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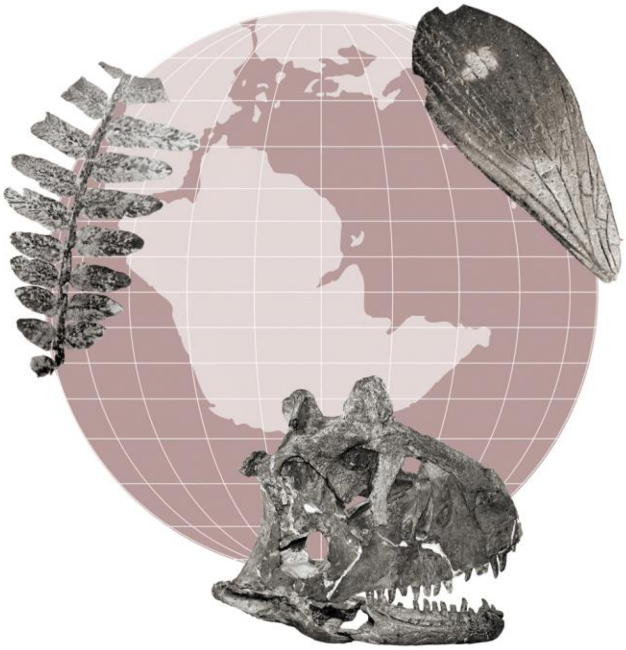

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PALYNOLOGY AND PALYNOFACIES OF THE RÍO TARDE FORMATION (LOWER CRETACEOUS), SOUTHERN PATAGONIA, ARGENTINA

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MATAMALA *ET AL.*: PALYNOLOGY OF THE RÍO TARDE FORMATION

First palynological study of the Río Tarde Formation reveals a low-diversity assemblage dominated by fern spores and gymnosperm pollen grains.

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Abstract. This work presents the first palynological and palynofacies analysis of the Río Tarde Formation (Aptian–Albian) from the Parque Nacional Perito Moreno, Santa Cruz Province, Argentina. Four samples from the lower member of the unit were analyzed, revealing a palynological assemblage composed of 13 species. Nine of these correspond to ferns from the families Anemiaceae, Cyatheaceae, Gleicheniaceae, Lygodiaceae, and Schizaeaceae; three are gymnosperms assigned to the families Araucariaceae, Hirmeriellaceae, and Podocarpaceae; and one species represents a freshwater alga of the genus *Botryococcu*s. The recovered association of palynomorphs allows us to infer temperate to warm and relatively humid paleoclimatic conditions. The palynological organic matter, dominated by dark brown to black translucent phytoclasts, suggests a significant contribution of continental material from macrophyte remains, consistent with a fluvial depositional environment.

Keywords. Palynology. Paleoenvironment. Paleoclimate. Santa Cruz. Palynofacies

Resumen. PALINOLOGÍA Y PALINOFACIES DE LA FORMACIÓN RÍO TARDE (CRETÁCICO INFERIOR) DEL SUR DE LA PATAGONIA, ARGENTINA. Este estudio presenta el primer análisis palinológico y de palinofacies de la Formación Río Tarde (Aptiano–Albiano) en el Parque Nacional Perito Moreno, provincia de Santa Cruz, Argentina. Se analizaron cuatro muestras del miembro inferior de la unidad, revelando una asociación compuesta por 13 especies. Nueve de ellas corresponden a helechos pertenecientes a las familias Anemiaceae, Cyatheaceae, Gleicheniaceae, Lygodiaceae y Schizaeaceae; tres son gimnospermas asignadas a las familias Araucariaceae, Hirmeriellaceae y Podocarpaceae; y una especie corresponde a un alga de agua dulce del género *Botryococcus*. La asociación de palinomorfos recuperada sugiere condiciones paleoclimáticas templadas a cálidas y relativamente húmedas. La materia orgánica palinológica, dominada por fitoclastos translúcidos de color marrón oscuro a negro, indica un alto aporte de material continental derivado de restos de plantas macrófitas, consistente con un ambiente de depositación fluvial.

Palabras clave. Palinología. Paleoambiente. Paleoclima. Santa Cruz. Palinofacies.

THE RÍO TARDE FORMATION (**RTF**) is part of the Cretaceous infill in the northwestern edge of the Austral-Magallanes Basin (**AMB**), in the Santa Cruz Province, Argentina. The AMB record begins with a Paleozoic basement, overlained by Jurassic volcaniclastic units followed by Cretaceous marine-continental sedimentary beds covered by Cenozoic basaltic volcanic effusions and intrusive bodies encompassing marine to continental sedimentary deposits (Aguirre-Urreta & Ramos, 1981; Giacosa & Franchi, 2001; Escosteguy *et al*., 2003).

During the Early Cretaceous, Patagonia had a temperate to warm climate (Smith *et al*., 1994; Scotese *et al*., 1999; Del Fueyo *et al*., 2007; Passalia, 2009), which enabled the proliferation of distinct plant assemblages. This environment was characterized by conifer forests developed at high elevations (Scotese *et al*., 1999; Del Fueyo *et al*., 2007; Greppi *et al*., 2020, 2023; Rombola *et al*., 2023). In lowlands and more humid areas, particularly along river margins, flooded areas, lakes, and swamps, vegetation was dominated by ferns, lycophytes, bryophytes, and equisetales (Villar de Seoane, 2005; Archangelsky *et al*., 2008). In contrast, open areas such as plains and dissected upland terrains were dominated by Cycadales and Bennettitales, which thrived under drier conditions (Del Fueyo *et al*., 2007).

The paleobotanical record of the lower member of the RTF is limited to silicified trunk and stem remains (Ramos & Drake, 1987; Ramos, 1979; Giacosa & Franchi, 2001; Aramendía *et al*., 2018). Rombola *et al*. (2023) described an assemblage of 84 wood specimens that constitute a para-autochthonous fossil forest composed mainly of conifer wood; nonetheless, to date, no studies have reported palynomorphs from this unit.

The aim of this study is to identify and report the first occurrence of palynomorphs recovered from the lower member of the RTF and evaluate the paleoenvironmental conditions inferred from the paleoecological requirements of the identified taxa. Furthermore, through the quantitative characterization of palynological organic matter and the assessments of palynomorph degradation types, this research seeks to refine and expand the current paleoenvironmental interpretation of the unit.

Institutional abbreviations. MACN, Museo Argentino de Ciencias Naturales, Ciudad Autónoma de Buenos Aires, Argentina.

Geological abbreviations. AMB, Austral-Magallanes basin; **SPA,** Southern Patagonian Andes; **RTF**, Río Tarde Formation.

GEOLOGICAL SETTINGS

The study area is located in the northwestern sector of the AMB, near the Río Roble Ranch, south of Burmeister Lake (Figs. 1.1, 1.3). The AMB lies on the southern edge of the South American Plate, bounded by the Southern Patagonian Andes (**SPA**) to the west, the Deseado Massif to the east, and the Fuegian Andes to the south, extending offshore across the Argentine continental shelf into the Malvinas Basin (Biddle *et al.*, 1986; Robbiano *et al.*, 1996; Ghiglione *et al.*, 2016; Aramendía *et al.*, 2018, 2019, 2022).

The AMB tectonic phases are closely linked to the Andean orogenesis and the opening of the Atlantic Ocean (Biddle *et al.*, 1986; Ghiglione *et al.*, 2016; Cuitiño *et al.*, 2019). The sedimentary succession begins with the Jurassic pre-rift (El Bello Formation) and syn-rift deposits (El Quemado Complex), followed by Lower Cretaceous sag-phase sediments (Springhill and Río Mayer formations). These are overlain by post-rift and early foreland basin deposits (Río Belgrano Formation and the lower member of the RTF). The uplift of the SPA exposed extensive Upper Cretaceous volcaniclastic sediments (*e.g.*, upper member of the RTF), associated with the eastward migration of the SPA fold-and-thrust belt (Biddle *et al.*, 1986; Giacosa & Franchi, 2001; Escosteguy *et al.*, 2003; 2017; Ghiglione *et al.*, 2016; Aramendía *et al.*, 2018; Cuitiño *et al.*, 2019).

Figure 1.

The RTF, defined by Ramos (1979), comprises two informal members (Fig. 2). The lower member consists of red and white clast-supported conglomerates and very coarse- to pebbly-grained sandstones, interpreted as high-energy braided fluvial deposits with channelized systems incising floodplain sediments (Aramendía *et al.*, 2018; Valle *et al.*, 2024). In contrast, the upper member is composed of multicolored ash- to lapilli-sized volcaniclastic rocks. The RTF forms a relatively continuous N–S outcrop belt along the foothills of the SPA (Giacosa & Franchi, 2001; Escosteguy *et al.*, 2003, 2017). The studied samples come from the same outcrop where fossil woods were previously found and described by Rombola *et al.* (2023). The age of the RTF was inferred based on the ammonoid fossil content of the Aptian Kachaike Formation and its relative stratigraphic position (Riccardi, 1971). Detrital zircon maximum depositional ages further constrain the lower member to 122–118 Ma, supporting an Aptian–Albian age (Ghiglione *et al.*, 2015).

Cenozoic sedimentation in the AMB includes upper Paleocene–lower Eocene continental deposits (Ligorio Márquez and Río Lista formations), which contain fossil wood and leaf remains overlying the Mesozoic units (Escosteguy *et al.*, 2003; Encinas *et al.*, 2019). Eocene deposits also include the subvolcanic intrusions and basaltic flows of the Posadas Basalt (Escosteguy *et al.*, 2003). Neogene synorogenic deposits include the Miocene El Chacay Formation, Río Zeballos Group, and Santa Cruz Formation

(Hatcher, 1897, 1900; Chiesa & Camacho, 1995; Cuitiño *et al*., 2012, 2016, 2019; Parras *et al*., 2012; Aramendía *et al*., 2019, 2022). These Miocene continental sediments are largely overlained by volcanic plateau effusions (Giacosa & Franchi, 2001; Escosteguy *et al*., 2003, 2017).

Figure 2.

MATERIAL AND METHODS

Four palynological samples from the lower member of the RTF were studied, and all of them were productive. These were collected from massive siltstones within the first 15 meters of the unit, outcropping south of Burmeister Lake (47° 59' 2.74" S; 72° 4' 32.00" W), in the former Río Roble Ranch, Parque Nacional Perito Moreno, Santa Cruz Province, Argentina (Figs. 1.2, 1.3). Sample processing was conducted at the Museo Argentino de Ciencias Naturales "Bernardino Rivadavia" (**MACN**) following standard palynological techniques (Riding, 2021). For the palynological analysis, the samples were filtered through 8 µm and 25 µm meshes, whereas for palynofacies analysis, only through 8 µm meshes were used (Batten, 1983; Tyson, 1995). All samples were mounted using UV-curing acrylate as the mounting medium (Noetinger *et al*., 2017). Due to the very low percentages of palynomorphs, no specific counts were performed, instead, occurrences were recorded on a presence/absence basis across the studied levels.

A quantitative palynofacies analysis was conducted, counting a minimum of 500 organic matter particles per sample, following the criteria of Batten (1983, 1996), Tyson (1995), and Oboh-Ikuenobe & Villiers (2003), who distinguish two main types of dispersed organic particles: structured (palynomorphs, opaque phytoclasts, and translucent phytoclasts) and unstructured (amorphous organic matter). These two broad categories are further subdivided based on the components of the samples analyzed.

