

THE GENUS *AEOLOSAURUS* (SAUROPODA:TITANOSAURIDAE) IN THE ALLEN
FORMATION (CAMPANIAN-MAASTRICHTIAN) OF RÍO NEGRO PROVINCE,
ARGENTINA.*

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ORIGINAL ENGLISH ABSTRACT: *THE GENUS AEOLOSAURUS (SAUROPODA:TITANOSAURIDAE) IN THE ALLEN FORMATION (CAMPANIAN-MAASTRICHTIAN) OF RÍO NEGRO PROVINCE, ARGENTINA.* Remains assigned to *Aeolosaurus* Powell, 1986 from the Allen Formation are described. The specimen differs from the holotype of *Aeolosaurus rionegrinus* Powell, 1986 in the length of the prezygapophyses, relative position of the postzygapophyses, and radius and ischium morphology. Considerations on a specimen tentatively assigned to the type species, and modified diagnosis of the genus are included. Association of dermal plates to the specimen here described is commented.

INTRODUCTION

The titanosaurids are the best represented dinosaurs in the Cretaceous of South America, consisting of a varied range of sauropods of diverse form and size.

Known principally in the South American continent, they managed to have representatives in almost all of the continents, which indicates a large adaptive quality of this group, and a large geographic distribution (see Powell, 1986). These factors determined the emergence of systematically distinct forms, that even managed to occupy distinct ecologic niches (Powell, 1986).

A revision of the South American forms was carried out recently by Dr. Jaime Powell (1986) of the Universidad Nacional de Tucumán, who evaluated the abundant information obtained until then by numerous authors as well as also describing new taxa and redefining various of those known.

The remains assigned to the Family Titanosauridae are very common in South America, and especially in Patagonia, of whose extensive Cretaceous outcrops (“Estratos con Dinosaurios”; Wichmann, 1916) have been recorded since the end of the last century and the beginnings of the current (Lydekker, 1893; Huene, 1929).

The example that is described here consists of various associated pieces. This is an uncommon characteristic within titanosaurid discoveries, since many of the investigations were carried out on the basis of isolated remains.

The material was extracted in June of 1989 by personnel of the Museo “Carlos Ameghino” de Cipolletti, the Museo de Ciencias Naturales of the Universidad Nacional del Comahue and the Museo “Carmen Funes” of Plaza Huincul.

The work was undertaken in the locality of Salitral Moreno, Río Negro Province, located some 20 km to the southwest of the city of General Roca (Fig. 1) where an

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important association of sauropods, hadrosaurs, theropods, turtles, and birds is located (Powell, op. cit.).

ABBREVIATIONS: MPCA, Museo Provincial “Carlos Ameghino”, Cipolletti, Río Negro, Argentina. MJG, Museo “Jorge Gerhold”, Jacobacci, Río Negro, Argentina. MACN-RN, Museo Argentino de Ciencias Naturales-Río Negro Collection, Buenos Aires, Argentina. DGM, Museo de la Divisao Geología y Mineralogía de Dir. Nac. Prod. Mineral, Río de Janeiro, Brazil.

SYSTEMATICS AND DESCRIPTION

Order SAURISCHIA Seeley, 1889
Suborder SAUROPODOMORPHA Huene, 1929
Family TITANOSAURIDAE Lydekker, 1893
Subfamily TITANOSAURINAE Lydekker, 1893

Aeolosaurus Powell, 1987 (1987b)

MODIFIED DIAGNOSIS: Caudal vertebrae with compressed centra, with high lateral and narrow ventral face starting from the 3=4 caudal. Neural arch inclined forward. Prezygapophyses longer than in other titanosaurids, projected forward and upward with the same inclination of the neural arch in the anterior caudals; and only forward beginning with the middle-posterior caudals. Very wide articular facets of the prezygapophyses on all of the anterior caudals. Postzygapophyses situated directed to the anterior half of the vertebral body beginning with the middle caudals. Neural spine inclined forward such that the end of the spine surpasses the anterior border of the vertebral centrum, at least beginning in the middle caudals. Haemopophyses with separated proximal ends, with double articular facets that follow distinct planes. Scapula with wide blade, somewhat distally expanded. Area of muscular attachment on the internal face proximal to the upper border prominent as in *Saltasaurus loricatus*. Robust humerus of the type of *Saltasaurus* with the apex of the deltoid crest for the insertion of the pectoral muscle prominent. Metacarpals relatively more robust than in *Titanosaurus*.

