

SHORT NOTE ON A CAUDAL VERTEBRA OF TITANOSAUR (SAUROPODA, LITHOSTROTIA) FROM THE LATE CRETACEOUS OF ATACAMA REGION

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ABSTRACT

We report here an isolated anterior caudal vertebra belonging to a lithostrotian titanosaur sauropod. The material comes from the Hornitos Formation (Late Cretaceous) at quebrada La Higuera, Atacama Region, North of Chile. Previous local records only included juvenile individuals. The new find represents the first evidence of adult titanosaurs in this locality. The sediment removed during preparation is similar to that found in the level with the two *in situ* specimens, suggesting similar environmental conditions, and possibly belonging to the same stratigraphical unit.

Keywords: Lithostrotia, titanosaur, Hornitos Formation.

RESUMEN

Nota breve sobre una vértebra caudal de titanosaurio (Sauropoda, Lithostrotia) del Cretácico Tardío de la Región de Atacama. Reportamos una vértebra caudal anterior aislada de un saurópodo titanosaurio Lithostrotia. El material proviene de la Formación Hornitos en quebrada La Higuera, Región de Atacama, norte de Chile. Los registros locales previos corresponden exclusivamente a individuos juveniles. El nuevo hallazgo representa la primera evidencia de titanosaurios adultos en esta localidad. El sedimento removido durante la preparación es similar al encontrado en los dos especímenes *in situ*, sugiriendo condiciones ambientales similares, perteneciendo posiblemente a la misma unidad estratigráfica.

Palabras clave: Lithostrotia, titanosaurio, Formación Hornitos.

INTRODUCTION

Titanosaur sauropods are the best represented dinosaurs in Cretaceous rocks of Chile. All the fossil record of this group comes from the northern regions of the country (*e.g.*, Rubilar-Rogers *et al.* 2012; Soto-Acuña *et al.* 2015). Indeed, the first new species of non-avian dinosaur described from Chile, *Atacamatitan chilensis* Kellner *et al.* 2011, belongs to this group.

Part of a left humerus and rib fragments were reported from Algarrobito hill (Chong 1985) in the Hornitos Formation (Segerstrom 1959; Arévalo 2005) Atacama Region, then identified by J.F. Bonaparte (*In* Chong 1985) as belonging to titanosaurs. Later in the vicinity and within same formation remains of two partial skeletons were collected. These also belong to titanosaurs of a new, yet unnamed taxon. The first skeleton was collected by staff of Sernageomin (National Service of Geology and Mining of Chile) in 1994 and includes part of the anterior and posterior limbs (humerus and femur), pelvis (ilium and ischium), cervical, and dorsal vertebrae (with their respective neural arches) and ribs, as reported by Iriarte *et al.* (1998). The second specimen was collected in two seasons by staff of the Museo Nacional de Historia Natural between 2007 and 2011 through heritage research funds of the Dirección de Bibliotecas, Archivos y Museos (DIBAM). This second skeleton, found in the same stratigraphic level and about 200 meters distant from the previous specimen (Rubilar-Rogers 2007) comprises part of the pelvis, femur, ulna, dorsal and caudal vertebrae. In both specimens, no neurocentral fusion is observed neither in dorsal or caudal vertebrae, supporting that these were possibly subadult individuals.

Along the quebrada La Higuera (La Higuera ravine), in the aforementioned and other reconnaissance visits, surface materials were collected. Such materials are very fragmentary and eroded, and some of

them apparently came from other stratigraphic levels. An interesting piece of those collected in surface corresponds to a caudal vertebra where the neural arch can be appreciated to be fused to the center, indicating an osteologically mature individual, unlike the other specimens previously collected from the same locality. Interestingly, the vertebra contained sediment removed during preparation that is similar to that found in the level with the two *in situ* specimens, suggesting similar environmental conditions as those described from the levels hosting the two previous known postcranial skeletons.