Subsequently, the relative frequencies of the components were determined to define the palynofacies. Finally, the degree of degradation of the palynomorphs was assessed, following the classification of Delcourt & Delcourt (1980).

Observations were made using a Leica DM2500 optical microscope, and photographs were taken with an integrated Leica DFC295 digital camera. Specimen measurements were obtained from photographs using the open-source software ImageJ 1.54g.

Palynomorphs were described using the terminology proposed by Punt *et al.* (2007) and were assigned to species when their specific characteristics could be identified.

Morphotypes were classified into families based on their botanical affinity and grouped into taxonomic categories. The coordinates of the described and illustrated specimens are provided in England Finder format.

The palynological slides and residues are deposited at the MACN under the acronym and repository numbers BA Pal 5495–5498.

RESULTS

Palynology

The four samples studied contain abundant organic matter from continental origin, composed of phytoclasts and amorphous organic matter, while spores and pollen grains are in smaller proportions and show poor preservation. Thirteen species were recorded for the formation, 9 of which are pteridophyte spores, 3 gymnosperm pollen grains, and 1 freshwater algae species (see botanical affinity in Table 1). Six species were left in open nomenclature (Table 1).

Table 1.

The spores are dominated by trilete forms with smooth (Figs. 3.1, 3.4), verrucated (Figs. 3.2, 3.3), or taeniate surfaces, while the few gymnosperm pollen grains (mostly deteriorated) are inaperturate, circunsulcate (Fig. 3.6) and bisaccate. In general, both the spores and pollen grains were observed isolated, while grains of *Classopollis* sp. and *Cicatricosisporites* spp. were documented in tetrads and polyads (Figs. 3.8, 3.9).

Figure 3.

Palynofacies

The palynological organic matter in the analyzed samples is composed exclusively of terrestrially derived particles (Fig. 3.10), with phytoclasts predominating in all cases, accounting for more than 62% of the total particles (Fig. 4). Given the limited number of samples analyzed and the similarity in their composition, facies are not grouped; instead, percentages are presented to facilitate the visualization of the paleoenvironment interpretation.

Sample BA Pal 5495 is dominated by phytoclasts, which constitute 62.6% of its composition (Fig. 4). They include black to dark brown fragments (28.0%, Fig. 3.10), wood remains (11.3%), equidimensional opaque phytoclasts (8.9%), blade-shaped opaque phytoclasts (6.8%), and yellow to light brown fragments of translucent phytoclasts (3.6%), among others in less proportions. Within the amorphous organic matter, granular (11.9%) and fibrous (8.0%) are the most abundant components. Palynomorphs are poorly represented in the sample, accounting for only 2.6%, and are mainly composed of pollen (1.6%), spores (0.6%), freshwater algae (0.2%), and fungal spores (0.2%).

Samples BA Pal 5496–5498 show similar compositions, dominated by phytoclasts (85.0–89.8%), followed by amorphous organic matter (9.8–14.2%), and with a low representation of palynomorphs (0.2–0.8%) (Fig. 4). Phytoclasts are mainly translucent, with more than 44% of dark brown to black fragments, followed by wood remains (15.1–31.9%). Equidimensional forms are the more abundant (2.8–6.3%) within the opaque phytoclasts. In all three samples, amorphous organic matter accounts for less than 15%, with the fibrous amorphous type as the dominant component (7.1–10.6%). As in sample BA Pal 5495, palynomorphs are the least represented component, comprising only 0.2–0.8%, mainly composed of pollen grains and trilete spores.

In general, translucent and opaque phytoclasts display subrounded to subangular shapes, with those measuring 10–20 µm being the most abundant (43.4–60.6% of the total phytoclasts). However, tracheid fragments (Figs. 3.11, 3.12), equidimensional opaque phytoclasts, and cuticles are commonly observed with subangular to angular edges. In sample BA Pal 5496, unlike the others, phytoclasts larger than 100 µm predominate (53.3%), while the 10–20 µm fraction is the lowest (15.2%).

The recovered palynomorphs generally exhibit a high degree of deterioration, primarily manifested by mechanical damage in spores (Figs. 3.1, 3.2), pyrite crystallization in bisaccate pollen grains and *Classopollis*, and degradation, in that order of abundance. In some cases, palynomorphs show more than one type of deterioration, such as pyrite crystallization combined with mechanical damage. On the other hand, *Botryococcus* colonies are amorphized and dark brown.

Figure 4.

DISCUSSION

Comparison with palynofloras from the Early Cretaceous of the AMB

The palynological assemblage recovered from the analyzed levels of the RTF shows similarities with other Early Cretaceous assemblages of southern Patagonia, particularly those from the Springhill, Kachaike, Piedra Clavada, and Río Mayer formations. In the Springhill Formation (late Barriasian–late Barremian, Baldoni & Archangelsky, 1983; Ottone & Aguirre-Urreta, 2000), similarities include the presence of some conifers of the Hirmeriellaceae and Podocarpaceae families (*Classopollis* sp. and *Podocarpidites* sp.), and spores of the family Cyatheaceae (*Cyathidites australis*). However, recent studies have recorded some angiosperm pollen grains in the mentioned unit (Quattrocchio *et al*., 2006; Guler *et al*., 2015; Martínez *et al*., 2023).

The Kachaike Formation (Early Albian–Cenomanian, Baldoni *et al*., 2001; Archangelsky *et al*., 2012; Perez Loinaze *et al*., 2012; 2015) shares with the RTF the presence of spores of the families Schizaeaceae, Gleicheniaceae, and Cyatheaceae (*Cicatricosisporites*, *Gleicheniidites,* and *Cyathidites*), gymnosperms of the families Hirmeriellaceae (*Classopolli*s), Podocarpaceae (*Podocarpidite*s), and Araucariaceae (*Cyclusphaera*), as well as algae of the genus *Botryococcus* in some localities (Baldoni *et al*., 2001; Perez Loinaze *et al*., 2012). However, angiosperm pollen was also found in this Formation, such as *Clavatipollenites* (Chlorantaceae) (Baldoni *et al*., 2001) and *Pennipollis* (Chlorantaceae-Ceratophyllum clade) (Barreda & Archangelsky, 2006; Perez Loinaze *et al*., 2015).

The Piedra Clavada Formation (Albian, Archangelsky *et al*., 2008; Medina *et al*., 2008) presents an association characterized by abundant continental palynomorphs, including bryophytes, lycophytes, ferns, some gymnosperm genera, angiosperm pollen grains, and continental microplankton.

The Río Mayer Formation (upper Aptian; Pöthe de Baldis & Ramos, 1980, 1983, 1988; Medina *et al*., 2008; Perez Loinaze *et al*., 2012) is characterized by the presence of tricolpate pollen grains, a palynological marker absent in the RTF. This unit also records primitive angiosperm evidence in the area, represented by members of the family Chloranthaceae, specifically the genus *Clavatipollenites*.

The absence of angiosperms in the RTF assemblage, despite their presence in coeval or older units, may be due to preservational or taphonomic processes. An interpretation that is also supported by the poor preservation of several specimens.

Paleoenvironmental interpretation: Palynoflora

Although no specific counts of palynomorphs were performed due to the low abundance and poor preservation of specimens, fern spores (9 species) appear to be more diverse than gymnosperm pollen grains (3 species) based on presence/absence data. This relative representation may reflect the development of an herbaceous community in the vicinity of the depositional area. The occurrence of fern spores has often been associated with warm to temperate climates and moderate to high humidity conditions (Vakhrameev, 1981; Van Konijnenburg-Van Cittert, 2002). The presence of some taxa from the families Anemiaceae and Cyatheaceae is frequent in this association and may suggest the development of the vegetation under humid conditions, likely close to bodies of water such as riverbanks, swamps, or as part of the understory (Van Konijnenburg-Van Cittert, 2002). Although Gleicheniaceae spores are also present, some members of this family such as the macrofossil *Gleichenites* are known to have tolerated stress-related conditions, as in semi-arid or fire-prone environments (Van Konijnenburg-Van Cittert, 2002). Regarding Anemiaceae, recent studies (Duarte *et al.*, 2021) highlight its broad paleoecological and paleoclimatic tolerance, from arid to humid and from warm to cold climates throughout the Cretaceous. Nonetheless, the overall palynological signal supports the interpretation of a predominantly humid local setting.

Gymnosperms constitute a relatively low proportion of the studied palynomorph assemblage, with three taxa assigned to the families Podocarpaceae, Araucariaceae, and Hirmeriellaceae. Their presence suggests the existence of a forest zone in the vicinity of the depositional area.

Among the conifers, *Classopollis* sp. constitutes a predominant part of the studied palynological assemblage and is a common component of the Jurassic–Cretaceous paleoflora of Argentine Patagonia (Vakhrameev, 1981; Archangelsky & Llorens, 2003, 2005, 2009; Barreda & Archangelsky, 2006; Villar de Seoane, 2014; Santamarina, 2019; Perez Loinaze *et al*., 2021; Chalabe *et al*., 2022). Its presence has been associated with diverse environmental conditions, ranging from transitional to continental environments (Vakhrameev, 1981; Alvin, 1982; Volkheimer *et al*., 2008; Barreda *et al*., 2012). In turn, its association with conifers of the Araucariaceae has been linked to warm to temperate and relatively humid climates (Vakhrameev, 1981; Volkheimer *et al*., 2008).

The extant Araucariaceae and Podocarpaceae grow in humid rainforests and mesothermal climates (Enright *et al*., 1995; Brodribb, 2010), so the presence of taxa from these families (*Cyclusphaera* sp. cf. *C. radiata* and *Podocarpidites* sp.) suggests warm to temperate climate and humid conditions. Furthermore, the presence of tetrads and polyads of spores and pollen grains would indicate a low-energy depositional environment (Tyson, 1995).

The conifer pollen grain records from the RTF assigned to the Hirmeriellaceae are consistent with the presence of *Brachyoxylon* Hollick and Jeffrey (Rombola *et al*., work in progress). Although there is no evidence of a direct organic connection and there is more than one type of conifer pollen grain, the occurrence of *Classopollis* suggests that *Brachyoxylon* in the RTF could be related to the Hirmeriellaceae, a criterion shared by other authors (*e.g*., Cheng *et al*., 2022). This association is consistent with other paleobotanical records that indicate a strong representation of Hirmeriellaceae in the arboreal stratum of southern Patagonia forests during the Early Cretaceous (*e.g*., Del Fueyo *et al*., 2007).

Within the aquatic palynomorphs, algae of the genus *Botryococcus* were recognized, with a cosmopolitan distribution ranging from tropical latitudes to Arctic regions (Aaronson *et al*., 1983; Traverse, 2007). Their record covers lacustrine, fluvial, and marsh environments; however, they can also grow in waters with unstable salinity (Tyson, 1995). Finally, the absence of marine palynomorphs is consistent with the interpretation of a continental environment for the unit, as suggested by previous authors (Giacosa & Franchi, 2001; Escosteguy *et al*., 2003; Aramendía *et al*., 2018; Valle *et al*., 2024).

Paleoenvironmental interpretation: Palynofacies

Although the number of samples studied is limited, they were collected from a restricted portion of the stratigraphic section previously interpreted as fluvial floodplain deposits (Aramendía *et al*., 2018; Valle *et al*., 2024). Therefore, analyzing the proportion of the components of organic matter allows for a better understanding of the paleoenvironmental conditions that gave rise to these clastic particles.

