Dinoflagellates from the Chorrillo Chico Formation (Paleocene) of southern Chile

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Abstract. Twenty-seven dinoflagellate taxa from the Chorrillo Chico Formation at Punta Prat, western side of the Brunswick Peninsula (Chile), are recognized. Stratigraphically important species include Cassidium fragile (Harris) Drugg, Deflandrea cygniiformis Pöthe de Baldis, D. fuegensis Menéndez, Eisenackia crassitubulata Deflandre and Cookson, Glaphyrocysta cf. retintexta (Cookson) Stover and Evitt, Impagidinium cuscimulum Wilson, Isabelidinium bakeri (Deflandre and Cookson) Lentin and Williams, Palaeocystodinium golzwense Alberti, Palaeoperidinium pyrophorum (Ehrenberg) Evitt, Damaza and Albert, Pyxidinopsis crassimurata Wilson, Spiniferida cornuta (Gerlach) Stover and Hardenboll, Spiniferites (Hafniasphaera) cryptovesiculata (Hansen) stat. nov. and Turbiosphaera filosa (Wilson) Archangelsky. The Tribe Spinidineae of Bujak and Davies is elevated to subfamily status and emended; its type genus, Spinidinium, is likewise emended. Two new genera, Volkheimeridium and Magallanesium, are proposed, nine species being placed within these genera. The genus Alisocysta Stover and Evitt is treated as a taxonomic synonym of Eisenackia Deflandre and Cookson; its constituent species are transferred to the latter genus and a new species, E. chilensis, is described. The species bergmannii, previously placed in Operculodinium, is transferred to Lingulodinium and emended. A mid to late Paleocene age is proposed for the studied section. Assemblages are compared with those reported from other basins, especially those of the Southern Hemisphere.

Key words. Dinoflagellates. Chorrillo Chico Formation. Paleocene. Southern Chile.

Introduction

A meeting organized by the South American Regional Committee on Paleogene Stratigraphy (IGCP Project 301 “Paleogene of South America” and 308 “Paleocene/Eocene Boundary Events”) was held in Punta Arenas, Tierra del Fuego on 23-30 November 1992. One of its most important events was visiting and sampling the classic marine Paleogene sequence of the Punta Arenas region, Chile (figure 1). This is the most complete exposure of earliest Tertiary strata in South America, and a system of local stages was proposed for it during the 1970’s (Natland et al., 1974). A complete spectrum of specialists sampled this section, including micropalaeontologists, palynologists, nannoplanktologists and magnetostratigraphers. The stratigraphic section (figure 2) was surveyed by L. Legarreta (this column was surveyed during a one day field trip, thus rock types, sequences boundaries and systems tracts are idealized, L. Legarreta pers. comm.).

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Figure 1. Paleogeography of southern South America during the Late Cretaceous-Early Tertiary (from Urien et al. 1995, with modifications) showing the studied area. Paleogeografía del sur de América del Sur durante el Cretácico Tardío-Cretácico Temprano (de Urien et al. 1995 con modificaciones) donde se muestra el área de estudio.
Dinoflagellates from the Paleocene of Chile

This paper is an account of the dinoflagellates present in one of the sampled units: the Chorrillo Chico Formation, named and characterized by Thomas (1949) and Charrier and Lahsen (1969). Previous studies in the Brunswick Peninsula correspond to the Leña Dura Formation, considered to be of Eocene or Oligocene age (Cookson and Cranwell, 1967), or Cretaceous-Tertiary (Troncoso and Doubinger, 1980). Morgans et al. (2000) provide preliminary dinoflagellate biostratigraphic results from Punta Prat and Punta Rocallosa localities.

The palynological preparations contain dinoflagellates, acritarchs and terrestrial palynomorphs. Except for the samples from the lower sections corresponding to fine calcareous sandstone to siltstone with rare thin beds of very coarse grit, the material is generally well preserved.

The dinoflagellates present are listed following the classification system proposed by Fensome et al., 1993 and their stratigraphic distribution is shown in figure 4.

Physiography of the study area

Southward from the Golfo de Penas (47° S), six morphostructural units can be distinguished along southern Patagonia (Natland et al., 1974; Ramos, 1989; see figure 1).

1. The Archipelago Mountain Range, which forms a row of islands along the Pacific coast as far south as Cape Horn and represents the southern continuation of the Coastal Range of central Chile. It consists of dioritic rocks of the Andean suite, Palaeozoic sedimentary rocks and scattered micaceous schists.

2. The Main or Patagonian Cordillera, which extends to the east of...
the foregoing unit. The core is largely formed by tectonized Palaeozoic rocks with some Jurassic volcanic deposits and Cretaceous sediments, intruded by ophiolites, granites, dioritic rocks of the Andean suite, and effusive masses of Pliocene-Holocene age.

3. The Austral or Magallanes Basin, which is a significant negative and asymmetrical structural feature lying between the Main Cordillera and the Río Chico Arc. It covers half of the Magallanes Province of Chile and part of the Santa Cruz and Tierra del Fuego Provinces of Argentina, its eastern boundary being interpreted as forming a line about 150 km off the Atlantic coast. The Magallanes Basin was established in the Early Tertiary.

4. The Río Chico Arc, which forms an elongate and structural unit in northeastern Santa Cruz province (Argentina), has been a positive area since the Early Palaeozoic.

5. The Upper Palaeozoic-Jurassic Basin, developed to the northeast of the Río Chico Arc into northern Patagonia (Argentina), includes only igneous rocks and continental sediments.

6. The Madre de Dios Allochthonous Block, representing the western coastal belt, is a highly deformed accretionary prism composed mainly of Late Palaeozoic turbidites.

Basin setting

Since the end of the Cretaceous and during the Cenozoic, Patagonia Extrandina was recurrently inundated by Atlantic transgressions; these alternate with periods of non-marine sedimentation and erosion. An extensive continental platform was developed over a passive margin of very low angle. The Austral (Magallanes) basin is located at the southern tip of South America, in Tierra del Fuego. The early history of the basin is one of Triassic and Jurassic extension associated with the opening of a small marginal sea behind a developing magmatic arc. That marginal sea closed in the mid-Cretaceous; the Late Cretaceous through Cenozoic history of the basin is one of a foreland basin in front of the rising Andes Mountains (Biddle et al., 1986; Malumián, 1999: 557).

The similarity in geological history between Patagonia and the Antarctic Peninsula indicates that they formed part of the same geological and palaeobiogeographic province, at least from the Late Cretaceous until the Drake Passage opened, an event which started in the late Eocene and developed further until the early Miocene (Malumián, 1999: 557).

The first phase of mountain building, representing the beginning of Andean deformation, is dated to Late Cretaceous-Paleocene time; this is broadly contemporaneous with the Laramide deformation of North America. The encroachment of early thrust belt loads at this time initiated the flexural foreland basin (Zambrano, 1987).

Stratigraphic setting

Punta Prat is located on the western side of the Brunswick Peninsula at 53° 10′ S-71° 20′ W (figure 1). Beds cropping out there belong to the Chorrillo Chico Formation and the lower portion of the Agua Fresca Formation. Outcrops were sampled within the abrasion marine platform, which is accessible during low tide.

Following Cortés and Herrero (1992), the oldest Tertiary rock unit recognized in this area is the Chorrillo Chico Formation, previously considered to be Danian to Paleocene in age, but probably late Paleocene (Martínez-Pardo, 1971). It is represented by a hard, shaly glauconitic siltstone with thin beds of limestone and limestone concretions. In its type locality - on the east side of Punta Rocallosa, at Seno Skyring - the characteristic foraminiferal assemblage (according to Cortés and Herrero 1992), includes Vaginulina midwayana, Alabamina wilcoxensis, Allomorphina paleocenica and Robulus degolyeri.

Methods

The position of levels sampled are shown in figure 2. The preparation of samples for palynological examination was conducted according to the standard procedures of the Laboratory of Palynology, University of Saskatchewan (Canada).

