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A new palm trunk from the Upper Cretaceous of Argentina

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Abstract. A new morphospecies of palm trunk, *Palmoxylon pichaihuensis* sp. nov., is proposed on the basis of several specimens recovered from a succession of tuffs and breccias at Pichaihue, Neuquén Province, Argentina. The specimens comprise atactosteles that display densely crowded fibrovascular bundles in the peripheral zone, and less congested fibrovascular bundles, randomly scattered or arranged in irregular circles in the central zone; sclerenchyma reniform; xylem with 1-4 large metaxylem vessels and 6-12 smaller protoxylem elements in the central zone, and an f/v ratio of 1.3-2:1. The Pichaihue fossil assemblage is similar to, and probably coeval with the flora of Bajo de Santa Rosa, Río Negro Province, reflecting a warm and relatively humid climate, at ca. 40- 45º S, in southern South America during the Late Cretaceous.

Resumen. UN NUEVO ESTÍPITE DE PALMERA DEL CRETÁCICO SUPERIOR DE ARGENTINA. Se propone una nueva morfoespecie de estípite de palmera, *Palmoxylon pichaihuensis* sp. nov., en base a varios especímenes recuperados del Cretácico Superior de Pichaihue, provincia del Neuquén, Argentina. Los especímenes incluyen atactostelas que muestran abundantes haces fibrovasculares en la zona perisférica, en tanto que en la zona central los mismos se encuentran en menor densidad y están dispuestos al azar o constituyendo círculos irregulares; esclerénquima reniforme; xilema de 1-4 vasos grandes y 6-12 elementos protoxilemáticos en la zona central, y una relación f/v de 1.3-2:1. La tafoflora de Pichaihue es similar, y probablemente coetánea, con la flora fósil del Bajo de Santa Rosa, provincia de Río Negro, reflejando un clima cálido y relativamente húmedo durante el Cretácico Tardío en América del Sur meridional a los 40-45º lat. S.

Key words. Palm. Upper Cretaceous. Argentina.

Palabras clave. Palmera. Cretácico Superior. Argentina.

Introduction

The Neuquén basin extends from 35-39º S to 69-70º W along the eastern foothills of the Andes in west-central Argentina. It comprises a succession of marine and continental sedimentary rocks, more than 6000 m thick, ranging in age from the Late Triassic to the Palaeogene (Howell *et al*., 2005). The Lower Cretaceous beds are represented by the Mendoza Group (that is mainly marine) and the Rayoso Group, which represent the end of the marine transgressions into the basin from the Pacific. The Upper Cretaceous comprises: (1) the continental beds of the Neuquén Group, which are rich in dinosaur remains, (2) the continental, volcaniclastic and marine beds of the Malargüe Group to the south of the basin, and (3) mostly volcanic beds of the Colipilli Group to the north. The Malargue Group includes a cycle of marine deposition, thought to be related to the opening of the Atlantic (Barrio, 1990). The Tertiary beds are characterized by the presence of volcanic rocks formed in connection with the Andes uplift.

The silicified plant material was recovered from the Upper Cretaceous-Palaeogene Colipilli Group (Zamora Valcarce *et al*., 2005, 2006) at Pichaihue, which is located ca. 55 km southwest of Chos Malal, near the village of Colipilli (figure 1). The Colipilli Group comprises volcanic breccias, volcanic agglomerates, pyroclastic deposits, lava flows, conglomeratic sandstones and stromatolites, generally considered to be predominantly Tertiary (Groeber, 1952; Llambías and Malvicini, 1978; Llambías and Rapela, 1987, 1989; Repol *et al*., 2002). However, on the basis of geological and radiometric dating (Ar- Ar single crystal ages), the plant bearing beds have been assigned a Late Cretaceous (65.5-73 Ma) age (Zamora Valcarce *et al*., 2006).

The Colipilli Group fossil assemblage includes abundant logs of pycnoxylic wood and palms together with rare trunks of cycads. The fossils are embedded in a friable, probably tuffaceous bed, 3-4 m thick, and are overlain by whitish tuffs. A thick