The palynofacies of the analyzed samples are primarily dominated by phytoclasts, suggesting a proximal source or a high input of material into the basin derived from macrophyte plant fragments, mainly wood or other plant tissues (Tyson, 1995; Mendonça Filho *et al*., 2012). The predominance of translucent and opaque phytoclasts with colors ranging from dark brown to black may indicate significant oxidation processes during sediment transport or diagenesis (Tyson, 1995; Oboh-Ikuenobe & Villiers, 2003). The degree of angularity observed in these phytoclasts, generally subrounded, suggests that the sediments underwent long-distance transport or may have originated from recycled sources (Oboh-Ikuenobe *&* Villiers, 2003).

The main type of degradation affecting the palynomorphs was identified as mechanical, which may have resulted from sediment transport in a high-energy environment and/or compaction during diagenesis (Delcourt & Delcourt, 1980; Martínez *et al*., 2016). The second most prevalent type of degradation observed was pyrite crystallization, as previously noted, mainly affecting pollen grains of *Podocarpidites* and *Classopollis*.

This type of alteration results in cavities with thickened edges, primarily in the sacci and exine of the affected palynomorphs, evidencing mineral growth under reducing conditions (Volkheimer, 1968; Delcourt & Delcourt, 1980; Tyson, 1995; Martínez *et al*., 2002; 2016). However, the pyrite crystals are not preserved, indicating that the sediments were later exposed to oxidizing conditions, which left behind cavities in the shape of the former crystals (Neves & Sullivan, 1964; Tyson, 1995). Some authors suggest that the type and degree of palynomorph preservation may be related to the intrinsic properties of the palynomorphs, particularly the structure of the exine (Volkheimer, 1968; Martínez *et al*., 2002; 2016), which could explain why this type of damage primarily affected the pollen grains recorded in this study and not the spores. Notably, sample BAPal 5495, the stratigraphically lowest of the four, shows a distinct palynofacies composition compared to the others. It contains a higher proportion of amorphous organic matter, along with the lower content of phytoclasts. In continental environments amorphous organic matter is often interpreted as the product of microbial degradation of terrestrial plant debris or product of the diagenesis of macrophyte tissues (Tyson 1995; Batten, 1996; Mendonça Filho *et al*., 2012), this occurs when organic matter remains suspended in the water column or near the sediment-water interface for prolonged periods, allowing bacterial activity to progressively break down structured plant fragments. The elevated amorphous organic matter content in this sample may thus reflect a combination of low energy, poorly drained depositional conditions and prolonged residence time of organic particles, favoring microbial processing. In contrast, the remaining samples (BAPal 5496-5498) are dominated by phytoclasts and contain a very low proportion of amorphous organic matter, consistent with increased oxidation and degradation in more dynamic or proximal fluvial floodplain environment.

CONCLUSIONS

The palynoflora recovered in this study consists exclusively of terrestrial elements, characterized by fern spores, gymnosperm pollen grains, and freshwater algae.

This assemblage represents the first palynological evidence from the RTF, offering new information on the composition of its fossil plant assemblage.

Comparison with Early Cretaceous palynofloras from the AMB reveals a closer affinity between the RTF and certain localities of the Springhill Formation, both of which lack angiosperm pollen and are dominated by particular genera of ferns and gymnosperms.

The dominance of fern spores, together with the presence of conifer pollen grains from the Araucariaceae, Podocarpaceae, and Hirmeriellaceae families, as well as freshwater algae of the genus *Botryococcus*, suggests that the sediments of the lower member of the RTF in Parque Nacional Perito Moreno were deposited under temperate to warm and relatively humid climatic conditions, likely in proximity to freshwater bodies.

The organic matter present in the analyzed samples, dominated by dark brown to black phytoclasts, indicates a significant terrestrial input of macrophyte-derived organic debris into the depositional system. This, combined with the presence of polyads and tetrads of pollen grains, suggests proximity to the source area.

The absence of angiosperms in the RTF assemblage, in contrast with their documented presence in coeval and older units of the region, may reflect taphonomic or preservational factors rather than a true paleofloristic signal.

Although the number of recovered palynomorphs is relatively low and preservation is variable, the assemblage offers paleoenvironmental insights based on palynofacies and general palynomorph composition. These results provide a valuable baseline for future palynological and stratigraphic studies in the Río Tarde Formation.

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REFERENCES

Aaronson, S., Bemer, T., Gold, K., Kushner, L., Patni, N.J., Repak, A., Rubin, D., Sciences, L., College, Q., & Swain, M. (1983). Some observations on the green planktonic alga, *Botryococcus braunii* and its bloom form. *Journal of Plankton Research*, *5*, 693–700.

Aguirre-Urreta, M. B., & Ramos, V. A. (1981). Estratigrafía y paleontología de la alta Cuenca del Río Roble, Cordillera Patagónica–Provincia de Santa Cruz. *Actas del 8° Congreso Geológico Argentino* (Vol. 3, pp. 101–138). San Luis.

Alvin, K.L. (1982). Cheirolepidiaceae: biology, structure and paleoecology. *Review of Palaeobotany and Palynology*, *37*, 71–98.

Aramendía, I., Cuitiño, J. I., Ghiglione, M., & Bouza, P. J. (2019). Tectonostratigraphic significance of the Neogene sedimentary record of northwestern Austral-Magallanes Basin, Argentinean Patagonia. *Latin American Journal of Sedimentology and Basin Analysis*, *26*(2), 99–126

Aramendía, I., Cuitiño, J. I., Ghiglione, M. C., & Bouza, P. J. (2022) Timing and stratigraphic evolution of a Miocene foreland unroofing sequence in the Austral–Magallanes Basin during Southern Patagonian Andes uplift. *Journal of the Geological Society*, *180*(1), 1–18. https://doi.org/10.1144/jgs2022-038

Aramendía, I., Ramos, M. E., Geuna, S., Cuitiño, J. I., & Ghiglione, M. C. (2018). A multidisciplinary study of the Lower Cretaceous marine to continental transition in the northern Austral-Magallanes basin and its geodynamic significance. *Journal of South American Earth Sciences*, *86*, 54–69.

Archangelsky, S. (1972). Esporas de la Formación Rio Turbio (Eoceno) Provincia de Santa Cruz. *Revista del Museo de La Plata*, *Paleontología 6*, 65–100.

Archangelsky, S., Archangelsky, A., & Cladera, G. (2012). Palinología y paleoambientes en el perfil de Bajo Comisión (Cretácico), provincia de Santa Cruz, Argentina. *Revista del Museo Argentino de Ciencias Naturales*, *14*(1), Article 1.

Archangelsky, A., Archangelsky, S., Poiré, D. G., & Canessa, N. D. (2008). Registros palinológicos en la Formación Piedra Clavada (Albiano) en su área tipo, provincia de Santa Cruz, Argentina. *Revista del Museo Argentino de Ciencias Naturales*, *10*(2), 186–198.

Archangelsky, S., Baldoni, A., Gamerro, J. C., & Seiler, J. (1983). Palinología estratigráfica del Cretácico de Argentina Austral. II. descripciones sistemáticas. *Ameghiniana*, *20*(3–4), 199–226.

Archangelsky, A., & Llorens, M. (2003). Palinología de la Formación Kachaike, Cretácico Inferior de la Cuenca Austral, provincia de Santa Cruz. I- Esporas lisas y cinguladas. *Ameghiniana*, *40*(1), 7–80.

Archangelsky, A., & Llorens, M. (2005). Palinología de la Formación Kachaike, Cretácico Inferior de la Cuenca Austral, provincia de Santa Cruz. II. Esporas. *Ameghiniana*, *42*(2), 311–328.

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.

Baldoni, A. M., Askin, R. A., & Ragona, D. (2001). Palynology of the Lower Cretaceous Kachaike Formation, Santa Cruz Province, Argentina. *Proceedings of the IX International Palynological Congress* (pp. 191–200). Houston, Texas.

Baldoni, A. M., & Archangelsky, S. (1983). Palinología de la Formación Springhill (Cretácico Inferior), subsuelo de Argentina y Chile Austral. *Revista Española de Micropaleontología*, *15*(1), 47–101.

Barreda, V., & Archangelsky, S. (2006). The southernmost record of tropical pollen grains in the mid-Cretaceous of Patagonia, Argentina. *Cretaceous Research*, *27*, 778–787.

Barreda, V. D., Cúneo, N. R., Wilf, P., Currano, E. D., Scasso, R. A., & Brinkhuis, H. (2012). Cretaceous/Paleogene floral turnover in Patagonia: drop in diversity, low extinction, and a *Classopollis* spike. *Plos One*, *7*, 1–8. https://doi.org/10.1371/journal.pone.0052455

Batten, D. J. (1983). Identification of Amorphous Sedimentary Organic Matter by Transmitted Light Microscopy. In J. Brooks (Ed.). *Petroleum Geochemistry and Exploration of Europe* (pp. 275–287). *Geological Society, London*, *Special Publications*, *12*(1).

Batten, D. J. (1996). Palynofacies and paleoenvironmental interpretation. In: Jansonius, J., McGregor, D. C. (Eds.), *Palynology: Principles and Applications* (pp. 1011–1064). American Association of Stratigraphic Palynologists Foundation, Vol. 3.

Biddle, K.T., Uliana, M.A., Mitchum, R.M., Fitzgerald, M.G., & Wright, R.C. (1986). The stratigraphic and structural evolution of the central and eastern Magallanes Basin, southern South America. En *P.A. Allen & P. Homewood* (Eds.), *Foreland Basins* (pp. 41–61). International Association of Sedimentologists, Special Publication.

Brodribb, T. (2010). A functional analysis of podocarp ecology. In B.L. Turner, & L.A. Cernusak (Eds.). *Ecology of the Podocarpaceae in Tropical Forests* (pp. 165–174). Smithsonian Institution Scholarly Press.

Chalabe, A. C., Martínez, M. A., Olivera, D. E., Canale, N., & Ponce, J. J. (2022). Palynological analysis of sandy hyperpycnal deposits of the Middle Jurassic, Lajas Formation, Neuquén Basin, Argentina. *Journal of South American Earth Sciences*, *116*, 103867. https://doi.org/10.1016/j.jsames.2022.103867

Cheng, S., Xu, S., Li, F., & Tian, N. (2022). Occurrence of *Brachyoxylon* wood from the Upper Jurassic of Beijing, northern China. *Historical biology*, *35*, 1941–1949.

Chiesa, J.O., & Camacho, H.H. (1995). Litoestratigrafía del Paleógeno marino en el noroeste de la provincia de Santa Cruz, Argentina. *Monografías de la Academia Nacional de Ciencias Exactas, Físicas y Naturales de Buenos Aires*, *11*, 9–15.

Couper R. A. (1953). Upper Mesozoic and Cainozoic spores and pollen grains from New Zealand. *New Zealand Geological Survey Palaeontological Bulletin*, *22*, 1–77.

Cuitiño, J.I., Fernícola, J.C., Kohn, M., Trayler, R., Naipauer, M., Bargo, M.S., Kay, R.F., & Vizcaíno, S.F. (2016). U-Pb geochronology of the Santa Cruz Formation (early Miocene) at the río Bote and río Santa Cruz (southernmost Patagonia, Argentina). *Journal of South American Earth Scienc*e, *70*, 198–210.