All holotypes and figured specimens are lodged in the collections of the Palynological Laboratory, Universidad Nacional del Sur, Bahía Blanca, Argentina. In the citation of specimens referred to or illustrated, the slide number (e.g. 2) is given first and the position on the slide indicated, primarily by stage readings (e.g. 2/115,2) and then by position as determined by England Finder (e.g. G36/4). The stage readings were taken from Olympus microscope BH-2, no. 222673, Palynological Laboratory, Universidad Nacional del Sur. In the figure captions, the length and breadth of specimens seen under the optical microscope are cited in micrometers and the magnifications under the scanning electron microscope are indicated alongside the picture.

Systematic palynology

In this section a full list of the dinoflagellate taxa observed is given, after which particular taxa are discussed. The classification follows that of Fensome et al. (1993) with taxonomic proposals. For citations of papers referred in the list below, see Williams et al. (1998); full citations of papers published since that work, or cited when taxonomic proposals are made, are presented in the "References". Definitions of all terms used herein may be found in the standard glossary (Williams et al., 2000).

List of species recognized

Class Dinophyceae Pascher 1914
Subclass Peridiniphycidae Fensome et al. 1993
Order Gonyaulacales Taylor 1980
Suborder Gonyaulacinae (Autonym)
Family Gonyaulacaceae Lindemann 1928
Subfamily Gonyaulicicini (Volkheimer and Sarjeant, 1959)
Emended diagnosis. Gonyaulicicines differ from Gonyaulacales in the epistome lacking "shoulders", the episomal tabulation being pentesiod, and the Kofoid section encompassing the cond anterior intercalary plate (2a). In other genera, the archaeopyle is formed only of plate 2a and the operculum is free. In some specimens, the operculum is no longer adnate to the type species, S. styloniferum. Our studies of specimens attributable to the type species, S. styloniferum, convinced us that archaeopyle sutures are developed on either side of plate 4" and that its operculum is typically adnate (though it may be torn off, or folded inside the pericyst). In some specimens, the operculum is no longer adnate and plate 4" is lost, along with plates 3'and 2a. In other specimens, however, the archaeopyle is formed only of plate 2a and the operculum is free.

The terms "episome" and "hyposome" are used above in the sense of Fensome et al. (1993, p. 253), as encompassing the more specific terms "epicone" and "hypocone", "epithea" and "hypotheca", and "epitract" and "hypotract". (The terms "episphere" and "hypisphere" were redundant at inception, being, as Fensome et al. 1993 recognized, mere synonyms of "epitract" and "hypotract").

It has become evident to us that a full reconsideration of the species presently placed into the genus Spinidinium necessitates its subdivision, with reallocation of certain species to other existing or new genera; this process is begun here. However, it is also clear that the resultant genera cannot properly be placed into the Deflandreoidae, a subfamily spe-

### Taxonomic proposals

- **Family PERIDINIAE** Ehrenberg 1831
  - **Subfamily SPINIDINIOIDEAE** (Bujak and Davies, 1983) stat. nov., emend.

  1983 Tribe Spinidiniae, Bujak and Davies, p. 131

### Original diagnosis.

"Fossil deflandreoidean dinoflagellates whose cysts are characterized by the formation of a steno- to iso-deltiform I (2a) archaeopyle, with the operculum often remaining attached along its posterior (H.) margin. A sessile archaeopyle sutures are frequently developed along the lateral margins of precingular plate 4". (Bujak and Davies, 1983, p. 131).

**Emended diagnosis.** Peridiniaeans in which the epistome tabulation is bipesiod and the Kofoid second anterior intercalary plate (2a) is of hexa type, stenodeltaform to steno-deltiform. The cyst is organic-walled. The archaeopyle consistently involves plate 2a, but also frequently involves an apical plate (3') and the opening of archaeopyle sutures alongside the fourth precingular plate (4'). The perioperculum is typically, but not consistently, adnate posteriorly.

**Description.** Spinidinioideans comprise cavate cysts exhibiting a somewhat elongate peridinoid outline. They have a well-developed apical horn, the episome lacking "shoulders", and a hyposome usually of smaller size, with two antapical horns. The left antapical horn is well defined, the right variably developed but always smaller. The frequent development of a combination archaeopyle distinguishes them from deflandreoideans, in which only plate 2a is lost (see Fensome et al., 1993, p. 132).

- **Type genus.** Spinidinium Cookson and Eisenack, 1962b, emend. Lentin and Williams, 1976.

- **Other genera.** Volkheimeridium Quattrocchio and Sarjeant, gen. nov., herein; M agallanescum Quattrocchio and Sarjeant, gen. nov., herein.

**Discussion.** In the emendation of Spinidinium by Lentin and Williams (1976, p. 62-63) -the generic diagnosis was modified, but not emended, by Stover and Evitt (1978, 124-125)- it was noted that the operculum is of variable character, sometimes involving an apical plate (3'). Our studies of specimens attributable to the type species, S. styloniferum, convinced us that archaeopyle sutures are developed on either side of plate 4" and that its operculum is typically adnate (though it may be torn off, or folded inside the pericyst). In some specimens, the pericyst (in Williams et al., 2000), in some specimens through the vicissitudes of diagenesis and preparation. In some specimens, the operculum is no longer adnate and plate 4" is lost, along with plates 3'and 2a. In other specimens, however, the archaeopyle is formed only of plate 2a and the operculum is free.

The terms "episome" and "hyposome" are used above in the sense of Fensome et al. (1993, p. 253), as encompassing the more specific terms "epicone" and "hypocone", "epithea" and "hypotheca", and "epitract" and "hypotract". (The terms "epicyst" and "hypocyst" were redundant at inception, being, as Fensome et al. 1993 recognized, mere synonyms of "epitract" and "hypotract").

It has become evident to us that a full reconsideration of the species presently placed into the genus Spinidinium necessitates its subdivision, with reallocation of certain species to other existing or new genera; this process is begun here. However, it is also clear that the resultant genera cannot properly be placed into the Deflandreoidae, a subfamily speci-
fied as having a periarchaeopyle involving plate 2a only (see Fensome et al., 1993, p. 132). In consequence, the “tribe” proposed by Bujak and Davies (1983) - a non-Linnaean taxonomic unit - is elevated to subfamilial status and emended to bring it into closer accord with current concepts.

Genus Spinidinium Cookson and Eisenack, 1962, emend. nov.


Emended diagnosis. Cornucavate peridinioid cysts of asymmetrical rhomboidal to somewhat rounded ambitus, longer than broad. Episome larger than hyposome, lacking “shoulders”. Apical horn well developed, of variable size and shape; hyposome with well
developed left antapical horn, but with right antapical horn always smaller and sometimes only feebly developed. The periphragma may be laevigate to granulose. Cingulum shallow, concave, bordered by raised ridges that may be spinose; sulcus only feebly marked as an area devoid of spines. Endoblast ovoidal to spheroidal or with antapical flattening. Archaeopyle of variable form, always involving the opening of anterior intercalary plate 2a and frequently involving apical plate 3’, with opening of archaeopyle sutures at either side of precingular plate 4”. The 3’ plate is of lenteloid hexa shape; 2a stenodeltaform to stenothetaform; 4” of flattened quadra shape. Operculum most often adnate posteriorly, but sometimes lost.

Discussion. From our examination of an abundance of Chilenian specimens referarable to S. stylonerum, and from the published photographs of the type material and other specimens, we believe the ar-

Figure 3. Eisenackia chilensis Quattrocchio and Sarjeant, sp. nov. Interpretation of the tabulation, with kofoidean tabulation compared to Taylor/Evitt (Y) tabulation/ Eisenackia chilensis Quattrocchio y Sarjeant, n. sp. con tabulación kofoidea comparada con la tabulación de Taylor/Evitt (Y).

