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Maniraptoran theropod ungual from the Marília Formation (Upper Cretaceous), Brazil

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Abstract: A new theropod record from the Marília Formation (Late Cretaceous, Minas Gerais, Brazil) is here described. It consists of an isolated manual ungual which exhibits derived maniraptoran features (*e.g.*, presence of proximodorsal lip). The ungual distinguishes by a set of unique features (*e.g.*, dorsoventrally low and proximodistally elongate profile in side view; block-like flexor tuberosity; proximal articular surface more dorsally oriented than in other theropods; cutting «keel» located distally on ventral surface) suggesting that the animal that produced it was a member of an unknown group of derived maniraptoran theropods, other than alvarezsaurids, deinonychosaurians and oviraptorosaurians already recorded in South America.

Key words. Theropoda, Maniraptora, Cretaceous, Marília Formation, Brazil.

The fossil record of Cretaceous theropod dinosaurs from Brazil is currently restricted to few incompletely known taxa. The Lower Cretaceous (?Albian) Santana Formation yielded the most complete and comprehensive theropod materials, including the spinosaurid *Irritator challengeri* (Martill *et al*., 1996; Kellner & Campos, 1996; Sues *et al*., 2002), the compsognathid *Mirischia asymmetrica* (Naish *et al*., 2004), and the maniraptoriform *Santanaraptor placidus*
(Kellner, 1999, 2001). Also coming from the Santana Formation is a theropod sacrum originally described as possibly oviraptorosaurian (Frey & Martill, 1995), but doubts have been rised about the correct assignment of this fragmentary specimen (Makovicky & Sues, 1998).

The Upper Cretaceous theropod record from Brazil is scarce, the only named taxon is the abelisaurid *Pycnonemosaurus nevesi*, collected from Upper Cretaceous strata of Mato Grosso (Kellner & Campos, 2002). Occurrences of theropod remains from Northern Brazil include some teeth, vertebrae and unguals from the São Luís Basin (Alcântara Formation, Cenomanian; Medeiros, 2001; Vilas Bôas *et al*., 1999). In regard with the Bauru Group, an inland basin partially covering the Brazilian states of São Paulo, Paraná, Mato Grosso do Sul, Minas Gerais and Goiás (Fig. 1), has yielded a variety of saurischian remains (*e.g.*, bones, teeth, eggs and eggshells; Bertini, 1996; Bertini *et al*., 1993; Magalhães Ribeiro & Ribeiro, 1999; Magalhães Ribeiro, 2000). However, evidence on theropod dinosaurs is restricted to isolated teeth presumaly belong-ing to Carcharodontosauridae (collected from Serra da Galga; Kellner & Campos, 1998), as well as teeth and skull fragments referred as to Abelisauridae *indet*. (Bertini, 1996).

In particular, excavations carried on at levels of the Marília Formation exposed at Serra do Veadinho, yielded abundant titanosaurid bones (Campos & Kellner, 1999). Despite the frequency of well preserved sauropod remains, only some isolated theropod elements (mainly teeth, fragment of distal end of a femur, isolated pedal phalanges) have been found at the moment.

We aim to improve the meager theropod record of the Upper Cretaceous Marília Formation with the study of an isolated manual ungual, the morphology of which reveals that the taxonomic diversity of South American theropod faunas was higher than expected.

Geology

The Bauru Basin accumulated sediments of the Cretaceous Bauru Group, which is divided

into three formations (from the bottom to top): Adamantina, Uberaba, and Marília (Fernandes & Coimbra, 1996). From these units, the Marília Formation has offered the most comprehensive collection of dinosaur remains. It consists of a sequence of coarse to conglomeratic sandstones, mudstones and carbonate levels (Soares *et al*., 1980), corresponding to alluvial fans, braided flu-vial systems, alluvial plains and ephemeral lakes deposited under a hot and dry climate (Goldberg & Garcia, 2000). The age of these deposits, based on charophyte and ostracod fossil records, is probably Maastrichtian (Dias-Brito *et al*., 2001).

