Rev. bras. paleontol. 16(2):237-244, Maio/Agosto 2013

doi: 10.4072/rbp.2013.2.06

A MID-CRETACEOUS PALYNOFLORA WITH *TUCANOPOLLIS CRISOPOLENSIS* FROM D-129 FORMATION, SAN JORGE GULF BASIN, ARGENTINA

PATRICIA VALLATI
Laboratorio de Bioestratigrafía, UNPSJB, Ciudad Universitaria, 9000, Comodoro Rivadavia, Argentina.
patricia.vallati@gmail.com

ABSTRACT – New data from the palynomorph assemblage with angiosperm pollen grains found in lacustrine sediments belonging to the terminal part of the D-129 Formation are herein presented. The fossiliferous section is included in the uppermost part of a thick lacustrine stratigraphic unit, which is widely distributed in the subsurface of the productive San Jorge Gulf Basin. The presence of the paleoequatorial marker *Tucanopollis crisopolensis* (Regali) in the studied sediments is emphasized and biostratigraphic as well as biogeographic aspects are discussed. Based on the information provided by the fossil record, a late Barremian?/early Aptian age is suggested for the end of the great-lake episode in the present district.

Key words: palynomorphs, angiosperm pollen grains, mid-Cretaceous, biogeography, biostratigraphy, San Jorge Gulf Basin.

RESUMO – Apresentam-se novos dados de uma assembleia de palinomorfos, com grãos de pólen de angiospermas, encontrados em sedimentos lacustres, ao longo da porção terminal da Formação D-129. A seção fossilífera está incluída na parte superior da fina unidade estratigráfica lacustre, que é amplamente distribuída em subsuperfície na produtiva bacia do Golfo de San Jorge. A presença do marcador equatorial, *Tucanopollis crisopolensis* (Regali), é enfatizada nos sedimentos estudados, assim como são discutidos os aspetos bioestratigráficos e biogeográficos. Com base nas informações provenientes do registro fóssil, sugere-se a idade Barremiano superior?/Aptiano inferior, para o final deste episódio do grande lago, no presente distrito.

Palavras-chave: palinomorfos, grãos de pólen de angiospermas, Cretáceo médio, biogeografia, bioestratigrafia, bacia do Golfo de San Jorge.

INTRODUCTION

The San Jorge Gulf Basin is an important oil-producing basin of Argentina with the D-129 Formation representing its main hydrocarbon source rock. This unit includes sediments deposited in a lacustrine system of ample areal extension, and it is mainly represented in the subsurface. The fertile levels with the palynoflora outcrop about 40 km north of Sarmiento City, in the Chubut Province (near 45º 30´S and 69º03´W) (Figures 1, 2).

In spite of several studies involving subsurface and outcrop samples, few fossils of biostratigraphic value have been reported from this unit of economic interest. Among these, the calcareous microfossils reported by Musacchio (*in* Hechem *et al*., 1987) in the exposed upper part of the unit at Cerro Chenques (Sierra Silva) including *Pattersoncypris* (Ostracoda) and the pair *Flabellochara harrisi*/*Porochara mundula* (Charophyta), are emphasized. Taking into account this calcareous assemblage an Aptian age was suggested for this same stratigraphic unit with the palynoflora (Musacchio *in* Hechem *et al*., 1987).

Previous palynologic reports from D-129 Formation involving subsurface samples include among other taxa *Botryococcus*, *Cyclusphaera*, *Classopollis* (Van Nieuwenhuise & Ormiston, 1988). Archangelsky *et al.* (1984) pointed out that at least part of the D-129 Formation in some wells could be related to the assemblage zone *Antulsporites*-*Clavatipollenites* of the Austral Basin. The presence of angiosperm pollen grains in the *Clavatipollenites* pollen assemblage recovered from the outcrops of Sierra Silva was reported by the author (Vallati, 1996, 2002, 2006). New data from this pollen assemblage, including regional correlation and biogeographic aspects are herein presented within the framework of studies involving cretaceous angiosperm grains from northern and central argentine Patagonia (Vallati, 2002, 2006, 2010).

The palynoflora from D-129 Formation includes some endemic and/or typical austral cretaceous species as *Cyclusphaera psilata*, *C. radiata* and *Balmeiopsis limbatus* together with taxa characteristic of the equatorial paleofloristic province (Herngreen *et al*., 1996), as the conspicuous angiosperm pollen grain *Tucanopollis crisopolensis*, suggesting a transitional character for this palynoflora.

STRATIGRAPHY

In spite of its entirely continental emplacement, at least during the Cretaceous, the San Jorge Gulf Basin roughly resembles other Cretaceous basins of the South Atlantic continental margin taking into account tectono-sedimentary features. This basin from argentine central Patagonia was

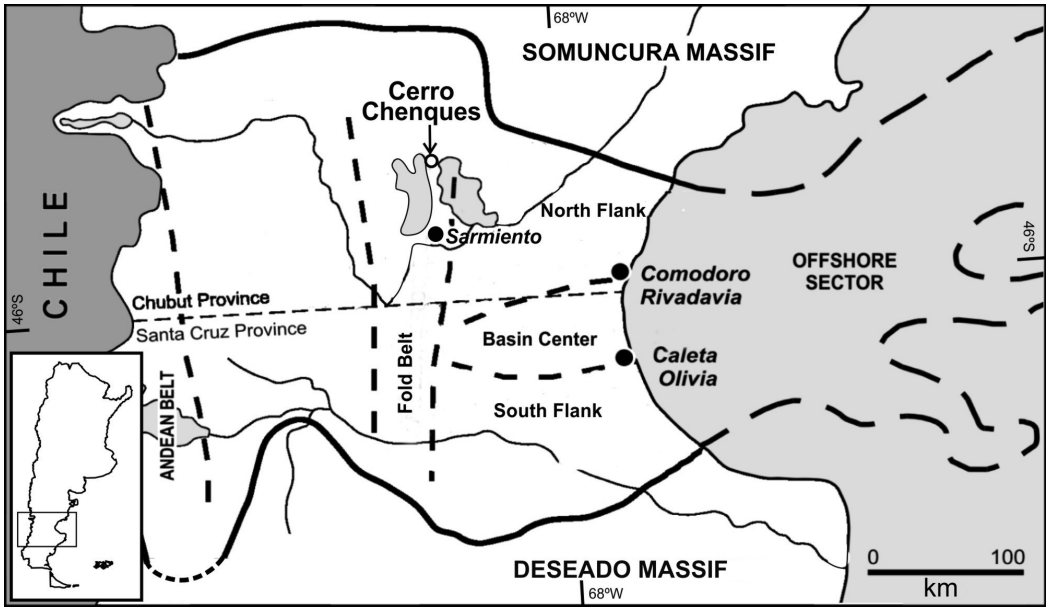

Figure 1. Location map of the studied site in the San Jorge Gulf Basin. Major structural subdivisions within the basin are indicated by the dotted lines (modified from Sylwan, 2001).