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chaeopyle of this genus to be variable, always involving plate 2a - though not the other anterior intercalary plates - but quite often also involving plate 3' and the opening of sutures on either side of 4'''. The operculum is often adnate; when lost, the detached portion may comprise only plate 2a but may also involve 3' and even 4'' (see figure 7.H).

Those three plates form a relatively slender strip on the cyst's dorsal surface; this is well illustrated by Bujak and Davies (1983, text-fig. 2), who contrast the shapes of these plates with those equivalent plates in genera which have well developed "shoulders". Typical features are the linteloid 3' and steno-deltaform 2a (though, in some species attributable to Spinidinium as here emended, 2a may be of stenothetaform shape).

Type species. Spinidinium styloniferum Cookson and Eisenack, 1962, p. 489, pl. 1, figs. 1-5, Holotype pl. 1, figs. 1-2. Late Cretaceous (Aptian-Albian), Australia. Holotype lodged in the National Museum, Melbourne, Australia.

Other accepted species. Spinidinium rhombicum (Cookson and Eisenack, 1974, pp. 49-50, pl. 20, figs. 5-9) Stover and Evitt, 1978, p. 124. Holotype: Cookson and Eisenack, 1974, pl. 20, fig. 7, as Deflandrea rhombica (reduced to a subspecies, as Spinidinium echinoideum subsp. rhombicum, by Lentin and Williams, 1976, p. 64). Late Cretaceous (Albian-Cenomanian), Australia. [Note: though neither the character of the archaeopyle nor that of the dorsal plates is evident from the illustrations, the shape and proportions suggest this genus and differentiate the species from Spinidinium echinoideum].

Spinidinium colemani Wrenn and Hart, 1988, pp. 366-367, figs. 36, nos. 1-2, fig. 39, no. 2 Holotype fig. 36, nos. 1-2. Late Paleocene-Eocene, Seymour Island, Antarctica [Note: archaeopyle, according to Wrenn and Hart, 1988, p. 367, formed by dorsal detachment of the 2a plate and occasionally also of plate 4'', the operculum being adnate. Their illustration (pl. 36, no. 2) shows an alignment of plates corresponding well with the emended diagnosis].

Spinidinium sagittula (Drugg, 1970) Lentin and Williams, 1976, p. 64. Holotype: Drugg, 1970, fig. 1a, as Deflandrea sagittula. Early Eocene, Alabama, U.S.A. [Note: the proportions of this species, and the irregularity of its spine scatter, correspond well with our

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Table: Preparations from the Paleocene of Chile

<table>
<thead>
<tr>
<th>Taxa</th>
<th>Preparations</th>
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<tbody>
<tr>
<td>Palaeocystodinium gonzowense</td>
<td>3969 PP5</td>
</tr>
<tr>
<td>Palaeoperidinium pyrophorum</td>
<td>3970 PP6</td>
</tr>
<tr>
<td>Eisenackia crassistablata</td>
<td>3971 PP7</td>
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<td>Spiniferites granulatus</td>
<td>3972 PP8</td>
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<td>Spiniferites membranaceous</td>
<td>3973 PP9</td>
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<td>Spinidinium styloniferum</td>
<td>3974 PP10</td>
</tr>
<tr>
<td>Isabelidinium bakeri</td>
<td>3975 PP11</td>
</tr>
<tr>
<td>Lingulodinium bergmannii</td>
<td>3976 PP12</td>
</tr>
<tr>
<td>Spiniferites ramosus</td>
<td>3977 PP13</td>
</tr>
</tbody>
</table>

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Figure 4. Stratigraphic distribution of dinoflagellate species in the Chorrillo Chico Formation, Punta Prat locality, Chile. Distribución estratigráfica de especies de dinoflagelados en la Formación Chorrillo Chico, en la localidad de Punta Prat, Chile.
revised concept; Drugg's illustrations suggest an identical dorsal paratabulation and indicate an adnate operculum).

Provisionally accepted species. Spinidinium? dentatum Pothè de Baldis and Ramos, 1983, p. 441, pl. 2, figs. 3.8. Late Cretaceous (early Aptian), Argentina. [Note: neither the character of the archaeopyle nor the shape of plates on the dorsal surface can be determined from text or illustrations, but the general outline corresponds with that of Spinidinium, as here restricted].

Spinidinium? echinoidum (Cookson and Eisenack, 1960, p. 2, pl. 1, figs. 5-6) Lentin and Williams, 1976, p. 64, emend. Sverdlove and Habib, 1974, p. 58. Holotype: Cookson: Cookson and Eisenack, 1960, pl. 1, figs. 5-6, as D'Andrea echinoida. Transferred to V azhenienvikia by Stover and Evitt, 1978, p. 130, but returned to Spinidinium by Lentin and Williams, 1981, p. 257. Late Cretaceous (Santonian-Campanian), Australia. [Note: the size and proportions of the archaeopyle, as illustrated by Sverdlove and Habib (1974, pl. 1, fig. 3, text-fig. 2b), appear intermediate between our present concepts of Spinidinium and M agallanesis. While the presence of sutures alongside plate 4" suggests Spinidinium, the size of this species is unusually large. In view of its earlier date, it may possibly have given rise to both genera].

Spinidinium styloniferum Cookson and Eisenack, 1962


Description. Cyst proximochorate, compressed peridinioid, cornucavate and relatively small. Ambitus somewhat biconical; ventral surface deeply concave. Episome slightly longer than hyposome. Apical horn (10 µm length in SEM) well developed, terminating in stout spines. Left antapical horn also well developed (10 µm length in SEM), but right antapical horn reduced (3.5 µm length in SEM). Cingulum well defined by sutures; it is relatively broad, with some indentation, and with ventral ends somewhat separated anterioposteriorly. Sulcus expressed without ornamentation and by a shallow depression, principally on the hypotrich. Periphragm ornamented by penitabular rows or intratabular clusters.

Illustrated specimens. 3974/ 5: 12b/ 144.5. Overall length: 66 µm; breadth: 50 µm. SEM 3974. Overall length: 60 µm; breadth 36 µm. SEM 3973. Overall length: 53 µm; breadth: 40 µm.

Figure 5. x 1000 (except when the sizes are given). A. O perculodinium erinaceum (Morgenroth, 1966a) Stover and Evitt 1978. B-D. Lingulodinium bergmannii (Archangelsky) comb. nov., B. Specimen 3977/ 4: 6.3/ 146.9 (T47) in dorsal view, C. Specimen 3977/ 4: 9.9/ 148.3 (Q49/ !) in dorsal view, D. Detached operculum 3977/ 4: 10.2/ 148.2 (P49), E. G. P yxidiophis crassimurata Wilson. Specimen 3979/ 5: 8.2/ 137.9 (R39/ !) in apical view, by transparency (E) and in antapical view (G), H. Spini odinium conicum (Gerlach) Stover and Hardenbol. Specimen 3974/ 5: 8.2/ 128 (Q27/ !), in lateral view (53x45 µm), I. F. Eisenackia crassitubulata Deflandre et Cookson emend. McLean. Specimen 3975/ 4: 7.4/ 136 (N 45), in ventral view (F) and specimen 3975/ 4: 15.3/ 147 (S 36) in lateral view (I).

Genus Volkheimeridium nov.

Derivation of name. In honour of the distinguished Argentinian palynologist Wolfgang Volkheimer, who has co-operated often with each of the authors to mutual satisfaction.

Diagnosis. Cornucavate cysts of asymmetrically rhomboidal ambitus, with a strong apical horn; hyposome with well developed left antapical horn, but with right antapical horn variably, and often feebly, developed. Crests bearing short spines define a tabulation (3', 3a, 7", Xc, 5"', 2''). Periphragm smooth to granulose or with small-scale ornamentation (granae, coni, baculae or spines). Cingulum well marked on periplast; it is broad and laevorotatory, bordered by continuous crests. Sulcus indicated by a shallow depression on the ventral surface. Endoblast ovoidal to spheroidal or with antapical flattening. Archaeopyle formed by the opening of plates 3' and 2a (3'of linteloid hexa shape, 2a stenodeltaform to stenothetaform), which retain attachment to plate 4" (of flattened quadra shape). Operculum most often adnate posteriorly, but sometimes lost.

