Journal of Iberian Geology
https://doi.org/10.1007/s41513-018-0047-5

RESEARCH PAPER

New Titanosauria (Dinosauria, Sauropoda) remains from the Upper Cretaceous (Plottier Fm) of the southern Neuquén Basin (Patagonia, Argentina)

Flavio Bellardini[1,2] · Mattia A. Baiano[1,3] · Francisco Barrios[3,4] · Borja Holgado[5] · Rodolfo A. Coria[1,2,3]

Received: 7 November 2017 / Accepted: 12 January 2018

Abstract

Purpose New sauropod remains (MCF-PVPH-889, MCF-PVPH-899, and MCF-PVPH-900) collected from the Plottier Fm (Coniacian–Santonian) in the south-west of the Neuquén Basin, are here reported. The materials proceed from a fluvial outcrop composed by siltstone and fine sandstone, whose fossil record is known for large-sized sauropod taxa.

Methods Due to the fragmentary condition of the dorsal ribs and the tibia, we focus the description mainly on the femur and the fibula.

Results The specimen MCF-PVPH-889 consists of partially associated postcranial elements represented by a left femur and three fragmentary dorsal ribs of a Titanosauria indet. A right fibula (MCF-PVPH-900) represents another titanosaurian element, while a proximal portion of a right tibia (MCF-PVPH-899) of a smaller individual than others is here referred to as a Sauropoda indet. MCF-PVPH-889 and MCF-PVPH-900 share some features with other titanosaurian taxa (e.g., a femur with medial deflection of the proximal end and elliptical mid-shaft cross-section, a fibula with slightly sigmoidal shaft and well-developed lateral tuberosity) like in *Epachthosaurus* and *Antarctosaurus*. However, the femur, with a poorly developed lateral bulge and a relatively low head, and a fibula, with a slender and nearly straight proximal third of the shaft, represent plesiomorphic conditions among titanosaurians.

Conclusions The new remains represent a new sauropod record from the Plottier Fm (Upper Cretaceous). Nevertheless, due to the lack of more diagnostic elements, we prefer to consider the specimens MCF-PVPH-889 and MCF-PVPH-900 as Titanosauria indet, and the MCF-PVPH-899 as Sauropoda indet. This new evidence expands the Coniacian sauropod record of the Neuquén Basin and contributes, in some measure, to our knowledge of the stratigraphical distribution of sauropods from the Patagonian Upper Cretaceous fossil-bearing levels.

Keywords Upper Cretaceous · Plottier Fm · Neuquén · Titanosaur · Osteology

Resumen

Objetivos se reportan nuevos ejemplares de saurópodos (MCF-PVPH-889, MCF-PVPH-899, y MCF-PVPH-900) coleccionados de la Fm Plottier (Coniaciense-Santoniense) en el suroeste de la Cuenca Neuquina. Los materiales provienen de un afloramiento fluvial con areniscas y limolitas finas, con un reconocido registro de taxones de saurópodos de gran porte.

Métodos Debido a la condición fragmentaria de la tibia y las costillas dorsales, la descripción está principalmente focalizada en el fémur y la fíbula.

Resultados El ejemplar MCF-PVPH-889 consiste en elementos postcranianos parcialmente asociados representados por un fémur izquierdo y tres fragmentos de costillas dorsales de un Titanosauria indet. Una fíbula derecha MCF-PVPH-900 representa otro elemento referible a Titanosauria, mientras una porción proximal de una tibia derecha (MCF-PVPH-899) de un individuo más pequeño que los otros es referida como Sauropoda indet. MCF-PVPH-889 y MCF-PVPH-900 comparten algunos caracteres con otros taxones de titanosaurios (p.e. un fémur con projección medial del extremo proximal y una sección transversal de forma elíptica a mitad de la diáfisis, y una fíbula con diáfisis ligeramente sigmoidea y un trocánter lateral bien desarrollado) como en *Epachthosaurus* y *Antarctosaurus*. Sin embargo, el fémur con una comba lateral poco

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Published online: 30 January 2018

desarrollada y una cabeza relativamente baja, y una fíbula con una diáfisis con el tercio proximal casi recto, representan condiciones plesiomórficas entre los titanosaurios.

Conclusiones Los nuevos elementos representan un nuevo registro de saurópodos de la Fm Plottier (Cretácico Superior). No obstante, debido a la falta de caracteres diagnósticos, preferimos considerar los ejemplares MCF-PVPH-889 y MCF-PVPH-900 como Titanosauria indet, y MCF-PVPH-899 como un Sauropoda indet, Esta nueva evidencia incrementa el registro de saurópodos del Coniaciense de la Cuenca Neuquina, y contribuye, en algo, a nuestro conocimiento sobre la distribución estratigráfica de los saurópodos provenientes de los niveles fosilíferos del Cretácico Superior de Patagonia.