Figure 2. Satellital image of the Sierra Silva, center of Chubut Province, Argentina.

settled on a continental Jurassic basement which includes volcanic rocks. Two rift stages of Jurassic and early Cretaceous ages are recognized. The later is unconformable overlain by mid and late Cretaceous non-marine units, in part of pyroclastic origin, followed by Paleogene and Neogene deposits resulting from Atlantic transgressions and regressions. Particularly, the lower part of the mid-Cretaceous post-rift sediments, including the thick lake deposits of D-129 Formation widely distributed in the subsurface (Fitzgerald *et al.*, 1990), are herein focused.

The D-129 Formation (Lesta, 1968) was formerly proposed within the framework of the oil exploration, having its type section in the electric log of the D-129 well in the Diadema oil field. It is overlain by the Castillo Formation, well exposed westward at the Sierra de San Bernardo folded-belt.

The reduced outcrops of the D-129 Formation at Cerro Chenques, in the center of the Chubut province, form part of the exposed nucleus of the Sierra Silva folded structure (Figure 2). The section shown in the profile of the Figure 3, which has provided the present palynoflora as well as the calcareous microfossil assemblage reported by Musacchio (*in* Hechem *et al.*, 1987), corresponds to the terminal part of the D-129 Formation. These outcrops include gray and gray-greenish silstones, scarce brown oolitic limestones and gray tuffaceous sandstones covered - and grading laterally - by variegated siltstones, sandstones and fluvial conglomerates. This set of variegated rocks can be visually correlated with the Matasiete Formation (Hechem *et al.*, 1987) and they are conformably covered, in turn, by the Castillo Formation (Late Aptian-Albian? after Barcat *et al.*, 1989). The Matasiete Formation (= *Areniscas y Tobas Coloradas* after Feruglio, 1949) appears well exposed few kilometers to the north-west of the present studied levels, at the Cañadón Matasiete. In this region, the Castillo Formation is overlain by the Bajo Barreal Formation, mainly including soft gray tuff with arenaceous lens which

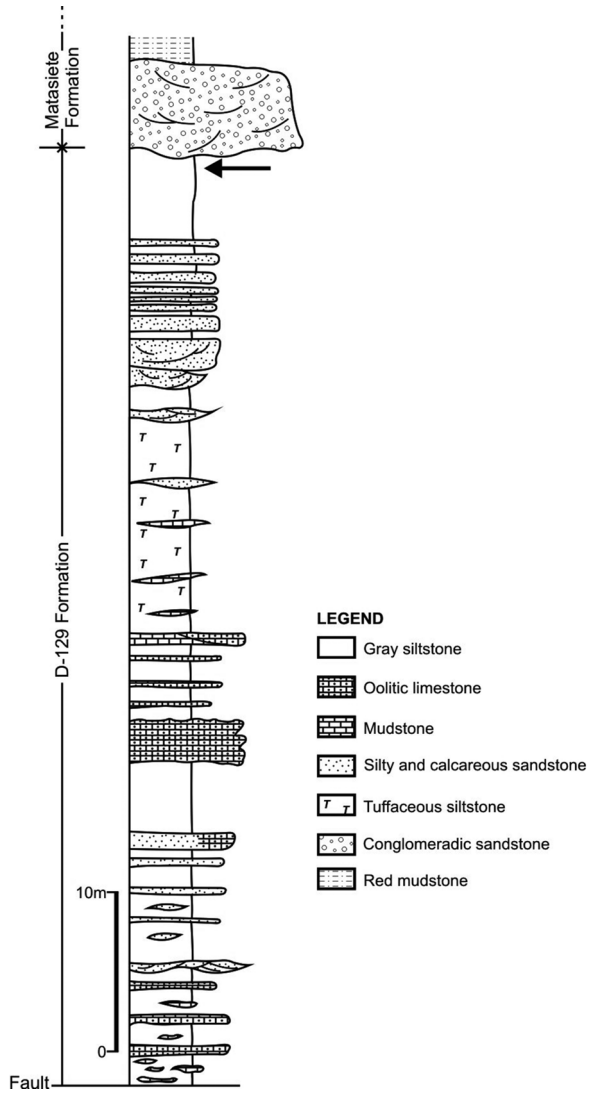

Figure 3. Schematic section of the D-129 Formation outcropping at Cerro Chenques. The arrow indicates the fertile level (after Hechem *in* Hechem *et al.*, 1987).

yielded remains of dinosaurian faunas of Late Cretaceous age (see Martinez & Novas, 2006; Casal *et al.*, 2007).

MATERIAL AND METHODS

In spite of intense search for palynomorphs in the outcrops of D-129 Formation only two samples from the upper siltstone levels resulted fertile (Figure 3). The samples were processed following the standard palynological processing techniques. The acid treatment involved hydrochloric and hydrofluoric acids in order to remove carbonates and silicates followed by a washing with concentrate hydrochloric acid at 90°C. Then, a brief oxidation of two to three minutes in nitric acid was necessary to clarify the palynomorphs. The organic residue was mounted on microscope slides using glycerine-gelatine. The samples were studied with a Carl Zeiss KF 2 microscope and the microphotographs were obtained with a digital Nikon Coolpix P2 camera.

All cited specimens are deposited in the collection of micropaleontology of the Universidad Nacional de la Patagonia San Juan Bosco, where the slides are filed under the initials CR.P.CV. The specimens are cited by the corresponding slide identification followed by the coordinates of the Vernier Scale in the Zeiss Microscope.

