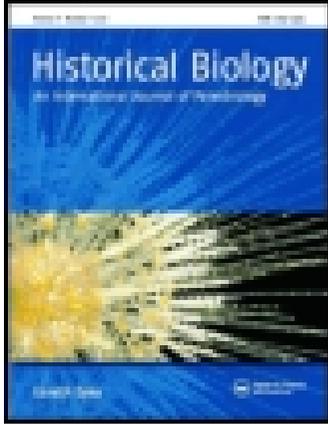


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### The femoral anatomy of *Pampadromaeus barberenai* based on a new specimen from the Upper Triassic of Brazil

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## The femoral anatomy of *Pampadromaeus barberenai* based on a new specimen from the Upper Triassic of Brazil

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Femora of the holotype and only previously known specimen of the early sauropodomorph *Pampadromaeus barberenai* are incomplete and fractured. Here, we describe a new complete femur assigned to *Pampadromaeus barberenai*, quarried from the same outcrop of original type specimen: 'Janner' site, (Carnian of the Paraná Basin). It shares with the holotype of *Pampadromaeus barberenai* a unique combination of features: anteromedial tuber slightly posteromedially displaced; lesser trochanter proximodistally oriented with the proximal tip gently connected to the femoral shaft; fourth trochanter located on the medial margin along the mediolateral axis of the femur and with an assymetrical outline. In addition, we propose a femoral autapomorphy for *Pampadromaeus barberenai*: lateral condyle of the distal end of the femur extremely reduced lateromedially. Two distinct phylogenetic analyses place the new specimen as the sister-group of the *Pampadromaeus barberenai* type-specimen and, in one of them, they are nested within Sauropodomorpha, corroborating the original description and taxonomic assignment.

**Keywords:** early dinosaur; Saurischia; Sauropodomorpha; Santa Maria Formation; Carnian; Brazil

### 1. Introduction

Triassic strata from South America provide the oldest worldwide unambiguous dinosaur record (Martínez et al. 2011). These come from the Carnian of the Ischigualasto Formation of northwest Argentina (Reig 1963; Sereno et al. 1993; Ezcurra 2010; Martínez et al. 2011) and Santa Maria Formation, southern Brazil (Colbert 1970; Langer et al. 1999; Cabreira et al. 2011). Besides the South American record, few dinosaurs with probable similar age were also documented from Africa and India (Chatterjee 1987; Raath 1996). Yet, the Carnian South American record is far more extensive, with at least ten already described species (Ezcurra 2012). This taxonomic improvement took place mainly in the last five years, with the description of four new species from the Ischigualasto Formation (Martínez and Alcober 2009; Alcober and Martínez 2010; Ezcurra 2010; Martínez et al. 2011) and one from the Santa Maria Formation (Cabreira et al. 2011).

These findings enhance the knowledge on early dinosaur anatomy, particularly on the femoral morphology. The femur provides crucial data (e.g. complex combination of unusual trochanters and soft tissue attachments, see Hutchinson 2001) for Dinosauriformes taxonomy. Such features evolved in response to significant postural changes during the evolutionary history of the avemetatarsalians (Carrano 2000; Hutchinson 2001). Accordingly, all dinosaur-related groups possess, to some extent, diagnostic

features related to femoral morphology (Nesbitt 2011) that allowed the establishment of several alternative cladistic hypothesis for these animals (e.g. Novas 1996; Langer and Benton 2006; Brusatte et al. 2010; Nesbitt 2011).

In general, the femoral morphology of early dinosaurs is marked by a sigmoid outline, an offset femoral head forming an angle of about 45° with the distal condyles, a concave emargination ventral to the femoral head and a reduced posteromedial tuber (Novas 1996; Langer and Benton 2006; Nesbitt 2011). Although that bone has been recovered for most species, it is not always complete or well-preserved. Often, it loses its original shape due to taphonomic processes; sometimes the articulations are either poorly or not preserved and, in other cases, the femur is not available in all views. Among Carnian dinosaurs, *Panphagia* is the only South American species which lacks a femur altogether (Martínez and Alcober 2009).

Among the Brazilian species, only the sauropodomorph *Saturnalia tupiniquim* (Langer et al. 1999) has complete and well-preserved femora (Langer 2003). The herrerasaurid *Staurikosaurus pricei* (Colbert 1970) comprises a single specimen (MCZ 1669) with both partially complete but badly preserved femora. On the contrary, the femur of the holotype (ULBRA-PVT016) of the sauropodomorph *Pampadromaeus barberenai* (Cabreira et al. 2011) has a well-preserved bone surface, but it is fractured and incomplete.

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Considering the potential of the femur in a phylogenetic context and the scarcity of early dinosaur remains, here we describe a complete femur from the Santa Maria Formation, tentatively assigned to *Pampadromaeus barberenai*. Its anatomy is compared with those of coeval taxa and new information on the femoral morphology of early dinosaurs is provided.

### 1.1 Institutional abbreviations

Centro de Apoio a Pesquisa Paleontológica, São João do Polêsine, Brazil (CAPPA/UFSM); Museu de Ciências Naturais, Universidade Luterana do Brasil, Canoas, Brazil (ULBRA); Museu de Ciências e Tecnologia PUCRS, Porto Alegre, Brazil (MCP); Museum of Comparative Zoology, Cambridge, USA (MCZ).