Palabras clave Cretácico Superior · Fm Plottier · Neuquén · Titanosaurios · Osteología

1 Introduction

The Neuquén Basin in south-western Argentina contains one of the most important successions of sedimentary Mesozoic rocks worldwide, and represents one of the more studied basins, especially due to its abundant marine and terrestrial tetrapod fauna (Gasparini et al. 2007). In particular, the well-known Upper Cretaceous beds, stratigraphically defined as the Neuquén Group, include thick outcrops showing fluvial, aeolian and shallow lacustrine faces (e.g. Ramos 1981; Garrido 2010). This sequence, developed from the lower Cenomanian (Candeleros Fm) up to the middle Campanian (Anacleto Fm), has yielded a large number of fossil reptiles, especially sauropod dinosaurs (Leanza et al. 2004; Gasparini et al. 2007). Rich and abundant vertebrate faunas have been found in different sites of the Portezuelo, Bajo de la Carpa and Anacleto formations of the Neuquén Group, composed of turtles, squamates, crocodiles, dinosaurs and mammals (e.g. Goin et al. 1986; Powell 1986; Bonaparte 1991; Alvarenga and Bonaparte 1992; Coria and Salgado 1996; Novas 1996; Calvo and González Riga 2003; De la Fuente 2003; Apesteguía 2004; Calvo et al. 2007; Fiorelli and Calvo 2007; Pol and Gasparini 2007; Scanferla and Canale 2007; Salgado and Coria 2009). Despite the palaeontological richness of these formations, the fossil record of the Plottier Fm is scarce, and limited to isolated elements of theropod dinosaurs, turtles (De la Fuente et al. 2007) and notosuchian crocodiles (Filippi et al. 2013). On the other hand, the sauropod fossil record is abundant, with taxa such as *Muyelensaurus pecheni* (Calvo et al. 2007), *Petrobrasaurus puestohernandezi* (Filippi et al. 2011), *Notocolossus gonzalezparejasi* (González Riga et al. 2016), from the northern outcrops of the formation, and *Antarctosaurus giganteus* (Huene 1929) from the southern ones. In this context, *Antarctosaurus* was one of the first dinosaur taxon discovered and formally described for the Neuquén Basin. In 2014, some disarticulated sauropod postcranial elements (MCF-PVPH-889, MCF-PVPH-899 and MCF-PVPH-900) were discovered in an oil-field base close to the city of Plottier, in Neuquén Province, Argentina (Fig. 1). The aim of this work is to describe these specimens and compare them with other sauropod taxa from the same formation, as well as from different Upper Cretaceous sites of Argentina and Gondwana, and to analyse the palaeoecological and palaeobiogeographical implications of a more heterogeneous ecosystem than previously known.

Institutional abbreviations: MAU, Museo Municipal 'Argentino Urquiza', Rincón de los Sauces, Neuquén Province, Argentina; MCF, Museo Municipal 'Carmen Funes', Plaza Huincul, Neuquén Province, Argentina; UNCUYO-LD, Universidad Nacional de Cuyo, Laboratorio de Dinosaurios, Mendoza, Mendoza Province, Argentina.

2 Geological setting

The sauropod remains proceed from the continental and fluvial sediments of the Plottier Fm, which is widely exposed at 5 km north of the city of Plottier. The fossil-bearing site is composed of a thick succession of poorly consolidated, reddish siltstones and fine sandstones, with sparse yellow to grey-green siltstone and thin limestone

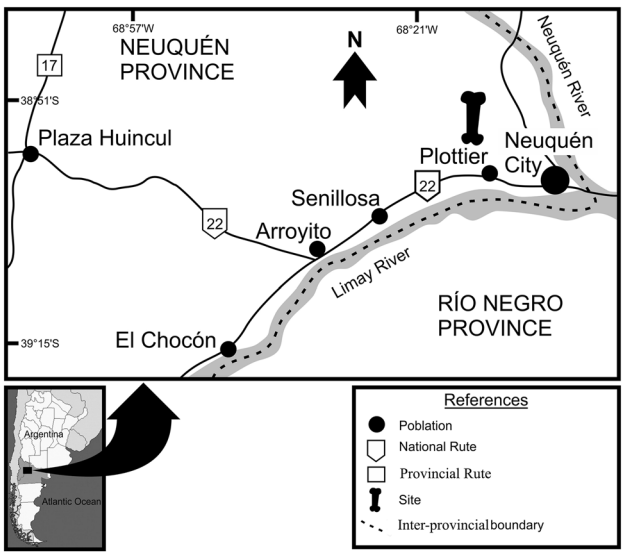

Fig. 1 Map showing the location where the specimens MCF-PVPH-889, MCF-PVPH-899 and MCF-PVPH-900 were collected

interbeddings. The fossil site represents a meandering fluvial palaeoenvironment, dominated by distal food-plains and reduced ephemeral lateral channels (Garrido 2010). Based on micropalaeontological content (Musacchio 2006; Musacchio and Vallati 2007), the Plottier Fm is considered late Coniacian in age (Fig. 2), whereas Garrido (2010) proposed a late Coniacian-early Santonian age for this formation, based on the lateral correlation with other closely related formations, like the Portezuelo Fm and the Sierra Barrosa Fm (Cruz et al. 1989; Legarreta and Gulisano 1989; Hugo and Leanza2001; Garrido 2010).