The percentage of palynomorphs mentioned in the analysis of the palynoflora was based on counts of 300 specimens.

COMPOSITION OF THE PALYNOFLORA

A taxonomic list of the palynomorphs identified in the D-129 Formation at Sierra Silva is presented below. The statistical diagram (Figure 4) illustrates the relative abundance of the different taxonomic groups recognized in the studied assemblage. The palynoflora is dominated by pollen of the conifer family Cheirolepidaceae with the widespread *Classopollis* representing more than 70% of the assemblage. Among the Araucariaceae, *Cyclusphaera* is well represented (13%) and it is diversified in the species *C. psilata*, *C. radiata* and *C. crassa.* Within the species *Cyclusphaera psilata* several forms with a very narrow equatorial thickening, previously included as *Cyclusphaera* morphotype 2 (Vallati, 1993) were identified (Figures 5M-N).

The spores of Bryophyta, Lycophyta and Pteridophyta are subrepresented in the assemblage (near 10%) but they are diversified in several genera as *Gleicheniidites*, *Cicatricosisporites*, *Taurocusporites*, *Interulobites* and *Antulsporites* among others.

The angiosperm record includes a low participation (near 2%) of primitive monoaperturate grains. The following genera are recognized: *Retimonocolpites*, *Clavatipollenites*, *Stellatopollis*, *Tucanopollis*. The paleoequatorial marker *Tucanopollis crisopolensis* (Regali *et al*., 1974; Regali, 1989) is the most conspicuous angiosperm grain in this palynoflora from the center of Chubut province. This record represents the southernmost register of the taxon.

Specimens with circular (Figures 6 A ,D, G) as well as oval sulcus (Figures 6 F, H) are registered, and a tendency to

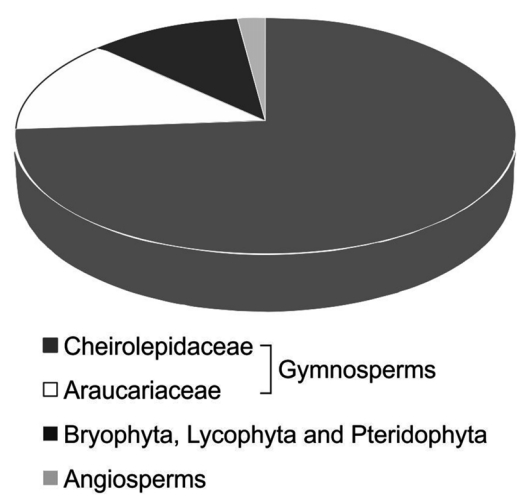

Figure 4. Diagram illustrating the relative abundances of the identified taxonomic groups.

