

FIRST REPORT OF A MAASTRICHTIAN PALYNOFLORA FROM THE GOLFO SAN JORGE BASIN, CENTRAL PATAGONIA, ARGENTINA

PATRICIA VALLATI
GABRIEL CASAL
NICOLÁS FOIX
JOSÉ ALLARD
ANDREA DE SOSA TOMAS
MARCOS CALO

Departamento de Geología, Facultad de Ciencias Naturales, Universidad Nacional de la Patagonia San Juan Bosco, Ciudad Universitaria, Km. 4 s/n, 9000 Comodoro Rivadavia, Argentina.

Submitted: August 22nd, 2015 - Accepted: December 28th, 2015

To cite this article: Patricia Vallati, Gabriel Casal, Nicolás Foix, José Allard, Andrea De Sosa Tomas, and Marcos Calo (2016). First report of a Maastrichtian palynoflora from the Golfo San Jorge Basin, central Patagonia, Argentina. *Ameghiniana* 53: 495–505.

To link to this article: <http://dx.doi.org/10.5710/AMGH.28.12.2015.2948>

PLEASE SCROLL DOWN FOR ARTICLE

Also appearing in this issue:

MARSUPIAL DIMORPHISM

Morphometric data suggest two species of *Acdestis* from the Miocene of Patagonia represent a single sexually dimorphic species.

ANTARCTIC BIVALVES

Morphometrics and growth lines indicate globoid morphotypes are gerontic specimens in Eocene and living species of *Retrotapes*.

CRETACEOUS PALYNOFLORA

Palynoflora of the Maastrichtian Colhue Huapi Formation shows mixed paleotropical and austral components.

FIRST REPORT OF A MAASTRICHTIAN PALYNOFLORA FROM THE GOLFO SAN JORGE BASIN, CENTRAL PATAGONIA, ARGENTINA

PATRICIA VALLATI, GABRIEL CASAL, NICOLÁS FOIX, JOSÉ ALLARD, ANDREA DE SOSA TOMAS, AND MARCOS CALO

Departamento de Geología, Facultad de Ciencias Naturales, Universidad Nacional de la Patagonia San Juan Bosco, Ciudad Universitaria, Km. 4 s/n, 9000 Comodoro Rivadavia, Argentina. *patricia.vallati@gmail.com*; *paleogac@yahoo.com.ar*; *nicofoix@hotmail.com*; *joseoallard@yahoo.com.ar*; *adesosatomas@gmail.com*; *marcos.calo@outlook.com*

Abstract. This paper reports on the biostratigraphic, paleobiogeographic and paleoecologic aspects of palynoflora recovered from sedimentary rocks preliminarily assigned to the Lago Colhué Huapi Formation, in the Golfo San Jorge Basin. The present palynological assemblage includes Maastrichtian marker species of the austral *Proteacidites/Nothofagidites* Province such as *Quadraplanus brossus* and *Tubulifloridites lilliei*. Typical species of the Maastrichtian paleotropical Palmae Province, *Buttinia andreevi* and *Gabonispuris vigourouxii*, are also recognized in the palynoflora. These facts indicate the mixed character of the paleoflora and the prevalence of transitional climatic conditions at the paleolatitude of the Chubut Province in the uppermost Cretaceous. The palynoflora composition suggests the local existence of a warm and low energy freshwater body.

Key words. Palynology. Maastrichtian. Paleobiogeography. Golfo San Jorge Basin. Chubut.

Resumen. PRIMER REPORTE DE UNA PALINOFLORA MAASTRICHTIANA EN LA CUENCA DEL GOLFO SAN JORGE, PATAGONIA CENTRAL, ARGENTINA. Este artículo informa sobre los aspectos bioestratigráficos, paleobiogeográficos y paleoecológicos de una palinoflora recuperada de rocas sedimentarias asignadas de forma preliminar a la Formación Lago Colhué Huapi, en la Cuenca del Golfo San Jorge. La asociación palinológica incluye especies marcadoras del Maastrichtiano de la Provincia austral *Proteacidites/Nothofagidites*, como *Quadraplanus brossus* y *Tubulifloridites lilliei*. También se reconocen en la palinoflora especies típicas del Maastrichtiano de la Provincia paleotropical Palmae como *Buttinia andreevi* y *Gabonispuris vigourouxii*. Estos hechos indican el carácter mixto de la paleoflora y la prevalencia de condiciones climáticas transicionales en la paleolatitude de la Provincia de Chubut. La composición de la palinoflora sugiere la presencia local de un cuerpo de agua dulce templada y de baja energía.

Palabras clave. Palinología. Maastrichtiano. Paleobiogeografía. Cuenca del Golfo San Jorge. Chubut.

THE productive Golfo San Jorge Basin is located in central Patagonia, between the Cañadón Asfalto Basin to the north and the Deseado Massif to the south (Allard *et al.*, 2015). It shows an elongated shape in the E–W direction and lies across both Chubut and Santa Cruz provinces. It includes a Late Jurassic to Cenozoic sedimentary filling with Cretaceous units involved in the main basin petroleum systems (Sylwan, 2001).

The palynoflora was recovered from sediments overlying an erosion surface at the top of the Lago Colhué Huapi Formation (Casal *et al.*, 2015) at the headwaters of the Río Chico (designated as the holostratotype of the unit) (Figs. 1, 2.1–3).

Several dinosaur remains, including hadrosaurids and titanosaurids, were identified from the Lago Colhué Huapi

Formation (see references in Casal *et al.*, 2015). Hadrosaurid remains, in particular, were recognized in levels close to the palynological site.

Previous Cretaceous palynological studies in the productive Golfo San Jorge Basin involve both subsurface and exposed units (Van Nieuwenhuise and Ormiston, 1988; Archangelsky *et al.*, 1984, 1994; Vallati, 2013a). Based on the stratigraphic distribution of selected species, Archangelsky *et al.* (1984) defined several palynological assemblages in the Lower Cretaceous (Berriasian–Aptian) of the basin. The Pozo D-129 Formation, which represents the main hydrocarbon source rock in the basin, includes late Barremian?–early Aptian palynoflora recovered from sediments exposed in the Sierra Silva. Such palynoflora, with primitive angiosperm pollen grains, includes the significant presence

of the paleotropical marker *Tucanopollis crisopolensis* (Regali *et al.*, 1974) Regali, 1989 (Vallati, 2013a). A middle Cretaceous microflora was previously reported from the Caleta Olivia Member of the Cañadón Seco Formation (subsurface of the Santa Cruz Province in the southern flank of the basin) by Archangelsky *et al.* (1994). This assemblage, for which an Albian–Cenomanian age was assigned, included eudicotyledonean angiosperms represented by tricolpate and tricolporoidate pollen grains.

The current study describes a younger palynoflora of biostratigraphic and paleobiogeographic interest. This assemblage represents the first report of a Maastrichtian palynoflora from the Golfo San Jorge Basin.

GEOLOGICAL SETTING

The Chubut Group (Lesta and Ferello, 1972), which represents the main sedimentary filling of the basin, is charac-

terized by Cretaceous lacustrine and fluvio-lacustrine deposits. In spite of intensive research, few biostratigraphically relevant fossils have been recovered from the Chubut Group in the Golfo San Jorge Basin. Calcareous microfossils reported by Musacchio (*in* Hechem *et al.*, 1987) and palynological studies performed by Vallati (2013a) suggest a late Barremian?–Aptian age for the basal Pozo D-129 Formation exposed at the Silva ranges.

