



Ursidae (Mammalia, Carnivora) from the Quaternary of western Rio Grande do Sul, Brazil: Taxonomical, stratigraphic, and chronological aspects

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ABSTRACT

All known Pleistocene South American fossil ursids belong to *Arctotherium*, an extinct genus of tremarctine bears. Its occurrence encompasses many countries in Central and South America, with findings mainly from Argentina. In Brazil, the genus is recorded in eight states, highlighting Rio Grande do Sul due to its provenance from fluvial deposits. In contrast, all other Brazilian records come from caves or fossil tanks. The *Arctotherium* material from Rio Grande do Sul comes from the Passo do Juquiry site, located on the banks of the Quaraí River, which marks the frontier between Brazil and Uruguay. The fossils are MCN-PV 1940/A-K, a set of postcranial bones: first to sixth lumbar vertebrae, sacrum, left scapula, left humerus, right portion of the pelvic girdle, and left femur. The anatomic description of these bones confirmed their belonging to *Arctotherium* sp. due to their size, the form of the vertebral processes, the presence of the entepicondylar foramen of the humerus, and the morphology of the trochlea and capitulum. Body mass estimates resulted in values mostly above 400 kg. The first absolute age from Passo do Juquiry indicated 40,000 years BP. The stratigraphic framework of the outcrop conformed to a floodplain fines facies association, a succession of mudstones with carbonate nodules on top. This facies association has lithological correlations to the Brazilian Touro Passo Formation, the Uruguayan Sopas Formation, and the Argentinean Toropí/Yupof Formation. While having similar features, the ages of the lithologically correlated facies associations do not always line up, indicating that the evolution of the Uruguay River basin throughout the Late Pleistocene followed a pattern, but not synchronously. The presence of carbonate levels suggests that the climate during the time of deposition was drier than the present one, with the carbonate-less middle layer representing a more humid period.

1. Introduction

The family Ursidae is currently distributed between the Arctic, Eurasia, North America, and northwestern South America and includes three subfamilies with living representatives: Ursinae, Ailuropodinae, and Tremarctinae (Collins, 2015; Kumar et al., 2017). Only the latter is found in South America, represented by the species *Tremarctos ornatus* (Cuvier, 1825) (Vela-Vargas et al., 2021). However, this subfamily had greater geographic distribution and diversity in the past. The genus with the oldest occurrence in the subfamily is *Plionarctos*, from the Late Miocene–Early Pliocene of North America (Tedford and Martin, 2001; Mitchell et al., 2016). *Arctodus* has records from the Late Pliocene–Pleistocene of North America (Krause et al., 2008). *Arctotherium*, in turn,

is a Pleistocene genus with occurrences from Central and South America and encompasses all South American Pleistocene ursids (Salis et al. 2021).

Soibelzon (2004) recognized five valid species for *Arctotherium*: *Arctotherium angustidens* Gervais and Ameghino, 1880; *Arctotherium vetustum* Ameghino, 1885; *Arctotherium bonariense* (Gervais, 1852); *Arctotherium tarijense* Ameghino (1902) and *Arctotherium wingei* Ameghino (1902). *Arctotherium angustidens* is the largest known species and is restricted to the Ensenadan Stage/Age (Early–Middle Pleistocene); *A. vetustum*, *A. bonariense*, and *A. tarijense* are known from the Bonaerian to the Lujanian Stages/Ages (Middle–Late Pleistocene to Late Pleistocene–Early Holocene); *A. wingei* does not have a well-defined biostratigraphic distribution, but a Lujanian Stage/Age occurrence has been

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inferred (Soibelzon et al., 2005).

Records of *Arctotherium* come mainly from Argentina, where fossils from all species, except *A. wingei*, have been found (Soibelzon et al., 2005). Other countries with Pleistocene records of the genus are Belize, Bolivia, Brazil, Chile, Mexico, Uruguay, and Venezuela (e.g., Ameghino, 1902; Perea and Ubilla, 1983; Prevosti et al., 2003; Soibelzon, 2004; Soibelzon and Rincón, 2007; Rodrigues et al., 2014; Mendoza et al., 2015; Ubilla et al., 2016; Schubert et al., 2019).

In Brazil, *Arctotherium* fossils were recorded in Ceará, Rio Grande do Norte, Piauí, Bahia, Tocantins, Minas Gerais, and Mato Grosso do Sul (Lund, 1841; Walter, 1940; Paula-Couto, 1960; Trajano and Ferrarezzi, 1994; Guérin et al., 1996; Cartelle, 1998; Porpino et al., 2004; Rodrigues et al., 2014; De Oliveira et al., 2017). There are records of Carnivora cf. Ursidae from the municipalities of Pantano Grande and Santa Vitória do Palmar, both located in the Rio Grande do Sul state (Scherer et al., 2003; Pereira et al., 2012). This work describes the first postcranial material from Rio Grande do Sul referred to *Arctotherium* and estimates the individual's body mass through allometric equations. It also establishes a stratigraphic framework for the fossil's outcrop of provenance, Passo do Juquiry, to which we associate a new dating, the first for the location. Using this information, correlations between the studied outcrop and other nearby Pleistocene sedimentary successions from Brazil, Uruguay, and Argentina are proposed, and paleoclimatic inferences are made.

2. Regional setting

The Passo do Juquiry (30°10'32" S, 56°42'20" W) outcrop is located on the banks of the Quaraí River, which marks the frontier between Brazil and Uruguay (Fig. 1). It is located within the Campanha region, in the Pampa Biome, an area with the occurrence of herbaceous steppe grasslands and steppe savannas (IBGE, 2004). Currently, about 54% of these fields are converted to agricultural use (Cordeiro and Hasenack,

2009).

Other Quaternary fossil mammal-bearing locations found on the banks of the Quaraí River in Rio Grande do Sul besides Passo do Juquiry are the Cerro da Tapera, Lagoa da Música, and Arroio Garupá outcrops (Fig. 1). In the Uruguayan side, the Estiba, Mina 1, Paso del León, and Piedra Pintada outcrops are known to have fossil mammal content (Ubilla et al., 2016). Of these, only Cerro da Tapera has a well-defined stratigraphic framework.

The Pleistocene sedimentary deposits of the Quaraí River are composed mainly of brown, muddy sandstones associated with occasional carbonate levels marked by the presence of rhizoconcretions and/or carbonate nodules. These levels are generally decimetric, with lateral extensions of tens of meters (Da-Rosa, 2003). We can recognize the Touro Passo Formation in these deposits, which encompasses all the Pleistocene fluvial deposits with fossil mammal content from southwestern Rio Grande do Sul (Da-Rosa, 2009). This formation is correlated to the Toropí/Yupoí Formation of the Argentinean Mesopotamia (Corrientes province) and to the Sopas Formation of Uruguay, which includes the outcrops from the Uruguayan side of the Quaraí River (Oliveira and Kerber, 2009).

The Passo do Juquiry outcrop presents fossil mammal records of Caviidae, Cricetidae, Cervidae, Equidae, Glyptodontidae, and Gomphoteriidae (Oliveira, 1992, 1996; Scherer et al., 2007a; Gaden-s-Marcon, 2008; Kerber and Oliveira, 2008a; Kerber et al., 2012). Most of the mammalian fossil genera found in Passo do Juquiry are also found in the other fossiliferous outcrops of the Quaraí River and correlated formations (see Appendix A). The fossil assemblage of Passo do Juquiry is characterized by the presence of both mammals typically associated with open field environments like *Equus neogeus* (Lund, 1840) and *Antifer* sp. (Scherer et al., 2007a; Kerber and Oliveira, 2008a), and animals associated with forest environments and perennial water bodies, like *Holochilus brasiliensis* (Desmarest, 1819), *Hydrochoerus hydrochaeris*