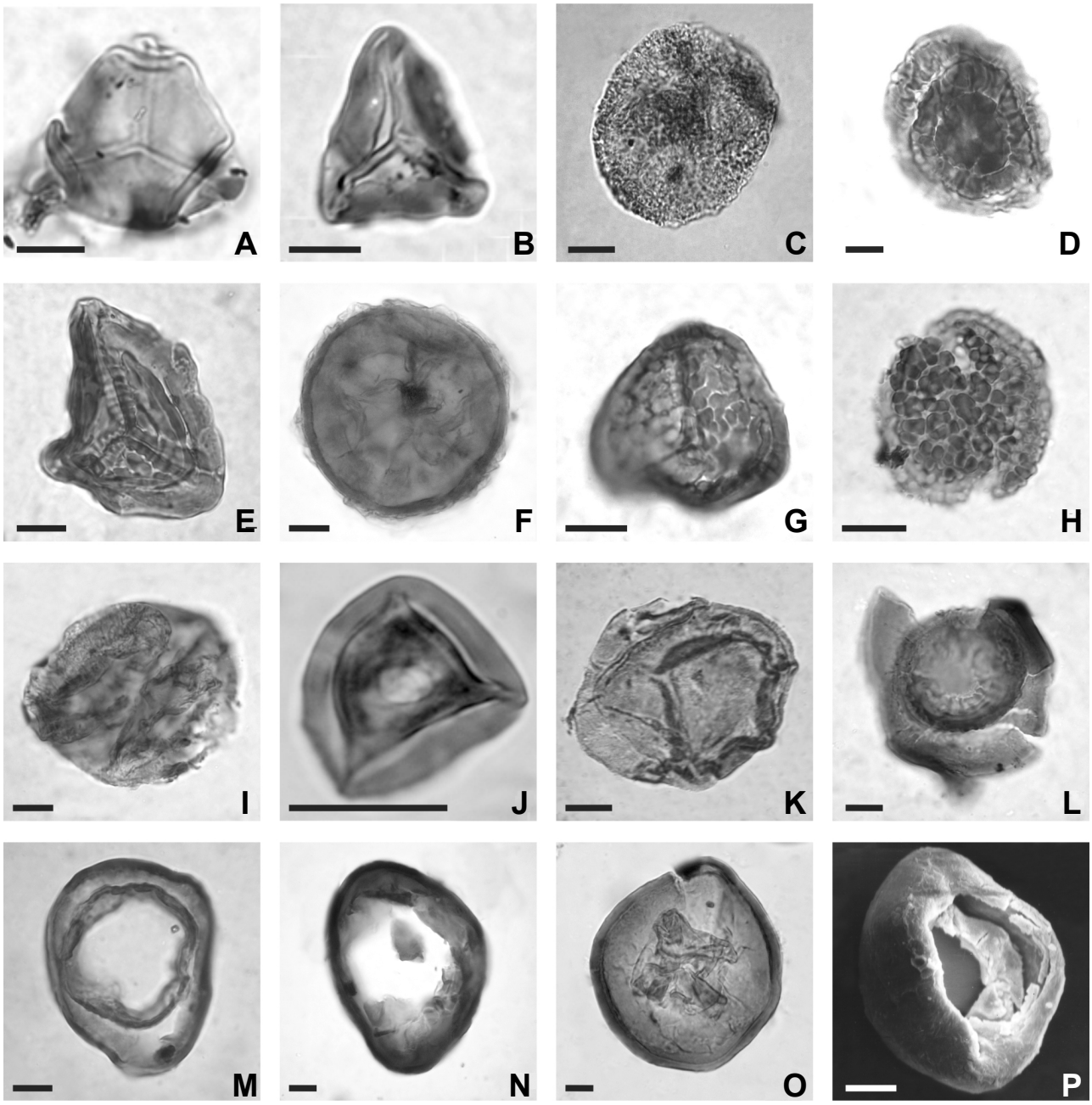

Figure 5. Some selected spores and gymnosperm pollen grains from D-129 palynoflora. In parenthesis are the slide number and the coordinates. **A**, *Cibotiumspora jurienensis* (Balme, 1957) Filatoff, 1975(CR.P.CV CCh7 22/110). **B**, *Gleicheniidites senonicus* (CR.P.CV CCh8 24/100). **C**, *Foraminisporis microgranulatus* (CR.P.CV CCh4u 15/92). **D**, *Taurocusporites* sp. (CR.P. CV CCh4d 4/99). **E**, *Taurocusporites segmentatus* (CR.P.CV CCh4w 11.5/104). **F**, *Densoisporites corrugatus* (CR.P.CV CCh9 1/109). **G**, *Interulobites intraverrucatus* (CR.P.CV CCh4 7.5/97). **H**, *Verrucosisporites* sp. (CR.P.CV CCh4d 22/90) distal view. **I**, *Podocarpidites* cf. *futa* (CR.P.CV CCh4b 3/96). **J**, *Classopollis*? sp. (CR.P.CV CCh4 8/99). **K**, *Araucariacites australis* (CR.P.CV CCh4b 22/86). **L**, *Cyclusphaera radiata* (CR.P.CV CCh4b 21.5/74). **M**, *Cyclusphaera psilata* (CR.P.CV CCh4b 15/99). **N**, *Cyclusphaera psilata* (CR.P.CV CCh4 14/97). **O**, *Balmeiopsis limbatus* (CR.P.CV CCh4u 7.5/87). **P**, *Cyclusphaera psilata* SEM image. Scale bars = 10 µm.

sexine detachment is observed in some specimens.

A piperalean affinity for *Tucanopollis* grains has been suggested taking into account pollen morphology (Friis *et al.*, 2010, 2011). In situ *Tucanopollis*-type grains have been reported on Early Cretaceous fruits of *Appomattoxia* of probable piperalean affinity (Friss *et al*., 2011).

Likewise, the monosulcate *Stellatopollis*, of uncertain affinity (Friis *et al.*, 2010), is another interesting Early to mid-Cretaceous angiosperm pollen grain recorded in D-129 assemblage. Other angiosperm taxa represented are the Chloranthaceae with the pollen type *Clavatipollenites hughesii* and *Retimonocolpites*-type grains which are suggested to represent the Monocotyledons.

Podocarpaceaen pollen is very rare and the plicate grains of the Ephedraceae, that appear well diversified in other Cretaceous patagonian palynofloras (Vallati, 1995, 2010), were not recognized in the present assemblage.

