A MID-LATITUDE MAASTRICHTIAN PALYNOLOGICAL RECORD FROM THE YACORAITE FORMATION (SALTA GROUP), NORTHWESTERN ARGENTINA

Magdalena Llorens[a, b,*], Valeria S. Pérez Loinaze[a, c], Paula L. Narváez[a, d], Alfredo M. Zelaya[e], Egly Pérez Pincheira[f], Sergio Gorustovich[e]

[a] Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET), Argentina

[b] Laboratorio de Botánica and Laboratorio de Palinología, Facultad de Ciencias Naturales, Universidad Nacional de la Patagonia San Juan Bosco, 9 de Julio 25, (U9100CKN) Trelew, Chubut, Argentina

[c] Museo Argentino de Ciencias Naturales "B. Rivadavia", Av. Ángel Gallardo 470 (C1405DJR), Buenos Aires, Argentina

[d] IANIGLA/CCT Mendoza. Av. Adrián Ruiz Leal s/n, Parque Gral. San Martín, (5500) Mendoza, Argentina

[e] Comisión Nacional de Energía Atómica, Gerencia Exploración de Materias Primas, Avenida del Libertador 8250, (1429) Ciudad Autónoma de Buenos Aires, Argentina

[f] Cátedra de Palinología, Facultad de Ciencias Naturales y Museo, Universidad Nacional de La Plata, Calle 64, 3 (B1904DZA) La Plata, Buenos Aires, Argentina.

*Corresponding author: Magdalena Llorens

E-mail address: magdalena.llorens@gmail.com

Abstract.

A palynological assemblage from one sample of the Yacoraite Formation outcrops (Maastrichtian–Danian of the Salta Basin) at the Valle del Tonco, Salta Province, Argentina, is described. The flora is distinctly continental and dominated by angiosperms, accompanying ferns and gymnosperms, along with few freshwater algae, bryophytes and fungi. The presence of taxa such as *Aquillapollenites magnus*, *Gabonisporis vigorouxii* and *Crassitricolporites brasiliensis*, together with the absence of typical ~~characteristic~~ taxa ~~from~~of the Danian *Mtchedlishvilia saltenia* Zone, allow to propose a late Maastrichtian age for this palynoflora. Due to its location at mid-latitudes, the palynoflora from the Yacoraite Formation is within a transitional or mixed flora zone with closer affinity to the equatorial Palmae Province. Therefore, the recorded flora has ~~represents~~ a good potential~~opportunity~~ to understand the transition between the floras of low and high latitudes and to know the floristic composition of the area before the K-Pg extinction event.

Keywords. Palynology; Late Cretaceous; Yacoraite Formation; Salta Group; Argentina.

1. Introduction

The Maastrichtian floras of South America are very well known at high latitudes (e.g., Clyde et al., 2021; Pérez Pincheira and Di Pasquo, 2021 and citations therein). On the other hand, coeval low-latitude floras are known in broad temporal contexts, with data obtained from borehole samples, mainly of marine environments and with a biostratigraphic approach (e.g., Regali et al., 1984 a, b; Muller et al 1987). However, there are very few records of palynofloras from mid-latitude regions (Pérez Leytón, 1987; Limarino et al., 2000; Quattrocchio et al., 2005).

In Argentina, the main unit with mid-latitude Cretaceous sediments is the Salta Group. It is a geological unit at the Northwest of Argentina widely extended that includes strata from the Lower Cretaceous to the Eocene (Salfity and Marquillas, 1994; Marquillas et al., 2005). It has economic interest due to its hydrocarbon and uranium content, but also its paleontological content is very relevant.

The fossil content of the Yacoraite Formation includes marine and continental biotas, and has been analyzed and discussed in several works. Fossil fishes (Benedetto and Sánchez, 1972; Cione, 1977; Cione et al., 1985; Cione and Pereyra, 1985), reptiles (Gasparini and Buffetaut, 1980), gastropods (Cónsole-Gonella, 2011 and citations therein), stromatolites (Villafañe et al., 2021), ostracods, scarce miliolid foraminifera (Kielbowicz de Stach and Angelozzi, 1984; and Méndez and Viviers, 1973), carophytes (Musacchio, 1972) and other algae, in addition to footprints of dinosaurs and birds (Alonso, 1980; Alonso and Marquillas, 1986; Marquillas et al., 2005; Marquillas et al., 2007; Marquillas and Salfity, 1994; de Valais and Cónsole-Gonella, 2018; Cónsole-Gonella et al., 2021), have been recorded.

Nevertheless, the scarcity of floristic records in the Yacoraite Formation is notorious. There are no reports of leaves or wood remains and the calcareous composition of the rocks in this formation makes it difficult for palynomorph preservation. Therefore, the palynomorph record is restricted to three preliminary reports. The first was made by Moroni (1982), who compared the palynological content from the Yacoraite and Olmedo formations at the Lomas de Olmedo sub-basin. Seven angiosperm taxa and the presence of polyplicate pollen grains were mentioned along with algae spores, but none were described or illustrated. Another work is a conference abstract where the finding of massulae of *Azolla cretacea* and dinoflagellates cysts is mentioned (Papú and Melendi, 1984). Finally, Narváez (2009) found a single sample from the Yacoraite Formation with palynological evidence limited to three types of freshwater algae (*Leiosphaeridia* sp. and *Pediastrum* spp.).

The aim of this contribution is to describe and illustrate for first time a palynological assemblage from the Yacoraite Formation at the Don Otto uranium mine. A comparison with other Late Cretaceous and Danian mid-latitude palynofloras, biostratigraphy and discussion of the age and paleoecological inferences are also included.

2. Geological setting

The Salta Basin in northwestern Argentina is relevant for its wide extent, and hydrocarbon production (Turic et al., 1987; Marquillas and Salfity, 1988; Gómez Omil et al., 1989; Salfity and Marquillas, 1994). The basin fill corresponds to the Salta Group (Turner, 1958~~9~~) deposited from the Early Cretaceous up to the Eocene and composed of three main units from base to top: Pirgua (Reyes and Salfity, 1973), Balbuena and Santa Bárbara subgroups (Moreno, 1970). It reaches 5000 m thick and crops out in seven sub-basins: Tres Cruces, Lomas de Olmedo, Alemanía, Metán, El Rey, Sey and Brealito (Marquillas et al., 2005 and citations therein).

During the Maastrichtian, two major factors controlled the Salta Basin fill, the decrease in tectonic subsidence and a relative sea level rise that affected South America (Marquillas et al., 2005). In northern Argentina, an extensive and shallow Atlantic marine ingression installed a carbonate system coincident with mainly humid conditions until the Danian (Marquillas et al., 2005). Due to its calcareous-dolomitic composition with an intense yellow of weathering color, the Yacoraite Formation (Groeber, 1952) constitutes an excellent marker horizon in the Salta Group (Marquillas et al., 2005). The Cretaceous–Paleogene transition is also contained in the Yacoraite Formation of Maastrichtian–Danian age (Sial et al., 2001; Marquillas et al., 2003).

The main lithology of the Yacoraite Formation are carbonate-calcareous rocks and dolomitic limestones, it also contains shales and sandstones, reaching a maximum thickness of 200 m (Marquillas et al., 2007). In the Alemanía sub-basin, the Yacoraite Formation (Balbuena Subgroup) crops out at the Valle del Tonco locality (Tonco River valley), where it overlies the Lecho Formation (Balbuena Subgroup) and underlies the Mealla Formation (Santa Bárbara Subgroup) within the Salta Group (Payrola et al., 2011). At the Don Otto mine vicinity (Fig. 1.A–E), the unit crops out with a thickness of 174 m mainly corresponding to the Don Otto Complex Member where Zelaya et al. (2014a, b) recognized eight sedimentary facies (F1–8) grouped into four facies associations (FA1–4) related to intertidal–subtidal deposits and lagoon-type environments with sporadic storm events and subaerial exposure. The palynological sample here studied was recovered from dark gray to black siltstones and claystones (facies F8) within FA2.

2.1. Age

The widely recorded dinosaur footprints in the Yacoraite Formation (e.g., Cónsole-Gonella et al., 2021) undoubtedly indicates a Cretaceous age for the unit. As aforementioned, palynological studies from well samples in the Lomas de Olmedo sub-basin, showed that the Yacoraite Formation finished its sedimentation in the Danian (Moroni, 1982, 1984). This is consistent with the interpretation of the Yacoraite Formation in the context of the transgressions that occurred in southern South America during the Maastrichtian–Paleocene (Marquillas, 1985; Marquillas and Salfity, 1988; Marquillas et al., 2005).

Despite having been the subject of diverse reviews (e.g., Castaños et al., 1975; Marquillas, 1985; Gómez Omil et al., 1989; Salfity and Marquillas, 1994; Marquillas et al., 2005), isotopic studies of this rock unit are still scarce (Matthews et al., 1996; Sial et al., 2001; Marquillas et al., 2007). An absolute U-Pb zircon dating has confirmed a Maastrichtian age for at least part of the unit, with a result of 71.9 ± 0.4 Ma and 68.4 ± 0.7 Ma from two tuff layers obtained from the Amblayo and Alemanía members of the Yacoraite Formation (Marquillas et al., 2011).

3. Materials and methods

Two samples were recovered from outcrops of the Yacoraite Formation in the Don Otto mine, located at the southernmost section of the Valle del Tonco (Tonco River valley; 25°36'39"S, 65°55'10.6"W) (Fig. 1A–E). Two levels of grey-black pelitic sedimentary rocks with high content of organic matter were sampled in the vicinity of the camp, but only one contained palynomorphs (CNS-M 001/A–H; Fig. 2). The samples were treated separely with hydrochloric and hydrofluoric acids following the palynological techniques for extraction and concentration of palynomorphs by Phipps and Playford (1984). The organic residues were sieved using 20µm and 10µm opening mesh and mounted in permanent slides. Observations were made with an Olympus BX-51 microscope. Photographs were taken with a Nikon DS-Fi1 digital camera. Reference to the illustrated specimens is given as England Finder coordinates. The resulting slides are deposited in the Microfossil Collection of the Universidad Nacional de Salta, Argentina, under the acronym CNS-M.

4. Results and discussion

Well-preserved palynomorphs were obtained from a single palynological sample recovered from the Yacoraite Formation outcrops. Fifty eight species have been identified, 38 angiosperms (two monocot families, eleven eudicot families and several of uncertain affinity), 7 gymnosperms of two families, and within the spores, 2 Marchanthiophyta, 6 ferns of 6 families and 4 of uncertain affinity, along with 1 freshwater algae). Brief description and comments of taxa are listed at Appendix 1. The identified palynomorphs and their botanical affinities are listed in Table 1, and illustrated in figures 3 through 5.

Based on a quantitative analysis with an N = 306 specimens, the palynological assemblage as a whole is dominated by angiosperm pollen grains (52.4%), followed by Monilophyta (24.5%), gymnosperm pollen grains (11.5%), and freshwater algae (4.8%), while bryophytes and fungi are scarce with 2.5 and 2.9%, respectively (see Appendix 2).

The sample is devoid of marine palynomorphs.

4.1. Comparisons

4.1.1. Argentina

Within the Salta Group, as previously mentioned, Moroni (1982) reported a palynoflora for the Yacoraite Formation, recovered from Lomas de Olmedo sub-basin sediments. Two different assemblages were identified. One with the presence of *Aquilapollenites magnus*, *Crassitriapertites brasiliensis* (=*Crassitricolporites brasiliensis*), *Gabonisporis vigorouxii*, *Psilastephanosporites brasiliensis*, the genus *Zlivisporis*, appearing together with numerous poliplicate grains (i.e. *Ephedripites* complex), and in less amounts *Tricolpites* sp., *Ulmoideipites* sp. (=*Verrustephanoporites*), algae and dinoflagellate cysts, to which Moroni (1982) assigned a Maastrichtian age. The other one, was described as a pollen assemblage with high Ulmaceae values, tricolpate, tricolporate, monocolpate, and triporate, along with *Pediastrum* sp. and *Mtchedlishvilia saltenia* Moroni 1984, and assigned to the Danian (Moroni, 1982, 1984). Our pollen assemblage shares all the characteristics and taxa described by Moroni (1982) for the Maastrichtian assemblage.

Quattrocchio et al. (2005) reported a palynoflora from transitional levels between the Los Blanquitos and Lecho formations (top of the Pirgua subgroup and base of the Balbuena Subgroup, respectively). This assemblage, dated as Campanian to early Maastrichtian, is characterized by typical Mesozoic taxa like *Classopollis* spp., *Callialasporites* spp. and *Todisporites major* together with angiosperm taxa previously reported in younger units from tropical South America and Africa such as *Reitrescolpites saturum*, *Retistephanocolpites regularis* and *Spinitricolpites jennerclarkei*. The last two taxa, together with *Verrustephanoporites simplex* (all typical of younger floras), are also present in our assemblage. The lack of the typical Mesozoic elements mentioned by Quattrocchio et al. (2005) would probably indicate that the Yacoraite flora is younger than that Campanian–early Maastrichtian flora. A preliminary conclusion subject to the fact that more samples are needed to make stronger biostratigraphic inferences based on the palynofloral diversity.

On the other hand, palynological assemblages from the Tunal Formation (Danian), which overlies the Yacoraite Formation, were studied by Quattrocchio and Volkheimer (1988), Quattrocchio et al. (1988) and Volkheimer et al. (2006) at southern Salta Province. These palynofloras are referred to the Danian *Mtchedlishvilia saltenia* palynozone (Quattrocchio et al., 2000), with *M. saltenia*, associated with *Pandaniidites texus*, *Gemmatricolpites subsphaericus* and *Clavatricolpites* sp. cf. *C. gracilis*. *Verrustephanoporites simplex* dominates (62%–88.5 %) the Tunal Formation palynological assemblages (Quattrocchio et al., 1988; Volkheimer et al., 2006). The species shared with the Tunal Formation are *Apiculatisporis* sp. cf. *A. charahuillaensis*, *Gabonisporis vigorouxii*, and *Polypodiaceoisporites* sp. cf. *P. retirugatus*, and the genera *Gleicheniidites* and *Zlivisporis*, among the spores; also some species from the *Ephedripites* complex and the genus *Podocarpidites*, among the gymnosperms; and *Gemmatricolpites subsphaericus*, *Tricolpites reticulatus* and *Verrustephanoporites simplex*, together with the genera *Myriophyllumpollenites*, *Retitricolporites*, *Rousea* and *Tricolpites* among the angiosperms. However, in our assemblage the typical Danian species are absent, and percentage of *Verrustephanoporites simplex* in the palynoflora we describe is far less (13.2 %) than that recorded for the Tunal Formation.

Finally, a palynoflora from the Ciénaga del Río Huaco Formation in the San Juan Province (central Argentina) was briefly described (Maastrichtian; Limarino et al., 2000). Fourteen species were identified, of which only *Gabosisporites vigorouxii* and *Ephedripites jansonii* are shared with our palynoflora.

4.1.2. Bolivia

Pérez Leytón (1987) reported palynological assemblages from two Upper Cretaceous formations from southwestern Bolivia. The assemblage from the Chaunaca Formation (Santonian–early Campanian) is characterized by several species from the *Ephedripites* complex, monocolpate, tricolpate and tricolporate grains and the presence of *Normapolles* spp. Our assemblage shares with the Chaunaca Formation palynoflora the presence of the genera *Podocarpidites, Aquillapollenites,* and a diverse *Ephedripites* complex. On the other hand, the palynoflora from the El Molino Formation (Maastrichtian) was described based on a single sample with 16 species of ferns and bryophyte spores, gymnosperm and angiosperm pollen grains, all in relatively equal proportions. The taxon *Gabonisporis vigorouxii* and the genus *Rhoipites* are considered abundant (appearing in more than 10 % of the total assemblage). In our assemblage the angiosperms are largely dominant, the genus *Rhoipites* is absent, and *Gabonisporis vigorouxii* has a lower proportion (1.8%).

