Revision of MUCPv 204, a Senonian Basal Titanosaur from Northern Patagonia

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Introduction

The titanosaurian sauropod comprises the most diverse group of terrestrial tetrapods from the Cretaceous of South America. With around thirty valid species, these dinosaurs covered many of the herbivorous eological niches in this continent (Salgado *e* Bonaparte, 2007). One of the first characters noted for the titanosaurians was the existence of procoelic caudal vertebrae, and originally was utilized in the diagnosis of the type of the group, the genus *Titanosaurus*. With a more complete fossil record, was evident that this character was distributed in a more compresive group, the traditional Titanosauridae (Powell, 2003). Salgado and Calvo (1993) described a notable partial skeleton of a titansaurian (MUCPv 204) that contained the tipical procoelic caudals restricted to the anterior caudals, but with "amphiplatyan" middle caudal vertebrae. These remains were recovered from sediments of Late Cretaceous age, and this animal was considered as a late survivor of basal titanosaur lineages, although their stratigraphic position was controversial (Juárez Valieri *et al*., this volume). A review of the type locality allow us to specify the stratigraphical unit of procedence.

Here, we redescribe the specimen MUCPv 204, generating comparisson with new titanosaur taxa with similar morphological conditions, and discusse the biostratigraphic implicances of this new taxon.

Intitutional Abbreviations: MUCPv: Universidad Nacional del Comahue, Paleovertebrate collection.

Metodology

Anatomical comparison with another titanosauriforms include: *Brachiosaurus brancai* (Janensch, 1929); *Venenosaurus dicrocei* (Tidwell *et al*., 2001); *Chubutisaurus insignis* (Salgado, 1993), *Phuwiangosaurus sirindhornae* (Suteethorn *et al*., 2009) sauropoda indet. (previously identified as *Janenschia robusta*, Janensch, 1929; Bonaparte *et al*., 2000); *Malarguesaurus florenciae* (González Riga *et al*., 2009) *Amargatitanis macni* (Apesteguía, 2007); *Andesaurus delgadoi* (Calvo and Bonaparte, 1991); *Mendozasaurus neguyelap* (González Riga, 2003); *Futalognkosaurus duke*i (Calvo *et al*., 2007b); *Argyrosaurus superbus*? (Powell, 2003);

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Aeolosaurus rionegrinus (Powell, 2003); *Aeolosaurus* sp. (MPCA 27174, Salgado and Coria, 1993; MPCA 27100 Salgado and Calvo, 1997); Titanosauridae indet. (MACN-RN 147, previously identified as *Aeolosaurus rionegrinus?*, Powell, 1987, 2003); *Aeolosaurus colhuehuapensis* (Casal *et al*., 2007); *Gondwanatitan faustoi* (Kellner and Azevedo, 1999); *Muyelensaurus pecheni* (Calvo *et al*., 2007a); *Rinconsaurus caudamirus* (Calvo and González Riga, 2003); *Epachthosaurus sciuttoi* (Martínez *et al*., 2004); *Pitekunsaurus macayai* (Filippi and Garrido, 2008); *Baurutitan britoi* (Kellner *et al*., 2005); *Trigonosaurus pricei* (Campos *et al*., 2005); *Maxakalisaurus topai* (Kellner *et al*., 2006); *Uberabatitan riberoi* (Salgado and Carvalho, 2006); *Adamantisaurus mezzalirai* (Santucci and Bertini, 2006)*; Opisthocoelicaudia skarzinskii* (Borsuk-Bialynicka, 1977); *Saltaurus loricatus* (Powell, 2003); and *Neuquensaurus australis* (Salgado *et al*., 2001).

For nomenclatural anatomy of the caudal sequences we follow to González Riga *et al*. (2009).

Systematic Paleontology

SAUROPODA
TITANOSAURIA
TITANOSAURIDAE
LOGNKOSAURIA?
Traukutitan eocaudata taxon nov.

Figure 2

Etymology: From *Trauku*, the araucanian mountain spirit, usually represented like a giant; *titan* is the name of the greek mythological giants. *Eocaudata*, in reference to the basal morphology displayed in the middle caudal vertebrae present in this form.

Type Species: *Traukutitan eocaudata* sp. nov., described below.