All elements were found in two nearby sites located a few meters apart, but in the same stratigraphical level (Fig. 2), which is composed of unbound, reddish fine sandstones with moderate-pink siltstone intercalation. The left femur and the rib fragments were found a few meters apart from the right fibula and the partial right tibia. All fossils exhibit marked pre-burial alterations and diagenetic deformations, probably because of exposure, transport, lithostatic pressures or a combination of these processes. Indeed, the femur was found incomplete, without the dorsal portion of the proximal articular surface and most of the distal end. The external surface of the bone is crossed by longitudinal and transversal fine fractures. On the other hand, the general preservation of the other bones is better, although the ribs and the right fibula were fragmentary and lack several portions of the bones. Despite the concordant dimensions between the femur (MCF-PVPH-889) and the fibula (MCF-PVPH-900), we prefer not to associate these elements as being part of a single individual, although they were found a few meters from each other. On the other hand, the presence of a partial tibia (MCF-PVPH-899) much smaller than the other bones, led us to consider this fossil as belonging to a different individual.

3 Description and comparison

The left femur (MCF-PVPH-889/02) is long (190 cm preserved) with a markedly crushed, antero-posteriorly compressed diaphysis, and it lacks the dorsal portion of the femoral head and the distal condylar end (Fig. 3). The preserved part of the femoral head is slightly antero-posteriorly expanded in medial view, whereas it is convex and not markedly dorsally projected in antero-posterior view, in contrast with *Petrobrasaurus*, *Antarctosaurus* and other titanosaurs (Wick and Lehman 2014) (Fig. 4). The femoral head is placed slightly above the greater trochanter, as in *Phuwiangosaurus* (Suteethorn et al. 2009) and other Titanosauriformes (Upchurch et al. 2004). Although not well preserved, the dorso-lateral portion of the proximal end exhibits a shallow and dorsally inclined depression that separates the greater trochanter from the femoral head. The greater trochanter is low and slightly convex dorsally, whereas it is very prominent posteriorly, as in *Opistocoelicaudia* (Borsuk-Białynicka 1977). Due to the poor preservation, it is not evident whether the rough surface of the greater trochanter is distally extended on both the anterior and posterior surface of the shaft. The proximal third is moderately deflected medially, as in *Muyelensaurus* and other basal titanosaurs (Salgado et al. 1997), resulting in an angle of 145° between the dorsal margin of the greater

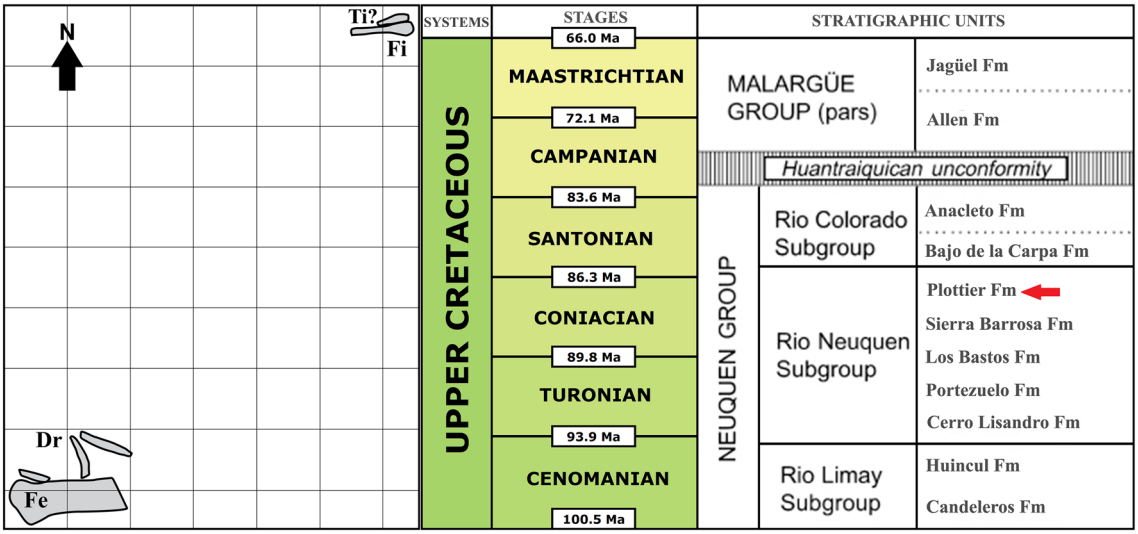

Fig. 2 Site map showing the location of the bones (left), and lithostratigraphic references (right) of the Upper Cretaceous of Neuquén Basin. All the fossils proceed from the same stratigraphical level of the Plottier Fm. *Dr* dorsal ribs, *Fe* femur, *Fi* fibula, *Ti?* hypothetical partial tibia. Grid is 1 m^2

