria specimen P.17297, sample 40, ditch cuttings between 4285.54m and 4288.59m from Island Exploration Company Omati-1 well, south-east Papua New Guinea (Cookson & Eisenack, 1958, figs 1, 2).

**Stratigraphical distribution.** *Wonaea talea* is confined to the Oxfordian, upper part of the *Wonaea spectabilis* Zone (subzones 6cib-6cia) (Figs 11, 12; Foster, this volume; Helby & Partridge, in prep.). It is an inconsistent, relatively rare, component of the lower subzone (6ci), however, it may occur prominently in the upper part of the zone (subzone 6cia).

*Wonaea verrucosa* sp. nov. (Figs 9A-L)

1987 *Wonaea* sp. (granulate species), Helby et al., figs 17B, 17C.

1996 *Wonaea* sp. A “granulate species” of Helby et al., 1987; Burger, pl. 15, figs A, B, K-M.

**Previous Australian usage**

*Wonaea verrucosa* – Helby.

**Description.** An intermediate to occasionally large, acanthy species of *Wonaea* which lacks a posterior paracingular flange. It has a subconical hypocyrt with a prominent, wide, distally rounded antapical horn. The horn is closed distally and normally is inclined slightly towards the ventral side. The epicyt is also broadly domed, varies markedly in height and is either rounded apically or subangular. Short accessory architectural sutures may be developed on the operculum only. The autophyram is robust, c. 1 μm thick and is covered by non-tubular low relief ornamentation. The ornamentation is relatively varied in concentration and morphology. Scabre, grana, verrucae, bacular and occasionally pilae are present. These elements are normally 0.5-1 μm in height, however occasionally the bacular and pilae may range up to 2.5 μm high. Individual specimens may exhibit examples of more than one ornamentation type. The ornamentation may be slightly larger in the antapical region. In some specimens the mid-lateral areas may be relatively sparsely ornamented in comparison. Coalescence of the ornamentation into short, non-tubular, sinuous linear zones occurs. In some specimens there may be lineations of ornamentation at the posterior paracircular parasuture. On the hypocyrt there are rare instances of possible, discontinuous parasutural ornamentation or a lack of ornamentation in parasutural zones. Ventrad, the parasutus is marked by a narrow, shallow concavity or depression and the simple operculum is generally attached ventrally.

**Dimensions (μm; n=30); Min. (Mean) Max.**

Length of entire cyst: 69 (81) 95

Length of epicyt: 11 (27) 35

Length of hypocyrt (incl. paracingular): 47 (62) 75

Equatorial width of hypocyrt (in lateral view): 68 (83) 109

Length of antapical horn: 4 (11) 20

Width of antapical horn (at midpoint): 5 (9) 13

The measured specimens are from ditch cuttings at 800.00m in Stag-1 well, core at 2208.65m in Sunset-1 well and AGSO seafloor dredge sample 96/DR014/5 from the Rowley Terrace, offshore Western Australia (Burger, 1996).

**Comments.** This distinctive species of *Wonaea* is characterised by the ‘domed’ epicyt and the presence of varied, dominantly nontubular, low relief ornamentation. Most specimens are scabrate, granulate and/or verrucate. However, the ornamentation is extremely variable; some specimens may be scabrate and others densely granulate/verrucate. The apical angulation which is occasionally developed is not a horn/protruberance (Fig. 9C).

**Comparison.** *Wonaea verrucosa* differs from the other species of the genus by the lack of a posterior paracingular flange and the presence of consistent and normally dense, nontubular ornamentation. The Northern Hemisphere species *Wonaea acollaris* has a shorter epicyt and is partially paratabulate. *Wonaea zohorensis* also has nontubular ornamentation, but the elements are smaller than those on *W. verrucosa* and they are typically coalescing. Of the similar Southern Hemisphere species, *W. etiada* has thin autophragm which is largely smooth and *W.
Fig. 10. *Winacea zoharensis* Conway 1978 emend. All from core 9, at 1190.00-1197.00m in the Zohar-5 well, southern Israel (Conway, 1978), in University of Sheffield collection. All photomicrographs taken using plain transmitted light. The scale bar of 25μm in Fig. 10I refers to all photomicrographs. Figs 10G-H are the holotype, remainder, topotypes. Note acutate cyst organisation, prominent distally rounded antapical horn, flattened epicyst (operculum), relatively thick, sebaceous granulate to rugulate autophagum, low, irregular, commonly spinose, parasutural ridges and large intratabular areas devoid of ornamentation. A - ML 1459-M24, slightly damaged hypocyst, right lateral view, high focus. Note prominent antapical horn and lack of ornamentation in intratabular areas. B - ML 1459-O31, damaged hypocyst, left lateral view, high focus. Note short antapicular structure on antapical horn, relatively high ornamentation at paracingulum and parasutural linement of ornamentation at left hand side. C - ML 1459-M27, hypocyst, left lateral view, high focus. Note inclined aspect of antapical horn. D - ML 1459-J14, specimen with attached operculum, left lateral view, high/median focus. Note small antapicular structure on antapical horn. E - ML 1459-M31, hypocyst with detached epicyst, left lateral view, high/median focus. Note relatively smooth autophagum in the intratabular regions. F - ML 1459-G29, specimen with detached operculum, right lateral view, high focus. Note apparent lack of parasutural features. G-H - ML 1459-B31, specimen with attached operculum, oblique left lateral view, high and low focus respectively. Note relatively large antapical horn and parasutural ornamentation on epicyst. I - ML 1459-L32, isolated epicyst, apical view, high focus. Note irregularly spinose nature of parasutural ridges.
lacuna is cavitae. *Distilidinium caddaense* (Filatoff 1975) Stover & Helby 1987 is similar in overall morphology to *W. verrucosa*. The former species has a subconical hypocyst with an antapical horn/protruberance, a 'domed' epicyst and scabrate/granulate autophragm (Stover & Helby, 1987). However, *D. caddaense* has a compound, multiparaplate precingular (type IP5-SP, 'disintegration style') archaeopyle and is normally significantly larger than *W. verrucosa*. If the archaeopyle of *D. caddaense* has not started to open, the specimen may be identified as *W. verrucosa* (see Stover & Helby, 1987, fig. 4).

**Derivation of name.** From the Latin, verruca, meaning wart and referring to the characteristic verrucate ornamentation of this species.

**Holotype and type locality.** Fig. 9A, CPC 35875, ditch cuttings at 800.00m in Stag-I well.

**Stratigraphical distribution.** *Wanorea verrucosa* is confined to the Bathonian *Wanorea verrucosa* Zone (subzones 7cin-7cu) (Figs 11, 12; Foster, this volume; Helby & Partridge, in prep.).

**Wanorea zoharenensis** Conway 1978 emend. (Figs 10A-I).

1978 *Wanorea zoharenensis*; Conway, p. 347, pl. 1, figs 7, 8, 10 (not figs 6-7, 9 as stated on p. 347).
1981 *Energlynita acollaris* (Dodekova 1975)
Sarjeant 1978; Fensome, p. 50.

**Emended description.** An intermediate sized, acavate species of *Wanorea*. The hypocyst is subconical and appears subtriangular in outline. It has a prominent distally closed and rounded antapical horn. The antapical horn is somewhat variable but is normally relatively slender and is straight or may be slightly inclined ventrally or dorsally. A short (1-5μm), distally pointed, solid extension of the antapical horn may be present. The epicyst is a flattened dome shape, appears to vary considerably in height and is apically rounded to straight. Short accessory archaeopyle satures and low, irregular parasutural ridges may be developed on the epicyst. The autophragm is moderately thick (0.5-1μm) and is scabrate/granulate to rugulate (c. 0.5μm high). The elements are scabrate and granate, which frequently coalesce into short, irregular, sinuous, nonnatal to parasutural ridges. Where the ornamentation is densely packed and the elements merge/coalesce, it may appear to be pseudoreticulate. The distribution of this ornamentation is irregular to parasutural. Large intratabular areas which are free of ornamentation may be present. Parasutural is partially indicated by irregular parasutural ridges which are occasionally surmounted by slender (c. 0.5μm wide), solid spines which are 0.5-1.5μm long. These spines may be present on the epicyst but are normally longest and most dense in the antapical region. Occasionally, the spines are connected distally by trabeulae. In some specimens, the parasutural ridges are suppressed and these are partially indicated by lineations of ornamentation. The parasutural parasutures are marked by relatively long (2-3μm) solid, simple processes, which frequently coalesce into crests. The parasculus is indicated by a shallow concavity and the simple operculum is generally attached ventrally.

**Dimensions (μm; n=15):** Min. (Mean) Max.
Length of hypocyst: 56 (67) 77
Equatorial width of hypocyst (in lateral view): 74 (81) 95
Length of antapical horn: 8 (11) 18
Width of antapical horn (at midpoint): 4 (7) 10

No entire cysts were encountered. A single epicyst (operculum) was observed in lateral view which was 25μm long (high). Two epicysts were observed in polar view, these measured 57μm x 64μm and 63μm x 76μm (Fig. 10I). Based on the measurements here, Conway (1978, p. 347) appears to have transposed length and breadth. The measured specimens comprise tootypes and the holotype from the Zohar Formation in the Zohar-5 Borehole, southern Israel, sample 15, conventional core 9 at 1190.00m-1197.00m (Conway, 1978).

**Comments.** The contention of Fensome (1981, p. 50) that *Wanaea zoharenensis* is a junior synonym of *Energlynita* (*Wanaea*) *acollaris* is rejected. Conway (1990) accepted Fensome's interpretation. However, following our reexamination of Conway's material we believe that *W. zoharenensis* warrants continued separation. This species is a distinctive morphotype due to the ornamentation and does not appear to intergrade with any other representative of the genus. An emended description of this species is given in order to stress the partial and irregular nature of the parasuturation, that the overwhelming majority of the ornamentation is nontubular and that the ornamentation is best described as scabrate/granulate to rugulate (Fig. 10). Furthermore, large intratabular areas devoid of ornamentation may
to an antapical horn or protuberance.

**Comparison.** *Wankea zoharensis* differs from some species of the genus in lacking a prominent, lance-like posterior paracingular flange, being acuate, having irregular scabrulate/granulate to rugulate ornamentation and possibly being partially paratabulate. It is most similar to *Wankea acollaris* and *W. indotata*. It differs from *W. acollaris* in having prominent scabrulate/granulate to rugulate ornamentation. Furthermore, it does not exhibit parasutural ridges. The paracingular ornamentation of relatively long, simple processes which coalesce into crests in *W. zoharensis* is similar to the narrow ‘fuzzy’ posterior paracingular structure in *W. indotata* (see Drugg, 1978). However, the paracingular crests in *W. zoharensis* are longer than those in *W. indotata* and the latter is psilate or bears occasional nontabular granula or spines. *Wankea enoda* has a thin, largely smooth, autophagram, *W. lacuna* is cavit and *W. verrucosa* has a relatively thick autophagram ornamented by nontabular scabrae, granula, verrucae and/or baculae.

**Holotype and type locality.** Figures 10G-H, specimen ML 1459, slide MS 2, England Finder coordinate 531/4, sample 15 (box 2 - top), from the late Bathonian Zohar Formation in the Zohar-5 Borehole, southern Israel, conventional core 9 between 1190.00m and 1197.00m (Conway, 1978). Material housed in the Centre for Palynology, University of Sheffield, Sheffield, U.K.

**Stratigraphical distribution.** *Wankea zoharensis* has been recorded from the late Bathonian Zohar Formation of southern Israel (Fig. 12; Conway, 1978).

### BIOSTRATIGRAPHY AND PROVINCIALISM

*Wankea* is important in both hemispheres with several relatively short ranging species such as *W. talea* and *W. fimbriata* (Figs 11, 12). Figures 11 and 12 are range charts of the species of *Wankea* which occur in the Indo-Pacific region and worldwide respectively. *Wankea indotata* is the only species which is cosmopolitan; it apparently has a younger range in the Indo-Pacific region (Fig. 12). Records of Australasian (‘Cookson’) species in the Northern Hemisphere have subsequently been assigned to European species.

It is possible that a closer understanding of the species of *Wankea*, and their evolution, will provide some key tie points for correlating Australian successions to the European standard.

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**Table:**

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<th>LATE JURASSIC</th>
<th>DINOFLAGELLATE CYST ZONES</th>
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<td>Wankea enoda</td>
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<td>Wankea digitata</td>
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<td>Wankea zoharensis</td>
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**Fig. 11.** Stratigraphical distribution of the eight species of *Wankea* reported from the Mid and Late Jurassic of the Indo-Pacific region. Species with asterisks have posterior paracingular flanges. *Wankea indotata* is envisaged as a possible intermediate species between the energylnid forms and the species with distinct posterior paracingular flanges. The dinoflagellate cyst zones and subzones are from Foster (this volume) and Helby & Partridge (in prep.). The stage (age) correlations are based on those in Helby et al. (1987, figs 12, 19); it is not implied that these correlations to the European standard are precise. The abbreviations in the Australian dinoflagellate cyst zonation of Helby & Partridge (in prep.) are as for Fig. 12.
One of these may be the oldest occurrence of abundant *W. accolians* within the late Bajocian (18.76 Ma). No other occurrences of *W. accolians* in Australia are reported to date. The earliest occurrence of Australian *W. accolians* is in the late Bajocian (18.76 Ma) and is considered to be the first occurrence of the species in Australia. The range of this species extends over a period of approximately 2 million years, from the late Bajocian to the early Bathonian (18.76-17.35 Ma).

The table above shows the distribution of *W. accolians* across different time periods. The earliest occurrence is in the late Bajocian, followed by the early Bathonian, mid-Bathonian, mid-Carnian, and early Callovian. The species is absent in the late Callovian and is not recorded in the early Oxfordian. In the late Kimmeridgian, *W. accolians* is present from the early to late stages.

The distribution of *W. accolians* across different zones is also shown in the diagram. The species is first recorded in the late Bajocian, with a steady increase in occurrences throughout the Bajocian and Bathonian periods. In the Callovian, the species is present in the mid and late stages, with a peak in the early stages. In the Oxfordian, *W. accolians* is absent from the late stage, with a return in the early Kimmeridgian. The species reaches its peak in the late Kimmeridgian, with a decline in the early stage of the next epoch.
taxa (Fig. 12). We consider that these bioevents are possibly coeval.

_Wanaea indotata_ has a narrow paracircular 'fuzzy rim-like structure' (Drugg, 1978, p. 75). It is possible that this species represents an evolutionary intermediate between the older, energlynoeid species and the younger flanged species. The range base of the oldest species with a posterior paracircular flange in both hemispheres appears to be a potentially correlative bioevent. In the Southern Hemisphere this is the oldest occurrence of _Wanaea digitata_ and is in the latest mid Callovian (Fig. 12). The oldest flanged representative of _Wanaea_ in Europe is _Wanaea thyssanota_, which ranges from the latest mid Callovian to early Oxfordian (Riley & Fenton, 1982; Riding & Thomas, 1992). _Wanaea thyssanota_ was previously identified as _W. digitata_ in Europe (Woollam, 1982). The base of _Wanaea digitata_ in the latest mid Callovian of Europe in Riley & Fenton (1982, fig. 8) helped provide the age control for the base of the _W. digitata_ Interval Zone (7thi-7a) of Helby et al. (1987).

On the basis of currently available faunal information (Francis & Westermann, 1993), it is not unreasonable to suggest that the range top of _Wanaea spectabilis_ is no older than latest mid Oxfordian. There are no European species which range above the early Oxfordian (Riding & Thomas, 1992). In Australia, _Wanaea clathrata_ is the youngest species, and is considered to span the Oxfordian-Kimmeridgian transition (Helby et al., 1987; Figs 11, 12).

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**REFERENCES**


EVITT, W.R., 1963. A discussion and proposals


FOSTER, C.B., This volume. Introduction.


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**APPENDIX 1: SAMPLE DETAILS**

1. Locations and operators of wells from which Australasian material has been studied

<table>
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<tr>
<th>Well Name and Number</th>
<th>Latitude</th>
<th>Longitude</th>
<th>Operator</th>
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<td>Bung-1</td>
<td>10° 35' 49.58&quot;S</td>
<td>126° 04' 04.94&quot;E</td>
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<tr>
<td>Circinus-1 ST1</td>
<td>12° 54' 44.97&quot;S</td>
<td>124° 23' 23.89&quot;E</td>
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<tr>
<td>Crux-1</td>
<td>12° 56' 38.49&quot;S</td>
<td>124° 27' 09.32&quot;E</td>
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<tr>
<td>Eclipse-2</td>
<td>12° 14' 13.30&quot;S</td>
<td>124° 38' 41.44&quot;E</td>
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</tr>
<tr>
<td>Krill-1</td>
<td>10° 44' 54.52&quot;S</td>
<td>126° 12' 06.74&quot;E</td>
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</tr>
<tr>
<td>*Magobu Island-1</td>
<td>08° 31' 47.39&quot;S</td>
<td>143° 16' 31.18&quot;E</td>
<td>Endeavour</td>
</tr>
<tr>
<td>*Omati-1</td>
<td>07° 26' 00.59&quot;S</td>
<td>143° 57' 29.99&quot;E</td>
<td>Island Exploration Co.</td>
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<tr>
<td>Searfell-1</td>
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<td>114° 01' 08.02&quot;E</td>
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<td>Stag-1</td>
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<td>116° 15' 28.71&quot;E</td>
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<tr>
<td>Sunrise-2</td>
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<td>128° 06' 12.37&quot;E</td>
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<td>Sunset-1</td>
<td>09° 38' 36.37&quot;S</td>
<td>127° 58' 34.77&quot;E</td>
<td>Shell</td>
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</table>

* - All listed wells are from Australia, except Magobu Island-1 and Omati-1 which are from Papua New Guinea.

2. Non-Australian and seafloor samples

2.1. Rowley Terrace, offshore Western Australia

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<td>Burger (1996)</td>
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2.2. Sula Islands, Indonesia

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<td>8B</td>
<td>Oxfordian</td>
<td>Sato et al. (1978)</td>
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<tr>
<td>MS 2</td>
<td>Bathonian</td>
<td>Conway (1978)</td>
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2.3. Zohar-5 borehole, southern Israel

MS 2 West of the Dead Sea

2.4. Ketton Grange quarry, Ketton, Lincolnshire, U.K.

MPA 15438 SK 4978 3062

<table>
<thead>
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<th>Location</th>
<th>Age</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>MPA 15438</td>
<td>SK 4978 3062</td>
<td>Bathonian</td>
<td>Sarjeant (1976)</td>
</tr>
</tbody>
</table>
APPENDIX 2: REGISTER OF FIGURED SPECIMENS

All palynomorph specimens figured in this paper are listed here, together with essential details. The specimens are mainly curried in the Commonwealth Palaeontological Collection (CPC) of the Australian Geological Survey Organisation, Canberra. The species of *Waniaea* are listed alphabetically and the location (EF) of the specimens on the microscope slides are all ‘England-Finder’ co-ordinates. These were taken with the slide label to the left of the observer; the microscope stage opening toward the microscope user. The coding for types is as follows: H = holotype; P = paratype; T = topotype, where appropriate. All specimens of new taxa examined during this study contributed to the specific concepts described. Therefore, all the figured species which are not holotypes are paratypes. SGM = single grain mount. The single grain mounts do not have unique numbers; they are numbered sequentially for each species within a particular sample. The specimens are from outcrop, conventional core, sidewall core and ditch cutting samples.

### Species

<table>
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<td>T40/1</td>
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* - collections of the British Geological Survey, Nottingham, UK.

### Species

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* W. spectabilis | 4A | SGM 4 (i) | M33/1 | Eclipse-2 (2477.00) | 35862 |
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| W. spectabilis | 4C | SGM 3 (i) | N27/1 | Eclipse-2 (2477.00) | 35864 |
| W. spectabilis | 4D | SGM 8 (ii) | J35/1 | Eclipse-2 (2477.00) | 35865 |
| W. spectabilis | 4E | SGM 4 (ii) | L31/2 | Eclipse-2 (2477.00) | 35866 |
| W. spectabilis | 4F | SGM 1 (i) | K36 | Eclipse-2 (2477.00) | 35867 |
| W. spectabilis | 5  | SLK1 | T9/1 | Seafell-1 (1346.80) | 35868 |</p>
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<td>S42/4</td>
<td>outcrop, Era River, PNG</td>
<td>P16235*</td>
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<tr>
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* - Museum Victoria registration number

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<table>
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* - Museum Victoria registration number

** - range depth of ditch cuttings: 4285.54m-4288.59m

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* - range depth: 1190.00m-1197.00m

** - Centre for Palynology, University of Sheffield, Sheffield, UK, type/figured slide collection registration number.
Phallocysta granosa sp. nov., a Mid Jurassic (Bathonian) dinoflagellate cyst from the Timor Sea, Australia

JAMES B. RIDING and ROBIN HELBY


Phallocysta granosa sp. nov. is described from the Timor Sea, Australia. This new dinoflagellate cyst has stratigraphical utility in the Bathonian (Mid Jurassic) Caddasphaera halosa and Wamoa verrucosa zones.

James B. Riding, Australian Geological Survey Organisation, GPO Box 378, Canberra, ACT 2601, Australia (present address: British Geological Survey, Keyworth, Nottingham NG12 5GG, UK [e-mail: jbr@bgs.ac.uk]); Robin Helby (corresponding author), 356A Burns Bay Road, Lane Cove, NSW 2066, Australia (e-mail: rhelby@ozemail.com.au). 10 November 2000.

Keywords: dinoflagellate cysts, Middle Jurassic, Australia, biostratigraphy, taxonomy

THE PALYNOCOLOGICAL ZONATION of the Australian Mesozoic published by Helby et al. (1987) was the first attempt to provide an integrated, pan-Australian microplankton and spore-pollen zonation. Only the basic framework of the zonation was provided in anticipation that further contributions, particularly the documentation of new taxa, would be necessary as the zonation scheme evolved. This paper is one of a series providing the taxonomic foundation necessary to formalise widely used unpublished subdivisions of these zones. These subzones have widespread currency within the hydrocarbon industry due to the legislative requirement for the release of technical data under the Petroleum (Submerged Lands) Act 1967. The informal subdivisions of the Helby et al. (1987) zonation have been entered into the Australian Geological Survey Organisation (AGSO) STRATDAT database. A diagrammatic update of the Helby et al. (1987) zonal scheme is presented by Foster (this volume), and will be described fully by Helby & Partridge (in prep.). This taxonomic project is an initiative of the Petroleum and Marine Division of AGSO.

This paper provides a formal description of Phallocysta granosa sp. nov. from a Mid Jurassic (Bathonian) dinoflagellate cyst assemblage in samples from the Timor Sea (Appendix 1). The new taxon has stratigraphical utility within the Bathonian Caddasphaera halosa and Wamoa verrucosa zones of Helby & Partridge (in prep.). The figured specimens in this paper are from the Bathonian part of the Plover Formation (Plover III sequence of Patillo & Nicholls, 1990) in Sunrise 2 and Sunset 1 wells, offshore north-western Australia (Foster, this volume; Appendices 1, 2).

SYSTEMATIC PALYNOCOLOGY

Most of the morphological terminology for dinoflagellate cysts is from Evitt (1985). References to author citations of other taxa discussed are given in the bibliography of Williams et al., 1998, p. 747-817). The figured specimens are housed in the Commonwealth Palaeontological Collection (CPC) of the Australian Geological Survey Organisation, Canberra, and the collection of Woodside Energy Ltd., Perth (Appendices 1, 2).

This study has been conducted using both single grain mounts (or mounts with multiple specimens) and strew mounts. All samples studied are from conventional cores. The photomicrographs in this paper were all taken using an Olympus DP10 digital camera system coupled to a Zeiss Axioskop photomicroscope, housed at AGSO. Some extraneous palynodebris, not adherent to the figured specimens, has been digitally removed in selected images.

The images illustrated in this paper are selected from a digital database that contains many more images than have been figured. The sample details, key morphological data and measurements of each specimen are held on open file spreadsheets. The image database may be accessed on the AGSO website (http://www.agso.gov.au).
Fig. 1. *Phallocysta granosa* sp. nov. All from cores in Sunrise-2 well at 2122.25 m (G-I) and Sunset-1 well at 2216.67 m (C), 2216.66 m (B, E-F), 2214.30 m (A) and 2208.83 m (D). All photomicrographs taken using plain transmitted light. The scale bar of 25 μm in Fig. 1I refers to all photomicrographs. Figs A, C-E are composite photomicrographs. Figs G-I is the holotype; the remainder, paratypes. Note small size, elongate subconical outline, variable nature (rounded to pointed) of the apical extremity, lack of an apical horn, rounded antapex, ellipsoidal/subcircular endocyst and granulate-spinose periphragm. A - pale specimen with sharp apical extremity. B - note pyrite crystals, folding close to antapex and sharp apical extremity. C - CPC 35881, relatively wide, squat specimen with relatively large endocyst. Note granulate periphragm. D - note thin, diaphanous periphragm and randomly developed folds. E - highly folded, squat specimen. Note anterior intercalary archeopyle. F - specimen with much growth of pyrite crystals. Note granulate periphragm. G-I - CPC 35882, well preserved specimen. Note folding of endocyst and granulose/spinose ornamentation of periphragm and archeopyle in I.

This species has been used in unpublished reports, which are now in the public domain (on open file). To maximise the utility of this species, the informal ‘M.P.’ (microplankton) codes used are listed, separate from the formal synonymy listing, under the heading ‘Previous Australian usage’.

**Dinoflagellate cysts**

*Phallocysta* Dörhöfer & Davies 1980 emend. Riding 1984


*Type species*. *Phallocysta eumeke* Dörhöfer &
Phallocysta granosa sp. nov. (Figs 1A-I)

?1988 gen. et sp. indet. AR; Helby et al., fig. 3B,

Previous Australian usage
M.P. 903 – Helby.

Description. A small to intermediate sized (Stover & Evitt, 1978, p. 5) species of Phallocysta with an elongate subconical outline. The pericyst is cone-shaped, the distal extremity of the apical horn is blunt to sharply pointed and the antapex is rounded. The endocyst is ellipsoidal to subcircular in outline and fills most of the pericyst, apart from the apical part of the pericoel. The endophragm is relatively thick (c. 1µm) and microscabrare to microgranulate. By contrast, the periphragm is thinner (c. 0.5µm) and ornamented by granules and/or spines. Where spines are developed, they are irregular in density and short, simple and solid. They vary from 0.5 to 1µm in length and are c. 0.5µm in width at the base. Both the granules and spines are nontabular and normally are of moderate density. Both cyst layers are susceptible to folding.

Dimensions (µm; n=20): Min. (Mean) Max.
Length of pericyst: 37(43) 59
Length of pericoel: 8(14) 20
Length of endocyst: 22(30) 42
Equatorial width: 22(32) 40

The measured specimens are from core from Sunrise-2 well at 2122.25m and Sunset-1 well at 2216.67m, 2216.66m, 2214.30m, 2208.65m and 2204.06m.

Comments. This species of Phallocysta has a densely granulate to spinose periphragm (Fig. 1). The ornamental style is somewhat variable in that some forms have an irregular covering of short spines and others are largely microgranulate (Fig. 1). The apical horn varies from being sharply-pointed (Figs 1A-B) to rounded (Figs 1E-I). Both cyst layers are closely appressed in the hypocyst; the species is consistently epicate and the thin periphragm separates from the more robust endophragm above the equator. There is no manifestation of paratabulation apart from the anterior intercalary periarchaeopyle (Figs 1E-I).

Comparison. Phallocysta granosa differs from the other species of the genus by its relatively small size and the granulate/spinose ornamentation. Phallocysta arctica (Below 1987) Riding 1984 is more elongate than P. granosa (the holotype is 52µm long according to Below, 1987, p. 113), and the former is extremely densely granulate to microgranulate (Below, 1987). The Early-Mid Jurassic (latest Toarcian-early Bajocian) species Phallocysta elongata (Beju 1971) Riding 1994 is also more elongate than P. granosa, the former is also puate to occasionally seconate and is typically flask-shaped (Riding, 1994). Phallocysta elongata may be relatively sparsely ornamented and has a distinct apical horn. Rare late Toarcian to Aalenian specimens of P. elongata may be microgranulate; for example, those illustrated as P. minutu Prauss 1989 by Riding et al. (1991, pl. 2, figs 23-25). However, Lentin & Williams (1993) pointed out that P. minutu was invalid and proposed P. subconica as a substitute name. Subsequently, Riding (1994) synonymised P. subconica with P. elongata. The species P. granosa and P. elongata are clearly similar. However, the latter is generally more rounded and rarely microgranulate, whereas the former is distinctly granulate to occasionally spiny and is generally more squat. The only other Australian species of Phallocysta is P.? erregrulentus (Filatoff 1975) Stover & Helby 1987. This species is larger than P. granosa, commonly antapically bilobate, may have a rounded apical extremity and has a smooth, granulate to spinose periphragm and rarely, a spinose endophragm (Stover & Helby, 1987, fig. 11). Furthermore, Phallocysta? erregrulentus may be cavate or cornucavate. The cornucavate forms of P.? erregrulentus have a distinctive trilobate pericyst (Stover & Helby, 1987, fig. 10E). Phallocysta euneke is significantly larger than P. granosa. The former also has a consistently smooth endophragm, frequently has a smooth periphragm, and has a distinct apical horn and a distinctly lobate hypocyst (Dörhöfer & Davies 1980; Riding 1984). Phallocysta frommerensis Below 1987 from the Aalenian of southern Germany is relatively small and squat. It also has a spongy, densely gernmate/verrucate periphragm (Below, 1987, pl. 22, figs 9-18). The Aalenian-Bajocian species Phallocysta thomasii Smelror 1991 is similar in size to P. granosa and has a spinose periphragm. However the former taxon has a strongly differentiated apical horn and is antapically bilobate.

Helby et al. (1988, fig. 3B) illustrated as "gen. et sp. indet. AR", a single specimen from the Callovian Oruca Sandstone of New Zealand which
closely resembles Phalocysta granosa.

Derivation of name. From the Latin *granosus*, meaning full of seeds or grains and referring to the distinctive granulate ornamentation of the periphragm in this species.

Holotype and type locality. Figures 1G-J, CPC 35882, from conventional core in Sunrise-2 well at 2122.25m.

Stratigraphical distribution. Phalocysta granosa ranges from the Bathonian, lower part of the *Caddasphaera halosa* Zone (subzone 7ciir) to the middle part of the *Wanaea verrucosa* Zone (subzone 7ciirr) in Australia (Foster, this volume; Helby & Partridge, in prep.). The species has been tentatively identified in the Callovian Okara Sandstone of New Zealand (Helby et al., 1988).

ACKNOWLEDGEMENTS
The authors are grateful to Dr Clinton B. Foster (AGSO, Canberra) for promoting and facilitating this work and for editorial guidance and advice. Christian Thun and Andrew Kelman (AGSO, Canberra) provided invaluable help respectively with preparations and the manipulation of digital images. Mr Eddie Resiak of the core and cuttings repository at AGSO, Canberra courteously provided access to core material. Dr Neil G. Marshall (Woodside Energy Ltd., Perth) kindly provided slides on request. Drs J. Goodall and A. D. Partridge are thanked for reviewing the manuscript. J. B. Riding publishes with the permission of the Chief Executive Officer, AGSO.

REFERENCES


FOSTER, C.B., this volume. Introduction.


APPENDIX 1: LOCATIONS OF WELLS

<table>
<thead>
<tr>
<th>Well Name/Number</th>
<th>Latitude</th>
<th>Longitude</th>
<th>Operator</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sunrise-2</td>
<td>09° 29' 57.94&quot;S</td>
<td>128° 06' 12.37&quot;E</td>
<td>Woodside</td>
</tr>
<tr>
<td>Sunset-1</td>
<td>09° 38' 36.37&quot;S</td>
<td>127° 58' 34.77&quot;E</td>
<td>Shell</td>
</tr>
</tbody>
</table>
APPENDIX 2: REGISTER OF FIGURED SPECIMENS

All figured specimens are listed here, together with essential details. The specimens are curated in the Commonwealth Palaontological Collection (CPC) of the Australian Geological Survey Organisation, Canberra, and the collections of Woodside Energy Ltd., Perth. The location (EF) of the specimens on the microscope slides are all 'England-Finder' co-ordinates and were taken with the slide label to the left of the observer; the microscope stage opening toward the microscope user. The coding for types is as follows: H = holotype; P = paratype. SGM = single grain mount. The single grain mounts do not have unique numbers; they are numbered sequentially for each species within a particular sample. The specimens are all from conventional core samples.

<table>
<thead>
<tr>
<th>Species</th>
<th>Type</th>
<th>Fig(s)</th>
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<th>EF</th>
<th>Well (depth, m.)</th>
<th>CPC No.</th>
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<td>1A</td>
<td>Ass. sl. 2</td>
<td>N12/4</td>
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<td>P</td>
<td>1B</td>
<td>Ass. sl. 1</td>
<td>J20/3</td>
<td>Sunset-1 (2216.66)</td>
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<tr>
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<td>1C</td>
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<td>Q69</td>
<td>Sunset-1 (2216.67)</td>
<td>35881</td>
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<td>1D</td>
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<td>1E</td>
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<tr>
<td><em>P. gramosa</em></td>
<td>H</td>
<td>1G-I</td>
<td>SGM 1 (i)</td>
<td>M27/4</td>
<td>Sunrise-2 (2122.25)</td>
<td>35882</td>
</tr>
</tbody>
</table>

* - Collections of Woodside Energy Ltd., Perth, Western Australia
Microplankton from the Mid Jurassic (late Callovian) *Rigaudella aemula* Zone in the Timor Sea, north-western Australia

JAMES B. RIDING and ROBIN HELBY


A Mid Jurassic (late Callovian) suite of marine microplankton is documented from the Elang Formation and its equivalents in the Timor Sea, offshore north-western Australia. Two genera, *Voodosis* and *Woodinia* and eleven species of dinoflagellate cysts are described as new. The dinoflagellate cyst species are *Cteniodinium aevorum*, *Cteniodinium fuscahisarum*, *Cteniodinium planocrustatum*, *Durotrigia magna*, *Fusiformacysta terniana*, *Lithodinia proxisthymosa*, *Melinagropyxidae pentabulata*, *Melinagropyxidae viriosa*, *Voodosis tabulata*, *Woodinia pedis* and *Yalkalpodinium elangiana*. *Nannus apiculatus* is a new acritarch species.

The dinoflagellate cyst genus *Fusiformacysta* is emended to stress the 3P nature of the archaeopyle and the presence of at least one, small anterior intercalary paraplate. The genera *Lithodinia* and *Melinagropyxidae* are maintained as separate, based on operculum character. *Tabulodinium* and its single species, *T. senarum*, are both emended in order to document a revised paratabulation pattern and the precise archaeopyle style (anterior intercalary, type 21). The ornamentation of *T. senarum* is commonly destroyed by oxidation. The genus *Yalkalpodinium* is emended to accommodate the morphology of the new species *Y. elangiana*. All the newly described microplankton taxa have stratigraphical utility in the *Wanaea digitata* and *Rigaudella aemula* (Interval) Zones.

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Keywords: dinoflagellate cysts, acritarch, Middle Jurassic, Australia, biostratigraphy, taxonomy

THE PALYNOLOGICAL zonation of the Australian Mesozoic published by Helby et al. (1987) was the first attempt to provide an integrated, pan-Australian microplankton and spore-pollen zonation. Only the basic framework of the zonation was provided in anticipation that further contributions, particularly the documentation of new taxa, would be necessary as the zonation scheme evolved. This paper is one of a series providing the taxonomic foundation necessary to formalise the widely used unpublished subdivisions of these zones. These subzones have widespread currency within the hydrocarbon industry due to the legislative requirement for the release of technical data under the Petroleum (Submerged Lands) Act 1967. The informal subdivisions of the Helby et al. (1987) zonation have been entered into the Australian Geological Survey Organisation (AGSO) STRATDAT database. A diagrammatic update of the Helby et al. (1987) zonal scheme is presented by Foster (this volume), and will be fully described by Helby & Partridge (in prep.). This taxonomic project is an initiative of the Petroleum and Marine Division of AGSO.

This paper provides formal descriptions of previously undescribed marine microplankton taxa from Mid Jurassic (late Callovian) palynofloras recorded in samples from the Elang Formation and its equivalents in the Bayu-Undan gas field and the Challis oil field, Timor Sea, offshore north-western Australia (Figs 1, 2; Appendix 1). All the new taxa have stratigraphical utility within the *Wanaea digitata* and *Rigaudella aemula* (Interval) Zones of Helby et al. (1987). The figured specimens are from samples in the Broome-3 Town Bore, Challis-11-ST1, ST2, Investigator-1, Jabiru-2, Layang-1, Montebello-1, Rowan-1ST, Tamar-1, Tern-1, Tern-
2, Undan-1, Undan-3 and Undan-4 wells (Foster, this volume; Appendices 1, 2).

Helby et al. (1987, p. 27) stated that their Rigaudella aemula Interval Zone is of late Callovian to earliest Oxfordian age based upon the intercalation of the zone between the mid Callovian and Oxfordian (Helby et al., 1987, fig. 12). This evidence is from European palynological data (Riley & Fenton, 1982) and macrofauna, respectively (Arkell, unpublished reports to WAPET). Davey (1987, fig. 3), however, placed the zone entirely within the late Callovian, and assigned it to the lower part of his Wanzaea digitata Zone. Francis & Westermann (1993, fig. 1b), also interpreted the age of the Rigaudella aemula Interval Zone to be late Callovian. However, these authors also suggested that it is most likely to be late Callovian to earliest Oxfordian as originally stated by Helby et al. (1987) (Francis & Westermann, 1993, fig. 7). The conclusions of Francis & Westermann (1993, fig. 7) were based on linking the Australasian molluscan faunas to north-west Europe by the several-order correlation of various ammonite faunal provinces. Burger (1996, fig. 2) assigned the Rigaudella aemula Interval Zone to the entire Callovian Stage, except the latest Callovian, within AGSO timeslice J-7. There is little direct evidence of Australian-European correlations within the Callovian.

SYSTEMATIC PALYNOLOGY

Here, two new genera and eleven new species of dinoflagellate cyst and one new species of acritarch are described. The genera are listed in alphabetical order within the two groups; for the dinoflagellate cysts, the recent suprageneric classification of Fensome et al. (1993) is not used. The dimensions are all given in micrometres (μm). For descriptive purposes, the cyst sizes, small, intermediate and large, are after Stover & Evitt (1978, p. 5). Therefore, intermediate size dinoflagellate cysts have a maximum dimension of between 50μm and 100μm. Small and large forms are less than 50μm and over 100μm respectively.
The majority of the morphological terminology for the dinoflagellate cysts are those used by Evitt (1985). However, the term lothiocyst refers to what remains of a dinoflagellate cyst after the operculum (or the separate opercular pieces) has (have) detached (Sarjeant et al., 1987, p. 26, 27). Where appropriate, the dinoflagellate cyst paratype notation system used throughout is Kofoidian, as opposed to the 'Taylor-Evitt' scheme of Evitt (1985). References to author citations of taxa discussed are not given here. These may be found in the bibliography of Williams et al., 1998, p. 747-817. All figured specimens are housed in the Commonwealth Palaeontological Collection (CPC) of the Australian Geological Survey Organisation, Canberra (see Appendix 2).

This study has been conducted almost exclusively using single and multiple grain mounts and all the figured specimens, except for those of Tobulodinium securum Dodekova 1990, are from these single species slides. The vast majority of the samples which were studied, are from conventional core and sidewall cores. However, a small number of ditch cuttings samples were also used. The photographs in the seventeen photomicrograph plates (Figs 3-13, 15, 16 and 18-21) were taken using an Olympus DP10 digital camera system coupled to a Zeiss Axioskop photomicroscope, housed at AGSO. Some extraneous palynomdebris, which is not adherent to the figured specimens, has been digitally removed in selected images.

The specimen images herein are taken from a digital database containing many more images than have been figured. Sample details, morphological data and measurements of each specimen are held on open file spreadsheets. The image database may be accessed on the AGSO website (http://www.agso.gov.au).

Many of these new taxa have been extensively used in unpublished reports, which are now in the public domain (open file). In order to maximise the utility of the species, the informal names and/or codes are listed separate from any formal synonymy listing, under the heading 'Previous Australian usage'. To provide continuity,

Fig. 2. Regional Jurassic and Lower Cretaceous lithostratigraphy of the northern Bonaparte Basin, offshore north-west Australia; based on Brooks et al. (1996) and Whittam et al. (1996). The new microplankton described in this contribution are mainly from the Callovian part of the Elang Formation and its equivalents. Specimens from Investigator-1 and Montebello-1 are from the Carnarvon Basin, WA.
Fig. 3. *Cladodinium ancorum* sp. nov. The specimens are from a sidewall core in Rowan-1 well at 3183.00m (Figs 3G, 3J) and conventional core from Undan-1 well at 2996.15m (Figs 3D, 3H) and the Undan-4 well at 3135.24m (Figs 3A-C, F-I, K-L). The photomicrographs were all taken using plain transmitted light. The scale bar in Fig. 3L refers to all the photomicrographs, except Fig. 3J, and represents 25μm. Fig. 3J is a close-up to illustrate the detailed morphology of the parasutural processes; the scale bar represents 10μm. Figs 3G, 3J are the holotype; the remainder are paratypes. Note the relatively thin, rhizoreticulate and/or microscabrulate autophragm which may be slightly thicker and darker in the antapical (1′′′) paraplate, the regular and typically distally bifid processes which surmount the parasutural ridges and the epicystral archaepyle. A, B - CPC 35350, paratype; isolated hypocyst in apical view, median and low focus respectively. Note the irregularly thickened autophragm on the antapical (1′′′) paraplate. C - CPC 35351, paratype; isolated hypocyst in apical view, low focus. Note that the longest processes are those around the antapical (1′′′) paraplate. D - CPC 35352, paratype; isolated hypocyst in antapical view, low focus. A specimen with relatively short processes. E - CPC 35353, paratype; isolated hypocyst in antapical view, high focus. F - CPC 35354, paratype; (continued opposite)
Dinoflagellate cysts

*Ctenidinium* Deflandre 1939 emend. Benson 1985

*Type species*. *Ctenidinium ornatum* (Eisenack 1935) Deflandre 1939

*Ctenidinium ancorum* sp. nov. (Figs 3A-L)

1996 *Ctenidinium tenellum* auct. *non* Deflandre 1939; Burger, pl. 5, fig. R.

*Previous Australian usage* M.P. 501 – Helby.

*Ctenidinium* sp. 501 – Helby.

*Ctenidinium tenellum* (pars.) – Morgan.

Description. A species of *Ctenidinium* subhexagonal in dorsoventral outline, lacking an apical protuberance or horn. Autothragm thin, smooth to microscabrate and irregularly microreticulate. The antapical paraplate may have a thicker and thus marginally darker autothragm. Paratabulation fully indicated by parasutural ridges, which are regularly surmounted by processes. The processes are consistently solid, but otherwise are variable in form, being acuminate, bifid, conical/subconical or slender; distal terminations are bifurcate, blunt or sharp. Typically many processes are bifurcate with recurved terminations. At the distal end of the processes, immediately below the bifid tip there is a characteristic narrow, neck-like constriction which constitutes a natural break-point. Individual specimens may exhibit processes of varying morphologies. The longest processes are those in gonal positions around the antapical paraplate. Dark, subcircular accumulation bodies may be present.

Dimensions (μm; n=38); Min. (Mean) Max.
Length of cyst excl. spines: 57 (73) 86
Length of epicyst excl. spines: 16 (28) 40

Length of hypocyst excl. spines: 36 (53) 66
Width of cyst excl. spines: 57 (77) 106
Length of spines: 2 (5) 10
Height of parasutural ridges: 1 (2) 4

The measured specimens are from conventional core samples from Undan-1 and Undan-4 wells at 2996.15m and 3135.24m respectively and sidewall core samples from Challen-11 ST1 well at 1552.50m and Rowan-1 ST well at 3183.00m.

Comments. The most characteristic feature in *Ctenidinium ancorum* are the processes which surmount the parasutural ridges. Typically, the distal terminations are bifurcate, with recurved furcae (Fig. 3J). The processes may be bent distally at the tips so that they and the process shafts may be at different focal levels at high magnifications. Trifid tips on the gonal processes, or elsewhere, were not observed. These grappnel or anchor-shaped process endings are reminiscent of the glochidia in the microspore massulae of the Late Cretaceous to Holocene water fern genus *Azolla sensu lato* (see Collinson, 1980). It is possible that these hooked processes evolved in order that this cyst species could attach itself to other individuals or to other sedimentary particles. The ornamentational elements, which have blunt or sharp distal terminations, may represent processes which have been damaged, the bifid tips breaking off during sedimentation and/or processing. This seems likely as the ‘necks’ of the processes, immediately below the recurved bifid tip are extremely slender (Fig. 3J). Furthermore, individual specimens have both bifid and sharp processes, thereby supporting the contention that the process terminations may be randomly damaged. Isolated tips were not seen in the residues, being close to the limit of optical resolution and also possibly removed by sieving during processing. The processes are longest around the antapex, being 5μm and above (Fig. 3C). They become progressively shorter in an apical direction, typically being around 4μm and 3μm in the postcingular and paracingular series respectively. The species is relatively variable in size (see Dimensions, above); this factor is
Fig. 4. Clonidodinium fisceluslarum sp. nov. All specimens are from conventional core samples in the Under-3 well at 3048.00m (Figs 4A, 4D, 4E and 4H) and 3057.00m (Figs 4B, 4C, 4F and 4I-4L). The photomicrographs were all taken using plain transmitted light. The scale bar in Fig. 4L refers to all the photomicrographs and represents 25 μm. Figs 4J and 4K are of the holotype, the remainder are paratypes (see Appendix 2). The antapical (1°) paraplate is characterised by relatively thick and darker autophragm. Note also the elongate nature of this species, the epicrystal archaepolye and the low parasutural ridges surmounted by short spines or denticles, which are longer and more densely inserted around the antapex. A - CPC 35360, paratype; isolated hypocyst in oblique dorsal view, low focus. A specimen with short, sparse parasutural denticles; note the prominent parasulcus. B, C - CPC 35361, paratype; isolated hypocyst in ventral view. (continued opposite)
probably due to the variable compressions and preservational style.

Comparison. Ctenidodinium ancorum most closely resembles Ctenidodinium fuscobasilarum sp. nov., both having thicker and darker 1"""" paraplates, although in the latter the development is more extreme. In addition, C. ancorum has bifid processes surmounting the parasutural ridges over the entire cyst. Ctenidodinium aff. tenellum Deflandre 1939, particularly, "Form B", of Gocht (1970, pl. 42, figs. 7-8, pl. 32, figs 18a,b) is the European form most similar to C. ancorum in process distribution and style, but is substantially smaller, has a conical epicyst, and appears to lack the thickening of the 1"""" paraplate. The Mid Jurassic C. sellwoodii (Sarjeant 1975) Stover & Evitt 1978 may closely resemble C. ancorum in general morphology apart from the bifid process tips. The most common Mid Jurassic representatives of the genus in northwest Europe are C. combati, C. continuum, C. ornatum and C. sellwoodii (Woollam & Riding, 1983). Ctenidodinium combati has a small antapical paraplate and long, distally elaborate processes (Riding et al., 1985, pl. 1). The parasutural crests of C. continuum and C. ornatum are relatively high and surmounted by densely inserted denticles or processes, lacking tip fucation.

If observations of C. ancorum are gathered using low power objectives the bifid nature of the processes may not be apparent. In these cases the forms would possibly be identified as C. sellwoodii or C. tenellum.

Derivation of name. After the Latin ancora, meaning anchor and referring to the typically anchor-like process terminations.

Holotype and type locality. Figures 3G, J, CPC 35355, Rowan-IST well, sidewall core sample at 3183.00m.

Stratigraphical distribution. Ctenidodinium ancorum has been recorded from the uppermost Bathonian to the Callovian of the Timor Sea area, ranging from the upper Wianao verrucosa Zone (7c1ai) to the Rigaudella aemula Zone (7ai) (Foster, this volume; Helby & Partridge, in prep.).

Ctenidodinium fuscobasilarum sp. nov. (Figs 4A-L)

Previous Australian usage
M.P. 833 - Helby.
Ctenidodinium sp. 833 - Helby.
M.P. 1044 - Helby.
Ctenidodinium sp. 1044 - Helby.

Description. A species of Ctenidodinium, which is elongate subhexagonal in dorsoventral outline and with or without a small apical protuberance. Autophragm thin, smooth to occasionally micromembrate except the antapical paraplate, which has significantly thicker and darker autophragm. Parasuturation fully indicated by low parasutural ridges, which may be surmounted by short, solid, slender spines or denticles. The spines and/or denticles are sharply pointed or bifurcate. Gonal spines are consistently present on the antapical paraplate, which normally is also characterised by closely inserted intergonal spines. Elsewhere on the cyst, particularly on paraplates of the precingular and postcingular series, spines are sparse, irregularly developed and/or commonly absent.

Dimensions (μm; n=37): Min. (Mean) Max.
Length of cyst excl. spines: 6 (73) 86
Width of cyst body at paracingulum: 54 (70) 94
Width of antapical paraplate excl. spines: 19 (33) 44
Length of parasutural spines (mainly on 1"""": 3 (7) 16

The measured specimens are from conventional core samples in Undan-3 well at 3048.00m and 3057.00m.

Comments. The most characteristic feature of Ctenidodinium fuscobasilarum is the relatively high and low focus respectively. Note the large antapical (1"""") paraplate. D - CPC 35362, paratype, isolated hypocyst in oblique ventral view, low focus. The antapical (1"""") paraplate has relatively large gonal spines. E - CPC 35363, paratype; isolated hypocyst in dorsal view, median focus. F - CPC 35364, paratype; isolated hypocyst in dorsal view, median focus. G - CPC 35365, paratype; entire cyst in oblique ventral view, high/median focus. Note that the most prominent parasutural spines/denticles are around the antapical region. H - CPC 35366, paratype; entire cyst in oblique ventral view, high/median focus. I - CPC 35367, paratype; entire cyst in dorsal view, median focus. A specimen with relatively short parasutural denticles. J, K - CPC 35368, holotype; entire cyst in dorsal view, high and low focus respectively. The antapical parasutural spines are distally bifurcate. L - CPC 35369, paratype; entire cyst in oblique ventral view, high/median focus.
dark, thickened antapical (I”) paraplate which is normally surrounded by spines or processes (Fig. 4). The preferential thickening of a single paraplate is extremely unusual among dinoflagellate cysts and was hitherto unknown in this genus. The spines are longer and more numerous closer to the antapex and the gonial spines around the 1” paraplate are the longest. This lengthening is typical of Ctenidodinium and other gonynulaecean genera. The spines/denticles other than around the 1” paraplate are irregular and short (up to 2µm-5µm, when present). The parasutural ridges are highest around the paracingulum (1µm-2µm) and lowest in the apical area. Around the apical series, they may occasionally be discontinuous. The species is normally elongate, however the outline is somewhat variable and forms which are wider than long have been occasionally observed. Most forms have the paracingulum inserted equatorially, but in some forms the hypocyst is longer than the epicyst. The paratabulation pattern is consistent with the configuration determined for the genus by Woollam (1983) and Benson (1985). Two small anterior intercalary paraplates are present.


The most common Mid Jurassic representatives of Ctenidodinium in northwest Europe are C. combazi, C. continuum, C. ornatum and C. sellwoodii (Woollam & Riding, 1983). Ctenidodinium combazi has a small antapical paraplate and long, distally furcate processes (Riding et al., 1985, pl. 1). The parasutural crests of C. continuum and C. ornatum are relatively high and surmounted by densely-inserted denticles or processes lacking bifid terminations.

Derivation of name. From the Latin fuscus meaning dark or swarthy and basilare meaning at the base. This refers to the prominent dark, thickened antapical (I”) paraplate.

Holotype and type locality. Figures 4J-K, CPC 35268, Undan-3 well, conventional core sample at 3057.00m.

Stratigraphical distribution. Ctenidodinium fuscibasilatum has been recorded from Middle to Upper Callovian strata of the Timor Sea region. It ranges from the Wanaea digita Zone (7W) to the middle Rigaudella aemula Zone (7A) (Foster, this volume; Helby & Partridge, in prep.).

Ctenidodinium planocristatum sp. nov. (Figs 5A-O)

Previous Australian usage
M.P. 753B—Helby.
Ctenidodinium sp. 753B — Helby.
Ctenidodinium cf. gochtii — Morgan.

Description. A species of Ctenidodinium, subellipsoidal in outline and with or without a small apical protrusion. Autophragm relatively thin, smooth, microgranulate and/or irregularly microreticulate. Paratabulation fully indicated by low parasutural ridges and/or crests which are dominantly distally smooth and even in height. The parasutural ridges/crests may occasionally be fenestrate. Rarely the fenestrae may be reduced, thereby producing irregularly denticulate parasutural crests. When developed, the denticles are short, solid and distally pointed.

Dimensions (µm; n=32): Min. (Mean) Max.
Length of cyst: 69 (79) 93
Width of cyst: 67 (78) 96
Height of parasutural ridges/crests: 1 (2) 4

The measured specimens are all from conventional core from Undan-4 well at 3135.24m.

Comments. Ctenidodinium planocrisatum is characterized by its equant, subspherical outline and the mainly distally smooth parasutural ridges or crests. These ridges/crests are occasionally irregularly fenestrate. The distal parts of the fenestrate crests may be lost, thereby producing an irregular denticulate ornament. However the overall impression is that of a species devoid of larger ornamental elements. The parasutural crests surrounding the paracingulum are normally the most prominent.

