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SHORT COMMUNICATION

The first record of a sauropod dinosaur from Antarctica

Ignacio A. Cerda · Ariana Paulina Carabajal · Leonardo Salgado · Rodolfo A. Coria · Marcelo A. Reguero · Claudia P. Tambussi · Juan J. Moly

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Abstract Sauropoda is one of the most diverse and geographically widespread clades of herbivorous dinosaurs, and until now, their remains have now been recovered from all continental landmasses except Antarctica. We report the first record of a sauropod dinosaur from Antarctica, represented by an incomplete caudal vertebra from the Late Cretaceous of James Ross Island. The size and morphology of the specimen allows its identification as a lithostrotian titanosaur. Our finding indicates that advanced titanosaurs achieved a global distribution at least by the Late Cretaceous.

Keywords Antarctic Peninsula · Upper Cretaceous · Titanosauria · Lithostrotia

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I. A. Cerda (✉) · L. Salgado
Consejo Nacional de Investigaciones Científicas y Tecnológicas (CONICET), INIBIOMA, Museo de Geología y Paleontología Universidad Nacional del Comahue,
Buenos Aires 1400, Neuquén Capital, Argentina
e-mail: nachocerda6@yahoo.com.ar

A. Paulina Carabajal · R. A. Coria
CONICET, Museo Carmen Funes,
Av. Córdoba 55,
Plaza Huincul, Neuquén, Argentina

R. A. Coria
Instituto de Investigación en Paleobiología y Geología,
Universidad Nacional de Río Negro,
Isidro Lobos y Belgrano CP 8332,
General Roca, Río Negro, Argentina

M. A. Reguero · C. P. Tambussi
CONICET, División Paleontología de Vertebrados,
Museo de La Plata,
Paseo del Bosque s/n, B1900FWA,
La Plata, Argentina

M. A. Reguero
Instituto Antártico Argentino,
Cerrito 1248,
1010, Ciudad Autónoma de Buenos Aires, Argentina

J. J. Moly
División Paleontología de Vertebrados,
Museo de La Plata,
Paseo del Bosque s/n, B1900FWA,
La Plata, Argentina

Introduction

With more than 150 valid recognized species, Sauropoda is the second most diverse group of dinosaurs and includes the largest terrestrial vertebrates that ever existed (Wilson 2002; Upchurch et al. 2004; Wilson and Curry Rogers 2005; Sander et al. 2011; Mannion and Upchurch 2011; Mannion et al. 2011). This lineage appeared in the Late Triassic and was the predominant megaherbivorous group throughout 150 Ma during the Mesozoic (Wilson 2002; Upchurch et al. 2004). Although abundant sauropod remains have been collected in the Southern Hemisphere (particularly in South America), there is no previous record of this lineage in Antarctica (Weishampel et al. 2004).

Despite the arduous collecting conditions there, important dinosaur discoveries have been made in the Upper Cretaceous of Antarctica in the last two decades. The principal Upper Cretaceous and Paleogene sedimentary sequence in Antarctica is located in the James Ross Basin, which is located in the Weddell Sea, adjacent to the northern part of the Antarctic Peninsula (del Valle et al. 1992). Cretaceous and Paleogene beds of the James Ross Basin are exclusively marine and are only exposed on James Ross, Vega, Snow Hill, Seymour, and the nearby Cockburn islands (Reguero and Gasparini 2007). The Upper Cretaceous beds of this basin comprise shallow marine shelf deposits of the Hidden Lake, Santa Marta, and López de Bertodano formations. The James Ross Basin has yielded a diverse assemblage of both marine and terrestrial fossil vertebrates, including non-avian dinosaurs (see overview by Reguero and Gasparini 2007). To date, the record of non-avian dinosaurs from the James Ross Basin includes the ankylosaur *Antarctopelta oliveroi* (Gasparini et al.

1987; Salgado and Gasparini 2006), indeterminate basal ornithopods and hadrosaurs (Cambiaso et al. 2002; Case et al. 2000; Coria et al. 2008; Hooker et al. 1991; Rich et al. 1999), and two indeterminate theropods (Case et al. 2007; Molnar et al. 1996). Apart from the hadrosaur, there is no record of large bodied herbivorous dinosaurs in the Upper Cretaceous of Antarctica.

In this contribution, we report the first finding of sauropod dinosaur remains from this continent, represented by an incomplete caudal vertebra recovered from Upper Cretaceous sediments of the James Ross Island. Since the dinosaurian record from Antarctica is exceptionally poor compared to that of other continents, the material reported here improves our current knowledge about the dinosaurian faunas during the Late Cretaceous in this continent.