Institutional abbreviation. SGO.PV. Museo Nacional de Historia Natural.

Geologic Setting

Segerstrom (1959) defined the Hornitos Formation as *ca.* 2,200 m section mainly sedimentary and secondarily volcanosedimentary, cropping out southeast of Copiapó. This formation is conformed by breccias and conglomerate levels in coarse sandstone matrix. These include lenses of sandstones, calcareous mudstones and limestones, with discrete volcanic levels to the roof. The Hornitos Formation unconformably overlays the Albian-Santonian Cerrillos Formation. Upper levels of the unit as well as volcanic deposits covering it, have been dated as latest Cretaceous – middle Eocene (Arévalo 2005). Thus, based on stratigraphic correlations, the Hornitos Formation can be assigned to the Campanian-Maastrichtian. The unit represents part of an extensional basin controlled by faults (Charrier *et al.* 2007).

Systematic Paleontology

Dinosauria Owen, 1842

Saurischia Seeley, 1887

Sauropodomorpha von Huene, 1932

Sauropoda Marsh, 1878

Titanosauria Bonaparte and Coria, 1993

Lithostrotia Upchurch *et al.*, 2004

Lithostrotia indet.

(Figure 2)

Material—SGO.PV.15001, an isolated caudal vertebra.

Locality, horizon and age—quebrada la Higuera, southeast Copiapó, Atacama Region (Figure 1). Hornitos Formation, Campanian-Maastrichtian.

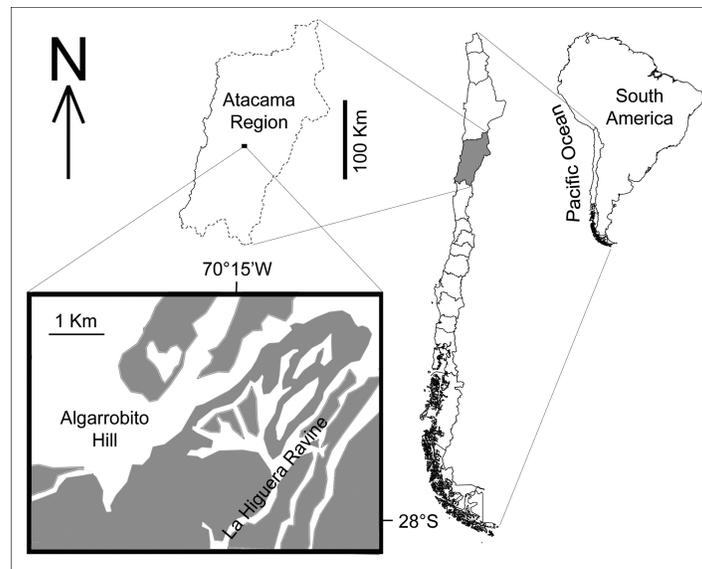


FIGURE 1. Map showing the site where the vertebra was found.

Description— A strongly focuses procoelous caudal with a strongly convex distal articular condyle (Figure 2), 16.6 cm maximum length, maximum width 13.1 at the level of the proximal face, 9.5 cm high maximum at level of the proximal face. The body of the vertebra is short and wide being subcircular in cross section. The ventral side has a smooth, wide concavity. The apex of the condyle occurs in the dorsal half of the centrum. It presents a distortion of the anteroposterior axis caused by diagenesis, noticeable in dorsal view. Although the neural spine is broken and very eroded, being almost absent, its base is preserved and continuous with the center, indicating complete fusion. In the upper half of the sides of the center the bases of the transverse process are seen which have broken off at both sides.

