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Arthritic lesions and congenital fusion in foot bones of *Panochthus* sp. (Xenarthra, Cingulata)

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Abstract: A set of lesions are re-described and new pathological findings in foot bones of *Panochthus* sp. (Xenarthra, Cingulata) are presented. The material reexamined in fact presents enthesiophytes instead of osteoartrithis, as previously interpreted. Furthermore, Calcium Pyrophosphate Deposition Disease (CPPD) was observed, a lesion absent in previous report. CPPD also was found in another set of foot bones and it was associated with a congenital fusion of two sesamoids. The material studied were collected in two natural tank deposits, one in Paraíba (material reexamined) and other in Rio Grande do Norte (new pathological findings) State.

Key words: Arthritis, Congenital Fusion, Glyptodont, *Panochthus* sp.

INTRODUCTION

Arthritis is an informal term encompassing more than 100 types of joint diseases with different etiologies. It is one of the three major causes of skeletal lesions found in osseous remains (the other two conditions being trauma and infections; Ortner 2003), and commonly found in the fossil record since Permian (Rothschild et al. 2012). Among xenarthrans – a notable group of endemic mammals of the Neotropical Region (Wetzel 1985) – arthritis has a modest record, including cases of spondyloarthropathy associated with calcium pyrophosphate deposition disease and osteoarthritis in the glyptodonts *Glyptotherium* sp. (Barbosa et al. 2014b) and *Panochthus* sp. (Barbosa and Luna 2014). Osteoarthritis also was identified on an axis of the giant ground-sloth *Eremotherium larillardi* (Barbosa et al. 2014a) and on a metatarsal III and an ectocuneiform assigned to *Panochthus* sp. (Henriques et al. 1998). Here we describe new cases of arthritic lesions in metatarsal and tarsal bones of

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Panochthus sp. from northeast Brazil, including a reevaluation of the diagnosis proposed for the specimens analyzed by Henriques et al. (1998). In addition, we describe the first case of a congenital anomaly in sesamoids bones in a glyptodont.

The genus *Panochthus* Burmeister, 1866 (Xenarthra, Cingulata, Gliptodontoideia) is one of the largest and best known genera among glyptodonts (Paula-Couto 1979, Zamorano et al. 2013). At least six valid species, which form a monophyletic group (Zamorano and Brandoni, 2013, Porpino et al. 2014), were assigned to this genus. They are known from the early-middle Pleistocene of Argentina (Zamorano et al. 2014a) to the Pleistocene-Holocene of northeast Brazil (Porpino et al. 2014) and a recent finding suggests that the genus would already be present in the late Pliocene (Zamorano et al. 2014b). They share a suite of remarkable characters, such as a well-developed caudal tube with striated conical tubercles on its sides and the absence of the rosette ornamentation pattern on most carapace osteoderms, typical of most glyptodonts (Zamorano et al. 2014a). Two valid species of this genus are recognized from northeast Brazil (Porpino et al. 2014): *Panochthus greslebini* Castellanos, 1941 and *Panochthus jaguaribenses* Moreira, 1965, both diagnosed by caudal tube characters.

MATERIALS AND METHODS

The specimens here analyzed are housed in the paleontological collections of the Museu Nacional, Universidade Federal do Rio de Janeiro (MN/UFRJ, Rio de Janeiro city, Rio de Janeiro State, Brazil) and Museu Câmara Cascudo, Universidade Federal do Rio Grande do Norte (MCC/UFRN, Natal city, Rio Grande do Norte State, Brazil). The specimens include a left metatarsal III (MN 3631-V), a left ectocuneiform (MN 3734-V), a right ectocuneiform (MCC 1559-V), a right mesocuneiform (MCC 1559-V), a right metatarsal IV (MCC 1559-V) and two sesamoids of metatarsal III (MCC 1559-V).

All material is assigned to *Panochthus* sp. and was collected in two natural tank deposits – sedimentary deposits occurring in natural depressions developed on basement rock outcrops by physical-chemical weathering, common in northeastern Brazil (Araújo-Júnior et al. 2013). MN/UFRJ specimens were collected at Campo Alegre site, Taperoá municipality, Paraíba State, Brazil and the MCC/UFRN specimens were collected at Lagoa do Santo site, Currais Novos municipality, Rio Grande do Norte State, Brazil (Fig. 1). The specimens from Campo Alegre site were found in association with two caudal tubes belonging to *P. greslebini* and *P. jaguaribensis* but, like most postcranial material found in this site, cannot be confidently assigned to any of these species (see Porpino et al. 2014 for a full explanation). The specimens belonging to MCC/UFRN collection received the same number because they were found articulated and are part of a near complete pes belonging to a single individual (Porpino and Bergqvist 2002).

