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A PARTIAL PTEROSAUR ULNA FROM THE CANDELEROS FORMATION (NEUQUÉN GROUP), LATE CRETACEOUS OF ARGENTINA

*Una ulna parcial de Pterosauria de la Formación Candeleros (Grupo Neuquén),
Cretácico tardío de Argentina*

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Resumen. Se describe la porción proximal de una ulna izquierda de un pterosaurio. El ejemplar procede de la Formación Candeleros (Cenomaniano), Grupo Neuquén, en Cabo Alarcón, provincia de Neuquén, Argentina. El análisis de este nuevo ejemplar permite la reinterpretación de una tibia de pterosaurio previamente descrita, hallada en la localidad de Los Catutos, Neuquén (MOZ 2280 P) como un proximal de ulna. El nuevo material pertenece a un pterosaurio de tamaño medio, considerablemente más grande que los pterosaurios previamente registrados de esta unidad geológica. El análisis de la correlación entre la longitud de la ulna-longitud del pie en pterosaurios pterodactyloideos bien conocidos muestra que la nueva ulna se corresponde bien con el tamaño inferido para el productor de *Pteraichnus* isp. registrado en la misma formación.

Palabras clave. Pterosauria, Cretácico, Grupo Neuquén, Formación Candeleros, Argentina.

Abstract. The proximal portion of the left ulna of a pterosaur is described. The specimen comes from the Candeleros Formation (Cenomanian), Neuquén Group, at Cabo Alarcón, Neuquén province, Argentina. The analysis of this new specimen allows the re-interpretation of a previously described pterosaur tibia founded at Los Catutos locality, Neuquén (MOZ 2280 P) as a proximal ulna. The new material belongs to a medium-sized pterosaur, considerably larger than previously recorded pterosaurs from this geological unit. The analysis of correlation between ulnar length-pes length in well-known pterodactyloid pterosaurs shows that the new ulna matches well with the inferred size of the *Pteraichnus* isp. trackmaker recorded from the same formation.

Key words. Pterosauria, Cretaceous, Neuquén Group, Candeleros Formation, Argentina.

INTRODUCTION

Pterosaur remains from the Cretaceous of South America are well represented only in the Early Cretaceous Crato and Romualdo formations of northeastern Brazil (Kellner, 1990; Kellner and Tomida, 2000; Martill, 1993; Price, 1971; Wellnhofer, 1985; Wellnhofer, 1991a; Wellnhofer 1991b), and Lagarcito Formation of western Argentina (Bonaparte, 1970; Chiappe, *et al.*, 1995; Chiappe *et al.*, 1998a, b). Otherwise, only a few Cretaceous units in South America have yielded fragmentary pterosaur remains. Pterosaurs are scarce in the Neuquén Group but some discoveries have been made in recent years. These records include a distal right ulna and partially preserved right wing from the “La Buitrera” locality (Candeleros Formation: Early Cenomanian) of Río Negro Province (Haluzá *et al.*, 2007), a proximal right ulna from the “Los Barreales” locality (Portezuelo Formation: Late Turonian-Early Coniacian) of Neuquén Province (Kellner

et al., 2007) and a phalanx I of manual digit IV from the “La Bonita” locality (Bajo de La Carpa Formation: Late Santonian-Early Campanian) of Río Negro Province (Apesteuguá pers. comm.).

Here we describe a new record of a pterosaur proximal left ulna collected from the lower levels of the Candeleros Formation at Cabo Alarcón, northwestern coast of Lake Ezequiel Ramos Mexía, Neuquén Province, Argentina (Figure 1).

Institutional abbreviations. **BSP**, Bayerische Staatssammlung für Paläontologie und historische Geologie, Munich, Germany. **MMCH-PV**, Museo Municipal “Ernesto Bachmann”, Villa El Chocón, Neuquén, Argentina. **MOZ**, Museo Provincial “Juan Olsacher”, Zapala, Neuquén, Argentina. **MPCN**, Museo Patagónico de Ciencias Naturales, General Roca, Río Negro, Argentina. **MUCPv**, Museo de la Universidad Nacional del Comahue, Paleontología de Vertebrados, Neuquén, Argentina.

