AMEGHINIANA (Rev. Asoc. Paleontol. Argent.) - 43 (3): 567-584. Buenos Aires, 30-9-2006 ISSN 0002-7014

Palynology and paleoenvironmental significance of the Tunal Formation (Danian) at its type locality, El Chorro creek (Salta, Argentina)

Wolfgang VOLKHEIMER[1], Martín G. NOVARA[2], Paula L. NARVÁEZ[1,2] and Rosa A. MARQUILLAS[2]

Abstract. The palynologic investigation of samples from the Tunal Formation at El Chorro creek (Salta, Argentina) resulted in the recovery of terrestrial assemblages of pollen and spores associated with freshwater algae (*Pediastrum* spp. and *Scenedesmus* sp.). Of the 43 species of sporomorphs identified for the Tunal Formation so far, 28 species are cited here for the first time. The spores and pollen indicate a Danian age at the type locality. Sedimentary proxidata including abundant evaporites suggest intervals of at least seasonal arid environmental conditions. In contrast, the palynologic assemblages recovered from the organic rich dark shales indicate the presence of swampy areas and forests surrounding them. The dominance of *Verrustephanoporites simplex* Leidelmeyer (corresponding to the modern *Phyllostylon*, Ulmaceae) indicates abundant seasonal rainfalls, warm humid conditions and subtropical climate.

Resumen. PALINOLOGÍA E IMPORTANCIA PALEOAMBIENTAL DE LA FORMACIÓN TUNAL (DANIANO) EN SU LOCALIDAD TIPO, QUEBRADA EL CHORRO (SALTA, ARGENTINA). La investigación palinológica de muestras extraídas de la Formación Tunal en la quebrada El Chorro (Salta, Argentina) resultó en la recuperación de una asociación de polen y esporas, juntamente con algas de agua dulce (*Pediastrum* spp. y *Scenedesmus* sp.). De las 43 especies de esporomorfos identificadas hasta el momento para la Formación Tunal, 28 se citan aquí por primera vez. Las esporas y polen indican edad Daniana en la localidad tipo. Los proxidata sedimentarios incluyendo abundantes evaporitas, sugieren intervalos al menos estacionales de condiciones ambientales áridas. Por otro lado, las asociaciones palinológicas recuperadas de las pelitas oscuras ricas en materia orgánica indican la presencia de áreas anegadas y selvas en sus alrededores. En las últimas, el predominio de *Verrustephanoporites simplex* Leidelmeyer (que se corresponde con el actual *Phyllostylon*, Ulmaceae) indica abundantes lluvias estacionales, condiciones cálido-húmedas y clima subtropical.

Key words. Palynology. Paleoenvironment. Paleogene. Danian. Tunal Formation. Salta Group Basin. Argentina.

Palabras clave. Palinología. Paleoambiente. Paleógeno. Daniano. Formación Tunal. Cuenca del Grupo Salta. Argentina.

Introduction

The Tunal Formation (Amengual, 1976) of the Alemanía Subbasin is part of the Salta Group (Neocomian-Paleogene, Turner, 1959) in northwestern Argentina (figures 1 and 2). The numerous outcrops of the Tunal Formation occupy the same stratigraphic position as the Olmedo Formation, which was defined by Moreno (1970) in the subsurface of the Lomas de Olmedo Subbasin (figure 3). The former situation was noted by Lencinas and Salfity (1973), while the beds corresponding to the Tunal Formation were informally known as the "Faja Verde Basal" of the Mealla Formation. The Olmedo/Tunal formations integrate the Balbuena Subgroup (figure 2). They overlie the Yacoraite Formation and are covered by the Mealla Formation (Moreno, 1970). In the northeastern extreme of the sedimentary basin (Lomas de Olmedo Subbasin), the Olmedo Formation overlies the Yacoraite Formation with a normal contact. Nevertheless, in most of the basin and specially in the southern part (Alemanía Subbasin), the Tunal Formation is cropping out and not the typical Olmedo Formation. In the western parts of the basin and in the Tres Cruces Subbasin (figure 3), over the gray limestones of the Yacoraite Formation lie the mudstones and red sandstones of the Mealla Formation, with a normal contact. Therefore, at those places, the green pelites of the Tunal Formation or the black pelites of the Olmedo Formation are not found (Salfity and Marquillas, 1981; Marquillas and Salfity, 1994).

[1]Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET) and Departamento de Geología y Paleontología del IANIGLA-CRICYT/CONICET, Av. Adrián Ruiz Leal s/n, Parque Gral. San Martín, 5500 Mendoza, Argentina.
volkheim@lab.cricyt.edu.ar, pnarvaez@lab.cricyt.edu.ar
[2]Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET) and Cátedra de Geología Histórica, Facultad de Ciencias Naturales, Universidad Nacional de Salta, Buenos Aires 177, 4400 Salta, Argentina.
marnov@unsa.edu.ar, ramarq@unsa.edu.ar

 AMGHB2-0002-7014/06$00.00+.50

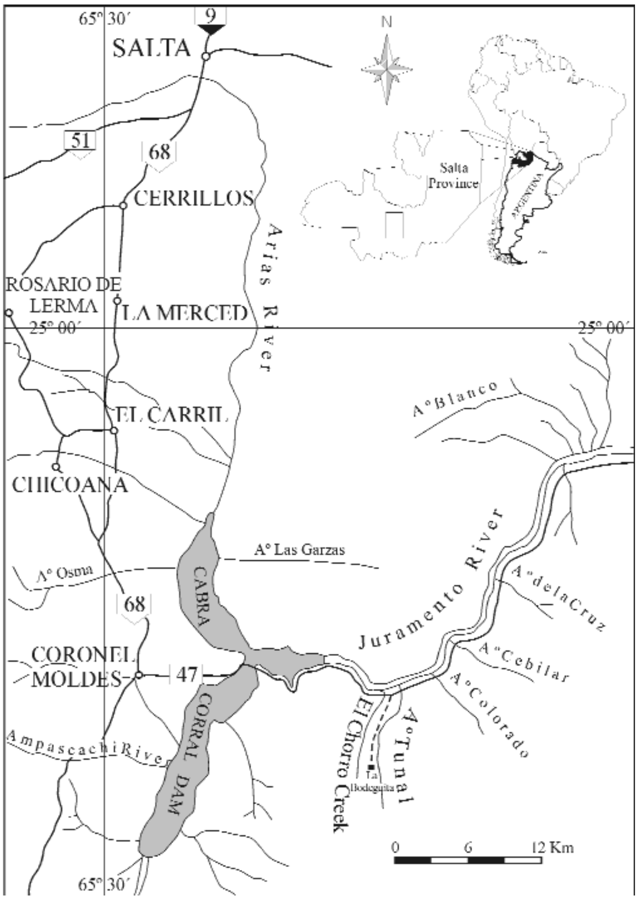


Figure 1. Location map / *mapa de ubicación*.

Chronostratigraphy			Lithostratigraphy		
Epoch		Stage	Formation	Subgroup	Group
Eocene		Bartonian	Lumbrera	Santa Bárbara (Late post-rift)	SALTA
Eocene		Lutetian	Lumbrera	Santa Bárbara (Late post-rift)	
Eocene		Ypresian	Maíz Gordo	Santa Bárbara (Late post-rift)	
Paleocene	Late	Thanetian	Maíz Gordo	Santa Bárbara (Late post-rift)	
Paleocene	Late	Selandian	Mealla	Santa Bárbara (Late post-rift)	
Paleocene	Early	Danian	Tunal / Olmedo	Balbuena (Early post-rift)	
Late Cretaceous		Maastrichtian	Yacoraite	Balbuena (Early post-rift)	
Late Cretaceous		Maastrichtian	Lecho	Balbuena (Early post-rift)	
Late Cretaceous		Campanian	Los Blanquitos	Pirgua (syn rift)	

Figure 2. Stratigraphic section of the Salta Group, Alemanía Subbasin (Adapted from Salfity and Marquillas, 1981, 1994; Marquillas *et al.*, 2005) / *cuadro estratigráfico del Grupo Salta, subcuenca de Alemanía (adaptado de Salfity y Marquillas, 1981, 1994; Marquillas* et al., *2005).*

The objective of this paper is to provide geologic, sedimentologic, palynologic and paleoenvironmental information about the Tunal Formation at its type locality. This multidisciplinary scope illustrates environmental fluctuations that would not be apparent using the sedimentologic or the palynologic evidence alone. In addition, the new results are compared with previous studies concerning other outcrops of the Formation.

Geologic setting

In the area of the Juramento river (figure 1), over the Precambrian basement, the Salta Group (Neocomian-Paleogene) is represented by the Los Blanquitos, Lecho, Yacoraite, Tunal, Mealla, Maíz Gordo and Lumbrera formations (figure 2). The outcrops of parts of the Los Blanquitos Formation (88 m thick) correspond to subarcosic reddish-brown sandstones and white fine-grained sandstones of a fluvial, meandering system (Galli and Marquillas, 1990). The Lecho Formation is of 115-151 m thickness and is composed of arcosic sandstones and wacke at the base and subarcosic sandstones at the top. The environment is fluvial, of anastomosing type, and at some places the deposits are definitely eolian (Galli and Marquillas, 1990). The Yacoraite Formation is composed of coarse oolitic grainstones and calcareous sandstones in the lower part; fine grained oolitic grainstones, calcareous sandstones, calcareous mudstones and some laminated pelites in the middle part, while the upper part is composed of green, black and gray shales, laminated calcareous mudstones, oolitic and intraclastic grainstones, and stromatolitic boundstones. The thickness of the Yacoraite Formation in this area is 200 m and corresponds to a shallow marine environment (Marquillas, 1986; Marquillas *et al.*, 2005).

The Tunal Formation rests, with a normal contact, on the stratigraphically uppermost stromatolitic boundstones of the Yacoraite Formation (Novara, 2003). It is composed of greenish-gray shales arranged in beds of 1 m thickness on average, interbedded with yellowish micritic limestones and very fine-grained sandstones, with wavy lamination and symmetric ripple marks, often containing gypsum. There are also nodules and continuous levels of gypsum, and scarse levels of massive red mudstones (figure 4).