Holotype: MUCPv 204: a partial semi-articulated skeleton including femora, and thirteen anterior and middle caudal vertebrae. A partial pubis mentioned as part of the holotypic skeleton was mentioned by Salgado and Calvo (1993), but it could not to be found in the repository of the Comahue University.

Horizon and locality

Lowermost section of the Bajo de la Carpa Formation, Río Colorado Subgroup, Neuquén Group. Sitio Trauku, 5 km southwestern to the Centro Paleontológico Lago Barreales, northern coast of Los Barreales lake, Neuquén Province, Argentina (figure 1).

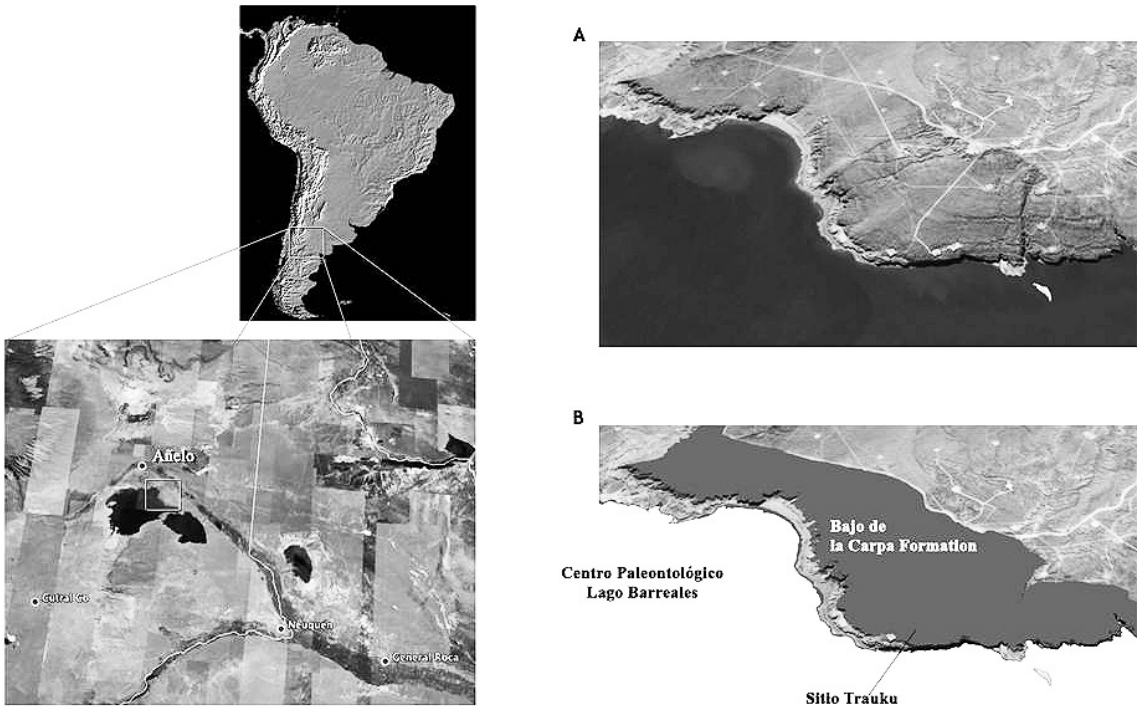

Figure 1. Geographical and stratigraphical provenance of *Traukutitan eocaudata* tax. nov. A. Location of Sitio Trauku, where the bones of the new species was recovered; B. Distribution of the stratigraphic units of the Neuquén Group in the northern coast of the Los Barreales Lake.

Diagnosis

Big sized titanosaurid characterized by the following unique association of characters: Proximal caudal vertebral centra higher than wider, with strongly procoelous center, with the ball placed in the middle-dorsal part of the centrum. Prezygodiapophyseal lamina subvertical, with a ventrocaudal placement of the transverse process at the first caudal. Presence of a single deep foramen ventral to the base of the transverse process. Middle caudal vertebrae wider than length, with procoelous-opisthoplatyan centra, with the upper border of the posterior face lightly enlarged.

