Journal of Micropalaeontology, **25:** 23–33.

Late Maastrichtian dinoflagellate cysts from the Cerro Butaló section, southern Mendoza province, Argentina

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ABSTRACT – The Late Cretaceous Atlantic transgression in southern South America is recorded in western Argentina in the upper part of the Malargüe Group. The Cerro Butaló section outcrops in the south of Mendoza Province and comprises sediments attributable to the Jagüel and Roca formations. Well-preserved palynological associations were recovered from this section. Only the marine associations – dinoflagellate cysts, acritarchs and green algae – are considered in this article. A Late Maastrichtian age is suggested for the Roca and Jagüel formations based on the presence of *Deflandrea galeata* and *Disphaerogena carposphaeropsis* in the lower part of the section and *Glaphyrocysta perforata* in the upper part of the section and the absence of any Danian cosmopolitan markers. Variations in dinoflagellate cyst species diversity throughout the section permit recognition of two intervals that are probably related to different palaeoenvironmental conditions connected with episodes of sea-level fluctuation. *J. Micropalaeontol*. **25**(1): 23–33, April 2006.

KEYWORDS: *Late Maastrichtian, dinoflagellate cysts, biostratigraphy, Southern Mendoza, Argentina*

INTRODUCTION

The Neuquen Basin is a depocentre in western Argentina with deposits ranging in age from the Late Triassic to the Palaeogene. Three major sedimentary Supercycles are represented: 'Jurásico' (Late Triassic–Late Jurassic); 'Andico' (Late Jurassic–Early Cretaceous); and 'Riograndico' (Late Cretaceous–Paleocene) (Groeber, 1947). The present study focuses on the upper part of the Riograndico Supersequence known as the Malargüe Group (Uliana & Dellape, 1981).

During the Campanian–Maastrichtian, the tectonic evolution of the Neuquen Basin changed abruptly with the Mirano orogenic phase, and a generalized marine transgression from the Atlantic Ocean took place in southern South America. The Andean magmatic arc separated southern South America from the Pacific Ocean, a compressional event produced the uplift of the back-arc and a foreland stage started in the Neuquen Basin. In the southern Mendoza segment of the Neuquen Basin, Upper Cretaceous sediments accumulated within a relatively confined back-arc setting. Deposition occurred in an elongated 120 km wide seaway (NNW–SSE) between the magmatic arc in Chile and the gently subsiding South American foreland to the east.

In the Andean area the Malargüe Group comprises the Loncoche, Jagüel, Roca and Pircala Formations (Fig. 1). The Cerro Butaló section crops out at 35° 50′ S and 69° 40′ W (Fig. 2), in the southern Mendoza Province, western Argentina and comprises sediments belonging to the Malargüe Group. The Jagüel Formation is 25 m thick at Cerro Butaló and is characterized by green laminated shales with interbedded calcareous sandstones, following Legarreta *et al.* (1989). This is overlain by the Roca Formation which comprises 30 m of limestone with abundant fragments of bivalves and gastropods, followed by 20 m of pelitic sandstone. The Pircala Formation (30 m thickness) is composed of massive brown-green claystones and siltstones. Near the top the lithology changes to red coarse-grained sandstones; occasional ashfalls are preserved as pyroclastic strata or as a mixture of pyroclastic and epiclastic sediments recycled and deposited by rivers.

The Malargüe Group in the south of Mendoza Province can be divided into five depositional sequences (Parras *et al.*, 1998). The Jagüel and Roca Formations correspond to the third depositional sequence deposited in a subtidal to intertidal environment (Fig. 1). Parras *et al.* (1998) indicate that in this

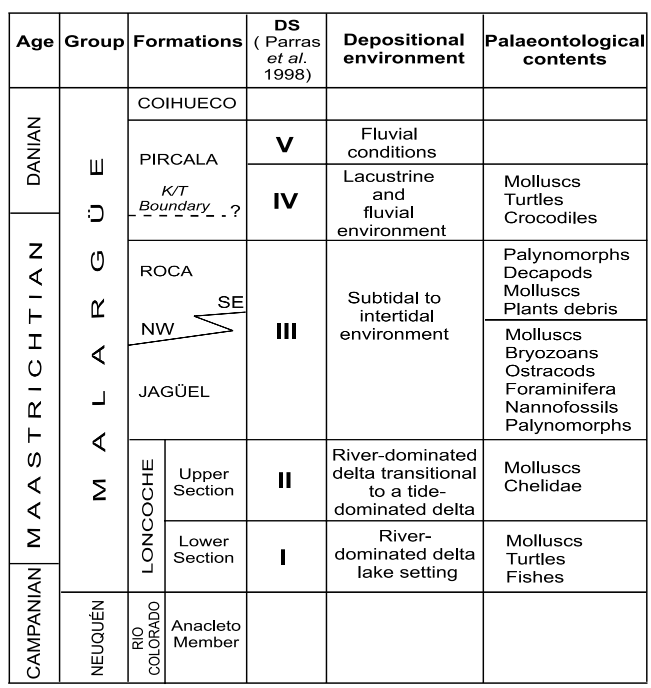


Fig. 1. Generalized integrated stratigraphical column of the Malargüe Group for the south of Mendoza Province with the depositional sequences (DS), corresponding depositional environments and palaeontological contents (after Parras *et al.*, 1998).

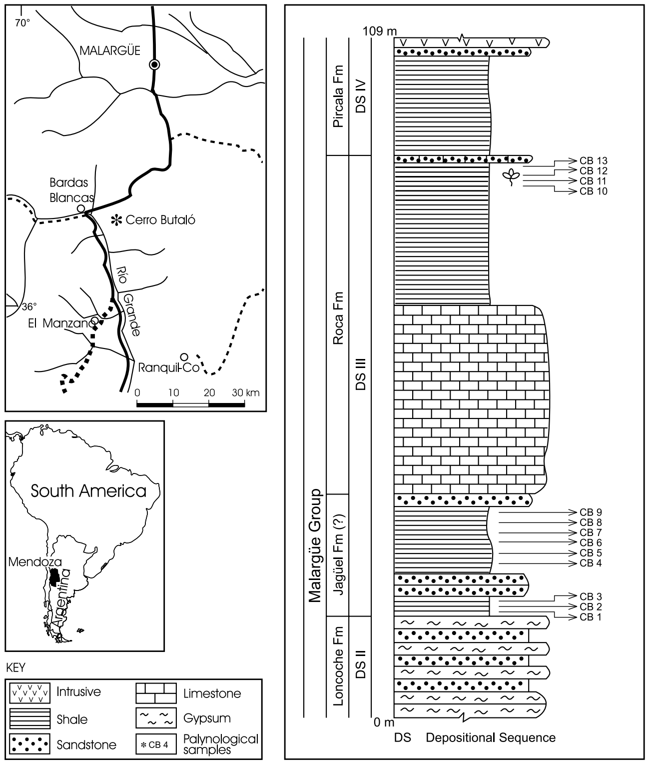


Fig. 2. Location map showing the outcrop of the Cerro Butaló section, south of Mendoza Province and the stratigraphical column of the Malargüe Group at the studied section, indicating the sampling levels.