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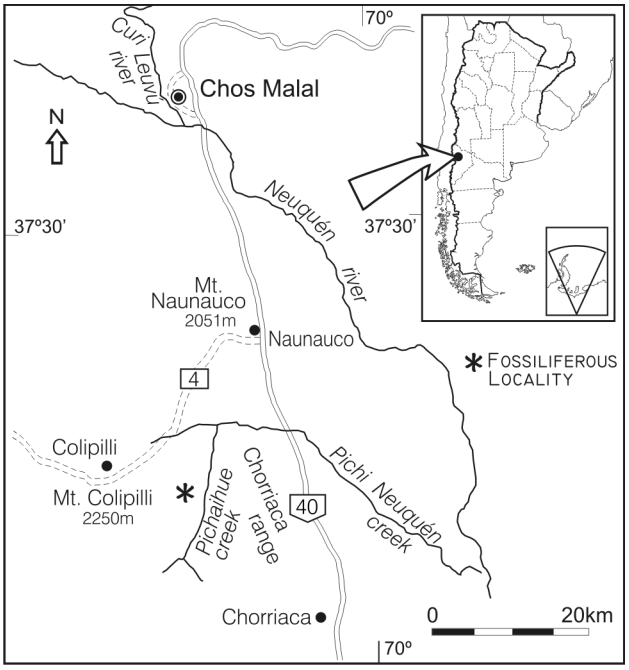

Figure 1. Location map of Pichaihue, Neuquén Province, Argentina/ *mapa de ubicación de Pichaihue, provincia del Neuquén, Argentina*.

succession of volcanic breccias underlies the fossiliferous bed. The silicified log stem material that forms the fossil assemblage exhibit random directional orientations and distributions and probably comprises an allochthonous or parautochthonous accumulation. Palms trunks up to 0.2 m in diameter are usually found as fragments less than 0.35 m in length rarely exhibiting good preservation. Although stems show a general indication of bundles shape and xylem elements, cellular detail is often poorly preserved. Logs of pycnoxylic wood are ca. 0.5 m in diameter, up to 1.40 m long and often display tree rings, yet the internal (celular) structure is not preserved. Rare cycads are found as fragments of trunks up to 0.3 m in diameter and 0.4 m in length bearing spirally arranged persistent foliar bases, but most of the framgents lack internal structural detail.

Material and methods

Polished transverse and longitudinal sections of the palm stems were made following conventional methods. One specimen (the holotype) was cut at one end, and transverse and longitudinal thin sections from this piece were prepared. Material was photographed on a Sony DSC-P93A camera attached to a Zeiss 9901 stereo microscope or to a Leitz Orthoplan light microscope. All material studied, including polished stem sections and slides, are deposited in the Palaeobotanical Collection of the Geological Sciences Department, Buenos Aires University (BAFC-Pb). Descriptive terminology of palm stems follows Sahni (1943).

Systematic palaeobotany

Division MAGNOLIOPHYTA
Class LILIOPSIDA
Subclass ARECIDAE
Order ARALES
Family ARECACEAE

Genus ***Palmoxylon*** Schenk 1882

Especie tipo. *Palmoxylon blanfordi* Schenk 1882.

Remarks. Mahabalé (1959), Kaul (1960) and Sahni (1964) provided comprehensive discussions on *Palmoxylon* Schenk 1882. Descriptions on the anatomy of extant palm trunks are given by Boureau (1957), Tomlinson (1961, 1990), and Zimmermann and Tomlinson (1972, 1974).

Palmoxylon pichaihuensis sp. nov.
Figure 2.1-2.5

Holotype. BAFC-Pb 16945.
Type Locality. Pichaihue, Loncopué Department, Neuquén Province, Argentina.
Type stratum. Colipilli Group, Upper Cretaceous (Campanian-Maastrichtian).

Name Derivation. After the type locality. Following the Recommendation 60D of the ICBN Saint Louis Code, Pichaihue takes the termination *-ensis* (Greuter *et al*., 2000).

Studied material. BAFC-PB 16943, 16945, 16953 and 16955.

Diagnosis. Cortex not clearly observed. Peripheral zone (possible dermal to subdermal zones) with densely crowded fibrovascular bundles (ca. 175-195/cm^2) with abaxial (externally orientated) reniform sclerenchyma; xylem with 1-5 large metaxylem vessels, f/v ratio ca. 3:1; protoxylem and phloem not preserved. Central zone with less congested fibrovascular bundles (ca. 85-105/cm^2), randomly disposed or occasionally arranged in irregular circles; sclerenchyma reniform; xylem with 1-4 large metaxylem vessels showing scalariform wall thickenings, and 6-12 smaller protoxylem elements with helical thickenings; f/v ratio of 1.3-2: 1, commonly 1.5-1.6:1; phloem badly preserved. Fibrous bundles absent. Ground tissue poorly preserved.