Cuitiño, J.I., Pimentel, M.M., Ventura Santos, R., & Scasso, R.A. (2012). High resolution isotopic ages for the early Miocene 'Patagoniense' transgression in Southwest Patagonia: stratigraphic implications. *Journal of South American Earth Sciences*, *38*, 110–122

Cuitiño, J. I., Varela, A. N., Ghiglione, M. C., Richiano, S., & Poiré, D. G. (2019). The Austral-Magallanes basin (Southern Patagonia): A synthesis of its stratigraphy and evolution. Latin American *Journal of Sedimentology and Basin Analysis*, *26*, 155–166.

Delcourt, P. A., & Delcourt, H. R. (1980). Pollen preservation and quaternary environmental history in the Southeastern United States. *Palynology*, *4*(1), 215–231.

Del Fueyo, G.M., Villar de Seoane, L., Archangelsky, A., Guler, V., Llorens, M., Archangelsky, S., Gamerro, J.C., Mussachio, E.A., Passalia, M.G. & Barreda, V.D. (2007). Biodiversidad de las paleofloras de Patagonia Austral durante el Cretácico Inferior. En S. Archangelsky, T. Sánchez & E.P. Tonni (Eds.). *Asociación Paleontológica Argentina, Publicación Especial*, *11*, 101–122.

Encinas, A., Folguera, A., Riffo, R., Molina, P., Fernández Paz, L., Litvak, V.D. and Carrasco, M. (2019). Cenozoic basin evolution of the Central Patagonian Andes: evidence from geochronology, stratigraphy, and geochemistry. *Geoscience Frontiers*, *10*, 1139–1165.

Duarte, S.G., Da Silva, F.J., Arai, M., Da Silva Silvestre, L., Wanderley, M.D., Jha, N., Joshi, H., Masure, E., & El Atfy, H. (2021). Paleoclimatic and paleoecological inferences of the Family Anemiaceae: A palynological investigation from variable spatial and temporal strata in some lithostratigraphic units of Brazil, India and France. *Review of Palaeobotany and Palynology*, *285*, 104316.

Enright, N.J, Hill, R.S., & Veblen, T.T. (1995). The Southern conifers-An introduction. In N. J. Enright, & R. S. Hill (Eds.), *Ecology of the Southern Conifers* (pp. 1–9). Melbourne University Press.

Escosteguy, L., Dal Molín, C., Franchi, M., Geuna, S., Lapido, O., & Genini, A. (2003). Hoja Geológica 4772–II, Lago Buenos Aires. Provincia de Santa Cruz. *Instituto de Geología y Recursos Minerales, Servicio Geológico Minero Argentino*. Boletín 339, 80 p.

Escosteguy, L., Etcheverría, M., Geuna, S., Franchi, M., Wilson, C., & Azcurra, D. (2017). Hoja Geológica 4972–I, Monte Tetris. Provincia de Santa Cruz. *Instituto de*

Geología y Recursos Minerales, Servicio Geológico Minero Argentino. Boletín 429, 87 p.

Ghiglione, M. C., Naipauer, M., Sue, C., Barberón, V., Valencia, V., Aguirre-Urreta, B., & Ramos, V. A. (2015). U–Pb zircon ages from the northern Austral basin and their correlation with the Early Cretaceous exhumation and volcanism of Patagonia. *Cretaceous Research*, *55*, 116–128.

Ghiglione, M.C., Ramos, V.A., Cuitiño, J., & Barberón, V. (2016). Growth of the southern Patagonian Andes (46°–53° S) and their relation to subduction processes. In: A. Folguera, M. Naipauer, L. Sagripanti, M.C. Ghiglione, D.L. Orts & L. Giambiagi (Eds.). *Growth of the Southern Andes* (pp. 201–240). Springer.

Giacosa, R., & M. Franchi. (2001). Hojas Geológicas 4772–III Lago Belgrano y 4772–IV Lago Posadas. Provincia de Santa Cruz. *Instituto de Geología y Recursos Minerales, Servicio Geológico Minero Argentino. Boletín 256*, 68 p.

Greppi, C.D., Pujana, R.R., Ruiz, D.P., Rombola, C.F., & Aramendía, I. (2023). Conifer fossil woods from the mid-Cretaceous (Albian) Kachaike Formation, Santa Cruz Province, Argentina. *Ameghiniana*, *60*, 3–17.

Greppi, C.D., Pujana, R.R., & Scasso, R.A. (2020). Fossil woods from the Lower Cretaceous Tres Lagunas Formation of central Patagonia (Chubut Province, Argentina). *Cretaceous Research*, *108*, 104322. https://doi.org/10.1016/j.cretres.2019.104322

Guler, V., Berbach, L., Archangelsky, A., & Archangelsky, S. (2015). Quistes de dinoflagelados y polen asociado del Cretácico Inferior (Formación Springhill) de la Cuenca Austral, Plataforma Continental Argentina. *Revista Brasileira de Paleontología*, *18*(2), 307–324.

Hatcher, J. B. (1897). Geology of southern Patagonia. *American Journal of Science*, *4*(23), 327–354.

Hatcher, J.B. (1900). Sedimentary rocks of Southern Patagonia. *American Journal of Science*, *9*, 85–108.

Martínez, L. C. A., Archangelsky, A., & Archangelsky, S. (2023). Algal association and angiosperm diversification from the early Cretaceous (Springhill Formation) of Patagonia: Insights into palaeoclimate and aquatic environments at Río Correntoso locality, Argentina. *Review of Palaeobotany and Palynology*, *317*, 104953. https://doi.org/10.1016/j.revpalbo.2023.104953

Martínez, M. A., Olivera, D. E., Zavala, C., & Quattrocchio, M. E. (2016). Palynotaphofacies analysis applied to Jurassic marine deposits, Neuquén Basin. *Facies*, *62*(10), 1–16. https://doi.org/10.1007/s10347-015-0457-1

Martinez, M. A., Quatrocchio, M. E., & Zavala, C. A. (2002). Análisis palinofacial de la Formación Lajas (Jurásico medio), Cuenca Neuquina, Argentina. Significado paleoambiental y paleoclimático. *Revista Española de Micropaleontología*, *34*(1), 81–104.

Mckellar, J. L. (1998). V*olume 1: Late Early to Late Jurassic palynology, biostratigraphy and palaeogeography of the Roma shelf area, northwestern Surat Basin Queensland, Australia*. (PhD thesis, Department of Earth Sciences, The University of Queensland). Available from / Retrieved from [https://espace.library.uq.edu.au/view/UQ:365865].

Medina, F., Archangelsky, S., Guler, V., Archangelsky, A., & Cárdenas, O. (2008). Estudio bioestratigráfico integrado del perfil La Horqueta (límite Aptiano-Albiano), lago Cardiel, Patagonia, Argentina. *Revista del Museo Argentino de Ciencias Naturale*s, *10*(2), 273–289.

Mendonça Filho, J.G., Menezes, T.R., de Oliveira Mendonça, J., de Oliveira, A.D., da Silva, T.F., Rondon, N.F., & da Silva, F.S. (2012). Organic facies: palynofacies and organic geochemistry approaches. In D. Panagiotaras (Ed.). *Geochemistry Earth System Processes* (pp. 211–248). InTech Rijeka.

Neves, R., & Sullivan, H. J. (1964). Modification of fossil spore exines associated with the presence of pyrite crystals. *Micropaleontology*, *10*(4), 443–452.

Noetinger, S., Pujana, R.R., Burrieza, A., & Burrieza, H. P. (2017). Use of UV-curable acrylates gels as mounting media for palynological samples. *Revista del Museo Argentino de Ciencias Naturales*, *19* (1), 19–23.

Oboh-Ikuenobe, F. E., & Villiers, S. E. (2003). Dispersed organic matter in samples from the western continental shelf of Southern Africa: Palynofacies assemblages and depositional environments of Late Cretaceous and younger sediments. *Palaeogeography, Palaeoclimatology, Palaeoecology*, *201*, 67–88.

Ottone, E. G., Aguirre-Urreta, M. B. (2000). Palinomorfos cretácicos de la Formación Springhill en Estancia El Salitral, Patagonia austral, Argentina. *Ameghiniana*, *37*(3), 379–382.

Parras, A., Dix, G.R. and Griffin, M. (2012). Sr-isotope chronostratigraphy of Paleogene-Neogene marine deposits: Austral Basin, southern Patagonia (Argentina). *Journal of South American Earth Sciences*, *37*, 122–135.

Passalia, M. G. (2009). Cretaceous pCO2 estimation from stomatal frequency analysis of gymnosperm leaves of Patagonia, Argentina. *Palaeogeography, Palaeoclimatology, Palaeoecology*, *273*, 17–24.

Perez Loinaze, V. S., Archangelsky, S., & Cladera, G. (2012). Palynostratigraphic study of the Early Cretaceous Río Mayer and Kachaike formations at the Quebrada El Moro Section, Austral Basin, southwestern Argentina. *Cretaceous Research*, *34*, 161–171.

Perez Loinaze, V. S., Barreda, V. D., Archangelsky, S., & Archangelsky, A. (2015). Cretaceous angiosperm pollen from the Kachaike Formation, south-western Santa Cruz Province, Argentina. *Historical Biology*, *28*(7), 941–951.

Perez Loinaze, V. S., Llorens, M., Cuitiño, J. I., Guler, M. V., & Villán, J. C. (2021). Palynostratigraphy of the Lower Cretaceous Río Mayer Formation in the Río Lista area, Austral Basin, southwestern Argentina. *Cretaceous Research*, *126*, 104916. https://doi.org/10.1016/j.cretres.2021.104

Pöthe de Valdis, D., & Ramos, V. A. (1980). Las microfloras de la Formación Río Mayer y su significado estratigráfico, Provincia de Santa Cruz, República Argentina. *Actas del 2° Congreso Argentino de Paleontología y bioestratgrafía y 1° Congreso Latinoamericano de Paleontología*, *31* (pp. 201–213). Buenos Aires.

Pöthe de Valdis, D., & Ramos, V. A. (1983). Dinoflagelados del Aptiano Inferior de Río Fósiles, Lago San Martín, provincia de Santa Cruz, Argentina. *Revista Española de Micropaleontología*, *15*(3), 427–446.

Pöthe de Baldis, E. D., & Ramos, V. A. (1988). Microplancton adicional del Aptiano de Río Fósiles Lago San Martín, Provincia de Santa Cruz, Argentina y su correlación con Australia. *Actas del 4° Congreso Argentino de Paleontología y Bioestratigrafía* (pp. 23–41). Mendoza

Punt, W., Hoen, P.P., Blackmore, S., Nilsson, S., & Le Thomas, A. (2007). Glossary of pollen and spore terminology. *Review of Palaeobotany and Palynology*, *143*, 1–81. https://doi.org/10.1016/j.revpalbo.2006.06.008

Quattrocchio, M. E., Martínez, M. A., Pavisich, A. C., & Volkheimer, W. (2006). Early Cretaceous palynostratigraphy, palynofacies and palaeoenvironments of well sections in northeastern Tierra del Fuego, Argentina. *Cretaceous Research*, *27*(4), 584–602.