Aeolosaurus sp.

Pl. 1 A, B, C, D, E, F, H, I and figs. 2 to 9

TYPE SPECIES *Aeolosaurus rionegrinus* Powell, 1987 (1987b).

MATERIAL: MPCA 27124. Five caudal vertebrae, right ulna, a metacarpal, left pubis, right ischium (Pl. I A, B, C, F, H, I and Figs. 2, 3, 4, 7, 8, 9); MPCA 27125, right ulna, right radius (Pl. I D, E and figs. 5 and 6); MPCA 27126 and MPCA 27177, two dermal plates (Pl. IG).

GEOGRAPHIC PROVENANCE: Salitral Moreno, some 20 km to the southwest of the city of General Roca, Province of Río Negro, Patagonia, Argentina.

STRATIGRAPHIC PROVENANCE: Allen Formation, Lower Member (Powell, 1986).

STAGE: lower Maastrichtian (Ballent, 1980) or Campanian-Maastrichtian (Uliana and Dellape, 1981).

DESCRIPTION: Anterior caudal (Pl. 1A and Fig. 2): The vertebral body is wide, compressed, markedly procoelous, with high lateral faces. The transverse processes are directed laterally toward the rear. The neural arch is found inclined forward. The prezygapophyses are robust and of notable development. They are projected forward and upward, following the same angle of inclination as the neural arch.

The articular facets of the prezygapophyses are very developed, their larger diameter being 9.2 cm, and their smaller diameter 5.1 cm. Their major axis is inclined backward. The articular facets of the postzygapophyses are equally developed on all, in dorsal-ventral aspect. They are oriented ventrolaterally, contained in planes that are inclined with respect to the axial axis. The neural spine is not preserved in the two anterior caudals recovered.

Middle caudal: (Pl. IB and Fig. 3): The vertebral body possesses high lateral faces, and a narrow ventral surface, differing from the anterior caudals. However, the apex of the prominent posterior condyle is located above of the midline of the body. In the posterior border of the ventral surface of the vertebral body, robust articular facets for the haemopophyses are observed.

The transverse processes are directed horizontally toward the rear. The neural arch is appreciably lower than in the anterior vertebra; it is located very anteriorly and is found strongly inclined forward (Fig. 10A). The prezygapophyses are long although not as much as in *Aeolosaurus rionegrinus*, and are projected forward and slightly upward. The articular facets are roughly triangular in outline. The postzygapophyses are located posteriorly in the base of the spine just above the neural canal. The articular facets are wide and of approximately triangular outline with the anterior margin almost vertical. The same are slightly concave in dorsoventral aspect in such a way that the dorsal portion of the articular facets is projected slightly outward.

The neural spine is laterally compressed mainly in its base and is found very inclined forward in such a way that its extreme anteriorly surpasses the border of the centrum (Fig. 10A).

Though this sector of the spine is not well preserved, the existence of a suprapostzygapophyseal lamina may be noted (Fig. 3A).

Middle-posterior caudal (Pl. IC and Fig. 4): This vertebra is almost complete. Only the transverse processes are not preserved. The vertebral body is somewhat more lengthened than in the anterior vertebrae. The neural arch is shortened and is located very anteriorly. The prezygapophyses are very robust, not very long, and are projected forward. Their section is approximately triangular. The articular facets are disposed in a vertical plane in their ventral portion and inclined laterally in their dorsal portion. The major axis of the articular facets is inclined forward. The postzygapophyses are wide. The articular facets are oriented vertically in their ventral portion and are projected laterally in their dorsal portion, in a manner similar to that which occurs in the middle caudal. The neural spine is short, very compressed laterally (Fig. 4A), and is found inclined forward, in a manner that the end barely surpasses the anterior end of the centrum (Fig. 4B).

Distal caudal: Only the body and part of the arch are preserved. The neural arch is located in the anterior half of the centrum and is inclined forward.

Ulna (Pl. IE, Fig. 5): The right ulna of the individual, and another right ulna with the same morphology but of less size than the previous, probably of a juvenile example,

have been recovered. This piece is basically similar to that of the holotype of *Aeolosaurus rionegrinus* although its ends are considerably less robust. Its proximal portion is triradiate with the olecranon prominent. In the radial face anteriorly a strong osseous ridge that is developed until the distal end is observed. Always in the radial face, posteriorly in the half of the bone, a second ridge, less defined than the previous, is observed.

