



## *Diconodinium lurese* sp. nov., a late Maastrichtian to Danian dinoflagellate cyst from southwest Atlantic basins

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**Abstract.** Upper Cretaceous and Cenozoic deposits from the Colorado and Austral basins, Argentina and the Punta del Este Basin, Uruguay contain diverse organic-walled dinoflagellate cysts, including *Diconodinium lurese* sp. nov. which occurs in the late Maastrichtian and Danian throughout the basins. The new species is characterized by an autophragm that is densely covered by short spines and by relatively long apical and antapical horns, and by a variable Ia to IPa archeopyle. On our evidence, the stratigraphical range of *Diconodinium lurese* sp. nov. is latest Maastrichtian to Danian, and is thus a useful biostratigraphical marker for the Cretaceous-Palaeogene transition in the southwest Atlantic basins.

**Resumen.** *DICONODINIUM LURENSE*, UNA NUEVA ESPECIE DE QUISTE DE DINOFLAGELADO DEL MAASTRICHTIANO TARDÍO-DANIANO DEL ATLÁNTICO SUDOCCIDENTAL. Los depósitos del Cretácico Superior y Cenozoico de las cuencas del Colorado y Austral, Argentina y Cuenca Punta del Este, Uruguay son portadores de asociaciones de quistes de dinoflagelados diversas. *Diconodinium lurese* sp. nov. es un elemento común en las asociaciones provenientes del Maastrichtiano tardío-Daniano en las distintas cuencas. Esta nueva especie se caracteriza por presentar un autofragma densamente cubierto por espinas cortas, cuernos apical y antapical relativamente largos y por un arqueopilo variable Ia-IPa. Nuestras evidencias indican que el rango estratigráfico de *Diconodinium lurese* sp. nov. se extiende desde al Maastrichtiano tardío hasta el Daniano, constituyendo un importante marcador bioestratigráfico para la transición Cretácico-Paleógeno en las cuencas del Atlántico Sudoccidental.

**Key words.** Biostratigraphy. Dinoflagellate cysts. Late Maastrichtian-Danian. Southwest Atlantic.

**Palabras clave.** Bioestratigrafía. Quistes de dinoflagelados. Maastrichtiano tardío-Daniano. Atlántico Sudoccidental.

### Introduction

The dinoflagellate cyst (dinocyst) *Diconodinium lurese* sp. nov., was recovered from wells, boreholes and outcrops from several Southwestern Atlantic basins (figure 1). It is present in the Maastrichtian-Danian Pedro Luro Formation (Kaasschieter, 1963), Colorado Basin, in an onshore borehole and from offshore wells. The species was also recorded as *Diconodinium* sp. in coeval deposits of the Maastrichtian-Mid Eocene Gaviotín Formation in an offshore well in the Punta del Este Basin, Uruguay (Daners and Guerstein, 2004). In both basins, the distribution of *Diconodinium lurese* seems to be consistent and characterizes the Cretaceous-Palaeogene (K/P) boundary. And, well

preserved specimens of this species from surface section of the Calafate Formation in the Austral Basin, allow determination of its first occurrence datum (FOD) in the latest Maastrichtian (Marensi *et al.*, 2004). The aim of the present contribution is to formally describe the new species and to emphasize its regional biostratigraphical potential in the Southwest Atlantic basins.

### Geological background

The development of the Colorado Basin, like that of other Southwest Atlantic basins, is related to the Late Jurassic-Early Cretaceous rifting and subsequent break up of Gondwana (Juan *et al.*, 1996). All these Southwest Atlantic basins were large areas of deposition during the Late Cretaceous and Cenozoic. Fryklund *et al.* (1996, fig. 5, p. 143) identified tectono-stratigraphic sequences characteristic of a passive margin setting in the Colorado Basin, including rift, sag and drift deposits. The Pedro Luro Formation constitutes the base of the drift sequence and was deposited during a widespread

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marine transgression of Maastrichtian-Danian age. The formation consists of marine siltstones and claystones with subordinate, sometimes glauconitic sandstones.

In the Punta del Este Basin, the Gaviotín Formation represents partially the passive margin deposits (Ucha *et al.*, 2003). Gaviotín Formation was defined by Ucha *et al.* (2003), which consists of a marine succession of dark-greenish to gray claystones, siltstones, and sandstones with occasional intervals of glauconitic beds. The dinocyst assemblages from the lower part of the formation suggest a Maastrichtian to Danian age (Daners and Guerstein, 2004).

In the Austral Basin, the age of the Calafate Formation has been widely discussed. Nullo *et al.* (1981) and Macellari *et al.* (1989) suggested a Maastrichtian-Paleocene age for this unit, whereas Malumián and Caramés (1997) indicate that in the area of Lago Argentino the Paleocene deposits were either missing or poorly developed. According to Marensi *et al.* (2004), the age of the Calafate Formation south of Lago Argentino is Maastrichtian to late Maastrichtian. The studied section at this area is characterized by a predominance of marine sandstones with minor conglomerate beds and a few mudstone beds.

