

## ARTICULAR DEPRESSION: A NEW TYPE OF ANTE-MORTEM BONE ALTERATION IN THE FOSSIL RECORD OF TETRAPODA

### DEPRESSÃO ARTICULAR: UM NOVO TIPO DE ALTERAÇÃO ÓSSEA ANTE-MORTEM NO REGISTRO FOSSILÍFERO DE TETRAPODA

**Fernando Henrique de Souza Barbosa**

ORCID: <https://orcid.org/0000-0002-9738-2468>

Departamento de Estratigrafia e Paleontologia

Faculdade de Geologia, Universidade do Estado do Rio de Janeiro, UERJ

E-mail para correspondência: [fhsbarbosa@gmail.com](mailto:fhsbarbosa@gmail.com)

Submetido: 15/12/2021; Aceito: 29/03/2022

#### Abstract

Articular depression is a type of bone modification often found in extant animals recovered from archeological sites, but not yet formally described in fossil remains. Here, these depressions are formally described for the first time in extinct animals. The depressions were identified through macroscopically analyses performed in eight bones assigned to at least three Quaternary mammals (*Eremotherium laurillardi*, *Ocnotherium giganteum* and *Toxodon* sp.). It was possible to recognize Type 1, Type 3 and Type 4 depressions; Type 2 and Type 5 depressions were not identified in this sample. The etiology of articular depression is still unclear, but it seems to be related to osteochondrosis.

**Keywords:** Disease, Megafauna, Paleopathology, Quaternary.

#### Resumo

Depressão articular é um tipo de modificação óssea frequentemente encontrada em animais atuais recuperados de sítios arqueológicos, mas ainda não formalmente descrita em fósseis de animais. Aqui, essas depressões são formalmente descritas pela primeira vez em animais extintos. As depressões foram identificadas através de análises macroscópicas realizadas em oito ossos atribuídos a pelo menos três mamíferos do Quaternário (*Eremotherium laurillardi*, *Ocnotherium giganteum* e *Toxodon* sp.). Foi possível reconhecer depressões classificadas como Tipo 1, Tipo 3 e Tipo 4; as depressões do Tipo 2 e Tipo 5 não foram identificadas nesta amostra. A etiologia da depressão articular ainda não é clara, mas parece estar relacionada à osteocondrose.

**Palavras-chave:** Doenças, Megafauna, Paleopatologia, Quaternário.

## INTRODUCTION

Paleopathology is the science that deals with the record of diseases in ancient humans and non-humans remains (RUFFER, 1913). Recently, paleopathological studies have received great attention, especially due to their usefulness in paleoecological investigations (e.g., BISHOP *et al.*, 2015; TOMASSINI *et al.*, 2020). Many types of diseases have been documented in the fossil record of Tetrapoda, with special attention, but not limited, to Dinosauria and the "Quaternary Megafauna". Infections, traumas, inflammatory and non-inflammatory joint diseases are among the pathological conditions more often recognized by paleopathologists worldwide (e.g., BROWN *et al.*, 2017; SURMIK *et al.*, 2018; BARBOSA *et al.*, 2019; ROTHSCILD; HAEUSLER, 2021). Despite this great documentation of paleopathologies, the area is far from exhausted, with the paleopathological record of several taxa still unknown. Moreover, the possibility of diseases not yet diagnosed, or ante-mortem bone alterations not properly explored cannot be disregarded. Additionally, biomechanical, paleoecological and paleoenvironmental inferences related to recognized paleopathologies are promising fields to be explored.

Amongst the conditions that have received little attention in the paleontological context is the articular depression, a type of bone defect particularly identified in joint surfaces of archeological and modern bovine phalanges (BAKER; BROTHWELL, 1980; THOMAS; JOHANNSEN, 2011). Originally, Braker and Bothwell (1980)

defined three types of articular depressions, named Type 1, Type 2 and Type 3. Later on, Thomas and Johannsen (2011) studying a large sample of archeological and modern populations of domestic cattle of North Europe recognized the Type 4 articular depression. Lastly, Telldahl (2012) defined the articular depression Type 5. These bone modifications are commonly found in fossils of Quaternary mammals from different paleontological sites in Brazil (author's experience), however, their occurrence has not been formally described and published so far.