## 2. Systematic palaeontology

**Dinosauriformes** Novas, 1992

**Dinosauria** Owen, 1842

**Saurischia** Seeley, 1887

**Sauropodomorpha** von Huene, 1932

cf. *Pampadromaeus barberenai* Cabreira, Schultz, Bittencourt, Soares, Fortier, Silva and Langer, 2011

### 2.1 Referred specimen

CAPPA/UFSM 0027, complete left femur with about 142 mm in length.

### 2.2 Locality and horizon

‘Janner’ outcrop, at the municipality of Agudo, Rio Grande do Sul state, southern Brazil (see Figure 1 of Cabreira et al. 2011). This fossiliferous locality is part of the Santa Maria Formation (*sensu* Andreis et al. 1980) of the Paraná Basin and belongs to the Santa Maria 2 Sequence of Zerbini et al. (2003), where non-laminated to finely laminated reddish mudstones predominate. The Carnian age of the ‘Janner’ outcrop relies on biostratigraphic correlations with the Ischigualasto Formation, based on the genera *Hyperodapedon* and *Exaeretodon* (Langer et al. 2007). This Argentinean unit was recently radioisotopically dated as  $231.4 \pm 0.3$  Ma (Martínez et al. 2011). Besides these two genera, the vertebrate fauna of the ‘Janner’ outcrop also comprises the ecteniniid cynodont *Trucidocynodon riograndensis* (Oliveira et al. 2010), the early dinosaur *Pampadromaeus barberenai*, and indeterminate dinosauriforms (Müller et al. 2014; Pretto et al. Forthcoming).

### 2.3 Amended diagnosis

In addition to the unique traits of *Pampadromaeus barberenai* listed by Cabreira et al. (2011), we add a

possible autapomorphy of the taxon based on the study of CAPPA/UFSM 0027: a distal femur with the lateral condyle lateromedially narrow.

### 2.4 Description and comparison

In spite of the overall good preservation of the specimen, the anterolateral surface of the shaft, between the cranial and caudolateral intermuscular lines (*sensu* Langer 2003), is crushed. As in most early dinosaurs, the femur is sigmoid, both in anterior and lateral views (Figure 1), but differs from that of *Sacisaurus agudoensis* (Ferigolo and Langer 2007) and sauropodiform sauropodomorphs (Otero and Pol 2013) such as *Mussaurus patagonicus* (Bonaparte and Vince 1979) and *Antetonitrus ingenipes* (Yates and Kitching 2003) where the femur is sigmoid only in lateral view.

The offset femoral head forms an angle of about of 45° with the intercondylar line. The proximal end is kidney-shaped, typical of early dinosaurs (Figure 1(C)). The proximal articulation has a straight transverse groove. In basal theropods, such as *Tawa hallae* (Nesbitt et al. 2009) and *Coelophysus bauri* (Cope 1889), this groove is curved (Nesbitt et al. 2009), whereas in the herrerasaurids *Herrerasaurus ischigualastensis* (Reig 1963) and *Sanjuansaurus gordilloi* (Alcober and Martínez 2010) there is no sign of a groove in this region (Novas 1994; Alcober and Martínez 2010) and a conspicuous straight groove is present in *Staurikosaurus pricei* (Bittencourt and Kellner 2009). A ventrally descended ‘facies articularis antitrochanterica’ (*sensu* Langer 2003) is present on the posterolateral portion of the head. This corresponds to the ‘posterolateral depression’ that Novas (1996) considers a diagnostic feature of Dinosauriformes. On the contrary, Nesbitt (2011) notes that the anterolateral and posterolateral sides of the proximal surface of the femoral head possess the same height in saurischians, lacking a ventrally descended ‘facies articularis antitrochanterica’ (Nesbitt 2011).

In proximal view, the anteromedial tuber is more pronounced than in *Staurikosaurus pricei* (Figure 2(D)), but not offset medially relative to the posteromedial tuber, as in neotheropods (Nesbitt 2011). Indeed, the area between the anteromedial and posteromedial tubers (Figure 2(A)) is reduced, what reduces the size of the femoral head in anterior view. This condition resembles that of the holotype of *Pampadromaeus barberenai*, whereas in *Saturnalia tupiniquim* the posteromedial tuber is located exactly at the mid-point of the posterior edge of the femoral head (Figure 2(B)). Such configuration creates a wider ‘sulcus for the ligamentum capitis femoris’ in *Saturnalia tupiniquim*, which is narrow in CAPPA/UFSM 0027 and ULBRA-PVT016 (Figure 2). This morphology is present in both femora of the holotype of *Saturnalia tupiniquim* (MCP 3944-PV), so this is probably not a taphonomic deformation. The small (lateromedially)