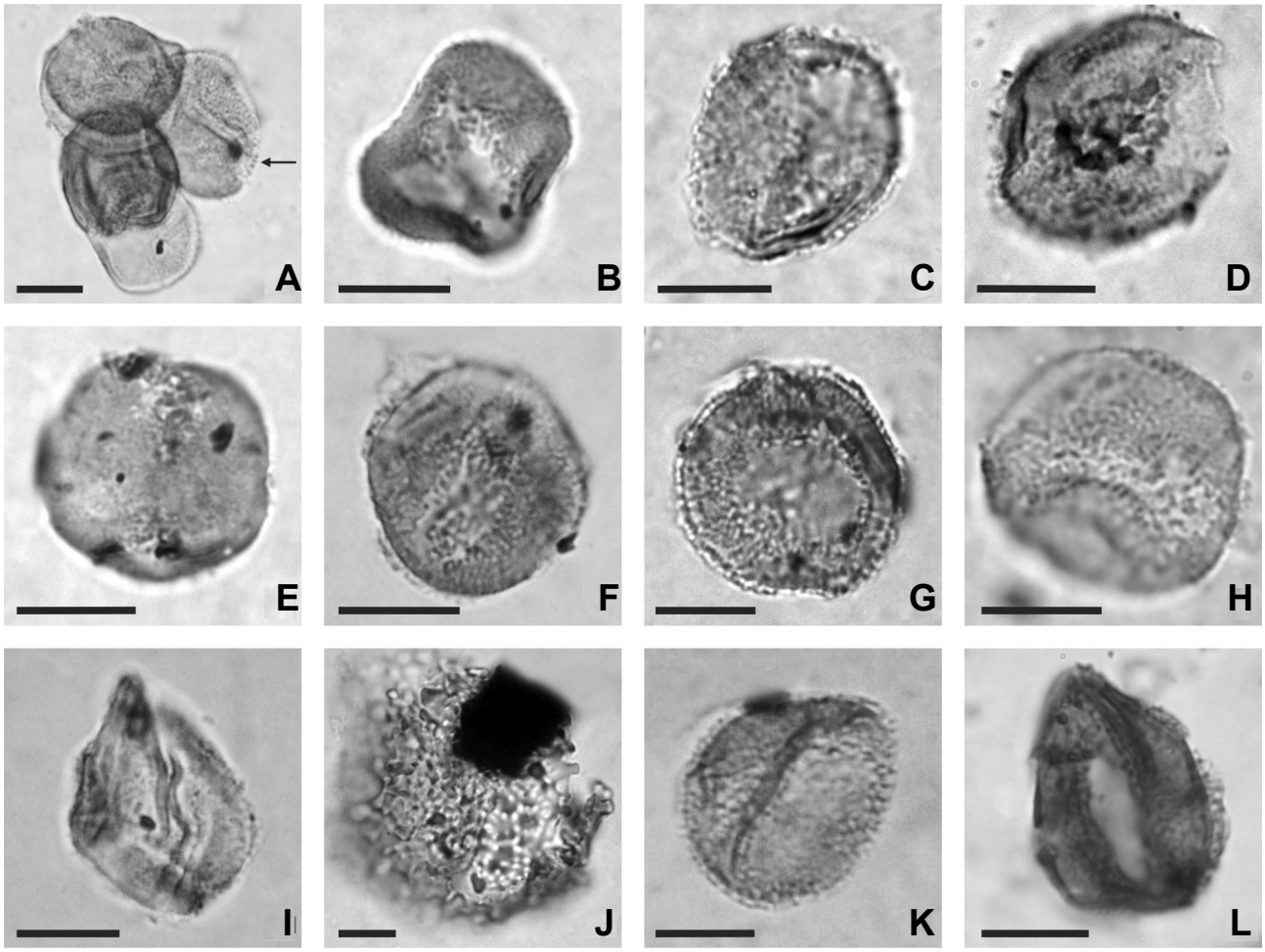

Figure 6. Angiosperm pollen grains from D-129 Formation. In parenthesis are the slide number and the coordinates. **A**, *Tucanopollis crisopolensis* (CR.P.CV CCh4d1 2/105) tetrad with visible circular aperture indicated by an arrow; **B**, *T. crisopolensis* (CR.P.CV CCh4d 4/104); **C**, *T. crisopolensis* (CR.P.CV CCh4b 23/87.5); **D**, *T. crisopolensis* (CR.P.CV CCh4b 2/96); **E**, *T. crisopolensis* (CR.P.CV CCH4b 18/99); **F**, *T. crisopolensis* (CR.P.CV CCh4c 8.5/85.7); **G**. *T. crisopolensis* (CR.P.CV CCh4e 20/110); **H**,*T. crisopolensis* (CR.P.CV CCh4i 12/94). **I**, *Retimonocolpites* sp. (CR.P.CV CCh4e 3/84). **J**, *Stellatopollis* sp. (CR.P.CV CCh4i 10/96). **K**, *Clavatipollenites hughesii* (CR.P.CV CCh4a 16/85). **L**, *Retimonocolpites*? sp. (CR.P.CV CCh4d 22/102). Scale bars = 10 µm.

The few specimens of *Botryococcus* (Botryococcaceae) and *Ovoidites* (Zygnemataceae) indicate a very low participation of the phytoplankton algae in this palynoflora from the uppermost part of the D-129 lake.

Taxonomic comments on the species *Tucanopollis crisopolensis*

The generic position of this taxon has changed several times since its original description as *Inaperturopollenites crisopolensis* by Regali *et al*., 1974. It was later included in the genus *Clavatipollenites* (Regali, 1987) and finally Regali (1989) created the genus *Tucanopollis* with *T. crisopolensis* as its type species. The later was based on dispersed pollen from the Early Cretaceous of Brazil. Subsequently, Dino (1994) revised this assignment and taking into account close morphological similarities concluded that *Tucanopollis* Regali, 1989 was a younger synonym of *Transitoripollis* Góczán & Juhász, 1984, a genus based on dispersed pollen from the Early Cretaceous of Hungary.

More recently, *Tucanopollis* is treated by some authors as a separate genus from *Transitoripollis*, arguing that, despite the similarity in morphology and wall structure exhibited by the two taxa, the circular aperture is a feature only known in *Tucanopollis* (Schrank & Mamhoud, 2002; Friis *et al.*, 2011).

Pollen grains of *Tucanopollis crisopolensis* presenting circular apertures are herein reported from the uppermost levels of D-129 Formation.

BIOSTRATIGRAPHY AND CORRELATION

Tucanopollis crisopolensis (Regali *et al.,* 1974) Regali, 1989 has been previously reported from the Barremian to early Aptian of South America (Brazil) and Gabon, Congo and Egypt (Africa) (Doyle *et al*., 1977; Regali, 1989; Herngreen *et al.*, 1996; Schrank & Mahmoud, 2002), where it represents one of the most primitive angiosperm records. The species *Tucanopollis* cf. *crisopolensis* from the upper Barremian of Egypt (Schrank & Mahmoud, 2002) and *Tucanopollis* aff. *crisopolensis* from the Aptian of Portugal (Heimhofer *et al*., 2007) present both a subrectangular aperture that seems comparable to the one illustrated in Figure 6 C.

Tucanopollis? sp. was reported from the Aptian La Cantera Formation, San Luis Basin, Argentina, where it is associated to *Afropollis* spp., *Clavatipollenites* and *Asteropollis* (Prámparo *et al.*, 2007).

The species figured as *Stellatopollis* sp. is best compared to *Stellatopollis dejaxii* which was first described from subsurface samples of the upper Barremian of the Western Desert, Egypt (Ibrahim, 2002). The poor preservation of the two specimens recognized in D-129 assemblage prevents a more precise assignment.

Patagonian Cretaceous palynofloras previously studied by the author in the area of the Chubut River valley, Chubut Province, include the neocomian Albornoz Formation at Cerro Guadal and the basal levels of Los Adobes Formation at Sierra de la Manea (Vallati, 1993, 2001). Both units include palynofloras of a clear austral character with *Cyclusphaera psilata* and *Microcachryidites antarcticus* among other taxa. No angiosperm grains were reported from the studied assemblages.

On the other hand, the Aptian Ranquiles palynoflora (Vallati 2002, 2006) from Bajada del Agrio in the Neuquén Basin, northern Patagonia, includes diversified angiosperm pollen types of the *Afropollis zonatus* Zone. The absence of *Afropollis* in D-129 Formation can be interpreted in evolutive terms, considering that the appearance of this taxon postdates the first record of *Tucanopollis crisopolensis* in Brazil and Africa (Doyle *et al*., 1982). Ecological conditions not conducive to the growth of *Afropollis* parent plants at the latitude of the present studied levels need to be analyzed taking into account the report of *Afropollis* and the close taxon *Schrankipollis* from an austral Patagonian microflora of mixed character (Barreda *et al*., 2006). The older zone of *Foraminisporis variornatus*, that underlies the mentioned *Afropollis* assemblage in the same profile of Bajada del Agrio, does not include angiosperms (Vallati, 2001, 2002).