## Materials and methods

Almost all the studied samples proceeding from the Maastrichtian-Danian interval of the Colorado and Punta del Este basins are cuttings, since there are no outcrops of Mesozoic or Palaeogene strata. In the Colorado Basin, we analyzed nine cutting samples from the offshore Cx-1 Well, between 1300 and 1600 metres depth (md) and one core and two cutting samples from the onshore Pedro Luro Borehole, between 1487 and 1550 md (figure 1). Eight cutting samples are derived from the Gaviotín Well, drilled offshore Punta del Este Basin, between 1658 and 1850 md.

The palynological material from the Austral Basin is derived from a surface section at the estancia 25 de Mayo, Southwestern Santa Cruz Province (figure 1). Eleven of the twenty samples processed for palynomorphs contain dinocysts.

The palynological treatment included hydrofluoric and hydrochloric acids, mild oxidation (10% nitric acid for one minute) and a 10% ammonium hydroxide wash for one minute. These procedures were followed by heavy liquid separation of the organic component, differential centrifugation to remove fine particles and screening to concentrate the 10 - 25 and 25-180  $\mu\text{m}$  fractions. The residues from the Cx-1 well were refined, stained with Bismarck C



**Figure 1.** Map of the southern part of South America that shows localities, wells and outcrops as well as basins mentioned in the text / Mapa de la parte sur de Sudamérica mostrando las localidades, pozos, afloramientos y cuencas mencionadas en el texto.

and mounted in Elvacite and Cellosize substitute at the Geological Survey of Canada (Atlantic). The residues from the other sites were mounted in glycerine jelly.

Morphologic studies were made using a Nikon Eclipse 600 microscope at the Universidad Nacional del Sur and specimens were photographed with a Nikon Coolpix 950 digital camera. Coordinates quoted from the Vernier scale of Nikon microscope serial n° 772751 follow the sample and slide number for each specimen illustrated. England Finder (EF) references are provided in the corresponding figure explanations. The types and figured specimens are kept in the Palynological Collection of the Departamento de Geología de la Universidad Nacional del Sur, Bahía Blanca, Argentina. The dinoflagellate cyst nomenclature follows Williams *et al.* (1998a) and the systematic section uses the classification of Fensome *et al.* (1993). The geological timescales are from Berggren *et al.* (1995) and Gradstein *et al.* (1995).

## Palynostratigraphy

The samples from the Colorado, Punta del Este and Austral basins are generally rich in dinocysts,

but contain variable amounts of spores, pollen, acritarchs and foraminiferal test linings. Age control is based on the correlation with the dinoflagellate range data of Williams *et al.* (1998b, 2004) and Brinkhuis *et al.* (2003). Dinocyst taxa cited in the text are listed in the Appendix 1 and are fully referenced in Williams *et al.* (1998a).

### Colorado Basin

**Cx-1 Well.** Dinocysts dominate the palynological assemblages throughout the Pedro Luro Formation of the Cx-1 Well. Since all the samples are cuttings, age assignments are based on the highest occurrences of dinoflagellate species.