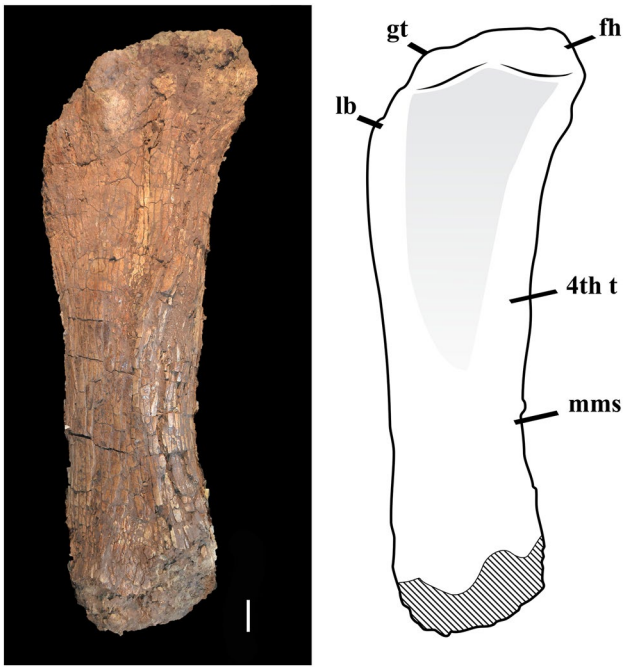

Fig. 3 Left femur MCF-PVPH-889/02 in posterior view (left), and line drawing with morphological references (right). The bone exhibits several diagenetic alterations, such as longitudinal and transversal fractures, as well evidence of strong lithological compression. The femur is partially preserved, lacking the dorsal portion of the femoral head and the distal ends. *4th t* 4th trochanter, *fh* femoral head, *gt* greater trochanter, *lb* 'lateral bulge' or abductor crest, *mms* minimal mid-shaft diameter. Scale-bar = 10 cm

trochanter and the well-defined lateral margin of the shaft. The dorso-lateral portion of the shaft exhibits a prominent, rounded, and incomplete lateral bulge (abductor crest, *sensu* Wick and Lehman 2014). Both anterior and posterior faces of the lateral bulge are widely furrowed by longitudinal scars of the abductor musculature. Between the lateral bulge and the distal projection of the greater trochanter, there is a wide, medio-laterally concave trochanteric shelf, like in *Lirainosaurus* (Diéz Díaz et al. 2013), *Neuquensaurus* (Salgado et al. 2005) and other derived titanosaurs (Otero 2010). The femoral shaft is elliptical in cross-section, being strongly compressed antero-posteriorly. However, this condition may have been diagenetically altered. The lateral and medial margins of the shaft are sub-parallels at the mid-shaft, being slightly divergent in the proximity of both articular ends.

In posterior view, a wide and well-marked 4th trochanter lies close to the medial margin of the mid-shaft, as in juvenile sauropods and several titanosaurians (Upchurch et al. 2004). This surface is transversally convex, longitudinally expanded and slightly dorso-medially inclined. Due to the poor preservation of the cortical surface of the bone, only a few muscular scars on the margins of the 4th trochanter are well identified. Although it lacks the condylar portion, the proximal half of the distal end is preserved, and part of the intercondyloid fossa is recognised.

Only three fragments of the distal portions of the shafts of the dorsal ribs (MCF-PVPH-889/01) are preserved. They are elliptical in cross-section and strongly compressed medio-laterally, suggesting they belong to the pectoral area of the rib-cage.

The almost complete right fibula (MCF-PVPH-900) is slender and long (114 cm), and better preserved than the femur (Fig. 5a). In lateral view, the proximal end is antero-posteriorly expanded and dorsally convex. In dorsal view, the articular surface is D-shaped, with the medial face being straight and slightly convex posteriorly, while the lateral face is strongly convex (Fig. 5b). Thus, the proximal epiphysis is more antero-posteriorly expanded than medio-laterally, as it is in other Titanosauriformes (*Tastavinsaurus*, *Phuwiangosaurus*, *Paluxysaurus*) and basal Titanosauria (*Epachthosaurus*, *Ligabuesaurus*). This condition contrasts with the convergent condition of some rebbachisaurids (*Zapalasaurus*, *Limaysaurus*) and more derived titanosaurians (*Rapetosaurus*, *Neuquensaurus*), where the proximal epiphysis is much more expanded antero-proximally. In medial view, a wide, concave and triangular surface defines the proximal