The presence of *Tucanopollis* in D-129 microflora seems to point out an intermediate age between the palynological zones of *Foraminisporis* cf. *F. variornatus* (late Barremian) and *Afropollis zonatus* (Aptian). Both mentioned units are suggested to be separated in between by a biostratigraphic "hiatus" at the Huitrín-Rayoso Group in the Neuquén Basin, probably related to the initial phase of the Miranic tectonic movements (Vallati, 2001, 2006).

Besides, the present pollen assemblage shares with assemblages from the Aptian Baqueró Group of the Santa Cruz Province the presence of primitive angiosperm pollen grains (*Clavatipollenites*, *Retimonocolpites*) and other significant palynomorphs as *Antulsporites baculatus* and *Cyclusphaera crassa* (Archangelsky *et al*., 1984; Llorens, 2003). However, the primitive marker *Tucanopollis* was not reported from the Baqueró Group palynofloras. Lately, a late Aptian age was suggested for the Punta del Barco Formation, the upper unit of the mentioned group, based on radiometric analysis (Césari *et al*., 2011).

From the same Austral Basin, an Aptian palynoflora with *Clavatipollenites* was recently reported from the upper levels of the Río Mayer Formation in the Santa Cruz Province (Perez Loinaze *et al.*, 2012).

The D-129 assemblage, with subordinate angiosperms and clearly dominated by gymnosperms, corresponds to the stage I of angiosperm evolution proposed by Archangelsky *et al.* (2009) for Cretaceous floras of southern South America.

From the above mentioned considerations the pollen assemblage suggests a late Barremian?/early Aptian age for D-129 Formation at Sierra Silva. Besides, the calcareous microfossils studied by Musacchio for these same levels suggest an Aptian age, without discarding a late Barremian age (Musacchio *in* Hechem *et al*., 1987; Musacchio *pers.com*.).

PALEOBIOGEOGRAPHICAL AND PALEOECOLOGICAL CONSIDERATIONS

Gondwanan affinities are relevant. The presence of *Tucanopollis crisopolensis* and *Stellatopollis* sp. suggests warm climatic conditions as well as interchange with Brazil and Africa. Affinities with South Africa and Brazil are suggested by the ostracod fauna recovered from the same levels with the present palynoflora. In particular, some species of *Pattersoncypris* and *Danielocandona* are emphasized (Musacchio, *pers. com*.).

The D-129 palynoflora includes the southernmost report of *Tucanopollis crisopolensis* and *Stellatopollis*, two characteristic components of equatorial palynofloral provinces (Herngreen *et al*., 1996). Besides, this palynoflora, practically barren of plicate and saccate grains, and with a conspicuous presence of the Cheirolepidaceae (*Classopollis*) and endemic araucariacean pollen (mainly *Cyclusphaera*) suggests mixed floristic character.

Other Cretaceous palynofloras from Patagonia have yielded assemblages suggesting transitional conditions. Among these, the Aptian Ranquiles Formation (Huitrín-Rayoso Group) and middle and Late Cretaceous formations (Neuquén Group) in the Neuquén Basin as well as the Albian Kachaique Formation in the Austral Basin. All of them include pollen grains endemic and/or typical in Cretaceous northern Gondwana phytoprovinces as *Afropollis* spp., *Schrankipollis*, *Elateroplicites africaensis*, *Confossia vulgaris*, *Cretacaeiporites* spp., *Tricesticillus* with different levels of participation within the corresponding assemblages (Vallati, 2002, 2006, 2010; Barreda & Archangelsky, 2006).

As it was already pointed out the D-129 assemblage is dominated by the thermophilous genus *Classopollis* with a subordinated participation of araucariacean pollen and the Podocarpaceae represented by few specimens of bisaccate pollen grains. Similar characteristics can be found in the Early-mid Cretaceous palynofloras of the Equatorial Region, where the climatic conditions were interpreted as warm and arid or semiarid. However, plicate pollen of Gnetophyta affinity, abundant in northern gondwanan palynofloras (Herngreen *et al.*, 1996) and well diversified in cretaceous palynofloras from northern Patagonia (Vallati, 2006, 2010), is not found in the D-129 assemblage.

CONCLUSIONS

Primitive angiosperm grains characterize the palynoflora from the uppermost part of D-129 Formation outcropping at Sierra Silva, in the center of Chubut Province.

The mixing of taxa from different paleofloristic regions is suggested by the presence of conspicuous paleoequatorial palynomorphs as *Tucanopollis crisopolensis* and *Stellatopollis* along with typical austral pollen as *Cyclusphaera psilata* as well as other coniferous pollen grains (Herngreen *et al*., 1996; Archangelsky & del Fueyo, 2010). *Tucanopollis crisopolensis*, which represents one of the oldest records of angiosperms in Brazil and Africa, is the best represented species in the angiosperm assemblage of the present lacustrine deposit in central Patagonia. The later is up to the present the southernmost record of this pollen species.

The D-129 palynoflora is assigned to a late Barremian?/ early Aptian interval taking into account the chronological significance of some pollen species. Its stratigraphic position is intermediate between the Barremian Zone of *Foraminisporis* cf. *variornatus* and the Aptian Zone of *Afropollis zonatus* in the oil producing Neuquén Basin.

ACKNOWLEDGEMENTS

This article is dedicated to the memory of E.A. Musacchio, who throughout his scientific career has contributed greatly to the knowledge of the micropaleontology and biostratigraphy of Mesozoic basins of Patagonia. This author will always be grateful for his constant support and encouragement in the development of her activity. Thank to M. Quatrocchio, L. Antonioli and J. Dejax whose comments and suggestions as reviewers of this contribution have undoubtedly improved the original manuscript, as well as C.C. Lana for her kind assistance and advices.

REFERENCES

Archangelsky, S.; Baldoni, A.; Gamerro, J.C. & Seiler, J. 1983. Palinología estratigráfica del Cretácico de Argentina austral II. Descripciones sistemáticas. *Ameghiniana*, **20**:199-226.

Archangelsky, S.; Baldoni, A.; Gamerro, J.C. & Seiler, J. 1984. Palinología estratigráfica del Cretácico de Argentina austral III. Distribución de las especies y conclusiones. *Ameghiniana*, **21**:15-33.