Above the Tunal Formation rests the Mealla Formation, of red color and of approximately 150 m

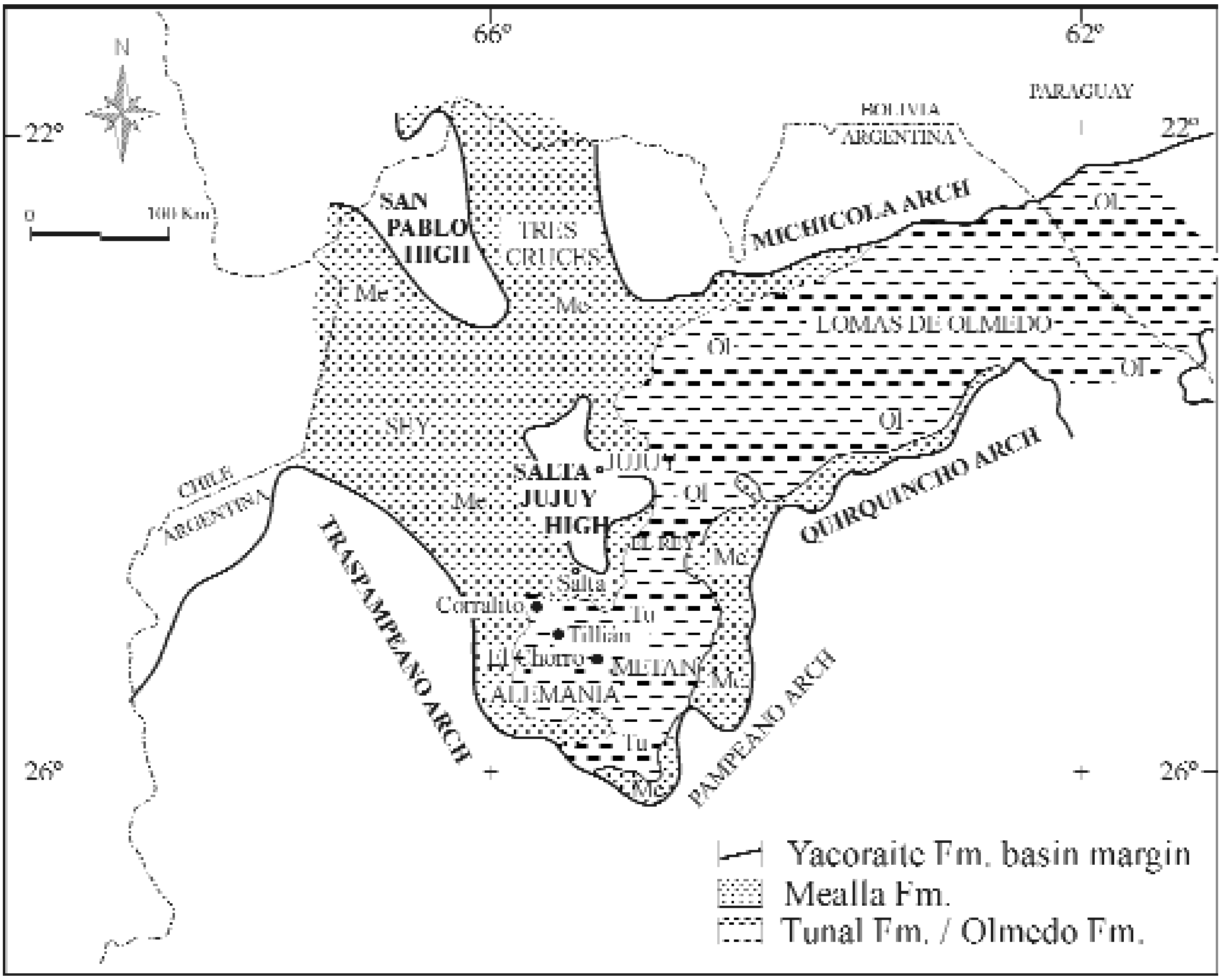


Figure 3. Stratigraphic units overlying the Yacoraite Formation (adapted from Salfity and Marquillas, 1994) / *unidades estratigráficas sobrepuestas a la Formación Yacoraite (adaptado de Salfity y Marquillas, 1994).*

thickness. It is composed of red sandy mudstones, fine to middle- grained sandstones capped by some green shales (Aguilera, 1981). It represents the deposit of a fluvial, mainly meandering environment which culminates with a transition to the lacustrine environment of the Maíz Gordo Formation (Cazau *et al.*, 1975), which is 158 m thick and composed of mudstones and green, gray and reddish-brown claystones, with intercalations of shales, stromatolitic boundstones and calcareous sandstones (Aguilera, 1981). It is a shallow lacustrine deposit with fluctuations of the water level (del Papa, 1994). The uppermost Formation of the Salta Group is the Lumbrera Formation, comprised of claystones, siltstones and some sandstones of brick red color and 405 m thickness. In the middle part it contains 25 m of greenish-yellowish-brown pelites. Overlying the Salta Group is the low-angle unconformable contact of the Orán Group (Neogene).

The studied samples are from the type locality of the Tunal Formation (Amengual in Turner *et al.*, 1979), which is the El Chorro creek, a right tributary of the Juramento river at the Cabra Corral locality (figure 1). It is similar to other outcrops of the same subbasin, characterized by greenish-gray and reddish-brown pelites, interbedded with fine-grained sandstones, micritic limestones, fine-grained sandstones containing gypsum, and by gypsum. There are intercalations of red-beds between 24 and 33 m and between 60 and 65 m above the base. The prevailing color of the section is greenish-gray to yellowish-green. The total thickness is 71 m, with 58 % shales. (Novara, 2003; Novara and Marquillas, 2004).

Previous palynologic studies

Previous palynologic data from the Tunal

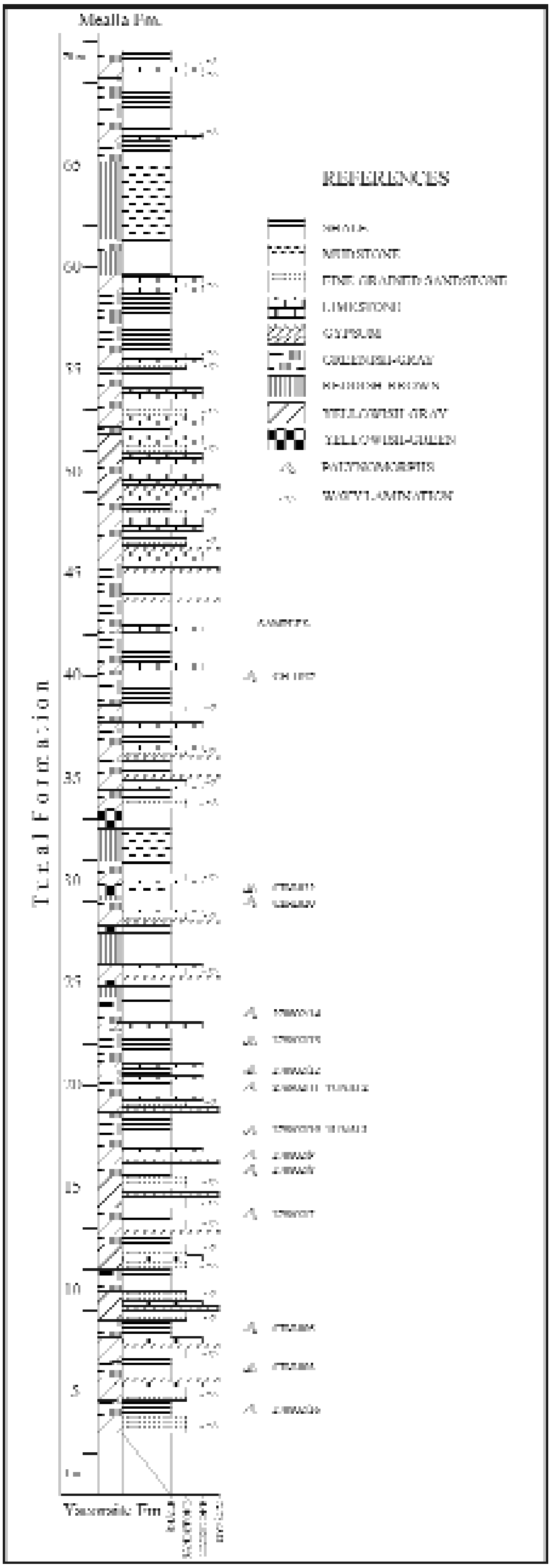


Figure 4. Columnar section of the Tunal Formation at El Chorro creek / *columna estratigráfica de la Formación Tunal en la quebrada El Chorro.*

Formation are those from the Corralito and Tilián sections, southern Salta province (figure 3). The species recognised in both sections (Quattrocchio and Volkheimer, 1988; Quattrocchio *et al.*, 1988) are represented on figures 5 and 6.

Moroni (1982, 1984) reported the presence of *Mtchedlishvilia saltenia* and *Pediastrum* sp. in samples of the Olmedo Formation, the equivalent of the Tunal Formation, from several wells of the Lomas de Olmedo Subbasin (figure 3). They are part of a palynologic assemblage assigned to the Paleocene (the wells are: YPF. St. LO. x-3, YPF. St. MDT. x-3, YPF. St. Ev. x-2, YPF. St. PGu. x-2, YPF. St. Cha. x-1 e YPF. St. SRo. x-1).

Quattrocchio *et al.* (2000) defined the *Mtchedlishvilia saltenia* palynozone, of Danian age, in deposits of the Tunal Formation at the Tilián locality. The palynozone is characterized by *Mtchedlishvilia saltenia* Moroni, associated with *Pandaniidites texus* Elsik, *Gemmatricolpites subsphaericus* Archangelsky and *Clavatricolpites* cf. *gracilis* González Guzmán.

Materials and methods

The fieldwork included the geologic mapping and stratigraphic-sedimentologic analysis of the section of the Tunal Formation outcropping at El Chorro creek (figures 1 and 4), with a complete sedimentologic and palynologic sampling. There were obtained 116 samples of which 26 samples were processed for palynology. Of these, 16 yielded palynomorphs.

The physical and chemical extraction of the palynologic samples was done by A. Moschetti in the Paleopalynologic Laboratory of IANIGLA (Instituto Argentino de Nivología, Glaciología y Ciencias Ambientales, Mendoza), using standard palynologic processing techniques (Volkheimer and Melendi, 1976) which involve treatment with hydrochloric and hydrofluoric acids. The palynologic slides are stored at the Paleopalynology Collection of the Department of Geology and Paleontology at IANIGLA as numbers of catalogue: 7448, 7449, 7777 through 7784, 7786, 7788, 7789, 7801, 7802, 7805 MPLP (Mendoza-Paleopalinoteca-Laboratorio-Paleopalinología).

The material was studied using a Leitz Dialux 20 microscope. Coordinates of specimens are denoted by an England Finder reference. The palynologic analysis included the systematics and comparison of the palynomorphs with modern taxa.