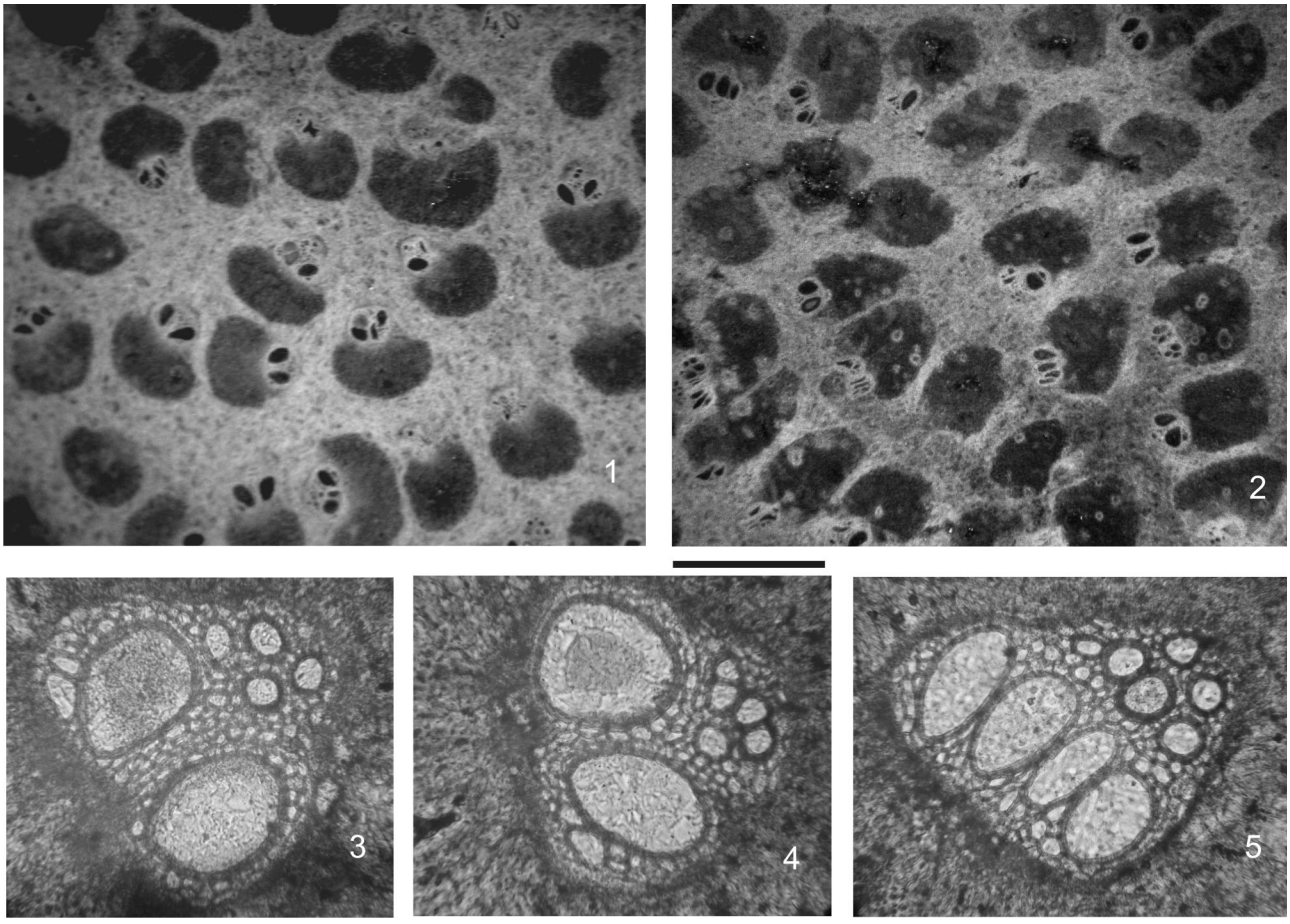

Figure 2. ***Palmoxylon pichaihuensis*** sp. nov., cross sections of the holotype/*secciones transversales del holotipo, BAFC-Pb 16945*. **1-2,** polished surfaces showing random distribution of fibrovascular bundles in central zone/ *superficies pulidas mostrando haces fibrovasculares distribuídos al azar en la zona central*. **3-5,** thin sections of different fibrovascular bundles magnified to show two-four metaxylem vessels and tracheary elements of protoxylem/ *secciones transversales de diferentes haces fibrovasculares (en corte delgado) para mostrar dos-cuatro vasos de metaxilema y los elementos traqueales del protoxilema*. The scale bar represents/ *la escala gráfica representa 2 mm (2-3), 200 µm (4-6).*

