

Microplankton from the Cape Lamb Member, López de Bertodano Formation (Upper Cretaceous), Cape Lamb, Vega Island

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Abstract: Samples from the lower Cape Lamb Member, López de Bertodano Formation, Cape Lamb, Vega Island, Antarctic Peninsula have yielded rich and diverse marine palynofloral assemblages. The overall character of the palynofloral assemblages indicate a latest Campanian–earliest Maastrichtian age. Four new dinoflagellate cyst species *Canninginopsis ordospinosa* sp. nov., *Microdinium* ? *gymnosuturum* sp. nov., *Phelodinium exilicornutum* sp. nov. and *Operculodinium radiculatum* sp. nov. are described. Certain key dinoflagellate cyst taxa such as *Operculodinium radiculatum* sp. nov., *Manumiella* n. sp. 3 and *Isabelidinium cretaceum* allow a correlation of the lower Cape Lamb Member with the upper palynomorph zone 1/lower zone 2 on nearby Seymour Island.

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Key words: Antarctic Peninsula, Campanian, dinoflagellate cysts, López de Bertodano Formation, Maastrichtian

Introduction

Vega Island lies c. 8 km off the north-east coast of James Ross Island, Antarctic Peninsula. Cretaceous strata at Cape Lamb and False Island Point (Fig. 1) belong to the Santa Marta and López de Bertodano formations which, together with the younger Sobral Formation form the Marambio Group. This group is considered to be Late Cretaceous–Early Palaeocene (Santonian–Danian) in age. The López de Bertodano Formation conformably succeeds the Santa Marta Formation, it is poorly indurated, at least 1200 m thick and consists of grey to light brown siltstones, with mudstones and calcareous horizons. A mid/late Campanian–Palaeocene age has previously been assigned to this formation based on macrofossil and palynofloral evidence (Dettmann & Thomson 1987, Askin 1988).

The sequence exposed at Cape Lamb is c. 480 m thick with no exposed base (Pirrie *et al.* 1991). It has been divided into three members: the Herbert Sound Member of the Santa Marta Formation, and the Cape Lamb and Sandwich Bluff members of the López de Bertodano Formation (Crame *et al.* 1991). The samples for this study were collected from the lower part of the Cape Lamb Member (Fig. 2).

The Herbert Sound Member at the base of the sequence is conformably overlain by the 319 m thick Cape Lamb Member which is composed typically of highly bioturbated silty mudstones to silty sandstones. A single inverse graded conglomerate at 310 m forms a useful marker horizon, traceable laterally for at least 4 km (Pirrie *et al.* 1991). The Cape Lamb Member is fossiliferous with an abundant molluscan fauna. It is disconformably overlain by c. 111 m of thinly bedded mudstones, sandstones, and conglomerates of the Sandwich Bluff Member, exposed only at Sandwich Bluff. In contrast with the underlying Herbert Sound and Cape Lamb members that unit is highly volcanoclastic. The top of the

sequence is overlain by a 1–2 m thick diamictite, followed by the James Ross Island Volcanic Group.

Pirrie *et al.* (1991) suggested that the Herbert Sound Member on Cape Lamb represents outer shelf conditions with the Cape Lamb Member probably representing a regressive-transgressive pulse within a shelf setting (sedimentation in an outer shelf sub-storm wave base palaeoenvironment prior to regression, a mid/?inner shelf palaeoenvironment during regression). The Sandwich Bluff Member represents a further regressive event with a transition through ?mid-shelf lower shoreface and finally marginal marine depositional environments.

Previous work

Dettmann & Thomson (1987) commented on the ammonite faunas present at Cape Lamb and suggested a correlation of the Cape Lamb beds with the lowermost strata on Seymour Island. A probable Maastrichtian age was proposed for these faunas based on the presence of *Diplomoceras lambi*, *Kitchinites darwini*, *Gunnarites* spp. and *Maorites densicostatus*. They examined one sample (D.3122.3) of López de Bertodano Formation material from Cape Lamb, which yielded abundant palynomorphs of dinophycean, prasinophycean/chlorophycean affinity and a terrestrial component dominated by angiosperm pollen. The co-occurrence of *Isabelidinium pellucidum* and *I. cretaceum* was considered diagnostic of the Campanian or early Maastrichtian *Isabelidinium korojonense* Zone of Helby *et al.* (1987). The taxa *Tricolpites gillii* Cookson 1956 and *Nothofagidites* spp., which dominate the angiosperm pollen assemblages from Cape Lamb, suggest a mid Campanian–Maastrichtian age.

Huber (1988) commented that the foraminiferal assemblages found at Cape Lamb, with the co-occurring agglutinated

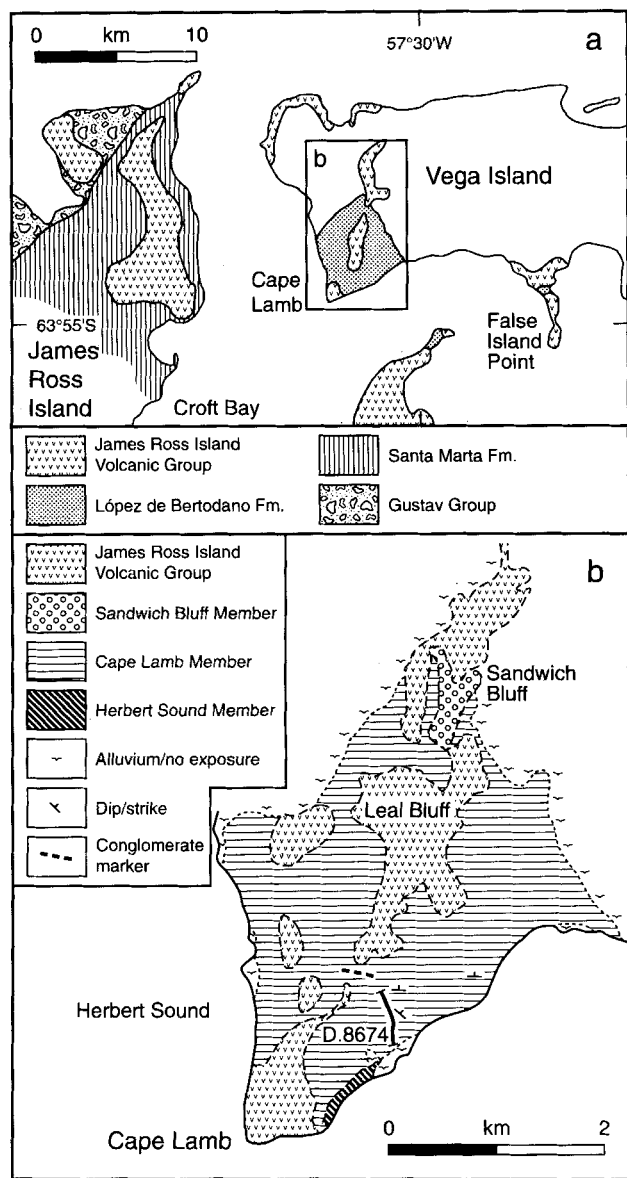


Fig. 1. Geological sketch maps of a. the Vega Island area, and b. Detail of Cape Lamb, showing the geology and the position of the section studied (D.8674).

species *Gaudryina healyi*, *Spiroplectolamina spectabilis*, and *Rzehakina epigona*, had greatest similarity with the assemblages found in the lowest strata on Seymour Island. These species are considered indicative of the *Gaudryina healyi* Assemblage-zone (Huber *et al.* 1983) to which unit 1 to lower unit 4 of the lower *Rotularia* units (Macellari 1988), on Seymour Island can be assigned. Huber (1988) also remarked that the Cape Lamb beds could be no older than mid Campanian because in New Zealand *Gaudryina healyi* is used as an index species for the Haumurian (mid Campanian–Maastrichtian).

Askin (1988) published a preliminary palynomorphozonation for the López de Bertodano Formation on Seymour Island,

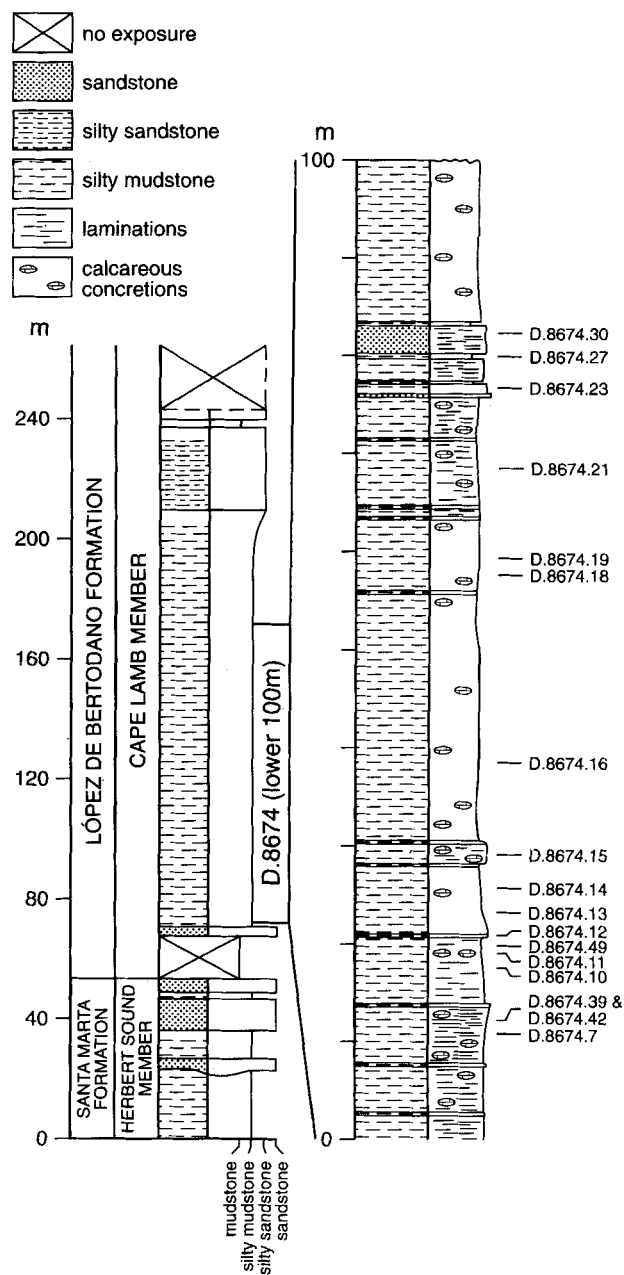


Fig. 2. Generalized section of part of the Cape Lamb sequence together with the relative position and detail of the lower 100 m of section D.8674 with sample positions.

which also included samples from Vega Island. However, as the stratigraphical relationship of the Vega Island samples to the Seymour Island sequence was then uncertain they were treated as separate entities. The Vega Island assemblage was described by Askin (1988) as being characterized by the first appearance of *Isabelidium cretaceum* and Dinocyst N. Gen. X. and a probable mid-late Campanian age was assigned.