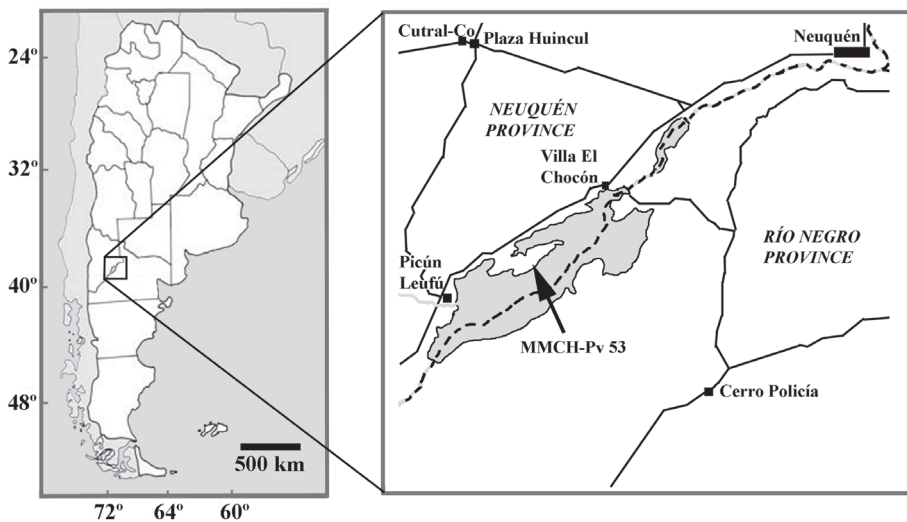


Figure 1. Map of Argentina showing the Cabo Alarcón fossil locality. The black arrow indicates the fossil site.

SYSTEMATIC PALEONTOLOGY

DESCRIPTION AND COMPARISONS

Pterosauria Kaup, 1834
 Pterodactyloidea Plieninger, 1901
 Genus and species indeterminate

Referred material. MMCH-Pv 53, proximal part of a left ulna.

Locality and horizon. The material was collected at Cabo Alarcón (S 39° 24' 16,4" - W 68° 58' 27,6") between Villa El Chocón and Picún Leufú (Fig. 1), from the lower levels of the Candeleros Formation (Early Cenomanian), Neuquén Group (Garrido, 2010).

The ulna is anteroposteriorly crushed and deformed, mainly in the proximal end, and the distal portion of the bone is lost (Figure 2). The bone is thin-walled (about 1 mm thick) as seen in all other pterosaurs. In anterior view the dorsal margin is straight, and the ventral margin is concave due to a ventral expansion of the proximal end. Below this expansion there is a prominence, the *tuberculum musculi bicipitis* (TMB), which is more ventrally displaced than in the ulna of *Santanadactylus pricei* (AMNH 22552: Wellnhofer, 1985, 1991a; Kellner