The Lago Colhué Huapi Formation, widely distributed in the basin, is predominantly composed of reddish mudstones of fluvial origin. According to the position in the basin, the Lago Colhué Huapi Formation overlies the Bajo Barreal Formation and underlies the marine Danian Salamanca Formation or the tuffaceous levels of the Laguna Palacios Formation (Casal *et al.*, 2015). In the upper part of the Lago Colhué Huapi Formation, at the headwaters of the Río Chico, an erosion surface underlies sedimentary rocks in-

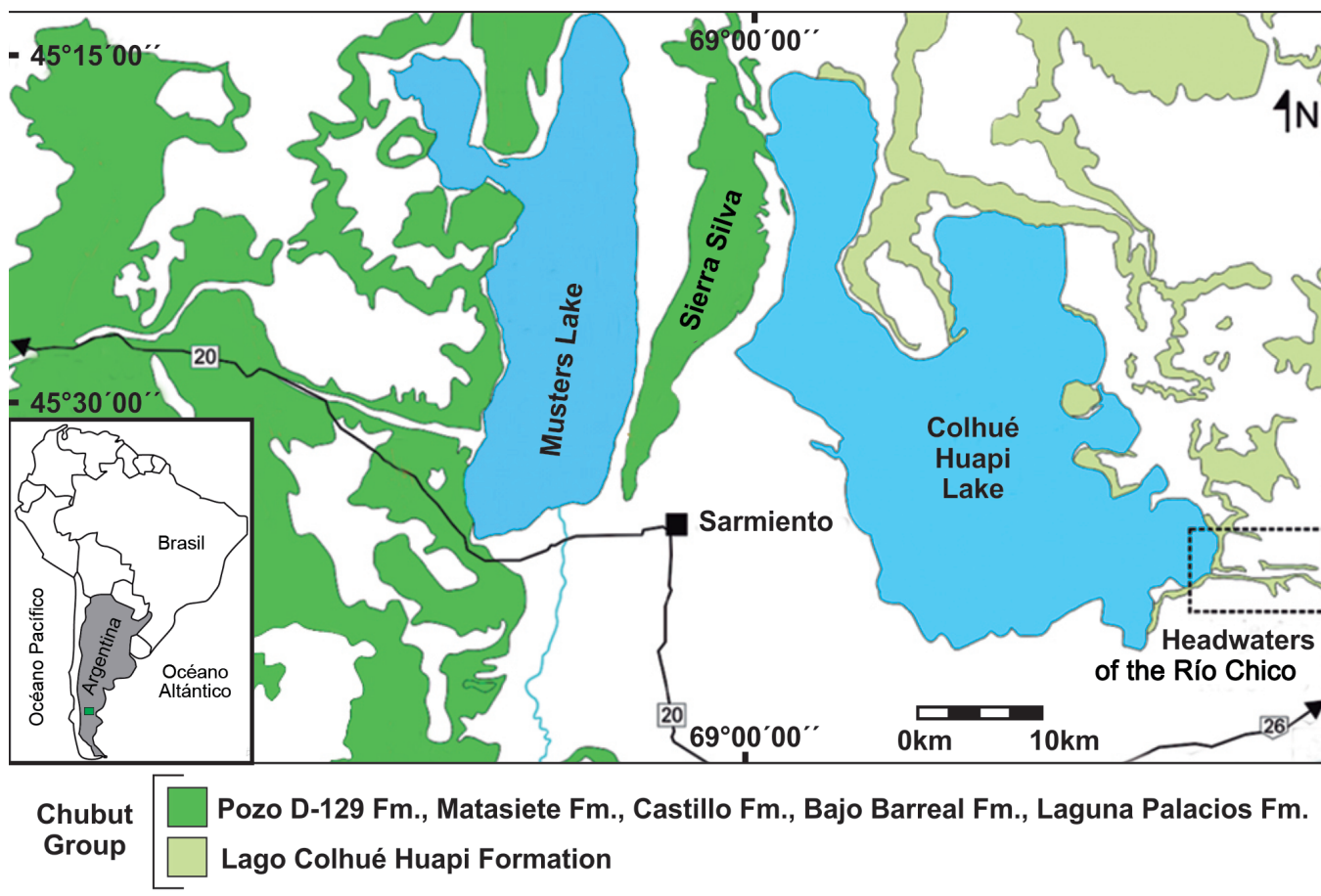


Figure 1. Location map of the studied locality in the Golfo San Jorge Basin (modified from Casal *et al.*, 2015).

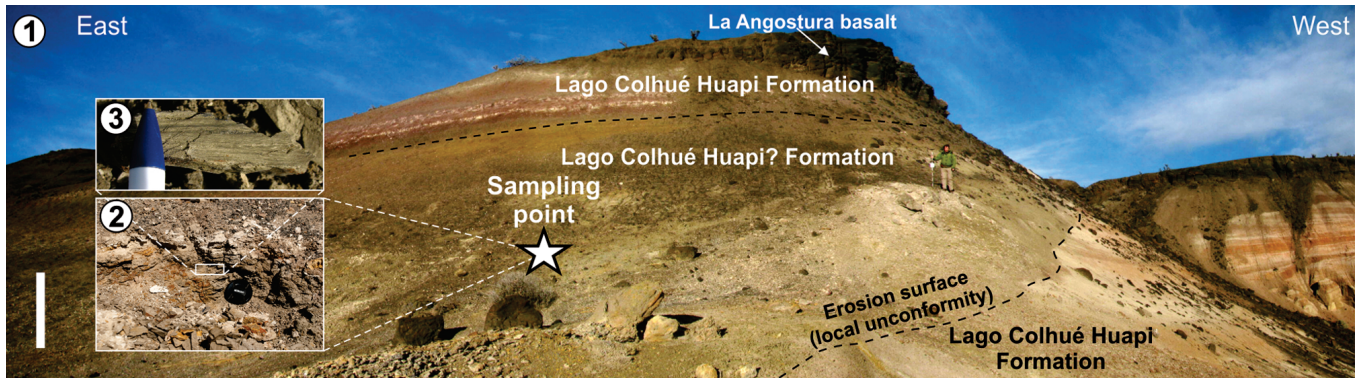


Figure 2. 1, Studied site at the headwaters of the Chico river; 2, Detail of a sampling point; 3, A fragment of the dark grey laminated siltstone. Scale bar= 3 m.

cluding the fertile levels (Lago Colhué Huapi? Formation, Fig. 2.1). Casal *et al.*, (2015) suggested that a comparable stratigraphic interval studied at this same locality could represent the lateral relationships between the uppermost part of the Chubut Group and the Salamanca Formation. At the headwaters of the Río Chico, a basalt flow with a radiometric age of 67.31 ± 0.55 Ma (La Angostura Basalt) lies on top of the Lago Colhué Huapi Formation (Clyde *et al.*, 2014) (Fig. 2.1).

MATERIALS AND METHODS

Five fertile samples were recovered from a 30 cm thick dark grey laminated siltstone. This bed overlies an erosion surface carved in the upper part of the Lago Colhué Huapi Formation, at the headwaters of the Río Chico ($45^{\circ} 37' S$, $68^{\circ} 26' W$) (Fig. 2.1–3).

The samples were processed following standard palynological methods including maceration with hydrochloric and hydrofluoric acids for carbonate and silicate removal. A brief oxidation of the residue with nitric acid was performed in order to improve the results. The organic residue was mounted on microscope slides using glycerine jelly. The samples were studied with a Carl Zeiss KF 2 microscope and the microphotographs were obtained with a digital Nikon Coolpix P2 camera at the Biostratigraphic Laboratory of the Universidad Nacional de la Patagonia San Juan Bosco. The relative abundance of palynomorphs mentioned in the analysis of the palynoflora was based on counts of 300 specimens.