Pirrie *et al.* (1991) recognized two ammonite assemblages

in the Cape Lamb sequence. The lower *Gunnarites* assemblage they suggested to be late Campanian–early Maastrichtian in age. The appearance of *Diplomoceras lambi* in this assemblage was suggested by Pirrie *et al.* (1991) to be a marker for the base of the Maastrichtian. The upper *Maorites* assemblage was given a mid to late Maastrichtian age. They suggested that the Cape Lamb strata are lateral equivalents of sediments on Seymour Island based on the presence of comparable ammonite faunas. The lower part of Cape Lamb Member was tentatively correlated with unit 6 of Macellari (1988) using the first appearance of *D. lambi* at the 490 m level on Seymour Island and with the first appearance of a form very close to *D. lambi* at the 139 m level at Cape Lamb. The upper part of the Cape Lamb Member was correlated with unit 7 of Macellari (1988) based on the occurrence of *Maorites densicostatus* morphotypes α and β of Macellari (1986). The Sandwich Bluff Member was correlated with the latest Maastrichtian units 8/9 (of Macellari 1988).

Pirrie *et al.* (1991) proposed an age no younger than early Maastrichtian for the Herbert Sound Member from the presence of the dinoflagellate cyst species *I. cretaceum*, *I. pellucidum* and *Canninginopsis bretonica*. The marine assemblages from the Cape Lamb Member were reported as more diverse than those found in the Herbert Sound Member. The co-occurrence of *I. cretaceum*, *I. pellucidum*, *Cerodinium diebelii*, and *Manumiella* n. sp. 3 of Askin (1988) below the the 310 m conglomerate horizon was taken by Pirrie *et al.* (1991) to indicate an age not younger than early Maastrichtian. They considered that the conglomerate represents a significant hiatus. However, the dinoflagellate cyst assemblages at this level were not considered as conclusive evidence for a Maastrichtian age.

The Sandwich Bluff Member yielded low diversity dinoflagellate cyst assemblages. The consistent occurrence of “*Manumiella*” n. sp. 2 of Askin (1988) was taken to indicate a late Maastrichtian age, and the base of Sandwich Bluff Member was correlated with upper zone 2 of Askin (1988). Above 60 m in the Sandwich Bluff Member the strata were assigned to zones 3 and 4 (latest Maastrichtian) based on the presence of *Alisocysta margarita* (Harland 1979) Harland 1979 and *A. cf. reticulata* Damassa 1979 associated with abundant “*Manumiella*” n. sp.2.

Present study

Seventeen samples were studied from the lower Cape Lamb Member, section D.8674 (70–170 m), located on the south-eastern side of Cape Lamb (Figs 1 & 2). The samples were processed using HCl, HF, concentrated HNO₃, and sieved through a 10 μ m mesh, before staining with safranin. For each assemblage a count of 250 marine palynomorphs was made and specimens were recorded using England Finder coordinates. The samples studied yielded abundant and generally well preserved marine palynofloral assemblages. Many of the assemblages studied are dominated by the acanthomorph

acritarch *Micrhystridium piliferum* (Fig. 11b).

Taxa characteristic of lower Cape Lamb Member include the *Isabelidinium cf. bakeri* –*I. cretaceum* –*I. pellucidum* complex (Fig. 7f, g & c), *Nummus cf. monoculatus* (Fig. 11 d & e), *Operculodinium flucturum* (Fig. 10 f & g), *Palaeocystodinium lidiae* (Fig. 7a), *Spiniferites ramosus* (Fig. 10d), and *Trichodinium castanea* (Fig. 10h). Other taxa present include *Chatangiella cf. campbellensis* (Fig. 7d), *Cribroperidinium muderongense*, *Diconodinium multispinum*, *Diconodinium?* sp. A (Fig. 11g), *Microdinium?* *gymnosuturum* sp. nov. (Figs 5a–f, 11j–l), *Odontochitina porifera* (Fig. 8f), *Operculodinium radiculatum* sp. nov. (Fig. 10e, i & j), *Palaeocystodinium granulatum* (Fig. 7e), *Phelodinium exilicornutum* sp. nov. (Fig. 8c, g–i), *Xenascus plotei* (Fig. 8m), and Dinocyst N. Gen. X. of Askin (1988) (Fig. 11 m–p). *Canninginopsis ordospinosa* sp. nov. (Figs 5g, h, k, l, n, p & 11i) is commonly encountered from sample D.8674.42 to sample D.8674.21 and reaches a maximum abundance of 56.8% of the total marine assemblages in D.8674.18. Rare specimens of *Manumiella* n. sp. 3 of Askin (1988) (Fig. 7k) are also recorded above sample D.8674.10.

Stratigraphical palynology

The presence and distribution of taxa within the sequence studied are shown in Fig. 3. No marked changes are apparent. By comparison with earlier work, the occurrence of *Odontochitina porifera* is taken to indicate a late Senonian age (Santonian–mid Campanian, western Australia, Helby *et al.* 1987; Santonian–late Campanian, New Zealand, Wilson 1984 [revised after Edwards *et al.* 1988]), whereas most of the characteristic taxa have ranges through the Campanian and into the Maastrichtian. These include *Odontochitina spinosa* (Fig. 8a) (early Campanian–latest Campanian/ earliest Maastrichtian, New Zealand, Wilson 1984 [revised]); *Isabelidinium korojonense* (Fig. 7j) (mid Campanian–early Maastrichtian marker species, Australia Helby *et al.* 1987); *I. pellucidum* (mid Campanian–mid Maastrichtian, Australia, Cookson & Eisenack 1958, Helby *et al.* 1987); and *I. cretaceum* (early Santonian–early Maastrichtian, Australia, Helby *et al.* 1987, and New Zealand, Wilson 1984 [revised]). Other indicators of a Campanian/Maastrichtian age include *P. granulatum* (offshore New Zealand DSDP Site 275, Wilson 1975), *P. stockmansii* (Africa, Boltenhagen 1977), *I. cf. bakeri* and *C. cf. campbellensis* (Antarctica, Dettmann & Thomson 1987 and New Zealand, Wilson 1967). Indications of a Maastrichtian age are provided by *Elytrocysta druggii* (Fig. 5i & j) (Maastrichtian–Danian, California, Drugg 1967) and *O. flucturum* (Maastrichtian/?Danian, South Africa, Davey 1969).

In an attempt to obtain some refinement of the age of the section, selected taxa with known ranges in the Southern Hemisphere were taken and the concurrence of ranges was established (Fig. 4). This shows the maximum concurrence to be latest Campanian/earliest Maastrichtian and it is

Sample number	Taxa
D.8674.30	<i>Kallosphaeridium</i> spp. <i>Chatangiella</i> cf. <i>campbellensis</i> <i>Cyclonephelium</i> cf. <i>clathromarginatum</i> <i>Odontochitina</i> <i>porifera</i> <i>Oligosphaeridium</i> complex <i>Cerodinium</i> <i>speciosum</i> <i>Elytrocysta</i> <i>druggii</i> <i>Microdinium</i> ? <i>gyrmosuturum</i> sp. nov. <i>Diconodinium</i> ? sp. A <i>Spiniferites</i> <i>ramosus</i> <i>Micrhystridium</i> <i>piliferum</i> <i>Micrhystridium</i> sp. A <i>Nummus</i> cf. <i>monoculatus</i> <i>Baltacasphaera</i> <i>reticulata</i> <i>Palaeocystodinium</i> <i>liljae</i> <i>Palaeocystodinium</i> <i>granulatum</i> <i>Isabelidinium</i> <i>cretaceum</i> <i>Trichodinium</i> <i>castanea</i> <i>Operculodinium</i> <i>radiculatum</i> sp. nov. <i>Sentusidinium</i> <i>spiculatum</i> <i>Phelodinium</i> <i>exilicornutum</i> sp. nov. <i>Diconodinium</i> <i>multispinum</i> <i>Isabelidinium</i> cf. <i>bakeri</i> <i>Odontochitina</i> <i>operculata</i> <i>Paralecaniella</i> <i>indentata</i> <i>Palaeocystodinium</i> <i>stockmansii</i> <i>Xenascus</i> <i>plotei</i> <i>Operculodinium</i> <i>flucturum</i> <i>Cribroperidinium</i> <i>muderorngense</i> <i>Dinocyst</i> N. gen. X. <i>Leiosphaeridia</i> spp. <i>Diconodinium</i> <i>psilatum</i> <i>Canninginopsis</i> <i>ordosipinosa</i> sp. nov. <i>Isabelidinium</i> <i>pellucidum</i> <i>Pterodinium</i> <i>cingulatum</i> <i>cingulatum</i> <i>Odontochitina</i> <i>rhakodes</i> (reworked) <i>Palambages</i> form A <i>Operculodinium</i> <i>baculatum</i> <i>Circulodinium</i> <i>distinctum</i> <i>distinctum</i> <i>Cymatosphaera</i> <i>wetzelii</i> <i>Cymatosphaera</i> cf. <i>costata</i> <i>Manumiella</i> n. sp. 3 <i>Canninginopsis</i> <i>bretonica</i> <i>Diconodinium</i> <i>davidii</i> (reworked) <i>Cymatosphaera</i> <i>nekouda</i> <i>Odontochitina</i> <i>spinosa</i> <i>Cerodinium</i> <i>diebellii</i> <i>diebellii</i> <i>Cerodinium</i> sp. A <i>Maduradinium</i> <i>pentagonum</i> <i>pentagonum</i> <i>Cyclonephelium</i> <i>compactum</i> (reworked) <i>Dapsilidinium</i> <i>duma</i> (reworked) <i>Spinidinium</i> <i>lanterna</i> <i>Isabelidinium</i> <i>koronense</i> <i>Pseudoceratium</i> <i>retusum</i> (reworked) <i>Pterospermella</i> <i>australiensis</i>
D.8674.27	
D.8674.23	
D.8674.21	
D.8674.19	
D.8674.18	
D.8674.16	
D.8674.15	
D.8674.14	
D.8674.13	
D.8674.12	
D.8674.49	
D.8674.11	
D.8674.10	
D.8674.42	
D.8674.39	
D.8674.7	

Fig. 3. Occurrence chart of marine palynomorphs in section D.8674.

suggested that this peak concurrence may be taken to indicate a latest Campanian/earliest Maastrichtian age for the assemblages. Furthermore, the range top of *O. porifera* (late Campanian) in sample D.8674.19 is potential evidence for the position of the Campanian/Maastrichtian boundary within the section, approximately coinciding with the first occurrence of the ammonite *D. lambi* at 139 m (Pirrie *et al.* 1991). However, it should be noted that *O. flucturum* and *P. lidiae*, typically Maastrichtian forms, range from the base of the studied section (*c.* 80 m level).