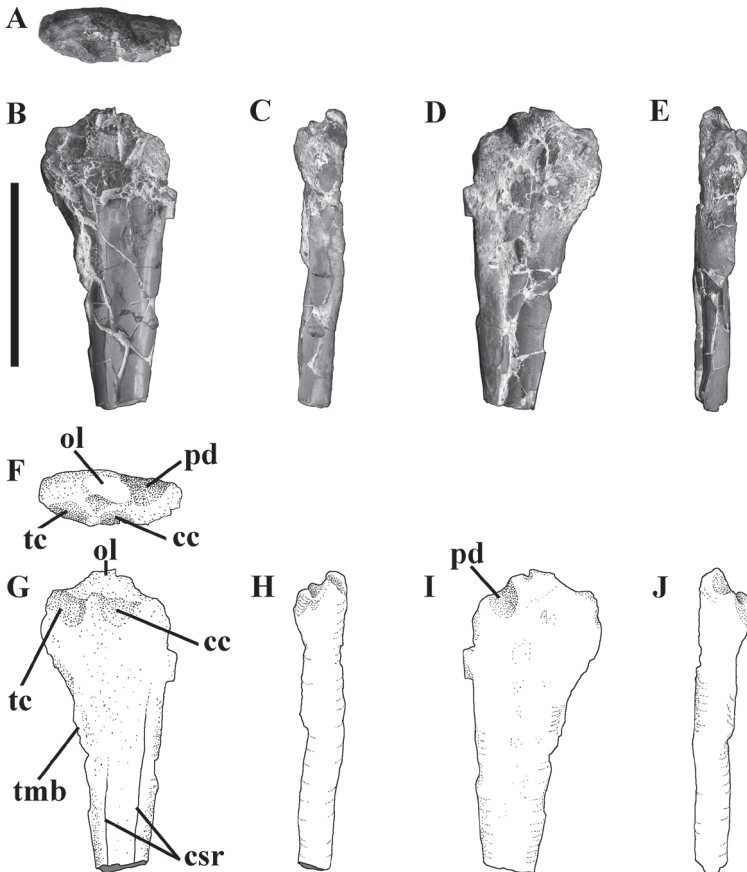


Figure 2 - MMCH-Pv 53 Pterosaur proximal ulna found at Cabo Alarcón in **A,F**, proximal, **B,G**, anterior, **C,H**, dorsal, **D,I**, posterior, and **E,J**, ventral views. **Abbreviations:** csr: contact surface with radius; cc: capitular cotyle; tc: trochlear cotyle; ol: olecranon; pd: posterior depression; tmb: tuberculum musculi bicipitis.

and Tomida, 2000; BSP 1980 I 122: Wellnhofer, 1985). A small pneumatic foramen is present proximal to the TMB of the above-mentioned species, but the preservation of MMCH-Pv 53 does not allow observation of this foramen. The preserved portion of the shaft shows in its anterior face two longitudinal low ridges that suggest the contact area with the radius (Figure 2 B, G). In proximal view there are two concave, anteroproximally facing articular surfaces: a dorsal one, the capitular cotyle (*sensu* Bennett, 2001), and the ventrally located trochlear cotyle (*sensu* Bennett, 2001), separated by a sharp prominence. Posterior to this small prominence is a dorsoventrally elongated depression. The posterior margin of the proximal end shows an overhanging rounded and dorsoventrally elongated prominence, the olecranon process: that corresponds to the insertion area for the *M. triceps brachii* (Figure 2 A, F). Dorsal to this prominence is a wide, posteriorly orientated depression, also present in BSP 1982 I 93 (Wellnhofer, 1985).

DISCUSSION

The analysis of the specimen presented here allowed the re-interpretation of previously published material. Wellnhofer (1985) described several associated pterosaur bones from the Early Cretaceous Romualdo Formation of Brazil, including some incomplete femora, tibiae and fibulae (BSP 1982 I 93) that were assigned to *Araripesaurus* sp. Later Wellnhofer (1988) reinterpreted this material, considering them to be the humeri, ulnae and radiae (see also Kellner 1990). Gasparini *et al.* (1987) described an incomplete pterosaur right tibia (P 2280 MOZ) from the Upper Jurassic (Tithonian) of Los Catutos, Neu-

quén, Argentina, (see also Codorníu and Gasparini, 2007); following the description of *Araripesaurus* sp. given by Wellnhofer (1985). The proximal end of pterodactyloid ulna presents a sub-triangular outline, with two anteriorly facing concave surfaces and a posterior prominence. This morphology is clearly seen in both MMCH-PV 53 and P 2280 MOZ. Following the considerations given by Wellnhofer (1988), Kellner (1990), and taking in count the anatomical features observed in Los Catutos material; we re-interpret P 2280 MOZ as an incomplete proximal ulna of an undetermined pterosaur.

The estimation of total ulnar length of MMCH-Pv 53 can be inferred using a correlation between the dorso-ventral ulnar shaft length/total ulnar length. This analysis derives from the methodologies used by Wellnhofer (1985); Wiffen and Molnar (1988) and Frey and Martill (1994) for other incomplete pterosaurian ulnae. The dorso-ventral ulna shaft length of the Cabo Alarcón material is about 13 mm. Thus the complete ulna length can be estimated at about 169-182 mm. It's important to note that the ulnar shaft might be a little narrower at its middle section, so the estimations based on this measurement should correspond to slightly lower values. Nevertheless, the inferred lengths can be considered as maxima and show that MMCH-Pv 53 represents a medium sized pterosaur. This new specimen is considerably bigger than pterosaur material previously recovered at Candeleros Formation (Haluza *et al.*, 2007), which were considered as an adult given the fusion of the extensor tendon process of the first wing phalanx and fusion of the proximal and distal syncarpal elements. The Candeleros Formation has yielded small fossil tracks that were assigned to *Pteraichnus* isp. (Calvo and Moratalla, 1998; Calvo, 1999; Calvo and Lockley, 2001). The