Ramos, V. A. (1979). Tectónica de la región del Río y Lago Belgrano, Cordillera Patagónica Argentina. *Actas B del 2° Congreso Geológico Chileno* (pp. 1–32). Arica.

Ramos, V. A., & Drake, R. (1987). Edad y significado tectónico de la Formación Río Tarde (Cretácico) Lago Posadas, Provincia de Santa Cruz. *Actas del Décimo Congreso Geológico Argentino* (pp. 143–147). San Miguel de Tucumán.

Riding, J. B. (2021). A guide to preparation protocols in palynology. *Palynology*, *45* (sup1), 1–110. https://doi.org/10.1080/01916122.2021.1878305

Riccardi, A.C. (1971). Estratigrafía en el oriente de la bahía La Lancha, lago San Martín, Santa Cruz. *Revista del Museo de La Plata*, *7*, 245–318.

Robbiano, J., Arbe, H., & Gangui, A. (1996). Cuenca Austral marina. In V. Ramos & M. Turic. (Eds.). *Actas 15 del 13° Congreso Geológico Argentino y 3° Congreso de Exploración de Hidrocarburos* (pp. 343–358). Buenos Aires

Rombola, C. F., Aramendía, I., Pujana, R. R., & García Massini, J. L. (2023). Remains of a Cretaceous Forest (fossil woods) in the Perito Moreno National Park, Santa Cruz Province, Argentina. *Serie Correlación Geológica*, *39*(2), 05–22.

Rombola, C. F., Pujana, R. R., Aramendía, I., & Greppi, C. D. (2024). Bosque fósil dominado por coníferas en el Parque Nacional Perito Moreno (Formación Río Tarde), Provincia de Santa Cruz. *Actas del 22° Congreso Geológico Argentino* (pp. 679–680). San Luis.

Ross, N.E. (1949). Investigations of the Senonian of the Kristianstad District, S. Sweden. I: On a Cretaceous pollen and spore bearing clay deposit of Scania. *Bulletin of the Geological Institutions of the University of Uppsala*, *34*, 25–43.

Santamarina, P. E. (2019). *Análisis palinoflorístico de la Formación Mata Amarilla (Cenomaniano de la provincia de Santa Cruz) con énfasis en el estudio de angiospermas*. (Tesis Doctoral, Facultad de Ciencias Naturales y Museo, Universidad

Nacional de La Plata, La Plata, Buenos Aires). Available from / Retrieved from [https://sedici.unlp.edu.ar/handle/10915/72117].

Scotese, C. R., Boucot, A. J., & Mckerrow, W. S. (1999). Gondwanan palaeogeography and palaeoclimatology. *Journal of African Earth Sciences*, *28*(1), 99–114.

Smith, A.G., Smith, D.G., & Funnell, M. (1994). *Atlas of Mesozoic and Cenozoic coastlines.* Cambridge University, Cambridge.

Traverse, A.T. (2007). *Paleopalynology*. Springer.

Tyson, R. V. (1995). *Sedimentary Organic Matter.* Springer.

Vakhrameev, V. A. (1981). Pollen *Classopollis*: indicator of Jurassic and Cretaceous climates. *Journal of Palaeosciences*, *28–29*, 301–307.

Valle, M.N., Paredes, J.M., Foix, N., & Frasette, M.J.P. (2024). Sedimentology and stratigraphic evolution of the Early Cretaceous regressive cycle at the northern edge of the Austral Basin, Santa Cruz, Argentina. *Journal of South American Earth Sciences*, *135*, 104812. https://doi.org/10.1016/j.jsames.2024.104812

Van Konijnenburg-Van Cittert, J. H. A. (2002). Ecology of some Late Triassic to Early Cretaceous ferns in Eurasia. *Review of Palaeobotany and Palynology*, *119*(1–2), 113–124.

Venkatachala, B. S., Kar, R. K., & Raza, S. (1968). Palynology of the Mesozoic sediments of Kutch, w. India–3. Morphological study and review of the spore genus Trilobosporites Pant ex Potonié, 1956. *Journal of Palaeosciences*, *17*(1-3), 123–126.

Villar De Seoane, L. (2005). *Equisetites pusillus sp. nov.* From the Aptian of Patagonia, Argentina. *Revista del Museo Argentino de Ciencias Naturales*, *7*(1), 43–49.

Villar De Seoane, L. (2014). Estudio morfológico del género *Classopollis* (Pflug) Pocock & Jansonius (Cretácico, Argentina). *Revista Brasileira de Paleontología*, *17*(1), 91–104.

Volkheimer, W. (1968). Esporas y granos de polen del Jurásico de Neuquén (República Argentina).1. Descripciones sistemáticas. *Ameghiniana*, *5*(9), 333–370.

Volkheimer, W., Quattrocchio, M.E., Cabaleri, N., & García, V. (2008). Palynology and paleoenvironment of the Jurassic lacustrine Cañadón Asfalto Formation at Cañadón Lahuincó locality, Chubut Province, Central Patagonia, Argentina. *Revista Española de Micropaleontología*, *40*, 77–96.

Figure captions

Figure 1. 1, Map of Patagonia indicating the study area of the Río Tarde Formation with the red rectangle; **2,** Satellite image (Google, CNES/Airbus) of Parque Nacional Perito Moreno showing the fossil locality with the red rectangle, modified from Rombola *et al.*, 2023; **3,** Satellite image (Google, Maxar Technologies) showing the sample collection site and the stratigraphic profile (red circle) within Parque Nacional Perito Moreno.

Figure 2. Stratigraphic section of the lower member of the Río Tarde Formation in the former Río Roble Ranch area, modified from Rombola *et al.*, 2023.

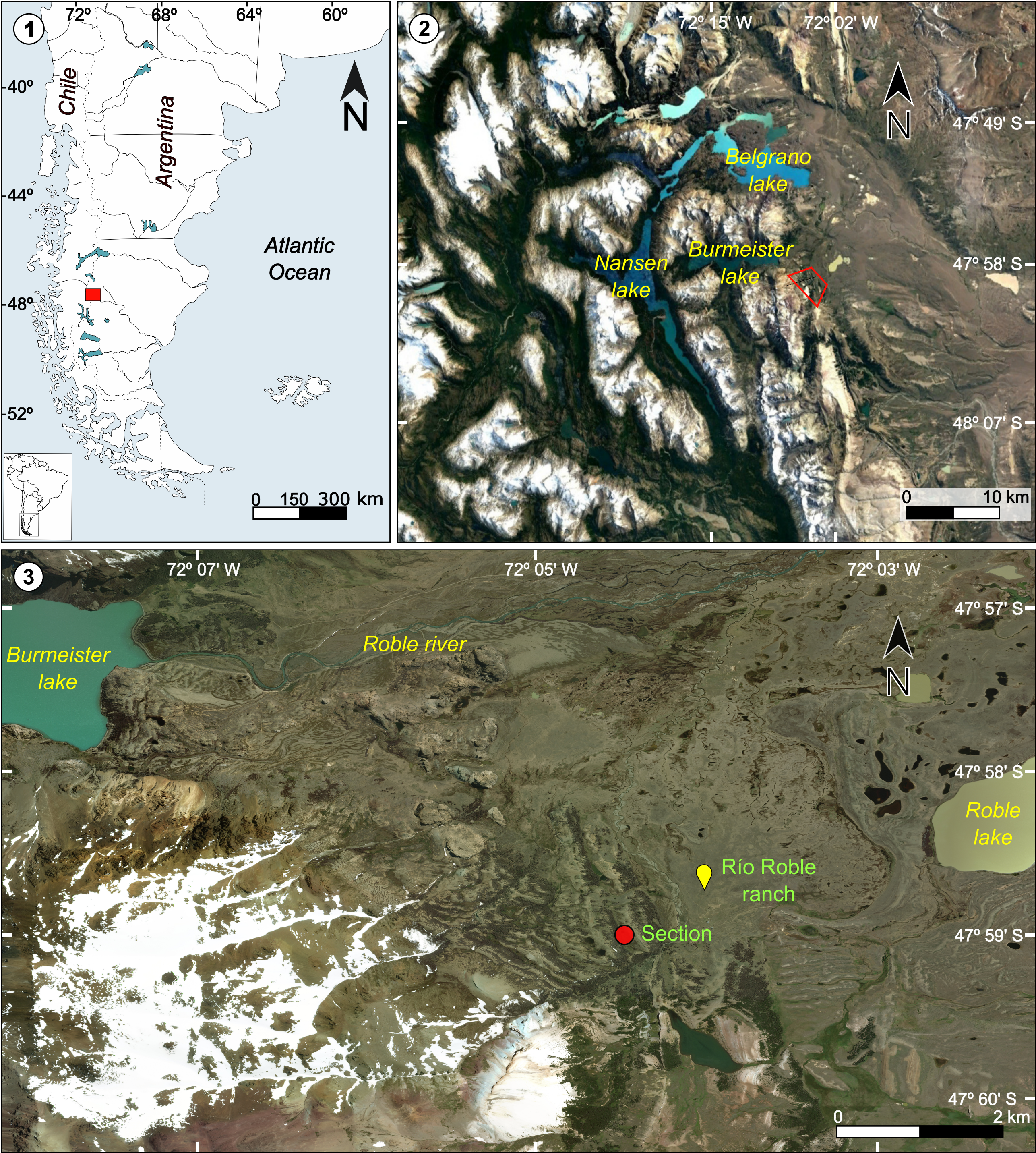
Figure 3. Selected spores and pollen grains from the Río Tarde Formation. The collection acronym, plate number and coordinates in England Finder are indicated below each morphotype. Scales bars: **1-7**=20 µm; **8-12**=50 µm. **1,** ***Cyathidites australis*** Couper, 1953, **BA Pal** 5495/+25(1): V21/2; **2,** ***Concavissimisporites verrucosus*** Delcourt & Sprumont *emend.* Mckellar, 1998*,* **BA Pal** 5495/+25(1): V49/2; **3,** ***Impardecispora apiverrucata*** (Couper) Venkatachala, Kar and Raza, 1968, **BA Pal** 5495/+25(1): Y43/4; **4,** ***Gleicheniidites senonicus*** Ross, 1949, **BA Pal** 5495/+25(1): Y25/3; **5,** ***Klukisporites variegatus*** Couper, 1953, **BA Pal** 5497/+8(1): Q22/0; **6,** ***Classopollis*** sp., **BA Pal** 5495/+25(1): L53/2; **7,** ***Cyclusphaera*** sp. cf. *C.* ***radiata*** Archangelsky emend Del Fueyo *et al.* 2012, **BA Pal** 5495/+25(1): C26/2; **8,** Polyad of

Classopollis spp., **BA Pal** 5495/+25(1): B31/3; **9,** Polyad of ***Cicatricosisporites*** spp., **BA Pal** 5497/+25(1): J46/1; **10,** General view of palynological organic matter indicating a spore with the red arrow, a tracheid with pits with the yellow arrow and dark brown to black translucent phytoclast with the white arrows, **BA Pal** 5495/+25(1): V21/0; **11,** Tracheid fragment with pits, **BA Pal** 5495/+25(1): F23/4; **12,** Fragment of translucent phytoclast and wood remain, **BA Pal** 5495/+25(1): Y29/4.

Figure 4. Relative frequencies of palynological organic matter components recognized in a 500-particle count per sample of the Río Tarde Formation. The relative frequencies of the main groups are shown on the right. **A.O.M.,** amorphous organic matter.

