

## Humerus of a basal abelisauroid theropod from the Late Cretaceous of Patagonia

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**Abstract:** Here we describe a partial humerus of a medium-sized theropod dinosaur from the Upper Cretaceous (Late Turonian - Early Coniacian) Portezuelo Formation, Neuquén Province, Argentina. The humerus shares with Abelisauroidea and *Elaphrosaurus* an articular head proximally oriented, and deltopectoral crest strongly reduced. The bone is referred to Abelisauroidea on the basis of the following derived features: proximal tuberosity on caudal surface of humeral shaft, and greater tubercle at level with the medial tuberosity. The gracile morphology of the humerus, as well as the poor development of its medial tuberosity, resemble more *Masiakasaurus* than the condition present in abelisauroids (e.g., *Carnotaurus*, *Aucasaurus*), in which the humerus is more robust and the medial tuberosity is prominent. Available information demonstrates that during deposition of the Portezuelo Formation large and bulky abelisauroids (e.g., *Ekrixinosaurus*) lived together with gracile and medium-sized abelisauroids.

**Key words:** Abelisauroidea, Upper Cretaceous, Patagonia, Argentina.

Abelisauroids constitute a group of predatory dinosaurs that were highly diversified and widely dispersed in Gondwana during the Cretaceous (e.g., Bonaparte, 1986; Sereno *et al.*, 2004). Abelisauroidea is usually split into two clades (Bonaparte, 1991): the small to medium-sized noasaurids, including *Noasaurus*, *Masiakasaurus*, *Laevisuchus* and *Deltadromeus* (Carrano *et al.*, 2002; Sereno *et al.*, 2004), and the medium to large-sized abelisauroids represented, among others by *Rugops*, *Carnotaurus*, *Abelisauroidea*, *Ekrixinosaurus*, and *Aucasaurus* (Bonaparte, 1985; Bonaparte & Novas, 1985; Bonaparte *et al.*, 1990; Coria *et al.*, 2002; Calvo *et al.*, 2004a; Sereno *et al.*, 2004).

The theropod record of the Upper Cretaceous Portezuelo Formation (Late Turonian-Early Coniacian; Leanza *et al.*, 2004) currently consists of the abelisauroid *Ekrixinosaurus novasi* (Calvo *et al.*, 2004a), the basal tetanuran *Megaraptor namunhuaiquii* (Novas, 1998; Calvo *et al.*, 2004b), the maniraptoran alvarezsaurid *Patagonykus puertai* (Novas, 1997), two yet undescribed coelurosaurians (Coria & Currie, 2002; Porfiri *et al.*, 2005), and the dromaeosaurid maniraptorans *Unenlagia comahuensis* (Novas & Puerta, 1997), *U. paynemili* (Calvo *et al.*, 2005), and *Neuquenraptor argentinus* (Novas & Pol, 2005). Here we describe a partial humerus that constitutes the first non-abelisauroid abelisauroid recorded in the Portezuelo Formation. This new

find improves our knowledge of the humeral morphology of basal abelisauroids.

### MATERIAL AND METHODS

**Institutional abbreviations.** MACN-CH, Museo Argentino de Ciencias Naturales "B. Rivadavia", Colección Chubut. MCF-PVPH, Museo Carmen Funes, Paleontología de Vertebrados, Plaza Huincul, Neuquén, Argentina.

**Systematic nomenclature.** We follow Sereno *et al.* (2004) and Rauhut (2003), regarding the phylogenetic relationships of Abelisauroidea within Ceratosauria. Abelisauroidea was defined by Holtz (1994) as a stem-based clade that includes all theropods closer to *Carnotaurus sastrei* than to *Ceratosaurus nasicornis*, thus *Elaphrosaurus bambergi* Janensch, 1920 and the specimen described here belong to this clade.

### SYSTEMATIC PALEONTOLOGY

Theropoda Marsh, 1881  
Neotheropoda Bakker, 1986  
Ceratosauria Marsh, 1884  
Abelisauroidea Bonaparte, 1991  
*Genus et sp. indet.*

*Material.* MCF-PVPH 53, proximal half of a right humerus.