part of the basin the K–T boundary would lie within the continental deposits of the Pircala Formation (their depositional sequence IV). This is based on a combination of isotope age determination and palaeontological data. A ^{40}K–^{40}Ar (58.4 ± 2.9 Ma) radiometric age was recorded from the Cerro Butaló section, from tuffs located 90 m above the youngest marine bed of the section. Maastrichtian bivalve species have been found within the limestone beds of the Roca Formation (i.e. *Ambigostrea clarae* Ihering, *Amphidonte mendozana* Ihering and *Pterotrigonia* sp.). Scarce, poorly preserved nannofossils (*Arkhangelskiella cymbiformis*, *Micula decussata*, *Watznaueria barnesae* and *Eiffellithus* sp.) and foraminifera (*Quinqueloculina* sp, *Cibicides* sp. and *Guttulina* sp.) occur within the lower part of the section studied (Jagüel Formation) (A. M. Parras, pers. comm.).

The aim of this paper is to report on the biostratigraphical results from the dinoflagellate cyst assemblages obtained from the K–T boundary strata of the Cerro Butaló section. Some local dinoflagellate cyst bioevents are suggested in order to refine both the age determination of the strata and palaeoenvironmental interpretations. This is the first illustrated report of Late Cretaceous dinoflagellate cyst associations from the NNW point of the Neuquen Basin, Mendoza Province, western Argentina.

MATERIAL AND METHODS

Thirteen samples were collected from the Cerro Butaló section, nine from the Jagüel Formation and four from the Roca Formation (Figs 1 and 2). The samples were processed using standard palynological techniques involving HF and HCl treatment. The residues were sieved to remove fine material using 10 µm nickel precision sieves, stained with safranine and finally mounted in glycerine jelly. The slides were studied using a light microscope (OLYMPUS BX50) and the photomicrographs were taken under phase and interference contrast illumination. England Finder coordinates are provided for the photographed specimens (Plates 1–4). All the material is stored in the palaeopalynological collection of the Unit of Palaeopalynology of the Argentinian Institute of Snow Research, Glaciology and Environmental Sciences (IANIGLA), CRICYT, Mendoza under the catalogue numbers CB1(5737), CB2(5738), CB3(5739), CB4(5740), CB5(5741), CB6(5742), CB7(5743), CB8(5744), CB9(5745), CB10(5746/7406), CB11(5747), CB12(5748) and CB13(5749/5864), followed by the abbreviation MPLP (Mendoza–Palaeopalinoteca–Laboratory of Palaeopalynology).

Well-preserved palynological assemblages were recovered. However, as the abundance of palynomorphs in most samples was low, only 100 or 150 specimens were counted per sample. The relative abundance (dinoflagellate cysts/terrestrial palynomorphs) is shown in Figure 3. Several taxa were represented by single occurrences in some samples, hindering taxonomic classification. Four slides per sample were scanned at about $400\times$ under phase illumination, and the distribution of the dinoflagellate cysts and algae is shown in Table 1. Only the microplankton associations (dinoflagellate cysts, acritarchs and green algae) are discussed herein.

DINOFLAGELLATE CYST DISTRIBUTION

Over 40 dinoflagellate taxa were recognized (see the taxonomic list at the end) and their distribution was analysed from the Jagüel and Roca Formations.