SYSTEMATIC PALEONTOLOGY

Dinosauria Owen, 1852
Theropoda Marsh, 1881
Coelurosauria Huene, 1920
Maniraptora Gauthier, 1986

***Gen. et sp.* indet.**

Horizon and Locality: The fossil level corresponds to beds of the Serra da Galga Member of the Marília Formation (Maastrichtian, Upper Cretaceous). Serra do Veadinho (Lat. 19° 43' 25,5'' S, Long. 47° 44' 45,4'' W), Peirópolis, Municipal-ity of Uberaba, Minas Gerais State, Brazil (Fig. 1).

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*Description of specimen.*The ungual (Figs. 2 & 3) is well preserved, but lacks its distal extremity. It is 55mm long at the outer curvature. Proximally, the bone is 13,7mm deep and 8mm wide. The size of the bone indicates that the animal that pro-duced the ungual was comparatively small and slender, probably reaching 2m long, if compared with *Oviraptor philoceratops*, for example.

The ungual almost probably belongs to the manus because it is widely curved (approximately 95 degrees; curvature of the ungual was calcu-lated following the method described by Ostrom, 1969), transversely compressed, with slightly asymmetrically arranged colateral grooves, and most important, the proximal articular facet is dorsally oriented and bears a proximodorsal lip. This combination of features is absent in the-ropod pedal unguals, including the specialized one of digit 2 of deinonychosaurian theropods (*e.g*., Ostrom, 1969; Novas & Pol, 2005). We ten-tatively interpret the ungual as corresponding to either manual digits II or III because of its de-gree of curvature and presence of proximodorsal lip (frenquently present in digits 2 and 3 of maniraptoran theropods). The ungual shows signs of a slight assymmetry: proximally, the left articular facet is more reduced than the right one, as well as the left colateral groove is located slightly below with respect to the right one. Comparing with the assymmetrical manual ungual of digit I of *Megaraptor* (Novas, 1998; Calvo *et al*., 2004), we tentatively interpret the ungual from Brazil as belonging to the right hand.

The ungual is elongate, dorsoventrally low, and sharply pointed in side view. The proximal articular facet bears a strong vertical ridge, and it is clearly delineated from adjacent surfaces. This is rectangular in shape, with the right facet (presumably the outer one) larger than the left (*i.e.*, the inner one). This possibly reflects an assymmetrically arranged distal gynglimoid of the corresponding penultimate phalanx. A transversely wide lip is present on the proximodorsal margin of the ungual. The flexor tubercle is adjacent to the ventral border of the articular facet. It is block-like, ventrally flat and slightly rug-ose. The proximal surface of the tuberosity is smooth and «saddle-shaped» (*i.e.*, transversely convex and slightly concave dorsoventrally).

Deeply excavated grooves are present on both left (*i.e*., medial) and right (*i.e.*, lateral) surfaces, extending from the base of the proximal articu-lar facet to the distal extremity of the phalanx. Albeit the medial groove is dorsoventrally nar-rower than the lateral one, they are almost sym-metrically situated near the ventral edge of un-gual. The medial groove bears some vascular channels spreading almost tangentially towards the proximal end of the bone. Besides, the distal extremity of ungual exhibits, on both sides, some slight, crescent-shaped marks of unknown ana-tomical significance (Fig. 2, cm).

Except for its distal third, the ventral surface of ungual is flat and clearly distinguished from the sides of the bone through sharp edges. The ventral surface bears longitudinal striations and some tiny foramina situated approximately at mid -length of ungual. Notably, the distal third of the ventral surface forms a sharp cutting edge or «keel», proximally preceeded by a conspicu-ous elliptical foramen.

In cross section, the ungual has a roughly «8-shaped» contour, a pattern that keeps at different levels even close to its distal extremity.

Comparisons and discussion. None of the currently theropod lineages recorded in the Cretaceous of South America (*e.g*., Abelisauroidea, *Megaraptor namunhuaiquii*, Spinosauridae, Alvarezsauridae; Carrano *et al*., 2002; Coria *et al*., 2002; Charig & Milner, 1997; Novas, 1996, 1997, 1998; Calvo *et al*., 2004) exhibit the combination of features as described for the ungual from Brazil.

