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New dinoflagellate cyst species from Cretaceous/Palaeogene boundary deposits at Ouled Haddou, south-eastern Rif, Morocco

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Abstract

A palynological investigation of the recently described and foraminifera-dated Ouled Haddou section (south-eastern Rif Corridor) in northern Morocco yielded eight new dinoflagellate cyst species within a rich and well-preserved assemblage as follows: *Batiacasphaera rifensis*, *Cerodinium mediterraneum*, *Damassadinium spinosum*, *Eisenackia msounensis*, *Impagidinium maghribensis*, *Lejeunecysta izerzenensis*, *Pterodinium cretaceum* and *Ynezidinium tazaensis*. They are described because they are likely to be important for recognition of the Cretaceous/Palaeogene boundary elsewhere in Morocco and at other locations.

Keywords: Cretaceous/Palaeogene boundary; Dinoflagellate cysts; Stratigraphy; Ouled Haddou section; South-eastern Rif; Northern Morocco

1. Introduction

Several studies have reported on the palynology of the Upper Cretaceous and Lower Palaeogene succession in Morocco. These were based on material from the Ganntour and Oulad Abdoun mining districts of the Phosphate Plateau (Prévôt et al., 1979; Rauscher and Doubinger, 1982; Rauscher, 1985; Soncini and Rauscher, 1988; Soncini, 1990; Rauscher et al., 1990) and the Bou Anguer Syncline of the Middle Atlas Mountains (Herbig and Fechner, 1994). The dinoflagellate assemblages recorded were diverse and well preserved but none of the sections studied encompassed a continuous succession across the Cretaceous/Palaeogene boundary. Our study is based on samples from a section at Ouled Haddou, the first Moroccan section with a complete record of the Cretaceous–Palaeogene transition (Toufiq et al., 2002).

This paper presents the results of part of a multidisciplinary research program carried out on this section, the aims of which are to report in detail the events around the Cretaceous/Palaeogene boundary and to compare the results with those of several reference sections that have been discussed previously including El Kef, El Haria, Elles and Aïn Settara (Tunisia), Caravaca (Spain), Braggs (Alabama, USA) and Stevns Klint (Denmark). A detailed lithostratigraphic and planktonic foraminiferal biostratigraphic study (Toufiq et al., 2002; Toufiq and Boutakiout, 2005; Toufiq, 2006) enabled the Maastrichtian and Danian deposits of the section to be subdivided. A preliminary biostratigraphic analysis of dinoflagellate cysts (Slimani et al., 2004) supported this biostratigraphic interpretation of the boundary section. In order to make a good correlation between the stratigraphic occurrences of the new dinoflagellate cyst species and the planktonic foraminiferal scale, our study is based on the same sampled levels as those of Toufiq et al. (2002).

2. Material and methods

The Ouled Haddou section is situated 48 km to the north of Taza, in the eastern external Rif of northern Morocco (Fig. 1), south-west Mediterranean region. The section is exposed along

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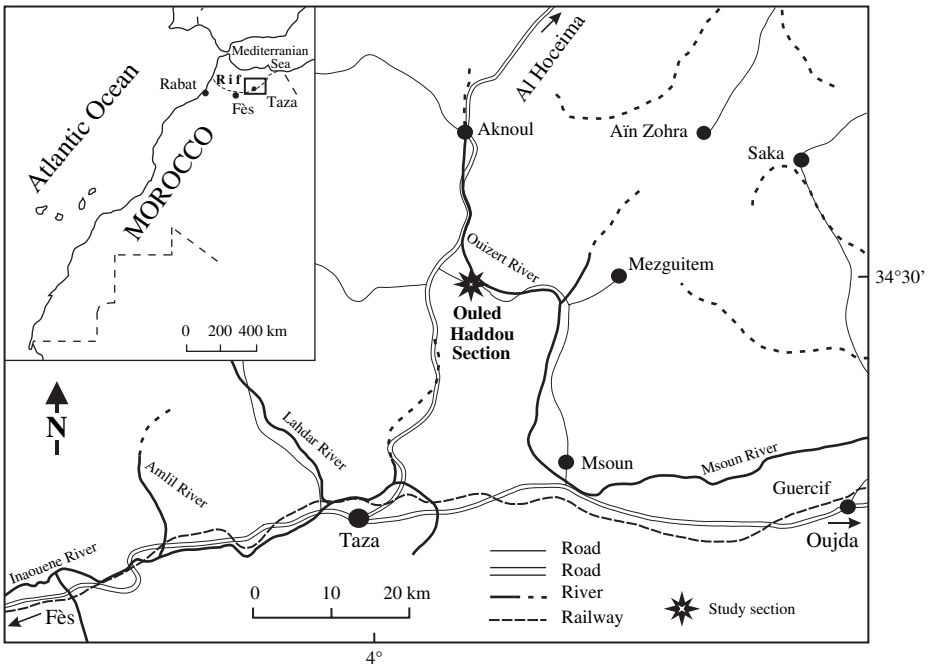


Fig. 1. Location map of the Ouled Haddou section.

the road connecting Aknoul to Mezguitem, on the northern flank of Jbel bou Izerzene. Maastrichtian and Danian deposits are visible in ravines of the Msoun River. The Maastrichtian is represented by marls with marly limestone intercalations. Deposits of the Mastrichtian–Danian transition consist of clayey marls and marls with limestone intercalations of Danian age (Fig. 2).

Nineteen samples were processed following standard palynological preparation techniques. Oxidizing agents and alkalis were not used. The residues were sieved on a nylon screen with a mesh of 20 μm, stained with methyl green and mounted in glycerine jelly on microscope slides.

3. Stratigraphy

The lithostratigraphic and planktonic foraminiferal subdivision of the pelagic deposits of the Ouled Haddou section by Toufiq et al. (2002) was based on 13 m of uppermost Maastrichtian and Danian sediments. Our study has focused on only 2.25 m of deposits around the Cretaceous/Palaeogene boundary (Fig. 2). The lowermost level consists of marls referable to the *Abathomphalus mayaroensis* Zone. These are overlain by clayey marls of the *Guembelitria cretacea* Zone, followed by marls of the *Parvularugoglobigerina eugubina* Zone.

4. Systematic palynology

The figured specimens, including holotypes and paratypes, are housed in the botanical collection of the National Herbarium, Department of Botany, Scientific Institute, Mohammed V-Agdal University, Rabat, Morocco. England Finder (EF) specimen coordinates are given in the text and figure captions.

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: Gonyaulacales Taylor, 1980
Suborder: Gonyaulacineae (autonym)
Family: Gonyaulacaceae Lindemann, 1928
Subfamily: Cribroperidinioideae Fensome et al., 1993
Genus *Damassadinium* Fensome et al., 1993

Type species. *Damassadinium californicum* (Drugg, 1967) Fensome et al., 1993.

Damassadinium spinosum sp. nov.
Fig. 3

Derivation of name. Latin ‘‘spina’’, spine, with reference to the processes.

Holotype. Sample OH 17, slide 1, EF F57/3 (Fig. 3A–C).

Type locality and stratigraphic horizon. Ouled Haddou section, north of Taza, northern Morocco; marls 65 cm above the K/T boundary, lower Danian.

Diagnosis. Intermediate spherical to ovoidal *Damassadinium* with tabulation indicated by annulate to soleate and linear complexes of relatively short processes and by occasional intratabular processes. Precingular archeopyle type P(3). Operculum free.