Archangelsky, S.; Barreda, V.; Passalia, M.; Gandolfo, M.; Prámparo, M.; Romero, E.; Cúneo, R.; Zamuner, A.; Iglesias, A.; Llorens, M.; Puebla, G.; Quattrocchio, M. & Volkheimer, W. 2009. Early angiosperm diversification: evidence from southern South America. *Cretaceous Research*, **30**:1073-1082. *doi: 10.1016/j.cretres.2009.03.001*.

Archangelsky, S. & del Fueyo, G. 2010. Endemism of Early Cretaceous Conifers in Western Gondwana. *In*: C.T. Gee (ed.). *Plants in Mesozoic Time: Innovations, Phylogeny, Ecosystems*. Indiana University Press, p. 247-268.

Barcat, C.; Cortiñas, J.S.; Nevistic, V.A. & Zucchi H. E. 1989. Cuenca Golfo San Jorge. *In*: G. Chebli & L. Spalletti (eds.). *Cuencas sedimentarias argentinas*, Serie de Correlación Geológica 6, p. 319-345.

Barreda, V. & Archangelsky, S. 2006. The southernmost record of tropical pollen grains in the mid-Cretaceous of Patagonia, Argentina. *Cretaceous Research*, **27**:778-787. *doi:10.1016/j.cretres.2006.02.002*.

Casal, G.R.; Martínez, M.; Luna, J.C.; Sciutto J.C. & Lamanna, M. 2007. *Aeolosaurus colhuehuapensis* sp. nov. (Sauropoda, Titanosauria) de la Formación Bajo Barreal, Cretácico Superior de Argentina. *Revista Brasileira de Paleontologia*, **10**:53-62. *doi:0.4072/rbp.2007.1.05*

Césari, S.N.; Limarino, C.O.; Llorens, M.; Passalia, M.; Loinaze, V.P. & Vera, E.I. 2011. High-precision late Aptian Pb/U age for the Punta del Barco Formation (Baqueró Group), Santa Cruz Province, Argentina. *Journal of South American Earth Sciences*, **31**:426-431. *doi:10.1016/j.jsames.2011.03.012*.

Dino, R. 1994. Some new pollen grain species from Lower Cretaceous in northeastern Brasil. *Boletim de Geociências da Petrobras*, **8**:257-273.

Doyle, J.A.; Biens, P.; Doerenkamp, A. & Jardiné, S. 1977. Angiosperm pollen from the Pre-Albian of equatorial Africa. *Bulletin des Centres Rechearches Exploralion Production Elf-Aquitaine*, **1**:451-473.

Doyle, J.A.; Jardiné, S. & Doerenkamp, A. 1982. *Afropollis*, a new genus of angiosperm pollen, with notes on the Cretaceous palynostratigraphy and paleoenvironments of Northern Gondwana. *Bulletin des Centres Recherches Exploration Production Elf-Aquitaine*, **6**:39-117.

Feruglio, E. 1949. Chubutense. *In*: *Descripción Geológica de la Patagonia*, Imprenta y Casa Editora Coni, 1, p. 1-6.

Fitzgerald, M. G.; Mitchum, R. M.; Uliana, M. A. & Biddle, T.K. 1990. Evolution of the San Jorge Basin, Argentina. *Bulletin of American Association Petroleum Geologists*, **74**:789-929.

Friis, E.M.; Crane, R. & Pedersen, K.R. 2011. *Early Flowers and Angiosperm Evolution*. Cambridge University Press, 596 p.

Friis, E.M.; Pedersen, K.R. & Crane, P.R. 2010. Diversity in obscurity: fossil flowers and the early history of angiosperms. *Philosofical Transactions of the Royal Society*, **365**:369-382. *doi:10.1098/rstb.2009.0227*

Góczán, F. & Juhász, M., 1984. Monosulcate pollen grains of angiosperms from Hungarian Albian sediments, I. *Acta Botanica Hungarica*, **30**:289-319.

Hechem, J.J.; Figari, E.G. & Musacchio, E. A. 1987. Hallazgo de la Formación Pozo Diadema 129 en superficie: información estratigráfica y paleontológica en la Cuenca del Golfo San Jorge. *Petrotecnia*, **28**:13-15.

Heimhofer, U.; Hochuli, P.A.; Burla, S. & Weissert, H. 2007. New records of Early Cretaceous angiosperm pollen from Portuguese coastal deposits: implications for the timing of the early angiosperm radiation. *Review of Palaeobotany and Palynology*, **144**:39-76. *doi:10.1016/j.revpalbo.2005.09.006.*

Herngreen, G.F.W.; Kedves, M.; Rovnina, L.V. & Smirnova, S.B. 1996. Cretaceous palynofloral provinces: a review. *In*: J. Jansonius & D.C. McGregor, D.C. (eds.) *Palynology: principles and applications*, American Association of Stratigraphic Palynologists Foundation, **3**:1157-1188.

Ibrahim, M.I.A. 2002. New angiosperm pollen from the Upper Barremian-Aptian of the Western Desert, Egypt. *Palynology*, **26**:107-133.

Lesta, P.J. 1968. Estratigrafía de la Cuenca del Golfo San Jorge. *In*: JORNADAS GEOLÓGICAS ARGENTINAS, 3, 1968. *Proceedings*, 1, p. 251-289.

Llorens, M., 2003. Granos de polen de angiospermas de la Formación Punta del Barco (Aptiano), provincia de Santa Cruz, Argentina. *Revista del Museo Argentino de Ciencias Naturales*, **5**:235-240.

Martinez, R. & Novas, F.E. 2006. *Aniksosaurus darwini* gen. et sp. nov., a new coelurosaurian theropod from the Early Late Cretaceous of Central Patagonia, Argentina. *Revista del Museo Argentino de Ciencias Naurales*, **8**:243-259.

Perez Loinaze, V.S.; Archangelsky, S. & Cladera, G. 2012. Palynostratigraphic study of the Early Cretaceous Río Mayer and Kachaike formations at the Quebrada El Moro Section, Austral Basin, southwestern Argentina. *Cretaceous Research*, **34**:161-171. *doi:10.1016/j.cretres.2011.10.015*.