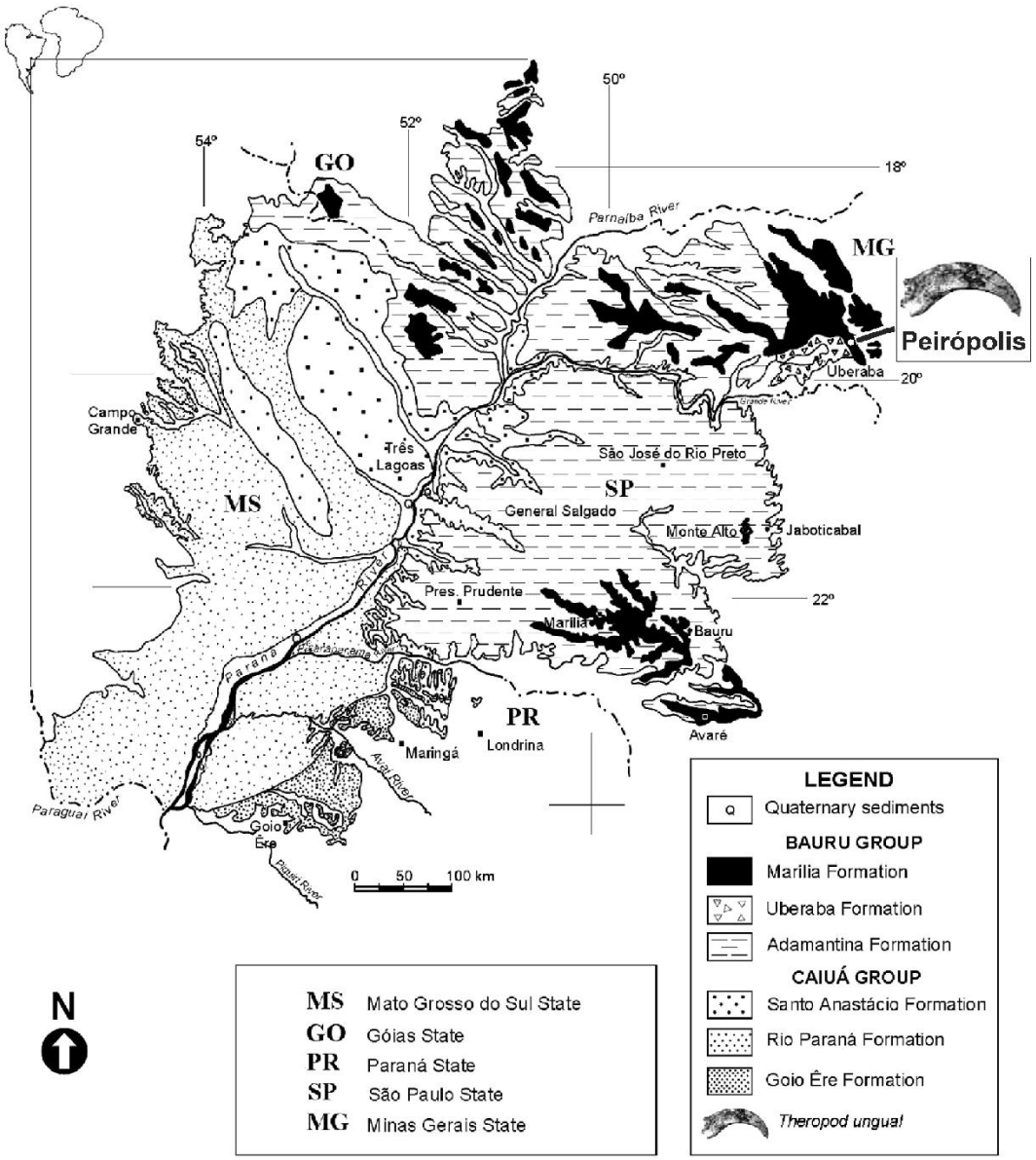

Fig. 1. Geological map of the Cretaceous Baurú Basin, Brazil, indicating fossil locality (Peirópolis).