The slides are stored in the micropaleontology collection

of the **UNPSJB** (Universidad Nacional de la Patagonia San Juan Bosco) under the initials **CR.P.CV**. The specimens are cited according to the corresponding slide identification followed by the coordinates of the Vernier Scale in the Zeiss Microscope.

PALYNOLOGICAL RESULTS

The studied samples yielded fairly well preserved palynomorphs. Twenty six spore and pollen species were recorded and additional taxa were identified to a genus rank (Appendix). The assemblage includes gymnosperm pollen grains (44%), angiosperm pollen grains (23%) and spores of Bryophyta, Lycophyta and Pteridophyta (17%) as well as algal forms (16%) (Fig. 3). The angiosperms include Proteaceae, with 5 species, as the most diversified taxonomic group.

The species *Catinipollis geiseltalensis* Krutzsch, 1966 (Fig. 4.11–12), of zygnetatalean affinity, was previously recorded in Danian sediments of the Golfo San Jorge Basin by Archangelsky and Zamalao (1986). Bowman *et al.* (2014) recorded very similar spores (identified as ?Zygnemataceae spore A) in the uppermost Cretaceous–lowermost Paleogene of the Antarctic Peninsula.

Non vascular plants are mainly represented by the species *Zlavisporis reticulatus* (Pocock, 1962) Pacltová and Simoncsics, 1970 (Fig. 4.9–10), which presents affinity with the Hepaticae. The Lycophyta include *Camarozonosporites* cf. *ohaiensis* (Couper, 1953) Dettmann and Playford, 1968 and the species of Selaginellaceae affinity *Ceratosporites equalis* Cookson and Dettmann, 1958 (Fig. 4.3). The Filicales are

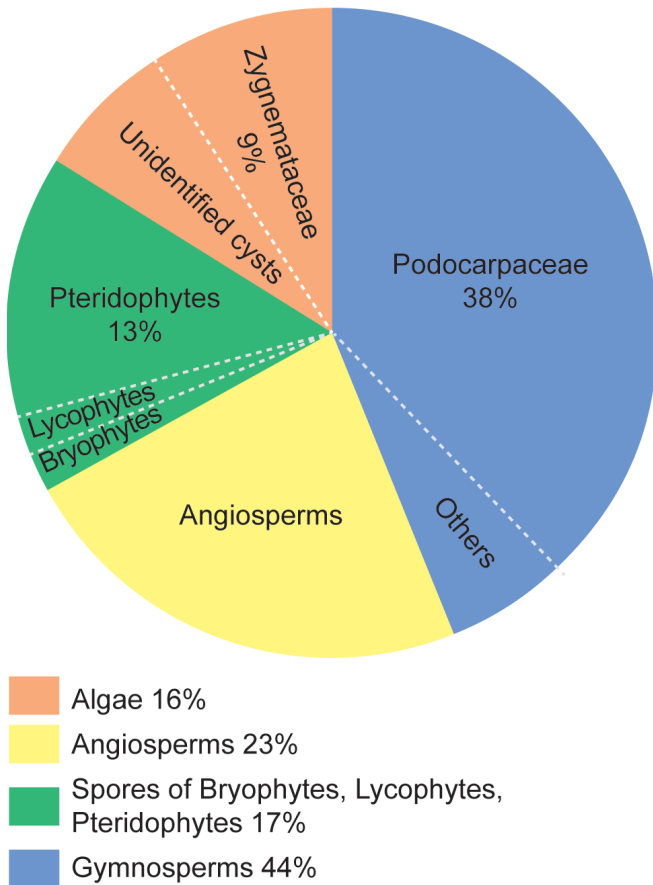


Figure 3. Diagram representing the percentages of the different taxonomic groups identified.

mainly represented by Cyatheaceae (*Cyathidites* sp.), Anemiaceae (*Cicatricosisporites* spp., Fig. 4.6–7; *Ruffordiaspora* sp., Fig. 4.8), Gleicheniaceae (*Gleicheniidites senonicus* Ross, 1949, Fig. 4.1) and the aquatic ferns Salviniales (*Azolla* spp., Fig. 4.13–15 and *Ariadnaesporites micromedusus* Stough, 1968, Fig. 4.16).

Conifers dominate the assemblage with abundant bisaccate and trisaccate pollen grains of the Podocarpaceae (38%). This family is represented by *Microcachrydites antarcticus* Cookson, 1947 (Fig. 5.4), *Podocarpidites* spp. (Fig. 5.7), *Rugubivesiculites* sp. (Fig. 5.8) and *Phyllocladidites mawsonii* Cookson, 1947 (Fig. 5.5–6). The latter species shows a close affinity to the pollen of the extant *Lagarostrobos franklinii* ("Huon pine"). The aforementioned extant taxon is restricted to the wet southwestern Tasmania, Australia, where it is usually found growing along rivers (Bowman *et al.*, 2014). Araucariaceae pollen is mainly represented by *Araucariacites australis* Cookson, 1947 (Fig. 5.2). Only one

specimen of the plicate pollen grain of Gnetophyta affinity, *Gnetaceapollenites barghoornii* Lima, 1980 (Fig. 5.3), was recognized in the present palynoflora. Pollen grains of Gnetophyta affinity are more diverse, with several species in other Late Cretaceous palynofloras from northern Patagonia (Vallati, 2013b).

Angiosperms are moderately diversified in the assemblage and mainly include monocolpate pollen grains of Liliaceae (*Liliacidites* cf. *kaitangataensis*, Fig. 6.2 and *Liliacidites regularis*, Fig. 6.1) and triporate and tricolpoidate pollen grains of Proteaceae. The latter family includes *Peninsulapollis gillii* (Cookson, 1957) Dettmann and Jarzen, 1988 (Fig. 6.14), *Peninsulapollis truswelliae* Dettmann and Jarzen, 1988 (Fig. 6.19), *Proteacidites scaboratus* Couper, 1960 (Fig. 6.17), *Beaupreaidites* cf. *elegansiformis* Cookson, 1950 (Fig. 6.16) and *Beaupreaidites orbiculatus* Dettmann and Jarzen, 1988 (Fig. 6.15). *Peninsulapollis gillii*, a species of probable proteaceous affinity, shares some morphological features with *Beauprea*, which is an extant genus endemic to the mountainous inland regions of New Caledonia (Askin and Baldoni, 1998). The species *Beaupreaidites orbiculatus*, previously recorded in uppermost Cretaceous sediments from the Otway Basin, southeastern Australia (Dettmann and Jarzen, 1988, 1996), is hereby mentioned in Argentina for the first time.

Spinizonocolpites, which represents the pollen of extant Arecaceae (*Nypa*-type), is present in the assemblage with specimens including baculae or spinae and exhibiting the hyaline exine described for *Spinizonocolpites hialinus* Archangelsky and Zamalao, 1986 from the Bororó and Salamanca formations (Archangelsky and Zamalao, 1986). The present specimens (Fig. 6.3–5) are only compared to the original species because they include more densely distributed sculptural elements.

Few specimens of *Tubulifloridites lilliei* (Couper) Farabee and Canright (1986) (Fig. 6.6) were recognized in the palynoflora. This tricolpate pollen grain presents a restricted stratigraphic distribution in the Late Cretaceous of the Southern Hemisphere (New Zealand, Australia, Antarctica and southern South America) (Vajda and Bercovici, 2012; Bowman *et al.*, 2014). Recently, an Asteraceae affinity was suggested for a particular morphological type of this species from the uppermost Cretaceous of the Antarctic Peninsula (Barreda *et al.*, 2015).

