# 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 cygniformis* Pöthe de Baldis, *D. fuegensis* Menéndez, *Eisenackia crassitabulata* Deflandre and Cookson, *Glaphyrocysta* cf. *retiintexta* (Cookson) Stover and Evitt, *Impagidinium cassiculum* Wilson, *Isabelidinium bakeri* (Deflandre and Cookson) Lentin and Williams, *Palaeocystodinium golzowense* Alberti, *Palaeoperidinium pyrophorum* (Ehrenberg) Evitt, Damaza and Albert, *Pyxidiniopsis crassimurata* Wilson, *Spiniferella 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.

**Resumen.** DINOFLAGELADOS DE LA FORMACIÓN CHORRILLO CHICO, PALEOCENO DEL SUR DE CHILE. Se reconocieron 26 taxones de dinoflagelados provenientes de la Formación Chorrillo Chico, localidad Punta Prat, en el lado oeste de la Península Brunswick (Chile). Las especies estratigráficamente importantes incluyen: *Cassidium fragile* (Harris) Drugg, *Deflandrea cygniformis* Pöthe de Baldis, *D. fuegensis* Menéndez, *Eisenackia crassitabulata* Deflandre y Cookson, *Glaphyrocysta* cf. *retiintexta* (Cookson) Stover y Evitt, *Impagidinium cassiculum* Wilson, *Isabelidinium bakeri* (Deflandre y Cookson) Lentin y Williams, *Palaeocystodinium golzowense* Alberti, *Palaeoperidinium pyrophorum* (Ehrenberg) Evitt, Damaza y Albert, *Pyxidiniopsis crassimurata* Wilson, *Spiniferella cornuta* (Gerlach) Stover y Hardenboll, *Spiniferites (Hafniasphaera) cryptovesiculata* (Hansen) stat. nov. y *Turbiosphaera filosa* (Wilson) Archangelsky. La Tribu Spinidineae de Bujak y Davies es elevada al status de subfamilia y emendada; su género tipo *Spinidinium* es asimismo emendado. Se proponen dos géneros nuevos, *Volkheimeridium* y *Magallanesium*, nueve especies fueron ubicadas en estos géneros. El género *Alisocysta* Stover y Evitt es tratado como un sinónimo taxonómico de *Eisenackia* Deflandre y Cookson; las especies integrantes fueron transferidas al último género y fue descripta una nueva especie, *E. chilensis*. La especie *bergmannii*, recientemente ubicada en *Operculodinium*, es transferida a *Lingulodinium* y emendada. Una edad paleocena media a tardía es propuesta para la sección estudiada. Se compara con otras cuencas, especialmente aquéllas del Hemisferio Sur.

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

**Palabras clave.** Dinoflagelados. Formación Chorrillo Chico. Paleoceno. Sur de 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 Palaeogene 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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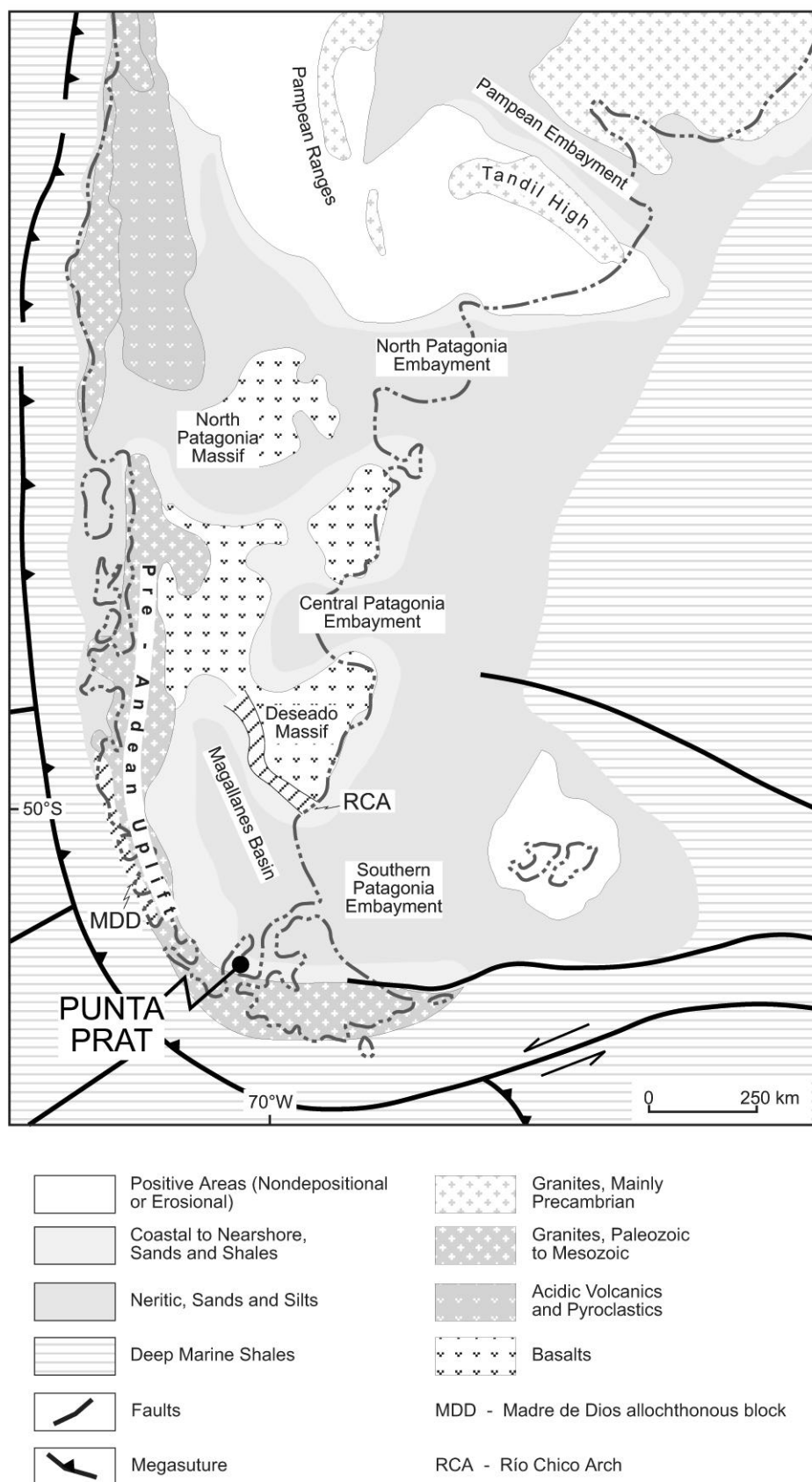
**Figure 1.** Paleogeography of southern South America during the Late Cretaceous-Early Tertiary (from Urien *et al.* 1995, with modifications) showing the studied area/ *Paleogeografía del sur de América del Sur durante el Cretácico Tardío-Cretácico Temprano (de Urien* et al. *1995 con modificaciones) donde se muestra el área de estudio.*