Table captions

Table 1. List of species recovered in the Río Tarde Formation at the Río Roble Ranch area.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72º 02' W
47º 49' S
47º 58' S
48º 07' S
Belgrano lake
Nansen lake
Burmeister lake
N
0 10 km
3
72º 07' W
72º 05' W
72º 03' W
47º 57' S
47º 58' S
47º 59' S
47º 60' S
Burmeister lake
Roble river
Roble lake
Río Roble ranch
Section
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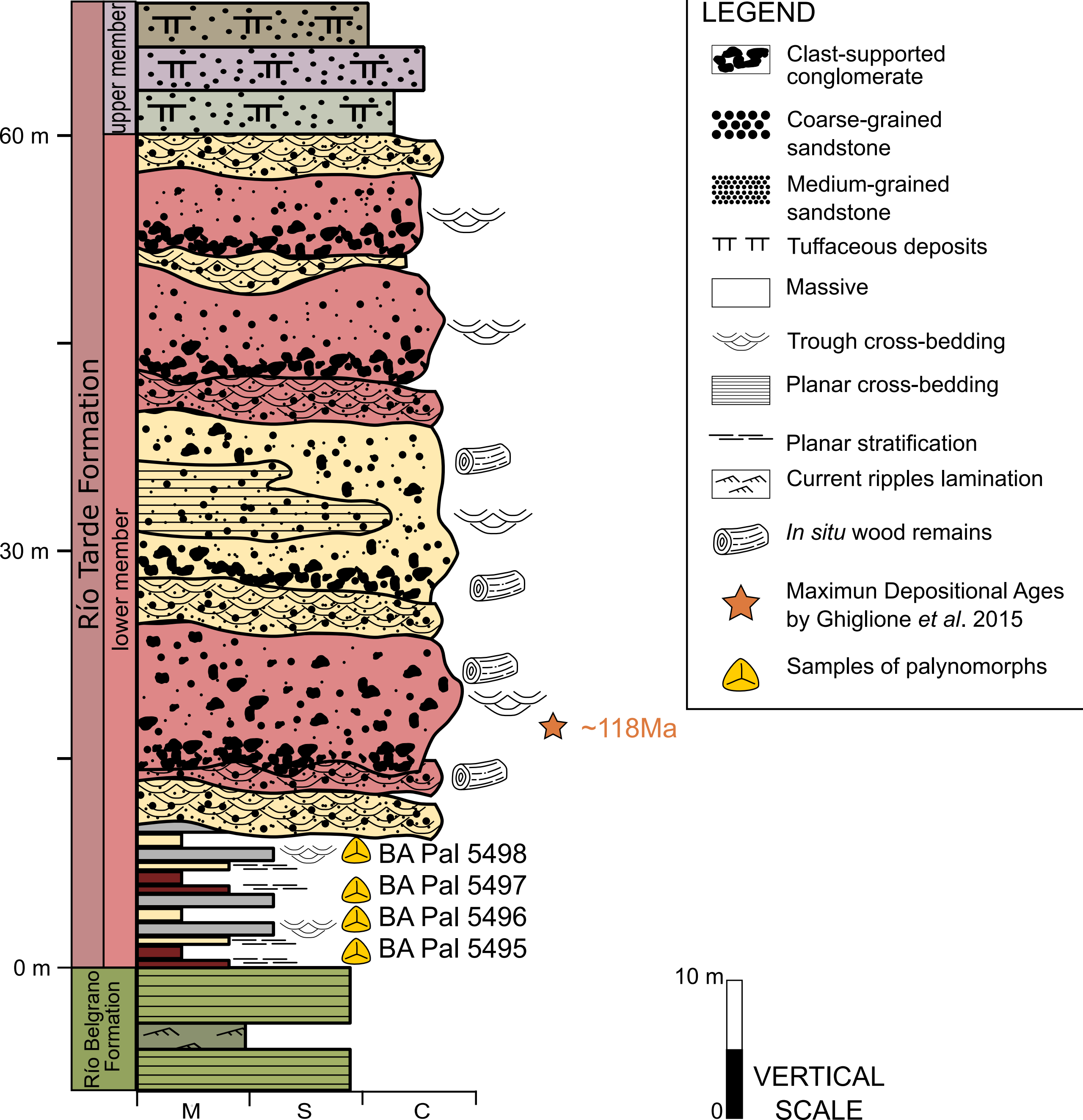
LEGEND
Clast-supported conglomerate
Coarse-grained sandstone
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ㄒㄒ ㄒㄒ Tuffaceous deposits
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Trough cross-bedding
Planar cross-bedding
Planar stratification
Current ripples lamination
In situ wood remains
Maximun Depositional Ages by Ghiglione *et al*. 2015
Samples of palynomorphs
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30 m
0 m
Río Tarde Formation
upper member
lower member
Río Belgrano Formation
~118Ma
BA Pal 5498
BA Pal 5497
BA Pal 5496
BA Pal 5495
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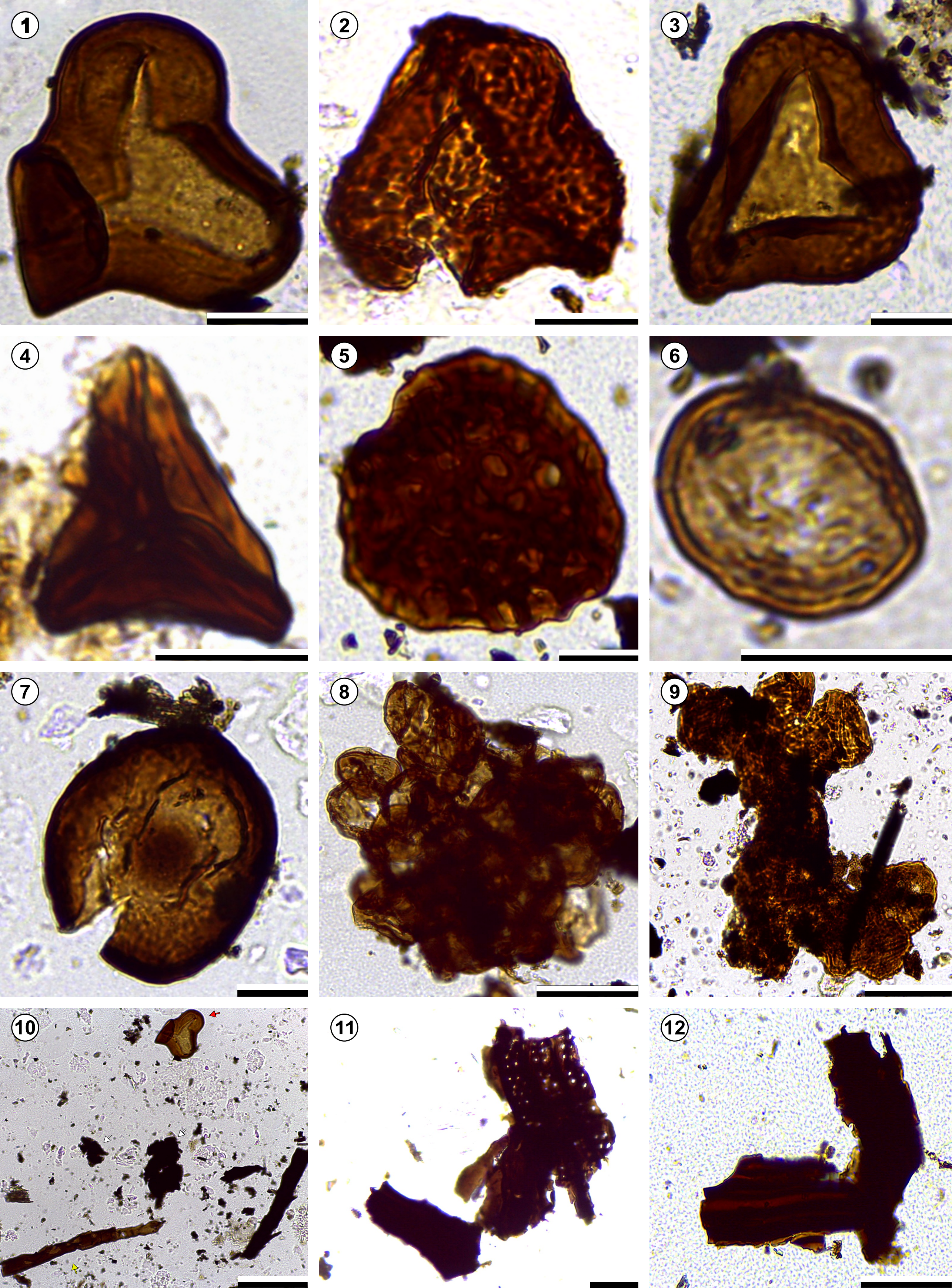
C
10 m
0
VERTICAL SCALE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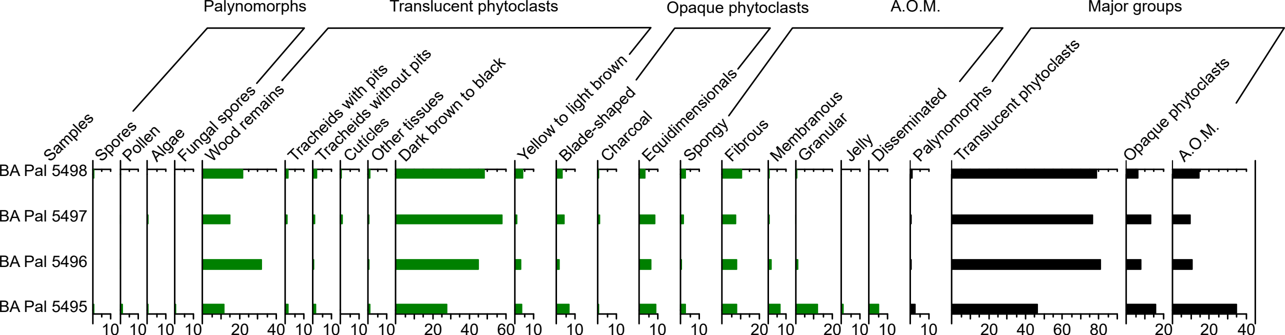
Palynomorphs
Translucent phytoclasts
Opaque phytoclasts
A.O.M.
Major groups
Samples
Spores
Pollen
Algae
Fungal spores
Wood remains
Tracheids with pits
Tracheids without pits
Cuticles
Other tissues
Dark brown to black
Yellow to light brown
Blade-shaped
Charcoal
Equidimensionals
Spongy
Fibrous
Membranous
Granular
Jelly
Disseminated
Palynomorphs
Translucent phytoclasts
Opaque phytoclasts
A.O.M.
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BA Pal 5497
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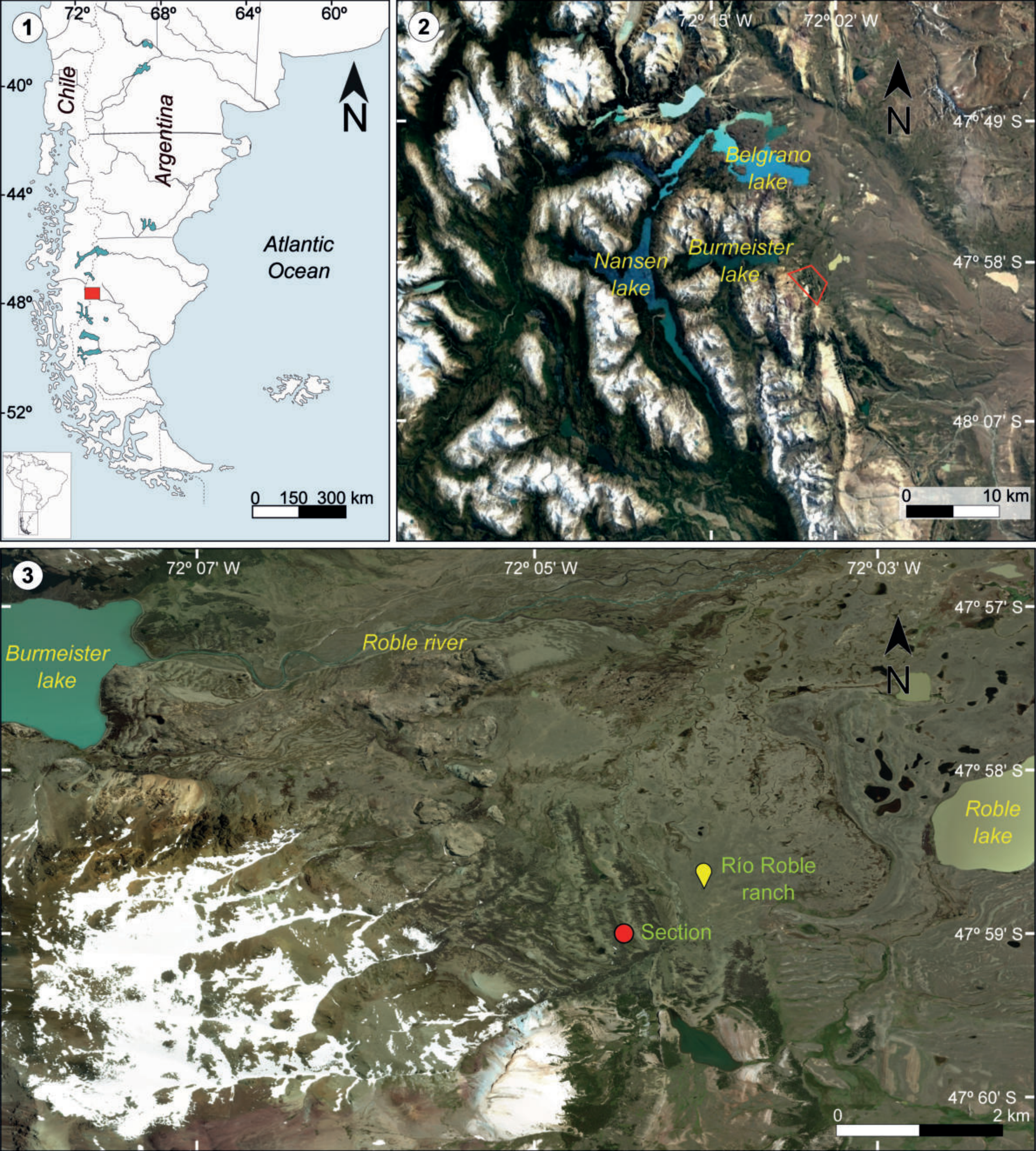
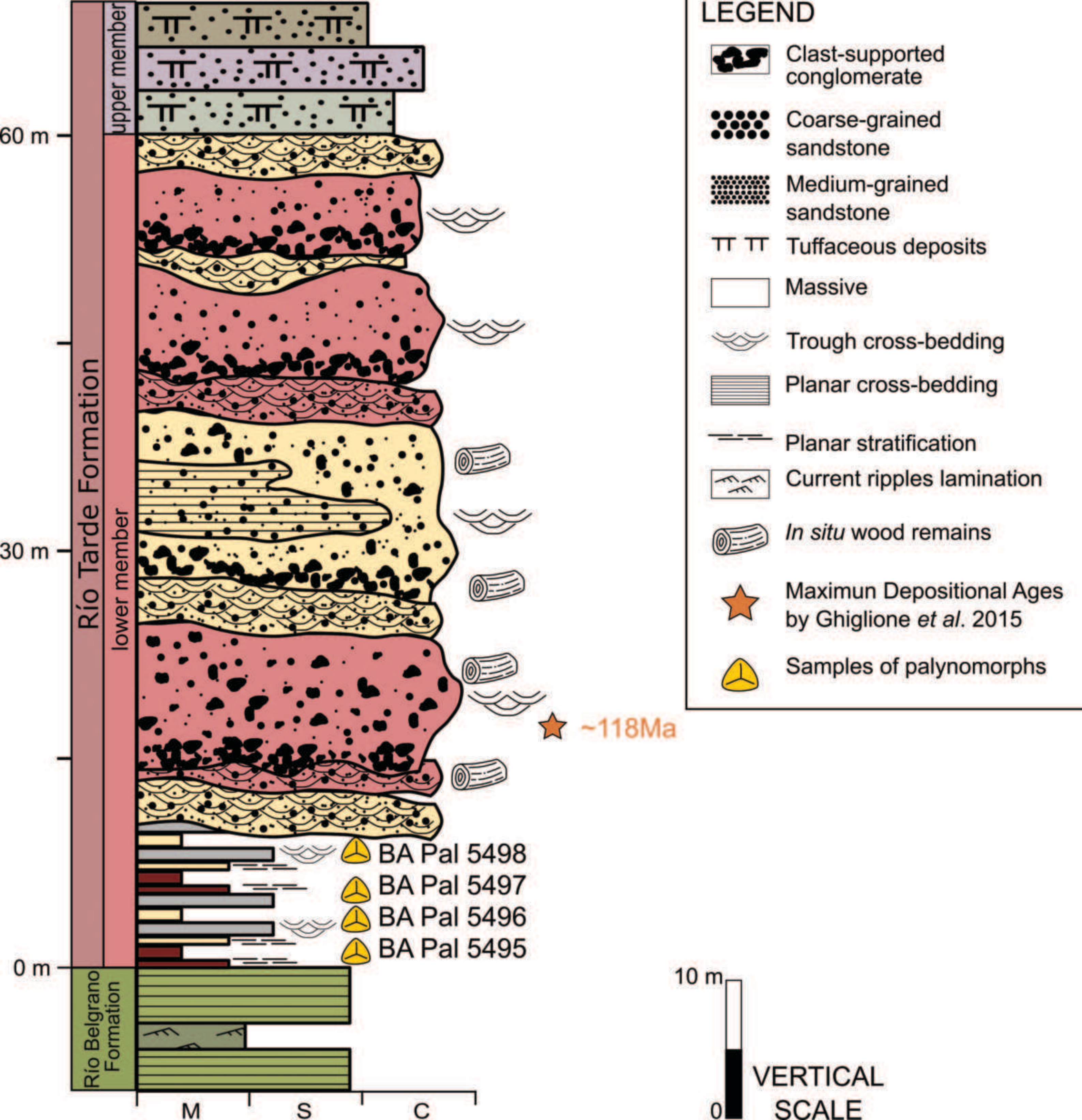
TABLE 1. List of species recovered in the Río Tarde Formation at the Río Roble Ranch area, Patagonia, Argentina.