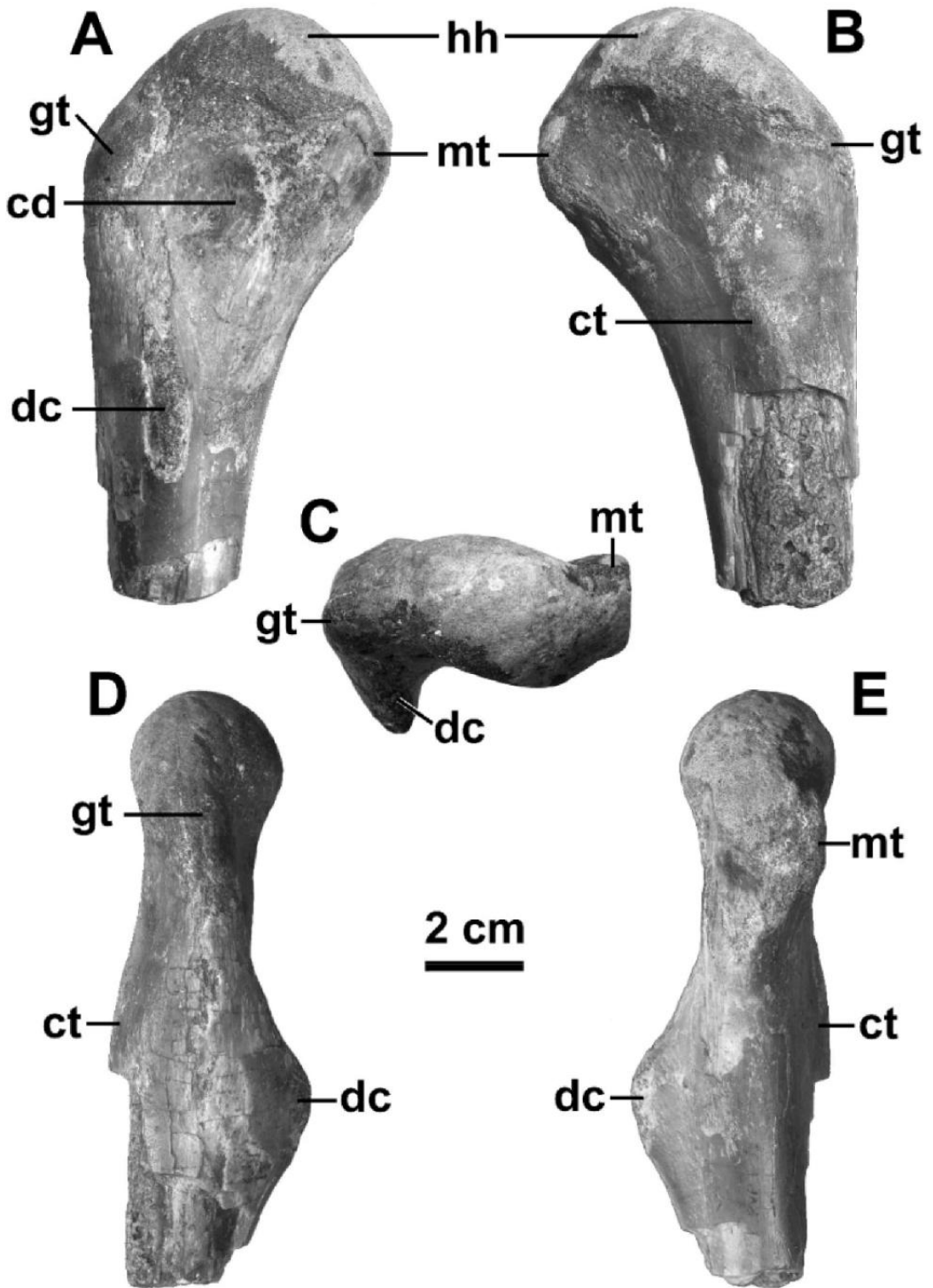


Fig. 1. MCF-PVPH 53 humerus. A) cranial, B) caudal, C) proximal, D) lateral, and E) medial views. Abbreviations: **cd**. coracobrachial depression, **ct**. caudal tuberosity **dc**. deltopectoral crest, **gt**. greater tubercle, **hh**. humeral head, **mt**. medial tuberosity. Scale bar 2 cm.