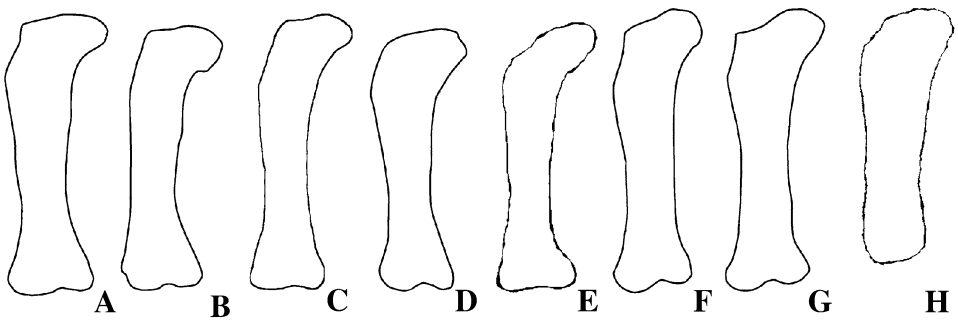

Fig. 4 Comparison between macronarian femora in anterior views. **a** *Giraffatitan*, **b** *Aragosaurus*, **c** *Petrobrasaurus*, **d** *Chubutisaurus*, **e** *Antarctosaurus*, **f** *Saltasaurus*, **g** *Opisthocoelicaudia*, **h** MCF-PVPH-889/02. Not to scale (**a**-**b**-**f** and **g** modified from Royo-Torres et al. 2012; **c** after Filippi et al. 2011; **d** after Carballido et al. 2011; **e** after Huene 1929)

Fig. 5 Right fibula MCF-PVPH-900 in medial (**a**), proximal (**b**), and distal view (**c**), and line drawing with morphological references (right). The bone was found almost complete and well preserved lacking only the anterior side. *at* anterior trochanter, *das* distal articular surface, *tas* tibial articular surface. Scale bar = 10 cm

articulation for the tibia. This surface bears slight striated scars for attachment of the anterior crest of the tibia, and is limited by a prominent anterior trochanter, as in several Titanosauriformes (Wilson and Upchurch 2009). Due to the fragmented condition of the anterior margin of the proximal half of the fibula, it is not possible to define the development and the orientation of such anterior crest, although it appears antero-medial directed, such as in *Tastavinsaurus*, *Paluxysaurus*, *Uberabatitan*, and *Bonatitan*. Although fragmentary, the anterior edge of the medial articular surface is antero-medially prominent and rounded. The shaft is slightly sigmoidal, as in *Epachtosaurus* (Powell 1990; Martínez et al. 2004) and basal titanosaurians. The prominent and well-marked lateral tuberosity is located near the mid-shaft of the bone, as is typical of Eusauropoda (Wilson and Sereno 1998), and in several derived titanosaurians (Gallina and Otero 2015). The distal articular surface is oval in shape, and slightly more expanded transversally (Fig. 5c). Although incomplete, the medial face of the distal end is straight, defining the contact for the astragalus, whereas the ventral surface is laterally concave and corresponds to the articular surface for the calcaneous.

The incomplete bone MCF-PVPH-899 is here referred to as a proximal portion of a right tibia (Fig. 6). The lateral side of the bone is proximally concave, representing the cnemial fossa for the articulation with the fibula. Although proximally incomplete, it is rounded in lateral view and prominent and antero-laterally projected. The projection posterior to the cnemial crest ('second cnemial crest', *sensu* Bonaparte et al. 2000) is absent and the cnemial fossa is deep but distally reduced, like in several titanosaurs (*Antarctosaurus*, *Bonitasaura*, *Rapetosaurus*, *Opisthocoelicaudia*). The medial surface is diagenetically altered in the proximal portion and strongly convex distally, as in all sauropods (Upchurch et al. 2004). Due to the general condition, no further morphological features can be identified from this element.

All appendicular measurements are provided in Table 1.

4 Discussion

The specimens MCF-PVPH-889 and MCF-PVPH-900 exhibit the typical morphology of sauropod dinosaurs, including a femur with the head not separated from the greater trochanter by a distinct elevated neck, a straight and antero-posteriorly compressed femoral shaft, an antero-posteriorly expanded proximal end and a fibula with a well-defined proximo-medial tibial triangular articular surface (Wilson and Sereno 1998; Upchurch et al. 2004).

The femur has a dorso-medially projected head, a prominent lateral bulge and the proximal third medially deflected, and a fibula with a well-developed lateral tuberosity and slightly sigmoidal diaphysis. These features allow the specimens to be referred to Titanosauria. Also, the less developed lateral bulge, relative low femur head, and slender and nearly straight fibula with a well-marked lateral tuberosity, represent plesiomorphic conditions among titanosaurs.