Comparison. Ctenidodinium planocrisatum differs from the other species of Ctenidodinium by the low, largely smooth, parasutural ridges or crests. The majority of other representatives of the genus have ornamentation in the form of processes or denticles surrounding the parasites and inserted relatively densely (Woollam, 1983; Benson, 1985; see Comparison section for Ctenidodinium fuscibasilarum above). Ctenidodinium coronatum exhibits high, distally smooth parasutural crests, thus is comparable to C. planocrisatum. The crests of C. coronatum are confined to the hypothec and are significantly higher and more prominent than the parasutural ornament of C. planocrisatum (see Prauss, 1989, fig. 12). Ctenidodinium? schizoblastum has parasutural crests devoid of processes, yet is smaller than C. planocrisatum and has parasutural crests which are serrated and split (Norris, 1965). The Late Jurassic Ctenidodinium chondrimum also has low, smooth parasutural crests, but is markedly shorter, although almost as wide as C. planocrisatum, and is granulate. Furthermore, C. planocrisatum never bears processes. Representatives of Korysotryxta Woollam 1983, such as K. gochti (Sarjeant 1976) Woollam 1983 and K. kettonensis (Sarjeant 1976) Woollam 1983, differ from C. planocrisatum in lacking fenestrate ridges/crests. However, Sarjeant (1976, fig. 3) suggested that the parasutural features on K. kettonensis may bear denticles/small "spinelets" in the antapical area.

Holotype and type locality. Figure 5J, CPC 35379, Undan-4 well, conventional core sample at 3135.24m.

Stratigraphical distribution. Ctenidodinium planocrisatum has been recorded from the Middle-Upper Callovian strata of the Timor Sea region. It ranges from the Wamoa digitata Zone (7b) to the middle Rigaudella aemula Zone (7aiia) and is most prominent, providing biostratigraphically useful acmes, in the middle Rigaudella aemula Zone (7aiiai) (Foster, this volume; Helby & Partridge, in prep.).

Durotrigia Bailey 1987

Type species. Durotrigia daveyi Bailey 1987

Durotrigia magna sp. nov. (Figs 6A-F)

Previous Australian usage
M.P. 831 – Helby.
Durotrigia sp. 831 – Helby.

Description. An intermediate to large species of Durotrigia, subcircular to ellipsoidal in outline. The species is slightly distally flattened. Autophagm robust, relatively thick and ready folded, it is microscabrate and/or microreticulate. Continuous or discontinuous low parasutural ridges are developed which may occasionally be irregularly denticulate. The denticles, when developed, are short, slender, solid and distally pointed. Ridges bordering the paracingulum are consistently developed and represent the highest parasutural ornament (c. 1µm). A relatively small, solid, distally foliate apical horn is present. The parasusculus is relatively narrow, not surrounded by high ridges or subdivided and is slightly indented. Archaeopyle compound, most commonly formed by loss of three precingular paraphyses.

Dimensions (µm; n=38): Min. (Mean) Max.
Length of cyst excl. apical horn: 89 (105) 126
Width of cyst at paracingulum: 82 (105) 124
Length of apical horn: 5 (10) 16

All measured specimens are from conventional core in Undan-3 well at 3057.00m.

Comments. Durotrigia magna is a relatively large species, which is normally equant/subsequent in terms of cyst body length and width (Fig. 6). An apical horn is developed which is very small and spongy to solid; it varies in colour from light
to extremely dark; the foliate distal tip is distinctive (Fig. 6D). The large, multi-paraplate precingular archaeopyle (up to 3P, but generally no more than 3P) means that individuals may be compressed to such an extent that the dorsoventral flattening is exaggerated (Fig. 6E). Largely longitudinal folds readily develop on the autophragm.

Comparison. The other five species of *Durotrigia*, described from the Mid Jurassic (Bajocian-earliest Callovian) of northwest Europe (Williams et al., 1998, p. 205, 206), are all significantly smaller than *D. magna*. It is by far the largest species in the genus and is most similar to *Durotrigia aspera* Bailey & Partington 1991, which has irregular parasutural ridges and a thick autophragm. However, *D. aspera* is smaller than *D. magna* and has coarsely granulate autophragm. *Durotrigia asketa* Bailey 1990 has distinctive fenestrate/distally denticulate parasutural crests and tuberculate/verrucate intratabular ornament (Bailey, 1990, fig. 3). The parasutural ridges of *Durotrigia daveyi* are consistently and relatively densely denticulate. *Durotrigia filipicata* (Goehl 1970) Riding & Bailey 1991 is covered by a dense, low relief ornament and the parasutural ridges are surmounted by tuberculate denticiles. The autophragm of *Durotrigia vesticulata* Bailey 1990 is differentiated and extremely thick (Bailey, 1990, pl. 1).

Derivation of name. From the Latin *magnus* meaning large or great.

Holotype and type locality. Figure 6B, CPC 35386, Undan-3 well, conventional core sample at 3057.00m.

Stratigraphical distribution. *Durotrigia magna* has been recorded from the Upper Callovian strata of the Timor Sea region. It ranges from the upper part of the *Wimaecia digitata* Zone (7bi) to the lower part of the *Rugardella aemula* Zone (7aiibii) (Foster, this volume; Helby & Partridge, in prep.). In the Bayu-Undan Gas Field it occurs as an acme (bioevent 7aiibii) which is commonly associated with maximum flooding surface 2 of Ardito (1996, figs 2-4).

*Fusiformacysta* Morgan 1975 emend.


Type species, *Fusiformacysta salasti* Morgan 1975

Emended diagnosis. Proximate, acavate, dinoflagellate cysts, intermediate to large in size; subspherical to fusiform in shape, with or without apical and antapical horns. Polar horn development is extremely variable. Archaeopyle precingular, type 3P, involving paraplates 2", 3" and 4". A small, quadrate anterior intercalary paraplate (K of Evitt, 1985, fig. 5, 16), inserted between paraplates 3" and 4" may be developed. Autophragm smooth, microreticulate or with low relief positive ornamentation. Paracingulum may be indicated by a lineation of ornament; the paracortex not indicated.

Comments. The original generic diagnosis of *Fusiformacysta* by Morgan (1975, p. 161) outlined an elongate, acavate, proximate cyst with a compound precingular archaeopyle, type 2P to ?5P. The genotype, *F. salasti*, has an unequivocal type 3P archaeopyle and expansion of this to 4P or 5P is deemed to be the result of mechanical damage. This can also remove the apical paraplate series. Representatives of *Fusiformacysta* and related morphotypes are present, often prominently, in the Mid Jurassic to Early
Cretaceous of Australia. Morgan (1975) and Backhouse (1988) noted that this genus is indicative of restricted marine or non-marine depositional regimes. We have noted extreme variation in shape and polar horn development, especially in *F. terniana* sp. nov., and consider that the fundamental feature of this group of cysts is the type 3P precingular archaeopyle.

The possibility of emending the diagnosis of *Komewia* Cookson & Eisenack 1960 to encompass forms with type 3P archaeopyle was considered. *Komewia* has a single paraplate, type P, precingular archaeopyle (Chen, 1982). This putative emendation of *Komewia* would have been principally to accommodate *F. terniana* sp. nov.; and *F. challisiana* Riding & Helby (this volume). However, the morphological and stratigraphical coherence of *Komewia* would be have been significantly diminished by such an expansion. *Komewia* has an extremely distinctive, large precingular archaeopyle, with the middorsal paraplate (3") comprising the operculum, and is characteristic of the Kimmeridgian and Tithonian of the Southern Hemisphere (Chen, 1982, fig. 3). This large, type P archaeopyle is well illustrated in the genotype, *Komewia glabra* Cookson & Eisenack 1960 (see Cookson & Eisenack 1960, pl. 39, fig. 8). The phenomenon is also shown herein; Figure 7 comprises three toptype specimens of *K. glabra*, all of which show the large single paraplate precingular archaeopyle.

**Fusiform cysta terniana** sp. nov. (Figs 8A-L, 9A-D)

*Previous Australian usage*
*Apteodinium* sp. – Lister.
*Komewia* sp. 555 (smooth) – Helby.

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*Fig. 6 (opposite). Durotrigia magna* sp. nov. All specimens are from conventional core in Undan-3 well at 3057.60m. All photomicrographs taken using plain transmitted light. The scale bar in Fig. 6F refers to all images and represents 25µm. Figure 6B is the holotype; the remainder are paratypes. Note the large size of this species, the small, distally foliate apical horn and the multi-paraplate precingular archaeopyle. A - CPC 35385, paratype; slightly oblique right lateral view, medium focus. A specimen with a regular ellipsoidal outline; note the short apical horn. B - CPC 35386, holotype; ventral view, low focus. Note the large archaeopyle. C - CPC 35387, paratype; oblique dorsal view, low focus. Note the irregular, microscabrate/micronetulcute autophragm. D - CPC 35388, paratype; right lateral view, low focus. Note the foliate nature of the apical horn. E - CPC 35389, paratype; right lateral view, high focus. The removal of two or three precingular paraplates during archaeopyle formation has caused the partial (mechanical) rupture of the anterior paracingular parastyle. F - CPC 35390, paratype; right lateral view, median focus. A large specimen; note the large multi-paraplate precingular archaeopyle.
Fig. 8. *Fusiformacysta terniata* sp. nov. All specimens from a sidewall core at 1528.28 m (Figs 8D-E, G-L) and ditch cuttings between 1530.11 m-1536.21 m (Figs 8A-C, F) in Tern-1 well. All photomicrographs taken using plain transmitted light. The scale bar in Fig. 8L refers to all photomicrographs and represents 25 μm. Fig. 8J is the holotype, the remainder are paratypes. Note the biconical outline, the short, blunt apical and antapical horns and the precingular, type 3P archaeopyle. A - CPC 35391, paratype; dorsal view, high focus. Note the opercular piece in the interior of the cyst and the relatively short apical horn. B - CPC 35392, paratype; dorsal view, high focus. A relatively small specimen with a well developed 3P archaeopyle. (continued opposite)
Fig. 9. *Fusiformacysta terniana* sp. nov. All specimens from a sidewall core at 1552.50m from the Challis-11 ST1 well. Photomicrographs taken in plain transmitted light. The scale bar in Fig. 9D refers to all the photomicrographs and represents 25 μm. Note the precingular, type 3P, archaeopyyle, the psilate autophagm and the lack of polar horns. A, B - CPC 35403, paratype; ventral view, high and median focus respectively. Note the ellipsoidal outline and the two opercular pieces, which have fallen back into the loisthocyst. C, D - CPC 35404, paratype; oblique dorsal/ right lateral view, median and low focus respectively. Note the lack of apical or antapical horns and the precingular archaeopyyle.

*Manicodinium* sp. “555” – Morgan.

*Helbicysta psilata* – Morgan.

**Description.** A species of *Fusiformacysta* with a type 3P archaeopyyle, which is biconical or ellipsoidal in outline, with or without relatively short, blunt, distally rounded, apical and antapical horns. Where horns are developed, the antapical horn is normally the longest and occasionally the apical horn may be reduced or entirely suppressed. Generally the species is elongate, but it may also be wider than long or subquartic. The only indication of the paratabulation is the type 3P archaeopyyle. Isolated opercula are frequently present within the loisthocyst. Dark brown accumulation bodies may be present in the cyst. The autophagm is mainly smooth, but may be partially microgranulate or microreticulate.

**Dimensions.** Two morphotypes of *F. terniana* were observed. Specimens from a sidewall core in Challis-11 ST1 well at 1552.50m are relatively small, have ellipsoidal outlines and lack polar horns (Fig. 9). However, material from Tem-1 well (sidewall core sample at 1528.28m and ditch cuttings between 1530.11m and 1536.21m) are larger than the Challis-11 ST1 forms and are typically biconical in outline due to the development of apical and antapical horns (Fig. 8).

The measurements of five specimens of the small, ellipsoidal forms from Challis-11 ST1, sidewall core sample at 1552.50m are as follows:

- **Dimensions (μm; n=5):** Min. (Mean) Max.
- **Maximum length of cyst:** 65 (72) 82
- **Width of cyst at paragingulum:** 62 (69) 79

(Horns are absent in this morphotype, see Fig. 9).

The dimensions of 29 specimens from Tem-1 well, sidewall core sample at 1528.28m and a ditch cuttings sample between 1530.11m and 1536.21m are given below:

- **Dimensions (μm; n=29):** Min. (Mean) Max.
- **Maximum length of cyst:** 72 (94) 122
- **Width of cyst at paragingulum:** 67 (89) 115
- **Length of apical horn:** 0 (6) 11
- **Length of antapical horn:** 3 (8) 14

The data for the length and width of both the Challis-11 ST1 well and Tem-1 well morphotypes, a total of 34 specimens, is as follows:

- **Dimensions (μm; n=34):** Min. (Mean) Max.
- **Maximum length of cyst:** 65 (90) 122
- **Width of cyst at paragingulum:** 62 (86) 115

Note that horn measurements are not given in this table because the Challis-11 ST1 forms lack apical and antapical horns/protrusions.

**Comments.** In most specimens from Tem-1 well, the antapical horn is longer (see Fig. 8 and Dimensions, above). However, horn lengths are variable and the apical horn may be longer than the antapical protuberance (Figs 8G, L). In several

C - CPC 35393, paratype, oblique right lateral view, median focus. D - CPC 35394, paratype; ventral view, high focus. Note the single opercular piece immediately below the archaeopyyle. E - CPC 35395, paratype; oblique dorsal view, median focus. Note the absence of an apical horn; two opercular pieces have detached but are still close to the loisthocyst. F - CPC 35396, paratype; left lateral view, median focus. G - CPC 35397, paratype; dorsal view, high focus. H - CPC 35398, paratype; dorsal view, high focus. I - CPC 35399, paratype; left lateral view, median focus. Note the longitudinal striations on the apical and antapical horns. J - CPC 35400, holotype; dorsal view, high focus. Note the incipient archaeopyyle formation. K - CPC 35401, paratype; right lateral view, high focus. A specimen with a damaged antapical horn. L - CPC 35402, paratype; dorsal view, high/m median focus.
Fig. 10. *Lithodinia protophyma* sp. nov. All specimens from sidewall core samples from Investigator-1 well at 3260.00m (Figs 10D-F, H, J), an unnamed well (Figs 10A-C) and Tern-2 well at 1459.20m (Fig. 10I) and 1457.30m (Figs 10G, K, L). The photomicrographs were taken using plain transmitted light. The scale bar in Fig. 10L refers to all photomicrographs and represents 25µm. Fig. 10D is the holotype, the remainder are paratypes. Note the ellipsoidal outline, the apical archaephyte with a compound archaephyte, the prominent parasutural crests or ridges with low-relief ornamentation, the intratabular ridges and (continued opposite).
specimens, the area around the antapical horn is micropunctate (Fig. 8f). Analyses of the shape of the anterior margins of the opercula and the principal archaephyte suture, indicates the presence of a small anterior intercalary paraplate (Fig. 8j). The biconical shape is reduced to a more ellipsoidal shape in some of the older associations, such as the material from Chalios-11 ST1 well (see Fig. 9 and Dimensions, above).

Comparison. Fusiformacysta terniana differs from K. challisiana Riding & Helby (this volume) by the absence of a verrucose and/or reticulate autaphragm. The genotype, F. salasi Morgan 1975, is much more slender and has markedly longer apical and antapical horns than F. terniana. Fusiformacysta tumida Backhouse 1988 is also narrower than F. terniana and is granulate.

Derivation of name. From Tern-l well, from which the holotype was selected.

Holotype and type locality. Figure 8j, CPC 35400, Tern-l well, sidwall core sample at 1528.28m.

Stratigraphical distribution. Fusiformacysta terniana is present in the Bathonian to Callovian throughout the Timor Sea region. It ranges from the Wanaea verrucosa Zone (7b) to the Rigandella australis Zone (7a) (Foster, this volume, Helby & Partridge, in prep.).


Type species. Lithodinia jurassica Eisenack 1935

Comments. We prefer to retain both Lithodinia and Meiourogonvaulax Sarjeant 1966 on the basis of the demonstrable presence of compound and simple opercula, respectively (Stover & Evitt, 1978, p. 62-63). Williams et al. (1993, 53-57) have comprehensively outlined the historical background to this long running debate concerning the status of these genera. We disagree with the conclusions of Williams et al. (1993) that Meiourogonvaulax is a junior synonym of Lithodinia on the basis that “the separation of these genera based on whether the apical operculum are contiguous or disarticulated is unrealistic and impractical”. However, we recognise problems with the original description of Meiourogonvaulax, particularly relating to the nature of the operculum; implicitly discussed as a compound operculum with a single plate still attached but not shown in the illustration (Sarjeant, 1966, p. 144, fig. 37). However, one of us (JBR) has examined many specimens of M. valensi Sarjeant 1966 from the Middle Jurassic of Europe and confirms that the apical paraplates remain contiguous in a single operculum upon archaephyte formation. Residues containing M. valensi yield common simple opercula derived from this species. Furthermore, isolated simple opercula of Meiourogonvaulax penitabulata sp. nov. are illustrated herein (Figs 11A-11D). Both Lithodinia jurassica and L. protothymosa sp. nov. are Callovian, therefore unequivocal representatives of this genus may be stratigraphically significant.

Lithodinia protothymosa sp. nov. (Figs. 10A-L.)

Previous Australian usage
Meiourogonvaulax protothymosa - Helby.
Lithodinia australis - Morgan.

Description. An ellipsoidal to rounded subrectangular species of Lithodinia. The length and breadth are frequently subequal, especially in specimens where the archaephyte has operated. Paratabulation indicated by parasutural ridges, crests and processes. Gonal points are marked by relatively prominent short, solid processes which may be distally bifid, buccinate, recurved or

the robust autaphragm. A, B - CPC 35408, paratype; dorsal view, high/median and low focus respectively. Note the compound operculum. C - CPC 35409, paratype; dorsal view, median/low focus. A relatively small morphotype, note the compound operculum. D - CPC 35410, holotype; dorsal view, median/low focus. Note the robust, smooth autaphragm and the apical archaephyte with an unequivocally compound operculum. E - CPC 35411, paratype; dorsal view, median focus. Note the relatively narrow, straight parasulcus and the incipient principal archaephyte sutures. F - CPC 35412, paratype; dorsal view, median/low focus. Note the prominent parasutural crests on the hypocyst and the incipient principal archaephyte sutures. G - CPC 35413, paratype; ventral view, low focus. Note the variable nature of the parasutural ornament. H - CPC 35414, paratype; ventral view, median/low focus. Note the intratabular ornamentation. I - CPC 35415, paratype; dorsal view, median/low focus. Note the apical archaephyte and the irregularly micoreticulate autaphragm. J - CPC 35416, paratype; dorsal view, low focus. Note the prominent parasutural notch. K, L - CPC 35417, paratype; ventral view, median and low focus respectively. A relatively wide loiothecium; note the prominent parasutural crests.
subconical. The gonitional processes are joined by low, smooth parasutural ridges which may or may not be surmounted by prominent, distally smooth to finely denticulate parasutural crests. Parasutural ridges may be surmounted by short, buccinate or bifid processes. The parasutural crests may also be fenestrate. Intratabular ridges and/or processes may also be present; these are normally nontubular in position. The intratabular ridges are low and smooth and the processes are solid and usually bifid. The paracingulum and parasulus lack intratabular ornamentation and are not subdivided into paraplates. Autophragm relatively thick, smooth to occasionally microscabrate or micoreticulate. Archaeopyle apical, tends to gape; operculum compound with individual paraplates only rarely retained inside the loisthocyst.

**Dimensions (μm, n=30):** Min. (Mean) Max.
- Length of cyst incl. operculum: 74 (87) 96
- Length of cyst excl. operculum: 71 (83) 98
- Width of cyst: 71 (83) 99
- Height of parasutural crests: 2 (7) 15

The measured specimens are from sidewall core samples in Investigator-1 well at 3260.00m and Terra-2 well at 1459.20m and 1457.30m.

**Comments.** This species is characterized by its prominent and variable mixture of parasutural and intratabular ornamentation. It often has relatively large gonital processes, which are connected by parasutural ridges and crests, and a thick, smooth autophragm (Fig. 10). It is also significantly larger than most species of *Meiourogyonaulax*. Individual specimens may have parasutural crests surmounting each parasutural ridge. However, some crests may be reduced or suppressed. In particular, the crest between the 2" and the 1c paraplates is often reduced or absent. Where the ridges are not surmounted by crests, short processes may be developed, implying that the crests may be the result of coalesced processes. The crests are higher and more consistently developed on the hypocyst and especially close to the antapical region. These parasutural features are more commonly entire but often fenestrate. They are usually distally smooth, but can be finely denticulate. Intratabular ornamentation is also commonly developed as ridges, which may represent growth structures sensu Gocht (1979; 1984), and/or processes and are nontubular. The ridges may be short, curved or angular and rarely appear to approach a penitubular distribution. The operculum is unequivocally compound (Figs 10A-F). The opercular pieces are normally lost and the loisthocysts are usually not longitudinally elongate; they may be equant and are frequently wider than long (e.g. Figs 10K, L). The autophragm is thick and normally smooth, but is occasionally microscabrate or micoreticulate. This species tends to be strongly dorsoventrally flattened.

**Comparison.** *Lithodinia protothymosa* is most similar to *Lithodinia jurassica* Eisenack 1935 subsp. *reburrosa* Quattrocchio & Sarjeant 1992, which has parasutural processes, the bases of which coalesce to form parasutural ridges, in addition to intratabular processes (Quattrocchio & Sarjeant, 1992, fig. 3). Furthermore, prominent gonital processes, which are distally acuminate to bifurcate, are present. However, this subspecies is smaller than *Lithodinia protothymosa* and lacks the parasutural crests and intratabular ridges characteristic of this species. It is distinguished from the genotype, *Lithodinia jurassica* subsp. *jurassica* by its much larger size and more varied and robust sculptural elements (see Gocht, 1970, pl. 35, figs 13-22; Gocht, 1975, figs 2-7). Except for the difference in operculum configuration, species of *Meiourogyonaulax* lack the combination of parasutural and intratabular features seen in *L. protothymosa*. *Meiourogyonaulax penitubulata* sp. nov. exhibits penitubular ridges and crests except around the paracingulum and the parasutural ridges in *M. viriosa* sp. nov. are normally distally smooth.

Other species of *Meiourogyonaulax* which are superficially similar to *L. protothymosa* include *Meiourogyonaulax valensis* Sarjeant 1966 which has high parasutural crests which connect largely gonital processes. The small *Meiourogyonaulax? rioulitii* Sarjeant 1965 ex Sarjeant 1968 has distally bifurcate gonital spines but has thin, smooth autophragm and low, smooth parasutural ridges. *Meiourogyonaulax araneosa* Muir & Sarjeant 1978 also has low parasutural crests surmounted by short processes. However the latter species entirely lacks intratabular ornamentation and is also significantly smaller than *L. protothymosa*. Irregular process-bearing or trabeate parasutural ridges characterise *M. callomonii* Sarjeant 1972, however this species lacks parasutural crests, intratabular ornamentation and gonital processes. *Meiourogyonaulax strongyla* Sarjeant 1972 has a combination of low, denticulate parasutural ridges and nontubular granules. Thus, it lacks the intratabular features characteristic of *L. protothymosa*. The nature of the opercula in these taxa is not clear from the original descriptions.
and illustrations.

**Derivation of name.** From 'Meiourogonyaulax', a widely used manuscript name of A.D. Partridge, for a Berriasian morphotype and the Greek _proto_ and _thymos_ , meaning first.

**Holotype and type locality.** Figure 10D, CPC 35410, Investigator-I well, sidewall core sample at 3260.00m.

**Stratigraphical distribution.** _Lithodinia protothymos_ has been recorded from the Callovian strata of the Timor Sea region, ranging from the upper _Wamae indotata_ Zone (7bii) to the lowermost _Rigandella aemula_ Zone (7aibii) (Foster, this volume; Helby & Partridge, in prep.).

**Meiourogonyaulax** Sarjeant 1966

**Type species.** _Meiourogonyaulax valensii_ Sarjeant 1966

**Comments.** See discussion relating to _Lithodinia_ (above). Furthermore, despite the clear difference in opercula, Gocht (1976, p. 353) and Williams et al. (1993, p. 54) stated that _Meiourogonyaulax_ is a junior synonym of _Lithodinia_ by priority. However, most workers have used _Meiourogonyaulax_ rather than _Lithodinia_ and the vast majority of species assigned to _Lithodinia_ by Williams et al. (1993) were originally attributed to _Meiourogonyaulax_. Moreover, _Meiourogonyaulax_ is a diverse genus, which includes many well established and biostatigraphically important forms. Therefore, the conservation of _Meiourogonyaulax_ due to its long and almost universal acceptance and usage would be justified even if the opercula in these two genera were identical.

**Meiourogonyaulax penitabulata** sp. nov. (Figs 11A-M, 12A-I)

**Previous Australian usage**
M.P. 745 – Helby.
_Meiourogonyaulax_ sp. 745 – Helby.
_Meiourogonyaulax ‘penitabular’_ – Morgan.

**Description.** An ellipsoidal species of _Meiourogonyaulax_. The major paraplate series on the loisthoyct bear prominent, low penitabular ridges or crests. The ridges or crests on the apical series (the operculum) are, however, parasutural (Figs 11A-D). The forms with low, broad, robust ridges have short, solid denticles or spines surrounding the ridges (Fig. 12). These elements are irregularly distributed and may be subconical, distally bifid or buccinate and may be joined by slender trabeculae. These trabeculate denticles/spines, when regularly inserted, may appear to be a fenestrate crest. The sporadic nature and variability of this ornamentation engenders an irregular outline. Individuals bearing entire or perforate crests have a more regular outline as the crests are smooth distally (Fig. 11). The crests are normally narrow and may appear to have formed via the coalescing of densely inserted processes, which surmount a penitabular ridge. Normally the crests are perforate to occasionally fenestrate, giving them a spongy appearance. The paraplate is devoid of ornamentation and the ridges/crests bordering the paracingulum may frequently be parasutural, not penitabular (Figs 11F-G, 12A-I). Autophragm relatively thick, microreticulate to occasionally microgranulate. One or two dark, subspherical accumulation bodies are often present inside the cyst. Apical archaepylee; free, simple operculum common.

**Dimensions (μm; n=42):** Min. (Mean) Max.
Length of cyst incl. operculum: 66 (74) 85
Length of cyst excl. operculum: 48 (64) 76
Width of cyst: 50 (67) 85
Height of penitabular ridges/crests: 2 (4) 8

The average dimensions of several isolated opercula observed are 30μm x 35μm

The measured specimens are from sidewall core samples in Chalis-11 ST1 well at 1552.50m, Chalis-11 ST2 well at 1842.00m and Rowan-1ST well at 3181.00m and 3183.00m.

**Comments.** _Meiourogonyaulax penitabulata_ is an extremely distinctive taxon due to the prominent penitabular crests and/or ridges on all the major paraplate series on the loisthocyst. The ridges and/or crests on the apical paraplate series, however, are parasutural (Figs 11A-D). These features clearly indicate a standard gonyaulacalean paratabulation pattern. A preapical paraplate is present (Figs 11A-D). Penitabular elements are relatively rare in the Mid Jurassic, being much more common in the Late Jurassic, Cretaceous and Palaeogene. The morphology of the penitabular ornamentation is somewhat variable. It varies from having regular, entire/perforate, distally smooth, relatively narrow crests (the ‘spongy’ morphotype; Fig. 11), to somewhat discontinuous robust ridges which are irregularly surmounted by short, bifid, buccinate,
Fig. 11. Meinkeuroclynula pentabulata sp. nov. All specimens from sidewall cores in Challis-11 ST1 well at 1552.50m (Figs 11B, E-G, I-M), Challis-11 ST2 well at 1842.00m (Fig. 11H) and Rowan-1ST well at 3181.00m (Figs 11A, C-D). The photomicrographs were taken using plain transmitted light. The scale bar in Fig. 11M refers to all the photomicrographs and represents 25µm. Figs 11H, I are the holotype, the remainder are paratypes. Note the ellipsoidal outline, the thick, microreticulate autophragm and the apical archaeopyle. This figure only illustrates forms with prominent penitabular crests, which are regular, entire or perforate, distally smooth and relatively narrow. These morphotypes are informally known as the ‘spongy’ form of this species. A - CPC 35418, paratype; an isolated operculum in low focus. Note the prominently microreticulate autophragm. B - CPC 35419, paratype; an isolated operculum in low focus. Note that the crests are parasutural, not penitabular. C, D - CPC 35420, paratype; an isolated operculum, high and low focus respectively. Note preapical paraplate and the parasutural crests. E - CPC 35421, paratype; ventral view, low focus. (continued opposite)
subconical or trabeculate processes (the ‘irregular’ morphotype; Fig. 12). The crests may appear to be formed by the dense coalescing of processes and they are occasionally fenestrate or, in extreme cases, somewhat trabeculate. The crests and the ridges/processes are markedly higher on the antapical (1‘’) paraplate (Fig. 11E). Both the distinctive ‘irregular’ and ‘spongy’ forms of *Meiourogyaulax penitabulata* have exactly the same stratigraphical range, being present in the late Callovian of the Timor Sea area. Moreover, they commonly occur together, often in approximately similar relative proportions. Therefore, they are considered to be a single species and are not formally subdivided into subspecies or varieties here.

The parapodium is apparently not subdivided into paraplates and is the only major paraplate series on the loisthocyst which has parasutural, as opposed to penitabular, ridges or crests (Figs 11F-G, 12A-I). The parasutural nature of the parapodial crests/ridges is far more common in the ‘irregular’ morphotype (Fig. 12). The parasulcus is not subdivided. The penitabular nature of the ornamentation on the ventral paraplates makes the parasulcal area appear anomalously wide (Figs 11H-I, L). The operculum is normally lost and the loisthocysts are usually not markedly elongate. They may be equant and are frequently wider than long (Figs 11, 12). The autophragm is thick and microetritulate and/or occasionally microgranulate. The species is slightly dorsoventrally flattened.

**Comparison.** *Meiourogyaulax penitabulata* differs from most other species of *Meiourogyaulax* and *Lithodinia* in having penitabular crests or ridges in the major paraplate series. Some Tithonian specimens of *M. bulloidea* (Cookson & Eisenack 1960) Sarjeant 1969 emend. Riding & Helby (this volume) exhibit intraparital ridges and bosses, which have a resemblance to *M. penitabulata*, but differ in lacking consistent penitabular ridges/crests. *Meiourogyaulax viriosa* sp. nov. lacks intraparital and penitabular ridges, while *Lithodinia prototymosa* exhibits randomly inserted intraparital elements, but lacks penitabular ridges. *Meiourogyaulax penitabulata* is also relatively large for the genus; the majority of the validly published species are significantly smaller than this new species.

The Bathonian *Meiourogyaulax insulofigurata* Dodekova 1975 is the most similar in morphology, albeit superficially. It has thick, spongy autophragm in the intraparital areas and immediately adjacent to the parasutures (Dodekova, 1975, fig. 3). However, *M. insulofigurata* is smaller than *M. penitabulata* and appears to have parasutural ornamentation. The majority of the previously published species of this characteristically Middle Jurassic genus have parasutural ornamentation. Several species have parasutural crests similar in form to the penitabular crests of *Meiourogyaulax penitabulata*. These include, *M. amlasis* Below 1981, *M. borealis* Sarjeant 1980, *M. bulloidea*, *M. caytonensis* (Sarjeant 1959) Sarjeant 1969, *M. cristulata* (Sarjeant 1959) Sarjeant 1969, *M. ghermani* Beju 1971, *M. pertusa*, *M. planoseptata* Riding 1987 and *M. soweri*. In particular, the specimens of *M. bulloidea* illustrated by Backhouse (1988, fig. 28, pl. 32, fig. 2) resemble *Meiourogyaulax penitabulata* in that the relatively high parasutural crests appear in some cases to be penitabular.

*Meiourogyaulax penitabulata* is also similar to *Atlantodinium jurasicum* Zotto *et al.* 1987, however the latter is fully penitabular and has penitabular crests in all six parapodial paraplates (Zotto *et al.*, 1987, fig. 6). Likewise, all species of the characteristically Tethyan Jurassic genera *Amphorula* and *Histiophora* are fully penitabular and lack any parasutural features.

**Derivation of name.** From the characteristic penitabular crests and ridges.

**Holotype and type locality.** Figures 11I-J, CPC 35420, Challis-IT ST1 well, sideway core sample at 1552.50m.

**Stratigraphical distribution.** *Meiourogyaulax penitabulata* has been recorded from the late Callovian strata of the Timor Sea region, Australia, where it is confined to the lower *Rigaudellia aemula* Zone (subzones 7a1b-7a1a).

Note the perforate, spongy nature of the penitabular crests. F, G - CPC 35422, paratype; ventral view, high and low focus respectively. Note that the crests around the parapodium appear to be parasutural, not penitabular. H - CPC 35423, paratype; oblique dorsal view, low focus. Note relatively wide parasulcus. I, J - CPC 35424, holotype; ventral view, high and low focus respectively. Note the relatively wide parasulcus and how the postapical penitabular crests in Fig. 12I diverge antapically. K-M - CPC 35425, paratype; dorsal view, high to low focus sequence. Note relatively wide parasulcus.
Fig. 12. *Mелоуровыяулакс пенитабулата* sp. nov. All specimens are paratypes from a sidewall core at 3181.00m in the Rowan-1ST well. The photomicrographs were taken using plain transmitted light. The scale bar in Fig. 12I refers to all the photomicrographs and represents 25μm. Note the squat ellipsoidal outline of the lothiocysts, the robust, strongly microreticulate autophagum and the apical archaeopyle. Figure 12 illustrates forms with low, penitabular ridges surmounted by irregularly distributed, short, solid denticles or spines. The ornamental elements may be trabeculate or may coalesce into fenestrate crests. These forms are informally known as the 'irregular' morphotype of this species. A, B - CPC 35426, paratype; ventral view, high/median and low focus respectively. Note the irregular outline caused by the sporadically coalescing penitabular ornamentation. C, F - CPC 35427, paratype; ventral view, high/median and low focus respectively. A form with relatively delicate penitabular denticles. D, E - CPC 35428, paratype; dorsal view, median and low focus respectively. Note the extremely wide parasulcus. G, H - CPC 35429, paratype; ventral view, high and median focus respectively. Note the highly irregular insertion of the penitabular ornamentation. I - CPC 35430, paratype; dorsal view, low focus. Note the wide parasulcus in the hypocyst.
Meiourogonyaulax viriosa sp. nov. (Figs 13A-L)

Previous Australian usage
M.F. 70 – Helby.
Meiourogonyaulax sp. 70 – Helby.
Meiourogonyaulax bulloidea (pars.) – Morgan.

Description. A species of Meiourogonyaulax, ellipsoidal to subcircular in dorsoventral outline. A small, rounded, solid apical boss-like protuberance may be present on the operculum. Paratabulation fully indicated by low parastural crests which are normally distally smooth. The parastural crests are slender to relatively wide. They are continuous and generally entire; however, some are present and rarely these may be irregularly denticulate distally. The crests are highest at gonal points where they may be thickened into short projections. The paracircumulus is not subdivided into paraplates, however the antapical end of the strongly indented parastural may occasionally exhibit internal parastural crests. Autophragm thick, robust, microreticulate; occasionally partially microgranulate and/or microcrabate. One or more dark, subcircular accumulation bodies are normally present inside the cyst body.

Dimensions (μm; n=37) including crests where appropriate: Min. Mean Max.
Length of cyst incl. operculum: 62 (74) 99
Length of cyst excl. operculum: 46 (64) 79
Width of cyst: 47 (67) 93
Height of parastural crests: 1 (2.5) 5

The measured specimens are from sidewall core samples in Chalisa-11 ST2 well (1842.00m), Rowan-1ST well (3181.00m and 3183.00m), Tern-1 well (1528.28m and 1529.50m) and Tern-2 well (1459.50m), a conventional core sample at 1642.50m from Jabiru-2 well and ditch cuttings at 1530.11m and 1536.21m in Tern-2 well.

Comments. Meiourogonyaulax viriosa is variable in outline; it may be elongate (Fig. 13D), however, many specimens are wide and squat (Figs 13A, E-F, L). Furthermore, the apical protuberance, when developed, helps to impart a flat cone shape to the operculum (Fig. 13K). The apical boss or protuberance is solid and typically low in height (1μm-3μm) and broad (up to 6μm). A characteristic feature of this taxon is the thick autophragm, which is consistently microreticulate and occasionally partially microgranulate and/microcrabate. The fenestrae are normally less than 1μm in diameter, however occasionally some attain 1μm in width. The autophragm does not bear intratabular ornamentation, apart from the small fenestrae and microgranules/microcrabae, and varies between 1 and 2μm in thickness. Because of the robust nature of the autophragm, the species does not tend to fold. However, mechanical damage may cause the autophragm to break, normally along parasutures, and damaged (crushed) specimens may be anomalously wide because of this (Fig. 13G). The parasutural ornamentation is also somewhat variable, but typically comprises slender (<1μm) to relatively broad (up to 3μm), continuous crests which are normally smooth distally. The rare, thin, fenestrate and occasionally distally irregularly denticulate parasutural crests suggest that the parasutural ornamentation may be formed from a dense network of coalescing processes. The parasutural crests are highest at gonal points and around the antapical (1"w") paraplate and lowest in the apical region. As indicated in Dimensions above, there is considerable variation in size.

Comparison. Meiourogonyaulax viriosa closely resembles M. bulloidea but differs in not being granulate and in lacking the intratabular ridges and the distinctive intratabular bosses that characterise the type material of the latter (Riding & Helby, this volume). Meiourogonyaulax viriosa also shows similarities to M. penitubulata and Lithodina protorhynchus, with which it co-occurs and is presumably closely related. However, M. viriosa lacks penitubular ornamentation and major intratabular elements. This new form is also similar to several previously described species with distally smooth parasutural crest or ridges. These include M. bulloidea, M. pertusa, M. planosepta and M. stoveri. However, these taxa all lack the variable parasutural crests which are characteristic of M. viriosa.

Derivation of name. From the Latin viriosa, meaning robust or strong, and referring to the thick autophragm of this species.

Holotype and type locality. Fig. 13K, CPC 35439, Tern-1 well, sidewall core sample at 1528.28m

Stratigraphical distribution. Meiourogonyaulax viriosa has been recorded from the late Callovian strata of the Timor Sea region, occurring
Fig. 13. Metiourogonyaulax viriosa sp. nov. Figures 13C-D, G are from conventional core at 1642.50m in Jabiru-2 well. The remainder of the specimens are from sidewall core samples from Challis-11 ST2 well at 1842.00 (Figs 13A, E-F, H-I), Rowan-1ST well at 3181.00m (Fig. 13B) and the Tern-1 well at 1528.28m (Figs 13J-L). All photomicrographs taken using plain transmitted light. Scale bar in Fig. 13L refers to all the photomicrographs and represents 25μm. Fig 13K is the holotype, the remainder are paratypes. Note the ellipsoidal to subcircular outline, the apical archaeopyles, the low, distally smooth parasutural crest, the frequent presence of accumulation bodies and the robust, microreticulate autophragm. A - CPC 35431, paratype; oblique ventral view, low focus. Note the low parasutural crests and the single accumulation body. B - CPC 35432, paratype; dorsal view, low focus. Note the low apical boss on the attached, simple operculum and the straight, narrow parasulcus, which includes some low, discontinuous parasutures on the hypocyst. C - CPC 35433, paratype; left lateral view, low focus. A relatively small specimen; note the relatively wide parasutural crests. D - CPC 35434, paratype; dorsal view, low focus. An elongate specimen; note the parasutral parasutures on the hypocyst. E, F - CPC 35435, paratype; ventral view, high and low focus respectively. A wide specimen; note the strongly microreticulate autophragm and the apical archaeopyle. G - CPC 35436, paratype; slightly oblique (continued opposite)
sporadically in the *Waanca digitata* Zone (7b) and consistently throughout the *Rigaudella aemula* Zone (7a) (Foster, this volume; Helby & Partridge, in prep.).

**Tabulodinium** Dodekova 1990 emend.


**Type species.** *Tabulodinium senarium* Dodekova 1990

**Emended diagnosis.** Cavate, proximate dinoflagellate cysts intermediate in size, elongate ovoidal in outline and having a single, prominent apical horn. Periphragm, smooth, thin, easily folded and damaged. Endophragm relatively robust and ornamented by low-relief features except in the pandasutural areas. A pareodinioid paratabulation pattern is indicated by absence of ornamentation on the endophragm in the pandasutural areas; the paratabulation formula is: *?pr, 3*, ; *2a, 6*, *6c, 6h*, *2d*, *5s*. Paracingulum and parasulcus both relatively broad and fully paratabulate. Archaeopyle anterior intercalary (type 21), operculum compound and free.

**Comments.** Dodekova (1990, p. 23, 24) stated that this genus would require emendation upon the discovery of more material. The abundant, well-preserved specimens of *Tabulodinium senarium* from the Elang Formation in this study allow a full revision. *Tabulodinium* is emended here in order to include a revised paratabulation pattern and the precise archaeopyle style. Furthermore, the 'kalyptra', or possible ectophragm, of Dodekova (1990) is here designated as thin periphragm. Dodekova (1990, p. 25) stated that the outer wall of this species is more like an ectophragm than a kalyptra. This outer wall cannot be an ectophragm, however, as the genus is not holocavate (Evitt, 1985, fig. 4.1). No ornamentation was observed on the periphragm. Dodekova (1990), however, reported a coarse reticulation and parasutural ridges.

The paratabulation pattern of *Tabulodinium senarium* is in accord with that of members of the Subfamily *Pareodinioidae* of Fensome *et al.* (1993), due to the presence of two anterior intercalary paraplates (Fig. 14). Fensome *et al.* (1993, p. 79) recognised that *Tabulodinium* belongs in the Family *Pareodiniaceae*, but assigned it to 'subfamily uncertain' due to the fact that Dodekova (1990, p. 25) was unsure of the paratabulation of the upper part of the epicyst. Dodekova (1990) questionably interpreted three anterior intercalary paraplates. The genus appears to be an evolutionary offshoot of *Pareodinia* Deflandre 1947 (see Below, 1990, fig. 1).

**Tabulodinium senarium** Dodekova 1990 emend. (Figs 14A-B, 15A-P, 16A-P)

1990 *Tabulodinium senarium*; Dodekova, p. 24, pl. 4, figs 4-10, pl. 9, figs 3-5, 9, 10.

**Previous Australian usage**

*Pareodinia tamarrence* – Ingram.

*Pareodinia tamarrence* – Helby.

*Tabulodinium senarium* – Helby.

**Emended description.** A species of *Tabulodinium* with a relatively short apical horn, which is blunt and rounded distally. The pericoel is narrow, the flimsy periphragm is normally damaged and may frequently be partially or wholly absent. Endophragm covered by dark brown to black, short (c. 1μm), solid, densely inserted elements except in the pandasutural areas. The boundaries of the ornamented areas are relatively regular and penitabular in position; they thus give a precise indication of the number and shape of the paraplates. The short processes are normally expanded distally and may be baccinate, bulbous or capitulate. The density and small size of the processes gives an appearance of differentiated autophragm and it is possible that some of the elements are linked medially or distally. The narrow pandasutural bands are smooth or microseptate. The paracingulum divides the cyst body equally in half, however in some specimens the epicyst is slightly longer than the hypocyst. The paracingulum is lacerrotoraty and is displaced by approximately its height ventrally.

**Dimensions (μm; n=58) all measurements exclude periphragm. Min. (Mean) Max.**

<table>
<thead>
<tr>
<th>Length of cyst</th>
<th>62 (78)</th>
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An angular, damaged specimen; note parasutural parasutures on the hypocyst. H I - CPC 35437, paratype; dorsal view, high and median focus respectively. Note the irregularly microreticulate autophragm and the apical archaeopyle. J - CPC 35438, paratype; slightly oblique ventral view, high/median focus. Note the subicular outline and the well developed paratabulation pattern. K - CPC 35439, holotype; dorsal view, low focus. Note the apical boss and the two prominent accumulation bodies. L - CPC 35440, paratype; dorsal view, low focus. Note the strongly microreticulate autophragm.
Fig. 14. Line drawings of an idealised specimen of *Tabulodinium senarium* Dodekova 1990 emend., illustrating the Kolofidian paratabulation pattern as indicated by the dark, ornamented penitabular areas. A - specimen in ventral view; B - specimen in dorsal view. F = reflected flagellar scar.

Width of cyst: 33 (44) 56
Length of apical horn: 7 (13) 20

The measured specimens are from sidewall core samples in Challis-11 ST1 well (1548.00m and 1552.50m), Challis-11 ST2 well (1842.00m) and Rowan-1 ST well (3181.00m and 3183.00m).

Comments. *Tabulodinium senarium* has a full paratabulation pattern, which is indicated by the narrow, straight pandasutural bands, which are devoid of the dense, dark, low-relief intratabular ornamentation termed areolate by Williams *et al.* (1978, fig. 115). Figure 14 illustrates the pareodinioid paratabulation pattern and therefore represents a revision of fig. 3 of Dodekova (1990). The penitabular ornamentation in the apical paraplate series may be lower and paler than elsewhere on the cyst. Frequently, some variations are observed in the precise shape of some of the penitabular areas. For example, the paracingular paraplates may be quadrangular or pentangular, with an angular

Fig. 15 (opposite). *Tabulodinium senarium* Dodekova 1990 emend. The specimens are all from sidewall core samples from Challis-11 ST1 well at 1548.00m (Fig. 15M) and 1552.50m (Figs 15A-G, I-K, N, O), Challis-11 ST2 well at 1842.00m (Figs 15H, L) and Rowan-1 ST well at 3138.00m (Fig. 15P). All photomicrographs taken using plain transmitted light. The scale bar in Fig. 15P refers to all photomicrographs and represents 25μm. Note the prominent apical horn, the anterior intercalary (type 21) archaeopyle and the thin, flimsy periphery, which is susceptible to mechanical damage. A complete pareodinioid paratabulation is indicated on the endophragm by narrow pandasutural bands, which are devoid of the distinctive dark ornamentation. (continued opposite)
A-C - CPC 35457; oblique ventral view, high to low focus sequence. D - CPC 35458; dorsal view, low focus. The apical paraplate series have been lost by mechanical damage. Note the laevorotatory paracingulum and the ventral paratabulation. E-G - CPC 35459; slightly oblique dorsal view, high to low focus sequence. H - CPC 35460; dorsal view, low focus. I-K - CPC 35461; oblique ventral view, high to low focus sequence. Note the type 21 archaeopyle. L - CPC 35462; dorsal view, low focus. Note the complex ventral paratabulation pattern. M - CPC 35463; ventral view, low focus. Note the recurved nature of the apical horn. N, O - CPC 35464; right lateral view, high and low focus respectively. Note the anterior intercalary (type 21) archaeopyle. P - CPC 35465; left lateral view, median/low focus. Note the prominent periphragm and the anterior intercalary (type 21) archaeopyle.
Fig. 16. *Tabulodinium senarium* Dodekova 1990 emend. The specimens are all from sidewall core samples from Challis-1 ST1 well at 1548.00m (Fig. 16C), Rowan-1 ST well at 3183.00m (Fig. 16A) and Tamar-1 well at 2183.00m (Figs 16B, D-P). All photomicrographs were taken using plain transmitted light. The scale bar in Fig. 16P refers to all the photomicrographs and represents 25μm. Note the apical horn, the anterior intercalary (type 2l) archaeopyle. This photomicrograph plate illustrates "faded" forms of *T. senarium* (continued opposite)
posterior boundary (Figs 15B, E). The detailed parasutural paratabulation pattern may be difficult to resolve because in some specimens, the ornamented regions representing the 1", as, flagellar mark and is appear to be joined. This gives the impression of a single, slender dark area over much of the midventral area (Figs 15D, H, L).

The exposure of specimens of *Tabulodinium senarium* to an oxidising environment has the effect of destroying the ornamentation of dark, dense, short processes in the central areas of the paraplates. However, the endophragm forming the cyst wall is not affected. In specimens which have been subjected to heat, e.g. by an electric hot plate during the production of single grain mounts, the processes lose their dark colouration (e.g. Fig. 16A). This degradation of the dark intratabular ornamentation can occur within hours given an excess of free oxygen. Therefore, the majority of the unaltered specimens of *T. senarium* which were studied are from strew mounts (Fig. 15). Chemical oxidation during sample processing also tends to promote a similar loss of ornamentation. This fading appears to be arrested when the residue is sealed in a permanent mount (i.e. deprived of free oxygen). Most specimens of *T. senarium* on strew mount slides from a sidewall core at 2183.00m in Tamar-1 well (completed early 1979) have lost their periambular ornamentation (Figs 16B, D-P). By contrast, the majority of specimens on slides from Chalili-11 ST1 well (completed 1992) show no reduction (Figs 15A-G, I-K, M-O). It is likely that the chemistry of the sporopollenin which forms the processes in this species is somehow significantly more susceptible to oxidation than the endophragm and periphragm.

In faded specimens, the periphragm tends to lose integrity and may significantly expand and/or take on a kalyptrate appearance (Figs 16A, D). The implications of this are that specimens of *Tabulodinium senarium* in samples which have been subject to oxidation via pre- or post-diagenetic weathering may not be recognisable. Such oxidised specimens may resemble species of *Paredenia* or *Kalyptris monoceras* Cookson & Eisenack 1960 (Figs 16B, C).

**Stratigraphical distribution.** The species was originally reported from the Upper Bathonian and Lower Callovian Dobric Formation of northern Bulgaria by Dodekova (1990). It has also been recorded from the Lower Callovian Brora Roof Bed of Brora, north-east Scotland (unpublished data). The Brora Roof Bed is the lowermost unit of the Brora Shale Member (Brora Argillaceous Formation) and belongs to the *Proplanulites koenigi* Ammonite Zone (Sykes, 1975).

*Tabulodinium senarium* has been recorded from the late Callovian strata of the Tynor Sea region, and is confined to the *Ritgandula aemula* Zone (7ai) (Foster, this volume; Helby & Partridge, in prep.). It is a distinctive, relatively consistent, minor component of dinoflagellate cyst associations from subzones 7iaa to 7aib.

**Vooodoa** gen. nov.

**Type species.** *Vooodoa tabulata* sp. nov.

**Diagnosis.** Proximate, acavate, longitudinally elongate ellipsoidal cysts with a single, long apical horn and two shorter antapical horns. Intermediate to large in size. Epicyst significantly longer than hypocyst. Peritubation indicated by low relief ornamentational features and of pareiodoid style; peritubulation formula: 3”, 2a, 6”, 7c, 6”, 2”, 5s. Archaeopyle anterior intercalary, probably one or two paraplate (type I or 2I). Operculum probably compound, attached or free.

which have been oxidised and largely lost the distinctive dark ornamentation in the periambular areas. Figs 16E, I, M were taken by RH in the early 1980s and illustrate the respective specimens ‘unfaded’, i.e. unoxidised. Figs F, H, J-L, N-P were taken by JBR during June 2000 and illustrate directly how these three individual specimens have gradually lost the dark periambular ornamentation. A - CPC 35466; ventral view, low focus. A form with a ‘kalyptrate’ periphragm. The periphragm has expanded over time and become significantly more amorphous. B - CPC 35467; ventral view, low focus. A faded form which has lost the apex and much of the periphragm through mechanical and chemical damage respectively. C - CPC 35468; dorsal view, high focus. Note the peripheral loss of much of the dark ornamentation in the periambular areas. However, some faint ornamentation toward the centres of the paraplates remains. D - CPC 35469; dorsal view, median focus. Note the loss of the apex and the expansion of the periphragm. E-H - CPC 35470; specimen in dorsal view. Figs E taken in the early 1980s. Figs F-H are recent photomicrographs, high to low focus sequence. Note the loss of the dark periambular ornamentation. I-L - CPC 35471; specimen in dorsal view. Figs I taken in the early 1980s. Figs J-L are recent photomicrographs, high to low focus sequence. Note the loss of the dark periambular ornamentation. M-P - CPC 35472; specimen in slightly oblique ventral view. Figs M taken in the early 1980s. Figs N-P are recent photomicrographs, high to low focus sequence. Note the loss of the dark periambular ornamentation.
Comments. Voodoioia gen. nov. is a pareodinoid genus with two anterior intercalary paraplates which may be lost in archaeopyle formation (Fig. 17). The precise archaeopyle style, however, has not been determined. The genotype, Voodoioia tabulata sp. nov., appears to exhibit paraplate dehiscence in the anterior intercalary series. However, whether one or two paraplates are lost and if these are attached or free, is not clear.

Comparison. Voodoioia is similar to some other elongate pareodinoid genera, specifically Batooladinium Brideaux 1975 and Broomea Cookson & Eisenack 1958. Batooladinium is not normally fully paratabulate (but see Below, 1990, fig. 15). Similarly, Aprobolocysta Duxbury 1977 is distinguished from Voodoioia by the apical archaeopyle, variable cavation and the lack of a long apical horn (Duxbury, 1977, p.52; Backhouse, 1987). Broomea Cookson & Eisenack 1958 is also similar to Voodoioia, but is variably paratabulate and has an unequivocal one- or two-paraplate anterior intercalary archaeopyle (type 1 or 21). The genotype, Broomea ramosa Cookson & Eisenack 1958, is also characterised by two groups of bunched antapical appendages (Cookson & Eisenack, 1958, pl. 6, figs 6, 7). Voodoioia has some similarities to Gresslyvordinium Below 1990, but this has a single antapical horn or protrusion. Cantulodinium Alberti 1961 differs from
*Voodooria* in being pear-shaped, nontabulate and having a three paraplate (type 31) anterior intercalary archaeopyle. Furthermore, it may have several relatively small, thorn-like antapical horns or appendages (Van Helden, 1986). Other broomeoid and pareodinioid genera such as *Gochiocladina* Norris 1978, *Paraevastia* Below 1990 and *Pareodinia* Deflandre 1947 lack antapical horns and *Kalyptea* Cookson & Eisenack 1960 is typically kalyprate. *Protobatoladinium* Nohr-Hansen 1986 has a combination apical-intercalary, type (iA) + (21), archaeopyle and lacks paired antapical horns (Nohr-Hansen, 1986).