Another palynological work from Bolivia is that of Vajda-Santivanez (1999) who studied the Eslabón (Maastrichtian) and Flora (Paleocene) formations from northwestern Bolivia. Both assemblages are of continental origin with their composition resembling that of the Late Cretaceous Palmae Province of Herngreen et al. (1996). A lacustrine paleoenvironment of deposition is suggested and a warm and humid (tropical) climate (Vajda-Santivanez, 1999). The Yacoraite palynoflora is very similar to that of the Maastrichtian Eslabón Formation in terms of proportions of each group, with angiosperms being clearly dominant, and with equivalent amounts of gymnosperms and ferns. Also shares the presence of several taxa, such as *Gabonisporis vigorouxii*, a diverse *Ephedripites* complex, together with the angiosperm species *Aquillapollenites magnus*, *Crassitricolporites brasiliensis*, *Ulmoideipites krempii* (=*Verrustephanoporites simplex*), and the genera *Retitricolporites*, *Tricolpites*, *Tricolporites*. The latter two genera and *Ulmoideipites krempii* (=*Verrustephanoporites simplex*) are also shared with the Flora Formation.

4.1.3. Brazil

Regali et al. (1974a, b) carried out a detailed palynological study from different Brazilian Cretaceous–Neogene coastal basins. Within them, those located further south would have developed in mid-latitudes (Campos Basin and Espírito Santo Basin). The authors described the *Crassitricolporites brasiliensis* superzone for the mid Campanian–Maastrichtian. The palynoflora of the Yacoraite Formation presents many taxa shared with that palynozone.The species *Crassitricolporites brasiliensis*, *Aquilapollenites magnus*, *Ulmoideipites krempii* (=*Verrustephanoporites simplex*), *Ephedripites* complex (e.g., *Gnetaceaepollenites*, *Ephedripites*), *Tricolpites* spp., the genera *Zlivisporis, Polypodiaceoisporites* (*P. potoniaei*) and *Triorites* (*T. africaensis*), *Psilastephanoporites brasiliensis*, *Gabonisporis vigorouxii* and *Crassitricolporites brasiliensis* are shared.

4.2. Bioestratigraphy and age determination

Some of the recorded species provide reliable information to constrain the age of the palynoflora studied here. *Aquillapollenites magnus*, *Gabonisporis vigorouxii* and

Crassitricolporites brasiliensis are typically recorded in Maastrichtian deposists from Brazil (Vajda-Santivanez, 1999), where they usually go extinct at the K–Pg boundary (Vajda and Bercovici, 2012). However, *Gabonisporis vigorouxii* is recorded in Santonian through middle Eocene deposits from Argentina (Quattrocchio, 1978; Moroni, 1982; Limarino et al., 2000; Volkheimer et al., 2006, 2007; Vallati, 2010). On the other hand, *Gemmatricolpites subsphaericus* presents its earliest records in Danian deposits of Argentina (Archangelsky, 1973; Quattrocchio and Volkheimer, 1988; Volkheimer et al., 2006, 2007). *Retistephanocolpites regularis* and *Spinitricolpites jennerclarkei* have been previously recorded in Campanian to early Maastrichtian sedimentary rocks from the Salta Basin (Quattrocchio et al., 2005), and the latter was also found in the Danian Olmedo Formation (Narváez, 2009). Finally, *Syncolporites marginatus* originally described for the Maastrichtian of Nigeria (Van Hoeken-Klinkenberg, 1964), is recorded from Campanian to Paleogene deposits (e.g., Schrank, 1984; Jaramillo and Dilcher, 2001; Eisawi et al., 2012; Cole et al., 2017).

Quattrocchio et al. (2000) proposed a palynological zonation for Paleocene–Eocene strata from the Salta Basin. The Danian *Mtchedlishvilia saltenia* Zone (Quattrocchio et al., 2000) is defined by the first appearance of *M. saltenia*, associated with *Pandaniidites texus*, *Gemmatricolpites subsphaericus* and *Clavatricolpites* sp. cf. *C. gracilis*. In the palynoflora studied here, *M. saltenia* is absent, and only *G. subsphaericus* was identified. On the other hand, Regali et al. (1974a, b) described the *Crassitricolporites brasiliensis* superzone and the distribution of many taxa that are also present in the flora of the Yacoraite Formation: *C. brasiliensis* and *Aquilapollenites magnus* are present since the early Maastrichtian and *Verrustephanoporites simplex* (a quite abundant -13.2%- element in our assemblage) since the late Maastrichtian through the Oligocene. Species from the *Ephedripites* complex (e.g., *Gnetaceaepollenites*, *Ephedripites*) and *Tricolpites* spp. appear in Upper Cretaceous levels. Moreover, the genera *Zlivisporis, Polypodiaceoisporites* (*P. potoniaei*; Campanian through Miocene from Brazil) and *Triorites* (*T. africaensis*; recorded in Cenomanian deposits), and the species *Psilastephanoporites brasiliensis* (Coniacian to Maastrichtian), *Gabonisporis vigorouxii* (Santonian to Maastrichtian) and *Crassitricolporites brasiliensis* (present in Campanian–Maastrichtian strata). Hence, based on the distribution and relative abundance of the mentioned taxa, a late Maastrichtian age could be suggested for the palynological assemblage studied herein, although more samples are needed to confirm this.

4.3. Paleoenvironment and paleoclimate

Several works discuss the depositional environment of the Yacoraite Formation (e.g., Marquillas, 1985, 1986; Salfity and Marquillas, 1994; Marquillas et al., 2005). Whole-rock sample analyses from the Metán sub-basin show carbon and oxygen isotope behavior typical of marine to freshwater transition within this formation (Marquillas et al., 2007). At the sampling area, Zelaya et al. (2014a, b) identified four facies associations that can be interpreted as a whole, as a paleoenvironment with shallow conditions near coastline settings, alternating with sub-littoral deposits. The palynological sample studied herein corresponds to F8 (dark gray to black siltstones and claystones), included in FA2 interpreted as deposits of tidal channels associated with intertidal mud flats, grading into a restricted sedimentary environment (Zelaya et al., 2014a, b).

Shallow marine conditions and localized mixing of fresh and brackish water are indicated by the invertebrate fossil record (e.g. euryhaline association composed of ostracods, bivalves, gastropods, and foraminifera and different types of charophytes; Marquillas et al., 2005); which is consistent with the palynological evidence of Papú and Melendi (1984) who reported the presence of the aquatic fern *Azolla cretacea* together with dinoflagellate cysts in the unit. However, some authors still question the presence of a marine environment, or restrict it to some parts of the basin. For example, Musacchio (1972) reported the presence of non-marine ostracod and charophytes at the Tres Cruces sub-basin. Similarly, based on the ichthyofaunal records, Cione and Pereira (1985) determined that the absence of shark remains denote that the water bodies present in this unit would not correspond to a marine environment. Furthermore, Starck (2011) considers that the fossil evidence (e.g., foraminifera, mollusks, fishes) consists mainly of non-diagnostic elements compatible with brackish waters, and that the most likely paleoenvironmental scenario would be that of a distant marine connection through the Bolivian Andean Basin. A connection that would have varied from moments of greater connection to others of total isolation during the deposition of the Yacoraite Formation (Starck, 2011).

De Valais and Cónsole-Gonella (2018) studied two ichnofossiliferous localities of the Yacoraite Formation, Maimará (Tres Cruces sub-basin) and Quebrada del Tapón (Alemanía sub-basin), the latter close to the Don Otto mine. Based on the record of avian footprints, they determined that in the Tres Cruces sub-basin, the facies correspond to a coastal environment, while in Quebrada del Tapón to a continental environment. This is consistent with our results, which show a distinctly continental palynological assemblage, without marine palynomorphs. Nevertheless, further studies with more palynological samples would help to make more conclusive paleoenvironmental inferences.

Considering the presence of *Verrustephanoporites simplex* in the described palynoflora, a paleoenvironment similar to the modern Transitional Forest (Cabrera, 1976) or Piedmont Semi-deciduous Rain Forest (Oyarzabal et al., 2018) within the Yungas

Province (350–500 m a.s.l.) could be preliminary inferred. *V. simplex* is related to *Phyllostylon rhamnoides* (Ulmaceae), a dominant tree in the Transitional Forest, as it was recognized by Quattrocchio et al. (1988) for the time of deposition of the Danian Tunal Formation in the Salta Basin. The climate of the Yungas Province is humid and warm, with summer rainfalls, some frost in winter and annual precipitations of approximately 700–1000 mm (Cabrera, 1976; Oyarzabal et al., 2018).

The presence of Haloragaceae (*Myriophyllumpollenites* spp.) together with Marsileaceae (*Gabonisporis vigorouxii*) and scarce *Ovoidites* sp. indicate a lacustrine environment during the deposition of at least part of the Yacoraite Formation. Moreover, the presence of *Gemmatricolpites subsphaericus* (Aquifoliaceae), *Retistephanocolpites regularis*, *Spinitricolpites jennerclarkei* (Valerianaceae?-Verbenaceae) and pollen grains related to Arecaceae (*Arecipites*, *Spinozonocolpites*), suggest warm and at least locally humid conditions.

The lack of gymnosperm taxa such as *Classopollis* and *Callialasporites* that were present in the transitional levels between the Los Blanquitos and Lecho formations (Campanian–early Maastrichtian; Quattrocchio et al., 2005) would suggest less dry conditions for the late Maastrichtian but as abovementioned, more samples are needed to confirm this.

4.4. Paleobiogeography

Herngreen et al. (1996) established two Late Cretaceous palynofloral provinces in South America: Palmae and *Proteacidites*/*Nothofagidites* provinces at low and high latitudes, respectively. The increase and diversity of monocolpate Palmae-type pollen and appearance of proteacean pollen, typifies the Palmae Province, together with a low abundance of gymnosperm pollen (e.g., decrease of *Ephedripites*-type species), and particularly, the absence of bisaccate pollen (Herngreen and Chlonova, 1981; Vajda-

Santivanez, 1999). On the other hand, the southern *Proteacidites*/*Nothofagidites* Province is defined by the presence of nothofagaceous pollen, together with *Beaupreaidites*, *Proteacidites* and *Peninsulapollis* taxa (with proteaceous affinity), and the abundance of podocarpaceous pollen (Herngreen et al., 1996). Later, Vajda and Bercovici (2012, 2014) defined a new zone between the two mentioned provinces, the transitional or mixed flora, with a mixed composition but also containing some endemic taxa.

The Yacoraite palynoflora developed at mid-latitudes, and is located on the northern edge of the transitional zone consisting of mixed floras (Vajda and Bercovici, 2012, 2014). The palynological assemblage has some characteristics that link it to the Palmae Province, such as the presence of *Gabonisporites vigorouxii*, *Aquillapollenites magnus*, and *Crassitricolporites brasiliensis*, together with the low abundance of gymnosperm pollen. But also has other characteristics that exclude it from that phytogeographic unit, such as the less diverse record of palmae-pollen (*Arecipites* sp. cf. *A. tenuiexinus*, and *Spinizonocolpites* sp.), and the scarcity of proteaceous pollen. As for bisaccate pollen-producing conifers, *Podocarpidites* sp. is very scarce (0.8%). The bond of the Yacoraite flora with the *Proteacidites*/*Nothofagidites* Province is even less clear due to the scarcity of Proteaceae (0.7%) and *Nothofagidites* sp. (1.9%). Representatives of the Nothofagaceae have anemophylous pollination, and its pollen can be dispersed over great distances, even thousands kilometers from its area of origin. This was recorded by Muñoz et al. (2017) who found *Nothofagus* pollen grains in Entre Ríos Province (central-eastern Argentina), which is at least 1500 km away from the Andean Patagonian forests where this taxon currently lives, being considered an extra-regional element of that pollen spectrum.

Moreover, several taxa present in the Yacoraite palynoflora such as *Crassitricolporites brasiliensis*, *Aquillapollenites magnus*, *Gabonisporis vigorouxii* and *Verrustephanoporites simplex* (=*Ulmoideipites krempii*), are also found in Maastrichtian deposits from northern South America (Brazil), included by Regali et al. (1974a, b) in the *Crassitricolporites brasiliensis* palynozone.

5. Concluding remarks

A single palynological sample from the Yacoraite Formation presented here yields palynomorphs of relatively good preservation that provide relevant information for a unit where the palynological records are scarce compared to other Maastrichtian formations in Argentina (mainly from high latitudes in Patagonia). This palynological record infers a late Maastrichtian age for the unit in the outcrops of the Valle del Tonco. The palynological assemblage does not present a clear relationship with any of the phytogeographic provinces described for the Late Cretaceous. Although it presents more similarities with the Palmae Province, it better fits with the transitional or mixed flora. The study of palynofloras from mid-latitudes can help understand the transition between tropical and temperate floras in South America during the Late Cretaceous.

Acknowledgements

This research was partially funded by the Consejo Nacional de Investigaciones Científicas y Técnicas (Project PIP CONICET 11220200101738CO).

We want to express our gratitude to Regional Noroeste of Gerencia Exploración de Materias Primas, Comisión Nacional de Energía Atómica (CNEA) for the palynological samples cession and for giving permission to publish these results; especially to Eng. Inés Torino Aráoz and Geol. Luis Ferreira for their attentive collaboration. The editor

Eduardo Koutsoukos and two anonymous reviewers are acknowledged for providing constructive comments that improved the manuscript.

References

Alonso, R.N., 1980. Icnitas de dinosaurios (Ornithopoda, Hadrosaurideae) en el Cretácico Superior del Norte de Argentina. Acta Geológica Lilloana 15 (2), 55–63.

Alonso R.N., Marquillas, R.A., 1986. Nueva localidad con huellas de dinosaurios y primer hallazgo de huellas de aves de la Formación Yacoraite (Maastrichtiano) del Norte argentino. IV Congreso Argentino de Paleontología y Bioestratigrafía (Mendoza, 1986). Proceedings 2, 33–41.

Archangelsky, S., 1973. Palinología del Paleoceno de Chubut. I Descripciones sistemáticas. Ameghiniana 10 (4), 339–399. https://www.ameghiniana.org.ar/index.php/ameghiniana/article/view/1423

Benedetto, J.L, Sánchez, T.M., 1972. *Coelodus toncoensis* nov. sp. (Pisces, Holostei, Pycnodontiformes) de la Formación Yacoraite (Cretácico Superior) de la provincia de Salta. Ameghiniana 9 (1), 59–71. https://www.ameghiniana.org.ar/index.php/ameghiniana/article/view/1366

Cabrera, A.L., 1976. Regiones Fitogeográficas Argentinas. Enciclopedia Argentina de Agricultura y Jardinería 1 (2), 1–85.

Castaños, A., Pinedo, R., Salfity, J., 1975. Nuevas consideraciones sobre la Formación Yacoraite del Cretácico Superior del norte argentino. Revista Técnica Y.P.F. Bolivianos, Publicación Especial 4 (3), 31–59.