Comparisons with published work based on material from Seymour Island suggest that the section studied can be correlated with uppermost zone 1, and lowermost zone 2 of Askin (1988). Marine palynomorphs characteristic of zone 1 commonly recorded in section D.8674, include *I. cretaceum* and *O. radiculatum* sp. nov. (= *Operculodinium* sp. of Askin 1988), together with *T. castanea* (= *Cribroperidinium* sp. of Askin 1988), *Dinocyst* N. Gen. X. of Askin 1988 and *P. exilicornutum* sp. nov. (= *Phelodinium* sp. of Askin 1988). Indications of lowermost zone 2 include the first appearance of specimens of *Manumiella* n. sp. 3 of Askin (1988) in sample D.8674.11 and the presence of *N. cf. monoculatus* (*Cyclopsiella* sp. of Askin 1988) and *Diconodinium* spp. throughout the section. Other important correlative evidence

is the dominance of *M. piliferum* in the samples studied (up to 91.2% of the assemblage). Similar acanthomorph floods are reported throughout zone 1 and lower zone 2 by Askin (1988).

Reworked dinoflagellate taxa

Sporadic occurrences of dinoflagellate cyst taxa considered to be reworked are *Pseudoceratium retusum* (Barremian–Albian of Canada, Brideaux 1977 and Morocco, Below 1981); *Dapsilidinium duma* (Barremian–Cenomanian of Morocco and Germany, Below 1982); *Cyclonephelium compactum* (Albian–Santonian of Australia, Deflandre & Cookson 1955); *Diconodinium davidii* (Aptian–Cenomanian of Australia, Morgan 1977); *Odontochitina rhakodes* Albian–Cenomanian of U.S.A., Bint 1986).

Palaeoenvironmental palynology

The dominant marine palynomorph *M. piliferum*, together with other subordinate acanthomorph taxa, indicates a relatively shallow, low energy environment close to a palaeoshoreline (Wall 1965). Large brittle pieces of cuticle and the persistent presence of terrestrially derived palynomorphs support this.

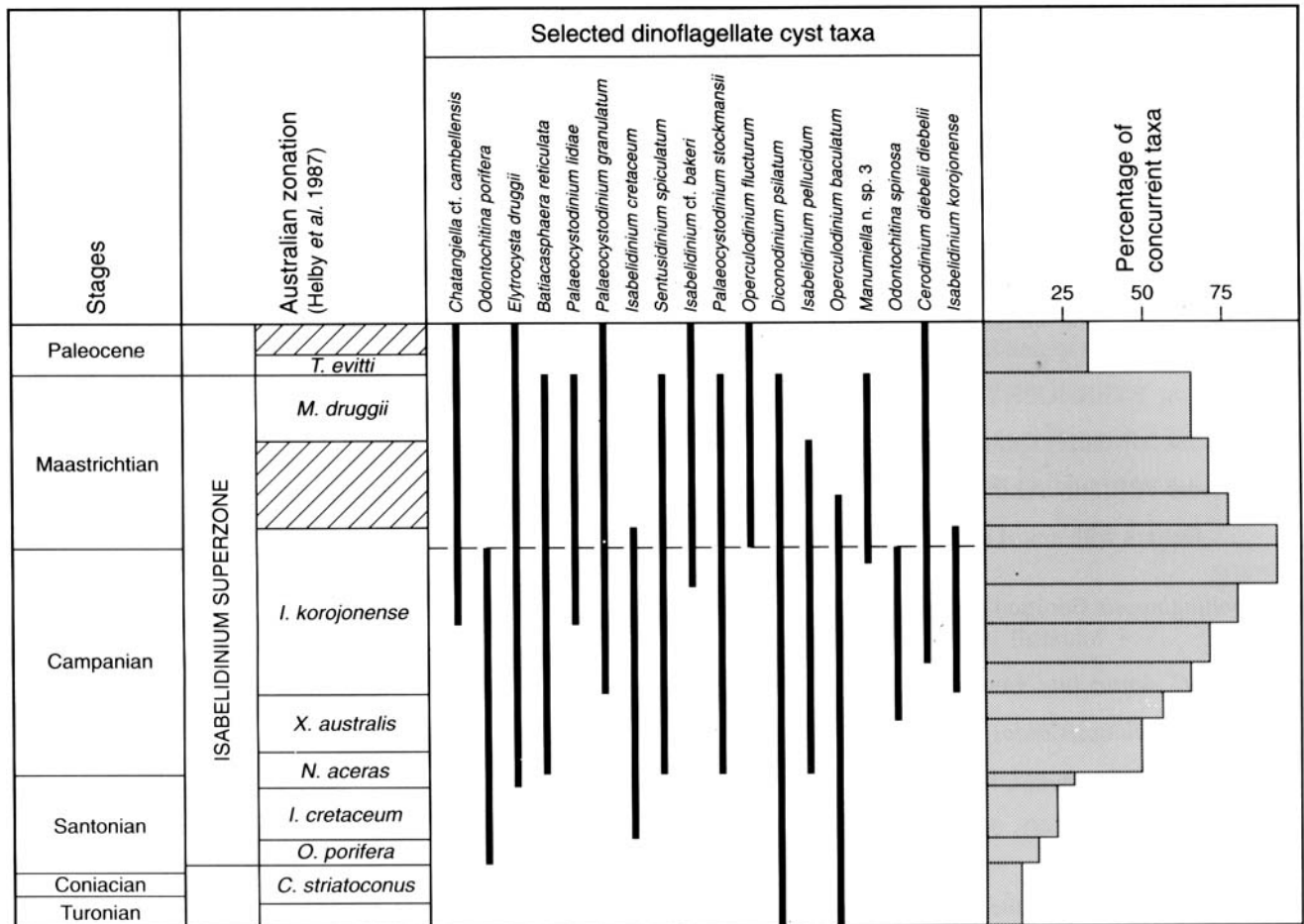


Fig. 4. Range chart and histogram to show the concurrence of selected dinoflagellate cyst taxa (mainly Southern Hemisphere).

The presence of *Spiniferites* spp. in the assemblages may indicate more open water influences (Downie et al. 1971, Wall et al. 1977)

This evidence supports the sedimentology (Pirrie et al. 1991) which suggests that the lower Cape Lamb Member of the López de Bertodano Formation was probably deposited in a low energy shelf setting, below storm wave base.

Provincialism

Lentin & Williams (1980) suggested that during the Late Cretaceous the distribution of dinoflagellate cysts was controlled by temperature and latitude. They described three suites of Late Cretaceous dinoflagellate cysts, including the Williams suite, essentially restricted to the Northern Hemisphere but to which Australian floras were also tentatively assigned. The assemblages found in this study also appear to have elements of Williams suite character (*Isabelidium*, *Chatangiella* and *Spinidinium* spp.). Dettmann & Thomson (1987) considered the Antarctic Peninsula marine palynofloras analogous to the Williams suite, despite some compositional differences.

The Late Cretaceous dinoflagellate cyst assemblages from Australia, New Zealand, the Antarctic Peninsula and the South Atlantic, although being similar to the Williams suite, could be regarded as a distinct Austral high latitude suite. Taxa characteristic of this suite would include *O. porifera* and some species of *Manumiella*. Evidence for the establishment of an Austral dinoflagellate cyst suite came from a study of DSDP Site 361 (off southwestern Africa) by Davey (1978), who suggested that after the Turonian, this area was isolated from European influences leading to domination of the marine palynofloras by Australian forms. Similar southern high latitude biotas have also been recognized in the Antarctic Peninsula, such as the Late Cretaceous Weddellian province ammonite faunas (Macellari 1986) and Austral province foraminiferal assemblages (Huber 1988).

Askin (1988) and Wrenn & Hart (1988) noted that, during the latest Cretaceous and Tertiary, the Antarctic Peninsula region contained a high proportion of endemic taxa (up to 20%). Species encountered in this study which may prove to be restricted to this region include Dinocyst N. Gen. X., *P. exilicornutum* sp. nov., *C. ordospinosa* sp. nov., and *M. ? gymnosuturum* sp. nov.

Systematic palynology

Full descriptions of new taxa are given here with remarks concerning some published taxa. The suprageneric classification employed follows that of Stover & Evitt (1978).

Morphological term: It has been found necessary to introduce a new morphological term in the description of *Microdinium ? gymnosuturum* sp. nov. Accessory archaeopyle fissure is used in place of accessory archaeopyle suture as it more accurately describes this feature. Archaeopyle fissures do not coincide exactly with the corresponding parasutures, they form slightly offset to one side.

Division PYRRHOPHYTA Pascher 1914

Class DINOPHYCEAE Fritsch 1929

Order PERIDINIALES Haeckel 1894

Genera with apical archaeopyles

Genus *Canninginopsis* Cookson & Eisenack 1962; emend Marshall 1990

Type species: *C. denticulata* Cookson & Eisenack 1962

Canninginopsis ordospinosa sp. nov.

Figs 5 g, h, k, l, n, p & 11 i

Holotype: Slide D.8674.14/1, F6/4. Repository: B.A.S. Cambridge.

Derivation of name: From the latin *ordo* and *spinus* meaning arranged thorns.

Diagnosis: A species of *Canninginopsis* which has two antapical, one postcingular, and one apical horn. The cyst surface bears variably developed granulate surface sculpture and pandasutural rows of spines.

Description: Acavate cyst, often showing development of two antapical, one postcingular, and one apical horn. The autophragm is thin (<0.5 μm) and bears an ornament of intratabular grana and two to three pandasutural rows of spines and/or grana. These spines are up to 6 μm in length and may furcate at their distal extremities. The spines present at the tips of the horns are always the largest and most elaborate in form. The reflected paratabulation is variably developed and is rarely fully present on any specimen, when present it is always best developed on the dorsal surface. The paratabulation formula is 4', 6", 5"', 1p, 1'''' Xs, Xc. The archaeopyle is apical, type (tA), and the operculum is free. The horns are between 5–15 μm in length. The left antapical horn is always larger than the right, and the right postcingular horn is variably developed from a small bulge to a prominent horn. The length of the apical horn is also variable.