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 generaly 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 Archipiélago 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.
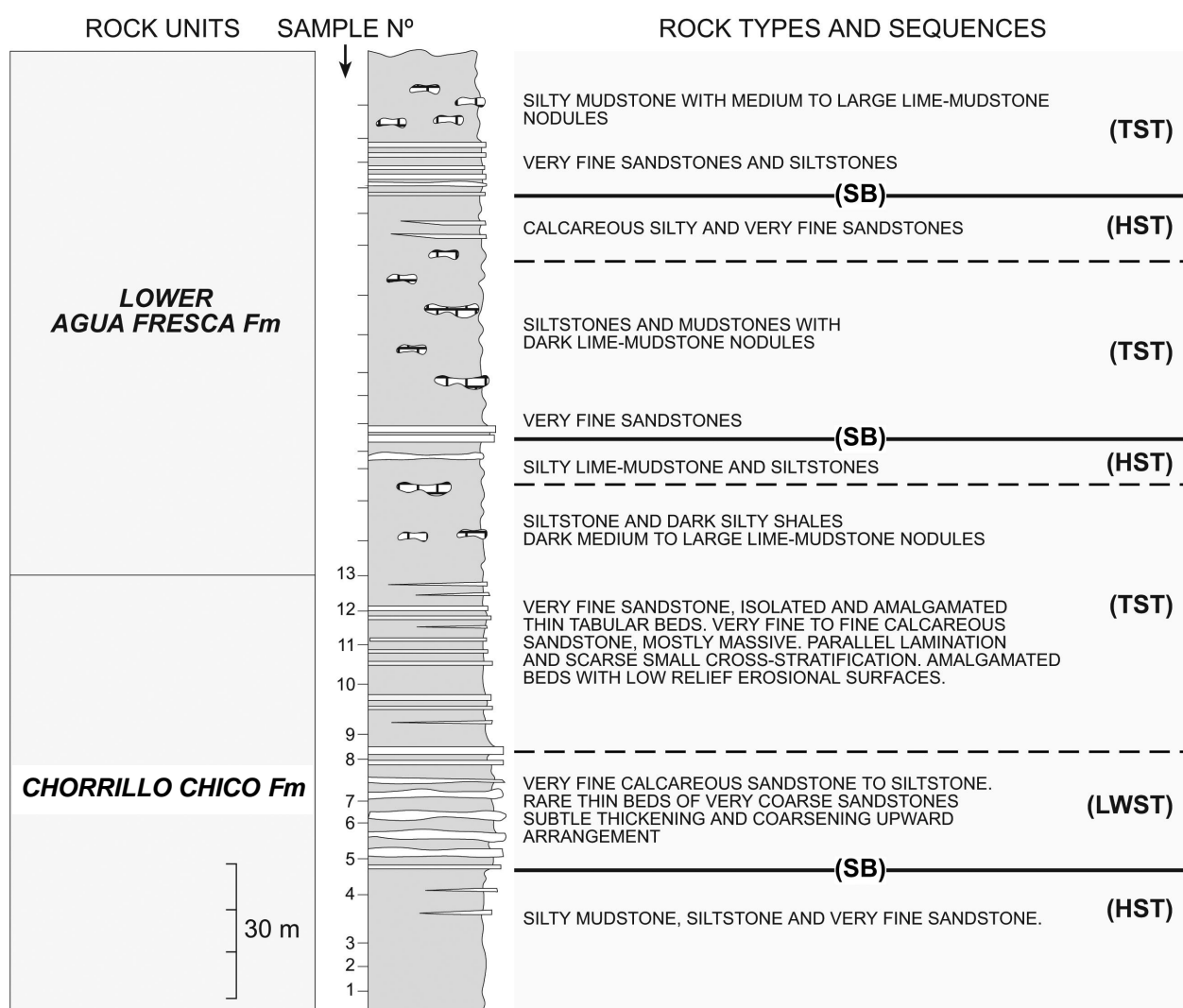2. The Main or Patagonian Cordillera, which extends to the east of



**Figure 2.** Stratigraphic column of the Chorrillo Chico Formation and lower Agua Fresca Formation, Punta Prat locality, Chile (by L. Legarreta). Sequences boundaries (SB) and systems tracts (TST) are tentative/ *Columna estratigráfica de la Formación Chorrillo Chico y Formación Agua Fresca inferior en la localidad de Punta Prat (por L. Legarreta). Los límites de secuencias (SB) y cortejos sedimentarios (TST) son tentativos.*