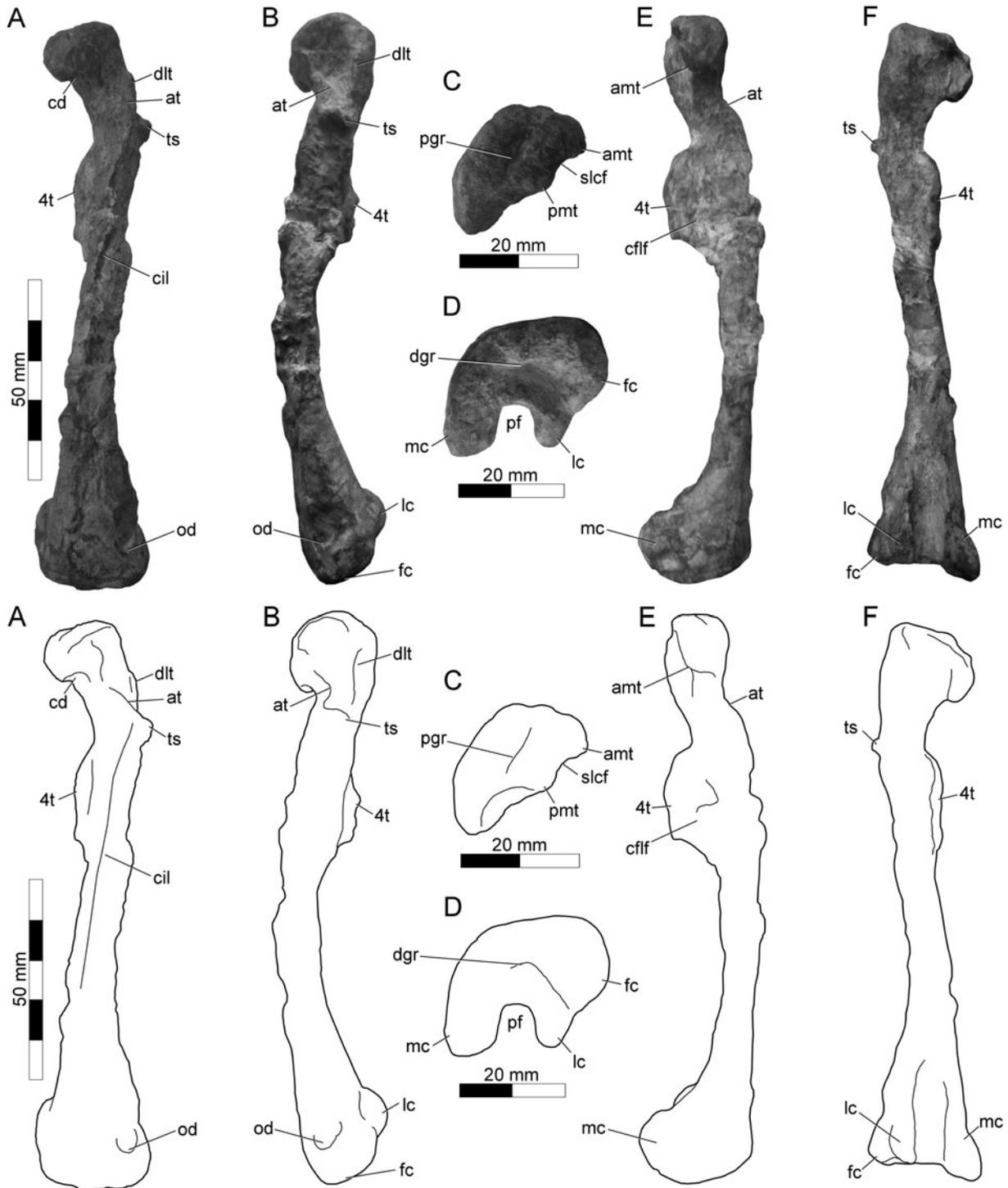


Figure 1. CAPP/UFMS 0027, a left femur in: (A) anterior; (B) lateral; (C) proximal; (D) distal; (E) medial; and (F) caudal views. *Abbreviations:* 4t, fourth trochanter; at, anterior trochanter; amt, anteromedial tuber; cd, concave depression; cflf, fossa for caudofemoralis longus; cil, cranial intermuscular line; dlt, dorsolateral trochanter; drg, distal groove; fc, fibular condyle; lc, lateral condyle; mc, medial condyle; od, ovoid depression; pf, popliteal fossa; pgr, proximal groove; pmt, posteromedial tuber; slcf, sulcus for ligamentum captis femoris; ts, trochanteric shelf.

femoral head of CAPP/UFMS 0027 also differs from that of herrerasaurids, which have a larger femoral head. Ventral to the femoral head, on the transition to the femoral

shaft, there is a concave depression in CAPP/UFMS 0027 (Figure 1(A)), which is the usual condition among early dinosaurs (Nesbitt, 2011).

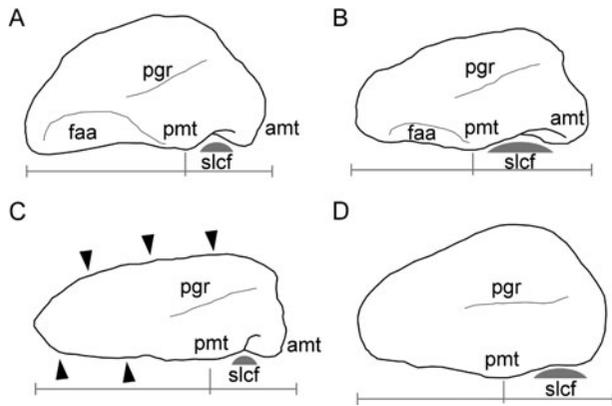


Figure 2. Proximal view of selected dinosaur femora from the Santa Maria Formation: (A) CAPP/UFSM 0027; (B) *Saturnalia tupiniquim*, MCP 3944-PV; (C) *Pampadromaeus barberenai*, ULBRA-PVT016 (arrows indicate sedimentary compaction); (D) *Staurikosaurus pricei*, MCZ 1669 (reversed). Notes: Images not to scale. The perpendicular trace on the line below the drawings corresponds to position of the posteromedial tuber along the posteromedial margin of the femoral head. Abbreviations: amt, anteromedial tuber; faa, facies articularis antitrochanterica; pgr, proximal groove; pmt, posteromedial tuber; slcf, sulcus for ligamentum captis femoris.