<i>Dimensions</i> (μm):	Min	Mean	Max
Overall length	97	101	108
Overall breadth	66	84	100
Length without operculum	55	72	85
Specimens measured:	12		

Remarks and comparisons: *Canninginopsis ordospinosa* sp. nov. differs from all others of the genus in having a postcingular horn and a distinctive spinose pandasutural ornament. The spines, when well developed, are similar to the spines found on *Pseudoceratium securigerum* (Davey & Verdier 1974) Bint 1986. *Canninginopsis ordospinosa* sp. nov. can be distinguished from *C. bretonica* by the development of a postcingular horn, a positive surface relief of grana, and pandasutural rows of spines which are often furcate at their distal extremities. *Canninginopsis bretonica* has a finely foveolate negative surface sculpture, more readily discernable perforate parasutural septa or denticulate ridges (due to damaged distal margin of septa) with only the occasional occurrence of two rows of penitabular septa. *Canninginopsis ordospinosa* sp. nov. has been recorded in sediments from James Ross and Vega islands (Askin 1988) and Cockburn Island (Askin *et al.* 1991) (R.A. Askin, personal communication 1991).

Occurrence: Samples D.8674.42, 11, 49, 16, 18, 19 & 21.

Genus *Microdinium* Cookson & Eisenack 1960; emend. Stover & Evitt 1978

Type species: *M. ornatum* Cookson & Eisenack 1960

Microdinium ? gymnosuturum sp. nov.

Figs 5 a–f, 6 & 11 j–l

Holotype: Slide D.8674.10/1, S21/3. Repository: B.A.S. Cambridge.

Paratypes: Slide D.8674.10/1, T8/2; D.8674.10/1, U17/3

Derivation of name: From the Greek *gymnos* “naked” and Latin *sutura* “seam”.

Diagnosis: A species, questionably placed in *Microdinium* having paratabulation on the epicyst only, which is expressed by lack of ornament on the parasutures. The epicyst has 1 apical closing plate (acp), 3–4 apical paraplates, 5–6 anterior intercalary paraplates, and 7 precingular paraplates. There is intraspecific variability in the number and arrangement of apical and anterior intercalary paraplates.

Description: Cyst is ellipsoidal with a simple autophragm bearing no horns or projections. The surface ornament is composed of a dense covering of small (<1 μm) grana over the entire cyst. The archaeopyle is apical and attached, of the type (tAtI)a. Accessory archaeopyle fissures (see Morphological term) are developed between the precingular paraplates, except between 6" and 7". A partial paratabulation is present,

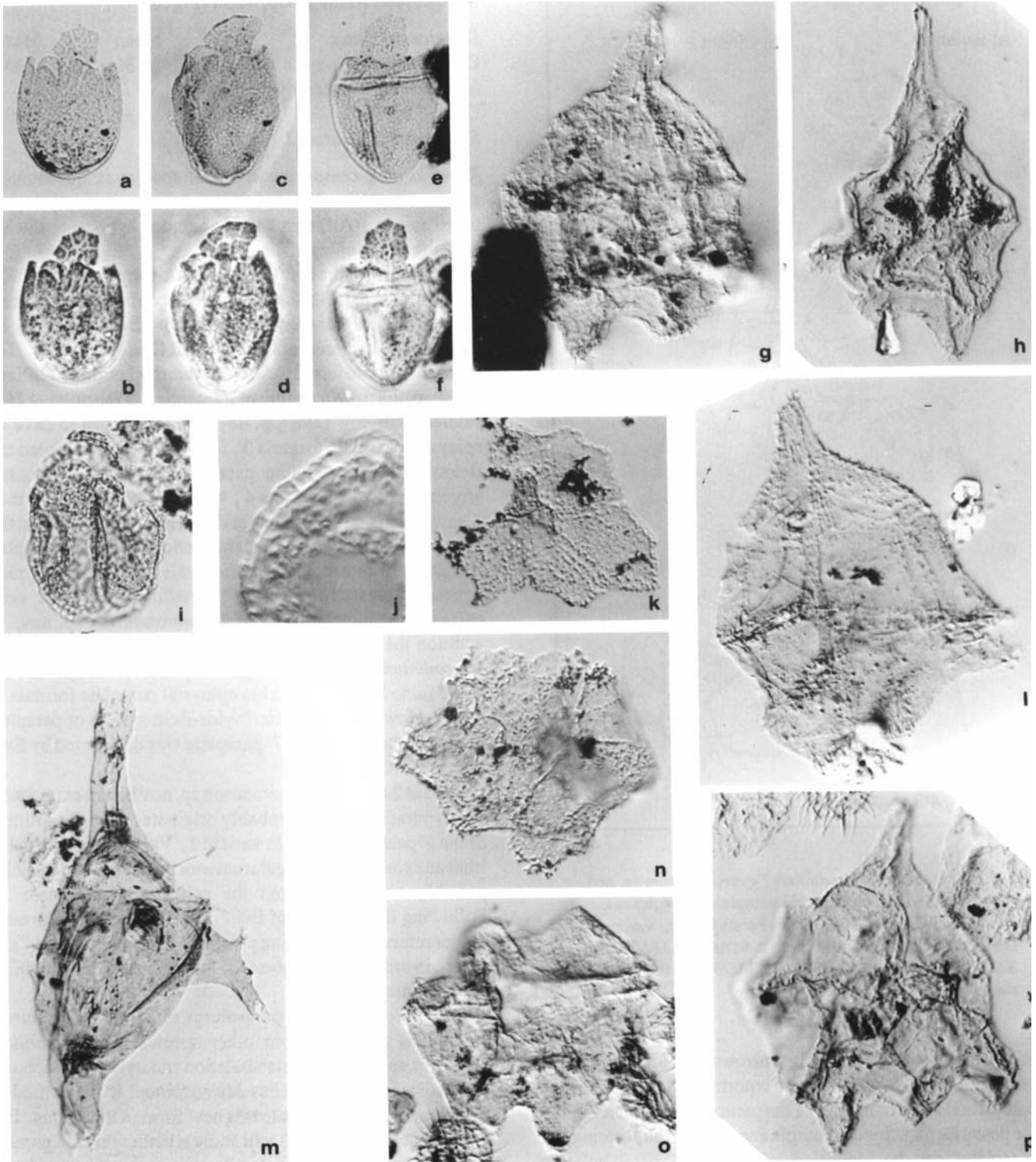


Fig. 5. Dinoflagellate cysts from the Cape Lamb Member; magnification $\times 600$ unless otherwise stated. All photomicrographs are taken using Interference contrast except those indicated P.C. which are taken using Phase contrast. **a.–f.** *Microdinium? gymnosuturum* sp. nov. [**b, d. & f.** P.C.]. **a. b.** variant 3 (Holotype) D.8674.10/1, S21/3. **c. d.** variant 1 (Paratype) D.8674.10/1, T8/2, **e. f.** variant 2 (Paratype) D.8674.10/1, U17/3. **g. h. k. l. n. p.** *Canninginopsis ordospinosa* sp. nov. **g.** D.8674.13/1, K22/1, **h.** D.8674.11/1, E43/1, **k.** D.8674.18/2, G11/2, **l.** Holotype D.8674.14/1, F6/4, **n.** D.8674.14/6, E5/1, **p.** D.8674.13/2, K23/4. **i. j.** *Elytrocysta druggii* Stover & Evitt 1978 D.8674.10/6, O18/3. **j.** $\times 1500$ detail of ectophragm. **m.** *Xenascus plotei* Below 1981 D.8674.21/2, X6/2. **o.** *Canninginopsis bretonica* Marshall 1990 D.8674.49/1, D38/2.

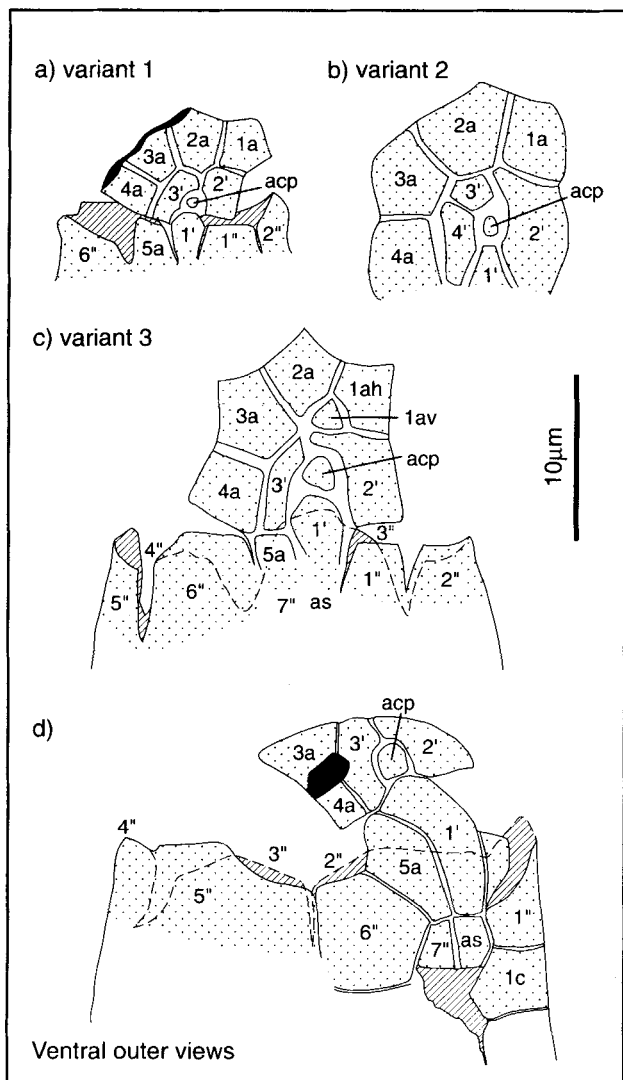


Fig. 6. Diagrams of *Microdinium? gymnosuturum* sp. nov. showing the variation in apical paraplate arrangement. **a.** variant 1 D.8674.10/1, T8/2 (Paratype). **b.** variant 2 D.8674.10/1, U17/3 (Paratype). **c.** variant 3 D.8674.10/1, S21/3 (Holotype). **d.** D.8674.7/2, M6/3 note the characteristic small 7'' paraplate.

the parasutures are expressed as furrows devoid of the surface granulation. This paratabulation is normally developed on the epicyst and anterior margin of the paracingulum only. Rarely the posterior paracingular margin and some of the postcingular paraplates can be identified. The partial paratabulation formula for the cyst is acp, 3–4', 5–6a, 7'', Xc, as, Xs. The 7'' paraplate is always very small (Fig. 6 d). The number and configuration of the apical and intercalary paraplates is variable, at least three configurations can be identified (see Fig. 6). Variant 1 has the epicystal paraplate formula acp, 3', 5a, variant 2 has the epicystal formula acp, 3', 6a, and variant 3 has

the epicystal formula acp, 4', 5a (Fig. 6).