Description

Caudal vertebrae

Thirteen caudal vertebrae has been recovered, corresponding to anterior and middle sequence of the tail. These preserves the base of the neural arches in the proximal caudal vertebrae, allowing observing the existence of well-developed prezygodiapohyseal laminae, connecting with the transverse processes, which are projected backward. The first caudal vertebra (Here considered based in the comparison with those of *Futalognkosaurus* and other titanosaurs, (figure 2.C), presents the orientation of the transverse process and the mentioned laminae in an almost vertical angle. This morphology is present in *Traukutitan* tax. nov. and *Futalognkosaurus*. The transverse processes in the first vertebra of *Traukutitan* tax. nov. are small and oriented caudoventrally, as present in *Malawisaurus*, *Mendozasaurus*, *Futalognkosaurus* and *Argyrosaurus*. In another titanosaurids, these elements are more developed and more laterally directed. The separation between the prezygodiapophyseal lamina and the centrum, not preserved to the top, in dorsal view, conforms a wide inner surface for the origin of the neural spine. The neural arch of the fourth more proximal caudal vertebrae recovered is the best preserved (figure 2. F). The top of the transverse process is more upwardly projected; therefore, the prezygodiapohyseal laminae are placed in a more horizontal angle. In general, all the sequence of proximal caudal vertebrae shows an increasing in the angle of the prezygadiapohyseal laminae; it implies a reduction of the separation between prezygapophysis and a lose in weight of the neural spine in transverse sence. Anterior caudals centra are clearly higher than wider, and this condition is changing along the sequence, developing the opposite condition in the middle caudal vertebrae. A strongly procoelic condition is present in the anterior caudals, with the posterior condyles located slightly dorsal to the middle of the centrum. In middle caudal centra, a procoelous-opisthoplatyan condition is present. Previously, these elements are described as amphiplatyan (Salgado and Calvo, 1993; Salgado and García, 2002). The first caudal presents a deep cavity placed below the inferior lamina that connects the transverse process with the posterior face of the centrum; it also presents an accessory horizontally lamina in the lateral face of the centrum. This morphology is similar to that present in *Futalognkosaurus dukei*, although in this taxon the placement of the cavity is more ventrally placed.