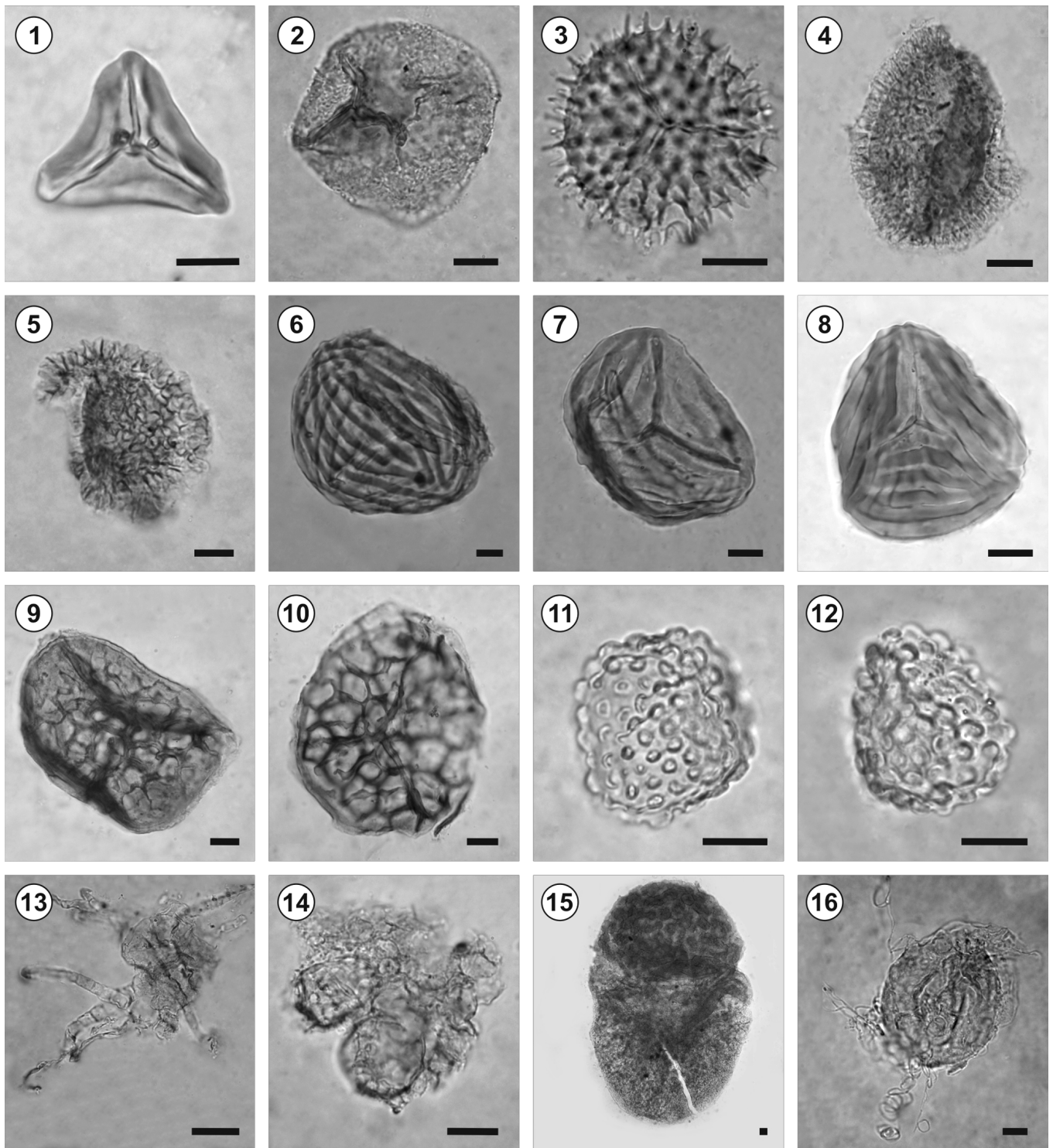


Figure 4. Selected spores and zygospores. 1, *Gleicheniidites senonicus*, CR.P.CV CH1 15/105; 2, *Baculatisporites comaumensis*, CR.P.CV CH1d 21/98; 3, *Ceratospores equalis*, CR.P.CV CH14 20/90; 4, *Gabonispores vigourouxii*, CR.P.CV CH1c 4/94; 5, *Gabonispores vigourouxii*, CR.P.CV CH1c 10/94; 6, *Cicatricosisporites* sp. 1, CR.P.CV CH1d 18/95.5; 7, *Cicatricosisporites* sp. 2, CR.P.CV CH1d 10/95; 8, *Ruffordiaspora* sp., CR.P.CV CH2a 15/100; 9, *Zlivisporis reticulatus*, CR.P.CV CH14-1 9/85; 10, *Zlivisporis reticulatus*, CR.P.CV CH2a 22/105; 11, *Catinipollis geiseltalensis*, CR.P.CV CH1e 15/105; 12, *Catinipollis geiseltalensis*, CR.P.CV CH1b 5/93; 13, *Azolla* sp.1, microspore massula with septate glochidia, CR.P.CV CH2b 16/109; 14, *Azolla* sp. 2, microspore massula fragment, CR.P.CV CH2c 22/102; 15, *Azolla*, megaspore apparatus, CR.P.CV CH14m 11/92; 16, *Ariadnaesporites micromedusus*, microspore, CR.P.CV Cho 18/96.5. Scale bars = 10 μ m.

BIOSTRATIGRAPHY AND PALEOBIOGEOGRAPHY

The palynoflora yields *Quadruplanus brossus* Stover and Partridge, 1973, and *Tubulifloridites lilliei* (Figs. 6.9–13 and 6.6, respectively), which are key Maastrichtian species of the southern *Proteacidites/Nothofagidites* Province (Herngreen *et al.*, 1996). Both species became extinct at the Cretaceous/Paleogene boundary in Australia, New Zealand and Seymour Island (Antarctica) (Vajda and Bercovici, 2012, 2014). *Quadruplanus brossus*, particularly, shows a stratigraphic distribution restricted to the upper Maastrichtian of sections also rich in dinoflagellates in the Southern Hemisphere (Raine and Schiøler, 2012; Vajda and Bercovici,

2012). The assemblage also includes some species characteristic of the Upper Cretaceous Palmae Province of Herngreen *et al.* (1996) such as the zonosulcate taxa *Proxapertites* and *Spinizonocolpites* and the typical Maastrichtian species *Buttinia andreevi* Boltenhagen, 1967 (Fig. 6.8) and *Gabonispuris vigorouxii* Boltenhagen, 1967 (Fig. 4.4). This supports both the Maastrichtian age of the palynoflora and the location of the Patagonian Region in a Late Cretaceous Transitional (Mixed) Province (Vajda and Bercovici, 2012, 2014). As suggested by the presence of several species of the tropical pollen grains *Tucanopollis* and *Afropollis* in Cretaceous Patagonian sediments (Vallati, 2006, 2013a), Pata-

