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Remains of a Cretaceous forest (fossil woods) in the Perito Moreno National Park, Santa Cruz Province, Argentina

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Resumen: *RESTOS DE UN BOSQUE CRETÁCICO (MADERAS FÓSILES) EN EL PARQUE NACIONAL PERITO MORENO, PROVINCIA DE SANTA CRUZ, ARGENTINA.* Se recuperó una asociación de 84 maderas fósiles de sedimentos del Aptiano del miembro inferior de la Formación Río Tarde en el Parque Nacional Perito Moreno, provincia de Santa Cruz, Argentina. Esta asociación se interpreta como un bosque fósil paraautóctono en base a la abundancia, tamaño y distribución de los troncos. La mayoría de los especímenes se recolectaron como madera rodada (58%), mientras que una proporción menor se encontró *in situ* (42%) en los sedimentos portadores y paralela a los estratos. Algunas maderas fósiles se estudiaron a partir de secciones delgadas obtenidas por técnicas comunes. En general, las maderas fósiles tienen una anatomía bien conservada. Las características anatómicas de los especímenes analizados indican que las coníferas dominan la asociación. Esto es consistente con lo observado en otras asociaciones de maderas fósiles del Mesozoico del sur de la Patagonia que estaban mayoritariamente dominadas por coníferas. Todos los especímenes observados mediante microscopía de luz transmitida muestran límites de anillos de crecimiento marcados, delimitados por unas pocas filas de traqueidas radialmente comprimidas. Estas características de los anillos indican una estacionalidad anual marcada durante la depositación de la Formación Río Tarde en el área de estudio. El tamaño de los ejemplares y la curvatura de los anillos son consistentes con la presencia de grandes árboles. Además, alrededor del 43% de las maderas fósiles estudiadas muestran evidencia externa de biodeterioro por artrópodos saproxílicos (p. ej., perforaciones y coprolitos) y por hongos que degradan la madera (p. ej., patrones de degradación fúngica). Esta evidencia sugiere que algunas de las maderas fósiles estudiadas se encontraban en un estado avanzado de descomposición antes de su fosilización.

Abstract: An assemblage of 84 fossil woods from Aptian sediments of the lower member of the Río Tarde Formation in the Perito Moreno National Park, Santa Cruz Province, Argentina, was recovered. This association is interpreted as a parautochthonous fossil forest based on the abundance, size, and distribution of the trunks. Most of the specimens were collected as float wood (58%) in the field, whereas a smaller proportion was found *in situ* (42%) embedded within the bearing sediments and parallel to the strata. Some fossil woods were studied by means of standard thin sections. In general, the fossil woods are well-preserved anatomically. Based on the anatomical characteristics of the specimens analyzed, conifers dominate the association. This is consistent with what has been observed in other Mesozoic fossil wood assemblages in southern Patagonia, which were mainly dominated by conifers. All the specimens observed by means of light microscopy show distinct growth ring boundaries, delimited by a few rows of radially compressed tracheids. These characteristics of the rings indicate marked seasonality during the deposition of the Río Tarde Formation in the study area. The size of the specimens and the curvature of the rings are consistent with the presence of large trees. In addition, about 43% of the fossil woods studied show external evidence of biodeterioration by saproxylic arthropods (e.g., borings and coprolites) and by wood-degrading fungi (e.g., fungal degradation patterns). This evidence suggests that some of the fossil woods studied were in an advanced stage of decomposition before their fossilization.

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Palabras clave: Formación Río Tarde. Aptiano. Patagonia. Coníferas.

Key words: Río Tarde Formation. Aptian. Patagonia. Conifers.

Introduction

During the Cretaceous, Patagonia extended from 30º to 60º in the Southern Hemisphere and was characterized by warm temperate climate (Smith *et al.*, 1994; Wilford and Brown, 1994; Scotese *et al.*, 1999). High CO_2 pressure inferred from cuticle analyses (Passalia, 2009), the presence of thermophilic plants (e.g., Hirmeriellaceae, Cyatheaceae, and Cycadales), and the accumulation of kaolinite deposits indicative of organic-rich, swampy environments are consistent with the suggested climate (Iglesias *et al.*, 2011). During the Early Cretaceous, the vegetation of southern Patagonia was dominated by conifers and ferns (Del Fueyo *et al.*, 2007). Among conifers, Hirmeriellaceae, Araucariaceae, and Podocarpaceae families formed high and medium canopy forests in continental (e.g., fluvial or lacustrine) and transitional (e.g., estuary or deltaic) sedimentary environments (Del Fueyo *et al.*, 2007; Greppi *et al.*, 2020, 2021). On the edge of rivers, lakes, or flooded areas, bryophytes, equisetaleans, and ferns were most abundant (Del Fueyo *et al.*, 2007). In open areas, smaller plants grew, including Cycads and Benettitals as the most prominent specimens (Del Fueyo *et al.*, 2007). This flora reached its maximum diversity during the middle Cretaceous (Aptian) (Del Fueyo *et al.*, 2007; Benedetto, 2018). This period coincided with the opening of the South Atlantic Ocean, which formed interior seas and contributed to increasing humidity in southern Patagonia (Benedetto, 2018). In these floristic associations, angiosperms show up in the Barremian - Aptian, being subordinate vegetation components, but gradually diversifying and becoming more abundant towards the Albian - Coniacian (Prámparo *et al.*, 2007; Archangelsky *et al.*, 2009). Finally, at the Cretaceous - Cenozoic boundary, angiosperm plant communities were dominant, whereas ferns and gymnosperms were of subordinate importance (Prámparo *et al.*, 2007).

Southern Patagonia contains numerous Cretaceous outcrops with abundant plant fossils that have been studied. These are fundamentally based on palynological associations, as well as on fossil leaf remains (e.g., Del Fueyo *et al.*, 2007; Archangelsky *et al.*, 2009; Prámparo, 2012). In addition, fossil wood assemblages are abundant during this period, although, there have been comparatively fewer floristic studies based on them. Most of these are based on a few specimens of coniferous fossil woods (e.g., Vera and Césari, 2015; Novas *et al.*, 2019; Del Fueyo *et al.*, 2021; Rombola *et al.*, 2022; Vera and Perez Loinaze, 2022). As of today, only a single fossil wood assemblage containing conifers and angiosperms from the Upper Cretaceous has been described, in the Cerro Fortaleza Formation.

The objective of this contribution is to describe a new fossil wood assemblage from continental deposits of the lower member of the Río Tarde Formation (middle Cretaceous) in the Perito Moreno National Park, Santa Cruz Province, Argentina, which is interpreted as a fossil forest based on the abundance, size, and distribution of trunks. Comments are made on the preservation of the collected fossil woods and the significance of the sedimentary environment that contained the studied specimens is interpreted.

Geologic Setting

The study area is located in the northwestern sector of the Austral - Magallanes Basin, near Río Roble Ranch on the southern margin of Burmeister Lake. The Austral - Magallanes Basin lies on the southern margin of the South American plate and is limited by the Southern Patagonian Andes (SPA) to the west, the Deseado Massif to the east, the

Fuegian Andes to the south, extending off - shore in the Argentinean marine platform, all the way to the Malvinas Basin (Biddle *et al.*, 1986; Robbiano *et al.*, 1996; Ghiglione *et al.,* 2016; Aramendía *et al.*, 2018, 2019, 2022).