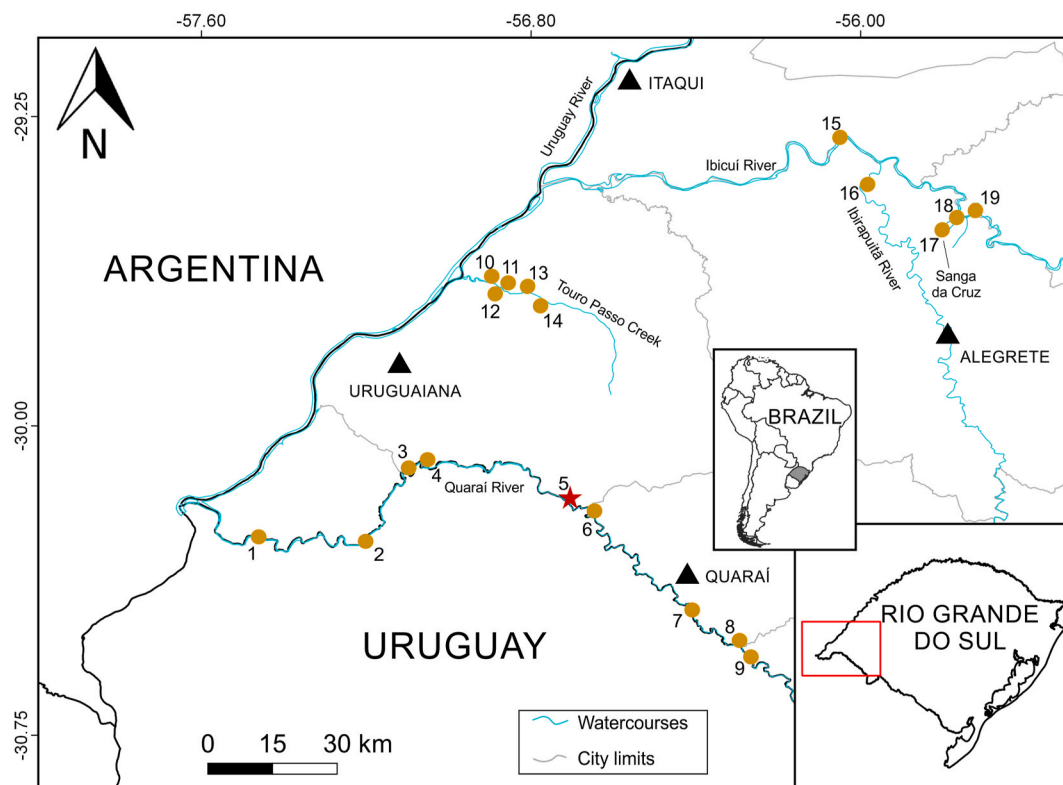


Fig. 1. Pleistocene fossiliferous outcrops of Southwestern Rio Grande do Sul, Brazil, including the ones from the Uruguayan margin of the Quaraí River. 1, Pay Paso; 2, Mina I; 3, Lagoa da Música; 4, Paso del León; 5, Passo do Juquiry; 6, Arroio Garupá; 7, Piedra Pintada; 8, Cerro da Tapera; 9, Estiba; 10, Ponte Velha II; 11, Ponte Velha I; 12, Barranca Grande; 13, Milton Almeida; 14, Confluência do Pindaí; 15, Agropecuária Sinasino; 16, Rio Ibirapuitã; 17, Foz da Sanga; 18, Salatiel I; 19, Salatiel II. The *Arctotherium* fossils were collected on Passo do Juquiry, marked by the red star. Adapted from Ribeiro and Scherer (2009).

(Linnaeus 1766) and *Notiomastodon platensis* (Ameghino, 1888) (Oliveira, 1992; Gadens-Marcon, 2008; Kerber et al., 2012). The presence of *Equus neogeus* in the fossil assemblage of Passo do Juquiry allows its correlation to the Lujanian Stage/Age (*sensu* Cione et al., 2015) of the Buenos Aires province, equivalent to the Late Pleistocene–Early Holocene.

There are no available ages for the sediments of Passo do Juquiry. Absolute dating from outcrops throughout the banks of the Quaraí River provided ages between 360,000 and 10,000 years BP, with the oldest ages, the ones of 360,000, 248,000, and 180,000 years BP, coming from the Piedra Pintada outcrop, in Uruguay. Most dates, coming from the other seven outcrops, resulted in ages from 35,000 to 10,000 years BP (Miller, 1987; Ribeiro et al., 2008; Ubilla et al., 2016) (see Appendix B; Austral, 1994; Kotzian et al., 2005; Martínez and Ubilla, 2004; Milder, 2000; Ubilla et al., 1995). These available ages for the deposits of the Quaraí River correspond to the latest Middle Pleistocene to Late Pleistocene and indicate a correlation with the Bonaerian and Lujanian Stages/Ages (Ubilla et al., 2004, 2016; Ubilla and Martínez, 2016).

3. Material and methods

3.1. Material

The studied material is deposited in the paleovertebrate collection of the Seção de Paleontologia do Museu de Ciências Naturais (MCN) da Secretaria Estadual do Meio Ambiente e Infraestrutura (SEMA), Porto Alegre, Rio Grande do Sul, under the acronym MCN-PV. It was collected in the Passo do Juquiry outcrop, but the specific layer of provenance was not informed. Anatomical comparisons for identification were made with recent material from the didactic collection of the Seção de Mastozoologia do MCN/SEMA and fossil material from both the Museo Argentino de Ciencias Naturales “Bernardino Rivadavia”, Buenos Aires, and the Museo de La Plata, La Plata, Argentina (Appendix C).

Further comparisons with the *Tremarctos* genus (including both the extant *Tremarctos ornatus* and *Tremarctos floridanus* (Gidley, 1928)) are based on descriptions and figures from Kurtén (1996). Comparisons with *Arctotherium wingei* are based on descriptions and figures from Winge (1895), Paula-Couto (1960), and Cartelle (1998), and with the *Arctodus* genus on descriptions and figures from Merriam and Stock (1925), Kurtén (1967), Nelson and Madsen (1983) and Sorkin (2006).

3.2. Methods

Anatomical nomenclature and measurements followed Torres (1988) and Cartelle (1998). Measurements, expressed in millimeters, were taken using a caliper rule with a precision of 0.02 mm.

Cronostratigraphical/geochronological units followed the South

American Stages/Ages proposed by Cione et al. (2015). Specifically, the Ensenadan (Early–Middle Pleistocene), Bonaerian (Middle–Late Pleistocene), and Lujanian (Late Pleistocene–Early Holocene).

Body mass estimate through allometric equations followed Soibelzon and Tarantini (2009), who tested more than sixty equations published by many authors (e.g., Van Valkenburgh, 1990; Anyonge, 1993; Viranta, 1994; Christiansen, 1999; Egi, 2001) to estimate the body mass of both extant and fossil South American tremarctine bears using craniodental and postcranial (humerus, femur, radius, and tibia) measurements. Of these, nine equations using femoral measurements (Anyonge, 1993; Viranta, 1994; Christiansen, 1999; Egi, 2001) and eight equations using humeral measurements (Anyonge, 1993; Christiansen, 1999; Egi, 2001) were found as reliable body size predictors for the different species of South American tremarctine bears. We could apply six of the equations based on the femur and four of the equations based on the humerus (Table 1).

The different lithologies outcropping in Passo do Juquiry were described, and representative stratigraphic columns were elaborated using the image editing software CorelDRAW X6. We used the facies code and definition of architectural elements of Miall (2010) to identify and interpret lithologies.

The dating from Passo do Juquiry was performed through the method of Optically Stimulated Luminescence (OSL) using quartz of Huntley et al. (1985). This method was chosen over ^{14}C for the greater temporal scope it covers and over thermoluminescence for its greater similarity to the natural processes of bleaching by solar exposure (Guedes et al., 2011).

A sediment core sampled from the middle layer of Passo do Juquiry was sent to Datação, Comércio e Prestação de Serviços Ltda. for OSL age determination. Accumulated dose analysis was conducted using a Thorn EMI Electron Tubes Photomultiplier, type 9235QA, model number H7360-020, coupled with a Hamamatsu photon counting unit with USB interface, model number C8855-01. Radioactive isotope concentrations (Th, U, K) used to calculate radiation dose rates were obtained through a Canberra Inspector Portable Spectroscopy Workstation (NAI-TL).

3.3. Institutional abbreviations

MACN: Museo Argentino de Ciencias Naturales “Bernardino Rivadavia”, Buenos Aires, Argentina; MCN-D: didactic collection of the Seção de Mastozoologia do Museu de Ciências Naturais da Secretaria Estadual do Meio Ambiente e Infraestrutura, Porto Alegre, Brazil; MCN-PV: paleovertebrate collection of the Seção de Paleontologia do Museu de Ciências Naturais da Secretaria Estadual do Meio Ambiente e Infraestrutura, Porto Alegre, Brazil; MLP: Departamento Científico de Paleontología de Vertebrados del Museo de La Plata, La Plata, Argentina.

Table 1

Equations used for body mass estimation. FGL = Femur greatest length; FMSC = Femur mid-shaft circumference; FMSW = Femur mid-shaft width; HMSC = Humerus mid-shaft circumference; HGVW = Humerus greatest ventral width. ID = equation identification. %SEE = percent standard error of estimate. Modified from Soibelzon and Tarantini (2009).