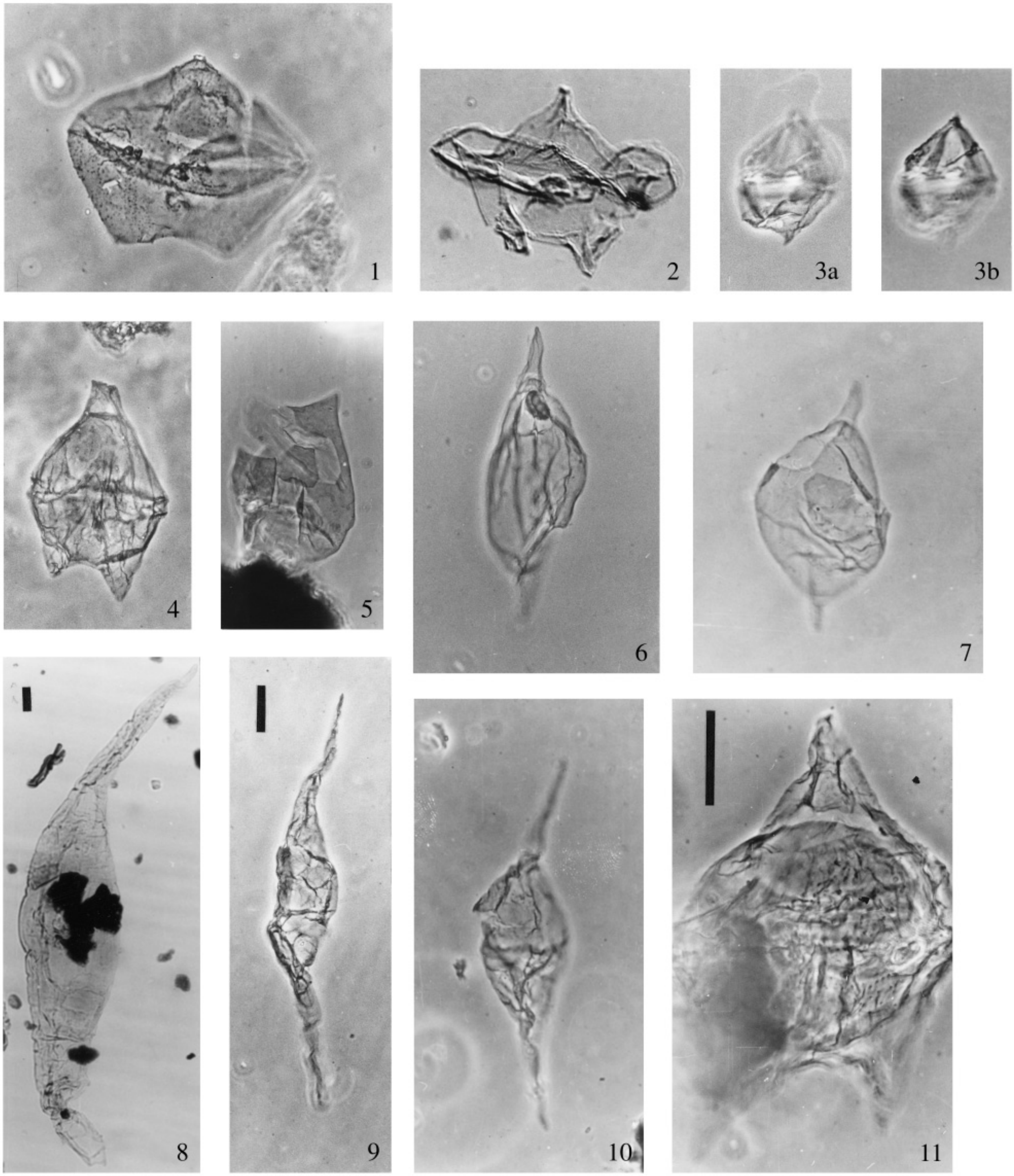
Jagüel Formation

Dinoflagellate cysts dominate the lower part of the section in almost all the samples studied (75–94%). Terrestrial palynomorphs are abundant only in CB4 (68%) and CB5 (57% of the assemblage). Within the Gonyaulacoid cyst group, representatives of the *Spiniferites*/*Achomosphaera* complex are the most common species in the Jagüel Formation, where they are coincident with high dinoflagellate cysts/terrestrial palynomorphs ratios. Species of *Glaphyrocysta*/*Areoligera* are also abundant, particularly in samples CB3 and CB6. *Hystrichosphaeridium tubiferum* has its lowest occurrence in CB4 and *Disphaerogena carposphaeropsis*, *Tityrosphaeridium tenuistriatum* and *Piercites pentagona* have lowest occurrences in CB1 and in CB2. Peridinioid cysts belonging to the *Andalusiella*/*Palaeocystodinium* complex are also present throughout. *Deflandrea galeata* has its lowest occurrence in CB1. *Phelodinium magnificum* occurs in CB2 and CB7 and *Lejeunecysta granosa* is only present in CB7; both are the most important species within the Protoperidiniaceae.

Freshwater algae (*Pediastrum* and *Botryococcus*) and marine algae (*Palambages morulosa* and *Pterospermella australiense*) occur in relatively low numbers, but are present in several samples (Table 1).

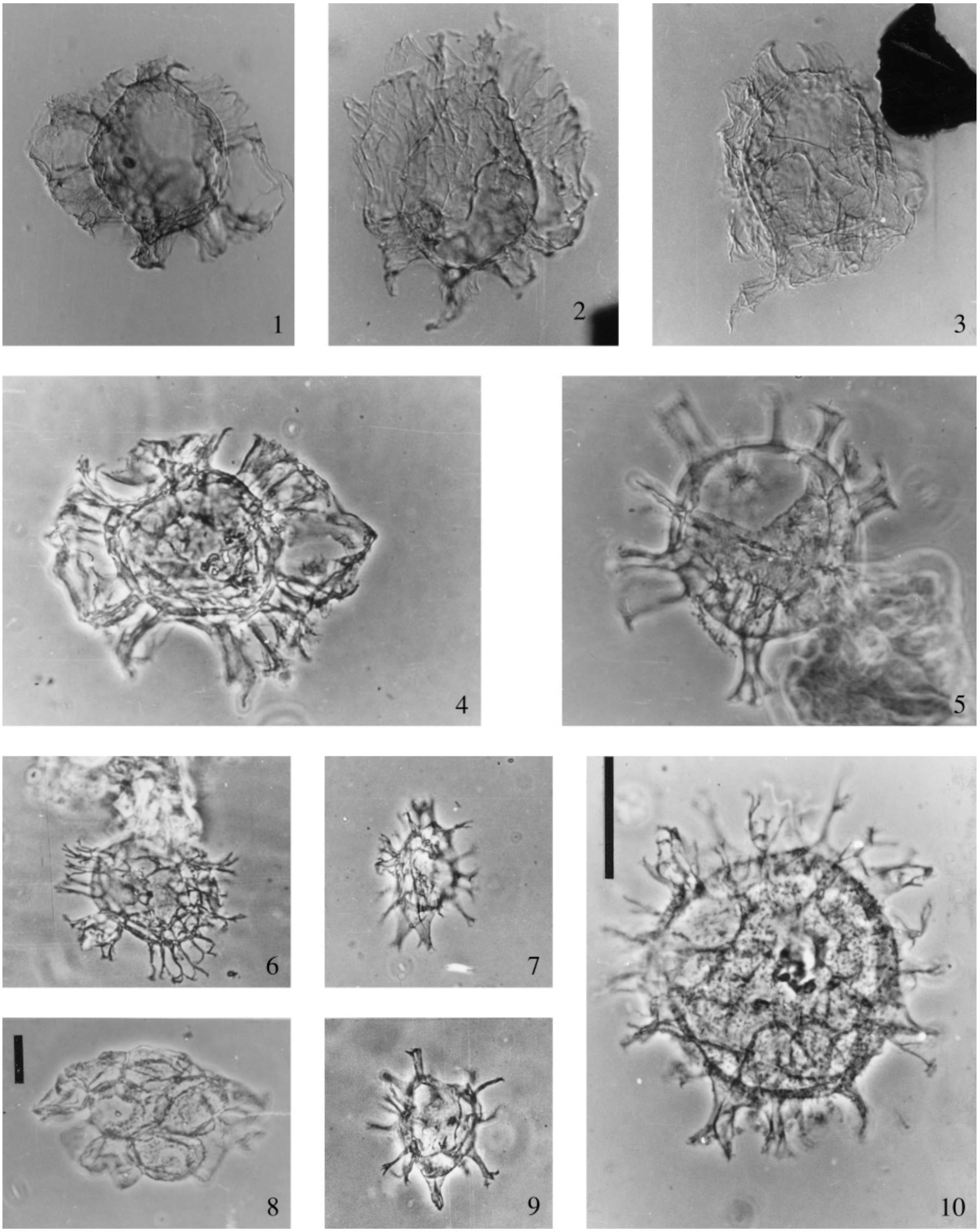
Roca Formation

A major change in the dinoflagellate cysts association was observed between the Roca and Jagüel Formations, with



