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A giant tooth from the Late Cretaceous (middle Campanian–lower Maastrichtian) of Patagonia, Argentina: An enormous titanosaur or a large toothed titanosaur?

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ABSTRACT

The tooth MML-Pv 1030 comes from the Upper Cretaceous (middle Campanian–lower Maastrichtian) strata of the Allen Formation at Salitral de Santa Rosa, Río Negro, Argentina and is the biggest titanosaur tooth yet described. The specimen is a cylindrical chisel-like tooth, its length is 75 mm, mesiodistally 15 mm and labiolingually 11 mm. The wear facet is single on the lingual side of the tooth, which has an oval outline with a low angle (10°) with respect to the axial axis of the tooth. This tooth is 32% greater in length than the longest tooth registered in a titanosaurid (*Nemegtosaurus*), and twice the tooth size of taxa as *Tapuiasaurus*, *Bonitasaura* and *Pitekunsaurus*. Detailed descriptions of the tooth morphology and a highlight of comparative relationships among known titanosaur teeth are provided. Finally, different aspects are suggested related to morphology and feeding behavior.

1. Introduction

Titanosaurs are a group of herbivorous dinosaurs that comprise nearly half of all sauropod genera. This group of neosauropods developed a highly specialized dentition that could be related to a distinct and specialized feeding behavior (Calvo, 1994; García and Cerda, 2010a). The numerous cylindrical chisel-like teeth, with acute wear facets allow to infer a specialized mechanism of consumption of plant material. The titanosaur dentition restricted to the front of the snout is practically constant (Pm 4, M 7–8/D 10–13), not only among different taxa, but also with respect to its ontogeny (García and Cerda, 2010a, b; García et al., 2010). Despite its morphological specialization and its large tooth development (four replacement teeth and several generations of teeth) their dentition and the feeding mechanisms are poorly understood.

In this paper, the biggest titanosaur tooth yet discovered is described. This record sheds light on titanosaur diversity, at least with respect to skull and dentition size.

2. Geological context

The unit that yielded the tooth is the Allen Formation, whose age was estimated by Ballent (1980) as middle Campanian–lower Maastrichtian. This geologic unit is widely exposed at Río Negro and Neuquén Provinces but the quarry of the MML-PV 1030 teeth is in Salitral de Santa Rosa area, approximately 120 km west from Lamarque city, Río Negro Province.

3. Systematic paleontology

Dinosauria Owen, 1842
Saurischia Seeley, 1888
Sauropoda Marsh, 1878
Titanosauria Bonaparte and Coria, 1993
Gen. et sp. Indet.
Figs. 1, 2A, B

4. Description

The MML-PV 1030 tooth (Fig. 1A) is a cylindrical and thick chisel-like tooth, bearing a slight lingual curvature. Its total length is 75 mm. though the base of the root is incomplete. The dental crown length is 56 mm. The labial side is slightly more curved than lingual side, similarly to that of other titanosaur tooth (Kellner, 1996; Upchurch, 1998; García and Cerda, 2010a). The crown has

Abbreviations: MAU-Pv, Museo Municipal "Argentino Urquiza", colección de paleovertebrados Rincón de los Sauces, Neuquén, Argentina; MML-Pv, Museo Municipal Lamarque, colección de paleovertebrados, Río Negro, Argentina; MPCA-PV, Museo Provincial "Carlos Ameghino", colección de paleovertebrados, Río Negro, Argentina; MZSP-PV, Museu de Zoologia da Universidade de Sao Paulo, Brasil; Z.PAL, Palaeontological Institute of the Polish Academy of Sciences, Warsaw, Poland.