Statistical counts: Only one of the palynologic samples (nº 7449, at 20 m above the base of the Formation) contained enough specimens (>400) to allow calculations of statistical reliability. It was impossible to obtain counts large enough to achieve

TAXA	FAMILY	CLASS	SUB DIVISION	DIVISION	KINGDOM
Pediastrum spp. (Fig. 9.D,G,H)	Hydrodictyaceae (Chlorococcales)	Chlorophyceae		Chlorophyta	Protoctista
Scenedesmus sp. (Fig. 9.E)	Scenedesmaceae				
Zlivisporis sp. 1 (Fig. 7.C)		Hepaticae		Bryophyta	Plantae (Embryophyta)
Zlivisporis sp. 2 (Fig. 7.A,B)					
Retitriletes austroclavatidites (Cookson) Döring *et al.* (Fig. 7.D)	Lycopodiaceae (*Lycopodium*)	Lycopodiopsida		Pteridophyta	
cf. *Verrucosisporites* sp. (Fig. 8.E)	Lycopodiaceae				
Apiculatisporis sp. cf. *A. charahuillaensis* Volkheimer (Fig. 8.A,B)		Filicopsida			
Cingulatisporites sp. (Fig. 7.E)					
Deltoidospora minor (Couper) Pocock (Fig. 8.D)	Cyatheaceae				
Deltoidospora neddeni Pflug					
Gabonisporis vigourouxii Boltenhagen (Fig. 7.K)					
Gleicheniidites cf. *argentinus* Volkheimer (Fig. 7.F)	Gleicheniaceae				
Polypodiaceoisporites cf. *retirugatus* Muller (Fig. 7.H)	Pteridaceae (*Pteris*?)				
Rugulatisporites sp.					
Cingulate spore *indet.* 1 (Fig. 7.G)					
Cingulate spore *indet.* 2 (Fig. 8.C)					
Araucariacites australis Cookson (Fig. 9.F)	Araucariaceae	Coniferophyta	Gymnospermae	Spermatophyta	
Araucariacites fissus Reiser and Williams (Fig. 9.C)					
Cyclusphaera cf. *psilata* Volkheimer and Sepúlveda (Fig. 9.B)					
Podocarpidites marwickii Couper	Podocarpaceae				
Rugumonocolpites sp. A (Fig. 7.I,J)					
Ephedripites cf. *E.* sp. 1 Frederiksen *et al.* Quattrocchio and Volkheimer	Ephedraceae	Gnetophyta			
Ephedripites sp. (Fig. 9.A)					
Ailanthipites sp. Quattrocchio and Volkheimer	Anacardiaceae	Dicotyledoneae	Angiospermae		
Ailanthipites sp. A (Fig. 10.K)					
Clavatricolpites cf. *gracilis* González Guzmán					
Corsinipollenites menendezii Quattrocchio (Fig. 10.D)	Oenotheraceae (*Jussiaea*)				
Gemmatricolpites subsphaericus Archangelsky (Fig. 10.H)	Aquifoliaceae				
Myriophyllumpollenites sp. 1 Quattrocchio and Volkheimer	Haloragaceae				
Myriophyllumpollenites sp. 2 Quattrocchio and Volkheimer					
Retitricolporites cf. *chubutensis* Archangelsky (Fig. 10.L)					
Retitricolporites sp. A Quattrocchio and Volkheimer					
Rhoipites sp. A Quattrocchio and Volkheimer					
Rhoipites sp. B Quattrocchio and Volkheimer (Fig. 10.M)					
Rhoipites sp. cf. *R. minusculus* Archangelsky Quattrocchio and Volkheimer	Loganiaceae				
Rousea patagonica Archangelsky (Fig. 10.F)	Salicaceae ?				
Tricolpites reticulatus Cookson (Fig. 10.G)	Haloragaceae (*Gunnera*)				
Tricolpites sp. A (Fig. 10.E)					
Tricolpites vulgaris Pierce (Fig. 10.I)	Hamamelidaceae (cf. *Hamamelis*)				
Verrustephanoporites simplex Leidelmeyer (Fig. 10.J,N)	Ulmaceae (*Phyllostylon*)				
Pandaniidites texus Elsik (10.C)	Pandanaceae	Monocotyledoneae			
Spinizonocolpites sp. (Fig. 10.A,B)	Palmae (*Nypa*)				
Mtchedlishvilia saltenia Moroni	Incertae sedis				

Figure 5. Specific and suprageneric assignations for the taxa identified in the Tunal Formation (Corralito, Tilián and El Chorro localities). / *asignaciones específicas y supragenéricas para los taxones identificados en la Formación Tunal (localidades de Corralito, Tilián y El Chorro).*

meaningful data for uncommon forms from the other stratigraphic levels; hence we have limited the statistical study to percentages of suprageneric groups: Green algae, Angiospermous pollen (without Ulmaceae), Ulmacean pollen, Gymnospermous pollen and spores of Bryophytes and Pteridophytes.

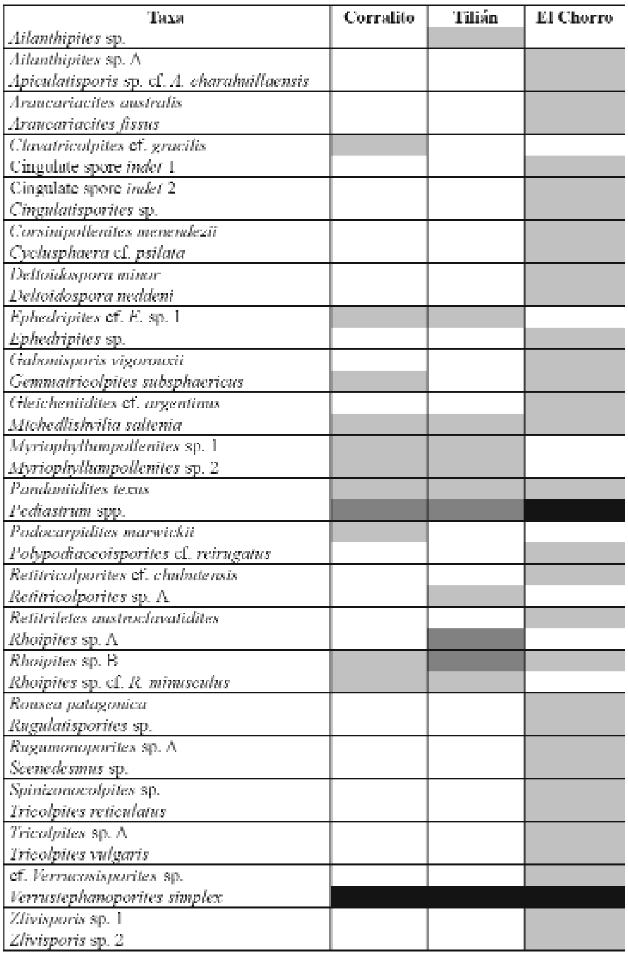


Figure 6. Comparison of the relative abundances of sporomorphs in three localities of the Tunal Formation (Corralito, Tilián and El Chorro). Data from Tilián and Corralito localities adapted from Quattrocchio and Volkheimer (1988) / *comparación de las abundancias relativas de esporomorfos en tres localidades de la Formación Tunal (Corralito, Tilián y El Chorro). Los datos de Tilián y Corralito adaptados de Quattrocchio y Volkheimer (1988).* ■ rare/*raro* (< 1-5%) ■ frequent/*frecuente* (5-30%) ■ abundant/*abundante* (> 30%).

Remarks on systematic palynology

The samples from the type locality of the Tunal Formation yielded high species diversity. Of the 43 species of sporomorphs identified from the Tunal Formation at present, 28 species are cited here for the first time. We describe in this paper only those taxa which have not been previously reported in the Tunal Formation. The taxa are listed in alphabetic order within three systematic groups: algae, trilete spores and pollen grains. A more detailed supra-generic systematic assignation for spores and pollen is given in figure 5.

Algae

Division CHLOROPHYTA Pascher 1914
Class CHLOROPHYCEAE Kützing 1843
Order CHLOROCOCCALES Marchand 1895
Family HYDRODICTYACEAE (Gray) Dumortier 1829

Genus ***Pediastrum*** Meyen 1829

Type species. *Pediastrum duplex* Meyen 1829

Pediastrum spp.
Figures 9.D, G, H

Size. 50-125 μm diameter.

Material. *Pediastrum* spp. are present in all samples.

Remarks. At least three different morphotypes of *Pediastrum* were recovered in this study which include clearly perforated specimens (*e.g.* figure 9.H) similar to *P. duplex* Meyen. Nevertheless, their preservation is not good enough to allow further taxonomic study.

Batten (1996, p. 193) mentions that all Cretaceous and Paleocene forms of *Pediastrum* are of the compact type and that the oldest perforated species are of Eocene age. In this study the perforated specimens are comparable to *P. duplex*, extending the range of perforated species to at least as old as Danian.

Botanical affinity. Hydrodictyaceae (Chlorococcales).