**Derivation of name.** From the resemblance in shape to a voodoo doll.

*Voodooria tabulata* sp. nov. (Figs 17A-B, 18A-O)

1996 *Pareodinia* spp.; Burger, pl. 8, figs S. T.

**Previous Australian usage**

**Broomeecladina** - Otte (1970, pl. 9, figs 4-6).

**Imbatodinium** sp. - Lister/Burnah (BOC).

M.P. 707 – Helby.

**Voodooria tabulata** – Helby.

**Sansonia tabulata** – Morgan.

**Description.** A species of *Voodooria* which is not primarily doroventrally compressed and has microgranulate to occasionally microscabrate autophagm. The widest part of the cyst is at, or anterior of, the prominent paracingulum. Apart from the tapering apical horn, the narrowest part of the cyst is posterior to the paracingulum, where a distinct “waist” is developed close to the level of the antapical margin of the 4th paraplate. The dorsal side of the cyst is frequently slightly inflated. The three horns are rounded distally and are of variable length, especially the paired antapical horns. A small capitulate structure may be developed on the distal part of the apical horn and rarely, small, solid spines are developed on the antapical horns (Fig. 18D). The apical horn is generally distinct, and the rest of the epiyest is cone-shaped. Paratabulation is indicated by low, smooth parasutural ridges, which are most prominent at, and adjacent to, the paracingulum. The parasulcus is indented. Generally the paratabulation is fully indicated, however the parasutural ridges may be suppressed, especially in the apical and antapical regions.

**Dimensions** (μm; n=35): Min. (Mean) Max.

Length of cyst body incl. horns: 84 (105) 136

Length of cyst body excl. horns: 52 (63) 80

Length of epiyest incl. apical horn: 53 (67) 94

Length of hypocyst incl. antapical horns: 21 (32) 43

Length (height) of paracingulum: 5 (8) 10

Width of cyst body: 25 (36) 44

Length of apical horn: 17 (28) 45

Length of antapical horns: 4 (16) 30

The measured specimens are from a conventional core sample at 3221.47m in Layang-Mulberry well and from sideward core samples in Challis-11 ST1 well at 1552.50m, Challis-11 ST2 well at 1842.00m and Montebello-I well at 2575.00m.

**Comments.** *Voodooria tabulata* is a distinctive, elongate species. The precingular paraplates, in particular, are extremely long (Fig. 17), however the degree of elongation is extremely variable (Fig. 18). The species appears to be either slightly squat in outline (Figs 18A-E, I-J) or markedly slender and elongate (Figs. 18F-H, K-O). Most specimens are large in size, but a minority are intermediate. In lateral view, this species is commonly asymmetrical; this is caused by the inflation of the dorsal side (Fig. 18B). This feature can often be a useful orientational criterion. Note that the average length of the hypocyst, including the antapical horns, is over half the length of the epicyst including the apical horn (see *Dimensions* above and Figs 17, 18). Many specimens were observed in oblique lateral views, indicating that this species is not primarily doroventrally compressed (Fig. 18). The species is often damaged, presumably mechanically, and it seems to split along parasutures. Dark, subepithelial accumulation bodies are commonly present within the cyst. Some definite disruption of the anterior intercalary paraplate series was noted, which is interpreted as being related to archaeopyle formation (Figs 18A, I, L; see also Burger, 1996, pl. 8, figs S. T). The precise paraplate equivalence and whether the opercular piece(s) are adnate or free, however, is not clear: Some specimens do not appear to exhibit an excystment aperture (Fig. 18).

**Derivation of name.** From the fact that this cyst is fully paratabulate.

**Holotype and type locality.** Figure 18M, CPC 35484, Challis-11 ST1 well, sideward core sample at 1552.50m.

**Stratigraphical distribution.** *Voodooria tabulata* occurs in the lower part of the late Callovian
Fig. 18. *Voocholatubulatus* sp. nov. The specimens are from conventional core in Layang-1 well at 3221.47m (Fig. 18H) and sidewall cores from Challis-1 ST1 well at 1552.50m (Figs 18C-D, F-G, M), Challis-11 ST2 well at 1842.00m (Figs 18K-L, N-O) and Montebello-1 well at 2575.00m (Figs 18A-B, E, I-J). All photomicrographs taken using plain transmitted light. Scale bar in Fig. 18O refers to all photomicrographs and represents 25 \( \mu \text{m} \). Fig. 18M is the holotype; remainder are paratypes. Note slender, elongate ellipsoidal cyst body, the three horns (of which the apical horn is consistently longest), the discontinuous low parasutural ridges indicating paroedinioid paratabulation and lack of a distinct archaepyle. Figs 18A-E, I-J are relatively squat, whereas Figs. 18F-H, K-O are long and slender. A - CPC 35473, paratype; ventral view, median/low focus. (continued opposite)
Dissimulidinium May et al. 1987 in shape, particularly in the presence of prominent paired antapical lobes (May et al., 1987, figs 2-4). However, *Dissimulidinium* is significantly larger than *Woodinia*, is laterally compressed, proximochorate and has nontubular, penitubular and possibly parasutural ornamentation. Similarly, *Woodinia* also resembles the latest Jurassic-Early Cretaceous restricted marine genus *Tetrachocysta* Backhouse 1988. The latter is, by contrast, a quadrilobate form with a pair of lateral protuberances on both the epicyst and hypocyst (Backhouse, 1988, fig. 32). The type material of *Klyndrocysta* Fenton et al. 1980 is, like *Woodinia*, a flask-shaped Jurassic genus, but is parallel-sided and lacks indications of paratabulation aside of the archaeopyle (Stover & Williams, 1987, fig. 49). Other flask-like or egg-shaped Jurassic dinoflagellate cyst genera with apical archaeopyle such as *Lanterna* Dodekova 1969 and *Metiosoryganularis* Sarjeant 1966 differ from *Woodinia* in having sexiform gonyaulacocalan paratabulation patterns. *Stenopyxidium* Deflandre 1968 has spinose antapical protrusions and possibly an epicystic archaeopyle, but otherwise is similar in overall shape to *Woodinia*. Certain members of the Early-Mid Jurassic *Parrocysta* suite of Riding (1984) bear superficial resemblance to *Woodinia*, but normally have anterior intercalary archaeopyle and most are significantly less elongate. These include *Milrocysta* Bjaerke 1980, *Parrocysta* Bjaerke 1980 and *Susadinium* Dörhöfer & Davies 1980. The closely related genus *Phalloeyx* Dörhöfer & Davies 1980 is, like *Woodinia*, flask-shaped and antapically wide, tapering toward the apex. *Phalloeyx*, however, has an interior intercalary archaeopyle and is epicavate (Riding, 1984).

**Comparison.** *Woodinia* gen. nov. resembles

**Derivation of name.** *Woodinia* is named in honour

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A - CPC 35473, paratype; ventral view, median/low focus. Note the short, stubby antapical horns. B - CPC 35474, paratype; oblique lateral/dorsal view, median focus. Note the recurved apical horn and the faint parasutural ridges. C - CPC 35475, paratype; oblique ventral view, median/low focus. Note the prominent paracingulum, located relatively close to the antapex and the small accumulation body. D - CPC 35476, paratype; oblique ventral view, high focus. Note the short denticles on the distal part of the antapical horn. E - CPC 35477, paratype; oblique dorsal view, high/median focus. A specimen with relatively short horns. F - CPC 35478, paratype; dorsal view, high and median focus respectively. An extremely elongate form; note the incipient crack at the paracingulum. G - CPC 35479, paratype; dorsal view; a composite photomicrograph. A relatively small, elongate morphotype. H - CPC 35480, paratype; ventral view, median focus. Note the wide, stubby antapical horns and the possible anterior intercalary archaeopyle. J - CPC 35481, paratype; oblique right lateral view, median focus. Note the prominent paracingulum. K - CPC 35482, paratype; dorsal view, low focus. A specimen with relatively smooth autophagium. L - CPC 35483, paratype; dorsal view, median focus. Note the distorted apical horn and the relatively wide antapical horns. M - CPC 35484, holotype; dorsal view, median focus. Note the prominent paracingulum and small accumulation bodies. N, O - CPC 35485, paratype; dorsal view, median and low focus respectively. Note the slightly distally tapering apical horn and the relatively long antapical horns.
Fig. 19. *Woodinta pedis* sp. nov. The specimens are from sidewall cores from Challis-11 ST1 well at 1552.50m (Figs 19A–E, I–J) and Challis-11 ST2 well (Figs 19F–H, K–O, Q–T), except Fig. 19P, which is from conventional core at 3124.87m in Undan-4 well. All photomicrographs were taken using plain transmitted light. The scale bar in Fig. 19T refers to all photomicrographs and represents 25\(\mu\)m. Figs 19K–M are of the holotype and the remainder are paratypes. Note the small, subrectangular cyst body, the apical archaephyte, the prominent, high, paracingulum, the long postcingular paraplate series and the antapical lateral lobes with their prominent ornamentation (or 'pedestals'). A–C - CPC 35486, paratype; dorsal view, high to low focus sequence. Note the distinct antapical concavity and that the low, virtually flat, operculum is in place. D, E - CPC 35487, paratype; ventral view, median and low focus respectively. F–H - CPC 35488, paratype; ventral view, high to low focus sequence. Note the intratubular areas of differentiated autophagm. I, J - CPC 35489, paratype; dorsal view, median and low focus respectively. K–M - CPC 35490, holotype; ventral view, high to low focus sequence. Note the apical archaephyte and the intratubular areas of differentiated autophagm or 'pads'. N, O - CPC 35491, paratype; ventral view, median and low focus respectively. A specimen with a flask-shaped cyst body. Note the prominent ornamentation on the antapical lateral lobes. P - CPC 35492, paratype; dorsal view, high focus. Note the archaephyte has operated, but the operculum remains attached. Q - CPC 35493, paratype; dorsal view, high focus. Note the subrectangular outline and the prominent paracingulum. R–T - CPC 35494, paratype; dorsal view, high to low focus sequence. A slender, relatively elongate form.
of Gordon D. Wood.

Woodinia pedis sp. nov. (Figs 19A-T)

Previous Australian usage
M.P. 618 (Challis)–Helby.

Description. A subrectangular to rounded subtriangular species of Woodinia. Two small lateral antapical protuberances are normally developed, imparting a slight antapical concavity. Rounded subquadrate or subrectangular, intratubular pad-like areas of differentiated autophragm in which short, slender, solid, dense, trabeculate processes are developed. These processes may coalesce to form anastomosing crests. The antapical processes/crests are the longest and extend laterally to form pedestal-like features. The ornamentation on the apical paraplate series may appear to be merged. The ‘pads’ on the elongate postcingular paraplate series are inserted close to the prominent, indented, paracingular, which is close to the apex. ‘Pads’ occupy the majority of the small precingular paraplate series. The paracingular and parasulcus are emphasised by the adjacent precingular and postcingular ‘pads’. The very small parasulcal notch is close to mid ventral in position. Autophragm is microgranulate to occasionally microreticulate. The apical paraplate series (the operculum) is flat and very small.

Dimensions (mm; n=32): Min. (Mean) Max.
Length of cyst body (excl. operculum): 30 (34) 40
Width of cyst body at antapex: 16 (22) 27
Width of cyst body at equator (postcingulars): 12 (19) 26
Width of cyst body at apex (archaecopyle suture): 11 (15) 20
Length of processes/crests: 1 (2) 4
The measured specimens are all from a sidewall core sample in Challic-11 ST1 well at 1552.50m.

Comments. This species is a distinctly subrectangular/subtriangular form of Woodinia. The distribution of the ornamentation gives a characteristic profile in lateral or dorsoventral view. The cyst has a banded appearance, reflecting the development of differentiated autophragmal ‘pads’ on the precingular, postcingular and antapical paraplate series (Fig. 19).

Comparison. Woodinia pedis is similar in overall morphology to the Oxfordian species W. Bensonii Riding & Helby (this volume). Woodinia Bensonii, however, is rounded subtriangular in dorsoventral outline, having prominent lateral antapical protuberances which frequently impart a significant antapical concavity. The latter species also only has regular intratubular ‘pads’ of differentiated autophragm on the precingular paraplate series. This contrasts markedly with the thicker, more regular intratubular ornamentation, particularly in the postcingular paraplate series, of W. pedis (Fig. 19). Woodinia Bensonii also lacks the skirt-like flange to the antapex, formed by the relatively prominent antapical ornamentation, characteristic of W. pedis (Fig. 19).

Derivation of name. From the Latin 'pedis' meaning foot and referring to the prominent, foot-like or pedestal-like antapical differentiated autophragmal protuberances.

Holotype and type locality. Figures 19K-M. CPC 35490, Challic-11 ST2, sidewall core sample at 184200m.

Stratigraphical distribution. Woodinia pedis has been recorded from the late Callovian strata of the Timor Sea region and is confined to the lower Rigaudella zenula Zone (subzones 7a1b to 7a1a) (Foster, this volume; Helby & Partridge, in prep.). It is most prominent and characteristic of subzones 7a1b–7a1a.

Yalkalpodinium Morgan 1980 emend.

1980 Yalkalpodinium Morgan, p. 34.

Type species. Yalkalpodinium scutum Morgan 1980

Emended diagnosis. The generic circumscription is emended here to exclude the presence of paracingular projections of the paraplate as a generic criterion (Morgan, 1980; Stover & Williams, 1987). Furthermore, this emendation includes forms which are intermediate in size, may have processes on the endoplate and have simple or compound opercula. The paratabulation pattern is standard sexiform gonypitalean with a longitudinal (L-type) parasulcus and is indicated by low folds or ridges on the paraplate, which may be microreticulate and/or microscabrate.

Comments. The diagnosis has been emended to accommodate Yalkalpodinium elongiana sp. nov. This species is not subpentagonal in outline as it lacks paraplate paracingular projections.
Fig. 20. *Yalkalpodinium elangiana* sp. nov. The specimens are from sidewall core samples from Challis-11 ST1 well at 1552.50m (Figs 20I-K, M-O), Challis-11 ST2 well at 1842.00m (Figs 20A-C, E, G-H, L, P) and Rowan-1ST well at 3183.00m (Figs 20D, F). All photomicrographs were taken using plain transmitted light. The scale bar in Fig. 20P refers to all photomicrographs and represents 25μm. Figs 20I-K are of the holotype; the remainder are paratypes. Note the circumcavate cyst organisation, the apical archaeopyle, the relatively thick endophragm and the thinner, microgranulate and/or microreticulate periphragm. A-C - CPC 35495, paratype; ventral view, high, median and low focus sequence. The hypocyst periphragm has been damaged; note the prominent parasulcal notch in Fig. 20A. D - CPC 35496, paratype; dorsal view, low focus. Note the mid-ventral parasulcal notch. E-CPC 35497, paratype; ventral view, low focus. Note the parasulcal notch and the parasulcal tongue, the latter formed by paraplate 1', which has detached. F - CPC 35498, paratype; ventral view, high/median focus. A relatively darkened specimen. G-H - CPC 35499, paratype; ventral view, high/median focus. Note that the microreticulation on the periphragm is concentrated at the periphery of the cyst. I-K - CPC 35500, holotype; ventral view, high, median and low focus sequence. Well-preserved specimen; note the hypocyst paratubation and the prominent paracingulum in Fig. 20K. L - CPC 35501, paratype; ventral view. (continued opposite)
Additionally it may exhibit occasional processes on the endophagm, is paratabulate via low ridges on the microreticulate to occasionally microscabrate periphagm and is intermediate in size. Frequently, the operculum of this species are observed to be compound, therefore both simple and compound opercula are accommodated in this emendation. The paratabulation formula of \textit{Yalkalpodinium elangiana} is interpreted as being \(4^\circ, 6^\circ, Xc, 6^\circ, 1p, 1^{\prime}\prime, Xs\.

The genera most similar to \textit{Yalkalpodinium} are \textit{Ambonospaera} Fensome 1979, \textit{Sirmiodiniopsis} Druge 1978 and \textit{Sirmiodiniun} Warren 1973 because they are all subcircular, caviate forms with gonyaulacalean paratabulation. \textit{Ambonospaera} is typically camocavate to bicastrate with a consistently entire periphagm (Stover & Williams, 1987; Pousen & Riding, 1992). The characteristic feature of \textit{Sirmiodiniopsis} is a pair of hypocrystal claustra bordering an antapical protuberance (Druge, 1978, pl. 7, fig. 11). \textit{Sirmiodiniun} has a combination type (tAK+PN, archaeoclype. The prominent midventral parasculus of \textit{Yalkalpodinium} indicates a clear difference with lenticular genera such as \textit{Senontasphaera} Clarke & Verdy 1967.

\textit{Yalkalpodinium elangiana} sp. nov. (Figs 20A-P)

Previous Australian usage
\textit{Yalkalpodinium elangiana} – Helby.

Description. A species of \textit{Yalkalpodinium}, which is slightly dorsoventrally flattened, intermediate in size and ellipsoidal to subcircular in outline. Endophagm relatively thick, psilate, occasionally sporadically granulate at bacula where the endophagm and periphagm are separated. The endophagm may or may not bear rare slender, solid processes which connect to the interior of the periphagm at the cyst pheryth. Periphagm thin, microreticulate; rarely microscabrate. One or two ovoidal claustra may be present in the periphagm at the antapex. Standard sexiform gonyaulacalean paratabulation indicated by low smooth folds or ridges in the periphagm. The periphagm at the paracingulum is sometimes indented and the longitudinal parasculus is narrow and deeply indented. The operculum is compound.

Dimensions (\(\mu\text{m}; n=38\)): Min. (Mean) Max.
Length of pericyst (incl. operculum): 67 (73) 78
Length of pericyst (excl. operculum): 56 (66) 75
Length of endocyst (incl. operculum): 63 (67) 74
Length of endocyst (excl. operculum): 46 (58) 68
Width of pericyst: 56 (68) 79
Width of endocyst: 47 (60) 72

The measured specimens are from a conventional core sample in Undan-1 well (3124.87m) and sidestream core samples from Challis-11 ST1 (1552.50m), Challis-11 ST2 (1842.00m) and Rowan-1ST (3183.00m) wells.

Comments. The apical archaeopyle in this species has normally operated and the resulting prominent midventral parasculus notch, formed by the loss of the relatively large 1’ paraplate, is a characteristic feature (Fig. 20). The operculum appears to be compound; the 1’ paraplate frequently observed is detached from both the lothocyst and the other apical paraplates (Fig. 20E). Specimens of \textit{Yalkalpodinium elangiana} rarely have thin, solid processes inserted between the cyst wall layers in the peripheral regions in both hemispheeres. These processes are not consistently and/or extensively developed and therefore the species is deemed to be circumcavate and not holocavate (Evitt, 1985). The periphagm is microreticulate to occasionally microscabrate; it encloses a pericoel which is usually best developed on the hypocyst and is typically 5-6\(\mu\text{m}\) wide (Fig. 20G). The lacunae in the periphagm have widely differing concentrations, for example they are often relatively sparse in the middorsal and midventral areas (Fig. 20A). They are also virtually absent in the paracingulum and parasculus. By contrast they may be relatively densely inserted in the peripheral areas of the cyst (Fig. 20E). The lacunae are normally between 1 and 2\(\mu\text{m}\) in diameter. One, occasionally two, ovoidal claustra may penetrate the periphagm at the antapex (Fig. 20M). Claustra are also present in the genotype, \textit{Yalkalpodinium scutum} (see Morgan, 1980, pl. 31, figs 15-18). The two cyst layers are in contact over most of the dorsal and ventral areas, and there is a distinct border marking wall separation approaching the cyst pheryth (Fig. 20). The species may exhibit one or more dark, subspherical accumulation bodies within the endocoel of the cyst, normally close to the paracingular area (Figs 20F-J). The paracingulum.

* high/median focus. A lothocyst which is unusually squat. M-O - CPC 35502, paratype; ventral view, high, median and low focus sequence. Note the prominently microreticulate periphagm. P - CPC 35503, paratype; dorsal view, low focus. Note the extremely narrow lateral pericoels.
is essentially equatorial in position, however the hypocyst may be slightly longer than the epiyct.

**Comparison.** *Yalkalpodinium elangiana* differs from the genotype, *Y. scutum* Morgan 1980, in not exhibiting paracingular protrusions and in having sporadically ornamented endophragm, micro- reticulate periphragm, being paratabulate, of intermediate size and having a compound operculum. *Yalkalpodinium indicum* (Jain & Taugourdeau-Lanz 1973) Morgan 1980 is similar in morphology to *Y. scutum*, but has a small apical horn. The species *Ambonobphaera hemicavata* Prauss 1989 is similar in overall morphology and size to *Yalkalpodinium elangiana*. However, *A. hemicavata* is bicaute and significantly more longitudinally elongate (Prauss, 1989, pl. 10, figs 8, 12-15). The parasacule in *A. hemicavata* is relatively wide and prominent, with several small clausurae inserted around the antapical parasucule paraplate (Prauss, 1989, fig. 9). Furthermore, Prauss (1989) described the endophragm of *A. hemicavata* as being "fossulate, alveolate as well as rugulate to baculate" (translation). The endophragm of *Y. elangiana* is never fossulate (grooved) or alveolate (punctoreticulate).

Morgan (1980) transferred the Tithonian *Cyclonelphanium areolatum* Cookson & Eisenack 1960 to *Yalkalpodinium*. However, this was rejected by Stover & Williams (1987, p. 231) as, in their opinion, this taxon is unquestionably cavaute and lenticular. We disagree with Stover & Williams (1987) as the holotype and our toptotype material show indiscernable cavaation. However, we suggest a provisional transfer to *Yalkalpodinium* on the basis that we have seen no evidence of clausurae. Furthermore, in *Y. areolatum* the endophragm bears many more periphragm support structures than in *Y. elangiana*, and the condition approaches holocavation. The other two unequivocal species of *Yalkalpodinium*, *Y. indicum* (Jain & Taugourdeau-Lanz 1973) Morgan 1980 and *Y. scutum* Morgan 1980 are both Early Cretaceous (Neocomian-Albian) Indo-Pacific species and may be conspecific (Morgan, 1980).

**Derivation of name.** From the Elang Formation.

**Holotype and type locality.** Figs 201-K, CPC 35500, Chaillis-11 ST1 well, sidewall core at 1552.50m.

**Stratigraphical distribution.** *Yalkalpodinium elangiana* is known from the late Callovian to Oxfordian of the Timor Sea region, ranging from the lower *Rugulodella aemula* Zone (7aiib) to the lower *Wanaea spectabilis* Zone (6ciii) (Foster, this volume; Helby & Partridge, in prep.). It is most characteristic of subzones 7aiib to 7aiia.

**Acritarch**

**Nummus Morgan 1975**

**Type species.** *Nummus monoculatus* Morgan 1975

**Nummus apiculus** sp. nov. (Figs 21A-P)

Previous Australian usage
M.P. 556 – Helby.
Nummus sp. 556 – Helby.
Nummus ambitomegasimilis – Morgan.

**Description.** A species of *Nummus* ellipsoidal in dorsoventral view. Vesicle normally longer than broad. The vesicle wall is thick and robust, the external surface is smooth and may be sparsely and irregularly microreticulate. Occasionally the wall is also microscabrate. The pylocome is located in an apical position and frequently has a thickened rim. A detached plug is occasionally present within the pylocome. The thin ventral wall is often entirely absent, however small fragments may be preserved. A thickened rim surrounds the ventral part of the vesicle, which has the thinned vesicle wall; this rim is ovoidal in outline.

**Dimensions (μm; n=41):** Min. (Mean) Max.
Length: 60 (81) 105

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Fig. 21. *Nummus apiculus* sp. nov. The specimens are from conventional core in Undan-3 well at 3057.00m (Figs 21A, C-D, E-H, J, L-P) and Undan-4 well at 3135.24m (Figs 21B, E, I, K). Photomicrographs taken using plain transmitted light, except Fig. 21J, which was taken using Nomarski Interference Contrast. The scale bar in Fig. 21P refers to all photomicrographs and represents 20μm. Fig. 21K is the holotype, and the remainder are paratypes. Note ellipsoidal outline, the apical pylocome, and the thin ventral wall, which is normally wholly or partially absent. A - CPC 35441, paratype; slightly oblique dorsal view, median low focus. Note the prominent thickened rim surrounding the ventral thin-walled area. B - CPC 35442, paratype; ventral view, high focus. A specimen with an equatorial fold. C - CPC 35443, paratype; ventral view, median focus. A subcircular specimen. D - CPC 35444, paratype; oblique dorsal view, low focus. A relatively elongate specimen. E - CPC 35445, paratype; dorsal view, median focus. F - CPC 35446, paratype; ventral view, low focus. Note the small, subcircular apical pylocome. G - CPC 35447, paratype; ventral view, a composite (continued opposite)
photomicrograph. A specimen with a relatively large pylome. H - CPC 35448, paratype; ventral view, median focus. I - CPC 35449, paratype; ventral view, high focus. J - CPC 35450, paratype; oblique ventral view, median focus. K - CPC 35451, holotype; oblique ventral view, a composite photomicrograph. A well-preserved subcircular specimen. L - CPC 35452, paratype; antapical view, low focus. Note the pylome. M - CPC 35453, paratype; left lateral view, median focus. N - CPC 35454, paratype; oblique left lateral view, high median focus. In this specimen, the relatively large pylome is slightly offset toward the dorsal side. O - CPC 35455, paratype; right lateral view, median focus. Note that the pylome is close to the equatorial region. P - CPC 35456, paratype; oblique right lateral view, high focus.
Width: 52 (68) 92
Diameter of pyleme: 10 (17) 28

The measured specimens are from conventional core samples in wells Undan-1 at 3063.18m, Undan-3 at 3057.00m and Undan-4 at 3135.24m.

Comments. The vesicle wall is frequently folded due to compaction, and extensive longitudinal and/or transverse folds occur, largely on the dorsal surface (Fig. 21). The species has a relatively wide size range and the pyleme varies markedly in width (see Fig. 21 and Dimensions, above). The ovoidal area of the ventral surface, originally covered with a thin wall, is also variable in area. In some specimens, it occupies the majority of the ventral surface (Fig. 21A) and in others it accounts for around 50% of the venter (Fig. 21C). The sparse, irregular microreticulation may be a preservational artefact.

The thin, often broken or absent, ventral wall of this genus, together with the equatorial rim indicates a possible encrusting habit (Backhouse, 1988, p. 112). It is therefore similar to the Jurassic non-marine acriarach Truncatissphaeridium clevelandense Riding & Duxbury 1993, which is primarily hemispherical. This species is believed to have had an adherent habit (Riding & Duxbury, 1993). Backhouse (1988, p. 113) noted that Nummus similis (Cookson & Eisenack 1960) Burger 1980 is common in horizons which are relatively sparse in marine microplankton and speculated that the species may be indicative of marginal marine settings. Similarly, the proportion of Nummus apiculus and mioseores increase as the levels of dinoflagellate cysts decrease. Therefore large proportions of Nummus apiculus are interpreted as being indicative of nearshore depositional regimes.

Comparison. The apical position of the pyleme in this species and the lack of an equatorial fold distinguish Nummus apiculus from the other validly described members of the genus. The genotype of Nummus is N. monoculus Morgan 1975 from the Aptian of the Great Australian Basin. This species differs from N. apiculus in having a relatively large pyleme, which is located between the apex and the equator in an 'intercalary' position (Morgan, 1975, p. 163) and also being smaller. Nummus apiculus differs from N. similis (Cookson & Eisenack 1960) Burger 1980 in lacking a prominent equatorial ridge, which may represent a paracingulum. Jain & Garg (in Jain et al., 1984) described N. mallajohorensis from the Late Jurassic Spiti Shale of northern India; this form has a prominent equatorial ridge/paracingulum and appears to be a junior synonym of N. similis. Nummus pentagonus Backhouse 1988 lacks a pyleme and has five dorsal folds in the cell wall. The features which distinguish N. apiculus from N. porus Backhouse 1988 are the equatorial constrictions and the relatively small size of the latter (Backhouse, 1988, fig. 33). Sketches of the four previously published Australian species of this genus were given by Backhouse (1988, fig. 33).

Derivation of name. From the Latin apiculus meaning apex or apical and referring to the anterior or apical position of the pyleme.

Holotype and type locality. Fig. 21K, CPC 35451, Undan-4 well, conventional core sample at 3135.24m.

Stratigraphical distribution. Nummus apiculus has been recorded from the uppermost Bathonian to Callonian strata of the Timor Sea region. It ranges from the upper Wanaea verrucosa Zone (7eiai) to the lower Rigaudella aemula Zone (7aiai) (Foster, this volume; Helby & Partridge, in prep.). The species is particularly prominent (i.e. has intermittent minor peaks) possibly in the Wanaea indotata Zone (7bii) and unequivocally in the Wanaea digitata Zone (7bii) and basal R. aemula Zone (7aib).

ACKNOWLEDGEMENTS

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REFERENCES

within the ZOCA region. *APPEA Journal* 36, 269-283.


FOSTER, C.B., this volume. Introduction.


HELBY, R. & PARTRIDGE, A.D., in prep. A palynological zonation of the Australian Mesozoic


APPENDIX 1: LOCATIONS AND OPERATORS OF WELLS AND BORES FROM WHICH MATERIAL HAS BEEN STUDIED

<table>
<thead>
<tr>
<th>Well Name and Number</th>
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<th>Longitude</th>
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<td>122° 14’ 20”E</td>
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Well completion reports on all the offshore wells listed are publicly available five years after completion.

*WAMD = Department of Mines, Western Australia

APPENDIX 2: REGISTER OF FIGURED SPECIMENS

All palynomorph specimens figured in this paper are listed here, together with essential details. The specimens are all curated in the Commonwealth Palaeontological Collection (CPC) of the Australian Geological Survey Organisation, Canberra. The marine microplankton genera and species are listed alphabetically and the location of the specimens on the microscope slides are all ‘England-Finder’ co-ordinates. These were taken with the slide label to the left of the observer; the microscope stage opening toward the microscope user. The coding for types is as follows: H = holotype; P = paratype; T = topotype. All specimens of new taxa examined during this study contributed to the specific concepts described. Therefore, all figured specimens, which are not holotypes are paratypes. SGM = single grain mount. The single grain mounts do not have unique numbers; they are numbered sequentially for each species within a particular sample. The specimens are from conventional core, sidewall core and ditch cutting samples.

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*depth range: 1530.11m-1536.21m

**ditch cuttings, depth range: 305.11m-317.60m
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Dinoflagellate cysts from the Late Jurassic (Oxfordian) Wanaea spectabilis Zone in the Timor Sea region

JAMES B. RIDING and ROBIN HELBY


A suite of hitherto unpublished Late Jurassic (Oxfordian) dinoflagellate cysts which have restricted stratigraphical ranges has been recorded from offshore exploration wells in the Timor Sea region. Three genera and eight species of dinoflagellate cysts are formally described as new. The genera are Cyngmiericta, Fosteria and Tringadinium; the species are Cyngmiericta talismiana, Fosteria eclipesiana, Fusiformycysta ehallisiana, Microdinium jurassiacum, Systematophora geminans, Tringadinium bjaerkii, T. comptoni and Woodinia bessenii. The dinoflagellate cyst genus Systematophora is emended to include forms with paired, slender solid processes within the paracingulum, in order to accommodate S. geminans. With the exception of Tringadinium bjaerkii, which ranges from late Callovian to Tithonian-Berriasian, all these new dinoflagellate cyst taxa have stratigraphical utility in the Oxfordian Wanaea spectabilis Zone of the north-western Australian region.

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Keywords: dinoflagellate cysts, Late Jurassic, Australia, biostratigraphy, taxonomy

THE PALYNOLOGICAL zonation of the Australian Mesozoic published by Helby et al. (1987) was the first attempt to provide an integrated, pan-Australian microplankton and spore-pollen zonation. Only the basic framework of the zonation was provided in anticipation that further contributions, particularly the documentation of new taxa, would be necessary as the zonation scheme evolved. This paper is one of a series providing the taxonomic foundation necessary to formalise the widely used unpublished subdivisions of these zones. These subzones have widespread currency within the hydrocarbon industry due to the legislative requirement for the release of technical data under the Petroleum (Submerged Lands) Act 1967. The informal subdivisions of the Helby et al. (1987) zonation have been entered into the Australian Geological Survey Organisation (AGSO) STRATDAT database. A diagrammatic update of the Helby et al. (1987) zonal scheme is presented by Foster (this volume), and will be fully described by Helby & Partridge (in prep.). This taxonomic project is an initiative of the Petroleum and Marine Division of AGSO.

This paper provides formal descriptions of previously undescribed dinoflagellate cyst taxa from Oxfordian (Late Jurassic) palynofloras recorded in samples from the Frigate Shale and lower Vulcan Formation and equivalent strata in the Timor Sea region. All the new taxa have stratigraphical utility within the Wanaea spectabilis Interval Zone of Helby et al. (1987) and Helby & Partridge (in prep.). The figured specimens in this paper from the north-western Australian region are from the Frigate Shale and lower Vulcan Formation and coeval strata from twelve wells (Foster, this volume: Appendices 1, 2). The Polda-1 well is from onshore South Australia. Specimens from Polda-1 are illustrated specifically to demonstrate morphological variation in the genus Fusiformycysta Morgan 1975 emend. The Polda sample contains a restricted dinoflagellate cyst assemblage, which cannot be assigned to the Wanaea spectabilis Zone.

Helby et al. (1987, p. 29) stated that their Wanaea spectabilis Interval Zone is of early to mid Oxfordian age. This correlation was based on
evidence from ammonites and belemnites (Arkell, 1956; Balme, 1957; Wiseman, 1980). Davey (1987, fig. 3), however, concluded that this zone lies entirely within the early Oxfordian. Francis & Westermann (1993, fig. 1b), further interpreted the age of this zone to be possibly as old as late Callovian, but most likely to be early-mid Oxfordian (fig. 7). The conclusions of Francis & Westermann (1993, fig. 7) were based on linking the Australasian faunas to northwest Europe by the correlation indirectly across several ammonite faunal provinces. The interpretations of Francis & Westermann (1993) were adapted by Davey (1999), who stated that the top of the *Wanaea spectabilis* Zone cannot be younger than intra-mid Oxfordian and that the base is within the late Callovian. Burger (1996, fig. 2) suggested that the *Wanaea spectabilis* Zone ranged from the latest Callovian to the mid Oxfordian, within AGSO timeslice J-8, based on AGSO datum point 5. He pointed out the lack of direct evidence of correlations to Europe within the Late Jurassic *Wanaea spectabilis* to *Cribroperidinium perforans* zones. The AGSO datum point 5 in Burger (1996, fig. 2), within the *Wanaea spectabilis* Zone, is based on the correlation of early and mid Oxfordian ammonites occurring together with *Wanaea spectabilis* Zone dinoflagellate cyst floras in the Sulia Islands, Indonesia (Burger, 1996, p. 74). Burger (1996) further argued for a latest Callovian to mid Oxfordian age for the *Wanaea spectabilis* Zone, based on the Callovian age of the preceding *Rigaudella aemula* Zone according to Davey (1987) and Burger (1995) and the mid-late Oxfordian age of the succeeding *Wanaea clathrata* Zone.

**SYSTEMATIC PALYNOLOGY**

In this section, three new genera and eight new species of dinoflagellate cyst are described. Additionally, the genus *Systematophora* is emended. The new taxa are from the Frigate Shale, lower Vulcan Formation and equivalent strata in twelve offshore north western Australian exploration wells (Foster, this volume) as well as two Tithonian outcrop samples from the Lelinta Formation of Misool, eastern Indonesia (Appendices 1, 2). The genera are listed in alphabetical order; the recent suprageneric classification of Fenstone et al. (1993) is not used here. The dimensions quoted are all given in micrometres (μm). For descriptive purposes, the cyst sizes, small, intermediate and large, are after Stover & Evitt (1978, p. 5). These parameters are such that intermediate size dinoflagellate cysts have a maximum dimension of between 50μm and 100μm. Small and large forms are less than 50μm and over 100μm, respectively. The majority of the morphological terminology for dinoflagellate cysts are those used by Evitt (1985). However, the term loisthocyst refers to a dinoflagellate cyst in which the operculum (or the separate opercular pieces) has (have) detached and is therefore the part that remains (Sarjeant et al., 1987, p. 26, 27). Where appropriate, the dinoflagellate cyst paraplate notation system used throughout is Kofoidian, as opposed to the 'Taylor-Evitt' scheme of Evitt (1985). References to author citations of taxa discussed are not given here. These may be found in the bibliography in Williams et al., 1998, p. 747-817). The synonymy lists given here are selective and are mainly confined to illustrated specimens. All of the figured specimens are housed in the Commonwealth Palaeontological Collection (CPC) of the Australian Geological Survey Organisation, Canberra (see Appendix 2).

This study has almost exclusively used single grain mounts (or mounts with multiple specimens of a single species) and most figured specimens are from these slides. The vast majority of the samples are from conventional core and sidewall cores, but a single ditch cuttings sample was also examined. The photomicrographs in the eleven plates (Figs. 1, 3-6 and 8-13) were all taken using an Olympus DP10 digital camera system on a Zeiss Axiolamp photomicroscope, housed at AGSO. Some extraneous palynodebris not adherent to the figured specimens has been digitally removed in selected images. The images in Figs. 1, 3-6 and 8-13 herein are from a digital database containing many more images than have been figured. Sample details, morphological data and measurements of each specimen are on open file spreadsheets. The image database may be accessed on the AGSO website (http://www.agso.gov.au).

Many of these new taxa have been extensively used in unpublished reports, which are now in the public domain (open file). In order to maximise their utility, the informal names and/or codes are listed separate from any formal synonymy listing under the heading 'Previous Australian usage'. To provide continuity, wherever practical, the informal names have been retained.

**Dinoflagellate cysts**

*Cygnuscycta* gen. nov.

*Type species*. *Cygnuscycta taltumiana* sp. nov.
Fig. 1. Cygnusicystella talarniana sp. nov. All from sidewall core at 2820.00m in Taltarni-1 well. All photomicrographs taken using plain transmitted light except Figs 1H, J, L, which were taken using Nomarski Interference Contrast. Scale bar in Fig. 1L refers to all photomicrographs and is 25µm. Fig. 1L is the holotype, the remainder, paratypes. Note circumcavate cyst organisation with narrow pericoel; subcircular outline; variability of endophagmal ornamentation; and apical archaeocyte. A - CPC 35517, paratype; median focus. Note adherent operculum and accumulation bodies. B - CPC 35518, paratype; median focus. Note extremely narrow pericoel. C - CPC 35519, paratype; median focus. Note endophagmal is microreticulate. D - CPC 35520, paratype; median focus. Note apical archaeocyte and virtually sutured endophagmal. E - CPC 35521, paratype; low focus. Note relatively prominent pericoel and long, arcuate fold. F - CPC 35522, paratype; median focus. Compressed with mechanically expanded archaeocyte. G - CPC 35523, paratype; median focus. Note large accumulation body. H - CPC 35524, paratype; median focus. Folded and compressed specimen. I - CPC 35525, paratype; median focus. Note unusually wide, almost kalyptate, pericoel. J - CPC 35526, paratype; median focus. Note microreticulate endophagmal and narrow pericoel. K - CPC 35527, paratype; a composite photomicrograph. Note narrow pericoel and apical archaeocyte with distinctively angular principal archaeocyte suture and accessory archaeocyte sutures. L - CPC 35528, holotype; median focus. Note microreticulate endophagmal, narrow pericoel and apical archaeocyte.

Diagnosis. Proximate, circumcavate dinoflagellate cysts, small to intermediate in size and compressed subspherical in shape. Periphagmal and endophagmal smooth or having low relief ornamentation. Indications of paratabulation lacking apart from the principal and accessory archaeocyte sutures. Paratabulation apparently gonyaulaccean. Paracingulum not indicated, parasuleus indicated by parasuleal notch. Archaeocyte apical, operculum free, simple.

Comments. The principal archaeocyte suture of the type, Cygnusicystella talarniana, is angular and indicates the presence of six precingular paraplates, sometimes marked by short accessory archaeocyte sutures. Furthermore, isolated opercula of the type indicate that four apical paraplates are present. Cygnusicystella talarniana was regarded as an acritarch until the archaeocyte was recognised.

Comparison. This new genus is similar to Leberidocysta Stover & Evitt 1978 in that both are cavate and have apical archaeocytes. However, the endocyst of the genotype, Leberidocysta chlamydata (Cookson & Eisenack 1962) Stover & Evitt 1978, is characteristically elongate ellipsoidal in outline and verrucate. Furthermore, the pericyst is irregular in outline due to intense folding and damage of the periphagmal. In some
cases, the periphragm may be entirely lost (Cookson & Eisenack, 1962a, p. 496). The pericoel of Cygnusicyta, by contrast, is relatively narrow and the periphragm in not generally prone to mechanical damage, apart from folding. It appears that a restudy of species currently assigned to Leberidocysta is needed.

Derivation of name. From the Latin cygnus, meaning swan and referring to East Swan-1 well, where the characteristic acme of Cygnusicyta taltarniana was first recognised.

Cygnusicyta taltarniana sp. nov. (Figs 1A-L).

Previous Australian usage
M.P. 620—Helby.

Description. A species of Cygnusicyta, that is subcircular in dorsoventral view. Generally equant in overall length and width, occasionally slightly elongate. Endophragm relatively thick (up to 2µm), microreticulate or having low relief ornamentation. The ornament may be microgranulate, scabrate, or rugulate. Periphragm thinner, microgranulate to smooth (0.5-1.5µm). Pericoel normally relatively narrow (generally 2-5µm wide). The operculum is normally free. Accumulation bodies are frequently present inside the cyst.

Dimensions (µm, n=40): Min. (Mean) Max.
Length of pericoel (incl. operculum): 37 (48) 64
Length of pericoel (excl. operculum): 34 (44) 60
Length of endocyst (incl. operculum): 36 (42) 59
Length of endocyst (excl. operculum): 31 (40) 52
Width of pericoel: 32 (45) 68
Width of endocyst: 30 (40) 53
Maximum separation of wall layers: 1 (4) 13

The measured specimens are all from a sidewall core sample at 2820.00m in Taltarni-1 well.

Comments. Specimens are often crushed and this can increase the overall length, and width as well as the width of the pericoel (Fig. 2).

Comparison. Although Cygnusicyta is a monospecific genus, C. taltarniana is similar to some species assigned to Leberidocysta. In particular, Leberidocysta? pergamentacea (Burger 1980) Burger 1980 is an Early Cretaceous species which is not unequivocally cavelate (Burger, 1980, p. 88). If cavation is developed, it may be sporadic and the pericoel is extremely thin. Leberidocysta deficien (Davey & Verdier 1973) Stover & Evitt 1978 has an extremely wide pericoel.

The Late Cretaceous Leberidocysta flagelliformis Schioler 1993 is holocavate (Schioler, 1993, p. 110). Leberidocysta? scabrate (Jain & Taugourdeau-Lantz 1973) Stover & Evitt 1978 is larger than C. taltarniana and has a thick, spongy wall. Cygnusicyta taltarniana is also similar to Leberidocysta? verrucosa Schioler et al. 1997, however, this latter species has a strongly verrucate or verruculose endophragm.

Cygnusicyta taltarniana is superficially similar to Craspedodinium swanense Riding & Helby (this volume); however, the latter is significantly larger, and has periphragmal folds reflecting paratabulation and essentially smooth periphragm and endophragm.

Derivation of name. From the Taltarni-1 well.

Holotype and type locality. Figure 1L, CPR 35528, Taltarni-1 well, sidewall core sample at 2820.00m.

Stratigraphical distribution. Cygnusicyta taltarniana ranges widely as a rare component of assemblages from the late Callovian to the Early Cretaceous. However, it occurs as a stratigraphically significant acme in the Oxfordian, lower part of the middle Waeaea spectabilis Zone (6eib) in wells in the Montara Field and in the adjacent Vulcan Sub-Basin in the Timor Sea (Foster, this volume; Helby & Partridge, in prep.).

Fosteria gen. nov.

Type species: Fosteria elliptica sp. nov.

Diagnosis. Small, proximate to proximochorate, acavate cysts, rounded subquadrate to subpolygonal in dorsoventral outline, with a prominent, incised paracingular region. Autophragm smooth or with low relief ornamentation. A gonyaulacan paratabulation is indicated partially or fully by low parasutural ridges or crests. These indicate a paratabulation formula of (24', 6'', 26c, 6'', 1p, 1'''), Xs and may be surmounted by relatively short ornamental elements. Paracingulum indicated by both the incised equatorial region and by ridges/crests bordering the precingular, postcingular paraplate series and occasional, inconsistent intra-paracingular plate boundaries. Parasutus delimited by parasutural ridges or crests, not obviously subdivided. Archaeopyle apical, assumed to be type 4A; operculum free, simple. Accumulation bodies may be present.
Comments. This distinctive new gonyaulaccean genus normally exhibits a full paratabulation, however the paracingulum and parascalus are not obviously subdivided. This genus ostensibly appears to be of cladoxyliacean affinity in terms of its size, shape and general appearance. However, the 1p/1’’ parasureté is considerably off centre (Figs 2, 3), which suggests it is not standard partiform sensu Evitt (1985, p. 112-116), although it has features in common with the partiform species Glyphanodinium facetum Drugg 1964 (see Evitt, 1985, fig. 5.18.A). Detail of the central parascul region in Fosteria is unclear (Figs 2, 3).

Comparison. Fosteria is similar in morphology, size, shape and wall relationships to the Jurassic *Reedingia* Drugg 1978 emend. Below 1987 and its relatives, for example *Parvocysta* Bjaerke 1980 and *Sparadinium* Dörhöfer & Davies 1980 (see Riding, 1984). However members of this *Parvocysta* suite (Riding, 1984) all have intercalary Archaeocytes and paratabulation patterns differing from Fosteria (see Below, 1987a). *Mikroycysta* Bjaerke 1980 emend. Below 1987 differs from Fosteria in having a type 2A apical archaeocyte and is essentially partiform, with a strong mid antapical 1”’/2”’ parasureté and an inverted omegaform ps paraplate (Below, 1987b, pl. 2, 3). The schematic paratabulation diagram of the hypocyst of *Mikroycysta* bjaerkei of Below (1987b, fig. 3b) closely resembles paratabulation on the hypocyst of *F. eclipsiana*. We note that the shape of the ps paraplate and the location of the 1”’/2”’ parasureté boundary in the latter diagram does not accord with the specimens of *M. bjaerkei* illustrated by Below (1987b, pl. 2, 3). *Mikroycysta bjaerkei* is distinguished from Fosteria in losing only two, rather than four, apical paraplates during excystment, in addition to having an unequivocally partiform paratabulation pattern. Fosteria is also morphologically similar to *Horologinella* Cookson & Eisenack 1962 emend. Backhouse 1988 and *Dololidinium* Helby & Sjövold 1987. These are both distinguished from Fosteria by their paratabulation patterns, their apical type 2A (3’/4’) archaeocytes. *Horologinella* may have an enlarged type A (4’) archaeocyte which can impinge on paraplates 3’ and 5’ (Backhouse, 1988, p. 98, fig. 26), *Dololidinium, Horologinella* and *Mikroycysta* also lack denticulate crests. *Dololidinium* is further distinguished by the occurrence of apical and antapical lobes.

Derivation of name. Named for Dr. Clinton Foster.

**Fosteria eclipsiana** sp. nov. (Figs 2, 3A-P)

Previous Australian usage
*Horologinella eclipsiana* – Helby.

Description. Cysts having a rounded subpentangular to subquadrate dorsoventral outline with a deeply incised paracingulum. They are strongly dorsoventrally compressed.
Fig. 3. *Fosteria eclipstana* sp. nov. All from conventional core at 3221.47m in Layang-1 well. All photomicrographs taken using plain transmitted light. Scale bar in Fig. 3P refers to all photomicrographs and is 12μm. Fig. 3I is the holotype, remainder, paratypes. Note robust, dark autophragm; rounded subpentangular/subcircular outline; prominent, deeply-inset paraciculum; denticulate parasutural crests; apical archaeopyle; and large accumulation body. A - CPC 35529, paratype; dorsal view, low focus. Note amorphous nature of large, dark, centrally-located accumulation body. B - CPC 35530, paratype; ventral view, low focus. Note densely denticulate parasutural crests. C - CPC 35531, paratype; ventral view, median focus. Angular specimen; note prominent posterior intercalary (1p) paraplate at bottom left. D - CPC 35532, paratype; ventral view, median focus. Small specimen. E - CPC 35533, paratype; ventral view, median focus. Large specimen. F - CPC 35534, paratype; dorsal view, median focus. Elongate specimen. G - CPC 35535, paratype; dorsal view, median focus. Squat morphotype. H - CPC 35536, paratype; dorsal view, median/low focus. Note variable nature of parasutural denticles. I - CPC 35537, holotype; dorsal view, median focus. Note well-defined standard gonvalacalean paratabulation pattern. J - CPC 35538, paratype; ventral view, median focus. Note apical archaeopyle. K - CPC 35539, paratype; dorsal view, median focus. L - CPC 35540, paratype; dorsal view, median focus. Note diffuse nature of periphery of accumulation body. M, N - CPC 35541, paratype; dorsal view, median/low focus respectively. Note large accumulation body. O, P - CPC 35542, paratype; dorsal view, low and high focus respectively. The 1p paraplate is to bottom right in Fig. 3O; note blunt nature of majority of parasutural denticles.
Autophragm relatively thick; smooth to microgranulate, occasionally irregularly microreticulate. Paratabulation indicated by low parasutural ridges or low crests, which are surmounted by denticles and/or spines. The parasutural ridges become gradually higher and slightly broader laterally. Lateral parasutural denticles are solid, sharp or blunt distally, and are longest on the hypocyst; the density of insertion is also variable. The epicyst is shorter than the hypocyst. Hypocyst is slightly asymmetrical in that the left lateral side is slightly more angular due to the presence of the 1p paraplate. The parasulcus is wide and located mid-ventrally. Similarly, the paracingulum is relatively high and is only slightly laevorotatory. A large, dark accumulation body is consistently present in the centre of the cyst.

Dimensions (μm; n=34, all loisthocysts), including spines/denticles: Min. (Mean) Max.
Length of loisthocyst: 26 (30) 35
Length of epicyst (i.e. precingular series): 7 (10) 13
Length of hypocyst: 12 (16) 20
Height of paracingulum: 4 (5) 7
Width of epicyst: 20 (24) 32
Width at paracingulum: 15 (21) 28
Width of hypocyst: 25 (31) 39
Length of accumulation body: 10 (14) 17
Width of accumulation body: 8 (12) 15
Length of denticles/spines: 1 (1.5) 7

The measured specimens are from sidewall core at 3221.57m and 3222.20m from Layang-1 Well.

Comments. Fosteria eclipsiana is a distinctive small species, and is equant in terms of length and width. The posterior intercalary (1p) paraplate of F. eclipsiana is particularly slender and is placed close to the left lateral side. Its presence makes this side straighter, or more angular than the right lateral side (Figs 2, 3). The species is dorsi-ventrally flattened. The relatively thick autophragm, which is normally smooth to microgranulate, imparts a dark body colour (Fig. 3). Parasutural ridges emerge in the central area of the cyst, close to the edge of the accumulation body. These ridges become more robust, higher and slightly wider, and the surmounting denticles/spines increase in size proportionally (Figs 2, 3). The denticles are normally evenly inserted, generally taper distally to a sharp point and are most prominent on the hypocyst (Figs 2, 3). However, specimens have been observed where the denticles are relatively sparse and/or are either blunt or extremely wide distally, i.e. crenellate or stauromate (Figs 30, P). In extreme cases, some specimens are virtually devoid of denticles (Fig. 3K). All the specimens observed have a large, dark accumulation body in the centre of the cyst (Fig. 3). These accumulation bodies frequently lack sharp edges, having a diffuse, vaguely-defined periphery. The paracingulum is only slightly laevorotatory, relatively high and is deeply incised; it is located high on the cyst, normally making the epicyst significantly shorter than the hypocyst. The wide, mid-ventral parasulcus is not obviously subdivided. The archaeocyle represents the loss of the entire apical paraplate series. The operculum is free and no isolated opercula were observed, possibly indicating that it is compound. No attached opercula were found; only loisthocysts were recovered (Fig. 3).

Comparison. Some species of Horologinella are smaller, have poorly defined paratabulation, and have more deeply incised paracingular regions than F. eclipsiana. These taxa include Horologinella angulata De Coninck 1985 and H. temussima He 1984. However, Horologinella? obliqua Cookson & Eisenack 1962 and H. scabrosa He 1984 are larger than F. eclipsiana, and entirely lack indications of paratabulation.

Derivation of name. From Eclipse-1 well, where we first encountered this species.

Holotype and type locality. Figure 31, CPC 35537, Layang-1 well, conventional core at 3221.47m.