Radius (Pl. ID, Fig. 6): A right radius whose dimensions perfectly correspond to the ulna assigned to the juvenile individual is noted. The radius is a thin bone and its extremes are found expanded. The planes that contain the ends form an angle of 20°. The ulnar face possesses approximately parallel osseous ridges in its distal portion. The two anterior ridges culminate distally originating a protuberance.

Metacarpal (Pl. IF, Fig. 7): A sole metacarpal, possibly metacarpal III, has been recovered. The same is robust with its extremes enlarged. The proximal end possesses a rugose articular surface of triangular contour, while the distal articulation is slightly convex.

Pubis (Pl. II, Fig. 8): The left pubis has been preserved. It is a laminar, robust bone. The articulation with the ilium has not been preserved completely. The pubic foramen is of oval contour and is completely closed. The process for the ischium is found in a plane that is inclined medially with respect to the plane of the process for the ilium and the acetabular portion. The distal process is found almost complete. It is wide although not very expanded. The lateral margin of the distal process is robust and markedly concave. The medial margin is fragile and not very well conserved. The internal face of the bone is smooth, while the external face possesses a longitudinal ridge that defines two planes. The ventral plane inclined medially and is slightly concave constituting a strong area of insertion of the external pubo-ischio femoralis muscle.

Ischium (Pl. IH, Fig. 9): A practically complete right ischium has been preserved. It is a laminar bone similar to that of *Aeolosaurus rionegrinus*. The iliac pedicel is short, with the acetabular margin significantly less concave than in the type species. The process that articulates with the pubis is planar in its ventral portion and the contact with the pubis is straighter and very extensive, in all in its ventral portion.

Plates (Pl. IG, Fig. 13): Two dermal plates have been recovered, that by being found associated to the material described previously, are tentatively referred to *Aeolosaurus*. The better preserved plate is of oval contour, with its major axis 15 cm and the minor axis 13 cm. The ventral face possesses a more irregular surface. The margin of the plate is rugose mainly ventrally.

COMPARISONS

The specimen that is described (MPCA 27124) presents similarities with the holotype of *Aeolosaurus rionegrinus* Powell, 1987 (1987b). The anterior caudal vertebrae are very similar, in the morphology of the vertebral centrum as well as the neural arch. Both specimens possess well defined prezygapophyses well directed upward and forward with the same angle of inclination as the neural arch. The articular facets are extraordinarily wide in both cases.

The middle caudals are similar in the characteristics of the vertebral body and in the pronounced forward inclination of the neural arch and spine in both cases. However

in the example from Salitral Moreno, the prezygapophyses are somewhat shorter and more robust, and the postzygapophyses are located not as far anteriorly as in the holotype of *Aeolosaurus rionegrinus*. In MPCA 27124 the major axis of the articular facets of the prezygapophyses are found inclined backward, in contrast to the holotype of *Aeolosaurus rionegrinus* in which they are inclined forward. In an equal way the major axes of the postzygapophyses are oriented vertically in MPCA 27124; in the holotype of *Aeolosaurus rionegrinus* they are strongly inclined forward (Fig. 10A and B).

Middle posterior caudals of the holotype of *Aeolosaurus rionegrinus* have not been recovered. Nevertheless, observing that which occurs in MPCA 27124, it is possible to suspect that the forward inclination of the neural spine, at least in the proximal two thirds of the tail, is a characteristic of the genus *Aeolosaurus*.

The radius of MPCA 27124¹ is gracile, very different from that of the holotype of *Aeolosaurus rionegrinus*, that is robust. In the first, the planes that contain the expansions of the ends are found forming an angle of 20°; while in the second the same angle is of 90°.

The ischium of the specimen from Salitral Moreno (MPCA 27124) is similar to that of the holotype of *Aeolosaurus rionegrinus*, although it possesses an iliac pedicel notably less robust and an acetabular contour appreciably less concave than in the type species. The process for the pubis in MPCA 27124 is more laminar in its ventral portion than in the holotype of *Aeolosaurus rionegrinus* (Fig. 10 D and E). A complete pubis deposited in the collections of the Museo “Jorge Gerhold” of Ing. Jacobacci, pertaining to the example that constitutes the holotype of *A. rionegrinus* (Casamiquela, pers. comm.) not described by Powell, possesses the end of the pubic process notably expanded, that is not observed in MPCA 27124. In the same way, the ventral lamina of the proximal portion is of a surface proportionally larger in the specimen from Salitral Moreno.