Main tectonic stages from Austral - Magallanes Basin are closely linked with the development of the Andean orogen and Atlantic Ocean opening (Biddle *et al.,* 1986; Ghiglione *et al.,* 2016; Cuitiño *et al.*, 2019). The sedimentary record includes Jurassic extensional pre - rift (El Bello Formation) to syn - rift deposits (El Quemado Complex). A Lower Cretaceous sag (Springhill, Río Mayer formations) overlies the Jurassic units and finally post - rift and compressive early foreland deposits are present (Río Belgrano Formation and the lower member of the Río Tarde Formation). Development of the SPA exposed extensive Upper Cretaceous volcaniclastic sediments (e.g., upper member of the Río Tarde Formation), which are closely linked to the eastwards migration of the Andean orogen (Russo *et al.*, 1980; Biddle *et al.*, 1986; Giacosa and Franchi, 2001; Escosteguy *et al.*, 2003; Ghiglione *et al.*, 2016; Escosteguy *et al.*, 2017; Aramendía *et al.*, 2018; Cuitiño *et al.*, 2019).

The Río Tarde Formation was defined and divided into two informal members by Ramos (1979). The lower member is composed of reddish - to whitish - colored, clast - supported conglomerates and very coarse - grained, to cobble - grained sandstones. These deposits are interpreted as a high - energy fluvial paleoenvironment with channels dissecting floodplain beds (Aramendía *et al.*, 2018). On the other hand, the upper member of the Río Tarde Formation is composed of varicolored ash to lapilli volcaniclastic rocks. The Río Tarde Formation is a relatively continuous N - S oriented outcrop, lying at the foothills of the SPA (Giacosa and Franchi, 2001; Escosteguy *et al.*, 2003; 2017). In the study zone, this unit crops out near Río Roble Ranch. The fossil woods were found primarily *in situ* in floodplain deposits. Occasionally, some of the fossil specimens were collected from the channel beds.

The age of the Río Tarde Formation was inferred from its stratigraphic relationship with the Kachaike Formation, dated as Aptian by the presence of ammonoids (e.g, Riccardi, 1971). Maximum depositional ages (MDA) in detrital zircon geochronology constrain the lower member of the Río Tarde Formation to between 112 - 118 Ma, suggesting an Aptian - Albian age for the formation (Ghiglione *et al.*, 2015).

The Cenozoic infill of the Austral - Magallanes Basin includes upper Paleocene - lower Eocene continental deposits of the Ligorio Márquez and Río Lista formations, with wood and leaves fossil remains overlying the Mesozoic units (Escosteguy *et al.*, 2003; Encinas *et al.*, 2019). The Eocene in the area includes subvolcanic intrusions and basaltic effusions, mainly represented by the Posadas Basalt (Escosteguy *et al.*, 2003). Sedimentary records from the Neogene synorogenic deposits are represented by the Miocene El Chacay Formation, Río Zeballos Group and Santa Cruz Formation (Hatcher, 1897, 1900; Chiesa and Camacho, 1995; Cuitiño *et al.*, 2012, 2016, 2019; Parras *et al.*, 2012; Aramendía *et al.*, 2019, 2022), which are covered by the Belgrano Basalt (Riggi, 1957). Miocene continental deposits are mainly covered by volcanic plateau effusions (Giacosa and Franchi, 2001; Escosteguy *et al.*, 2003, 2017).

Material and methods

An assemblage of 84 fossil woods was collected from sediments of the Río Tarde Formation in the Perito Moreno National Park, Santa Cruz Province, Argentina (Figure 1 - 2). Stratigraphical and geographical data were collected for all the specimens (Figure 3; Table 1). Most specimens are silicified, but frequently they are partially or more rarely totally carbonized (Table 1). Fossil woods are well - preserved, but some specimens display fungal decay and boring patterns by saproxylic organisms.

The specimens are housed at the paleobotany collection of the Museo Provincial Padre Jesús Molina (MPM PB) in Río Gallegos, Santa Cruz Province, Argentina, with accession numbers 23111 to

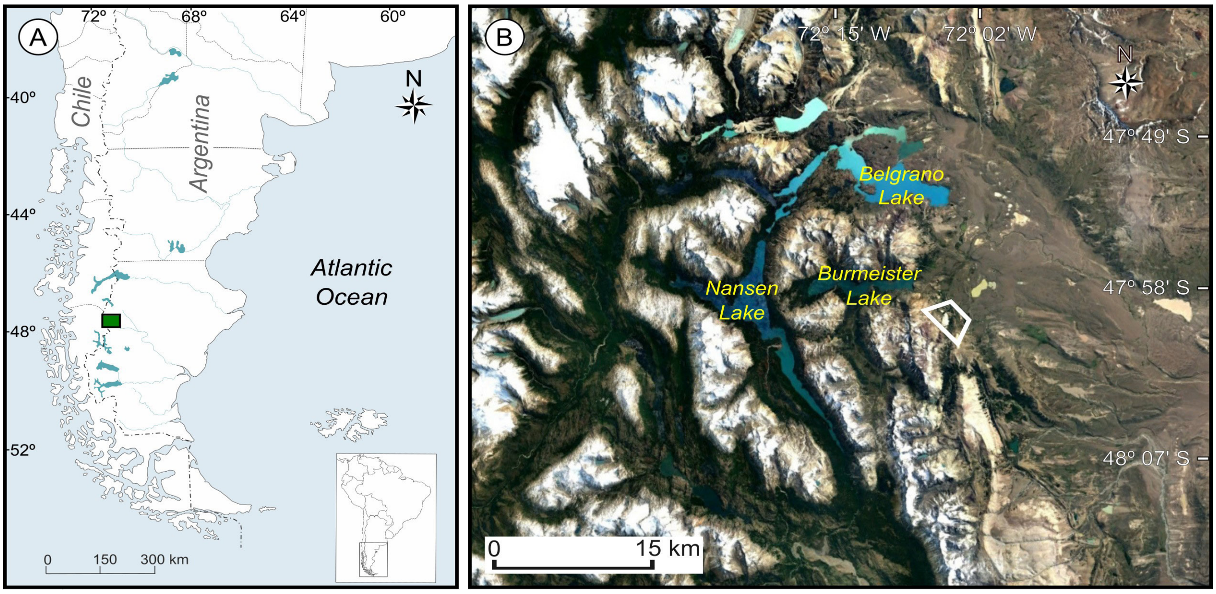

Figure 1. A) Map of Patagonia showing the fossiliferous locality of the Río Tarde Formation (rectangle). **B)** Satellite image (Google, CNES/Airbus) of the south of Perito Moreno National Park, showing the fossiliferous locality (polygon). **/ Figura 1. A)** *Mapa de la Patagonia que muestra la localidad fosilífera de la Formación Río Tarde (rectángulo).* **B)** *Imagen satelital (Google, CNES/Airbus) del sur del Parque Nacional Perito Moreno, mostrando la localidad fosilífera (polígono).*

23194 (Table 1). We prepared thin sections (transverse section - TS) of some specimens following standard techniques (Hass and Rowe, 1999) at the Museo Argentino de Ciencias Naturales (MACN) to observe their preservation. Thin sections were observed using light microscopy (Leica DM2500 and DM500) and the photographs were taken with Leica DFC295 and ICC50HD digital cameras.

The descriptive terminology is based on the recommendations of the IAWA Committee (2004). The analysis of the growth rings includes the presence or absence of growth ring boundaries, the detection of false rings, and all other evidence of climatic disturbance (e.g., frost rings) (Fritts, 1976; Schweingruber, 1988). Finally, to calculate the height of the fossil woods from their diameters we used the formulae of Niklas (1994) and Mosbrugger *et al.* (1994).