Element	Measurement	Equation	ID	%SEE	References
Femur	FGL	$\ln y = -13.61 + \ln x * 3.206$	F1	9.2	Egi (2001)
	FGL	$\ln y = -11.72 + \ln x * 2.936$	F2	11.2	Egi (2001)
	FMSC	$\log y = 2.88 * \log x - 3.40$	F3	30	Anyonge (1993)
	FMSC	$\log y = 0.0005 + 2.808 * \log x$	F4	33	Christiansen (1999)
	FMSC	$\log y = 0.0003 + 2.956 * \log x$	F5	14	Christiansen (1999)
	FMSW	$\log y = 3.26 * \log x - 2.68$	F6	22	Viranta (1994)
Humerus	HMSC	$\log y = 2.47 * \log x - 2.72$	H1	29	Anyonge (1993)
	HMSC	$\log y = 0.001 + 2.604 * \log x$	H2	34	Christiansen (1999)
	HMSC	$\log y = 0.0009 + 2.645 * \log x$	H3	13	Christiansen (1999)
	HGDW	$\ln y = 0.002 + 2.511 * \ln x$	H4	53	Christiansen (1999)

4. Results

4.1. Systematic paleontology

Order CARNIVORA Bowdich, 1821

Suborder CANIFORMIA Kretzoi, 1943

Family URSIDAE Fischer de Waldheim, 1817

Subfamily TREMARCTINAE Merriam and Stock, 1925

Genus *Arctotherium* Burmeister, 1879

Arctotherium sp. (Gervais, 1852)

(Figs. 2–4)

Material: MCN-PV 1940/A–F, lumbar vertebrae; MCN-PV 1940/G, sacrum; MCN-PV 1940/H, left humerus; MCN-PV 1940/I, left scapula; MCN-PV 1940/J, fragmented right portion of the pelvic girdle; MCN-PV 1940/K, left femur. All the material belongs to the same individual.

Geographic provenance: Passo do Juquiry outcrop (30°10'32" S, 56°42'20" W), banks of the Quaraí River, Uruguaiana municipality, Rio Grande do Sul, Brazil.

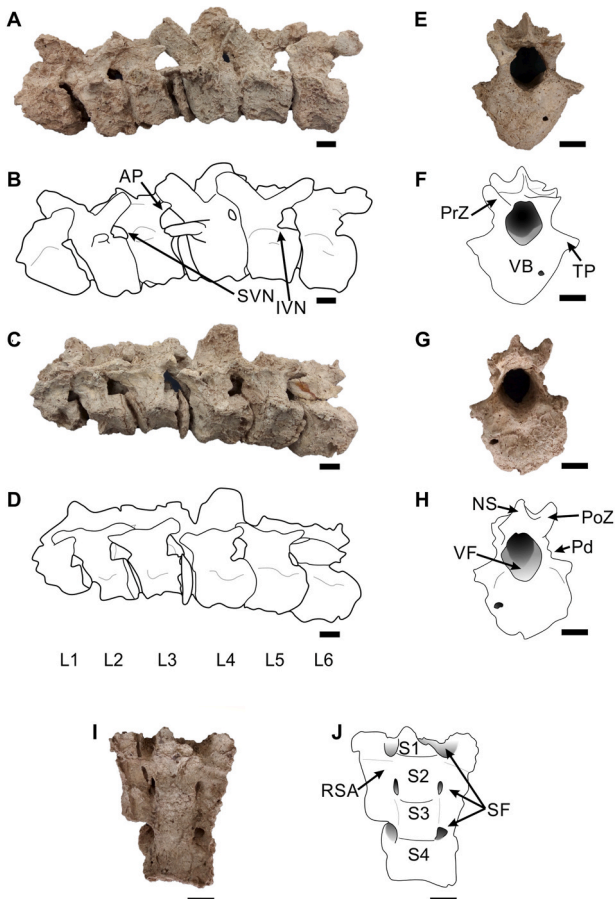


Fig. 2. *Arctotherium* sp., A–D, MCN-PV 1940/A–F, lumbar vertebrae in right lateral (A–B) and left lateral (C–D) views; E–H, MCN-PV 1940/F, sixth lumbar vertebra in cranial (E–F) and caudal (G–H) view; I–J, MCN-PV 1940/G, sacrum in ventral view. AP, accessory process; IVN, inferior vertebral notch; NS, neural spine; Pd, pedicle; PoZ, postzygapophysis; PrZ, prezygapophysis; RSA, right sacral ala; S1, first sacral vertebra; S2, second sacral vertebra; S3, third sacral vertebra, S4, fourth sacral vertebra; SF, sacral foramen; SVN, superior vertebral notch; TP, transverse process; VB, vertebral body; VF, vertebral foramen. Scale = 2 cm.

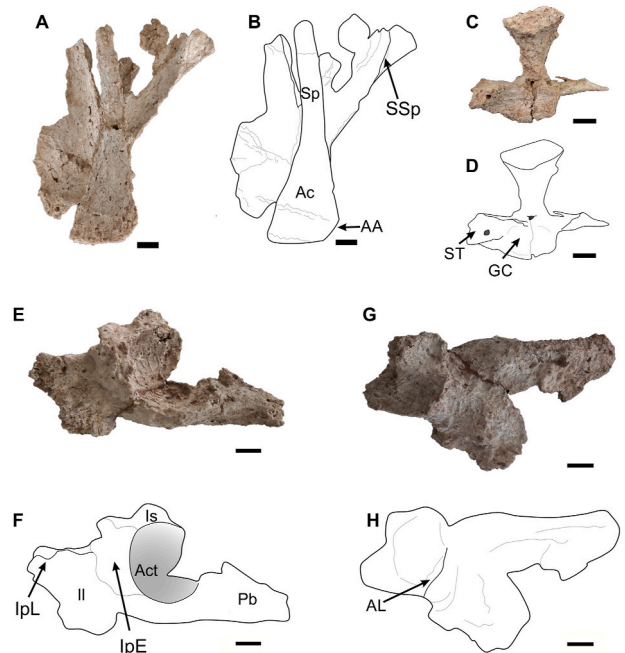


Fig. 3. *Arctotherium* sp., A–D, MCN-PV 1940/H, right scapula in lateral (A–B) and ventral (C–D) views; E–H, MCN-PV 1940/J, right portion of the pelvic girdle in lateral (E–F) and medial (G–H) views. AA, acromial angle; Ac, acromion; Act, acetabulum; AL, arcuated line; GC, glenoid cavity; II, ilium; IpE, iliopectineal eminence; IpL, iliopectineal line; Is, ischium; IT, infraglenoid tubercle; Pb, pubis; Sp, scapular spine; Ssp, secondary spine, ST, supraglenoid tubercle. Scale = 2 cm.

4.1.1. Description

4.1.1.1. Lumbar vertebrae (Fig. 2 A–H). There are six preserved vertebrae, from L1 to L6. The L1–L3 vertebrae are articulated, as are L4–L5. L1 does not have the vertebral body preserved. Some of the epiphyses are unfused. The neural spines are fractured, with L4 having the most well-preserved one. The zygapophyses are tall and squared. The L1–L3 vertebrae possess accessory processes lateral to the postzygapophyses. These assist on the articulation with the posterior vertebrae, lodging themselves on the lateral face of the prezygapophyses. The accessory processes of L1 and L2 are flat and elongated, while the one from L3 is short and wedge-shaped. The transverse processes are fractured, except for the right one of L4, which is flat, cranioventrally oriented, and positioned on the dorsal-most part of the vertebral body. In lateral view the inferior vertebral notch is quite marked, with a sharp, cranially oriented, curvature, while the superior vertebral notch is only slightly prominent.

4.1.1.2. Sacrum (Fig. 2 I–J). The sacrum is composed by four vertebrae fused through their transverse processes, vertebral bodies, and neural arches, with a fragmented cranial-most portion of S1. Thus, the prezygapophyses for articulation with the last lumbar vertebra are missing. The sacrum has a trapezoidal shape, narrowing caudally. The sacral alae are fractured, missing the lateral-most portions. In cranial view it is possible to observe the intervertebral foramen, which is oval and dorsoventrally flattened. Two pairs of sacral foramina are preserved, which are oval, with the greater axis oriented cranio-caudally. In dorsal view the observation of the spinous processes is impeded by concretions. Only the cranial portion of the right lateral sacral crest is preserved, and it is projected laterally.