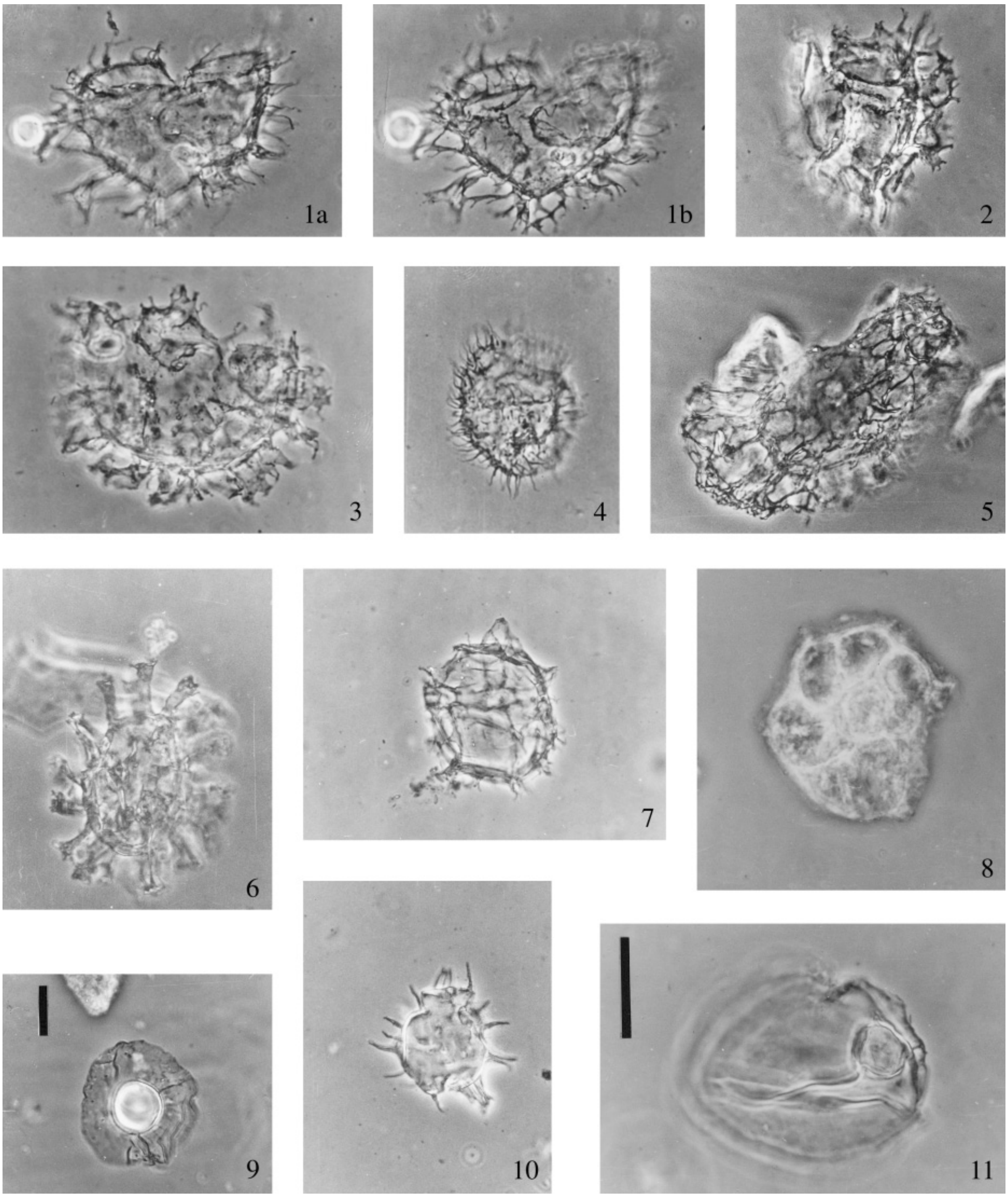
Explanation of Plate 1.

Dinoflagellate cysts from the Jagüel Formation, Cerro Butaló section. All figures were taken under phase contrast illumination, except figure 2 which was taken under interference contrast illumination. All figures correspond to the same magnification (400 ×), except figures 8 (200 ×) and 11 (800 ×). Scale bars equal 20 µm. **fig. 1.** *Lejeunecysta granosa*, CB7d: L18/0, dorsal view, dorsal surface. **fig. 2.** *Phelodinium magnificum*, CB2a: X37/3, high focus. **figs 3a & b.** *Laciniadinium arcticum*, CB6c: L28/2 – (**a**) low focus, view of the oblique antapical spine; (**b**) high focus. **fig. 4.** *Cerodinium* cf. *pannuceum*, CB3b: M23/3, ventral view, dorsal surface; specimen with short antapical horns. **fig. 5.** *Piercites pentagona*, CB2a: L34/4, ventral view, dorsal surface, archaeopyle with one of the opercular pieces (2a) in place. **fig. 6.** *Andalusiella* sp. CB2a: P28/1, ventral view, dorsal surface. **fig. 7.** *Andalusiella mauthei*, CB2c: U32/0, right lateral view. **fig. 8.** *Palaeocystodinium australinum*, CB0b: X36/4, high focus, very large specimen of 340 µm. **fig. 9.** *Palaeocystodinium golzowense*, CB2d: X41/3, high focus. **fig. 10.** *Palaeocystodinium lidiae*, CB3c: U38/1, right lateral view. **fig. 11.** *Deflandrea galeata*, CB2: W42/3, dorsal view, dorsal surface, 100 µm high.