The aim of this paper is to document the presence of articular depressions in the fossil record for the first time.

## MATERIAL AND METHODS

The specimens analyzed include eight bones assigned to at least three different taxa of Quaternary mammals: the giant ground sloths *Eremotherium laurillardi* and *Ocnotherium giganteum* and the rhino-like South American native ungulate *Toxodon* sp., while one of the specimens was identified solely as Folivora (Table 1). It is possible to determine that all specimens belong to adult individuals, since the growth plates are close to each other.

**Table 1.** List of material analyzed.

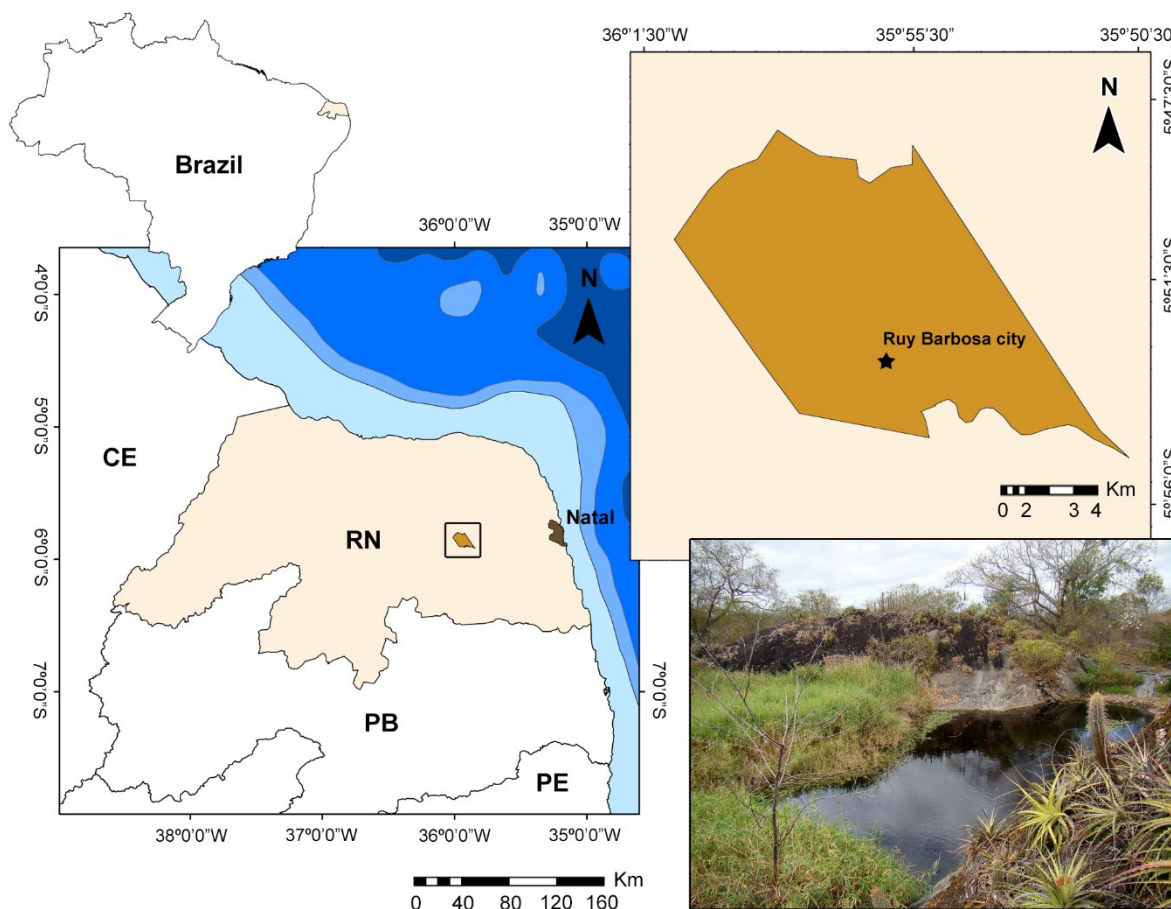
| Catalog number | Taxon                           | Bone              | Type of depression |
|----------------|---------------------------------|-------------------|--------------------|
| MCC 1523-V     | <i>Toxodon</i> sp.              | scaphoid          | type 3             |
| MCC 1524-V     | <i>Eremotherium laurillardi</i> | scaphoid          | type 1 + 4         |
| MCC 1525-V     | <i>Eremotherium laurillardi</i> | cuneiform         | type 4             |
| MCC 1526-V     | Folivora <i>Incertae sedis</i>  | medial phalange   | type 4             |
| MCC 1569-V     | <i>Eremotherium laurillardi</i> | proximal phalange | type 1             |
| MCC 1574-V     | <i>Ocnotherium giganteum</i>    | medial phalange   | type 1             |
| MCC 1575-V     | <i>Ocnotherium giganteum</i>    | medial phalange   | type 1             |
| MCC 1597-V     | <i>Toxodon</i> sp.              | tibia             | type 4             |