pes track was described as plantigrade, elongate (three times longer than wider), with a total length of 10 cm. To establish if MMCH-Pv 53 might correspond to the *Pteraichnus* isp. trackmaker of the Candeleros Formation an analysis of the correlation between the ulnar length and the pes length of well preserved pterodactyloid pterosaurs (where both measurements can be taken) was made (Figure 3; Table 1). There is a clear correlation between both measurements ($R^2 = 0,8945$), even when some variability within the data can be explained by phylogenetic biases. The results show that the inferred size matches well with the maker of the pterosaurian

ichnites *Pteraichnus* isp., recovered from the same geological unit.

CONCLUSIONS

The analysis of the material presented here allows a re-interpretation of MOZ 2280 P as a proximal pterosaur ulna, rather than a tibia, as previously described (Gasparini *et al.* 1987; Codorniu and Gasparini, 2007). Estimations of size made on MMCH Pv 53, suggests that this new osteological record matches well with the putative *Pteraichnus* isp. trackmaker of the Candeleros Formation. This bone belonged to a medium-sized pterosaur,

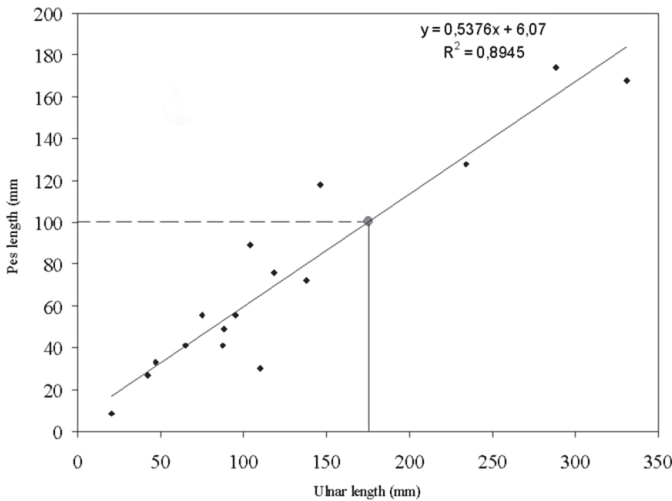


Figure 3 - Scatter plot of ulnar length versus pes length of well-preserved pterosaurs (black squares) showing the correlation line between the variables. The grey circle shows the estimated ulnar length of MMCH-Pv 53, plotted to estimate its probable pes length.

Taxon	Data Source	Ulnar length (mm)	Pes length (mm)
<i>Beipiaopterus chenianus</i>	Lu, 2003	75	55,5
<i>Boreopterus cuiiae</i>	Lü and Ji, 2005	110	30,1
<i>Ctenochasma gracile</i>	Buissonjé, 1981	65	41
<i>Eosipterus yangi</i>	Ji and Ji, 1997	95	55,5
<i>Huanhepterus quinyangensis</i>	Dong Zhiming, 1982	138	72,3
<i>Huaxipterus corollatus</i>	Lü <i>et al.</i> 2006	118	76
MOZ 3625P	Codorniu <i>et al.</i> , 2006	88	49
<i>Nemicolopterus cripticus</i>	Wang <i>et al.</i> , 2008	20	8,7
<i>Noriopterus complicitens</i>	Young, 1973	288	174
<i>Pteranodon longiceps</i>	Bennett, 2001	331	168
<i>Pterodactylus antiquus</i>	Wellnhofer, 1970	47	33
<i>Pterodactylus kochi</i>	Wellnhofer, 1968	42	27
<i>Pterodaustro quinzui</i>	Bonaparte 1970	146	118
<i>Shenzhoupterus chaoyangensis</i>	Lü <i>et al.</i> , 2008	104	89
<i>Sinopterus dongi</i>	Wang and Zhou, 2003	87,5	41
<i>Zhejiangopterus linhaiensis</i>	Cai and Wei, 1994	234	128
MMCH-Pv 53	This paper	175,5	100,4188

Table 1. Ulnar and pes lengths of well-preserved pterosaurs. Data source of these measurements are cited. The estimation of the pes length of MMCH-Pv 53 based on the correlation between both variables is also provided.

considerably larger than previously recorded pterosaurs from this formation (Apesteguía *et al.*, 2007; Haluza *et al.*, 2007).

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