Cione, A.L., 1977. Algunas consideraciones sobre Pycnodontiformes (Pisces, Holostei) procedentes de la Formación Yacoraite, Cretácico tardío de la provincia de Salta, Argentina. Ameghiniana 14, 315–316. https://www.ameghiniana.org.ar/index.php/ameghiniana/article/view/1539

Cione, A.L., Pereira, S. M., 1985. Los peces de la Formación Yacoraite (Cretácico tardío–Terciario?, Noroeste argentino) como indicadores de Salinidad. Revista de la Asociación Geológica Argentina 40, 83–88. https://revista.geologica.org.ar/raga/issue/view/241/184

Cione, A.L., Pereira, S.M., Alonso, R., Arias, J., 1985. Los bagres (Osteichthyes, Siluriformes) de la Formación Yacoraite (Cretácico tardío). Consideraciones biogeográficas y bioestratigráficas. Ameghiniana 21, 294–304. https://www.ameghiniana.org.ar/index.php/ameghiniana/article/view/2792

Clyde, W.C., Krause, J.M., De Benedetti, F., Ramezani, J., Cúneo, N.R., Gandolfo, M.A., Haber, P., Whelan, C., Smith, T., 2021. New South American record of the CretaceousPaleogene boundary interval (La Colonia Formation, Patagonia, Argentina). Cretaceous Research 126, 104889. https://doi.org/10.1016/j.cretres.2021.104889

Cole, J.M., Abdelrahim, O.B., Hunter, A.W., Schrank, E., Bin Ismail, M.S., 2017. Late Cretaceous spore-pollen zonation of the Central African Rift System (CARS), Kaikang Trough, Muglad Basin, South Sudan: angiosperm spread and links to the Elaterates Province. Palynology 41 (4), 547–578. https://doi.org/10.1080/01916122.2017.1303795

Cónsole-Gonella, C.A, 2011. Nuevo registro de gasterópodos en la Formación Yacoraite (Maastrichtiano–Daniano) Cordillera Oriental de Jujuy, Argentina. Sistemática, bioestratigrafía y correlación geológica. Serie Correlación Geológica 27 (1), 45–64. https://www.insugeo.org.ar/scg/ver-articulo.php?id=40

Cónsole-Gonella, C.A., Díaz-Martínez, I., Citton, de Valais, S., 2021. New record of Late Cretaceous vertebrate tracks from the Yacoraite Formation (Juella, Quebrada de Humahuaca, northwestern Argentina): aerial drone survey, preservation and sedimentary context. Journal of South American Earth Sciences 107, 103116. https://doi.org/10.1016/j.jsames.2020.103116 de Valais, S., Cónsole-Gonella, C., 2018. An updated review of the avian footprint record from the Yacoraite Formation (Maastrichtian–Danian), Northwestern Argentina, Ichnos 26 (3), 224–241. https://doi.org/10.1080/10420940.2018.1538982

Eisawi, A., Ibrahim, A.B., Abdelrahim, O.B., Schrank, E., 2012. Palynozonation of the Cretaceous to Lower Paleogene strata of the Muglad Basin, Sudan. Palynology 36, 191–207. https://doi.org/10.1080/01916122.2011.633634

Gasparini, Z., Buffetaut, E., 1980. *Dolichochampsa minima*, n.g.n.sp., a representative of a new family of eusuchian crocodiles from the Late Cretaceous of northern Argentina. Neues Jahrbuch für Geologie und Paläontologie Monatshefte 8, 257–271.

Gómez Omil, R.J., Boll, A., Hernández, R.M., 1989. Cuenca cretácico–terciaria del Noroeste argentino (Grupo Salta). In: Chebli, G.A., Spalletti, L.A. (Eds.), Cuencas Sedimentarias Argentinas. Serie de Correlación Geológica 6. Universidad Nacional de Tucumán, Tucumán, 43–64.

Gorustovich, S., Molina Castillo, J.I., Zelaya, A.M., 2013. Exploración en el tramo norte de la mina de uranio Don Otto, provincia de Salta. X Congreso Argentino de Geología Económica (San Juan, 2013). Proceedings, 102–109.

Groeber, P., 1952. Mesozoico, Ándico. In: Groeber, P., Stipanicic, P.N., Mingramm, A.R.G. (Eds.), Geografía de la República Argentina. Sociedad Argentina de Estudios Geográficos, GÆA 2, 349–541.

Herngreen, G.F.W., Chlonova, A.F., 1981. Cretaceous microfloral provinces. Pollen et Spores 23, 441–555.

Herngreen, G.F.W., Kedves, M., Rovnina, L.V., Smirnova, S.B., 1996. Chapter 29C. Cretaceous palynofloral provinces: a review. In: Jansonius, J., McGregor, D.C. (Eds.), Palynology: principles and applications. American Association of Stratigraphic Palynologists Foundation, Volume 3, 1157–1188.

Jaramillo, C.A., Dilcher, D.L., 2001. Middle Paleogene palynology of central Colombia, South America: A study of pollen and spores from tropical latitudes. Palaeontographica B 258, 87–213.

Kielbowicz de Stach, A., Angelozzi G., 1984. Microfósiles calcáreos de la Formación Yacoraite en la subcuenca Lomas de Olmedo, provincia de Salta. Actas 9th Congreso Geológico Argentino 4:508–522

Limarino, O., Net, L., Gutiérrez, P., Barreda, V., Caselli, A., Ballent, S., 2000. Definición de la Formación Ciénaga del Río Huaco (Cretácico Superior), Precordillera central, San Juan, Argentina. Revista de la Asociación Geológica Argentina 55 (1-2), 83–99. https://revista.geologica.org.ar/raga/issue/view/22

Marquillas, R.A., 1985. Estratigrafía, sedimentología y paleoambientes de la Formación Yacoraite (Cretácico Superior) en el tramo austral de la cuenca, norte argentino (Unpubl. PhD thesis). Universidad Nacional de Salta, 139 pp.

Marquillas, R.A., 1986. Ambiente de depósito de la Formación Yacoraite, Grupo Salta, Cretácico–Eoceno, Norte Argentino. I Simposio Proyecto 242, PICG–UNESCO (La Paz, 1986). Proceedings, 157–173.

Marquillas, R.A., Salfity, J.A., 1988. Tectonic framework and correlations of the Cretaceous-Eocene Salta Group, Argentine. In: Bahlburg, H., Breitkreuz, Ch., Giese, P. (Eds.) The Southern Central Andes, Lecture Notes on Earth Sciences 17. Springer-Verlag, Berlin, 119–136.

Marquillas, R.A., Salfity, J.A., 1994. Las relaciones estratigráficas regionales de la Formación Yacoraite (Cretácico Superior), Norte de la Argentina. VII Congreso Geológico Chileno (Concepción, 1994). Proceedings, 479–483.

Marquillas, R.A., del Papa, C., Sabino, I., Heredia, J., 2003, Prospección del límite K/T en la cuenca del Noroeste, Argentina: Revista de la Asociación Geológica Argentina 58 (2), 271–274. https://revista.geologica.org.ar/raga/article/view/1514

Marquillas, R., del Papa, C., Sabino, I.F., 2005. Sedimentary aspects and paleoenvironmental evolution of a rift basin: Salta Group (Cretaceous–Paleogene), northwestern Argentina. International Journal of Earth Sciences 94, 94–113. https://doi.org/10.1007/s00531-004-0443-2

Marquillas, RA., Sabino, I.F., Nóbrega Sial, A., del Papa, C., Ferreira, V., Matthews, S., 2007. Carbon and oxygen isotopes of Maastrichtian–Danian shallow marine carbonates: Yacoraite Formation, northwestern Argentina. Journal of South American Earth Sciences 23 (4), 304–320. https://doi.org/10.1016/j.jsames.2007.02.009

Marquillas, R.A., Salfity, J.A., Matthews, S.J., Matteini, M., Dantas, E., 2011. U-Pb zircon age of the Yacoraite Formation and its significance to the Cretaceous–Tertiary boundary in the Salta basin, Argentina. In Salfity, J.A., Marquillas, R.A. (Eds.), Cenozoic geology of the Central Andes of Argentina. SCS Publisher, Salta, 227–246.

Matthews, S.J., Marquillas, R.A., Kemp, A.J., Grange, F.K., Gardeweg, M.C., 1996. Active skarn formation beneath Lascar Volcano, northern Chile: a petrographic and geochemical study of xenoliths in eruption products. Journal of Metamorphic Geology 14 (4), 509–530. https://doi.org/10.1046/j.1525-1314.1996.00359.x

Méndez. I., Viviers M.C., 1973. Estudio micropaleontológico de sedimentitas de la Formación Yacoraite (provincias de Salta y Jujuy). Actas 5th Congreso Geológico Argentino 3: 467–470.

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 25, 9–44. https://revista.geologica.org.ar/raga/issue/view/184

Moroni, A.M., 1982. Correlación palinológica en las Formaciones Olmedo y Yacoraite. Cuenca del Noroeste Argentino. III Congreso Geológico Chileno (Concepción, 1982). Proceedings, 340–349.

Moroni, A.M., 1984. *Mchedlishvilia saltenia* n sp. en sedimentitas del Grupo Salta, provincia de Salta. III Congreso Argentino de Paleontología y Bioestratigrafía (Corrientes, 1982). Proceedings, 129–140.

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

Muñoz, N.E., Di Pasquo, M., Biganzoli, F., Batista, W.B., 2017. Análisis aeropalinológico en tres áreas de vegetación dentro del Parque Nacional El Palmar (Colón, Entre Ríos) y su relación con la vegetación local y regional. Boletín de la Sociedad Argentina de Botánica 52 (3), 473–496. https://botanicaargentina.org.ar/analisis-aeropalinologico-en-tres-areas-de-vegetacion-dentro-del-parque-nacional-el-palmar-colon-entre-rios-y-su-relacion-con-la-vegetacion-local-y-regional/

Musacchio, E.A., 1972. Charophytas de la Formación Yacoraite en Tres Cruces y Yavi Chico, Jujuy, Argentina. Ameghiniana 9 (3), 223–237. https://www.ameghiniana.org.ar/index.php/ameghiniana/article/view/1386

Narváez, P.L., 2009. Palinoestratigrafía, paleoambientes y cambios climáticos durante el Cretácico final y Paleógeno de la Cuenca del Grupo Salta, República Argentina (Unpubl. PhD thesis). Universidad Nacional de Salta, 229 pp.

Oyarzabal, M., Clavijo, J., Oakley, L., Biganzoli, F., Tognetti, P., Barberis, I., Maturo, H.M., Aragón, R., Campanello, P.I., Prado, D., Oesterheld, M., León, R.J.C., 2018. Unidades de vegetación de la Argentina. Ecología Austral 28 (1), 40–63. https://doi.org/10.25260/EA.18.28.1.0.399

Papú, O.H, Melendi, D.L., 1984. Sobre el hallazgo de másulas de *Azzolla* Lamark (Salviniaceae) en las Formaciones Yacoraite y Paso del Sapo. Asociación Paleontológica Argentina, Circular Informativa 13, 2.

Payrola, P.A., Hongn, F., del Papa, C., Aramayo, A. Gorustovich, S., 2011. Inversión tectónica y variaciones estructurales a lo largo del Valle del Tonco, Valles Calchaquíes, Noroeste de la Argentina. Acta geológica lilloana 23 (1-2), 27–45. https://dialnet.unirioja.es/servlet/articulo?codigo=4388063

Pérez Leytón, M., 1987. Datos palinológicos del Cretácico Superior de la secci6n estratigráfica de Carata, Potosí, Bolivia. IV Congreso Latinoamericano de Paleontologia (Santa Cruz de la Sierra, 1987). Proceedings, 739–756.

Pérez Pincheira, E., di Pasquo, M., 2021. First palynological study of the Jagüel Formation (Maastrichtian-Danian), Patagonian Río Negro province: Paleobiogeographic importance for the Neuquén Basin, Argentina. Cretaceous Research 127, 104932. https://doi.org/10.1016/j.cretres.2021.104932

Phipps, D., Playford, G., 1984. Laboratory techniques for extraction of palynomorphs from sediments. Papers of the Department of Geology, University of Queensland 11, 1–23. https://espace.library.uq.edu.au/view/UQ:179170

Quattrocchio, M., 1978. Contribución al conocimiento de la palinología estratigráfica de la Formación Lumbrera (Terciario Inferior, Grupo Salta). Ameghiniana 15 (3-4), 285–300. https://www.ameghiniana.org.ar/index.php/ameghiniana/article/view/1561

Quattrocchio, M.E., 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. IV Congreso Argentino de Paleontología y Bioestratigrafia (Mendoza, 1986). Proceedings 3, 109–120.

Quattrocchio, M.E., Marquillas, R.A., Volkheimer, W., 1988. Palinología, paleoambientes y edad de la Formación Tunal, cuenca del Grupo Salta (Cretácico–Eoceno), República Argentina. IV Congreso Argentino de Paleontología y Bioestratigrafia (Mendoza, 1986). Proceedings 3, 95–107.

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

Quattrocchio, M.E., Volkheimer, W., Marquillas, R.A., Salfity, J.A., 2005. Palynostratigraphy, palaeobiogeography and evolutionary significance of the Late Senonian and Early Palaeogene palynofloras of the Salta Group, northern Argentina. Revista Española de Micropaleontología 37, 259–272.

Regali, M.S.P., Uesugui, N., Santos, A.S., 1974a. Palinologia dos sedimentos Meso-Cenozóicos do Brasil (1). Boletim Técnico da Petrobrás 17 (3), 177–191.

Regali, M.S.P., Uesugui, N., Santos, A.S., 1974b. Palinologia dos sedimentos Meso-Cenozóicos do Brasil (2). Boletim Técnico da Petrobrás 17 (4), 263–301.

Reyes, F.C., Salfity, J.A., 1973. Consideraciones sobre la estratigrafía del Cretácico (Subgrupo Pirgua) del noroeste argentino. V Congreso Geológico Argentino (Villa Carlos Paz, 1972). Proceedings 3, 355–385.

Salfity, J.A., Marquillas, R.A., 1994. Tectonic and sedimentary evolution of the Cretaceous-Eocene Salta Group Basin, Argentina. In: Salfity, J.A. (Ed.). Cretaceous tectonics of the Andes, Earth Evolution Sciences. Friedrich Vieweg & Sohn Verlag, Brunswick, 266–315.

Sial, A.N., Ferreria, V.P., Toselli, A.J., Parada, M.A., Aceñolaza, F.G., Pimentel, M.M., Alonso, R.N., 2001. Carbon and oxygen isotope compositions of some Upper Cretaceous–Paleocene sequences in Argentina and Chile. International Geological Review 43 (10), 892–909. https://doi.org/10.1080/00206810109465054

Schrank, E., 1984. Organic-geochemical and palynological studies of a Dakhla Shale profile (Late Cretaceous) in southeast Egypt. Berliner geowissenschaftliche Abhandlungen, Reihe A 50, 189–207.

Starck, D., 2011. Cuenca Cretácica-Paleógena del Noroeste Argentino. VIII Congreso de Exploración y Desarrollo de Hidrocarburos, Simposio Cuencas Argentinas: visión actual (Mar del Plata, 2011). Proceedings, 407–453.

Turic, M., Aramayo Flores, F., Gómez Omil, R., Pombo, R., Sciutto, J., Robles, D., Cáceres, A., 1987. Geología de las cuencas petroleras de la Argentina. In: Felder, B.A. (Eds.), Evaluación de las Formaciones en la Argentina. Schlumberger I, 1–41.

Turner, J.C.M., 1958**.** Estratigrafía del cordón de Escaya y de la sierra de Rinconada (Jujuy). Revista de la Asociación Geológica Argentina 13 (1), 15–39. https://revista.geologica.org.ar/raga/issue/view/133

Vajda-Santivanez, V., 1999. Miospores from Upper Cretaceous-Paleocene strata in northwestern Bolivia. Palynology 23, 181–196. https://doi.org/10.1080/01916122.1999.9989527

Vajda, V., Bercovici, B., 2012. Pollen and Spore stratigraphy of the Cretaceous–Paleogene Southern Hemisphere. Journal of Stratigraphy 36, 153–164.

Vajda, V., 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. https://doi.org/10.1016/j.gloplacha.2014.07.014

Vallati, P., 2010. Asociaciones palinológicas con angiospermas en el Cretácico Superior de la Cuenca Neuquina, Argentina. Revista Brasileira de Paleontologia 13 (2), 143–158. https://www.sbpbrasil.org/revista/edicoes/13_2/Artigo%207%20-%20Vallati.pdf

Van Hoeken-Klinkenberg, P.M.J., 1964. A palynological investigation of some Upper Cretaceous sediments in Nigeria. Pollen et Spores 6 (1), 209–231.

Villafañe, P.G., Cónsole-Gonella, C., Citton, P., Díaz-Martínez, I., de Valais, S., 2021. Three-dimensional stromatolites from Maastrichtian–Danian Yacoraite Formation, Argentina: modelling and assessing hydrodynamic controls on growth patterns. Geological Magazine 158 (10), 1–17. https://doi.org/10.1017/S0016756821000315

Volkheimer, W., Novara, M.G., Narváez, P.L., Marquillas, R.A., 2006. Palynology and paleoenvironmental significance of the Tunal Formation (Danian) at its type locality, quebrada El Chorro (Salta, Argentina). Ameghiniana 43 (3), 567–584. https://www.ameghiniana.org.ar/index.php/ameghiniana/article/view/780

Volkheimer, W., Scafati, L., Melendi, D.L., 2007. Palynology of a Danian warm climatic wetland in Central Northern Patagonia, Argentina. Revista Española de Micropaleontología 39, 117–134.