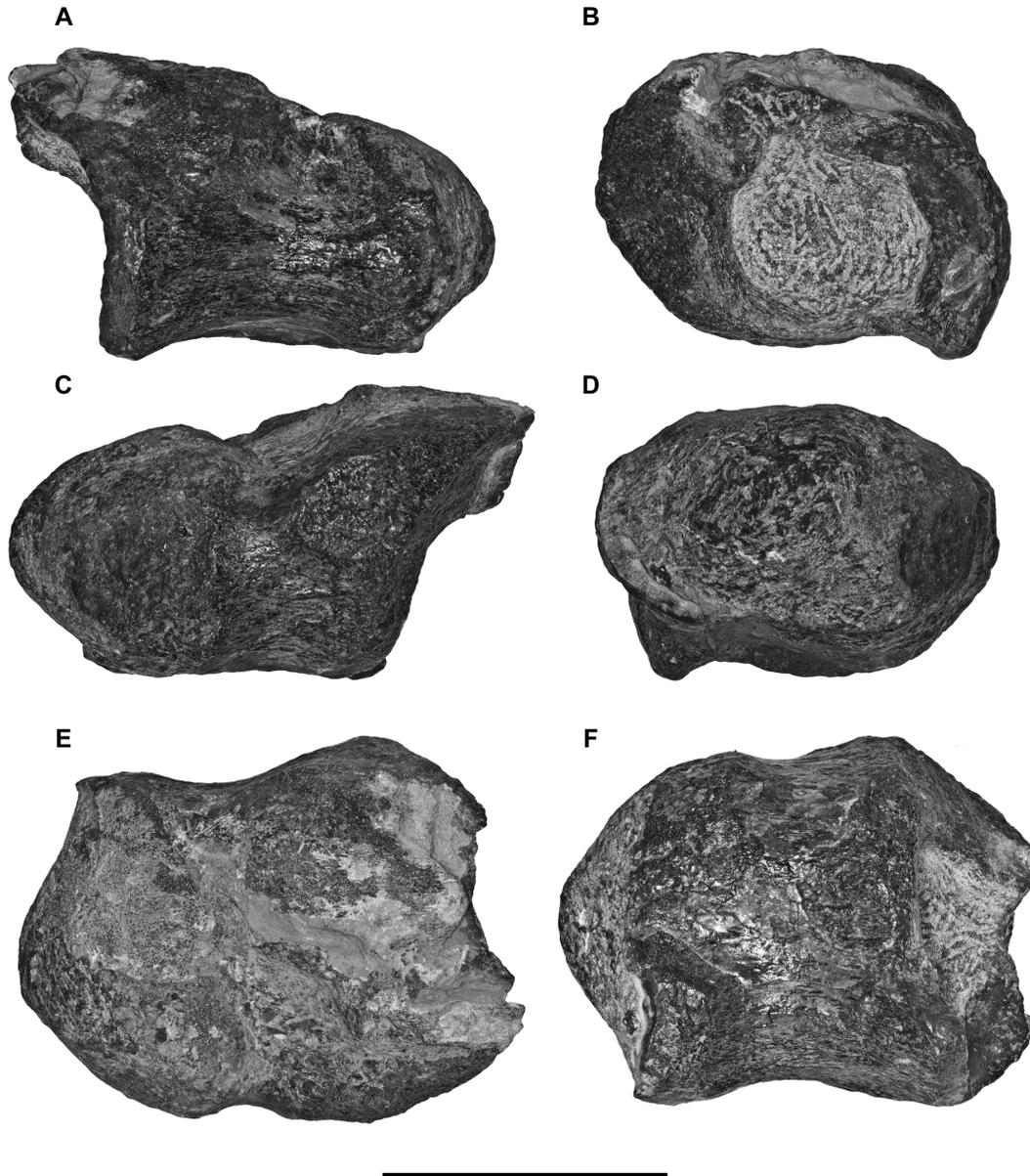


FIGURE 2. *Lithostrotia* indet. SGO.PV.15001. A, left lateral view; B, anterior view; C, right lateral view; D, posterior view; E, dorsal view; F, ventral view. Scale bar = 10 cm.