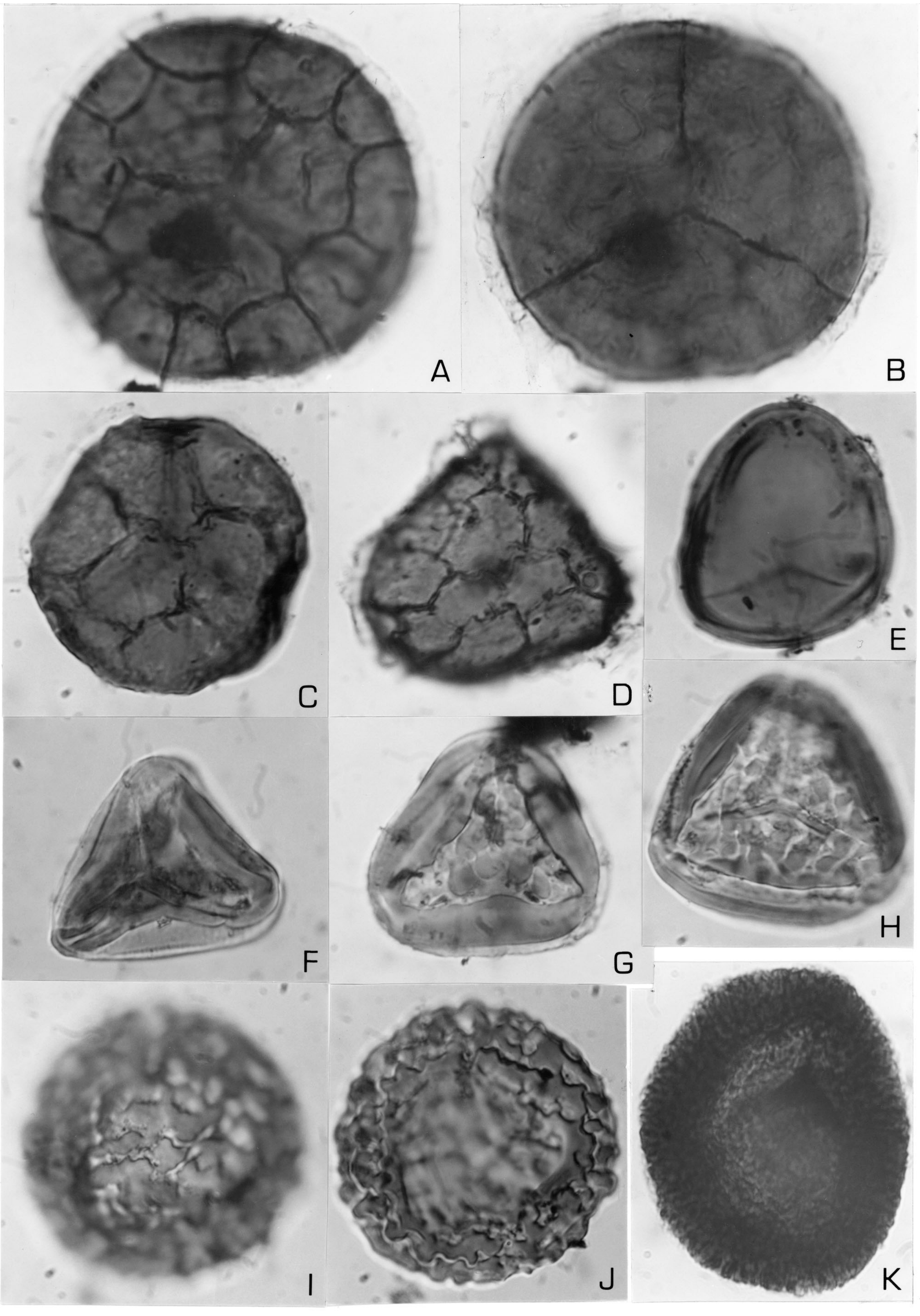
Family SCENEDESMACEAE Oltmanns 1904

Genus ***Scenedesmus*** Meyen 1829

Type species. *Scenedesmus* obtusus Meyen 1829

Scenedesmus sp.
Figure 9.E

Figure 7. A-B, ***Zlivisporis*** sp. 2. 7449O: H34/4 MPLP, 56 μm. **C,** ***Zlivisporis*** sp. 1. 7449Q: F48/1 MPLP, 42 μm. ***D, Retitriletes austroclavatidites*** (Cookson) Döring *et al.* 7449L: Q36 MPLP, 39 μm. **E,** ***Cingulatisporites*** sp. 7449R: X45/1 MPLP, 38 μm. **F,** ***Gleicheniidites*** cf. ***argentinus*** Volkheimer. 7449D: Z27/4 MPLP, 32 μm. **G,** Cingulate spore indet. 1. 7449F: J37/1 MPLP, 36 μm. **H,** ***Polypodiaceoisporites*** cf. ***retirugatus*** Muller 1968. 7449F: M24/2 MPLP, 38 μm. **I-J,** ***Rugumonoporites*** sp. 7449C: E39/4 MPLP, 44 μm. **K,** ***Gabonisporis*** sp. 7449E: D42/3 MPLP, 55 μm.


A
B
C
D
E
F
G
H
I
J
K

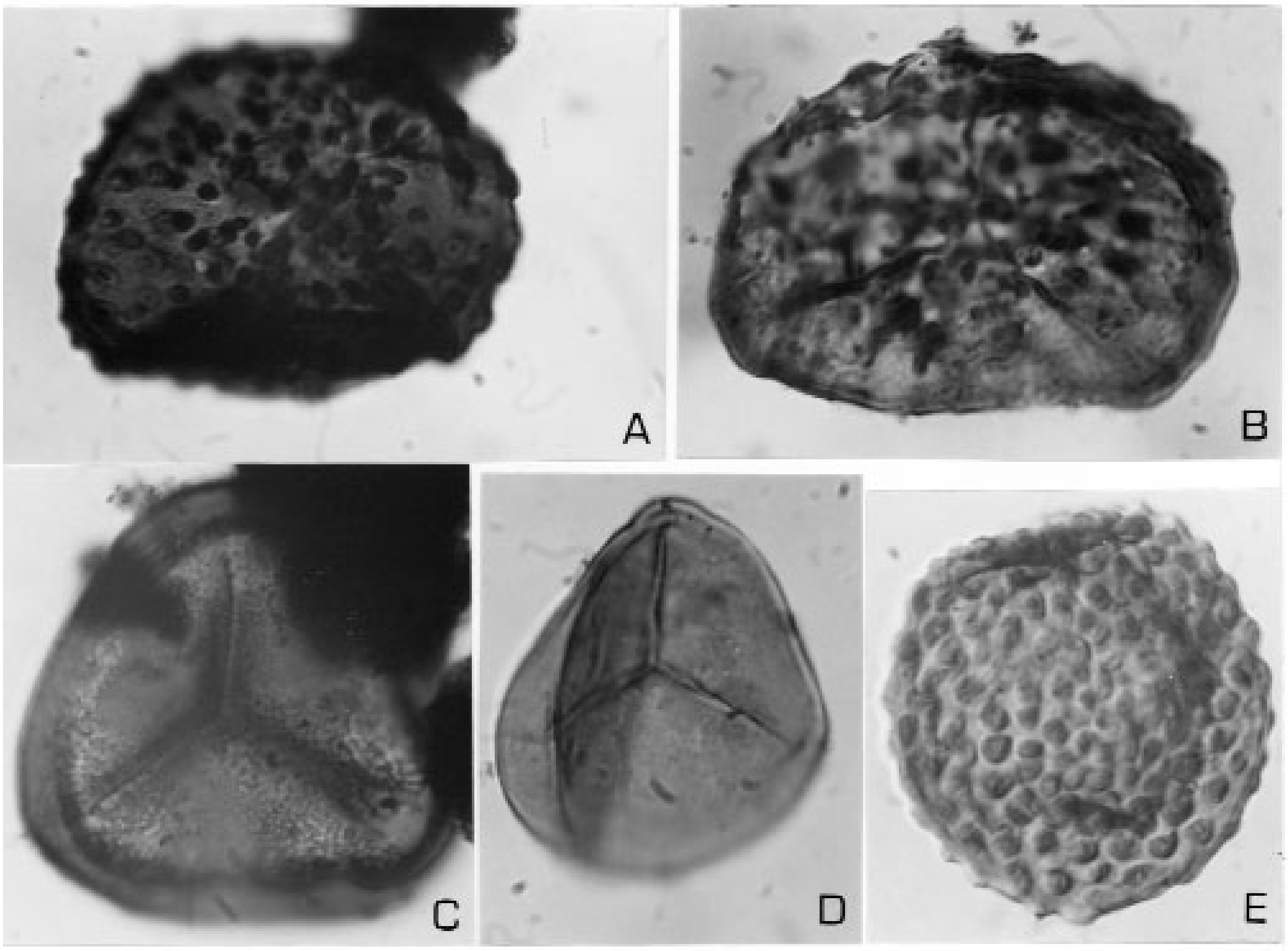


Figure 8. A, ***Apiculatisporites*** sp. cf. ***A. charahuillaensis*** Volkheimer. 7449Q: K33/1 MPLP, 50 µm. **B,** ***Apiculatisporites*** sp. cf. ***A. charahuillaensis*** Volkheimer. 7449L: P32/2 MPLP, 56 µm. **C,** Cingulate spore indet. 2. 7449E: J39/3 MPLP, 51 µm. **D,** ***Deltoidospora minor*** (Couper) Pocock. 7449Q: O29/3 MPLP, 36 µm. **E,** cf. ***Verrucosisporites*** sp. 7449O: X23/2 MPLP, 47 µm.

Description. Cenobium composed of approximately 24 cells, presented in linear orientation. The cells are more or less rectangular, occasionally rounded to rare crescent shaped cells.
Size. Total length of the cenobium: 102 µm. Mean length of cells: 4 µm. Mean width of cells: 5 µm (in perpendicular direction of the extension of the cenobium); (1 specimen).

Material. 7449F: M42/4 MPLP.

Stratigraphic distribution. Tunal Formation at the type locality, El Chorro creek.

Botanical affinity. Family Scenedesmaceae Oltmanns.

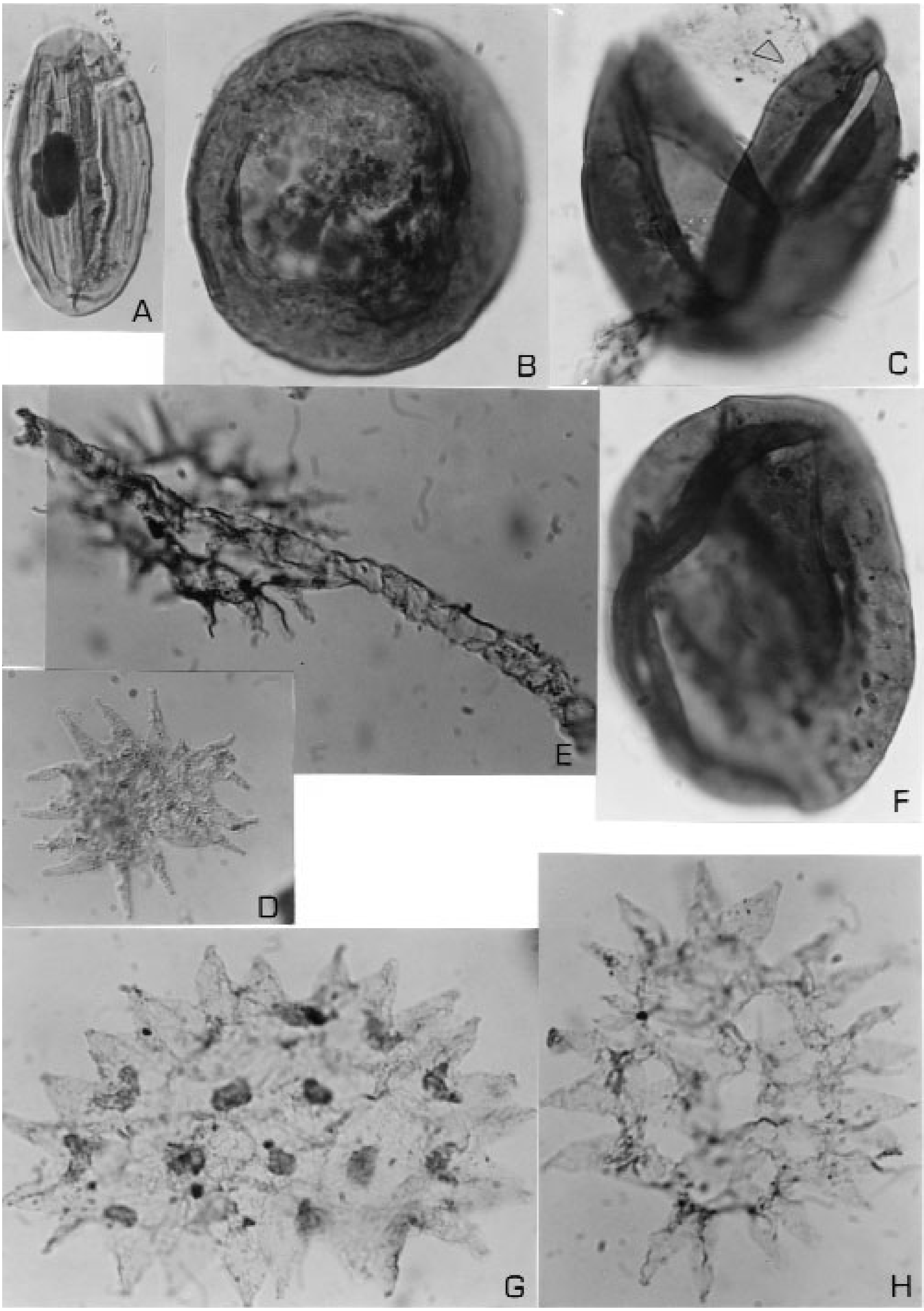
Trilete spores

Genus *Apiculatisporis* Potonié and Kremp 1956

Type species. *Apiculatisporis* (al. *Apiculatisporites*) *aculeatus* (Ibrahim) Potonié 1956.