Zelaya, A.M., Gorustovich, S., Ceballos, E.F., Guidi, F., 2014a. Paleoambiente del Miembro Don Otto (Formación Yacoraite) como factor de control del depósito de uranio en la mina Don Otto, provincia de Salta. XIV Reunión Argentina de Sedimentología (Puerto Madryn, 2014). Proceedings, 305–306.

Zelaya, A.M., Gorustovich, S., Sánchez, M.C., 2014b. Paleoambiente del Miembro Complejo Don Otto de la Formación Yacoraite (Maastrichtiano–Daniano) en el tramo sur del valle del río Tonco -mina de uranio Don Otto, provincia de Salta, Argentina. XIX Congreso Geológico Argentino, Simposio de exploración de uranio en la Argentina (Córdoba, 2014). Proceedings, 897–898.

Captions

Table 1. Taxonomic and botanical affinity of the taxa recorded in the Yacoraite Formation at the Don Otto mine vicinity.

Fig. 1. Location map of the study area. A. General location, B. Salta Province, C. Location of study área, D. Geological map of the Valle del Tonco (modified from Gorustovich et al., 2013).

Fig. 2. Lithostratigraphic section with palynological sample location (modified from Zelaya et al., 2014a).

Fig. 3. Spores and gymnosperm pollen grains of the Yacoraite Formation. A. *Apiculatisporis* sp. cf. *A. charahuillaensis*, CNS-M 001/C: M43/3; B. *Baculatisporites comaumensis*, CNS-M 001/G: G39/0; C. *Concavissimisporites* sp., CNS-M 001/B: Z30/1; D. *Fisciniasporites* sp., CNS-M 001/B: X57/4; E. *Gabonisporis vigorouxii*, CNS-M 001/E: B45/2; F. *Gleicheniidites* sp., CNS-M 001/G: U58/1; G. *Microreticulatisporites* sp., CNS-M 001/G: Y36/0; H, *Polypodiaceoisporites retirugatus*, CNS-M 001/E: A24/3; I. *Verrucosisporites* sp. 1, CNS-M 001/G: G39/2; J.*Verrucosisporites* sp. 2, CNS-M 001/A: S45/0; K. *Zlivisporis reticulatus*, CNS-M 001/D : A59/4; L. *Zlivisporis* sp., CNS-M 001/A: L28/4; M. *Equisetosporites* sp. cf. *E. concinnus*, CNS-M 001/G: P31/4; N. *Equisetosporites* sp. cf. *E. notensis*, CNS-M 001/G: Y59/1; O. *Gnetaceaepollenites jansonii*, CNS-M 001/C: T61/2; P. *Gnetaceaepollenites* sp. cf. *G. barghoornii*, CNS-M 001/G: N43/2; Q. *Gnetaceaepollenites* sp., CNS-M 001/F: G51/4; R. *Singhia multicostata*, CNS-M

001/H: G51/1; S. *Podocarpidites* sp., CNS-M 001/B: Z28/0; T. *Ovoidites* sp., CNS-M 001/B: Y29/1. Scale bar: 10µm.

Fig. 4. Angiosperm pollen grains of the Yacoraite Formation. A–B. *Aquillapollenites magnus;* A. CNS-M 001/B: Z34/1; B. CNS-M 001/G: L58/1; C–D, *Crassitricolporites brasiliensis;* C. CNS-M 001/E: J46/1; D. SEM; E. *Cupanieidites* sp. cf. *C. orthoteichus*, CNS-M 001/F: L40/3; F. *Gemmatricolpites subsphaericus*, CNS-M 001/H: S51/0; G–H. *Gemmatricolpites pergemmatus*; G. CNS-M 001/H: T48/3; H, SEM; I. *Margocolporites* sp. cf. *M. lihokus*, CNS-M 001/E: K47/0; J. *Diporites* sp., CNS-M 001/A: Z26/3; K. *Myriophyllumpollenites* sp. in Quattrocchio and Volkheimer 1988, CNS-M 001/E: U44/0; L. *Penetetrapites* sp. cf. *P. mollis*, CNS-M 001/E: Z20/4; M. *Peninsulapollis gillii*, CNS-M 001/G: Y34/3; N. ?*Psilabrevitricolpites* sp., CNS-M 001/G: Z26/2; O. *Psilastephanoporites brasiliensis*, CNS-M 001/E: G55/4; P. *Psilatricolpites* sp., CNS-M 001/E: S37/2; Q. *Arecipites* sp. cf. *A. tenuiexinus*, CNS-M 001/H: W33/0; R. *Liliacidites variegatus*, CNS-M 001/G: Z40/4; S. *Psilatricolporites* sp. 1, CNS-M 001/E: F50/2; T. *Psilatricolporites* sp. 2, CNS-M 001/H: D50/0; U. *Retistephanocolpites regularis*, CNS-M 001/H: T27/3; V. *Nothofagidites* sp., CNS-M 001/H: T53/2; W–X. *Retitricolporites* sp. cf. *R. multibaculates;* W, CNS-M 001/A: W28/0; M43/3; X, CNS-M 001/B: H30/1; Y. *Retitricolporites* sp., CNS-M 001/F: O57/0. Scale bar: 10µm.

Fig. 5. Angiosperm pollen grains of the Yacoraite Formation. A. *Rousea patagonica*, CNS-M 001/E: H49/3; B. *Spinitricolpites jennerclarkei*, CNS-M 001/D: E34/1; C. *Spinizonocolpites* sp., CNS-M 001/G: C28/3; D. *Syncolporites* sp. cf. *S. marginatus*, CNS-M 001/H: J51/3; E. *Syncolporites* sp., CNS-M 001/H: Q40/3; F–G.

Striatricolporites sp.; F, CNS-M 001/E: Y39/0; G, CNS-M 001/E: L32/2; H–I. *Tricolpites* sp. cf. *T. bathyreticulatus;* H, CNS-M 001/A: N49/3; I, SEM; J. *Tricolpites reticulatus*, CNS-M 001/G: S47/2; K. *Tricolpites* sp. cf. *T cellatus*, CNS-M 001/A: V47/0; L. *Tricolpites* sp., CNS-M 001/H: G35/0; M–N. *Verrustephanoporites simplex*; M, CNS-M 001/E: R51/0; N, CNS-M 001/E: B21/4; O. *Triorites* sp. cf. *T. tenuiexinus*, CNS-M 001/E: C36/4; P. *Verrutricolpites* sp., CNS-M 001/C: Q40/0; Q. *Tricolporites* sp. 1, CNS-M 001/H: U44/3; R. *Tricolporites* sp. 2, CNS-M 001/H: B20/0; S. *Tricolporites* sp. 3, CNS-M 001/B: M36/4; T. *Tricolporites* sp. 4, CNS-M 001/E: C19/0. Scale bar: 10µm.

Figure

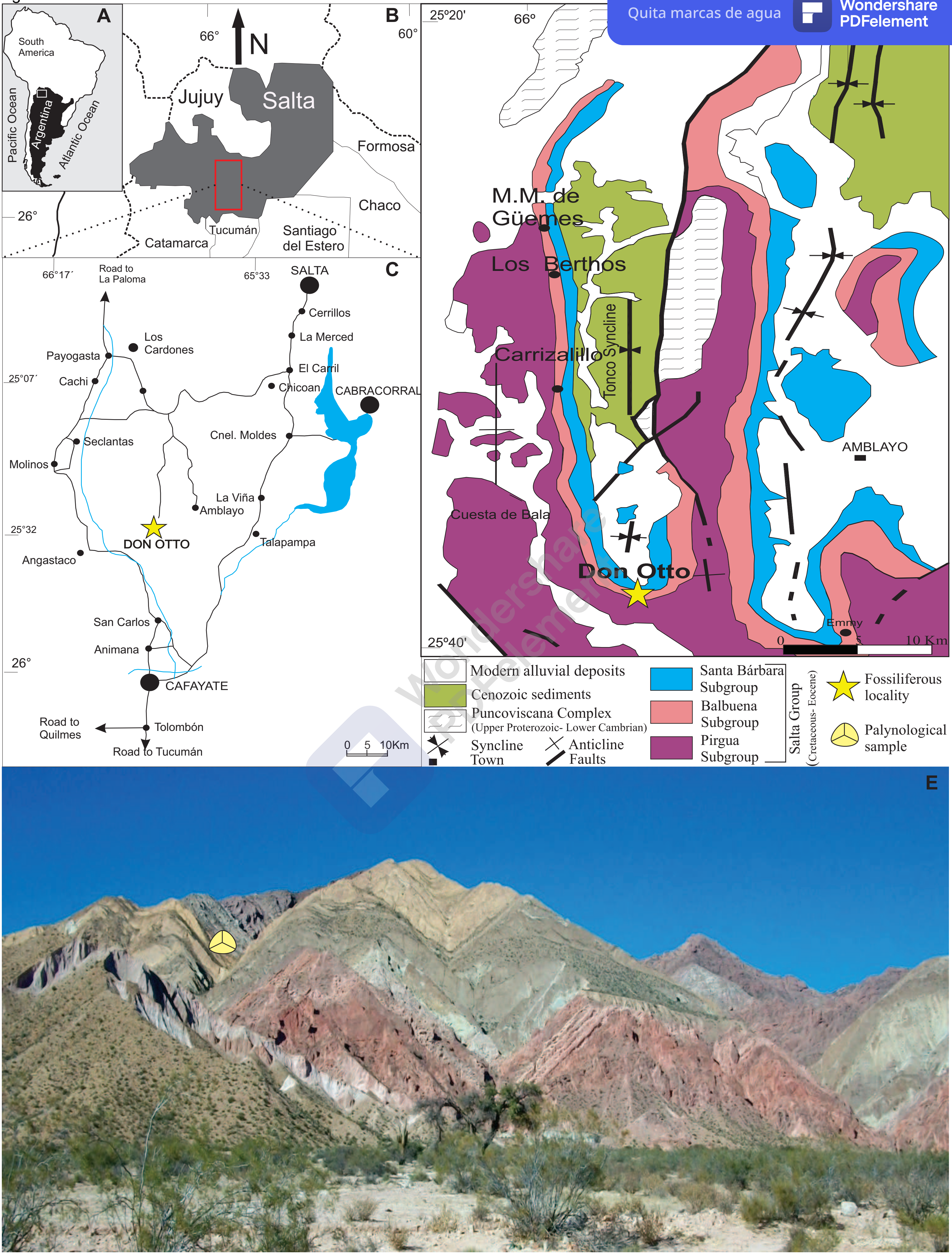


Figure 1. Location of the study area

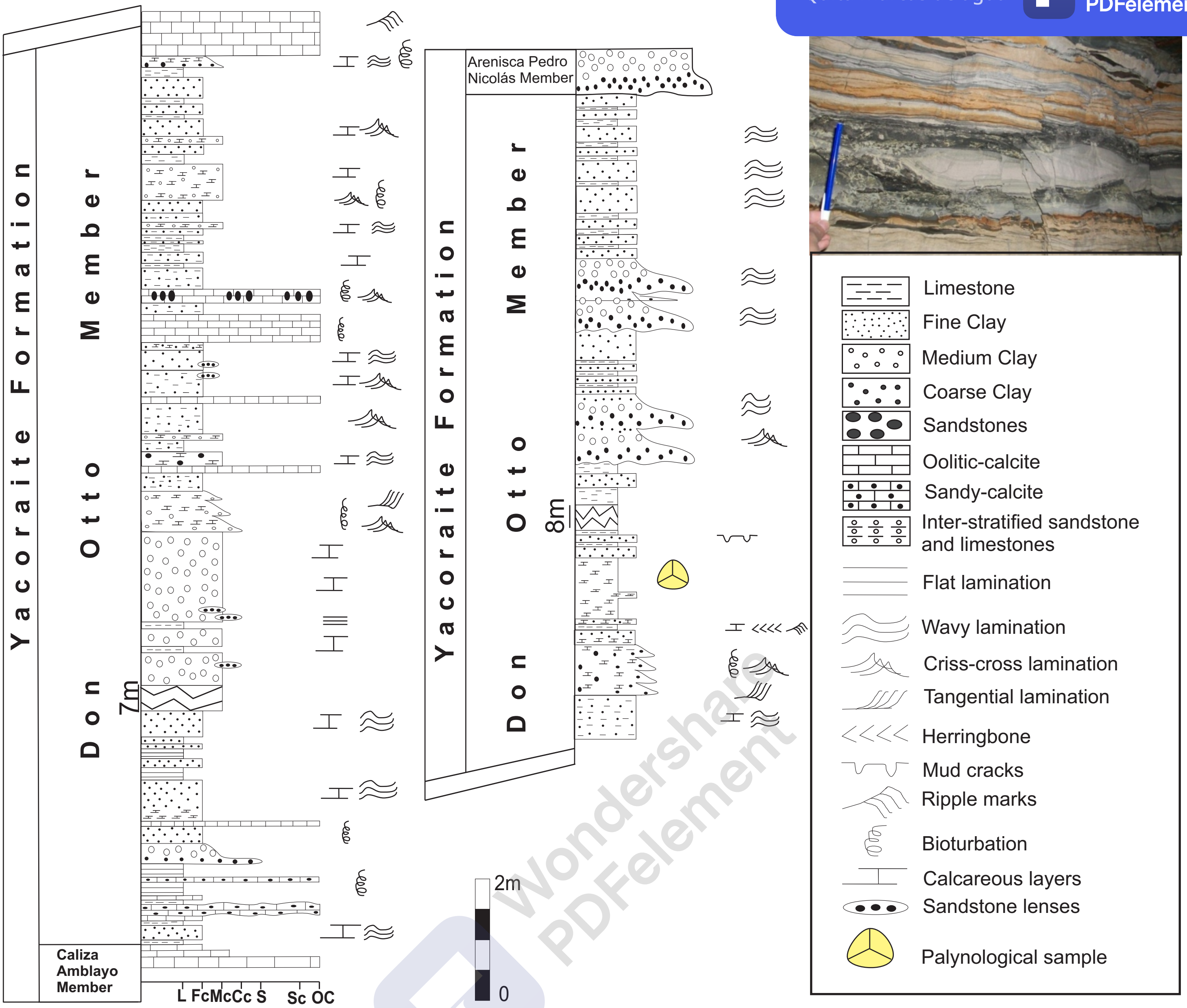
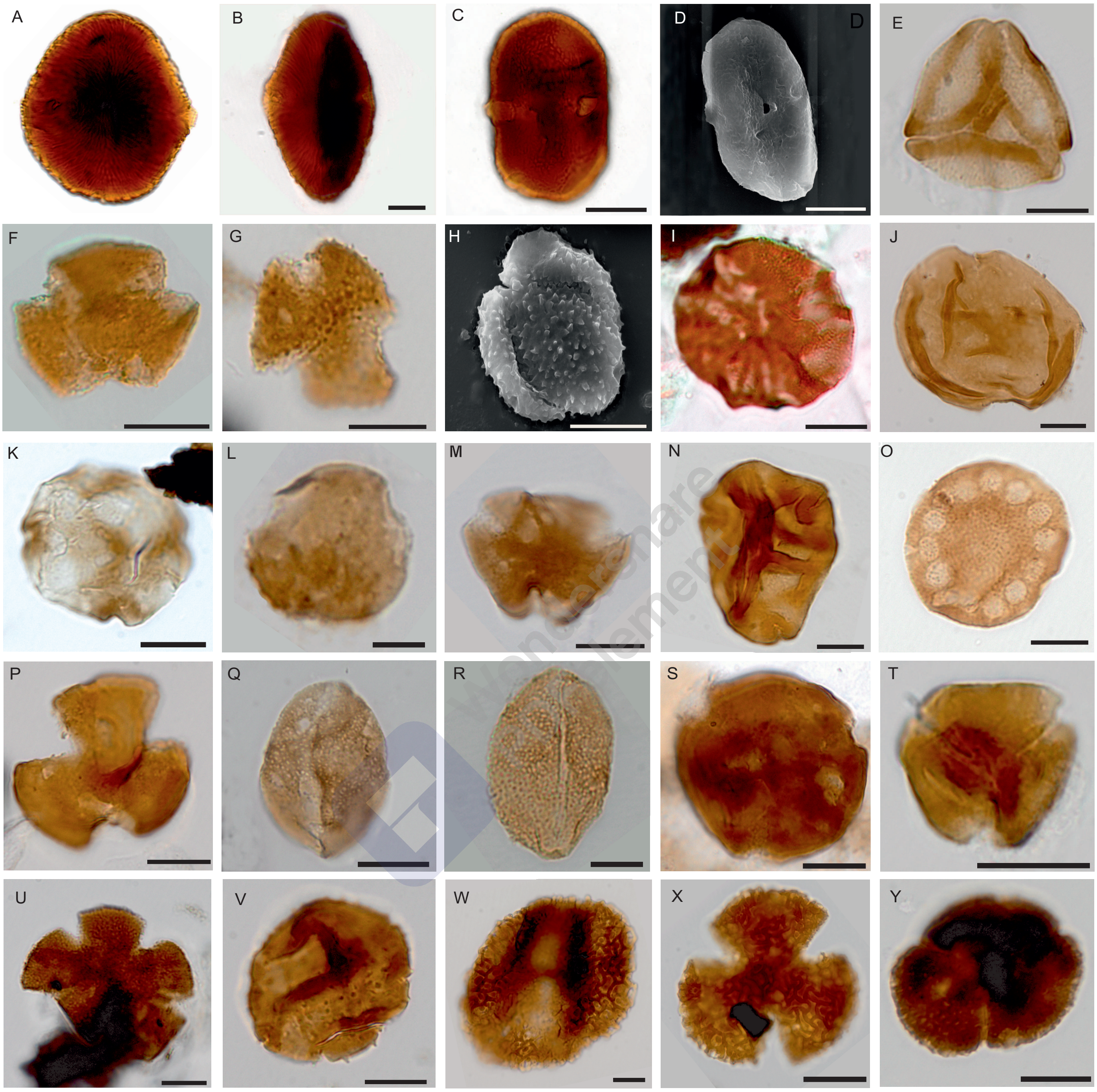