Aeolosaurus differs with *Titanosaurus* (sensu Powell, 1986, 1987a) in that the prezygapophyses are longer and the articular facets are wider. In turn, in *Aeolosaurus*, the postzygapophyses are located in the anterior half of the vertebral body, practically all the length of the caudal series. In *Titanosaurus* the postzygapophyses are displaced toward the posterior half of the centrum in the middle caudals, and the neural spine is inclined toward the rear, differing from that which occurs in *Aeolosaurus* (Fig. 10C).

From the Río Negro locality of Los Alamitos, a partially articulated series of 15 caudal vertebrae referred by Powell (1986, 1987b) with doubts to *Aeolosaurus rionegrinus* is known. However, we observe differences with the vertebrae of the holotype of *Aeolosaurus rionegrinus* and MPCA 27124. First, the vertebral centra possess a notably wide ventral face after the 4th caudal in the titanosaurid from Los Alamitos, differing from that occurring in the holotype of *Aeolosaurus rionegrinus* and MPCA 27124. Also, the prezygapophyses in the titanosaurid from Los Alamitos are projected forward and slightly upward, determined in all the series to be at an angle with the axis of inclination of the neural arch. In *Aeolosaurus* the prezygapophyses are projected upward and forward, with practically the same inclination of the neural arch, at least in the anterior and middle caudals. In the caudal series from Los Alamitos it is observed that although in the first vertebrae the postzygapophyses are located on the anterior half of the vertebral centrum, in the posterior they are situated on the distal half of the vertebral body, as is observed in *Titanosaurus*. Lastly, the neural spine of

¹ This specimen probably pertains to MPCA 27125, as a radius is not known in MPCA 27124.

Aeolosaurus is found inclined forward, which does not occur in any of the fifteen vertebrae recovered from Los Alamitos.

The plates recovered in Salitral Moreno (MPCA 27176 and 27177) are more solid than those referred to *Saltasaurus loricatus* (Bonaparte and Powell, 1980). In turn, in the Patagonian species a central projection in the dorsal face and a depression in the ventral surface as observed in *Saltasaurus* are not observed.

DISCUSSION AND CONCLUSIONS

For the determination of the relative length of the prezygapophysis, and the relative position of the postzygapophyses in the caudal vertebrae, we have established relations between segments determined by points located arbitrarily in distinct elements of a middle caudal vertebra (Fig. 11.1). The relations were obtained in middle caudal vertebrae of *Aeolosaurus rionegrinus*, MPCA 27124, and *Titanosaurus* sp. (Fig. 11.2). The relations obtained were plotted in a graph of coordinates (Fig. 11.3). From the resulting graph it is possible to recognize an intermediate morphologic position for MPCA 27124, between the holotype of *Aeolosaurus rionegrinus* and *Titanosaurus* sp. Considering that the holotype of *Aeolosaurus rionegrinus* and the specimen from Salitral Moreno share the following characters: forward inclination of the neural spine in the middle and posterior caudal vertebrae; prezygapophyses relatively longer than in *Titanosaurus*; articular facets of the prezygapophyses extraordinarily wide; postzygapophyses located on the anterior half of the vertebral body starting from the middle caudals; metacarpals proportionally more robust than in *Titanosaurus*, it is proposed to assign the materials that are described to the genus *Aeolosaurus* Powell, 1987 (1987b). The differences that were pointed out may indicate the presence of a species distinct from *Aeolosaurus rionegrinus* in the north of the Province of Río Negro. However, the formal proposal of a new species is not, for the moment, recommended, due principally to our lack of knowledge on the individual variation in the titanosaurids. On the other hand, we believe that the titanosaurid of Los Alamitos (MACN-RN 107) assigned by Powell (1986, 1987b) to *Aeolosaurus rionegrinus*? does not pertain that genus, mainly for: a) the morphology of the vertebral body, b) distinct inclination of the prezygapophyses with respect of the plane that contains the neural arch, c) neural spine never inclined forward, d) the relative position of the postzygapophyses in the middle caudals.