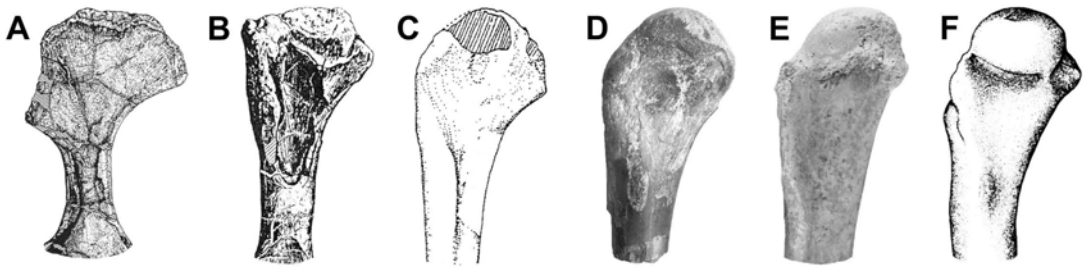


Fig. 2. Humeral proximal halves of several theropods in cranial view. A) *Baryonyx* (from Charig & Milner, 1986), B) *Ceratosaurus* (from Madsen & Wells, 2000), C) *Elaphrosaurus* (from Galton, 1982), D) MCF-PVPH 53, E) *Masiakasaurus* (from Carrano *et al.*, 2002) and F) *Carnotaurus* (from Bonaparte *et al.*, 1990). Not to scale.

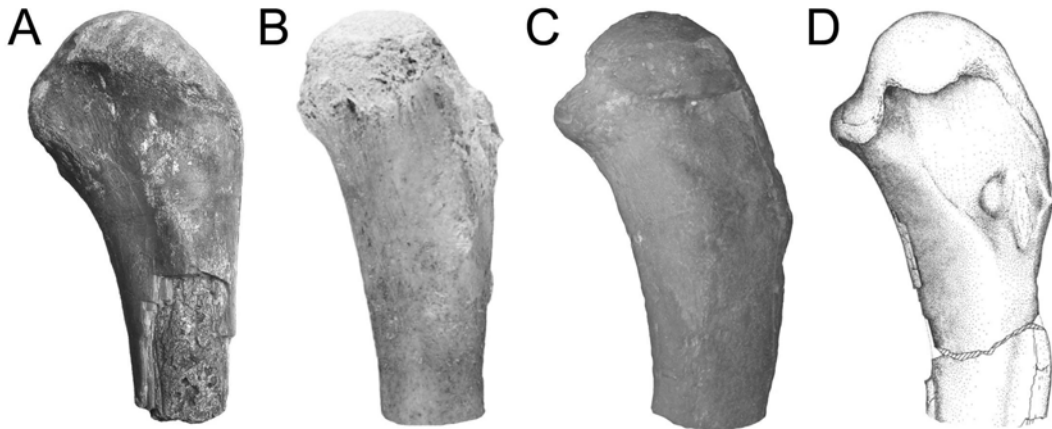


Fig. 3. Humeral proximal halves of several abelisauroids in caudal view. A) MCF-PVPH 53, B) *Masiakasaurus* (from Carrano *et al.*, 2002), C) *Carnotaurus* (MACN-CH 894) and D) *Aucasaurus* (from Coria *et al.*, 2002). Not to scale.

**Locality and horizon.** The material was collected at Sierra del Portezuelo, 20 km West from Plaza Huinul, Neuquén Province, Argentina, from levels corresponding to the Portezuelo Formation.