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 Gonyaulacineae (Autonym)
Family Gonyaulacaceae Lindemann 1928
Subfamily Cribroperidinioideae Fensome *et al.* 1993)
  *Lingulodinium bergmannii* (Archangelsky, 1969) comb. nov.
  *Operculodinium azcaratei* Troncoso and Doubinger, 1980
  *Operculodinium erinaceum* (Morgenroth, 1966) Stover and Evitt, 1978
  *Tityrosphaeridium tenuistriatum* (Heisecke, 1970) Quattrocchio and Sarjeant, 1996.
  *Turbiosphaera filosa* (Wilson, 1967) Archangelsky 1969
Subfamily Gonyaulacoideae (Autonym)
  *Impagidinium cassiculum* Wilson 1988
  *Spiniferella cornuta* (Gerlach, 1961) Stover and Hardenboll, 1994
  *Spiniferites (Hafniasphaera) cryptovesiculatus* (Hansen, 1977), stat. nov.
  *Spiniferites granulatus* (Davey, 1969) Lentin and Williams, 1973
  *Spiniferites membranaceus* (Rossignol, 1964) Sarjeant, 1970
  *Spiniferites ramosus* (Ehrenberg, 1838) Mantell, 1854
Subfamily uncertain
  *Pyxidiniopsis crassimurata* Wilson, 1988
Family Areoligeraceae Evitt 1963
  *Cassidium fragile* (Harris, 1965) Drugg, 1967
  *Glaphyrocysta* cf. *retiintexta* (Cookson, 1965) Stover and Evitt, 1978
Suborder Goniodomineae Fensome *et al.* 1993
Family Goniodomaceae Lindemann 1928
Subfamily Pyrodinioideae Fensome *et al.* 1993
  *Eisenackia chilensis* Quattrocchio and Sarjeant, sp. nov., herein
  *Eisenackia crassitabulata* Deflandre and Cookson, 1955 emend. McLean, 1973
  *Hystrichosphaeridium tubiferum* (Ehrenberg, 1838) Deflandre, 1937b
Order Peridiniales Haeckel 1894
Suborder Peridiniineae (Autonym)
Family Peridiniaceae Ehrenberg 1831
Subfamily Palaeoperidinioideae (Vozzhennikova, 1961) Bujak and Davies, 1983
  *Palaeoperidinium pyrophorum* (Ehrenberg, 1838) emend. Evitt, Damassa and Albert, 1998
Subfamily Deflandreoideae Bujak and Davies, 1983
  *Deflandrea boloniensis* (Riegel) Wrenn and Hart, 1988
  *Deflandrea cygniformis* Pöthe de Baldis, 1966
  *Deflandrea fuegensis* Menéndez, 1965
  *Deflandrea granulata* Menéndez, 1965
  *Isabelidinium bakeri* (Deflandre and Cookson, 1955) Lentin and Williams, 1977
  *Palaeocystodinium golzowense* Alberti, 1961
Subfamily Spinidinioideae (Bujak and Davies, 1983) stat. nov., emend.
  *Spinidinium colemanii* Wrenn and Hart, 1988
  *Spinidinium styloniferum* Cookson and Eisenack, 1962
  *Volkheimeridium lanterna* (Cookson and Eisenack, 1970) comb. nov. (genus proposed herein)

## Taxonomic proposals

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

1983 *Tribe Spinidineae.* Bujak and Davies, p. 131

**Original diagnosis**. "Fossil deflandreoidean dinoflagellates whose cysts are characterized by the formation of a steno- to iso-deltaform I (2a) archaeopyle, with the operculum often remaining attached along its posterior ($H_4$) margin. Accessory archaeopyle sutures are frequently developed along the lateral margins of precingular plate 4''." (Bujak and Davies, 1983, p. 131).

**Emended diagnosis.** Peridiniaceans in which the episomal tabulation is bipesioid and the Kofoid second anterior intercalary plate (2a) is of hexa type, stenodeltaform to stenothetaform. 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 periopherculum 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; *Magallanesium* 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 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", "epitheca" 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 Deflandreoideae, a subfamily speci-
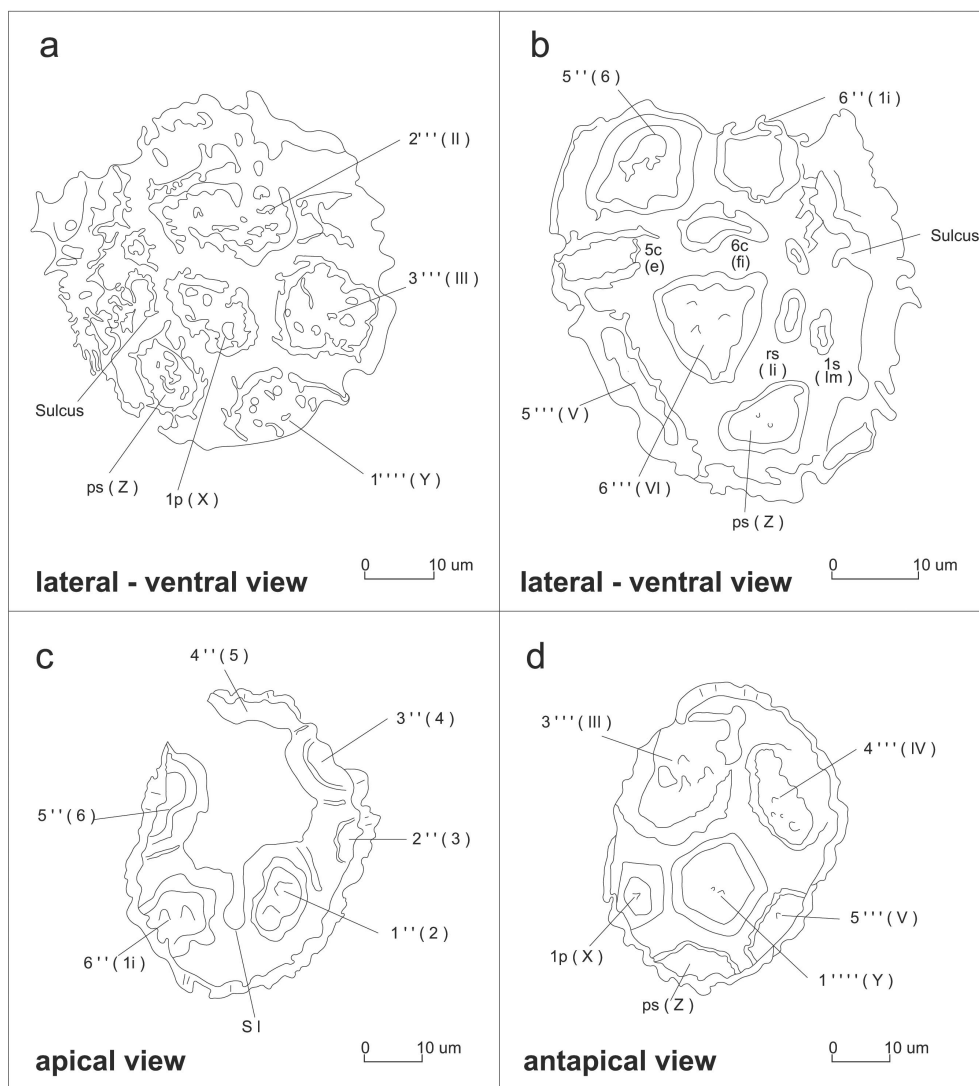
**Figure 3.** *Eisenackia chilensis* Quattrocchio and Sarjeant, sp. nov. Interpretation of the tabulation, with kofoidean tabulation compared to Taylor / Evitt (Y) tabulation / *Eisenackia chilensis Quattrocchio y Sarjeant, n. sp. con tabulación kofoidea comparada con la tabulación de Taylor/Evitt (Y).*