Results

Of the total of 84 samples, 35 were found *in situ* in the sedimentary beds (42%) and 49 were collected as float wood (58%) in the field adjacent to the depositional system (Table 1). All specimens *in situ* have a surrounding carbon lens (Figure 4). In some cases, the samples that were not *in situ* were right next to the *in situ* trees and very close to each other, which suggests that they were part of the same parental tree. However, each fragment was considered a separate specimen and given a different collection number. In turn, a few specimens could not be collected *in situ* because they were inaccessible for sampling.

Most of the fossil woods found *in situ* are carbonized - silicified (*ca.* 53% of the specimens), whereas almost all of the samples collected as float wood in the field are silicifications (*ca.* 37% of the specimens). Most of the *in situ* trunks (*ca.* 63%) are arranged parallel to the stratification surface, with a strike of *ca.* 170º and, some of them (*ca.* 37%) have a perpendicular position with respect to the bearing strata (Figure 4). There are 35 fossil woods *in situ* in *ca.* 600 m of the same stratigraphic level (frequency 1 per *ca.* 16 m). This stratigraphic level extends at least 15 km further to the south, but this study was limited to the surroundings of the Río Roble ranch (see Figure 1B). The size of the fossil woods varies significantly. The diameter of the trunks ranges from 0.04 to 0.83 m, with 0.22 m as the average diameter (Table 1). Trunk lengths

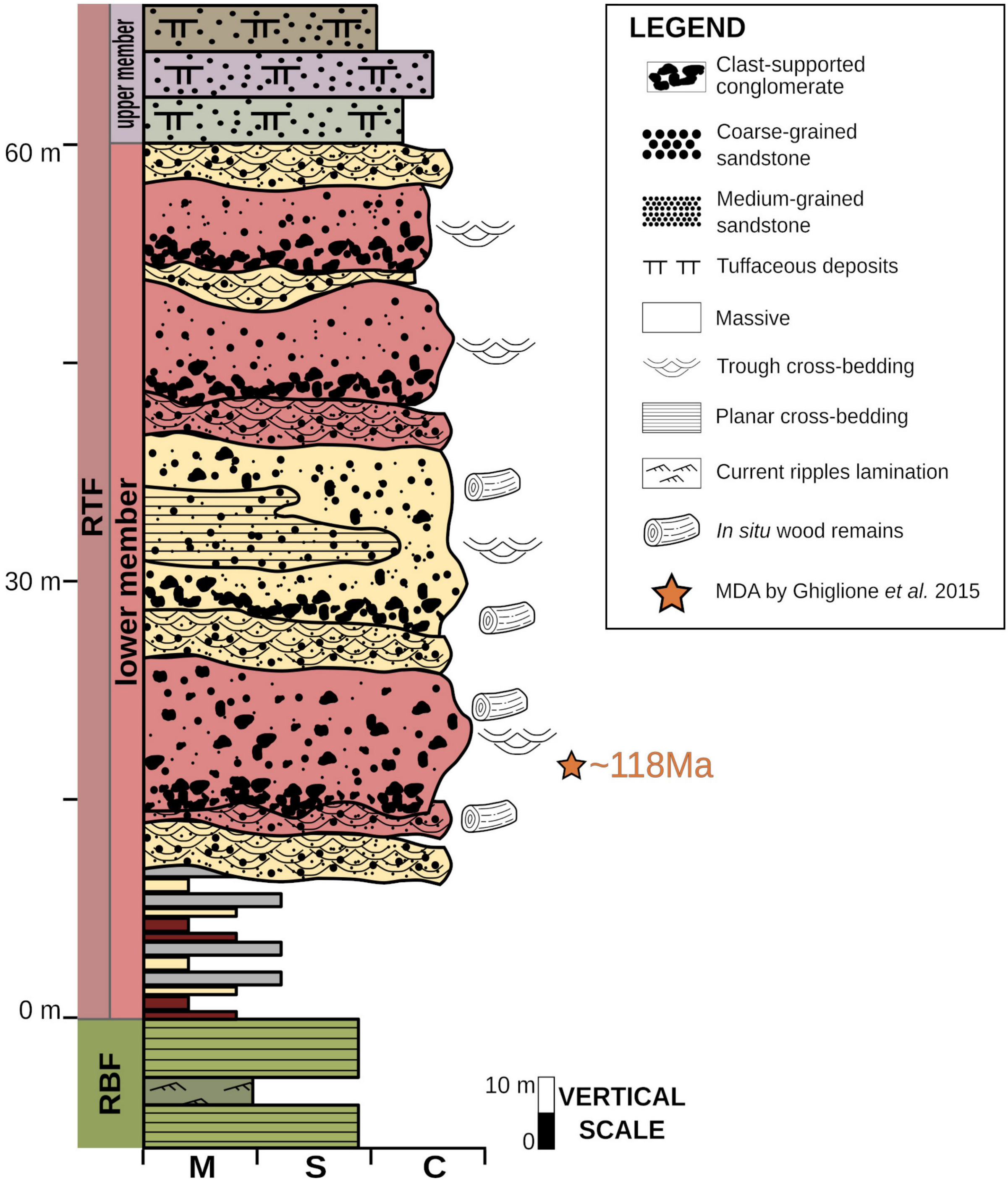

Figure 2. Stratigraphic section of the lower member of the Río Tarde Formation at Río Roble Ranch area. / **Figura 2.** *Sección estratigráfica del miembro inferior de la Formación Río Tarde en el área de la Estancia Río Roble.*

are highly variable and were difficult to measure because many were covered by the stratification surface.

Based on their anatomical characteristics the specimens can be classified as conifers. In general, fossil woods are well - preserved. In cross-section the trunks have roundish to polygonal cells and distinct growth ring boundaries, latewood with 1 - 6 rows of tracheids with reduced radial diameter (Figure 5). Transition from early- to latewood is abrupt. Clearly identified growth rings have a width of *ca.* 0.70 - 2.80 mm. Some specimens have false growth rings (Figure 5). In some specimens, the presence of borings of different shapes and sizes containing coprolites of saproxylic organisms, as well as fungal degradation patterns are observed (Figure 5). Based on the diameter of the fossil woods, we can infer that the woods were part of trees of *ca.* 3 - 36 m of height (Table 1, Figure 6).

The Río Tarde Formation in the Perito Moreno National Park has an ample distribution and is characterized by coarse material that varies between red coarse-grained sandstones and conglomerates that form a vertical succession of 40 m. The conglomerates occur in strata of up to 2 m thick, with cross-bedding stratification, having frequent sandy lenses arranged as channel infilling. They present clasts of up to 0.10 m in diameter, composed of quartz, as well as metamorphites and volcanites, immersed in a sandy matrix with calcareous and ferruginous cement. In this area, the Río Tarde Formation has a transitional passage at its base with the Río Belgrano Formation. Towards the top, the study unit maintains an erosive contact with the tuffaceous deposits of the Kachaike Formation.

Discussion

The sedimentological characteristics of the study area are similar to previous descriptions of the Río Tarde Formation at the homonymous canyon (Ramos, 1979). The conglomerate and sandstone, wood-bearing deposits are characterized by trough to planar cross-bedding, typically formed in a high - energy fluvial paleoenvironment. The fossil woods were found as inclusions within the floodplain strata. However, the presence of large trunks, such as the specimen MPM PB 23171, with a length of at least 14 m and a diameter of *ca.* 0.80 m, suggests that the specimens were locally deposited. It is also likely that the studied association represents a parautochtonous assemblage of a forest that did not necessarily developed in the study area.