The specimens were recovered from a natural tank deposit – a natural depression formed by physico-chemical weathering in fractures on basement rock outcrops that were filled by clasts and bioclasts through hydraulic and aeolian agents during the Late Pleistocene/Early Holocene (OLIVEIRA; HACKSPACHER, 1989; OLIVEIRA *et al.*, 1989) – located at Acauã Farm, Ruy Barbosa municipality, Rio Grande do Norte State, Brazil (SANTOS, 2001; Figure 1). All material is housed at the Paleontological Collection Onofre Lopes of the Museu Câmara Cascudo of Universidade Federal do Rio Grande do Norte (MCC/UFRN), Natal city, Rio Grande do Norte State, Brazil.

Each specimen was examined macroscopically in order to identify articular depressions based on the criteria proposed by Braker and Brothwell (1980), Thomas and Johannsen (2011) and Telldahl (2012). Taphonomic alterations were discarded as the cause of bone modifications according to recommendations of Ortner (2003), Waldron (2009) and Barbosa *et al.*, (2020).

The criteria used for diagnosis of each type of articular depression were: (i) Type 1, a shallow oval mark antero-posteriorly oriented, which can occur on the proximal or distal articular surface of all phalanges; (ii) Type 2, a narrow slit of variable length between the articular facet, often found on the lower extremity of the second phalange; (iii) Type 3, a narrow slit of variable length running across the articular facets in a line slightly oblique to the mediolateral axis (BRAKER; BROTHWELL, 1980; see figures 3-5); (iv) Type 4, a circular pinprick depression observed on the articular surfaces of first, second and third phalanges (THOMAS; JOHANNSEN, 2011; see figure 5); and (v) Type 5, an irregular or linear depression often recognized in medio-lateral direction in proximal metatarsal (TELLDHAL, 2012; see figure 2E).

**Figure 1.** Location map and panoramic view of the fossiliferous tank deposit. Abbreviations: CE, Ceará State; PB, Paraíba State; PE, Pernambuco State; and RN, Rio Grande do Norte State.