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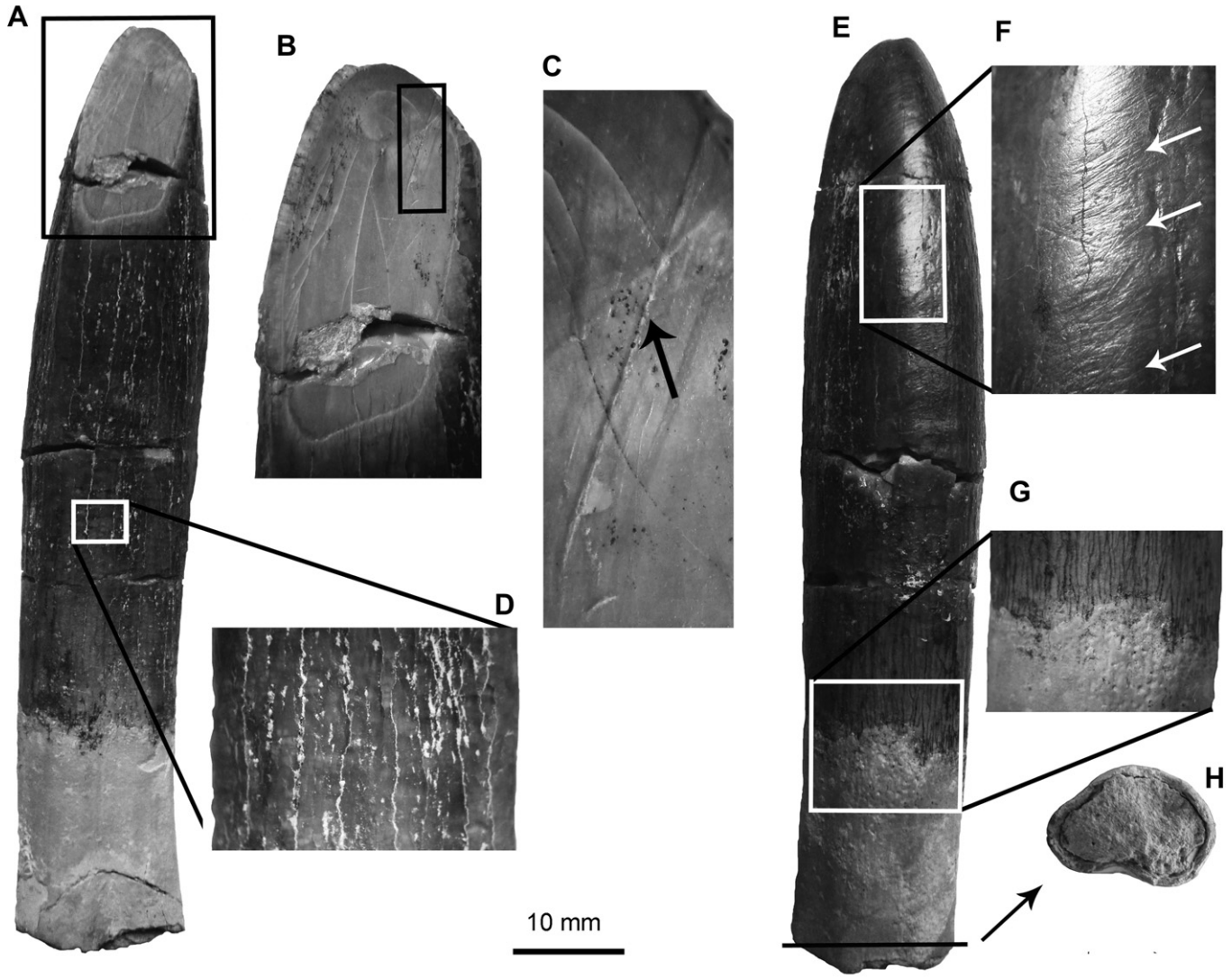

Fig. 1. MML-Pv 1030 titanosaur tooth. A, in lingual view; B, magnified view of the wear facet; C, magnified view of the wear plane, arrow show a large scratch; D, surface view of the wrinkled enamel; E, in labial view; F, magnified view of the polished surface, arrows show numerous and diminute scratches; G, magnified view of the crown–root transition; H, in transversal section of the root view.

the margins mesiodistally parallel, one of the main differences with the mesiodistally expanded crown of other sauropods (e.g., *Brachiosaurus* Carpenter and Tidwell, 1998; *Camarasaurus* Madsen et al., 1995; *Malawisaurus*, Gomani, 2005; Upchurch et al., 2004). The lingual surface of the crown is almost mesiodistally planar, while the labial surface is notably curved in the same direction. Both surfaces, labial and lingual are connected medially by a curved edge and distally by a carina that runs longitudinally through the tooth decreasing toward the root. A distal carina was also noted in *Antarctosaurus* (von Huene, 1929); *Rinconsaurus* (Calvo and Gonzalez-Riga, 2003); and *Bonitasaura* (Apesteguía, 2004; Gallina and Apesteguía, 2011). Denticles are absent on both margins, mesial and distal, as a derived state for sauropods (Wilson and Sereno, 1998 character 78). The other measurements of MML-PV 1030 are labiolingually 11 mm, and mesiodistally 15 mm.