Description. Proximate to proximo-chorate dinoflagellate cyst with a spherical to ovoid central body. No antapical protrusion or distinct process is observed. Cyst wall 0.5–1 μm thick, composed of a smooth, dense endophragm and a

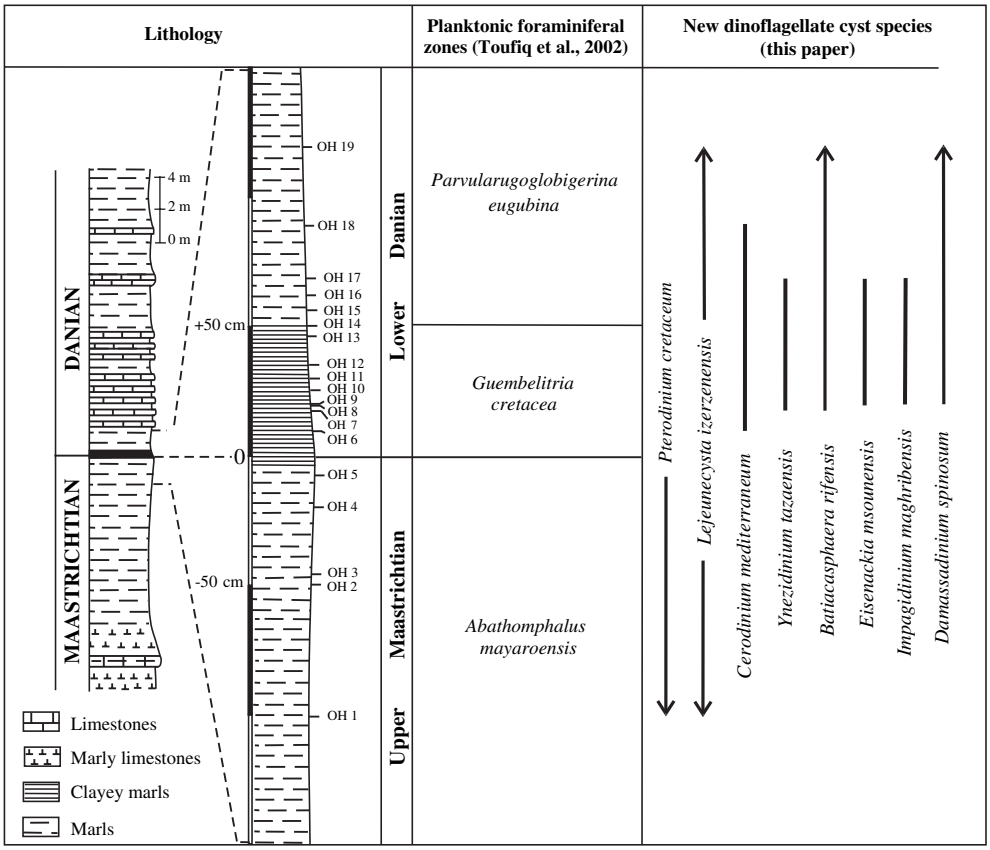


Fig. 2. Stratigraphic distribution of the new dinoflagellate cyst species relative to the existing planktonic foraminiferal zonation across the Cretaceous/Palaeogene boundary at the Ouled Haddou section.

fibrous periphragm; both layers closely appressed. Periphragm forms fibrous, acuminate or distally bifid processes that are simple or proximally to medially branched 2–5 times and irregularly connected at their bases by low fibrous ridges forming annulate or soleate and linear process complexes. Distribution of the processes reflects one apical plate, four precingular (1″, 2″, 4″, 5″) and four postcingular (3‴, 4‴, 5‴, 6‴) plates and one antapical (1⁗) plate. Central precingular process complex corresponds to the archeopyle. Processes are occasionally grouped in very reduced clusters that indicate precingular (6″), postcingular (1‴, 2‴) and posterior (1p) intercalary plates (Fig. 3F). Cingulum represented by six linear process complexes. Occasional isolated processes are distributed in sulcal area but do not clearly reflect a tabulation pattern. Intratabular processes occur occasionally and are sometimes joined proximally by low ridges. Apical process is branched and arises within apical process complex. It often consists of a protuberance surmounted by short and slender processes.

Dimensions (in μm). Holotype and range for 10 specimens measured: length of central body 60, 50(55)62; width of central body 60, 45(53)60; length of processes 5–12, 5–12.

Discussion. *Damassadinium spinosum* sp. nov. is unique in possessing short processes and a tabulation indicated only by process complexes. *Damassadinium heterospinosum* (Matsuoka, 1983) Fensome et al., 1993 and *D. californicum* (Drugg, 1967) Fensome et al., 1993 are almost twice as large and possess an antapical protrusion. Both latter species also have strongly fibrous and reticulate walls. Furthermore, the other species of this genus differ essentially from *D. spinosum* in possessing only septa or ridges.

Stratigraphic occurrence. Samples OH 9–19, planktonic foraminiferal *Guembelitria cretacea* and *Parvularugoglobigerina eugubina* zones (lower Danian).

Subfamily: Gonyaulacoideae (Autonym)
Genus *Impagidinium* Stover and Evitt, 1978

Type species. *Impagidinium dispertitum* (Cookson and Eisenack, 1965) Stover and Evitt, 1978.

Impagidinium maghribensis sp. nov.
Fig. 4G–L

Derivation of name. Arabic "*Al maghrib*", with reference to the country of Morocco.

Holotype. Sample OH 17, slide 1, EF M27 (Fig. 4G–K).

Type locality and stratigraphic horizon. Ouled Haddou section, north of Taza, northern Morocco; marls 65 cm above the K/T boundary, lower Danian.

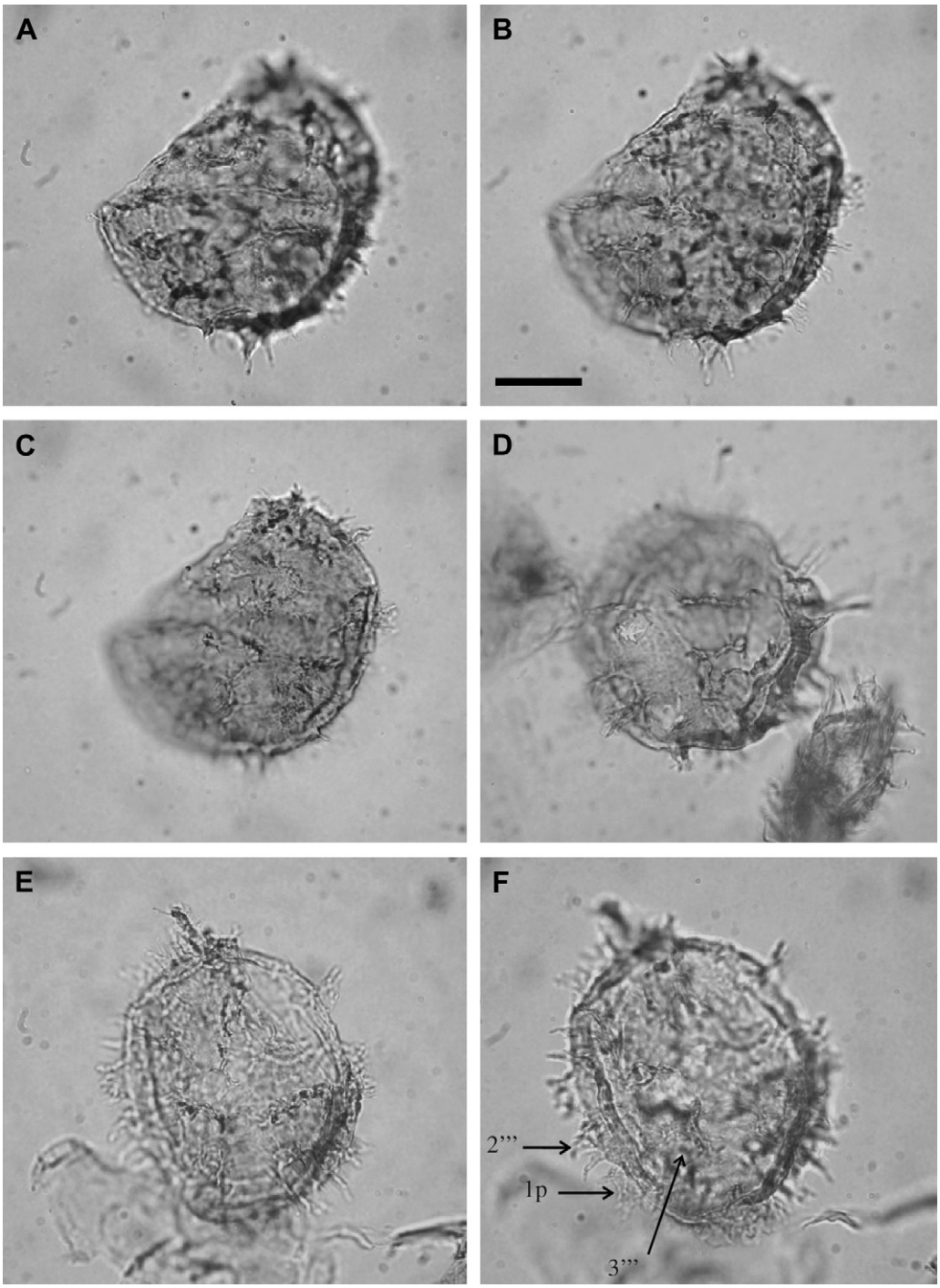


Fig. 3. *Damassadinium spinosum* sp. nov. from the Cretaceous/Palaeogene boundary section of Ouled Haddou. A–C, holotype, right lateral view, sample OH 17, slide 1, England Finder reference F57/3. A, left lateral surface; B, optical section; C, right lateral surface, high focus on wall structure and processes. D, OH 12, slide 1, U31/3, focus on cingular and postcingular process complexes. E, F, left laterodorsal view, OH 12, slide 1, T42/3. E, left laterodorsal surface, high focus on processes; F, right lateroventral surface. Scale bar in B represents 20 μm for all specimens illustrated.