<i>Dimensions</i> (μm):	Min	Mean	Max
Overall length (not including adnate operculum)	32	36	40
Overall breadth	28	31	35
Specimens measured: 10			

Remarks and comparisons: This species is questionably assigned to *Microdinium* as it possesses seven precingular paraplates, a (tAtI)a archaeopyle and a hypocyst which is larger than the epicyst.

Variant 1 with the epicystal paraplate formula acp, 3', 5a, 7'' is considered to be the basic paraplate configuration which is consistent with *Phanerodinium carinatum* Below (1987, p. 42, fig. 10) a typical representative of fossil Cladopyxiaceae. This species was transferred to *Microdinium* by Lentin & Williams (1989, p. 290). *Microdinium dentatum* Vozzhenikova 1967 studied by Below (1987, p. 45) was also shown to have the epicystal paraplate formula 3', 5a, 7''. It should be noted that Below (1987) stated the paraplate formulae of the two aforementioned species as 4', 4a, 7'', as he regarded the 5a paraplate as part of the apical series. This author feels that this paraplate is better regarded as an anterior intercalary paraplate as it does not contact the acp. From this it appears that typical representatives of the genus *Microdinium* have the same epicystal paratabulation as *M.? gymnosuturum* sp. nov. In addition the epicystal paratabulation of the type species of *Microdinium*, *M. ornatum* figured by Evitt (1985, p. 114, fig. 5.18 I) also has a comparable epicystal paraplate formula 3', 6a, 7''. However, using the Taylor-Evitt system of paraplate nomenclature, the small 7'' paraplate was designated by Evitt (1985) as 1i.

Variant 2 of *M.? gymnosuturum* sp. nov. has an extra fourth apical paraplate which probably originates from the splitting of the 3' paraplate found in variant 1. Variant 3 is unusual as it has an exotic small triangular anterior intercalary paraplatelet, possibly originating from the splitting of paraplate 1a. Following the proposal of Evitt (1985 p. 92–93) the present author refers to the resulting paraplate fragments as "1av" and "1ah", in order not to confuse the numbering of the remaining anterior intercalaries.

The expression of the parasutures in *M.? gymnosuturum* sp. nov. is different from other species in *Microdinium*. However, as the partial paratabulation and style of archaeopyle is consistent with the genus *Microdinium*, it is justified to questionably accommodate this new form in this genus. It is hoped that further studies will show whether this assignment can be maintained, either necessitating an eventual emendation of the generic diagnosis or the erection of a new genus.

Specimens of *M.? gymnosuturum* sp. nov. (variant 1) have been illustrated by Askin *et al.* 1991 (figs 13 m, n) in sediments from Cockburn Island as *Microdinium/Druggidium* sp., specimens of variants 1 and 2 are also present in material from False Island Point, Vega Island (personal observation).

Occurrence: Samples D.8674.7, 42, 10, 11, 49, 12–16, 18, 19, 21 & 23.

Genera with intercalary archaeopyles

Genus *Cerodinium* Vozzhennikova 1963; emend. Lentin & Williams 1987

Type species: *C. sibiricum* Vozzhennikova 1963

Cerodinium sp. A

Fig. 7 i

Description: Elongate cyst with one apical and two antapical horns which are usually broken. The cyst is cornucavate to bicavate with small epi- and hypoperiocoels. The periphragm is usually smooth to microgranulate. No paratabulation is expressed, apart from the archaeopyle and an extremely faint paracingulum in some specimens, developed as very minimal thickenings of the periphragm. The endophragm is closely appressed to the periphragm, except at the periocoels, and is normally elongate sub-rectangular in shape. Both walls are quite thin (<1 μm) and delicate, the endophragm being often marginally thicker than the periphragm. The archaeopyle is intercalary (2a) and iso-deltaform. The endopericulum and periopericulum are closely appressed and operate as one piece. The apical horn is longer than the two equal antapical horns (no specimens were observed with complete horns, so no accurate measurements can be provided). Some longitudinal folding of the periphragm may be present.

Remarks and comparisons: This taxon has the generic characteristics of *Cerodinium* as given by Lentin & Williams (1987). It is probably a new species but is not formally named until better preserved and more complete specimens are available. The specimens studied appear to be close to *C. diebelii* subsp. *diebelii* (Alberti 1959) Lentin & Williams 1987 but differ in lacking the prominent longitudinal folds, the longer horns and in being more elongate in shape. The appressed endo- and periarchoepyles are an unusual feature for *Cerodinium*. The general ambitus shape is reminiscent of the genus *Broomea* Cookson & Eisenack 1958; emend. Lentin & Williams 1976 but *Broomea* is acavate.

Dimensions (μm):	Min	Mean	Max
Overall length	78	86	95
Overall breadth	33	38	45
Endophragm length	53	67	73
Endophragm breadth	33	38	45
Specimens measured: 6			

Occurrence: Samples D.8674.15 & 19

Genus *Isabelidinium* Lentin & Williams 1977; emend. Marshall 1988

Type species: *I. korojonense* (Cookson & Eisenack 1958) Lentin & Williams 1977

Isabelidinium cf. *bakeri* –*I. cretaceum* –*I. pellucidum* complex

Fig. 7 f, g & c

Remarks: The specimens recorded here are considered to represent a plexus of forms in which specimens assignable to *Isabelidinium* cf. *bakeri* sensu Dettmann & Thomson (1987), *I. cretaceum* and *I. pellucidum* are present with other transitional morphologies which can only be tentatively placed in one of the above species. All three taxa have a distinctive thickened periphragm sometimes ornamented internally with closely packed low, broad bosses. These are most prominent apically and antapically. The size of the species is also very similar. Recognition of the species was based upon selected morphological features from the original descriptions; *I. cretaceum* was used for forms without any major horns or breaks in the sub-circular ambitus, plus an iso- to eury-deltaform archaeopyle. Often small nipple-like projections develop apically, antapically, or in both positions; *I. cf. bakeri* sensu Dettmann & Thomson (1987) was used for forms which exhibit an exceptionally thick periphragm (up to 5 μm thick), truncated antapex bearing two short blunt horns with a third sub-median conical expansion, and an iso- to eury-deltaform archaeopyle. In addition some specimens have an indented apical horn imparting a sub-rectangular ambitus; and *I. pellucidum* forms have a simple truncated antapex and the development of a broad apical horn, usually with an iso-deltaform archaeopyle.

The recently described and extremely variable species *Isabelidinium greenense* Marshall 1990 from the mid-late Campanian of Australia is similar to this plexus and also has the characteristic thickened periphragm and ornament. *Isabelidinium greenense* can be differentiated from this complex by having indications of a paracingulum. However, Marshall (1990) noted that this feature is extremely variable.

Dimensions (μm):

	Min	Mean	Max
Overall length	87	107	120
Overall breadth	70	79	90
Endophragm length	55	74	87
Endophragm breadth	67	74	85
Specimens measured: 20			

Occurrence: Samples D.8674.7, 39, 42, 10, 11, 49, 12–16, 18, 19, 21, 23, 27 & 30.

Genus *Phelodinium* Stover & Evitt 1978; emend. Mao Shaozhi & Norris 1988

Type species: *P. pentagonale* (Corradini 1973) Stover & Evitt 1978

Phelodinium exilicornutum sp. nov.

Fig. 8 c, g–i

Holotype: Slide D.8674.39/1, C41/3. Repository: B.A.S.