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.

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

</div>

1962. *Spinidinium* Cookson and Eisenack, 1962b, p. 489.
1976. *Spinidinium* Cook. and Eis. *emend.* Lentin and Williams, p. 62-63.
1978. *Spinidinium* Cook. and Eis.,"modified". Stover and Evitt, p. 124-125.

**Emended diagnosis**. Cornucavate peridinioid cysts of asymmetricaly 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 linteloid 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 referrarable to *S. styloniferum,* and from the published photographs of the type material and other specimens, we believe the ar-

| Preparations | 3969 | 3970 | 3971 | 3972 | 3973 | 3974 | 3975 | 3976 | 3977 |
|---|---|---|---|---|---|---|---|---|---|
| Taxa / Samples | PP5 | PP6 | PP7 | PP8 | PP9 | PP10 | PP11 | PP12 | PP13 |
| *Palaeocystodinium golzowense* | — | — | | — | — | — | — | | |
| *Palaeoperidinium pyrophorum* | — | | — | | — | — | — | | |
| *Eisenackia crassitabulata* | — | | | | — | | | | |
| *Spiniferites granulatus* | — | | | | | | | | |
| *Spiniferites membranaceous* | — | | | | | | | — | |
| *Spinidinium styloniferum* | | — | | | | — | | | |
| *Isabelidinium bakeri* | | — | | | | | | — | |
| *Lingulodinium bergmannii* | | — | | | — | — | | | |
| *Spiniferites ramosus* | | — | | | — | — | | | — |
| *Deflandrea boloniensis* | | | — | | | | | | |
| *Tityrosphaeridium tenuistriatum* | | | | — | — | — | — | | |
| *Eisenackia chilensis* | | | | | — | | | | |
| *Pyxidiniopsis crassimurata* | | | | | — | | | | |
| *Spinidinium colemanii* | | | | | — | | | | |
| *Spiniferites (H.) cryptovesiculatus* | | | | | | — | | | |
| *Deflandrea cygniformis* | | | | | | — | | | |
| *Operculodinium azcaratei* | | | | | | — | | | |
| *Turbiosphaera filosa* | | | | | | — | | | |
| *Spiniferella cornuta* | | | | | | — | | | |
| *Hystrichosphaeridium tubiferum* | | | | | | — | | | |
| *Volkheimeridium lanterna* | | | | | | — | | | |
| *Cassidium fragile* | | | | | | | — | — | |
| *Deflandrea fuegiensis* | | | | | | | — | | |
| *Deflandrea granulata* | | | | | | | — | | |
| *Glaphyrocysta* cf. *retiintexta* | | | | | | | — | | |
| *Impagidinium cassiculum* | | | | | | | | | — |
| *Operculodinium erinaceum* | | | | | | | | | — |

**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.*

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 stenodeltaform 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, fig. 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 colemanii* 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

revised concept; Drugg's illustrations suggest an identical dorsal paratabulation and indicate an adnate operculum].

**Provisionally accepted species.** *Spinidinium? denticulatum* Pothë de Baldis and Ramos, 1983, p. 441, pl. 2, figs. 3,8. Holotype: 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? echinoideum* (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 and Eisenack, 1960, pl. 1, figs. 5-6, as *Deflandrea echinoidea.* Transferred to *Vozzhennikovia* 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 *Magallanesium.* 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
### Figures 7.G-H and 11.F-G

**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 hypotract. Periphragm ornamented by widely to closely spaced spinules and by infrequent capitate or evexate processes (2.5 μm to 3.0 μm height). These are intratabulate and either separated by pandasutural areas or, in some cases, by sutures; endophragm smooth (± 1 μm thickness). Tabulation indicated by penitabular and intratabular features, in conjuction with sutural areas and sutures; peridinacean hexa style formula 3", 3a, 7'', Xc, 5''', 2''''. Archaeopyle intercalary, type I or Ia (SEM); operculum free or adnate posteriorly (SEM).

**Illustrated specimens.** 3974/5: 12,6/144,5. 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.

### 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 4', 3a, 7'', Xc, 5''', 2''''. Periphragm smooth to granulose or with small-scale ornamentation (granae, coni, baculae or spines). Cingulum well marked on periblast; 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, Manumiella* 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* (Cookson and Eisenack, 1970, pp. 144-145, pl. 12, figs. 1-3), 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: Harland, 1973, pl. 84, figs. 9, 10 as *Spinidinium clavum*. Late Cretaceous (Campanian), Alberta. [Note: Harland's illustrations of

**Figure 5.** x 1000 (except when the sizes are given). **A.** *Operculodinium 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 (Q49/1)in dorsal view, **D.** Detached operculum 3977/4: 10,2/148,2 (P49), **E,G.** *Pyxidiniopsis crassimurata* Wilson. Specimen 3973/5: 8,2/137,9 (R38/3)E in apical view, by transparency (E) and in antapical view (G), **H.** *Spiniferella cornuta* (Gerlach) Stover and Hardenboll. Specimen 3974/5: 8,2/128 (Q27/4), in lateral view (53x45 μm), **F, I.** *Eisenackia crassitabulata* 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).

this markedly elongate cyst clearly indicate that plates 3'', 2a and 4'' correspond with the generic concept].