Discussion. This genus is distinguished from Spinidinium Cookson and Eisenack 1962, as here emended, by the presence of crests delimiting most (though not necessarily all) plates; in the latter genus these are not developed, the spinose ornamentation constituting penitabular rows or intratabular clusters. Nevertheless, the two genera are evidently very closely related. This casts doubt upon the opinion of Bujak and Davies (1983) who, in their stimulating discussion of the evolution of peridinioid cysts, suggested that Spinidinium formed part of "a possible cyst lineage represented by the genera Alterbia [now Alterbidinium], Diconodinium, Isabelidinium, M anumielia and Spinidinium" (Bujak and Davies, 1983, p. 66). Instead, we would suggest that Spinidinium may have been derived from Volkheimeridium and that its relation to those other genera is questionable.

Type species. Volkheimeridium lanterna (Harland, 1973, pp. 664-673, pl. 84, figs. 5-6, 10; text-fig. 9) comb. nov. Holotype: specimen F7964, lodged in the palynological collections of the Geological Survey of Western Australia, and illustrated, as Spinidinium lanterna, by Cookson and Eisenack, 1970, pl. 12, figs. 1-2. Late Cretaceous (Senonian), Western Australia.

Other accepted species. Volkheimeridium clavum (Harland, 1973, pp. 674-675, pl. 84, figs. 5-6, 10; text-fig. 9) comb. nov. Holotype: specimen F7963, lodged in the palynological collections of the Geological Survey of Western Australia and illustrated, as Spinidinium clavum, by Cookson and Eisenack, 1970, pl. 12, figs. 1-2. Late Cretaceous (Senonian), Western Australia.
this markedly elongate cyst clearly indicate that plates 3', 2a and 4'' correspond with the generic concept.

Genus Volkheimeridium (Heisecke, 1970, p. 230, pl. 1, fig. 3, pl. 2, figs. 2-3) comb. nov. Holotype: Heisecke, 1970, pl. 1, fig. 3; pl. 2, figs. 2-3, as Deflandrea irmoechinata. Transferred to Gonyaulacysta by Lentin and Williams, 1976, p. 41 and to Spinidiunium by Stover and Evitt, 1978, p. 125. [Note: the holotype was stated by Heisecke to be in dorsoventral orientation; we believe instead that it is in slightly oblique lateral orientation. Plates 3', 2a and 4'' appear to form the strip at right in Heisecke's pl. 1, fig. 3 and to correspond with our concept of Valkheimeridium and Spinidiunium emended herein].

Volkheimeridium luciae (Wrenn and Hart, 1988, p. 368, fig. 35, nos. 1-3; fig. 38, nos. 1-5; fig. 39, no. 4) comb. nov. Holotype: Wrenn and Hart, 1988, fig. 35, nos. 1-3 as Spinidiunium luciae. Early Eocene, Antarctica. [Note: Wrenn and Hart, 1988, p. 368, reported that the operculum, formed by plate 2a, may be posteriorly adnate or free, that the sutures bounding plate 4'' were typically "partially open"and that 4'' might be lost in archaeopyle formation "probably fortuitously". One of their SEM illustrations (pl. 39, fig. 4) suggests a possible involvement also of plate 2'].

Volkheimeridium lanterna (Cookson and Eisenack, 1970) comb. nov. Figures 7.E-F and 11.C-D

1970 Spinidiunium lanterna Cookson and Eisenack, pl. 12, figs. 1-3.

Original diagnosis. "Shell somewhat biconical, clearly divided by a relatively conspicuous girdle into a longer epitheca with straight to slightly convex slanting sides and a short apical horn and a shorter, somewhat broader hypotheca with slanting, slightly convex sides and a narrow, pointed antapical horn to one side of the midline. The girdle is relatively broad, interrupted laterally on the dorsal surface, its ends on the ventral surface being rather widely separated.

The tabulation, which is most evident in the epitheca, is difficult to determine. The plates appear to be long, narrow and triangular in outline and to extend from the girdle to near the apex. There seem to be six precingular plates in the epitheca; the number in the hypotheca has not been determined. However, in several specimens, a small semicircular area, outlined by a single row of small, evenly-spaced thickenings, which extends between the two lateral breaks in the girdle, has been evident on the dorsal surface of the hypotheca (figure 7.F).

The outlines of both the shell and plates are ornamented with distinctly pointed spines which vary somewhat, both in size and density, in individual specimens.

The archaeopyle is small, intercalary and high in the epitheca. The internal body is large, thin and smooth-walled and, except at the extreme apex, almost fills the shell." (Cookson and Eisenack, 1970, p. 144).

Emended diagnosis. Cyst proximate compressed peridinioid, cornucave. Ambitus asymmetrically rhomboidal, with a strong apical horn and a well-developed left antapical horn, but with the right antapical horn feebly developed. Crest, bearing short spines and baculate (1-2 µm), define a tabulation 4', 3a, 7", Xc, 5"", 2''", this is most evident on the epi-tract. The plates appear to be long, narrow and triangular in outline. Periphragma smooth to granulose with scarce coni, baculate or spines. Cingulum well marked on periblast; it is broad, laevo-rotatory, and bordered by continuous hystrichate crests, up to 3 µm in height. Sulcus indicated by a shallow depression on the ventral surface. Endoblast ovoidal to spheroidal or with antapical flattening. Archaeopyle combination: 3' and 2a (3' of linteloid hexagon, 2a stenodetaform to stenothetaform). Operculum most often adnate posteriorly, but sometimes lost.

Illustrated material. 3974/5; 2,9/143. Overall length: 60 µm; breadth 35 µm. 3974/5; 1,7/143,8. Overall length: 61 µm; breadth: 45 µm. SEM 3974. Overall length: 43 µm; breadth 33µm. SEM 3974. Overall length: 42 µm; breadth 26 µm.


Comments. This species is very abundant in PP 10 sample (slide 3974). The ornamentation varies between the different specimens, from well to poorly defined.

Genus Magallanesium nov.

Diagnosis. Cornucave peridinioid cysts of asymmetrically rhomboidal to somewhat rounded ambitus. Episome larger than hyposome, lacking "shoulders". Apical horn well developed, of variable size and shape; hyposome with well-developed left antapical horn, but with right antapical horn always short and sometimes feebly developed. The periphragma may be laevigate to granulose; it bears a general cover of spines, sometimes aligned or concentrated into penitabular groups, sometimes without apparent arrangement. Cingulum shallow, concave, bordered by raised ridges that may be spinose; sulcus only feebly marked, as an area devoid of spines. Archaeopyle formed by anterior intercalary plate 2a, which is hexa and isodetaform. Operculum adnate posteriorly or lost.

Derivation of name. After the province of Magallanes, Chile, the study of whose microfloras stimulated the present taxonomic analysis.

Discussion. (On 32 specimens of M. macmurdouense, Quattrocchio and Sarjeant, 1996). This genus is differentiated from Spinidinium and Völkhämmerud by the form of the archaeopyle and additionally from Völkhämmerud by the lack of raised ridges or crests along sutures (though, in some species, lines of spines may indicate the position of plate boundaries). Plate 2a is proportionately larger in this genus than in either Spinidinium or Völkhämmerud, while the archaeopyle sutures on either side of plate 4" are less consistently developed or not at all. The proportions and the general cover of spines distinguish this genus from all others yet reported from late Cretaceous-Tertiary sediments.

Type species. M. agalinense macmurdouense (Wilson, 1967, pp. 60-62, figs. 11-16, 22; text-fig. 2a) comb. nov. Holotype: Wilson 1967, figs. 11-13, as D. filandrea macmurdouense; transferred to Spinidinium by Lentin and Williams, 1976, p. 64. Early Tertiary, Antarctica.