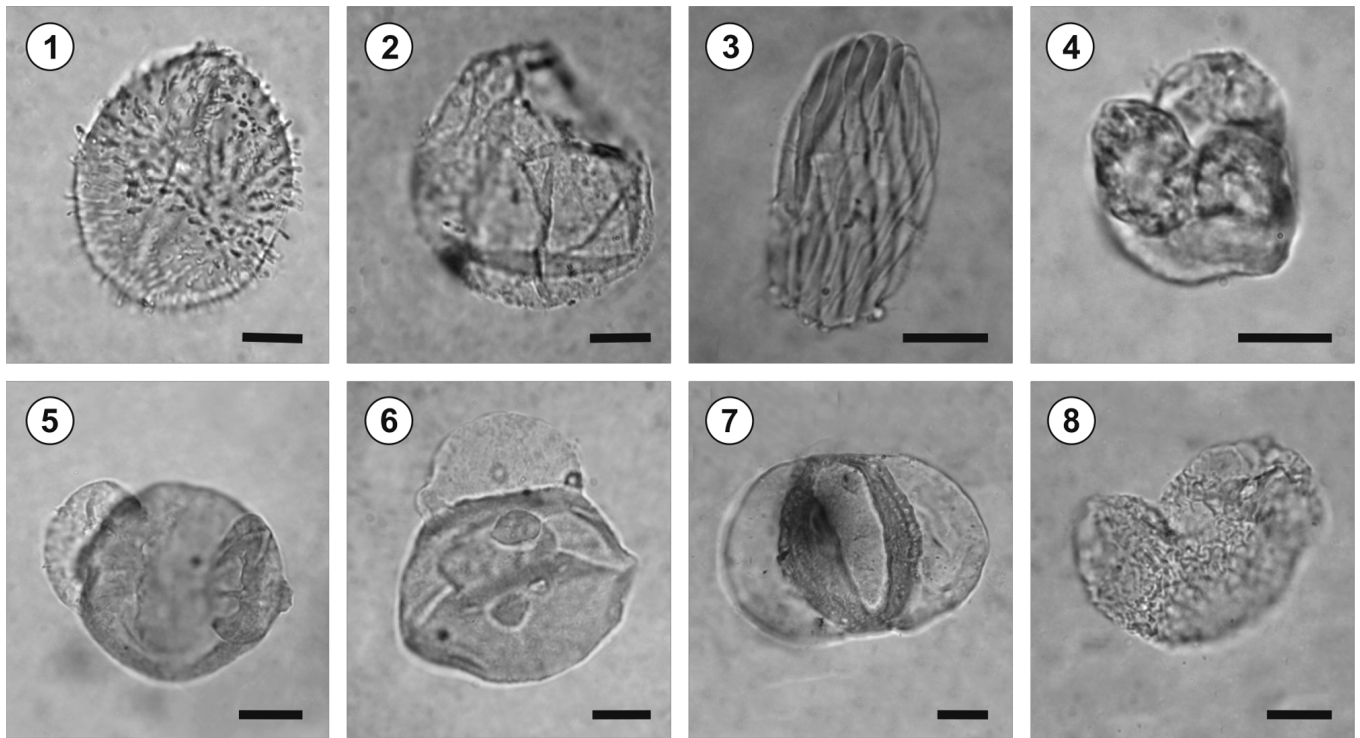
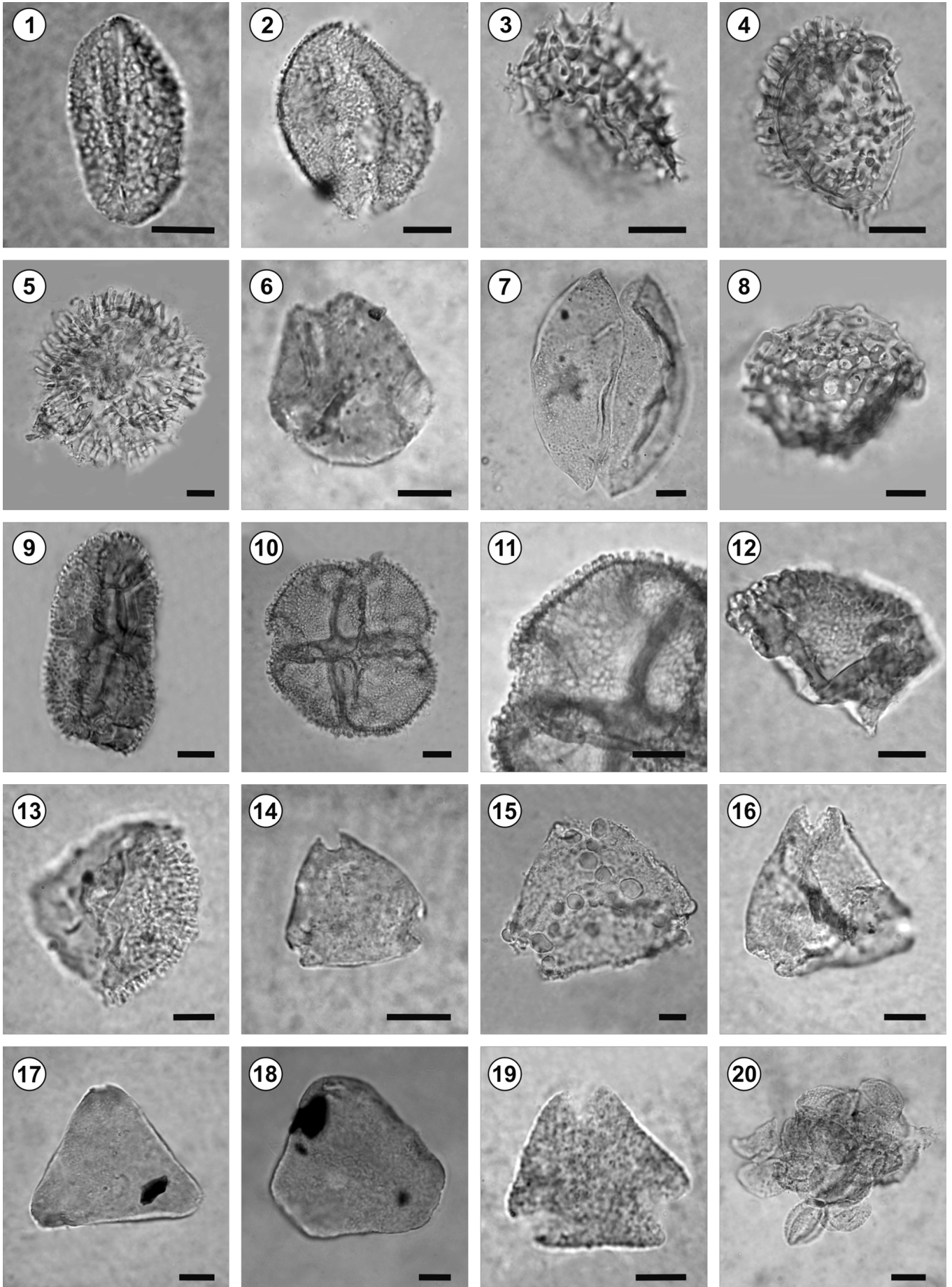


Figure 5. Selected gymnosperm pollen grains. 1, *Echimonocolpites* sp., CR.P.CV CH1d 15/95; 2, *Araucariacites australis*, CR.P.CV CH2j 12/ 98; 3, *Gnetaceapollenites barghoornii*, CR.P.CV CHw 12.5/115; 4, *Microcachrydites antarcticus*, CR.P.CV CH14 99/19.2; 5, *Phyllocladites mawsonii*, CR.P.CV CHy 11/90; 6, *Phyllocladites mawsonii*, CR.P.CV Ch2 16/102; 7, *Podocarpidites* sp., CR.P.CV CH1a 12/94; 8, *Rugubivesiculites* sp., CR.P.CV CH1p 117/105. Scale bars= 10 µm.