Apiculatisporis sp. cf. *A. charahuillaensis* Volkheimer 1972 Figures 8.A,B

Figure 9. A, ***Ephedripites*** sp. 7448D: D34/4 MPLP, 44 µm. **B,** ***Cyclusphaera*** cf. ***psilata*** Volkheimer and Sepúlveda. 7449A: P28/2 MPLP, 54 µm. **C,** ***Araucariacites fissus*** Reiser and Williams. 7449D: Q23 MPLP, 59 µm. **D,** ***Pediastrum*** sp. 7449E: R43 MPLP, x 1200. **E,** ***Scenedesmus*** sp. 7449F: M42/4 MPLP, x 1200. **F,** ***Araucariacites australis*** Cookson. 7449D: L25 MPLP, 64 µm. **G,** ***Pediastrum*** sp. 7449Q: S30/2 MPLP, x 1200. **H,** ***Pediastrum*** sp. 7449O: H33 MPLP, x 1200. Note that the illustrated specimen is clearly perforate / *nótese que el ejemplar ilustrado está claramente perforado.*


A
B
C
D
E
F
G
H

Description. Trilete spores. Amb subcircular to subtriangular. Laesurae extend almost to the equator. Exine 1.5-3 µm. The distal hemisphere is sculptured with coni, verrucae and some interspersed baculae. The contact faces are very sparsely ornamented.
Size. 50-71 µm (4 specimens).

Material. 7449L: K34/2 MPLP; 7449L: P32/2 MPLP; 7449Q: H43/1 MPLP; 7449Q: K33/1 MPLP.

Remarks. The cf. refers to the size of these specimens which are larger than the original material of *A. charahuillaensis* (35-40 µm; Volkheimer, 1972).
Stratigraphic distribution. Tunal Formation at the type locality, El Chorro creek.

Genus ***Cingulatisporites*** Thomson in Thomson and Pflug 1953

Type species. *Cingulatisporites levispeciosus* Pflug in Thomson and Pflug 1953

Cingulatisporites sp.
Figure 7.E

Description. Trilete spore. Triangular to subcircular outline with convex sides and rounded angles. Exine laevigate (1 µm). Laesura almost reaching the cingulum. Cingulum 2.5-3 µm wide.
Size. 38 µm (1 specimen).

Material. 7449R: X45/1 MPLP.

Stratigraphic distribution. Tunal Formation at the type locality, El Chorro creek.

Genus ***Gleicheniidites*** (Ross, Delcourt and Sprumont) Skarby 1964

Type species. *Gleicheniidites senonicus* Ross 1949.

Gleicheniidites cf. ***argentinus*** Volkheimer 1972
Figure 7.F

Description. Trilete spore. Amb triangular with straight to slightly concave or convex sides. Exine smooth with a discontinuity of the equatorial thickening at the apices.
Size. 32 µm (1 specimen).

Material. 7449D: Z27/4 MPLP.

Remarks. The cf. refers to the presence of undulated borders on two of the fold-tori, which are not present in the original material (of the Jurassic) described by Volkheimer (1972). The other morphological features including size are the same as in the type species.

Stratigraphic distribution. From the Early Jurassic through to the Paleogene in southern South America (Neuquén Basin, Salta Group Basin). Tunal Formation at the type locality, El Chorro creek.
Botanical affinity. Gleicheniaceae.

Genus ***Polypodiaceoisporites*** Potonié *ex* Potonié 1956

Type species. *Polypodiaceoisporites speciosus* Potonié *ex* Potonié 1956.

Polypodiaceoisporites cf. ***retirugatus*** Muller 1968
Figure 7.H

Size. 38 µm (1 specimen).

Material. 7449D: M24/2 MPLP.

Remarks. The *cf.* refers to the less conspicuous lips and the smaller size of these specimen (38 µm) than in the original material (47-65 µm).
Stratigraphic distribution. Late Cretaceous to Early Tertiary of Sarawak, Malaysia (Muller, 1968). Neogene of Papua New Guinea (Playford, 1982). Tunal Formation at the type locality, El Chorro creek.
Botanical affinity. Muller (1968) mentions the probable affinity with the fern genus *Pteris* L.

Genus ***Verrucosisporites*** Ibrahim *emend.* Potonié and Kremp 1954

Type species. *Verrucosisporites verrucosus* Ibrahim *emend.* Potonié and Kremp 1955.

cf. ***Verrucosisporites*** sp.
Figure 8.E

Description. Amb circular. Distal exine sculptured with regular, more or less hemispheric verrucae to granules (diameter 2-4 µm). The sculptural elements are spaced so closely, that a similar element could not fit in between.
Size. 47 µm (1 specimen).

Material. 7449O: X23/2 MPLP.

Remarks. The generic designation can not be assertained as the proximal face of the specimen is not visible.
Stratigraphic distribution. Tunal Formation at the type locality, El Chorro creek.

Genus ***Zlivisporis*** Pacltová 1961

Type species. *Zlivisporis blanensis* Pacltová 1961.

Zlivisporis **sp. 1**
Figure 7.C

Description. Trilete spores. Amb subcircular. The laesurae reach the equator. Curvatur imperfect. Proximal exine laevigate. Distal reticulum conspicuous. Muri of the reticulum arranged into a predominantly hexagonal ornamentation. Lumina 15-20 µm wide; muri of the reticulum 1.5-1.7 µm. Exine 1.2-1.5 µm in the equator. A hyaline perine is present in all specimens.
Size. Maximum diameter: 41-51 µm (3 specimens).

Material. 7449Q: F48/1 MPLP; 7449Q: N37/4 MPLP; 7449Q: Y47/3 MPLP.

Remarks. Our material is similar to the illustrated specimen *Zlivisporis* sp. B (Braman, 2001) from the Late Cretaceous of Alberta, Canada.
Stratigraphic distribution. Tunal Formation at the type locality, El Chorro creek.
Botanical affinity. Hepaticae.

Zlivisporis **sp. 2**
Figures 7.A,B

Description. Trilete spores. Amb subcircular. The laesurae reach the equator. Proximal exine with faint muri which form an irregular and incomplete reticulum. Muri of the distal exine are arranged into a conspicuous reticulum with predominantly hexagonal lumina. Lumina 10-25 m wide. Muri of the reticulum 0.8-1 µm. Equatorial exine 1.2-2 µm. A hyaline perine is present in both specimens.
Size. Maximum diameter: 56-59 µm (2 specimens).

Material. 7449O: H34/4 MPLP; 7449Q: N38/4 MPLP.

Comparisons. *Zlivisporis* sp. 2 is larger than Z. sp. 1 and has, in addition, a proximal reticulum which has not been observed in Z. sp. 1.
Stratigraphic distribution. Tunal Formation at the type locality, El Chorro creek.
Botanical affinity. Hepaticae.

Cingulate spore **indet. 1**
Figure 7.G

Description. Trilete cingulate spore. Amb triangular. Sides straight to slightly convex. Angles well rounded. Cingulum narrow, 2-3 µm wide. Trilete rays almost reach the cingulum. Proximal exine laevigate. Distal exine covered with large verrucae of up to 7 µm in diameter.
Size. 37 µm (1 specimen).

Material. 7449F: J37/1 MPLP.

Remarks. The only specimen recovered appears incomplete with an irregularly triangular piece from the proximal polar area missing.
Stratigraphic distribution. Tunal Formation at the type locality, El Chorro creek.

Cingulate spore **indet. 2**
Figure 8.C

Description. Trilete spore. Amb triangular. Sides straight to slightly convex. Exine width approximately 1.5 µm in the equator. Proximal exine (?) laevigate, with an 8 µm diameter ring at the equator. The remaining proximal exine is thinner. The laesura rays almost reach the continuous thick border that can be easily confused with a cingulum. The rays have margins of ca. 5 µm wide (both margins). The distal side is densely covered with foramin that are frequently fused. The diameter of the foramin is less than 1 µm.
Size. 51 µm (1 specimen).

Material. 7449E: J39/3 MPLP.

Stratigraphic distribution. Tunal Formation at the type locality, El Chorro creek.

Pollen grains

Genus ***Ailanthipites*** Wodehouse 1933

Type species. *Ailanthipites berryi* Wodehouse 1933.

Ailanthipites **sp. A**
Figure 10.K

Description. Prolate to ellipsoidal tricolporate pollen grains. Thin colpi almost reaching the poles. Colpal margins broaden in the equator (2-3 µm) and narrowing towards the poles. Lalongate pores (3.5-4 µm long) with diffuse *costae pori*. Exine of 0.8-1 µm with a finely reticulate pattern not parallel to the polar axis.
Size. 25-27.5 x 15-18 µm (2 specimens).

Material. 7449A: Q35/2 MPLP; 7449D: M25/1 MPLP.

Comparisons. *Ailanthipites* sp. (Quattrocchio and Volkheimer, 1988) has the same features but a larger size of 33 x 22.5 µm. *Rhoipites* sp. B is similar but its reticulate pattern is not parallel to the polar axis.
Stratigraphic distribution. Tunal Formation in Tilián (Quattrocchio and Volkheimer, 1988) and El Chorro creek (this paper).

Genus *Cyclusphaera* Elsik 1966

Type species. *Cyclusphaera euribei* Elsik 1966.

Cyclusphaera* cf. *psilata Volkheimer and Sepúlveda 1976
Figure 9.B

Size. 54 µm (1 specimen).

Material. 7449A: P28/2 MPLP.

Remarks. The only specimen identified is probably redeposited, considering that the known stratigraphic range of *C. psilata* is limited to the Early Cretaceous.
Stratigraphic distribution. Tunal Formation at the type locality, El Chorro creek.

Genus ***Ephedripites*** Bolkhovitina *ex* Potonié 1958

Type species. *Ephedripites mediolobatius* Bolkhovitina ex Potonié 1958.