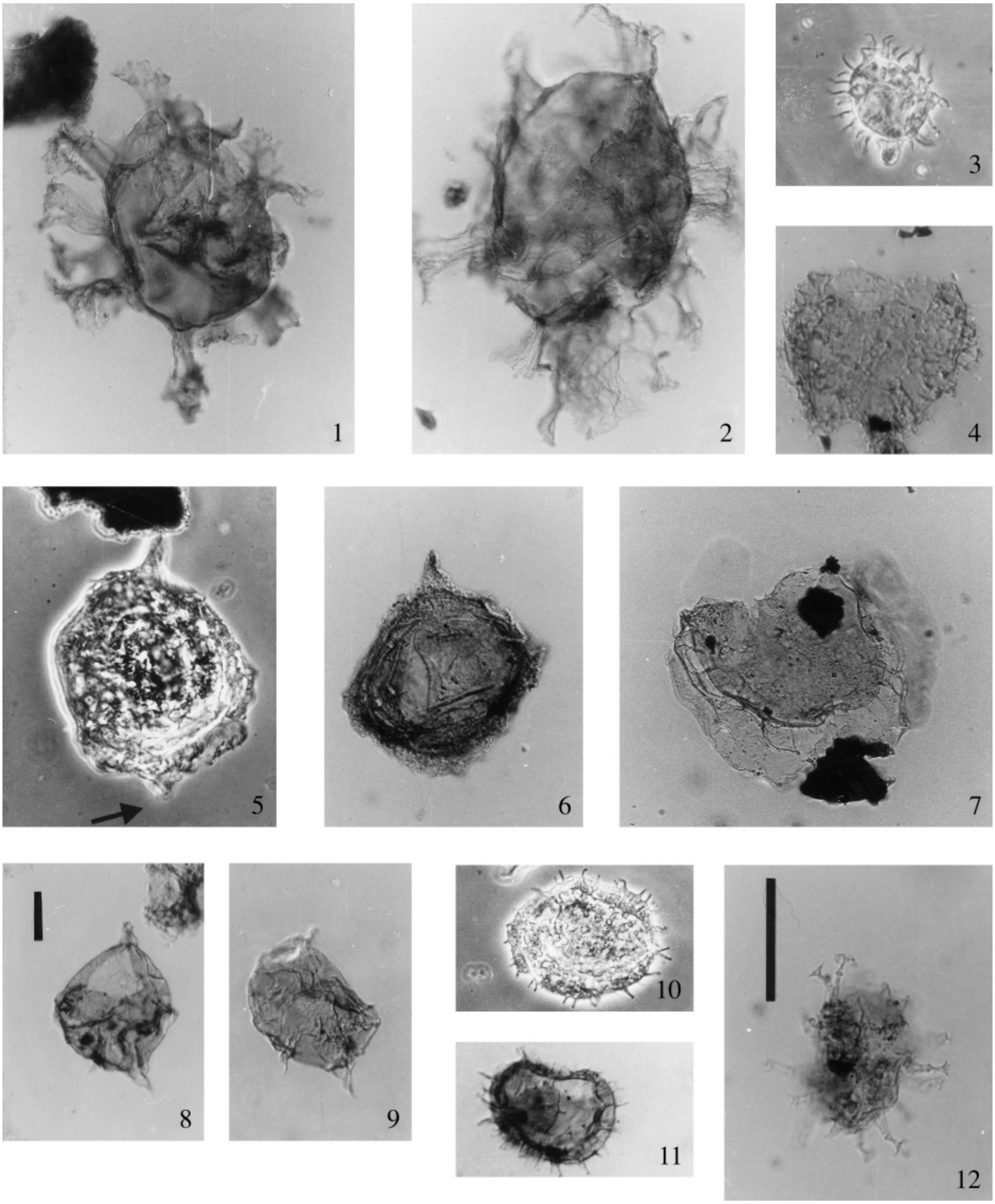
Explanation of Plate 2.

Dinoflagellate cysts from the Jagüel Formation, Cerro Butaló section. All figures correspond to the same magnification (400×) except figure 10 (1000×); all were taken under phase contrast illumination except figures 2 and 3, which were taken under interference contrast illumination. Scale bars equal 20 µm. **figs 1–4.** *Disphaerogena carposphaeropsis*: **1,** CB3a: O38/3, ventral view, ventral surface; **2,** CB5c: R31/1, dorsal view, dorsal surface; **3,** CB5b: V39/3, dorsal view, dorsal surface, specimen with long developed antapical horn; **4,** CB3c: S37/0, ventral view, ventral surface. **fig. 5.** *Tityrosphaeridium tenuistriatum*, CB3c: Q24/4, ventral view, dorsal surface. **fig. 6** *Achomosphaera*/*Spiniferites* group, CB6b: K31/1, intermediate focus. **fig. 7.** *Spiniferites ramosus*, CB3b: K22/1, intermediate focus. **fig. 8.** *Palambages morulosa*, CB5c: Q24/2, high focus. **fig. 9.** *Florentinia* sp., CB2c: D40/4, low focus. **fig. 10.** *Spiniferites ramosus* group, CB3a: V40/3, intermediate focus, body ornamented with coni and baculae.



Explanation of Plate 3.

Marine palynomorphs from the Jagüel Formation except figure 10 which belongs to the Roca Formation. All figures correspond to the same magnification 400×, except figure 11 (800×). Taken under phase contrast illumination. Scale bars equal 20 µm. **figs 1 a–b.** *Areoligera medusettiformis*, CB3c: M22/3 – (**a**) dorsal view, ventral surface; (**b**) dorsal view, dorsal surface. **fig. 2.** *Areoligera* cf. *tauloma*, CB3a: O27/4, mid focus. **fig. 3.** *Areoligera coronata*, CB3a: R28/1, dorsal view, dorsal surface. **fig. 4.** *Cleistosphaeridium?* cf. *aciculare*, CB3c: K25/0, high focus. **fig. 5.** *Glaphyrocysta retiintexta*, CB6b: U24/1, high focus. **fig. 6.** *Hystrichosphaeridium tubiferum*, CB7d: M38/1, high focus. **fig. 7.** *Spiniferites ramosus* group, CB9a: C27/3. **fig. 8.** Foraminifer lining, CB9b: O28/0. **fig. 9.** *Pterospermella australiense*, CB6c: R42/1, high focus. **fig. 10.** Acritarch indet., CB10a: W38/0, intermediate focus. **fig. 11.** *Cyclopsiella* sp., CB3b: K40/1.



Explanation of Plate 4.

Dinoflagellates cysts from the Roca Formation. All figures correspond to the same magnification 400 ×, except figure 12 (1000 ×). Taken under interference contrast illumination except figures 3, 5 and 10, which were taken under phase contrast illumination. Scale bars equal 20 µm. **figs 1, 2.** *Cordosphaeridium* sp.: **1,** CB10a: R35/2, ventral view, ventral surface, 130 µm; **2,** CB10a: H21/0, right lateral view? 150 µm. **fig. 3.** ?*Diphyes colligerum*, CB10c: F25/0, left lateral view, specimen with a combined archaeopyle. **fig. 4.** ?*Circulodinium distinctum*, CB10c: C33/3, ventral view, dorsal surface. **figs 5, 6.** *Apteodinium* cf. *australiense*: **5,** CB10a: E36/1, dorsal view, dorsal surface – the arrow shows the incipient antapical horn, present in some specimens; **6,** CB10b: V39/0, dorsal view, dorsal surface? **fig. 7.** *Glaphyrocysta perforata*, CB10a:F32/3, low focus. **figs 8, 9.** *Senegalinium bicavatum*: **8,** CB10a: D35/0, ventral view, dorsal surface; **9,** CB10a: C24/0, dorsal view, dorsal surface. **figs 10, 11.** *Operculodinium centrocarpum*: **10,** CB13d*: H42/2, high focus; **11,** CB12b: D35/2, high focus. **fig. 12.** Acritarch? indet., C10h*: S43/0, with a singular shape of the processes (8–10 µm long).