Most of the *in situ* fossil woods (*ca.* 63%) have an orientation parallel to the stratification surface with an approximately north - south orientation, while a smaller percentage (*ca.* 37%) are arranged perpendicularly with an east - west orientation. An important factor

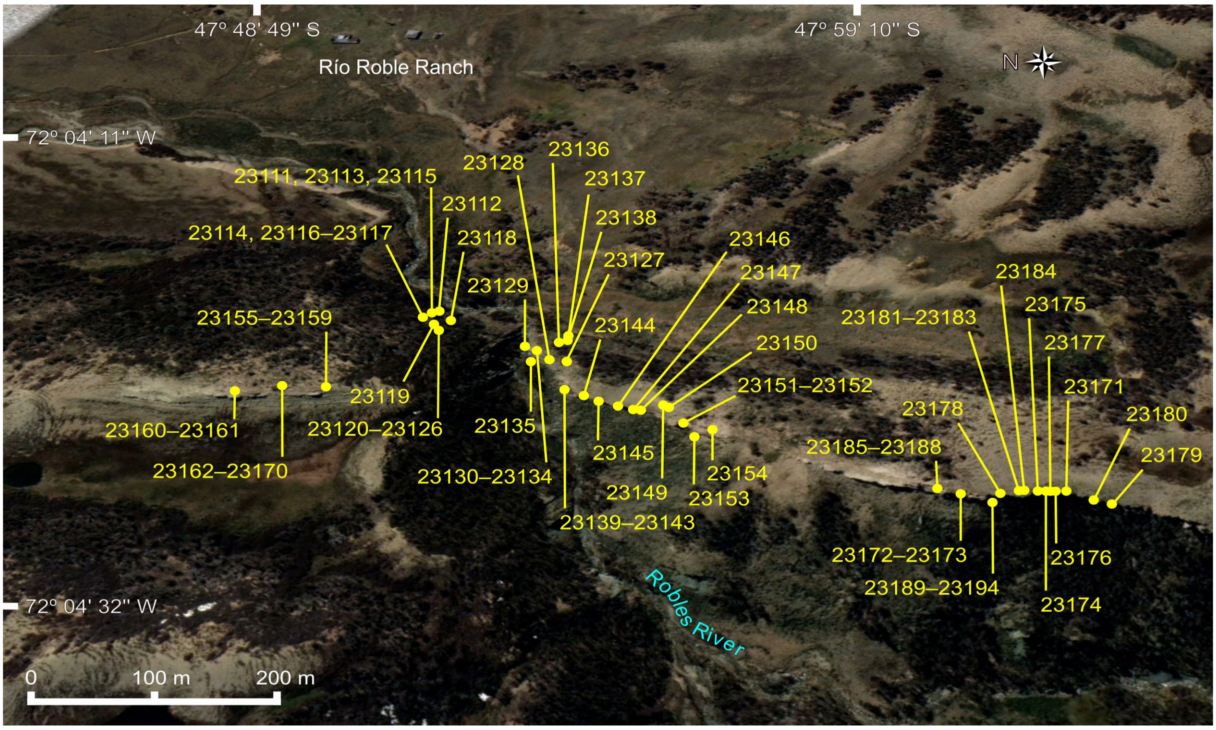

Figure 3. Satellite image (Google, CNES/Airbus) showing the specimens locations in the Perito Moreno National Park. The image is tilted and the scale varies across it. / **Figura 3.** *Imagen satelital (Google, CNES/Airbus) que muestra los lugares de muestreo de los ejemplares en el Parque Nacional Perito Moreno. La imagen está inclinada y la escala varía en la misma.*

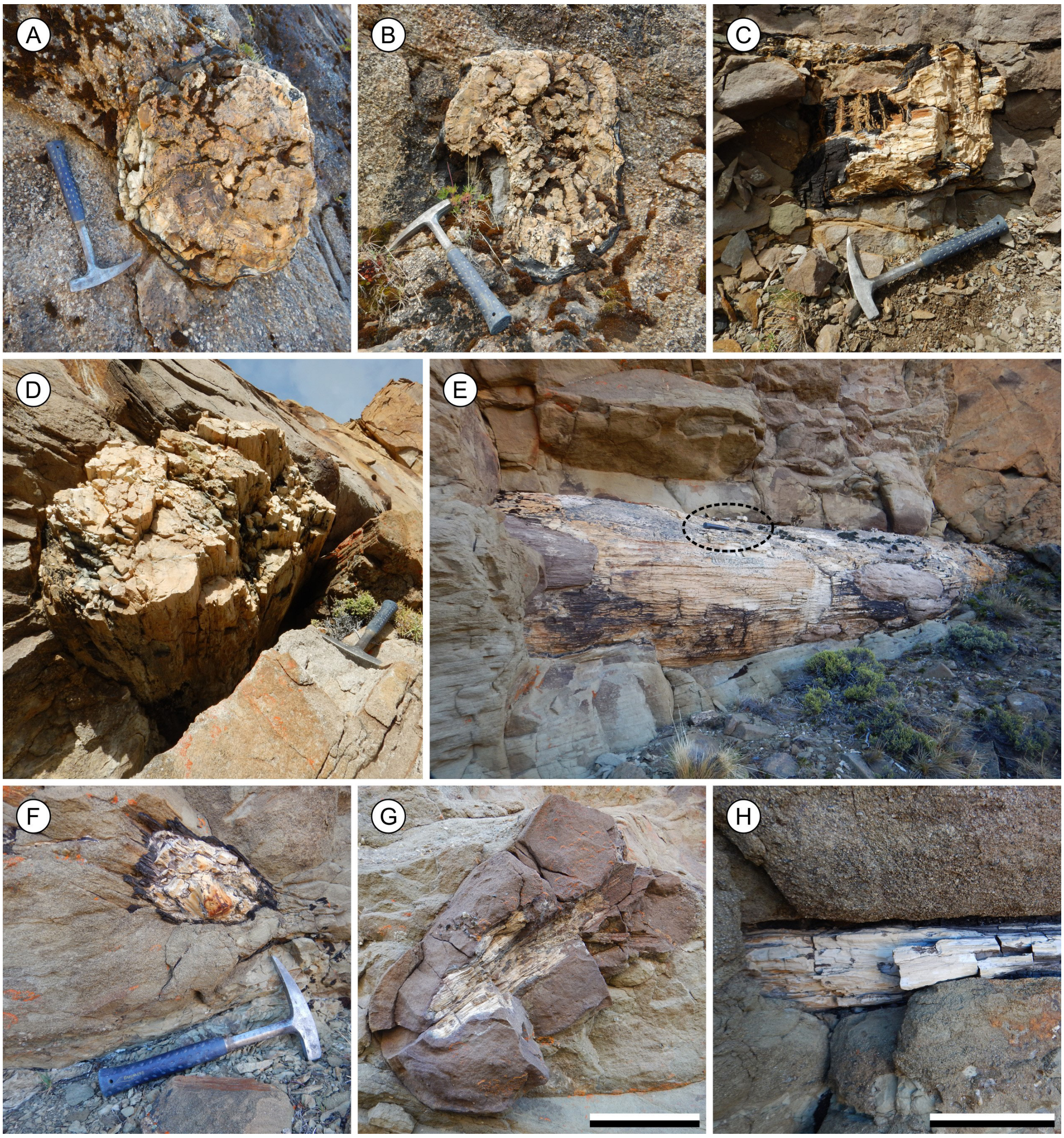

Figure 4. Some *in situ* fossil woods samples of the lower member of the Río Tarde Formation at the Perito Moreno National Park. A. MPM PB 23111. B. MPM PB 23118. C. MPM PB 23135. D. MPM PB 23154. E. MPM PB 23171. F. MPM PB 23176. G. MPM PB 23177. H. MPM PM 23180. Scale hummer: 32 cm. Scale bars equals 32 cm (G), 10 cm (H). / **Figura 4.** *Algunas maderas fósiles* in situ *del miembro inferior de la Formación Río Tarde en el Parque Nacional Perito Moreno. A. MPM PB 23111. B. MPM PB 23118. C. MPM PB 23135. D. MPM PB 23154. E. MPM PB 23171. F. MPM PB 23176. G. MPM PB 23177. H. MPM PM 23180. Escala piqueta: 32 cm. Las barras equivalen a 32 cm (G), 10 cm (H).*