4.1.1.3. Scapula (Fig. 3 A–D). The scapula is very fragmented. In lateral view, the acromion is triangular, with a straight outline and the

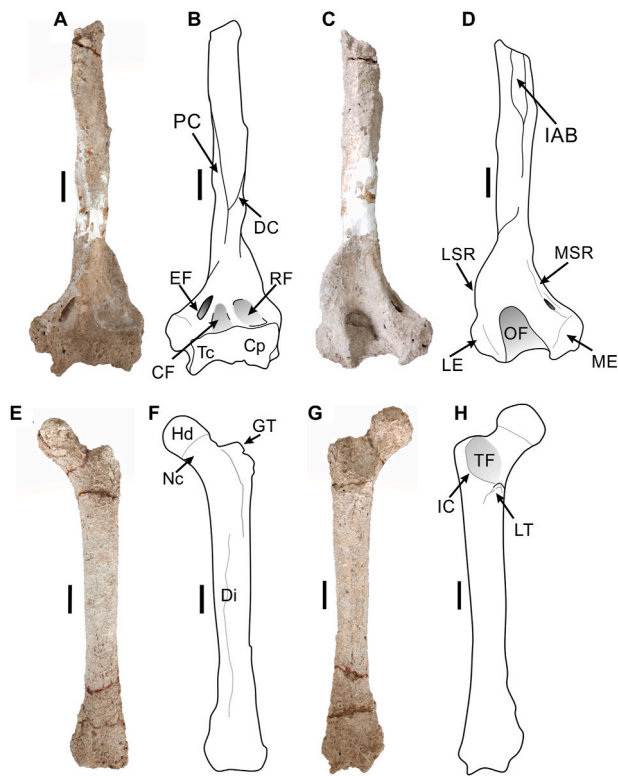


Fig. 4. *Arctotherium* sp., A-D, MCN-PV 1940/I, left humerus in cranial (A-B) and caudal (C-D) views; E-H, MCN-PV 1940/K, left femur in cranial (E-F) and caudal (G-H) views. CF, coronoid fossa; Cp, capitulum; DC, deltoid crest; Di, diaphysis; EF, entepicondylar foramen; GT, greater trochanter; Hd, head of the femur; IAB, insertion for the accessory belly of the *m. triceps brachii*; IC, intertrochanteric crest; LE, lateral epicondyle; LSR, lateral supracondylar ridge; LT, lesser trochanter; ME, medial epicondyle; MSR, medial supracondylar ridge; Nc, neck of the femur; OF, olecranon fossa; RF, radial fossa; Tc, trochlea. TF, trochanteric fossa. Scale = 4 cm.

cranioventral end as the most prominent. The acromial angle is not very sharp, presenting a rounded contour. The scapular spine is robust. It projects laterally from the acromion, with a slight cranial turn. A foramen can be observed in the ventral end of its caudal side, near the top. A slender second spine can be clearly observed in the caudal border. In ventral view, the preserved portion of the glenoid cavity is concave, shallow, and smooth, showing a cranioventrally elongated appearance. The supraglenoid tubercle is positioned cranial to the glenoid cavity.

4.1.1.4. Humerus (Fig. 4 A–D). The humerus is fragmented, missing its dorsal end. Its body exhibits a flat and rectangular aspect in cranial view. This view allows to observe the pronounced pectoral crest extending itself dorsoventrally from the dorsal end to the middle of the diaphysis, where it coalesces with the deltoid crest, also very pronounced, forming a “Y” shape. These crests provide insertion for the *m. pectoralis profundus* and *superficialis*, respectively. The ventral end of the deltoid crest and the part where both crests coalesce mark the origin of the *m. brachialis*. The ventral portion of the humerus has a triangular shape and is most developed lateromedially. The entepicondylar foramen is present in the medioventral portion. This foramen has an oval shape, with the greater axis oriented dorsoventrally, and it is closed by an osseous bridge. Lateral to the entepicondylar foramen is the coronoid fossa, which is oval and shallow. Lateral to the coronoid fossa, separated from it by a discrete crest, is the larger, radial fossa, of semicircular shape and equally shallow. The two epicondyles can be well observed in the lateral and medial ends, with the medial one being larger. The lateral supracondylar ridge extends itself dorsally from the lateral epicondyle, starting with a light depression and transitioning to a convex contour,

broadly opening itself in the lateral direction. The trochlea and capitulum are present in the ventral end of the humerus. They are lateromedially aligned, with the ventral margin of the trochlea being more deeply projected than the capitulum's. However, the capitulum is overall larger and rounder. In caudal view, two crests oriented dorsoventrally can be found near the dorsal end. Initially parallel to each other, forming a plateau, they converge near the caudal end of the first third of the diaphysis, forming a singular crest that appears to be continuous with the lateral supracondylar ridge. The plateau they form marks the area of insertion for the accessory belly of the *m. triceps brachii*. The olecranon fossa is remarkably deep.

4.1.1.5. Pelvic girdle (Fig. 3 E–H). Part of the acetabulum can be observed in lateral view. It seems to be circular, having a deep concavity. Its most well-preserved part is the lunate surface. The body of the ilium is found cranial to the acetabulum, showing a portion of the iliopectineal line continuous to the iliopectineal eminence. In a medial view, there is a fragmented portion of the arcuated line, dorsoventrally oriented on the caudal limit of the iliac fossa. Only the cranial portion of the pubis and the ventral portion of the ischium are preserved, lacking features of interest.

4.1.1.6. Femur (Fig. 4 E–H). In cranial view, the head is spheric and prominent presenting a deep, small, fovea in its medial side. The neck is long, flattened, and strongly projected in the craniomedial direction. Its diameter is only slightly smaller than that of the head. The greater trochanter is fractured. The lesser trochanter is small and has a conical shape, with its apex projected caudally. The trochanteric fossa is shallow, and only the outline of the intertrochanteric crest can be observed. The body of the femur is rectangular, craniocaudally flattened, and widens gradually towards its dorsoventral ends. Due to the apparent lack of the ventral epiphysis, the condyles and other features of interest are missing. In lateral view, the region of the third trochanter shows a flat appearance. The lateral supracondylar line is conspicuous and can be observed following the caudolateral margin of the ventral portion of the body, while the medial supracondylar line is discrete and found in the caudomedial margin. They do not appear to converge. Their function is to serve as an insertion for the *m. vastus lateralis* and *medialis*, respectively.

4.2. Body mass estimation

Using allometric equations based on selected measurements of the femur and humerus, we estimate that the specimen described here had a body mass between 336.59 kg and 555.20 kg. The body masses predicted using femoral measurements are shown in Table 2, while the ones predicted using humeral measurements appear in Table 3. Considering all equations, the mean and median are 437.80 kg and 445.89 kg, respectively.

4.3. Stratigraphy of the outcrop

Passo do Juquiry is an outcrop with decametric extension oriented approximately E-W. Volcanic rocks from the Serra Geral Group with vesicles on top are found when accessing the site through its western side. Above them is a 1 m thick layer of medium sandstone with low-angle cross-stratification from the Botucatu Formation, on top of which the Quaternary fluvial sediments are deposited. The Quaternary sediments have a uniform brown color. They consist of three layers separated by discrete bounding surfaces, forming steps in certain portions of the outcrop. Each layer is distinct from the other in texture and sedimentary structures. For this study, they were identified as JA, JB, and JC, from top to base (Fig. 5).

The JC layer is the most basal, 150 cm thick. It is composed of mudstone with marked plasticity and presents parallel lamination (Fl

Table 2

Body mass estimation (kg) of MCN-PV 1940 from femoral measurements (mm) applying the equations F1 to F6 (see Table 1). FGL = Femur greatest length; FMSC = Femur mid-shaft circumference; FMSW = Femur mid-shaft width. Adapted from Soibelzon and Tarantini (2009), Soibelzon and Schubert (2011).

Specimen	FGL	F1	F2	FMSC	F3	F4	F5	FMSW	F6	Mean	Median
MCN-PV 1940/K	466	440.65	555.20	119	378.07	336.59	409.67	43.6	441.68	426.97	445.89

Table 3

Body mass estimation (kg) of MCN-PV 1940 from humeral measurements (mm) applying the equations H1 to H4 (see Table 1). HMSC = Humerus mid-shaft circumference; HGVW = Humerus greatest ventral width. Adapted from Soibelzon and Tarantini (2009), Soibelzon and Schubert (2011).

Specimen	HMSC	H1	H2	H3	HGVW	H4	Mean	Median
MCN-PV 1940/H	148	437.06	448.08	494.97	131	414.47	448.64	454.72

facies). Discreet carbonate levels can be found on it in some points of the outcrop.

The JB layer, 80 cm thick, corresponds to mudstone without apparent lamination (Fm facies), also quite plastic, but with an increase in the content of very fine sand towards the top.

The JA layer is 130 cm thick and composed of massive mudstone. Carbonate nodules are found from 80 cm high to the top (P facies) and are more numerous in the eastern portion of the outcrop. Due to the greater carbonate content, it has a notably lesser plasticity than the sediments of the subjacent layers. Overlying the Quaternary sediments is a 1 m thick Holocene black soil layer, clayish and rich in organic matter, itself superimposed by a 50 cm thick layer of sandier brown soil.

4.4. Geochronology

Age determination by optically stimulated luminescence using quartz of sediments from the JB layer of Passo do Juquiry, the only one of the three with a confirmed fossil record (a vertebra attributed to Cervidae indet.), resulted in an age of $40,500 \pm 7500$ years BP (Tables 4 and 5). This corresponds to the Lujanian Stage/Age (Late Pleistocene), in accordance with the fossil content of *Equus neogeus*. It also correlates to the Marine Isotope Stage 3 (MIS-3), which covers from 60 ky BP to 30 ky BP.