The Titanosauria is a world-wide, high-diverse and derived clade of neosauropods that is widely known in many late Cretaceous vertebrate faunas from all landmasses, including Antarctica (Upchurch et al. 2004; Cerda et al. 2012). Although the highest taxonomical diversity was achieved during latest Cretaceous (Barrett and Upchurch 2005; Barrett et al. 2009), titanosaurian sauropods exhibit an early morphological variability and a wide geographical distribution from the Cenomanian, when two principal dispersal areas can be recognised: one in the northern hemisphere, especially with the abundant East Asia 'middle-Cretaceous' sites (You et al. 2003, 2008; Ksepka and Norell 2009; Lü et al. 2007, 2008, 2009; Zhang et al. 2009), and the other in south-west Gondwana, where both Brazilian and Patagonian Upper Cretaceous titanosaur findings represent most of the Titanosauria global fossil record (Candeiro 2006; Santucci and Bertini 2006; Salgado and Carvalho 2008; Santucci and Arruda-Campos 2011; Filippi 2015; Bandeira et al. 2016). In this context, the study of this clade and its palaeobiological implications has been the focus of most multidisciplinary research in the last 20 years, which has shed light on the evolution of Titanosauria (e.g. Sander et al. 2004, 2011;

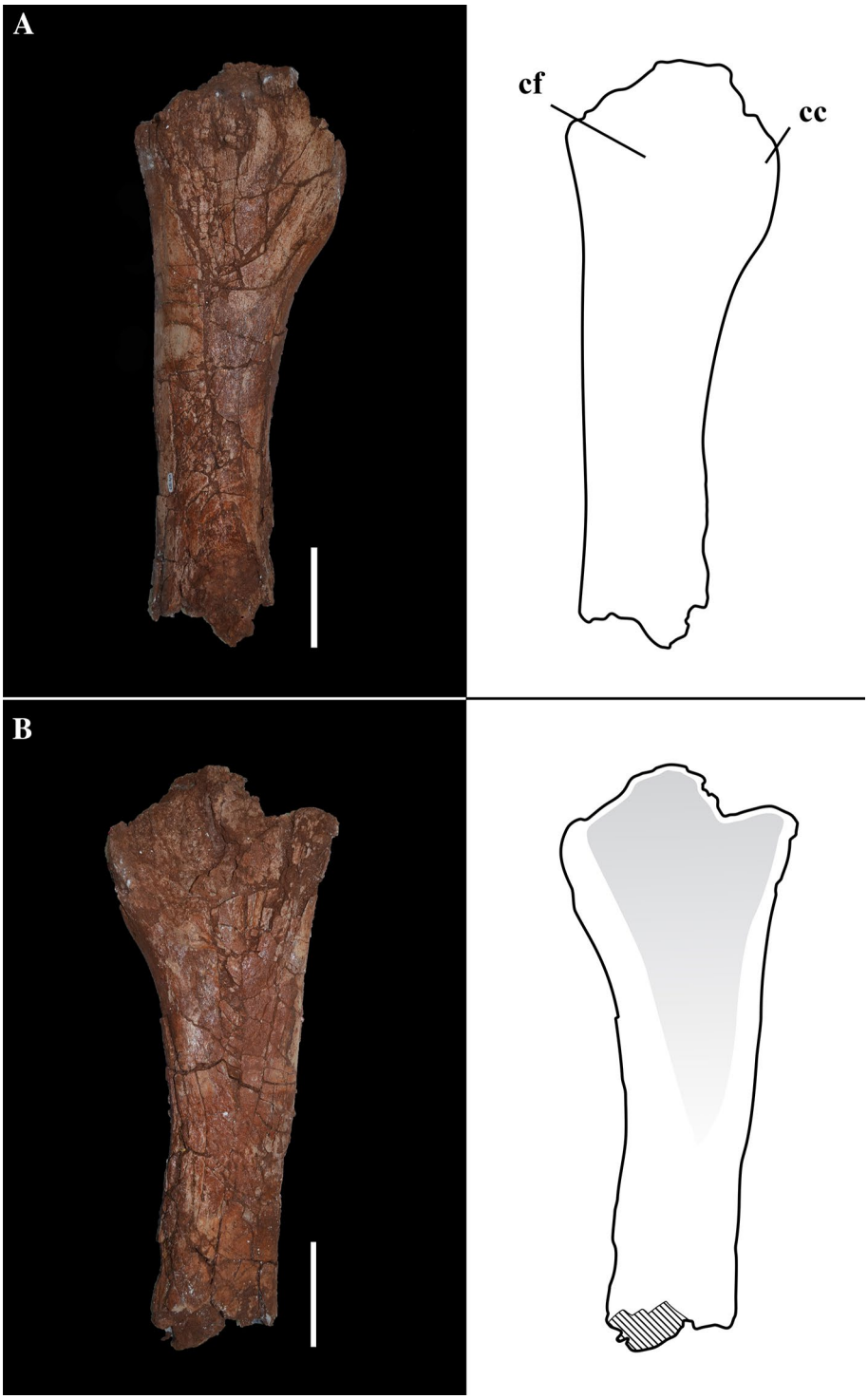

Fig. 6 Right tibia? MCF-PVPH-899 in lateral (**a**), and medial view (**b**), and line drawing with morphological references (right). The bone preserved part of the diaphysis, and it was found close to the fibula. *cc* cnemial crest, *cf* cnemial fossa. Scale bar = 10 cm