Diagnosis. Ellipsoidal and granulate to verrucate species of *Impagidinium* with a gonyaulacoid tabulation expressed by low, narrow sutural septa, and a characteristic absence of a sutural septum between apical plates 1′ and 4′. Precingular, pentagonal archeopyle formed by loss of plate 3″. Operculum detached.

Description. Proximate autocyst with an ellipsoidal ambitus. Cyst wall 1–1.5 μm thick, massive and coarsely granulate to verrucate. Granules and verrucae 0.5–2 μm diameter, densely and regularly distributed on wall surface. Hyaline, low and narrow sutural septa (up to 2 μm high) with solid bases reflect a tabulation pattern (4′, 6″, 6c, 6‴, 1p, 1⁗). Distal margins of processes curved to undulating. No septum observed between apical plates 1′ and 4′ (Fig. 4H, I, L). Precingular plate 6″ subtriangular (Fig. 4L). Cingulum 4–5 μm wide. Tabulation of straight sulcal area not developed apart

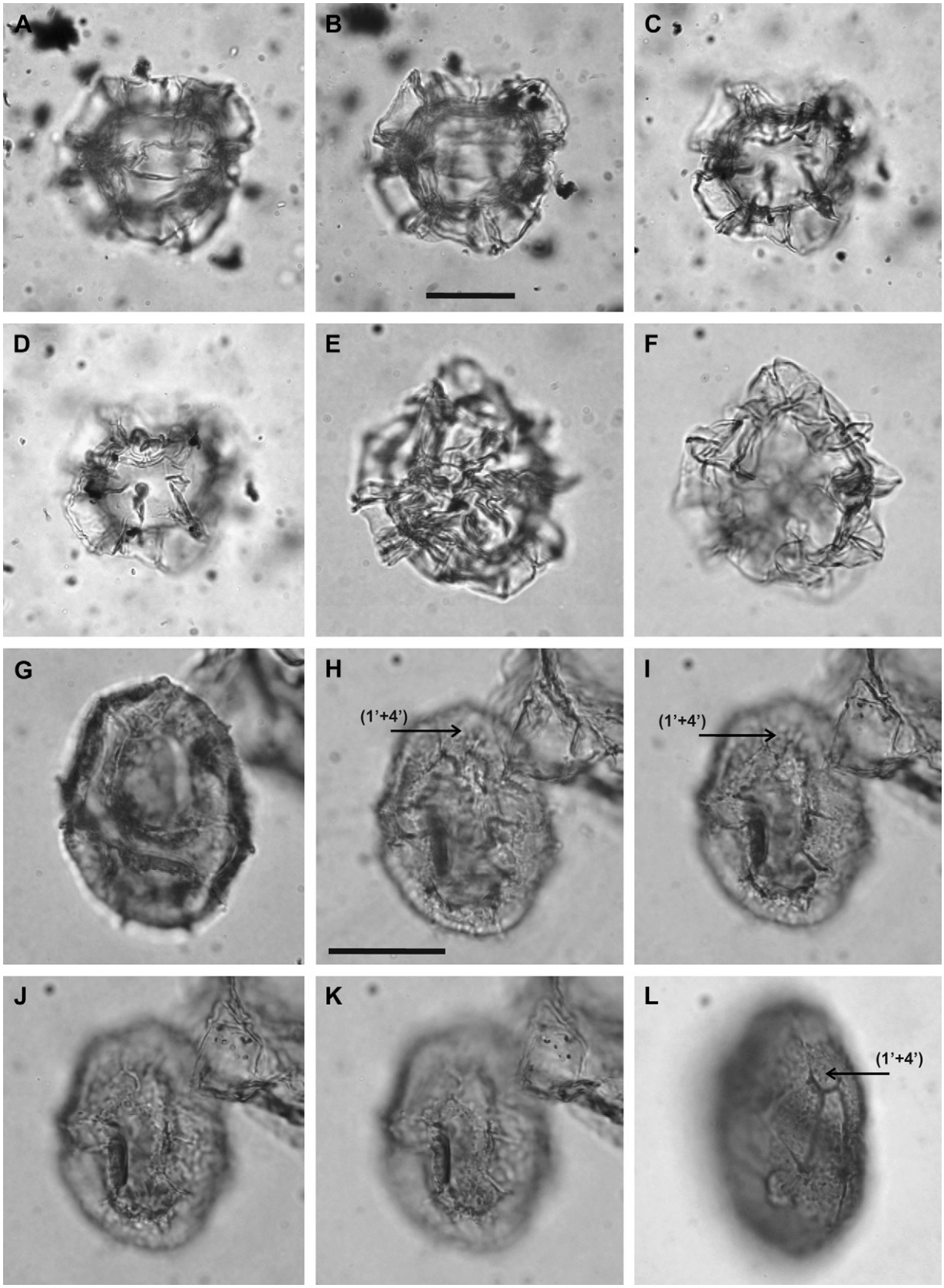


Fig. 4. A−F, *Pterodinium cretaceum* sp. nov. from the Cretaceous/Palaeogene boundary section of Ouled Haddou. A−D, holotype, ventral view, sample OH 2, slide 2, England Finder reference R45/3. A, dorsal surface, low focus on archeopyle; B, C, optical sections; D, ventral surface. E, F, ventral view, OH1, slide 1, S28/1. E, dorsal surface; F, ventral surface. G−L, *Impagidinium maghribensis* sp. nov., holotype, ventral view, OH 17, slide 1, M27. G, dorsal surface, low focus on wall structure and operculum; H−K, ventral surface, slightly differing levels of focus showing wall structure, $1' + 4'$ without $1'/4'$ contact, $1''$, $6''$, $1'''$, $6'''$, $1''''$ and 1p plates, and the untabulated sulcal area. L, right ventral view, right ventral surface showing the absence of $1'/4'$ suture, $6''$ and undifferentiated sulcal area, OH 12, slide 2, U40/1. Scale bars in B and H represents 20 μm for all specimens illustrated.

from posterior intercalary plate 1p, which is sometimes partially separated from sulcus by a discontinuous septum.

Dimensions (in μm). Holotype and range for 10 specimens measured: length 43, 42(45)50; width 32, 32(38)45.

Discussion. *Impagidinium maghribensis* sp. nov. is characterised by its coarsely granulate to verrucate wall surface, its narrow and low sutural septa, and the absence of a septum between plates 1′ and 4′. *Impagidinium maculatum* (Cookson and Eisenack, 1961) Stover and Evitt, 1978 has a similar ornamentation but differs in its larger size, ovoid to nearly spherical shape, higher sutural septa, and the presence of a septum between 1′ and 4′. *Impagidinium* sp. cf. *I. patulum* (Wall, 1967) Stover and Evitt, 1978 of Jan du Chêne (1988, pl. 20, figs 6–10; pl. 28, figs 1–4; text-fig. 4) has a granulate wall surface, but differs by having a septum that separates 1′ and 4′. *Impagidinium eugubinum* Biffi and Manum, 1988 has an ornamentation of dome-shaped to nipple-like prominences rather than granules or verrucae, and also differs in having well-delimited apical plates 1′ and 4′, and posterior sulcal plates. *Impagidinium aspinatum* (Cookson and Eisenack, 1974) Damassa, 1979a resembles *I. maghribensis* in its wall ornamentation, but differs in having an apical horn and a septum between 1′ and 4′.

Stratigraphic occurrence. Samples OH 9–17, planktonic foraminiferal *Guembelitria cretacea* and *Parvularugoglobigerina eugubina* zones (lower Danian).

Genus *Pterodinium* Eisenack, 1958, emend. Yun, 1981

Type species. *Pterodinium aliferum* Eisenack, 1958

Pterodinium cretaceum sp. nov.
Fig. 4A–F

1993 *Pterodinium* sp. B, Schiøler and Wilson, figs. 3–10, pl. 4, figs. 13, 14.
1997a *Pterodinium* sp. B, Schiøler and Wilson, 1993; Roncaglia and Corradini, figs. 6–8.
1997b *Pterodinium* sp. B, Schiøler and Wilson, 1993; Roncaglia and Corradini, fig. 4, pl. 3, figs. 6, 8.
2003 *Pterodinium* sp. B sensu Schiøler and Wilson, 1993; Torricelli and Amore, pl. 1, figs. 19, 20.