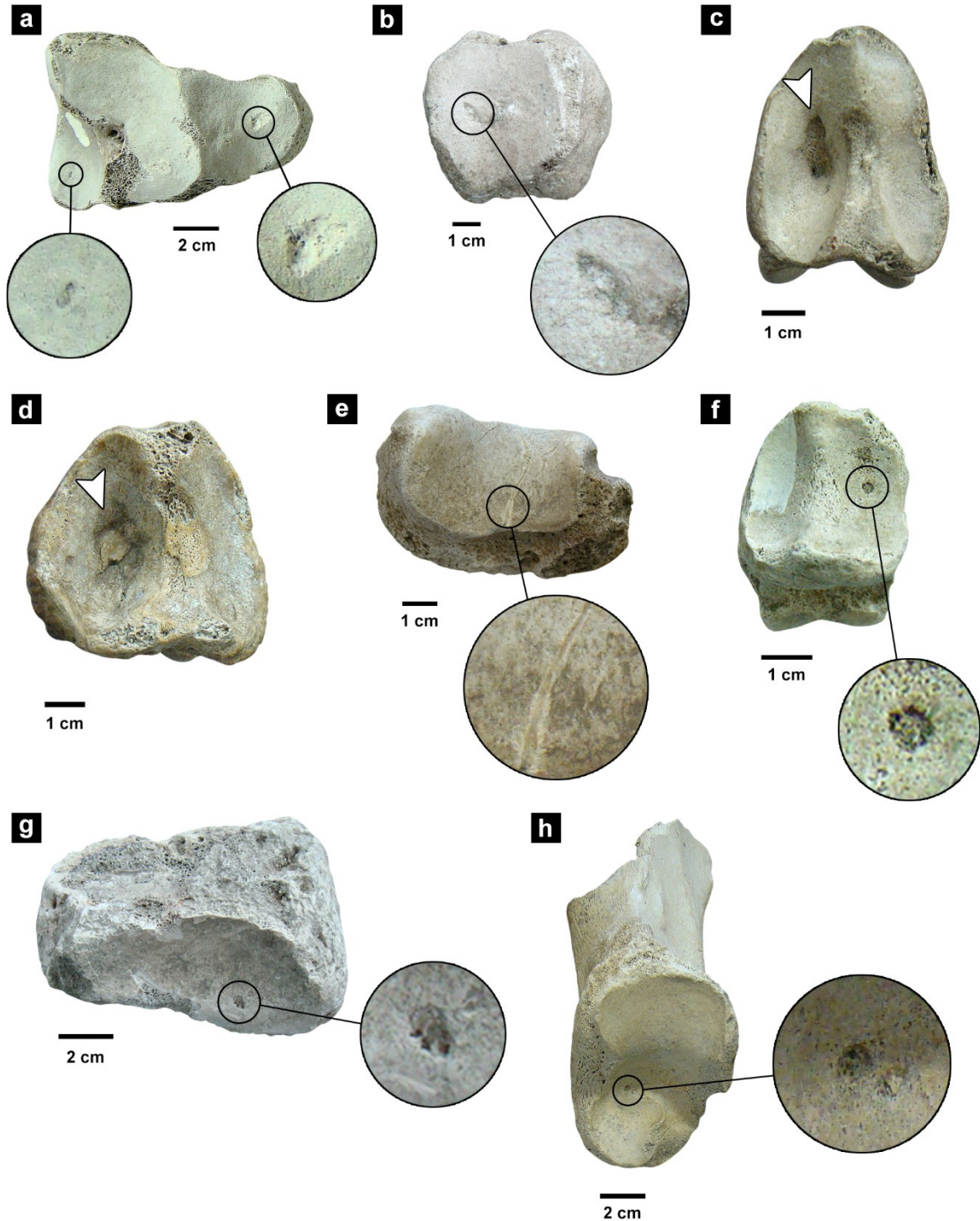


## RESULTS AND DISCUSSION

The examination of the articular surfaces of the referred material shows a set of different types of articular depressions, classified according to the system previously explained, as follows (see Table 1): four specimens (MCC 1524-V, MCC 1569-V, MCC 1574-V and MCC 1575-V) present Type 1 depression, one specimen (MCC 1523-V) presents Type 3 depression and four specimens (MCC 1524, MCC 1525-V, MCC 1526 and MCC 1597) present Type 4 depression. One single bone (MCC 1524-V) has both Type 1 and Type 4 depressions. Type 2 and Type 5 depressions were not identified in this sample.