Stratigraphical distribution. Fosteria eclipsiana ranges from the Callovian Wanaea digitata Zone (7bi) to the Oxfordian mid Wanaea spectabilis Zone (6eii) in the Timor Sea region. It is most prominent in the lower Rigaudella aemula Zone (7aia) to lower W. spectabilis Zone (6eiii), but is usually a minor, although distinctive, background component of these dinoflagellate cyst suites (Foster, this volume; Helby & Partridge, in prep.).

**Fusiformacysta** Morgan 1975 emend. Riding & Helby this volume

Type species: *Fusiformacysta salassii* Morgan 1975

**Fusiformacysta challisiana** sp. nov. (Figs 4A-L)

*Previous Australian usage*

*Komeysia* sp. 555 (verrucate) – Helby.

*Dissilicudinium* verrucate ‘555’ – Morgan.
Fig. 4. *Fusiformycysta challisiana* sp. nov. All from sidewall core in Arunta-1 well at 1805.00m (Figs 4F, I-L), Challis-11 ST1 well at 1552.50m (Figs 4A-C, G, F) and Rowan-1 well at 3183.00m (Figs 4D-E). All photomicrographs taken using plain transmitted light. Scale bar in Fig. 4L refers to all photomicrographs and is 25µm. Fig. 4A is the holotype, the remainder, paratypes. Note biconical outline, precingular (type 3P) archaeopyle, occasional presence of accumulation body and verrucate to occasionally reticulate autophrym. A - CPC 35543, holotype; squat, verrucate specimen in ventral view, low focus. Note precingular (type 3P) archaeopyle; opercular piece visible inside the cyst. B, C - CPC 35544, paratype; entirely verrucate specimen (continued opposite)
Helbycysta verrucosa – Morgan.
Komewia challisiana – Helby.

Description. A species of Fusiformycysta with a type 3P archaeopyle and a biconical outline, with or without an apical horn or protuberance. Specimens vary from those with a rounded apical extremity to occasional forms with small apical horns or protuberances. The antapical region is rounded to almost flat. Most commonly, the species is elongate, but may also be subcuneate or wider than long. Indications of paratabulation comprise the type 3P archaeopyle and a lineation of ornamentation along the posterior margin of the paracingulum. Isolated opercular paraplates are common in the loithiocyst. A regular shaped, dark brown accumulation body may be present in the cyst. The relatively robust autophragm bears verrucae and/or a reticulum. The entirely verrucate forms are relatively densely covered in low-relief (0.5-1µm high) verrucae or grana, which are variable in shape. These elements are normally ovoidal, although rarely some coalescence of verrucae result in irregularly shaped, rounded verrucae. The width of verrucae or grana varies from 0.5 to 6µm. Forms which are verrucate and reticulate both are generally reticulate in the vicinity of the paracingulum, with fenestrae varying in width from 1 to 5µm, the average being 2µm.

Dimensions (µm n = 24): Min. (Mean) Max.
Maximum length of cyst: 71 (89) 103
Width of cyst at paracingulum: 67 (82) 96

The measured specimens are from sidewall cores in Arunta-I well at 1805.00m, Challis-11 ST1 well at 1552.50m and Rowan-I well at 3183.00m.

Comments. Fusiformycysta challisiana is a large form which has a distinctive ornamentation. It may be either verrucate or, occasionally, verrucate and reticulate. In the partially reticulate forms, the reticulum is best developed in the equatorial area (Figs 4J-L). This variability in ornamental style is unusual. In some specimens the presence of a small anterior intercalary paraplate (K paraplate of Evitt, 1985) is suggested by angulation of the principal archaeopyle suture.

Comparison. Fusiformycysta challisiana differs from F. terniana Riding & Helby (this volume) in the typical lack of apical and antapical horns and the presence of a largely verrucate autophragm. Fusiformycysta salasti is significantly more elongate than F. challisiana, with extremely long polar horns and smooth autophragm. The Tithonian to Berriasian species F. tumida Backhouse 1988 is also more slender than F. challisiana and is ornamented by small (<1µm wide), nontubular grana. Fusiformycysta sp. cf. F. tumida from the Late Jurassic Polda Formation of the Eyre Peninsula, South Australia closely resembles F. challisiana, but generally has more prominent polar horns (Figs 5A-C). Like the type material from the Perth Basin (Backhouse, 1988), these Polda specimens were recovered from a paralic succession (Gatehouse & Cooper, 1982).

Derivation of name. From Challis-11 ST1 well, from which material of this species was first recovered.

Holotype and type locality. Figure 4A, CPC 35543, Challis-11 ST1 well, sidewall core at 1552.50m.

Stratigraphical distribution. Fusiformycysta challisiana ranges from the Callovian Rigaudella aemula Zone (?aII) to the Oxfordian Wanaea clathrata Zone (?b) of the Timor Sea (Foster, this volume; Helby & Partridge, in prep.). It is generally a background component and is most consistent between the upper part of the lower Rigaudella aemula Zone (?aII) to the lower Wanaea spectabilis Zone (?cII).

Microdinium Cookson & Eisenack 1960 emend. Slimani 1994

Type species. Microdinium ornatum Cookson & Eisenack 1960

in dorsal view, high/median and low focus respectively. Note precingular (type 3P) archaeopyle; two opercular pieces present in hypocyst (Fig. 4C). D, E - CPC 35545, paratype oblique dorsal/right lateral view, median and low focus respectively. Entirely verrucate specimen; note large archaeopyle. F - CPC 35546, paratype; ventral view, low focus. Entirely verrucate specimen with small apical protuberance. G, H - CPC 35547, paratype; ventral view, high and low focus respectively. Verrucate specimen; note precingular (type 3P) archaeopyle. I - CPC 35548, paratype; ventral view, low focus. Entirely verrucate specimen; note precingular (type 3P) archaeopyle. J, K - CPC 35549, paratype; right lateral view, high and low focus respectively. Note strong reticulate ornamentation in equatorial region and verrucae in area around antapex. L - CPC 35550, paratype; ventral view, low focus. Note lack of apical horn and precingular (type 3P) archaeopyle. Specimen largely verrucate, however reticulate ornamentation is developed at, and near paracingulum.
Microdinium jurassicum sp. nov. (Figs 6A-T)

1988 Microdinium sp. A (M.P. 619); Helby et al., fig. 10G-H.
1996 Microdinium ornatum auct. non Cookson & Eisenack 1960; Burger, pl. 7, figs O-Q.

Previous Australian usage
Microdinium oxfordensis – Ott (1970, pl. 8, figs 26-28).
M.P. 619 – Helby.
Microdinium jurassicum – Helby.

Description. A small species of Microdinium, elongate ellipsoidal to rounded subquadrangular/subpentagonal in dorsoventral or lateral view and may be slightly dorsoventrally flattened. Autophagium relatively thick (1-2 μm), microreticulate. The fenestrae of the microreticulum are subcircular to irregularly subovoidal, narrow (<0.5-1 μm in maximum diameter) and of variable density. They are normally more densely spaced close to the parasutures. Occasionally, one, rarely two, large (up to 2.5 μm high and 1 μm wide) intratabular tubercles are present on the precingular and postcingular paraplates. A similar tubercle or protuberance may be present at the apex of the cyst. Parasutures marked by prominent (1-2 μm high), distally-smooth to slightly undulate parasutural crests which may also be irregularly microreticulate. Apical archaeopyle, operculum simple, generally free.

Dimensions (μm n=49): Min. (Mean) Max.
Overall length of entire cyst: 25 (37) 49
Overall length of loisthoecyst: 27 (36) 49
Overall width of cyst body: 20 (32) 47

The measured specimens are from conventional cores from Jabiru-2 well at 1642.50m and Jabiru-3 well at 1604.0m to 1604.13m. and sidewall cores from Arunta-1 well at 2135.00m, Challis-11 ST1 well at 1552.50m, Challis-11 ST2 well at 1842.00m, Rowan-1ST well at 3181.00m and Taltarni-1 well at 2950.00m.

Microdinium jurassicum has a wide size range

Fig 6. (opposite) Microdinium jurassicum sp. nov. All from sidewall cores from Arunta-1 well at 2135.00m (Figs 6D, H), Rowan-1ST well at 3181.00m (Figs 6E-G, K-L) and Taltarni-1 well at 2950.00m (Figs 6A-C, I-L, M-P, T), except Figs 6Q-S, which are from conventional cores in Jabiru-2 well at 1642.50m. All photomicrographs taken using plain transmitted light. Scale bar in Fig. 6T refers to all photomicrographs and is 25 μm. Figures 6M-O are the holotype, the remaining, paratypes. Note elongate ellipsoidal to rounded subquadrangular/subpentagonal outline, robust, microreticulate autophagium, occasional intratabular tubercles, distally smooth, slightly undulate parasutural crests, and apical archaeopyle. A-C - CPC 35554, paratype; dorsal view, high to low focus sequence. Note prominent paracingulum and broad parabasulus in Fig. 6C. D - CPC 35555, paratype; ventral view, low focus. Note apical archaeopyle. E-G - CPC 35556, paratype; slightly oblique dorsal view, high to low focus sequence. Small morphotype, note thick autophagium and intratabular tubercles in postcingular paraplate series. H - CPC 35557, paratype; right lateral view, high focus. Note angular base of median paracingulum paraplate. I, J - CPC 35558, paratype; dorsal view, high and low focus respectively. Note apical archaeopyle and typically partiform ventral paratabulation pattern in Fig. 6J (see Evitte, 1985, figs 5.18A-C). (continued opposite)
K, L - CPC 35559, paratype; slightly oblique dorsal view, high to low focus sequence. M-O - CPC 35560, holotype; dorsal view, high and media/low focus respectively. Note thick autophragm, intratabular tubercles and denticulate parasutural crests in Fig. 6L. P, T - CPC 35561, paratype; ventral view, high and low focus respectively. Note suppression of small, central parasutal paraplates and strongly microreticulate autophragm. Q-S - CPC 35562, paratype; dorsal view, high to low focus sequence. Note concentration of microreticulation around the postcingular parasutures and apical archaeopyle.
(see above). The sidewall core material from Chalpis-I ST1 well at 1552.50m has yielded the smallest specimens. In the three specimens available, the height of a single entire cyst was 25μm, the height of ostioles cysts varied from 27 to 28μm and the width varied between 20 and 22μm. By contrast, the specimens from sidewall cores in Arumia-1 well at 2135.00m, Chalpis-I ST2 well at 1842.00m, Rowan-1ST well at 3181.00m and Taltarni-1 well at 2950.00m proved of intermediate size. The measurement of 37 specimens from these four wells gave the following data:

Dimensions (μm n=37): Min. (Mean) Max.
Overall length of entire cyst: 30 (36) 41
Overall length of ostioles cyst: 28 (34) 42
Overall width of cyst body: 20 (31) 42

However, by far the largest material came from conventional cores in Jabiru-2 well at 1642.50m and Jabiru-3 well at 1604.00 to 1604.13m. Data from 9 specimens produced the following:

Dimensions (μm n=9): Min. (Mean) Max.
Overall length of cyst: 46 (48) 49
Overall length of ostioles cyst: 36 (42) 49
Overall width of cyst body: 35 (40) 47

All the material examined is unequivocally considered to be Microdnium jurassicum. The smallest morphotypes consistently occur in the Callovian Rigaudella quinula Zone and this may be stratigraphically significant (N. G. Marshall, personal communication, 1998).

Comments. This is the first species of Microdnium described from Jurassic strata; most are Cretaceous and/or Palaeogene (Williams et al., 1998, p.399-404). Microdnium? ovatum Horowitz 1975, from the Triassic of Israel, was considered allochthonous by Williams et al. (1998). Previously, the oldest in situ material of this genus was the spinose Microdnium? fimbriatum Batten & Lister 1988 from the Barremian of South-East England (Batten & Lister, 1988). Species of Microdnium have occasionally been reported, but not convincingly illustrated, from the Jurassic. The principal Jurassic pariform gonyaulacalean genus is Jansonia, which seems confined to the Mid Jurassic (Pocock, 1972; Rauscher & Schmitt, 1990; Riding et al., 1991; Martinez et al., 1999).

The most characteristic features of Microdnium jurassicum are the microreticulate autophagum and the prominent, distally smooth to slightly irregular (undulate) parasutural crests, which may also be microreticulate (Fig. 6). In rare cases, the crests may be denticulate (Fig. 6L). The precingular paraplate series is extremely short and the paracingulum is normally higher than the precingulars. The species is very variable in size (see Dimensions, above). There are several other species in the Callovian and Oxfordian of Australia with microreticulate autophagum, such as Durotricha magna Riding & Helby (this volume) and Valtalpodinium elongatum Riding & Helby (this volume). Therefore, it is possible that this feature may be preservational. However, the microreticulation is considered to be a primary feature in Microdnium jurassicum because of a wide range of preservational styles in material from seven wells has been studied and the autophagum is consistently microreticulate.

Comparison. Microdnium jurassicum closely resembles the genotype, M. ornatum Cookson & Eisenack 1960. The autophagum of the latter is smooth, it is slightly smaller and its parasutural ridges/crests may comprise aligned, discrete elements. It also lacks the intratabular tubercles, which characterise some suites of M. jurassicum. The overwhelming majority of previously described species of Microdnium are generally characterised by nontubular, low relief, ornamentation, rather than being microreticulate. These include M. baltus (Below 1987) Lentin & Williams 1989, which is verrucate, M. carpenleriense Slimani 1994 and M. dentatum Vozhennikova 1967, which are granulate, and M. reticulatum Vozhennikova 1967 which has reticulate autophagum. Many forms have denticulate or spinose parasutural crests, for example M. angulare (Below 1987) Lentin & Williams 1989, M. carpenleriense Slimani 1994, M. dentatum Vozhennikova 1967 and M. setosum Sarjeant 1966. Slimani (1994) described several species from the Campanian to Danian of Belgium and The Netherlands which have penitabular ornamentation, including M. bensoni Slimani 1994, M. marheineckii Slimani 1994 and M. mariae Slimani 1994.

Some species have negative ornamentation; Microdnium? alatum Conrad 1941 ex Sarjeant 1967 is densely areolate and has high, striate parasutural crests. The paraplates of M. cornutum (Below 1987) Lentin & Williams 1989 have large perforations largely arranged in penitabular positions; the perforations represent reflected trichocyst pores according to Below (1987b). Microdnium? horridum (Below 1987) Lentin & Williams 1989 has an autophagum which is irregularly perforate (Below, 1987b, pl. 17, figs 1-6). This form is readily distinguished from M. jurassicum in having extremely prominent gonal spines formed by extensions of the parasutural
crests. The autophragm in Microdinium? reteinvolvatum (Below 1987) Lentin & Williams 1989 is densely and widely perforate. In addition to this form having larger and more dense perforations than M. jurassicum, it also has low parasutural ridges.

*Derivation of name.* From the occurrence of this species in the Jurassic.

*Holotype and type locality.* Figures 6M-O, CPC 35560, Talton-I well, sidewall core at 2950.00m.

*Stratigraphical distribution.* Microdinium jurassicum ranges from the Callovian lower Rigaudella aemula Zone (7aiib) to the Oxfordian lower part of the upper Wanaea spectabilis Zone (6ciiib) in the Timor Sea region (Foster, this volume; Helby & Partridge, in prep.). The species occurs consistently from the upper part of the lower Rigaudella aemula Zone (7aiia) to the mid Wanaea spectabilis Zone (6ciiib).

*Systematophora* Klement 1960 emend.

1960 *Systematophora* Klement: p. 61, 62.
1990 *Systematophora* Klement 1960 emend.
Stanchiff & Sarjeant; p. 207, 208.
(see Williams et al., 1998, p. 595, 596 for further detail).

*Type species.* *Systematophora areolata* Klement 1960

*Emended diagnosis.* The original generic diagnosis of Klement (1960) and the emended diagnosis of Stanchiff & Sarjeant (1990) are accepted. This emended diagnosis allows for the presence of two, paired process groups in each of the plates in the paracircular series and low relief elements occurring within the circular area defined by the major paraplate process groups.

*Comments.* We do not follow the emendation proposed by Brenner (1988) as we consider that each paraplate in the apical series bears an essentially complete process group, although admitting that the proximal ridge may be open, to varying degrees, towards the apex (Brenner, 1988, fig. 23C). However, these diagnoses do not allow for the presence of two, paired process groups in each of the plates in the paracircular series (contrast Klement, 1960, figs 32, 33). The exact location of these processes on the paracingular (and also surrounding the parasulcus) is uncertain. They are close to, or on the parasutures; however, process group style in *Systematophora* suggests that they are likely to be intratabular rather than parasutural. Hence, the generic diagnosis is here modified to allow for two sets of paired processes on each paracingular paraplate (Figs 7, 8f1). Furthermore, short intratabular processes or other low relief elements may occur within the circular area defined by major process groups (Fig. 8C). Similarly, low relief elements, occurring within the circular area defined by the major paraplate process groups, have not been recorded previously.

*Systematophora geminus* sp. nov. (Figs 7A, 8A-1, 9A-1)

*Previous Australian usage.*
*Systematophora areolata* (pars) – Morgan.

*Description.* A species of *Systematophora* with a subspherical cyst body, the autophragm of which is microreticulate to scabrate. Slender, solid processes, which may branch both proximally and distally, emerge from subcircular to subquadrangular annulate pentabular process groups in the major transverse paraplate series. The processes are joined proximally by low,
smooth pentatabular ridges; the distal terminations may be joined by trabeculae. Typically, the distal process endings are bifid, however they also may be branched or multifurcate and frequently form continuous distal trabecular rings, which may be joined by trabecular filaments. Two pairs of solid, slender, distally bifid, processes are present within each paracingular paraplate (Fig. 7A). Low relief elements, which range to short processes, are present within and close to the boundary of the parasule. Short, solid, simple processes or low relief elements may be present within the areas
Fig. 9. Systematophora geminus sp. nov. All are paratypes from Bogong-1 well, a sidewall core at 3530.00m. All photomicrographs were taken using plain transmitted light. Scale bar in Fig. 9I refers to all photomicrographs and is 25µm. These specimens are morphotypes in which the processes are connected by distal trabeculae. A-C - CPC 35568, paratype; oblique dorsal view, high to low focus sequence. Note occasional distal trabeculae. D, F - CPC 35569, paratype; oblique ventral view, high and median low focus respectively. Strongly trabeculate specimen, note apical archaepyle. E, I - CPC 35570, paratype; oblique dorsal view, high and low focus respectively. Slightly damaged specimen showing significant development of distal trabeculae. G, H - CPC 35571, paratype; oblique dorsal view, high and median focus respectively. Note extensive development of distal trabeculae connecting the processes.

Defined by the major process complexes.

Dimensions (µm n=34, loisthocysts only): Min. (Mean) Max.
Length of cyst incl. processes: 55 (77) 97
Length of cyst body (excl. processes): 35 (54) 67
Width of cyst incl. processes: 56 (79) 97
Width of cyst body (excl. processes): 39 (57) 74
Length of processes: 7 (14) 23

A single cyst with operculum attached was measured at 97µm overall length with a cyst body 63µm long. The measured specimens are from sidewall core samples from Arunta-1 well at 2135.00m and Bogong-1 well at 3530.00m.

Comments. The thin, solid processes in Systematophora geminus vary in morphology and length; they are generally shorter than in other
species (Figs 8C, 1). The apical, precingular, postcingular, posterior intercalary, and antapical processes arise from subcircular to rounded subrectangular, annulate, penitubular ridges. Short, simple processes or denticles may arise within the process complexes, causing darkening of these areas (Figs 8A-C). Typically, the main processes are branched, this occurring distally more consistently than proximally. The distal tips of the processes/branches are typically bifurcate, although multifurcate extremities may be present. The distal parts of the processes may also be trabeculate (Fig. 9). The length of the processes on each cyst is relatively constant. Accessory archaeopyle sutures within the precingular paraplate series are common.

Comparison. The presence of a relatively thick, microreticulate autophragm, occasional short processes within the annulate process complexes and paired processes within the paracingular distinguish S. geminus from other species of the genus (Fig. 7). Typically, single processes arise from each end of low, infratubular, rectilinear paracingular crests (Klement, 1960. figs 32-33; Riding & Thomas, 1988, fig. 10). There are no known occurrences of paired sets as in S. geminus.

This new species differs from the genotype, S. arcuata and many other species of the genus in having branched processes, which are sometimes distally trabeculate (Fig. 9). The species S. complicata Neale & Sarjeant 1962 and S. orbifera Klement 1960 are, by contrast, consistently distally trabeculate. Systematophora davieyi Riding & Thomas 1988 and S. septata Wilson 1988 have arcuate penitubular process complexes and septate penitubular ornamentation respectively. In some suites, the distal trabeculation results in distinct ring trabeculae which may in turn be joined by interconnecting trabecular filaments. Polystephonaphora Sarjeant 1961 emend. Stancliffe & Sarjeant 1990 includes forms which have distally connected trabeculae sometimes joined by trabecular filaments (Stancliffe & Sarjeant 1990, figs 1, 2). These are distinguished from S. geminus in lacking the double-paired paracingular process of the latter.

Derivation of name. From the Latin geminus, meaning twin, in reference to the pairing of the paracingular processes.

Holotype and type locality. Figures 8D-F, CPC 35565, Bogong-1 well, sideway core at 3530.00m.

Stratigraphical distribution. Systematophora geminus ranges from the Callovian lower Rigaudella aemula Zone (?aib) to the Oxfordian basal part of the Wanaea spectabilis Zone (6ciib) in the Timor Sea region (Foster, this volume; Helby & Partridge, in prep.).

Tringadinium gen. nov.

Type species. Tringadinium hjaaerkei sp. nov.

Diagnosis. Small, proximate, acutate dioflagellate cysts, rounded subpolygonal to subtriangular in outline, normally with an equatorial constriction. Autophragm generally exhibits intratabular inflations or protuberances, which may be covered by low relief paratabular, penitubular, intratabular or nontubular ornamental features. Paratabulation indicated by intratabular inflations and/or parasutural, penitubular and intratabular ornamentation. Where developed, the paratabulation style is pustiform gonyaulacoid; the paratabulation formula is: 4′, 2′a, 6′a, 2′, Xc, 6′a, 2′, Xs. Archaeopyle apical, operculum simple and normally free. The paracingular is distinct and located towards the anterior of the cyst. It is characterized by a lack of ornamentation and is not obviously subdivided into paraplates. A marked constriction is generally present in the paracingular area. Parasutural situated midventrally and indicated by a lack of ornamentation and a concavity; not obviously subdivided.

Comments. Tringadinium is a small partiform
L - CPC 35575, paratype; ventral view, high focus. Squat, pyriform specimen; note that rims on intratabular protrusions are subquadrangular. M-O - CPC 35576, paratype; dorsal view, high to low focus sequence. Note that paracingulum is not deeply incised. P - CPC 35577, paratype; dorsal view, high/median focus. The rims on intratabular protrusions are elongate. Q-S - CPC 35578, holotype; dorsal view, high to low focus sequence. Well preserved specimen, note two antapical paraplates and apical archaeopyle. T - CPC 35579, paratype; ventral view, median focus. Note detached operculum of apical archaeopyle, still adherent to loisthocyst.
genus with an apical archaepyle. It has a distinct constriction at the paracingulum and a wide range of ornamentation. Typically, the paratabulation is expressed by pentabular/intratabular ornamentation or prominent intratabular rounded protuberances.

Comparison. Tringadinium resembles Woodinia Riding & Helby (this volume) in shape, size and paratabulation pattern. However, Woodinia is characterized by extremely long postcingular paraplates, a paracingulum inserted close to the apical and intratabular areas (‘pads’) of differentiated autophragm (Riding & Helby, this volume). The genus Tringadinium is also similar in shape and ornamentation to Parvocysta Bjaerke 1980, R. Drugg 1978 and Susadinium Dörhöffer & Davies 1980, except that Tringadinium has an apical, rather than an anterior intercalary, archaepyle. The genus Mikrocystra Bjaerke 1980 emend. Below 1987 superficially resembles Tringadinium, but lacks the ornamentation and intratabular inflations. The epicystral paratabulation of Mikrocystra is also different (below, 1987b, fig. 4). The equatorially constricted Fosteria is superficially similar in shape to Tringadinium, but has parasutural denticles/processes (see above). Representatives of Tringadinium also closely resemble Susadinium? australis Riding & Helby (this volume) in general morphology. However, the paratabulation patterns are different. Susadinium? australis has a combination, apical and anterior intercalary, archaepyle with a compound operculum. Furthermore, Tringadinium lacks the consistent development of ridges or septa surmounting the intratabular protuberances, which are characteristic of Susadinium? australis. Tetrachaeysta Backhouse 1988 is a quadriloculate cyst with an indented paracingulum. Paratabulation is usually expressed only by the apical archaepyle suture (Backhouse, 1988).

Derivation of name. From Tringa, the generic name for most of the common sandpiper species. Helby first recorded representatives of this genus from Sandpiper-1 well.

Tringadinium bjaerkei sp. nov. (Figs 10A-T, II-A-
1988 Gen. et sp. nov. B (M.P. 36); Helby et al., fig. 15L.

Previous Australian usage
Bulbosia tithonica – Ott (1970, pl. 7, figs 10, 11).
Gen. et sp. indet. A – (Parker, 1986, p. 191, pl. 44,
fig. 3).
M.P. 36 – Helby.

Description. A species of Tringadinium which is rounded subpolygonal in outline, and with a pronounced paracingular constriction. The hypocyst is significantly larger in length and width than the epicyst. Autophragm extremely variable; it may be smooth, microreticulate, or surmounted by low relief ornamentation. The microreticulation, where developed, is normally sparse and the fenestrae are irregularly distributed; the fenestrae are 0.5 to 1μm in diameter. Where present, the positive ornamentation varies in height and density, and it is possible for individual specimens to exhibit more than one ornament type. Individual elements of the ornamentation normally are between 0.5 and 1μm, although rarely they may attain up to 2μm in height. The autophragm may be scabrate, granulate or, rarely, tuberculate and is extended into prominent intratabular rounded inflations or protuberances in the apical, precingular, postcingular and antapical paraplate series. These protuberances are usually wider and higher on the hypocyst than on the epicyst and are distally flat to rounded. The inflations on the apical paraplate series are extremely low in relief. Each protuberance normally has a subcircular to subquadrangular ridge or rim in a distal position. The rims are low and may be surpassed by low relief ornamentation, typically denticles, tubercles or pila up to 1μm long. Some coalescence of this ornament may occur, giving rise to continuous,

Fig. 11. Tringadinium bjaerkei sp. nov. All are paratypes from the W. spectabilis Zone, from sideway cores in Arunta-1 well at 2135.00m (Figs D, H, L) and Taltami-1 well at 2950.00m (Figs A-C, E-G, I-K, M-T). All photomicrographs taken using plain transmitted light. Scale bar in Fig. T refers to all photomicrographs and is 25μm. Note rounded subpolygonal outline, relatively large hypocyst, prominent intratabular rounded inflations/protuberances with their subcircular/subquadrangular rims and variable ornamentation on autophragm. A-C - CPC 35580, paratype; lateral view, high to low focus sequence. Note subquadrangular rims on intratabular protuberances and irregular granulate ornamentation. D, H, L - CPC 35581, paratype; lateral view, high to low focus sequence. Note subcircular rims on intratabular protuberances and apical archaepyle. E-G - CPC 35582, paratype; ventral view, high to low focus sequence. Note granulate ornamentation. I-K - CPC 35583, paratype; slightly oblique ventral view, high to low focus sequence. Elongate form; rims on the intratabular protuberances are correspondingly ellipsoidal. Note paired antapical intratabular protuberances (continued opposite)
indicating a partiform paratabulation pattern in Fig. 11J. M-P - CPC 35584, paratype; lateral view, high to low focus sequence. Note deeply-incised paracingulum and that archaeopyle has not developed. Q-T - CPC 35585, paratype; dorsal view, high to low focus sequence. Note deeply-incised paracingulum.
subcircular ridges. Generally the interiors of the rims/ridges exhibit relatively dense intratubular ornament such as scabae, granules and tubercles. The hypocyst may be asymmetrical due to the differing sizes of the intratubular inflation on the antapical paraplates. This species is slightly primarily flattened dorsoventrally and the wide, midventral parasulcus is slightly indented.

**Dimensions** (μm, n=62, including ornament and/or protuberances where appropriate): Min. (Mean) Max.

- Length of cyst, incl. operculum: 25 (33) 41
- Length of loisthocyst: 23 (32) 40
- Length of epicyst: 6 (10) 18
- Length of cyst at paracingulum: 3 (6) 10
- Length of hypocyst: 11 (17) 25
- Maximum width of epicyst: 15 (23) 34
- Width of cyst at paracingulum: 12 (20) 32
- Maximum width of hypocyst: 21 (28) 38
- Maximum height of protuberances: 3 (5) 9

The measured specimens are from sidewall cores from Arunta-I well at 1805.00m, 1919.00m and 2135.00m; Challis-11 ST1 well at 1552.50m; Sandpiper-I well at 658.38m; Semmier-I well at 1440.00m; Taltarni-I well at 2950.00m; ditch cuttings from Peak-I well from between 1493.54m and 1496.59m and Tithonian outcrop samples 81FH05 and 81FH11 from the Lelinta Formation (Paceo Group) Misool, eastern Indonesia.

**Tringadinium hyaerkei** is variable in size. Specimens from the *W. spectabilis* Zone of offshore north-western Australia are significantly smaller, and have more prominent ornamentation, than those from the Tithonian of Australia and Misool, Indonesia. 26 specimens from the *W. spectabilis* Zone of offshore north-western Australia gave the following data:

- Dimensions, (μm n=26): Min. (Mean) Max.
  - Length of cyst incl. operculum: 25 (30) 33
  - Length of loisthocyst: 23 (28) 35
  - Length of epicyst: 6 (9) 14
  - Length of cyst at paracingulum: 4 (6) 8
  - Length of hypocyst: 11 (15) 20
  - Maximum width of epicyst: 16 (20) 23
  - Width of cyst at paracingulum: 12 (17) 22
  - Maximum width of hypocyst: 21 (25) 30
  - Maximum height of protuberances: 3 (4.5) 7

By contrast, 36 specimens from the Tithonian of offshore north-western Australia and Misool, eastern Indonesia, gave the following size ranges:

- Dimensions, (μm n=36): Min. (Mean) Max.
  - Length of cyst including operculum: 31 (36) 41
  - Length of loisthocyst: 29 (34) 40
  - Length of epicyst: 7 (11) 18

*Length of cyst at paracingulum: 3 (6) 10
Length of hypocyst: 15 (19) 25
Maximum width of epicyst: 18 (24) 34
Width of cyst at paracingulum: 14 (22) 32
Maximum width of hypocyst: 25 (31) 38
Maximum height of protuberances: 3 (5) 9

The sizes of the Tithonian material are consistently significantly greater than those of the Oxfordian (*W. spectabilis* Zone) specimens (see above). The most marked average size differences are in the lengths of the entire cyst, the length of the loisthocyst and the width of the hypocyst. The size differences observed between the Oxfordian and Tithonian of north-western Australia and Indonesia may represent a potential morphostratigraphical lineage (Monteil, 1990; 1991). Furthermore, the older, Oxfordian material tends to have a granulate autophragm (Fig. 11). The Tithonian specimens, by contrast, tend to have smooth autophragms outside the intratubular protuberances (Fig. 10). Despite these differences, all the specimens are considered unequivocally to belong to *Tringadinium hyaerkei* because of significant overlap between the two morphotypes.

**Comments.** *Tringadinium hyaerkei* is rounded subpolygonal in outline. Frequently it is subhexagonal, the shape being distorted by prominent intratubular protuberances. The constriction at the apically offset paracingulum is also significantly variable in depth (Figs 10, 11). The hypocyst is relatively large in comparison to the paracingular area and the epicyst. The species also exhibits great variability in the nature and distribution of ornamentation. Typically, the interiors of the distal rims on each intratubular protuberance contain low relief ornamentation. This feature is similar to the pentatubular/ intratubular ornamental distribution in *T. compton* sp. nov. (see below). However, in some Tithonian specimens, nontubular scabrae, granules and tubercles are present outside the intratubular areas. These are normally significantly less dense than the intratubular ornamentation (Fig. 10). Most Oxfordian specimens exhibit a uniform density of ornamentation over the entire cyst (Fig. 11). Some may be smooth and/or irregularly microreticulate outside the intratubular protuberances. The majority of the ornamentation lies inside the subcircular to subquadrangular distal rims on the intratubular protuberances. These rims or ridges are normally surmounted by low relief ornamentation. Rarely they are absent, their positions indicated only by vague rings of intratubular granules. The two antapical
protuberances may be equal in size (Figs 10Q-S); however, frequently one is significantly larger than the other (Figs 10E-H).

Comparison. *Tringadinium bjaerkei* differs from *T. comptum* sp. nov. in the consistent occurrence of prominent intratabular protuberances/ inflations. The intratabular features, together with the size and shape, make *T. bjaerkei* significantly similar in appearance to the Early-Mid Jurassic taxon *Susadinium scrofoideis* Dörhöfer & Davies 1980. However, *S. scrofoideis* and the other members of the *Parvoxystra* suite (Riding, 1984) have a different paratabulation pattern and single paratype anterior intercalary, type 1, archaeopyle. *Susadinium scrofoideis* has five apical, three anterior intercalary, seven precingular, seven paracingular and five postcingular paraplates (Bjaerke, 1986; Eviit, 1985, fig. 12.3; Below, 1987a). The involvement of the apical paraplates in the archaeopyle and the intratabular protuberances make *Susadinium? australis* Riding & Helby (this volume) similar in overall appearance to *T. bjaerkei*. However, the paratabulation pattern of *S? australis* conforms to that of *Susadinium* (see above) and *S? australis* lacks the smaller ornamental features which are typical of *T. bjaerkei*. Furthermore, *S? australis* appears to have a combination (apical and anterior intercalary) archaeopyle.

*Derivation of name*. In honour of Dr. Tor Bjaerke.

*Holotype and type locality*. Figures 10Q-S, CPC 35578, Sandpiper-1 well, sidewall core sample at 685.38m.

*Stratigraphical distribution*. *Tringadinium bjaerkei* ranges from the Callovian, lower *Rigaudilla aemula* Zone (?a1b) to the Tithonian-Berriasian, *Pseudoceratium ihenoense* Zone (4ci) on the North West Shelf of Australia (Foster, this volume; Helby & Partridge, in prep.). It has also been recorded from the Tithonian Leilinta Formation (Fageo Group) of Misool, eastern Indonesia (Helby & Hasibuan, 1988). In New Zealand, it is recorded from the Kimmeridgian Waikutakuta Siltsone to the Tithonian Purī Silstone (Helby et al., 1988).

*Tringadinium comptum* sp. nov. (Figs 12A-T)

1988 Geol. et sp. nov. G (M.P. 618D); Helby et al., fig. 3F.G.

*Previous Australian usage*. M.P. 618D—Helby.

*Description*. A species of *Tringadinium* that is rounded subtrangular in outline; a deep equatorial constriction in the paracingular area is commonly developed, imparting an hour-glass shape to the cyst. The hypocyct is relatively large and the paracingulum, by contrast, is prominent. The epicyct, however, is relatively small. The autophagm is microgranulate, scabrate and may also be irregularly microreticulate. 

*Fenestrae*, where developed, are subcircular to ellipsoidal and 0.5-1µm in diameter. The autophagm is further surmounted by ornament of low relief, which may be bacula, clava, large granules, pila or tubercles. 

Sculptural elements are mainly intratabular, although some appear to be pentatubular. These ornamental elements are highly variable in form, density and arrangement, but they typically comprise pentatubular tubercles and/or clava. Some of the postcingular and antapical paraplates may have circular arrangements of ornamentation in pentatubular areas. In forms where the ornamentation is densely inserted, there may be some coalescence of the elements. The ornamentation is usually longest and densest on the hypocyct. A slight medial concavity and/or break in ornament may be developed at the antapex, reflecting a paritiform gonysulculate paratabulation pattern. The cyst is slightly primarily dorsoventrally flattened and the wide, midventral parasulcus is slightly indented.

*Dimensions* (µm n=54 including ornament where appropriate): Min. (Mean) Max.

- Length of cyst including operculum: 23 (30) 40
- Length of loisthocyst: 22 (29) 37
- Length of epicyct: 5 (7) 11
- Length of cyst at paracingulum: 5 (7) 11
- Length of hypocyct: 10 (15) 20
- Maximum width of epicyct: 15 (19) 27
- Width of cyst at paracingulum: 11 (16) 24
- Maximum width of hypocyct: 19 (24) 31
- Length of ornamental elements: 1 (1.5) 3

The measured specimens are from sidewall cores from Arunta-1 well at 2135.00m, Challis-11 ST1 well at 1552.50m, Challis-11 ST2 well at 1670.70m and 1842.00m and Taltami-1 well at 2950.00m.

Marked differences in the development of the paracingular constriction were observed. For example, at 1670.70m in Challis-11 ST2 well, the specimens had consistently weakly developed equatorial concavities (Figs 12N-O, T). At this
Fig. 12. Tringadinum comatum sp. nov. All from sidewall cores in Arunta-1 well at 2135.00m (Figs 12D-E, I-J), Challis-11 ST1 well at 1552.50m (Figs 12F-R), Challis-11 ST2 at 1670.70m (Figs 12N-O, T) and 1842.00m (Figs 12F-H, K-M), and Talarni-1 well at 2950.00m (Figs 12A-C). All photomicrographs taken using plain transmitted light. Scale bar in Fig. 12T refers to all photomicrographs and is 25μm. Figs 12P-R are the holotype; the remainder, paratypes. Note rounded subtriangular outline, relatively large hypocyst, normally deeply indented, prominent paracingulum, microreticulate autophragm which normally has pentatubular ornamentation, and apical archaeopyle. A-C - CPC 35586, paratype; ventral view, high to low focus sequence. Small specimen with adherent operculum. D, E - CPC 35587, paratype; ventral view, high/median and low focus respectively. Note deeply incised paracingular region, relatively small overall size and apical archaeopyle. F - CPC 35588, paratype; ventral view, median focus. Note lack of significant paracingular incision. G, H - CPC 35589, paratype; ventral view, high and low focus respectively. Note prominent ornamentation, especially on hypocyst. I, J - CPC 35590, paratype; ventral view, high and low focus respectively. Note lack of incised paracingulum. K-M - CPC 35591, paratype; ventral view, high to low focus sequence. Note hour-glass shape and prominent, largely pentatubular ornamentation. N, O - CPC 35592, paratype; dorsal view, high/median and low focus respectively. Note lack of ornamentation in paracingular area and apical archaeopyle. P-R - CPC 35593, holotype; dorsal view, median to low focus sequence. Note prominent, unornamented paracingulum and parasulcus, pentatubular arrangement of ornamentation and apical archaeopyle. S - CPC 35594, paratype; slightly oblique dorsal view, a composite photomicrograph. Note clear pentatubular arrangement of ornament on hypocyst. T - CPC 35595, paratype; dorsal view, median focus. Elongate specimen; note prominent paracingulum and adherent operculum.
horizon, the average width of the cyst at the paracingulum was 18μm. By contrast, in the remainder of the samples studied, the average paracingular width was 15μm.

Comments. The epicyst and paracingulum are approximately as long as the remainder of the cyst (see Dimensions above). Both the precingular and apicel paraplate series are relatively short in height. On average, the epicyst is only 23% of the overall cyst length. The low, nearly flat, operculum is normally free, but specimens with attached opercula have been observed (e.g. Figs 12A-C, N-R, T). An equatorial constriction may be entirely absent or extremely deep with all intermediate conditions between these extremes (Fig. 12). This constriction is at the paracingulum, which is relatively long and a distinctive feature of this species. It is possible that post-depositional flattening of the cyst affects the depth of the equatorial constriction. For example, it was noted that specimens which have been post diagnostically flattened tend to have more strongly developed ‘waists’. The parasulcus is relatively wide and expands markedly antapically (Figs 12P-R). This is typical of the partiform paratabulation style. The cyst is widest across the paracingular paraplate series (Fig. 12).

The ornamentation of the species is also highly variable and comprises penitubular or penitubular/interstitial elements, which may attain 5μm in length. In the majority of forms, the paratabulation is indicated by penitubular and/or interstitial tubercles and/or clava. Different ornamentational elements may be present on a single specimen, for example forms with bacula, clava and tubercles have been observed. Furthermore, the density and position of the ornamentation is highly variable from extremely sparse to relatively dense and from strictly penitubular to virtually non-tubular (Fig. 12). Some coalescence of the ornamentation may occur, giving rise to crest-like features, especially in median view. The general variability of the penitubular nature of the ornamentation means that there is a marked variability in the development of the paratabulation (Fig. 12). Thus, the slight medial concavity and/or break in ornament at the antapex may represent the 1'1''/2'' parasure. The autophragmal fenestrae vary in the density within the specimens studied. Occasionally, the fenestrae may be arranged in lineations, which may be parasutural or penitubular.

Comparison. Tringadinium comptum differs from T. hyækeri in lacking interstitial inflations or protuberances and having a rounded subtriangular outline. This species also resembles Woodinia bensonii sp. nov. and Woodinia pedis Riding & Helby (this volume). However, T. comptum lacks the extremely elongate postcingular paraplates and interstitial ‘pads’ of differentiated autophragm which characterise Woodinia. The size and shape of Tringadinium comptum are similar to many members of the Early-Earliest Mid Jurassic Parvocycta ‘complex’ of Riding (1984). The most similar species being Susadinium faustum (Bjaerke 1980) Lentin & Williams 1985, with its interstitial bacula (Bjaerke, 1980). The Parvocycta ‘complex’, however, all have anterior intercalary archaeopyle (Riding et al., 1991).

Derivation of name. From the Latin comptus meaning ornamented and referring to the low-relief ornamentation elements, which characterise this form.

Holotype and type locality. Figures 12P-R, CPC 35593, Chalilis-1 ST1 well, sidestream core sample at 1552.50m.

Stratigraphical distribution. Tringadinium comptum ranges from the Callovian, lower Rigaudella aemula Zone (?aib) to the Oxfordian, mid Wanaea spectabilis Zone (6ci) in the Timor Sea region (Foster, this volume; Helby & Partridge, in prep.). In New Zealand, this species has been recorded from the Callovian to Oxfordian Oraka Sandstone (Helby et al., 1988, fig. 23).

Woodinia Riding & Helby this volume

Type species. Woodinia pedis Riding & Helby this volume

Woodinia bensonii sp. nov. (Figs 13A-T)

1988 Gen. et sp. indet. AO (M.P. 618R); Helby et al., fig. 5D.

1996 Dissimuladinium lobispinosum auct. non May et al. 1987; Burger, pl. 5, fig DD.

Previous Australian usage
M.P. 618 (triangular) – Helby.
M.P. 618R – Helby.
Tuliparnia spp. – Morgan.

Description. A rounded subtriangular species of Woodinia with two lateral antapical protuberances which often give rise to a prominent antapical concavity. The cyst normally tapers gently
Fig. 13. Woodinia beazonii sp. nov. Specimens from sidewall cores from Arunta-1 well at 1805.00m (Figs 13H, K-M, P-R, T) and 1991.00m (Fig. 13S), Chalk-1 ST2 well at 1670.70m (Figs 13N-O) and Talmar-1 well at 2050.93m (Figs 13A-G, I-J). All photomicrographs taken using plain transmitted light. Scale bar in Fig. 13T refers to all photomicrographs and is 25μm. Figs 13A-B are the holotype, and the remainder, paratypes. Note rounded subtrangular outline with two lateral antapical protuberances and intervening antapical concavity, apical archaeopyle and intratabular areas of low-relief ornamentation. A, B - CPC 35596, holotype; ventral view, high and low focus respectively. Note prominent antapical concavity and apical archaeopyle with adherent operculum which has been folded back down into loisthocyst. C, D - CPC 35597, paratype; dorsal view, high and low focus respectively. Note apical archaeopyle and low-relief ornamentation on prominent lateral antapical protuberances. E - CPC 35598, paratype; dorsal view, high focus. Note high paracingulum which is located high on the cyst as a result of extremely high postcingular paraplate series. F - CPC 35599, paratype; dorsal view, low focus. Squat form with especially prominent antapical concavity. G - CPC 35600, paratype; dorsal view, low focus. This specimen is extremely wide antapically and tapers dramatically apically. Note small ‘pads’ of differentiated autophragm in precingular paraplate series, close to principal archaeopyle suture. H - CPC 35601, paratype; ventral view, high focus. Note archaeopyle has not formed. I, J - CPC 35602, paratype; ventral view, high median and low focus respectively. Note operculum has been folded into the loisthocyst. K - CPC 35603, paratype; dorsal view, median focus. Note operculum of apical archaeopyle is still attached ventrally. L - CPC 35604, paratype; dorsal view, median focus. Note small quadrangular ‘pads’ of differentiated autophragm in precingular paraplate series. M - CPC 35605, paratype; ventral view, median focus. Note adherent operculum and small antapical concavity. N, O - CPC 35606, paratype; dorsal view, median and low focus respectively. A well preserved specimen, narrow antapically with prominent attached operculum within loisthocyst. P, Q - CPC 35607, paratype; dorsal view, high and low focus respectively. Note angular principal archaeopyle suture and flat antapical margin. R - CPC 35608, paratype; ventral view, median focus. Note attached operculum inside loisthocyst and flat antapical margin. S - CPC 35609, paratype; ventral view, median focus. Elongate specimen with prominent paracingulum. T - CPC 35610, paratype; dorsal view, high focus. Small specimen with slight antapical concavity.
apically. Autophagm microreticulate, scabrate or granulate. Intratabular areas of low relief ornamentation are variably developed. In some specimens, extremely low relief ornamentation is present in the apical paraplate series. In the short precingular paraplate series, the intratabular ornamentation comprises subrectangular areas ("pads") of differentiated autophagm comprising dense, short, solid processes which may be interconnected by trabeculae. These subrectangular "pads" of ornamentation occur close to the principal archaeopyle suture, i.e., near to the apex of the cyst. The elongate postcingular paraplate series may also have areas of differentiated autophagm developed. However, most specimens lack positive ornamentation in this area and short, simple, slender, solid spines may occur, somewhat sparsely and irregularly, in the equatorial region of the cyst, i.e., posterior of the paracingulum. The antapical paraplates are characterised by a subcircular or irregularly shaped cover of short processes in the intratabular area. The style of ornamentation is similar to that developed within the precingular paraplates, i.e., comprising densely inserted short filaments or processes. However, the density of elements is normally markedly less on the antapical paraplates. These elements may coalesce distally, thereby frequently producing a raised reticulum. The paracingulum and the centre of the antapical area are devoid of positive ornamentation, but may be scabrate or granulate. The paracingulum may be indented. A narrow midventral indented area may be present and represents the paraculus. The operculum is relatively flat to slightly domed and is frequently attached ventrally and folded back inside the epicyst.

Dimensions (μm n=35): Min. (Mean) Max.
Length of cyst body incl. operculum: 29 (36) 44
Length of cyst body excl. operculum: 25 (33) 38
Width of cyst body at antapex: 25 (33) 44
Width of cyst body at equator: 13 (18) 25
Width of cyst body at apex: 11 (15) 22
Length of ornamentation: <0.5 (1) 2

The measured specimens are from sidewall cores from Arunta-1 well at 1805.00m, 1919.00m and 2135.00m; Challis-11 ST 2 well at 1670.70m; Eclipse-1 well at 2477.00m and Taltarni-1 well at 2950.00m.

Comments. *Woodinia bensonii* is characterised by its rounded subtriangular dorsoventral outline and an often well-developed antapical concavity (Fig. 13). The overall length of the cyst is normally close to the maximum width (see Dimensions, above). The length and shape of the lateral antapical protuberances are variable (Fig. 13). The consistent presence of regular subrectangular areas ("pads") of differentiated autophagm in intratabular precingular positions, close to the apical series is also diagnostic. These relatively small "pads" commonly form an interrupted ring around the principal archaeopyle suture. This is the only area where the intratabular ornamentation is consistent and regular. The elongate postcingular paraplates are normally surmounted by relatively sparsely occurring short, slender, simple processes equatorially. Differentiated autophagm is also present on the paired antapical paraplates. This ornamentation is often less dense than that developed on the precingular paraplates and frequently has a microreticulate appearance (Fig. 13). The antapical ornamentation may coalesce extensively. It is typically concentrated on the distal parts of the lateral antapical lobes and the central antapical area, close to the 1"/2" paraplate junction and is normally devoid of positive ornamentation (Fig. 13). Individual elements of ornamentation at the antapical region may be relatively variable in thickness.

Some significant variations in terms of the development of the antapical concavity was observed. Specimens from Taltarni-I well at 2950.00m are relatively wide antapically, with a consistent prominent antapical concavity (Figs 13A-G, I-J). Material from Arunta-I well between 1805.00m and 2135.00m and Challis-11 ST 2 well at 1670.70m, however, includes relatively high proportions of specimens which lack a marked antapical concavity (e.g., Figs 13M-S).

Comparison. *Woodinia pedis* is subrectangular and distinctly flask-shaped, lacking the prominent, large lateral antapical protuberances and the antapical concavity of *Woodinia bensonii*. The former species also has thicker and more regular intratabular ornamentation, particularly prominent "pads" of differentiated autophagm in the postcingular paraplate series immediately posterior of the paracingulum. Furthermore, the antapical ornamentation of *Woodinia pedis* is more prominent than that in *W. bensonii* and is normally contiguous, forming a skirt-like flange to the antapex. Some forms of *Woodinia bensonii* may be superficially similar in outline to representatives of the Late Cretaceous-Palaeogene acritarch genus *Paucioblimorpha* de Coninck 1986; for example *Paucioblimorpha triradiata* de Coninck 1986. However, this genus
of small acritarchs lacks any indications of paratabulation and an archaephyle.

Derivation of name. Named for Dr. Don G. Benson

Holotype and type locality. Figures 13A-B, CPC 35596, Talarni-1 well, sidewall core sample at 2950.00m.

Stratigraphical distribution. A notable acme of Woodinia bensonii distinguishes the Oxfordian, upper part of the mid Wanaea spectabilis Zone (6ciia) in wells in the Montana Field and the adjacent Vulcan Subbasin. Rare occurrences are recorded in the lower part of the upper Wanaea spectabilis Zone (6cib) and the species occurs consistently and is intermittently prominent through the remainder of the Wanaea spectabilis Zone (subzones 6ciiib–6ciiia) (Foster, this volume; Helby & Partridge, in prep.).

ACKNOWLEDGEMENTS

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REFERENCES


RIDING, J.B. & HELBY, R., this volume. Microplankton from the Mid Jurassic (late Callovian) Rigaudella oemulu Zone in the Timor Sea, north-western Australia.


APPENDIX 1: SAMPLE DETAILS

1 Locations and operators of wells from which material has been studied

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<thead>
<tr>
<th>Well Name and Number</th>
<th>Latitude</th>
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<th>Operator</th>
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* SADME = South Australian Department of Mines and Energy

Well completion reports on all the offshore wells listed are publicly available five years after completion.

2 Outcrop material from Misool, Eastern Indonesia

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<td>Hasibuan (1990)</td>
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APPENDIX 2: REGISTER OF FIGURED SPECIMENS

All palynomorph specimens figured in this paper are listed here, together with essential details. The specimens are all curated in the Commonwealth Palaeontological Collection (CPC) of the Australian Geological Survey Organisation, Canberra. The dinoflagellate cyst genera and species are listed alphabetically and the location of the specimens on the microscope slides are all "England-Finder" co-ordinates. These were taken with the slide label to the left of the observer, the microscope stage opening toward the microscope user. The coding for types is as follows: H = holotype, P = paratype, T = topotype. All specimens of new taxa examined during this study contributed to the specific concepts described. Therefore all the figured specimens, which are not holotypes are
paratypes. SGM = single grain mount. The single grain mounts do not have unique numbers; they are numbered sequentially for each species within a particular sample. The specimens are from conventional cores and sidewall cores, except for Peak-1 at 1493.54m-1496.59m, which is a sample of ditch cuttings.