Derivation of name. After ‘‘Cretaceous’’, with reference to the Campanian–Maastrichtian occurrences of the species.

Holotype. Sample OH 2, slide 2, EF R45/3 (Fig. 4A–D).

Type locality and stratigraphic horizon. Ouled Haddou section, north of Taza, northern Morocco; marls 50 cm below the K/T boundary; upper Maastrichtian.

Diagnosis. Spherical to ovoid, smooth and thin-walled *Pterodinium* characterised by high sutural septa with slightly convex distal margin. Gonyaulacoid tabulation with discontinuous septa on ventral area. Archeopyle formed by release of precingular plate 3’’. Operculum free or in place.

Description. Acavate to murochorate, spherical to ovoidal autocyst. Cyst wall 0.5–1 μm thick, smooth. Hyaline, smooth and high septa (about one-third of central body diameter) arise from cyst body. Distal margins of septa are slightly convex and enlarged. Observed tabulation is gonyaulacoid (4′, 6″, 6c, 6‴, 1p, 1⁗), but difficult to observe when septa are folded. Cingulum 5–12 μm wide, slightly laevorotatory. Discontinuous septa in sulcal area do not reflect tabulation. Sutural septa 1″/1c, 6″/6c, 1c/1‴, 6c/6‴ and those between the sulcus and 1″, 6″, 1c, 6c are usually absent (Fig. 4D, F).

Dimensions (in μm). Holotype and range for 10 specimens measured: length of central body 28, 27(30)32; width of central body 28, 25(28)30; height of septa 6–12, 5–12.

Discussion. The new species is conspecific with *Pterodinium* sp. B of Schiøler and Wilson (1993, pl. 4, figs 13–14). It differs from other species of the genus in having discontinuous septa in the ventral area.

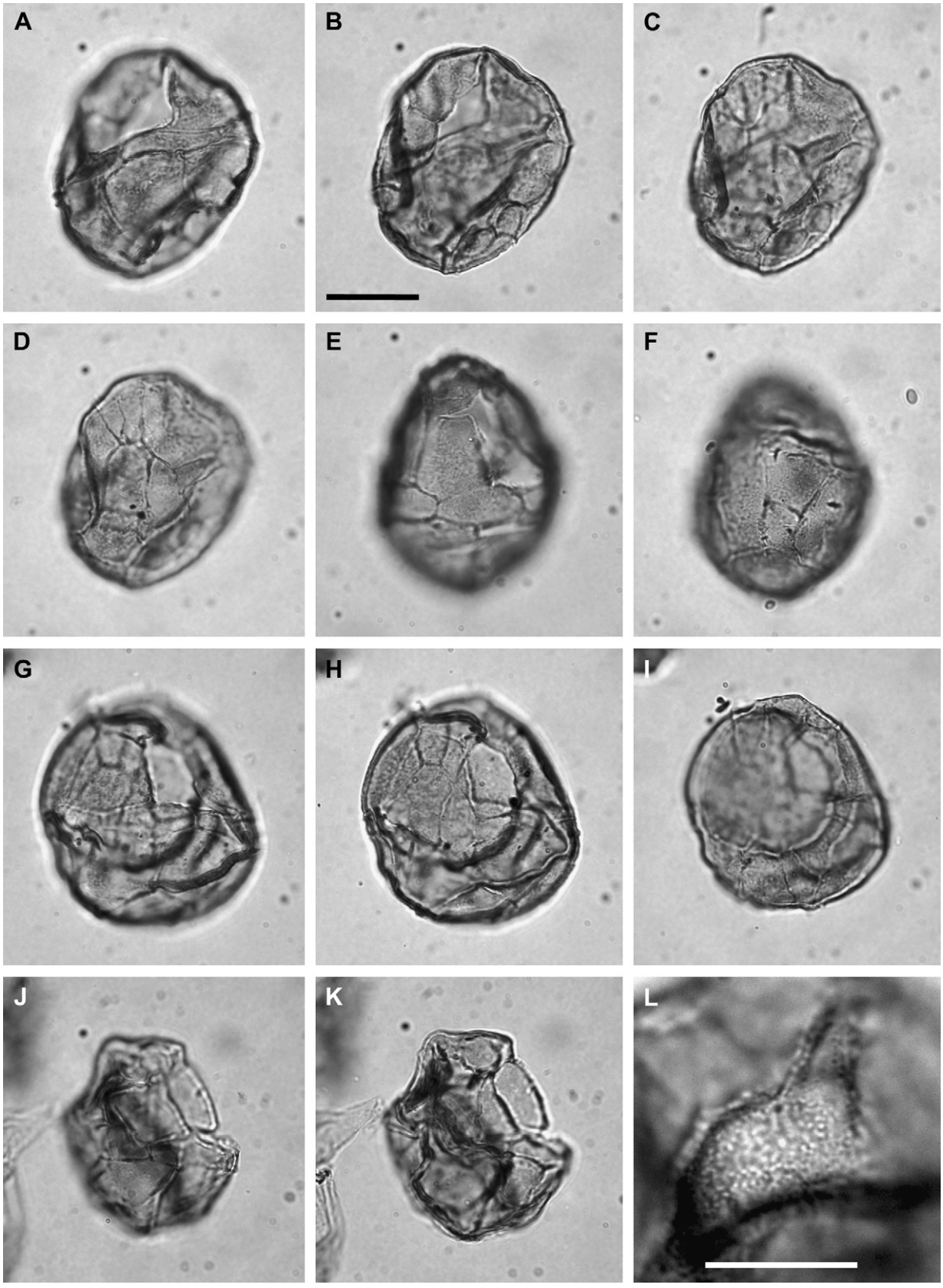
Stratigraphic occurrence. Samples OH 1–5, planktonic foraminiferal *Abpthomphalus mayaroensis* Zone (upper Maastrichtian), Ouled Haddou section; Maastrichtian of the Danish North Sea (Schiøler and Wilson, 1993); upper Campanian–lower Maastrichtian of Turnhout (Belgium) (Slimani, 1995, 2000, 2001); Maastrichtian of northern Apennines (Italy) (Roncaglia and Corradini, 1997a,b); Upper Campanian–Lower Maastrichtian of Calabria (Italy) (Torricelli and Amore, 2003).

Subfamily: Leptodinioideae Fensome et al., 1993
Genus *Ynezidinium* Lucas-Clark and Helenes, 2000

Type species. *Ynezidinium malloyi* Lucas-Clark and Helenes, 2000

Ynezidinium tazaensis sp. nov.
Figs. 5 and 6

Fig. 5. *Ynezidinium tazaensis* sp. nov., from the Cretaceous/Palaeogene boundary section of Ouled Haddou. A–D, holotype, ventral view, sample OH 14, slide 1, England Finder reference J48/4. A, dorsal surface, low focus on wall structure and archeopyle; B, optical section showing the 1⁗, 1p and ps plates; C, optical section, 1⁗ has a contact with 5‴ but not with 6‴; D, ventral surface showing the apical (1′, 4′) and precingular (1″, 5″, 6″) plate arrangement. E, F, left ventroantapical view, OH 15, slide 2, H57/4. E, right dorsoapical surface, low focus on wall structure and archeopyle; F, left ventroantapical surface, high focus on 1⁗, 1p and ps plates; 1⁗ has a narrow contact with 6‴. G–I, L, paratype, left ventrolateral view, OH 17, slide 2, B50/4; G, right dorsal surface, low focus on archeopyle; H, left ventral surface, showing the apical and precingular plate arrangement; I, left ventral surface, high focus on 1p, ps and 1⁗ plates; L, focus on wall structure. J, K, left lateral view, slightly differing focuses on left lateral surface, showing the archeopyle and apical boss, OH 8, slide 1, L44/3. Scale bars in B and L represent 20 μm for A–K and 10 μm for L.


A
B
C
D
E
F
G
H
I
J
K
L

Derivation of name. After the city of Taza near which the type locality is located.

Types. Holotype, sample OH 14, slide 1, EF J48/4 (Figs. 5A–D and 6A, B). Paratype, sample OH 17, slide 2, EF B50/4 (Fig. 5G–I, L).

Type locality and stratigraphic horizon. Ouled Haddou section, north of Taza, northern Morocco; clayey marls 50 cm above the K/T boundary; lower Danian.

Diagnosis. A species of *Ynezidinium* with an ovoidal to spherical microreticulate autocyst and a small apical protrusion. Gonyaulacoid tabulation with a characteristic epicystal plate arrangement, expressed by low and narrow sutural crests. Precingular, pentagonal archeopyle formed by loss of the precingular plate 3″. Operculum detached.