The lateral margin of the femoral head bears a proximodistally rugose, elongated and sharp ridge, which corresponds to the dorsolateral trochanter (Figure 3(A)). It resembles that of *Eoraptor lunensis* (Sereno et al. 1993), *Saturikosaurus pricei* and *Eodromaeus murphi* (Martínez et al. 2011), and the holotype of *Pampadromaeus barberenai*, whereas in *Herrerasaurus ischigualastensis* and *Saturnalia tupiniquim* this ridge is rounded (Novas 1994; Langer 2003). However, Nesbitt (2011) notes that a sharp-ridged dorsolateral trochanter occurs in small femora of the silesaurid *Silesaurus opolensis* (Dzik 2003), and a rounded ridge is present in larger specimens, whereas in the dinosaur *Coelophysis bauri* all ontogenetic stages bear a rounded ridge. As such, the value of this structure for early dinosaur taxonomy must be seen with caution.

More medially, still on the lateral surface of the proximal portion of the femur lies the anterior trochanter [sometimes also referred as a ‘lesser trochanter’ (e.g. Langer et al. 2010; Cabreira et al. 2011)] (Figure 3(A)), which corresponds to insertion of either the *Musculus iliofemoralis cranialis* (Rowe 1986) *Musculus ilioprochantericus caudalis* and *puboischiofemoralis internus 2* (Hutchinson 2001). The proximal portion of the anterior trochanter is fully connected to the shaft, as in the holotype of *Pampadromaeus barberenai* (Figure 3(B)) and *Tawa hallae*. In *Saturnalia tupiniquim*, the proximal tip is separated from the shaft by a small cleft (Figure 3(C)) (Langer and Ferigolo 2013), as seen in *Coelophysis bauri* and in some silesaurids (Ezcurra 2006; Langer and Ferigolo 2013). The extreme condition (known as ‘wing-

like’) is present in ornithischians and Jurassic theropods, where the anterior trochanter is well pronounced with a large cleft between its anterior portion and the femoral shaft (Langer and Ferigolo 2013). In contrast, *Staurikosaurus pricei* bears only a rugose surface on the corresponding (Bittencourt and Kellner 2009). CAPP/UFSM 0027 also bears a cranial intermuscular line, which starts from the distal portion of the anterior trochanter and extends along the shaft (Figure 1(A)).

In addition to the cranial intermuscular line, a well-developed trochanteric shelf also extends from the distal portion of the anterior trochanter (Figure 3(A)). According to Hutchinson (2001), the trochanteric shelf is regarded as the insertion point of *M. iliofemoralis externus*. In CAPP/UFSM 0027, the trochanteric shelf reaches the posterolateral corner of the femoral shaft, differently from that of *Chromogisaurus novasi* (Ezcurra 2010), which is shorter and, merges with the shaft before reaching the posterolateral corner (Ezcurra 2010). This structure is present in several dinosauriforms (e.g. Novas 1994;

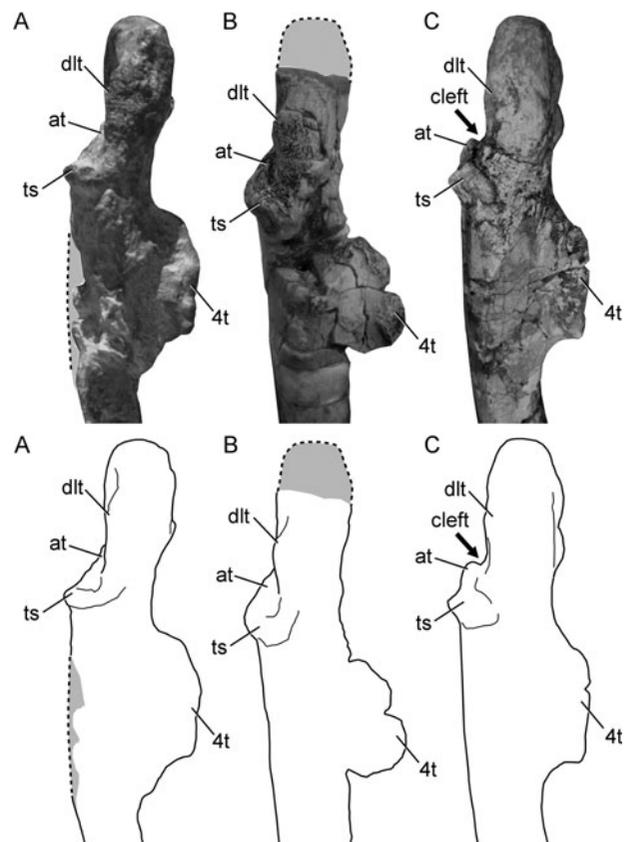


Figure 3. Posterolateral view of selected dinosaur femora from the Santa Maria Formation: (A) CAPP/UFSM 0027; (B) *Pampadromaeus barberenai* ULBRA-PVT016 (reversed to match the other specimens); (C) *Saturnalia tupiniquim*, MCP 3944-PV. Note: Images not to scale. Abbreviations: 4t, fourth trochanter; at, anterior trochanter; dlt, dorsolateral trochanter; ts, trochanteric shelf.