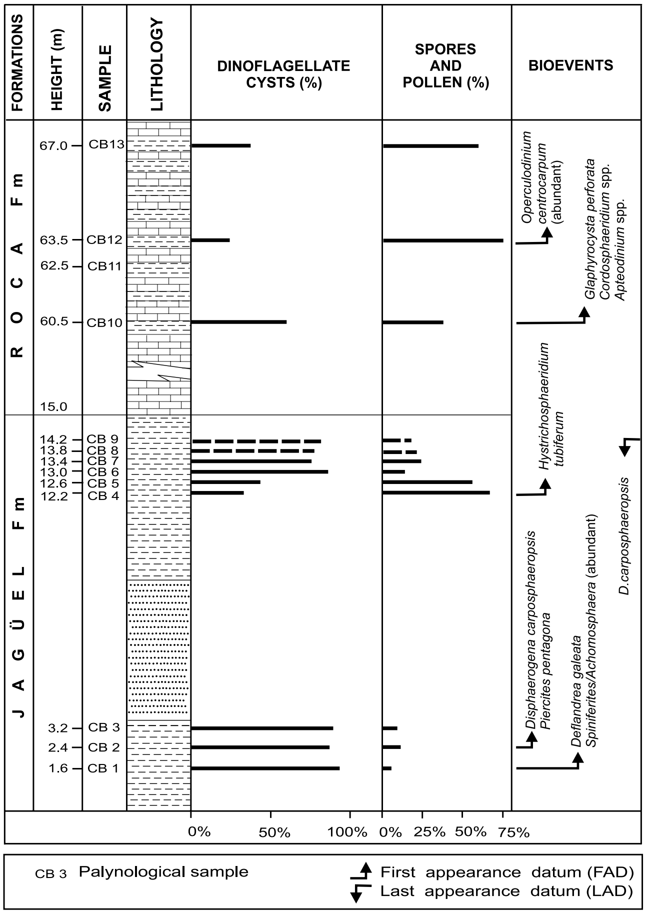


Fig. 3. Relative abundance of dinoflagellate cysts/terrestrial palynomorphs (spores and pollen grains) and suggested local dinoflagellate cyst bioevents based on the first (FAD) and last (LAD) appearance of some selected taxa in the Cerro Butaló section. The dashed lines at samples CB8 and CB9 indicate a statistical result calculated from a count of less than 100 specimens.

virtually no common species between the formations. Marine microplankton are dominant only in sample CB10 (61% of the palynomorph assemblage), in which members of the *Cordosphaeridium*/*Fibrocysta* complex are abundant, in association with *Apteodinium* cf. *australiense*, ?*Diphyes colligerum*, *Glaphyrocysta perforata*, *Circulodinium distinctum* and *Senegalinium bicavatum*. At the top of the Cerro Butaló section (CB12, CB13), a decrease in microplankton diversity and abundance (only 26% are dinoflagellate cysts in CB12 and 38% in CB13) and an increase in the dominance of *Operculodinium centrocarpum* is observed. This species appears high in the section at CB10 and becomes dominant in CB12 and CB13, where it is associated with a sharp increase in the relative abundance of structured plant debris, wood fragments and algal debris.

BIOSTRATIGRAPHY

There are only a few published dinoflagellate cyst studies on the K–T boundary in Argentina and southern South America (Colorado Basin: Gamerro & Archangelsky, 1981; Quattrocchio & Sarjeant, 1996; Guerstein & Junciel, 2001; Neuquén Basin: Papú *et al.*, 1999; Palamarczuk & Habib, 2001; Palamarczuk, 2002; Austral Basin: Martinioni *et al.*, 1999; Guler *et al.*, 2003; Brasil, Campos Basin and Pernambuco Basin: Arai, 1994, Sarkis *et al.*, 2002; Punta del Este Basin: Daners & Guerstein, 2004). Most of these contributions are only abstracts, and so comparisons have been made with selected dinoflagellate cyst species ranges from outside South America in order to determine the age of the strata. Some important dinoflagellate cyst bioevents, based on selected first appearance datum (FAD), abundance and last appearance datums (LAD) of selected dinoflagellate cyst species are illustrated in Figure 3.

Deflandrea galeata has its first occurrence in the middle late Maastrichtian of the Danish part of the North Sea, Dan Field (Schiøler & Wilson, 1993); Maastricht Formation, Borehole Bunde in The Netherlands (Herngreen *et al.*, 1986) and onshore west Greenland (Nøhr-Hansen, 1996). In Argentina, it has been recorded in the Late Maastrichtian of the Jagüel Formation in two sections located in Neuquen Province, to the southeast of the Cerro Butaló section (Papú *et al.*, 1999; Palamarczuk, 2002). In the Cerro Butaló section the FAD of *Deflandrea galeata* is in CB1.

Disphaerogena carposphaeropsis (taxonomic junior synonym: *Cyclapophysis monmouthensis* Benson) is a useful Late Maastrichtian world-wide marker and its distribution in various K–T boundary localities is well documented (e.g. Benson, 1976; Firth, 1987; Brinkhuis & Leereveld, 1988; Brinkhuis & Schiøler, 1996). In northern South America, Yepes (2001) reported its occurrence in the upper part of the Maastrichtian. In the South Atlantic (Brazil) it has been found in the Campos Basin (Arai, 1994) in the uppermost Maastrichtian and also in the K–T boundary section of Pernambuco Basin (Sarkis *et al.*, 2002). In Argentina, *D. carposphaeropsis* has been reported from the Jagüel Formation in the east of the Neuquén Basin, including the Opaso (Papú *et al.*, 1999) and Jagüel (type section) sections (Palamarczuk & Habib, 2001), where Late Maastrichtian ages have been assigned. Recently, Williams *et al.* (2004) published for the first time a detailed Southern Ocean calibration of dinoflagellate cyst events, based on studies of two Ocean Drilling Project (ODP) sites offshore Tasmania; they indicated the FAD of *D. carposphaeropsis* at 67 Ma. In the studied section *D. carposphaeropsis* has its FAD in CB1 and its LAD in CB6. This species was not recorded in the upper part of the section in the Roca Formation, probably due to changes in environmental conditions.