Systematic paleontology

Dinosauria Owen 1842
Saurischia Seeley 1888
Sauropoda Marsh 1878
Titanosauria Bonaparte and Coria 1993
Lithostrotia Upchurch et al. 2004
Genus and species indeterminate.

Material

MLP (Museo de La Plata, Argentina) 11-II-20-1, incomplete middle caudal vertebra.

Locality and horizon

The specimen was collected in shallow marine shelf deposits referred to the upper Campanian (Santa Marta Formation) (Crame et al. 1991; Olivero et al. 1986), from Santa Marta Cove in the northern part of James Ross Island (Fig. 1).

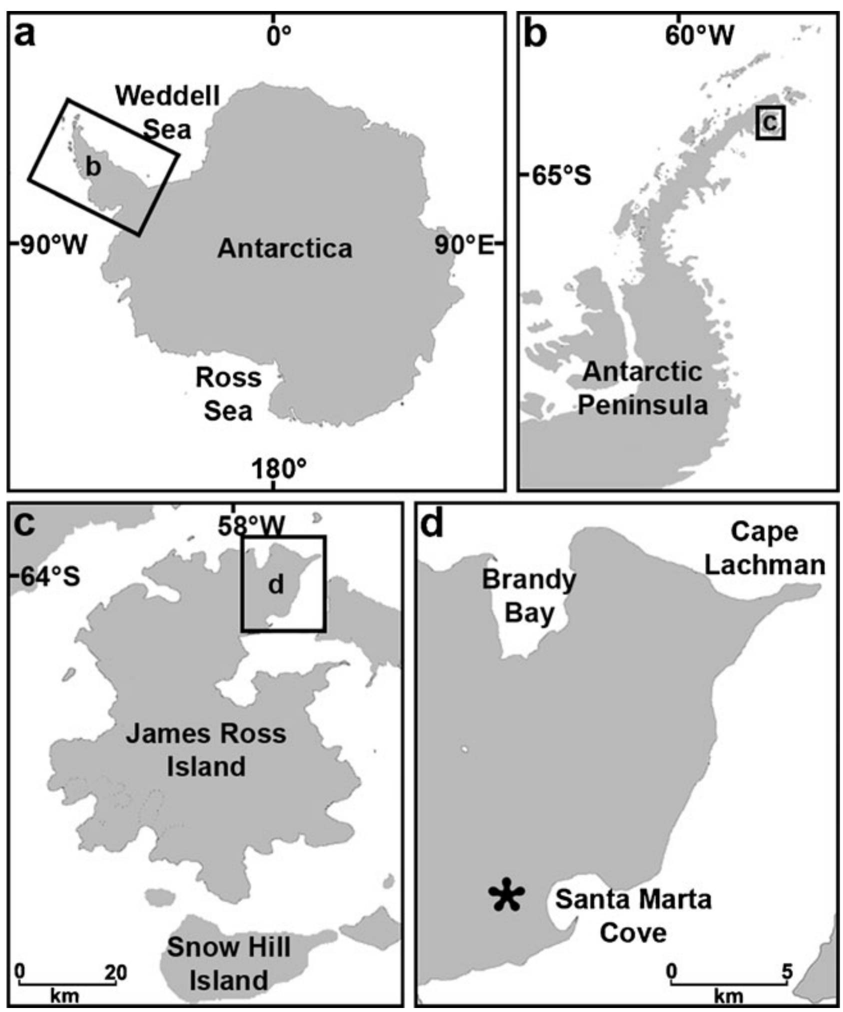

Fig. 1 Locality map of the Antarctic Peninsula and the James Ross Island showing the fossil site of MLP 11-II-20-1 (*asterisk*)