Langer et al. 1999; Ezcurra 2010; Nesbitt et al. 2010; Cabreira et al. 2011; Martínez et al. 2011) and quite common and well-developed in early dinosaurs (e.g. *Saturnalia tupiniquim*, *Eodromaeus murphi*, *Herrerasaurus ischigualastensis*). On the contrary, in *Guaibasaurus candelariensis* (Bonaparte et al. 1999), there is only a faint scarred surface at the area of the trochanteric shelf (Langer et al. 2010) and this is usually absent in ornithischians and derived sauropodomorphs (Langer and Benton 2006).

The sharp-flanged fourth trochanter of CAPP/UFMS 0027 is located on the posterior surface of the proximal half of the femur, on the medial corner of the shaft (Figure 1(F)). As in many basal saurischians, it has an asymmetric outline in lateral or medial views (Langer and Benton 2006), with the distal portion forming a steeper angle to the shaft (Figure 1(E)). This differs from the pendant fourth trochanter of ornithischians (Ezcurra 2012) and from that of all well-known basal theropods, which have a symmetrical outline (Langer and Benton 2006). On the medial surface of the fourth trochanter there is a concavity that probably corresponds to the insertion of the M. caudofemoralis longus (Langer 2003). The distal portion of this concavity is bounded by a faint ridge, as in *Saturnalia tupiniquim* and the holotype of *Pampadromaeus barberenai*. However, in *Sanjuansaurus gordilloi*, a large and rugose protuberance overlaps the corresponding surface of the concavity in the medial aspect of the fourth trochanter (Alcober and Martínez 2010).

In the anterolateral surface of the distal portion of the femur, it is possible to see an ovoid shallow fossa (Figure 1(A),(B)). This resembles that mentioned by Novas (1994) for *Herrerasaurus ischigualastensis*. In addition, Langer (2003) recognises a circular muscle scar at a similar position in *Saturnalia tupiniquim* and suggests that it corresponds to the insertion of an ansa of M. iliofibularis. Also in a similar position, Martínez et al. (2011) describe a 'broad rugose depression' in the distal portion of the femur of *Eodromaeus murphi*. Finally, Sereno et al. (2012) discuss the presence of a 'subtriangular rugose area' on the anterior surface of the distal end of the femur of *Eoraptor lunensis*. Unfortunately, this condition is unknown in the holotype of *Pampadromaeus barberenai*, given the incompleteness of its femur.

As in *Guaibasaurus candelariensis*, the anterior surface of the distal most portion of the femur is flat, differing from the convex surface seen in *Herrerasaurus ischigualastensis*, *Staurikosaurus pricei* and *Saturnalia tupiniquim*. There is no sign of an anterior sulcus intercondylaris, which is difficult to identify in distal view. Although present in more derived forms, the absence of this structure is documented in several early dinosaurs (e.g. Novas 1994; Langer 2003; Sereno et al. 2012). The distal surface of the femur comprises the medial, lateral and fibular condyles (Figure 1(D)). These are posteriorly

divided by a deep popliteal fossa, which excavates the bone deeper than in *Saturnalia pricei* (Figure 4(D)). A deep groove also separates the fibular from the lateral condyle distally. The medial condyle is larger than the lateral, unlike the enlarged crista tibiofibularis of lagerpetids (Langer et al. 2013). Indeed, the lateral condyle is lateromedially narrow, as also found in the holotype of *Pampadromaeus barberenai* (Figure 4(C)). Although *Eoraptor lunensis* also shows a somewhat reduced condyle, it is not as marked as in CAPP/UFMS 0027 and ULBRA-PVT016. These specimens also share a U-shaped rather than V-shaped as in *Eoraptor lunensis*, popliteal fossa in distal view. In addition, the distal margin of the lateral condyle is not pointed as in *Saturnalia tupiniquim* (Figure 4(B)).

### 3. Phylogenetic analysis

To examine the relationship of CAPP/UFMS 0027 within basal dinosaurs, it was scored into two published data-sets. First, the specimen was codified in the data-matrix published by Martínez et al. (2012a), which is mainly modified from Yates (2007), Smith and Pol (2007) and Ezcurra (2010). It includes 51 taxa plus CAPP/UFMS 0027 and 378 characters. An additional character (379) describing the transverse width of the lateral condyle of the femur was incorporated in the data-set (Appendix 1). CAPP/UFMS 0027 was scored for 21 characters (Table 1). The data-matrix was processed with TNT v1.1