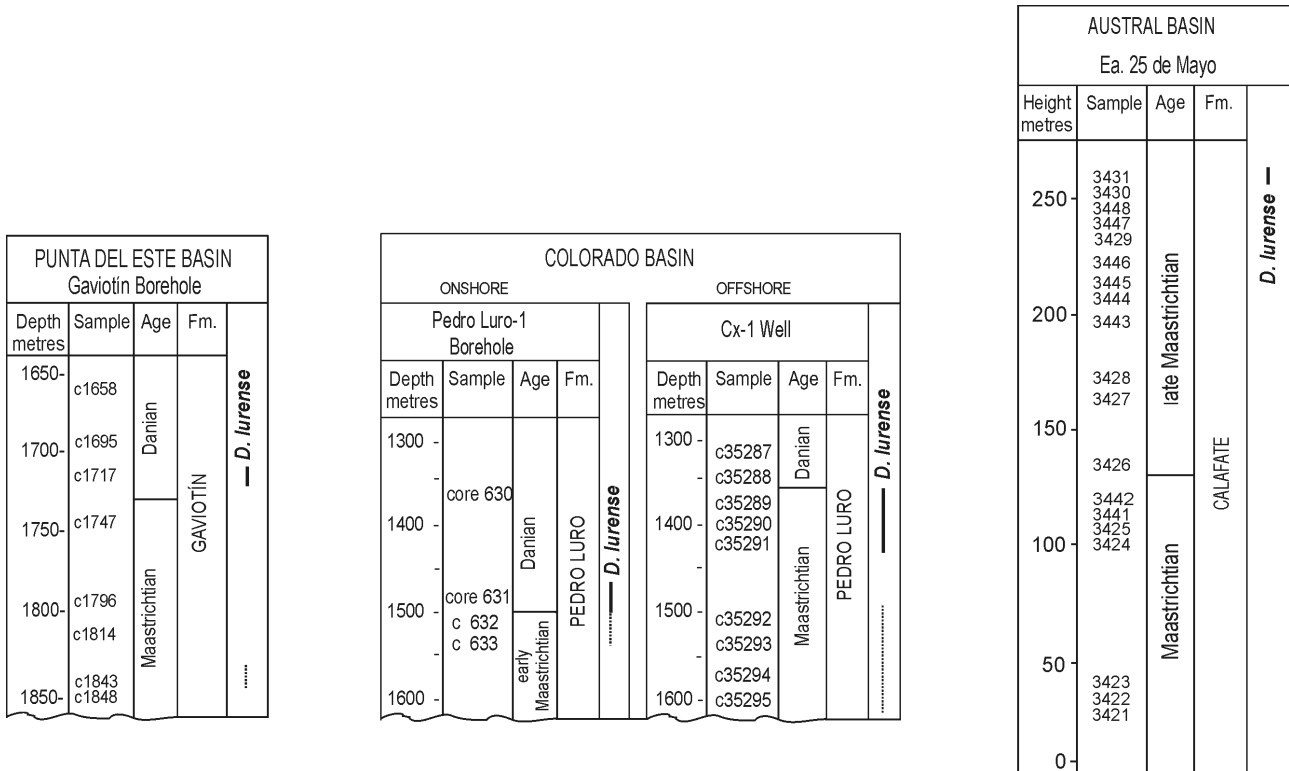
Danian strata extend from 1340 to 1365 m (figure 2). Ten taxa have their highest occurrences in this interval, including *Areoligera medusettiformis* O. Wetzel *ex* Lejeune-Carpentier, *Disphaerogena carposphaeropsis* O. Wetzel *emend.* Sarjeant, *Palaeoperidinium pyrophorum* (Ehrenberg *ex* O. Wetzel) Sarjeant, and *Senoniasphaera inornata* (Drugg) Stover and Evitt. Based on Williams *et al.* (1998b), *Areoligera medusettiformis* O. Wetzel *ex* Lejeune-Carpentier, which appeared during the Late Cretaceous persisted into the Palaeogene (Lutetian). According to Williams *et al.* (2004) the Last Occurrence Datum (LOD) of *Palaeoperidinium pyrophorum* (Ehrenberg *ex* O. Wetzel) Sarjeant, is at about 58 Ma at mid latitudes in the Northern Hemisphere and at high latitudes in the Southern Hemisphere. Moreover, Brinkhuis *et al.* (2003) found the last abundant occurrence of this taxon in ODP site 1172 East Tasman Plateau (44°S), at approximately 63 Ma (Danian). Williams *et al.* (2004) gave a range for *Senoniasphaera inornata* (Drugg) Stover and Evitt of 64.95 to 62.6 Ma within the Danian at mid latitudes. This species is thus the best stratigraphic marker, suggesting an age no younger than late Danian for this interval.

Maastrichtian or older strata occur below 1380 m, as indicated by the presence of *Dinogymnium undulosum* Cookson and Eisenack. Williams *et al.* (2004) placed the LO of the genus *Dinogymnium* at the Cretaceous/Palaeogene boundary. *Diconodinium lureense* sp. nov. has its highest stratigraphical occurrence at 1380 m and is quite common in underlying deposits. **Pedro Luro -1 Borehole.** Kaasschieter (1963) defined the type section of the Pedro Luro Formation between 1360 and 1508 md (1339 to 1487 m below mean sea level) in the Pedro Luro -1 (figure 2). In our study, the highest productive palynology sample bearing dinocysts proceed from 1487- 1488 m sidewall core sample. The dinocyst assemblages from 1487-1488 m and 1492 m cutting sample are not as diverse as those from the Cx-1 Well but contain taxa such as *Alisocysta*

*circumtabulata* (Drugg) Stover and Evitt, *Diconodinium lureense* sp. nov. and *Trithyrodinium evittii* Drugg. Following Williams *et al.* (2004), the LODs of *Alisocysta circumtabulata* (Drugg) Stover and Evitt is recorded in mid latitudes Northern Hemisphere at 58.5 Ma whereas the last common occurrence is placed at 57 Ma in mid-high latitudes Southern Hemisphere; Brinkhuis *et al.* (2003) found the LOD of *Trithyrodinium evittii* Drugg in the Tasman Plateau at 57.3 Ma. In this way, the age of the interval 1487-1492 m is believed to be Selandian or older. It is impossible to determine whether *Diconodinium lureense* sp. nov. extends above 1487 m, because of poor sample control.

Underlying sediments appear to be Campanian or early Maastrichtian in age or older. This determination is based on the presence of *Odontochitina* sp. at 1505 m. Helby *et al.* (1987, fig. 40, p. 65) showed the LOD of *Odontochitina* spp. in their Australasian *Isabelidinium korojonense* Range Zone, which is mid Campanian to early Maastrichtian. Taking into account the information published by Wilson (1984), Wood and Askin (1992) considered the ranges of *Odontochitina* spp. in both Australia and New Zealand to be equivalent, and placed its LOD at the end of the Campanian. Williams *et al.* (2004) considered that the range of *Odontochitina operculata* (O. Wetzel) Deflandre and Cookson extends into the early Maastrichtian (68.5 Ma) at high latitudes Southern Hemisphere and *Odontochitina costata* Alberti and *Odontochitina operculata* (O. Wetzel) Deflandre and Cookson has its LOD at 70 Ma at mid latitudes Northern Hemisphere. Thus, the age of the bottom of the Pedro Luro Formation in this borehole is taken to be possibly as young as early Maastrichtian.