that controls the orientation of the specimens with respect to the interpreted flowing current direction is shape eccentricity (Macdonald and Jefferson, 1985). Specimens that present asymmetric shapes tend to be oriented parallel to the currents, whereas woods with rather symmetrical shapes are more commonly oriented transversely (Macdonald and Jefferson, 1985). However, factors such as mutual interference among wood fragments, bedforms, and current magnitude also play a major role in their orientation in the bearing strata (Macdonald and Jefferson, 1985).

The thin sections indicate that the fossil woods studied from the Río Tarde Formation have distinct growth ring boundaries and overall anatomical features consistent with conifers. Growth rings are of the type D of Creber and Chaloner (1984), with an abrupt transition from earlywood to latewood. In conifers, such as extant Araucariaceae, the earlywood/latewood ratio is not significantly affected by environmental factors (Creber and Chaloner, 1984; Brison *et al.*, 2001). The study of growth rings in these taxa would not reflect climatic conditions and should not be used in growth ring analyses that go further than suggesting seasonality (Creber and Chaloner, 1984; Brison *et al.*, 2001). The presence of distinct growth ring boundaries indicates seasonality, whereas their absence indicates lack of it (Creber, 1977; Brison *et al.*, 2001; Pujana *et al.*, 2007, 2020). The fossil woods recovered from the Perito Moreno National Park have distinct growth ring boundaries, suggesting seasonality. False rings are a non - periodic, sporadic occurrence of more or less distinct ring boundaries (IAWA Committee, 2004). This type of ring was observed in some specimens (Figure 5A - B). They could be the result of traumatic biological events or they could have been triggered by adverse weather conditions during the life of the parental trees.

No evidence of the causes of dead of the studied parental trees was observed (e.g., fire marks or frost rings). However, a possible cause of death of these specimens could be due to volcanism that occurred in the study area (where volcanic levels have been identified), which could cause these specimens to fall.

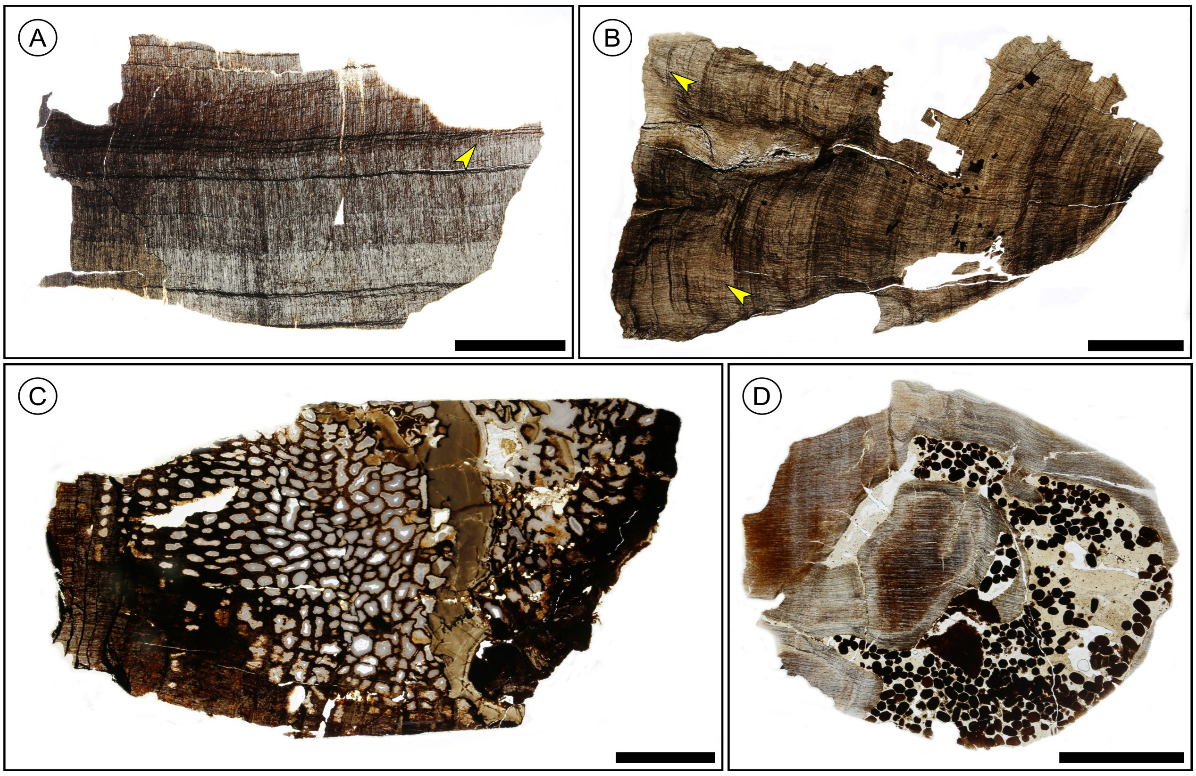

Figure 5. Transverse sections of some fossil woods recollected in the Perito Moreno National Park. **A.** MPM PB 23171, showing growth and false rings (arrowhead). **B.** MPM PB 23177, showing growth and false rings (arrowheads). **C.** MPM PB 23117, showing fungal rot pattern. **D.** MPM PB 23167, showing arthropod biodeterioration. Scale bars: 2 cm. / **Figura 5.** *Cortes transversales de algunas maderas fósiles recolectadas en el Parque Nacional Perito Moreno.* **A.** *MPM PB 23171, mostrando anillos de crecimiento y falsos anillos (flecha).* **B.** *MPM PB 23177, mostrando anillos de crecimiento y falsos anillos (flechas).* **C.** *MPM PB 23117, mostrando un patrón de pudrición fúngica.* **D.** *MPM PB 23167, mostrando biodeterioro de artrópodos. Escalas: 2 cm.*