Figure 6. Selected angiosperm pollen grains. 1, *Liliacidites regularis*, CR.P.CV CH2s 16.5/99; 2, *Liliacidites* cf. *kaitangataensis*, CR.P.CV CH2j 20/105; 3, *Spinizonocolpites* cf. *hialinus*, CR.P.CV CH1d 21/92; 4, *Spinizonocolpites* cf. *hialinus*, CR.P.CV CHx 24/100; 5, *Spinizonocolpites* cf. *hialinus*, CR.P.CV CH 18/108; 6, *Tubulifloridites lilliei*, CR.P.CV CH1e 11/94; 7, *Proxapertites* sp., CR.P.CV CH2m 23/105; 8, *Buttinia andreevi*, CR.P.CV CH1 8/95; 9, *Quadruplanus brossus*, CR.P.CV CH1x 14/94; 10, *Quadruplanus brossus*, CR.P.CV CH2m 20/94; 11, *Quadruplanus brossus*, detail of the sculpture in the specimen of Fig. 10; 12, *Quadruplanus brossus*, individual grain, CR.P.CV CH2s 15/102; 13, *Quadruplanus brossus*, individual grain, CR.P.CV CH2s 12/95; 14, *Peninsulapollis gillii*, CR.P.CV CH2s 11/100; 15, *Beaupreaidites orbiculatus*, CR.P.CV CH2 5/107; 16, *Beaupreaidites* cf. *elegansiformis*, CR.P.CV CHx 16/100; 17, *Proteacidites scaboratus*, CR.P.CV CHx 20/104; 18, *Proteacidites* cf. *scaboratus*, CR.P.CV CH2s 18/105; 19, *Peninsulapollis truswelliae*, CR.P.CV CH2s 8/96; 20, *Tricolpites* sp., pollen grain mass, CR.P.CV CH1b 6/95. Scale bars= 10 µm.



gonia occupied this Transitional Province at least since Aptian times.

The angiosperm family Proteaceae is represented by several species in the studied palynoflora. This extant Gondwanan group of plants has a significant fossil record in Australia, New Zealand and the Antarctic Peninsula (Wanntorp *et al.*, 2011). The proteaceous and species of probable proteaceous affinity recognized in the present assemblage include several taxa initially described for the uppermost Cretaceous strata of southeastern Australia and the Antarctic Peninsula (Dettmann and Jarzen, 1988).

Nothofagidites, a characteristic taxon of the austral *Proteacidites/Nothofagidites* Province, was not recognized in the studied assemblage. The oldest record of this taxon in Patagonia was reported from the middle Maastrichtian of the Jagüel Formation, in the Neuquén Basin, by Romero (1973). The absence of this taxon could be due to the palynoflora predating the incoming of *Nothofagidites* in the Golfo San Jorge Basin or to environmental conditions.

The studied assemblage bears more similarities to the Maastrichtian Patagonian palynofloras from the lower Lefipán Formation in Chubut Province (Baldoni, 1992; Baldoni and Askin, 1993; Barreda *et al.*, 2012) and the Monte Chico Formation in Santa Cruz Province (Povilauskas, 2011, 2012, 2013). The present palynoflora shares the marker *Quadruplanus brossus* and the species *Baculatisporites comamensis*, *Ceratosporites equalis*, *Araucariacites australis*, *Phyllocladidites mawsonii*, *Microcachryidites antarcticus*, *Ericipites scabratus* and *Peninsulapollis gillii* with both above-mentioned assemblages. Additionally, it shares the marker *Tubulifloridites lilliei* with the lower Lefipán Formation.

Regarding Maastrichtian assemblages from other regions in Argentina, the Ciénaga de Río Huaco Formation in San Juan Province includes a mixed palynoflora with some spores and pollen grains characteristic of the paleotropical Province (Limarino *et al.*, 2000).

PALEOENVIRONMENTAL CONSIDERATIONS

The presence of frequent monospecific masses of spores and pollen grains in the assemblage (Fig. 6.20) is probably indicative of the autochthonous nature of some of its components and of a low energy environment at the time of deposition.

Aquatic fern spores (*Azolla* spp.; *Ariadnaesporites mi-*

cromedusus) together with lycophytes and algal elements suggest the local existence of a freshwater body and a warm climate. Particularly, zygospores of the green filamentous algae Zygnemataceae such as *Catinipollis geiselta-lensis* Krutzsch, 1966 imply warm, shallow and low energy freshwaters (Scafati *et al.*, 2009; Bowman *et al.*, 2014).

Terrestrial bryophytes (*Zlivisporis reticulatus*) and ferns of Anemiaceae (*Cicatricosisporites*, *Ruffordiaspora*), Cyatheaceae (*Cyathidites*) and Selaginellaceae (*Ceratosporites equalis*) represent the local vegetation that grew around the freshwater body. Proteaceae and Podocarpaceae probably occupied the humid riverbanks under a temperate warm climate. Bowman *et al.* (2014) drew attention to the fact that the abundance of wind-pollinated conifers in comparison to that of Proteaceae is probably related to their different pollination mechanisms. Palmae-type pollen grains (*Spinizonocolpites* cf. *hialinus* Archangelsky and Zamaloea, 1986, Fig. 6.3–5) suggest the presence of *Nypa*-type palms, which currently inhabit warm marine coastal environments (Scafati *et al.*, 2009).

In central Patagonia, similar freshwater paleocommunities were reported from the Danian Cerro Bororó Formation (Scafati *et al.*, 2009) and from the Late Cretaceous La Colonia Formation (Cúneo *et al.*, 2014).

CONCLUSIONS

The palynoflora from the studied levels at the headwaters of the Río Chico, in the Golfo San Jorge Basin, includes austral Maastrichtian key species such as *Quadruplanus brossus* and *Tubulifloridites lilliei*. The assemblage is also typified by paleotropical Maastrichtian markers such as *Buttinia andreevi* and *Gabonisporsis vigourouxii*. All above-mentioned taxa characterize late Maastrichtian assemblages and become extinct at the Cretaceous/Paleogene boundary thus suggesting a late Maastrichtian age for the studied palynoflora.

The species *Buttinia andreevi* and *Beaupreaidites orbiculatus* are recorded for the first time in Argentina.

The co-occurrence of key species from both paleotropical and austral Provinces corroborates the presence of the mixed flora that characterizes the Transitional Upper Cretaceous Floristic Province of southern South America (Vajda and Bercovici, 2012) at the latitude of the studied locality.

The recovered palynoflora suggests local depositional

conditions related to a low energy freshwater body and a warm climate. The presence of pollen grains of the marine coastal *Nypa*-type Arecaceae such as *Spinizonocolpites* together with *Proxapertites* (Fig. 5.7) probably indicates the close proximity of a shoreline.

ACKNOWLEDGMENTS

This paper is dedicated to the memory of our professor and colleague Eduardo Musacchio. We thank Antonio Perujo (†), Héctor Martínez, C. Martínez and Luis Insúa, landowners at the headwaters of the Chico river. Marcelo Luna is acknowledged for fieldwork assistance. The authors would like to thank the artwork editor, Alejandro Otero, the Scientific Editor, Viviana Barreda, and two anonymous reviewers for their suggestions and comments that greatly improved the manuscript.