**Other boreholes.** *Diconodinium lureense* sp. nov. was previously recorded (as "*Lejeunia*" sp.) by Gamero and Archangelsky (1981) in the two offshore boreholes Ranquel x-1 and Puelche x-1. In the Ranquel x-1 Borehole, the Pedro Luro Formation extends from 2050 to 2300 m. The top of this unit is marked by the highest occurrences of several species, such as *Diconodinium lureense* sp. nov. as well as *Manumiella? cretacea* (Cookson) Bujak and Davies (as *Isabelidinium cretaceum*). The top of Pedro Luro Formation in Puelche x-1 Borehole, at 1600 m corresponds to the highest occurrences of *Trithyrodinium evittii* Drugg (as *T. fragile*), *Palaeocystodinium australinum* (Cookson) Lentin and Williams and *Cerodinium dartmoorium* (Cookson and Eisenack) Lentin and Williams (as *Deflandrea dartmooria*). Although *Diconodinium lureense* sp. nov. ranges into the overlying units (dated as Eocene to Oligocene), this species seems to be consistently present only below the top of Pedro Luro Formation. We therefore consider the presence of



**Figure 2.** Stratigraphical occurrence of *Diconodinium lurese* sp. nov. in Colorado, Punta del Este and Austral basins, c: cutting sample / *Distribución estratigráfica de Diconodinium lurese* sp. nov. en las cuencas de Colorado, Punta del Este y Austral, c: muestra de cutting.

*Diconodinium lurese* in the Eocene to Oligocene indicates reworking.

Williams *et al.* (1998b) placed the LOD of *Manumiella? cretacea* (Cookson) Bujak and Davies close to the end of the Danian (at about 61 Ma). A re-evaluation of the stratigraphical significance of LODs of selected dinocyst species suggests that the age of the Pedro Luro Formation, and therefore the youngest deposits containing *Diconodinium lurese* sp. nov. are not younger than Danian. Moreover, Archangelsky *et al.* (1997) studied the Pejerrey x-1 Well, drilled offshore Colorado Basin, where they recorded our new species in strata assigned to Maastrichtian-Danian age.

*Punta del Este Basin*

According to Daners and Guerstein (2004), based on dinoflagellate cysts, the transition between Cretaceous and Palaeogene strata in the Gaviotín borehole is placed between 1717 and 1747 md (figure 2). The presence of *Damassadinium californicum* (Drugg) Fensome *et al.* between 1582 and 1658 md. suggests a Danian or earliest Selandian age since Williams *et al.* (2004) recorded the LOD of this

species for mid latitudes in the Northern Hemisphere at 60.3 Ma. At 1717 and 1814 md the highest occurrences of *Tanyosphaeridium variecalamum* Davey and Williams and *Alisogymnium euclaense* (Cookson and Eisenack) Lentin and Vozzhennikova, confirm an age no younger than Maastrichtian for the lower part of the selected interval (Williams *et al.*, 1998b). Thus, *Diconodinium lurese* sp. nov. (as *Diconodinium* sp.) was recorded from Maastrichtian to lowermost Danian sediments.

*Austral Basin*

The dinocyst assemblages studied in the Austral Basin are recovered from the Calafate Formation, which outcrops south of Lago Argentino, southwestern Santa Cruz Province. *Diconodinium lurese* sp. nov. is recorded (as *Diconodinium* sp.) only in the uppermost part of the section (figure 2). The presence of *Manumiella druggii* (Stover) Bujak and Davies and *Alisocysta circumtabulata* (Drugg) Stover and Evitt indicate a maximum late Maastrichtian age for the middle part of the section and upwards. Despite the ranges of the recorded dinocyst species extending

into the Early Palaeogene, the absence of species first appearing in the Danian is noticeable.

Sedimentological studies suggest that the Cretaceous-Palaeogene boundary deposits have been eroded in this area. Marensi *et al.* (2002) recognized that southern Lago Argentino, the Eocene Man Aike Formation unconformably overlies the Late Cretaceous Calafate Formation. This is supported by the persistent presence of the megaspore *Grapnelispora loncochensis* Papú 1997 in the uppermost part of this section. This species, which has hitherto only been recovered from Maastrichtian deposits of Patagonia and would reinforce an age no younger than late Maastrichtian (Marensi *et al.*, 2004). This data provide the evidence for considering the FO of *Diconodinium lurese* to be late Maastrichtian.

### Summary

The distribution of *Diconodinium lurese* sp. nov. in the three basins confirms it as a consistent component of K/P boundary dinocyst assemblages. The new species probably appeared during the late Maastrichtian and disappeared around about the Danian/Selandian boundary. Thus, *Diconodinium lurese* sp. nov. seems to be a good biostratigraphical marker for deposits related to the Maastrichtian-Danian transition in the Southwest Atlantic Basins.