The discovery of isolated dermal plates, assigned to titanosaurids, is frequent in Salitral Moreno, as well as in distinct localities of the Cretaceous of Patagonia.

These plates integrated an armor or dermal cuirass unique among the sauropods that was recognized for the first time in *Saltasaurus loricatus* (Bonaparte and Powell, 1980; Powell, 1980).

If the assignment of these plates to *Aeolosaurus* is confirmed, this would be the first representative of the Subfamily Titanosaurinae (sensu Powell, 1986) and the first Patagonian genus of the Family Titanosauridae (sensu Powell, 1986) in which the presence of armor would be documented.

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BIBLIOGRAPHY see original publication

FIGURE CAPTIONS

Figure 1. Location map of the locality of Salitral Moreno, Río Negro, Argentina.

Figure 2. **Aeolosaurus** sp. (MPCA 27124). Anterior caudal in lateral (A) and posterior (B) view. Abbreviations: CN, neural canal; PRZ, prezygapophysis; PT, transverse process; PZ, postzygapophysis. Scale: 5 cm.

Figure 3. **Aeolosaurus** sp. (MPCA 27124). Middle caudal in posterior (A) and lateral (B) view. Abbreviations: see Fig. 1 and LP, posterior lamina. Scale: 5 cm.

Figure 4. **Aeolosaurus** sp. (MPCA 27124). Middle-posterior caudal in posterior (A) and lateral (B) view. Abbreviations: see Fig. 1. Scale: 5 cm.

Figure 5. **Aeolosaurus** sp. (MPCA 27124)². Right ulna in radial view. Abbreviations: CR, radial surface; O, olecranon. Scale: 5 cm.

Figure 6. **Aeolosaurus** sp. (MPCA 27124)³. Right radius in ulnar view. Scale: 5 cm.

Figure 7. **Aeolosaurus** sp. (MPCA 27124). Metacarpal in lateral view. Scale: 5 cm.

Figure 8. **Aeolosaurus** sp. (MPCA 27124). Left pubis in lateral view. Abbreviations: F, pubic foramen; RL, longitudinal ridge. Scale: 10 cm.

Figure 9. **Aeolosaurus** sp. (MPCA 27124). Right ischium in medial view. Scale: 10 cm.

Figure 10. Schematic representations of middle caudal vertebrae in lateral view of A) **Aeolosaurus** sp. (MPCA 27124), B) Holotype of **Aeolosaurus rionegrinus**, C) **Titanosaurus** sp.: and lateral view of the ischia of D) **Aeolosaurus** sp. (MPCA 27124) and E) holotype of **Aeolosaurus rionegrinus**. (B and E redrawn from Powell, 1986; C, taken from Powell, 1987a).

² Although an ulna is known in MPCA 27124, Figure 5 may instead depict the ulna of MPCA 27125, as stated under the “Material” heading of the “Systematics and Description” section.

³ Figure 6 almost certainly depicts the radius of MPCA 27125, because a radius is not known in MPCA 27124, and because this is stated under the “Material” heading of the “Systematics and Description” section.

Figure 11. 1) Schematic of a middle caudal vertebra with location of the principal points for the determination of parameters. A: anterior end of the articular surface of the prezygapophyses; B: ventral border of the anterior face of the vertebral centrum; C: anterior end of the articular face of the postzygapophysis; D: posterior end of the vertebral body taken in the apex of the articular condyle. 2) Table with the figures that arise from the relation between the segments determined by the points indicated in the schematic (a). AD/BD = length of the prezygapophysis with respect to the length of the vertebral body. CD/BD = location of the postzygapophysis with respect to the length of the vertebral centrum, (1) taken from POWELL, 1987a. 3) Representation in Cartesian coordinates of the figures of the table (b). 1. **Titanosaurus** sp., 2. **Aeolosaurus** sp. (MPCA 27124), 3: **Aeolosaurus rionegrinus** (holotype).

PLATE CAPTIONS

Plate I. **Aeolosaurus** sp. (MPCA 27124): A) anterior caudal vertebra in lateral view, B) middle caudal vertebra in lateral view, C) middle posterior caudal vertebra in posterior view, F) metacarpal, H) right ischium, I) left pubis. MPCA 27125: D) right radius, E) right ulna. **Aeolosaurus?** (MPCA 27126), dermal plate.