5. Discussion

5.1. Taxonomy

The studied material was attributed to the family Ursidae due to characteristics of the humerus: trochlea and capitulum lateromedially aligned and with slight arching, the larger size of the medial epicondyle in relation to the lateral and the prominent lateral supracondylar ridge (Gervais, 1873; Torres, 1988; Prevosti et al., 2003). Furthermore, the lumbar vertebrae present rectangular transverse processes, only slightly ventrally curved, and spinous processes projected exclusively to the dorsal side, features also found in other ursids like *Arctodus simus* (Cope, 1879) and *Ursus arctos horribilis* (Linnaeus, 1758), indicative of an animal that was not a pursuit predator (Sorkin, 2006).

All ursids known for South America belong to the subfamily Tremarctinae (Soibelzon et al., 2005). The entepicondylar foramen in the humerus is a characteristic feature of this subfamily and is present in MCN-PV 1940/H (Cartelle, 1998; Soibelzon, 2002). Three genera of Tremarctinae are known for the Pleistocene, *Arctodus*, *Tremarctos* and *Arctotherium*. The latter two are recorded in South America, with *Arctotherium* encompassing all Pleistocene fossil forms (Stucchi et al., 2009; Mitchell et al., 2016).

Compared to *Arctodus* the lumbar vertebrae of MCN-PV 1940 present spinous processes of lower height and craniocaudally narrower transverse processes (Sorkin, 2006). The sacrum has a similar trapezoidal shape, but smaller sacral foramina (Merriam and Stock, 1925; Kurtén, 1967). The shape of the acromion is different, with the material from Rio

Grande do Sul presenting straighter margins. Merriam and Stock (1925) described the presence of a foramen at the base of the scapular spine in *Arctodus*, which is also present in *Tremarctos*. Our fossil presents a similar structure, but the foramen is located nearer to the top of the scapular spine. The humerus of *Arctodus* is longer and more robust than MCN-PV 1940/H (Table 6). It also presents an auxiliary crest between the deltoid and pectoral crests that is absent in MCN-PV 1940/H. The lateral supracondylar ridge appears to be lateromedially narrower in *Arctodus*, with a stronger medial projection in the ventral portion compared to the material from Rio Grande do Sul. The area of insertion for the accessory belly of the *m. triceps brachii* is also proportionally narrower in *Arctodus* (Merriam and Stock, 1925; Kurtén, 1967; Sorkin, 2006). The diameter of the acetabulum is greater in *Arctodus* (87–101 mm) than in MCN-PV 1940/J (62 mm) (Nelson and Madsen, 1983). The femur from Rio Grande do Sul is shorter than that of *Arctodus* (Table 7). The neck of the femur is more cranially projected, and the lesser trochanter is less prominent than that of the North American taxon. In *Arctodus* the intertrochanteric ridge does not appear to connect the greater and lesser trochanter, which happens in the fossil from Rio Grande do Sul (Merriam and Stock, 1925; Nelson and Madsen, 1983).

Comparisons with *Tremarctos* showed that the height of the spinous processes in the fossil lumbar vertebrae is lower. The shapes of the zygapophyses are different: rectangular in MCN-PV 1940 A-F and slightly triangular in the extant tremarctine. The transverse process is more cranially tilted. The sacrum has a general configuration similar to the male *T. ornatus*. The acromion has a straight lateral margin, in contrast to the curved outline of *Tremarctos*. The glenoid cavity appears to be more elongated than in *Tremarctos*, especially when compared to *T. floridanus* (Kurtén, 1996). In both humeri, the pectoral and deltoid crests converge, but *Tremarctos* presents an auxiliary crest in the middle, absent in the material from Passo do Juquiry. The fossil has clearly separated coronoid and radial fossae, whereas in *Tremarctos* they are coalesced together. The lateral supracondylar ridge is different: it has a similar curved outline in *T. ornatus*, but it lacks the ventral depression found in MCN-PV 1940/H. In *T. floridanus*, this ridge is completely straight. The mediodorsal extremity of the trochlea is more pronounced than the capitulum, as it is in *T. ornatus*. In *T. floridanus* the reverse is true (Winge, 1895 plate VII, Kurtén, 1996; Cartelle, 1998). The body of the ilium in MCN-PV 1940/J is proportionally shorter than that of *T. ornatus*. Consequently, the iliopectineal line is continuous from the iliopectineal eminence in the fossil, while they are separated in the extant tremarctine. The diameter of the acetabulum is quite large (62 mm), surpassing the male *T. ornatus* (22 mm). The strong cranial projection of the neck of the femur present in the fossil seems to be a feature affected by individual variation in *Tremarctos* (Kurtén, 1996, Fig. 47). Due to the lack of most of the greater trochanter, the trochanteric fossa in our material appears to be shallow, while in *Tremarctos* it is deep. The preserved part of the intertrochanteric crest in the material from Passo do Juquiry shows that it connected the greater and lesser trochanter. This was not observed in *Tremarctos*. The third trochanter is absent in our material, but the surface where it would be located is flat. This same

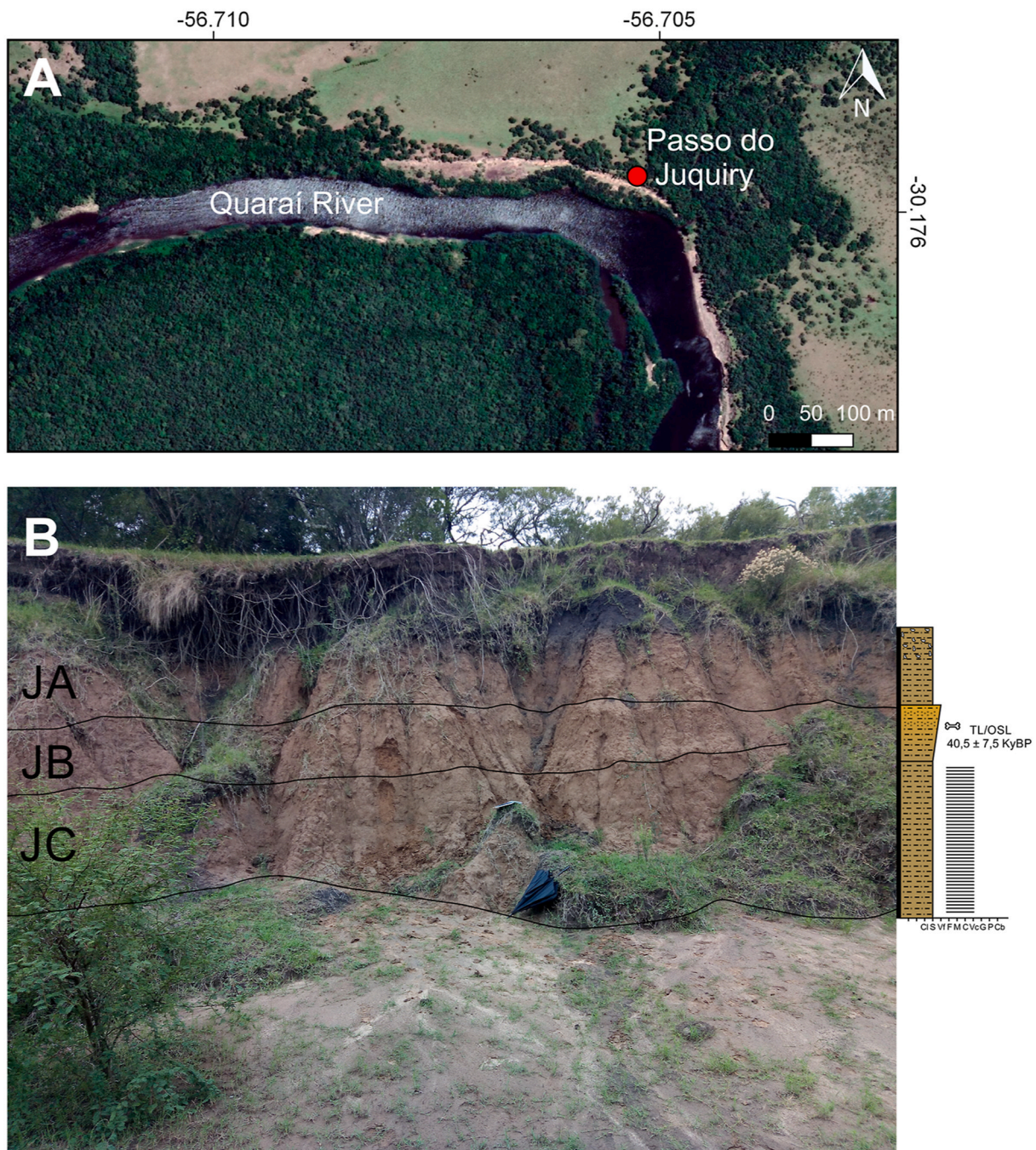


Fig. 5. A, Satellite view of the Passo do Juquiry outcrop; B, General view of the studied outcrop, outlining the different layers and their contact surfaces; JA, laminated mudstone; JB, massive mudstone; JC, mudstone with carbonate nodules. Umbrella for scale (70 cm).