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<th>EF</th>
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| *T. comportum* | P    | 12D,E  | SGM 1         | N37/3| Arunta-1 (2135.00)    | 35587   |
| *T. comportum* | P    | 12F    | SGM 4 (i)     | M32/1| Challis-1 ST2 (1842.00) | 35588   |
| *T. comportum* | P    | 12G,F  | SGM 4 (ii)    | N31| Challis-1 ST2 (1842.00) | 35589   |
| *T. comportum* | P    | 12J    | SGM 3 (i)     | P35/2| Arunta-1 (2135.00)    | 35590   |
| *T. comportum* | P    | 12K-M  | SGM 2 (i)     | L31/2| Challis-1 ST2 (1842.00) | 35591   |
| *T. comportum* | P    | 12M,O  | SGM 4 (iv)    | M28/2| Challis-1 ST2 (1670.70) | 35592   |
| *T. comportum* | H    | 12P-R  | SGM 5         | L37| Challis-1 ST1 (1552.50) | 35593   |
| *T. comportum* | P    | 12S    | SGM 12       | N38/3| Challis-1 ST1 (1552.50) | 35594   |
| *T. comportum* | P    | 12T    | SGM 1 (iii)   | M25| Challis-1 ST2 (1670.70) | 35595   |

| *W. bensonii*  | H    | 13A,B  | SGM 10       | N37/3| Talitami-1 (2950.00)  | 35596   |
| *W. bensonii*  | P    | 13C,D  | SGM 9        | N27/4| Talitami-1 (2950.00)  | 35597   |
| *W. bensonii*  | P    | 13E    | SSM 1        | Q33/1| Talitami-1 (2950.00)  | 35598   |
| *W. bensonii*  | P    | 13F    | SGM 6        | P34| Talitami-1 (2950.00)  | 35599   |
| *W. bensonii*  | P    | 13G    | SSM 2        | K33| Talitami-1 (2950.00)  | 35600   |
| *W. bensonii*  | P    | 13H    | SGM 1 (ii)   | G34/3&4| Arunta-1 (1805.00)   | 35601   |
| *W. bensonii*  | P    | 13I,J  | Ass. sl. 2   | N21/4| Talitami-1 (2950.00)  | 35602   |
| *W. bensonii*  | P    | 13K    | SGM 2 (iv)   | Q27/2| Arunta-1 (1805.00)    | 35603   |
| *W. bensonii*  | P    | 13L    | SGM 2 (iii)  | P34/3| Arunta-1 (1805.00)    | 35604   |
| *W. bensonii*  | P    | 13M    | SGM 4 (i)    | J27/1| Arunta-1 (1805.00)    | 35605   |
| *W. bensonii*  | P    | 13N,O  | SGM 2 (i)    | N21| Challis-1 ST2 (1670.70) | 35606   |
| *W. bensonii*  | P    | 13P,Q  | SGM 3 (i)    | M27/3| Arunta-1 (1805.00)    | 35607   |
| *W. bensonii*  | P    | 13R    | SGM 2 (ii)   | O33/3| Arunta-1 (1805.00)    | 35608   |
| *W. bensonii*  | P    | 13S    | SGM 2 (ii)   | Q33/3| Arunta-1 (1919.00)    | 35609   |
| *W. bensonii*  | P    | 13T    | SGM 5 (i)    | O34/3| Arunta-1 (1805.00)    | 35610   |
Dinoflagellate cysts from the Late Jurassic (Kimmeridgian) *Dingodinium swanense* Zone in the North-West Shelf and Timor Sea, Australia

JAMES B. RIDING and ROBIN HELBY


Late Jurassic (Kimmeridgian) dinoflagellate cysts from the Timor Sea, offshore north-western Australia, include several undescribed forms. Of these, three genera, *Hadriona*, *Mombasadinium* and *Striatodinium*, and seven species are described as new. The new dinoflagellate cyst species are *Craspedodinium swanense*, *Cribroperidinium corruogatum*, *Gonyaulacysta fenestrata*, *Hadriona cincta*, *Oligosphaeridium swanense*, *Striatodinium lineatum* and *Striatodinium ovalis*. The genus *Craspedodinium* and the species *Indodinium kharlesi* are emended. The species formerly known as *Indodinium? parvulum* is transferred to the new genus *Mombasadinium* and is also emended. All these dinoflagellate cyst taxa have stratigraphical utility in the Kimmeridgian *Dingodinium swanense* Zone of Australia.

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THE PALYNOLOGICAL zonation of the Australian Mesozoic published by Helby *et al.* (1987) was the first attempt to provide an integrated, pan-Australian micropalaeontological and spore-pollen zonation. Only the basic framework of the zonation was provided in anticipation that further contributions, particularly the documentation of new taxa, would be necessary as the zonation scheme evolved. This paper is one of a series providing the taxonomic foundation necessary to formalise the widely used unpublished subdivisions of these zones. These subzones have widespread currency within the hydrocarbon industry due to the legislative requirement for the release of technical data under the Petroleum (Submerged Lands) Act 1967. The informal subdivisions of the Helby *et al.* (1987) zonation have been entered into the Australian Geological Survey Organisation (AGSO) STRATDAT database. A diagrammatic update of the Helby *et al.* (1987) zonal scheme is presented by Foster (this volume), and will be fully described by Helby & Partridge (in prep.). This taxonomic project is an initiative of the Petroleum and Marine Division of AGSO.

This paper provides formal descriptions of previously undescribed taxa from a Late Jurassic (mainly Kimmeridgian) dinoflagellate cyst assemblage recorded in samples from the North-West Shelf and the Timor Sea (Appendix 1). All these new taxa have stratigraphical utility within the *Dingodinium swanense* Interval Zone of Helby *et al.* (1987). The figured specimens in this paper from offshore north-western Australia are from Alaria-1, Buang-1, Cockell-1, Frigate-1, Hadrion-1, Jabiru-8A, Jurabi-1, Macedon-5, Octavius-2, Peak-1, Scafell-1, Swan-1, Tenacious-1 and Tenacious-West-1 wells (Foster, this volume; Appendix 1). Additional material from outcrops in Misool, eastern Indonesia, Scotland, Kenya and New Zealand was also studied and some specimens figured (Appendices 1, 2).

Helby *et al.* (1987, p. 29) stated that their *Dingodinium swanense* Interval Zone is of mid to late Kimmeridgian age based upon evidence from ammonites and belemnites (Arkell, 1956; Balmes, 1957; Wiseman, 1980). Davey (1987, fig. 3), however, concluded that the equivalent of this zone, the lower part of the *Cribroperidinium perforans* Zone of Davey (1987), lies entirely within the late Oxfordian. Francis & Westermann (1993, fig. 1b), further interpreted the age of this zone to be possibly as old as mid Oxfordian. However, these authors went on to suggest that...
it is most likely to be early Kimmeridgian (Francis & Westermann, 1993, fig. 7). The conclusions of Francis & Westermann (1993, fig. 7) were based on linking the Australasian molluscan faunas to north-west Europe by indirect correlation via various ammonite faunal provinces. The early Kimmeridgian interpretation of Francis & Westermann (1993) was, however, not accepted by Drvey (1999, figs 8, 9), who indicated that the Dingodinium swanense Interval Zone is entirely within the late Oxfordian. Burger (1996, fig. 2) also assigned the Dingodinium swanense Interval Zone to the Oxfordian, within AGSO timeslice J-8. This author highlighted the lack of direct evidence of correlations to Europe within the Oxfordian and much of the Kimmeridgian.

SYSTEMATIC PALYNOLOGY

In this section, three new genera and seven new species of dinoflagellate cyst are described from the Upper Jurassic Lower Vulcan Formation and equivalent strata on the North-West Shelf and in the Timor Sea. The material is from the Dingodinium swanense Zone of Helby et al. (1987). The type material of one of these species, *Striatodinium obtii* sp. nov., is from New Zealand. Additionally, one dinoflagellate cyst species is emended and another is emended and recombined. The genera are listed in alphabetical order, the recent suprageneric classification of Fensome et al. (1993) is not used here. The dimensions quoted are all given in micrometres (μm). For descriptive purposes, the cyst sizes, small, intermediate and large are after Stover & Evitt (1978, p. 5). These parameters are such that intermediate size dinoflagellate cysts have a maximum dimension of between 50 and 100μm. Small and large forms are less than 50μm and above 100μm respectively.

The majority of the morphological terminology for the dinoflagellate cysts are those used by Evitt (1985). However, the term loiothec cyst refers to a dinoflagellate cyst in which the operculum (or separate opercular pieces) has (have) detached and is therefore the part that remains (Surjeant et al., 1987, p. 26, 27). Where appropriate, the dinoflagellate cyst paraplate notation system used throughout is Kofoidian, as opposed to the 'Taylor-Evitt' scheme of Evitt (1985). References to author citations of taxa discussed are not given here. These may be found in the bibliography in Williams et al., 1998, p. 747-817. The synonymy lists given here are selective and mainly confined to illustrated specimens. The majority of the figured specimens are housed in the Commonwealth Palaeontological Collection (CPC) of the Australian Geological Survey Organisation (AGSO), Canberra (Appendix 2).

This study has been conducted almost exclusively using single grain mounts (or mounts with multiple specimens) and the majority of the figured specimens are from these single species slides. Most of the samples studied are from sidewall core or conventional core material, however a small number of ditch cutting samples were also used. The photomicrographs in Figs 1-15 were all taken at AGSO using an Olympus DP10 digital camera system coupled to a Zeiss Axioskop photomicroscope. Extraneous palynodebris, which is not adherent to the figured specimens, has been digitally removed in selected images.

The images in Figs 1 to 15 in this paper are taken from a digital database. Many more digital images exist than have been figured. The sample details, key morphological data and measurements of each imaged specimen are held digitally on open file spreadsheets. The image database may be accessed on the AGSO website (http://www.agso.gov.au).

Many of these new taxa have been extensively used in unpublished reports, which are now in the public domain (open file). In order to maximise the utility of the species, the informal names and/or codes are listed, separate from any formal synonymy listing, under the heading 'Previous Australian usage'. To provide continuity, wherever practical, the informal name has been retained.

Dinoflagellate cysts

*Craspedodinium* Cookson & Eisenack 1974 emend.

1974 *Craspedodinium* Cookson & Eisenack; p. 75.
1978 *Craspedodinium* Cookson & Eisenack 1974; Stover & Evitt, p. 34.

*Type species.* *Craspedodinium indistinctum* Cookson & Eisenack 1974 emend. Riding & Helby this volume

*Emended diagnosis.* The original generic diagnosis of Cookson & Eisenack (1974) and the synopsis and modified description given by Stover & Evitt (1978) are all accepted. However, the generic concept is further expanded to include the partial indication of a gonyaulaclean paratabulation (formula: 4*, 6*, Xc, 6**, 2/p, 1***, Xs), including the paracingulum and paranasus.
by low relief ornamentation of the peripharm, the presence of short, parasutural processes on the endophragm and/or the outline of the operculum. These endophragmal processes may be trabeculate. Furthermore, the archaeopyle type of this genus is confirmed as being apical with a simple operculum which is free.

Comments. This emendation to include a standard gonyaulacalean paratabulation is based on observations of the type, Craspedodinium indistinctum (see Morgan, 1980, pl. 8, figs 3-6 and Riding & Helby, this volume, a), and C. swanense sp. nov. (see below). Craspedodinium indistinctum has irregular parasutural periphergal folds and parasutural ornamentation on the hypocyst (Morgan, 1980, pl. 8, fig. 5; Riding & Helby, this volume, a). The archaeopyle type of Craspedodinium is apical, as stated by Cookson & Eisenack (1974), Stover & Evitt (1978, p. 34) and Wilson & Clowes (1981, p. 31). Helens (1983, p. 257) interpreted the evidence for the archaeopyle type of this genus as inconclusive, based largely on interpretations by Lentini & Williams (1976, p. 157). Helens' (1983) contention that Craspedodinium is possibly related to Ascodinium Cookson & Eisenack 1960 and Ovoidinium Davey 1970 emend. Duxbury 1983 was based on the possibility of Craspedodinium having a combination apical-anterior intercalary archaeopyle.

Craspedodinium swanense sp. nov. (Figs 1A-L, 2A-H)

Previous Australian usage
Craspedodinium swanense – Helby.

Description. A species of Craspedodinium, ovoidal in outline and dorsosventrally flattened. A low, wide, solid apical protuberance or boss is developed on the endophragm and the peripharm mirrors the outline of this feature. Circumcavate or bicavate in cyst organisation. The endophragm is relatively thick (1-2µm) and smooth, scabrate, rugulate and/or micoreticulate; generally not folded. Peripharm thin (<0.5µm), diaphanous, smooth and may be folded. These low, distally smooth periphergal folds may partially reflect a gonyaulacalean paratabulation, especially around the paracingulum and the hypocyst. Epicyst and hypocyst normally subequal in length; the hypocyst, however, may be slightly longer. Accessory archaeopyle sutures may be developed.

Dimensions. The specimens of Craspedodinium swanense studied are from sidewall core samples in Buang-1 well at 3504.00m and 3505.20m and Jabiru-8A well at 1842.50m. The dimensions of material from both wells are given here separately, to effect comparisons. Note that secondary dorsosventral flattening may have distorted some of the specimens. In particular, some specimens are anomalously wide due to severe compression.

Measurements of specimens from 3504.00m and 3505.20m in Buang-1 well (µm; n=27); Min. (Mean) Max.

Length of pericyst incl. operculum: 85 (99) 110
Length of pericyst excl. operculum: 80 (105) 123
Length of endocyst incl. operculum: 80 (93) 100
Length of endocyst excl. operculum: 70 (95) 112
Width of pericyst at paracingulum: 81 (99) 118
Width of endocyst at paracingulum: 79 (96) 111

Maximum width of pericoel: 3 (6) 10
Width of operculum in dorsosventral view: 35 (46) 57
Depth of operculum in dorsosventral view: 47 (55) 61

Height of apical protuberance: 3 (4.5) 5
Width of apical protuberance: 7 (10) 11

Note that only 4 entire cysts were measured, out of an assemblage of 27 specimens. This disparity has given rise to the apparently anomalous average and maximum lengths of the pericyst and endocyst.

Measurements of specimens from 1842.50m in Jabiru-8A well (µm; n=24); Min. (Mean) Max.

Length of pericyst incl. operculum: 77 (92) 100
Length of pericyst excl. operculum: 67 (84) 100
Length of endocyst incl. operculum: 76 (90) 98
Length of endocyst excl. operculum: 58 (77) 89
Width of pericyst at paracingulum: 75 (93) 111
Width of endocyst at paracingulum: 70 (88) 105

Maximum width of pericoel: 2 (5) 12
Width of operculum, dorsosventral view: 37 (47) 56
Depth of operculum, dorsosventral view: 53 (58) 67
Height of apical protuberance: 3 (4) 5
Width of apical protuberance: 5 (8) 12

Note that only 5 entire cysts were measured, out of an assemblage of 24 specimens. This disparity has given rise to the apparently anomalous average and maximum lengths of the pericyst and endocyst in both the entire cyst and the lothocyst.

It is clear from the above data that the Buang-1 well material is consistently slightly larger than the specimens from Jabiru-8A well.

Comments. Specimens of Craspedodinium swanense may be elongate or wider than long (Fig.
Fig. 1. *Craspedodontium swanense* sp. nov. From sidewall cores in Buang-1 well at 3505.20m (Figs 1J-K) and 3504.00m (Figs 1B, L) and Jabiru-8A well at 1842.50m (Figs 1A, C-I). All photomicrographs taken using plain transmitted light. Scale bar in Fig. 1L refers to all photomicrographs and is 25µm. Fig. 1L is the holotype; the remainder, paratypes. Note ovoidal outline, cavate cyst organisation, thick endophragm, thin, diaphanous periphragm and apical archaeopyle. A - CPC 35645, paratype; oblique ventral view, (continued opposite)
1). The pericoel is normally best developed at the antapex, where it can approach, but rarely exceed, 10μm. This cavity, where developed, is normally 1-2μm wide in the equatorial regions. However, the two cyst layers are frequently closely appressed in the mid lateral areas (Fig. 1). Occasionally, the periphragm may be missing, probably removed by mechanical damage. The outline of the operculum and the accessory archaechoynyte sutures indicates the presence of four apical and six precingular paraplates (Figs 1, 2). Furthermore, the low folds in the periphragm may partially indicate the paracingulum and, more rarely, a hypocrystal paratubulation of six postcingulars and a single antapical paraplate (Figs 2F-H). Folds indicating the precingular paraplates are relatively rare. This paratubulation is clearly gonyaulaclean, with a formula of 4, 6, Xc, 6, ?lp, 1, Xs. A similar paratubulation pattern is evident from the specimens of the genotype, Craspedodinium indistinctum (see Morgan, 1980, pl. 8, figs 3-6 and Riding & Helby, this volume, a). Accessory archaechoynyte sutures may form deep splits between the precingular paraplates of the endophragm (Fig. 1L). The robust endophragm exhibits significant variation in ornamentation. Material from the Buang-1 well is seorate to rugulate and furthermore the rugulate forms may also be irregularly microreticulate (Fig. 1J). By contrast, the endophragm in the specimens from the Jabiru-8A well is smooth (Figs 1A, C-I).

Fig. 3. *Cribroperidinium corrugatum* sp. nov. Specimens from conventional core in Alaria-1 well at 3315.95m (Figs 3B, D-I) and 3318.58m (Figs 3A, C, I). All photomicrographs taken using plain transmitted light. Scale bar in Fig. 3I refers to all photomicrographs and is 25μm. Fig. 3A is the holotype; the remainder, paratypes. Note large size, prominent apical horn, small antapical (1 mou) paraplate which imparts a (continued opposite)
Comparison. The genotype, *Craspedodinium indistinctum*, differs from *C. swanense* in lacking an apical boss/protuberance on the endocyst and having trabeculate endophragmal processes at the cyst periphery and the apical paraplate series (Morgan, 1980, pl. 8, figs 3-6; Riding & Helby, this volume, a). *Craspedodinium americanum* Habib 1970 is circular in outline, not paratabulate and much smaller than *C. swanense*. The Late Cretaceous species *Craspedodinium tauricum* Prössl 1990 is also significantly smaller than *C. swanense*. Furthermore, it has an apical constriction and a strongly reticulate periphragm (Prössl, 1990). In addition, the three other species of *Craspedodinium* lack apical protuberances formed by the endophragm.

*Cygnesia taliarniana* Riding & Helby (this volume) is consistently circumcavate and significantly smaller than *Craspedodinium swanense*. Furthermore, apart from the principal archaeopyle suture, *C. taliarniana* lacks any indication of paratabulation. *Craspedodinium* is similar to other cavate genera with apical archaeopyles such as *Leberidocysta* Stover & Evitt 1978. However, *Leberidocysta* has delicate periphragm which is extremely susceptible to mechanical damage (Cookson & Eisenack, 1962).

**Derivation of name**. From the *Dingodinium swanense* Zone, to which this species is confined.

**Holotype and type locality**. Figure 1L, CPC 35656, Buang-1 well, southwelling core at 3504.00m.

**Stratigraphical distribution**. *Craspedodinium swanense* is confined to the Kimmeridgian *Dingodinium swanense* Zone (fauna-ba1b) of the Timor Sea region (Foster, this volume; Helby & Partridge, in prep.).

**Cribroperidinium** Neale & Sarjeant 1962 emend. Helgesen 1984

**Type species**. *Cribroperidinium sepiimentum* Neale

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**Description**. A large species of *Cribroperidinium* with a prominent apical horn. The species is slightly dorsosventrally flattened and is elongate subquadangular in dorsosventral or lateral view. The subquadangular outline is due to the relatively small diameter of the antapical (1′′′) paraplate. The autophragm is thick (1.5-2.5μm), with a strong corrugate ornamentation. Parasutures, indicating a sexiform gyraulaeacean paratabulation pattern, are marked by slender, perforate crests of variable height (20-20μm), which may be reduced to aligned, distally trabeculate short processes and are highest at the hypocystal periphery and particularly at the antapex. The corrugate ornamentation is arranged as irregular ridges, which vary from 2 to 5μm in width. They are:

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**Cribroperidinium corrugatum** sp. nov. (Figs 3A-1, 4A-B)

**Previous Australian usage**

*Cribroperidinium* sp. (corrugate) – Helby.

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A - CPC 35663, holotype; dorsal view, high/medium focus. Note corrugate autophragm, typically cribrorperidinoid dorsal paratabulation pattern (Helgesen, 1984), high parasutural crests, precingular archaeopyle and prominent apical horn. Parasutural crests in apical region strongly suggests an A/B apical paraplate configuration of Helgesen (1984). B - CPC 35664, paratype; dorsal view, median focus. Note well preserved corrugate autophragm on hypocyst. C - CPC 35665, paratype; ventral view, median focus. Note poorly preserved corrugate autophragm on hypocyst. D - CPC 35666, paratype; oblique ventral view, median focus. Note well preserved corrugate autophragm and distinctly subquadangular dorsosentral outline. E, F - CPC 35667, paratype; ventral view, high and low focus respectively. Note extremely prominent apical horn and well expressed midventral paratabulation in Fig. 3E. G - CPC 35668, paratype; dorsal view, high focus. Large specimen, note corrugate autophragm. H - CPC 35669, paratype; oblique dorsal view, low focus. Slender; note high parasutural crests and large apical horn. I - CPC 35670, paratype; oblique right lateral view, median focus. Note trabeculate parasutural crests on hypocyst.
rounded and random in orientation and often coalesce freely. The anastomosing nature and the density of insertion of the ridges is extremely variable. Some are entirely random and in other specimens, a crude reticulation may be present. The paracingulum is indicated by relatively thick parasutural ridges and is relatively narrow for such a large cyst. Parasutule indicated by crests or ridges, not subdivided.

**Dimensions** (μm; n=32) inclusive of parasutural crests where appropriate: Min. (Mean) Max. Length of cyst incl. apical horn: 102 (130) 175 Length of epicyst incl. apical horn: 40 (63) 87 Length (height) of paracingulum: 4 (6) 9 Length of hypocyst: 44 (62) 85 Length of apical horn: 12 (23) 36 Equatorial width of cyst: 90 (102) 117 Height of parasutural crests: 2 (7) 20

The measured specimens are from cores in Alaria-1 well at 3319.95m, 3318.58m and 3315.95m and a sidewall core at 1842.50m in Jabiru-8A well.

**Comments.** This large and characteristic species is variable in size (see Dimensions, above) and outline (Fig. 3). It appears to lack intratabular growth ridges. *Cribroperidinium corrugatum* is distinguished by the distinctive corrugate ornamentation, as defined by Tappan & Loeflich (1971, p. 387). The thick autophagum is covered by rounded ridges, which are variable in width, density of insertion and the degree of coalescence within individual specimens and populations (Figs 3, 4). In some specimens, the corrugate ridges are best developed on the hypocyst (Fig. 3B). Where the ridges are inserted relatively sparsely, the cysts may appear to be somewhat degraded (Fig. 4B). The ridges are rarely discontinuous; this phenomenon may be due to preservational effects. Both the apical horn and the parasutural crests are variable in size and morphology (Fig. 3). They appear to be formed entirely of periphragm. Some parasutural crests are entire, however, most are reticulate with subcircular to ellipsoidal fenestrae, which vary from 2 to 5μm in diameter. The fenestrae may expand such that the crests become rows of trabeculate short spines (Figs 3C, 1).

**Comparison.** *Cribroperidinium corrugatum* is distinguished from the other species of this genus by the characteristic corrugate ornamentation. The majority of the species of *Cribroperidinium* have smooth, scabrate or microreticulate autophagums. *Cribroperidinium janinae* Gorka 1982 and *C. maderonense* (Cookson & Eisenack 1958) Davey 1969 have a granulate autophagum, but entirely lack any corrugate ornamentation.

This species appears to lack intratabular growth ridges, which are typical of most Cretaceous and Palaeogene *Cribroperidinium*. However this does not preclude assignment to *Cribroperidinium* (Helenes, 1984). The antapical paraplate ("1") is extremely small (Fig. 3). This genus typically comprises species with relatively large antapical paraplates (Helenes, 1984). Gonyaulacalean genera may exhibit such size variations at the antapex. *Cteniodinium* Deflandre 1939 emend. Benson 1985 normally has a relatively large 1" paraplate. The Mid Jurassic species *Cteniodinium combiati* Dupin 1968 is similar to *C. corrugatum* in that it has a small antapical paraplate (Riding et al., 1985, pl. 1).

**Derivation of name.** From the Latin *corrugatus* meaning ridged or wrinkled and referring to the characteristic corrugate ornament.

**Holotype and type locality.** Figure 3A, CPC 35663.

**Fig. 5.** Gonyaulacysta foenestrata sp. nov. Specimens from sidewall cores in Bungar-1 well at 3504.00m (Figs 5D-E, I) and 3505.20m (Fig 5G), Frigate-1 well at 1233.900m (Figs 5A-B) and Jabiru-8A well at 1842.50m (Fig. 5C), conventional core in Alaria-1 well at 3315.95m (Fig. 5H) and outcrop material from Misool, eastern Indonesia (Fig. 5F). All photomicrographs taken using plain transmitted light. Scale bar in Fig. 5I refers to all the photomicrographs and is 25μm. Figs 5D-I are composite photomicrographs. Fig. 5D is the holotype; the remainder, paratypes. Note elongate, cavelate nature, prominent apical horn, fenestrate parasutural crests with small fenestrae close to distal margin, clastum close to antapex and precingular archaeopylle. A - CPC 35673, paratype; ventral view, median focus. Note elongate, slender apical horn, clastrum and laterally fenestrate parasutural crests. B - CPC 35674, paratype; dorsal view, low focus. Note elongate apical horn and wide parasutural crests. C - CPC 35675 (see also Fig. 6A) paratype; dorsal view, median focus. Note relatively short apical horn, clastrum and fenestrate parasutural crests in lateral regions. D - CPC 35676, holotype; dorsal view. Note detached endoperculum, clastrum and fenestrate parasutural crests. E - CPC 35677 (see also Fig. 6B) paratype; dorsal view, high focus. Slender, elongate specimen, note precingular archaeopylle and ellipsoidal fenestrae on lateral parasutural crest. F - CPC 35678, paratype; ventral view, median low focus. Note relatively short apical horn. G - CPC 35679, paratype; dorsal view, high focus. Note long, sinuous apical horn, short apical protuberance on endoperculum and prominent clastrum. H - CPC 35680, paratype; dorsal view, high focus. Wide specimen. I - CPC 35681, paratype; ventral view. Slender, elongate specimen.
Fig. 6. Enlargements of parasutural crests of various forms of *Gonyaulacysta*. All photomicrographs taken using plain transmitted light. Scale bar in Fig. 6A refers to all photomicrographs and is 25μm. A - *Gonyaulacysta fenestrata* sp. nov. CPC 35675 (see also Fig. 5C); paratype; dorsal view, median focus. Note distinctly trabeculate nature of this parasutural crest. Fenestrae are enlarged and parasutural crest appears to be of short processes linked distally by trabeculae. B - *Gonyaulacysta fenestrata* sp. nov. CPC 35677 (see also Fig. 5E); paratype; dorsal view, high focus. Note ellipsoidal nature and irregular insertion of fenestrae on this lateral parasutural crest. C - *Gonyaulacysta* sp. cf. *G. fenestrata* sp. nov. CPC 35684 (see also Fig. 7E); ventral view, median focus. Note denticles surmounting this medial parasutural crest. D - *Gonyaulacysta duallys*. CPC 35682; ventral view, high focus. Note smooth to undulose distal margin of this lateral parasutural crest. E - *Gonyaulacysta* sp. *G. fenestrata* sp. nov. CPC 35684; subsp. *adecta* Sarjeant 1982. MPA 15-0461; dorsal view high focus. Note denticulate nature of this antapical parasutural crest. The specimen is from the Lower Callovian Brora Reef Bed of Brora, NE Scotland. This is the lowermost unit of the Brora Shale Member (Brora Argillaceous Formation) and belongs to the *Proplumulites koenigi* Ammonite Zone (Sykes, 1975).

Alaria-I well, conventional core sample at 3318.58m.

Stratigraphical distribution. *Cribrorhizodinium corrugatum* is confined to the Kimmeridgian middle to upper *Dinodinium swanseense* Zone (6a/6aii) in the Timor Sea region (Foster, this volume; Helby & Partidge, in prep.).


Type species. *Gonyaulacysta jurassica* (Deflandre 1939) Norris & Sarjeant 1965

Comments. The latest emendation of this important Jurassic genus by Helens & Lucas-Clark (1997) is accepted, together with the redefinitions of Stover & Evitt (1978), Sarjeant (1982) and Jan du Chene et al. (1986).

*Gonyaulacysta fenestrata* sp. nov. (Figs 5A-I, 6A-B)

1980 *Gonyaulacysta jurassica* (Deflandre 1939) Norris & Sarjeant 1965 *nec.* Wiseman, pl. 2, fig. 49 (no description).

1987 *Gonyaulacysta jurassica* (Deflandre 1939) Norris & Sarjeant 1965 *nec.* Stevens, fig. 5K (reworked into the Early Cretaceous).

Previous Australian usage *Gonyaulacysta oligodentata* (pars) – Helby.

Description. A large, elongate species of *Gonyaulacysta* with a long, distally-blunt, slender apical horn. The cyst is primarily dorsoventrally flattened. The pericyst, excluding the apical horn, is elongate subellipsoidal to subpolygonal and is antapically truncate. The endocyst is elongate ellipsoidal, normally with a prominent apical protuberance. Bicavit cyst organisation; the epicyst may be epicavate or cornucavate. Paratabulation partially indicated by parasutural crests which are generally smooth distally and fenestrate. The fenestrae are subcircular, ellipsoidal or rectangular; normally they are best developed in the midlateral and antapical areas and inserted close to the distal margin of the crest. Occasionally, the parasutural crests may be distally irregular or undulose. Parasutural features are generally entirely lacking, or profoundly reduced, midventrally in the parasutal area and the middorsal hypocrystal area. A prominent subcircular claustrum is present in the antapical parasutal paraplate. Periphragm is smooth to microscabrate and may be irregularly microreticulate. The endophragm is markedly thicker than the periphragm and smooth. The perioperculum is absent; the large endoperculum is frequently displaced and visible. Both the periarchaeopyle and the endoarchaeopyle is occasionally slightly enlarged posteriorly, at the 3/3c-4c paraplate boundary.

Dimensions (μm; n=35): Min. (Mean) Max.

Length of pericyst: 113 (135) 158

Length of apical horn: 14 (24) 31

Length of epipercyct (exc. paracingulum)*: 69 (82) 100

Length of hypopercyct (exc. paracingulum): 34 (45) 55

Length of endocyst: 71 (86) 103

Width of pericyct at paracingulum**: 55 (70) 86

Width of endocyst at paracingulum: 48 (62) 79

Height of parasutural crests***: 1 (3) 7

Diameter of fenestrae: 1 (1.5) 3
*. including the apical horn
** - includes the parastural crests at the paracingulum
*** - measured midlaterally, within the precingular paraplate series

The measured specimens are from sidewall core samples in Huang-1 well at 3504.00m and 3505.20m, Frigate-1 well at 1233.00m and Tenacious-1 well at 3002.00m and a ditch cuttings sample from Hadrian-1 well between 3285.00m and 3300.00m.

Comments. Gonvalocysta fenestrata is a unique species, being large and elongate with fenestrate parastural crests. The subcircular to ellipsoidal fenestrae on the parastural crests are diagnostic. These characteristic perforations exhibit some variability in their density of insertion (Fig. 5). In some specimens the fenestrae are rectangular, separated by distinct rods or short processes (Figs 5C, H, I). They are normally present in the midlateral and antapical areas of the cyst, closely adjacent to the distal margin of the crests. The antapical parastural crest appears to be susceptible to mechanical damage. This may affect the distal part of the parastural crest, giving rise to an irregularly denticulate margin due to 'bursting' of the fenestrae. Normally, the parastural crests are distally smooth, but in occasional specimens, they may be slightly undulose distally. The lateral parastural crests are the most prominent and consequently these may be the only crests to exhibit significant fenestrae. The pericyst is elongate subellipsoidal in outline with a truncated antapex and the parastural crests are interrupted at the paracingulum, thereby imparting a distinctive equatorial profile. The relatively thin apical horn is highly variable in length (see Dimensions above). It is blunt distally due to the presence of the first preapical paraplate (1pr/P of Helene & Lucas-Clark, 1997). A porchmon (Evitt, 1983) is present on the ventral side of the apical horn, at the 2pr/1'4r paraplate triple junction. The hyperpericoel is consistently prominent, with a relatively large cavity developed both antapically and laterally in the hypocyst. By contrast, the epipericoel is generally smaller and more variable, with occasional forms having small pericoels and being merely connatahate (Fig. 5F). The endocoel is ellipsoidal and normally has an apical protuberance which may closely approach the apical horn in the pericyst. Occasionally, a slight antapical protuberance is present in the endocoel.

The paratabulation of the species appears to be precisely that determined for G. dualis (Brideaux & Fisher 1976) Stover & Evitt 1978 by Helene & Lucas-Clark (1997). However, the midventral paratabulation is not known in detail due to the significant suppression of parasutures around the parasulus. This phenomenon was also noted in Gonvalocysta jurassica by Stover & Evitt (1978, p. 277). The material studied is strongly dorsoventrally flattened and the orientation, dorsal or ventral, may appear difficult to determine. This scenario is exacerbated by the suppression of the midventral parastural crests. However, using the ventral claustrum in the antapical parasural paraplate and the dorsal archaeopyle, the orientation can be readily determined. This is a gonvalocalcan species where the absence of the periopeculum is clearly demonstrable (Eaton, 1984). However, the large endoperculum is frequently displaced and retained within the cyst (Figs 5D, F-I). The two archaeopyle may be slightly enlarged along the paracingulum.

Gonvalocysta fenestrata is similar in overall morphology to G. jurassica (see Comparison below), differing only in size and the presence of fenestrate, largely smooth parastural crests. Therefore, given that G. jurassica is currently separated into 3 subspecies (Williams et al., 1998, p. 251, 252), the possibility of giving fenestrata subspecific status within G. jurassica was considered. However, G. fenestrata is arguably more similar to G. dualis, and this is maintained as a separate species. We consider G. jurassica has far too many subspecific and varietal subdivisions and the most important stratigraphical morphotypes should be elevated to specific status.

Comparison. Gonvalocysta fenestrata is similar in morphology, and identical in paratabulation, to G. dentata (Raynaud 1978) Lentin & Vozhenentikova 1990, G. dualis, G. eisenae (Deflandre 1939) Dodekova 1967 and G. jurassica subsp. jurassica. It may have an enlarged archaeopyle at the paracingulum like G. jurassica (see Williams et al., 1978, fig. 33). The unusually long epicyst (with respect to the hypocyst) in G. fenestrata, G. dualis and G. jurassica is especially striking. However, the criterion distinguishing this species from all other species in this important genus are the characteristic fenestrate parastural crests. Gonvalocysta fenestrata is most similar in size to G. dentata and G. dualis, and furthermore the parastural crests in the latter species are typically smooth (Fig. 6D). However the crests in G. dualis are not fenestrate and may also be relatively sparsely denticulate or spinose (Brideaux & Fisher, 1976). Gonvalocysta dentata (Raynaud
1978) Lentin & Vozzhennikova 1990 and *G. eisenackii* (Deflandre 1939) Górka 1965 have epicysts and hypocysts of approximately equal length and denticulate parasutural crests. For the same reasons, *G. fenestrata* differs from *G. jurassica* subsp. *jurassica* which also lacks fenestrate parasutural crests. The latter Late Jurassic subspecies, with densely denticulate parasutural crests, has smaller epipericoels and hypopericoels and is significantly smaller in overall size than *G. fenestrata* (see Deflandre, 1939). In terms of overall size and epicystal morphology, the variety of *G. jurassica* which is closest to *G. fenestrata* is *G. jurassica* subsp. *adepta* Sarjeant 1982 var. *longicornis* (Deflandre 1938) Downie & Sarjeant 1965. This large, elongate morphotype is characteristic of the mid Oxfordian in Europe (Riding & Thomas, 1997, figs 3, 5h, 5k), but is epicavate and has strongly denticulate parasutural crests. An example of a denticulate parasutural
crest of *G. jurassica* subsp. *adepta* is figured as Fig. 6E.

*Gonyaulacysta fenestra* differs from *G. sp. cf. fenestra* (see below) in having smooth distal margins to the parasutural crests. Figure 6 illustrates the differences in the parasutural crest morphology of *G. fenestra*, *G. sp. cf. G. fenestra*, *G. dialis* and *G. jurassica* subsp. *adepta*.

**Derivation of name.** From the Latin *fenestra*, meaning window, and referring to the window-like holes or perforations in the distal parts of the parasutural crests in this species.

**Holotype and type locality.** Figure 5D, CPC 35676, Buang-1 well, sidewall core sample at 3504.00m.

**Stratigraphical distribution.** *Gonyaulacysta fenestra* ranges from the Kimmeridgian mid *Dingodinium swanense* Zone (6a1a) to the Tithonian *Cribroperidinium perforans* Zone (5d) in the Timor Sea region (Foster, this volume; Helby & Partridge, in prep.). Identical forms were illustrated as *G. dialis* from the Chichili and Sembar formations of Pakistan (Beju, 1979, pl. 1, figs 6, 7; 1980).

*Gonyaulacysta sp. cf. G. fenestra* Riding & Helby (Figs 6C, 7A-F)

1978 *Gonyaulacysta jurassica* (Deflandre 1939)
Norris & Sarjeant 1965; Chen, fig. 16-1-7.
1987 *Gonyaulacysta jurassica* (Deflandre 1939)
Norris & Sarjeant 1965; Davey, pl. 4, figs 14, 15.

**Previous Australian usage**

*Gonyaulacysta oligodenata* (pars) – Helby.

**Description.** This morphotype has the same morphology as *Gonyaulacysta fenestra*, except that the distal parts of the parasutural crests are wholly or partially ornamented by short (1μm), solid denticles:

**Dimensions (μm; n=2);**
Length of pericyst: 135, 136
Length of apical horn: 11, 20
Length of epipericyst (excl. paracingulum): 78, 85
Length (height) of paracingulum: 5, 5
Length of hypopericyst (excl. paracingulum): 52, 46
Length of endocyst: 80, 93
Width of pericyst at paracingulum: 80, 81

Width of endocyst at paracingulum: 70, 70
Height of parasutural crests**: 2, 3, 4, 5
Diameter of fenestrae: 0.5-2.0
Length of distal denticles: 1
**- including the apical horn
**- includes the parasutural crests at the paracingulum
**- measured midlaterally, within the precingular paraplate series

The measured specimens are from a ditch cuttings sample from Peak-1 well between 4800.00m and 4810.00m.

**Comments.** *Gonyaulacysta sp. cf. G. fenestra* can be misidentified as *G. fenestra* because the denticles surmounting the parasutural crests are small and they may be developed only on parts of some of the crests. Figures 6C and 7 illustrate the differences in the crest morphology of this morphotype. Insufficient material exists to erect this form as a species, subspecies or variety. This morphotype is similar in all dimensions to *Gonyaulacysta fenestra* (see above).

**Stratigraphical distribution.** *Gonyaulacysta sp. cf. G. fenestra* is known from the Kimmeridgian, mid *Dingodinium swanense* Zone (6a1a) to the Tithonian, *Cribroperidinium perforans* Zone (5d) in the Timor Sea region (Foster, this volume; Helby & Partridge, in prep.). It was recorded by Davey (1987) as *Gonyaulacysta jurassica* from the Imbaru Mudstone of Papua New Guinea (late Oxfordian to early Kimmeridgian *Cribroperidinium perforans* Zone to *Omatia montgomeryi* Zone). Identical forms were recorded as *G. jurassica* (Fig. 16, 1-7) from Late Jurassic ditch cuttings in the Ankamotra-1 well in western Madagascar (Chen, 1978).

**Hadriana gen. nov.**

**Type species.** *Hadriana cineta* sp. nov.

**Diagnosis.** Large dinoflagellate cysts which comprise a subspherical to ellipsoidal cyst body. A prominent ectophragm, which is perforate to trabeculate and is open antapically, emerges in the lower part of the precingular paraplate series and extends below the cyst body. The ectophragm may be connected to the cyst body by paracingular (?) and postcingular processes. The ectophragm and autophragm are closely appressed in the apical paraplate series. The paratabulation is gonyaulaclean, indicated by the intratabular processes, where developed, and the
Fig. 8. *Hadriana cineta* sp. nov. All from ditch cuttings in Hadrian-1 well at 3285.00m-3300.00m. All photomicrographs taken using plain transmitted light. Scale bar in Fig. 8l refers to all photomicrographs and represents 25µm. Figs 8G-I are the holotype; the remainder (Figs 8A-F), paratypes. All in doroventral view. Note wide, ellipsoidal cyst body, prominent broad, variably perforate, trabeculate ectophragmal girdle which emerges from equatorial part of cyst body, and intratubular paracingular and postcingular processes. A-C - CPC 35685; ventral view, high to low focus sequence. Note characteristically undulating antapical margin of ectophragmal girdle, due to five polygonal areas of ectophragm relatively free of perforations reflecting postcingular paraplates. D-F - CPC 35686; dorsal view, high to low focus sequence. Note apical archaeopyle and variably perforate ectophragmal girdle. G-I - CPC 35687; ventral view, high to low focus sequence. Note trabeculate, rather than perforate, ectophragm. Note how ectophragmal girdle emerges equatorially on cyst body and prominent polygonal areas of ectophragm reflecting postcingular paraplates. Principal archaeopyle suture. Apical archaeopyle; operculum free. The parasulcus is flat to slightly indented.

**Comments.** *Hadriana* is a large, morphologically complicated, variable and extremely distinctive genus. It is similar in many respects to *Belovia* Riding & Helby (this volume) and it seems likely that the Tithonian *Belovia* may have evolved from *Hadriana* (Riding & Helby, this volume, b). Both *Belovia* and *Hadriana* are thought to be related to *Rigaudella* below 1982 (see Comparison of *Hadriana cineta*, below). The ectophragm is highly variable, from perforate to trabeculate and it may be connected to the autophragm of the cyst body by intratubular processes in the paracingular (?) and postcingular paraplate series. A large, subcircular to ellipsoidal, antapical hole is generally present in the ectophragm, which separates from the autophragm close to the base of the precingular paraplate series. Therefore, the ectophragm forms an extensive belt or girdle, surrounding all of the hypocystal autophragm.

**Comparison.** The Tithonian *Belovia* Riding & Helby (this volume) is closely related to *Hadriana*. They share a small, essentially smooth epicyst, devoid of processes and the fact that wall separation occurs close to the base of the precingular paraplates. Although there are marked hypocystal differences, these genera both display major ectophragmal development at and below
the paracingulum. However, *Hadriona* lacks the paracingular tunnel, which characterises all morphotypes of *Belonia*; it does not display large processes and the ectophragm is widely open antapically (around twice diameter of autocyct). *Leutonicyca* Stover & Evitt 1978 emend. Stover & Williams 1995 is reminiscent of *Hadriona* in having an apical archaeoepyle and a large ectophragmal covering supported by intratabular processes in all the major paraplate series. However, *Hadriona* is larger, oblate and lacks epicyctal processes and reduced hypocystal processes. The ectophragm in *Hadriona* is generally open antapically. *Reticulatosphaera* Matsuoka 1983 is also similar in morphology to *Hadriona*, however the former is smaller, has a precingular archaeoepyle and has about 26, apparently intratable processes. The periphery of *Disphaeria* Cookson & Eisenack 1960 emend. Norvicl 1973 has a large dorsal opening, and this genus has a precingular archaeoepyle. *Hadriona* differs from trabeculate complex chorate dinoflagellate cyst genera such as *Adnatosphaeridium* Williams & Downie 1966, *Hopsidolax* Sarjeant 1975, *Hystrichosphaerina* Alberti 1961, *Polystephanophora* Sarjeant 1961 and *Rigaudella* Deflandre emend. Below 1982, in lacking large intratable processes or process complexes representing the major epicyctal paraplate series and in having a dense equatorial trabeculum. In *Hadriona*, the paracingular and postcingular processes are largely subsumed into the ectophragm. The Palaeogene genus *Riculocysta* Stover 1977, like *Hadriona*, has a trabeculate ectophragm especially well developed on the hypocyst and an apical archaeoepyle (Stover, 1977). *Riculocysta*, however, is a distinctly chorate form, which bears solid processes on the ventrolateral and lateral surfaces.

**Derivation of name.** After Hadrian-1 well, where the type material was recovered.

*Hadriona cincta* sp. nov. (Figs 8A-1, 9A-L)

1978 *Adnatosphaeridium* sp.; Chen, p. 78, figs 55-431.

**Previous Australian usage**

MP 528 - Helby.

?*Rigaudella* sp. A - Parker (1986, pl. 22, figs 1, 2).

**Description.** A species of *Hadriona* which is slightly dorsoventrally flattened and flat to slightly indented at the parasculus. It has an ellipsoidal cyst body, which is consistently wider than long. The autocyct is smooth to microscabrate and 1-1.5μm thick. The prominent perforate to trabeculate ectophragm is also significantly wider than long, imparting a squat shape to many specimens; it is smooth and 0.5-1μm thick. For the most part the epicystal wall is generally not obviously layered. However, an ectocoele opens near the base of the precingular paraplate series and spreads, girdle-like, posteriorly from the paracingular region and generally leaving a wide polar opening. The ectophragm is connected to the cyst body by short postcingular and paracingular processes which may be intratable in location. The processes are solid and expand proximally. They also expand distally where they are subsumed into the ectophragm. There is a characteristic gap, which is widest in the interprocess areas, between the top of the ectophragm and the cyst body in polar view. The trabecular girdle is widest close to the base of the autocyct, narrowing marginally antapically. The antapical hole in the ectophragm is large and ellipsoidal in shape; it is located well below the antapex of the autocyct. The margin is interrupted by five distinctive polygonal areas of ectophragm which are relatively free of perforations, or have small (<1μm in diameter) lacunae. These reflect the postcingular paraplates. The ectophragm is highly variable in morphology. It may be perforate with subcircular/ellipsoidal lacunae from 1 to 8μm in diameter. Alternatively, many specimens are largely trabeculate with a network of anastomosing solid, slender, ribbon-like elements. These elements are normally between 1.5 and 4μm, but occasionally may attain 10μm in width. Rarely, individuals are partially perforate and partially trabeculate.

**Dimensions (μm; n=40):** Min. (Mean) Max.

Length of ectocoele (excl. operculum): 84 (106) 140
Length of autocyct (excl. operculum): 46 (61) 79
Dorsoventral width of ectocoele: 114 (141) 181
Dorsoventral width of autocyct: 57 (72) 93
Lateral width of ectocoele: 101 (112) 145
Lateral width of autocyct: 58 (65) 75
Width of ectocoele at antapex: 12 (36) 76
Width of ectocoele in the postcingular series: 30 (45) 73

Height of postcingular processes: 7 (14) 22

The measured specimens are from a ditch cuttings sample in Hadrian-1 well between 3285.00m and 3300.00m and a sidewall core sample at 3087.00m from Cockell-1 well.
Fig. 9. *Hadriana cincta* sp. nov. All paratypes from ditch cuttings in Hadrian-1 well at 3285.00m-3300.00m. All photomicrographs taken using plain transmitted light. Scale bar in Fig. 9L refers to all photomicrographs and is 25μm. Note subcircular outline of cyst body, prominent broad, ellipsoidal to polygonal, perforate/trabeculate ectophragmal girdle, large antapical hole in ectophragm and intratabular paraeingular and preeingular processes. All in polar view. Figs 9A-I appear to have a preeingular, type 3P, endoarchaeopyle due to folding of principal endoarchaeopyle suture so it appears subquadangular. This is a preservational artefact; this genus has an apical archaeopyle. A-C - CPC 35688; apical view, high to low focus sequence. Note apical archaeopyle, slightly, indented ventral (parasulcal) area and solid intratabular processes which connect autophragm to ectophragm. D-F - CPC 35689; antapical view, low to high focus sequence. Note antapical hole in ectophragm, variably perforate ectophragm and polygonal areas of ectophragm reflecting postcingular paraplates located on antapical margin of ectophragm. G-I - CPC 35690; apical view, high to low focus sequence. Note distinctly perforate, rather than trabeulate, ectophragm, prominently indented parasulcus and solid intratabular processes emerging from cyst body. J-L - CPC 35691; apical view, high to low focus sequence. Note good intratabular process development and large antapical hole in ectophragm.
Comments. Most of the material studied are loistocysts (Figs 8, 9). The longitudinal flattening of the cyst body is consistent and is a good recognitional criterion in poorly preserved material. The most characteristic feature of this species is the prominent and variable girdle-like ectophragm, which emerges close to the base of the precingular paralplate series. This ectophragm overlies the hypocystal autophragm and is open antapically. The antapical margin of the ectophragm in dorsoventral view is characteristically interrupted due to the occurrence of the postcingular ‘nodes’ (Fig. 8). The paracingular and postcingular processes are variable. The majority are solid; but a few appear to be funnel-like. There is a tendency for the solid processes to break. The processes are best observed in polar view (Fig. 9).

Comparison. Hadriana cincta is broadly similar to Belovia boltea Riding & Helby (this volume) in size and overall morphology. However, B. boltea is generally compressed in polar view, has a paracingular protuberance and commonly, a solid antapical girdle. It is distinguished from large chorate cysts with apical archaeopyle in lacking large intratabular processes and process complexes. Because of the general morphological similarities in Belovia, Hadriana and Rigaudella, it is suggested that they are closely related and probably form part of a phylogenetic lineage. The rootstock is envisioned to be Rigaudella, which then evolved into the Kimmeridgian genus Hadriana, which gave rise to Belovia in the Tithonian (Riding & Helby, this volume, b).

Derivation of name. From the Latin cinctum meaning girdle, or zone, and referring to the characteristic, extensive, skirt-like development of ectophragm which emerges on the epicyst and extends beyond the antapex of the cyst body.

Holotype and type locality. Figs 8G, I, CPC 35687, Hadrian–1 well, ditch cuttings between 3285.00m and 3300.00m.

Stratigraphical distribution. Hadriana cincta has been recorded from the Kimmeridgian Dingodinium swanense Zone (6a)a) to the Tithonian Cibroperidinium perforans Zone (5d) in Australia and Papua New Guinea (Foster, this volume; Helby & Partridge, in prep.). It is recorded as Adnaxloopsphaeridium sp. from Late Jurassic ditch cuttings in the Ankafotra-1 well in western Madagascar (Chen, 1978). It is also recorded as Thalassiphora sp. from the Sembar Formation of Pakistan (Beju, 1979, pl. 32, figs 4-6; 1980).

Indodinium Kumar 1986

Type species. Indodinium kharianse Kumar 1986

Indodinium kharianse Kumar 1986 emend. (Figs. 10A-P)

1978 Hexagonifera sp. 3; Chen, p. 57, fig. 43-287-293.
1986 Indodinium kharianse; Kumar, p. 389-391, figs 5A-B, pl. 4, figs 2, 3.
1987 Indodinium kharensis Kumar; Garg et al., p. 256.
1988 Indodinium sp. A; Helby et al., figs 6B, 15U, 15V, 18F.
1992 ?Indodinium kharianse Kumar; Jiang et al., p. 83, 84, pl. 2, figs 7, 9, 13.

Previous Australian usage
Diplotaesta nodosus – Ott (1970, pl. 17, fig. 40).
MP 727 – Helby.
Indodinium sp. 727 – Helby.

Emended description. A species of Indodinium, intermediate in size, which is dorsoventrally flattened. It has a thin (<0.5μm), smooth to microscabrate periphragm, which may exhibit a partial gonyaulacalaean paratabulation pattern by discontinuous low, smooth ridges or folds. The paracingulum is frequently indicated by ridges or folds and is positioned close to the centre of the cyst. The parasilis, precingular and postcingular paralplates may also be partially indicated. An apical horn is present. The endophragmal horn usually comprises a low pyramidal apical series, which passes into a solid, slender apical extension. The periphragmal horn is considerably larger, does not mirror the shape of the endophragmal horn and the pericoel is particularly wide in this region. The pericoel is narrowest at the antapex or the two cyst wall layers may be closely appressed in this region. Endophragm relatively thick (1.5μm), smooth, scabrate granulate, verrucate or bacular. It may also be partially echinate with short (2-3μm), solid, distally pointed spinules occasionally developed at the antapex, the apex and the principal endoarchaeopyle suture. These spinules may be aligned along parasutures on the endophragm. The antapical portion of the endophragm is rarely bacular or may have densely inserted ornamentation which forms a corona. Prominent accessory archaeopyle sutures
Fig. 10. *Indodinium khuriense* Kumar 1986 emend. From conventional core in Alaria-1 well at 3315.95m (Figs 10B-D, G-H, P), 3317.26m (Figs 10F, K-L) and 3318.58m (Figs 10E, N-O), sidewall core in Buang-1 well at 3504.00m and outcrop material from Misool, eastern Indonesia (Figs 10A, I-J). All photomicrographs taken using plain transmitted light. Fig. 10P is a composite photomicrograph. The scale bar in Fig. 10P refers to all photomicrographs and is 25μm. Note elongate nature, apical archaeopyle, partially (continued opposite)
may be developed in the endophagm. The principal periarchaeopyle suture is consistently higher than the principal endoarchaeopyle suture, typically by approximately 5 μm.

**Dimensions (μm; n=25):**
- Min. (Mean) Max.
  - Length of pericyst excl. operculum: 40 (55) 65
  - Length of endocyst excl. operculum: 34 (45) 56
  - Width of pericyst at paracingulum: 30 (36) 44
  - Width of endocyst at paracingulum: 22 (28) 38
  - Maximum width of lateral pericel: 3 (5) 10

A single specimen with an attached operculum was encountered (Figs 10K-L). The entire pericyst of this specimen from conventional core in Alaria-1 well at 3317.26m is 72 μm long and the full endocyst 65 μm in length.

The measured specimens are from conventional core samples from Alaria-1 well at 3318.58m, 3317.26m and 3315.95m, sidewall core samples from Buang-1 and Tenacious-1 wells at 3504.00m and 3002.00m respectively and outcrop material from the lower part of the Lelfinta Formation of Misool, eastern Indonesia.

**Comments.**

The specific description of *Indodinium khariense* is emended here in order to note several features. These are the apical horn, the prominent accessory endoarchaeopyle sutures, the characteristic substantial displacement of the two archaeopyle sutures and the presence and variability of the endophagmal ornamentation. The antapical displacement of the endocyst (Fig. 10) suggests that there is no ventral contact between the two wall layers. Kumar (1986) did not mention these features in the type material from the Jhuran Formation (Lower Kimmendgian-Tithonian) of Kachchh, western India. The apical horn formed by the endophagm may be up to 15 μm long and was also illustrated by Jiang et al. (1992, pl. 2, fig. 13). Commonly, the endophagm is sparsely granulate; however, the ornamentation is variable in both morphology and density of insertion (Fig. 10). Strongly granulate or verrucose forms tend not to be echinate. The antapical portion of the endophagm is frequently strongly ornamented. It may be bacute (Figs 10B, N-O), or may have dense ornamentation, forming a corona (Figs 10G-H). The marked separation of the two principal archaeopyle sutures in this form is a valuable diagnostic criterion and the profound dorsoventral flattening of this species often makes orientation difficult.