*Volkheimeridium irmoechinatum* (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 *Spinidinium* 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 *Volkheimeridium* and *Spinidinium* 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 *Spinidinium 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 *Spinidinium 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 peridinoid, cornucavate. 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 epitract. The plates appear to be long, narrrow and triangular in outline. Periphragm smooth to granulose with scarce coni, baculate or spines. Cingulum well marked on periblast; it is broad, laevorotatory, and bordered by continuos 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 hexa shape, 2a stenodeltaform to stenothetaform). Operculum most often adnate posteriorly, but sometimes lost.

**Illustrated material**. 3974/5; 2,9/143. Overall length: 60 µm; breadth 35 µm. S974/5: 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.

**Dimensions.** Range: 55-62 µm long, 38-45 µm broad (10 specimens).

**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.** Cornucavate 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 isodeltaform. Operculum adnate posteriorly or lost.

**Figure 6.** x 1000 (except when the sizes are given). **A, B.** *Tityrosphaeridium tenuistriatum* (Heisecke) Quattrocchio and Sarjeant. Specimen 3975/4: 16,5/135 (H35/3), in oblique ventral view **(A)**; specimen 3975/418,3/134,5 (G34/2) in oblique dorsal view **(B)**. **C.** *Turbiosphaera filosa* (Wilson) Archangelsky. Specimen 3974/5: 9,6/128,5 (R28/2), in dorsal view by transparency (103x78 µm). **D.** *Hystrichosphaeridium tubiferum* (Ehrenberg) Deflandre. Specimen 3974/5: 9,1/128,7(P28/3), in oblique ventral view (102x113 µm). **E, H. Impagidinium cassiculum** Wilson. Specimen 3977/4: 18/136,2 (G36/4), in oblique dorsal view **(E)**; Specimen 3977/4: 9,2/129,2 (Q 39), in left lateral view (55x49 µm) **(H)**. **F. Spiniferites (Hafniasphaera) cryptovesiculatus** (Hansen) stat. nov., Specimen 3974/4: 18,2/139 (G39), in ventral view. **G. Glaphyrocysta** cf. **retiintexta** (Cookson) Stover and Evitt. Specimen 3975/4: 16,5/146,3(J47/10), in dorsal view. (82x98 µm). **I. Spiniferites ramosus** (Ehrenberg) Mantell. Specimen 3973/6: 5,9/144,1 (V44/1), in ventral view (70x70 µm).

**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. macmurdoense*, Quattrocchio and Sarjeant, 1996). This genus is differentiated from *Spinidinium* and *Volkheimeridium* by the form of the archaeopyle and additionally from *Volkheimeridium* 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 *Volkheimeridium*, 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.** *Magallanesium macmurdoense* (Wilson, 1967, pp. 60-62, figs. 11-16, 22; text-fig. 2a) comb. nov. Holotype: Wilson 1967, figs. 11-13, as *Deflandrea macmurdoense*; 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:

*Magallanesium balmei* (Cookson and Eisenack, 1962, p. 486) comb. nov. Holotype: Cookson and Eisenack, 1960, pl. I, fig. 1 (also illustrated by Morgan, 1977, text-fig. 2). Originally *Deflandrea minor* (name illegitimate); subsequently renamed *Deflandrea balmei* by Cookson and Eisenack, 1960. Transferred illegitimately to *Alterbia minor*, and emended, by Morgan 1977, p. 130; legitimately to *Isabelidinium* by Stover and Evitt, 1978, p. 109 and to *Spinidinium* by Ioannides, 1986, p. 35. Late Cretaceous (Turonian-middle Senonian), Australia.

*Magallanesium denticulatum* (Pothë de Baldis and Ramos, 1983, p. 438, pl. 2, figs. 7, 11; pl. 4, fig.2) comb. nov. Holotype: Pothë de Baldis and Ramos, 1983, pl. 2, figs. 7,11, pl. 4, fig.2 as *Dioxya denticulata*. (Upon transfer to *Spinidinium* by Lentin and Williams 1985, p. 325, the trivial name became illegitimate, since it was a nomenclatural synonym of *S. denticulatum* Pothë de Baldis and Ramos; the new name *argentinum* was substituted, but now becomes superfluous). Late Cretaceous (Early Aptian), Argentina.

*Magallanesium densispinatum* (Stanley, 1965, p. 226-227, pl. 21, figs. 1-5) comb. nov. Holotype: Stanley, 1965, pl. 21, figs. 1-3 as *Spinidinium densispinaton*. Palaeocene, South Dakota, U.S.A.

*Magallanesium essoi* (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.

*Magallanesium asymmetricum* (Wilson, 1967, pp. 62-63, figs. 17-21) comb. nov. Holotype: Wilson, 1967, figs. 19-21, as *Deflandrea asymmetrica*. Transferred illegitimately to *Alterbia* by Lentin and Williams, 1976, p. 48, and legitimately but hesitantly to *Senegalinium* by Stover and Evitt, 1978, p. 123. Early Tertiary erratics, Antarctica.

*Magallanesium rallum* (Heisecke, 1970, pp. 226, 228, pl. 1, figs. 1-2, pl. 2, fig. 1) comb. nov. Holotype: Heisecke, 1970, pl. 1, fig. 2 as *Spinidinium rallum*. Paleocene (Danian), Argentina.

*Magallanesium pilatum* (Stanley, 1965, p. 222, pl. 21, figs. 12-16) comb. nov. Holotype: Stanley, 1965, pl. 21, figs. 14-16, as *Wetzeliella pilata*. Transferred doubtfully to *Spinidinium* by Costa and Downie, 1979, p. 43. Paleocene, South Dakota, U.S.A.