### Systematic palynology

Division DINOFLAGELLATA (Bütschli 1885)

Fensome *et al.* 1993

Subdivision DINOKARYOTA Fensome *et al.* 1993

Class DINOPHYCEAE Pascher 1914

Subclass PERIDINIPHYCIDAE Fensome *et al.* 1993

Order PERIDINIALES Haeckel 1894

Suborder PERIDINIINEAE Autonym

Family PERIDINIACEAE Ehrenberg 1831

Genus *Diconodinium* Eisenack and Cookson 1960  
*emend.* Morgan 1977

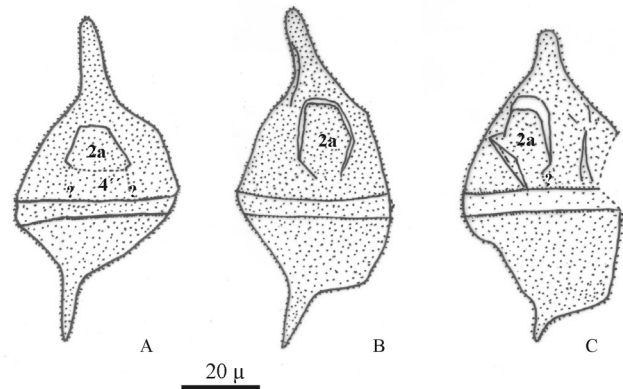
**Type species.** *Diconodinium multispinum* Deflandre and Cookson, 1955, pl.1, fig.5, as *Palaeohystrichophora multispina*.

*Diconodinium lurese* sp. nov.

(Figures 3.A-C, Figure 4.A-I, Figure 5.A-I)

1981 "*Lejeunia*" sp. Gamero and Archangelsky: page 123, pl II, fig. 6.

**Holotype.** Slide PL-1: 631(2), coordinates: 31/94.8 (England Finder reference: D 45/4) Figure 3.A, Figure 4.A.



**Figure 3.** *Diconodinium lurese* sp. nov., line drawings of external views. For those illustrations indicated as being reversed views, the drawings are a mirror image of the appearance of the specimen in the microscope / *Diconodinium lurese* sp. nov., dibujos esquemáticos de vistas externas. Para todas las ilustraciones indicadas como vistas reversas, los dibujos son una imagen especular de la observada en el microscopio. **A**, PL -1 sample 631(2): 31/94.8, D 45/4. Holotype, dorsal surface (reversed view) / holotipo, superficie dorsal (imagen invertida). **B**, Cx-1 sample P35295(1): 48/103, N 28/1, dorsal surface (reversed view) / superficie dorsal (imagen invertida). **C**, Cx-1 sample P35295(1): 29/92, A 47/4, dorsal surface (reversed view) / superficie dorsal (imagen invertida).

**Paratype.** Slide PL-1: 632(1), coordinates: 41/109 (England Finder reference: T 35/0) Figures 4.D, G. Repository. Palynological Collection, Departamento de Geología de la Universidad Nacional del Sur, Bahía Blanca, Argentina.

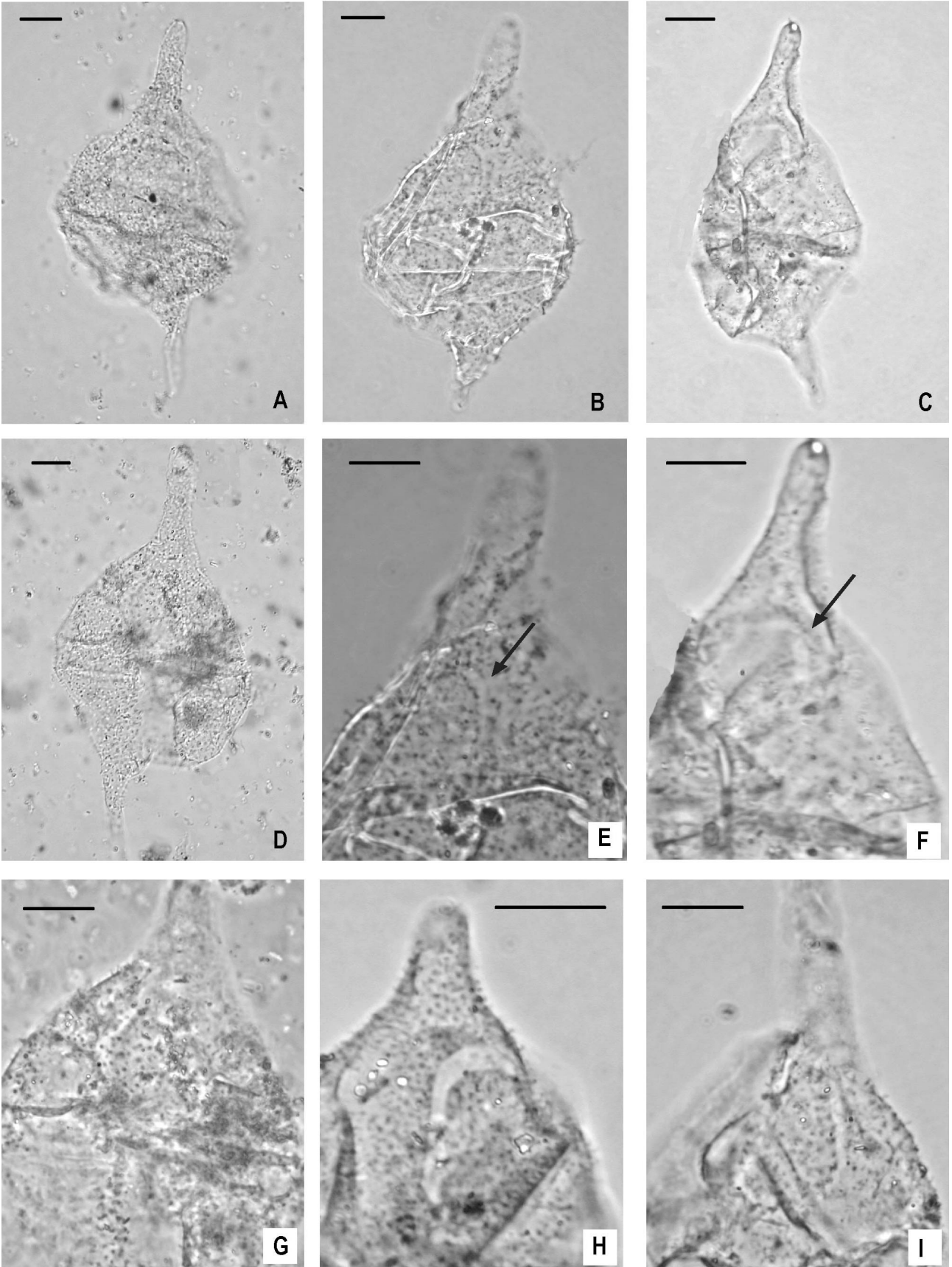
**Type locality.** Pedro Luro-1 Borehole, Buenos Aires Province, Argentina.