REFERENCES

- Allard, J.O., Paredes, J.M., Foix, N., and Giacosa, R.E. 2015. Conexión Cretácica entre las cuencas del golfo San Jorge y Cañadón Asfalto (Patagonia): paleogeografía, implicancias tectonoestratigráficas y su potencial en la exploración de hidrocarburos. *Revista de la Asociación Geológica Argentina* 72: 25–41.
- Archangelsky, S., Baldoni, A., Gamero, J.C., and Seiler, J. 1984. Palinología estratigráfica del Cretácico de Argentina austral III. Distribución de las especies y conclusiones. *Ameghiniana* 21: 15–33.
- Archangelsky, S., Bellosi, E.S., Jalfin, G.A., and Perrot, C. 1994. Palynology and alluvial facies from the mid-Cretaceous of Patagonia, subsurface of San Jorge Basin, Argentina. *Cretaceous Research* 15: 127–142.
- Archangelsky, S., and Zamalao, M.C. 1986. Nuevas descripciones palinológicas de las formaciones Salamanca y Bororo, Paleoceno de Chubut (República Argentina). *Ameghiniana* 23: 35–46.
- Askin, R.A., and Baldoni, A.M. 1998. The Santonian through Paleogene record of Proteaceae in the southern South America-Antarctic Peninsula Region. *Australian Systematic Botany* 11: 373–390.
- Baldoni, A.M. 1992. Palynology of the lower Lefipán Formation (Upper Cretaceous) of Barranca de los Perros, Chubut Province, Argentina. Part I. Cryptogam spores and gymnosperm pollen. *Palynology* 16: 117–136.
- Baldoni, A.M., and Askin, R.A. 1993. Palynology of the lower Lefipán Formation (Upper Cretaceous) of Barranca de los Perros, Chubut Province, Argentina. Part II. Angiosperm pollen and discussion. *Palynology* 17: 241–264.
- Barreda, V., Cúneo, R., Wilf, P., Currano, E.D., Scasso, R.A., and Brinkhuis, H. 2012. Cretaceous/Paleogene floral turnover in Patagonia: drop in diversity, low extinction, and a *Classopollis* Spike. *Plos One* 7: e52455. doi:10.1371/journal.pone.0052455
- Barreda, V., Palazzesi, L., Tellería, M.C., Olivero, E.B., Rainee, J.I., and Forest, F. 2015. Early evolution of the angiosperm clade Asteraceae in the Cretaceous of Antarctica. *Proceedings of the National Academy of Sciences* 112: 10989–10994. doi:10.1073/pnas.1423653112
- Boltenhagen, E. 1967. Spores et pollen du Crétacé Supérieur du Gabon. *Pollen et Spores* 9: 335–355.
- Bowman, V., Francis, J.E., Askin, R., Riding, J.B., and Swindles G.T. 2014. Latest Cretaceous–earliest Paleogene vegetation and climate change at the high southern latitudes: palynological evidence from Seymour Island, Antarctic Peninsula. *Palaeogeography, Palaeoclimatology, Palaeoecology* 408: 26–47.
- Casal, G., Allard, J., and Foix, N. 2015. Análisis estratigráfico y paleontológico del Cretácico Superior en la Cuenca del Golfo San Jorge: nueva unidad litoestratigráfica para el Grupo Chubut. *Revista de la Asociación Geológica Argentina* 72: 81–99.
- Clyde, W.C., Wilf, P., Iglesias, A., Slingerland, R.L., Barnum, T., Bijl, P.K., Bralower, T.J., Brinkhuis, H., Comer, E.E., Huber, B.T., Ibañez-Mejía, M., Jicha, B.R., Krause, M., Schueth, J.D., Singer, B.S., Raigemborn, M.S., Schmitz, M.D., Sluijs, A., and Zamalao, M. del C. 2014. New age constraints for the Salamanca Formation and lower Río Chico Group in the western San Jorge Basin, Patagonia, Argentina: correlations. *Geological Society of American Bulletin* 126: 289–306. doi:10.1130/B30915.1
- Cookson, I.C. 1947. Plant microfossils from the lignites of the Kerguelen Archipelago. *British and New Zealand Antarctic Research Expedition, 1929–1931. Reports Series A 2*: 129–142.
- Cookson, I.C., and Dettmann, M.E. 1958. Some trilete spores from Upper Mesozoic deposits in the eastern Australian region. *Proceedings of the Royal Society of Victoria* 70: 95–128.
- Cookson, I.C., and Dettmann, M.E. 1959. On *Schizosporis*, a new form genus from Australian Cretaceous deposits. *Micropaleontology* 5: 213–216.
- Cúneo, R., Gandolfo, M.A., Zamalao, M.C., and Hermsen, E. 2014. Late Cretaceous aquatic plant world in Patagonia, Argentina. *Plos One* 9: e104749. doi:10.1371/journal.pone.0104749
- Dettmann, M.E., and Jarzen, D.M. 1988. Angiosperm pollen from uppermost Cretaceous strata of southeastern Australia and the Antarctic Peninsula. *Association of Australasian Palaeontologists* 5: 217–237.
- Dettmann, M.E., and Jarzen, D.M. 1996. Pollen of proteaceous-type from latest Cretaceous sediments, southeastern Australia. *Alcheringa: An Australasian Journal of Palaeontology* 20: 103–160.
- Dettmann, M.E., and Playford, G. 1968. Taxonomy of some Cretaceous spores and pollen grains from eastern Australia. *Proceedings of the Royal Society of Victoria* 81: 69–94.
- Farabee, M.J., and Canright, J.E. 1986. Stratigraphic palynology of the lower part of the Lance Formation (Maastrichtian) of Wyoming. *Palaeontographica* 199: 1–89.
- Harris, W.K. 1965. Basal Tertiary microfloras from the Princetown area, Victoria, Australia. *Palaeontographica, Abteilung B* 15: 75–106.
- Hechem, J.J., Figari, E.G., and Musacchio, E.A. 1987. Hallazgo de la Formación Pozo Diadema 129 en superficie: información estratigráfica y paleontológica en la Cuenca del Golfo San Jorge. *Petrotecnica* 28: 13–15.
- Herngreen, G.F.W., Kedves, M., Rovnina, L.V., and Smirnova, S.B. 1996. Cretaceous palynofloral provinces: A review. In: J. Jansoni, and D.C. McGregor (Eds.), *Palynology: Principles and applications*. American Association of Stratigraphic Palynologists Foundation, Salt Lake City, p. 1157–1188.
- Krutzsch, W. 1966. Zur Kenntnis der praequartaeren periporaten Pollenformen. *Geologie Beihefte* 15: 16–71.
- Lesta, P., and Ferello, R. 1972. Región extraandina del Chubut y norte de Santa Cruz. In: A.F. Leanza (Ed.), *Geología Regional Argentina*. Academia Nacional de Ciencias, p. 601–654.
- Limarino, C., Net, L., Gutierrez, P., Barreda, V., Caselli, A., and Ballent, S. 2000. Definición litoestratigráfica de la Formación Ciénaga de Río Huaco (Cretácico Superior), Precordillera Central, San Juan, Argentina. *Revista de la Asociación Geológica Argentina* 55: 83–99.
- Pačtová, B., and Simoncsics, P. 1970. New types of spores (genera and species) from the Bohemian Miocene. *Paläontologische Abhandlungen B (Paläobotanik)* 3: 599–617.