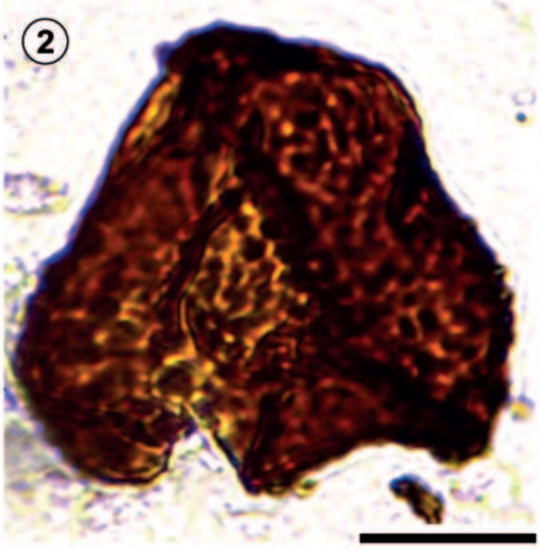
Affinity	Taxa	BA Pal 5495	BA Pal 5496	BA Pal 5497	BA Pal 5498
POLYPODIOPSIDA					
Gleicheniaceae	***Gleicheniidites senonicus*** Ross, 1949 (Fig. 3.4)	X			
Lygodiaceae	***Impardecispora apiverrucata*** (Couper) Venkatachala, Kar and Raza, 1968 (Fig. 3.3)	X			
Anemiaceae	***Cicatricosisporites*** spp.	X	X	X	X
Schizaeaceae	***Klukisporites variegatus*** Couper, 1953 (Fig. 3.5)			X	
Cyatheaceae, Dicksoniaceae, Dipterideaceae or Matoniaceae	***Cyathidites australis*** Couper, 1953 (Fig. 3.1)	X	X		
	Cyathidites patagonicus Archangelsky, 1972	X			
	Cyathidites minor Couper, 1953	X			
Incertae sedis	***Concavissimisporites verrucosus*** Delcourt & Sprumont emend. Mckellar, 1998 (Fig. 3.2)	X			
	Converrucosisporites sp.	X			
GYMNOSPERMAE					
Araucariaceae	***Cyclusphaera*** sp. cf. ***C. radiata*** Archangelsky emend. Del Fueyo et al. 2012 (Fig. 3.7)	X			X
Hirmeriellaceae (=Cheirolepidiaceae)	***Classopollis*** sp. (Fig 3.6)	X	X		X
Podocarpaceae	***Podocarpidites*** sp.	X		X	
ALGAE					
Botryococcaceae	***Botryococcus*** sp.	X			X


1
72º
68º
64º
60º
40º
44º
48º
52º
Chile
Argentina
Atlantic Ocean
N
0 150 300 km
2
72º 15' W
72º 02' W
47º 49' S
47º 58' S
48º 07' S
N
Belgrano lake
Burmeister lake
Nansen lake
0 10 km
3
72º 07' W
72º 05' W
72º 03' W
47º 57' S
47º 58' S
47º 59' S
47º 60' S
N
Burmeister lake
Roble river
Roble lake
Río Roble ranch
Section
0 2 km


Río Tarde Formation
upper member
lower member
Río Belgrano Formation
60 m
30 m
0 m
~118Ma
BA Pal 5498
BA Pal 5497
BA Pal 5496
BA Pal 5495
M
S
C
LEGEND
Clast-supported conglomerate
Coarse-grained sandstone
Medium-grained sandstone
Tuffaceous deposits
Massive
Trough cross-bedding
Planar cross-bedding
Planar stratification
Current ripples lamination
In situ wood remains
Maximun Depositional Ages by Ghiglione et al. 2015
Samples of palynomorphs
10 m
0
VERTICAL SCALE

①

②



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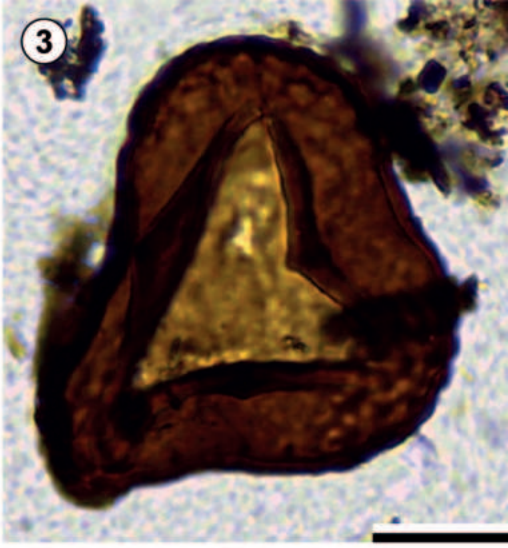