Table 4

Radiation dose rate, accumulated dose and age results obtained through optically stimulated luminescence using quartz on sediments from Passo do Juquiry.

Sample	Radiation dose rate (μGy/year)	Accumulated doseOSL (Gy)	OSL age
2989	894 ± 123	36.2	40,500 ± 7500

structure is remarkably prominent in *Tremarctos*.

When compared to *Arctotherium*, we observed that the height of the spinous processes in the lumbar vertebrae and the rectangular outline of the zygapophyses is very similar to that of *A. bonariense*. The converging

Table 5

Radioactive isotope concentration of ²³²Th, ²³⁸U + ²³⁵U, ⁴K, used to calculate Radiation dose rate.

Sample	Th (ppm)	U (ppm)	K (%)
2989	3.792 ± 0.135	1.594 ± 0.436	0 ± 0

pectoral and deltoid crests can also be observed in the humerus of *A. wingei*, which presents an auxiliary crest in the middle, absent in the fossil from Passo do Juquiry. Those crests do not converge in most *A. angustidens* humeri (MACN 5132 being the exception), and only some present the auxiliary crest. The radial and coronoid fossae are clearly separated in both MCN-PV 1940/H and *Arctotherium*. The outline of the

Table 6

Comparisons between measurements, in millimeters, of MCN-PV 1940/I (humerus) with those of Tremactinae. N = number of individuals measured; HGL = humerus greatest length; HMSW = humerus mid-shaft width; HGVW = humerus greatest ventral width; GWVC = greatest width of the ventral condyle. *A. simus* data obtained in Merriam and Stock (1925) and Kurtén (1967); *Tremarctos* data in Kurtén (1996), Soibelzon and Tarantini (2009) and based on MCN-D 338 and MCN-D 536; *A. angustidens* data in Soibelzon and Tarantini (2009) and Soibelzon and Schubert (2011); *A. wingei* data in Kurtén (1967) and Cartelle (1998) and *Arctotherium* sp. data in Soibelzon and Tarantini (2009).

	HGL	HMSW	HGVW	GWVC
MCN-PV 1940/I	412 ^a	40	131	95
<i>Arctodus simus</i>	438-633; N = 10	39.6–64; N = 12	113.5–178; N = 10	88-130; N = 12
<i>Tremarctos floridanus</i>	334-430; N = 7	27.2–46; N = 9	89-128; N = 9	63-86; N = 9
<i>Tremarctos ornatus</i>	215-274; N = 7	13.2–26; N = 7	51–84.7; N = 7	39.1–53.3; N = 6
<i>Arctotherium angustidens</i>	476-620; N = 5	47.9–90; N = 5	134-205; N = 6	–
<i>Arctotherium bonariense</i>	249-270; N = 2	23–24.1; N = 2	64-65; N = 2	47; N = 1
<i>Arctotherium wingei</i>	–	–	127; N = 1	–

^a Lacking the dorsal portion.

Table 7

Comparisons between measurements, in millimeters, of MCN-PV 1940/K (femur) with those of Tremarctinae. N = number of individuals measured; FGL = femur greatest length; D = dorsoventral diameter of the head; GDW = greatest dorsal width; FMSW = femur mid-shaft width. *A. simus* data obtained in Merriam e Stock (1925), Kurtén (1967) and Nelson and Madsen (1983); *Tremarctos* data in Kurtén (1996), Soibelzon and Tarantini (2009) and based on MCN-D 338 and MCN-D 536; *A. angustidens* data in Soibelzon and Tarantini (2009) and Soibelzon and Schubert (2011); *A. bonariense*, *A. tarijense* and *Arctotherium* sp. data in Soibelzon and Tarantini (2009) and *A. wingei* data in Cartelle (1998).

	FGL	D	GDW	FMSW
MCN-PV 1940/K	466	39	111	43.6
<i>Arctodus simus</i>	501.8–723; N = 16	61-77; N = 13	122-191; N = 12	41.3–64; N = 16
<i>Tremarctos floridanus</i>	355-451; N = 9	43.7–58.2; N = 10	87-118; N = 10	32.6–43.7; N = 10
<i>Tremarctos ornatus</i>	230-310.5; N = 7	28.2–35.3; N = 6	56.4–70.6; N = 6	16.4–28.2; N = 6
<i>Arctotherium angustidens</i>	471-655; N = 3	–	–	–
<i>Arctotherium bonariense</i>	443; N = 1	–	–	–
<i>Arctotherium tarijense</i>	441; N = 1	–	–	–
<i>Arctotherium wingei</i>	287; N = 1	–	60; N = 1	25; N = 1
<i>Arctotherium</i> sp.	490; N = 1	–	–	–

lateral supracondylar ridge in the material from Rio Grande do Sul is most similar to that of *A. angustidens*, only more pronounced. This same structure lacks the ventral depression in the smaller species (*A. wingei*). The trochlea is more mediodorsally pronounced than the capitulum in MCN-PV 1940/H, and the same is true for *Arctotherium*. The diameter of the acetabulum (62 mm) is greater than that of *A. bonariense* (53 mm). The steep cranial projection of the neck of the femur observed in MCN-PV 1940/K is similar to that of *A. angustidens* and *A. wingei*. Femora from *A. bonariense* and *A. tarijense* show a weaker cranial projection. Still, as only one femur for each of these two species is known, we cannot rule out the possibility of this being a feature affected by individual variation in *Arctotherium*. While the material from Passo do Juquiry presents a shallow trochanteric fossa (once again, most likely due to the missing greater trochanter), in *Arctotherium*, the trochanteric fossa is frequently quite deep, being somewhat narrower in *A. angustidens* and *A. tarijense*. The intertrochanteric crest connecting the regions of the greater and lesser trochanter is a feature present in both MCN-PV 1940/K and *Arctotherium*. In our fossil, the only feature found in the region of the third trochanter is a flat surface. This same structure is quite conspicuous in *A. bonariense* and *A. tarijense*, while it is more discreet in *A. angustidens* and *A. wingei*. In *Arctotherium*, however, this structure seems to consistently present a flat surface, similar to what is observed in MCN-PV 1940/K, only more prominent.

Taphonomic features present in the fossils include a series of burrows and hollow structures on their surface. Lopes (2009) studied these structures on MCN-PV 1940/A–F (lumbar vertebrae) and MCN-PV 1940/H (humerus) and interpreted them as a *post-mortem* product of insect activities, probably by Coleoptera larvae. This same author also identified root casts in these fossils. The presence of articulated vertebrae in the fossil ensemble tends to preclude redeposition, meaning that the material is arguably contemporary to the depositional process and did not go through significant fluvial transportation (Voorhies, 1969;

Behrensmeier, 1975). The fossils also appear to have been deformed by compression during fossilization, something especially visible in the long bones which appear to be craniocaudally flattened, a feature that might slightly overestimate width measurements. This deformation may be the reason why some structures that were expected to be present in the bones, such as the third trochanter in the femur, are not visible, despite indications of their presence (in the case of the third trochanter, a flat surface in its place) and no signs of fracturing.

Considering that the Passo do Juquiry material presents characteristics such as rectangular zygopophyses, clearly separated radial and coronoid fossae, and the intertrochanteric crest connecting the greater and lesser trochanters, absent in *Tremarctos* (the latter also absent in *Arctodus*) and present in *Arctotherium*, we opted to attribute it to the latter genus.

The individual represented by these fossils was probably juvenile, as some epiphyses are still not fused in the lumbar vertebrae and the distal epiphysis of the femur seems to be absent (Weinstock, 2009). This causes its measurements to be underestimated (Tables 6 and 7). The sexual dimorphism present in Ursidae must also be considered when concerning sizes. In *Tremarctos ornatus*, males can be 1/3 larger than females (García-Rangel, 2012). Soibelzon (2002) identified that *Arctotherium* canine teeth are generally 8% larger in males. Comparison with both male and female *Tremarctos* humeri showed more similarities between MCN-PV 1940/K and the male humerus in the way the crests are projected. These structures are more developed in males due to the larger size and weight (especially so in a very sexually dimorphic group such as Ursidae), which in turn lead to proportionally larger muscles and stronger bony attachments (Ruscillo, 2000). However, the *Arctotherium* material used for comparison does not have its gender identified. As such, we cannot make a definite assessment about the gender of the individual represented by the Passo do Juquiry fossils.