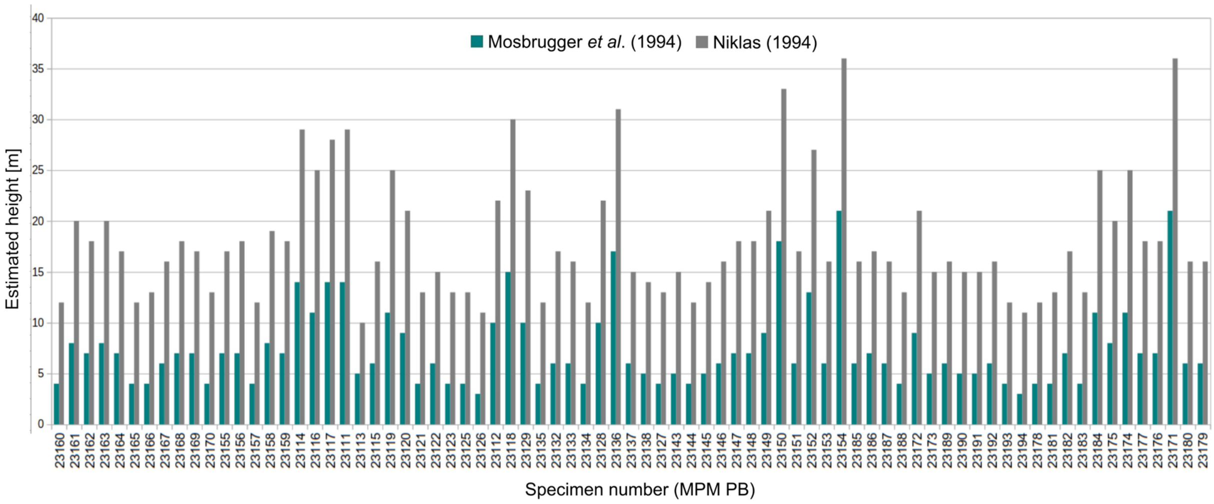

Figure 6. Histogram showing the estimated height of the parental trees. Specimens are ordered from north to south (see Figure 3). / **Figura 6.** *Histograma mostrando la altura estimada de los árboles parentales. Los especímenes están ordenados de norte a sur (ver Figura 3).*

Another possibility could be that the specimens have been incorporated into the rivers during catastrophic events, such as torrential rains or periods of overflowing.

About 43% of the fossil woods studied from the Río Tarde Formation show external evidence of biodeterioration. This includes patterns of fungal decomposition comparable to white rot caused by extant wood decomposing fungi (Figure 5C). Additionally, galleries filled with coprolites with hexagonal to subcircular cross - sections, similar to those of modern termites were also observed (Figure 5D). This evidence suggests that some of the specimens from the Río Tarde Formation were heavily affected by different organisms in the forest and, as a result, in an advanced state of decomposition before their fossilization.

Based on the width of the rings and the diameter of the trunks, the age of the biggest specimen found (MPM PB 23154) was estimated at *ca.* 170 years. In modern temperate forests, some conifers can achieve great longevity (Coomes and Bellinghaam, 2011). Estimated age, size, and height of the studied fossil woods suggests that the specimens were mature trees (Niklas, 1994; Mosbrugger *et al.*, 1994). However, Mosbrugger (1990) considers that a critical diameter of less than 8 cm should not be considered since these could correspond to that of lateral branches. In this study, we consider trees of all sizes. Apparently, some of the taller trees appear to be grouped in three or four areas (Figure 6), which probably reflects variable sedimentary inputs.

Other fossil forests from Patagonia (large accumulations of fossil woods of more than 20 specimens) have been described in some locations. Older than the Cretaceous is the well - known La Matilde Formation (Middle Jurassic) fossil forest in the Santa Cruz Province, Argentina, which is a protected area (*Bosques Petrificados de Jaramillo National Park*). In that area, more than 200 silicified trees have been identified both, in life positions and as fallen trunks, with a diameter of up to 3.40 m (Cúneo and Panza, 2008). The preservation of the specimens is regular, and up to date paleoxylological studies reveal that the fossil forest of the La Matilde Formation was dominated by conifers (Gothan, 1925; Wieland, 1935; Mansfeld, 1948; Calder, 1953; Selmeier, 1992; Zamuner and Falaschi, 2005; Gnaedinger 2007a, b; Kloster and Gnaedinger, 2018).

From the Lower Cretaceous of southern Patagonia, an assemblage of 21 silicified fossil woods dominated by conifers has been documented in the Kachaike Formation (Albian), collected in the Tucu Tucu Ranch (Greppi *et al.*, 2023). In the Upper Cretaceous Varela *et al.* (2016) reported the presence of a fossil forest exclusively of conifers (more than 45 permineralized trunks with diameters of up to 1.2 m, an age range of 140 - 337, and a height range of 15.6 - 30.0 m) from the Cenomanian Mata Amarilla Formation (Varela *et al.*, 2016). Egerton *et al.* (2016) described an association of 20 permineralized fossil woods from the Cerro Fortaleza Formation (Campanian) recovered on the western flank of Cerro Fortaleza. In this area, the samples reach 0.50 m in diameter with a length of up to 2.50 m (Egerton *et al.*, 2016). Conifers dominate the assemblage with a 75:25 ratio with respect to the angiosperms (Egerton *et al.*, 2016). From the Lower Cretaceous of central Patagonia, Greppi *et al.* (2020) studied a collection of 23 silicified fossil woods of conifers, generally well - preserved, collected in the Tres Lagunas Formation (late Valanginian), in the Tres Lagunas Locality (Greppi *et al.*, 2020). From the Upper Cretaceous Puntudo Chico Formation (Campanian - Maastrichtian) at the El Quiosco and Estancia María de las Nieves localities, Vera *et al.* (2019, 2020) described 21 silicified fossil woods dominated by conifers with a few angiosperms (Vera *et al.*, 2019, 2020). Recently, Passalia *et al.* (2023) documented a fossil forest dominated by conifers from the Allen Formation (middle - upper Campanian - lower Maastrichtian) from Valcheta town in northern Patagonia. In this area, the fossil woods have a mean length of 5.40 m (0.9 - 23.02 m), a mean diameter of 0.58 m (0.21 - 1.62 m), and an estimated age of 125 - 514 years.

From the Paleocene, Petriella (1972) reported more than 30 silicified fossil woods recovered from the Cerro Bororó Formation near the Las Plumas Locality, Chubut Province, with lengths of up to 10 m and diameters of 0.60 m, most of which are conifers, along with a few angiosperms. Pujana and Ruiz (2019) described 81 fossil woods from the Río Turbio Formation (Eocene - Oligocene) in the Río Turbio Locality. Of the total number of fossil woods, conifers represent 71% of the fossil wood association (Pujana and Ruiz, 2019). Brea *et al.* (2015) carried out a three - dimensional reconstruction of an *in situ* fossil forest recovered from the Rancahué Formation (Upper Oligocene) located to the west of the Aluminé town, Neuquén Province; the specimens are exclusively angiosperms. Three - dimensional reconstruction of this fossil wood assemblage revealed a mean estimated tree height of 15.22 m, and a mean estimated tree age of 223 years (31 - 700 years). Finally, Pujana (2008, 2009a, b) studied a large assemblage of 173 silicified fossil woods from various localities of the Río Leona Formation (Upper Oligocene - Lower Miocene) dominated by angiosperms. The samples have an estimated minimum diameter between 0.30 - 0.60 m (Pujana, 2008, 2009a, b). The importance of studying large assemblages of fossil woods relies mainly on the discovery of new taxa. The characterization of the canopy composition, and the study of the anatomical variation of the samples, which is a measure of the plant paleodiversity. In addition, the gradually increasing number of fossil wood studies in Argentina is steadily facilitating a deeper understanding of Patagonian paleofloras (Pujana, 2022).

Fossil forests in Patagonia are not rare and some of them are tourist attractions, such as the Jurassic *Bosques Petrificados de Jaramillo National Park* in Santa Cruz Province or the Paleocene fossil forest in Sarmiento (a Provincial Park), Chubut Province. The fossil forest described herein from the Río Tarde Formation in the Perito Moreno National Park is in line with recent governmental efforts intended to promote the numerous tourist attractions in this area of Patagonia. By describing the first known fossil forest of unique location and composition characteristics within this national park it is hoped that the tourist offer should be greatly invigorated.