#### Description

The preserved portion of humerus (Fig. 1) closely matches the morphology of the Malagasy abelisauroid *Masiakasaurus knopfleri* (Carrano *et al.*, 2002), thus suggesting that the bone, as in this dinosaur, was long and slender when complete. On the basis of the maximum proximal width of humerus (5.1 cm), we estimate that the whole length of the bone was roughly 30 cm.

The humeral head is rounded and proximally inflated, resembling the basal ceratosaurian *Elaphrosaurus* (Galton, 1982) and the abelisauroids *Carnotaurus*, *Aucasaurus*, and *Masiakasaurus* (Figs. 2-4). This condition distin-

guishes MCF-PVPH 53 (together with the four taxa cited before) from the remaining theropods (e.g., *Syntarsus*, *Ceratosaurus*, *Allosaurus*, *Deinonychus*), in which the humeral head is kidned-shaped (in proximal view) and flattened (in cranial aspect). However, MCF-PVPH 53 has a humeral head that looks more plesiomorphic than *Carnotaurus* and *Masiakasaurus*, in being craniocaudally more compressed than in the later two taxa (Fig. 4).

In MCF-PVPH 53 the greater tubercle is located on the proximolateral corner of humerus; it is reduced and located at level with the internal tuberosity, as it occurs in other abelisauroids (e.g., *Masiakasaurus*, *Aucasaurus*, *Carnotaurus*). This condition differs from that of basal theropods (e.g., *Syntarsus*), basal ceratosaurians (e.g., *Ceratosaurus*) and most tetanurans (e.g., *Allosaurus*, *Deinonychus*), in which the greater tubercle is more prominent and more proximally



Fig. 4. Humeri of several abelisauroids in proximal view. A) MCF- PVPH 53, B) *Masiakasaurus* (from Carrano *et al.*, 2002) and C) *Carnotaurus* (MACN-CH 894). Not to scale.

located with respect to the internal tuberosity. In *Elaphrosaurus* the greater tubercle is weakly developed (as in abelisauroids), but it is located more proximally as in Theropoda ancestrally.

In MCF-PVPH 53 the internal tuberosity is highly reduced, as it occurs in *Masiakasaurus* and probably also in *Elaphrosaurus*. However, this condition is not uniformly present among abelisauroids because in abelisauroids (*e.g.*, *Aucasaurus*, *Carnotaurus*) the internal tuberosity is prominent and conical-shaped (Fig. 2). A similar condition to that of Abelisauridae is present in most theropods, including *Herrerasaurus* (Sereno, 1993), coelophysoids (*e.g.*, *Syntarsus*; Raath, 1977), *Dilophosaurus* (Welles, 1984), and basal tetanurans (*e.g.*, *Allosaurus*, *Acroncanthosaurus*; Madsen, 1976; Currie & Carpenter, 2000).

On the cranial surface of humeral shaft, and immediately distal to the humeral head, a shallow sulcus is present, presumably for attachment of the acrorachohumeral ligament (Baumel & Raikow, 1993). The shallow condition of this sulcus contrasts with the deep ligament groove present in *Carnotaurus* and *Masiakasaurus*. Congruently, the caudal surface of MCF-PVPH 53 is devoid of a sulcus below the humeral head, resembling *Masiakasaurus* but contrasting with *Carnotaurus* and *Aucasaurus*, in which a deep groove is present.

In MCF-PVPH 53 the deltopectoral crest is strongly reduced and triangular in side view, being transversely thick and cranially projected. This peculiar condition is shared with other abelisauroids (*e.g.*, *Masiakasaurus*, *Carnotaurus*), albeit at least some of these features (*i.e.*, deltopectoral crest reduced and triangular shaped) are also present in *Elaphrosaurus*. MCF-PVPH 53 differs from *Carnotaurus* in that in the latter the deltopectoral crest is even more reduced.