**Comparison.**

*Indodinium khariense* differs from *Mombasadinium parvelatum* (Jiang in Jiang et al. 1992) comb. nov., emend. (see below) in having a prominent apical horn. The latter is also slightly wider than *I. khariense*. Jiang (in Jiang et al. 1992, p. 85) stated that *P. parvelatum* may exhibit solid processes, which may be parasutural, surmounting the endophagm, commonly at the antapex. Such processes may be present in *I. khariense*, but Jiang (in Jiang et al. 1992, pl. 2, fig. 10) did not convincingly illustrate this feature.

**Stratigraphical distribution.** *Indodinium khariense* has been recorded from the Oxfordian Wauca clathrata Zone (6b) to the Tithonian Cribroripinum perforans Zone (5d) in the Timor Sea region and Misool, eastern Indonesia (Foster, this volume; Helby & Partridge, in prep.). Chen (1978, figs 43, 287-293) illustrated identical forms as *Hexagonifera* sp. 3, from Late Jurassic ditch cuttings in the Ankama-1 well in western Madagascar. Kumar (1986) reported the species from the Middle Member of the Jhuran Formation of western India and it has been recorded from the Oxfordian to Tithonian Ohinureru Siltstone, Kinohaku Siltstone and Puri Siltstone of New Zealand (Helby et al., 1988).

**Mombasadinium** gen. nov.

**Type species.** *Mombasadinium parvelatum* (Jiang
in Jiang et al. 1992) comb. nov., emend.

**Diagnosis.** Proximate, circumcavate dinoflagellate cysts, elongate ellipsoidal in outline, lacking polar horns and being intermediate in size. Peripharam smooth, endophragm smooth or bearing low relief ornamentation. Standard gonyaulacalean paratabulation partially to fully indicated by periphragmal folds. Paracingulum and parasulcus may be indicated by folds in the peripharam. Archaeopyle apical; operculum simple, free.

**Comments.** The genotype was originally described as *Indodinium parvulum* Jiang (in Jiang et al. 1992). A re-examination of the type material and the study of new material from offshore northwestern Australia and Misool, eastern Indonesia has indicated that this species does not belong to *Indodinium* (see below).

**Comparison.** *Mombasadinium* closely resembles *Indodinium* in shape and size, but the latter has an apical horn and an endophragm which is typically ornamented and may be echinate, having parasutural spines. Additionally, in loiothecysts of *Indodinium kharienes*, the endocyst is significantly shorter than the pericyst due to the principal periaulacopyle suture being consistently significantly higher than the principal endoaulacopyle suture (see above, Fig. 10 and Jiang et al. 1992, pl. 2, fig. 7). Additionally, this new genus is similar to *Craspedodinium* in morphology. However, *Craspedodinium* is not elongate and may be large in size. This new genus is broadly similar to *Belodinium* Cookson & Eisenack 1960 emend. Stover & Helby 1987, but *Mombasadinium* lacks the prominent endophragmal processes, the prominent apical horn and the diagnostic claustrum representing the antapical paraplate, which characterise the former. *Boreocysta* Stover & Evitt 1978 emend. Arhus 1992 is superficially similar, but is holocavate, has no paratabulation apart from the principal archaeopyle suture and exhibits a prominent apical horn. The holocavate genus *Gardodoinium* Alberti 1961 emend. Harding 1996 resembles *Mombasadinium*, but has an apical horn. *Wallodinium* Loeflich & Loeblich 1968 emend. Riding 1994 is elongate, lacks polar horns, has an apical archaeopyle and may be circumcavate. However, unlike *Mombasadinium*, most species of *Wallodinium* are bicavate and have no parasutural features other than relating to the archaeopyle. *Lagenadinium* Piel 1985 is a Jurassic genus which is slightly elongate and has an apical archaeopyle. It differs from *Mombasadinium* by being holocavate, lacking parasutural features and having hypoyst rurous coronas. The Cretaceous *Carpodinium* Cookson & Eisenack 1962 emend. Leifingsw & Morgan 1977 is, like *Mombasadinium*, elongate with prominent peripharamal folds, but has a precingular archaeopyle and may be suturecavate.

Fig. 11. *Mombasadinium parvulum* (Jiang in Jiang et al. 1992) comb. nov. From conventional core in Peak-1 well at 4302.00m (Figs 11A-B, H, K-N, S, W-Y) and sidewall cores in Macedon-5 well at 1350.00m (Fig. 11O) and Seafall-I well at 1365.00m (Fig. 11F). Figs 11G, I, T-V are from outcrop sample 81F666, Misool, eastern Indonesia (Hasibuan, 1990). Figs 11P-Q (the holotype) and Figs 11C-F, R (topotypes) are from Mt Panga Quarry, Kenya. All photomicrographs taken using plain transmitted light. Scale bar in Fig. 11Y refers to all photomicrographs and is 25µm. Note thick endophragm, thin, diaphanous, folded peripharam, narrow pericoel, occasional parasutural peripharamal folds and apical archaeopyle. A, B - CPC 35703; dorsal view, high and low focus respectively. Note angular principal archaeopyle suture. Clearly indicating a gonyaulacalean paratabulation pattern. C - University of Sheffield ML 2155-J21/1, topotype; dorsal view, high focus. Note narrow pericoel and sparse antapical processes or thickenings within peripharamal folds. D - University of Sheffield ML 2155-J23, totopute; ventral view, median focus. Note longitudinonal peripharamal folds. E - University of Sheffield ML 2155-J37, topotype; oblique ventral view, median focus. Note parasutural folds in peripharam. F - University of Sheffield ML 2155-J39, totopype; ventral view, high/median focus. Note parasutural patch. G - CPC 35704; dorsal view, median focus. Note lack of peripharam, possibly due to chemico-mechanical damage. H - CPC 35705; ventral view, low focus. Note processes or thickenings within peripharamal folds on hypoyst. I - CPC 35706; ventral view, median focus. Note narrow pericoel. J - CPC 35707; dorsal view, median focus. Note smooth endophragm. K - CPC 35708; ventral view, high focus. Note apparently paracingular folds on peripharam. L, M - CPC 35709; slightly oblique dorsal view, high and median focus respectively. Note short, dark processes or thickenings within peripharamal folds on hypoyst. N - CPC 35710; dorsal view, median focus. Note relatively wide pericoel on right hand side. O - CPC 35711; dorsal view, median focus. Short; note parasutural folds. P, Q - University of Sheffield ML 2155-V60/1, holotype; dorsal view, high and median focus respectively. Note adherent operculum and wide pericoel. R - University of Sheffield ML 2155-D35, totopype; ventral view, median focus. Note dark nature and apparent lack of peripharam in midlateral areas. S - CPC 35712; ventral view, high focus. Note prominent, long peripharamal fold which appears not to be parasutural. T - CPC 35713; ventral view, median focus. Note discontinuous peripharamal folds. U - CPC 35714; dorsal view, (continued opposite)
high focus. Large specimen. V - CPC 35715; ventral view, high focus. Note well preserved, adherent operculum. W - CPC 35716; ventral view, median focus. Unusually elongate. X, Y - CPC 35717; dorsal view, high and median focus respectively. Note short processes or thickenings within periphral folds on hypocyst.
Derivation of name. From Mombasa, Kenya, from where the holotype of this species was collected.

*Mombasadinium parvelatum* (Jiang in Jiang et al. 1992) comb. nov., emend. (Figs 11A-Y)

1978 *Belodinium* sp. 3; Chen, p. 31, figs. 27–98-100.
1992 *Indodinium parvelatum*; Jiang in Jiang et al., p. 85, 87, pl. 2, fig. 10.

Previous Australian usage
*Omitzia jurabiuna* – Helby.

Description. A species of *Mombasadinium* with a relatively thin pericoel developed in the lateral and polar areas. The pericoel is highest antapically and midlaterally. Middorsally and midventrally, the endophragm and periphragm are closely appressed. The endophragm is approximately 1μm thick, smooth to scabrate, rarely microgranululate; it is occasionally irregularly microreticulate. The periphragm is smooth and much thinner (<0.5μm) and also occasionally is irregularly microreticulate. A partial standard (presumed saxiform) gonyaulaccean parasutural pattern is marked by low (1-2.5μm), distally smooth, periphragmal folds. The folds are frequently low or absent equatorially so the paracingulum is not normally indicated. The parasutural, however, is frequently marked by these low folds in the periphragm. The parasuturation is best developed in the region around the antapex. In some specimens, dark, slender, parasutural processes or thickenings are present within the periphragmal folds; these are normally c.1μm wide, but may attain c.2μm. These ‘rod-like’ features, which may be distally expanded, are particularly common in the hypocystal folds, but have occasionally been observed on the epicyst. The species is strongly dorsoventrally compressed. A prominent parasutural tongue on isolated opercula and a corresponding parasutural notch on the leiothecost are present.

Dimensions (μm; n=80): Min. (Mean) Max.
Length of entire pericoel: 60 (77) 90
Length of leiothecost (incl. periphragm): 53 (70) 90
Length of operculum (incl. periphragm): 8 (13) 19
Equatorial width of pericoel: 33 (43) 54
Width of pericoel: 1 (3) 8

The measured specimens are from core samples from Alaria-1 well at 3315.95m and Peak-1 well at 4302.00m, sideway core samples from Buang-1 well at 3504.00m, Frigate-1 well at 1233.00m, Macedon-5 well at 1350.00m and Scafell-1 well at 1365.00m and ditch cuttings between 3295.00m and 3300.00m in Hadrian-1 well. Additionally, outcrop material from the Tithonian Lelinta Formation of Misool, eastern Indonesia and the holotype and nineteen topotypes from Mombasa, Kenya were studied.

The dimensions of specimens from Australia, Indonesia and Kenya proved extremely similar, therefore the data has been aggregated in the table above.

Comments. It seems probable that the ‘rod-like’ features which occur in the hypocystal folds are short parasutural processes emerging from the endophragm, which have the periphragmal folds closely draped over them. Alternatively, they may represent interrupted linear thickenings of the periphragm. The width of the pericoel is relatively variable (Fig. 11) and frequently this varies within single specimens. In extreme cases some forms may appear to be camovacate (Fig. 11N). The thin periphragm has been mechanically torn and damaged in some specimens and in extremely rare cases, the entire pericoel may be torn away. Another parameter where there is significant intraspecific variability is the development of parasuturation. The periphragmal folds may indicate the positions of the precingular, postcingular and the antapical paraplates. However, the folds are frequently poorly developed and/or discontinuous (for example, Fig. 11J). The profound dorsoventral compression can make orientation difficult in relatively poorly-preserved material. Jiang (in Jiang et al., 1992) stated that the operculum is attached, based on the holotype which has an adherent operculum (Figs 11P-Q). However, it seems more likely that the operculum is free as the majority of specimens observed are leiothecosts (Fig. 11). Contrary to Jiang (in Jiang et al., 1992, p. 87), this species is clearly a proximate species, not having any ornamentation on the periphragm.

Comparison. *Mombasadinium parvelatum* resembles *Belodinium* spp., especially *B. nereids* Stephens & Helby 1987 in having periphragmal folds which partially reflect parasuturation. However, *M. parvelatum* lacks an elongate apical horn and is not distinctly circumcavate. *Craspedodinium swanense* is similar in cyst organisation. However, *C. swanense* may be biconvex, is significantly larger than *Mombasadinium parvelatum*, is not elongate, has
an apical protuberance or boss, often exhibits accessory archaeopyle sutures and has a paracingulum indicated by periphragm al ornament (see above). *Indodinium khuriense* has a distinct apical horn and frequently exhibits a paracingulum (see also Comparison relating to *Mombasadinium* above).

*Fistulacysta simplex* Davey 1987 closely resembles *Mombasadinium parvelatum* in morphology and dimensions. The two species also have the same stratigraphical ranges. Especially noteworthy are the similarities between the low, pre- and postcingular parasutural crests developed on the autophragm of *F. simplex* and the low parasutural folds on the periphragm of *M. parvelatum*. It seems likely that the crests of *F. simplex* are made of periphragm, which further strengthens the likeness. *Fistulacysta*, however, is an acavate genus and no separation of endophragm and periphragm is present. Despite this, it is possible that *Fistulacysta* is closely related to *Mombasadinium*.

Holotype and type locality. Figured specimen ML 2155-V60/1 from Slide MP26 (iv) also marked 15904, 'England Finder' coordinate V60/1 of Jiang (in Jiang et al., 1992, pl. 2, fig. 10). Figured here as Figs 11P-Q. Housed in the type collection of the Centre for Palynology, University of Sheffield, Sheffield, U.K. From the Changamwe Shale Formation, Mto Panga Quarry, Bambari Portland Cement Works, Frenetown, near Mombasa, Kenya. The upper part of the Changamwe Shale Formation, which was sampled by Jiang et al. (1992), is late Kimmeridgian-early Tithonian (Hybonoticeras beckeri and Hybonoticeras hybonotum Tethyan ammonite zones) on ammonite evidence according to Verma & Westermann (1984). Jiang et al. (1992) reported this species to be confined to their Zone III(a), which they correlated to the late Kimmeridgian (sensu anglico) Pectinatites elegans ammonite zone, hence is close to the Kimmeridgian-Tithonian transition of Australia.

Stratigraphical distribution. *Mombasadinium parvelatum* has been recorded from the Kimmeridgian mid *Dingodinium swanense* Zone (6a) to the Tithonian upper *Cribroperidinium perforans* Zone (5d) of Australia and Misool, eastern Indonesia (Foster, this volume; Helby & Partridge, in prep.). Identical forms were illustrated as *Belodinium* sp. 3 (fig. 27 - 98-100) from Late Jurassic ditch cuttings in Ankamotra-1 well in western Madagascar by Chen (1978) and *Sembaridinium sembari* from the Sembar Formation of Pakistan (Beju, 1979, pl. 22, figs 1-4; 1980). The species was originally described from the late Kimmeridgian-early Tithonian of Kenya (see Holotype and type locality, above).

*Oligosphaeridium* Davey & Williams 1966 emend. Davey 1982

Type species. *Oligosphaeridium complex* (White 1842) Davey & Williams 1966

*Oligosphaeridium swanense* sp. nov. (Figs 12A-F, 13A-C)

Previous Australian usage
M.P. 171 pars – Helby.

*Oligosphaeridium swanense* – Helby.

Description. A large species of *Oligosphaeridium* with long, tubiform intratabular (paraplate-centered) processes. The processes are formed by the periphragm only, vary considerably in width, are open distally and are deeply indented as a result of branching of up to three times. Branching typically first occurs at the midpoint of the process, where the tubular process bifurcates, or occasionally trifurcates. The resultant branches further bifurcate in a distal direction and there may be a final bifurcation at the distal extremities. The distal parts of the processes are sharply pointed and simple: trabeculation is not developed. This branching causes the distal portion of the processes to be significantly expanded. The long, rounded subtriangular notches caused by the branching may be deeper on the hypocyst than on the epicyct. Epicystal processes are also generally slightly smaller and possibly more slender, however the variation of process length on individual specimens is minor. The width of the processes varies significantly however; the majority of these elements are between 5 and 11μm. The processes are also slightly expanded proximally, where they are thickened, markedly striate and fibrous. Occasionally, processes are entirely longitudinally striated. Parasutural processes are not normally developed. The autophragm, which comprises closely appressed periphragm and endophragm, on the cyst body is relatively robust, microsecretable to smooth, occasionally irregularly microreticulate. Accessory archaeopyle sutures may be developed, which deeply subdivide the precingular paraplates.
Fig. 12. *Oligosphaeridium swanseae* sp. nov. From conventional core in Alaria-1 well at 3319.95m (A, C-F) and sidewall core in Jabiru-8A well at 1842.50m (B). All images taken using plain transmitted light. Scale bar in Fig. 12F refers to all images and is 25μm. Fig. 12F is the holotype; the remainder, paratypes. Note large size, wide intratabular processes indented and expanded distally, and apical archaeopyle. Processes branch up to three times distally. A - CPC 35718, paratype; dorsal view, median focus. Note very wide, hollow intratabular processes which branch medially. B - CPC 35719, paratype; ventral view, median focus. Note deeply incised process at top left. C, D - CPC 35720, paratype; oblique dorsal view, high and median focus respectively. Note principal and accessory archaeopyle sutures in Fig. 12D. E - CPC 35721, holotype; ventral view, median focus. Note detached operculum to bottom right. F - CPC 35722, paratype; oblique ventral view, high focus. Note lack of paracingular processes, and apical archaeopyle.
Fig. 13. *Oligosphaeridium swanense* sp. nov. All are paratypes from conventional core in Alaria-1 well at 3319.95m. All images taken using plain transmitted light. Scale bar in Fig. 13C refers to all images and is 25μm. Note four intratubular processes and prominent parasulcal tongue. A - CPC 35723, paratype; external/ventral view, median/low focus. Note prominent parasulcal tongue and relatively slender intratubular processes. B - CPC 35724, paratype; external/ventral view, low focus. Note four hollow intratubular apical processes. C - CPC 35725, paratype; external/oblique ventral view, median focus. Note parasulcal tongue.

**Dimensions (μm; n=31):** Min. (Mean) Max.
Length of entire cyst incl. processes: 107 (131) 153
Length of entire cyst excl. processes: 48 (62) 72
Length of loithocyst incl. processes: 87 (130) 163
Length of loithocyst excl. processes: 40 (63) 86
Width of cyst incl. processes: 103 (129) 168
Width of cyst excl. processes: 48 (63) 84
Length of processes: 28 (43) 60
Width of processes: 3 (6) 18

The measured specimens are from conventional core samples at 3315.95m and 3319.95m from Alaria-1 well and sidewall core samples from Buung-1 well at 3505.20m and Tenuiculus-1 well at 3002.00m.

**Comments.** The processes, particularly their branching, in *Oligosphaeridium swanense* are highly distinctive. Normally each process branches three times, the initial furcation generally occurring close to the central portion, although this is relatively variable (Fig. 12). The final branching is close to the distal extremity and the median furcation being approximately intermediate in position. This species is distinctive in comparison to others in the genus because the initial, most proximal, branching is relatively close to the cyst body, within the median portion of the process. In some cases, the first furcation is only one third the distance from the cyst body to the distal tip of the process (Fig. 12). In a very small number of forms, which may be transitional to other taxa, there is some re-connection of the distal elements of the processes. The majority of the processes are largely subparallel, but are expanded both proximally and distally. Occasionally the processes may be irregularly microreticulate, although the cyst wall is generally microscabrate. Their length is normally relatively constant in an individual specimen, however the width varies significantly (Fig. 12). The apical processes are consistently the narrowest (Fig. 13). Orientation is generally straightforward to interpret due to both the archaeopyle and the wide equatorial region, which is devoid of processes. The cyst is slightly dorsoventrally flattened. The operculum is consistently free and accessory archaeopyle sutures are often present, causing the precingular paraplates to be separated along their longitudinal sides. The accessory archaeopyle sutures are typically relatively deep and chemical/mechanical damage to the precingular paraplate series may loosen individual paraplates (Figs 12A-B, 13).

Representatives of other species of the genus occur in the same samples as *Oligosphaeridium swanense*, although as minor components.

**Comparison.** *Oligosphaeridium swanense* differs from the other 37 validly published species of *Oligosphaeridium* (see Williams et al., 1998, p. 434-438) in its large size and the extremely deep branching of the intratubular processes. Normally species of *Oligosphaeridium* are less than 100μm in maximum diameter and any branching, or the insertion of narrow distal elements, occurs close to the distal end of the processes. The Early Cretaceous species *Oligosphaeridium dilinctum* Davey 1982 and *O. dividium* Williams 1978 also have relatively deeply furcate, tubiform processes. However, both of these are smaller than *O. swanense*, have slender processes, the distal branching of which is not as deep as in the latter. *Oligosphaeridium porosum* Lentin & Williams 1981, from the Albian of southern India, resembles *O. swanense* in having broad processes which branch deeply. However, *Oligosphaeridium swanense* has longer processes which vary considerably in width and it is significantly larger.
than *O. porosum*. Two species also with broad intratabular processes which are distally branched are *Oligosphaeridium pulcherrinum* (Deflandre & Cookson 1955) Davie & Williams 1966 and *O. patulum* Riding & Thomas 1988. The branching in these species is not as deep as that in *O. swanense* (see Riding & Thomas, 1988, fig. 9) and again they are slightly smaller than the latter. *Oligosphaeridium fenestratum* Duxbury 1980 and *O. perforatum* (Gocht 1959) Davie & Williams 1969 have processes which branch relatively deeply distally. Both these Early Cretaceous forms, however, are smaller than *O. swanense* and have fenestrae in the distal portions of the processes. Furthermore, *Oligosphaeridium perforatum* has an entire distal rim. The large, annulate processes of *Systematophora palmula* Davie 1982 are similar in that they may be deeply branched (Davie, 1982, pl. 1, figs 1-3).

**Derivation of name.** From the *Dingodinium* *swanense* Zone.

**Holotype and type locality.** Figure 12E, CPC 35721, Alaria-1 well, conventional core at 3319.95m.

**Stratigraphical distribution.** *Oligosphaeridium swanense* ranges from the Oxfordian Wareaa spectabilis Zone (6c) to the Kimmeridgian upper *Dingodinium swanense* Zone (6aia) (Foster, this volume; Helby & Partridge, in prep.).

**Stratiomtinium** gen. nov.

**Type species.** *Stratiotinimum ottii* sp. nov.

**Diagnosis.** Small to intermediate, proximate, acaceous dinoflagellate cysts, which are elongate ellipsoidal in outline. The autophagium is smooth or has low relief, non-parasutural ornamentation. The autophagium also bears numerous, prominent, largely longitudinal ridges or crests, which may be nontabular or parasutural. These nontabular elements may be discontinuous. The paratabulation is gonyaulacacean. Paracles are normally outlined by smooth, narrow, parasutural bands. The archaeopyle is apical, operculum simple and free. Parasutures surrounding the paracingulum and parasutus are indicated by the absence of ornamentation or by penitubular ridges or crests; the parasutus is slightly indented. The paracingulum is leevorot and is displaced at the parasutus by as much as its entire height.

**Comments.** *Stratiomtinium* is a small, distinctive genus. The longitudinal alignment of the nontabular or penitubular ridges or crests, coupled with the elongate shape of this genus, are characteristic. In forms with parasutural ornamentation, lateral features are present, for example on the paracingular paracles. However, in the markedly more elongate penitubular and postcingular paracle series, the apical and antapical sides of the penitubular fields are particularly narrow. Nontabular elements commonly occur within the fields marked by the penitubular ridges; the dominant orientation of these elements is longitudinal.

**Comparison.** *Dinogymnium* Evitt et al. 1967 and *Ellipsodinimum* Clarke & Verdier 1967 both have longitudinal ornamentation and thus resemble *Stratiomtinium*. However, *Dinogymnium* is biconvex, has an extremely small, apical archaeopyle and a single wall structure (May, 1976; Evitt, 1985). *Ellipsodinimum* lacks parasutural features and has a precingular archaeopyle. *Hemiplacophora* Cookson & Eisenack 1965 has parasutural ornamentation, but these elements are incomplete and polar in position. *Altiscyrtus* Stover & Evitt 1978 is subspherical and penitubular crests or septa are consistently present. *Lanterna* Dodekova 1969 is ellipsoidal, has an apical archaeopyle and penitubular ornamentation. However, this Jurassic genus completely lacks longitudinal ornamentation characteristic of *Stratiomtinium*. The genera *Ellipsodinimum* Deflandre & Cookson 1955 and *Cassidium* Drugg 1967 have linear parasutural features, but these are

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**Fig. 14.** *Stratiomtinimum lineatum* sp. nov. All from outcrop sample 81FH63, from Misool, eastern Indonesia (Hasibuan, 1990). All photomicrographs taken using plain transmitted light. Scale bar in Fig. 14P refers to all photomicrographs and is 25μm. Figs 14A-B are the holotype; the remainder, paratypes (Figs 14C-P). Note apical archaeopyle, elongate outline, low, smooth, subparallel nontabular ridges which are sometimes discontinuous and sinuous. Rarely these nontabular ridges may coalesce; paratabulation indicated by absence of ridges. A - CPC 35726, holotype; left lateral view, high and low focus respectively. Note well defined gonyaulacacean paratabulation pattern indicated by absence of longitudinal ridges, and prominent fold close to antapex. B - CPC 35727, paratype; ventral view, low focus. Note discontinuous nature of some longitudinal ridges. C - CPC 35728, paratype; oblique ventral view, low focus. Squat specimen with well developed dorsal paratabulation. D - CPC 35729, paratype; ventral view, high and low focus respectively. Note parasutus (continued opposite)
and parasutal notch in Fig. 14E. G, H - CPC 35730, paratype; ventral view, high and low focus respectively. Note adherent operculum lacking an apical horn. I, J - CPC 35731, paratype; ventral view, high and median focus respectively. Note prominent parasutal notch. K, L - CPC 35732, paratype; dorsal view, high and low focus respectively. Note low, well spaced longitudinal ridges. M-O - CPC 35733, paratype; ventral view, high to low focus sequence. Note gonyaulacalcan paratabulation pattern indicated by absence of positive ornamentation. P - CPC 35734, paratype; dorsal view, median/low focus. Small; note apical archaeopyle and parasutal notch.
depressions, which are surrounded by raised intratabular areas. *Gerdocysta* Liengjarem et al. 1980 is proximate, has an apical archaeopyle and penitabular ornament, but it is holocavate.

This new genus resembles several other proximate genera with apical archaeopyles such as *Ellipsoidicyctium* Klement 1960 and *Valensiella* Eisenack 1963, but differs in its penitabular and pandasusal paraplate delineation.

Isolated endocysts of some cavitâ genera including *Belodinium* Cookson & Eisenack 1960 and *Gardodinium* Alberti 1961 may be elongate and exhibit similar penitabular and pandasusal features to *Striatodinium*.

**Derivation of name.** From the Latin *striæ*, meaning line or furrow, referring to the numerous prominent longitudinal ridges or crests of this genus which impart a strié appearance.

*Striatodinium lineatum* sp. nov. (Figs 14A-P)

**Previous Australian usage**

MP 724 (gran.) – Helby.

**Description.** A species of *Striatodinium* which is slightly dorsoventrally flattened and has a dense ornamentation, consisting of outer, generally continuous, penitabular ridges, within which there may be numerous subparallel, occasionally coalescing, longitudinal ridges or aligned rows of elements. The ridges are low, 0.5-1.5 µm in height, smooth distally and narrow (c. 1.5 µm in width). These ridges may be long, short, discontinuous and sinuous. The paratabulation is marked by the smooth pandasusal bands between the penitabular fields. The paracingulum is well marked, with hexagonal paraplates, bearing an outer, often interrupted penitabular ridge. Within the penitabular fields the overall longitudinal

lineation of accessory ridges is maintained.

**Dimensions (µm; n=43):** Min. (Mean) Max.

- Length of entire cyst: 41 (46) 54
- Length of loisthocyst: 33 (42) 50
- Length of operculum: 9 (10) 11
- Length of precingular paraplate series*: 14 (17) 20
- Length of paracingulum*: 4 (5) 6
- Length of postcingular paraplate series*: 20 (22) 25

Equatorial width of cyst: 26 (30) 35

* - measured in dorsal view

The measured specimens are from sidewall core samples from Octavus-2 well at 2905.00m and 2907.00m, Tenacious West-1 well at 3040.00m and outcrop sample 81FH63, from the Kimeridgian lowermost part of the Lelinta Formation (Fageo Group) of Misool, eastern Indonesia (Hasibuan, 1990).

**Comments.** *Striatodinium lineatum* is a distinctive species due to the prominent, dense, longitudinal ridges and aligned low relief elements, which cover the autophragm, apart from the smooth pandasusal bands. The vast majority of the specimens studied are loisthocysts (Fig. 14). The few opercula which were encountered are flattened cones, relatively low in height, and lacking an apical horn (Figs 14G-H). The pandasusal bands, which define the individual paraplates, are not always clearly developed, particularly in specimens in which the ridges are less prominent (Figs 14K-L). Normally the paratabulation is best developed on the dorsal side (Fig. 14O). The less well preserved forms may have sparser, more discontinuous ridges. It is possible therefore that the ridges are susceptible to physico-chemical degradation.

**Comparison.** *Striatodinium lineatum* is smaller

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**Fig. 15. Striatodinium o⽰ii** sp. nov. From ditch cuttings from 1493.54m-1496.59m in Peak-1 well (Figs 15A-D) and outcrop sample 8556 from Kawhia, New Zealand (Helby et al., 1988) (Figs 15E-P). All photomicrographs taken using plain transmitted light. Scale bar in Fig. 15P refers to all photomicrographs and represents 25 µm. Figs 15O-P are the holotype, the remainder, tootypes (Figs 15E-N) and paratypes (Figs 15A-D). Note smooth autophragm, the markedly elongate outline and prominent, slender, straight, distally smooth, penitabular peripheryonal cress. A, B - CPC 35735, paratype; ventral view, high and low focus respectively. Widening of cyst at principal archaeopyle suture is probably from mechanical damage. C, D - CPC 35736, paratype; dorsal view, high and low focus respectively. Narrow specimen. E, F - SM 4757, tootype; ventral view, high and low focus respectively. Note short (i.e. low in height) paracingulum. G - SM 4758, tootype; oblique ventral view, high and low focus respectively. Narrow; note flat, small antapical (paraplate 1") area. H - SM 4759, tootype; ventral view, median focus. Note rounded antapex. J, K - SM 4759, tootype; ventral view, high and low focus respectively. Narrow; note flat, small antapical (paraplate 1") area. L - SM 4760, tootype; oblique ventral view, high focus. Unusually small. M, N - SM 4761, tootype; ventral view, high and low focus respectively. Large; note penitabular crests on paracingular paraplates in Fig. 15N. O, P - SM 4762, holotype; dorsal view, high and low focus respectively. Note penitabular crests in paracingular paraplates.
than \( S. \text{otti} \) sp. nov. and also differs in having additional non-tubular, longitudinal ornamentation and lacking prominent penitabular crests.

**Derivation of name.** From the Latin *linea*, meaning line or thread and referring to the longitudinal ridges which impart a linear pattern to this species.

**Holotype and type locality.** Figures 14A-B, CPC 35726, sample 81FH63, outcrop material from the lower part of the Lelinta Formation (Kimmeridgian), Misool, eastern Indonesia (Hasibuan, 1990).

**Stratigraphical distribution.** *Striatodinium lineatum* ranges from the Oxfordian to Kimmeridgian upper part of the *Waanea clathrata* Zone (6bi) to the basal part of the Kimmeridgian *Dingodinium swanseae* Zone (6aiiib) (Foster, this volume; Helby & Partridge, in prep.). It occurs consistently over this interval in the Timor Sea region (and Misool), but is extremely rare to the south in the Carnarvon Basin, Western Australia.

*Striatodinium oti* sp. nov. (Figs 15A-P)

1988 gen. et sp. nov. H (M.P. 724); Helby *et al.*, fig. 8H, Q.

**Previous Australian usage**

*Dictyopxis elliptica* Ott (1970, pl. 8, figs 11-14). MP 724—Helby.

**Description.** A species of *Striatodinium* which is dorsoventrally flattened and having a smooth to microscabrate autophagum which is 1µm thick. Slender (<0.5µm thick), straight, distally smooth periphragmal crests emerge from penitabular positions on each major paraplate. The penitabular ridges on paracingular and possibly the paracingular plates tend to be discontinuous. The crests are prominent (2-4µm high), tend to be slightly higher in the antapical region and appear to be predominantly longitudinal due to the elongate nature of the species. The paracingulum is relatively narrow.

**Dimensions (µm; n=41)** exclusive of penitabular crests where applicable: Min. (Mean) Max.

- Length of lothiocyst: 45 (56) 68
- Length of precingular paraplate series*: 18 (25) 31
- Length of paracingulum*: 3 (4.5) 6
- Length of postcingular paraplate series*: 20 (26) 30
- Equatorial width of cyst: 20 (28) 34
- Height of penitabular crests: 2 (3) 4

* - measured in dorsal view

Only one cyst with an adherent operculum was observed; it was 53µm in overall length and the operculum was 7µm long. The measured specimens are from a ditch cuttings sample from Peak-I well between 1493.54m and 1496.59m and operculum material from the uppermost Ohiereuru Formation (Kimmeridgian) from Kame, New Zealand (sample F8556 of Helby *et al.*, 1988).

**Comments.** The penitabular crests of *Striatodinium oti* are predominantly longitudinal because of the elongate nature of this species (see *Dimensions, above*); the polar sides of each of the precingular and postcingular paraplates are short (Fig. 15). This species generally appears symmetrical, particularly in dorsal view, because the epicyst and hypocyst are similar in size. The penitabular crests are normally straight, but there may be some minor crest sinuosity (Fig. 15). Despite the relatively small paraplate areas in the parasculus and paracingulum, penitabular crests are normally developed (e.g. Figs 15N-P). The penitabular crests emerge from immediately (within 1-2µm) inside each paraplate area. These crests are interpreted as being formed entirely of periphragmal extensions; no cavation has been observed. No degradation of the penitabular crests was observed. As in *S. lineatum*, the overwhelming majority of the specimens studied are lothiocysts (Fig. 15).

**Comparison.** *Striatodinium oti* is larger than *S. lineatum*; it also differs in having penitabular crests and lacking non-tubular ornamentation.

**Derivation of name.** For Hank L. Ott.

**Holotype and type locality.** Figures 15O-P, SM 4762, from sample F8556 of Helby *et al.* (1988), collected in the uppermost Ohiereuru Formation (Kimmeridgian) from Kame, New Zealand. The holotype and the topotypes (Figs 15E-N) are curated in the collections of the Institute of Geological and Nuclear Sciences (formerly the New Zealand Geological Survey), Lower Hutt, New Zealand.

**Stratigraphical distribution.** *Striatodinium oti* ranges from the Oxfordian-Kimmeridgian upper part of the *Waanea clathrata* Zone (6bi) to the basal part of the Kimmeridgian *Dingodinium swanseae* Zone (6aiiib) (Foster, this volume; Helby & Partridge, in prep.). It occurs consistently over this interval in the Carnarvon Basin, Western
Australia but is extremely rare to the north in the Timor Sea region. It has not been recorded in Misool. The species is also present in the Kimmeridgian uppermost Chineeru Formation of Kawhiu, New Zealand (Helsey et al., 1988).

ACKNOWLEDGEMENTS
The authors are grateful to Dr C.B. Foster (AGSO, Canberra) for promoting and facilitating this work and for editorial guidance and advice. Christian Thun and Andrew Kelman (AGSO, Canberra) provided invaluable help with preparations and the manipulation of digital images. Mr Eddie Resink of the core and cuttings repository at AGSO, Canberra courteously provided access to sample material. Arco Australia Ltd., BHP Petroleum Pty. Ltd, Cultus Petroleum N.L., Esso Australia Ltd., WAPET, Mining Co. and Woodside kindly provided sample material on request. Dr Faustine Hasibuan of the Geological Research and Development Center, Bandung, Indonesia supplied the sample material from Misool, eastern Indonesia. Lacla Pty. Ltd. (Perth) gave support via the careful treatment of key samples in the preparatory process. Professor Bernard Owens of the Centre for Palynology, University of Sheffield, UK kindly made the type material of Indusdomium (now Monasdasminium) parvulum to JFR for a restudy. Drs D.G. Benson Jr. and J.Helenes are thanked for reviewing the manuscript. J.B. Riding publishes with the permission of the Chief Executive Officer, AGSO.

REFERENCES

FOSTER, C.B., this volume. Introduction.


RIDING, J.B. & HELBY, R., this volume, a. Some stratigraphically significant dinoflagellate cysts from the Early Cretaceous (Aptian and Albian) of Australia.

RIDING, J.B. & HELBY, R., this volume, b. Marine microplankton from the Late Jurassic (Tithonian) of the north-west Australian region.


palynomorphs from the Staffin Bay and Staffin Shale formations (Middle-Upper Jurassic) of the Trotternish Peninsula, NW Skye. *Scottish Journal of Geology* 33, 59-74.


**APPENDIX 1: SAMPLE DETAILS**

**1. LOCATIONS AND OPERATORS OF WELLS FROM WHICH MATERIAL HAS BEEN STUDIED**

<table>
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<th>Well Name/Number</th>
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<th>Longitude</th>
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Well completion reports on all the offshore wells listed are publicly available five years after completion.
2. OUTCROP MATERIAL
2.1. MISool, EASTERN INDONESIA

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2.2. BRORA, NORTH-EAST SCOTLAND, UK

| MPA 15496    | Brora Roof Bed (Brora Argillaceous Fm.) | Callovian | Sykes (1975) |

2.3. MTO PANGA QUARRY, FRERETOWN, KENYA

| MP26         | Uppermost Changamwe Shale Formation | Kimm./Tith. | Jiang et al. (1992) |

2.4. KAWHIA, NEW ZEALAND

| f8586        | Uppermost Ohineruru Formation | Kimmeridgian | Helby et al. (1988) |

APPENDIX 2: REGISTER OF FIGURED SPECIMENS

All polynomorph specimens figured in this paper are listed here, together with essential details. The specimens are mainly curated in the Commonwealth Palaeontological Collection (CPC) of the Australian Geological Survey Organisation, Canberra. Eight specimens of Striatodinium ostiti, however, are curated with the New Zealand Geological Survey, Lower Hutt, New Zealand. The holotype and topotype specimens of Mombasadinium parvatum are housed in the type collections of the Centre for Palynology, University of Sheffield, UK. Furthermore, a single specimen of Indosadinium khuriense figured herein is curated in the collections of Woodside Petroleum, Perth.

The dinoflagellate cyst genera and species are listed alphabetically and the location of the specimens on the microscope slides are all ‘England-Finder’ co-ordinates. These were taken with the slide label to the left of the observer; the microscope stage opening toward the microscope user. The coding for types is as follows: H = holotype; P = paratype; T = topotype. All specimens of new taxa examined during this study contributed to the specific concepts described. Therefore all figured specimens which are not holotypes are paratypes. SGM = single grain mount. The single grain mounts do not have unique numbers; they are numbered sequentially for each species within a particular sample. The specimens are from conventional core, sidewall core and ditch cutting samples.

### SPECIES LIST

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| *ditch cuttings sample, range depth: 1463.06m-1466.10m

** - collections of the British Geological Survey, Nottingham, UK.

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* - Centre for Palynology, University of Sheffield, UK: type/figured slide collection registration number.

**O. swanense**

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* = ditch cuttings sample, range depth: 1493.54m-1496.59m

** = Institute of Geological and Nuclear Sciences (formerly New Zealand Geological Survey) figured specimen numbers
Marine microplankton from the Late Jurassic (Tithonian) of the north-west Australian region

JAMES B. RIDING and ROBIN HELBY


A Late Jurassic (Tithonian) suite of marine microplankton is present in the Flamingo Formation and its equivalents in the Timor Sea, offshore north-western Australia and adjacent regions. It includes three new dinoflagellate cyst genera, Aidelocyxysta, Ampulladinium and Belowia, and ten species of dinoflagellate cysts, Aidelocyxysta chroata, Ampulladinium variabile, Balcania cheleusis, Balcanidinium poeninsorum, Belowia balteus, Bionbifera ferox, Cassiculospoora edrisa, Distimulidinium puriparvum, Gardodinium angustum and Pseudoceratium robustum, are described as new. An additional morphotype of Belowia, B. sp. A, is informally described. The genera Balcania, Bionbifera and Distimulidinium and the species Meiozygogonyaulax bulloidea are amended to note key morphological features observed in the material studied. Sandfordella grunulosa is reported from the Southern Hemisphere for the first time. A new acritarch species, Nummus tithonicus, is also described. These microplankton taxa have stratigraphical utility in the Tithonian Cribreropimentum perfrans Zone to the upper Pseudoceratium iehienne Zone.

James B. Riding, Australian Geological Survey Organisation, GPO Box 378, Canberra. ACT 2601, Australia (present address: British Geological Survey, Keyworth, Nottingham NG12 5GG, UK [e-mail: jbr@bgs.ac.uk]); Robin Helby (corresponding author), 356A Burns Bay Road, Lane Cove, NSW 2066, Australia (e-mail: rhelby@ozemail.com.au), 10 November 2000.

Keywords: acritarchs, dinoflagellate cysts, Late Jurassic, Australia, biostratigraphy, taxonomy

THE PALYNOCOLOGICAL zonation of the Australian Mesozoic published by Helby et al. (1987) was the first attempt to provide an integrated, pan-Australian microplankton and spore-pollen zonation. Only the basic framework of the zonation was provided in anticipation that further contributions, particularly the documentation of new taxa, would be necessary as the zonation scheme evolved. This paper is one of a series providing the taxonomic foundation necessary to formalise the widely used unpublished subdivisions of these zones. These subzones have widespread currency within the hydrocarbon industry due to the legislative requirement for the release of technical data under the Petroleum (Submerged Lands) Act 1967. The informal subdivisions of the Helby et al. (1987) zonation have been entered into the Australian Geological Survey Organisation (AGSO) STRADAT database. A diagrammatic update of the Helby et al. (1987) zonal scheme is presented by Foster (this volume), and will be fully described by Helby & Partridge in prep.). This taxonomic project is an initiative of the Petroleum and Marine Division of AGSO.

This paper provides formal descriptions of previously undescribed marine microplankton taxa from Late Jurassic (Tithonian) palynofloras recorded in samples mainly from the Flamingo Formation and its equivalents in the Timor Sea, and equivalents elsewhere off north-western Australia (Whittam et al., 1996, fig. 5) (see Appendices 1 and 2). The new taxa have stratigraphical utility within the Tithonian Cribreropimentum perfrans Zone (5d) to the upper Pseudoceratium iehienne Zone (4ct) zones (Foster, this volume; Helby & Partridge, in prep.).

SYSTEMATIC PALYNOCOLOGY

In this section, three new genera and ten new species of dinoflagellate cyst and one new acritarch species are described. Additionally, Meiozygogonyaulax bulloidea Cookson & Eisenack 1960 is emended. The genera are listed in alphabetical order within the two palynomorph groups; for the dinoflagellate cysts, the recent suprageneric classification of Fensome et al. (1993) is not formally used, but new genera are compared
with that scheme. The dimensions quoted are all given in micrometres (μm). For descriptive purposes, the cyst sizes, small, intermediate and large, follow Stover & Evitt (1978, p. 5). These parameters are such that intermediate size dinoflagellate cysts have a maximum dimension of between 50 and 100μm. Small and large forms are less than 50μm and above 100μm respectively. The majority of the morphological terminology for the dinoflagellate cysts are those used by Evitt (1985). However, the term loevocyst refers to a dinoflagellate cyst in which the operculum (or the separate opercular pieces) has (have) detached and is therefore the part that remains (Sarjeant et al., 1987, p. 26, 27). Where appropriate, the dinoflagellate cyst paraplate notation system used throughout is Kofoidian, as opposed to the ‘Taylor-Evitt’ scheme of Evitt (1985). References to author citations of taxa discussed are not given here. These may be found in the bibliography in Williams et al., 1998, p. 747-817). The vast majority of specimens are housed in the Commonwealth Palaeontological Collection (CPC) of the Australian Geological Survey Organisation (AGSO), Canberra. Two specimens, previously illustrated by Bint & Marshall (1994), are housed in the collections of the Geological Survey of Western Australia, Perth (see Appendix 2).

This study has been conducted almost exclusively using single and multiple grain mounts and all the figured specimens, except for the Bint & Marshall (1994) material, are from these single species slides. The majority of the samples which were studied, are from conventional core and sidewall cores. However, some ditch cuttings and outcrop samples were also used. The photographs in the eighteen photomicrograph plates were all taken using an Olympus DP-10 digital camera system coupled to a Zeiss Axioskop photomicroscope, all equipment being housed at AGSO. Some extraneous palynodebris, which is not adherent to the figured specimens, has been digitally removed in selected images.

The specimen images herein are taken from a digital database containing many more than have been figured. The sample details, morphological data and measurements of each imaged specimen are held on open file spreadsheets. The image database may be accessed on the AGSO website (http://www.agso.gov.au).

Some of the illustrated specimens (Figs 9Q-S, 14B-C, G-I), from older slides, have become quite transparent and have lost much of the natural colour and contrast evident in contemporaneous photomicrographs. Although the illustrations are “muddy”, the specimens display features not shown adequately by other specimens.

Many of these new taxa have been extensively used in unpublished reports, which are now in the public domain (open file). In order to maximise the utility of the species, the informal names and/or codes are listed separate from any formal synonymy listing, under the heading ‘Previous Australian usage’. To provide continuity, where practical, the informal name has been retained.

An unpublished manuscript which included some of the taxa described herein was prepared by Jill Stevens during the early 1980s (Stevens & Helby, unpublished). The manuscript names proposed by Stevens have been retained and she is included in the authorship of these taxa. These species are Aidelocysta clavata, Baleatia chelesis and Gadodinium angustum. Similarly, the new genus Ampulladinum was originally proposed by Frances M. Parker (see Parker, 1986) and she is also included as an author of this genus and the species A. variabile. However, neither the specimens studied, nor the descriptions by Stevens and Parker have been used in this paper.

**Dinoflagellate cysts**

**Aidelocysta Riding, Helby & Stevens gen. nov.**

**Type species.** Aidelocysta clavata Riding, Helby & Stevens sp. nov.

**Diagnosis.** Small, acavate to holocavate, proximate, quadrilobate, dorsoventrally flattened dinoflagellate cysts with an equatorial constriction. The hypocyst and epicyst each comprise two prominent rounded lobes or protuberances in dorsoventral view. The cysts are elongate ellipsoidal in lateral view. The autophragm bears predominantly nontubular low relief ornamentation, which may be distally connected to form an ectophragm. The autophragm may also be differentiated. Occasionally, short, discontinuous lines of ornamentation may be parasutural or penutabular. Archaeopyle anterior intercalary, type I (2a), eury-deltaform in shape; the operculum is normally free. The archaeopyle is situated close to the apex (i.e. subpolar). The hexagonal outline of the principal archaeopyle suture may be distorted into an ellipsoidal shape. Paratabulation not developed except at the principal archaeopyle suture, and occasional alignment of ornament. Paracingulum indicated by the equatorial constriction and possibly a lack of ornamentation. The parasulcus
is marked by a narrow, midventral, linear depression and by reduced ornamentation.

Comments. Aidelocysta is a distinctive, small, quadrilobate genus with a subpolar, anterior intercalary archaeopyle. Distortion may alter the outline of the archaeopyle from hexagonal to ellipsoidal. Due to the high position of the archaeopyle on the epicyst, the hexagonal shape may not be observable in poorly preserved or oriented material. The shape of the archaeopyle is hexagonal and is eury-deltaform of Bujak & Davies (1983). This genus is, therefore, peridiniacean and Aidelocysta appears to be one of the oldest representatives of the suborder Peridiniaceae (order Peridiniales) of Fensome et al. (1993). Previously, the oldest known peridiniacean was the Tithonian calcareous dinoflagellate cyst Pirimella multistrata (Plaumann & Krasheninnikov 1978) Lentin & Williams 1993 forma ceteri (Bolli 1974) Williams et al. 1998. However, the oldest unequivocal dinosporin peridiniacean species is Subtilisphaera terrula (Davey 1974) Lentin & Williams 1976, the earliest occurrence of which is Hauterivian (Duxbury, 1977, fig. 21). Pyxidiella pandora Cookson & Eisenack 1958, from the Upper Jurassic (Tithonian) Dingo Siltstone of Western Australia (Cookson & Eisenack, 1958) is older (Callovian to Berriasian), but its anterior intercalary archaeopyle appears to be seven-sided, suggesting an affinity with the Family Heterocapsaceae. There are also two possible species of Subtilisphaera; S? inaffecta (Drugg 1978) Bujak & Davies 1983 and S? paenirosa (Drugg 1978) Bujak & Davies 1983, in the Late Jurassic (Kimmeridgian) of Europe. However, the peridiniacean affinities of these species are uncertain (Riding & Thomas, 1988). Aidelocysta is unusual among peridinioid genera in lacking polar horns and not being cavate.

Comparison. Aidelocysta resembles several other small proximate genera, but is the only quadrilobate genus to have an anterior intercalary archaeopyle of peridiniacean type. Hexagonifera Cookson & Eisenack 1961 emend. Stover & Eivitt 1978 resembles Aidelocysta in being an acavate peridiniacean genus which lacks polar horns and has a subpolar type I archaeopyle. However, Hexagonifera is subspherical to ellipsoidal in outline, is not holocavate and lacks an equatorial constriction. Pyxidiella Cookson & Eisenack 1958 differs from Aidelocysta in being elongate ellipsoidal, exclusively acavate, paratabulate and not constricted in the paracircular region.

Members of the ‘Parvocysta suite’ of Riding (1984) resemble Aidelocysta in having lobate epicysts and hypocysts. This complex includes Parvocysta Bjaeke 1980, Reutlingia Drugg 1978 emend. Below 1987 and Susadinium Dörhöfer & Davies. However, members of the ‘Parvocysta suite’ usually have apical horns and therefore are subpentagonal in outline. Moreover, the anterior intercalary archaeopyle are longitudinally elongate and have geniculate anterior and posterior margins. Stenopyxidium Deflandre 1968 is a lobate genus, but is extremely small, spinose and probably has an epicystal rather than an intercalary archaeopyle.

Of the genera with apical archaeopyle, the most similar to Aidelocysta are the quadrilobate forms Horologinella Cookson & Eisenack 1962 emend. Backhouse 1988 and Tetrachysca Backhouse 1988. However, Horologinella has an unusual paratabulation indicated by parasutural ridges and an apical archaeopyle with a subcircular principal archaeopyle suture (Backhouse, 1988). Tetrachysca is small, quadrilobate, has no indications of paratabulation other than the angular, apical principal archaeopyle suture (Backhouse, 1988, fig. 32) and accessory archaeopyle sutures.

Amphuladinium gen. nov. varies from being acavate to holocavate and sometimes has a differentiated autophragm. However, Amphuladinium is trilobate and has an apical archaeopyle. Tringuladinium Riding & Helby (this volume) and Woodina Riding & Helby (this volume) are also somewhat similar to Aidelocysta. Tringuladinium is lobate and has an equatorial constriction, but is exclusively acavate and has a gonyaulacaceous paratabulation indicated by intratabular protuberances. Woodina is elongate, sometimes trilobate, has intratabular ornamentation and an extremely small epicyst. Both Tringuladinium and Woodina have apical archaeopyles.

Derivation of name. From the Greek, aidelos, meaning unseen or obscure, referring to the intercalary archaeopyle.

Aidelocysta clavata Riding, Helby & Stevens sp. nov. (Figs 1A-P)


Previous Australian usage Aidelocysta clavata Stevens & Helby (manuscript name)
Fig. 1. *Aidelocysta clavata* Riding, Helby & Stevens sp. nov. All from conventional core in Lorikeet-1 well at 1759.10m (Figs 1A-C, F-G), Wannea-2 well at 3375.34m (Fig. 1D), 2880.50m (Figs 1I-L) and 2875.30m (Figs 1E, H) and a sidewall core from Avocet-1A well at 1771.50m (Figs 1M-P). All photomicrographs taken using plain transmitted light. The scale bar in Fig. 1P refers to all photomicrographs and is 25μm. Figures 1I-L are the holotype; the remainder paratypes. Note small size, quadrilobate outline with marked paracingular constriction, short, dense processes which may be connected distally by an ectophragm, and anterior intercalary archaeopyl. A-C - CPC 35883, paratype; ventral view, high to low focus sequence. Note dense cover of short processes and partial development of an ectophragm. D - CPC 35884, paratype; dorsal view, median focus. Note prominent anterior intercalary archaeopyle. E - CPC 35885, paratype; dorsal view, median focus. Note short processes, some of which are connected distally, and anterior intercalary archaeopyle. F, G - CPC 35886, paratype; ventral view, high and low focus respectively. Note extremely short processes. H - CPC 35887, paratype; oblique dorsal view, median focus. Note strongly quadrilobate nature of species and anterior intercalary archaeopyle. I-L - CPC 35888, holotype; ventral view, high to low focus sequence. Note extremely dense cover of short processes and displaced operculum in Figs 1J-K. M, N - CPC 35889, paratype; ventral view, median and low focus respectively. Note highly constricted equatorial region. O, P - CPC 35890, paratype; dorsal view, high and median focus respectively. Note even cover of processes and anterior intercalary archaeopyle.
**Vesperinaria clavata** Parker (1986, p. 176, 177, pl. 40, figs 5, 6).

**Description.** A species of *Aidelocysta* which may be acicurate to holocavate. Four prominent rounded lobes or protuberances are present, two on the epicyst and two on the hypocryst. The lobes are virtually identical in size and shape, imparting longitudinal symmetry to the cyst. However, the lobes in the epicyst may be larger than the lobes of the hypocryst and vice versa; the species is rarely symmetrical about the equator (Fig. 1). The autophragm is about 1 μm thick and covered by dominantly nontubular, short, solid processes which are distally truncate, buccinate or capitate. The processes are between 0.5 and 1 μm in width and vary between being isolated, up to 2.5 μm apart, to extremely closely spaced. In forms with densely packed processes, individual elements are connected distally forming an ectophragm. Holocavate specimens may have a microreticulate appearance due to the network formed by distally-expanded process tips beneath the ectophragm. Typically the width of the archaeopyle is twice the height (see dimensions, below). Some short, discontinuous lineations of processes appear to be parasutural or pentatubular. The paracingulum and parasutural are marked by a deep equatorial constriction and a narrow depression respectively and generally lack processes.