Conclusions

An assemblage of 84 fossil woods recovered from the Río Tarde Formation, in the Perito Moreno National Park, Santa Cruz Province, Argentine Patagonia, is introduced. This is dominated by gymnosperms and no angiosperms were recorded. This is consistent with other studies based on a large accumulation of fossil woods in southern Patagonia, where the forests were dominated by conifers. The specimens have distinct growth ring boundaries, which suggest annual seasonality for the region during the deposition of the unit. In some specimens, the presence of false growth rings could be the result of traumatic biological events or triggered by adverse weather conditions during the life of parental trees. Additionally, about half of the woods show some external evidence of biodeterioration. The presence of large trunks (e.g., 0.80 m in diameter and a length of at least 14 m) suggests that the samples were deposited as parautochthonous accumulations of a nearby forest.

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Apéndice

	Sample (MPM PB)	Sample position in the field	Diameter [cm]	Estimated height [m]	Position/GPS	Observations
1	23111	*In situ*	46 (a)	14/29	47º 59' 3.7'' S 75º 4' 16.3'' W	Carbonized silicification
2	23112	*In situ*	25 (b)	10/22	47º 59' 3.7'' S 72º 4' 16.2'' W	Carbonized silicification
3	23113	*In situ*	4 (b)	5/10	47º 59' 3.7'' S 72º 4' 16.3'' W (f)	Carbonized
4	23114	*In situ*	46 (a)	14/29	47º 59' 3.7'' S 72º 4' 16.4'' W	Carbonized silicification
5	23115	*In situ*	11 (b)	6/16	47º 59' 3.7'' S 72º 4' 16.3'' W	Carbonized silicification
6	23116	*In situ*	33 (b)	11/25	47º 59' 3.7'' S 72º 4' 16,4'' W	Carbonized silicification
7	23117	*In situ*	44 (a)	14/28	47º 59' 3.7'' S 72º 4' 16.4'' W	Carbonized silicification. Fungal rot pattern
8	23118	*In situ*	51 (a)	15/30	47º 59' 4.1''S 72º 4' 16.4'' W	Carbonized silicification
9	23119	*In situ*	33 (a)	11/25	47º 59' 3.4'' S 72º 4' 16.4'' W (f)	Carbonized silicification
10	23120	Float wood	22 (b)	9/21	47º 59' 4'' S 72º 4' 17.2'' W (g)	Carbonized silicification
11	23121	Float wood	8 (c)	4/13	47º 59' 4'' S 72º 4' 17.2'' W (g)	Carbonized silicification
12	23122	Float wood	11 (c)	6/15	47º 59' 4'' S 72º 4' 17.2'' W (g)	Carbonized silicification
13	23123	Float wood	8 (c)	4/13	47º 59' 4'' S 72º 4' 17.2'' W (g)	Carbonized silicification
14	23124	Float wood	- (c)	-	47º 59' 4'' S 72º 4' 17.2'' W (g)	Carbonized silicification
15	23125	Float wood	8 (c)	4/13	47º 59' 4'' S 72º 4' 17.2'' W (g)	Carbonized silicification
16	23126	Float wood	5 (c)	3/11	47º 59' 4'' S 72º 4' 17.2'' W (g)	Carbonized silicification
17	23127	*In situ*	7 (b)	4/13	47º 59' 5.7'' S 72º 4' 17.4'' W (f)	Carbonization
18	23128	*In situ*	25 (a)	10/22	47º 59' 5.3'' S 72º 4' 17.5'' W	Carbonization
19	23129	Float wood	28 (b)	10/23	47º 59' 4.5'' S 72º 4' 17'' W (g)	Carbonized silicification
20	23130	Float wood	- (b)	-	47º 59' 4.7'' S 72º 4' 17'' W (g)	Carbonization. Arthropod biodeterioration
21	23131	Float wood	- (d)	-	47º 59' 4.7'' S 72º 4' 17'' W (g)	Carbonization
22	23132	Float wood	13 (d)	6/17	47º 59' 4.7'' S 72º 4' 17'' W (g)	Carbonized silicification
23	23133	Float wood	12 (d)	6/16	47º 59' 4.7'' S 72º 4' 17'' W (g)	Carbonized silicification
24	23134	Float wood	6 (d)	4/12	47º 59' 4.7'' S 72º 4' 17'' W (g)	Carbonized silicification
25	23135	*In situ*	30 (b)	11/24	47º 59' 4.8'' S 72º 4' 17.5'' W	Carbonized silicification
26	23136	*In situ*	58 (a)	17/31	47º 59' 5.4'' S 72º 4' 16.4'' W (f)	Carbonized silicification
27	23137	*In situ*	11 (b)	6/15	47º 59' 5.5'' S 72 º4' 16.3'' W (f)	Carbonized silicification. Fungal rot pattern. Arthropod biodeterioration
28	23138	*In situ*	9 (b)	5/14	47º 59' 5.5'' S 72º 4' 16.2'' W (f)	Carbonized silicification. Arthropod biodeterioration
29	23139	Float wood	-	-	47º 59' 5.9'' S 72º 4' 18.5'' W (g)	Carbonization
30	23140	Float wood	- (e)	-	47º 59' 5.9'' S 72º 4' 18.5'' W (g)	Carbonization
31	23141	Float wood	- (e)	-	47º 59' 5.9'' S 72º 4' 18.5'' W (g)	Carbonization
32	23142	Float wood	- (e)	-	47º 59' 5.9'' S 72º 4' 18.5'' W (g)	Carbonization

33	23143	Float wood	10 (e)	5/15	47º 59’ 5.9’’ S 72º 4’ 18.5’’ W (g)	Carbonized silicification
34	23144	*In situ*	6 (b)	4/12	47º 59’ 7.0’’ S 72º 4’ 19.7’’ W (f)	Carbonized silicification
35	23145	*In situ*	9 (b)	5/14	47º 59’ 7.3’’ S 72º 4’ 18.7’’ W (f)	Carbonized silicification. Arthropod biodeterioration
36	23146	Float wood	12 (b)	6/16	47º 59’ 7.6’’ S 72º 4’ 19.2’’ W (g)	Silicification. Arthropod biodeterioration
37	23147	*In situ*	15 (b)	7/18	47º 59’ 8’’ S 72º 4’ 19.8’’ W	Carbonized silicification. Arthropod biodeterioration
38	23148	Float wood	15 (b)	7/18	47º 59’ 8’’ S 72º 4’ 19.5’’ W	Carbonized silicification. Arthropod biodeterioration
39	23149	*In situ*	23 (b)	9/21	47º 59’ 8.7’’ S 72º 4’ 18.9’’ W	Carbonized silicification. Arthropod biodeterioration
40	23150	*In situ*	65 (a)	18/33	47º 59’ 9.0’’ S 72º 4’ 19.1’’ W (f)	Carbonized silicification. Fungal rot pattern
41	23151	*In situ*	13 (b)	6/17	47º 59’ 9.4’’ S 72º 4’ 19.5’’ W	Carbonized silicification
42	23152	*In situ*	41 (a)	13/27	47º 59’ 9.4’’ S 72º 4’ 20.2’’ W	Carbonized silicification
43	23153	*In situ*	12 (b)	6/16	47º 59’ 9.5’’ S 72º 4’ 19.8’’ W	Carbonized silicification
44	23154	*In situ*	83 (a)	21/36	47º 59’ 9.7’’ S 72º 4’ 19.7’’ W	Carbonized silicification. Fungal rot pattern. Arthropod biodeterioration
45	23155	Float wood	14 (b)	7/17	47º 59’ 0.8’’ S 72º 4’ 22.1’’ W (g)	Silicification. Arthropod biodeterioration
46	23156	Float wood	16 (b)	7/18	47º 59’ 0.8’’ S 72º 4’ 22.1’’ W (g)	Silicification. Arthropod biodeterioration
47	23157	Float wood	6 (b)	4/12	47º 59’ 0.8’’ S 72º 4’ 22.1’’ W (g)	Silicification. Arthropod biodeterioration
48	23158	Float wood	18 (b)	8/19	47º 59’ 0.8’’ S 72º 4’ 22.1’’ W (g)	Silicification. Arthropod biodeterioration
49	23159	Float wood	16 (b)	7/18	47º 59’ 0.8’’ S 72º 4’ 22.1’’ W (g)	Silicification. Arthropod biodeterioration
50	23160	Float wood	6 (b)	4/12	47º 58’ 59.0’’ S 72º 4’ 23.4’’ W (g)	Silicification. Arthropod biodeterioration
51	23161	Float wood	20 (b)	8/20	47º 58’ 59.0’’ S 72º 4’ 23.4’’ W (g)	Silicification. Arthropod biodeterioration
52	23162	Float wood	16 (b)	7/18	47º 58’ 60.0’’ S 72º 4’ 22.6’’ W (g)	Silicification. Arthropod biodeterioration
53	23163	Float wood	20 (b)	8/20	47º 58’ 60.0’’ S 72º 4’ 22.6’’ W (g)	Silicification. Arthropod biodeterioration
54	23164	Float wood	14 (b)	7/17	47º 58’ 60.0’’ S 72º 4’ 22.6’’ W (g)	Silicification. Arthropod biodeterioration
55	23165	Float wood	6 (b)	4/12	47º 58’ 60.0’’ S 72º 4’ 22.6’’ W (g)	Silicification. Arthropod biodeterioration
56	23166	Float wood	8 (b)	4/13	47º 58’ 60.0’’ S 72º 4’ 22.6’’ W (g)	Silicification. Arthropod