In the scaphoid of *Eremotherium laurillardi* (MCC 1524-V) there are two types of articular depression, Type 1 and Type 4. The Type 1 is located at the articular surface to lunar, while the Type 4 is present on the articular surface to metacarpal-carpal complex (Figure 2a.). In the proximal phalange of *E. laurillardi* (MCC 1569-V) the articular depression Type 1 was identified at the distal articular surface (Figure 2b). In the medial phalanges of *Ocnotherium giganteum* (MCC 1574-V and MCC 1575-V), the articular depressions Type 1 are located at the proximal articular surfaces (Figure 2c-d). The articular depression Type 3 in the scaphoid of *Toxodon* sp. (MCC 1523-V) is located at the trapezium facet (Figure 2e). In the medial phalange MCC 1526-V, the articular depression Type 4 is located at the proximal articular surface (Figure 2f), while in the cuneiform of *E. laurillardi* (MCC 1525-V) and in the tibia of *Toxodon* sp. (MCC 1597-V) this same alteration is located at the articular surface to unciform and distal articular surface, respectively (Figure 2g-h).

**Figure 2.** Articular depressions in the bones. (a) scaphoid of *Eremotherium laurillardi* (MCC 1524-V); (b) proximal phalange of *E. laurillardi* (MCC 1569-V); (c) medial phalange of *Ocnotherium giganteum* (MCC 1574-V); (d) medial phalange of *O. giganteum* (MCC 1575-V); (e) scaphoid of *Toxodon* sp. (MCC 1523-V); (f) medial phalange of *Folivora Incertae sedis* (MCC 1526-V); (g) cuneiform of *E. laurillardi* (MCC 1525-V); and (h) fragment of tibia of *Toxodon* sp. (MCC 1597-V). White arrowheads indicate Type 1 depression.



All types of depressions are easily distinguished from taphonomic features as *ante-mortem* bone modifications have smooth or rounded edges, while post-mortem changes exhibit sharp, irregular, and jagged edges (ORTNER, 2003; WALDRON, 2009). It is noteworthy that no other type of pathological condition was

present in the specimens studied here. There are some types of arthritic diseases (e.g., spondyloarthropathy, calcium pyrophosphate deposition disease, gout, rheumatoid arthritis) that can produce destructive joint alterations. However, in all these cases, the erosive alterations are more extensive than those point defects observed here (see ROTHCHILD; MARTIN, 2006 for more details).

Articular depression has predominantly been recognized in archeological and modern domestic cattle *Bos taurus* (BAKER; BROTHWELL, 1980; THOMAS; JOHANNSEN, 2011; RASSADNIKOV, 2012; TELLD AHL, 2012). However, it has also been diagnosed in other animals retrieved from archeological sites such as the domestic sheep *Ovis aries*, the red deer *Cervus elaphus*, a camelid from Ecuador, the reindeer *Rangifer tarandus*, the European rabbit *Oryctolagus cuniculus* and a domesticated Iron Age horse not further identified (BAKER; BROTHWELL, 1980; BEIJERSBERGEN, 2016; BULATOVIĆ *et al.*, 2014; LLOVERAS *et al.*, 2021). Regarding extinct animals, a single articular depression was identified in the large wild cattle *Bos primigenius*, but this record is a non-illustrated personal observation (THOMAS; JOHANNSEN, 2011). Joint changes described in ichthyosaur bones may be a possible source of confusion (PARDO-PEREZ *et al.*, 2016). Such bone changes are morphologically described as depressions on the joint surface associated with avascular necrosis and not as a class of lesion called articular depression. Therefore, the report presented here seems to be the first formal documentation of articular depression in extinct animals, including at least three different taxa, *Eremotherium laurillardi*, *Ocnotherium giganteum*, and *Toxodon* sp.

The etiology of articular depressions is still unclear, but all types seem to have a common origin. Thomas and Johannsen (2011) ruled out bone infection/inflammation, primary trauma, neoplasia, degenerative bone diseases, as well as a link between age and Type 1 depression as possible etiologies. These authors have proposed that osteochondrosis – a common developmental joint disease with multifactorial origin including trauma or biomechanical factors on cartilage (THOMPSON, 2007) – is most likely the cause for these bone modifications. Nevertheless, the authors have been cautious with the diagnosis of osteochondrosis and do not completely rule out the possibility that the depressions are a result of a benign condition (i.e., non-pathological alteration) rather than a true pathological process.