RESULTS

In dorsal view, the left metatarsal III (MN 3631-V) has reactive new bone formation near the proximal articular surface of the ectocuneiform, forming a rugous bony spur (Fig. 2b). The same type of bone overgrowth is evident on lateral view, near the articular surface for the left metatarsal IV (Fig. 2c). The left ectocuneiform (MN 3734-V) exhibits the same bone overgrowth on its lateral face (Fig. 3b). Additionally, the left metatarsal III manifests bone formation marginally located and projecting onto the proximal articular surface (ectocuneiform articulation) (Fig. 2d).

The two sesamoids associated with the right metatarsal III (MCC 1559-V) are fused (Fig. 4b). Lateral view of the right mesocuneiform and the

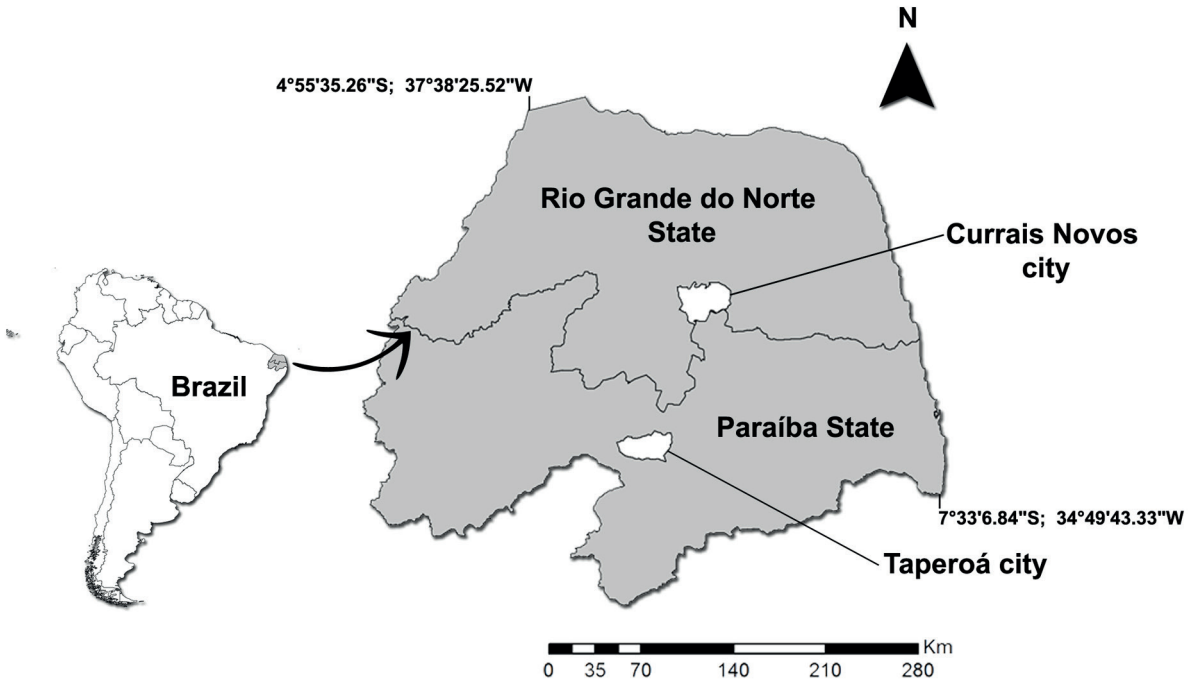

Figure 1 - Location map of the fossil localities (Lagoa do Santo site, Currais Novos municipality, Rio Grande do Norte State and Campo Alegre site, Taperoá municipality, Paraíba State).

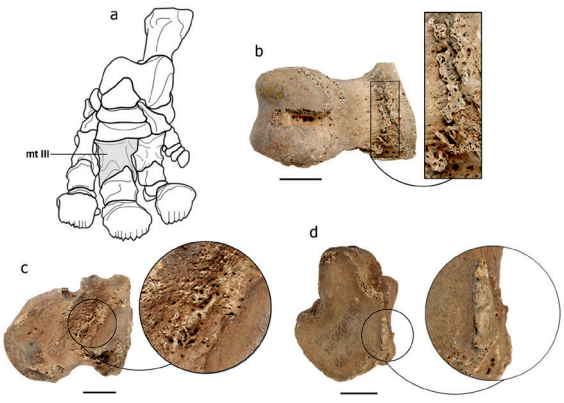

Figure 2 - (**a**) scheme of the foot of *Panochthus* sp. (modified from Burmeister, 1874); (**b**) left metatarsal III (MN 3631-V) in dorsal view with highlight of the lesion; (**c**) left metatarsal III (MN 3631-V) in lateral view with highlight of the lesion; (**d**) proximal articulation of left metatarsal III (MN 3631-V) with highlight of the lesion. Scale bar = 2.0 cm. Abbreviation: mt III: metatarsal III.