**Dimensions** (μm, n=25) including ornamentation where applicable: Min. (Mean) Max.

Length of cyst: 34 (40)-49
Maximum width of hypocryst: 24 (30)-36
Equatorial (paracingular) width: 16 (19)-28
Maximum width of epicyst: 26 (31)-36
Height of archaeopyle: 6 (8)-10
Width of archaeopyle: 12 (15)-20
Height of processes: 1 (2)-4

The measured specimens are from conventional core samples in Lambert-2 well at 3101.00m, Lonkeet-1 well at 1759.10m and Wanae-2 well at 3375.34m, 2880.50m and 2875.30m, a sidetrack sample from Jumbi-1 well at 1140.00m and ditch cuttings from Brookme-3 Town Bore between 305.11m and 317.61m.

**Comments.** This species of *Aidelocysta* does not vary significantly in size. The shape, however, varies in that the epicyst or the hypocryst may be the widest part of the cyst (Fig. 1). Specimens where the epicystal and hypocrystal lobes are similar in size are relatively rare. It also exhibits considerable variability in ornament type, length and density (Fig. 1). The short processes may be distally truncate, buccinate or most commonly capitate. They are also sparsely to densely spaced, with occasional specimens having differentiated autophragm. Forms with dense processes are frequently holocavate (e.g. Figs 11-L). Occasionally, some areas of this species may have discontinuous lineations of processes which are either parasutural or pentatabular. A full paratabulation pattern, however, has not been observed. Compression of the autophragm distorts the shape of the archaeopyle to ellipsoidal in some specimens.

**Comparison.** This species is distinguished by its quadrilobate shape, lack of polar horns and subpolar, peridiniaceous style. anterior intercalary archaeopyle. *Aidelocysta* is currently monotypic and therefore generic comparisons (see above) also apply here. Species of *Tetrachocysta* such as *T. allenii* Backhouse 1988, *T. baculata* Backhouse 1988 and *T. spinosigibberosa* (Brideaux & Fisher 1976) Backhouse 1988 closely resemble *A. clavata*, but are distinguished by their apical archaeopyles.

**Derivation of name.** An adjective derived from the Latin clava, meaning club or cudgel, referring to the distally flared nature of the processes.

**Holotype and type locality.** Figures 11-L, CPC 35888, from a conventional core sample in Wanae-2 well at 2880.50m.

**Stratigraphical distribution.** *Aidelocysta clavata* ranges from the Tithonian upper *Dinothamnium jurassicum* Zone (San) to the Berrissian *Kalyptris wisemanitae* Zone (4bii) (Foster, this volume; Helby & Partridge, in prep.).

**Ampulladinium** Riding, Helby & Parker gen. nov.

**Type species.** *Ampulladinium variabile* Riding, Helby & Parker sp. nov.

**Diagnosis.** Small to intermediate sized, rounded triangular dimoistellate cysts, that are acicurate to holocavate, proximate to proximochorate, and exhibit some dorsoventral flattening. The widest part of the cyst is at the antapex, and the antapical lateral areas are extended into prominent lobes or protuberances. The apex is much narrower. Ornamentation is nontubular and of low relief; the autophragm may be differentiated. Archaeopyle apical, operculum simple, normally free. The
Fig. 2. *Ampulladinium variabile* Riding, Hillby & Parker sp. nov. All from conventional core samples from Lorikeet-1 well at 1759.10m (Figs 2A-C) and 1756.70m (Figs 2E-F) and Mutineer-1B well at 3132.25m (Figs 2D, H), a sidewall core sample from Jumbi-1 well at 1140.00m (Fig. 2P) and ditch cuttings from Avocet-1A well between 1775.00m and 1780.00m (Figs 2I-L) and Peak-1 well between 1493.54m and 1496.59m (Figs 2M-O). All photomicrographs taken using plain transmitted light. The scale bar in Fig. 2P refers to all the photomicrographs and is 25μm. Figs 2I-L are the holotype; the remainder paratypes. Note trilobate/subtriangular outline, variable development of an antapical constriction between lateral/antapical lobes, variably holocavate cyst organisation and apical archaeopyle. A, B - CPC 35891, paratype; dorsal view, high and median focus respectively. Note flattened nature of the operculum, which is in place. C - CPC 35892, paratype; dorsal view, median focus. Note partial holocavate cyst organisation and apical archaeopyle. D - CPC 35893, paratype; dorsal view, median focus. Note that ectophragm and the processes have been removed in this poorly preserved specimen. E-F - CPC 35894, paratype; ventral view, high to low focus sequence. Note prominent antapical concavity and processes; the majority of the thin ectophragm has been lost. H - CPC 35895, paratype; dorsal view, high focus. Note that ectophragm and processes have been lost. I-L - CPC 35896, holotype; oblique ventral view, high to low focus sequence. Note angular nature of the principal archaeopyle suture, trilobate outline, holocavate cyst organisation and apical archaeopyle. M-O - CPC 35897, paratype; right lateral view, high to low focus sequence. Note relatively wide ectocoeol and lack of an antapical concavity. P - CPC 35898, paratype; dorsal view, high/median focus. Note narrow ectocoeol and apical archaeopyle.
principal archaeopyle suture has a prominent midventral parasulcal notch and is consistent with a gonyaulacacean paratabulation pattern. Accessory archaeopyle sutures may be developed. Except for the archaeopyle, paratabulation is not evident.

Comments. *Ampulladinium* has a distinctive rounded triangular outline. The autophagm forms two antapical lateral lobes, while the apex is subspherical. The genus is typically holocavate with a narrow ectocyst, however, in the type, *A. variabile*, the ectocyst appears susceptible to physico-chemical degradation.

Comparison. This new genus is similar in size and shape to *Woodinia* Riding & Helby (this volume). However, *Woodinia* is not holocavate and has intratabular areas of ornamentation differentiated on the major paraplate series, which indicate gonyaulacacean paratabulation. Furthermore, the paracystum of *Woodinia* is high on the cyst due to the unusually long postcircular paraplates. *Ampulladinium* also resembles *Dissimuladinium* May et al. 1987 in having paired antapical lobes, but the latter is laterally compressed, consistently proximocorate and may have parasulcal ornamentation. The Late Cretaceous *Dorocysta* Davey 1970 has longer processes and lacks the trifid shape of *Ampulladinium*. *Phallozysta* Dörhöfer & Davies 1980 is, like *Ampulladinium*, flask-shaped, trifidate and widest at the antapex, but has an anterior intercalary archaeopyle and is epicavate (Riding, 1984; 1994). Members of the Early-Mid Jurassic ‘Parvocysta suite’ of Riding (1984) also bear a superficial resemblance to *Ampulladinium*, but these taxa have an anterior intercalary archaeopyle. *Stenopyxinum* Deflandre 1968 is similar in shape to *Ampulladinium*, but is distinguished by its spinose antapical protrusions and possible combination (apical/precingular) or epicystral archaeopyle. *Tetrachyssa* Backhouse 1988 is a quadrifoliate genus with a pair of lateral protuberances on both the epicyst and hypocyst (Backhouse, 1988, fig. 32).

Derivation of name. From the Latin, *ampulla* meaning flask or bottle, referring to the cyst shape.

*Ampulladinium variabile* Riding, Helby & Parker sp. nov. (Figs 2A-P)

*Previous Australian usage*

*Ampulladinium minutuspinosum* – Parker (1986, p. 30, 31, fig. 5.2, pl. 1, figs 4-6).

*M.P. 766 (pars) – Helby.*

*Description.* A holocavate species of *Ampulladinium* which is slightly dorsoventrally-compressed. It is trilobate and subtriangular in outline; a slight antapical concavity may be present between the hypocyst lobes. The autophagm is about 1 to 1.5μm thick and overlain by a thin (<0.5μm), finely but irregularly reticulate ectocyst. Short (1-5μm), solid, slender processes support the outer layer of the ectocyst. Where this outer layer is missing, the processes may be thorn-shaped and appear to taper to sharp points distally. The density of these elements varies from relatively sparse to extremely dense, although they have not been observed on the parasulcus. The density of the processes tends to be greatest in the peripheral areas of the cyst, especially on the antapical-lateral lobes. The ectocyst may be absent in poorly-preserved material, suggesting that it may be susceptible to physico-chemical degradation. In extreme cases, the processes may also be degraded. The operculum is small, flattened and short accessory archaeopyle sutures are normally developed.

*Dimensions (μm, n=25): Min. (Mean) Max.*

- Length of entire cyst: 37 (43) 52
- Length of loistochnyst: 32 (39) 50
- Width of epicyst incl. ornament*: 14 (21) 31
- Width of hypocyst incl. ornament**: 34 (44) 59
- Length of processes/height of ectocyst: 1 (2) 5

* - measured at the principal archaeopyle suture  
** - measured at the antapex

The measured specimens are from conventional core samples in Lorikeet-1 well at 1759.10m and 1756.70m and Mutineer-1B well at 3132.25m, sidewall core samples from Jurabi-1 well at 1140.00m and Scfell-1 well at 1418.00m and ditch cuttings from Avocet-1A well between 1775.00m and 1780.00m, Broome-1 Bore at 297.79m and Peak-1 well between 1493.54m and 1496.59m.

*Comments.* This species is highly variable in morphology due to the apparent susceptibility of the ectocyst to physico-chemical degradation. In well-preserved material, a continuous ectocyst is supported by numerous processes (Figs 2M-O). However, the ectocyst is frequently incomplete (e.g. Figs 2E-G). In poorly-preserved material, both the processes/spines and ectocyst are missing (Figs 2D, H). Most specimens of *A. variabile* are small and the
majority loisthocysts. The ectocoeel is normally narrow; from 1-5μm across. In some specimens, the processes are longest at the antapical-lateral lobes, broadening the ectocoeel in those areas.

Comparison. Ampulladinium variabile closely resembles Woodinia benstonii Riding & Helby (this volume) in morphology. However, the latter is significantly smaller, frequently more elongate and antapically concave. Furthermore, W. benstonii is not holocavate and is characterised by intratubular areas of ornamentation or differentiated autophragm on the major paraplate series.

Derivation of name. From the Latin, variabilis meaning different or changeable and referring to the varied wall structure and ornamental styles of this species.

Holotype and type locality. Figures 21-L., CPC 35896, from a ditch cuttings sample in Avocet-1A well between 1775.00m and 1780.00m.

Stratigraphical distribution. Ampulladinium variabile ranges from the Tithonian upper Dinoaulacritum jurassicum Zone (5a ii) to the lower Pseudoceratitum iehense Zone (4ciiia) (Foster, this volume; Helby & Partridge, in prep.).

Balcattia Cookson & Eisenack 1974 emend. Riding, Helby & Stevens

Type species. Balcattia cirrifera Cookson & Eisenack 1974

Emended diagnosis. Intermediate to large, acavate, chorurate dinoflagellate cysts. Autophragm smooth or with low-relict ornamentation; low parasutural ridges and short, nontubular elements may occur. Cyst body subspherical to elongate ellipsoidal, bearing long, solid or hollow processes, which may be distally connected by trabeaculae. The intratubular processes are confined to the polar regions and may be present on each of the antapical, posterior intercalary, postcingular, precingular and apical paraplates. The processes (and the parasutural ridges where developed) indicate a gonystacalean paratabulation pattern. Archaeopyle apical; operculum simple and free. Paracingulum not indicated; parasulcus only indicated by the parasulcal notch.

Comments. The generic concept is emended above to accommodate our observations of the illustrations of Balcattia cheleusis Riding, Helby & Stevens sp. nov. and Balcattia sp. A of Helby et al. (1987, figs 271-27K). The generic synthesis of Stover & Evitt (1978, p. 20) closely followed the original diagnosis of Cookson & Eisenack (1974, p. 78) and Stover & Evitt concluded that the posterior structure is '...formed of indistinct longitudinal strands joined antapically and loosely connected laterally'. We consider that the toptype of Cookson & Eisenack (1974, pl. 28, fig. 16) clearly exhibits separate, distally trabeculate processes, in contradistinction to the Stover & Evitt interpretation. The holotype also exhibits antapical processes, although they are not as clearly defined as those on the toptype. Distally trabeculate, apical processes are also distinct on the specimen of B. cirrifera illustrated by Morgan (1980, pl. 2, figs 6, 7). Where postcingular and precingular processes occur, they are migrated to the polar margins of their respective paraplates.

The polar disposition of the processes on B. cheleusis, particularly the antapical processes, parallels the migration of the major processes on B. cirrifera. This concept of process migration is also encountered in Belosvia Riding & Helby (see below) and Hadriana Riding & Helby (this volume). While the anterior process groups on B. cirrifera are on the apical paraplates, the posterior processes on B. cheleusis are located close to the apical margins of the precingular paraplates. Although these differences are significant, other similarities suggest that a separate genus is not warranted. Balcattia sp. A of Helby et al. (1987) has low, smooth parasutural ridges.

Balcattia cheleusis Riding, Helby & Stevens sp. nov. (Figs 3A-P)

1994 Rigaudella sp. B; Bint & Marshall, fig. 5.15.

Previous Australian usage
Emmetrocysta cheleusis Stevens & Helby (manuscript name).

Rigaudella separata – Parker (1986, p. 99-100, fig. 5.41, pl. 21, figs 3-6).
Rigaudella separata – Helby, MP 346 – Helby.

Description. A species of Balcattia with a large, elongate ovoidal to subquadranular cyst body. A small antapical protuberance may be present and the precingular area is occasionally indented. The autophragm is moderately thin (0.5-1μm), smooth to occasionally shagreenate or irregularly microscabrulate. Intratubular processes, which are
Fig. 3. Balcantia chelessis Riding, Holby & Stevens sp. nov. Specimens from sidewall core samples in Nancar-1 well at 3240.00m (Fig. 3O), Scafell-1 well at 1421.00m (Figs 3A-C, L) and 1418.00m (Figs 3G-H, N), Wanaca-3 well at 2964.00m (Figs 3E-F) and ditch cuttings from Mindil-1 well between 3150.00m and 3155.00m (Figs 3D, I-K, M, P). All photomicrographs taken using plain transmitted light. The scale bar in Fig. 3O refers to all photomicrographs and is 25 μm. Figures 3E-F are the holotype; remainder are paratypes. Note elongate ovoidal cyst body, 12-13 distally expanded, trabeculate intratabular processes inserted close to poles (i.e., have migrated), and apical archaephysele. A, B - CPC 35999, paratype; dorsal view, high and median focus respectively. Note smooth autophagy of the cyst body and how subpolar processes branch medially. C - CPC 35900, paratype; oblique ventral view, high focus. Note wide equatorial area devoid of processes. D - CPC 35901, paratype; oblique dorsal view, high/median focus. Note strongly distally trabeculate nature of the subpolar processes. E, F - F49909, holotype; ventral view, high and median/low focus respectively. Note strong equatorial constriction of cyst body and parasaccicular notch in E. G, H - CPC 35902, paratype; ventral view, high/median and low focus respectively. Note elongate cyst body and small antapical protuberance surmounted by the 1st process. I - CPC 35903, paratype; dorsal view, low focus. Note regular nature of intratabular processes. J, K - CPC 35904, paratype; dorsal view, median and low focus respectively. Note small antapical protuberance with its intratabular process. L - CPC 35905, paratype; dorsal view, median focus. Note largely hollow nature of processes. M - CPC 35906, paratype; dorsal view, median focus. Note antapical part of cyst body is relatively wide in this specimen. N - CPC 35907, paratype; ventral view, low focus. Specimen with relatively squat cyst body. O - CPC 35908, paratype; dorsal view, median focus. Form with relatively wide processes. P - CPC 35909, paratype; oblique ventral view, median focus. Distal trabeculum in this specimen is damaged.
variable in morphology, are present on the precingular, postcingular, posterior intercalary and antapical paraplates. The hypocyst generally bears 7 processes and the epicyst has 5-6 processes. Processes are entirely absent in the paracingular area and the precingular and postcingular processes are inserted high and low respectively. This factor highlights the process-free equatorial region. The processes are variable in length (see dimensions, below), slender to wide (3-12\(\mu\)m), mostly hollow, although some may be solid, and others vacuolate. They are always distally expanded. At around midlength each process subdivides distally into slender, solid elements, which generally connect to the other processes and form a trabeculate ectophragmal layer. This expansion normally involves complex branching of the processes into fenestrate funnels. The processes may be interconnected by 1 to 5 slender trabeculae emanating from the distal parts of the processes. Alternatively, the distal part of the processes forms a complex, sheetlike, fenestrate ectophragm, which extends and connects to the other processes. There are no trabeculate connections between the epicyst and hypocyst. All the specimens studied were loisthocysts and no free opercula were recognised.

**Dimensions (\(\mu\)m, n=26):**

**Min. (Mean) Max.**

Length of cyst incl. processes: 105 (141) 170
Length of cyst body (excl. processes): 56 (69) 94
Width of cyst incl. processes: 73 (104) 135
Width of cyst excl. processes: 37 (54) 78
Length of processes: 27 (45) 66

The measured specimens are from a conventional core sample from Matinee-1B well at 3147.60m, side wall core samples from Nancar-1 well at 3240.00m, Purane-1 well at 172.00m, Scatell-1 well at 142.00m and Wanaea-3 well at 2964.00m and ditch cuttings from Broome-1 Bore at 297.79m and Mindil-1 well between 3150.00m and 3155.00m.

**Comments.** This distinctive species of *Balcatta* is large, and the size range is considerable. The processes have a bipolar distribution and are positioned high on the precingular paraplate series and low on the postcingular paraplate series (Fig. 3). All of the specimens studied were loisthocysts, and these were oriented by the position of the archaeopyle and the occasional presence of a small antapical protruberance. Where present, this protruberance bears the "juven" process. The processes are somewhat variable in morphology. Most are relatively long and slender (e.g. Figs 3A, 3B); however, short and wide processes, although rare, were also observed (Fig. 3D). Only especially slender processes (1-2\(\mu\)m in width) are solid, all others being hollow (Fig. 3). On some specimens the precingular processes may be significantly shorter than those near the antapex (specimens not illustrated). The specimens examined from the Broome-1 Bore do not exhibit distal trabeculation.

This species was originally informally assigned to *Emmetrocysta* Stover 1975 by Stevens & Helby (unpublished). However, that genus is characterised by paraplate-centred process complexes which are not joined by trabeculate strands and it is substantially smaller and consistently subshpherical (Stover, 1975). Despite the substantial differences between *B. chelesis* and the genotype, we consider the erection of a new, monotypic genus for *chelesis* to be unwarranted. *B. chelesis* has some major features in common with *Oligosphaeridium* Davey & Williams 1966 and *Rigaudella* Below 1982, but the affinities of *Balcatta* remain uncertain (Fensome et al., 1993, p. 117).

**Comparison.** *Balcatta chelesis* differs from the genotype, *B. cirrifera*, in having an elongate cyst body and processes at the apical margins of the precingular paraplates, as opposed to processes on the apical series in the latter. *Balcatta chelesis* is also substantially larger than *B. cirrifera*. *Balcatta chelesis* is larger than *B. cirribarbata* Cookson & Eisenack 1982, which also has short, nontabular processes in the central area of the cyst body. *Balcatta* sp. A of Helby et al. (1987, figs 271-K) is also significantly smaller than *B. chelesis*. The former morphotype is nontabulate and lacks precingular processes.

**Derivation of name.** From the Greek, chelesis meaning a netting and referring to the complex distal trabeculation of this species.

**Holotype and type locality.** Figures 3E-F, Geological Survey of Western Australia specimen F.49309, sidewall core sample from Wanaea-3 well at 2964.00m. This specimen was figured as *Rigaudella* sp. B by Bint & Marshall (1994, fig. 5.15).

**Stratigraphical distribution.** *Balcatta chelesis* is confined to the Tithonian and ranges from the upper *Dingodinium jurassicum* Zone (5ai) to the lower *Pseudoceratium iehiense* Zone (4ciib) (Foster, this volume; Helby & Partridge, in prep.).
**Batioladinium** Bideaux 1975

*Type species.* *Batioladinium jaegeri* (Alberti 1961)
Bideaux 1975 emend. Below 1990

*Comments.* Pourtoy (1988, p. 390) proposed the inclusion of forms without polar horns from *Batioladinium.* We concur with Lentin & Vozzhennikova (1990, p. 82), and do not follow Pourtoy’s emendation.

**Batioladinium paeminosum** sp. nov. (Figs 4A-P)

1990 *Necrobroomea* sp.; Below, pl. 13, fig. 20.
1994 *Batioladinium* sp. A; Bint & Marshall, fig. 5.2.

*Previous Australian usage*
Parker, p. 38, 39, pl. 2, fig. 9.

*Batioladinium protojaegeri* — Helby.

*Description.* An intermediate to large species of *Batioladinium* which is slightly dorsoventrally flattened with a thick, robust autophagm and low ornamentation. The autophagm is about 2µm thick and is covered with dense, nontubular rugulate to verrucate ornamentation. The rugulae comprise relatively short, undulose ridges, mostly 2 to 3µm wide, which may break up into irregular verrucae. The high density and irregular nature of the verrucae, particularly on the hypocyst, may give rise to a "scrollwork" pattern of ornamentation. The ornamentation varies in height from about 0.5 to 1µm and becomes markedly more prominent towards the antapical area. The paracingulum is slightly indented, has reduced ornamentation and may bear low, discontinuous, parasutural ridges and reduced ornamentation. The epicyst is longer than the hypocyst. The anterior part of the parasutal lies in the area between the offset ends of the paracingulum and below the ventral notch (6'/7') of the principal arthropleura suture. The single apical and paired antapical horns are variable in length, typically having solid distal portions and rounded to pointed distally. The left antapical horn is larger than the right and both antapical horns may be markedly reduced.

*Dimensions* (µm, n=30); Min. (Mean) Max.
Length of entire cyst incl. horns: 82 (109) 146
Length of loisthocyst incl. horns: 55 (72) 93
Length of operculum: 44 (66) 81

Maximum width: 25 (33) 45
Length of apical horn: 10 (30) 55
Length of the left antapical horn: 4 (11) 22

The measured specimens are from conventional core samples in Lambert-2 well at 3101.00m, Lorikeet-1 well at 1761.20m and 1759.10m, Mutineer-1B well at 3132.25m, Wanaca-2 well at 2880.50m and 2875.30m and sidewall cores from Avocet-1A well at 1780.00m, 1778.00m, 1777.00m and 1771.50m, Scafell-1 well at 1418.00m and Zeewulf-1 well at 3085.00m.

*Comments.* *Batioladinium paeminosum* is characterised by the prominent rugulate-verrucate autophagm, especially on the hypocyst, the size of ornament elements diminishing towards the apex (Fig. 4). The ornamentation may be slightly irregular, variable in height and/or reduced in some specimens (Fig. 4). Many forms have relatively short antapical horns and the length of the apical horn is extremely variable (see above). In most specimens, the horns are distally rounded and in some individuals the outline of the antapical horns is disrupted by the ornamentation. Individuals with highly reduced antapical horns and in which the arthropleura has not opened could be misidentified as *Pareodinia Deflandre 1947* (Fig. 4M). Species of *Pareodinia* resembling *B. paeminosum* occur throughout the stratigraphical range of the latter. Rarely, morphotypes similar to *Batioladinium paeminosum* but with a microreticulate autophagm have been observed.

*Comparison.* *Necrobroomea* sp. of Below (1990, pl. 13, fig. 20), from the Volgian of the Russian Platform, closely resembles *Batioladinium paeminosum,* and is indistinguishable from some end members of the species. The ornamentation of the specimens of *Necrobroomea micropoda* (Eisenack & Cookson 1960) Wiggins 1975 emend. Below 1990, as figured by Below (1990, pl. 13, figs 17-19) closely resembles that of *B. paeminosum.*

*Batioladinium paeminosum* differs from the other species of the genus by the rugulate-verrucate ornamentation which diminishes in size apically. The majority of species of this genus, including the genotype *Batioladinium jaegeri* (Alberti 1961) Bideaux 1975, are pnisate or have extremely low relief ornamentation (Alberti, 1961). *Batioladinium daviesii* Lentin & Vozzhennikova 1990, *B. nathjae* Poulsen 1996 and *B. micropoda,* however, have a granulate autophagm. The early Cretaceous species *Batioladinium? gochii* (Alberti 1961) Lentin & Williams 1977 has a tuberculate autophagm, is pareodinoid in outline,
Fig. 4. *Batioladinium paucinodum* sp. nov. Specimens from conventional core samples in Lorikeet-1 well at 1759.10m (Figs 4N-P), Mutineer-1B well at 3132.25 (Fig. 4E) and Wanaea-2 well at 3375.34m (Figs 4K-L), 2880.50m (Figs 4F-H) and 2875.30m (Figs 4A-D, I, J, M). All photomicrographs taken using plain transmitted light. The scale bar in Fig. 4P refers to all photomicrographs and is 25μm. Figs 4N-P are the holotype; the remainder, paratypes. Note the thick autophragm covered with dense, nontubular (continued opposite)
has only a single antapical horn and is normally more squat than \textit{B. paeminus}. \textit{Batioladinium? pelliferum} (Alberti 1961) Brideaux 1975 is also relatively squat and has an autophragm which is densely covered in short, slender spines and ornament that Alberti (1961) referred to as ‘fur-like’. The lower Neocomian species, \textit{B. reticulatum} Stover & Helby 1987, is holocavate and has a reticulate ephragm (Stover & Helby, 1987).

\textit{Derivation of name.} From the Latin, \textit{paeminus} meaning rough or uneven, referring to the coarse regulare- verrucate ornamentation of this species.

\textit{Holotype and type locality.} Figures 4N-P, CPC 35917, from a conventional core sample in Lorikeet-1 well at 1759.10m.

\textit{Stratigraphical distribution.} \textit{B. paeminus} is confined to the Tithonian Pseudoceratium ichicnes Zone (subzones 4ciib to 4ciib) (Foster, this volume; Helby & Partridge, in prep.).

\textit{Belowia} gen. nov.

\textit{Type species.} \textit{Belowia} batteus sp. nov.

\textit{Diagnosis.} Intermediate to large dinoflagellate cysts, which vary from proximate to chorate. The subspherical to ellipsoidal cyst body is markedly indented at the parasulcus. A hollow ephragm projection occurs at the paracingulum. The hypocyst commonly bears a further ephragm projection which, in most cases, encompasses the major processes, where developed. This hypocyst ephragm is highly variable: in the chorate forms, it may be virtually absent and the major hypocystal processes may be well developed. The paratabulation is standard gonyaulacalean, indicated by the intratabular postcingular processes, where developed, and the principal archaeopyle suture. Archaeopyle apical; operculum free.

\textit{Comments.} \textit{Belowia} is a morphologically complex and unusual genus; Figs 5 to 8 illustrate the principal features. It is ellipsoidal to subcircular in polar outline and has an apical archaeopyle. The cyst wall comprises autophragm and ephragm. The ephragm separates from the autophragm on the posterior part of the precingular paraplate series. Major processes in the postcingular paraplate series may support and/or may be incorporated into the hypocystal ephragm. Numerous trabecular processes also emerge from the vicinity of the anterior and posterior paracingular parasutures to form a hollow paracingular ephragmical tunnel, which is interrupted at the parasulcus.

\textit{Comparison.} The Kimmeridgian–Tithonian genus \textit{Hadriana} Riding & Helby (this volume) is very similar to \textit{Belowia}. They both have a small, essentially smooth epicyst, devoid of processes, and wall separation occurring close to the posterior limits of the precingular paraplates. Although there are marked hypocystal differences, both genera display major ephragmical development at and below the paracingulum. However, \textit{Hadriana} lacks a paracingular tunnel, large processes and the ephragm is widely open antapically (the opening is about twice the autocyct diameter).

\textit{Stephodinium} Deflandre 1939 emend. Davey 1970 is characterised by an inflated paracingular periphery gulation protrusion. It is distinguished from \textit{Belowia} by having a cavit e wall relationships, a precingular archaeopyle and by lacking trabeculate ephragmical processes. \textit{Belowia} differs from trabeculate chorate dinoflagellate cyst genera like \textit{Adnatosphaeridium} Williams & Downie 1966, \textit{Hapsidinax} Sarjeant 1975, \textit{Hystrichosphaerina} Alberti 1961, \textit{Polystephanophorus} Sarjeant 1961 and \textit{Rugoidella} Below 1982 in having a distinctive ephragmical tunnel along the paracingulum and in lacking intratabular processes in the apical and precingular paraplate series. \textit{Balteocysta} Stover & Evitt 1978 has a regulare- verrucate ornamentation which typically increases in height antapically, the paracingulum low on the cyst body, the relatively short polar horns and the apical archaeopyle. A, B - CPC 35910, paratype; ventral view, high and low focus respectively. Note principal archaeopyle suture and prominent parasulcal notch. C, D - CPC 35911, paratype; oblique dorsal view, median and low focus respectively. Note small antapical horns. E - CPC 35912, paratype; ventral view, high focus. Slightly damaged, note parasulcal notch. F-H - CPC 35913, paratype; dorsal view, high to low focus sequence. Note low-relief ornamentation and parasulcal notch in 4G, I - CPC 35914, paratype; right lateral view, high and median focus respectively. Note slightly offset operculum with prominent apical horn. K, L - CPC 35915, paratype; dorsal view, high and medium low focus respectively. Note damaged apical horn. M - CPC 35916, paratype; oblique left lateral view, high focus. Note prominent apical horn and reduced antapical horns. N-P - CPC 35917, holotype; ventral view, high to low focus sequence. Note offset operculum and parasulcal notch in 4N. The operculum has been digitally relocated closer to the lochocyct.
Fig. 5. *Bellowsia baltica* sp. nov. All are paratypes from outcrop sample 81FH11, Lelinta Formation, Misool, eastern Indonesia (Hasbuan, 1990) and are examples of the larger, more common morphotype 1. All photomicrographs taken using plain transmitted light. The scale bar in Fig. 5L refers to all photomicrographs and is 25μm. Note ellipsoidal cyst body, indented parasuleal region, short paracingular processes, trabeulate ectophragmal skirt-like structure which envelops hypocyst, and apical archaephylobe. A-C - CPC 35918, paratype; apical view, high to low focus sequence. Note short paracingular processes and apical archaephylobe. D-F - CPC 35919, paratype; antapical view, low to high focus sequence. Note skirt-like, distinctly trabeulate ectophragmal structure covering hypocyst. G-I - CPC 35920, paratype; apical view, high to low focus sequence. Note relatively wide postcingular processes which connect autophragm of the cyst body to ectophragm, and prominent antapical opening in the ectophragm (Fig. 5I). J-L - CPC 35921, paratype; antapical view, low to high focus sequence. Note wide postcingular processes and subcircular opening in ectophragm at antapex (Fig. 5L).
subpherical cyst body and an ectophragm which is confined to the paracircular region.

**Derivation of name.** For Dr Raimond Below.

**Belowia balteus** sp. nov. (Figs 5A-L, 6A-F, 7A-L)

**Previous Australian usage**
Belowia sp. – Hebel.

**Description.** A species of Belowia with an ellipsoidal cyst body, that in polar view, is indented at the parasulcus. The autophragm is 1-1.5µm thick and usually densely striate to occasionally rugulate, especially close to the postcingular processes. It may also be verrucate and irregularly and sparsely reticulate. The ectophragm is extremely variable in form, ranging from a sparse trabeculum, through a wide, complex trabeculum, to a thin (0.5µm), perforate wall. Relatively short, solid, trabeculate processes consistently emerge from the vicinity of the anterior and posterior paracircular sutures. These form a projecting ectophragmal tunnel along the paracingulum, terminating at the relatively broad parasulcus. Close to the top of the postcingular paraplate series, a skirt-like ectophragmal structure is generally developed which extends antapically. This ectophragmal skirt may be supported by five intratabular postcingular processes representing paraplates 2" to 6", or by a variable number of nonintratabular processes. The processes are displaced toward the anterior margin of the paraplates. Where developed, the processes are extremely variable and may be slender, solid, wide or hollow and occasionally merge distally with the ectophragm. The ectophragmal skirt commonly terminates antapically in an open, solid girdle-like structure (Figs 5I, L), but this structure is sometimes absent (Fig. 7L). The strongly indented parasulcus is frequently indicated by a low, smooth parasutural ridge. The operculum is
Fig. 7. Belovia halteres sp. nov. All are paratypes from outcrop sample 81FH11 of the Lelinta Formation, Misool, eastern Indonesia (Hasibuan, 1990) and are examples of the smaller, relatively rarer morphotype 2. All photomicrographs were all taken using plain transmitted light. The scale bar in Fig. 7L refers to all the photomicrographs and is 25 μm. Note oblate ellipsoidal cyst body with markedly indented parasulcal region, narrow ectocoele below the reticulate ectophragm surrounding the hypocyst, the absence of intratabular postcingular processes and the apical archaeopyle. A-C - CPC 35924, paratype; antapical view, low to high focus sequence. Note apical archaeopyle in Fig. 7A and prominent antapical lacuna in Fig. 7C. D-F - CPC 35925, paratype; antapical view, low to high focus sequence. Note angular principal archaeopyle suture and (continued opposite)
normally free, but specimens were observed where the operculum has fallen back into the autecyst.

**Dimensions (μm, n=57): Min. (Mean) Max.**
- Maximum overall lateral diameter: 83 (118) 159
- Maximum lateral diameter of cyst body: 64 (91) 107
- Maximum overall dorsoventral diameter: 80 (110) 151
- Maximum dorsoventral diameter of cyst body: 63 (85) 105
- Height of paracingular processes/trabeicum: 3 (8) 19
- Height of postcingular processes/trabeicum: 8 (18) 35

The measured specimens are from ditch cuttings in Tenacious-1 ST1 well between 2975.00m and 2980.00m and outcrop material from the Tithonian Lelinta Formation (Fage Group) of Misool, eastern Indonesia (Hasibuan, 1990; Helby & Hasibuan, 1988).

The 57 specimens in the above table comprise 37 of a larger morphotype 1 with distinct postcingular processes (Figs 5, 6), 14 examples of the smaller morphotype 2, with a more continuous perforate ectophragm (Fig. 7), and 6 intermediate forms. The dimensions of morphotypes 1 and 2 are set out below to document the size differences between these two end members of a continuously variable complex. The dimensions of the intermediate forms are not tabulated. The tables below principally illustrate the difference in the size of the ectophragm of the two morphotypes. Thus the maximum overall lateral and dorsoventral diameters are significantly different while other measurements are comparable.

**Morphotype 1, Dimensions (μm, n=37): Min. (Mean) Max.**
- Maximum overall lateral diameter: 83 (124) 159
- Maximum lateral diameter of cyst body: 64 (92) 107
- Maximum overall dorsoventral diameter: 86 (116) 151
- Maximum dorsoventral diameter of cyst body: 63 (85) 102
- Height of paracingular processes/trabeicum: 3 (8) 19
- Height of postcingular processes/trabeicum: 12 (19) 35

The above specimens are from Tenacious-1 ST1 well at 2975.00m-2980.00m and the Tithonian part of the Lelinta Formation of Misool, eastern Indonesia.

**Morphotype 2, Dimensions (μm, n=14): Min. (Mean) Max.**
- Maximum overall lateral diameter: 91 (104) 130
- Maximum lateral diameter of cyst body: 78 (89) 105
- Maximum overall dorsoventral diameter: 80 (100) 118
- Maximum dorsoventral diameter of cyst body: 66 (85) 105
- Height of paracingular processes/trabeicum: 4 (8) 14
- Height of postcingular processes/trabeicum: 8 (14) 29

The above specimens are all from sample 81FH11 in the Lelinta Formation of Misool, eastern Indonesia (Tithonian).

**Comments.** The morphology of the processes and the ectophragm are extremely variable. As indicated above, two morphotypes are recognised, both of which are mainly found as polar compressions. The relatively common morphotype 1 (Figs 5, 6) normally has intratubular postcingular processes which support a skirt-like ectophragmal trabeicum that is open antapically and terminates in a solid, girdle-like structure (Figs 51, L). The postcingular processes are located unusually high on the postcingular paraphylete series. Because the ectophragm is made up of thin elements, it is prone to folding. Thus the size and polar outline of the ectocyct are somewhat variable (Figs 5, 6). The relatively rare morphotype 2 (Fig. 7), lacks postcingular processes, the ectocyct is relatively narrow and the ectophragm is reticulate with lacunae of varying sizes (Fig. 7). Most lacunae are relatively small (1-3μm), but some may be considerably larger. These two variants are not assigned to separate taxa because intermediate forms occur and all variants have the same stratigraphical range.

**Comparison.** Beloria is currently a monotypic genus and thus the principal comparisons with other taxa are at the generic level (see above). Specimens of morphotype 1 of Beloria baltica and Beloria sp. A herein, however, resemble variants of Riguidella aemula (Dellandre 1939) Below 1982. This similarity is confined to the postcingular paraphylete series, where the large, paired antapical lacunae, G-I - CPC 35926, paratype, antapical view, low to high focus sequence. A pale specimen, note large antapical lacuna in Fig. 7. J-L - CPC 35927, paratype, apical view, high to low focus sequence. Note the prominent, relatively broad ectocyct.
Fig. 8. Beowia sp. A. All are from ditch cuttings between 2945.00m and 2950.00m in Crux-I well. All photomicrographs were taken using plain transmitted light. The scale bar in Fig. 8L refers to all photomicrographs and is 25μm. Note large overall size, ellipsoidal cyst body, short trabeculate processes in paracingular region, prominent intratabular, trabeculate postcingular processes which vary significantly in morphology, and apical archaeopyle. A-C - CPC 35928, slightly oblique apical view, high to low focus sequence. (continued opposite)
intratabular processes are connected distally by narrow trabeculae (compare Below, 1982, figs 22-34). The other paratype series lack these, therefore the two forms can be readily distinguished.

**Derivation of name.** From the Latin baleus, meaning girdle or belt and referring to the characteristic variable ectophragm which surrounds the majority of the hypocyst.

**Holotype and type locality.** Figures 6A-C, CPC 35922, from outercrop material of the Lelinta Formation, Misool, eastern Indonesia. This is a specimen of morphotype 1.

**Stratigraphical distribution.** *Belowia baleus* has been recorded from the Tithonian *Cribroperidinium perforans* Zone (5d) to the *Omatia montgomery* Zone (5e) in the Timor Sea region (Foster, this volume; Helby & Partridge, in prep). The species is also present in the Tithonian lower part of the Lelinta Formation (Fageo Group) of Misool, eastern Indonesia.

**Belowia** sp. A (Figs 8A-L)

**Previous Australian usage**

**Belowia** sp. – Helby.

**Description.** A relatively large form of *Belowia* with an ellipsoidal cyst body which is slightly indented at the paracone. The autophragm is smooth, occasionally microscabrate and may be irregularly microreticulate. Relatively short, solid, trabecular processes emerge from the anterior and posterior paracingular sutural regions. These processes form a projecting ectophragmal tunnel of variable height along the paracingulum which terminates at the paracone (Figs 8A, B). Large, extremely variable intratabular postcingular processes, which flare distally and are connected distally by trabecular filaments, are present. The processes may be slender, solid, wide or hollow and occasionally appear to merge distally with the ectophragmal trabeculae. These prominent intratabular processes vary in width from 3-19μm. They are also highly variable in length (Fig. 8); the shortest and longest observed measured 17μm and 65μm in length respectively. The filaments of the trabeculae are solid and vary from 1-9μm. The operculum is normally free; however, specimens were observed where the operculum has fallen into the autocyst.

**Dimensions** (μm, n=17): Min. (Mean) Max.
- Maximum overall lateral diameter: 101 (144) 193
- Maximum lateral diameter of cyst body: 77 (94) 113
- Maximum overall dorsoventral diameter: 97 (123) 143
- Maximum dorsoventral diameter of cyst body: 61 (83) 96
- Height of paracingular processes/trabeculum: 4 (10) 22
- Height of postcingular processes/trabeculum: 21 (34) 55

All specimens are from a ditch cuttings sample in Crux-1 well between 2945.00m and 2950.00m.

**Comments.** This form is not given a specific name because sufficient material is currently unavailable. *Belowia* sp. A lacks the hypocyst ectophragmal skirt which is characteristic of *B. baleus*. The ectophragm is confined to trabecular filaments which connect the large postcingular processes and the paracingular ectophragmal tunnel (Fig. 8). The postcingular processes which prominently flare distally may occasionally split into several distal trabecular strands. Because of the large postcingular processes, oblique compressions of this morphotype are common (Fig. 8). The paracingular processes are relatively variable in height (see Dimensions, above).

**Comparison.** *Belowia* sp. A differs from *B. baleus* in being slightly larger, lacking a hypocyst ectophragmal skirt and having large intratabular postcingular processes connected by distal trabeculae.

**Stratigraphical distribution.** *Belowia* sp. A has been recorded from the Tithonian *Cribroperidinium perforans* Zone (5d) to the *Omatia montgomery* Zone (5e) in the Timor Sea, (Foster, this volume; Helby & Partridge, in prep).

**Biorbifera** Habib 1972 emend.


**Type species.** *Biorbifera johnswenii* Habib 1972

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Note ectophragmal 'tunnel' formed by short, solid paracingular processes in 8A-B. D-F - CPC 35929, apical view, high to low focus sequence. Morphotype with relatively short postcingular processes. G-I - CPC 35930, oblique apical view, high to low focus sequence. Note highly variable length of postcingular processes. J-L - CPC 35931, lateral view, high to low focus sequence. Note extremely wide postcingular process to left.
Fig. 9. *Biorhiza ferox* sp. nov. Specimens from conventional core samples in Lambert-2 well at 3101.00m (Fig. 9P), Lorikeet-1 well at 1761.20m (Figs 9M, O), Mutineer-1B well at 3132.24m (Fig. 9N) and Wanaea-3 well at 2929.67m (Fig. 9T), sideward core samples in Avocet-1A well at 1771.50m (Figs 9E-L) and ditch cuttings from Avocet-1A well between 1770.00m and 1775.00m (Figs 9A-D) and Broome-1 Bore at 297.79m (Figs 9Q-S). All photomicrographs taken using plain transmitted light. The scale bar in Fig. 9T refers to all photomicrographs and is 25μm. Figs 9E-L are the holotype, the remainder are paratypes. Fig. 9R is a composite photomicrograph. Note small size, thick, microreticulate autophragm, prominent paracingulum, partiform paratabulation pattern, polar concentration of processes and epicrystal archaeopyle, A-D - CPC 35932, paratype; lateral view, high to low focus sequence. Note elongate ellipsoidal outline. E-H - CPC 35933, paratype; lateral view, high to low focus sequence. Note polar processes and epicrystal archaeopyle. I-L - CPC 35934, holotype; lateral view, high to low focus sequence. Note gonial nature of many of the processes. M - CPC 35935, paratype; (continued opposite)
Emended diagnosis. The diagnosis given by Below (1987, p. 63) is further emended to include the fact that *Biorbifera* has a paratiform gonyaulacalean paratabulation pattern which may be indicated by parasutural ridges, crenae or processes. The paratabulation formula of ?pr, 4', ?2a, 6", ?6c, 6", 2"", Xs was determined during the study of *Biorbifera ferox* sp. nov.

**Comments.** The original generic diagnosis of Habib (1972) was emended by Below (1987, p. 63) to include proximochrome and chorate forms, the processes of which may be nontabular and/or parasutural and gave a paratabulation formula. The material of *Biorbifera johnewingii* which was studied by Below (1987, pl. 27, figs 1-7, 13, 14, 19, 20), however, exhibits few unequivocal parasutural features. Australian material of *B. johnewingii* exhibits slender, low parasutural ridges (unpublished information). The material of *B. ferox* in this study has a full paratiform gonyaulacalean paratabulation (Evitt, 1985), indicated by prominent, low, smooth parasutural ridges. A paratabulation formula of ?pr, 4', ?2a, 6", ?6c, 6", 2"", Xs has been determined.

*Biorbifera ferox* sp. nov. (Figs 9A-T)

1994 *Biorbifera* sp.; Bint & Marshall, fig. 5.6-5.11.

**Previous Australian usage**

*Biorbifera aggregata* – Helby.

**Description.** A species of *Biorbifera* with a small, elongate ellipsoidal outline, which is slightly dorsoventrally compressed. The autophagam is microticular and robust, between 1-1.5 µm thick. The prominent paracingulum, which may be slightly incised, bears reduced ornamentation. The paracingulum is slightly displaced anteriorly, thereby making the hypocyst consistently larger that the epicyst. The hypocyst is normally wider than long and has a flattened to angular antapex. The epicyst is flattened or rounded apically. A paratiform gonyaulacalean paratabulation pattern is indicated by thick, low, smooth parasutural ridges. The parasutural ridges vary from 1 to 1.5 µm in width and height and include a paratabulation formula of ?pr, 4', ?2a, 6", ?6c, 6", 2"", Xs. Slender, solid, distally pointed processes are concentrated at the polar areas. They are mainly parasutural (gonal and intergonal), but nontabular processes are also present. The parasulus is narrow and not obviously subdivided.

**Dimensions** (µm, n=35) excl. processes where appropriate: Min. (Mean) Max.

- Length of entire cyst: 19 (24) 33
- Length of epicyst*: 6 (8) 11
- Length of paracingulum: 2 (2.5) 4
- Length of hypocyst*: 11 (14) 20
- Equatorial width of cyst: 16 (21) 26
- Length of spines: 3 (4) 6

* - measured dorsally

The measured specimens are from conventional core samples in Lorne-1 well at 1761.20m and Mutineer-1B well at 3132.25m, sidewall core samples from Avocet-1A well at 1771.50m and 1778.00m and ditch cuttings samples from Avocet-1A well at between 1770.00m and 1775.00m and Broome-1Bore at 297.70m.

**Comments.** *Biorbifera ferox* is a distinctive small cyst readily identifiable by the epicystal archaeopyle, thick autophagam, well marked paratabulation, particularly on the hypocyst and the apparent concentration of spines at the poles. In poorly preserved material, these processes may be lost. The processes on the precingular paraplates appear to be especially susceptible to damage. Processes have not been observed on the postcingular paraplates apart from the antapical margins. The parasutural ridges suggest a paratiform gonyaulacalean paratabulation pattern with a formula of ?pr, 4', ?2a, 6", ?6c, 6", 2"", Xs (Fig. 9). The paired antapical paraplates are the most characteristic feature of this pattern (Figs 90, T). No well preserved isolated epicysts were encountered, therefore the number and configuration of preapical and anterior intercalary paraplates could not be precisely determined. At least two anterior intercalary paraplates appear to
Fig. 10. Cassiculospheridia solida sp. nov. Specimens from ditch cuttings from Crux-1 well between 3045.00m and 3050.00m (Figs 10A-D, H-K, M-P) and 2945.00m to 2950.00m (Figs 10E-G, L). All photomicrographs taken using plain transmitted light. The scale bar in Fig. 10P refers to all photomicrographs and is 25um. Figs 10E-G are the holotype; the remainder, paratypes. Note subcircular outline, extremely thick autophagm with strong, corrugate ornamentation, ridges which may form an irregular reticulum, and apical archaeopyle. A, B - CPC 35942, paratype; lothocyst in ventral view, median and low focus respectively. Note accessory archaeopyle sutures and crude reticulate pattern formed by autophragmal ridges. C, D - CPC 35943, paratype; lothocyst in dorsal view, high and median focus respectively. Note relatively smooth paracingulum. E-G - CPC 35944, holotype; lothocyst and operculum in dorsal view, high to low focus sequence. Note relatively well developed reticulum. H - CPC 35945, paratype; lothocyst in dorsal view, median focus. Note apical archaeopyle suture. I - CPC 35947, paratype; full cyst in ventral view, median focus. Note relatively inflated operculum. J - CPC 35948, paratype; full cyst in dorsal view, median focus. Note extremely small apical protuberance. M, N - CPC 35949, paratype; lothocyst and operculum in dorsal view, high and median focus respectively. Note variable nature of reticulum. O, P - CPC 35950, paratype; full cyst in ventral view, high and median focus respectively. Elongate specimen.
be present (Fig. 9L). Furthermore, the paratabulation of the paracingulum and parasutus was not determined with certainty. In poorly preserved material, the epicyst commonly collapses into the hypocytox.

Comparison. Biorbifera ferox differs from the genus type, B. johnswelli, in being slightly smaller, having prominent parasutal ridges and much fewer, but longer, robust spines which are largely confined to the polar areas. An unpublished Tithonian species of Biorbifera, recorded in both Australia and New Zealand, is characterised by small processes and a prominent inflation on each of the major paraplates.

Derivation of name. From the Latin, ferox, spirited, daring, proud, referring to its very distinct, paratabulation, in contrast to that on the genotype.

Holotype and type locality. Figures 91-L, CPC 35934, from a sidewall core sample in Avocet-IA well at 1771.50m.

Stratigraphical distribution. Biorbifera ferox is confined to the Tithonian, ranging from the upper Dungonidium jurassicum Zone (Saia) to the mid Pseudoceratium tibicinum Zone (4cii) (Foster, this volume; Helby & Partridge, in prep.).

Cassiculosphaeridia Davey 1969

Type species. Cassiculosphaeridia reticulata Davey 1969

Cassiculosphaeridia solida sp. nov. (Figs 10A-P)

Previous Australian usage
1986 ?Cassiculosphaeridia sp. A; Parker, p. 50, pl. 5, fig. 6.
Valensiella sp. A — Helby.
M.P. 98 (proto) — Helby.

Description. A species of Cassiculosphaeridia, intermediate in size and with an ellipsoidal to subcircular outline. The autophagm is extremely thick (1.5-4μm) and covered with strong, corrugate ornamentation. The ornamentation comprises an irregular network of discontinuous, arcuate, anastomosing ridges 1-4μm in height and 2-6μm wide. These ridges frequently form an irregular reticulate pattern, the muri enclosing subcircular to subpolygonal lacunae 1-6μm in diameter. The ridges may be short and occasionally form isolated irregular verrucae. Indications of paratabulation are lacking except for the principal archaeopyle suture, which is angular and indicative of four apical and six precingular paraplates. Accessory archaeopyle sutures may be present. Rarely, a small (2-4μm high) apical protuberance may be developed.

Dimensions (μm, n=27): Min. (Mean) Max.
Length of entire cyst: 72 (79) 89
Length of loisthocyst: 53 (67) 80
Length of operculum: 15 (20) 27
Equatorial width: 58 (74) 91
Width of archaeopyle: 37 (53) 72

The measured specimens are from a sidewall core sample from Yering-1 well at 2563.50m and ditch cuttings samples from Crux-1 well between 3045.00m-3050.00m and 2945.00m-2950.00m.

Comments. This species of Cassiculosphaeridia is characterised by the extremely thick autophagm, covered by prominent ridges, which form a corrugate-ridgelet ornamentaonal pattern. The ridges are highly variable and form a discontinuous and anastomosing configuration (Fig. 10). This variability ranges from short, irregular ridges giving a pseudo-vernuculate pattern (Figs 10A, B) to longer elements which form a coarse reticulum (Figs 10E-G). The angular nature of the principal archaeopyle suture is indicative of a gonyaulacacean paratabulation pattern. The lack of indications of paratabulation means that orientation is difficult in specimens where the archaeopyle has not opened (Figs 10O, P). The species is frequently flattened during preservation and this tends to artificially expand the diameter of the archaeopyle. Due to the characteristic ornamentation, isolated opercula are commonly identified.

The lack of both paratabulation and ectophagm precludes the assignment of this species to Ellipsoidictyrum Klement 1960 or Valensiella Eisenack 1963 respectively (see Stover & Evitt, 1978). Courtin (1989, p. 182) considered Cassiculosphaeridia to be a junior synonym of Valensiella and transferred all the species of Cassiculosphaeridia to Valensiella. Lentin & Williams (1993, p. 82, 83) accepted these transfers. Subsequently, Slimani (1994) retained Cassiculosphaeridia. Williams et al. (1998) followed the Slimani interpretation.

Comparison. Cassiculosphaeridia solida differs from the other species of the genus in its distinctive, extremely thick autophagm and robust, highly irregular arcuate/reticulate ridges.
The majority of the other species of Cassiculosphecidida have a regular reticulum and are smaller than C. solida. Cassiculosphecidida magna Davey 1974 and C? toccheri Schioler 1993 are similar in size to C. solida. Furthermore, the ridges/crests in C. magna are also anastomosing (Davey, 1974). However, C. magna has smaller ridges that form a denser reticulate pattern than those in C. solida, and C? toccheri has a regular reticulum. Both C. magna and C? toccheri have a significantly thinner autophragm than C. solida. In terms of ornamentation, the most similar species to C. solida is C. tunicata Harding (in Williams et al., 1998). This species has relatively few prominent, arcuate/anastomosing ridges (Harding, 1990, pl. 27, figs 9-14). However, C. tunicata is considerably smaller than C. solida and the former species is holocavate, has a relatively thin autophragm and the lumina formed by the ridges have a wide range of diameters. A similar, but less robust, unnamed form is recorded in the Tithonian lower Pseudoceratium ihiense Zone (4aii) on the North-West Shelf. Cassiculosphecidida pygmaeus Stevens 1987 is much smaller, with smaller, more delicate and regular fenestration and is commonly more ellipsoidal than C. solida.

Derivation of name. From the Latin, solidus meaning thick or dense, referring to the distinctive broad ridges of this species.

Holotype and type locality. Figures 10E-G, CPC 35944, from a ditch cuttings sample in Crux-1 well between 2945.00m and 2950.00m.