Ephedripites sp.
Figure 9.A

Description. Polyplicate pollen grain. Oval elongate outline. Ratio of length/width: 2/1. Approximately 22 longitudinal ridges of 1-1.3 µm width, which extend from pole to pole.
Size. Total length: 44 µm (1 specimen).

Material. 7448D: D34/4 MPLP.

Stratigraphic distribution. Tunal Formation at the type locality, El Chorro creek.
Botanical affinity. Ephedraceae.

Genus ***Retitricolporites*** (Van der Hammen) Van der Hammen and Wijmstra 1964

Type species. *Retitricolporites normalis* (Van der Hammen) Van der Hammen and Wijmstra 1964.

Retitricolporites* cf. *chubutensis Archangelsky 1973
Figure 10.L

Size. 29 x 22.5 µm (1 specimen).

Material. 7449E: M33/4 MPLP.

Remarks. The cf. refers to the fact that although the reticulum becomes smaller towards the poles, the lumina do not diminish in size towards the colpi and the pores are not as clearly defined as in the original material of *R. chubutensis* (Archangelsky, 1973). All the other features are consistant with those of the type material.
Stratigraphic distribution. Tunal Formation at the type locality, El Chorro creek.

Genus ***Rugumonoporites*** Pierce 1961

Type species. *Rugumonoporites convolutus* Pierce 1961.

Rugumonoporites sp. A
Figures 7.I, J

Description. Monoporate pollen grains. Amb circular. Pore represented by a distal circular area of ca. 22-24 µm in diameter. Exine sculptured by convolute ridges (rugulae) which are arranged in several (3-5) irregular concentric rings. On the proximal hemisphere, large (up to 20 µm) insular rugulae and coarsely structured verrucae can be observed.
Size. 40.5-44 µm (2 specimens).

Material. 7449C: E39/4 MPLP; 7449O: W23/3 MPLP.

Remarks. The material recovered represents the typical "cauliflower" aspect mentioned by Pierce (1961) as observed in Late Cretaceous material from Minnesota.
Stratigraphic distribution. Tunal Formation at the type locality, El Chorro creek.
Botanical affinity. Coniferophyta.

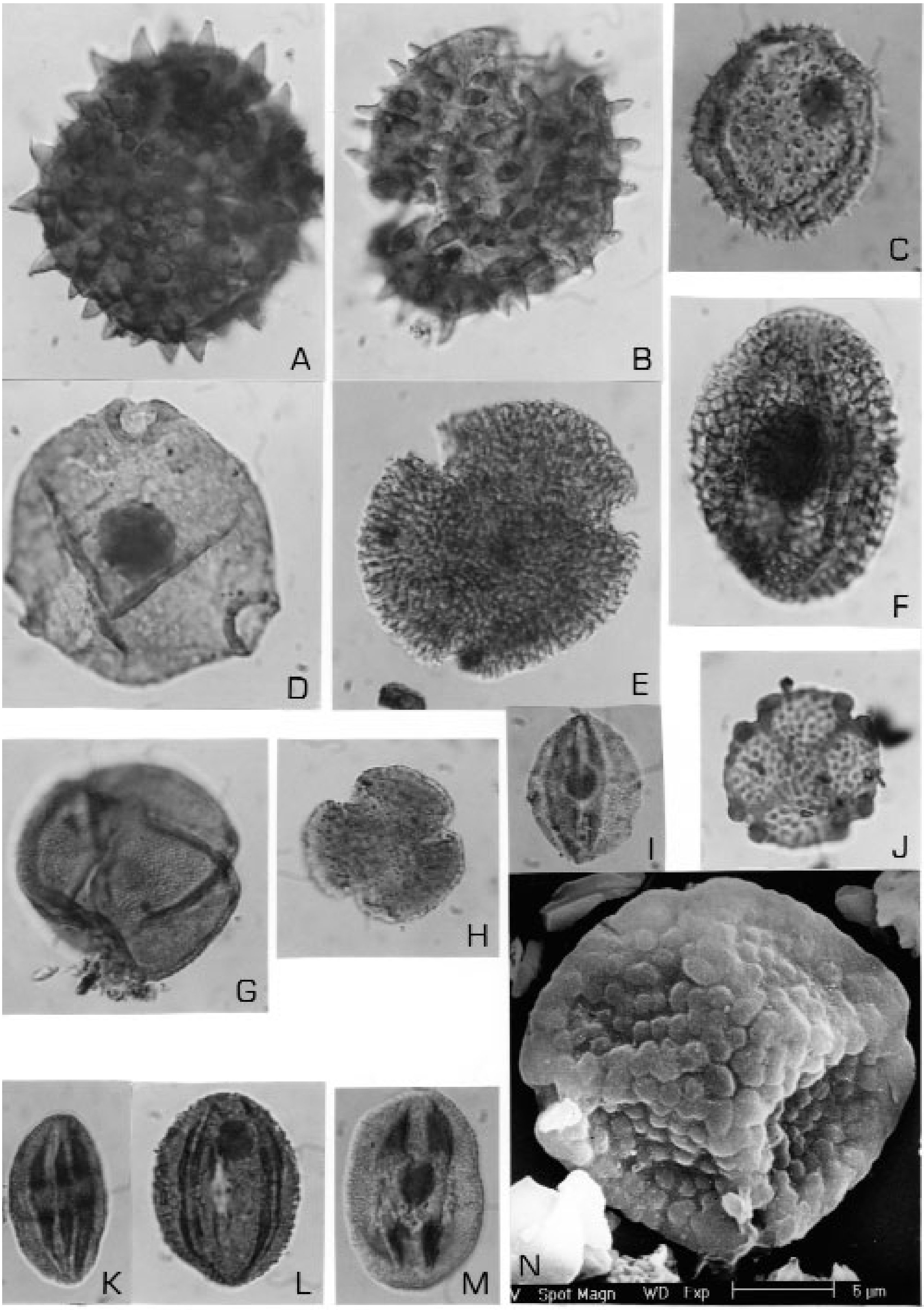
Genus ***Spinizonocolpites*** Muller *emend.* Muller *et al.* 1987

Type species. *Spinizonocolpites equinatus* Muller 1968.

Spinizonocolpites sp.
Figures 10.A,B

Description. Pollen grains circular to subcircular in outline, with one ringlike colpus parallel to the polar axis. Surface covered with scattered conical spines, 5-7µm long and 2-3.5µm of cross-section at their base.

Figure 10. A, ***Spinizonocolpites*** sp. 7449R: L29/4 MPLP, 42 µm. **B,** ***Spinizonocolpites*** sp. 7449D: C27 MPLP, 45 µm. **C,** ***Pandaniidites texus*** Elsik. 7449A: O34/2 MPLP, 32 µm. **D,** ***Corsinipollenites menendezii*** Quattrocchio. 7449O: P33/2 MPLP, 43 µm. **E,** ***Tricolpites*** sp. A. 7449A: Y30/1 MPLP, 45 µm. **F,** ***Rousea patagonica*** Archangelsky. 7449F: J37/4 MPLP, 46x33 µm. **G,** ***Tricolpites reticulatus*** Cookson. 7449A: V23/1 MPLP, 33 µm. **H,** ***Gemmatricolpites subsphaericus*** Archangelsky. 7449F: E44/2 MPLP, 23 µm. **I,** ***Tricolpites vulgaris*** Pierce. 7449E: E27/2 MPLP, 24x17 µm. **J,** ***Verrustephanoporites simplex*** Leidelmeyer. 7449SEMa: P33/4 MPLP, 24 µm. **K,** ***Ailanthipites*** sp. A. 7449A: Q35/2 MPLP, 25 µm. **L,** ***Retitricolporites*** cf. ***chubutensis*** Archangelsky. 7449E: M33/4 MPLP, 24x22,5 µm. **M,** ***Rhoipites*** sp. B Quattrocchio and Volkheimer. 7449A: N40 MPLP, 31 µm. **N,** ***Verrustephanoporites simplex*** Leidelmeyer. SEM, 38 µm.


A
B
C
D
E
F
G
H
I
J
K
L
M
N
V Spot Magn WD Exp
5 µm

Assemblages	A	B	C	D	E	F
Meters above base of the Fm. / Sample Nº	14 m / 7777 (270802/7)	18 m / 7448 (Tunal 1)	20 m / 7449 (Tunal 2)	21 m / 7782 (270802/12)	29 m / 7801 (CH-L020)	40 m / 7805 (CH-L027)
Green algae (Chlorococcales): *Pediastrum* spp.	21 %	33 %	77 %	67 %	92 %	20 %
Angiospermous pollen (without Ulmaceae)	10 %	19 %	4,75 %	1 %	3 %	20 %
Ulmacean pollen. *Verrustephanoporites simplex*	62 %	46 %	16,75 %	28 %	2 %	8 %
Gymnospermous pollen	2 %	1 %	0,5 %	1 %	0 %	6 %
Spores of Bryophytes and Pteridophytes	5 %	1 %	1 %	3 %	3 %	46 %
Total sum	100 %	100 %	100 %	100 %	100 %	100 %

Figure 11. Frequency of the main taxonomic groups of palynomorphs observed in the Tunal Formation at its type locality, El Chorro creek (Salta, Argentina) / *frecuencia de los principales grupos taxonómicos de palinomorfos observados en la Formación Tunal en su localidad tipo, quebrada El Chorro (Salta, Argentina).*

Exine: 2.3 µmm. The specimens tend to split into two halves.
Size. Body: 38-42 µm (4 specimens).

Material. 7449D: C27 MPLP; 7449O: D41/2 MPLP; 7449Q: V30/3 MPLP; 7449R: L29/4 MPLP.

Remarks. Specimens recovered are similar to *Spinizonocolpites* sp. (Frederiksen 1994, Pl. 12, Fig. 3) from the Bara Formation (Paleocene of the Lower Indus region, Pakistan). According to Thanikaimoni's terminology (1966), the aperture of *Spinizonocolpites* is meridionosulcate.
Comparisons. S. sp from the Paleocene of Chubut (Bororó Formation; Archangelsky, 1973) has similar dimensions, but the spines are shorter and the hyaline exine is thinner.
Stratigraphic distribution. Tunal Formation, El Chorro creek.
Botanical affinity. As stated by Muller (1968) and Frederiksen (1994), the pollen grains of this genus are related to the modern *Nypa* (brackish-water tropical palms) which occur in mangrove environments.

Genus ***Tricolpites*** Cookson *ex* Couper *emend.* Potonié 1960

Type species. *Tricolpites reticulatus* Cookson 1947.

Tricolpites sp. A
Figure 10.E

Description. Prolate to subsphaerical tricolpate pollen grains. Amb circular. Colpi straight, reaching to ca. 15-18 µm from the poles. Exine 4-5 µm thick; semitectate. Columellae 0.8 µm thick and 0.6 µm apart basally. The baculae are distinctly apically digitate.
Size. 38-45 µm (5 specimens).