DISCUSSION

In the original diagnosis of Titanosauridae (Lydekker 1893) the South American forms were related with the poorly represented species *Titanosaurus indicus* (Lydekker, 1877) from India. The only shared feature was the presence of procoelous caudal vertebrae. Its taxonomic validity has been questioned by Wilson and Upchurch (2003) who changed the diagnosis based on this genus for one based on *Isisaurus* (Wilson and Upchurch 2003), however, these same authors state in the diagnosis of *Isisaurus* the presence of procoelous anterior caudal vertebrae. This diagnosis is not applicable to many forms of titanosaurs in which intercalating morphologies are found in the caudal sequence; for example, *Rinconsaurus* which characterized by the intercalation of amphicoelous-biconvex or amphicoelousopisthocelous-biconvex caudal centres (Calvo and González Riga 2011). Despite this, and before the review of Wilson and Upchurch (2003), historically the presence of procoelous caudals has been used as a diagnostic character in various higher taxonomic levels of these sauropods, for example, Wilson (2002) proposed three anterior procoelous caudal vertebrae and the absence of forked chevrons as synapomorphies of Titanosauria. Subsequently Upchurch *et al.* (2004), defined the taxonomic clade Lithostrotia as equivalent to the Titanosauridae family, using this term for those who have at least anterior caudal vertebrae strongly procoelous with prominent condyles, and lunate sternal plates.

Being Upchurch *et al.* (2004) the most recent and effective definition of clade Lithostrotia, replacing Titanosauridae, we prefer to use this definition, referring this caudal vertebra SGO.PV.15001 to the Lithostrotia clade.

Ibiricu *et al.* (2014) conducted a study on the influence of caudofemoral musculature on the skeleton of titanosaur tails. They used specimens as complete as possible and distinguish three types of stages of evolution in titanosaurids which are consistent with the proposed phylogenies for the group. For example, *Andesaurus* and *Epachthosaurus* as basal forms of Titanosauria; saltasaurines as derived Titanosauria and “intermediate forms”, non-saltasaurine lithostrotians as *Baurutitan*, *Laplataosaurus* and *Pellegrinisaurus*. Based on this study differences are distinguished in the form of the caudal series. In the basal forms two types of caudal intercentral joints are distinguished: strongly procoelous throughout the series in *Epachthosaurus*, proximals slightly procoelous with the rest of the series amphicoelous in *Andesaurus*. In non-saltasaurine lithostrotians caudals are strongly procoelous with a prominent distal condyle and a fairly deep proximal concavity. In these vertebrae neural arches are arranged on the anterior half of the centrum and the transverse processes disappear into the caudal 8 and 10 (Ibiricu *et al.* 2014). The same authors point out that in these taxa proximal caudal centers are much wider transversely. Finally, in saltasaurines although the proximal caudals are deeply procoelous with a proximal deep concavity and well-developed distal condyle, in the case of *Nequensaurus* they have convex lateral sides, while in the case of *Saltasaurus* the center is short and wide, its ventral side has a smooth and wide concavity that deepens and tapers towards posterior (Powell 1992). In the middle caudals of *Saltasaurus* and *Nequensaurus* a marked longitudinal depression with a distinct median ridge is observed. All saltasaurine caudals have camellate tissue structure. Of all the features mentioned above characters of non-saltasaurine lithostrotian are present in SGO.PV.15001. In the case of saltasaurines, anterior caudals are strongly procoelous and wide in the case of *Saltasaurus*, but camellate (spongy) structure is not observed in SGO.PV. 15001.

CONCLUSION

The studied material SGO.PV. 15001 represents an additional specimen from quebrada La Higuera. This material is referred to a non saltasaurine lithostrotian titanosaur, based mainly by the absence of spongy tissue in the centrum. Previous records from this locality are represented by partial postcranial skeletons of juvenile individuals. Possibly this material comes from the same stratigraphic level from previously specimens. Even in its fragmentary condition, SGO.PV. 15001 represents the first evidence of a likely adult titanosaur found in this site belonging to Late Cretaceous of the Hornitos Formation.

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