**Type stratum.** 1487-1488 m depth (core sample).

**Derivation of name.** After the Pedro Luro Formation, from which this species was first recorded.

**Diagnosis.** A species of *Diconodinium* characterized by relatively long apical and antapical horns and with an autophragm densely covered by short nontabular spines.

**Description.** Cyst fusiform in shape, consisting of a subtriangular epitract slightly larger than the rounded hypotract. The epitract extends into a 20 to 30  $\mu$ m long apical horn with a rounded distal tip. The hypotract bears a single, pointed, 15 to 25  $\mu$ m long antapical horn clearly offset to the left from the midline of the cyst. The cingulum is about 4  $\mu$ m wide, and slightly offset at the sulcus. The autophragm is densely covered by thin, solid spines up to 1.5  $\mu$ m high. The spines are all of the same type and size. They are distributed randomly except along the margin of the cingulum, where they are always aligned in rows (figures 3.A-C). The archeopyle is rarely discernible but, when visible, is intercalary normally type Ia but occasionally IPa. The former type includes the steno-deltaform plate 2a only with clear apical and lateral sutures (figures 3.B, 4.H). When having a type IPa archeopyle the lateral sutures of plate 4'' are partly



open but never reach the cingulum (figures 3.A, 4.F, G). In both archeopyle types the operculum remains *in situ* and is always adnate posteriorly (figures 4.H, I, 5.H, I).

**Dimensions.** Overall length: 55 (80) 110  $\mu\text{m}$ ; width: 30 (41) 50  $\mu\text{m}$  (53 specimens measured).

**Stratigraphic distribution.** Late Maastrichtian to Danian.

**Comparison.** *Diconodinium lurensense* differs from most other described species of *Diconodinium* in having a fusiform shape and relatively long apical and antapical horns. Other species also bearing relatively long horns are *Diconodinium martianum* Srivastava and *Diconodinium longicorne* Orlau. The former resembles *Diconodinium lurensense* closely in shape and size, but differs in having the antapical horn located close to the midline and in having a smooth autophragm. *Diconodinium longicorne* Orlau is characterized by having a subspherical to rhomboidal body, an epitract that is bigger than the hypotract, and an apical horn that is longer than the shorter antapical horn. In addition, its surface is finely granulate and shows tabulation on both epitract and hypotract. *Diconodinium davidii* Morgan is similar in size to *Diconodinium lurensense* sp. nov. and also has a slightly offset antapical horn, but differs in having coarser, aligned spines that may reveal traces of tabulation. *Diconodinium pusillum* Singh also has an asymmetrically aligned antapical horn and an epitract that is longer than the hypotract. It differs from the new species by having a shorter, bifid apical horn and finer spines 0.5  $\mu\text{m}$  long, and in being smaller. *Diconodinium lurensense* also resembles *Diconodinium multispinum* (Deflandre and Cookson) Eisenack and Cookson *emend.* Morgan, however, the latter shows signs of paratabulation, especially on the epitract. Furthermore, *Diconodinium multispinum* has ornamentation which is slightly larger and adjacent ornamentation elements may be fused to form discontinuous parasutural ridges. *Diconodinium vitricornu* Roncaglia *et al.* differs from *Diconodinium lurensense* in having a smooth autophragm, mostly thin but thickened at the apex to form a solid