Material. 7449A: Y30/1 MPLP; 7449E: E25/4 MPLP; 7449E: J28/1 MPLP; 7449E: S44 MPLP; 7449F: F40/2 MPLP.

Comparisons. *Perfotricolpites maculosus* from the Neogene of Papua (Playford, 1982) is similar but larger (74-96 µm), possessing a perforate tectum and digitate columellae.
Stratigraphic distribution. Tunal Formation at the type locality, El Chorro creek.

Age

The Danian age of the Tunal Formation at the type locality is indicated by the presence of *Mtchedlishvilia saltenia* Moroni (*Mtchedlishvilia saltenia* palynozone: Quattrocchio *et al.*, 2000). Associated taxa such as *Gemmatricolpites subsphaericus* Archangelsky and *Pandaniidites texus* Elsik confirm the Paleocene age of the Formation.

Paleoenvironments and biostatistic data

The presence and abundance of *Pediastrum* spp. (20-92%) recovered here and of Haloragaceae (*Myriophyllumpollenites* spp.) in nearby localities (figures

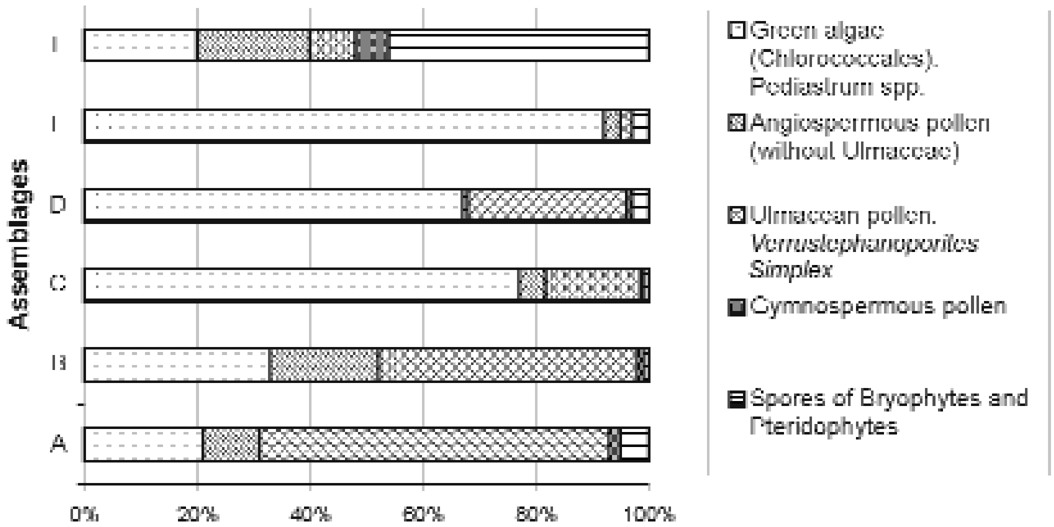


Figure 12. Histograms illustrating the frequency of suprageneric taxonomic groups of palynomorphs occuring in the lower half of the Tunal Formation at its type locality. Based on data reported in figura 11 / *histogramas ilustrando la frecuencia de los grupos taxonómicos supragenéricos presentes en la mitad inferior de la Formación Tunal en su localidad tipo. Basado en los datos representados en la figura 11.*

11, 12), indicate a swamp environment for deposition of the Tunal Formation. *Pediastrum* is usually found floating among aquatic plants but rarely in deep water (Prescott, 1984). Abundant amorphous organic matter was found together with the *Pediastrum* and it is probably the remains of the aquatic plants. Pandanaceae pollen (*Pandaniidites texus* Elsik) also indicates swampy areas (Quattrocchio *et al.*, 1988).

Verrustephanoporites simplex Leidelmeyer has affinities with *Phyllostylon* (Ulmaceae), which is a dominant tree in the modern Transitional Forest District (350-500 m a.s.l.) of the Yungas Province, Amazonic Domain (Cabrera, 1976). Therefore, it is inferred that the environment during the time of accumulation of part of the Tunal Formation was similar to the Transitional Forest, as evidenced by the predominance of Ulmaceae (figuras 11 and 12). Nevertheless, there may have been differences between the equivalent Danian and modern forests, considering that evolution of some new species and extinction of some old species has probably occurred. Also, a quantitative palynologic analysis of recent lacustrine and swamp sediments and the different types of pollen rain which characterize these biotypes may make a closer comparison of the Danian and modern forests possible.

The presence of Podocarpaceae (*Podocarpidites marwickii* Couper), Rutaceae (*Rhoipites* sp. A Quattrocchio and Volkheimer) and Anacardiaceae (Retitricolporites sp. A Quattrocchio and Volkheimer) in nearby areas of the same subbasin, would indicate an association similar to that of the Montane Forest District, located in the upper part of the Yungas Province (1200-2500 m a.s.l.). Today the ecozone between the Transitional Forest District and the Montane Forest District is the Cloud Forest District (550-1600 m a.s.l.) which in the fossil forests of the Tunal Formation is possibly indicated by pollen of Aquifoliaceae (*Gemmatricolpites subsphaericus* Archangelsky) (Quattrocchio *et al.*, 1988; Quattrocchio and Volkheimer, 2000b and this paper), hence the Cloud Forest may be represented also.

At present, the climate of the Yungas Province (known in northwestern Argentina as the Subtropical Jungle of Tucumán and Orán) is humid and warm, with summer rainfalls, some frost in winter and annual precipitations of approximately 700-1000 mm (Cabrera, 1976). It has been inferred that similar conditions would have existed during the deposition of the Tunal Formation (Quattrocchio *et al.*, 1988; Quattrocchio and Volkheimer, 2000b). The detailed sedimentologic analysis (Novara, 2003) however, indicated climatic fluctuations. The frequent presence of analcyme, filling the pores and alcoves in sandstones and limestones, and the abundant evaporites show that the climate became drier periodically. These climatic fluctuations were not sufficient to cause change in the surrounding forest vegetation.

The paleoenvironmental information is supported by palynologic data (figures 11 and 12). Data were recovered from only a few stratigraphic levels containing well preserved palynomorphs. These were obtained between 14 and 40 m above the base of the Tunal Formation; 6 assemblages, from A (14 m) through F (at the 40 m level). The absence of palynomorphs in the upper part of the Formation (interval between 40 and 71 m) was possibly caused by an increase in alcalinity, subsequently destroying any palynomorph deposited in this interval. Furthermore, if the swamps dried out periodically, these conditions could not be good for pollen preservation.

Palynofloral provincialism

Based on the reported palynologic record, two major phytogeographic provinces have been identified for the Danian in Argentina (Quattrocchio and Volkheimer, 2000a). The southern temparate province known as the *Nothofagidites* Phytogeoprovince, includes South-Patagonia (Austral Basin) and Antarctica (Antarctica Basin). The northern tropical and subtropical province, represented in this area by the Tunal Formation, is known as the Ulmaceae Phytogeoprovince. Palynomorphs recovered from the Tunal Formation further indicate a subprovince characterized by "triprojectate" pollen (*Mtchedlishvilia*), as observed both in the Danian of the Salta Group Basin and in the North-Patagonian Colorado Basin. Warm and humid climatic conditions are indicated for the Ulmaceae Province and more temperate conditions for the *Nothofagidites* Province.

Conclusions

Previous sedimentological studies in concert with palynologic assemblages recovered here indicate fluctuating climatic conditions during deposition of the Tunal Formation. Dry intervals are indicated by evaporites and humid episodes are indicated by statistically high numbers of fresh water colonial green algae (*Pediastrum* spp.) along with palynomorphs representing hydrophylic plant communities consisting of Haloragaceae, Pandanaceae and Ulmaceae.

At the type locality of the Tunal Formation, El Chorro creek, microfloristic assemblages were deposited in a swampy environment characterized by the abundance of *Pediastrum*, representing between 33 and 77 % of the total palynofloristic assemblage.

The Ulmacean forest (*Verrustephanoporites simplex* Leidelmeyer with up to 62% of total sporomorphs) was by far the most widely distributed phytogeographic unit during the deposition of the Tunal Formation at the type locality. It may be comparared with the modern Transitional Forest found today at 350-500 m a.s.l.

Acknowledgements

This research was supported by the Agencia Nacional de Promoción Científica y Tecnológica (ANPCyT, PICT 12419), Consejo de Investigación de la Universidad Nacional de Salta (CIUNSa, projects 876/4 and 1220) and Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET, PIP 2905/00). This is a contribution to the Instituto del Cenozoico (INCE, Universidad Nacional de Salta). The authors wish to thank very specially to H. Martin for her important advice and comments concerning the paleoecology of the Tunal Formation; to S. Gaponoff for her contribution to improve the manuscript, C. del Papa and I. Sabino for their enthusiastic collaboration during fieldwork and M. Quattrocchio for the critical reading of the manuscript.

References

Aguilera, N. 1981. [*Estratigrafía de los Grupos Salta y Orán en el arroyo Piedra Blanca, departamento Metán, Salta*. Tesis Profesional, Facultad de Ciencias Naturales, Universidad Nacional de Salta, Salta, 98 pp. Unpublished.].

Amengual, R. 1976. [*Geología de la comarca ubicada al N-NO de la localidad de Metán, Provincia de Salta, República Argentina*. Tesis Doctoral, Facultad de Ciencias Exactas, Físicas y Naturales, Universidad Nacional de Córdoba, Córdoba, 75 pp. Unpublished.].

Archangelsky, S. 1973. Palinología del Paleoceno de Chubut. I Descripciones sistemáticas. *Ameghiniana* 10: 339-399.

Batten, D.J. 1996. Chapter 7C. Colonial Chlorococcales. In: J. Jansonius and D.C. Mc.Gregor (eds.), *Palynology: principles and applications*, American Association of Stratigraphic Palynologists Foundation, 191-203.

Braman, D.R. 2001. Terrestrial palynomorphs of the Upper Santonian-¿Lowest Campanian Milk River Formation, southern Alberta, Canada. *Palynology* 25: 57-107.

Cabrera, A. 1976. Regiones fitogeográficas argentinas. *Enciclopedia argentina de agricultura y jardinería* 2: 1-85.

Cazau, L.B., Cellini, N. and Gascón Oliver, J. 1975. El Subgrupo Santa Bárbara (Grupo Salta), en la porción oriental de las Provincias de Salta y Jujuy. *6º Congreso Geológico Argentino* (Bahía Blanca), *Actas* 1: 341-356.

Cookson, I.C. 1947. Plant microfossils from the lignites of Kerguelen Archipielago. *Reports of BANZ Antarctic Research Expedition* 1929-1931, Series A 2: 127-142.

del Papa, C. 1994. [*Estratigrafía y Sedimentología de la Formación Maíz Gordo (Terciario Inferior) en el sur de la cuenca del Grupo Salta*. Tesis Doctoral, Facultad de Ciencias Naturales, Universidad Nacional de Salta, Salta, 124 pp. Unpublished.].