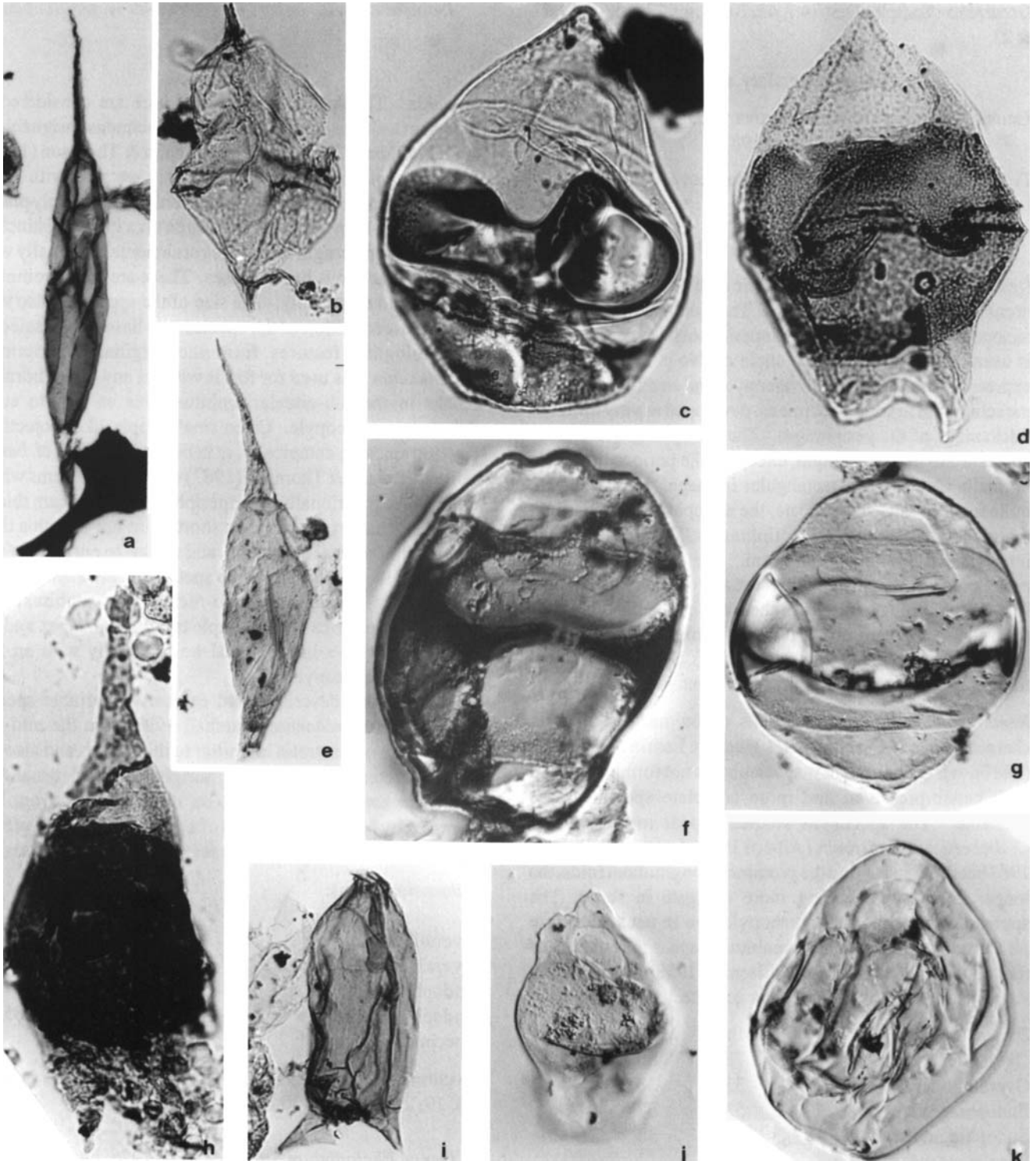


Fig. 7. Dinoflagellate cysts from the Cape Lamb Member. All photomicrographs are taken at a magnification $\times 600$ and in transmitted light except those indicated I.C. which are taken using Interference Contrast. a. *Palaeocystodinium lidiae* (Gorka 1963) Davey 1969 D.8674.49/1, H50/2 $\times 375$ [I.C.]. b. *Diconodinium multispinum* (Deflandre & Cookson 1955); emend. Morgan 1977 D.8674.30/6, J15/2. c. *Isabelidinium pellucidum* (Deflandre & Cookson 1955) Lentin & Williams 1977 D.8674.23/3, N22/4. d. *Chatangiella* cf. *campbellensis* (Wilson 1967) Lentin & Williams 1976 *sensu* Dettmann & Thomson 1987 D.8674.7/1, R16/4. e. *Palaeocystodinium granulatum* (Wilson 1967) Lentin & Williams 1976 D.8674.30/6, S10/1 $\times 375$ [I.C.]. f. *Isabelidinium* cf. *bakeri* (Deflandre & Cookson 1955) Lentin & Williams 1977 *sensu* Dettmann & Thomson 1987 D.8674.42/1, F47/4 [I.C.]. g. *Isabelidinium cretaceum* (Cookson 1956) Lentin & Williams 1977 D.8674.30/1, M20/1 [I.C.]. h. *Cerodinium diebelii* subsp. *diebelii* (Alberti 1959) Lentin & Williams 1987 D.8674.14/5, B10/2. i. *Cerodinium* sp. A D.8674.19/2, T24/4 [I.C.]. j. *Isabelidinium korojonense* (Cookson & Eisenack 1958) Lentin & Williams 1977 D.8674.23/2, M23/4 [I.C.]. k. *Manumiella* n. sp. 3 of Askin 1988 D.8674.11/1, G49/3 [I.C.], note the small archaeopyle and faint endophragm.

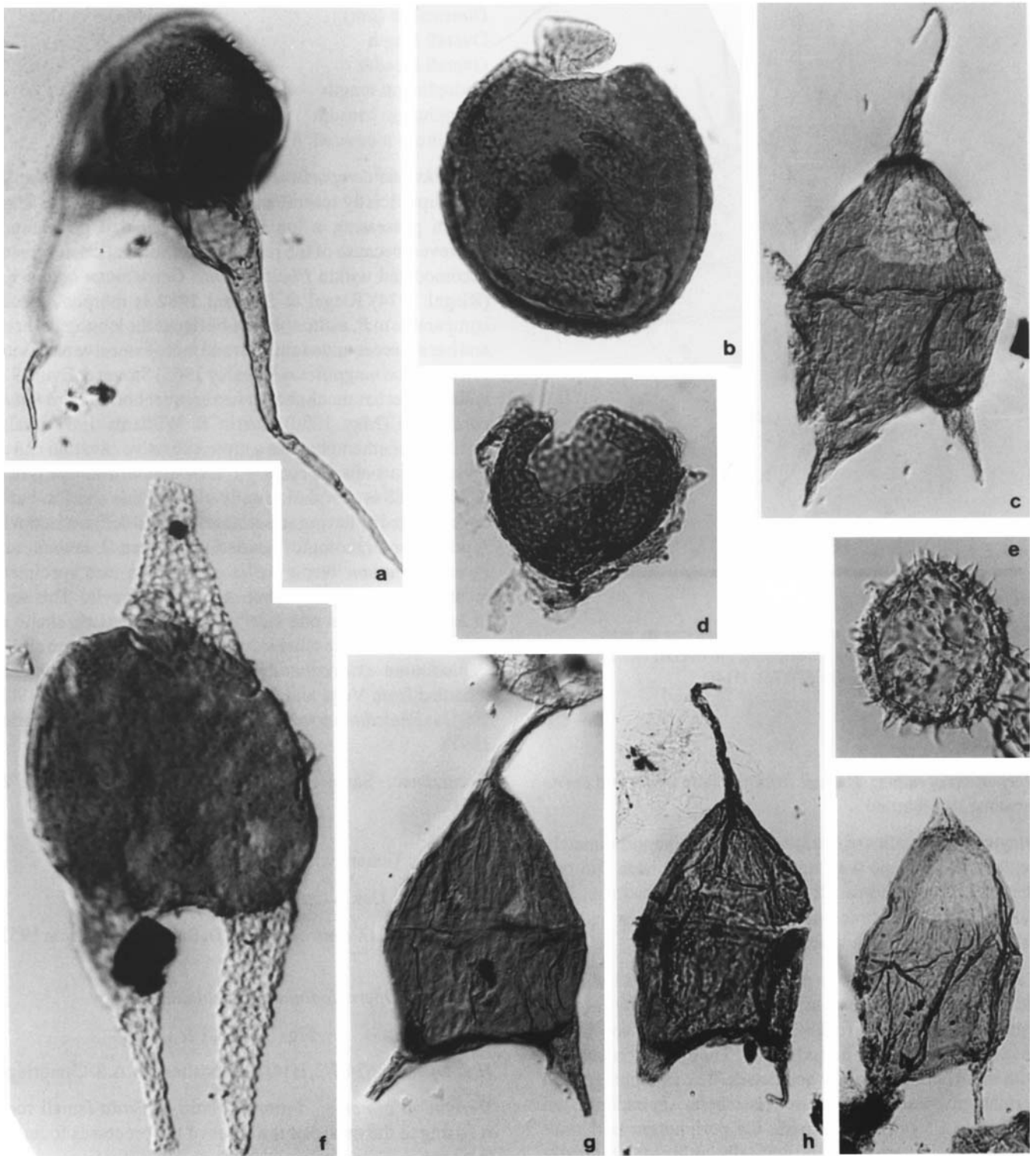


Fig. 8. Dinoflagellate cysts from the Cape Lamb Member; magnification $\times 600$ unless otherwise stated. All photomicrographs are taken in transmitted light except those indicated I.C. which are taken using Interference Contrast. a. *Odontochitina spinosa* Wilson 1984 D.8674.14/2, F25/4 [I.C.] b. *Batiacasphaera reticulata* (Davey 1969) Davey 1979 D.8674.30/2, M29/2. c, g–i. *Phelodinium exilicornutum* sp. nov. c. (Holotype) D.8674.39/1, C41/3 [I.C.], g. D.8674.19/1, M45/2 [I.C.], h. D.8674.39/1, Q45/1, i. D.8674.39/1, M48/3. d. *Cyclonephelium* cf. *clathromarginatum* Cookson & Eisenack 1962 D.8674.7/6, N4/2. e. *Sentusidinium spiculatum* Yu Jingxian & Zhang Wangping 1980 D.8674.7/6, R7/3 [I.C.]. f. *Odontochitina porifera* Cookson 1956 D.8674.7/2, W20/2 [I.C.].

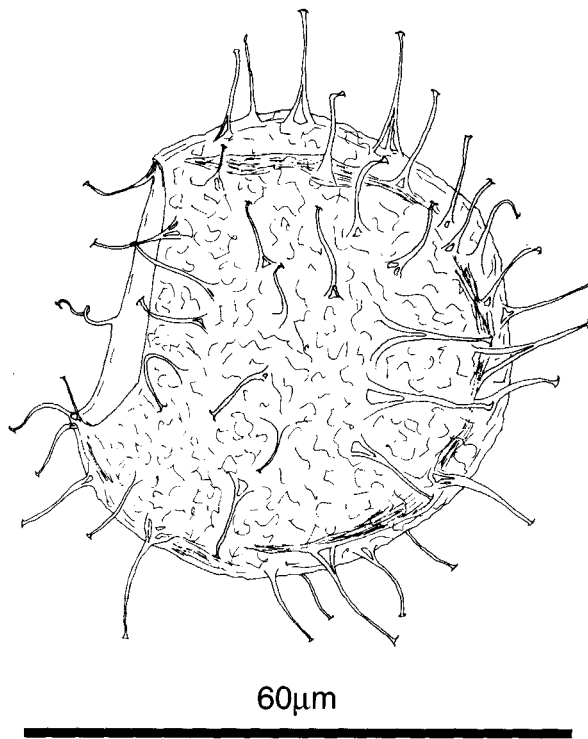


Fig. 9. Drawing of *Operculodinium radiculatum* sp. nov. (holotype in lateral view) illustrating the overall character of the cyst and processes. D.8674.7/2, H14/1.

Cambridge.

Derivation of name: Named from the latin *exilis* and *cornu* meaning thin-horned.

Diagnosis: A species of *Phelodinium* which is approximately pentagonal in shape with one slender apical horn and two slender antapical horns. It has small cornucavations. The periphragm bears numerous longitudinal wrinkles with the paracingulum being indicated by lateral folding.

Description: The cyst has a pentagonal ambitus with straight sides. It bears one long apical horn (c.55 µm) and two shorter equal antapical horns (c.25–30 µm). Often the specimens have one or more of the horns broken. The cyst is cornucavate with small periocoels at the horn bases. The endophragm and periphragm are closely appressed elsewhere. The endophragm is thick (c.1.5 µm) and smooth, the periphragm is thinner (<1 µm), slightly scabrate, and normally highly longitudinally wrinkled giving the cyst a pseudo-striate appearance. The paracingulum is indicated by prominent lateral folding. No other paratabulation is indicated other than the archaeopyle. The archaeopyle is normally iso-deltaform intercalary (2a) and large. The operculum is free.