Barrett 2014; Curry Rogers 2005; Amiot et al. 2006; Brusatte 2012; Brusatte et al. 2008a, Brusatte et al. 2008b, 2015). Indeed, most recent palaeoecological and palaeobiogeographical hypotheses about the evolution of titanosaur sauropods (Poropat et al. 2016; Carballido et al. 2017) remark on the presence of a high-level of endemism within Eutitanosauria (e.g., Rinconsauria, Longkosauria, Aeolosaurini, Saltasaurinae), especially during the Upper Cretaceous, that is probably due to world-wide Upper Jurassic distributed ancestors (Titanosauriformes, non-eutitanosaurians Titanosauria).

Table 1 Measurements of the appendicular elements of MCF-PVPH-889 and MCF-PVPH-900

Skeletal element	Tot L	Prox W	Prox L	MS W	Dist W	Dist L
Femur (MCF-PVPH-889/02)	190[a]	50[a]	–	41.3	–	–
Fibula (MCF-PVPH-900)	114	27	16.2	9.2	17.8	16.75

All measurements in cm

Tot L proximo-distal length, *Prox W* medio-lateral width of proximal end, *Prox L* antero-posterior length of proximal end, *MS W* mid-shaft width, *Dist W* medio-lateral width of distal end, *Dist L* antero-posterior length of distal end

[a]Preserved

In Patagonia, this transition is depicted by the sauropod Cretaceous fossil record. During the early Cretaceous and throughout the transition into the late Cretaceous, several continental ecosystems were ecologically dominated by heterogeneous mega-vertebrate faunas. The members of both principal clades of Neosauropoda, the Diplodocoidea and the Macronaria, probably coexisted (Salgado et al. 2004; Bonaparte et al. 2006; Martinelli et al. 2007; Carballido et al. 2012; Fanti et al. 2014, 2015). In the early Upper Cretaceous (Cenomanian–Turonian), taxa of non-titanosaur Titanosauriformes represented the dominant mega-herbivorous fauna in terrestrial ecosystems. Later, the global extinction of Diplodocimorpha allowed the diversification of the titanosaurs until the end of the Cretaceous (Curry Rogers 2005; D'Emic 2012). We consider that the morphological analysis and the taxonomical identification of every new sauropod record, although fragmentary, especially during the "middle" Upper Cretaceous, is important for reconstructing the evolutionary history of the Sauropoda. Thus, we identify some of these new sauropod specimens (MCF-PVPH-889 and MCF-PVPH-900) to be among the basal members of the clade. Comparisons with other sauropod taxa from the same formation, as well as from other equivalent Upper Cretaceous outcrops, reveal affinities with some Patagonian and Gondwanan titanosaur forms. The specimen MCF-PVPH-889 shares with *Antarctosaurus giganteus* (Huene 1929) a moderately dorso-medially directed femoral head, low and rounded margin of the lateral bulge, and medially inclined proximal half of the femur. In contrast, the 4th trochanter is markedly more prominent in transversal view in *A. giganteus* than in MCF-PVPH-889/02, although in both specimens it is latero-medially inclined and close to the mid-shaft. Furthermore, MCF-PVPH-889/02 seems to be more robust than both femora (MLP-26-316) from Aguada del Caño site (Huene 1929), although this condition may have been caused by diagenesis. The femur of *Petrobrasaurus puestohernandezi* (Filippi et al. 2011), also from the Plottier Fm, resembles MCF-PVPH-889/02 in the general morphology of the femoral head, the development of the lateral bulge, and the morphology of the medial margin of proximal third of the femur. In contrast, *P. Puestohernandezi* exhibits the 4th trochanter above the mid-shaft and lacks the trochanteric shelf in the lateral margin of the posterior surface of the proximal end. Following recent stratigraphic revisions of Neuquén Group (Garrido 2010), *Muyelensaurus pecheni* is here assigned to the Plottier Fm (*contra* Calvo et al. 2007). The femur of *M. pecheni* is slenderer than MCF-PVPH-889/02, and the lateral bulge is less developed. On the other hand, the fibula (MCF-PVPH-900) resembles the slender and slightly sigmoidal fibulae of *Muyelensaurus*, which exhibits a posteriorly convex proximal articular surface, a well-defined lateral tuberosity, and a triangular tibial articulation in the proximo-medial surface. However, *Muyelensaurus* (MAU-PV-LL-90 and 271) fibulae exhibit a more transversally compressed proximal articular surface, and a more prominent lateral margin of the distal epiphysis in transversal view. Furthermore, the distal articular surfaces of *Muyelensaurus* fibulae are sub-rectangular, unlike the oval articular surfaces of MCF-PVPH-900. Considering other Upper Cretaceous Gondwanan titanosaurs, the fibula (MCF-PVPH-900) shares several features with *Laplatasaurus*, *Uberabatitan*, and *Epachtosaurus*, such as the poor expansion of the anterior margin of the distal epiphysis, and the convex distal articular surface and proximal end, not anteriorly deflected. Despite these morphological similarities, the new specimen from the Plottier Fm does not show the diagnostic features of any of these sauropod taxa. Notwithstanding the poor preservation stage and lack of further diagnostic elements, MCF-PVPH-900 is here regarded as Titanosauria indet.