The enamel has a brownish color with the surface finely wrinkled (Fig. 1D), except for the central part of the labial side that appears polished, presumably due to constant tooth-food abrasion. Diminutive scratches have been observed on the polished surface with a magnifying glass, parallel and obliquely with respect to the axial axis of the tooth (Fig. 1F). The enamel thickness is 0.75 mm and its enamel/dentine ratio (total enamel area/total tooth area) at the base of the wear facet is 0.11, a similar value to that obtained by García and Cerda (2010b) for numerous adult titanosaurs. The surface of the root has a smooth, whitish color with cement present. The center of the lingual side bears a groove oriented apicobasally to the base of the root (Fig. 1H).

The wear facet is type 1, according to the classification proposed by García and Cerda (2010a), a single facet on the lingual side of the tooth (Fig. 1B). The outline of the facet is oval with a vertical axis of 18 mm and a transversal axis of 9 mm. The wear plane of the tooth shows a growth line on dentine. Similar lines have been found in the dentine of other dinosaurs and crocodiles (Erickson, 1996). The MML-PV 1030 crown shows a low-angled wear facet (10°) with respect to the main axis of the tooth (Fig. 2A, B). The described tooth is a functional one, and according to the dentary wear hypothesis proposed by García and Cerda (2010a), is probably it an upper (maxillary or premaxillary?) tooth.

The tooth outline differs according to the location of the cross-section, at the root it shows a "kidney shape" (Fig. 1H). The crown–root transition is subcircular in cross-section, whereas the crown is semi-circular labially and mostly planar lingually or