Glaphyrocysta perforata is also a good marker for the uppermost Maastrichtian and occurs in CB10. It was reported by Schiøler *et al.* (1996) in the ENCI Quarry, Upper Maastrichtian Gulpen Formation, The Netherlands and by Yepes (2001) immediately below the K–T boundary in Rio Loro section, western Venezuela (northern South America).

One taxonomic feature of the biostratigraphical analysis is the development of distinct apical and antapical horns in specimens of *D. carposphaeropsis* (Pl. 2, figs 2–4) and *Cordosphaeridium* sp. (Pl. 4, figs 1, 2) in both the Jagüel and Roca Formations. This is a typical feature of forms in the *Disphaerogena–Cordosphaeridium–Damassadinium–Thalassiphora–Carpatella–Fibrocysta* complex close to, and above, the K–T boundary (Brinkhuis & Schiøler, 1996; Herngreen *et al.*, 1998). Some of the specimens assigned to *Apteodinium* cf. *australiense*

Taxon	Jaguel Formation									Roca Formation		
	Metres from base up											
	1.6	2.4	3.2	12.2	12.6	13.0	13.4	13.8	14.2	60.5	63.5	67.0
Achomosphaera ramulifera	1	6	1	1		2	2					
Andalusiella mauthei		1										
Andalusiella spp.		3	2				3					
Apteodinium cf. *australiense*										7	1	
?*Apteodinium* sp.										35	1	
Areoligera coronata			7									
Areoligera medusettiformis			4			2	2	2				
Areoligera cf. *tauloma*		1	5									
Areoligera spp.	2	5	13			7	1	2	2			
Cerodinium cf. *pannuceum*	1	6	7	1		1	5					
?*Circulodinium distinctum*										18	12	1
Cleitosphaeridium? cf. *aciculare*			4		2	2						
Cordosphaeridium spp.		1	10		7	11	10	2		25		
Deflandrea galeata	1	2	3				1					
?*Diphyes colligerum*										1		
Disphaerogena carposphaeropsis	1	16	60	1	6	27						
Fibrocysta sp.			2		2	3	4					
Florentinia sp.		2	1		1	1	3	1				
Glaphyrocysta perforata										2	1?	
Glaphyrocysta retiintexta		1	2			20						
Hystrichosphaeridium tubiferum				2	8	7						
Laciniadinium arcticum						1						
Lejeunecysta granosa							1			1?		
Operculodinium centrocarpum			1							3	80	40
Palaeocystodinium australinum			4		1	2						
Palaeocystodinium golzowense	1	5	13	1	1	2	1					
Palaeocystodinium lidiae	1	1	3		1	3						
Palaeocystodinium spp.	3					7	3			1		
Phelodinium magnificum		2										
Piercites pentagona		2										
Senegalinium bicavatum	1	1	4			1	1			10		
Spiniferites granulatus		3	8		5	2		4				
Spiniferites spp. (Complex)	30	90	254	20	21	77	115	55	20	2	2	1
Tityrosphaeridium tenuistriatum		8	34		3	2	6					
Dinoflagellate cysts indet.	20	6	2	8	3	5	5	10	5	5	5	
Botryococcus sp.		1	1	1	4							
Palambages morulosa	1	1			1		1				1	
Pediastrum spp.			2		1	1	5	1				
Pterospermella australiense	1	2	1	1					3		4	
Zygnemataceae							4			2		2
Foraminifer linings					1	10						
Acritarchs										12		
	CB1	CB2	CB3	CB4	CB5	CB6	CB7	CB8	CB9	CB10	CB12	CB13
	Samples											

Table 1. Dinoflagellate cyst distribution range chart (samples CB1 to CB9) Jagüel Formation and (CB10 to CB13) Roca Formation at the Cerro Butaló section, south of Mendoza Province, NNW of Neuquén Basin

(Pl. 4, fig. 5) may also be transitional forms within the *Carpatella cornuta* complex, based on the presence of an incipient antapical horn. This feature may be elucidated by further study and comparison of more specimens in the future, obtained from other sections of the basin. Representatives of *Dinogymnium* do not occur in the studied association, whereas this genus was mentioned for the Jagüel Formation in the Lomas Coloradas section of the Neuquen Basin (Palamarczuk, 2002).

Palamarczuk & Habib (2001) reported that the K–T boundary interval occurred within the Jagüel Formation in the Jagüel section (type section) of Neuquen Province (38° 06′ 25″ S, 68° 23′ 36″ W). This was based on the presence of *D. carposphaeropsis*, indicative of the latest Maastrichtian, and *Senoniasphaera inornata* which occurs at the earliest Danian. They also reported a peak abundance of *Manumiella druggii,* just below the K–T boundary but it was not observed in the Cerro Butaló section. In Australia, *M. druggii* is a good marker for the Late Maastrichtian to earliest Danian *Manumiella druggii* Interval Zone (Helby *et al.*, 1987), just below the K–T boundary. However, it was not observed at the Cerro Butaló section.

In summary, the occurrence in the lower part of the section studied of *Deflandrea galeata* and *Disphaerogena carposphaeropsis* and *Glaphyrocysta perforata* in the upper part of the section associated with an absence of any unequivocal Danian markers (e.g. *Danea californica*, *Carpatella cornuta* or *Senonia-*

sphaera inornata) is interpreted as being indicative of a latest Maastrichtian age for the Jagüel and Roca Formations in the Cerro Butaló section.

PALAEOENVIRONMENTAL INTERPRETATION

Throughout the Cerro Butaló section, dinoflagellate cyst species diversity variation was observed which allowed the recognition of two main intervals, probably related to palaeoenvironmental conditions. This may be connected with episodes of sea-level fluctuations, related to the existence of a narrow and shallow seaway (Legarreta *et al.*, 1989). The first interval (CB1 to CB9) (Fig. 3) corresponds to the Jagüel Formation and is dominated by representatives of the complex *Spiniferites/Achomospharera*, whilst specimens of *Glaphyrocysta/Areoligera* were subordinate. *Spiniferites/Achomospharera* are cosmopolitan neritic genera (Head & Westphal, 1999). Yepes (2001), after a discussion about the environmental conditions indicated by the *Spiniferites/Achomosphaera* group, concluded that environmental interpretations are still incomplete, as they could suggest a range of inner to outer neritic conditions. Based on the analysis of the situation of Cerro Butaló section in the basin, the high number of *Spiniferites* (Table 1) in coincidence with a high ratio of dinoflagellate cysts/terrestrial palynomorphs (Fig. 3) in nearly all the samples (CB1, 2, 3, 6, 7, 8, 9), and a high dinoflagellate cyst diversity associated with the presence of foraminifer linings, indicates a more marine influence for the lower part of the Cerro Butaló section when compared with the upper part.