Dimensions (µm) :	Min	Mean	Max
Overall length	95	116	162
Overall breadth	50	57	65
Endophragm length	68	74	80
Endophragm breadth	50	57	65

Specimens measured: 8

Remarks and comparisons: *Phelodinium exilicornutum* sp. nov. superficially resembles species of *Cerodinium* in shape and in possessing a longitudinally wrinkled periphragm. However, because of the restricted cornucavation, it is better accommodated within *Phelodinium*. *Cerodinium boloniense* (Riegel 1974) Riegel & Sarjeant 1982 is morphologically comparable to *P. exilicornutum* but lacks the long apical horn, and has a more rounded ambitus and more extensive cavations. *Phelodinium magnificum* (Stanley 1965) Stover & Evitt 1978 is similar but has much shorter and broader horns. *Cerodinium cordiferum* (May 1980) Lentin & Williams 1987 is also similar in character but has a more extensive cavation and an inverted heart-shaped endocyst. *Octodinium askinae* Wrenn & Hart 1988 is morphologically close to this species, but is differentiated by having an octoform (eight sided) archaeopyle. A possible morphological gradation between *O. askinae* and *P. exilicornutum* seems to be possible as rare specimens recorded here possess a seven sided archaeopyle. This style of archaeopyle has one side in the characteristic shape of *O. askinae*, and the other side in a standard deltaform shape. *Phelodinium exilicornutum* sp. nov. has previously been recorded from Vega and Cockburn islands by Askin (1988, 1991) as *Phelodinium* sp. (R.A. Askin, personal communication 1991).

Occurrence: Samples D.8674.7, 39, 10, 12, 16, 19, 23, 27 & 30.

Genera with precingular archaeopyles

Genus *Operculodinium* Wall 1967

Type species: *O. centrocarpum* (Deflandre & Cookson 1955) Wall 1967

Operculodinium radiculatum sp. nov.

Figs 9, 10 e, i & j

Holotype: D.8674.7/2, H14/1. Repository: B.A.S. Cambridge.

Derivation of name: From the latin *radicula* (small root) referring to the nature of the bases of the processes found on this cyst.

Diagnosis: A species of *Operculodinium* characterized by capitate processes with extensively clathrate bases; the surface sculpture is of irregular thickenings.

Description: A chorate cyst with a spherical ambitus. The process tips subtend a similar shape to that of the cyst. There is no apparent indication of a paracingulum, parasulcus or

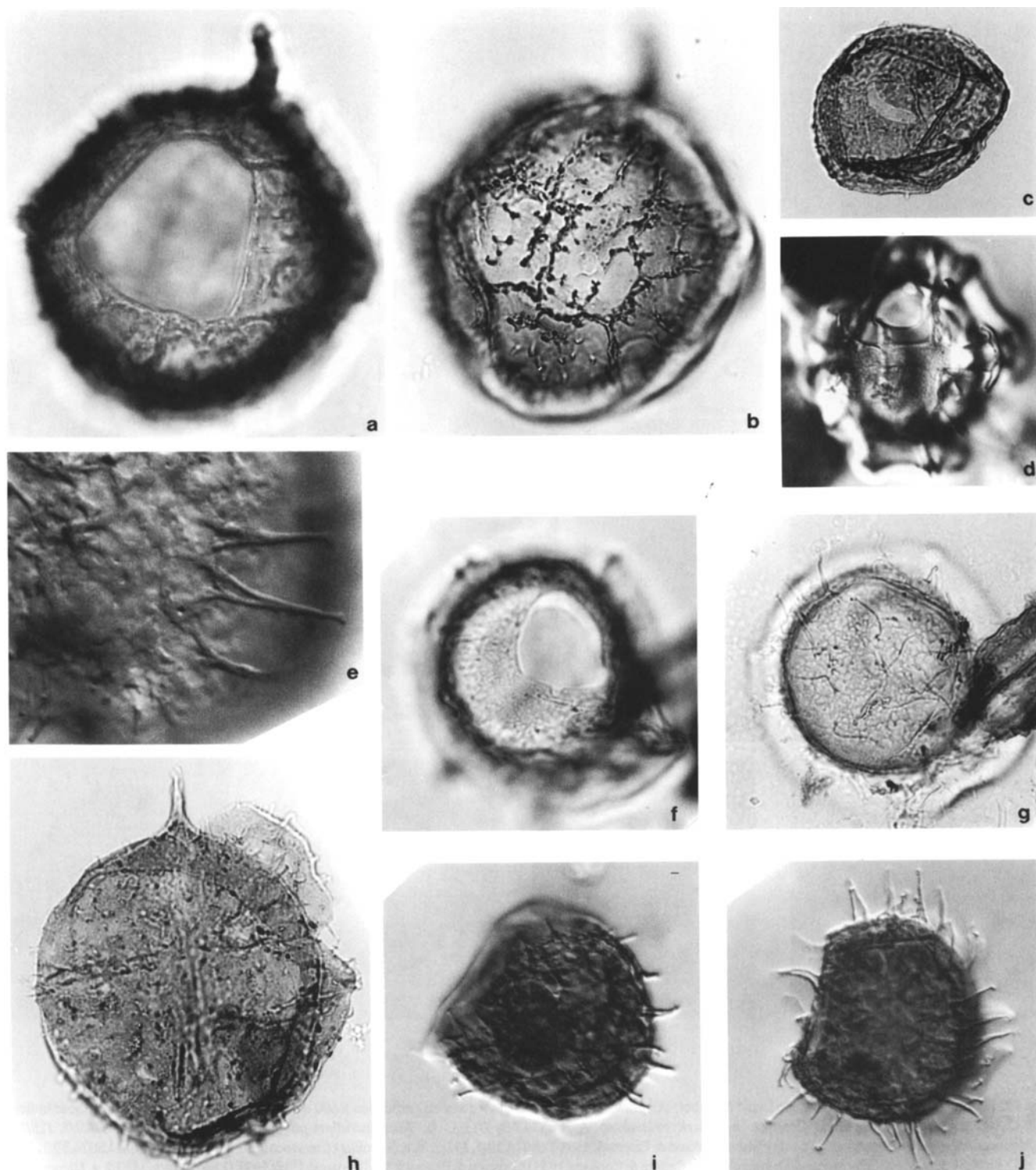


Fig. 10. Dinoflagellate cysts from the Cape Lamb Member; magnification x 600 unless otherwise stated. All photomicrographs are taken in transmitted light except those indicated I.C. which are taken using Interference Contrast. a. b. *Cribooperidinium muderongense* (Cookson & Eisenack 1958) Davey 1969 D.8674.49/1, U41/3 [I.C.]. c. *Operculodinium baculatum* Yu Jingxian & Zhang Wangping 1980 D.8674.30/6, L30/4. d. *Spiniferites ramosus* (Ehrenberg 1838) Loeblich & Loeblich 1966 D.8674.39/1, H46/3 [I.C.]. e. i. j. *Operculodinium radiculatum* sp. nov. e. Close up of process bases x 1500 [I.C.]. j. Holotype D.8674.7/2, H14/1. i. D.8674.7/2, J15/4. f. g. *Operculodinium flucturum* Davey 1969 D.8674.39/1, G44/1 [I.C.]. h. *Trichodinium castanea* (Deflandre 1935) Clarke & Verdier 1967 *sensu* Stover & Helby 1987 D.8674.7/2, V11/3.

