



# A new sauropod (Macronaria, Titanosauria) from the Adamantina Formation, Bauru Group, Upper Cretaceous of Brazil and the phylogenetic relationships of Aeolosaurini

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## Abstract

Remains of a new titanosaur, *Aeolosaurus maximus* sp. nov., from the Adamantina Formation (Upper Cretaceous), Bauru Group, São Paulo State of Brazil are described. The new species is represented by a single partially articulated skeleton and is characterized by having a well-developed posterior protuberance below the articular area on the anterior and middle haemal arches and a lateral bulge on the distal portion of the articular process of the mid-posterior haemal arches. It shares with other *Aeolosaurus* species the presence of prezygapophyses curved downward on anterior caudal vertebrae and haemal arches with double articular facets set in a concave posterodorsal surface. These two characteristics are interpreted here as synapomorphies for the genus *Aeolosaurus*. The new diagnosis for the genus *Aeolosaurus* does not support the inclusion of *Gondwanatitan* within *Aeolosaurus* as previously proposed by some authors. The phylogenetic analysis recovered the two *Aeolosaurus* from Argentina as sister groups with *A. maximus* and *Gondwanatitan* as progressively more basal taxa (*Gondwanatitan* (*A. maximus* (*A. rionegrinus*, *A. colhuehuapensis*))). Additionally, according to the results of the phylogenetic analysis performed in this work, the taxa *Panamericansaurus*, *Rinconsaurus*, and *Maxakalisaurus* are also nested within Aeolosaurini, being more basal than *Aeolosaurus* and *Gondwanatitan*. On the basis of the stratigraphic

ical range of the *Aeolosaurus* occurrences in Argentina and the age proposals based on microfossils for the Bauru Group, it is assumed a Campanian–Maastrichtian age for the top of the Adamantina Formation for the Monte Alto region in São Paulo State and the bottom of the Marília Formation in Peirópolis, Minas Gerais State—the places where *Aeolosaurus* remains have been reported in Brazil.

**Key words:** Dinosauria, Sauropoda, Titanosauriformes, Aeolosaurini, *Aeolosaurus*, cladistic analysis

## Introduction

The knowledge of titanosaur diversity and geographical distribution has witnessed an extreme increase during the last decades with the description of new material (and species) from Asia (Martin *et al.* 1994; Jain and Bandyopadhyay 1997), Europe (Le Loeuff 1993, 1995; Sanz *et al.* 1999), Africa (Jacobs *et al.* 1993; Curry Rogers and Forster 2001; Gomani 2005), Australia (Molnar and Salisbury 2005; Hocknull *et al.* 2009), and South America (Powell 1986, 2003; Calvo and Bonaparte 1991; Bonaparte and Coria 1993; Salgado and Coria 1993; Salgado and Azpilicueta 2000). In Brazil new forms have also been reported lately such as *Gondwanatitan faustoi* (Kellner and Azevedo 1999), *Baurutitan britoi* (Kellner *et al.* 2005, first reported in Powell, 1986), *Trigonosaurus pricei* (Campos *et al.* 2005, first reported in Powell 1986), *Adamantisaurus mezzalirai* (Santucci and Bertini 2006a), *Maxakalisaurus topai* (Kellner *et al.* 2006), *Uberabatitan ribeiroi* (Salgado and Carvalho 2008), and *Tapuiasaurus macedoi* (Zaher *et al.* 2011). Additionally, fragmentary remains have been described from Minas Gerais State (Santucci and Bertini 2006b; Lopes and Buchmann 2008; Santucci 2008), and Morro do Cambambe, Mato Grosso State (Franco-Rosas *et al.* 2004). Curiously, although well known by numerous remains around the world, the inter-relationships within the clade Titanosauria are not well understood yet.

In 1997 and 1998 the staff of the Museu de Paleontologia de Monte Alto (Monte Alto Paleontological Museum) collected a partially articulated skeleton of a large titanosaur (Fig. 1), here called *Aeolosaurus maximus* **sp. nov.** The skeleton has been found with the cervical vertebrae (only the pairs of the mid-cervical ribs and two posterior cervical vertebrae), caudal vertebrae, humeri, and femora approximately in their anatomical position, whereas some distal caudal vertebrae, ribs, and other limb elements were slightly scattered away. Near the skeleton were also several theropod and crocodylomorph teeth, these were found in close association with the hind limb elements and probably belong to the animals that scavenged the carcass.

In this paper we describe this skeleton as a new species and establish its phylogenetic relationships by using previous data matrices and character lists for sauropods available in the literature. Additionally, a review of the material referred to the genus *Aeolosaurus* together with a phylogenetic approach of the characters that support both the genus *Aeolosaurus* and the clade Aeolosaurini are also addressed in this paper. *Aeolosaurus maximus* **sp. nov.** is the first well-preserved *Aeolosaurus* reported outside Argentina and broadens the geographic distribution of this genus in South America.

## Historical background

During the last decades some titanosaurs have been referred to the genus *Aeolosaurus* in Argentina. Although not complete, these specimens preserve anterior caudal vertebrae and, in some instances, several appendicular elements, which allow for good comparison among them. Because anterior caudal vertebrae are present in all these specimens, the diagnosis for the genus is mainly based on the morphology of these axial elements. On the other hand, as different authors have reported new specimens referred to the genus *Aeolosaurus*, the original diagnosis has been emended several times.

*Aeolosaurus rionegrinus* (Powell 1987) was the first Aeolosaurini to be described. This species is represented by a partial skeleton comprising anterior caudal vertebrae and appendicular elements (MJG-R 1) collected from the Angostura Colorada Formation in Río Negro Province, Argentina (Powell 1986, 1987, 2003). Unfortunately, the original description is part of Powell's PhD, which is not in line with the ICZN rules (item 8.1.3) for naming new taxa. At that time, Powell (1986) accommodated *Aeolosaurus*, together with the genus *Titanosaurus*, within the subfamily Titanosaurinae mainly on the basis of the presence of caudal vertebrae with narrow ventral face, high lateral face, and facets of the prezygapophyses facing laterally. However, this assignment was not supported by subse-