On the contrary, the set of characters described above are only documented in a restrictive group of derived maniraptoran theropods, including oviraptorosaurs, *Microvenator celer*, troodontids, dromaeosaurids, and birds (Rauhut, 2003). For example, ungual lips are pronounced among Elmisauridae (*e.g.*, *Chirostenotes, Elmisaurus*) and in the basal oviraptorosaur *Microvenator* (Currie, 1990). Proximodorsal lips are also present in Troodontidae (Osmólska & Barsbold, 1990), but not uniformly in all manual unguals.

Lips are also present in early birds, being *Archaeopteryx* an oustanding example (Wellnhofer, 1988, 1993). Also, manual unguals of digits II and III of *Deinonychus* (Ostrom, 1969) exhibit proximodorsal lips, although less developed than in the above mentioned taxa. In the therizinosauroid *Alxasaurus* a lip is present on the ungual of digit II (Russell & Dong, 1993). Proximal lips are absent in manual unguals of *Compsognathus* (Ostrom, 1978) and *Ornitholestes* (Rauhut, 2003).

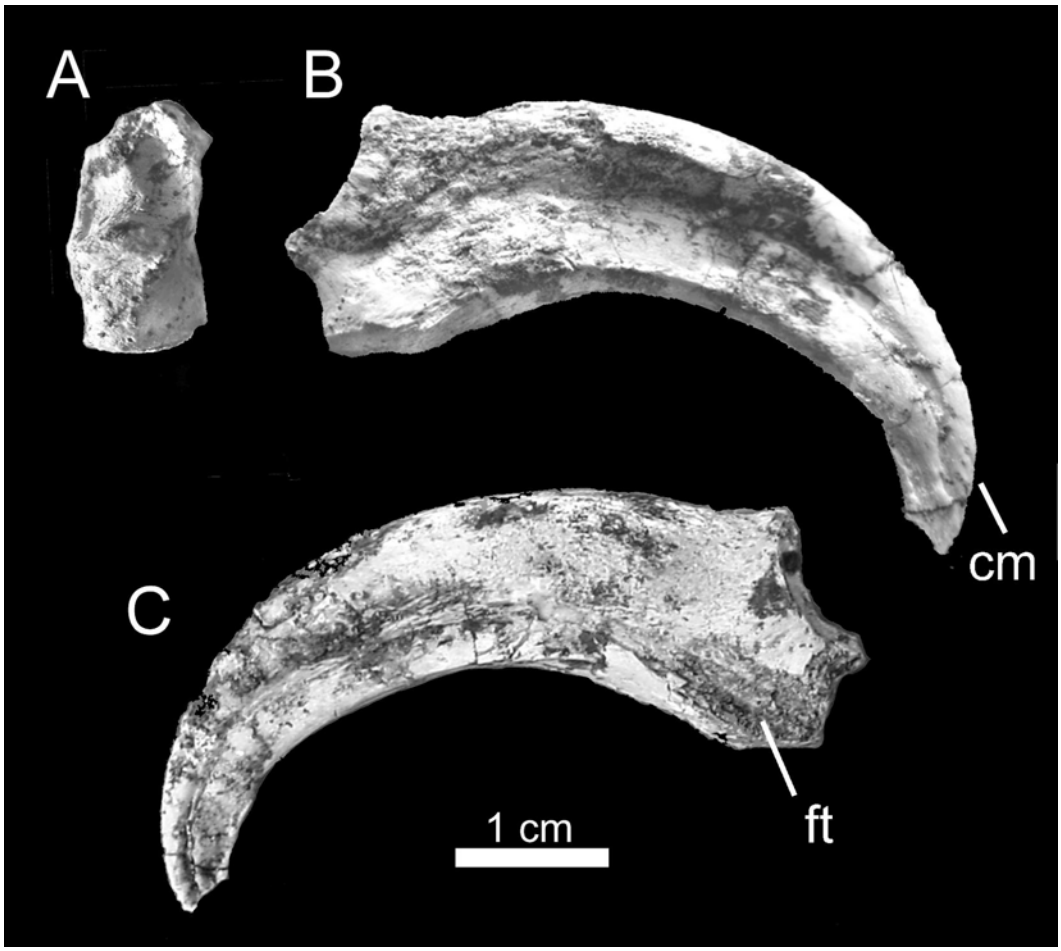

Fig. 2. Theropod ungual in A, proximal, B, right (lateral) view, and C, left (medial) views. Abbreviations: cm, crescent-shaped marks; ft, flexor tuber.