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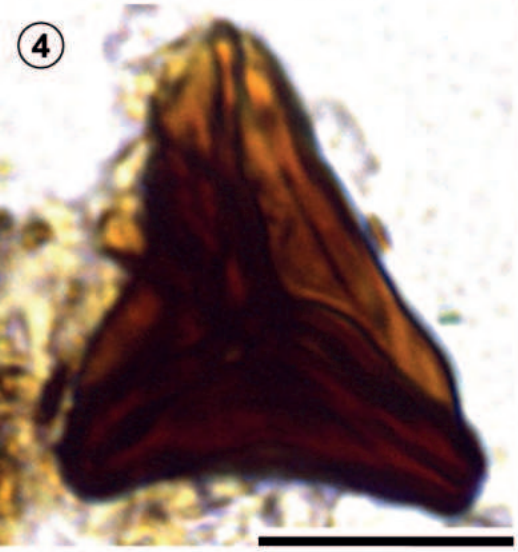

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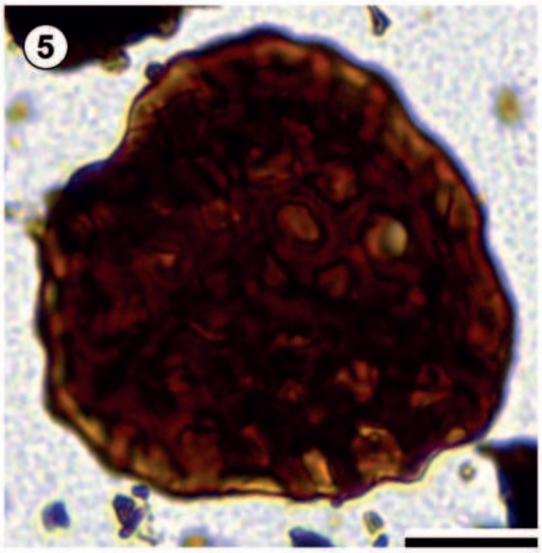
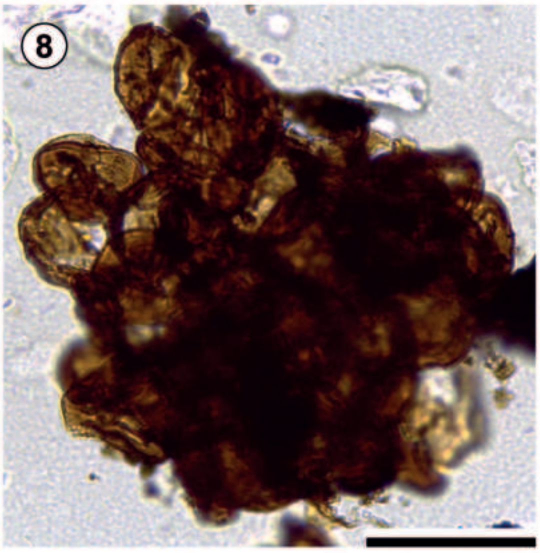


⑥

⑦

⑧



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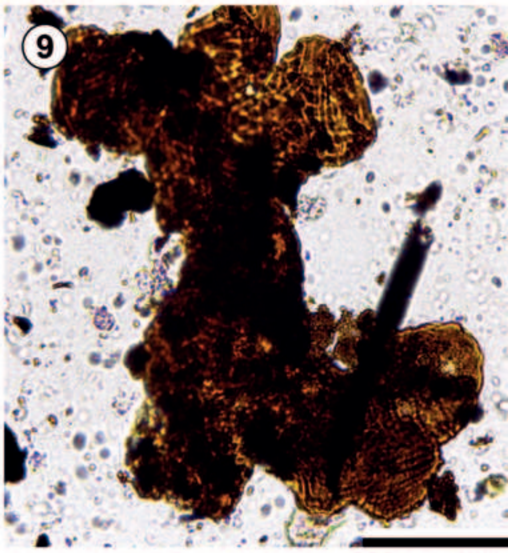

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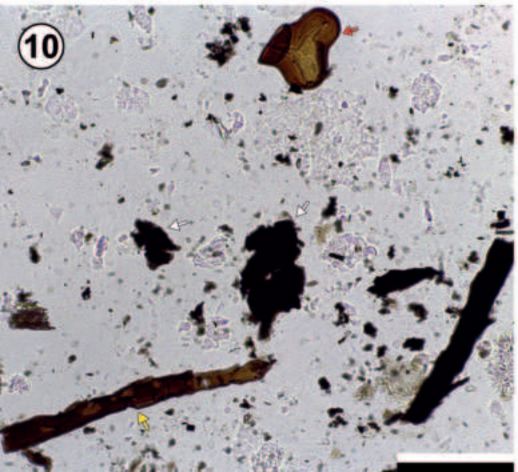

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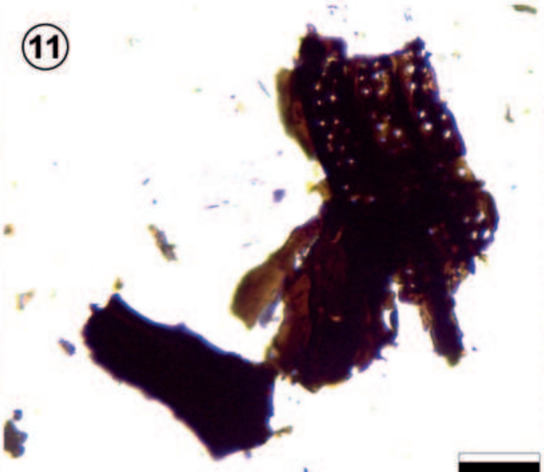

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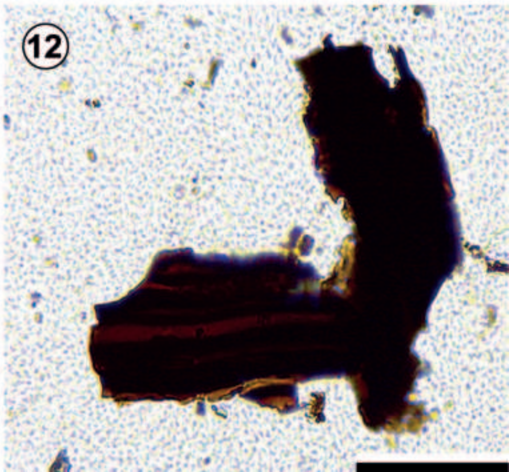

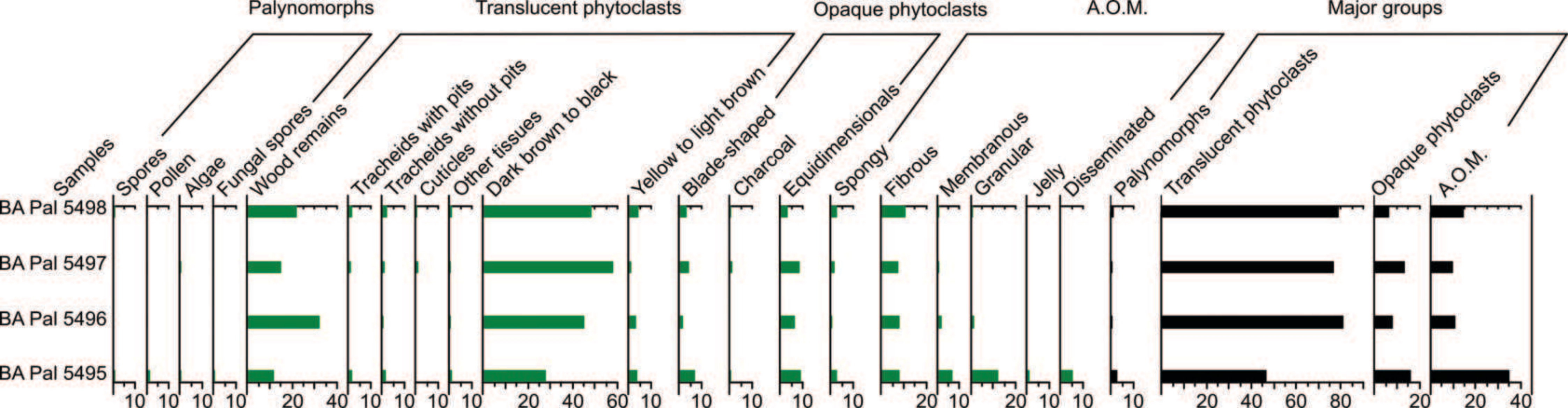
Palynomorphs
Translucent phytoclasts
Opaque phytoclasts
A.O.M.
Major groups
Samples
Spores
Pollen
Algae
Fungal spores
Wood remains
Tracheids with pits
Tracheids without pits
Cuticles
Other tissues
Dark brown to black
Yellow to light brown
Blade-shaped
Charcoal
Equidimensionals
Spongy
Fibrous
Membranous
Granular
Jelly
Disseminated
Palynomorphs
Translucent phytoclasts
Opaque phytoclasts
A.O.M.
BA Pal 5498
BA Pal 5497
BA Pal 5496
BA Pal 5495
10
10
10
10
20
40
10
10
10
10
20
40
60
10
10
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10
10
20
10
20
10
10
10
20
40
60
80
20
20
40

TABLE 1. List of species recovered in the Río Tarde Formation at the Río Roble Ranch area, Patagonia, Argentina.

Affinity	Taxa	BA Pal 5495	BA Pal 5496	BA Pal 5497	BA Pal 5498
POLYPODIOPSIDA					
Gleicheniaceae	***Gleicheniidites senonicus*** Ross, 1949 (Fig. 3.4)	X			
Lygodiaceae	***Impardecispora apiverrucata*** (Couper) Venkatachala, Kar and Raza, 1968 (Fig. 3.3)	X			
Anemiaceae	***Cicatricosisporites*** spp.	X	X	X	X
Schizaeaceae	***Klukisporites variegatus*** Couper, 1953 (Fig. 3.5)			X	
Cyatheaceae, Dicksoniaceae, Dipterideaceae or Matoniaceae	***Cyathidites australis*** Couper, 1953 (Fig. 3.1)	X	X		
	Cyathidites patagonicus Archangelsky, 1972	X			
	Cyathidites minor Couper, 1953	X			
Incertae sedis	***Concavissimisporites verrucosus*** Delcourt & Sprumont emend. Mckellar, 1998 (Fig. 3.2)	X			
	Converrucosisporites sp.	X			
GYMNOSPERMAE					
Araucariaceae	***Cyclusphaera*** sp. cf. ***C. radiata*** Archangelsky emend. Del Fueyo et al. 2012 (Fig. 3.7)	X			X
Hirmeriellaceae (=Cheirolepidiaceae)	***Classopollis*** sp. (Fig 3.6)	X	X		X
Podocarpaceae	***Podocarpidites*** sp.	X		X	
ALGAE					
Botryococcaceae	***Botryococcus*** sp.	X			X