Description. Acavate, proximate autocyst, oval to round. Cyst wall 1–1.5 μm thick, microreticulate (Fig. 5L). An apical boss c. 3 μm in height and 10 μm in diameter is often present. Crests very low (0.5–1 μm high), solid and narrow (c. 0.5 μm wide). Reflected tabulation is 4′, 6″, 6c, 6‴, 1p, 1⁗, as, ps, 2s. The precingular (6″) plate is subpentagonal to subhexagonal. In many specimens the three anterior sides are almost equal in length and contact apical (1′, 4′) plates and sulcus (Figs. 5D and 6B). Plates 1′ and 4′ are rectangular to subrectangular, longitudinally parallel and of about equal length. Contacts 1′/6″ and 1′/sulcal area are almost equal in length. Plate 1′ is separated from a large, straight, undifferentiated sulcal area (5–8 μm wide) by a small, narrow (1–2 μm wide), subrectangular sulcal field, limited posteriorly by a crest and located between precingular 1″ and 6″ plates (Figs. 5D and 6B). Cingulum 4–7 μm wide. Anterior sulcal plate narrows anteriorly and widens posteriorly to meet posterior sulcal plate (ps), which is partially separated from sulcus by a short extension of a low crest (Fig. 6B). Postcingular plate 1‴ is not visible. Antapical plate 1⁗ is generally pentagonal and borders 3‴, 4‴, 5‴, 1p and ps (Figs. 5C and 6B), but rarely subpentagonal to subhexagonal with a narrower contact with 6‴.

Dimensions (in μm). Holotype, paratype and range for 12 specimens measured: length 48, 49, 38(45)50; width 45, 45, 35(41)50.

Discussion. *Ynezidinium tazaensis* sp. nov. is easily recognized by the combination of a microreticulate wall surface, low, narrow sutural crests and the subpentagonal to subhexagonal shape of the precingular 6″ plate. It differs from *Y. brevisulcatum* (Michoux, 1985) Lucas-Clark and Helenes, 2000 and *Y. pentahedrias* (Damassa, 1979b) Lucas-Clark and Helenes, 2000 and other species in being rounded in outline and in having a thinner and microreticulate wall, lower and narrower sutural crests, subpentagonal to subhexagonal 6″, a narrower anterior sulcal area and an apical boss. *Ynezidinium pentahedrias* also has a preapical tabulation, and *Y. waipaense* (Wilson, 1988) Lucas-Clark and Helenes, 2000 and *Y. malloyi*

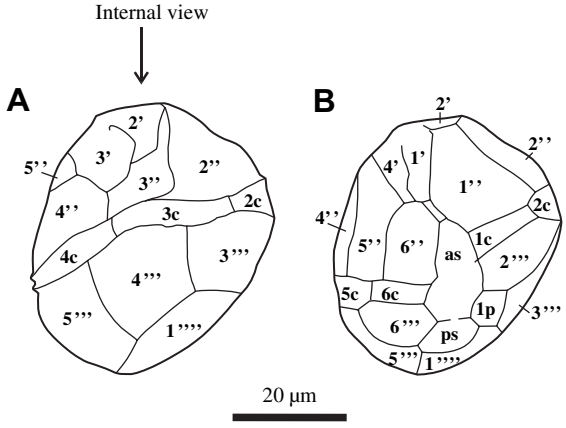


Fig. 6. *Ynezidinium tazaensis* sp. nov., holotype, sample OH 14, slide 1, England Finder reference J48/4. A, internal view of dorsal surface. B, ventral view, ventral surface showing the apical (1′, 4′) and precingular (1″, 5″, 6″) plate arrangement; 1⁗ has a contact with 5‴ but not with 6‴.

Lucas-Clark and Helenes, 2000 have a prominent apical horn rather than an apical boss.

Stratigraphic occurrence. Samples OH 7–17, planktonic foraminiferal *Guembelitria cretacea* and *Parvularugoglobigerina eugubina* zones (lower Danian).

Suborder: Goniodomineae Fensome et al., 1993
Family: Goniodomaceae Lindemann, 1928
Subfamily: Pyrodinioideae Fensome et al., 1993

Genus *Eisenackia* Deflandre and Cookson, 1955, emend. Quattrocchio and Sarjeant, 2003

Type species. *Eisenackia crassitabulata* Deflandre and Cookson, 1955

Eisenackia msounensis sp. nov.
Figs. 7 and 8

Derivation of name. After the River Msoun which crosses the type locality.

Holotype. Sample OH 12, slide 1, EF V39/1 (Figs. 7A–F, J, and 8A, B).

Type locality and stratigraphic horizon. Ouled Haddou section, north of Taza, northern Morocco; clayey marls 35 cm above the K/T boundary, lower Danian.

Diagnosis. A species of *Eisenackia* with a finely granulate wall surface. Gonyaulacoid tabulation indicated by very low penitabular and intratabular (one per plate) ridges or thickenings. Archeopyle apical, type (tA). Operculum free.

Description. Proximate, subspherical to ovoid autocyst with intratabular (one per plate) low sinuous ridges (maximum height 1 μm). Phragm is massive, thick (up to 2 μm) and finely