On the caudal surface of the humeral shaft, MCF-PVPH 53 bears a longitudinal and conspicu-

ous tuberosity. On the caudolateral edge of the bone, a smaller and lesser developed second tuberosity is present. Thus, the caudal surface of the humerus exhibits a double prominence located almost at level with the proximal end of the deltopectoral crest. This caudal tuberosity is documented also in *Aucasaurus* and *Carnotaurus*. In *Masiakasaurus* a prominence is visible, but its double condition can not be discerned (Carrano *et al.*, 2002; fig. 11). The condition in *Ceratosaurus* is inconclusive (Madsen & Welles, 2000), but in coelophysoids (*e.g.*, *Syntarsus*, *Liliensternus*) and basal tetanurans (*e.g.*, *Baryonyx*, *Torvosaurus*, *Allosaurus*, *Deinonychus*) this caudal tuberosity is lacking.

## CONCLUSIONS

The humerus of abelisauroid theropods is well represented by *Carnotaurus* and *Aucasaurus*. The same bone, however, remains poorly known in non-abelisauroid abelisauroids, the main source of information being currently restricted to the noasaurid *Masiakasaurus* (Carrano *et al.*, 2002; due to the highly fragmentary condition of the holotype specimen of *Deltadromeus agilis* Sereno *et al.*, 1996, and the few available descriptions and illustrations of the forelimb bones, we did not include this taxon in the present analysis). The humerus here described adds some new data on forelimb morphology of this group of ceratosaurian theropods.

MCF-PVPH 53 is interpreted as belonging to an abelisauroid theropod, as supported by the presence of a proximally inflated humeral head, a reduced deltopectoral crest, greater tubercle located at level with medial tuberosity, and tuberosity on caudal surface of humeral shaft (all these features are present in *Elaphrosaurus*; O. Rauhut, pers. comm.). Additionally, the humerus described here is not assigned to Abelisauridae because it retained a strongly reduced medial tuberosity that contrasts with the well developed one of *Carnotaurus* and *Aucasaurus*. The condi-

tion of the humeral head in MCF-PVPH 53 looks more primitive than in *Elaphrosaurus*, *Masiakasaurus*, *Aucasaurus* and *Carnotaurus*, because the first one lacks a rounded humeral head (in proximal aspect), a greater tubercle that is clearly offset from the humeral head (O. Rauhut, pers. comm.), and a deep cranial ligament sulcus. In this context, MCF-PVPH 53 seems to be one of the most basal abelisauroids, even more basal than the Jurassic *Elaphrosaurus*. MCF-PVPH 53 opens a new panorama regarding to the radiations of basal members of Abelisauroidea, where stem-abelisauroids survived until late Turonian-early Coniacian times, thus depicting a currently covered radiation of basal abelisauroids from Middle Jurassic times, at least (as it is indicated by *Elaphrosaurus*), up to the Late Cretaceous.

Among Abelisauroidea two different kinds of humeri can be recognized: a plesiomorphic, gracile and elongate morphotype represented by *Masiakasaurus* and MCF-PVPH 53, and a shorter and stouter kind of humerus as present in abelisauroids (e.g., *Aucasaurus* and *Carnotaurus*). Curiously, they are reminiscent of the humerus of ornithomimosaurids and tyrannosaurids, respectively, in which the deltopectoral crest is proximodistally reduced and subtriangular in side view (e.g., Gauthier, 1986; Rauhut, 2003). Moreover, in *Tyrannosaurus* (Brochu, 2002) the humeral head is also proximally inflated, resembling the condition present in abelisauroids.

The non-abelisauroid abelisauroid condition of MCF-PVPH 53 indicates that during the deposition of the Portezuelo Formation two kinds of abelisauroid theropods co-existed. On the one hand, the large-sized and bulky abelisauroid *Ekrixinatosaurus*; on the other hand, a smaller and gracile basal abelisauroid (MCF-PVPH 53). Thus, the abelisauroid faunistic component of Portezuelo Formation resembles to that of other Cretaceous Gondwanan outcrops (e.g., India, Madagascar), which shows the simultaneous presence of large-sized abelisauroids (*Indosuchus*, India; *Majungatholus*, Madagascar) and smaller non-abelisauroid abelisauroid theropods (*Laevisuchus*, India; *Masiakasaurus*, Madagascar).

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