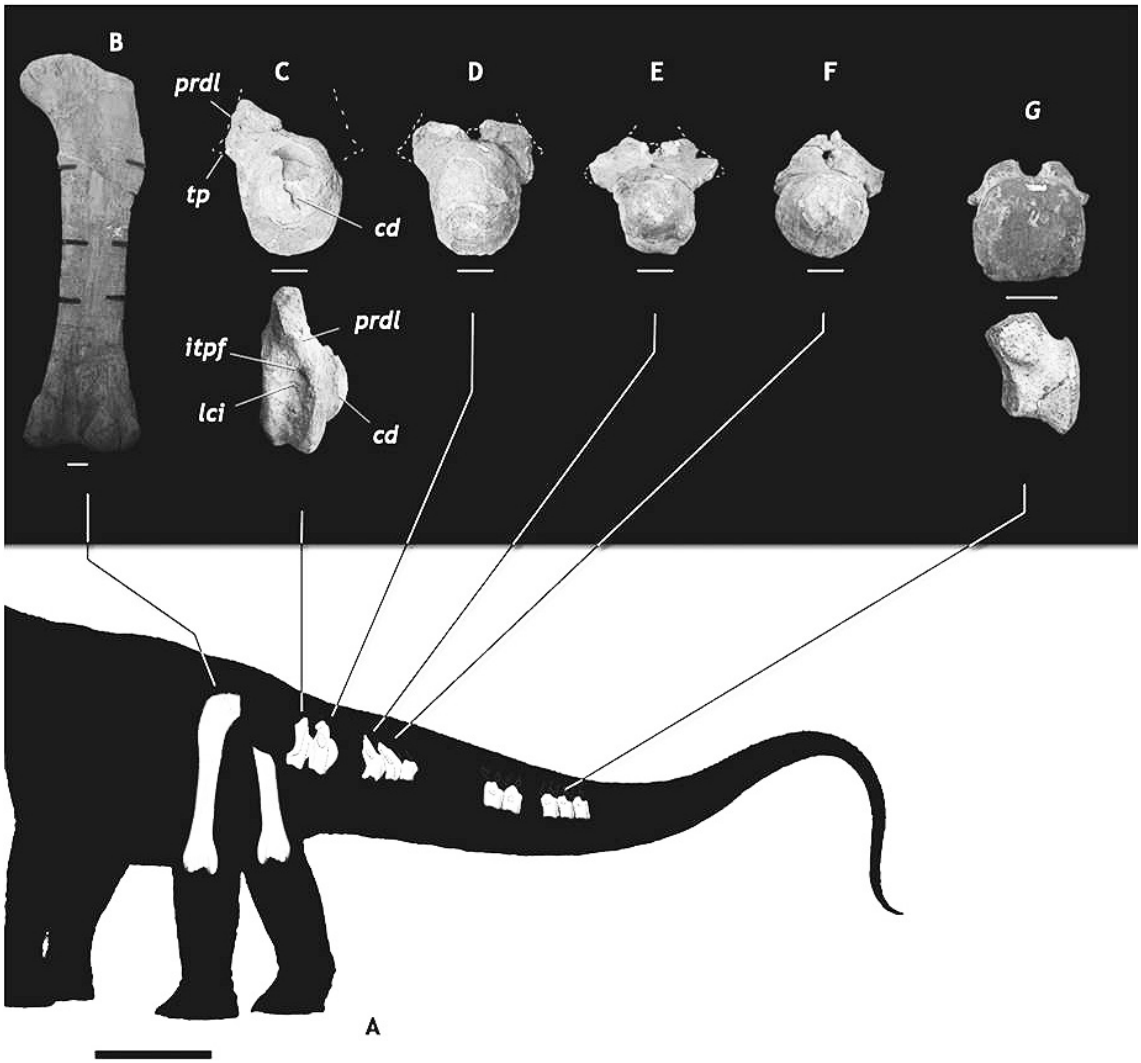

Figure 2. *Traukutitan eocaudata* taxon nov. **A.** Sketch of the siluete and preserved skeleton; **B.** Left femur in anterior view; **C.** First caudal vertebra in posterior and lateral view; **D.** Second caudal vertebrae in posterior view; **E.** and **F.** Possibly fourth and fifth anterior caudal vertebrae in posterior view; **G.** Middle caudal vertebrae in posterior and lateral view. Scale 10 centimeters. Abbreviations: **cd**, condyle ; **itpf**, infra transverse process foramina; **lci**, central inferior lamina; **prdl**, prezygodiapophyseal lamina; **tp**, transverse process.

Femur

Both the left and right femora of *Traukutitan tax. nov.* are preserved. They display the tipical titanosauriform features such as the development of the lateral bulge; however, in the new taxon,

there are no evidence of a dorsomedially bevelled distal condyles and these are not expanded in the anterior shaft.

Discussion

Originally reported by Salgado and Calvo (1993) from the Río Colorado Formation, this sauropod was subsequently assigned to the Río Neuquén subgroup and considered as a representant of a more ancient faunnal association that the original authors (Leanza *et al*. 2004; Salgado *e* Bonaparte, 2007). A revision of the type locality and surrounded areas allows us to confirm the provenance of it from the base of the Bajo de la Carpa Formation, the basal unit of the Río Colorado subgroup, as originally proposed by Salgado and Calvo (1993). This contradict the biostratigraphic interpretations given in Leanza *et al*. (2004) and Salgado and Bonaparte (2007), among others, about the time of extinction of basal titanosaurs in the Neuquén basin previous to the deposition of the Bajo de la Carpa Formation.

In addition to *Traukutitan* tax. nov., others titanosaurs without completely procoelous caudal sequences has been previously reported from South America. Huene (1929) described the existence of amphicoelic caudal vertebrae for titanosaurians in two localities of Patagonia, Rancho de Ávila and Cañadón el Valleche, and dessigned these as cf. *Macrurosaurus* sp. These from the Rancho de Ávila locality represent distal caudal vertebrae. Amphicoelic distal caudals have been reported in titanosaurs as *Rinconsaurus*, *Pitekunsaurus*, and an indeterminated titanosaur from Brazil (DGM 497-R, Trotta *et al*., 2002). The remaining compared titanosaurid taxa with known distal caudal vertebrae presents a biconvex morphology. Since the holotype of *Traukutitan eocaudata* tax. nov. does not contain distal caudal vertebrae, this trait is not comparable, although is evident that the procoelic condition was restricted only to the anterior and middle caudals in the derived titanosaurs. The vertebrae reported by Huene from Cañadón el Valleche resembles to the vertebrae of basal ornithopods and hadrosaurs (Juárez Valieri, pers. obs.), and could represent a form of these groups.