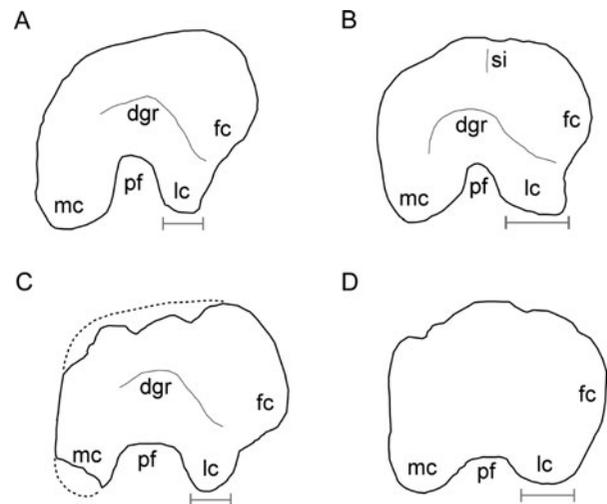


Figure 4. Distal view of selected dinosaur femora of the Santa Maria Formation: (A) CAPP/UFMS 0027; (B) *Saturnalia tupiniquim*, MCP 3944-PV; (C) *Pampadromaeus barberenai*, ULBRA-PVT016; (D) *Staurikosaurus pricei*, MCZ 1669 (reversed). Notes: Images not to scale. The line below the drawings corresponds to lateromedial expansion of the lateral condyle. Abbreviations: dgr, distal groove; fc, fibular condyle; lc, lateral condyle; mc, medial condyle; pf, popliteal fossa; si, sulcus intercondylaris.

Table 1. Codification for CAPP/UFMS 0027 of the 378 characters of Martínez et al. (2012a) and the one new character added here.

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(Goloboff et al. 2008) using ‘traditional search’ mechanism with the following parameters: random seed = 0, random additional sequences = 1000, hold = 20. All characters were equally weighted and unordered. As in the analyses by Ezcurra (2010) and Martínez et al. (2012a), we excluded *Agnosphitys* given its fragmentary condition. Bremer support and bootstrap values (1000 replicates) were also obtained from TNT v1.1 (Goloboff et al. 2008).

The first analysis recovered twenty most parsimonious trees (MPTs) of 1211 steps (Consistence Index = 0.36; Retention Index = 0.69). In all trees, CAPP/UFMS 0027 is nested as the sister-group of the holotype of *Pampadromaeus* (ULBRA-PVT016), within Sauropodomorpha. The node connecting CAPP/UFMS 0027 and ULBRA-PVT016 is supported by two synapomorphies: (i) fourth trochanter positioned in the medial margin along the mediolateral axis of the femur [character 296, state (1)] and (ii) lateromedial reduction of the lateral condyle of the femur [character 379, state (1)]. In the ‘strict consensus tree’ (Figure 5), herrerasaurids form a monophyletic group, but their inner relationships are unresolved. Herrerasauridae is the sister group of Theropoda plus Sauropodomor-

pha. The relationships of derived sauropodomorphs (e.g. *Blikanasaurus*, *Lessemsaurus*, *Antetonitrus* and *Vulcanodon*) are also unresolved, but this is not the focus of this analysis (see McPhee et al. (2014) to this matter). As in Martínez et al. (2012a), *Panphagia* is recovered as the basal most member of Sauropodomorpha, followed by *Eoraptor*, and the clade that includes ULBRA-PVT016 and CAPP/UFMS 0027, which forms the sister group to the clade including *Chromogisaurus*, *Saturnalia*, *Pantydraco*, *Thecodontosaurus* and other Sauropodomorpha. *Saturnalia* and *Chromogisaurus* form the sister clade to *Pantydraco*, *Thecodontosaurus* and other sauropodomorphs. *Guaibasaurus* is nested within Theropoda, corroborating the position recovered by Martínez et al. (2012a), rather than at the sauropodomorph line as for Ezcurra (2010).

The second analysis employed the data-matrix of Bittencourt et al. (2014), which modified the data-set published by Nesbitt (2011). The version of Bittencourt et al. (2014) includes 33 taxa plus 291 characters. As in the first analysis, we added the already mentioned new character, and CAPP/UFMS 0027 was scored for 27 characters (Table 2). The data were processed with TNT v1.1 (Goloboff et al. 2008) following the same parameters of the first analysis (seed = 0, replicates = 1000, hold = 20).

Twenty-seven MPTs of 783 steps were recovered (Consistence Index = 0.43; Retention Index = 0.60), with Bremer support and bootstrap values calculated also with the same parameters of the first analysis. As in that analysis, CAPP/UFMS 0027 is placed as the sister-group of the holotype of *Pampadromaeus* in all trees, but the node connecting CAPP/UFMS 0027 and ULBRA-PVT016 is supported only by one synapomorphy: the lateromedial reduction of the lateral condyle of the femur

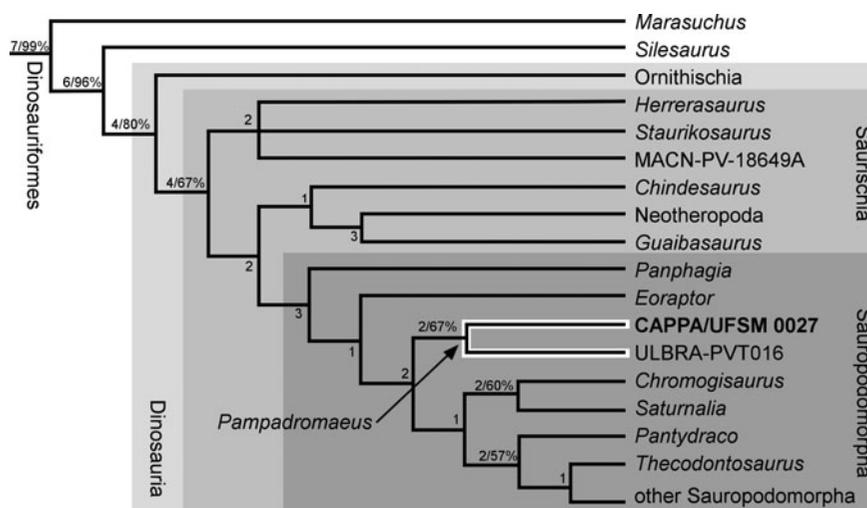


Figure 5. Simplified strict consensus of the 20 most-parsimonious trees depicting the phylogenetic relationships of CAPP/UFMS 0027, based on the data-matrix of Martínez et al. (2012a). Note: Numbers associated with nodes represent Bremer support values and bootstrap values (above 50%).