Yacoraite Formation
Don Otto Member
Caliza Amblayo Member
7m
L FcMcCc S Sc OC
Arenisca Pedro Nicolás Member
Yacoraite Formation
Don Otto Member
8m
2m
0
Limestone
Fine Clay
Medium Clay
Coarse Clay
Sandstones
Oolitic-calcite
Sandy-calcite
Inter-stratified sandstone and limestones
Flat lamination
Wavy lamination
Criss-cross lamination
Tangential lamination
Herringbone
Mud cracks
Ripple marks
Bioturbation
Calcareous layers
Sandstone lenses
Palynological sample

Figure 3

Plate 1


A
B
C
D
D
E
F
G
H
I
J
K
L
M
N
O
P
Q
R
S
T
U
V
W
X
Y

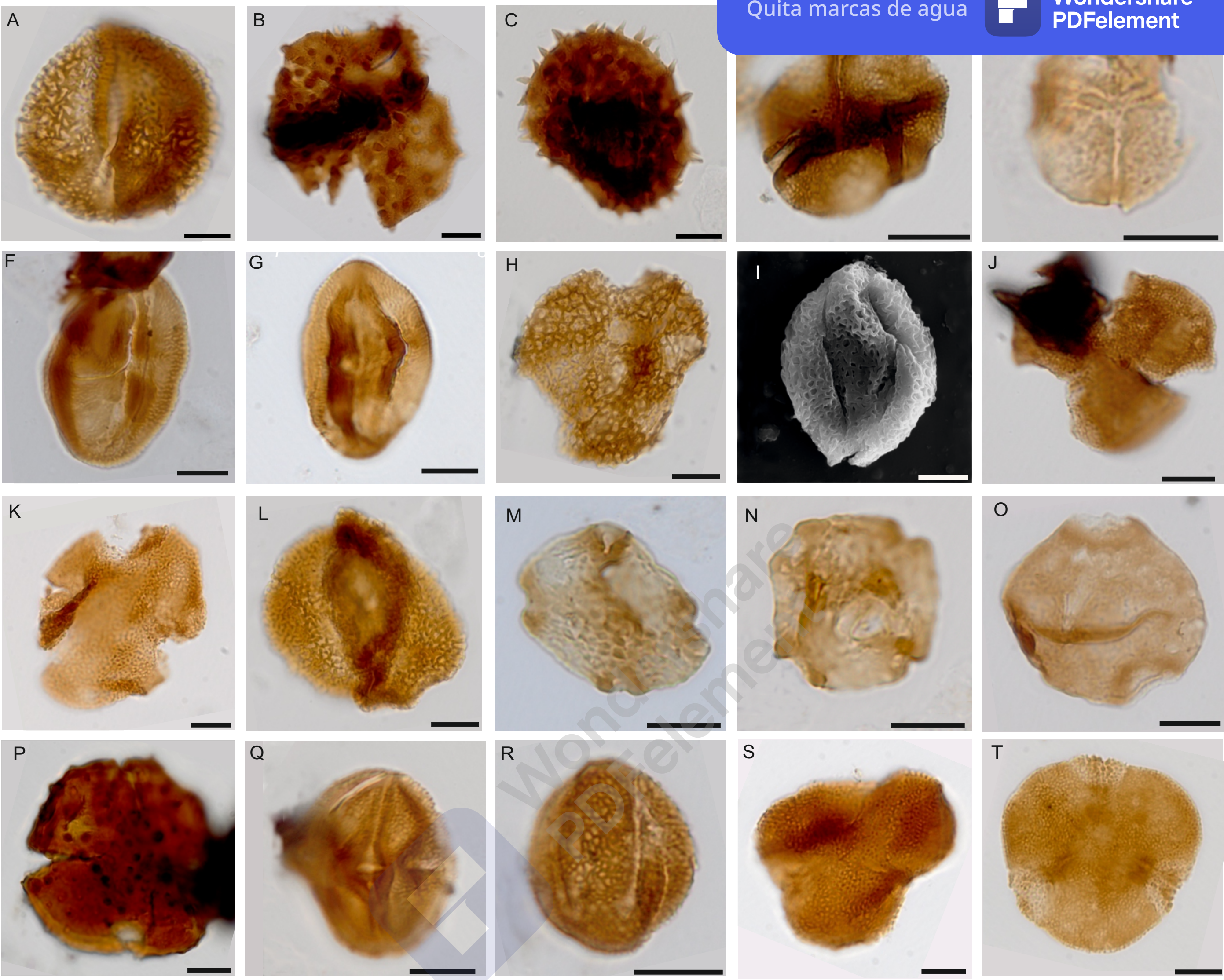


Figure 5

Table

Table 1

Group	**Family**	**Species**
Spores		
Marchanthiophyta		*Zlivisporis reticulatus* (Pocock) Pacltova and Simoncsics 1970 (Fig. 3K)
		Zlivisporis sp. (Fig. 3L)
Monilophyta	Schizaeaceae	*Fisciniasporites* sp. (Fig. 3D)
	Polypodiaceae	*Polypodiaceoisporites retirugatus* Muller 1968 (Fig. 3H)
	Osmundaceae	*Baculatisporites comaumensis* (Cookson 1953) Potonie 1956 (Fig. 3B)
	Gleicheniaceae	*Gleicheniidites* sp. (Fig. 3F)
	Dicksoniaceae	*Concavissimisporites* sp. (Fig. 3C)
	Marsileaceae	*Gabonisporis vigorouxii* Boltenhagen 1967 (Fig. 3E)
Incertae sedis		*Microreticulatisporites* sp. (Fig. 3G)
		Verrucosisporites sp. 1 (Fig. 3I)
		Verrucosisporites sp. 2 (Fig. 3J)
		Apiculatisporis sp. cf. *A. charahuillaensis* (Fig. 3A)
Algae	Zignemataceae	*Ovoidites* sp. (Fig. 3T)
Fungi		various spores
Gymnosperm pollen grains		
Conipherophyta	Podocarpaceae	*Podocarpidites* sp. (Fig. 3S)
Gnetophyta	Ephedraceae	*Equisetosporites* sp. cf. *E. concinnus* Singh 1964 (Fig. 3M)
		Equisetosporites sp. cf. *E. notensis* (Cookson) Romero 1977 (Fig. 3N)
		Gnetaceaepollenites jansonii (Pocock) Lima 1980 (Fig. 3O)
		Gnetaceaepollenites sp. cf. *G. barghoornii* (Pocock) Lima 1980 (Fig. 3P)
		Gnetaceaepollenites sp. (Fig. 3Q)
		Singhia multicostata (Brener) Lima 1980 (Fig. 3R)
Angiosperm pollen grains		
Monocots	Arecaceae	*Arecipites* sp. cf. *A. tenuiexinus* Leffingwell 1971 (Fig. 4Q)
		Spinizonocolpites sp. (Fig. 5C)
	Liliaceae	*Liliacidites variegatus* Couper 1953 (Fig. 4R)
Eudicots	Proteaceae	*Peninsulapollis gillii* (Cookson) Dettmann y Jarzen 1988 (Fig. 4M)
	Nothofagaceae	*Nothofagidites* sp. (Fig. 4V)
	Ulmaceae	*Verrustephanoporites simplex* Leidelmeyer 1966 (Fig. 5M–N)
	Loranthaceae	*Syncolporites* sp. cf. *S. marginatus* Van Hoeken-Klinkenberg 1964 (Fig. 5D)
		Syncolporites sp. (Fig. 5E)
	Aquifoliaceae	*Gemmatricolpites subsphaericus* Archangelsky 1973 (Fig. 4F)
		Gemmatricolpites pergemmatus Muller 1968 (Fig. 4G–H)
	Onagraceae	*Diporites* sp. (Fig. 4J)
	Gunneraceae	*Tricolpites reticulatus* Cookson 1947 ex Couper 1953 (Fig. 5J)
		Tricolpites sp. cf. *T. bathyreticulatus* Stanley 1965 (Fig. 5H–I)
		Tricolpites sp. cf. *T. cellatus* Norton in Norton and Hall 1967 (Fig. 5K)
		Tricolpites sp. (Fig. 5L)
	Verbenaceae	*Spinitricolpites jennerclarkei* Scholtz 1985 ex Jansonius and Hills 1990 (Fig. 5B)
	Fabaceae	*Margocolporites* sp. cf. *M. lihokus* Srivastava 1972 (Fig. 4I)
	Sapindaceae	*Cupanieidites* sp. cf. *C. orthoteichus* Cookson and Pike 1954 (Fig. 4E)
	Haloragaceae	*Myriophyllumpollenites* sp.1 in Quattrocchio and Volkheimer 1988 (Fig. 4K)
	Incertae sedis	*Aquillapollenites magnus* Regali et al. 1974 (Fig. 4A–B)
		Crassitricolporites brasiliensis Herngreen 1972 (Fig. 4C–D)
		Psilatricolpites sp. (Fig. 4P)
		Psilatricolporites sp. 1 (Fig. 4S)
		Psilatricolporites sp. 2 (Fig. 4T)
		Psilastephanoporites brasiliensis Regali et al. 1974 (Fig. 4O)
		?*Psilabrevitricolpites* sp. (Fig. 4N)
		Penetetrapites sp. cf. *P. mollis* Hedlund and Norris 1968 (Fig. 4L)
		Retistephanocolpites regularis Hoeken-Klinkenberg 1966 (Fig. 4U)
		Retitricolporites sp. cf. *R. multibaculates* Takahashi 1997 (Fig. 4W–X)
		Retitricolporites sp. (Fig. 4Y)
		Rousea patagonica Archangelsky 1973 (Fig. 5A)
		Striatricolporites sp. (Fig. 5F–G)
		Tricolporites sp. 1 (Fig. 5Q)
		Tricolporites sp. 2 (Fig. 5R)
		Tricolporites sp. 3 (Fig. 5S)
		Tricolporites sp. 4 (Fig. 5T)
		Triorites sp. cf. *T. tenuiexinus* Muller 1968 (Fig. 5O)
		Verrutricolpites sp. (Fig. 5P)

TRILETE SPORES

- *Apiculatisporis* sp. cf. *A. charahuillaensis* Volkheimer 1972

Diameter: 68–71 µm (6 specimens).
The original material of *A. charahuillaensis* has diameters of 35–40 µm (Volkheimer, 1972). Our specimens are larger, such as the specimens recorded in the Olmedo and Tunal formations by Narváez (2009).
Argentina. *A. charahuillaensis* was originally described for the Calovian of the Neuquén Basin (Volkheimer, 1972). The species is also recorded in the Danian of the Tunal Formation (Volkheimer et al., 2006; Narváez, 2009).
Rest of the world: not recorded.
Botanical affinity: unknown.

- ***Baculatisporites comaumensis* (Cookson 1953) Potonie 1956**

Diameter: 31–33 µm (2 specimens).
Worldwide distribution.
Botanical affinity. Osmundaceae.

- ***Concavissimisporites* sp.**

Diameter: 49–58 µm (8 specimens).
Botanical affinity. Dicksoniaceae.

- ***Fisciniasporites* sp.**

Diameter: 61(67)77 µm (16 specimens).
Botanical affinity. Schizaeaceae.

- ***Gabonisporis vigorouxii* Boltenhagen 1967**

Diameter: 41(49)58 µm (12 specimens).
Argentina: Maastrichtian–Danian and early to middle Eocene (Quattrocchio, 1978; Moroni, 1982; Limarino et al., 2000; Volkheimer et al., 2006, 2007; Narváez, 2009, Vallati et al., 2016, 2017).
Rest of the world: Bolivia: Maastrichtian (Vajda-Santivanez, 1999). Brazil: Coniacian-Maastrichtian (Regali et al., 1974b; Ashraf and Stinnesbeck, 1988). Gabón: Upper Cretaceous (Boltenhagen, 1967).
Botanical affinity. Marsileaceae (Ashraf and Stinnesbeck, 1988).

- *Gleicheniidites* sp.

Diameter: 35–42 µm (4 specimens).
Worldwide distribution.
Botanical affinity. Gleicheniaceae.

- *Microreticulatisporites* sp.

Diameter: 36(38)47 µm (10 specimens).
Botanical affinity: unknown.

- *Polypodiaceoisporites retirugatus* Muller 1968

Diameter: 41(47) 57 µm (29 specimens).

Argentina: Volkheimer et al. (2006) cites as cf. for the Tunal Formation at the type locality.
Rest of the world: *P. retirugatus* was recorded from the Late Cretaceous to Early Paleogene of Malaysia (Muller, 1968) and Neogene of Papua and New Guinea (Playford, 1982).
Botanical affinity. Polipodiaceae Family. Muller (1968) mentions the probable affinity with the extant fern genus *Pteris* L.

***Verrucosisporites* sp. 1**
Diameter: 44–66 µm (6 specimens).
Botanical affinity: unknown.

- *Verrucosisporites* sp. 2
Diameter: 60 µm (6 specimens).
Botanical affinity: unknown.

- *Zlivisporis reticulatus* (Pocock) Pacltova y Simoncsics 1970
Diameter: 48(59)68 µm (19 specimens).
Argentina: Albian (Archangelsky and Llorens, 2005)
Worldwide distribution for the Cretaceous.
Botanical affinity: Marchanthiophyta.

- *Zlivisporis* sp.
Diameter: 51–62 µm (6 specimens).
Smooth proximal face, and reticulated distal face.
Botanical affinity: Marchanthiophyta.

GYMNOSPERM POLLEN GRAINS

- *Podocarpidites* sp.
Diameter: 56–58 µm (2 specimens).
Worldwide distribution.

- ***Equisetosporites* sp. cf. *E. concinnus* Singh 1964**
Equatorial diameter: 66–88 µm, polar diameter: 20–39 µm (2 specimens).
Equisetosporites concinnus has 10–12 ribs of 7–10µm in the thinner middle part, our specimens have less ribs (7–8).
Argentine: not previously recorded.
Rest of the world: a single record for the Maastrichtian.
Botanical affinity. Ephedraceae.

- ***Equisetosporites* sp. cf. *E. notensis* (Cookson) Romero 1977**
Equatorial diameter: 25–47 µm, polar diameter: 14–28 µm (6 specimens).
Argentina: Kachaike Formation (Archangelsky and Llorens, 2009), Upper Cretaceous of the Lefipán Formation (Baldoni, 1992) and for the Eocene of the Río Turbio Formation (Romero, 1977). Middle to Upper Miocene (Barreda and Palazzesi, 2007).