- Paden Phillips, P., and Felix C.J. 1971. A study of Lower and Middle Cretaceous spores and pollen from Southeastern United States. I. Spores. *Pollen et Spores* 13: 279–348.
- Potonié, R., 1956. Synopsis der Gattungen der Sporae dispersae. I. Teil: Sporites. *Beihefte zum Geologischen Jahrbuch* 23. Hannover, 103 p.
- Povilauskas, L. 2011. Palinología de la Formación Monte Chico (Cretácico Tardío) de la Provincia de Santa Cruz, Argentina: Esporas. *Revista Brasileira de Paleontología* 14: 255–268. doi:10.4072/rbp.2011.3.05
- Povilauskas, L. 2012. Palinología de la Formación Monte Chico (Cretácico Tardío) de la Provincia de Santa Cruz, Argentina: Gimnospermas. *Revista Brasileira de Paleontología* 15: 85–94. doi:10.4072/rbp.2012.1.07
- Povilauskas, L. 2013. Palinología de la Formación Monte Chico (Cretácico Tardío) de la Provincia de Santa Cruz, Argentina: Angiospermas. *Revista Brasileira de Paleontología* 16:115–126. doi:10.4072/rbp.2013.1.09
- Raine, J.I., and Schiøler, P. 2012. Upper Cretaceous biostratigraphy of Maui-4 and Tane-1, *Taranaki Basin*. *GNS Science Report*, 29 p.
- Regali, M.S.P. 1989. *Tucanopollis*, a new genus of early angiosperms. *Boletim Técnico Petrobras* 3: 395–402.
- Romero, E.J. 1973. Polen fósil de *Nothofagus* (*Nothofagidites*) del Cretácico y Paleoceno de Patagonia. *Revista del Museo de La Plata* 7: 291–303.
- Ross, N.E. 1949. Investigations of the Senonian of the Kristianstad district, S. Sweden. I. On a Cretaceous pollen and spore bearing clay deposit of Scania. *Bulletin of the Geological Institution of the University of Upsala* 34: 25–43.
- Scafati, L., Melendi, D.L., and Volkheimer, W. 2009. A Danian subtropical lacustrine palynobiota from South America (Bororó Formation, San Jorge Basin, Patagonia–Argentina). *Geologica Acta* 7: 35–61. doi: 10.1344/105.000000270
- Stough, J.B. 1968. Palynomorphs from South America. Part 1. New Late Cretaceous palynomorphs from southern South America. *The University of Kansas Paleontological Contribution Papers* 32: 1–8.
- Stover, L.E., and Partridge, A.D. 1973. Tertiary and Late Cretaceous spores and pollen from the Gippsland Basin, southeastern Australia. *Proceedings of the Royal Society of Victoria* 85: 237–286.
- Sylwan, C.A. 2001. Geology of the Golfo San Jorge Basin, Argentina. *Journal of Iberian Geology* 27: 123–157.
- Vajda, V., and Bercovici, A. 2012. Pollen and Spore stratigraphy of the Cretaceous–Paleogene Southern Hemisphere. *Journal of Stratigraphy* 36: 153–164.
- Vajda, V., and Bercovici, A. 2014. The global vegetation pattern across the Cretaceous–Paleogene mass extinction interval: A template for other extinction events. *Global and Planetary Change* 122: 29–49.
- Vallati, P. 2006. Las primeras angiospermas en el Cretácico de la Cuenca Neuquina (centro-oeste de Argentina): aspectos geológicos relacionados. *Revista Brasileira de Paleontología* 9: 83–92.
- Vallati, P. 2013a. A mid Cretaceous palynoflora with *Tucanopollis crisopolensis* from D-129 Formation, San Jorge Gulf Basin, Argentina. *Revista Brasileira de Paleontología* 16: 237–244. doi: 10.4072/rbp.2013.2.06
- Vallati, P. 2013b. Paleotropical pollen grains from the Neuquén Group, Patagonia, Argentina. *Carnets de Géologie [Notebooks on Geology] - Letter 2013/05 (CG2013_L05)*: 273–279.
- Van Nieuwenhuise, D.S., and Ormiston, A.R. 1988. A model for the origin of source-rich lacustrine facies, San Jorge Gulf Basin, Argentina. *1^{er} Congreso Nacional de Exploración de Hidrocarburos*

(Mar del Plata), *Actas*: 852–871.

- Wanntorp, L., Vajda, V., and Raine, J.I. 2011. Past diversity of Proteaceae on subantarctic Campbell Island, a remote outpost of Gondwana. *Cretaceous Research* 32: 357–367.

APPENDIX

Taxonomic list of identified taxa

Zygnemataceae (filamentous green algae)

Catinipollis geiseltalensis Krutzsch, 1966 (Figure 4.11,12)

Ovoidites sp.

Schizosporis reticulatus Cookson and Dettmann, 1959

Bryophyta

Zlavisporis reticulatus (Pocock 1962) Pacltová and Simoncsics, 1970

(Figure 4.9,10)

Lycophyta

Camarozonosporites cf. *ohaiensis* (Couper, 1953) Dettmann and Playford, 1968

Ceratospores equalis Cookson and Dettmann, 1958 (Figure 4.3)

Pteridophyta (Filicales)

Ariadnaesporites micromedusus Stough, 1968 (Figure 4.16)

Azolla sp.1 massula (Figure 4.13)

Azolla sp.2 massula (Figure 4.14)

Azolla megaspore apparatus (Figure 4.15)

Baculatisporites comaumensis (Cookson 1953) Potonie, 1956

(Figure 4.2)

Cicatricosisporites sp. 1 (Figure 4.6)

Cicatricosisporites sp. 2 (Figure 4.7)

Ruffordiaspora sp. (Figure 4.8)

Cyathidites sp.

Gabonispores vigourouxii Boltenhagen, 1967 (Figure 4.4,5)

Gleicheniidites senonicus Ross, 1949 (Figure 4.1)

Spore of uncertain botanical affinity

Interlobites intraverrucatus (Brenner, 1963) Paden Phillips, 1971

Gymnosperms

Araucariacites australis Cookson, 1947 (Figure 5.2)

Classopollis sp.

Cycadopites sp.

Echimonocolpites sp. (Figure 5.1)

Gnetaceaepollenites barghoornii Lima, 1980 (Figure 5.3)

Microcachrydites antarcticus Cookson, 1947 (Figure 5.4)

Phyllocladidites mawsonii Cookson, 1947 ex Couper, 1953 (Figure 5.5,6)

Podocarpidites spp. (Figure 5.7)

Rugubivesiculites sp. (Figure 5.8)

Angiosperms

Buttinia andreevi Boltenhagen, 1967 (Figure 6.8)

Beaupreaidites cf. *elegansiformis* Cookson, 1950 (Figure 6.16)

Beaupreaidites orbiculatus Dettmann and Jarzen, 1988 (Figure 6.15)

Ericipites scabratus Harris, 1965

Liliacidites cf. *kaitangataensis* Couper, 1953 (Figure 6.2)

Liliacidites regularis Archangelsky, 1973 (Figure 6.1)
Peninsulapollis gillii (Cookson, 1957) Dettmann and Jarzen, 1988
(Figure 6.14)
Peninsulapollis truswelliae Dettmann and Jarzen, 1988 (Figure 6.19)
Proteacidites scaboratus Couper, 1960 (Figure 6.17)
Proteacidites cf. *scaboratus* Couper, 1960 (Figure 6.18)
Proxapertites sp. (Figure 6.7)
Quadraplanus brossus Stover and Partridge, 1973 (Figure 6.9-13)
Spinizonocolpites cf. *hialinus* Archangelsky and Zamalao, 1986
(Figure 6.3-5)
Tricolpites sp. (Figure 6.20)
Tubulifloridites lilliei (Couper) Farabee and Canright, 1986 (Figure 6.6)

doi: 10.5710/AMGH.28.12.2015.2948

Submitted: August 22nd, 2015

Accepted: December 28th, 2015