Elsik, W.C. 1966. New sporomorph genera from the Upper Cretaceous of Perú. *Pollen et Spores* 8: 553-564.

Frederiksen, N.O. 1994. Middle and Late Paleocene angiosperm pollen from Pakistan. *Palynology* 18: 91-137.

Galli, C.I. and Marquillas, R.A. 1990. Análisis ambiental de las Formaciones Los Blanquitos y Lecho (Cretácico Superior, Grupo Salta) en Cabra Corral, provincia de Salta. *11º Congreso Geológico Argentino* (San Juan), *Actas* 2: 165-168.

Lencinas, A. and Salfity, J.A. 1973. Algunas características de la Formación Yacoraite en el oeste de la cuenca Andina, provincias de Salta y Jujuy, República Argentina. *5º Congreso Geológico Argentino* (Villa Carlos Paz, 1972), *Actas* 3: 253-267.

Marquillas, R.A. 1986. Ambiente de depósito de la Formación Yacoraite (Grupo Salta, Cretácico-Eocénico), Norte argentino. *1º Simposio Proyecto 242 PICG-UNESCO* (La Paz, 1986), *Actas*: 157-173.

Marquillas, R.A. and Salfity, J.A. 1994. Las relaciones estratigráficas regionales de la Formación Yacoraite (Cretácico

Superior), Norte de la Argentina. *7º Congreso Geológico Chileno* (Concepción), *Actas* 1: 479-483.

Marquillas, R.A., del Papa, C. and Sabino, I.F. 2005. Sedimentary aspects and paleoenvironmental evolution of a rift basin: Salta Group (Cretaceous-Paleogene), northwestern Argentina. *International Journal of Earth Sciences* (*Geologische Rundschau*) 94: 94-113.

Meyen, F.I.F. 1829. Beobachtungen über einige niedrige Algenformen. *Nova Acta Physico-Medica Academiae Caesareae Leopoldino-Carodinae* 14: 771-778.

Moreno, J.A. 1970. Estratigrafía y paleogeografía del Cretácico Superior en la cuenca del Noroeste argentino, con especial mención de los Subgrupos Balbuena y Santa Bárbara. *Revista de la Asociación Geológica Argentina* 24: 9-44.

Moroni, A.M. 1982. Correlación palinológica en la Formaciones Olmedo y Yacoraite. Cuenca del Noroeste Argentino. *3º Congreso Geológico Chilen*o (Concepción), *Actas* 340-349.

Moroni, A.M. 1984. *Mtchedlishvilia saltenia* sp. en sedimentitas del Grupo Salta, provincia de Salta. *3º Congreso Argentino de Paleontología y Bioestratigrafía* (Corrientes), *Actas* 1: 129-139

Muller, J. 1968. Palynology of the Pedawan and Plateau Sandstone Formations (Cretaceous-Eocene) in Sarawak, Malaysia. *Micropaleontology* 14: 1-37.

Muller, J., Di Giacomo, E. and Van Erve, A.W. 1987. A palynological zonation for the Cretaceous , Tertiary, and Quaternary of northern South America. *American Association of Stratigraphic Palynologists, Contribution Series* 19: 7-76.

Novara, M.G. 2003. [*Caracterización estratigráfica de la Formación Tunal (Paleoceno) en la quebrada El Chorro (Departamento La Viña). Comparación con la sección del río Corralito (Departamento Rosario de Lerma)*. Tesis Profesional, Facultad de Ciencias Naturales, Universidad Nacional de Salta, Salta, 92 pp. Unpublished.].

Novara, M.G. and Marquillas, R.A. 2004. Litología y Contactos de la Formación Tunal (Daniano) en la Quebrada El Chorro, Departamento La Viña, Salta. *10º Reunión Argentina de Sedimentologí*a (San Luis), *Actas* :116-118.

Oltmanns, F. 1904. *Morphologie und Biologie der Algen I*. Gustav Fisher, Jena, 733 pp.

Pactlová, B. 1961. On some plant microfossils from fresh-water sediments of the Upper Cretaceous (Senonian) in the South-Bohemian basins. Part I (Summary of the Czech text). *Sborník Ústredního Ústavu Geologického, Oddíl Paleontologický* 26: 38-56.

Pascher, A. 1914. Über Flagellaten und Algen. *Berichte deutsche Botanische Gesellschaft* 32: 136-160.

Pierce, R.L. 1961. Lower Upper Cretaceous plant microflora from Minnesotta. *Bulletin Minnesota Geological Survey* 42: 1-86.

Playford, G. 1982. Neogene palynomorphs from the Huon Peninsula, Papua New Guinea. *Palynology* 6: 29-54.

Potonié, R. 1956. Synopsis der Gattungen der *Sporae dispersae*. I. Teil: Sporites. *Beihefte zum Geologischen Jahrbuch* 23: 1-103 pp.

Potonié, R. 1958. Synopsis der Gattungen der *Sporae dispersae*. II. Teil: Sporites (Nachträge), Saccites, Aletes, Praecolpates, Monocolpates. *Beihefte zum Geologischen Jahrbuch* 31: 1-114.

Potonié, R. 1960. Synopsis der Gattungen der *Sporae dispersae*. III. Teil: Nachträge Sporites, Fortsetzung Pollenites. Mit Generalregister zu Teil I-III. *Beihefte zum Geologischen Jahrbuch* 39: 1-189.

Potonié, R. and Kremp, G. 1954. Die Gattungen der palaozoischen *Sporae Dispersae* und ihre Stratigraphie. *Geologischen Jahrbuch* 69: 111-194.

Potonié, R. and Kremp, G. 1955. Die *Sporae Dispersae* des Ruhrkarbons. Teil I. *Palaeontographica* B 98: 1-136.

Potonié, R. and Kremp, G. 1956. Die *Sporae Dispersae* des Ruhrkarbons, ihre Morphographie und Stratigraphie mit Ausblicken auf Arten anderer Gebiete und Zeitabschnitte. Teil II. *Palaeontographica* B 99: 85-191.

Prescott, G.W. 1964. *How to know the fresh-water algae*. Wm. C. Brown, Dubuque, Iowa, 272 pp.

Quattrocchio, M.E. and Volkheimer, W. 1988. Microflora de los estratos limítrofes entre Cretácico y Terciario en las localidades de Tilián y Corralito, cuenca del Grupo Salta. Descripciones Sistemáticas. *4º Congreso Argentino de Paleontología y Bioestratigrafia* (Mendoza), *Actas* 3: 109-120.

Quattrocchio, M.E. and Volkheimer, W. 2000a. Danian microfloral provinces in Argentina. *Revista Española de Paleontología* 15: 3-11.

Quattrocchio, M.E. and Volkheimer, W. 2000b. Paleoclimatic changes during the Paleocene-Lower Eocene in the Salta Group Basin, NW Argentina. In: P.P. Smolka and W. Volkheimer (eds.), *Southern Hemisphere Paleo- and Neoclimates*, Springer-Verlag, Berlin, pp. 353-367.

Quattrocchio, M.E., Marquillas, R.A. and Volkheimer, W. 1988. Palinología, paleoambientes y edad de la Formación Tunal, cuenca del Grupo Salta (Cretácico-Eoceno), República Argentina. *4º Congreso Argentino de Paleontología y Bioestratigrafia* (Mendoza), *Actas* 3: 95-107.

Quattrocchio, M.E., Ruiz, L. and Volkheimer, W. 2000. Palynological zonation of the Paleogene of the Colorado and Salta Group Basins, Argentina. *Revista Española de Micropaleontología* 32: 61-78.

Ross, N.E. 1949. On a Cretaceous pollen and spore bearing clay deposit of Scania. *Bulletin Geological Institute, University of Upsala* 34: 25-43.

Salfity, J.A. and Marquillas, R.A. 1981. Las unidades estratigráficas cretácicas del norte de la Argentina. In: W. Volkheimer and E.A. Musacchio (eds.), *Cuencas Sedimentarias del Jurásico y Cretácico de América del Sur 1*, Comité Sudamericano del Jurásico y Cretácico, Buenos Aires, pp. 303-317.

Salfity, J.A. and Marquillas, R.A. 1994. Tectonic and Sedimentary Evolution of the Cretaceous-Eocene Salta Group Basin, Argentina. In: J. Salfity (ed.), *Cretaceous Tectonics of the Andes*, Earth Evolution Sciences, Braunschweig-Wiesbaden, Vieweg, pp. 266-315.

Skarby, A. 1964. A revision of *Gleicheniidites senonicus* Ross. *Stockholm Contributions in Geology* 11: 59-77.

Thanikaimoni, G. 1966. Contribution à l'étude palynologique des palmiers. *Institut Français de Pondichéry, Travaux de la Section Scientifique et Technique* 5: 1-91.

Thompson, P.W. and Pflug, H. 1953. Pollen und Sporen des mitteleuropäischen Tertiärs. *Palaeontographica* B 94: 1-138.

Turner, J.C.M. 1959. Estratigrafía del cordón de Escaya y de la sierra de Rinconada (Jujuy). *Revista de la Asociación Geológica Argentina* 13: 15-39.

Turner, J.C.M., Méndez, V., Lurgo, C., Amengual, R. and Viera, O. 1979. Geología de la región noroeste, provincias de Salta y Jujuy, República Argentina. *7º Congreso Geológico Argentino* (Neuquén), *Actas* 1: 367-387.

Van der Hammen, T. and Wijmstra, T.A. 1964. A palynological study on the Tertiary and Upper Cretaceous of British Guiana. *Leidse Geologische Mededelingen* 38: 37-48.

Volkheimer, W. 1972. Estudio palinológco de un carbon caloviano en Neuquén y consideraciones sobre los paleoclimas

jurásicos de la Argentina. *Revista del Museo de la Plata* (Nueva Serie), *Paleontología* 6: 101-157.
Volkheimer, W. and Melendi, D.L. 1976. Palinomorfos como fósiles guía (3ª parte). Técnicas de laboratorio palinológico. *Revista Minera Geología y Mineralogía* 34: 19-30.
Volkheimer, W. and Sepúlveda, E. 1976. Biostratigraphische Bedetung und mikrofloristische Assoziation von *Cyclusphaera psilata* n. sp., einer Leitform aus der Unterkreide des Neuquén-Beckens (Argentinien). *Neues Jahrbuch für Geologie und Paläontologie*, Monatshefte 2: 97-108.
Wodehouse, R.P. 1933. Tertiary pollen II. The oil shales of the Eocene Green River Formation. *Bulletin of the Torrey Botanical Club* 60: 479-524.

Recibido: 17 de mayo de 2005.
Aceptado: 6 de octubre de 2005.