However, the flexor tuber in the Brazilian specimen is proportionally lower than the proximal articular surface, in contrast with troodontids, dromaeosaurids, and birds in which the height of the tuber exceeds half the height of the articular facet (Rauhut, 2003).

Following this, the specimen under study may represent a non-paravian maniraptoran more derived than *Ornitholestes* and Alvarezsauridae. The ungual from Brazil superficially resembles some oviraptorosaurs (*e.g.*, elmisaurids) in being elongate and dorsoventrally depressed, but the absence of proximally bifurcated grooves, that characteristically occur in elmisaurids (Currie, 1990), dissmiss referal of the isolated ungual to this theropod clade.

In most theropods (*e.g.*, *Allosaurus*, elmisaurids, deinonychosaurians, basal birds), the flexor tuberosity forms a ventrally convex prominence. In the ungual of Brazil, instead, the flexor tuberosity is shallower and is almost continuous with the ventral margin of ungual.

Several non-avian maniraptorans have been recorded in South America (*e.g.*, Alvarezsauridae, possible Oviraptorosauria, Deinonychosauria; Novas, 1996, 1997; Novas & Puerta, 1997; No-vas & Agnolín, 2004; Novas & Pol, 2005; Frank-furt & Chiappe, 1999). Despite the apomorphic resemblances with maniraptorans, the ungual from Brazil lacks features seen in these groups: for example, alvarezsaurids retained only one large ungual on digit 1 (Novas, 1996), the mor-phology of which is quite different from that of the ungual here described. In reference with deinonychosaurians (*i.e.*, troodontids and dromaeosaurids) they have strongly curved, tren-chant unguals on digits 1-3, that are easily dis-tinguished from the ungual from Brazil in its

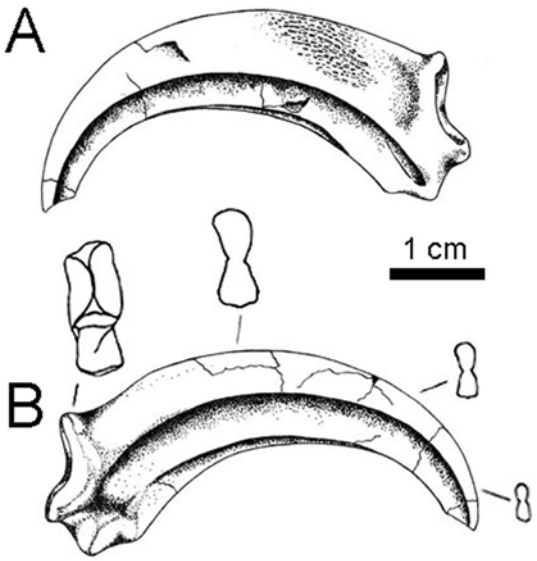

Fig. 3. Theropod ungual in A, left (medial) and B, right (lateral) views.

major degree of transverse compression and development of the ventral tuberosity. Finally, oviraptorosaurs (*e.g.*, Clark *et al*., 1999) show unguals that, albeit less curved than in deinonychosaurs, are dorsoventrally deeper than in the ungual under study.

Moreover, several unique features, absent in the maniraptoran clades listed above, distinguish the ungual from Brazil: lateral profile dorsoventrally low and proximodistally elongate; block-like flexor tuberosity, almost continuous with the ungual ventral margin; proximal articular sur-face more dorsally oriented than in other the-ropods; proximodorsal lip transversely wide; and ventral surface flat but with a cutting «keel» lo-cated distally.

In sum, the bizarre features present in the studied ungual strongly suggest that it may represent a new example of derived maniraptorans unknown so far in this continent, not necessar-ily belonging to the currently recognized the-ropod clades.

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