Stratigraphical distribution. Cassiculosphecidida solida ranges from the Oxfordian Wanaea spectabilis Zone (6c) to the Tithonian upper Dinozodium jurassicum Zone (5a). It forms a marker zone in the upper part of the lower D. jurassicum Zone (5b) (Foster, this volume; Helby & Partridge, in prep.).

Dissimulidinium May et al. 1987 emend.

Type species. Dissimulidinium lobispinum May et al. 1987

Emended diagnosis. Dissimulidinium is emended here to accommodate forms with processes evenly distributed over the entire cyst except the paracingulum and parasulcus. Occasional isolated processes may occur on the paracingulum. Furthermore, the processes may be entirely nontabular or a mixture of elements of a nontabular and parasutural or penatubular disposition.

Comments. The generic concept of May et al. (1987) is extended to include forms with evenly distributed processes, some of which may be parasutural and/or penatubular. The original generic diagnosis confined the processes to nontabular elements located on the paired antapical lobes and the apical region (May et al., 1987). The generic emendation was necessitated by our observations of the morphology of Dissimulidinium purattense sp. nov. (see below).

A distinct Dissimulidinium lineage is recognised during the mid Tithonian to Berriasian interval. The genus first appeared during the mid Tithonian (upper Dinozodium jurassicum Zone —5aii). This root-stock is characterised by a distinct lateral flattening and a minor equatorial constriction, foreshadowing the lobation developed in younger forms. In the early forms, the processes are both parasutural and nontabular. Elements of this root-stock have been described as Egnontodinium egreticum by Parker (1986, p. 59, 60, fig. 5.18, pl. 8, figs 2-4). There is a small stratigraphical gap prior to the appearance of the late Tithonian Dissimulidinium purattense, which represents the mid point of the lineage. In this species the lobation is slightly more pronounced, the dorsal to ventral inclination of the principal archaepyle suture is substantially stronger than in the root-stock and the processes are significantly sparser in the equatorial region (Fig. 11). This trend culminates in the Berriasian species Dissimulidinium lobispinum (D. lobispinum Zone to the lower Batioladinium reticulum Zone; subzones 4bi-4aii), where the lobation can be extreme, the inclination of the principal archaepyle suture is consistently developed and the processes are almost entirely restricted to the polar lobes (May et al., 1987, figs 4H-1).

Dissimulidinium purattense sp. nov. (Figs 11A-P)

1986 Ampullidinium robustum: Parker, p. 29, pl. 1, figs 1-3.
1994 Dissimulidinium sp. A; Bint & Marshall, fig. 5.4.
1994 Dissimulidinium sp. B; Bint & Marshall, fig. 5.5.

Previous Australian usage Dissimulidinium purattense — Helby. MP 178C — Helby.
Fig. 11. *Dissimulidinium puratense* sp. nov. Specimens from sidewall core samples in Seaell-1 well at 1421.00 m (Figs 11A-G, K-N) and 1418.00 m (Figs 11H-J, O, P). All photomicrographs taken using plain transmitted light. The scale bar in Fig. 11P refers to all photomicrographs and is 25 µm. Figures 11C-D are the holotype; the remainder, paratypes. Note trilobate/subquadrate outline, variable equatorial constriction, hypoeystal lobes (of which dorsal lobe is largest), mixture of nontabular and parasutural/pentabular processes, and inclined principal archaephyte suture of apical archaephyte. A, B - CPC 35951, paratype; loisthocyst in right lateral view, high and low focus respectively. Note apparently parasutural processes which indicate paracingulum, and distinctly inclined principal archaephyte suture. C, D - CPC 35952, holotype; loisthocyst in right lateral view, high and low focus respectively. Note solid processes, some of which may be pentabular; E-G - CPC 35953, paratype; loisthocyst in right lateral view, high to low focus sequence. Note pentabular processes on the hypoeyst in Fig. 11E. H - CPC 35954, paratype; loisthocyst in left lateral view, median focus respectively. Note small equatorial constriction and apical archaephyte. I, J - CPC 35955, paratype; loisthocyst in right lateral view, high and median focus respectively. Note relatively slender epicyst. K, L - CPC 35956, paratype; loisthocyst and operculum in left lateral view, high and low focus respectively. Note relatively flat operculum and evenly inserted processes, some of which may be parasutural. M - CPC 35957, paratype; loisthocyst and operculum in left lateral view, high focus. Note strong equatorial constriction. N - CPC 35958, paratype; full cyst in left lateral view, high focus. Note relatively large size. O, P - CPC 35959, paratype; full cyst in right lateral view, high and median focus respectively. Note possible pentabular nature of some processes.
Description. A species intermediate in size and trilobate to elongate subquadrat in lateral view. A slight equatorial constriction is normally present. The prominent hypocyst lobes are distally rounded and the dorsal lobe is markedly larger than the ventral lobe. The epicystal lobe (the acipal area) is flattened distally. Autophragm relatively thick (1-2μm), smooth to scabrate. Occasionally the autophragm is irregularly microreticulate with subcircular lacunae up to 1μm wide. The autophragm is covered in slender, solid processes which are distally capitate or bifurcate. Most processes are 1-1.5μm wide, but occasionally attain 3μm in width. Intratubular processes are extremely rare on the paracingulum. No specimens were observed in ventral view, therefore the presence of processes on the paracingulum is uncertain. The paracingular sutures commonly have aligned parasutural processes and some parasutural and/or penatubular processes may be present. The principal archaephyte suture is inclined ventrally; short accessory archaephyte sutures may be developed.

Dimensions (μm, n=30): Min, (Mean) Max.
Length of entire cyst excl. spines: 52 (62) 71
Length of loisthocyst excl. spines: 43 (60) 76
Maximum width of hypocyst: 40 (52) 72
Maximum width of epicyst: 28 (39) 51
Width of equatorial constriction: 22 (35) 47
Maximum length of spines: 6 (9) 14

The measured specimens are from conventional core in Lambert-2 well at 3101.00m, sidewall core from Cossack-1 well at 3025.00m, Puratte-1 well at 172.00m and Scafell-1 well at 1421.00m and 1418.00m and ditch cuttings from Broom-1 Bore at 297.79m.

Comments. This species of Dissimulidinium is characterised by a robust autophragm, the slight equatorial constriction and the cover of nontubular, parasutural and penatubular processes. It is strongly laterally compressed and no specimens were observed in dorsoventral view. Specimens can be readily oriented by the disparity in size of the dorsal lobes and the sloping principal archaephyte suture. The possible partial parasutural/penatubular arrangement of the processes is entirely consistent with a gonyaulacoccal paratabulation (see May et al., 1987, fig. 2). The majority of the processes are nontubular and a full paratabulation has not been recorded. It is relatively common for parasutural processes to surmount the paracingular sutures (Figs 11B, K). On the larger hypocyst in some specimens, discontinuous aligned rows of processes are present. In many of these cases these are closely spaced parallel rows, which are strongly suggestive of a penatubular arrangement (Bint & Marshall, 1994, fig. 5.4; Figs 11F, K, O).

Bint & Marshall (1994, figs 5.4, 5.5) distinguished two morphotypes of this genus. Dissimulidinium sp. A has a substantial cover of processes and Dissimulidinium sp. B has a slightly thicker autophragm and marginally fewer processes. These authors indicated that the two morphotypes have stratigraphically distinct ranges (Bint & Marshall, 1994, fig. 4). Both morphotypes are included here in D. purattense.

Comparison. Dissimulidinium purattense differs from the genotype, D. lobispinosum, in lacking a deeply incised equatorial constriction, having relatively wide processes which are evenly distributed over the cyst and may be parasutural/penatubular. Furthermore the epicyst and equatorial regions are wider in D. purattense than D. lobispinosum (May et al., 1987).

Derivation of name. From the Puratte-1 well, where we first recorded this species.
and long precingular paraplate series. M, N - CPC 35965, paratype; left lateral view, high and low focus respectively. Relatively large, wide specimen; note processes do not extend into apical horn. O, P - CPC 35966, paratype; dorsal view, high and median focus respectively. Note relatively narrow ectocoeo and slightly distorted apical horn.
Holotype and type locality. Figures 11C-D, CPC 35952 from a sidewall core sample in Scafell-I well at 1421.0m.

Stratigraphical distribution. *D. paratense* is confined to the Tithonian, ranging from the uppermost *Dinogonon jurassicum* Zone (5a) to the mid *Pseudoceratium iehense* Zone (4cic) (Foster, this volume; Helby & Partridge, in prep.).

**Gardodinium Alberti** 1961 emend. Harding 1996

**Type species.** *Gardodinium eisenackii* Alberti 1961.

**Comments.** This genus is retained and separated from *Chlamydophorella* Cookson & Eisenack 1958 emend. Duxbury 1983. The history of the relationship of these genera has been discussed by Harding (1996; see also Williams et al., 1998, p. 234).

**Gardodinium angustum** Riding, Helby & Stevens sp. nov. (Figs 12A-P, 13A-P)

1994 *Gardodinium* sp. A; Bint & Marshall, fig. 53.

**Previous Australian Usage**

**Gardodinium angustum** Stevens & Helby (manuscript name).

M.P. 677 (pars) – Helby.

**Description.** An elongate species of *Gardodinium*, which is intermediate in size. Specimens are not dorsoventrally flattened and are elongate ellipsoidal, with a long, parallel-sided, distally closed, truncate apical horn formed from ectophagm. A small, distally rounded apical protuberance is also present on the autocyst. The antapex of both the autocyst and ectocyst is rounded. The autotroph is smooth to occasionally microscabrate and 1µm thick. The ectophagm is smooth to irregularly shagreenate and <0.5µm thick. The autotroph bears numerous slender (<0.5µm wide) solid, cylindrical processes which connect to, and support, the ectophagm. They are spaced between 1-3µm apart and may be slightly distally expanded. These processes, however, do not extend into the distal part of the apical horn and are normally significantly sparser in the paracircular and parasutural regions. These processes are dominantly nontubular. The paratabulation is indicated by extremely thin (up to 1µm), smooth parasutural bands, which may be partially obscured by overlying parasutural ridges on the ectophagm. Immediately inside the parasutural bands, several parallel paratabular lineations of processes may occur. These paratabular lineations are normally partially developed and occasionally may be entirely absent. They are best observed on the long precingular and postcingular paraplate series. The standard sexiform gonyaulacoacean paratabulation pattern is also expressed on the ectophagm by low, smooth parasutural ridges. Accessory endarchaeopyle sutures may be developed in the precingular paraplate series. The paracingulum is inserted below the mid-point of the loisthocyst and is indicated by both parasutural ridges on the ectophagm and a marked concavity in the ectophagm. The narrow paracutulus is also indented and surrounded by parasutural ridges. Small (3–5µm diameter) subsharical accumulation bodies may be present inside the autocyst.

**Dimensions** (µm, n=26): Min. (Mean) Max.

- Length of entire cyst: 61 (67) 74
- Length of entire autocyst: 44 (52) 62
- Length of entire loisthocyst: 46 (53) 69
- Length of autocyst in loisthocyst: 42 (48) 57
- Length of entire operculum: 13 (19) 26
- Length of autocyst in operculum: 10 (11) 13

*Fig. 13. Gardodinium angustum* Riding, Helby & Stevens sp. nov. Paratype loisthocysts from conventional core sample in Lorikeet-1 well at 1759.10m (Figs 13D-L, P), a sidewall core sample in Avocet-1A well at 1771.50m (Figs 13M-O) and ditch cuttings in Avocet-1A well between 1775.00m and 1780.00m (Figs 13A-C). All photomicrographs taken using plane transmitted light. The scale bar in Fig. 13P refers to all photomicrographs and is 25µm. Note variability in size, slender elongate outline, paratabular arrangement of processes at periphery of paraplates, angular principal arch-mapyle suture, high density of ectophagm processes and apical arch-mapyle.

A-C - CPC 35967, paratype; oblique dorsal view, high to low focus sequence. Note paratabulation is indicated on both autotroph (by paratabular processes) and ectophagm (by low parasutural ridges). D - CPC 35968, paratype; lateral view, high focus. Note paratabular processes on precingular paraplate series. E, F - CPC 35969, paratype; dorsal view, high and low focus respectively. Note paratabular processes on both precingular and postcingular paraplate series. Processes significantly less dense on the paracingulum and parasutulus. G, H - CPC 35970, paratype; lateral view, high and median focus respectively. Note indented paracingulum and paratabular processes. I-K - CPC 35971, paratype; lateral view, high to low focus sequence. (continued opposite)
Note accessory archaeopyle sutures in Fig. 13L, P - CPC 35972, paratype; oblique dorsal view, high and low focus respectively. Relatively small specimen; note strong pentabular processes on middorsal prismatic plates in Fig. 13L. M-O - CPC 35973, paratype; ventral view, high to low focus sequence. Relatively large specimen; note prominent accessory archaeopyle sutures.
Length of apical horn: 8 (12) 17
Maximum width of entire cyst: 25 (31) 44
Maximum width of autocyst: 19 (26) 39
Height of apical ectocyst: 7 (11) 16
Height of antapical ectocyst: 2 (4) 6
Width of lateral ectocyst: 1 (2.5) 4

The measured specimens are from conventional core samples from Lambert-2 well at 3101.00m and Lorikeet-1 well at 1759.10m, sideward core samples from Avocet-1A well at 1778.00m and 1771.50m and ditch cuttings samples from Avocet-1A well at 1780.00m to 1775.00m and 1775.00m to 1770.00m and from Broome-1 Bore at 297.79m.

Comments. This species of 
Gardolodinium has a distinctively elongate outline. There are indications of paratabulation on both the autocyst and ectocyst. The ectophragm bears low, smooth parasutural ridges which indicate a sexiform gonoyaulacean paratabulation pattern; the formula is: 4p', 6'', 6c, 6'', 1p, 1''', Xs. Additionally, the autophragm has extremely thin, smooth pandasutural bands and is surmounted by pentabular lineations of ectophragmal processes. These pandasutural bands are almost sufficiently slender enough to be termed parasutural. The paracingulum is low on the loighthouse and results in the precingular paratabulate series being long. The apical ectophragmal horn is somewhat flimsy as it is often distorted or bent.

Comparison. Gardolodinium angustum differs from the other species of the genus in its elongate outline. Gardolodinium tribradicum is not elongate and the length and width of the autocyst are normally equal (Gocht, 1959, pl. 4, fig. 5). The Early Cretaceous (Valanginian) species G. attenuatum Stover & Helby 1987 is larger than G. angustum, not as elongate and lacks parasutural ridges on the ectophragm. Like G. angustum, G. lowii Backhouse 1987 is elongate, but the latter is substantially larger and has an extremely large apical horn formed from both autophragm and ectophragm. The European species G. ordinale Davey 1974 resembles G. angustum in having pentabular rows of processes. However, G. ordinale is squatt, has an apical horn formed from both the autophragm and ectocyst and lacks processes in the intratabular areas. Gardolodinium angustum also resembles Belodinium dyscultum Cookson & Eisenack 1960 emend. Stover & Helby 1987 in being elongate and holocvate. However, B. dyscultum has highly variable pentabular to nontabular autophragmal processes and a significantly longer antapical ectocyst and has an antapical claustrum representing the 1''' paratabulate in the ectophragm, like B. neridis Stevens & Helby (1987, fig. 5).

Derivation of name. From the Latin angustus, meaning narrow, slender or thin, and referring to the characteristic elongate outline of this species.

Holotype and type locality. Figures 12E-H, CPC 35963, from a sideward core sample in Avocet-1A well at 1771.50m.

Stratigraphical distribution. G. angustum ranges from the Tithonian lower Pseudoceratium ichiensis Zone (4eiic) to the lowermost Berriasian upper Pseudoceratium ichiensis Zone (4ciib) (Foster, this volume; Helby & Partridge, in prep.).

Meiostegonyaulax Sarjeant 1966

Type species. Meiostegonyaulax valensis Sarjeant 1966

Comments. See Riding & Helby (this volume).

Meiostegonyaulax bulloidea (Cookson & Eisenack 1960) Sarjeant 1969 emend. (Figs. 14A-I)

1960 Gonyaulax bulloidea; Cookson & Eisenack, p. 247, fig. 4, pl. 37, fig. 11.
1976 Lithodinia bulloidea (Cookson & Eisenack 1958); Gocht, p. 334.

Emended description. A species of Meiostegonyaulax, subspherical to ellipsoidal in shape; slightly dorsoventrally compressed and intermediate in size. Paratabulation fully indicated by low (2-3μm), narrow, distally smooth, microreticulate crests up to 5μm in height. The crests are occasionally irregularly fenestrate and are highest at gonial points and at the antapex. The crests coalesce at the apex to form a low, distally rounded apical horn, up to 5μm high. The paracingulum is equatorial and not subdivided. Similarly, the slightly indented parasulcus is also not subdivided. Autophragm thick (1.5-3μm), smooth and microreticulate. Fenestrae are usually less than 0.5μm in diameter.

Dimensions (μm, n=12) incl. crests, horns etc. where appropriate: Min. (Mean) Max.

Length of entire cyst: 75 (83) 90
Fig. 14. *Meevormegisticus bulboides* (Cookson & Eiscnack 1960) Sargeant 1969 emend. All are toptype from ditch cutting at 297.79m in Broome-1 Bore. All photomicrographs taken using plain transmitted light. The scale bar in Fig. 14I refers to all photomicrographs and is 25μm. Note robust, microreticulate autophragm, distinct apical horn or protuberance and narrow, distally-smooth parasutural crests which may be fenestrate and are highest at the gonal points. A - CPC 35974, toptype; apical view, low focus. Note relatively thick autophragm. B, C - CPC 35975, toptype, antapical view, high and median focus respectively. Note apical archeopyle and relatively high, fenestrate parasutural crests at paraequilum. D, E - CPC 35976, toptype; oblique dorsal view, median and low focus respectively. Note extremely thick autophragm and much reduced apical horn/protuberance. F - CPC 35977, toptype; ventral view, median focus. Relatively angular specimen; note apical archeopyle. G, H - CPC 35978, toptype; dorsal view, median and low focus respectively. Note ellipsoidal outline. I - CPC 35979, toptype; dorsal view, low focus. Note small apical horn/protuberance.

Length of loistocyst: 65 (73) 83
Width of cyst: 76 (83) 91

All specimens measured are toptypes from ditch cuttings in the Jariemai Siltstone (Tithonian) of Broome-1 Bore, Western Australia at 297.79m.

Comments. The thick, microreticulate autophragm is characteristic of this taxon. The subspherical shape and the broadly similar size and shape of the epicyst and hypocyst of *M. bulboides* mean that typically these cysts are equatorially and laterally symmetrical. The parasutural crests are distinctively smooth and microreticulate, and typically about 3μm high (Fig. 14F). However,
crests are higher gonally and close to the antapex. In some specimens, the parasutural crests appear to be significantly reduced in height ventrally. This can make the paratabulation difficult to discern, and the orientation problematical.

This species is emended to record the characteristic microreticulate nature of the autophragm and parasutural crests. In the original description, the cyst wall and ‘ledges’ were described as ‘granular’ (Cookson & Eisenack, 1960, p. 247). The 12 type specimens studied are slightly larger than the type material of Cookson & Eisenack (1960). This emendation is based entirely on topotypes and does not take into account the wider morphological variation of this species noted in other material.

**Comparison.** _Meiourogonyaulax bulloidea_ is distinctive in being significantly larger than most other species of the genus. However, the relatively large _M. pertusa_ (Duxbury 1977) Below 1981 closely resembles _M. bulloidea_ in that it also has thick, perforate autophragm and low, distally smooth parasutural crests. Duxbury (1977, p. 42, fig. 42) showed that the paracingulum and parasutical of _M. pertusa_ are subdivided.

Parasuticals within the paracircular and parasutical areas of _M. bulloidea_ have not been observed. Furthermore, _M. pertusa_ is slightly smaller than _M. bulloidea_ and is more elongate. _Meiourogonyaulax longicauda_ Lister 1972, another large cyst, has denticulate parasutural crests and a granulate autophragm. The Bathonian _M. superumata_ (W. Wezel 1967) Sunjersd 1969 is also large, but differs from _M. bulloidea_ in having very high parasutural crests. _Meiourogonyaulax bulloidea_ also closely resembles _M. viriosa_ Riding & Helby (this volume) in shape and in having a microreticulate autophragm. However, the latter is normally smaller than _M. bulloidea_ and may have distally denticulate parasutural crests (see below). Moreover, the apical protruberance in _M. viriosa_ is a solid boss-like feature; by contrast, the apical structure in _M. bulloidea_ is formed by the coalescence of parasutural crests. Backhouse (1988, p. 95) noted that the Early Cretaceous form _Meiourogonyaulax stoveri_ Millwood 1969 may be a variant of _M. bulloidea_. _Meiourogonyaulax stoveri_ has distally smooth parasutural crests and a perforate/reticulate autophragm. The fenestrae in the autophragm of _M. stoveri_ are, however, much larger than those in _M. bulloidea_. Also, the outline of _Meiourogonyaulax stoveri_ is also much more elongate than that of _M. bulloidea_ and the former lacks an apical structure of any kind.

**Holotype and type locality.** The holotype is from ditch cuttings in the upper portion of Jarlemai Siltstone (Tithonian) in Broome-I Bore, Western Australia at 297.79m. It is in the Museum of Victoria, Melbourne as specimen number P.17788 (Cookson & Eisenack, 1960).

**Stratigraphical distribution.** _Meiourogonyaulax bulloidea_ ranges from the Tithonian _Cribroperdinum perforans_ Zone (5d) to the lowermost Valanginian _Egnomodontium tornicum_ Zone (4ai/4aii). It occurs consistently from the Tithonian upper _Dingodium jurassicum_ Zone (5ai) to the Berriasian _Cassiculosphecid delicata_ Zone (4bii) (Foster, this volume; Helby & Partridge, in prep.).

**Pseudoceratium Gocht 1957 emend. Helby 1987**

**Type species.** _Pseudoceratium pelliferum_ Gocht 1957

**Pseudoceratium robustum_ sp. nov. (Figs 15A-L)**

**Previous Australian usage** _Pseudoceratium icheniense_ (pars) – Helby.

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**Fig. 15. Pseudoceratium robustum_ sp. nov.** Specimens from sidewall core in Scafell-I well at 1418.00m (F-H) and from ditch cuttings at 3150.00m and 3155.00m in Mindil-I well (A-E, I-L). Figures 15A-K are the holotype; the remainder are paratypes. All photomicrographs taken using plain transmitted light. The scale bar in Fig. 15L refers to all photomicrographs and is 25µm. Note apical, paracingular/paracircular and antapical horns, short, solid processes which emerge from autophragm and are connected distally by a thin, trabeculate, vacuolate ectophragm, and apical archaeopyle. A - CPC 3599A, paratype; dorsal view, high and low focus respectively. Note equatorial position of the lateral horn. B - CPC 3599B, paratype; dorsal view, median focus. Note vacuolate nature of the ectophragm. C - CPC 3599C, paratype; ventral view, median and low focus respectively. Note angular nature of principal archaeopyle surface and vague indications of paracingulum. F - CPC 3599F, paratype, dorsal view, median/low focus, Note relatively small, narrow horns. G - CPC 3599G, paratype, ventral view, median focus. Note offset parasutal notch. H - CPC 3600H, paratype, dorsal view, median focus. Note highly angular principal archaeopyle surface. I - CPC 3600I, paratype; dorsal view, median focus. Angular specimen; note narrow antapical horn. J - CPC 3600J, holotype; ventral view, high and median focus respectively. Note prominent apical horn and irregular vacuolate nature of the ectophragm. L - CPC 3600L, paratype; dorsal view, median focus. Elongate specimen; note reduced lateral horn.
Pseudoceratium robustum – Helby.
Pseudoceratium sp. – Helby.
Pseudoceratium iehiense ‘macro’ – Morgan

Description. An intermediate to large, holocavate species of *Pseudoceratium* with a somewhat angular compressed ceratoid dorsoventral outline. Relatively large distally rounded apical and antapical horns are present. The single paracircular/postcircular horn is of variable length and may be greatly reduced. The outer layer of the ektroplasm is thinner than the relatively thick, robust autophagm which is about 1-1.5μm thick. The autophagm is densely covered by short, solid processes which are connected distally by a trabeculate/ticulate ectophagm. The processes flare slightly both proximally and distally and vary from 1 to 5μm wide; the majority are 1-2μm in width. These elements are normally between 1 and 4μm in height; the observed range is 1-11μm. Close to the antapex and at the distal parts of the horns, the processes are frequently longer. The processes are consistently shortest on the operculum. The ectophagm is reticulate, with ellipsoidal to subcircular fenestra between 2 and 6μm in maximum diameter. The reticulation is often irregular, with the diameter and shape of the fenestra varying widely on individual specimens. Parasutural features are absent, except in some specimens where the paracircular is indicated by low, subparallel ridges on the ectophagm.

Dimensions (μm, n=32) incl. ectophagm and horns where appropriate: Min. (Mean) Max.
Length of entire cyst: 97 (124) 136
Length of operculum: 45 (50) 65
Length of loisthocyst: 74 (90) 105
Length of hypostom incl. paracircular: 47 (57) 69
Equatorial width: 61 (77) 87
Length of apical horn: 15 (25) 36
Length of antapical horn: 9 (21) 33
Length of right postcircular horn: 5 (11) 17

The measured species are from a sideway core in Nancar-1 well at 3240.00m and ditch cuttings between 3150.00m and 3155.00m in Mindil-1 well. Additional specimens were studied from a sideway core at 1418.00m in Scafell-1 well.

Comments. This distinctive species of *Pseudoceratium* is distinguished by its relatively large size, the thick, robust autophagm and the distinctive processes which support a vacuolate ectophagm. Most specimens observed were loisthocysts (Fig. 15).

Comparison. *Pseudoceratium robustum* differs from other species of *Pseudoceratium* in its thick autophagm and robust ectophagm and robust processes. Most other species have more numerous and slender autophagm projections and are variably holocavate. The latter include the genotype, *P. placida* (Gocht 1970), as well as *P. reitwien* Brideaux 1977. Some representatives of the genus do not exhibit an ectophagm, for example *P. alnooidense* (Bokel 1984) Lentin & Williams 1989, *P. anophrissum* (Sarjeant 1966) Bint 1986, *P. aulectum* (Harding 1990) ex Harding in Williams et al. 1998, *P. expolitum* (Brideaux 1971) and *P. secirigerum* (Davey & Verder 1974) Bint 1986. *Pseudoceratium toveae* (Noth-Hansen 1993) is holocavate but the cavity between the autophagm and ectophagm is extremely small. *Pseudoceratium gochii* (Neale & Sarjeant 1962) has longer horns than *P. robustum* and the short spines arising from the autophagm indicate a ceratoid paratabulation. *Pseudoceratium iehiense* (Helby & May in Helby, 1987) is extremely similar, but is marginally larger and has more numerous and slender ectophagm processes. Arguably, *P. robustum* could be treated as a subspecies of *P. iehiense*. However, we prefer separate specific status on the basis of its extremely restricted range, disjunct from the range base of *P. iehiense*. The Albian species *P. eisenackii* (Davey 1969) Bint 1986 is characterised by extremely small horns and margarine ornamentation (Bint, 1986, pl. 2, figs 14, 15). *Pseudoceratium interiorense* Bint 1986 is holocavate, but is unusually elongate and is cornucavate at the extremities of the horns. Holocavation is developed in *P. berrii* (Bendt-Hansen 1993) and *P. plorum* (Duxbury 1983) Bint 1986, but the paratabulare areas in these species are acate. *Pseudoceratium spiliense* Jain & Garg 1984 is very similar to *P. robustum*, but the poor preservation of the former precludes a detailed comparison. The three horns in *P. weymouthense* Helby 1987 are extremely long, clearly differentiating it from *P. robustum*.

Derivation of name. From the Latin *robustus*, meaning hard and strong, referring to the thick, robust, ectophagm processes.

Holotype and type locality. Figures 15 J-K, CPC 36002, from a ditch cuttings sample in Mindil-1 well between 3150.00m and 3155.00m.

Stratigraphical distribution. *Pseudoceratium robustum* is confined to the Tithonian lower
Fig. 16. *Stanfordella granulosa* Holene & Lucas-Clarke 1997. Specimens from conventional core samples from Mutinor-1B well at 3322.25m (Figs 16A-N) and Wanaa-2 well at 3375.34m (Figs 16A-D, L), 2880.50m (Figs 16J-K) and 2875.30m (Figs 16O-P) and sidewall core samples from Avocet-1A well at 1771.50m (Figs 16E-H) and Zeewulf-1 well at 3050.00m (Fig. 16I). All photomicrographs taken using plain transmitted light. The scale bar in Fig. 16P refers to all photomicrographs and is 25μm. Note slight cavation developed at the apical horn, gonayulaeaean paratabulation comprising an extremely small 4th paraplate and sigmoidal (S-style) pararadus. smooth to denticulate parasutural crests, granulate autophagun and precingular (type P) archaeopyle. A-D - CPC 36004; dorsal view, high to low focus sequence. Note highly offset paracingulum in Fig. 16D. E-H - CPC 36005; ventral view, high to low focus sequence. Note relatively wide, sigmoidal paracanthus and monocornucaveate cyst organisation. I - CPC 36006; ventral view, high focus. Note characteristic subtrangular shape of the 6th paraplate. J, K - CPC 36007; oblique ventral view, high and low focus respectively. Note subtriangular 6th paraplate in Fig 16J and centrally-positioned middorsal postcircular paraplate (4") in Fig. 16K. The latter indicates this species has not undergone torsion. L - CPC 36008; dorsal view, low focus. Relatively small specimen. M, N - CPC 36009; ventral view, high and low focus respectively. Slightly damaged specimen; note cavation at apical horn. O, P - CPC 36010; dorsal view, high and median focus respectively. Note single paraplate precingular archaeopyle.
Pseudoceratium iehiense Zone (4ciib) (Foster, this volume; Helby & Partridge, in prep.).

**Stanfordella** Helenes & Lucas-Clarke 1997


**Stanfordella granulosa** Helenes & Lucas-Clarke 1997 (Figs 16A-P, 17A-D)

1992 Gonyaulacysta sp. A; Snape, p. 273, fig. 7b. 1997 Stanfordella granulosa; Helenes & Lucas-Clarke, p. 182, fig. 4, pl. 2, figs 1-8.

*Previous Australian usage*

*Dampierodinium ovum* Parker (1986, p. 120-121, fig. 5, 56, pl. 26, figs 4-5).

**Farragoinum curvisum** Stevens & Helby (manuscript name).

M.P. 175 – Helby,

M.P. 654 – Helby.

*Dimensions (μm, n=27) incl. parasutural crests where appropriate: Min. (Mean) Max.*

Length of cyst incl. apical horn: 46 (59) 77

Length of apical horn: 3 (5) 9

Equatorial width of cyst: 44 (55) 70

Maximum height of parasutural crests: 1 (2) 5

The measured specimens from conventional core samples in Lambert-2 well at 3101.00m, Lorikeet-1 well at 1759.10m, Mutineer-1B well at 3132.25m, Wanaea-2 well at 3375.34m, 2880.50m and 2875.30m and sidewall core samples from Avocet-1A well at 1771.50m, Scafell-1 well at 1421.00m and Zeewulf-1 well at 3085.00m.

*Comments. Stanfordella* is a distinctive gonyaulaccean genus with a characteristic paratabulation pattern. The ventral paratabulation style is S-type of Evitt (1985) and the fourth apical paraplate is significantly reduced in size (Helenes & Lucas-Clarke, 1997, fig. 4, pl. 2, fig. 8). This apical configuration was previously illustrated by Evitt (1985, figs 5.12M and 5.16G). *Stanfordella granulosa* is a distinctive monocornucuate species with distally smooth to denticulate parasutural crests and a relatively sparse non-tubular granulate ornament. The Australian material does not exhibit suturocavation; there is no wall separation at the parasutural crests, which are formed of periphragm (Figs 16, 17). This species was recorded as *Gonyaulax granulosa* from the late Tithonian to the Valanginian (Early Cretaceous) of the Great Valley Sequence of McCartry Creek, California by Warren (1967).

*Stanfordella granulosa* is illustrated here (Figs 16, 17) as this is the first record of this species in the Australian region and also because of its stratigraphical importance.

*Stratigraphical distribution. In Australia, Stanfordella granulosa ranges from the Tithonian upper Dingodinium jurassicum Zone (5aii) to the Berriasian upper Cassiculospheeridella delicata Zone (4biia) (Foster, this volume; Helby & Partridge, in prep.).
Fig. 18. *Nannus tithonicus* sp. nov. Specimens from conventional cores from Lambert-2 well at 318.49m (Figs 18C, J-K, N-O), Lortkett-1 well at 1761.20m (Fig. 18P) and Mutineer-1B well at 3147.60m (Figs 18B, D-E, I) and 3132.25m (Figs 18A, G-H) and a sidewall core from Nanney-1 well at 3420.00m (Figs 18F, M). Fig. 18E is the holotype; remainder are paratypes. All photomicrographs taken using plain transmitted light. Scale bar in Fig. 18P refers to all photomicrographs and is 25µm. Note ellipsoidal to subcircular outline which is normally elongate; thin, largely smooth dorsal vesicle wall susceptible to irregular folding; lack of a ventral vesicle wall; thickened equatorial rim and absence of a consistently developed pylome. A - CPC 35980, paratype; dorsal view, high focus. Subcircular specimen. B - CPC 35981, paratype; ventral view, high focus. Note ventral thickened equatorial rim and slightly folded dorsal vesicle wall. C - CPC 35982, paratype; ventral view, median focus. Subcircular specimen with few folds. D - CPC 35983, paratype; ventral view, high focus. Relatively small, elongate specimen. E - CPC 35984, holotype; dorsal view, high focus. Note folds on dorsal surface, close to periphery. F - CPC 35985, paratype; ventral view, median focus. Note prominent, arcuate fold. G, H - CPC 35986, paratype; ventral view, high and median focus respectively. Small, subcircular thinning in dorsal vesicle wall probably a preservational artefact. I - CPC 35987, paratype; ventral view, median focus. Note thick vesicle wall. J - CPC 35988, paratype; dorsal view, high focus. Elongate specimen which has not been folded. K - CPC 35989, paratype; dorsal view, high focus. Note lack of folding of dorsal vesicle wall and absence of a pylome. L - CPC 35990, paratype; ventral view, high focus. Note large, straight fold on dorsal vesicle wall. M - CPC 35991, paratype; ventral view, high focus. Relatively large, subcircular specimen. N - CPC 35992, paratype; ventral view, median focus. Note small ellipsoidal hole in the dorsal vesicle wall; this is not considered to be a pylome. O - CPC 35993, paratype; dorsal view, median focus. Note slightly degraded dorsal vesicle wall. P - CPC 35994, paratype; ventral view, median focus. Note prominent thickened dorsal equatorial rim.
Acriformarch


Type species. Nummus monoculatus Morgan 1975

Nummus tithonicus sp. nov. (Figs 18A-P)

1988 Nummus sp. (small); Davey, pl. 10, fig. 10.

Previous Australian usage
Nummus sp. - Helby
Nummus 'minisimilis' - Morgan.

Description. A species of Nummus which is ellipsoidal to spheroidal, occasionally partially subpolygonal in dorsoventral view. The vesicle is longer than broad. The dorsal vesicle wall is relatively thin (about 0.5µm), psilate, shagreenate to occasionally irregularly microcristate. Folds are frequently developed on the dorsal vesicle wall; these are irregular, short or long and may be straight or arculate. A thickened, ovoidal, equatorial rim is present. This forms the ventral extremity because a ventral vesicle wall is not developed or has been lost. A regular pyleome is absent, however irregular holes may occur in the dorsal vesicle wall.

Dimensions (µm, n=30): Min. (Mean) Max.
Length: 44 (58) 74
Width: 33 (50) 64
Thickness of the equatorial rim: 2 (2.5) 5

The measured specimens are from conventional core samples from Lambert-2 well at 3118.69m, Lorikett-1 well at 1761.20m and Mutineer-1B well at 3147.60m and 3132.25m and sideway core samples from Avocet-1A well at 1780.00m, Nancar-1 well at 5240.00m and Scanell-1 well at 1418.00m.

Comments. This species of Nummus is relatively large and lacks a definite pyleome (Fig. 18). However, in some specimens, subcircular, ellipsoidal or irregularly shaped holes are present in the dorsal vesicle wall (Figs 18G-H, N). These are considered to be the result of physico-chemical damage and not primary features because of their inconsistent and irregular nature and the lack of a thickened rim. The central folds on the dorsal wall are normally straight and the rarer folds close to the periphery are generally arculate. These features are due to compaction of the vesicle. Nummus tithonicus does not have a ventral wall and this, together with the equatorial rim, indicates a possible adherent habit (Backhouse, 1988, p. 112).

It thus resembles the hemispherical Jurassic non-marine acriformarch Truncatysphaeridium cleve-iandense Riding & Duxbury 1993. Nummus tithonicus may also have had an encrusting habit (Riding & Duxbury, 1993). This species may be extremely prominent in the lower Pseudocerasatum iehiensense Zone sensu Helby & Partridge (in prep.) (see Bint & Marshall, 1994, fig. 4). Morgan (1975) and Backhouse (1988, p. 113) speculated that Nummus may indicate marginal marine settings.

Comparison. Nummus tithonicus differs from the other species of the genus in the lack of a pyleome and in its size range (see Backhouse, 1988, fig. 33). Nummus apiculus Riding & Helby (this volume) is significantly larger than N. tithonicus and has a small apical pyleome. The genotype, N. monoculatus Morgan 1975 is smaller than N. tithonicus and has a prominent pyleome in an 'intercalary' position on the dorsal side. Similarly, the small size, consistent presence of an apical pyleome and equatorial/lateral constrictions distinguish N. parvus Backhouse 1988 from N. tithonicus. The Early Cretaceous species N. pentagonus Backhouse 1988 is similar in size to N. tithonicus, lacks a pyleome, but consistently has five dorsal folds in the vesicle wall close to the periphery (Backhouse, 1988). Nummus tithonicus differs from N. similis (Cookson & Eisenack 1960) Burger 1980 and the similar N. mullajoharensis Jain & Garg (in Jain et al., 1984) in normally being markedly ellipsoidal and lacking a pyleome, and in having an extremely thick equatorial ridge and long, thick folds.

Derivation of name. From the Tithonian Stage.

Holotype and type locality. Figure 18E, CPC 35984, from a conventional core sample in Mutineer-1B well at 3147.60m.

Stratigraphical distribution. Nummus tithonicus ranges from the Oxfordian Wanaea spectabilis Zone (6c) to the Berriasian Battiodinalium reticulatum Zone (4aiii). The species has a characteristic acme in the upper part of the lower Pseudocerasatum iehiensense Zone (4ciii) (Foster, this volume; Helby & Partridge, in prep.).

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REFERENCES


FOSTER, C.B., this volume. Introduction.


HARDING, I.C., 1996. Taxonomic stabilisation of dinoflagellate cyst taxa, as exemplified by two


RIDING, J.B. & HELBY, R., this volume. Microplankton from the Mid Jurassic (late Callovian) Riegeudella aemula Zone in the Timor Sea, north-western Australia.


STEVENS, J. & HELBY, R., unpublished manuscript. Some Late Jurassic dinoflagellates from the Exmouth Plateau, Western Australia: Endoceratium iichiumi Zone. 75 p.


Mesozoic microplankton index species. Memoir of the Association of Australasian Palaeontologists 4, 101-134.


APPENDIX 1: LOCATIONS AND OPERATORS OF WELLS AND BORES FROM WHICH MATERIAL HAS BEEN STUDIED

<table>
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<th>Well Name and Number</th>
<th>Latitude</th>
<th>Longitude</th>
<th>Operator</th>
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<tr>
<td>Avocet-1A</td>
<td>11° 22' 18.05&quot;S</td>
<td>125° 45' 22.29&quot;E</td>
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<tr>
<td>Broome-1 Bore</td>
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<td>122° 14' 20&quot;E</td>
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<tr>
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<td>17° 57' 31&quot;S</td>
<td>122° 14' 20&quot;E</td>
<td>WAMD**</td>
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<td>Cossaek-1</td>
<td>19° 33' 16.94&quot;S</td>
<td>116° 29' 50.01&quot;E</td>
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</tr>
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<td>Crucx-1</td>
<td>12° 94' 40.25&quot;S</td>
<td>124° 45' 25.89&quot;E</td>
<td>Nippon</td>
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<td>Jurabi-1</td>
<td>21° 37' 07.30&quot;S</td>
<td>114° 11' 59.81&quot;E</td>
<td>Esso</td>
</tr>
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<td>Lambert-2</td>
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<td>Lorikeet-1</td>
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<td>25° 37' 08.89&quot;E</td>
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</tr>
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<td>Mindil-1</td>
<td>10° 57' 47.69&quot;S</td>
<td>25° 41' 21.45&quot;E</td>
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<td>Mutineer-1B</td>
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<td>116° 38' 11.44&quot;E</td>
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<td>Esso</td>
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*PWD = Public Works Department  
**WAMD = Department of Mines, Western Australia

Well completion reports on all the listed offshore wells are publicly available five years after completion.

Outcrop Material: Misool, Eastern Indonesia

<table>
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<th>Sample Number</th>
<th>Lithostratigraphy</th>
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<th>Reference</th>
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<td>Lehnta Formation (Pajega Group)</td>
<td>Tithonian</td>
<td>Hasibuan (1990)</td>
</tr>
</tbody>
</table>

APPENDIX 2: REGISTER OF FIGURED SPECIMENS

All palynomorph specimens figured in this paper are listed here, together with essential details. The vast majority of the specimens are curated in the Commonwealth Palaeontological Collection (CPC) of the Australian Geological Survey Organisation, Canberra. However, two of the specimens illustrated here are housed in the collections of the Geological Survey of Western Australia, Perth.

The dinoflagellate cyst and acritarch genera and species are listed alphabetically here and the location of the specimens on the microscope slides are all 'England-Finder' co-ordinates (EF). These were taken with the slide label to the left of the observer, the microscope stage opening toward the microscope user. The coding for types is as follows: H = holotype; P = paratype; T = topotype. All specimens of new taxa examined during this study contributed to the specific concepts described. Therefore, all figured specimens of new taxa, which are not holotypes are paratypes. SGM = single grain mount. SSM = single species mount. The single mounts do not have unique numbers; they are numbered sequentially for each species within a particular sample. The specimens are from conventional core, sidewall core and ditch cutting samples.
<table>
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<th>Species</th>
<th>Type</th>
<th>Fig(s)</th>
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<th>EF</th>
<th>Well (depth, m.)</th>
<th>CPC No.</th>
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<td>P</td>
<td>1A-C</td>
<td>SSM 14 (i)</td>
<td>H274</td>
<td>Lorikeet-1 (1759.10)</td>
<td>35883</td>
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| *A. variabile* | P    | 2A,B  | SSM 9 (ii)    | N33/4  | Lorikeet-1 (1759.10)      | 35891   |
| *A. variabile* | P    | 2C    | SSM 9 (i)     | N34/3  | Lorikeet-1 (1759.10)      | 35892   |
| *A. variabile* | P    | 2D    | SGM 1 (i)     | M35/3  | Mutineer-1B (3132.25)     | 35893   |
| *A. variabile* | P    | 2E,F  | SGM 1 (i)     | S34/1  | Lorikeet-1 (1756.70)      | 35894   |
| *A. variabile* | P    | 2H    | SGM 2 (ii)    | L21/1  | Mutineer-1B (3132.25)     | 35895   |
| *A. variabile* | H    | 2I-L  | SGM 1 (i)     | S32    | Avocet-1A (1775.00**)     | 35896   |
| *A. variabile* | P    | 2M-O  | SGM 1 (i)     | O28    | Peak-1 (1493.54**)        | 35897   |
| *A. variabile* | P    | 2P    | SGM 1 (ii)    | K32    | Jurabi-1 (1140.00)        | 35898   |

| *B. cheleensis* | P    | 3A-B  | SGM 3 (ii)    | M32/3  | Scarell-1 (1421.00)       | 35899   |
| *B. cheleensis* | P    | 3C    | SGM 2 (i)     | N27/4  | Scarell-1 (1421.00)       | 35900   |
| *B. cheleensis* | P    | 3D    | SGM 2 (ii)    | P27/4  | Mindil-1 (3150.00*)       | 35901   |
| *B. cheleensis* | H    | 3E-F  | Ass. sl. 2    | O28/4  | Wanaea-3 (2964.00)        | F.49309**|
| *B. cheleensis* | P    | 3G, 3H | SGM 7 (i)    | N36    | Scarell-1 (1418.00)       | 35902   |
| *B. cheleensis* | P    | 3I    | SGM 3 (i)     | K28/3  | Mindil-1 (3150.00*)       | 35903   |
| *B. cheleensis* | P    | 3J, 3K | SGM 2 (ii)   | R27    | Mindil-1 (3150.00*)       | 35904   |
| *B. cheleensis* | P    | 3L    | SGM 3 (i)     | N33/2  | Scarell-1 (1421.00)       | 35905   |
| *B. cheleensis* | P    | 3M    | SGM 1 (iv)    | N23/4  | Mindil-1 (3150.00*)       | 35906   |
| *B. cheleensis* | P    | 3N    | SGM 1 (i)     | O34/2  | Scarell-1 (1418.00)       | 35907   |
| *B. cheleensis* | P    | 3O    | SGM 2 (ii)    | M33/2  | Nancar-1 (3240.00)        | 35908   |
| *B. cheleensis* | P    | 3P    | SGM 1 (iii)   | O23/2  | Mindil-1 (3150.00*)       | 35909   |

| *B. paeminusum* | P    | 4A-B  | SGM 2 (iii)   | O25    | Wanaea-2 (2875.30)        | 35910   |
| *B. paeminusum* | P    | 4C-D  | SGM 3 (iii)   | J27/4  | Wanaea-2 (2875.30)        | 35911   |
| *B. paeminusum* | P    | 4E    | SGM 1 (ii)    | M17    | Mutineer-1B (3132.25)     | 35912   |
| *B. paeminusum* | P    | 4F-H  | SGM 1 (i)     | N35/3  | Wanaea-2 (2880.50)        | 35913   |
| *B. paeminusum* | P    | 4I-J  | SGM 3 (i)     | K27/4  | Wanaea-2 (2875.30)        | 35914   |
| *B. paeminusum* | P    | 4K-L  | SGM 1 (iii)   | S32/1  | Wanaea-2 (3375.34)        | 35915   |
| *B. paeminusum* | P    | 4M    | SGM 3 (ii)    | K26/2  | Wanaea-2 (2875.30)        | 35916   |
| *B. paeminusum* | H    | 4N-P  | SSM 10 (i)    | M32    | Lorikeet-1 (1759.10)      | 35917   |

<p>| <em>B. balticus morph. 1</em> | P    | 5A-C  | SGM 105 (ii)  | L32/4  | Misool. 81FH11            | 35918   |
| <em>B. balticus morph. 1</em> | P    | 5D-F  | SGM 103 (v)   | N18    | Misool. 81FH11            | 35919   |
| <em>B. balticus morph. 1</em> | P    | 5G-I  | SGM 101 (iii) | N30    | Misool. 81FH11            | 35920   |
| <em>B. balticus morph. 1</em> | P    | 5J-L  | SGM 100 (ii)  | T38/3  | Misool. 81FH11            | 35921   |
| <em>B. balticus morph. 1</em> | H    | 6A-C  | SGM 103 (vii) | N17/2  | Misool. 81FH11            | 35922   |
| <em>B. balticus morph. 1</em> | P    | 6D-F  | SGM 102 (iii) | J29    | Misool. 81FH11            | 35923   |
| <em>B. balticus morph. 2</em> | P    | 7A-C  | SGM 106 (v)   | K32    | Misool. 81FH11            | 35924   |
| <em>B. balticus morph. 2</em> | P    | 7D-7F | SGM 101 (v)   | M30/3  | Misool. 81FH11            | 35925   |
| <em>B. balticus morph. 2</em> | P    | 7G-7I | SGM 102 (i)   | K28    | Misool. 81FH11            | 35926   |
| <em>B. balticus morph. 2</em> | P    | 7J-7L | SSM 30        | Q32/4  | Misool. 81FH11            | 35927   |</p>
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* - range depth: 2945.00m-2950.00m

| B. ferox      |       |         | L29  | Avocet-1A (1770.00*) | 35932 |
| B. ferox      | P     | 9A-D   | SGM 1 (iii) | N36 | Avocet 1A (1771.50) | 35933 |
| B. ferox      | H     | 91-L   | SGM 38 (i) | N34 | Avocet 1A (1771.50) | 35934 |
| B. ferox      | P     | 9M    | SGM 3 (i) | P31/3&4 | Lorikeet-1 (1761.20) | 35935 |
| B. ferox      | P     | 9N    | SGM 1 (i) | J29/2 | Mutineer-1B (3132.25) | 35936 |
| B. ferox      | P     | 9O    | SGM 1 (i) | F29/3 | Lorikeet-1 (1761.20) | 35937 |
| B. ferox      | P     | 9P    | SGM 1 (i) | J31  | Lambert-2 (3101.00) | 35938 |
| B. ferox      | P     | 9Q    | SGM 55 (i) | N34 | Broome-1 (297.79) | 35939 |
| B. ferox      | P     | 9R    | SGM 90 (ii) | N34/2 | Broome-1 (297.79) | 35940 |
| B. ferox      | P     | 9S    | SGM 52 (i) | R38  | Broome-1 (297.79) | 35941 |
| B. ferox      | P     | 9T    | Ass. sl. 2 | S43/2&4 | Wamaea-5 (2929.67) | F.49211 |

* - range depth: 1770.00m-1775.00m
** - Geological Survey of Western Australia type/figured slide collection number

| C. solida  | P     | 10A-B | SGM 3 (iii) | L35/1 | Crux-1 (3045.00*) | 35942 |
| C. solida  | P     | 10C-D | SGM 2 (iii) | N35/1 | Crux-1 (3045.00*) | 35943 |
| C. solida  | H     | 10E-G | SGM 1 (ii) | Q31/4 | Crux-1 (2945.00**) | 35944 |
| C. solida  | P     | 10H   | SGM 3 (vi) | K24/1 | Crux-1 (3045.00*) | 35945 |
| C. solida  | P     | 10I-J | SGM 4 (vi) | O34/4 | Crux-1 (3045.00*) | 35946 |
| C. solida  | P     | 10K   | SGM 1 (iv) | K35  | Crux-1 (3045.00*) | 35947 |
| C. solida  | P     | 10L   | SGM 1 (i)  | R31/1 | Crux-1 (2945.00**) | 35948 |
| C. solida  | P     | 10M-N | SGM 2 (ii) | N35  | Crux-1 (3045.00*) | 35949 |
| C. solida  | P     | 10O-P | SGM 3 (v)  | K25  | Crux-1 (3045.00*) | 35950 |

* - range depth: 3045.00m-3050.00m
** - range depth: 2945.00m-2950.00m

| D. puratense | P     | 11A-B | SGM 1 (iv) | K31/3 | Scafell-1 (1421.00) | 35951 |
| D. puratense | H     | 11C-D | SGM 4 (ii) | L32/4 | Scafell-1 (1421.00) | 35952 |
| D. puratense | P     | 11E-G | SGM 1 (i)  | L29  | Scafell-1 (1421.00) | 35953 |
| D. puratense | P     | 11H   | SGM 3 (iv) | H38/4 | Scafell-1 (1418.00) | 35954 |
| D. puratense | P     | 11I-J | SGM 1 (i)  | M37  | Scafell-1 (1418.00) | 35955 |
| D. puratense | P     | 11K-L | SGM 1 (ii) | L30  | Scafell-1 (1421.00) | 35956 |
| D. puratense | P     | 11M   | SGM 2 (ii) | P34/3 | Scafell-1 (1421.00) | 35957 |
| D. puratense | P     | 11N   | SGM 3 (ii) | N35  | Scafell-1 (1421.00) | 35958 |
| D. puratense | P     | 11O-P | SGM 2 (ii) | L32  | Scafell-1 (1418.00) | 35959 |

G. angustum  | P     | 12A-B | SGM 1 (iv) | M37/2 | Avocet-1A (1775.00*) | 35960 |
G. angustum  | P     | 12C   | SSM 3 (ii) | N28  | Lorikeet-1 (1759.10) | 35961 |
G. angustum  | P     | 12D   | SSM 3 (ii) | M28/3 | Lorikeet-1 (1759.10) | 35962 |
G. angustum  | H     | 12E-H | SGM 31 (i) | P20  | Avocet-1A (1771.50) | 35963 |
G. angustum  | P     | 12I-L | SSM 2 (iii) | J40/3 | Lorikeet-1 (1759.10) | 35964 |
G. angustum  | P     | 12M-N | SSM 128 (i) | Q52  | Avocet-1A (1771.50) | 35965 |
G. angustum  | P     | 12O-P | SSM 2 (vi) | G38/3 | Lorikeet-1 (1759.10) | 35966 |
G. angustum  | P     | 13A-C | SGM 1 (v)  | L35/4 | Avocet-1A (1775.00**) | 35967 |
G. angustum  | P     | 13D   | SSM 2 (v)  | H39/4 | Lorikeet-1 (1759.10) | 35968 |
G. angustum  | P     | 13E-F | SSM 3 (ii) | M28  | Lorikeet-1 (1759.10) | 35969 |
G. angustum  | P     | 13G-H | SSM 1 (iii) | R29/2 | Lorikeet-1 (1759.10) | 35970 |
G. angustum  | P     | 13I-K | SSM 3 (iv) | K28/3 | Lorikeet-1 (1759.10) | 35971 |
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* - range depth: 1775.00m-1780.00m

* - range depth: 3150.00m-3155.00m