Other accepted species. The following species accord with this new genus, in general features and in the style and proportions of the archaeopyle:


M. agalinense denticulatum (Potthë de Baldis and Ramos, 1963, p. 438, pl. 2, figs. 7, 11; pl. 4, fig.2) comb. nov. Holotype: Potthë de Baldis and Ramos, 1963, pl. 2, figs. 7,11, pl. 4, fig.2 as D. loyana denticulatæ. (Upon transfer to Spinidinium by Lentin and Williams, 1965, p. 325, the trivial name became illegitimate, since it was a nomenclatural synonym of S. denticulatum). Early Tertiary (early Danian), Argentina.

M. agalinense densispinatum (Stanley, 1965, p. 226-227, pl. 21, figs. 1-5) comb. nov. Holotype: Stanley, 1965, pl. 21, figs. 1-3 as Spinidinium densispinum. Paleocene, South Dakota, U.S.A.

M. agalinense eosi (Cookson and Eisenack, 1967, p. 135, pl. 19, figs. 1-8) comb. nov. Holotype: Cookson and Eisenack, 1967 pl. 19, figs. 1-2, as Spinidinium. Late Paleocene, Australia.


M. agalinense raimlov (Héseiteké, 1970, pp. 226, 228, pl. 1, figs. 1-2, pl. 2, fig. 1) comb. nov. Holotype: Héseiteké, 1970, pl. 1, fig. 2 as Spinidinium raimlov. Paleocene (Danian), Argentina.

M. agalinense piquetum (Stanley, 1965, p. c22, pl. 21, figs. 18-16) comb. nov. Holotype: Stanley, 1965, pl. 21, figs. 14-16, as A. etzeliella pilata. Transferred doubtfully to Spinidinium by Costa and Downie, 1979, p. 43. Paleocene, South Dakota, U.S.A.

M. agalinense pulchrum (Benson, 1976, p. 194, pl. 9, figs. 4-9) comb. nov. Holotype: Benson, 1976, pl. 9, figs. 4-7, as D. filandrea pulchra. Transferred to Spinidinium by Lentin and Williams, 1977, p. 147. Paleocene, Maryland, U.S.A.

Genus Spiniferites Mantell, 1850, emend. Sarjeant, 1970


Discussion. Hansen (1977, p. 13) proposed this taxon as a genus, specifying a tabulation which, as Stover and Williams (1987, p. 117) recognized, corresponds in all features with that of Spiniferites; consequently, they treated it as a taxonomic junior synonym of the latter genus. Subsequently Edwards (1996, p. 989) reinstalled the genus, without any explanation of that action; her decision was accepted without comment by Williams et al. (1998, p. 261).

The only difference between this taxon and typical Spiniferites lies in the nature of the cyst wall which, as Hansen states (1977, p. 13), contains "numerous evenly distributed vesicles (vacuoles). The vesicles are spherical or, interconnected, they may form a fine reticulum internal in the cyst wall".

Though the basis for generic differentiation must always be a matter of subjective judgement, the primacy of tabulation (or paratabulation), in combination with the style of cyst opening, has come to be generally recognized as fundamental. On those bases there is, as Stover and Williams (1987) pointed out, no justification for retaining Hafniasphaera as a distinct genus. On the other hand, as R. Guerstein has noted (pers. comm.), this type of phragma structure characterises a group of species that appear confined to a limited stratigraphic interval (late Maastrichtian-early Eocene) and thus have stratigraphic value.

In consequence, we propose the compromise of treating Hafniasphaera as a subgenus of Spiniferites, in accordance with accepted procedures of botanical taxonomy. The reported simultaneous presence of six species of this subclass in the latest Cretaceous and earliest Tertiary of Denmark may, in view of the high morphological variability characteristic of Spiniferites ramosus (see Williams et al., 1998, pp. 577-580; Lewis et al., 1999), require critical investigation.


Spiniferites (Hafniasphaera) fluens (Hansen, 1977, p. 16, figs. 13-14, 19 C-D) Stover and Williams, 1987, p. 117. Holotype: Hansen, 1977, figs. 19 C-D, as Hafniasphaera fluens. Late Cretaceous (late Maastrichtian - early Paleocene (early Danian), Denmark.


Spiniferites (Hafniasphaera) gracicus (Hansen, 1977, p. 15, pls.
Dinoflagellates from the Paleocene of Chile

Figure 7. x 1000 (except when the sizes are given). A. Cassidium fragile (Harris) Drugg. Specimen 3976/1: 1, 2/142 (Y 42/3-4), in oblique ventral view (49x50 µm). B-C. Eisenackia chilensis sp. nov. The holotype, specimen 3973/6: 19, 29/129.9 (E 30/3). A pical view (B); slightly oblique antapical view by transparency (54x42 µm) (C). D. Operculodinium azcaratei Troncoso and Doubinger. Specimen 3974/4: 7, 9/146.2 (S 47/1), in right lateral view. (55 x 47 µm). E-F. Volkheimeridium lanterna (Cookson and Eisenack) comb. nov. Specimen 3974/5: 2, 9/143 (X 43), in dorsal view (E); specimen 3974/5: 5, 1/143.8 (Y 44/1-3), in ventral view by transparency (F). G-H. Spinidinium styloniferum Cookson and Eisenack. Specimen 3974/5: 1,5/144,5 (Y 44/2), in dorsal view (G); specimen 3974/5: 12, 6/144,5 (N 44), in dorsal view (H). I. Isabelidinium bakeri (Deflandre and Cookson) Lentin and Williams. Specimen 3975/5: 5, 4/140,3 (U 40/2-4), in dorsal view (65x40 µm).
Genus Lingulodinium Wall, 1967
emend. Dodge, 1989

Lingulodinium bergmannii (Archangelsky, 1969) comb. nov., emend.

Type specimen. 710: 43,3/113,9 (LP-PB: Lodged in the collections of the División Paleobotánica, Museo de La Plata, Argentina).

Type locality and horizon. D-15 borehole, Sierra Dorotea, Santa Cruz province, Argentina, at a depth of 372-373m; Río Turbio Formation, Eocene.

Emended diagnosis. Cysts skolochorate, acavate, subspherical. Processes nontubular, more than 50 in number, acuminate to buccinate, hollow and tapering. Surface of phragma between process bases granular. Tabulation indicated by archaeopyle and cingulum when archaeopyle is compound. Archaeopyle simple or compound, precingular or combination. It may be formed by four methods: loss of the single precingular plate 3", loss of two small precingular plates (2" plus 3")*, loss of those plates plus the whole apex, or by loss of the apex, accompanied by opening of sutures between 1" and 2", 2" and 3", 3" and 4", those plates remaining adnate.

Dimensions. Holotype: length of central body without operculum 40 µm, width of central body 42 µm, length of processes 8 µm. Range of 19 specimens: length of central body 30-62 µm, width of central body 27-58 µm, length of processes 6-10 µm. Details: Remarks. In an earlier paper (Quattrocchio and Sarjeant, 1996, p. 119-120), we discussed this species briefly. On the basis of the observation of specimens presenting an apical archaeopyle, we rejected its assignation to O. pereculodinium by Stover and Evitt (1978) and placed it instead into the genus Downiesphaeridium Islam, 1993. Our subsequent joint study of more extensive material involved the reconsideration of specimens reported from Seymour Island, Antarctica, by Wrenn and Hart (1988, p. 361). One of their two illustrations (ibid., fig. 30-1) shows a specimen in which the archaeopyle is clearly precingular (though, in our view, probably formed by loss of the two small precingular plates 2" and 3" rather than one large one).