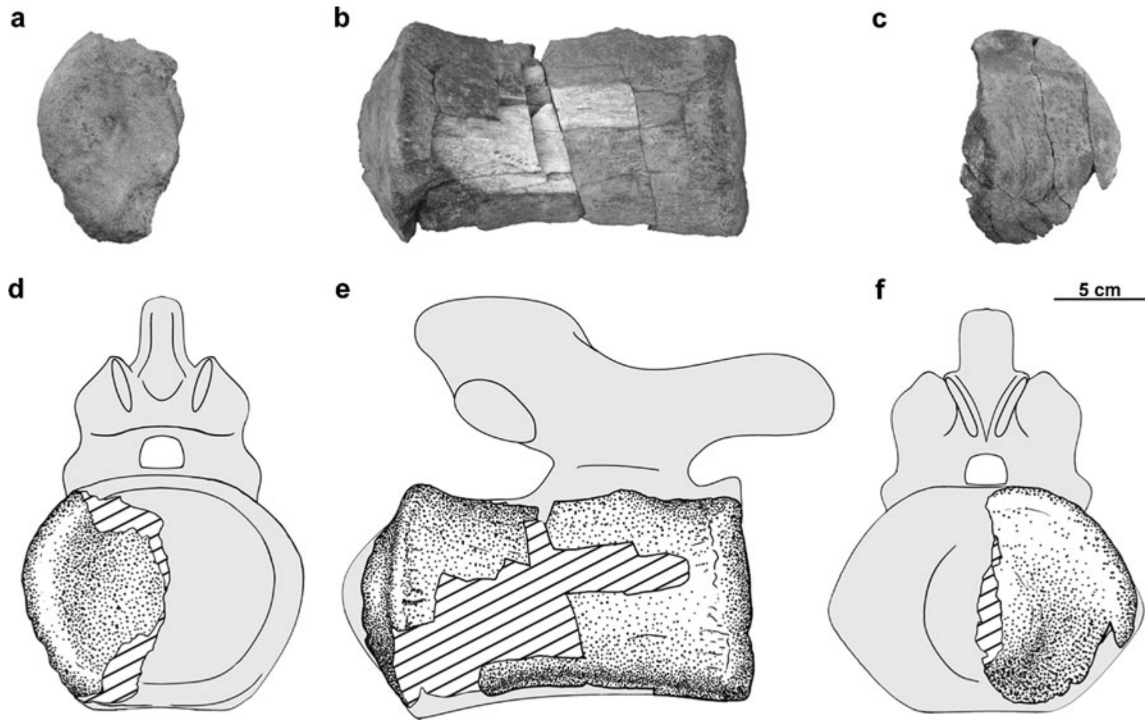

Fig. 2 Lithostrotian gen. et sp. indet. MLP 11-II-20-1 caudal vertebra centrum, photograph (**a**–**c**) and interpretative drawing (**d**–**f**) in anterior (**a**, **d**), right lateral (**b**, **e**), and posterior (**c**, **f**) views

Description

MLP 11-II-20-1 consists of the right half of a caudal centrum (Fig. 2). The largest dimension of the centrum is proximodistal, and it shows a "ball-and-socket" (concave and convex) articulations. Although the neural arch is missing, the preserved dorsal surface of the centrum indicates that the neural arch was not located toward the convex articular end. The lateral surface is concave in ventral view, and there is no evidence of a transverse process. The concave articular surface is quite deep with a distinct rim. The convex articular surface shows a small, protuberant condyle that appears to be restricted to the center of the articular surface, surrounded by shallow, concentric grooves. No chevron facets are preserved. The sagittal fracture allows observation that the internal bone structure is not camellate, which is a condition in which the bone contains numerous small, irregular internal spaces (Britt 1997; Wedel 2003). Instead, the centrum is filled with cancellous bone tissue (Fig. 3). The centrum length (excluding the articular condyle) is 169 mm, and the total preserved centrum length is 194 mm. The height of the preserved portion of the posterior articular surface is 117 mm. The centrum length:centrum height ratio and the absence of a transverse process suggest a location in the middle third of the tail for the specimen.

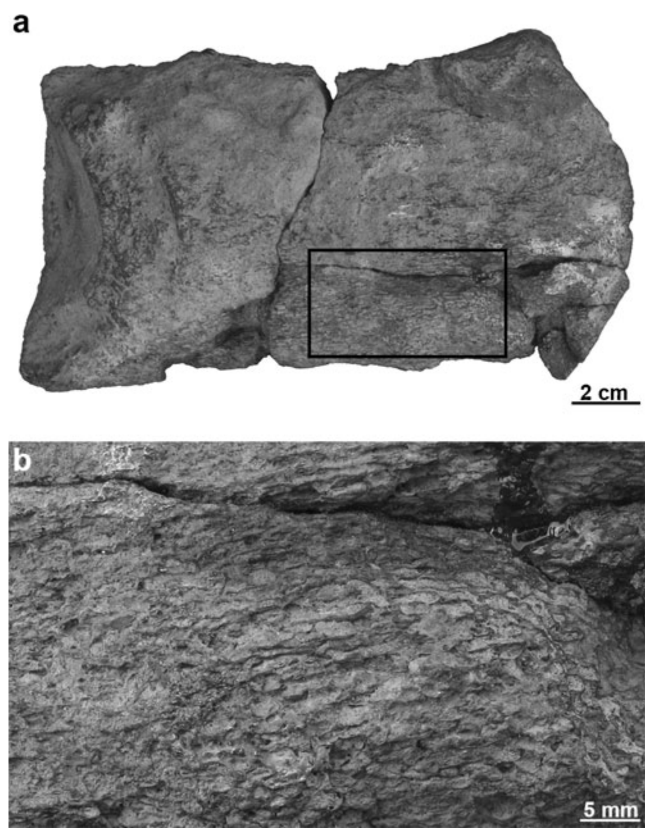

Fig. 3 Lithostrotian gen. et sp. indet. MLP 11-II-20-1 caudal vertebra centrum. **a** General view of the broken surface. Note the absence of camellate bone tissue. **b** Inset of box in **a** showing a detailed view of the internal cancellous bone tissue