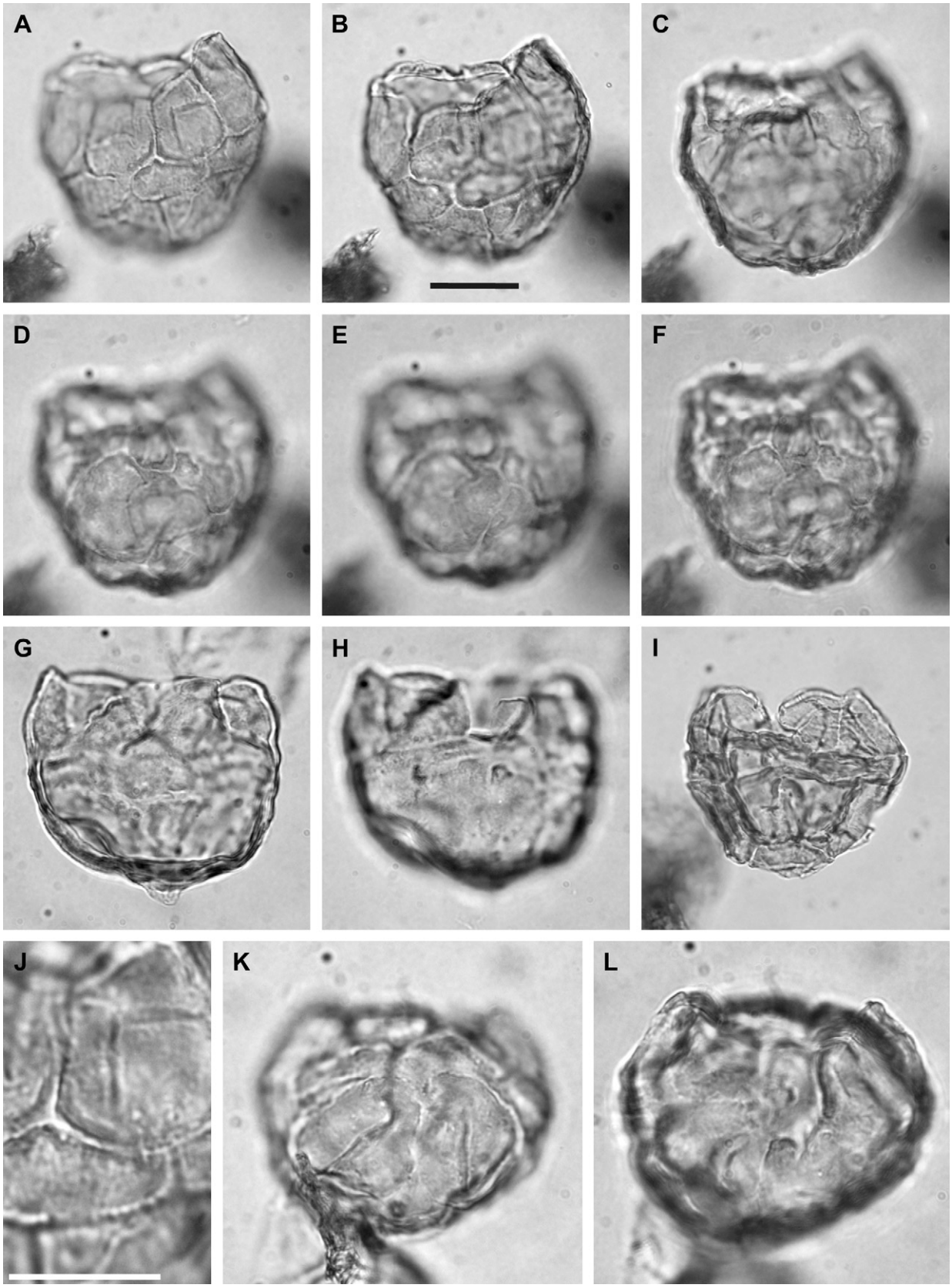


Fig. 7. *Eisenackia msounensis* sp. nov., from the Cretaceous/Palaeogene boundary section of Ouled Haddou. A–F, J, holotype, dorsoapical view, sample OH 12, slide 1, England Finder reference V39/1. A, dorsoapical surface, high focus on intratabular ridges and wall structure; B, optical section; C–F, slightly differing focuses on ventroantapical surface showing sulcal, cingular, precingular, postcigular and antapical plates; J, high focus on wall structure and intratabular ridges. G, H, right laterodorsal view, OH 12, slide 1, Y27/4. G, right dorsal surface; H, left ventral surface. I, dorsal view, dorsal surface, high focus on 1′′′′, 3′′′, 4′′′ and 5′′′ plates, OH 8, slide 1, K36. K, L, dorsal view, OH 12, slide 1, B28. K, dorsal surface; L, ventral surface. Scale bars in B and J represent 20 μm for A–I, K, L, and 10 μm for J.

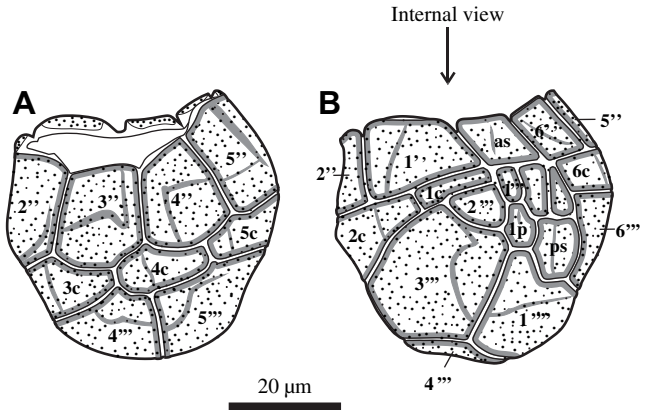


Fig. 8. *Eisenackia msounensis* sp. nov., holotype, sample OH 12, slide 1, England Finder reference V39/1. A, dorsal view, dorsal surface. B, holotype, internal view of ventral surface.

granular (Fig. 7J), but smooth and thinner (c. 1 μm) in sutural areas. Plates delimited by low ridges or thickenings (maximum height 1 μm), which are sometimes absent, especially on ventral surface of some specimens. Reflected tabulation is 4′, 6″, 6c, 6‴, 1p, 1⁗, 4s (Fig. 8A, B). Precingular plates are subpentagonal to nearly square. Cingular plates subrectangular (4–9 μm wide) and transversely elongate. 1‴ is small and inconspicuous. 2‴ is much smaller than the other postcingular plates. Antapical 1⁗ plate is hexagonal and borders 3‴, 4‴, 5‴, 6‴, 1p and ps. Archeopyle apical, type (tA) with a zigzag margin and accessory sutures; operculum free.

Dimensions (in μm). Holotype and range for 10 specimens measured: length (without operculum) 46, 38(44)45; width 50, 38(48)52.

Discussion. The finely granulate autophragm and low penitabular and typical intratabular ridges serve to distinguish *Eisenackia msounensis* from other species of the genus. *Eisenackia crassitabulata* Deflandre and Cookson, 1955 differs in its reticulate wall without intratabular ornament. *Eisenackia circumtabulata* Drugg, 1967 has higher penitabular ridges and a smooth wall without intratabular ornament. *Eisenachia margarita* (Harland, 1979) Quattrocchio and Sarjeant, 2003, *Eisenackia reticulata* (Damassa, 1979a) Quattrocchio and Sarjeant, 2003, and *E. chilensis* Quattrocchio and Sarjeant, 2003 also have higher penitabular ridges and in addition, respectively, accessory ridges, reticulation and coni.

Stratigraphic occurrence. Samples OH 8–17, planktonic foraminiferal *Guembelitria cretacea* and *Parvularugoglobigerina eugubina* zones, lower Danian.

Suborder and family uncertain

Genus *Batiacasphaera* Drugg, 1970, emend. Dörhöfer and Davies, 1980

Type species. *Batiacasphaera compta* Drugg, 1970

Batiacasphaera rifensis sp. nov.
Fig. 9A–F

?1995 *Batiacasphaera* cf. *reticulata* Schrank and Ibrahim, pl. 9, fig. 7.

?2004 *Batiacasphaera* cf. *kekerengensis* Schiøler and Wilson; Marenssi et al., fig. 4, pl. 5, figs N, O.

Derivation of name. After the Rif mountains of northern Morocco.

Types. Holotype, sample OH 12, slide 1, EF Y54/3 (Fig. 9A, B). Paratype, sample OH 14, slide 1, EF O34/4 (Fig. 9D, E).

Type locality and stratigraphic horizon. Ouled Haddou section, north of Taza, northern Morocco; clayey marls, 35 cm above the K/T boundary; lower Danian.

Diagnosis. Ovoid to subspherical *Batiacasphaera* with relatively thick and reticulate autophragm. Reticulum irregular, with low muri delimiting small, variable lumina. Large apical archeopyle, type tA, with zigzag margin, operculum mostly free, occasionally in place. Tabulation not indicated apart from archeopyle margin and operculum outline.

Description. Acavate, proximate, ovoid to subspherical gonyaulacoid dinoflagellate cyst. Cyst wall consists of a massive, relatively thick (up to 2 μm) and irregularly reticulate autophragm. Lumina of reticulum small (up to 3 μm), vary in size and shape on a single specimen. Muri low (up to 0.5 μm) and variable in thickness. Cingulum and sulcus not indicated. Archeopyle is apical type (tA), large with a sulcal notch and zigzag margin. On some specimens accessory sutures are present; operculum is angular in shape, simple and generally free but sometimes attached (Fig. 9A, B). Tabulation not indicated apart from archeopyle margin and operculum outline, suggesting six precingular and four apical plates.

Dimensions (in μm). Holotype, paratype and range for 26 specimens measured: length (with operculum, holotype) 45, 42(48)52; length (without operculum, paratype) 45, 35(40)47; width 42, 40, 35(43)47.

Discussion. *Batiacasphaera rifensis* sp. nov. is similar to *B.* cf. *reticulata* figured by Schrank and Ibrahim (1995, pl. 9, fig. 7) in having a large archeopyle and pronounced reticulum. It differs from *B. reticulata* (Davey, 1969) Davey, 1979 in being much larger, and in having a more pronounced and irregular reticulum, and a larger archeopyle with a strongly angular margin. As described by Davey (1969), *B. reticulata* has a very delicate surface reticulation, which can only be observed under high magnification. *Batiacasphaera cassiculus* Wilson, 1988 differs from *B. rifensis* in being larger and in having a thicker autophragm and a much more variable reticulum with more pronounced and thicker muri; *B. imperfecta*