Description. The holotype, BAFC-Pb 16945 is a stem fragment measuring 10 cm long and 18 cm in diameter. Cortex was not observed. Peripheral zone (possible dermal to subdermal zones) badly preserved. Central zone possessing 85-105 fibrovascular bundles per cm^2; fibrovascular bundles commonly 0.9-1.1 mm long, 0.6-1.1 mm wide, randomly disposed, with the sclerenchyma oriented in various directions or occasionally arranged in irregular circles (figure 2.1-2.2). All dorsal sclerenchyma reniform, with a broadly rounded sinus and rounded lobes; sclerenchyma cells 15-30 µm in diameter; ventral sclerenchyma not clearly observed. Xylem with 1-5, usually 2, large, circular to oval metaxylem vessels, each measuring 150-200 µm in diameter, with scalariform wall thickening; protoxylem comprised of 6-12 smaller tracheary elements with helical thickenings, 35-70 µm in diameter (figure 2.3-2.5). Fibrovascular bundles containing only metaxylem occasionally present. Stegmata in the fibres are absent. Fibrovascular bundles commonly display more fibrous than vascular tissue, with an f/v ratio of 1.3-2:1, commonly 1.5-1.6:1. Phloem badly preserved. Tabular and radiate parenchyma not clearly observed. Fibrous bundles absent. Ground tissue is poorly preserved, comprised of irregular shaped cells. Leaf traces not clearly observed.

A second specimen, BAFC-Pb 16943 exhibits the peripheral zone (possible dermal to subdermal zones) having densely crowded fibrovascular bundles (175-194 fibrovascular bundles per cm^2) mostly orientated with the sclerenchyma outwards; fibrovascular bundles badly preserved, ca. 1 mm in diameter, displaying more fibrous than vascular tissue, with an f/v ratio of ca. 3:1. Central zone is similar to the holotype. BAFC-Pb 16953 and 16955 are probably poorly preserved specimens of *Palmoxylon pichaihuensis* sp. nov.

Remarks. Morphospecies of the highly artificial morphogenus *Palmoxylon* Schenk 1882 are distinguished from each other by size and form of sclerenchyma

Table 1. Comparison of ***Palmoxylon pichaihuensis*** sp. nov. with 1) selected morphospecies of Late Cretaceous to Tertiary fossil palm trunks with ground tissue lacking fibrous strands (top), and 2) all *Palmoxylon* morphospecies cited in Argentina (bottom). Parts: parts preserved; FV/cm²: fibrovascular bundles per cm²; F/V: fibrovascular ratio; SCL: typical shape of schlerenchyma in the fibrovascular bundles; MX: number of metaxylem vessels. C: cortex; D: dermal zone; SD: subdermal zone; C: central zone; Complanata, Cordata, Lunaria, Reniformia, Sagittata and Vaginata are different forms of schlerenchyma in Stenzel's (1904) classification/ *Comparación de* **Palmoxylon pichaihuensis** *sp. nov. con 1) morfoespecies seleccionadas de estípites de palmeras fósiles del Cretácico Tardío a Terciario con parénquima fundamental sin haces fibrosos (arriba), y 2) todas las morfoespecies de* Palmoxylon *citadas en Argentina (abajo). parts: zona conservada; FV/cm²: haces fibrovasculares por cm²; F/V: relación parte fibrosa/parte vascular; SCL: forma típica del esclerénquima en los haces fibrovasculares; MX: número de vasos metaxilemáticos; C: corteza; D: zona dermal; SD: zona subdermal; C: zona central; Complanata, Cordata, Lunaria, Reniformia, Sagittata y Vaginata son distintas formas de esclerénquima según la clasificación de Stenzel (1904).*