Table 2. Codification for CAPP/UFMS 0027 of the 291 characters of Bittencourt et al. (2014) and the one new character added here.

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? = missing data.

[character 292, state (1)]. The remaining of the topology is the same as recovered by Bittencourt et al. (2014). Saurischia forms a monophyletic group (Figure 6), but basal saurischian phylogeny is poorly resolved. *Eoraptor*, *Panphagia*, *Guaibasaurus*, *Chromogisaurus* and *Pampadromaeus* (ULBRA-PVT016 plus CAPP/UFMS 0027) form a large polytomy along with the three main saurischian groups (Herrerasauridae, Theropoda and Sauropodomorpha). Herrerasauridae is composed of *Staurikosaurus* as the sister-taxon of *Herrerasaurus* plus *Sanjuansaurus*. *Eodromaeus* and *Tawa* are placed in a trichotomy with more derived theropods. Sauropodomorpha is represented by *Saturnalia* as sister-taxon of *Plateosaurus* and *Efraasia*.

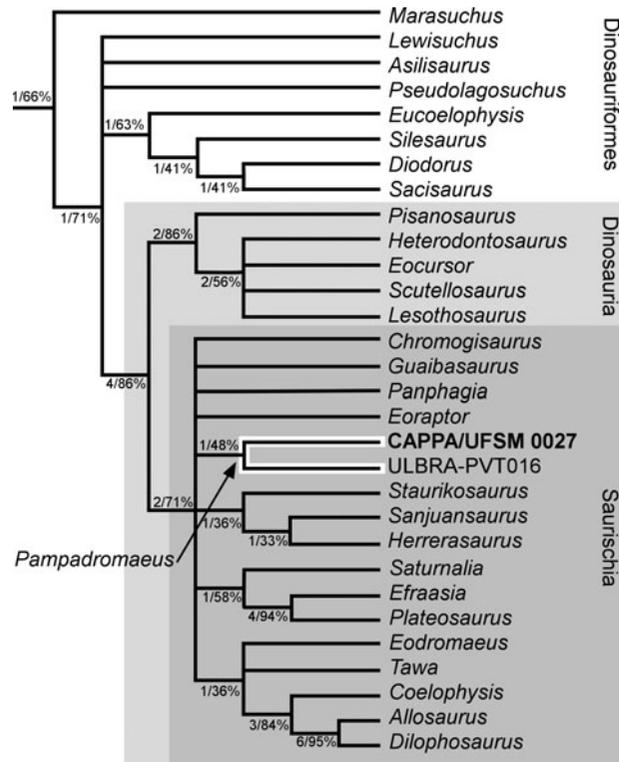


Figure 6. Simplified strict consensus of 27 MPTs depicting the phylogenetic relationships of CAPP/UFMS 0027, based on the data-matrix of Bittencourt et al. (2014). Note: Numbers associated with nodes represent Bremer support values and bootstrap values.

#### 4. Discussion

The femoral morphology of CAPP/UFMS 0027 does not match that of basal ornithischians due the following features: (i) presence of the posteromedial tuberosity (Langer and Benton 2006); (ii) anterior trochanter not wing-like (Langer and Ferigolo 2013); (iii) presence of a well-developed trochanteric shelf, which is absent or present just as a discrete scar in basal ornithischians (Langer and Benton 2006) and (iv) the fourth trochanter that is not pendant (Ezcurra 2012). These traits suggest an early saurischian affinity for CAPP/UFMS 0027, which is fully supported by the present phylogenetic analyses.

The phylogenetic relation of early saurischians is still controversial (Langer 2014), as indicated by the alternative placements of *Eoraptor lunensis*, *Guaibasaurus candelaar-iensis*, and herrerasaurids (e.g. Sereno et al. 1993, 2012; Langer and Benton 2006; Ezcurra 2010; Langer et al. 2010; Martínez et al. 2011; Nesbitt 2011). This discussion is beyond the scope of this article, which aims to test the position of CAPP/UFMS 0027 in relation to other early dinosaurs and evaluate its potential assignment to *Pampadromaeus barberenai*. The results corroborate the proximity of CAPP/UFMS 0027 to the holotype of *Pampadromaeus barberenai* (ULBRA-PVT016), and they may well belong to the same taxon. Indeed, both specimens share a lateromedially small lateral condyle, which differs from the condition of all other early dinosaurs known so far. Accordingly, this trait may represent an autapomorphy of *Pampadromaeus barberenai*. Moreover, several features are shared only by ULBRA-PVT016 and CAPP/UFMS 0027 among the dinosaurs known from the Santa Maria Formation (as fully described and commented earlier).