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

Genus **Spiniferites** Mantell, 1850,
*emend.* Sarjeant, 1970

**Spiniferites** subgen. **Hafniasphaera**
(Hansen, 1977), stat. nov.

1977 *Hafniasphaera* Hansen, pp. 13-14.

**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.

**Type species.** *Spiniferites (Hafniasphaera) hyalospinosus* (Hansen, 1977, p. 14, figs. 7-8, 18A) Stover and Williams, 1987, p. 117. Holotype: Hansen, 1977, fig. 18A, as *Hafniasphaera hyalospinosa*. Early Paleocene (Danian), Denmark.

**Other species.** *Spiniferites (Hafniasphaera) cryptovesiculata* (Hansen, 1977, pp. 14-15, figs. 9-10; 18 C, E-F; 19, A-B) Stover and Williams, 1987, p. 117. Holotype: Hansen, 1977, figs 18C, E-F as *Hafniasphaera cryptovesiculata*. Early Paleocene (Danian), Denmark.

*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) goodmanii* (Edwards, 1982) Stover and Williams, 1987, p. 117. Holotype: Edwards, 1982, pl. 1, figs. 1-3 as *Hafniasphrea goodmanii*). Early Eocene, Maryland, U.S.A.

*Spiniferites (Hafniasphaera) graciosus* (Hansen, 1977, p. l5, pls.

**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: 19,9/129,9 (E 30/3). Apical 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: 1,7/143,8 (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 (N44), in dorsal view **(H)**. **I. *Isabelidinium bakeri*** (Deflandre and Cookson) Lentin and Williams. Specimen 3975/5: 5,4/140,3 (U40/2-4), in dorsal view (65x40 µm).

11-12, 18B-D) Stover and Williams, 1987. Holotype: Hansen, 1977, fig. 18 B (as *Hafniasphaera graciosa*). Early Paleocene (early Danian), Denmark.

*Spiniferites (Hafniasphaera) septatus* (Cookson and Eisenack, 1967, pp. 253-254, pl. 42, figs. 6-10, text-fig. 1) emend. McLean, 1971, p. 730). Holotype: Cookson and Eisenack, 1967, pl. 42, fig. 6, as *Baltisphaeridium septatum*; also attributed at different times to the genera *Achomosphaera* and *Rivernookia*. Late Paleocene, Australia.

## Genus *Lingulodinium* Wall, 1967
### *emend.* Dodge, 1989

### *Lingulodinium bergmannii* (Archangelsky, 1969)
### comb. nov., *emend.*
### Figures 5.B-D and 9.A-C

1966. *Baltisphaeridium* cf. *machaerophorum* (Deflandre and Cookson) Pothë de Baldis, p. 220- 221, pl. 1, fig. a).
1969. *Cleistosphaeridium bergmannii* Archangelsky, pp. 414-415, pl. 2, figs. 8-11.
1970. *Solisphaeridium filamentosum* Heisecke, p. 256, pl. 8, fig. 6, pl. 11, figs. 2-3.
1978. *Operculodinium bergmannii* (Arch.) Stover and Evitt, p. 178.
1980. *Impletosphaeridium charrieri* Troncoso and Doubinger, p. 102, pl. 2, figs. 7-8.
1988. *Operculodinium bergmannii* (Arch.) Wrenn and Hart, p. 361, figs. 30.1-30.2.
?1992. *Operculodinium radiculatum* Smith, pp. 348, 351, figs. 9, 10e,i-j.
1996. *Downiesphaeridium bergmannii* (Arch.) Quattrocchio and Sarjeant, p. 119-120, pl. 2, fig. 5, pl. 3, fig. 4, pl. 5, fig.4).
non 1988. *Operculodinium bergmannii* (Arch.) Mao Shaozhi and Norris, pl. 5, fig. 8.

**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 nontabular, 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 *Operculodinium* by Stover and Evitt (1978) and placed it instead into the genus *Downies-*

*phaeridium* 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 problematical. In *Operculodinium*, only plate 3'' is lost in archaeopyle formation; in the genera *Kiokansium* Stover and Evitt, 1978, and *Nexosispinum* 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 epitract.

| Studied material | Overall length (μm) | Overall width (μm) | Central body length (μm) | Central body width (μm) |
|---|---|---|---|---|
| 3077/4: 16,8/141,2 | 68 | 57 | 57 | 41 |
| 3977/4: 18, 1/143 | 58 | 43 | 51 | 38 |
| 3977/4: 11, 6/147, 5 | 65 | 53 | 54 | 40 |
| 3977/4: 11, 2/142, 2 | 71 | 54 | 58 | 47 |
| 3977/4: 7, 7/138, 2 | 62 | 50 | 48 | 40 |
| 3977/4: 9, 9/148, 3 | 60 | 56 | 48 | 48* |
| 3977/4: 6, 3/146, 9 | 65 | 56 | 75 | 60** |

Length of processes between 6 and 8 μm.
*Illus.
**Illus., without operculum.

*Lingulodinium bergmannii* is only one of several names given to specimens of the same species from the Paleocene of South America. The photograph accompaning the earliest record, by Pothë de Baldis (1966, pl. 1, fig. a), sufficiently resembles this species as to suggest her specimen belongs in *L. bergmannii*; however, the archaeopyle is not visible and the description inadequate for certainty. In contrast, Heisecke's illustration of the "holotype" of *Impletosphaeridium charrieri* (see Troncoso and Doubinger, 1980, pl. 2, fig. 7) suggests a large archaeopyle on the upper surface; again, the nature of the processes indicates that this taxon corresponds with *L. bergmannii. Operculodinium radiculatum* Smith, 1992, may also be a nomenclatural synonym of this species since the structure, placement, number and length of the processes are closely comparable. In contrast, the specimen from China attributed to *O.*

**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 cygniformis*** Pöthe 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).

*bergmannii* by Mao Shaozhi and Norris (1988, pl. 8, fig. 5) is considered not to be referable to this species; the processes are proportionally too long and the single-plate precingular archaeopyle too large.