Morphospecies	Parts	FV/cm²	F/V	SCL	MX
P. pichaihuensis sp. nov.	possible D/SD, C	D/SD 175-195 C 85-105	D/SD 3:1C 1.3-2:1	reniform	1-4
P. arcotense Ramanujam 1953	D, SD, C	D 110 SD 50-65 C 20-25	D 15-1 SD 50-65:1 C 2-3:1	orbicular to reniform	2
P. blandfordi Schenk 1882 (Schenk, 1890; Stenzel 1904; Sahni, 1964)	C	C 15	C 2-3:1	Reniformia	2
P. chhindwarense Prakash 1960	CX, SD,D, C	D 297-625 SDS 156-250 C 60-130	D 4.5-8:1 SD 3-5:1 C 2.5-3:1	orbicular to oval, rarely reniform	2
P. eocenum Prakash 1962	D, SD, C	D 30-366 SD 66-132 C 30-60	D 6.5-10.5:1 SD 3-6:1 C 2.5-3.5:1	orbicular to reniform	2
P. livistoniforme Cevallos-Ferriz and Ricalde-Moreno 1995	possible SD	SD 29	SD 4:1	Reniformia	2
P. queenslandicum Conran and Rozenfelds 2003	CX, D,SD, C	D 215 SD 75-80 C 65-70	D 7:1 SD 5:1 C 5:1	oval to flabellate	2
P. sagari Sahni 1964	SD	SD 10-12	SD 3:1	Reniformia	2
P. wadiai Sahni 1931 (Sahni, 1964; El-Saadawi *et al*., 2004)	SD, C	SD 30C 20-25	SD2.5-4:1C 2.5:1	Reniformia	1
P. bororense Arguijo 1979	SD, C	SD 84 C 85	SD 2:1C 1.4:1	Vaginata, Lunaria	2-4
P. concordiense Lutz 1980 (Lutz, 1986)	CX, PF,C	PF 94-118 C 47-87	PF 2.5-3:1 C 1.8-1.9:1	Sagittata, Complanata,Cordata	2
P. patagonicum Romero 1968	CX,PF, C	PF 147 C 14-20	PF 3.6:1C 2.9:1	Complanata, Cordata	1-4
P. riograndense Ancibor 1995	?	?	?	Lunaria/ Reniformia?	4-6
P. santarosense Ancibor 1995	?	?	?	Reniformia?	1-2
P. valchetense Ancibor 1995	?	?	?	Lunaria/ Reniformia?	1-3
P. vaterum Arguijo 1981	C	C 50-65	C 2.5:1	Vaginata	2-7
P. yuqueriense Lutz 1984	PF, C	C 64	PF 1:1C 1.1:1	Cordata, Complanata	2

sheath, size and number of vessels and frequency of fibrovascular bundles per unit area. All these characters usually vary according to position whithin the trunk, and are thus inadequate for taxonomic distinction (Kaul, 1960; Sahni, 1964). The documentation of the new morphospecies intend o better understanding of South American palaeofloras even though the taxonomic value of the species is inconsequential. The holotype, BAFC-Pb 16945, displays the best preserved fibrovascular bundles, although additional features such as the phloem are not clearly preserved. Several additional stem- fragments, badly deteriorated and lacking any detail on their fibrovascular bundles, were also recovered from this locality. However one of the distinguish features is that they exhibit a similar number of fibrovascular bundles per unit area, as the holotype. This suggests that the whole palm stem collection could have originated

from one taxon and thus represents a morphotaxon distinct from other *Palmoxylon* morphospecies published to date.

Comparisons. Table 1 illustrates the main differences of *Palmoxylon pichaihuensis* sp. nov. with: 1) selected morphospecies of Late Cretaceous to Tertiary fossil palm trunks with ground tissue lacking fibrous strands (top), and 2) all *Palmoxylon* morphospecies cited in Argentina (bottom) and thus justifies the erection of a new morphospecies.

Definitions of extant palm species rely on characters not found in fossil stems (Tomlinson, 1961), comparisons of *P. pichaihuensis* sp. nov. with published descriptions of extant palms is thus problematic.

Discussion

It is not possible to reconstruct the plant to which this morphospecies belonged since *Palmoxylon pichaihuensis* sp. nov. forms only part of a palm stem, with no attached or associated leaves or reproductive organs. Moreover, no clear leaf traces were observed in the fossil. This suggests that the stem had elongated internodal sections (Stenzel, 1904; Boureau, 1957). Interestingly, stem diameter and average height of palms from lowland and montane moist forests are significantly lower than those from dry or xeric environments. Mean stem diameter of palms from moist forests is ca. 0.1 m, whilst mean stem diameter of palms from dry forests, grasslands, savannas and shrublands is ca. 0.3 m, attaining to 0.4 m in deserts (Henderson, 2002). *P. pichaihuensis* sp. nov. thus might to represent a palm with a cylindrical stem and elongate internodes, probably growing in a relatively humid environment.