Our examination of additional material showed that, in the species L. bergmannii, excystment may occur by any of the four methods specified in the emended diagnosis. If our interpretation is correct, the generic placement of bergmannii becomes problematic. In O. pereculodinium, only plate 3" is lost in archaeopyle formation; in the genera Kokia and Doubinger, 1978, and N. spinosum Davey, 1979, two precingular plates are lost but the apical plates are not involved; and in Downiesphaeridium only the apical plates are lost. The most appropriate generic placement is, therfore, into Lingulodinium, whose various species include forms losing one to five precingular plates and sometimes the whole epi-tract.
**Figure 8.** x 1000 (except when the sizes are given). **A.** *Palaeoperidinium pyrophorum* (Ehrenberg) emend. Evitt et al. Specimen 3974/5: 19.5/131.2 (F31/1), in dorsal view. **B.** *Deflandrea fuegensis* Menéndez. Specimen 3975/4: 4.4/133.9 (U 34/1), in slightly oblique dorsal view. (125x85 µm). **C.** *Deflandrea granulata* Menéndez. Specimen 3975/4: 16.9/141.9 (J42/1), in dorsal view. (82x69 µm). **D.** *Deflandrea boloniensis* (Riegel) Wrenn and Hart. Specimen 3971/5: 5.4/139.9 (U40), in dorsal view. **E.** *Deflandrea cygniiformis* Póthe de Baldis 1966. Specimen 3974/4: 19.3/139.2 (F39/2), in dorsal view. (160x88 µm). **F.** *Palaeocystodinium golzowense* Alberti. Specimen 3974/5: 15.3/130.2 (K36), in dorsal view. (200x46 µm).
Laevigate or with subdued ornamentation. Alternative diagnosis. 

Of twelve species considered by Williams et al. (1998, p. 374-376) to be legitimately placed into Lingulodinium, most are of Oligocene or later date. The exception is Lingulodinium varispinosum Slimani, 1994, which was reported from the Late Cretaceous (early Campanian to early Maastrichtian) of Belgium. This reattribution thus bridges the gap in the stratigraphical record of Lingulodinium.

**Genus Operculodinium** (Wall, 1967) 
Matsuoka et al., 1997

**Operculodinium erinaceum** (Morgenroth, 1966) Stover and Evitt 1978

*Figure 9A.*

1966. Impletosphaeridium erinaceum Morgenroth, p. 33-34, pl. 8, figs. 10-12.

**Illustrated specimen.** 397/4: 15.3/138.2 (M 39/2).

**Overall length:** 60 µm; **width:** 50 µm.

**Remarks.** The specimen illustrated by Wrenn and Hart, 1988, is considered by us to be instead referable to *O. erinaceum*. In the Chilean material, a single specimen referable to this species was observed.

**Genus Eisenackia** Deflandre and Cookson, 1955, emend. nov.

1979. Agerasphaera Harland, p. 28-29 (subsequently shown to be a nomenclatural junior synonym of Alisocysta; see Lentin and Williams, 1998, p. 29).

**Original diagnosis.** “Cell globular, without appendages. Transverse girdle and longitudinal furrow not marked by a depression of the membrane, which has a completely continuous outline. Transverse girdle delimited by the bases of the plates. Tabulation 2-, 3-, 6-, 76, 6′′, 2p, 1′′″. The epitheca has, amongst others, an elongated ventral plate, and the hypotheca a ventral area consisting of several small plates.” (Deflandre and Cookson, 1955, p. 258).

**Emended diagnosis.** Cyst proximate to proximochorate, subspherical; tabulation gonyaulacacean (4′, 6′, 6′′, 1-72 p, 1′′″, 2-5s), indicated by peniplates (Williams et al., 2000). The phragma surface may be laevigate or with subdued ornamentation. Alternatively, a reticulate ornamentation may cover the whole phragma surface or may be confined within the peniplates. Anterior and posterior sulcal peniplates consistently delimited and typically larger than the other sulcal pairs, which may be absent.

**Discussion.** When Deflandre and Cookson (1955, p. 258) proposed the genus Eisenackia, the concept of a penitabular replication of plate patterns had not been developed. Since the height of the ornamentation within the plates of *E. crisstabilata* almost matched that of the crests bounding the plates, they considered that the plate boundaries were marked by “depression(s) of the membrane”, an idea that later gave rise to the term “fossa” (see Sarjeant, 1966). In their overview of dinoflagellate cysts, Stover and Evitt (1978, p. 16) accepted the concept of fossae in Eisenackia and proposed the genus Alisocysta for forms having a closely comparable tabulation indicated by peniplates.

The high degree of similarity between Eisenackia and Alisocysta has been stressed by Helby (quoted in Damassa 1979, p. 198), who considered the only difference between *E. crisstabilata* and *A. reticulata* to lie in the development of the intratabular reticulation that characterises both species. The argument was developed by Partridge (quoted in Wilson, 1988, p. 20), who considered that the two species - and, implicitly, the two genera - might be indistinguishable.

We concur in part with their judgement. The ridges within the peniplates of Eisenackia crisstabilata approach the height of the bounding crests, but the depth of the lumina attains the same level as the surface of the phragma outside the plates. The concept of “fossae” - i.e. hollows outlining the tabulation which reach below the phragma within the peniplates - is herewith abandoned. Since this eliminates the one feature that differentiated the two species, we consider that Eisenackia must be treated as a senior taxonomic synonym of Alisocysta and that the latter name cease to be used. The constituent species of the latter taxon are therefore reassigned herein to Eisenackia.

Concerning the two species *E. crisstabilata* and *E. reticulata*, we consider that the height and coarseness of the reticulation differentiates them. In the former species, the lumina are small and often approximately circular, while the ridges approach in height that of the bounding crests. In *E. reticulata*, the reticulation within the peniplates is lower than that of the bounding crests, with wider meshes and lumina of more polygonal aspect. It remains possible, as Partridge has suggested, that there is a complete intergradation between the two.
between the two species, however, until this has been demonstrated (ideally, through restudy of the type material of E. crassitabulata), we consider it preferable to continue to differentiate these taxa.


**Type species.** Eisenackia crassitabulata Deflandre and Cookson, 1955, p. 258-260, pl. 5, fig. 2, text-figs 6-16 (holotype pl. 5, fig. 2, text-fig. 6-7). Pebble Point Formation (Lower Eocene), Victoria, Australia. Lodged in the collections of the National Museum, Melbourne, Australia.

**Other included species.** Eisenackia brevivalvata (Harker and Sarjeant in Harker et al., 1990, pp. 97-98, ex Harker and Sarjeant, 1991, p. 208), comb. nov. Holotype: Harker et al., 1990, pl. 5, figs. 11-12; text-figs 20a-b. Late Cretaceous (late Campanian), Manitoba, Canada.

Eisenackia chilensis Quattrocchio and Sarjeant (defined below).


**Remarks.** Eisenackia brevivalvata (Harker and Sarjeant in Harker et al., 1990, pp. 97-98, ex Harker and Sarjeant, 1991, p. 208), comb. nov. Holotype: Harker et al., 1990, pl. 5, figs. 11-12; text-figs 20a-b. Late Cretaceous (late Campanian), Manitoba, Canada.

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**Derivatio nominis.** Of Chile, in reference to the source of the specimens.
Overall length (without operculum): 82 µm; breadth: 98 µm. Phragma length 61 µm; breadth 80 µm.

**Remarks.** These specimens show a close morphological resemblance to *G. retiintexta*, the type material differing only in that it is much larger than the Argentinean specimens (holotype: overall length 177 µm; breadth 117 µm).

Cyclonephelium sp. of Troncoso and Doubinger (1980, p. 120, pl. 1, fig. 11), from the Chorrillo Chico Formation (Magallanes, Chile) is very similar to the material studied. Those authors compared other specimens with *G. retiintexta* but cited, as differentiating features, the reduced development of the trabeculae and the ampler ramifications of the processes of their specimens.