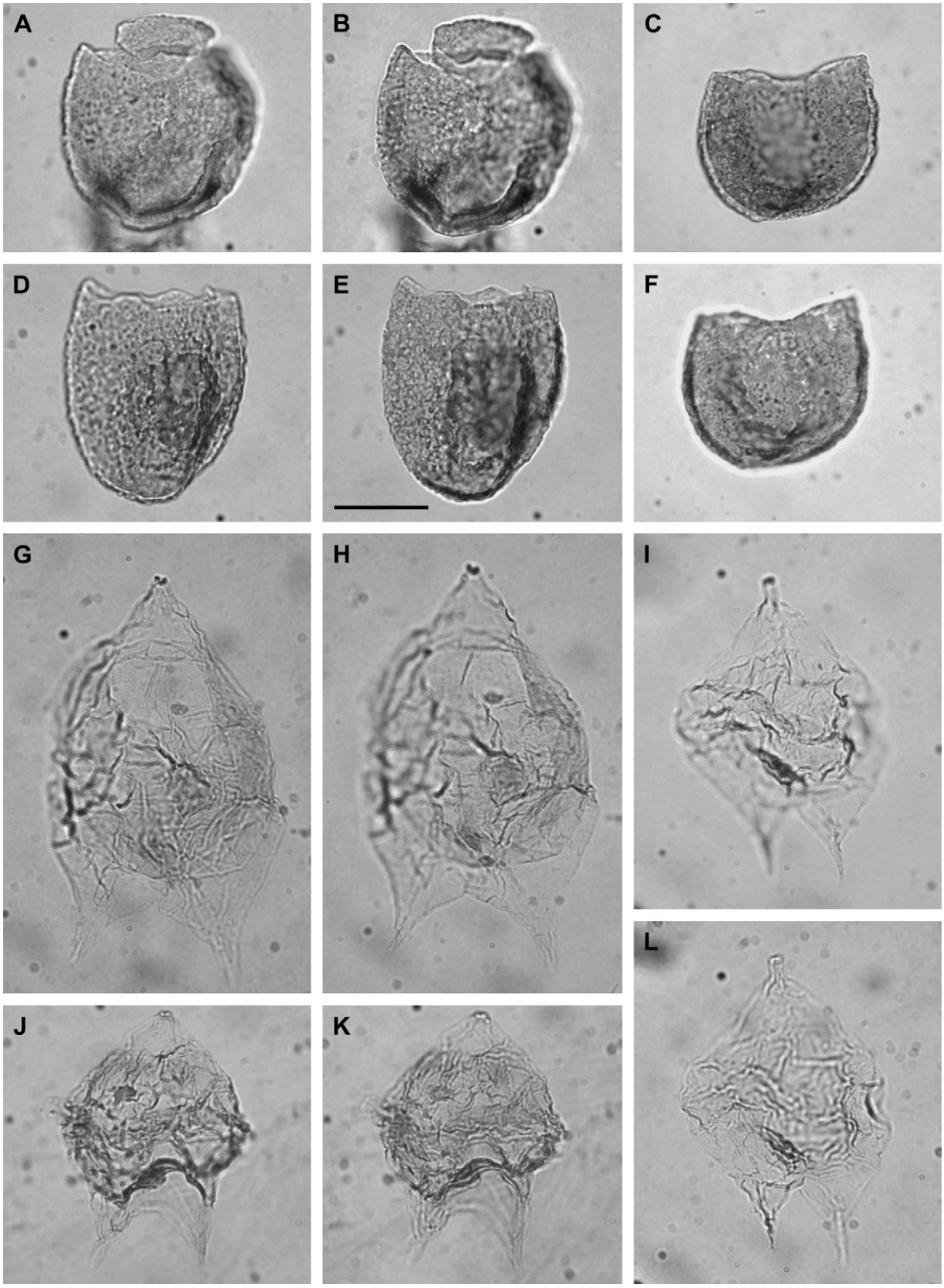


Fig. 9. A–F, *Batiacasphaera rifensis* sp. nov. from the Cretaceous/Palaeogene boundary section of Ouled Haddou. A, B, holotype, ventral view, sample OH 12, slide 1, England Finder reference Y54/3. A, ventral surface; B, dorsal surface. C, F, ventral view, slightly differing focuses on ventral surface, OH 14, slide 1, K38/2. D, E, paratype, ventral view, ventral surface, slightly differing focuses on operculum and wall structure, OH 14, slide 1, O34/4. G, H, *Cerodinium mediterraneum* sp. nov., holotype, dorsal view, OH 12, slide 1, U33. G, dorsal surface; H, ventral surface. I, L, paratype, ventral view, OH 12, slide 1, Y31/4. I, dorsal surface; L, ventral surface. J, K, ventral view, OH 12, slide 1, O26/1; J, dorsal surface; K, ventral surface. Scale bar in B represents 20 μm for all specimens illustrated.

Stover and Helby, 1987 has an imperfect reticulum; *B. kekerengensis* Schiøler and Wilson, 1998 is larger and has a regular reticulum.

Stratigraphic occurrence. Samples OH 7–19, planktonic foraminiferal *Guembelitria cretacea* and *Parvularugoglobigerina eugubina* zones; lower Danian, Ouled Haddou section;?-Campanian–Maastrichtian of northwest Egypt (Schrank and Ibrahim, 1995); Maastrichtian of southern Patagonia, Argentina (Marenssi et al., 2004).

Order: Peridiniales Haeckel, 1894
Suborder: Peridiniineae (Autonym)
Family: Peridiniaceae Ehrenberg, 1831
Subfamily: Deflandreoideae Bujak and Davies, 1983
Genus *Cerodinium* Vozzhennikova, 1963, emend. Lentin and Williams, 1987

Type species. *Cerodinium sibiricum* Vozzhennikova, 1963, emend. Lentin and Williams, 1987.

Cerodinium mediterraneum sp. nov.
Fig. 9G–L

1995 *Senegalinium* sp., Kurita and McIntyre, text-figs 3, 4, p. 133, pl. 2, figs 7, 8.
1998 *Cerodinium* sp. A, Oboh-Ikuenobe et al., fig. 2, pl. 4, figs 2, 3.

Derivation of name. After the Mediterranean Sea.

Types. Holotype, sample OH 12, slide 1, EF U33 (Fig. 9G, H). Paratype, sample OH 12, slide 1, EF Y31/4 (Fig. 9I, L).

Type locality and stratigraphic horizon. Ouled Haddou section, north of Taza, northern Morocco, clayey marls 35 cm above the K/T boundary, lower Danian.

Diagnosis. Small ovoid, convex-sided, thin-walled *Cerodinium* with narrow pericoels separating horns from endocyst. Cingulum indicated by transverse ledges or folds. Sulcus expressed by a longitudinal depression and folds. Intercalary archeopyle of standard hexa type, expressed by loss of intercalary plate 2a.

Description. Peridinioid, proximate, bicavate to circumcavate, dorsoventrally compressed cyst, which consists of a thin (<0.5 μm), smooth endophragm and a thinner, smooth, finely folded periphram. Endocyst generally oval, only slightly smaller than pericyst. Apical horn conical with a blunt tip, broadening proximally to merge with epipericyst. Antapical horns elongate, more or less equal in size, broad-based and tapering distally to pointed tips. They are separated from endocyst by a hypo-pericoel. Slightly laevorotatory cingulum is indicated by transverse ledges or folds. Sulcus is indicated by a slight longitudinal depression of periphragm, often delimited between two longitudinal folds, which are sometimes extended to distal ends of antapical horns (Fig. 9H). When developed, intercalary archeopyle is of type 2a (Fig. 9G) and located on mid-dorsal line. Operculum is free.

Dimensions (in μm). Holotype, paratype and range for 13 specimens measured: overall length 86, 65, 57(69)86; length excluding horns 55, 35, 35(41)55; overall width 50, 42, 40(45)50.

Discussion. *Cerodinium mediterraneum* sp. nov. closely resembles *Senegalinium* sp. of Kurita and McIntyre (1995, text-figs 3, 4, p. 133, pl. 2, figs 7, 8) and *Cerodinium* sp. A of Oboh-Ikuenobe et al. (1998, fig. 2, pl. 4, figs 2, 3). *Alterbidinium*? *bicellula* (Islam, 1983) Lentin and Williams, 1985 is similar in shape and also bicavate, but differs in being smaller and in having relatively short and unequal antapical horns. *Cerodinium depressum* (Morgenroth, 1966) Lentin and Williams, 1987 is smaller, has a longitudinally striated periphragm, and much more developed pericoels in comparison to the size of the cyst; *C. bolniense* (Riegel, 1974) Lentin and Williams, 1989 is larger, has a pentagonal outline, a striated periphragm, and an endocyst that completely fills the pericyst. However, the specimen included in *C. boloniense* and interpreted by Riegel (1974, pl. 1, fig. 6) as an unusually small form with convex sides resembles *C. mediterraneum*.

Stratigraphic occurrence. Samples OH 6–18, planktonic foraminiferal *Guembelitria cretacea* and *Parvularugoglobigerina eugubina* zones (lower Danian), Ouled Haddou section; Paleocene of southwest Manitoba, Canada (Kurita and McIntyre, 1995) and lower Campanian–upper Maastrichtian of the Côte d'voire-Ghana transform margin (Oboh-Ikuenobe et al., 1998).

Family: Congruentidiaceae Schiller, 1935
Subfamily: Congruentidioideae (autonym)
Genus *Lejeunecysta* Artzner and Dörhöfer, 1978, emend Kjellström, 1972

Type species. *Lejeunecysta hyalina* (Gerlach, 1961) Artzner and Dörhöfer, 1978.