Today, palms are found in tropical and subtropical climates. In southern South America, *Jubaea chilensis* (Molina) Baillon reaches 35º 30' S in Chile, whilst *Syagrus romanzoffiana* (Chamiso) Glasman attains 34º S in eastern Argentina, and *Trithrinax campestris* (Burmeister) Drude and Griesbach reaches 33º S in central-western Argentina (Castellanos, 1926; Dimitri *et al*., 1987; Zizka, 1989). *Jubaea chilensis* is one of the most cold tolerant of all palms, surviving at ca. -15º C during short periods in winter (Zizka, 1989).

The Pichaihue fossil assembage, including palms but also pycnoxilic wood and less frequently encountered cycads, is similar to the rich Upper Cretaceous (Campanian-Maastrichtian) fossil assemblage from the Allen Formation of Bajo de Santa Rosa, Río Negro province, Argentina, which includes podocarpaceous conifers, cycads and palms together with vertebrate remains (Andreis *et al*., 1991; Ancibor, 1995; Del Fueyo, 1998; Artabe *et al*., 2004). The Allen Formation, basal unit of the Malargüe Group, represents the beginning of a cycle of marine deposition related to the opening of the Atlantic (Legarreta and Uliana, 1999; Page *et al*., 1999).

The knowledge of Campanian-Maastrichtian floras of north Patagonia is complemented by palynological information. Microfloral assemblages mainly include pollen of conifers, spores and dicot pollen, together with monocolpate Arecaceae-like pollen and smooth monocolpates similar to those produced by Cycadales (Ruiz *et al*., 1999; Papú, 2002; Quattrocchio, 2006).

The fossil floras of Pichaihue and Santa Rosa, together with palynological data from north Patagonia indicate the existence of a palaeoflora dominated by conifers and ferns, with locally abundant palms and subdominant cycads and dicots. This vegetation grew under a warm and relatively humid climate towards the end of the Cretaceous, at ca. 40-45º S, towards the southwestern extreme of South American landmass (figure 3).

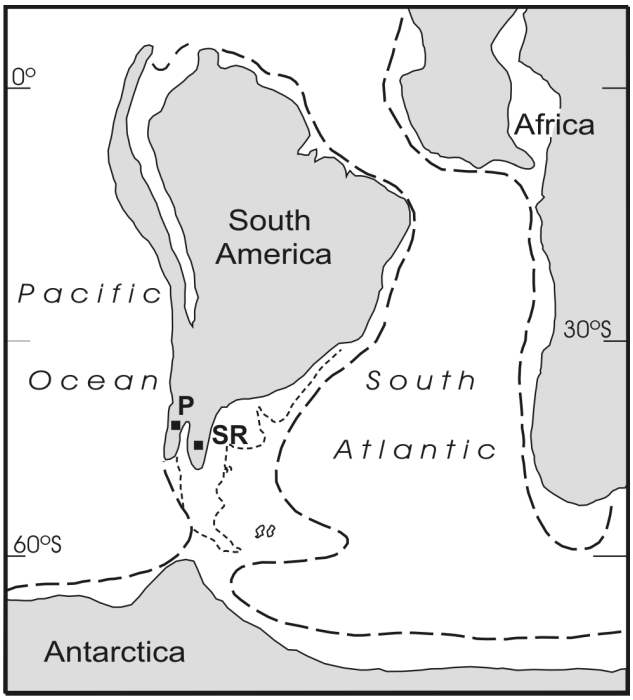

Figure 3. South America during the Campanian-Maastrichtian (83-65 Ma), modified from Vrielynck and Bouysse (2003). Full lines represent boundaries of exposed landmass; dashed lines represent continental margins; dotted lines represent southern South America exposed landmass today; P, Pichaihue; SR, Bajo de Santa Rosa/ *Sud América durante el Campaniano-Maastrichtiano (83-65 Ma), modificado de Vrielynck y Bouysse (2003). Las líneas enteras representan los límites entre las masas continentales emergidas; las líneas cortadas representan los márgenes continentales; las líneas punteadas representan la masa continental emergida de Sud América meridional en la actualidad; P, Pichaihue; SR, Bajo de Santa Rosa.*

The fossil floras of Pichaihue and Santa Rosa are distinct from coeval southern Patagonian and Antarctic fossil floras. These high latitude assem-

blages contain mainly dicots such as Nothofagaceae, Myrtaceae, Lauraceae, Monimiaceae and Eucryphiaceae along with conifers of the families Cupressaceae, Araucariaceae and Podocarpaceae, and are similar to cool temperate rainforest of southeastern South America today (Romero, 1993; Poole *et al*., 2003). Further comparisons with Upper Cretaceous plant fossil assemblages from central Argentina are hindred by the deficit of fossil material.

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