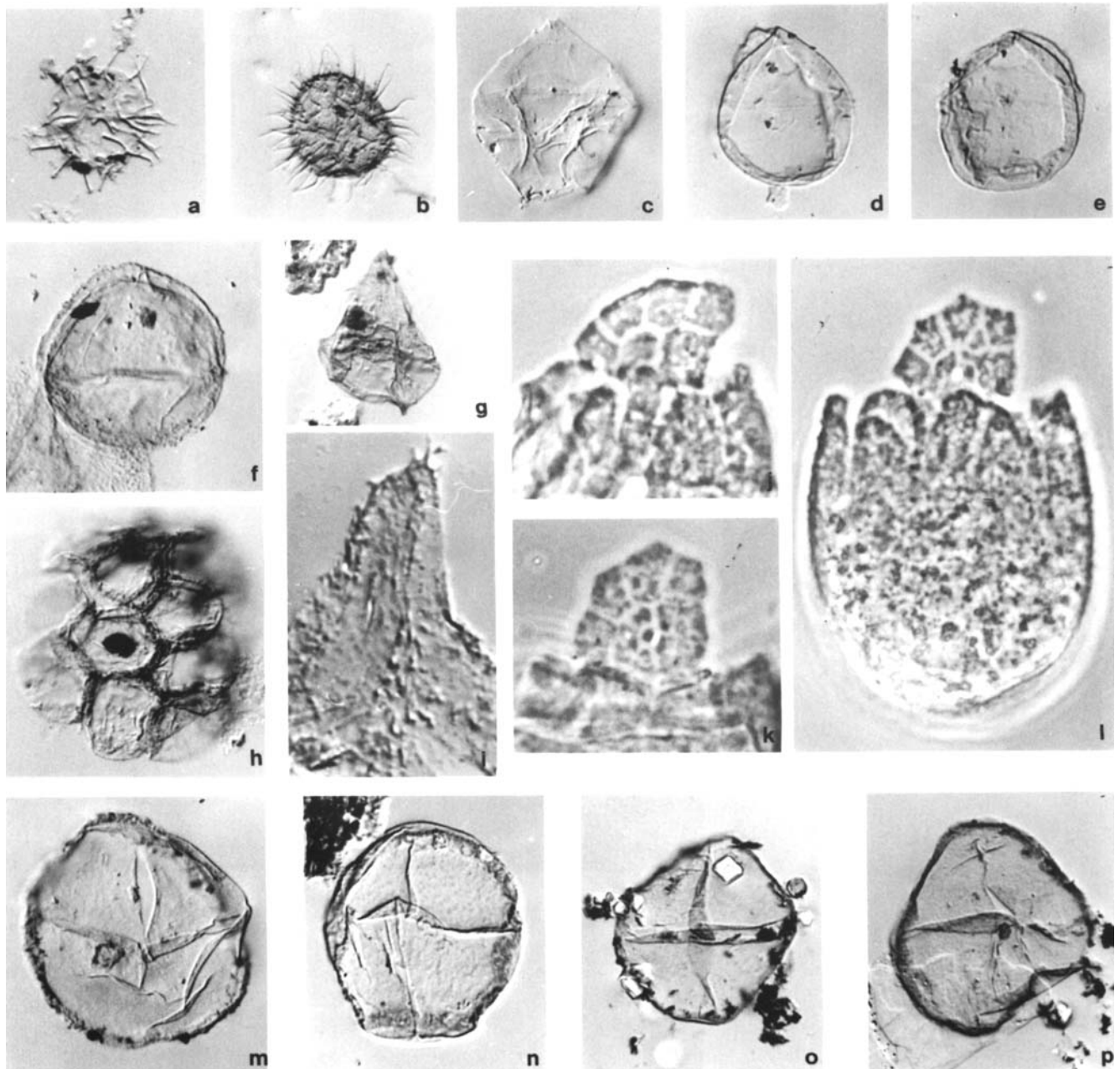


Fig. 11. Dinoflagellate cysts from the Cape Lamb Member. All photomicrographs are taken at a magnification $\times 600$ using Interference contrast except those indicated P.C. which are taken using Phase Contrast. a. *Michrhystridium* sp. A D.8674.7/3, D15/1. b. *Michrhystridium piliferum* Deflandre 1937 D.8674.7/1, J15/3. c. *Maduradinium pentagonum* subsp. *pentagonum* Cookson & Eisenack 1979 D.8674.19/1, J33/2. d. e. *Nummus* cf. *monoculatus* Morgan 1975. d. D.8674.39/1, L37/2. e. D.8674.39/1, M37/4. f. *Paralecaniella indentata* (Deflandre & Cookson 1955) Cookson & Eisenack 1970; emend. Elsik 1977 D.8674.39/1, M33/2 g. *Diconodinium* ? sp. A D.8674.7/3, D20/2. h. *Palamblages* Form A Manum & Cookson 1964 D.8674.10/6, Q13/4. i. *Canninginopsis ordospinosa* sp. nov. Holotype D.8674.14/1, F6/4, close-up of spinose ornament $\times 1500$. j–l. *Microdinium* ? *gymnosuturum* sp. nov. j. variant 1 (Paratype) D.8674.10/1, T8/2 [P.C.]. k. variant 2 (Paratype) D.8674.10/1, U17/3 [P.C.]. l. variant 3 (Holotype) D.8674.10/1, S21/3 [P.C.], close-up of paraplate configurations $\times 1500$. m–p. Dinocyst N. Gen. X. of Askin 1988. m. D.8674.39/1, F38/4. n. D.8674.14/2 M17/1. o. D.8674.14/2 O12/4. p. D.8674.14/2 R30/4.

differentiated processes at the apex or antapex. The cyst body is covered in non-tabulate, partially hollow, non-fibrous, closed, capitate and recurved processes. The processes arise from several proximal stems which coalesce distally to form a single process. The length of these processes varies between 9 μm and 18 μm , and they are 2–4 μm wide at the base. The body wall is irregularly thickened giving the cyst surface a coarse, scabrate appearance. The archaeopyle is type 1P (3"), which is rounded and large.

<i>Dimensions</i> (μm):	Min	Mean	Max
Overall diameter	55	57	60
Specimens measured: 8			

Remarks and comparisons: This taxon is assigned to *Operculodinium* due to the absence of differentiated apical and/or antapical processes (present in the genus *Exochosphaeridium* Davey *et al.* 1966), partially hollow non-fibrous processes, and a 1P archaeopyle. *Operculodinium radiculatum* sp. nov. is similar to *O. flucturum* Davey 1969 but can be distinguished primarily by the coarsely scabrate surface as opposed to the latter species reticulate surface and slightly larger size. Although *O. flucturum* can possess processes which have flared clathrate bases, in *O. radiculatum* sp. nov. this feature is developed to extremes, the proximal stems extending for two thirds the length of the process. Although within a population the length of process can vary, it is usually homogenous on each specimen.

Occurrence: Samples D.8674.7, 39, 10, 12, 14, 16, 23 & 30.

Group ACROTARCHA Evitt 1963

Subgroup ACANTHOMORPHITAE

Downie *et al.* 1963

Genus *Micrhystridium* Deflandre 1937; emend. Lister 1970

Type species: *M. inconspicuum* (Deflandre 1935) Deflandre 1937

Micrhystridium sp. A

Fig. 11 a

Remarks and comparisons: Thin walled, sub-spherical acanthomorph acritarch possessing typically less than 30 solid spines 7–10 μm in length and 1 μm wide, bifurcate at their distal extremities. These processes are randomly distributed over the shell wall which has a smooth to scabrate surface sculpture. No regular excystment aperture was noted but several have slit-like apertures.

This morphotype differs from *M. piliferum* in having fewer, thicker and often bifurcate spines.

<i>Dimensions</i> (μm):	Min	Mean	Max
Overall diameter	24	26	28
Specimens measured: 6			

Occurrence: Samples D.8674.7, 39, 42, 10, 11, 49, 12–15, 19, 21 & 30.

Subgroup Uncertain

Genus *Nummus* Morgan 1975; emend. Backhouse 1988

Type species: *N. monoculatus* Morgan 1975

Nummus cf. *monoculatus* Morgan 1975

Fig. 11 d & e

Remarks and comparisons: The specimens accord closely with those described by Morgan (1975, p.163) and Backhouse (1988, p.112) showing the characteristic marginal flange, loss of the ventral wall and the presence of a faint equatorial girdle expressed as a narrow (<0.5 μm) linear thickening. In some specimens fragments of the ventral surface are observed attached to the thickened edge of the marginal flange. *Nummus* cf. *monoculatus* can be differentiated from the type material by the presence in most specimens of an apical prominence giving the cyst a characteristic teardrop shape. *Nummus* cf. *monoculatus* is superficially similar to *Cyclopsiella* Drugg & Loeblich 1967; emend. Head *et al.* 1989 but *Cyclopsiella* does not consistently lose the ventral surface. *Nummus* cf. *monoculatus* appears to have been recorded from Vega and Seymour islands by Askin 1988 as *Cyclopsiella* sp.

Occurrence: Samples D.8674.7, 39, 42, 10, 11, 49, 12–14, 19, 21, 23, 27 & 30.

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Appendix I. List of marine taxa recorded in this study

* Indicates reworked taxa.

Dinoflagellate cysts

Apical archaeopyles

- Batiacasphaera reticulata* (Davey 1969) Davey 1979 Fig. 8 b
Canninginopsis bretonica Marshall 1990 Fig. 5 o
Canninginopsis ordospinosa sp. nov., Figs 5 g, h, k, l, n, p & 11 i
Circulodinium distinctum subsp. *distinctum* (Deflandre & Cookson 1955) Jansoniuss 1986
Cyclonephelium cf. *clathromarginatum* Cookson & Eisenack 1962 Fig. 8 d

Cyclonephelium compactum Deflandre & Cookson 1955*
Dapsilidinium duma (Below 1982) Lentin & Williams 1985*
Elytrocysta druggii Stover & Evitt 1978, Fig. 5 i & j
Kallosphaeridium spp.
Microdinium ? *gymnosuturum* sp. nov. Figs 5 a-f, 6 & 11 j-l
Odontochitina operculata (O. Wetzel 1933) Deflandre & Cookson 1955
Odontochitina porifera Cookson 1956 Fig. 8 f
Odontochitina rhakodes Bint 1986*
Odontochitina spinosa Wilson 1984, Fig. 8 a
Oligosphaeridium complex (White 1842) Davey & Williams 1966
Pseudoceratium retusum Brideaux 1977*
Sentusidinium spiculatum Yu Jingxian & Zhang Wangping 1980 Fig. 8 e
Xenascus plotei Below 1981 Fig. 5 m

Intercalary archaeopyles

Cerodinium diebelii subsp. *diebelii* (Alberti 1959) Lentin & Williams 1987 Fig. 7 h
Cerodinium speciosum (Alberti 1959) Lentin & Williams 1987
Cerodinium sp. A Fig. 7 i
Chatangiella cf. *campbellensis* (Wilson 1967) Lentin & Williams 1976 sensu Dettmann & Thomson 1987 Fig. 7 d
Diconodinium davidii Morgan 1975*
Diconodinium multispinum (Deflandre & Cookson 1955) Eisenack & Cookson 1960; emend. Morgan 1977 Fig. 7 b
Diconodinium psilatium Morgan 1977
Diconodinium ? sp. A Fig. 11 g
Isabelidinium cf. *bakeri* (Deflandre & Cookson 1955) Lentin & Williams 1977 sensu Dettmann & Thomson 1987 Fig. 7 f
Isabelidinium cretaceum (Cookson 1956) Lentin & Williams 1977, Fig. 7 g
Isabelidinium korojonense (Cookson & Eisenack 1958) Lentin & Williams 1977 Fig. 7 j
Isabelidinium pellucidum (Deflandre & Cookson 1955) Lentin & Williams 1977 Fig. 7 c
Manumiella n. sp. 3 of Askin 1988 Fig. 7 k
Palaeocystodinium granulatum (Wilson 1967) Lentin & Williams 1976 Fig. 7 e
Palaeocystodinium lidiae (Gorka 1963) Davey 1969 Fig. 7 a
Palaeocystodinium stockmansii Boltenhagen 1977
Phelodinium exilicornutum sp. nov. Fig. 8 c, g-i
Spinidinium lanterna Cookson & Eisenack 1970

Precingular archaeopyles

Cribooperidinium muderongense (Cookson & Eisenack 1958) Davey 1969 Fig. 10 a & b
Maduradinium pentagonum subsp. *pentagonum* Cookson & Eisenack 1970 Fig. 11 c
Operculodinium baculatum Yu Jingxian & Zhang Wangping 1980 Fig. 10 c
Operculodinium flucturum Davey 1969 Fig. 10 f & g
Operculodinium radiculatum sp. nov. Figs 9, 10 e, i & j
Pterodinium cingulatum subsp. *cingulatum* (O. Wetzel 1933) Below 1981
Spiniferites ramosus (Ehrenberg 1838) Loeblich & Loeblich 1966 Fig. 10 d
Trichodinium castanea (Deflandre 1935) Clarke & Verdier 1967 sensu Stover & Helby 1987 Fig. 10 h.
 Specimens of similar morphological character herein are also figured by Harris (1976) and Schrank & Perch-Nielsen (1985).

Other and unknown archaeopyle types

Paralecaniella indentata (Deflandre & Cookson 1955) Cookson & Eisenack 1970; emend. Elsik 1977 Fig. 11 f

Chlorophycean & Prasinophycean Algae

Palamblages Form A Manum & Cookson 1964 Fig. 11 h
Cymatiosphaera cf. *costata* Davey 1970
Cymatiosphaera nekouda Rossignol 1964
Cymatiosphaera wetzeli Deflandre 1954 *Nomen nudum*
Pterospermella australiensis (Deflandre & Cookson 1955) Eisenack et al. 1973

Acritarcha

Acanthomorphae
Micrhystridium piliferum Deflandre 1937 Fig. 11 b
Micrhystridium sp. A Fig. 11 a

Sphaeromorphae

Leiosphaeridia spp.

Subgroup uncertain

Nummus cf. *monoculatus* Morgan 1975 Fig. 11 d & e
 Dinocyst N. Gen. X. of Askin 1988 Fig. 11 m-p