Rest of the world: Cretaceous to Neogene.
Botanical affinity. Ephedraceae.

- ***Gnetaceaepollenites jansonii*** **(Pocock) Lima 1980**
  Equatorial diameter: 75–111 µm, polar diameter: 40–42 µm (5 specimens).
Argentina: Ciénaga del Rio Huaco Formation, Maastrichtian (Limarino et al., 2000).
Rest of the world: Maastrichtian of Bolivia (Vajda-Santivanez, 1999); Albian–Cenomanian of Brasil (Herngreen, 1973; Lima, 1980); Albian of Canada (Pocock, 1964; Burden y Hills, 1989); and Aptian–Maastrichtian of Africa (Kotova, 1978; Schrank and Ibrahim, 1995).
Botanical affinity. Ephedraceae.

- ***Gnetaceaepollenites*** **sp. cf.** ***G. barghoornii*** **(Pocock) Lima 1980**
  Equatorial diameter: 42–45 µm, polar diameter: 20–21 µm (3 specimens).
Specimens in a poor state of preservation with 8–9 ribs, *Gnetaceaepollenites barghoornii* differs in having 10–12 ribs.
Botanical affinity. Ephedraceae.

- ***Gnetaceaepollenites*** **sp.**
  Equatorial diameter: 42 µm, polar diameter: 21 µm (1 specimens).
Botanical affinity. Ephedraceae.

- ***Singhia multicostata*** **(Brener) Lima 1980**
  Equatorial diameter: 31-41 µm, polar diameter: 24-33 µm (9 specimens).
Lima (1980) makes a combination, considering *Ephedripites multicostatus* Brenner 1963 and *Equisetosporites multicostatus* Norris 1967 as synonyms of *Singhia multicostata*.
Argentina: Albian–Danian (Papú, 1990, 2002; Papú and Sepúlveda, 1995; Ruiz et al., 1999; Vallati, 2001; Narváez and Sabino, 2008; Narváez, 2009).
Rest of the world: Brazil: Albian (Lima, 1980). Canada: Albian–Campanian (Burden and Hills, 1989; Braman, 2001). USA: Albian (Hedlund and Norris, 1968). Gabon: Lower Cretaceous (Wood et al., 1997). Egipt: Barremian–Aptian (Sultan, 1986). Sudan: Cenomanian–Turonian (Schrank, 1994). Spain: Aptian–Albian (Arias and Doubinger, 1980).
Botanical affinity. Ephedraceae.

ANGIOSPERM POLLEN GRAINS

- ***Aquillapollenites magnus*** **Regali et al. 1974**
  Diameter: 38(52)62 µm (16 specimens).
Argentina: Yacoraite Formation (Moroni 1982).
Rest of the world: *Tricornites elongatus* Zone, Maastrichtian of Brazil (Regali et al. 1974).
Botanical affinity. *Aquillapollenites* complex were produced by members of the Santalales Order, based on their resemblance to some extant pollen grains of the families Loranthaceae and Santalaceae (Jarzen, 1977, Muller, 1984).

- ***Arecipites*** **sp. cf.** ***A. tenuiexinus*** **Leffingwell 1971**
  Diameter: 29–32 µm (8 specimens).

According to the original description it has 0.5 µm lumina and a dark exine, in our specimens the lumina are smaller than 1 µm.

Argentine: not previously recorded.

Rest of the world: Paleocene (Leffingwell, 1971), Maastrichtian (Nichols, 2002), Paleocene (Nichols and Brown, 1992), Santonian–Campanian (Braman, 2001).

Botanical affinity: Arecaceae.

- *Crassitricolporites brasiliensis* Herngreen 1972

Diameter: 35–53 µm (7 specimens).

Argentina: Yacoraite Formation (Moroni, 1982).

Rest of the world: Senonian of Brazil (Herngreen, 1972), *Crassitricolporites brasiliensis* Zone, Maastrichtian (Regali et al., 1974).

Botanical affinity: unknown.

- *Cupanieidites* sp. cf. *C. orthoteichus* Cookson and Pike 1954

Diameter: 25 µm (3 specimens).

Argentine: not previously recorded.

Rest of the world: Maastrichtian of Antarctica (Askin, 1990)

Botanical affinity: Sapindaceae, Cupaniae tribe.

- *Diporites* sp.

Diameter: 44 µm (1 specimens).

Botanical affinity: Onagraceae Family.

- *Gemmatricolpites subsphaericus* Archangelsky 1973

Diameter: 22–32 µm (2 specimens).

Argentina: Salta Basin: Mealla Formation (Selandian, Quattrocchio et al., 1997); Maíz Gordo Formation (Tanetiano, Quattrocchio and del Papa, 2000); Tunal Formation (Daniano, Quattrocchio and Volkheimer, 1988; Volkheimer et al., 2006). Patagonia: Salamanca Formation (Paleoceno, Archangelsky, 1973); Cerro Bororó Formation (Danian, Volkheimer et al., 2007).

Rest of the world: not previously recorded.

Botanical affinity: Aquifoliaceae.

- *Gemmatricolpites pergemmatus* Muller 1968

Diameter: 20–21 µm (2 specimens).

Argentina: not previously recorded.

Rest of the world: The species has its first record from the Senonian to Eocene sediments of Sarawak (Muller, 1968) and later from the Campanian–Maastrichtian of Egypt (Schrank, 1987) and from late Maastrichtian–Paleocene of Sudan (Awad, 1994; Eisawi and Schrank, 2008; Eisawi, 2015).

Botanical affinity: Aquifoliaceae, *Ilex* sp. (Muller, 1968).

- *Liliacidites variegatus* Couper 1953

Diameter: 28(30)44µm (12 specimens).

Argentine and rest of the world: widely recorded since Cenomanian.

Botanical affinity: Liliaceae Family.

- ***Margocolporites*** **sp. cf.** ***M. lihokus*** **Srivastava 1972**

Diameter: 30 µm (3 specimens), colpi long, with 1.5 µm thick margo. Exine reticulate, meshes subcircular, ranging from 0.3–0.7 µm.

Margocolporites lihokus haver larger diameter and thicjer margo.

Argentina: not previously recorded.

Rest of the world: Paleocene, USA (Elsik, 1968; Srivastava, 1972), Maastrichtian (Farabee and Canright, 1986; Nichols 2002).

Botanical affinity: Fabaceae.

- ***Myriophyllumpollenites*** **sp. in Quattrocchio and Volkheimer 1988**

Diameter: 24(27)29 µm (10 specimens).

Argentina: Salta Basin: Tunal and Olmedo formations (Danian; Quattrocchio and Volkheimer, 1988; Volkheimer et al., 2006; Narvaez, 2009), Mealla Formation (middle Paleocene, Quattrocchio et al., 1997).

Rest of the world: not previously recorded.

Botanical affinity: Haloragaceae.

- ***Nothofagidites*** **sp.**

Diameter: 26–30 µm (4 specimens).

Botanical affinity: Nothofagaceae.

- ***Penetetrapites*** **sp. cf.** ***P. mollis*** **Hedlund and Norris 1968**

Diameter: 15–24 µm (2 specimens).

Argentina: Santonian of the Río Guanaco Formation (Pothe de Baldis, 1995).

Rest of the world: Albian–Campanian.

Botanical affinity: unknown.

- ***Peninsulapollis gillii*** **(Cookson) Dettmann and Jarzen 1988**

Diameter: 25 µm (1 specimens).

Argentina: Late Cretaceous of Chubut Province (Papu, 1989; Baldoni and Askin, 1993); Maastrichtian from Mendoza Province (Papú, 2002); Late Cretaceous of Mendoza Province (Papú, 1990, 2002); Maastrichtian–Paleocene of the Colorado Basin (Ruiz and Quattrocchio, 1997; Quattrocchio and Ruiz, 1999); Maastrichtian of Santa Cruz Province (Povilauskas et al., 2008); Paleocene–Danian of Chubut Province (Archangelsky, 1973; Volkheimer et al., 2007); Paleocene–Eocene (Baldoni, 1987); Eocene of Santa Cruz Province (Romero and Zamaloa, 1985); Eocene of Santa Cruz Province (Romero and Castro, 1986), Campanian of Río Negro Province (Papú and Sepúlveda, 1995), Paleogene of Río Negro and Neuquén provinces (Melendi et al., 2003), Campanian–Maastrichtian of Salta Province (Narváez and Sabino, 2008).

Rest of the world: Early Eocene and Late Eocene–Early Oligocene (Fasola, 1969). Antarctica: Late Campanian–Paleocene (Baldoni and Barreda, 1986; Cao, 1992; Dolding, 1992; Amenábar and Di Pasquo, 2008); Santonian–Paleogene (Askin and Baldoni, 1998); Eocene and Oligocene (Mohr, 1990); Cenozoic (Bratzeva, 1983). Australia: Campanian and Early Eocene (Dettmann and Jarzen, 1988); Late Cretaceous to Early Eocene (Cookson, 1957). New Zealand: Late Cretaceous to Neogene (Mc Intyre, 1968, Raine et al., 2008).

Botanical affinity: Proteaceae.

- ?*Psilabrevitricolpites* sp.

Diameter: 38 µm (3 specimens), short (8–10 µm) and thickened (2,8 µm) colpi.

Botanical affinity: unknown.

- *Psilastephanoporites brasiliensis* Regali et al. 1974

Diameter: 29–32 µm (7 specimens).

Argentina: as cf., in the Yacoraite Formation (Moroni 1982)

Rest of the world: Cenomanian of Brazil (Jaramillo et al., 2010); Santonian of Brazil (Lima, 1981; Muller, 1987).

Botanical affinity: unknown.

- *Psilatricolpites* sp.

Diameter: 35–42 µm (3 specimens).

Botanical affinity: unknown.

- *Psilatricolporites* sp. 1

Diameter: 37 µm (1 specimen), exine 1–1.2 µm. Subcircular amb.

Botanical affinity: unknown.

- *Psilatricolporites* sp. 2

Diameter: 19 µm (1 specimen). Subtriangular amb.

Botanical affinity: unknown.

- ***Retistephanocolpites regularis* Hoeken-Klinkenberg 1966**

Diameter: 29-37 µm (8 specimens).

Argentina: Campanian to Early Maastrichtian, Salta Basin (Quattrocchio et al., 2005)

Rest of the world: Middle Eocene of Nigeria (Van Hoeken-Klinkenberg, 1964), Paleogene (Zaklinskaja, 1978), Paleocene–Earlyl Eocene (Bio-lokoto et al,. 1998).

Botanical affinity: unknown.

- *Retitricolporites* sp. cf. *R. multibaculates* Takahashi 1997

Diameter: 46–57µm (3 specimens); muri 0,9–1,1µm, lumina 1.7–5 µm irregular to subpolygonal with a loose columella on the floor of many lumina; exine 2.3–3 µm.

Argentine: not previously recorded.

Rest of the world: Campanian of Russia (Takahashi, 1997)

Botanical affinity: unknown.

- *Retitricolporites* sp.

Diameter: 28 µm; muri 0,5–0,6µm, lumina 0.5–1.2 µm, muri wider than lumina (except at elongated lumina) (1 specimens).

Botanical affinity: unknown.

- *Rousea patagonica* Archangelsky 1973

Diameter: 31–45 µm (8 specimens).

Argentina: Maastrichtian to Paleocene (Archangelsky, 1973; Papu, 1989 (as cf.), Baldoni and Askin, 1993; Quattrocchio et al., 1997, 1999, 2000; Prámparo and Papú, 2003; Volkheimer et al., 2006, 2007; Narváez and Sabino, 2008; Narváez. 2009, Povilauskas, 2013).
Rest of the world: Eocene (Kedves, 1986).
Botanical affinity: unknown.

- *Spinitricolpites jennerclarkei* Scholtz 1985 ex Jansonius y Hills 1990
Diameter: 50–53µm (2 specimens).
Argentina: Los Blanquitos and Lecho formations (Late Senonian) (Quattrocchio et al., 2005).
Rest of the world: Paleocene of South Africa (Scholtz 1985).
Botanical affinity: Verbenaceae (Quattrocchio et al., 2005).

- *Spinizonocolpites* sp.
Diameter: 42 µm, broad-based spines (1.7–2.1 µm) and 3–3.5 µm long (1 specimens).
Botanical affinity: Arecaceae.

- *Syncolporites* sp. cf. *S. marginatus* Van Hoeken-Klinkenberg 1964
Diameter: 18–24µm (2 specimens).
Argentine: not previously recorded.
Rest of the world: Maastrichtian of Sudan (Awad, 1994), Egypt (Schrank, 1984), and Nigeria (Van Hoeken-Klinkenberg 1964), Assemblage Zone K-IV Campanian–Maastrichtian (Cole et al., 2017), Assemblage Zone V Maastrichtian of Sudan (Eisawi et al., 2012), Paleogene of Colombia (Jaramillo and Dilcher, 2001).
Botanical affinity: Loranthaceae.

- *Syncolporites* sp.
Diameter: 18 µm (1 specimens).
Botanical affinity: Loranthaceae.

- *Striatricolporites sp*.
Diameter: 38–42 µm (16 specimens), tricolporate, subprolate to prolate, regulate Exine, colpi long thickened, ora discernible.
Comparison: *Striatricolporites gamerroi* Archangelsky 1973 presents smaller diameter and exine microreticulate with stries development in polar way.
Botanical affinity: unknown.

- *Tricolpites reticulatus* Cookson 1947
Diameter: 24(32)44 µm (23 specimens).
Argentina: Late Campanian–Miocene (Archangelsky, 1973; Quattrocchio, 1978a, 1980b; Romero and Zamaloa, 1985; Guerstein, 1990; Baldoni and Askin, 1993; Papú and Sepúlveda, 1995; Prámparo et al., 1995, 1996; Barreda, 1996, 1997; Quattrocchio et al., 1997; Ruiz and Quattrocchio, 1997; Quattrocchio and Ruiz, 1999; Ruiz et al., 1999; Barreda and Palamarczuk, 2000; Palamarczuk and Barreda, 2000; Papú, 2002; Melendi et al., 2003; Volkheimer et al., 2006, 2007; Barreda and Palazzesi, 2007; Prámparo et al., 2007).
Rest of the world: Antarctica: Middle Miocene (Cookson, 1947; Cranwell, 1969). Chile: Eocene–Early Oligocene (Fasola, 1969). Canada: Late Cretaceous (Jarzen and Norris, 1975). New Zealand: Late

Oligocene–Early Miocene (Pocknall and Mildenhall, 1984). Indian Ocean: Middle Paleocene (Harris, 1974); Late Oligocene (Kemp, 1974); Middle Cenozoic (Kemp and Harris, 1977). New Guinea: Pliocene (Cookson and Pike, 1954).
Botanical affinity: Gunneraceae (*Gunnera* sp.).

- *Tricolpites* sp. cf. *T. bathyreticulatus* Stanley 1965
Diameter: 30–46 µm (4 specimens).
It differs by having a larger diameter than *T. bathyreticulatus*.
Argentina: Eocene Río Turbio Formation, Santa Cruz Province (Fernández, 2018).
Rest of the world: widespread species widely distributed in Cenomanian to early Miocene deposits (see citations in White, 2006 and Raine et al., 2011).
Botanical affinity: Gunneraceae.

- ***Tricolpites* sp. cf. *T cellatus* Norton in Norton and Hall 1967**
Diameter: 44–55 µm (6 specimens), muri 0.4–0.7 µm, irregular lumina up to 1 µm and elongated ones up to 1.5 µm, exine 0.9–1 µm.
Tricolpites cellatus has a smaller diameter (32–40 µm), and an exine of 1.5 µm.
Argentina: not previously recorded.
Rest of the world: Upper Cretaceous–Lower Paleogene of USA (Norton and Hall 1967, 1969), K–Pg of Canada (Jerzykiewick and Sweet, 1986).
Botanical affinity: Gunneraceae.

- ***Tricolpites* sp. 1**
Diameter: 31–45 µm (2 specimens), muri 0.8–1 µm, lumina 0.8–3 µm irregular, often elongated, exine 1.5–1.8 µm.
Retitricolpites virgeus presents smaller diameter and size of luminae.
Botanical affinity: Gunneraceae.