Prámparo, M.B.; Quatrocchio, M.; Gandolfo, M.A.; Zamaloa, M.C. & Romero, E. 2007. Historia evolutiva de las angiospermas (Cretácico-Palógeno) en Argentina a través de los registros paleoflorísticos. *Ameghiniana 50º Aniversario*, p. 157-172.

Regali, M.S.P. 1987. Palinomorfos do Barremiano/Albiano brasileiro. *In*: CONGRESSO BRASILEIRO DE PALEONTOLOGIA, 10, 1987. *Anais*, Rio de Janeiro, 2, p. 637-645.

Regali, M.S.P. 1989. *Tucanopollis*, a new genus of early angiosperms. *Boletim Técnico Petrobras*, **3**:395-402.

Regali, M.S.P.; Uesugui, N. & Santos, A. S. 1974. Palinologia dos sedimentos meso-cenozoicos do Brasil (II). *Boletim Tecnico da Petrobras*, **17**:263-301.

Schrank, E. & Mahmoud, M.S. 2002. Barremian Angiosperm pollen and associated palynomorphs from the Dakhla Oasis area, Egypt. *Palaeontology*, **45**:33-56.

Sylwan, C.A. 2001. Geology of the Golfo San Jorge Basin, Argentina. *Journal of Iberian Geology*, **27**:123-157.

Vallati, P. 1993. Palynology of the Albornoz Formation (Lower Cretaceous) in the San Jorge Gulf Basin (Patagonia, Argentina), *Neues Jahrbuch für Geologie und Paläontologie. Abhandlungen*, **187**:345-373.

Vallati, P. 1995. Presencia de *Afropollis* (Polen de Angiosperma) en el Cretácico Inferior de la Cuenca Neuquina. *In*: CONGRESO ARGENTINO DE PALEONTOLOGÍA Y BIOESTRATIGRAFÍA, 4, 1995. *Actas*, Trelew, p. 277-290.

Vallati, P. 1996. Palynology of the D-129 Formation in the San Jorge Gulf Basin, Lower Cretaceous, Patagonia, Argentine. *In*: CONGRESO BRASILEIRO DE GEOLOGIA, 39, 1996. *Anais*, 7, Salvador, p. 423-426.

Vallati, P. 2001. *Bioestratigrafía (Palinología) del Cretácico temprano y medio en Patagonia septentrional y central*. Universidad Nacional de la Patagonia San Juan Bosco, Ph.D. thesis, 278 p.

Vallati, P. 2002. Asociaciones palinológicas en el Cretácico temprano y medio de Patagonia septentrional: algunas consideraciones paleobiogeográficas. *In*: SIMPOSIO SOBRE EL CRETÁCICO DE AMÉRICA DEL SUR, 2, 2002. *Resumos expandidos*, São Pedro, UNESP, p. 57-161.

Vallati, P. 2006. Las primeras angiospermas en el Cretácico de la Cuenca Neuquina (centro-oeste de Argentina): aspectos geológicos relacionados. *Revista Brasileira de Paleontologia*, **9**:83-92.

Vallati, P. 2010. Asociaciones palinológicas con angiospermas en el Cretácico Superior de la Cuenca Neuquina, Argentina. *Revista Brasilera de Paleontologia*, **13**:143-158. *doi:10.4072/rbp.2010.2.07*

Van Nieuwenhuise, D.S. & Ormiston, A.R. 1988. A model for the origen of source-rich lacustrine facies, San Jorge Gulf Basin, Argentina: *In*: CONGRESO NACIONAL DE EXPLORACIÓN DE HIDROCARBUROS, 1, 1988. *Actas*, Mar del Plata, p.852-871.

Received in August, 2012; accepted in May, 2013.

Appendix. Complete taxonomic list of palynomorph species recognized in D-129 Formation.

Bryophyta, Lycophyta and Pteridophyta
Antulsporites baculatus (Archangelsky & Gamerro, 1966) Archangelsky & Gamerro, 1967
Biretisporites sp.1 Vallati, 2001
Cicatricosisporites hughesi ? Dettmann, 1963
Cibotiumspora jurienensis (Balme, 1957) Filatoff, 1975 (Figure 5A)
Densoisporites corrugatus Archangelsky & Gamerro, 1965 (Figure 5F)
Foraminisporis microgranulatus Archangelsky, 1983 (Figure 5C)
Foraminisporis sp. (Figure 5H)
Gleicheniidites senonicus Ross, 1949 (Figure 5B)
Interulobites intraverrucatus (Brenner, 1963) Phillips, 1971 (Figure 5G)
Interulobites sp. cf. *Interulobites* sp. Archangelsky, 1983
Laevigatosporites sp.
Taurocusporites segmentatus Stover, 1962 (Figure 5E)
Taurocusporites sp. (Figure 5D)
Gymnosperms
Araucariacites australis Cookson, 1947 (Figure 5K)
Balmeiopsis limbatus (Balme, 1957) Archangelsky, 1977 (Figure 5O)
Classopollis classoides (Pflug, 1953) Pocock & Jansonius, 1961
Classopollis simplex (Danzé-Corsin & Laveine, 1963) Reiser & Williams, 1969
Classopollis sp. (Figure 5J)
Cyclusphaera psilata Volkheimer & Sepúlveda, 1976 (Figure 5M-N,P)
Cyclusphaera crassa Archangelsky *et al*., 1983
Cyclusphaera radiata (Archangelsky *in* Archangelsky *et al*., 1983) Archangelsky, 2012 (Figure 5L)
Cycadopites nitidus (Balme, 1957) de Jersey, 1964
Podocarpidites cf. *futa* Archangelsky & Villar de Seoane, 2005 (Figure 5I)
Angiosperms
Clavatipollenites hughesii (Couper, 1958) Kemp, 1968 (Figure 6K)
Retimonocolpites sp. (Figure 6I)
Retimonocolpites sp. Vallati, 2006
Retimonocolpites? sp. (Figure 6L)
Stellatopollis sp. (Figure 6J)
Tucanopollis crisopolensis (Regali *et al.,* 1974) Regali, 1989 (Figure 6A-H)
Phytoplancton
Botryococcus sp.
Ovoidites sp.