The measurements of MCN-PV 1940/H and MCN-PV 1940/K

indicate that it probably belongs to a different species than the one known for Brazil, *A. wingei*. The femur (the most complete fossil from those studied) of MCN-PV 1940/K is approximately 60% longer (Table 7), despite the possible absence of the distal epiphysis. This difference is greater than the one expected due to sexual dimorphism in *Tremarctos* (about 30%). The length of the femur from Rio Grande do Sul is most similar to that of *A. bonariense* and *A. tarijense* (Table 7).

Body mass estimates based on allometric equations resulted in values between 336.59 kg and 555.20 kg (Tables 2 and 3). Following the example of Soibelzon and Schubert (2011), we consider the total mean and median values (437.80 kg and 445.89 kg, respectively) to be the most likely estimates for the mass of the studied individual. We also consider equation H1 a very reliable size predictor, as it correctly estimated the mass of both *T. ornatus* and *A. angustidens*, which stand at the opposite ends of tremarctine size (Soibelzon and Tarantini, 2009) and predicted a value extremely close to the mean for our fossil. Equations F1 and H2 also reached similar results.

The distinction between *Arctotherium* species is based on cranial features (Soibelzon, 2002, 2004). Postcranial samples from the different species are too scarce to establish new diagnostic features (especially for the medium-large species *A. bonariense*, *A. vetustum* and *A. tarijense*). Therefore, we cannot make a specific attribution for MCN-PV 1940 on morphological grounds, and attributed it to *Arctotherium* sp. However, comparing the upper mass limits estimated by Soibelzon and Tarantini (2009) for the *Arctotherium* species (*A. wingei* 150 kg; *A. vetustum* 300 kg; *A. tarijense* 400 kg; *A. bonariense* 500 kg; *A. angustidens* 1200 kg), with the body mass estimates for the studied material varying from 336.59 kg to 555.20 kg (Tables 2 and 3), they show a greater similarity to the values expected for *A. tarijense* and *A. bonariense*. The size of MCN-PV 1940 is also quite similar to that of these two species (Table 7) and both of them have a Bonaerian-Lujanian Stages/Ages distribution (Soibelzon et al., 2005), consistent with the OSL age from Passo do Juquiry. *Arctotherium tarijense* and *Arctotherium* cf. *bonariense* are also known for the Sopas Formation of Uruguay (Manzuetti, 2022), to which the deposits of the Quaraí river are correlated.

5.2. Stratigraphy and chronology

The *Arctotherium* material from Rio Grande do Sul is the only one in Brazil coming from fluvial deposits, with other fossils attributed to the genus coming from caves or fossil tank (Lund, 1841; Walter, 1940; Paula-Couto, 1960; Trajano and Ferrarezi, 1994; Guérin et al., 1996; Cartelle, 1998; Porpino et al., 2004; Rodrigues et al., 2014; De Oliveira et al., 2017). Defining an accurate stratigraphic framework in fluvial deposit outcrops is simpler than in caves since they consist mainly of vertically stacked clastic lithofacies organized according to fluvial architecture. In contrast, cave deposits are extremely diverse, with sediments of various origins accumulating simultaneously in a same layer (Collinson, 1996; Farrand, 2001; Miall, 2006).

Only one kind of architectural element (*sensu* Miall, 2010) was identified to be represented by the facies from Passo do Juquiry: a floodplain fines facies association (FF). The transition from F1 to Fm facies indicates a transition from deposition through both weak traction currents and suspension to one purely through suspension. The P facies-bearing upper level is indicative of semiarid climate and of exposure to weathering of the floodplain, allowing the formation of carbonate nodules, which result from pedogenic processes occurring in floodplains when exposed to weathering by seasonal or long-term drying (Miall, 2006).

In contrast, Cerro da Tapera, another fossiliferous outcrop on the banks of the Quaraí River, presents a higher diversity of facies. The outcrop is characterized by a succession of intercalating sandstone and mudstone, typical of a lateral accretion facies association, with the top-most layer presenting mudstone with carbonate nodules similar to that of the floodplain fines from Passo do Juquiry. TL dating of sediments from Cerro da Tapera resulted in ages of $11,000 \pm 2000$ years BP and

$13,000 \pm 2150$ years BP (Ribeiro et al., 2008, 2009; Pitana, 2011).

Floodplain fines and lateral accretion facies associations have also been found in outcrops of the Touro Passo River, on the basis of which the Touro Passo Formation was defined (Bombin, 1976). Brazilian authors have attributed outcrops from the Quaraí River to this formation (Da-Rosa, 2007, 2009; Oliveira and Kerber, 2009). The FF element facies are recognized in the Barranca Grande outcrop and represented by levels of massive mudstones with carbonate nodule-rich paleosol horizons on top (Fm and P facies). They present an abundant content of well-preserved fossil vertebrates (Oliveira and Kerber, 2009; Kerber et al., 2014a).

For the Sopas Formation, lithologically and biostratigraphically correlated to the Touro Passo Formation and in which the Uruguayan outcrops of the Quaraí River are included, three typologies of facies were identified: a conglomeratic facies, a sandstone facies and a mudstone facies. The mudstone facies are described as mudstones with granules spread through the matrix, traction structures and carbonate nodules and duricrust accompanied by rhyzoconcretions on top (Fm facies), similar to those of the FF facies association of Passo do Juquiry. These mudstones are also rich in vertebrate fossil content (Ubilla et al., 2004; Ubilla and Martínez, 2016).

The Toropí/Yupoí Formation, correlated to both the Touro Passo and Sopas formations (Oliveira and Kerber, 2009; Francia et al., 2012; Kerber et al., 2014a), like Passo do Juquiry, presents only fine sedimentary facies (very fine sand + siltstone + claystone) (Herbst, 1971; Iriondo, 2010). It consists of an inferior member of mudstone with horizontal lamination and sparse carbonate nodules (F1 facies) and a superior member of massive mudstone with rhyzoconcretions and cylindrical bioturbations (Fr facies). Fossil vertebrates can be found in both members (Francia et al., 2019). The facies association of the Toropí/Yupoí formation was interpreted by Erra et al. (2013) as representing a floodplain environment (FF architectural element) and by Iriondo (2010) as one of abandoned channel fill (CH(FF) architectural element). Both these architectural elements are composed by fine lithofacies deposited in the surroundings of a fluvial channel.

By comparing the stratigraphic framework of Passo do Juquiry with those of Cerro da Tapera, the Touro Passo River, Sopas Formation, and Toropí/Yupoí Formation, it is possible to establish lithological correlations between the similar levels (Fig. 6). The FF facies from Passo do Juquiry can be clearly correlated to the uppermost layer of Cerro da Tapera, to the floodplain facies of the Barranca Grande outcrop, to the mudstone facies of the Sopas Formation, and to both members of the Toropí/Yupoí Formation. These mudstone successions present levels with carbonate nodules, occasional rhyzoconcretions, and abundance of vertebrate fossils. They also overlie lateral accretion facies when those are present (Ribeiro et al., 2008; Oliveira and Kerber, 2009; Ubilla and Martínez, 2016; Francia et al., 2019). This reinforces the proposed correlation between the three formations by previous authors (e.g., Da-Rosa, 2003, 2007, 2009; Oliveira and Kerber, 2009; Ubilla and Martínez, 2016).

However, absolute ages indicate that lithologically correlated facies are not necessarily contemporaneous (Fig. 6), only that they originated from the same types of fluvial dynamic processes. Floodplain facies in Passo do Juquiry and in the Toropí/Yupoí Formation have relatively close ages ($40,500 \pm 7500$ years BP and $56,000\text{--}36,000$ years BP, respectively). In contrast, the same facies association in the Barranca Grande and Cerro da Tapera outcrops is quite more recent ($10,810 \pm 275\text{--}9903 \pm 3510$ years BP and $<11,000 \pm 2000$ years BP, respectively) (Ribeiro et al., 2008; Francia et al., 2015; Vidal, 2019). This shows that the evolution of fluvial deposits in the Uruguay River basin region during the Late Pleistocene followed a typical pattern, but it did not happen simultaneously. To clearly reconstruct the changes in fluvial dynamic with time, a larger body of data and a sequence stratigraphy approach are needed.