Discussion

Taxonomy

The morphology and size of the specimen indicate affinities with derived sauropod dinosaurs. Middle caudal vertebra with ball and socket articulations (procoelous or opisthocoelous) is a common character of advanced titanosauriform sauropods (Titanosauria) (Powell 2003; Upchurch et al. 2004; Wilson 2002). The anteroposterior orientation of the caudal centrum can be established on the basis of the position of the neural arch. The absence of neural arch pedicles toward the convex articular end in MLP 11-II-20-1 indicates that the neural arch was located in the middle of the centrum or slightly displaced toward the concave articular end. Since in all titanosauriformes, the neural arches of the middle caudals lay on the anterior half of the centrum (Salgado et al. 1997; Upchurch et al. 2004), we interpret the specimen as a procoelous middle caudal centrum. A procoelous condition in middle caudal vertebrae has been proposed as a diagnostic feature of lithostrotian titanosaurs (Upchurch et al. 2004). The absence of camellate internal structure in the caudal centrum suggests that the specimen does not belong to Saltasaurini (Saltasaurinae sensu Salgado et al. 1997), a highly derived clade of lithostrotian titanosaurs that includes the South American forms *Saltasaurus loricatus* and *Neuquensaurus australis* (Powell 2003; Salgado and Bonaparte 2007). Given the fragmentary nature of MPL 11-II-20-1 and the lack of autapomorphic features, we refrain from naming the specimen and do not refer it to any named lithostrotian taxon. We regard it as an indeterminate non-Saltasaurini lithostrotian.

Paleobiogeography

Lithostrotian titanosaurs originated during the Early Cretaceous (Wilson and Upchurch 2003; Zaher et al. 2011; Mannion et al. 2011) and were the predominant group of sauropod dinosaurs until the extinction of all non-avian dinosaurs at the end of the Cretaceous (Upchurch et al. 2004). Members of this lineage have been found in North and South America, Africa, Asia, Australia, and Europe, with their remains particularly abundant in South America (Upchurch et al. 2004; Weishampel et al. 2004). Although lithostrotian titanosaurs were one of the most widespread and successful lineages of sauropod dinosaurs, their origin and dispersion is incompletely understood (Mannion and Upchurch 2010). The occurrence of lithostrotian titanosaurs in Antarctica could be explained by two, non-mutually exclusive, paleobiogeographic hypotheses. The first one involves a dispersal event from South America through a paleoisthmus between Patagonia and the Antarctic Peninsula during the Late Cretaceous (Shen 1995), as proposed for hadrosaur dinosaurs in Antarctica (Case et al. 2000). The second hypothesis considers that titanosaur sauropods were already present in Antarctica during the Early Cretaceous or earlier. This idea is supported by the occurrence of lithostrotian titanosaurs in the Albian of Australia (Hocknull et al. 2009). Also, this hypothesis is consistent with the cladistic biogeographic study of Upchurch et al. (2002), which was based on all dinosaur groups and that supports the hypothesis that many clades spread across Pangaea or Gondwana prior to Cretaceous continental fragmentation. Nevertheless, the scarcity of specimens and the poor knowledge of the Early and middle Cretaceous dinosaur faunas from Antarctica preclude speculation about the paleobiogeographic relationships of Antarctic titanosaur.

Based on the record of a possible titanosaurian caudal vertebra from the Campanian of New Zealand, Molnar and Wiffen (2007) suggested that titanosaur sauropods were also present in Antarctica, since both continental areas were connected during most of the Cretaceous. The data provided here indicates that advanced titanosaurs with characteristic procoelous mid-caudal vertebrae achieved a global distribution by the Late Cretaceous.

MLP 11-II-20-1 is the second sauropodomorph dinosaur recorded from Antarctica. The first one is a basal sauropodomoph dinosaur, *Glacialisaurus hammeri*, collected from the Beardmore Glacier region of the Central Transantarctic Mountains (Early Jurassic, Hanson Formation) (Hammer and Hickerson 1994; Smith and Pol 2007). The absence of sauropodomorph material between the Lower Jurassic and the Upper Cretaceous in Antarctica is more probably related to a poor sampling than a genuine absence of members of this lineage during this time.

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