The second interval, covering CB 10 to CB13, corresponding to the Roca Formation, is characterized by low diversity and numbers of dinoflagellate cysts when compared with the massulae of aquatic ferns, plant tissues, algal remains and a high dominance of *Operculodinium centrocarpum.* Head (1998) considered a high abundance of the *O. centrocarpum/israelianum* group to be indicative of shallow waters. Therefore, a relative nearshore environment with increasingly shallower conditions is considered for the upper part of the Cerro Butaló section. This overall interpretation is supported by the regional and sedimentological results, Legarreta *et al.* (1989) proposed that the maximum expansion of the area under marine influence was reached during the deposition of the Jagüel Formation. After that episode, the areal extent of the region under marine influence became smaller and retracted to the southeast of the basin.

ACKNOWLEDGEMENTS

The authors thank Dr W. Volkheimer for critically reading an earlier version of the manuscript. Dr Leslie A. Riley (England) made useful suggestions on the manuscript and improved the English of the text. The authors are indebted to Drs J. Riding and F. John Gregory for their helpful suggestions which improved the final presentation of the paper. This work was supported by the National Research Council of Argentina (CONICET), Project 4674/96 and 02905/2000.

LIST OF DINOFLAGELLATE CYSTS, ACRITARCHS AND GREEN ALGAE FROM THE JAGÜEL AND ROCA FORMATIONS

Dinoflagellate cysts from the Jagüel and Roca formations are listed alphabetically by genera. Acritarchs and green algae are listed below. Illustrated taxa are followed by plate and figure references in brackets. Systematic classification follows Fensome *et al.* (1993) and the taxa listed are referenced fully by Williams *et al.* (1998).

Dinoflagellate cysts

Achomosphaera ramulifera (Deflandre) Evitt, 1963
Andalusiella mauthei (Riegel) Riegel & Sarjeant, 1982 (Pl. 1, fig. 7)
Andalusiella spp.
Apteodinium cf. *australiense* (Deflandre & Cookson, 1955) Williams, 1978 (Pl. 4, figs 5, 6)
?*Apteodinium* sp.
Areoligera coronata (Wetzel, 1933b) Lejeune-Carpentier, 1938 (Pl. 3, fig. 3)
Areoligera medusettiformis (Wetzel, 1933b) Lejeune-Carpentier, 1938 (Pl. 3, figs 1a, b)
Areoligera cf. *tauloma* Eaton, 1976 (Pl. 3, fig. 2)
Areoligera spp.
Cerodinium cf. *pannuceum* (Stanley) Lentin & Williams, 1987 (Pl. 1, fig. 4)
?*Circulodinium distinctum* (Deflandre & Cookson) Jansonius, 1986 (Pl. 4, fig. 4)
Cleitosphaeridium? cf. *aciculare* Davey, 1969a (Pl. 3, fig. 4)
Cordosphaeridium spp. (Pl. 4, figs 1, 2)
Deflandrea galeata (Lejeune-Carpentier, 1942) Lentin & Williams, 1973 (Pl. 1, fig. 11)
?*Diphyes colligerum* (Deflandre & Cookson, 1955) Cookson, 1965 (Pl. 4, fig. 3)
Disphaerogena carposphaeropsis (Wetzel, 1933b) Sarjeant, 1985 (Pl. 2, figs 1–4)
Fibrocysta sp.
Florentinia sp. (Pl. 2, fig. 9)
Glaphyrocysta perforata Hultberg & Malmgren, 1985 (Pl. 4, fig. 7)
Glaphyrocysta retiintexta (Cookson, 1965a) Stover & Evitt, 1978 (Pl. 3, fig. 5)
Hystrichokolpoma sp.
Hystrichosphaeridium tubiferum (Ehrenberg) Deflandre emend. Davey & Williams, 1966 (Pl. 3, fig. 6)
Laciniadinium arcticum (Manun & Cookson) Lentin & Williams, 1980 (Pl. 1, figs 3a, b)
Lejeunecysta granosa Biffi & Grignani, 1983 (Pl. 1, fig. 1)
Operculodinium centrocarpum (Deflandre & Cookson, 1955) Wall, 1967 (Pl. 4, figs 10, 11)
Palaeocystodinium australinum (Cookson, 1965) Lentin & Williams, 1976 (Pl. 1, fig. 8)
Palaeocystodinium golzowense Alberti, 1961 (Pl. 1, fig. 9)
Palaeocystodinium lidiae (Gorka, 1963) Davey, 1969b (Pl. 1, fig. 10)
Phelodinium magnificum (Stanley, 1965) Stover & Evitt, 1978 (Pl. 1, fig. 2)
Piercites pentagona (May, 1980) Habib & Drugg, 1987 (Pl. 1, fig. 5)
Senegalinium bicavatum Jain & Millepied, 1973 (Pl. 4, figs 8, 9)
Spiniferites granulatus (Davey) Lentin & Williams, 1973
Spiniferites ramosus ramosus (Ehrenberg) Mantell 1854 (Pl. 2, figs 7, 10)
Spiniferites spp. (complex) (Pl. 2, fig. 6; Pl. 3, fig. 7)

Tityrosphaeridium tenuistriatum (Heisecke, 1970) Quattrocchio & Sarjeant, 1996 (Pl. 2, fig. 5)

Acritarchs and algae

Acritarch gen. et sp. indet. 1 (Pl. 3, fig. 10)
Acritarch gen. et sp. indet. 2 (Pl. 4, fig. 12)
Botryococcus sp.
Cyclopsiella sp. (Pl. 3, fig. 11)
Palambages morulosa Wetzel emend. Gocht & Wille, 1972 (Pl. 2, fig. 8)
Pediastrum spp.
Pterospermella australiense (Deflandre & Cookson) Eisenack, 1972 (Pl. 3, fig. 9)
Pterosphaeridia sp.
Zygnemataceae

Manuscript received 7 April 2003
Manuscript accepted 17 June 2005

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