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*.

<div align="center">

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

***Operculodinium erinaceum*** (Morgenroth, 1966)
Stover and Evitt 1978
Figure 5.A

</div>

1966. *Impletosphaeridium erinaceum* Morgenroth, p. 33-34, pl. 8, figs. 10-12.
1978. *Operculodinium erinaceum* (Morg.) Stover and Evitt, p. 178.
1988. *Operculodinium bergmannii* (Archangelsky, 1969) Stover and Evitt. Wrenn and Hart, 1988, p. 361, figs. 30.1-30.2.

**Illustrated specimen.** 3977/4: 15,3/138,2 (M39/2). 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.

<div align="center">

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

</div>

1955. *Eisenackia* Deflandre and Cookson, p. 258.
1966. *Eisenackia* Defl. and Cooks. *emend.* Sarjeant, p. 152.
1973a. *Eisenackia* Defl. and Cooks. *emend.* McLean, p. 262.
1978. *Alisocysta* Stover and Evitt, p. 15-16.
1978. *Eisenackia* Defl. and Cooks. *emend.* Stover and Evitt, p. 42.
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'', ?6, 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'', 6c, 6''', 1-?2 p, 1'''', 2-5s), indicated by peniplates (Williams *et al.*, 2000). The phragma surface may be laevigate or with subdued ornamentation. Alternati-

vely, 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 sulcals, 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. crassitabulata* 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 betweeen *E. crassitabulata* and *A. reticulata* to lie in the degree of 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 crassitabulata* 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 genera, 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. crassitabulata* 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

**Figure 9. A-C.** ***Lingulodinium bergmannii*** (Archangelsky) comb. nov., in lateral view **(A, B)** and dorsal view **(C)**. **D.** ***Tityrosphaeridium tenuistriatum*** (Heisecke 1970) Quattrocchio and Sarjeant (1996). **E.** ***Spiniferites granulatus*** (Davey 1969) Lentin and Williams, in oblique left lateral view. **F.** ***Glaphyrocysta*** cf. ***retiintexta*** (Cookson) Stover and Evitt, in dorsal view.

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.

The emended diagnosis incorporates the concepts of Stover and Evitt (1978), concerning these genera. *Eisenackia* differs from *Schematophora* Deflandre and Cookson, 1955, *emend.* Stover and Evitt, 1978, in exhibiting cingular peniplates and from *Cassidium* Drugg, 1967, in its clearer development of peniplates and less dense phragma ornamentation.

**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 brevivallata* (Harker and Sarjeant in Harker *et al.*, 1990, pp. 97-98, ex Harker and Sarjeant, 1991, p. 708), 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).

*Eisenackia circumtabulata* Drugg, 1967, p. 15, pl. 1, figs. 12-13. Holotype: Drugg, 1967, pl. 1, fig. 12: reillustrated by Damassa, 1979, pl. 3, figs. 14-16. The transfers as type species to *Hystrichokolpoma* by Schumacker-Lambry (1978, p. 42) and to *Alisocysta* by Stover and Evitt (1978) are not accepted by us; the combination *Agerasphaera circumtabulata* Harland, 1979, p. 29, was not validly published. Early Paleocene (Danian), California, U.S.A.

*Eisenackia hatai* Fuji, 1966, p. 62, pl. 12, figs. 1-2. Holotype: Fuji, 1966, pl. 12, figs. 1-2. Late Miocene, Japan.

*Eisenackia margarita* (Harland, 1979, pp. 29, 31, 33, pl. 1, figs. 1-12, pl. 2, figs. 2-10) comb. nov. Holotype: Harland 1979, pl. 1, figs. 5-6, pl. 2, figs. 5-6, as *Agerosphaera margarita*; subsequently, and transferred from, *Alisocysta*. Late Paleocene, southern England. [Note: the phragma may be laevigate or micropunctate to microreticulate].

*Eisenackia reticulata* (Damassa, 1979, pp. 196, 198, 200, pl. 3, figs. 1-6; pl. 4, figs. 4-5; text-fig. 3) comb. nov. Holotype: Damassa, 1979, pl. 4, figs. 4-5; text-fig. 3 as *Alisocysta reticulata*). Early Paleocene (Danian), California, U.S.A. [Note: this species has an intratabular ornamentation resembling a low reticulation; the reticulation may extend into the parasutural areas].

*Eisenackia rugolirata* (Damassa, 1979, pp. 193-194, 196, pl. 3, figs. 7-13, 21, 23, 27, text-fig. 2) comb. nov. Holotype: Damassa, 1979, pl. 3, figs. 7-11, as *Alisocysta rugulirata*. Early Paleocene (Danian), California, U.S.A. [Note: this species is characterized by the presence of accessory ridges on the large dorsal plates and by the wrinkled character of the penitabular and accessory ridges].

**Species questionably included.** The following species are listed by Lentin and Williams (1998, p. 209), but considered by them and us to be of questionable assignment.

*Eisenackia? knokkensis* Louwye, 1997, pp. 149-150, pl. 1, figs. 7-9. Holotype: Louwye, 1997, pl. 1, figs. 8-9. Late Cretaceous (Campanian), Belgium. [Note: the generic assignation was questioned by the author himself].

*Eisenackia? scrobiculata* Morgenroth, 1996, pp. 12-13, pl. 2, fig. 12, pl. 3, fig. 1. Holotype: Morgenroth, 1966, pl. 2, fig. 12. Early Eocene, north Germany. [Note: the generic assignation was viewed as questionable by Stover and Evitt, 1978, p. 43].

*Eisenackia? senticeta* (Below, 1987, p. 52, pl. 9, figs. 11-15) Lentin and Williams, 1989, p. 124. Holotype: Below 1987, pl. 9, figs. 11-15

as *Phanerodinium senticetum*; reproduced in Fensome *et al.*, 1993, p. 1329, figs. 1-4. Upper Cretaceous (Late Albian). [Note: the generic assignment was viewed as questionable by Lentin and Williams, 1989, p. 124].