- *Tricolporites* sp. 1
Diameter: 25–31 µm (3 specimens), muri 0.2–0.3µm, lumina 0.2–0.4 µm, colpi and pore thickened.
Botanical affinity: unknown.

- *Tricolporites* sp. 2
Diameter: 23–27 µm (3 specimens), muri 0.3 µm, subpolygonal to irregular lumina 0.2–1.4 µm (3 specimens).
Botanical affinity: unknown.

- *Tricolporites* sp. 3
Diameter: 29–39 µm (2 specimens), muri 0.2–0.3µm, subpolygonal to irregular lumina 0.3–0.5 µm (2 specimens).
Botanical affinity: unknown.

- *Tricolporites* sp. 4
Diameter: 35–46 µm (4 specimens), muri 0.3–0.4µm, lumina 0.3–1µm, exine 0.8–0.9µm, colpi membrane with grains of 0.8–0.9 µm.
Botanical affinity: unknown.

- *Triorites* sp. cf. *T. tenuiexinus* Muller 1968

Diameter: 35 µm (1 specimens).

A single specimen not well preserved.

Argentina: not previously recorded.

Rest of the world: Cenomanian of Nigeria (Oloto and Yikarebogha, 2013), (Muller 1968), Paleocene (Salard-Cheboldaeff, 1979).

Botanical affinity: unknown.

- ***Verrustephanoporites simplex* Leidelmeyer 1966**

Diameter: 28(25)35µm (14 specimens).

Argentina: Salta Basin: transitional strata of Los Blanquitos and Lecho formations (Late Senonian) (Quattrocchio et al., 2005), Tunal Formation (Danian, Quattrocchio and Volkheimer, 1988; Volkheimer et al., 2006), Olmedo Formation (Danian, Narváez, 2009), Mealla Formation (Selandian, Quattrocchio et al., 1997) and Maíz Gordo Formation (Tanetian) (Volkheimer et al., 1984); Colorado Basin: Pedro Luro Formation (Paleocene) (Ruiz and Quattrocchio, 1997; Quattrocchio and Ruiz, 1999); Neuquén Basin: Jagüel Formation (upper Maastrichtian; Prámparo y Papú, 2003). Anta Formation (Early/Mid Miocene, Quattrocchio et al., 2003).

Rest of the world: Paleocene of Guyana (Leidelmeyer, 1966).

Botanical affinity: Ulmaceae (*Phyllostylon* sp.).

- ***Verrutricolpites* sp.**

Diameter: 46µm, exine 2µm, warts 1.4–2µm wide at base and 0.9–1.6µm high (1 specimens).

Botanical affinity: unknown.

References

Amenábar, R.C., Di Pasquo, M. 2008. Nuevos resultados palinológicos de la Formación Snow Hill Island (Cretácico Superior) en Sanctuary cliffs, Isla Cerro Nevado, Península Antártica. XII Simpósio de Paleobotânicos e Palinólogos. Florianópolis, SC, Brasil.

Archangelsky, S. 1973. Palinología del Paleoceno de Chubut. I Descripciones sistemáticas. Ameghiniana 10 (4), 339–399.

Archangelsky, A., Llorens, M. 2009. Palinología de la Formación Kachaike, Cretácico Inferior de la Cuenca Austral, provincia de Santa Cruz. Granos de polen de Gimnospermas. Ameghiniana 46 (2): 225-234.

Arias, C., Doubinger, J. 1980. La Limite Aptien-Albien Dans le Secteur du Mompichel (Albacete). Cretaceous Research 1: 235-251.

Ashraf, A.R., Stinnesbeck, W. 1988. Pollen und Sporen an der Kreide-Tertiärgrenze im Staate Pernambuco, ne Brasilien. Palaeontographica, Abteilung B 208: 39-51.

Askin, R. A., 1990. Campanian to Paleocene spore and pollen assemblages of Seymour Island, Antarctica. Review of Palaeobotany and Palynology 65:105–113.

Askin, R.A., Baldoni, A.M. 1998. The Santonian through Paleogene record of Proteaceae in the southern South America-Antarctic Peninsula Region. Austral. Syst. Bot 11:373–390.

Awad, MZ. 1994. Stratigraphic, palynological and Palaeoecological studies in the East-Central Sudan (Khartoum and Kosti Basins), Late Jurassic to Mid-Tertiary. Berliner Geowissenschaftliche Abhandlungen, Reihe A 161:163.

Baldoni, A.M. 1987a. Estudios palinológicos de la zona de Collón Curá, Provincia del Neuquén, sobre elementos del Terciario Inferior y redepositados del Cretácico Inferior. Revista Española de Micropaleontología 19: 367-411.

Baldoni, A.M. 1992. Palynology of the lower Lefipán Formation (Upper Cretaceous) of Barranca de los Perros, Chubut Province, Argentina. Part 1. Cryptogam spores and gymnosperm pollen. Palynology 16: 117-136.

Baldoni, A.M., Askin, R.A. 1993. Palynology of the lower Lefipán Formation (Upper Cretaceous) of Barranca de los Perros, Chubut Province, Argentina. Part 2. Angiosperm pollen and discussion. Palynology 17: 241-264.

Baldoni, A.M., Barreda, V. 1986. Estudio palinológico de las formaciones López de Bertodano y Sobral, Isla Comodoro Marambio, Antártida. Paleobotánica e Palinología na America do Sul, Boletim Instituto de Geociências, Universidade de São Paulo, Brasil, Serie Científica 17: 89-98.

Barreda, V.D. 1996. Bioestratigrafía de polen y esporas de la Formación Chenque, Oligoceno Tardío?–Mioceno de las provincias de Chubut y Santa Cruz, Patagonia, Argentina. Ameghiniana 33(1): 35-56.

Barreda, V.D. 1997a. Palinoestratigrafía de la Formación San Julián en el área de la Playa La Mina (Provincia de Santa Cruz), Oligoceno de la Cuenca Austral. Ameghiniana 34(3): 283-294.

Barreda, V.D. 1997b. Palynomorph assemblage of the Chenque Formation, Late Oligocene?-Miocene from Golfo San Jorge Basin, Patagonia, Argentina. Part 2. Gymnosperm and colpate pollen. Ameghiniana 34(1): 81-92.

Barreda, V., Palamarzuk, S. 2000. Palinoestratigrafía de depósitos del Oligoceno Tardío–Mioceno en el área sur del Golfo San Jorge, Provincia de Santa Cruz, Argentina. Ameghiniana 37(1): 103–117.

Barreda, V.D., Palazzesi, L. 2007. Patagonian vegetation turnovers during the Paleogene– Early Neogene: origin of arid-adapted floras. The Botanical Review 73(1): 31–50. Bio-lokoto et al. 1998

Boltenhagen, E. 1967. Spores du Cretacé supérieur du Gabon. Pollen et Spores 9: 335-355.

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

Bratzeva, G. M., 1983. Spores and pollen from Cenozoic sediments of the Falkland Plateau, Site 511, Deep Sea Drilling Project Leg 71. Pp. 907-932 in: Ludwig, W. J.; Krasheninninnikov, V. A., et al. (Eds). "Initial reports of the Deep Sea Drilling Project", 71. Washington (U.S. Government Printing Office).

Burden, E.T., Hills, L.V. 1989. Illustrated key of Lower Cretaceous terrestrial palynomorphs (excluding megaspores) of western Canada. American Association of Stratigraphic Palynologists, Contribution Series 21: 1-147.

Cao, L. 1992. Late Cretaceous and Eocene palynofloras from Fildes Peninsula, King George Island (South Shetland Islands), Antarctica. En: Y. Yoshida et al. (eds.), Recent Progress in Antarctic Earth Science, Terra Scientific Publishing Company (TERRAPUB), Tokyo, pp. 363-369.

Cole, J.M., Abdelrahim, O.B., Hunter, A.W., Schrank, E., Bin Ismail, M.S., 2017. Late Cretaceous spore-pollen zonation of the Central African Rift System (CARS), Kaikang Trough, Muglad Basin, South Sudan: angiosperm spread and links to the Elaterates Province. Palynology 41 (4), 547–578. https://doi.org/10.1080/01916122.2017.1303795

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

Cookson, I. C., 1957. On some Australian Tertiary spores and pollen grains that extend the geological and geographical distribution of living genera. Proceedings of the Royal Society of Victoria 69: 41-53.

Cookson, I.C., Pike, K.M. 1954a. Some dicotyledonous pollen types from Cainozoic deposits in the Australian region. Australian journal of botany, 2(2): 197-219.

Cranwell, L. M., 1969. Palinological intimations of some Pre-Oligocene Antarctic climates. En: Zinderen Bakker, E. M. van (Ed.). Palaeoecology of Africa, A. A. Balkema, Cape Town 5: 1-19.

Dettmann, M.E., Jarzen, D.M. 1988. Angiosperm pollen from uppermost Cretaceous strata of southeastern Australia and the Antarctic Peninsula. Association of Australasian Palaeontologists, Memoir 5: 217-237.

Dolding, P.J.D. 1992. Palynology of the Marambio Group (Upper Cretaceous) of northern Humps Island. Antarctic Science 4(3): 311-326.

Eisawi, A., Ibrahim, A.B., Abdelrahim, O.B., Schrank, E., 2012. Palynozonation of the Cretaceous to Lower Paleogene strata of the Muglad Basin, Sudan. Palynology 36, 191–207. https://doi.org/10.1080/01916122.2011.633634

Eisawi, A.M., 2015. Palynological Evidence of a Campanian-Maastrichtian Age of the Shendi Formation (Shendi Basin, Central Sudan). American Journal of Earth Sciences 2, 206–210. Eisawi A, Schrank E. 2008. Upper Cretaceous to Neogene palynology of the Melut Basin, southeast Sudan. Palynology 32:101–129.

Elsik, W.C., 1968. Palynology of a Paleocene Rockdale Lignite, Milam County, Texas. I. Morphology and taxonomy. Pollen et spores 10, 263–314.Farabee, M.J., Canright, J.E., 1986. Stratigraphic palynology of the lower part of the Lance Formation (Maestrichtian) of Wyoming. Palaeontographica Abteilung B 199, 1–89. Fasola, A. 1969. Estudio palinológico de la Formación Loreto (Terciario Medio), provincia de Magallanes. Chile. Ameghiniana 6(1): 3-19.

Fernández, D.A. (2018). Análisis paleoflorístico de la Fm Río Turbio (Eoceno de la provincia de Santa Cruz) y su relación con los cambios paleoclimáticos globales: evidencias esporopolínicas. [PhD unpublished Thesis, Facultad de Ciencias Naturales y Museo, Universidad Nacional de La Plata].

Guerstein, G.R. 1990. Palinología estratigráfica del Terciario de la Cuenca del Colorado, República Argentina. Parte 3: Estudio sistemático y estadístico de la perforación Puerto Belgrano Nº 20. Revista Española de Micropaleontología 22: 459-480.

Harris, W. K., 1974. Palynology of Paleocene sediments at site 214, Ninetyeast Ridge. Pp. 503-519 in: Borch, C.C., von der; Sclater, J.G.; et al. (Eds). "Initial reports of the Deep Sea Drilling Project", 12. Washington (U.S. Government Printing Office).

Hedlund, R.W. y Norris, G. 1968. Spores and pollen grains from Fredericksburgian (Albian) strata, Marshall County, Oklahoma. Pollen et Spores 10(1): 129-159.

Herngreen, C.F.W. 1972 Some new pollen grains from the Upper Senonian of Brazil. Pollen et Spores, XIV (1): 97-112.

Herngreen, G.F.W. 1973. Palynology of Albian-Cenomanian strata of borehole 1-QS-1- MA, state of Maranhao, Brazil. Pollen et Spores 15: 515-555.

Jaramillo, C.A., Dilcher, D.L., 2001. Middle Paleogene palynology of central Colombia, South America: A study of pollen and spores from tropical latitudes. Palaeontographica B 258, 87–213.

Jaramillo, C.A., Ochoa, D., Contreras, L., Pagani, M., Carvajal-Ortiz, H., Pratt, L. M., Rodriguez, G. 2010. Effects of rapid global warming at the Paleocene-Eocene boundary on neotropical vegetation. Science, 330(6006), 957-961

Jarzen, D.M., 1977. *Aquilapollenites* and Some Santalalean Genera, Grana 16, 29–39, Jarzen, D. M. y Norris, G., 1975. Evolutionary significance and botanical relationships of Cretaceous angiosperm pollen in the Western Canadian Interior. Geoscience and man 11: 47-60.

Kemp, E. M., 1974. Preliminary palynology of samples from site 254, Ninetyeast Ridge. Pp. 815-823 in: Davis, T.A.; Luyendyk, B.P.; et al. (Eds). "Initial reports of the Deep Sea Drilling Project", 26. Washington (U.S. Government Printing Office).

Kemp E. M., Harris, W. K., 1977. The palynology of early Tertiary sediments, Ninetyeast Ridge, Indian Ocean. The Palaeontological Association, London, Special papers in palaeontology 19: 1-70.

Kotova, I.Z. 1978. Spores and pollen from Cretaceous deposits of the eastern north Atlantic Ocean, deep sea drilling project, Leg 41, Sites 367 and 370. En: Y. Lancelot, E. Siebold et al. (eds.), Initial Reports of the Deep Sea Drilling Project, Volumen 41, U.S. Printing Office, Washington, pp. 841-881.

Leffingwell, H.A., 1971. Palynology of the Lance (Late Cretaceous) and Fort Union (Paleocene) formations of the type Lance area, Wyoming. In: Kosanke, R.M., Cross, A.T. (Eds). "Symposium on palynology of the Late Cretaceous and Early Tertiary". Geological Society of America paper 127, 1– Leidelmeyer, P. 1966. The Paleocene and Lower Eocene pollen flora of Guyana. Leidse Geologische Mededelingen 38: 49-70.

Lima, M.R. de. 1980. Palinologia da Formação Santana (Cretáceo do nordeste do Brasil). 3. Descrição sistemática dos polens da Turma Plicates (Subturma Costates). Ameghiniana 17: 15-47.

Lima, M.R. de. 1981. Palinologia do Mesozoico brasileiros uma sintese. Comité Sudamericano del Jurásico y Cretácico: Cuencas sedimentarias del Jurásico y Cretácico de América del Sur, 2: 445-660. Buenos Aires.

Limarino, C., Net, L., Gutierrez, P., Barreda, V., Caselli, A., Ballent, S. 2000. Lithostratigraphical definition of the Cienaga del Rio Huaco Formation (Cretaceous), Precordillera central, San Juan, Argentina, 2000. Revista de la Asociación Geológica Argentina. 55(1-2):83-99.

Mautino, L. R., Anzótegui, L.M. (2014). Palinología de la Formación Chiquimil (Mioceno Superior), en Río Vallecito, provincia de Catamarca, Argentina. Parte 3. Polen. Ameghiniana, 39(3), 271-284.

Mc Intyre, D.J. 1968. Futher new pollen species from New Zealand Tertiary and uppermost Cretaceous deposits. New Zealand Journal of Botany 6 (2): 177- 204.

Melendi, D.L., Scafati, L.H., Volkheimer, W. 2003. Palynostratigraphy of the Paleogene Huitrera Formation in N-W Patagonia, Argentina. Neues Jahrbuch für Geologie und Paläontologie, Abhandlungen 228(2): 205-273.

Milne, L.A. 1988. Palynology of a late Eocene lignitic sequence from the western margin of the Eucla Basin, Western Australia. Memoir of the Association of Australasian Palaeontologists 5: 285-310.

Mohr, B.A.R. 1990. Eocene and Oligocene sporomorphs and dinoflagellate cysts from Leg 113 drill sites, Weddell Sea, Anatrctica. p. 595-612 in: Barker, P.F.; Kennett, J.P.; et al. (Eds). "Proceedings of the Ocean Drilling Program, scientific results volume 113". College Station, Texas (Ocean Drilling Program).

Moroni, A.M. 1982. Correlación palinológica en las Formaciones Olmedo y Yacoraite. Cuenca del Noroeste Argentino. III Congreso Geológico Chileno (Concepción, 1982). Proceedings, 340–349.