Although this report is an interesting documentation, it only represents the first step towards understanding articular depressions. In my own experience diagnosing bone diseases in the “Quaternary Megafauna” of Brazil, these depressions are very common in different species, especially in ground sloths (unpublished data). Therefore, it is essential to carry out more robust analyses on the subject with regards to frequency, distribution, and relationship with age, body size and other injuries among the different extinct taxa.

## GENERAL CONSIDERATIONS

The eight bones of Quaternary mammals investigated herein revealed the presence of articular depressions in at least three extinct taxa (*Eremotherium laurillardi*, *Ocnotherium giganteum* and *Toxodon* sp.) for the first time. Up to now, articular depressions have been identified solely in archeological and modern animals. This intriguing *ante-mortem* condition has an unclear etiology, but it seems to be associated to osteochondrosis, a multifactorial developmental joint disease.

**Acknowledgements.** I thank L. V. Santos (PUC-MG) for the crucial help in the taxonomic identification of the material, I. Veiga (UFRJ) for all suggestion in the manuscript and A. C. Paiva (UERJ) for your help in cataloging the specimens. I also thank the Museu Câmara Cascudo of the Universidade Federal do Rio Grande do Norte (MCC/UFRN), that gently give us access to the material studied in this work. This work was supported by the Fundação Carlos Chagas Filho de Amparo à Pesquisa do Estado do Rio de Janeiro under Grants [numbers E-26/201.881/2020].