56	23166	Float wood	8 (b)	4/13	47º 58’ 60.0” S 72º 4’ 22.6” W (g)	Silicification. Arthropod biodeterioration
57	23167	Float wood	11 (b)	6/16	47º 58’ 60.0” S 72º 4’ 22.6” W (g)	Silicification. Arthropod biodeterioration
58	23168	Float wood	16 (b)	7/18	47º 58’ 60.0” S 72º 4’ 22.6” W (g)	Silicification. Arthropod biodeterioration
59	23169	Float wood	14 (b)	7/17	47º 58’ 60.0” S 72º 4’ 22.6” W (g)	Silicification. Arthropod biodeterioration
60	23170	Float wood	8 (b)	4/13	47º 58’ 60.0” S 72º 4’ 22.6” W (g)	Silicification. Arthropod biodeterioration
61	23171	*In situ*	80 (b)	21/36	47º 59’ 18” S 72º 4’ 19.1” W	Carbonized silicification
62	23172	Float wood	22 (b)	9/21	47º 59’ 16” S 72º 4’ 20.2” W (g)	Silicification
63	23173	Float wood	10 (b)	5/15	47º 59’ 16” S 72º 4’ 20.2” W (g)	Silicification
64	23174	*In situ*	33 (b)	11/25	47° 59' 17.60" S 72° 4' 19.33" W (f)	Carbonized silicification
65	23175	*In situ*	19 (a)	8/20	47° 59' 17.53" S 72° 4' 19.35" W (f)	Carbonized silicification
66	23176	*In situ*	16 (b)	7/18	47° 59' 17.82" S 72° 4' 19.32" W (f)	Carbonized silicification
67	23177	*In situ*	15 (b)	7/18	47° 59' 17.68" S 72° 4' 19.39" W (f)	Carbonized silicification. Preserved in a concretion
68	23178	*In situ*	6 (b)	4/12	47° 59' 16.82" S 72° 4' 19.76" W (f)	Carbonized silicification
69	23179	*In situ*	12 (b)	6/16	47° 59' 19.03" S 72° 4' 19.16" W (f)	Carbonized silicification
70	23180	*In situ*	11 (b)	6/16	47° 59' 18.74" S 72° 4' 19.18" W (f)	Carbonized silicification
71	23181	*In situ*	7 (b)	4/13	47° 59' 17.16" S 72° 4' 19.60" W (f)	Silicification
72	23182	*In situ*	14 (b)	7/17	47° 59' 17.16" S 72° 4' 19.60" W (f)	Silicification
73	23183	Float wood	8 (b)	4/13	47° 59' 17.16" S 72° 4' 19.60" W (g)	Silicification
74	23184	*In situ*	35 (b)	11/25	47° 59' 17.38" S 72° 4' 19.48" W (f)	Carbonized silicification
75	23185	Float wood	12 (b)	6/16	47° 59' 15.48" S 72° 4' 20.22" W (g)	Silicification. Arthropod biodeterioration
76	23186	Float wood	14 (b)	7/17	47° 59' 15.48" S 72° 4' 20.22" W (g)	Silicification. Arthropod biodeterioration
77	23187	Float wood	12 (b)	6/16	47° 59' 15.48" S 72° 4' 20.22" W (g)	Silicification
78	23188	Float wood	8 (b)	4/13	47° 59' 15.48" S 72° 4' 20.22" W (g)	Silicification. Arthropod biodeterioration
79	23189	Float wood	12 (b)	6/16	47° 59' 16.80" S 72° 4' 19.92" W (g)	Silicification. Arthropod biodeterioration
80	23190	Float wood	10 (b)	5/15	47° 59' 16.80" S 72° 4' 19.92" W (g)	Silicification. Arthropod biodeterioration
81	23191	Float wood	10 (b)	5/15	47° 59' 16.80" S 72° 4' 19.92" W (g)	Silicification. Arthropod biodeterioration
82	23192	Float wood	12 (b)	6/16	47° 59' 16.80" S 72° 4' 19.92" W (g)	Silicification. Arthropod biodeterioration
83	23193	Float wood	6 (b)	4/12	47° 59' 16.80" S 72° 4' 19.92" W (g)	Silicification. Arthropod biodeterioration
84	23194	Float wood	5 (b)	3/11	47° 59' 16.80" S 72° 4' 19.92" W (g)	Silicification. Arthropod biodeterioration

Table 1. Geographical coordinates of the fossil wood locations. In the column of estimated height, the first value was obtained from the Mosbrugger *et al.* (1994) formula, while the second value was obtained from the Niklas (1994) formula. Abbreviations: **(a)** diameter measured directly from the field or field photo (trunk with the center); **(b)** diameter measured directly from the field or field photo; **(c)** probably same parental tree as MPM PB 23120; **(d)** probably same parental tree as MPM PB 23130; **(e)** probably same parental tree as MPM PB 23139; **(f)** *in situ* samples, GPS point approximate; **(g)** float samples, GPS point approximate. **Tabla1.** *Coordenadas geográficas de las ubicaciones de las maderas fósiles. En la columna altura estimada, el primer valor fue obtenido de la fórmula de Mosbrugger et al. (1994), mientras que el segundo valor fue obtenido de la fórmula de Niklas (1994). Abreviaturas:* **(a)** *diámetro medido directamente del campo o foto de campo (tronco con el centro);* **(b)** *diámetro medido directamente del campo o foto de campo;* **(c)** *probablemente el mismo árbol parental que MPM PB 23120;* **(d)** *probablemente el mismo árbol parental que MPM PB 23130;* **(e)** *probablemente el mismo árbol parental que MPM PB 23139;* **(f)** *muestras* in situ *puntos aproximados de GPS;* **(g)** *muestras rodadas, punto GPS aproximado.*