These new findings, as fragmentary and taxonomically indeterminate as they are, nourish the sauropod fossil record for the Coniacian–Santonian transition of Neuquén Basin, and define more taxonomical variability for the southern ecosystems of the Plottier Fm. Indeed, the identification in this southern stratigraphic context of a more complex sauropod community, which is also taxonomically distinct from its northern counterpart, has certain palaeoecological and palaeobiogeographical implications. The sauropod fossil record from the northern Plottier Fm outcrops is composed of *Petrobrasaurus*, *Notocolossus*, *Muyelensaurus* and two incomplete specimens (four anterior caudal vertebrae, MZU-pv-N-414 and a partial appendicular skeleton, UNCUYO-LD-313), tentatively referred to indeterminate

titanosaurs (González Riga et al. 2016). On the other hand, in the southern counterpart are the recognised cf. *Antarctosaurus giganteus* and the new material presented here. These autochthonous sauropod associations were likely developed in different palaeoenvironments and palaeoecological contexts. Despite the extensive lateral facial variation of the Plottier Fm, it is possible to identify two different paleo areas representing different environmental conditions: A south-east paleo area dominated by distal food-plains and reduced ephemeral lateral channels, and a north-west paleo area with a fluvial environment and meandering channel systems.

5 Conclusions

New sauropod remains from Plottier Fm (MCF-PVPH-889 and MCF-PVPH-900) exhibit a miscellany of plesiomorphic and derived morphological features that allow these specimens to be referred to Titanosauria. The less developed lateral bulge, relative low femur head, and slender and proximally straight fibula with a well-marked lateral tuberosity, represent plesiomorphic conditions among titanosaurs, whereas the trochanteric shelf, medially inclined proximal third and strongly antero-posteriorly compressed shaft of the femur are common features of more derived taxa. Despite several similarities with other Cretaceous Patagonian taxa, such as *Epachthosaurus* and *Antarctosaurus*, these specimens cannot be referred to any of these or other known sauropod taxa. In this context, during the Coniacian–Santonian transition, there were established different sauropod faunas composed by both basal and more derived members of Titanosauria clade: basal lithostrotians (UNCUYO-LD 301), basal lognkosaurians (MAU-Pv-PH-449), and probably Aeolosaurini (MAU-pv44), which preceded the most derived communities of the uppermost Cretaceous.

Acknowledgements We thank S. Segel for reporting the fossil find; the Dirección Provincial de Patrimonio Cultural of Neuquén Province for legal and partial financial support of the field-work; the Museo Municipal 'Carmen Funes' of Plaza Huincul for technical and logistical support during the field-work; E. Montes (MCF) for assisting in the lab-preparation of the material; U. Abendaño and F. Perri for field-work assistance and logistics. V. Díez Díaz and J. A. Whitlock reviewed the manuscript and provided constructive comments and suggestions. K. Kamra helped with the English editing. BH is the beneficiary of a PhD scholarship (140789/2016-2) granted by the Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) from the Brazilian Ministry of Science, Technology, Innovation and Communication.

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Affiliations

Flavio Bellardini[1,2] · Mattia A. Baiano[1,3] · Francisco Barrios[3,4] · Borja Holgado[5] · Rodolfo A. Coria[1,2,3]

✉ Flavio Bellardini
flaviobellardini@gmail.com

Mattia A. Baiano
mbaiano@unrn.edu.ar

Francisco Barrios
Argentina.fbarrios84@gmail.com

Borja Holgado
borja.holgado@mn.ufrj.br

Rodolfo A. Coria
rcoria@unrn.edu.ar

[1] Museo Municipal 'Carmen Funes', Av. Córdoba, 55, 8318 Plaza Huincul, Neuquén, Argentina

[2] Subsecretaría de Cultura, Dirección Provincial de Patrimonio Cultural, Vuelta de Obligado, 50, 8300 Neuquén, Neuquén, Argentina

[3] CONICET-IIPG, Universidad Nacional de Río Negro, Av. General Roca 1242, 8332 General Roca, Río Negro, Argentina

[4] CONICET-Museo Provincial de Ciencias Naturales 'Prof. Olsacher', Ejercito Argentino y Etcheluz, 8340 Zapala, Neuquén, Argentina

[5] Laboratory of Systematics and Taphonomy of Fossil Vertebrates, Departamento de Geologia e Paleontologia, Museu Nacional/Universidade Federal do Rio de Janeiro, Quinta da Boa Vista, s/n, São Cristóvão, Rio de Janeiro, RJ 20940-040, Brazil