The affinity of CAPP/UFMS 0027 to *Pampadromaeus barberenai* is also corroborated by topotypical principles. Langer et al. (2007) proposes the subdivision of the Brazilian *Hyperodapedon* Assemblage-Zone (AZ) into two portions, based on its correlation with the Ischigualasto Formation, northwest Argentina. Langer et al. (2007) named its basal portion as *Hyperodapedon* Acme-Zone, where the abundance of *Hyperodapedon* concurs with no records of *Exaeretodon*. *Staurikosaurus pricei* and *Saturnalia tupiniquim* come from this Acme-Zone. The overlaying subdivision of the *Hyperodapedon* AZ is characterized by a substantial decrease of *Hyperodapedon* records and the overwhelming occurrence of *Exaeretodon*

(Langer et al. 2007). In the Ischigualasto Formation, this event was quantified by Martínez et al. (2012b) with a decrease that eventually resulted in the disappearance of *Hyperodapedon* (= *Schaphonyx*) from lower to upper levels of the Argentinean unit. As previously mentioned, the holotype of *Pampadromaeus barberenai* was exhumed from the reddish mudstones of the ‘Janner’ outcrop, the same outcrop from where CAPP/UFMS 0027 was recovered. This outcrop was placed in the upper portion of *Hyperodapedon* AZ by Langer et al. (2007) due to the dominant presence of *Exaeretodon*, also commented by Liparini et al. (2013) who described new specimens of *Exaeretodon* from the outcrop.

Previously to the description of *Pampadromaeus barberenai* (Cabreira et al. 2011), there was no formal record of dinosaurs or other dinosauriforms in the ‘Janner’ outcrop. Recently, two fragmentary dinosauriform specimens were reported for this site (Müller et al. 2014; Pretto et al. Forthcoming). CAPP/UFMS 0027 increases this record, as they are still very scarce in the ‘Janner’ outcrop and even in the Santa Maria Formation as a whole, when compared with coeval Argentine deposits. It is reasonable to consider that, with the increase of prospecting activities, the ‘Janner’ outcrop will probably become a hot spot-for early dinosaurs’ studies in the next years.

In conclusion, phylogenetic, morphological and stratigraphic data support the assignment of CAPP/UFMS 0027 as a new specimen of *Pampadromaeus barberenai*, which brings new information about the femoral anatomy of that dinosaur, previously restricted to the two heavily fractured femora of the holotype. This provides new data on this important anatomical part for future phylogenetic studies of basal dinosaurs.

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## Appendix 1. Additional character description and codification

It was coded as character 379 in Martínez et al. (2012b) and as 292 to Bittencourt et al. (2014) matrices.

Definition: ratio between the transverse width of the distal end of the femur and the transversal width of the lateral condyle (tibiofibular crest of some): more than 0.25 (0) or less than 0.25 (1).

Codification of the new character (379) for taxa from the data-matrix of Martínez et al. (2012a):

*Euparkeria* (?), *Crurotarsi* (?), *Marasuchus* (0), *Agnosphitys* (?), *Achisaurus* (?), *Antetonitrus* (0), *Barapasaurus* (0), *Blikanasaurus* (?), *Camelotia* (?), *Cetiosaurus* (0), *Chindesaurus* (?), *Coloradisaurus* (0), *Efraasia* (?), *Eucnemosaurus* (0), *Gongxiansaurus* (?), *Plateosaurus ingens* (?), *Guaibasaurus* (?), *Herrerasaurus* (0), *Isanosaurus* (?), *Jingshanosaurus* (?), *Lessemsaurus* (0), *Lufengosaurus* (?), *Mamenchisaurus* (?), *Massospondylus* (?), *Melanorosaurus* (?), *Neosauropoda* (?), *Neotheropoda* (?), *Omeisaurus* (?), *Ornithischia* (?), *Patagosaurus* (?), *Plateosaurus engelhardti* (0), *Plateosaurus gracilis* (?), *Plateosaurus avus* (?), *Riojasaurus* (?), *Ruehleia* (?), *Shunosaurus* (?), *Silesaurus* (0), *Staurikosaurus* (0), *Tazoudasaurus* (?), *Thecodontosaurus* (0), *Pantyraco*(0), *Unaysaurus* (?), *Vulcanodon* (?), *Yunnanosaurus* (0), *Glacialisaurus* (0), *MCN PV 18649a* (?), *Saturnalia* (0), *Chromogisaurus* (0), *Eoraptor* (0), *Panphagia* (?), *Pampadromaeus* (1).

Codification of the new character (292) for taxa from the data-matrix of Bittencourt et al. (2014):

*Euparkeria* (?), *Lagerpeton* (0), *Dromomeron gregorii* (0), *Dromomeron romeri* (0), *Marasuchus* (0), *Eucoelophysis* (?),

*Lewisuchus* (?), *Silesaurus* (0), *Pseudolagosuchus* (0), *Sacisaurus* (0), *Saturnalia* (0), *Efraasia* (?), *Plateosaurus* (0), *Eoraptor* (0), *Staurikosaurus* (0), *Herrerasaurus* (0), *Sanjuansaurus* (?), *Tawa* (?), *Coelophysis* (?), *Dilophosaurus* (0),

*Allosaurus* (1), *Pisanosaurus* (?), *Heterodontosaurus* (?), *Lesothosaurus* (?), *Eocursor* (0), *Scutellosaurus* (?), *Panphagia* (?), *Pampadromaeus* (1), *Guaibasaurus* (?), *Chromogisaurus* (0), *Eodromaeus* (0), *Diodorus* (0), *Asilisaurus* (0).