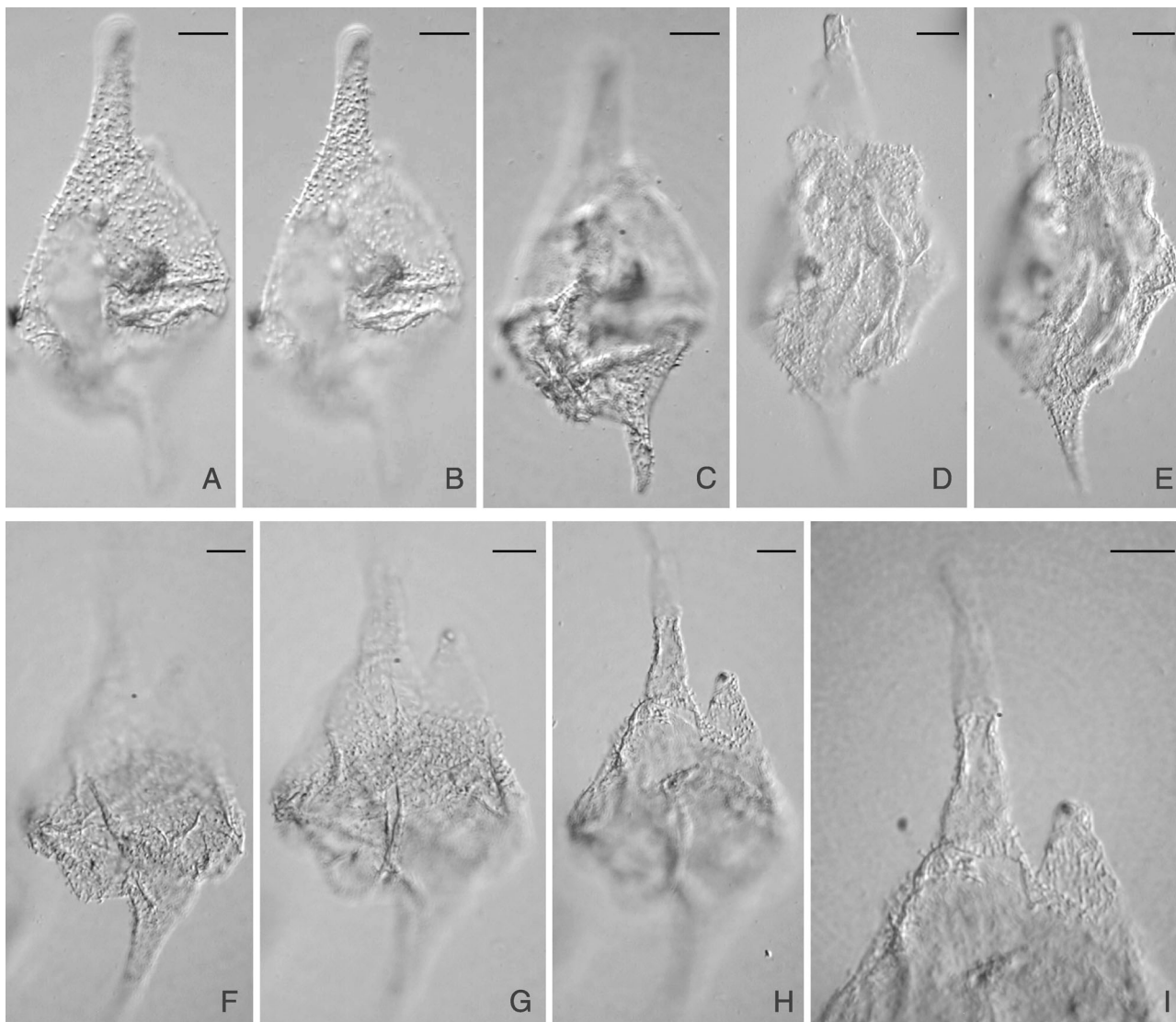
tip of the horn. *Alterbidinium acutululum* (Wilson) Lentin and Williams possesses a similar outline and comparable horns to *Diconodinium lurensense*, and also has an epitract larger than the hypotract. However, *Alterbidinium acutululum* (Wilson) Lentin and Williams is characteristically circumcavate and both endophragm and periphragm are smooth.

**Remarks.** A few specimens of *Diconodinium lurensense* appear to show cavation, especially below the apical horn (figures 4.F, H). A detailed examination of our specimens revealed that this is an optical effect, produced by folding of the thin autophragm at the anterior margin of the archeopyle, and does not indicate a second wall layer. According to Fensome *et al.* (1993, p. 131), *Diconodinium* is morphologically intermediate between the two subfamilies Palaeoperidinioideae and Deflandroideae, since the type species can have either a single plate intercalary archeopyle type 1Ia or a single plate intercalary plus single plate precingular archeopyle type 1I1Pa. Although the archeopyle sutures are not always clearly discernible, most of our specimens have an archeopyle type Ia and just a few of them seem to present an Ipa type. This variation reinforces the comments of Fensome *et al.* (1993).