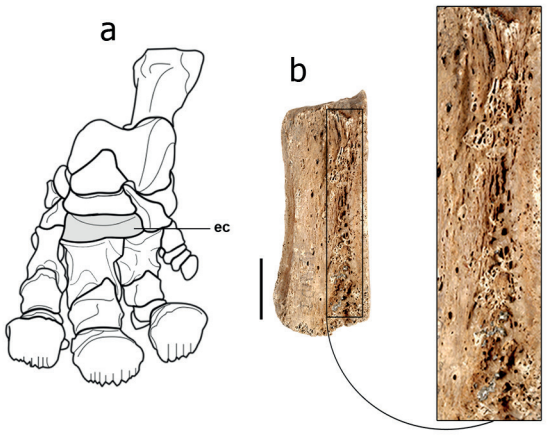

Figure 3 - (**a**) scheme of the foot of *Panochthus* sp. (modified from Burmeister, 1874); (**b**) left ectocuneiform (MN 3734-V) in lateral view with highlight of the lesion. Scale bar = 2.0 cm. Abbreviation: ec: ectocuneiform.

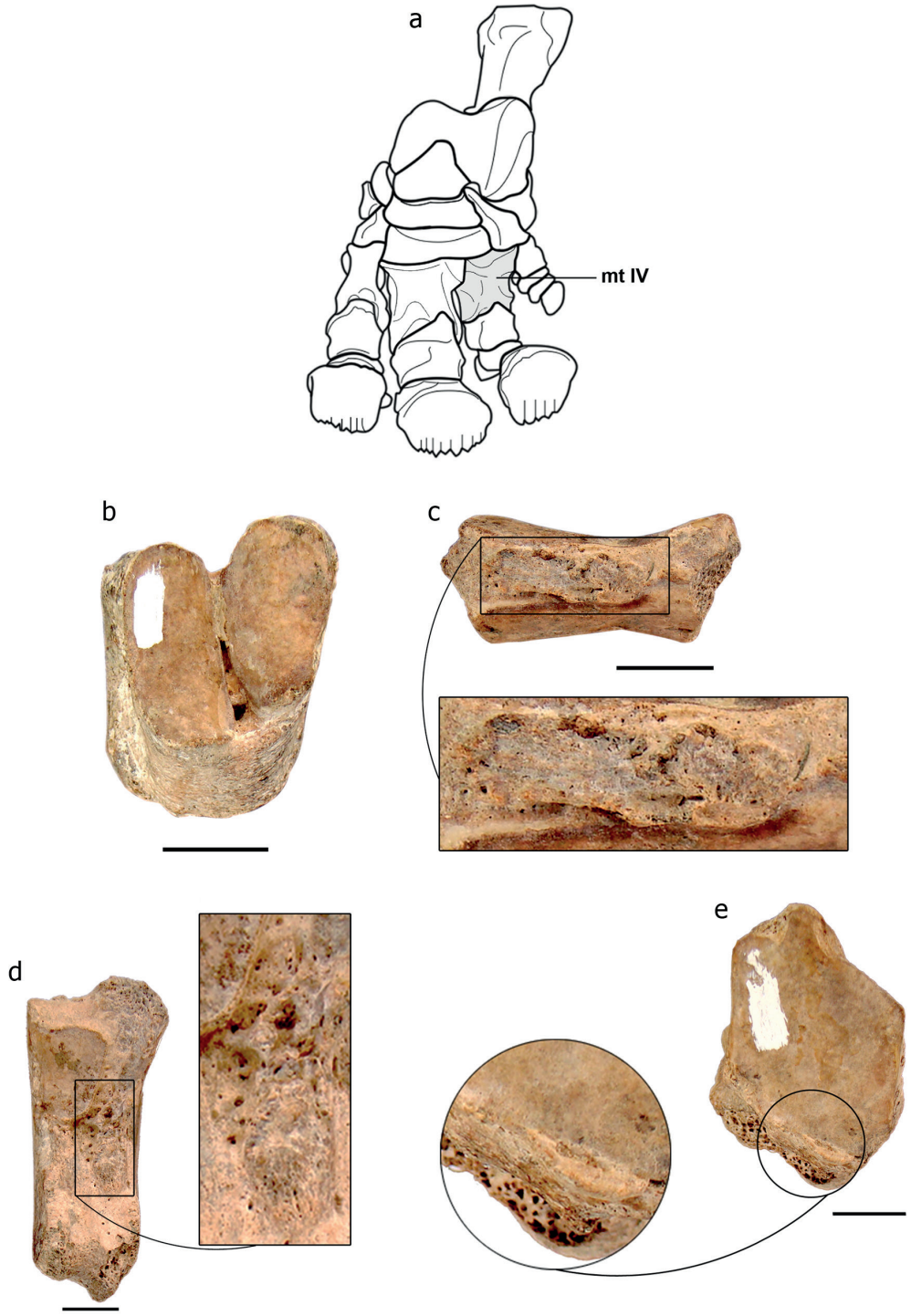

Figure 4 - (**a**) scheme of the foot of *Panochthus* sp. (modified from Burmeister, 1874); (**b**) right sesamoids (MCC 1559-V) associated with metatarsal III fused; (**c**) right mesocuneiform in lateral view with highlight of the lesion; (**d**) right sesamoid (MCC 1559-V) associated with metatarsal II in lateral view with highlight of the lesion; (**e**) proximal articulation of the metatarsal IV (MCC 1559-V) with highlight of the lesion. Scale bar = 2.0 cm. Abbreviation: mt IV: metatarsal IV.

sesamoid associated with the right metatarsal II reveal an extensive reactive new bone formation similar to that observed in MN 3631-V and MN 3734-V (Fig. 4c-d). Metatarsal IV (MCC 1559-V) exhibits new bone formation projecting onto the proximal joint surface of the entocuneiform (Fig. 4e). This lesion is identical in appearance to that recognized in the left metatarsal III (MN 3631-V).

DIFFERENTIAL DIAGNOSIS

The lesions in the left metatarsal III (MN 3631-V) and left ectocuneiform (MN 3734-V) were originally interpreted as osteophytes (Henriques et al. 1998; figures 1-4), i.e., bone overgrowth on marginal edges of the synovial joint surface (Ortner 2003), which is considered the diagnostic indicator of osteoarthritis (Rothschild and Martin 2006). However, reexamination of the material revealed that these bone alterations are not actually located on the marginal edges of the synovial articular surfaces. Therefore, they cannot be considered osteophytes and are not indicative of osteoarthritis. In fact, the bone overgrowth observed in both specimens represent enthesiophytes, that is, bone reaction at the sites of attachment of tendons, ligaments or capsule insertion (Jacobs 1983, Rothschild and Martin 2006). Enthesitis was in the past considered suggestive of spondyloarthropathy (Rothschild 1982, Resnick 2002). However, it is frequently observed in healthy individuals (human population). When occurring in isolation