**Tityrosphaeridium** Sarjeant, 1981

**Remarks.** This genus was rejected by Lentin and Williams (1985, p. 355) and Stover and Williams (1987, p. 215), on the basis of a reinterpretation of the drawing presented by Sarjeant (1981, text-fig. 1) of the type specimen of *Cordosphaeridium inodes* (Klumpp, 1953). They contended that the processes in that drawing, which Sarjeant had numbered as 2'' and 3'', in fact corresponded to circular plates 3c and 4c.

If they are correct, Sarjeant’s statement, in his emendation of *Cordosphaeridium*, that the genus lacks circular processes (Sarjeant, 1981, p. 101) may indeed be wrong (though those authors did not present any reinterpretation of Sarjeant’s sketch of the holotype, to show where they believed 2'' and 3'' to be truly located). Their comments, if confirmed, may require a further emendation of the diagnosis of *Cordosphaeridium*.

They do not, however, invalidate the genus *Tityrosphaeridium* in which, as Sarjeant (1984, p. 94) pointed out, there are some 24 processes (sulcals omitted) corresponding to five major Kofoidean plate series, whereas in *C. inodes* there are only 18, corresponding to only four series. It should be noted that, following our earlier comments (Quattrocchio and Sarjeant, 1996, p. 118), the genus *Tityrosphaeridium* was retained by Williams et al. (1998, p. 612).

**Age of the assemblages**

The assemblages here reported are, beyond doubt, of post-Cretaceous age. There is only a very small microfossiliferous overlap with Maastrichtian assemblages. Of 132 species reported by Schioler et al. (1997) from the type Maastrichtian strata of the Netherlands, only five (Hystrichosphaeridium tubiferum, Palaeoperidinium pyrophorum, Spiniferites ramosus, Turbicosphaera filosa and Spiniferella cornuta) occur in our assemblages. In the later study of Herngreen et al. (1998) of strata at the Cretaceous-Tertiary boundary in the Netherlands (Maastricht and Southern Formations), 70 species were reported; only some five species occur in common with our assemblages, though certain taxa identified only to generic level - *Palaeocystodinium* sp. plur., *Operculodinium* sp. and a species of Eisenackia [as Aliscyctea] - are also present. The assemblage recorded by Roncaglia and Corradini (1997), from the Late Campanian to Maastrichtian of Italy, is again profoundly different: of 142 species, only six (S. ramosus, S. membranaceous, S. granulatus, H. tubiferum, *Palaeoperidinium* golzowense and Isabelidinae bakeri) are held in common. The studies of Maastrichtian assemblages from Nigeria (Oloto, 1989), Texas (Srivastava, 1995) and China (Mao Shaozhi and Norris, 1988) contain so few species in common with our assemblage as to confirm that this is a temporal, not merely a palaeogeographic, difference.

The age, then, is certainly Late Paleocene, confirming the evidence of the foraminifera. However, comparisons with earlier Paleocene (Danian) assemblages show only a small level of correspondence. From the type Danian of Denmark, Hansen (1977) reported 55 taxa; only a handful of these (H. tubiferum, S. ramosus, S. (H.) cryptovesiculatus, Spiniferella cornuta, P. pyrophorum and perhaps *Palaeocystodinium* sp.) occur in our assemblages, while a number of genera prominent in the Danish material - notably Areligera, *Cordosphaeridium*, *Danea*, Kenleyia and Thalassiphora - are unrepresented. Overlap in species content with Danian microfloras reported from Tunisia (Lassoued and Taougourdeau, 1984; Brinkhuis and Leereveld, 1988) is minimal. Comparison with the assemblages reported from Senegal by Jan du Chêne (1987) and from Alabama by Moshkovitz and Habib (1993) is more difficult, since many of their identifications are to generic level only; however, of 74 Senegalese morphotypes, not more than five are present in Argentina, while in the Alabama assemblage the number is at most five out of fifty. With respect to the Danian assemblage described earlier by us from the Colorado Basin of Argentina (Quattrocchio and Sarjeant, 1996), the overlap is predictably higher, with six of twenty species represented (S. ramosus, S. membranaceous, P. pyrophorum, Galaphycosta retiintexta, Lindulodinium bergmannii and *Tityrosphaeridium* tenuistratum).

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**Figure 11. A, B. Spinidinium colemannii** Wrenn and Hart, in dorsal view (A) and in lateral view (B). C, D. *Volkheimeridium lanterna* (Cookson and Eisenack) comb. nov., dorsal view (C,D). E. Distorted specimen of *Palaeocystodinium golzowense* Alberti, 1961, in lateral view. F, G. *Spinidinium styloniferum* Cookson and Eisenack, in left lateral view (F) and in dorsal view (G). H. *Isabelidinium bakeri* (Deflandre and Cookson) Lentin and Williams 1977.

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Even so, the differences remain profound. In consequence, the assemblages from Tierra del Fuego quite evidently represents a higher level in the Palaeocene, i.e. post-Danian.

Comparison with other southern basins

New Zealand

Comparison with the Paleocene and Eocene dinoflagellates from Waipawa, Hawkes Bay, New Zealand by Wilson (1988), shows the present assemblage to correlate with Wilson's Palaeocystodinium golzowense Zone (Middle to Late Paleocene), due to the presence of the following stratigraphically important species: P. golzowense, Eisenackia circumtabulata, E. crassitabulata, Cassidium fragile, Glaphyrocysta reticulata, Isabelidinium bakeri, and Turboosphera filosa.

Two species that are present in Chile from PP9 upwards were considered to characterize the Apectodinium homomorphum Zone (Late Paleocene-Early Eocene); these are Pyxidiniopsis crassimurata and Impagidinium coccum. Pyxidiniopsis crassimurata is present also in the overlying Wilsonidiunum echinosuturatum Zone (Middle Eocene), but the general species constitution of that zone is markedly different.

Antarctica

Rich palynomorph assemblages occur throughout the Campanian to Eocene stratigraphic section of Seymour Island, northeastern Antarctic Peninsula. The work of Askin (1988a and 1988b), focuses on the Campanian through Paleocene part of the succession, with only brief comments on Eocene palynology. The Eocene marine palynomorphs are described by Wrenn and Hart (1988). Six palynomorphs zones, informally designated 1 through 6 and based on dinocyst species, are recognized (Askin 1988a). In common with Zone 5 considered early Paleocene (Danian), Spinidinium spp., Deflandrea spp., Palaeoperidinium pyrophorum, Alysocysta spp. (=Eisenackia this paper) and Cassidium fragile are registered in Punta Prat locality. Zone 6 is characterized by the predominance of Spinidinium sp. cf. S. lanternum (here Volkhmeridium lanterna) and the absence of Palaeoperidinium pyrophorum, suggesting an age younger than early late Paleocene for this Zone. In this paper these two species are associated. The absence of P. pyrophorum is registered in the upper levels (PP12-PP13).

The lower Tertiary marine sediments of Seymour (Vicecomodoro Marambio) Island contain the only known in situ early Tertiary dinoflagellate floras from Antarctica (Wrenn and Hart, 1988). The early late Paleocene dinoflagellate species recovered from the Cross Valley Formation are all cosmopolitan taxa, with perhaps one exception; O. pyrophorum bergmanii had been reported only from southern South America (Archangelsky 1968; Quattrrocchio and Sarjeant, 1996). Species in common with the Chilean assemblages are: Palaeoperidinium pyrophorum, Eisenackia circumtabulata, Palaeocystodinium golzowense, Lingulodinium bergmanii, Deflandrea boloniensis, D. cyniformis, Spiniferites ramosus, Volkmheridium lanterna and Hystrophesphaeridium tubiform.

The overlapping ranges of the taxa and their co-occurrence indicate an early late Paleocene age for this section in Seymour Island. The distribution of this dinoflagellate microflora indicates that a marine seaway connected the South Atlantic Ocean and the Seymour Island area with Australia, New Zealand and the Ross Sea area (Wrenn and Hart, 1988).