### *Eisenackia chilensis* sp. nov.
Figures 3, 7.B-C and 10.A-B

**Derivatio nominis.** Of Chile, in reference to the source of the specimens.

**Diagnosis**. A species of *Eisenackia* having a subsphaerical to ovoidal cyst; tabulation indicated by low penitabular ridges with beaded bases. Intratabular ornamentation with few to more or less densely distributed coni. Archaeopyle type (tA); operculum free.

**Description**. Cysts proximochorate subsphaerical to ovoidal. Tabulation indicated by thin, transparent penitabular ridges (3 µm in height). The phragma is up to 2 µm thick, only the periphragm making up the penitabular membranes. Contact between the membranes and phragma is marked by thickenings in the periphragm, which in optical section give the appearance of beads. Intratabular ornamentations of coni (up to 3 µm in height), sparsely (3 to 4 per peniplate) to more or less densely (8 to 10) distributed. Sulcal notch well developed. Plate 6'' is reduced with respect to others in the precingular series. Cingular plates indicated by elongate, subrectangular penitabular ridges. Postcingular plates completely developed, although plate 1''' is small and inconspicuous. Five sulcal plates indicated. Antapical plate pentagonal in shape, bordered by 1p, 3''', 4''', 5''', ps; pattern quinqueform. The sulcus includes the right sulcal and posterior sulcal homologues (Ii and Z). Archaeopyle type (tA); operculum free and not observed.

**Holotype**. 3973/6: 19,9/129,9 (E30/3). Overall length: 54 µm, breadth: 42 µm.

**Illustrated specimen.** SEM sample PP08 (2891/59) (Figure 10 A), Specimen PP08 (2893/59) (Figure 10 B). 3973/6: 19,9/129,9 (E30/3).

**Dimensions.** Sample 2891/59: overall length 55 µm; breadth 55 µm. Specimen 2893/59: overall length 47 µm; breadth 42 µm. 3973/6: 19,1/129,9 (E30/3): overall length 52 µm; breadth 42 µm.

**Remarks.** The most similar species is *Eisenackia reticulata*, which is differentiated from *E. chilensis* by its reticulate ornament.

### Genus *Glaphyrocysta* Stover and Evitt, 1978

### *Glaphyrocysta* cf. *retiintexta* (Cookson, 1965)
Stover and Evitt, 1978
Figure 6.G

**Illustrated specimen.** 3975/4: 16,5/146,3 (J47/10).

**Figure 10. A-D.** *Eisenackia chilensis* n. sp., in lateral-ventral view **(A,B)** and lateral-antapical view **(C,D). E, F. *Cassidium fragile*** (Harris 1965) Drugg 1967. In, dorsal view **(E)** and in apical view, with operculum attached **(F)**.

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 cingular plates 3c and 4c.

If they are correct, Sarjeant's statement, in his emendation of *Cordosphaeridium*, that the genus lacks cingular 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 *Tityrosphaeridinium* 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 microfloristic 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*, *Turbiosphaera 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 Houthern 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 *Alisocysta*] - 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 *Isabelidiniae 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 Paleocene, confirming the evidence of the foraminifera. However, comparisons with early 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 *Palaeocystodinim* sp.) occur in our assemblages, while a number of genera prominent in the Danish material - notably *Areoligera*, *Cordosphaeridium*, *Danea*, *Kenleyia* and *Thalassiphora* - are unrepresented. Overlap in species content with Danian microfloras reported from Tunisia (Lassoued and Taugourdeau, 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. membranaceus*, *P. pyrophorum*, *Glaphyrocysta retiintexta*, *Lindulodinium bergmannii* and *Tityrosphaeridium tenuistriatum*).

**Figure 11. A, B.** *Spinidinium colemanii* 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.

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 retiintexta, Isabelidinium bakeri,* and *Turbiosphaera 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 cassiculum. Pyxidiniopsis crassimurata* is present also in the overlying *Wilsonidinium 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 and surrounding islands, 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 *Volkheimeridium 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; *Operculodinium bergmannii* had been reported only from southern South America (Archangelsky 1968; Quattrocchio and Sarjeant, 1996). Species in common with the Chilean assemblages are: *Palaeoperidinium pyrophorum, Eisenackia circumtabulata, Palaeocystodinium golzowense, Lingulodinium bergmanni, Deflandrea boloniensis, D. cygniformis, Spiniferites ramosus, Volkheimeridium lanterna* and *Hystrichosphaeridium tubiferum.*

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, *Cordosphaeridium* 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 Maestrichtian association with *Manumiella* spp., *Palaeocystodinium* spp. and *Operculodinium* cf. *azcaratei.* A monospecific association with *Palaeocystodinium golzowense* was tentatively assigned to the Palaeocene. Above it is an association that includes the first occurrence in Argentina of *Apectodinium*; this genus, related to the *Wetzelliela* 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 dartmooria*, *Hystrichosphaeridium tubiferum*, *Arachnodinium antarcticum*, and *Impagidinium waipawaense*.

### 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 fuegensis* and *Lingulodinium bergmannii* (as *Impletosphaeridium 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 foveolata*, *Alysocysta reticulata*, *Isabelidinium bakeri*, *I. cingulatum*, *Alterbidinium pentaradiatum*, *Cassidium fragile* and *C. filosum*.

## Conclusion

In view of the presence of *Palaeoperidinium 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-ocurrence, 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 (Palamarczuk, 1992; Wrenn and Hart, 1988).

The work of Palamarzuk 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 Palaeocene) 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.

## Acknowledgements

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# COMENTARIO BIBLIOGRÁFICO

**Micropaleontología,** E. Molina (editor), Prensas Universitarias de Zaragoza, Colección Textos Docentes, 93, 634 pp., 2002. Primera Edición.

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 particularidades 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, tintínidos, bacterias, cocolitofóridos, diatomeas y silicoflagelados, dinoflagelados y quitinosos, polen y esporas, algas calcáreas, briozoos, 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, paleooceanografía 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-mal: *puz@posta.unizar.es*

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