Although the strong procoelic anterior caudal centra is a character present in diverse sauropod taxa and is not ussefull as a isolated character (Bonaparte *et al*., 2000), the morphology of the femora and the additional characters of the vertebrae confirm to *Traukutitan eocaudata* tax. nov. as a titanosaur more derived than *Andesaurus* and another forms as *Brachiosaurus*, *Venenosaurus*, *Chubutisaurus*, *Amargatitanis*, *Malarguesaurus*, and *Phuwiangosaurus*, which present amphicoelic, amphiplatyan, or slowly procoelic centra in their anterior caudal vertebrae. The remaining taxa utilized for comparison, including to *Malawisaurus* and more derived taxa present strongly procoelic anterior caudals, except *Opisthocoelicaudia*, but their opistocoely has been interpreted as a derived condition (Salgado *et al*., 1997).

Titanosaurs with strong procoely in anterior caudals followed by slightly procoelus to platycoelous elements are restricted to *Traukutitan* tax. nov., *Malawisaurus* and *Mendozasaurus*. Following the phylogenetic interpretations given by Calvo *et al*. (2007a) and González Riga *et al*.

(2009), these represent a basal branch of Titanosauridae, together with *Futalognkosaurus*, which preserves only the first caudal vertebra. More derived taxa in these analyses displays continuous sequences of procoelous anterior and middle caudal centra. This topology in the phylogeny is consistent with a progressive adquisition of the procoely along the caudal sequence (Tidwell *et al*., 2001), and the morphology of *Traukutitan* tax. nov. is then interpreted as plesiomorphic condition. The basal titanosauriform *Malarguesaurus* present a unusual sequence of procoelous-opisthoplatyan proximal and middle caudal vertebrae associated with procoelous distal caudal centra. This condition is interepreted here as independienly obtained and not related with the process present in the titanosaurids.

An articulated caudal sequence assigned to *Aeolosaurus rionegrinus?* was recovered from Los Alamitos Formation (MACN-RN 147, Powell, 1987, 2003), late Campanian to early Maastrichtian preserves fifteen elements, all procoelous except the last vertebra, which was reported as amphicoelic, although in the terminology used here is better described as procoelous-opisthoplatyan. Posterior review excluded this material from *Aeolosaurus* (Salgado and Coria, 1993; Salgado and Calvo, 1997b). Based in the elongation and shape of the centra and the development of the transverse process, evidence that the position of the first non-procoelous element is sensibly more posterior in the vertebral sequence, in a medio-distal caudal position. In turn, *Traukutitan* tax. nov., *Malawisaurus* and *Mendozasaurus* present proximal-medial caudal without stongly procoelous elements. Then, MACN-RN 147 represents a more derived taxon, with presence of the strongly procoelous condition coming to the distal medial vertebral sequence.

A depression in the lateral face of the centrum of the first caudal vertebra as observed in *Traukutitan* tax. nov. is also present in another taxa as *Futalognkosaurus* (pers. obs.), *Paralititan* and *Alamosaurus* (Lamanna *et al*., 2002), but it is not reported in taxa as *Malawisaurus*, *Mendozasaurus*, or *Epachtosaurus*, then it does not represent a common character among the titanosaurids.

As mentioned above, *Traukutitan* tax. nov. resemble to *Futalognkosaurus* and *Mendozasaurus* in the morphology of the base of the neural archs and the transverse processes, suggesting that *Traukutitan* tax. nov. could represent a later Longkosauria. A simmilar placement also has been suggested for *Puertasaurus reuili* (Calvo *et al*. 2007b; Navarrete *et al*., 2009). Then, *Traukutitan eocaudata* tax. nov. represent the last definitive basal titanosaurid that survived to the senonian times in northern Patagonia, and possibly correspond to a basal brach of Titanosauridae, wich diverged in latter Early Cretaceous times.

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