A smaller and less similar assemblage, interpreted to be Danian in age, has been reported from the area where Sections 15 and 16 of Wrenn and Hart (1988) were collected - i.e., in the Cape Witman area, Seymour Island (Palamarczuk, 1992).

Argentina

Following Palamarczuk et al., 1998 and taking into account the dinoflagellate distribution in central-southern Argentina, Chile and Antarctica, an assemblage of Areoligera spp. can be recognized in the Maastrichtian of Colorado and Neuquén basins, Chubut Province and in the Austral/Magallanes Basin of Chile. This association had disappeared by the Danian. Instead, an assemblage of Manumiella spp. is present in Tierra del Fuego and Antarctica, associated with Palaeocystodinium granulatum. Also Askin (1988a) mentioned an evolving complex of dinocyst species of Manumiella and related genera (Phelodinium sp., Albertidinium acutulum, etc.) for her informal zones 1 to 4 (Seymour and adjacent islands, northeastern Antarctic Peninsula).

In the Danian, Cordosphaeriadum and Disphaerogena are abundant everywhere except in Tierra del Fuego and Antarctica. In these two regions (also in the present Punta Pratt assemblage), Palaeoperidinium pyrophorum is very abundant.

From the Isla Grande de Tierra del Fuego, Palamarczuk and Olivero (2000) recognized a Maastrichtian association with Manumiella spp., Palaeocystodinium spp. and O. pyrophorum cf. azcarate. A monospecific association with Palaeocystodinium golzowense was tentatively assigned to the Palaeocene. Above it is a complex of the genus, related to the Wetzelliëa complex, is typical of the Palaeogene of the Northern Hemisphere and New Zealand. It is associated with Deflandrea spp., Palaeocystodinium golzowense, Octodinium askiniae and
Lejeunecysta sp. An Eocene association is also present; it includes, among other species, Deflandrea dartinoria, Hystrichosphaeridium tubiferum, Arachnodinium antarcticum, and Impagidinium waipawaeense.

**Chile**

A previous study concerning the Chorrillo Chico Formation was reported by Troncoso and Doubinger (1980) from the El Ganzo Number 1 borehole, located to the west of Punta Arenas. 28 taxa were recorded; the species in common with this paper are Palaeocystodinium golzowense, Spiniferella cornuta, Hystrichosphaeridium tubiferum, Isabelidinium bakeri, Deflandrea fuchsensis and Lingulodinium bergmannii (as Implesosphaeridium charrieri).

Recently Morgan et al. (2000) collected twenty-nine samples from Punta Pratt section, during a field party of GNS (Geological & Nuclear Sciences) and Oxford geologists in Chile. Four samples were examined. All are considered mid to late Paleocene in age and belong to the P. golzowense Zone. Key taxa include Palaeocystodinium golzowense, Deflandrea foevolata, Alyseysta reticulata, Isabelidinium bakeri, I. cingulatum, Alterbidinium pentaradiatum, Cassidium fragile and C. filosum.

**Conclusion**

In view of the presence of Palaeoperaudinium pyrophorum (Upper Campanian - Middle Thanetian), the assemblages here described cannot be younger than Middle Thanetian. From the comparison with other basins and the stratigraphic ranges of the characteristic taxa and their co-occurrence, a Late Danian to Middle to Late Paleocene (Middle Thanetian) age is proposed for this assemblage. It may well correspond with the Paleocene of Seymour Island, Antarctica (Palmarzuk, 1992: Wrenn and Hart, 1988).

The work of Palmarzuk and Olivero (2000), who mention the presence of P. golzowensis associated with the genus Apectodinium, might cause us to predict that, in southern Argentina, these species will also prove to be associated. This does not happen in New Zealand, where P. golzowensis is absent from the Apectodinium homomorphum zone (Waipawan; Late Paleocene/Early Eocene). Consequently, this association can be tentatively correlated with the Paleocene/Eocene transition, and considered younger than the assemblages reported here. This accords well with the opinion of Biddle et al. (1986), who viewed the top of the Chorrillo Chico Formation as being a mid-Thanetian (late Paleocene) unconformity. This unconformity is of regional extent and can be seen in outcrop in southern South America and in the subsurface of both the Magallanes and Malvinas (Falklands) basins.

The studied section from the Punta Prat locality (Chile) affords a new record for the Paleocene marine microflora in the southern high latitudes. As research develops, it should furnish the most complete profile of this microflora at a single locality.

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**References**


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COMENTARIO BIBLIOGRÁFICO


Una de las dificultades para la enseñanza de la Micropaleontología en países de habla hispana es la escasez de textos en castellano. Este vacío se llena ahora con el libro “Micropaleontología”, un texto de excelente nivel y muy completo, editado por Eustoquio Molina. Aunque destinado inicialmente para la enseñanza de la materia en el Departamento de Ciencias de la Tierra de la Universidad de Zaragoza, se adapta ampliamente a cualquier programa clásico de enseñanza de la materia. Los autores de los diferentes capítulos forman parte del reconocido equipo de profesores e investigadores en micropaleontología de la mencionada Universidad (Eustoquio Molina, Laisa Alegret, Ignacio Arenillas, José A. Arz, Beatriz Azanza, José I. Canudo, Concepción Gonzalvo y Silvia Ortiz).

El libro está dividido en tres partes. La primera corresponde a conceptos y fundamentos generales de la micropaleontología, y trata aspectos básicos y particulareidades propias de los microfósiles: incluye capítulos dedicados a la historia y estado actual de la micropaleontología, metodología de estudio, tafonomía, y la clasificación biológica en micropaleontología.

La segunda parte del libro trata numerosos grupos de microfósiles: foraminíferos, radiolarios, tintinívidos, bacterias, coccolitofóridos, diatomeas y silicoflagelados, dinoflagelados y quitinosos, polen y esporas, algas calcáreas, brizosos, ostrácodos, conodontes, y otros grupos menores y de afinidades inciertas. Varios capítulos de esta segunda parte del libro han sido dedicados a los foraminíferos, pues ha sido tomado como el grupo básico y de ejemplo para el acceso de los estudiantes a los microfósiles. Este enfoque es adecuado, considerando que los foraminíferos han sido y son el grupo de microfósiles más estudiado, y que tienen una amplia gama de aplicaciones en distintos temas como la bioestratigrafía, paleoecología, paleoceanografía y evolución. Cada uno de los restantes grupos de microfósiles ha sido tratado en capítulos independientes, brindando un completo panorama de cada uno de ellos. La mayoría de los capítulos han sido revisados por prestigiosos especialistas en el tema, asegurando la calidad en el tratamiento.

La tercera parte del libro está destinada a las aplicaciones de los microfósiles en diversas áreas como bioestratigrafía, paleoecología, reconstrucción paleoambiental y paleobiogeografía. Incluye asimismo capítulos sobre modalidades y causas de evolución y extinción, origen de la vida e historia de la microbiota desde el Precámbrico y a lo largo del Fanerozoico, y microfacies.

Finalmente, incluye un diccionario de términos micropaleontológicos en varios idiomas (español, inglés, alemán, francés e italiano), para facilitar a los estudiantes el acceso a la bibliografía específica incluida al final de cada capítulo. El desarrollo de los diversos temas está acompañado por buenas y adecuadas ilustraciones, incluyendo fotografías de microscopio electrónico de barrido.

En definitiva, se trata de un libro dedicado a la enseñanza, muy completo y de calidad, con un tratamiento claro y didáctico. Seguramente será de amplio uso por parte de estudiantes, docentes, así como por profesionales en geociencias que deseen consultar diferentes aspectos de los microfósiles. El precio de venta es accesible (25 euros), aun para nuestra alicaída economía, y para mayor información puede consultarse a la editorial: Prensas Universitarias de Zaragoza, c/ Pedro Cerbuna 12, E-50009 Zaragoza, España, e-mail: puz@posta.unizar.es

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