Lejeunecysta izerzenensis sp. nov.
Fig. 10

1967 *Lejeunecysta* sp., Drugg, p. 14, pl. 1, fig. 16.
?1975 *Lejeunecysta* sp., Jain et al., p. 12, pl. 6, fig. 66.
1995 *Lejeunecysta* sp. (cf. *Phelodinium tricuspis*), Schrank and Ibrahim, text-fig. 5, pl. 9, fig. 15.

Derivation of name. After Bou Izerzene Mountain in northern Morocco, where the type locality Ouled Haddou is situated.

Holotype. Sample OH 1, slide 1, EF L27 (Fig. 10A, B).

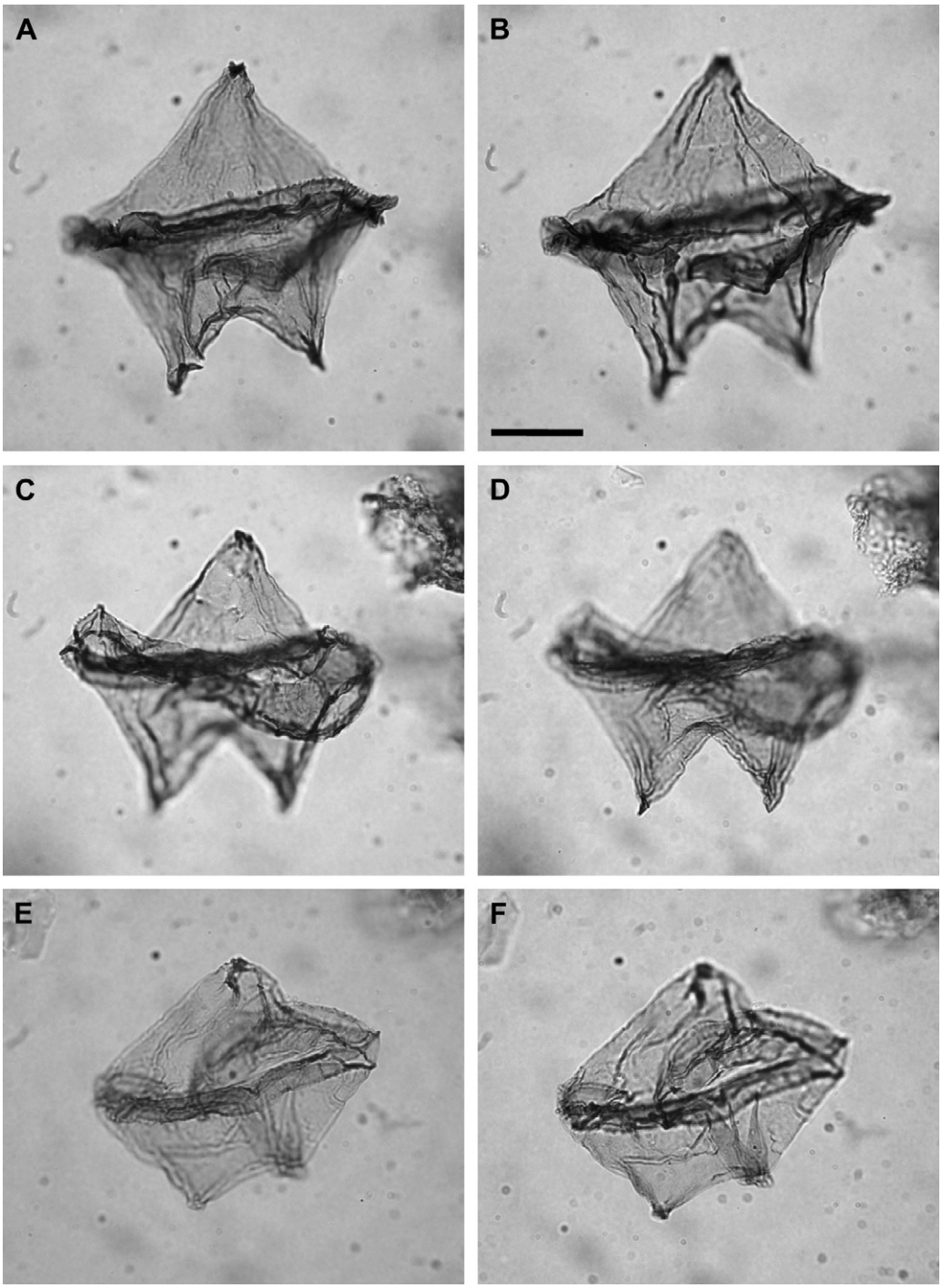


Fig. 10. *Lejeunecysta izerzenensis* sp. nov. from the Cretaceous/Palaeogene boundary section of Ouled Haddou. A, B, holotype, dorsal view, sample OH 1, slide 1, England Finder reference L27. A, dorsal surface, high focus on cingular denticulate septa; B, dorsal surface, high focus on archeopyle. C, D, dorsal view, OH 5, slide 1, X39. C, high focus on archeopyle and apical horn; D, high focus on cingular denticulate septa and antapical horns. E, F, dorsal view, OH 1, slide 1, S30/2; E, dorsal surface; F, ventral surface. Scale bar in B represents 20 μm for all specimens illustrated.

Type locality and stratigraphic horizon. Ouled Haddou section, north of Taza, northern Morocco; marls 1 m below the K/T boundary, upper Maastrichtian.

Diagnosis. Pentagonal, laevigate to chagrinate, thin-walled *Lejeunecysta* with a truncate to slightly bifid apical horn, two long, conical, pointed antapical horns, a prominent antapical depression, and a laevorotatory cingulum marked by two transverse denticulate septa. When visible, the archeopyle is intercalary, type 2a.

Description. Proximate, pentagonal, dorsoventrally compressed peridinioid autocyst. Cyst wall c. 0.5 μm thick, laevigate to chagrinate with a few longitudinal folds. Epicyst

conical. Hypocyst and epicyst are of approximately equal length and have slightly concave sides. Apical and antapical horns often distally solid. Cingulum indicated by two denticulate septa c. 4 μm high (Fig. 10A). Sulcal area indicated by two longitudinal folds. Antapical depression, situated between the two long antapical horns, is prominent.

Dimensions (in μm). Holotype and range for 10 specimens measured: length 70, 40(63)80; width 74, 45(65)80.

Discussion. *Lejeunecysta izerzenensis* sp. nov. is similar to *Lejeunecysta* sp. of Drugg (1967, p. 14, pl. 1, fig. 16) and *L.* sp. cf. *Phelodinium tricuspis* of Schrank and Ibrahim (1995, text-fig. 5, pl. 9, fig. 15), especially with respect to the prominent antapical depression and the denticulate cingular septa. *Lejeunecysta* sp. of Jain et al. (1975, p. 12, pl. 6, fig. 66) is conspecific with the new species. *Lejeunecysta cinctoria* (Bujak in Bujak et al., 1980) Lentin and Williams, 1981 and *L. lata* Biffi and Grignani, 1983 also have denticulate septa indicating the cingulum, but they differ from *L. izerzenensis* in having a shallow rather than a prominent antapical depression. *Lejeunecysta izerzenensis* generally has the same overall morphology as *Phelodinium magnificum* (Stanley, 1965) Stover and Evitt, 1978, but differs in being acavate; *L. decorinassa* Srivastava, 1995 is larger and possesses a cingulum expressed by folds rather than denticulate septa.

Stratigraphic occurrence. Samples OH 1–19, planktonic foraminiferal *Abpthomphalus mayaroensis* Zone (Upper Maastrichtian), *Guembelitria cretacea* and *Parvularugoglobigerina eugubina* zones (lower Danian), Ouled Haddou section; Maastrichtian–Danian of Escarpado Canyon, California, USA (Drugg, 1967) and Lower Assam, India (Jain et al., 1975); Maastrichtian of northwest Egypt (Schrank and Ibrahim, 1995); Danian of Senegal (Jan du Chêne, 1988).

5. Conclusions

Rich and well-preserved palynological material from the marly deposits of the Ouled Haddou section in the south-eastern Rif Corridor, northern Morocco, contains eight previously undescribed species of organic-walled dinoflagellate cysts, five of which are gonyaulacoid (*Damassadinium spinosum*, *Eisenackia msounensis*, *Impagidinium maghribensis*, *Pterodinium cretaceum* and *Ynezidinium tazaensis*), two are peridinioid (*Cerodinium mediterraneum* and *Lejeunecysta izerzenensis*) and one is of an unknown tabulation type (*Batiacasphaera rifensis*). *Damassadinium spinosum*, *E. msounensis*, *I. maghribensis* and *Y. tazaensis* are entirely new; the other taxa have been figured previously by authors but not formally described.

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