it cannot be considered a diagnostic criterion for spondyloarthropathy (Rothschild 2013). Enthesitis was noted in the right mesocuneiform and the sesamoid associated with the right metatarsal II recovered from the Lagoa do Santo site. As for the aforementioned specimens, these alterations cannot be attributed to spondyloarthropathy due to the lack of additional evidence (e.g. subcondral erosions, syndesmophyte; Rothschild 2013).

Interestingly, metatarsal III (MN 3631-V) presents new bone formation projecting onto the joint surface, a critical observation lacking in the report by Henriques et al. (1998; Fig. 2d). It is also observed in metatarsal IV (MCC 1559-V). Such new bone formations are actually calcific sheets, which are diagnostic of calcium pyrophosphate deposition disease (CPPD; Rothschild 1982, Markel and Hart 1982, Resnick 2002), a variety of crystalline arthritis (Rothschild 1982, Resnick 2002). Although the calcific sheets are marginally located, they differ from osteophytes because they are projected onto the articular surface instead of being parallel to it.

Among the types of arthritis, spondylo-arthropathy is the most common in the fossil record (Rothschild and Martin 2006), while CPPD and osteoarthritis are rare in free-raging animals. However, Pleistocene Xenarthra, especially cingulates, has presented a different story so far. The association of CPPD with other types of arthritis in fossil xenarthrans (Barbosa et al. 2014b, Barbosa and Luna 2014), suggests that it was not as rare as in recent animals, at least in this group. Nevertheless, new investigations are necessary to evaluate the prevalence of this and other kinds of arthritic lesions within this group, as well as their potential causes.

The merging of the sesamoids of the metatarsal III into a single piece (Fig. 4b) likely represents an abnormal fusion. This type of fusion is commonly congenital and results from an abnormal differentiation and segmentation of primitive mesenchyme (Jack 1954). Abnormal fusion of foot bones is well known in humans (e.g. De Villiers Minnaar 1952, Jack 1954, Newman and Newberg 2000), but, until now, unknown in the mammalian fossil record of South America.

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