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**Figure 4. A-I.** *Diconodinium lurensense* sp. nov. from the Pedro Luro Formation, Colorado Basin. Scale bar represents 10  $\mu\text{m}$  for all specimens. The digital images were taken using phase contrast, unless otherwise stated / *Diconodinium lurensense* sp. nov. proveniente de la Formación Pedro Luro, cuenca del Colorado. La escala gráfica representa 10  $\mu\text{m}$  para todos los especímenes. Las imágenes digitales fueron tomadas con contraste de fase, excepto cuando es indicado. **A**, PL-1 sample 631(2): 31/94.8, D 45/4. Holotype, ventral view, dorsal surface, interference contrast / holotipo, vista ventral, superficie dorsal, contraste de interferencia. **B**, **E**, Cx-1 sample P35298(1): 48/109, T 28/1. **B**, ventral view, optical section / vista ventral, sección óptica; **E**, ventral view, dorsal surface, archeopyle arrowed / vista ventral, superficie dorsal, arqueopilo señalado. **C**, **F**, Cx-1 sample P35295(1): 48/103, N 28/1. **C**, ventral view, dorsal surface / vista ventral, superficie dorsal; **F**, detail of the archeopyle, arrowed / detalle del arqueopilo, señalado. **D**, **G**, PL-1 sample 632(1): 41/109, T 35/0. **D**, dorsal view, dorsal surface, interference contrast / vista dorsal, superficie dorsal, contraste de interferencia; **G**, detail showing archeopyle and cingulum / detalle mostrando el arqueopilo y el cíngulo. **H**, Cx-1 sample P35295(1): 29/92, A 44/4. detail, ventral view, dorsal surface showing the archeopyle / detalle, vista ventral, superficie dorsal mostrando el arqueopilo. **I**, Cx-1 sample P35290(1): 42/104.5, O 34/3. detail, dorsal view, dorsal surface showing the archeopyle / detalle, vista dorsal, superficie dorsal mostrando el arqueopilo.



**Figure 5.** A-I, *Diconodinium lurese* sp. nov. from the Calafate Formation, which outcrops at the Estancia 25 de Mayo, Austral Basin. Scale bar represents 10  $\mu$ m for all specimens. The digital images were taken using interference contrast / *Diconodinium lurese* sp. nov. proveniente de la Formación Calafate aflorante en la Estancia 25 de Mayo, cuenca Austral. La escala gráfica representa 10  $\mu$ m para todos los especímenes. Las imágenes digitales fueron tomadas con contraste de interferencia. A-C, Sample 3431(1): 40/96.5, U40/4; ventral view / vista ventral; A, B, ventral surface / superficie ventral; C, dorsal surface / superficie dorsal. D, E, sample 3431(1): 22/108, H22/3, dorsal view / vista dorsal; D, dorsal surface / superficie dorsal; E, ventral surface / superficie ventral. F-I, sample 3431(2): 45/91.5, Z45/4, ventral view / vista ventral; F, G, ventral surface / superficie ventral; H, dorsal surface / superficie dorsal; I, close-up of posteriorly attached operculum / detalle mostrando el opérculo adherido posteriormente.

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**Appendix 1****List of dinocyst species names cited in the text**

(See Williams *et al.*, 1998a for references, except when indicated).

*Alisocysta circumtabulata* (Drugg 1967) Stover and Evitt 1978.  
*Alisogymnium euclaense* (Cookson and Eisenack 1971a) Lentin and Vozzhennikova 1990.  
*Alterbidinium acutulium* (Wilson 1967b) Lentin and Williams 1985 *emend.* Khowaja-Ateequzaman *et al.* 1991.  
*Areoligera medusettiformis* Wetzel 1933b *ex* Lejeune-Carpentier 1938a.  
*Cerodinium dartmoorium* (Cookson and Eisenack 1965) Lentin and Williams 1987.  
*Damassadinium californicum* (Drugg 1967) Fensome *et al.* 1993b.  
*Diconodinium davidii* Morgan 1975.  
*Diconodinium longicorne* Olaru 1978a.  
*Diconodinium lurensense* sp. nov. herein.  
*Diconodinium martianum* Srivastava 1995.

*Diconodinium multispinum* (Deflandre and Cookson 1955) Eisenack and Cookson 1960 *emend.* Morgan 1977.  
*Diconodinium pusillum* Singh 1971.  
*Diconodinium vitricornu* Roncaglia *et al.* 1999.  
*Dinogymnium undulosum* Cookson and Eisenack 1970a.  
*Disphaerogena carposphaeropsis* O. Wetzel 1933b *emend.* Sarjeant 1985b.  
*Manumiella? cretacea* (Cookson 1956) Bujak and Davies 1983.  
*Manumiella druggii* (Stover 1974) Bujak and Davies 1983.  
*Odontochitina costata* Alberti 1961 *emend.* Clarke and Verdier 1967.  
*Odontochitina operculata* (O. Wetzel 1933a) Deflandre and Cookson 1955.  
*Palaeocystodinium australinum* (Cookson 1965b) Lentin and Williams 1976.  
*Palaeoperidinium pyrophorum* (Ehrenberg 1838 *ex* O. Wetzel 1933a) Sarjeant 1967b.  
*Senoniasphaera inornata* (Drugg 1970b) Stover and Evitt 1978.  
*Tanyosphaeridium varicalamum* Davey and Williams 1966b.  
*Trithyrodinium evittii* Drugg 1967.