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

Muller, J. 1984. Significance of fossil pollen for angiosperm history. Ann. Missouri Bot. Gard. 71: 419-443.

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

Narváez, P.L. 2009. Palinoestratigrafía, paleoambientes y cambios climáticos durante el Cretácico final y Paleógeno de la Cuenca del Grupo Salta, República Argentina (Unpubl. PhD thesis). Universidad Nacional de Salta, 229 pp.

Narváez, P.L., Sabino, I.F. 2008. Palynology and paleoenvironment of the Las Curtiembres Formation (Late Cretaceous, Salta Group Basin), Las Conchas creek area, northwestern Argentina. Ameghiniana 45(2): 473-482.

Nichols, D.J., 2002. Palynology and palynostratigraphy of the Hell Creek Formation in North Dakota: A microfossil record of plants at the end of Cretaceous time. Geological Society of America Special Papers 361, 393–456.

Nichols, D.J., Brown, J.L. 1992. Palynostratigraphy of the Tullock Member (lower Paleocene) of the Fort Union Formation in the Powder River Basin, Montana and Wyoming. U.S. Geological Survey Bulletin 1917-F; p. 35.

Oloto, I.N., Yikarebogha, Y. 2013. High Resolution Palynological Studies Of Upper Cretaceous Succession of Mushe-1 Well, Central Chad Basin, Nigeria. International Journal of Scientific & Technology Research 2(6), 204–211.

Palamarczuk, S., Barreda, V. 2000. Palinología del Paleógeno Tardío-Neógeno Temprano, pozo Aries x-1, Plataforma Continental Argentina, Tierra del Fuego. Ameghiniana 37(2): 221-234.

Papú, O.H. 1989. Estudio palinológico de la Formación Paso del Sapo (Cretácico Superior), valle medio del Río Chubut. Granos de polen, consideraciones estadísticas, paleoecológicas y paleoambientales. Ameghiniana 25(3): 193-202. Papú, O.H. 1990. Contribución a la palinología estratigráfica de la Formación Malargüe, Cretácico Superior, sur de la provincia de Mendoza, Argentina. Parte 1: Especies terrestres y de aguas continentales. Ameghiniana 27: 289-303. Papú, O.H. 2002. Nueva microflora de edad maastrichtiana en la localidad de Calmu-Co, sur de Mendoza, Argentina. Ameghiniana 39: 415-426.

Papú, O.H., Sepúlveda, E.G. 1995. Datos palinológicos de la Formación Los Alamitos en la localidad de Montoniló, departamento 25 de Mayo, Río Negro, Argentina. Sus relaciones con unidades colindantes coetáneas. 6º Congreso Argentino de Paleontología y Bioestratigrafía (Trelew, 1995), Actas: 195-200.

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

Pocknall, D.T., Mildenhall, D.C. 1984. Late Oligocene-early Miocene spores and pollen from Southland, New Zealand. New Zealand Geological Survey paleontological bulletin 51: 66 p.

Pocock, S.A.J. 1964. Pollen and spores of the Chlamydospermidae and Schizaeaceae of the Saskatoon area of Saskatchewan. Grana Palynologica 5(2): 129-209.

Pothe de Baldis, E.D. 1995. Santonian microflora of Rio Guanaco Formation (continental facies) from Rio Turbio profile, Santa Cruz province, Argentine. Southern hemisphere correlation. SAMC News 2: 20.

Povilauskas, L. 2013. Palinología de Angiospermas de la Formación Monte Chico (Cretácico Tardío) de la Provincia de Santa Cruz, Argentina. Revista Brasileira de Paleontología, 16, 115–126.
Povilauskas, L., Barreda, V., Marenssi, S. 2008. Polen y esporas de la Formación La Irene (Maastrichtiano), sudoeste de la Provincia de Santa Cruz, Argentina: primeros resultados. Geobios 41: 799-817.

Prámparo, M.B., Papú, O.H. y Milana, J.P. 1995. Estudio palinológico del Miembro Inferior de la Formación Pachaco, Terciario de la Provincia de San Juan. Análisis estadístico y conclusiones paleoecológicas. 6º Congreso Argentino de Paleontología y Bioestratigrafía (Trelew, 1995), Actas: 207-212.

Prámparo, M.B., Papú, O.H., Milana, J.P. 1996. Estudio palinológico del Miembro Inferior de la Formación Pachaco, Terciario de la Provincia de San Juan. Descripciones sistemáticas. Ameghiniana 33(4): 397-407.

Prámparo, M.B., Quattrocchio, M.E., Gandolfo, M.A., Zamaloa, M.C., Romero, E. 2007. Historia evolutiva de las angiospermas (Cretácico-Paleógeno) en Argentina a través de los registros paleoflorísticos. Ameghiniana, Suplemento 50º Aniversario: 157-172.

Prámparo, M.B., Papú, O.H. 2003. Palinomorfos terrestres del Maastrichtiano superior en el cerro Butaló, sur de Mendoza, Argentina. Ameghiniana 40(4) Suplemento: 14R.

Quattrocchio, M. 1978. Contribución al conocimiento de la palinología estratigráfica de la Formación Lumbrera (Terciario Inferior, Grupo Salta). Ameghiniana 15 (3-4), 285–300.

Quattrocchio, M. 1980. Estudio palinológico preliminar de la Formación Lumbrera (Grupo Salta), localidad Pampa Grande, Provincia de Salta, República Argentina. 2º Congreso Argentino de Paleontología y Bioestratigrafía y 1º Congreso Latinoamericano de Paleontología (Buenos Aires, 1978), Actas 2: 131-149.

Quattrocchio, M., del Papa, C. 2000. Paleoambiente de la secuencia Maíz Gordo (¿Paleoceno Tardío-Eoceno Temprano?), Arroyo Las Tortugas, Cuenca del Grupo Salta (NO Argentina). Palinología y sedimentología. Revista Española de Paleontología 15(1): 57-70.

Quattrocchio, M.E., Ruiz, L.C. 1999. Paleoambiente de la Formación Pedro Luro (Maastrichtiano?-Paleoceno) en base a palinomorfos, Cuenca del Colorado, Argentina. Ameghiniana 36(1): 37-47.

Quattrocchio, M.E., 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. IV Congreso Argentino de Paleontología y Bioestratigrafia (Mendoza, 1986). Proceedings 3, 109–120.

Quattrocchio, M.E., Volkheimer, W., Marquillas, R.A., Salfity, J.A. 2005. Palynostratigraphy, palaeobiogeography and evolutionary significance of the Late Senonian and Early Palaeogene palynofloras of the Salta Group, northern Argentina. Revista Española de Micropaleontología 37, 259–272.

Quattrocchio, M.E., Volkheimer, W., del Papa, C. 1997. Palynology and paleoenvironment of the "Faja Gris" Mealla Formation (Salta Group) at Garabatal creek (NW Argentina). Palynology 21: 231-247.

Quattrocchio, M.E., Martínez, M.A., García, V.M. 1999. Análisis palinológico de la Formación Mulichinco en el sector centro-oriental de la Cuenca Neuquina, Argentina. 14º Congreso Geológico Argentino (Salta, 1999), Actas 1: 52.

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

Quattrocchio, M., Martínez, M. A., García, V. M., Zavala, C.A. 2003. Palinoestratigrafía del Tithoniano-Hauteriviano del Centro-Oeste dela Cuenca Neuquina, Argentina. Revista Española de Micropaleontología 35: 51-74.

Raine, J.I., Mildenhall, D.C., Kennedy, E.M. 2008. New Zealand fossil spores and pollen: an illustrated catalogue. 3rd edition. GNS Science Miscellaneous Series 4. http://www.gns.cri.nz/what/earthhist/fossils/spore_pollen/catalog/index.htm

Regali, M.S.P., Uesugui, N., Santos, A.S., 1974. Palinologia dos sedimentos Meso- Cenozóicos do Brasil (2). Boletim Técnico da Petrobrás 17 (4), 263–301.

Romero, E.J., 1977. Polen de gimnospermas y fagáceas de la Formación Río Turbio (Eoceno), Santa Cruz, Argentina. Fundación para la Educación, la Ciencia y la Cultura, Buenos Aires.

Romero, E.J., Castro, M.T. 1986. Material fúngico y granos de polen de angiospermas de la Formación Río Turbio (Eoceno) de la provincia de Santa Cruz, República Argentina. Ameghiniana 23: 101-118.

Romero, E.J., Zamaloa, M.C. 1985. Polen de angiospermas de la Formación Río Turbio (Eoceno), provincia de Santa Cruz, República Argentina. Ameghiniana 22(1-2): 43-51.

Ruiz, L.C., Quattrocchio, M.E. 1997. Estudio palinológico de la Formación Pedro Luro (?Maastrichtiano-Paleoceno), en la Cuenca del Colorado, República Argentina. Parte II: Turma Saccites, Plicates, Poroses e Incertae sedis. Revista Española de Micropaleontología 29(2): 115-137.

Ruiz, L., Quattrocchio, M., Guerstein, R.G., Volkheimer, W. 1999. Rangos estratigráficos de palinomorfos del Paleógeno de Argentina, Antártida y Chile. Simposio Paleógeno de América del Sur (Buenos Aires, 1996), Actas, Subsecretaría de Minería de la Nación, Servicio Geológico Minero Argentino, Anales 33: 89-103.

Salard-Cheboldaeff M. 1979. Palynologie Maestrichtienne et Tertiaire du Cameroun. Etude qualitative et repartition verticale des principales especes. Review of Palaeobotany and Palynology 28:365–388.

Scholtz, A., 1985. The palynology of the upper lacustrine sediments of the Arnot Pipe, Banke, Namaqualand. Annals South African Museum 95, 1–109.

Schrank, E. 1984. Organic-walled microfossils and sedimentary facies in the Abu Tartur Phosphates (Late Cretaceous, Egypt). Berliner Geowiss Abeilung A 50:177–187.

Schrank, E. 1987. Biostratigraphic importance of microfloras from the Late Cretaceous clastic series of northwestern Sudan. Cretaceous Research 8:29–42

Schrank, E. 1994. Nonmarine Cretaceous palynology of northern Kortdofan, Sudan, with notes on fossil Salviniales (water ferns). Geol Rundsch 83: 773-786.

Schrank, E., Ibrahim, M.I.A. 1995. Cretaceous (Aptian-Maastrichtian) palynology of foraminifera-dated wells (KRM-1, AG-18) in northwestern Egypt. Berliner geowissenschaft, Abhandlungen A 177: 1-44.

Srivastava, S.K., 1972. Some spores and pollen from the Paleocene Oak Hill Memeber of the Naheola Formation, Alabama (U.S.A.). Review of Palaeobotany and Palynology 14: 217-285.

Sultan, I.Z. 1986. Playnostratigraphy of Lower Cretaceous sediments in the Nyle Delta region, Egypt. Revista Española de Micropaleontología 18(1): 55-70.

Takahashi, M. 1997. Fossil spores and pollen grains of Cretaceous (Upper Campanian) from Sakhalin, Russia. Journal of Plant Research 110, 283–298.Vajda-Santivanez, V., 1999. Miospores from Upper Cretaceous-Paleocene strata in northwestern Bolivia. Palynology 23, 181–196.

Vallati, P. 2001. Middle Cretaceous microflora from the Huincul Formation (“Dinosaurian beds”) in the Neuquén Basin, Patagonia, Argentina. Palynology 25: 179-197.

Vallati, P., Casal, G., Foix, N., Allard, J., Tomas, A.D.S., Calo, M. (2016). First report of a Maastrichtian palynoflora from the Golfo San Jorge Basin, central Patagonia, Argentina. Ameghiniana, 53(4), 495–505.

Vallati, P., De Sosa Tomas, A., Casal, G., Calo, M. 2017. Salviniales from the Late Cretaceous of the Golfo San Jorge Basin. Cretaceous Research, 74: 45–55.Van Hoeken-Klinkenberg, P.M.J., 1964. A palynological investigation of some Upper Cretaceous sediments in Nigeria. Pollen et Spores 6 (1), 209–231.

Volkheimer, W. 1972. Estudio palinológico de un carbón 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., Quattrocchio, M., Salfity, J. 1984. Datos palinológicos de la Formación Maíz Gordo, Terciario Inferior de la Cuenca de Salta. 9º Congreso Geológico Argentino (San Carlos de Bariloche, 1984), Actas 4: 523-538.

Volkheimer, W., Novara, M.G., Narváez, P.L., Marquillas, R.A. 2006. Palynology and paleoenvironmental significance of the Tunal Formation (Danian) at its type locality, quebrada El Chorro (Salta, Argentina). Ameghiniana 43 (3), 567–584.

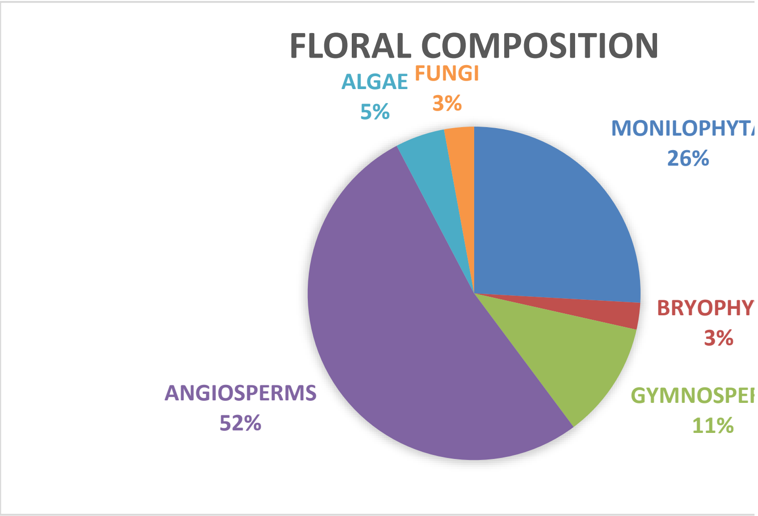
Volkheimer, W., Scafati, L., Melendi, D.L., 2007. Palynology of a Danian warm climatic wetland in Central Northern Patagonia, Argentina. Revista Española de Micropaleontología 39, 117–134.

Wood, G.D., Miller, M.A., Sofer, Z., Krebs, W.N., Hedlund, R.W. 1997. Palynology, palynofacies, paleoenvironments and geochemistry of the Lower Cretaceous (pre-salt) Cocobeach Group, North Gabon Subbasin, Gabon. Africa Geoscience Review 4(3-4): 481-497.

Zaklinskaya, E.D., 1978. Die Floren des Oberkreide und des Frühen Paläogen (nach palynologischen Angaben). In: V.A. Vakhrameev, I. Dobruskina, S. Meyen, E.D. Zaklinskaya (Eds.), Paläozoische und mesozoische Floren Eurasiens und die Phytogeographie dieser Zeit, Veb. Gustav Fischer, Berlin (1978), pp. 195–229.

Appendix

MONILOPHYTA	25.90%
BRYOPHYTA	2.60%
GYMNOSPERMS	11.30%
ANGIOSPERMS	52.50%
ALGAE	4.80%
FUNGI	2.90%
	100.00%



A

TA

RMS

Tci (Briophyta)	2.60%
TA	3.7
TT	2.5
TS	3.9
TP (*Gabonisporites* sp.)	1.8
TC (*Polypodiaceoisporites* sp.)	14
Total Monylophyta	25.90%
Fungi	2.90%
Ovoidites sp.	4.80%

PP	10.30%
2S	1.00%

3C	20.50%
3P	2.60%
3CP	7%
1C	9.10%
4P	13.20%
	52.40%

	Pollen grains	Taxon	
3C	Tricolpated		Tci
3P	Triporated		TA
3CP	Tricolporated		TT
1C	Monocolpated		TL
4P	Tetraporated	*Verrustephanocolpites* sp.	TP
PP	Poliplicated		TC
2S	Bisacated		

Spores	Taxon
Trilete cingulated	Briophyta
Trilete apiculated	
Trilete tricrassated	
Trilete smooth	
Trilete perisporated	*Gabonisporites* sp.
Trilete cingulated	*Polypodiaceoisporites* sp.

Conflict of Interest: none