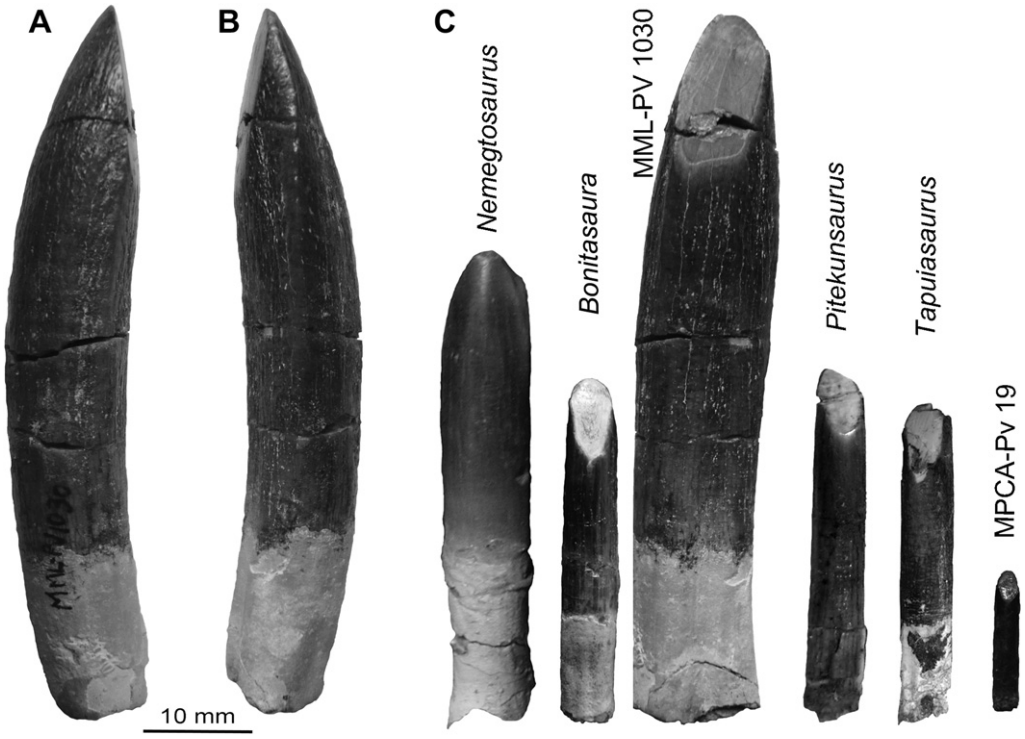

Fig. 2. MML-Pv 1030 titanosaur tooth. A, in mesial view; B, in distal view; C, comparison among different titanosaur taxa: *Nemegtosaurus* Z.PALMgD-1/9, *Bonitasaura* MML-Pv 460, MML-Pv 1030, *Pitekunsaurus* MAU-Pv-AG 446/2, *Tapuiasaurus* MZSP-PV807, MPCA-PV19.

D-shaped in cross-section, as described by Gallina et al. (2010) for teeth from Arroyo Morterito (Salta), Los Alamitos (Río Negro) and the Allen Formation.

Micro-wear scratches of diverse sizes are displayed on the wear facet. These scratches are oriented parallel to the main axis of the facet, although other are somewhat oblique (Fig. 1C). The presence of randomly distributed pits is very common in sauropods (Fiorillo, 1998; García and Cerda, 2010a; Whitlock, 2011), but they are absent in this specimen.

The root does not evidence appear to be from a replaced tooth, since it does not show reabsorption marks, as typical of a replaced tooth (Kues et al., 1980; Kellner, 1996).

5. Discussion and conclusion

The largest titanosaur tooth that has been reported is the second upper left tooth of *Nemegtosaurus mongoliensis* Nowinski (Wilson, 2005). The MML-Pv 1030 tooth is 32% greater in length, 9.1% greater mesiodistally and 40% greater labiolingually than that of the Asian taxon. Meanwhile with taxa as *Rapetosaurus*, *Tapuiasaurus*, *Pitekunsaurus*, *Petrobrasaurus* and *Bonitasaura* the difference is 38–46% greater in length (Curry Rogers and Forster, 2004; Zaher et al., 2011; Filippi and Garrido, 2008; Filippi et al., 2011; Gallina and Apesteguía, 2011) (Fig. 2C).

The Allen Formation is characterized by its great paleo-faunal diversity (Martinelli and Forasiepi, 2004), in particular for its titanosaur diversity (García and Salgado, in press). Despite this, the size of the known titanosaur teeth remained medium to small, e.g., *Bonatitan*, *Rocasaurus*, *Aeolosaurus* (Martinelli and Forasiepi, 2004; Salgado and Azpilicueta, 2000; Salgado and Coria, 1993). In this way, the unusual dimensions of the tooth described here, suggest different hypotheses about the specimen. The MML-Pv 1030 tooth could have belonged to a specimen with disproportionately large teeth, "a big-toothed titanosaur". However, it is also possible that this tooth belonged to an individual with an enormous skull, probably to a short-necked titanosaur or to a taxon of unusual dimensions for a titanosaur. Whatever the option mentioned above, this taxon has characteristics never previously recorded for the Upper Cretaceous (middle Campanian–lower Maastrichtian).

Another interesting aspect with regard to the studied specimen is its total absence of pits on its wear facet or enamel surface, a condition that differs from that of numerous titanosaurs (García and Cerda, 2010a). The absence of pits suggests a diet with scarce grit (Fiorillo, 1998) or an absence of hard vegetable material able to mark the teeth. On the other hand, the tooth scratches on the labial face suggest a feeding mechanism type where the collection of food was performed with the anteriormost teeth, cropping or, stripping of leaves from the branches (Barrett and Upchurch, 1994; Stevens and Parrish, 2005) but in an oblique way.

Finally, though the tooth does not provide specific information about the skull, the overall specimen adds a new actor to a scenario previously thought as restricted to only small titanosaurs (e.g. Apesteguía, 2002). In this way, the field work at the MML-Pv 1030 tooth quarry will continue.

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