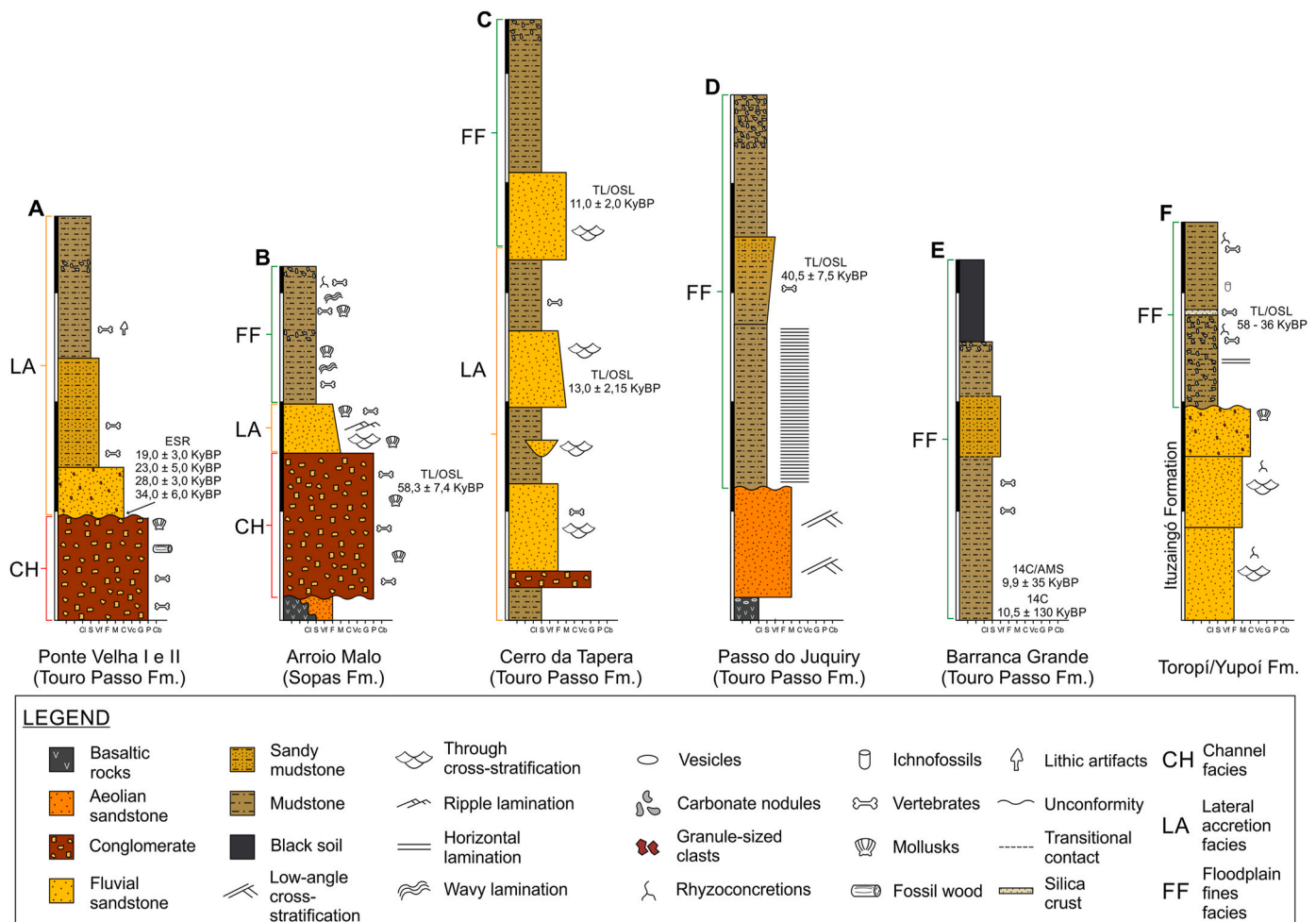


Fig. 6. Correlation diagram between the stratigraphic columns of different outcrops of the Touro Passo Formation, Sopas Formation and Toropí/Yupoi Formation. A and E adapted from Oliveira and Kerber (2009); B adapted from Ubilla et al. (2004); C adapted from Pitana (2011); D this work; F adapted from Zacarias et al. (2013).

5.3. Paleoclimate and paleoenvironments

The presence of rhyzoconcretions in floodplain facies indicates a moment of colonization by plants and represents soil development in a humid climate (Miall, 2006; Nichols, 2009). The absence of rhyzoconcretions in Passo do Juquiry and the occurrence of both the discrete carbonate levels in the JC layer and the carbonate nodules in the JA layer indicated a largely arid climate for the region during the Late Pleistocene. Such a climate would favor the quick evaporation of water after flooding and expose sediments to weathering, favoring the chemical reactions responsible for carbonate paleosol generation, and preventing the formation of forest vegetation with expressive roots (Sobecki and Wilding, 1983; Guo and Fedoroff, 1990; Li et al., 2018). The JB layer, which does not present carbonate concretions, would represent a moment of more humid climate at the time of its deposition (circa 40,000 years BP), between the two more arid periods.

The alternation between colder, drier climate pulses and more humid pulses during the Late Pleistocene has also been recognized in other deposits of the Uruguay River basin region (Carlini et al., 2004; Ubilla et al., 2004; Francia et al., 2012, 2019). Paleoenvironmental hypotheses based on fossil content for the Touro Passo, Sopas, and Toropí/Yupoi formations tend to indicate a predominance of open field vegetation, with arboreal vegetation present as gallery forests (e.g., Ubilla et al., 2004; Oliveira and Kerber, 2009; Erra et al., 2013; Ubilla et al., 2016). Recent paleoenvironmental studies in the nearby region of northern

Uruguay, covering ages between 50–30 ky BP, indicated that the environment was one of open canopy forests, like forested savannahs or semi-open woodlands (Morosi and Ubilla, 2017, 2019).

6. Conclusion

MCN-PV 1940 presents typical ursid characteristics, such as the lateromedially aligned and only slightly arched trochlea and capitulum, the larger medial epicondyle compared to the lateral in the humerus, and the pronounced lateral supracondylar ridge. The morphology and orientation of the processes of the lumbar vertebrae are also ursid-like. The entepicondylar foramen in the humerus indicates it belongs to the Tremarctinae subfamily. Comparison with the North American tremarctine genus *Arctodus* and both South American tremarctine genera *Tremarctos* and *Arctotherium* showed that MCN-PV 1940 presents a stronger similarity to *Arctotherium* (larger size, rectangular zygapophyses, clearly separated radial and coronoid fossae, and intertrochanteric crest connecting the greater and lesser trochanters). The possible absence of the distal epiphysis of the femur and the presence of some still-not-fused epiphyses in the lumbar vertebrae indicate that it represents a juvenile individual. Yet, it still surpasses the dimensions of *A. wingei*, the only species of *Arctotherium* confirmed for Brazil. While its size is similar to *A. bonariense* and *A. tarijense* and smaller than *A. angustidens*, it was impossible to define the species on a morphological basis, as the diagnostic features are cranial. Therefore, we attributed

MCN-PV 1940 to *Arctotherium* sp.

Body mass estimates through allometric equations show that the studied individual likely weighed between 437.80 kg and 445.89 kg, with equations F1, H1, and H2 being the most reliable body size predictors. With its size, MCN-PV 1940 seems to represent the largest known ursid for Brazil. These estimates also show a greater similarity to the *Arctotherium tarijense* and *Arctotherium bonariense* species, who are the ones expected to typically reach masses between 400 and 500 kg. Powerful crests in the humerus indicate the individual was probably male.

The Passo do Juquiry outcrop's stratigraphic framework is composed by three layers configuring a floodplain fines facies association, characterized by carbonate-rich levels on the top and bottom layers and lack of rhyzoconcretions. The middle layer was dated through the OSL method and resulted in an age of $40,500 \pm 7500$ years BP. This facies association is also found in other Pleistocene fluvial deposits of the Quaraí River, such as Cerro da Tapera, and in the Touro Passo River outcrops, part of the Touro Passo Formation. They also possess correspondents in their correlated formations, the Sopas Formation from Uruguay, and the Toropí/Yupofí Formation from Argentina. While it is possible to establish lithological correlations between the facies of Passo do Juquiry, Cerro da Tapera, and the three geologic formations, absolute ages show that their origin was not contemporaneous, indicating that while the evolution of fluvial deposits in the Uruguay River basin region during the Late Pleistocene followed a clear pattern, it did not happen simultaneously. Finally, the sediments of Passo do Juquiry indicated the presence of two distinct periods of arid climate separated by a period of increased humidity at circa 40,500 years BP.

Author contributions

Alexsander Trevisan: Conceptualization, Investigation, Writing - Original Draft, Visualization, Project Administration, Funding Acquisition. **Ana Maria Ribeiro:** Validation, Resources, Writing - Review & Editing, Funding Acquisition. **Átila Augusto Stock Da-Rosa:** Investigation, Writing - Review & Editing, Funding Acquisition. **Patrícia Hadler:** Validation, Resources, Writing - Review & Editing, Supervision.

Data availability

Datasets related to this article can be found in [Tables 1-7](#) and [Appendices A-C](#).

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Supplementary data

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