**Author contribution:** FHSB wrote the manuscript, discussed the results and provided illustrations.

## REFERENCES

- BAKER, J.; BROTHWELL, D. **Animal Diseases in Archaeology**. London: Academic, 1980.
- BARBOSA, F.H.S.; PORPINO, K.O.; ARAÚJO-JÚNIOR, H.I.; BERGQVIST, L.P.; ROTHSCCHILD, B.M. Articular and vertebral lesions in the Pleistocene sloths (*Xenarthra*, *Folivora*) from the Brazilian Intertropical Region. **Historical Biology**, v. 31, n. 5, p. 544-458, 2019.
- BARBOSA, F.H.S.; SILVA, L.H.M.; ARAÚJO-JÚNIOR, H.I. Differentiating taphonomic and paleopathological features in Vertebrate Paleontology: a study case with Quaternary mammals. **PalZ**, v. 94, p. 595-601, 2020.
- BEIJERSBERGEN, L.M.T. Heaps of fascinating fragments: reconstructing a medieval reindeer population based on bone middens from the Hardangervidda high mountain plateau, Norway. **Acta Zoologica (Stockholm)**, v. 0, p. 1-22, 2016.
- BISHOP, P.J.; WALMSLEY, C.W.; PHILLIPS, M.J.; QUAYLE, M.R.; BOISVERT, C.A.; MCHENRY, C.R. Oldest Pathology in a Tetrapod Bone Illuminates the Origin of Terrestrial Vertebrates. **PLoS ONE**, v. 10, n. 5, p. e0125723, 2015.
- BROWN, C.; BALISI, M.; SHAW, C.A.; VAN VALKENBURGH, B. Skeletal trauma reflects hunting behaviour in extinct sabre-tooth cats and dire wolves. **Nature Ecology and Evolution**, n. 1, p. 0131, 2017.
- BULATOVIĆ, J.; BULATOVIĆ, A. MARKOVIĆ, N. Paleopathological changes in an early iron age horse skeleton from the Central Balkans (Serbia). **International Journal of Paleopathology**, v. 7, p. 76-82, 2014.
- LLOVERAS, L.; THOMAS, R.; MORENO-GARCÍA, M.; NADAL, J.; TOMÀS-GIMENO, X.; RISSECH, C.; BELLIS, L. Pathological and sub-pathological changes in European rabbit bones: Two reference cases to be applied to the analysis of archaeological assemblages. **International Journal of Paleopathology**, v. 34, p. 90-100, 2021.
- OLIVEIRA, L.D.D.; HACKSPACHER, P.C. Gênese e provável idade dos tanques fossilíferos de São Rafael-RN. In: XI CONGRESSO BRASILEIRO DE PALEONTOLOGIA, 1., 1989, Curitiba. **Comunicações do XI CONGRESSO BRASILEIRO DE PALEONTOLOGIA**. Curitiba: Sociedade Brasileira de Paleontologia 1989. p. 541-549.
- OLIVEIRA, L.D.D.; DAMASCENO, J.M.; LINS, F.A.P.; WALTER, E.M.; MOREIRA, J.A. Estudo macrofossilífero dos tanques da Fazenda Capim Grosso, São Rafael-RN, auxiliado por métodos geofísicos In: XI CONGRESSO BRASILEIRO DE PALEONTOLOGIA, 1., 1989, Curitiba. **COMUNICAÇÕES DO XI CONGRESSO BRASILEIRO DE PALEONTOLOGIA**. Curitiba: Sociedade Brasileira de Paleontologia, 1989. p. 551-570.
- ORTNER, D.J. Methods used in the analyses of skeletal lesions. In: ORTNER, D.J. Identification of pathological conditions in human skeletal remains. San Diego: Academic Press, 2003. p. 45-64.
- PARDO-PÉREZ, J. M.; KEAR, B. P.; GÓMEZ, M.; MORONI, M., MAXWELL, E. E. Ichthyosaurian palaeopathology: evidence of injury and disease in fossil 'fish lizards'. **Journal of Zoology**, v. 304, n. 1, p. 21-33, 2018.
- RASSADNIKOV, A. Bone pathologies of modern non-draft cattle (*Bos Taurus*) in the context of grazing systems and environmental influences in the South Urals, Russia. **International Journal of Paleopathology**, v. 32, p. 87-102, 2021.
- ROTHSCCHILD, B.M.; HAEUSLER, M. Possible vertebral brucellosis infection in a Neanderthal. **Scientific Reports**, v. 11, p. 19846, 2021.
- ROTHSCCHILD, B.M.; MARTIN, L. D. **Skeletal Impact of Disease**. Albuquerque: New Mexico Museum of Natural History and Science, 2006.
- RUFFER, S.A.M. Studies in Palaeopathology in Egypt. **The Journal of Pathology and Bacteriology**, v. 18, p. 149, 1913.
- SANTOS, Maria de Fátima Cavalcante Ferreira dos. **Geologia e Paleontologia de depósitos fossilíferos pleistocênicos do Rio Grande do Norte**. 2001. Dissertação (Mestrado em Geodinâmica e Geofísica) – Departamento de Geologia, Universidade Federal do Rio Grande do Norte, Natal, 2001.
- SURMIK, D.; SZCZYGIELSKI, T.; JANISZEWSKA, K.; ROTHSCCHILD, B.M. Tuberculosis-like respiratory infection in 245-million-year-old marine reptile suggested by bone pathologies. **Royal Society Open Science**, v. 5, p. 180225, 2018.
- TELLDAHL, Y. Skeletal changes in lower limb bones in domestic cattle from Eketorp ringfort on the Öland island in Sweden. **International Journal of Paleopathology**, v. 2, p. 208-216, 2012.
- THOMAS, R.; JOHANNSEN, N. Articular depressions in domestic cattle phalanges and their archaeological relevance. **International Journal of Paleopathology**, v. 1, n. 1, p. 43-54, 2011.
- THOMPSON, K. Bones and joints. In: MAXIE, M.G. Jubb, Kennedy and Palmer's Pathology of Domestic Animals. **Amsterdam: Elsevier Saunders**, 2007. p. 1-184.
- TOMASSINI, R.L.; MONTALVO, C.I.; GARRONE, M.C.; DOMINGO, L.; FERIGOLO, J.; CRUZ, L.E.; SANZ-PÉREZ, D.; FERNÁNDEZ-JALVO, Y.; CERDA, I. A. Gregariousness in the giant sloth *Lestodon* (*Xenarthra*): multi-proxy approach of a bonebed from the Last Maximum Glacial of Argentine Pampas. **Scientific reports**, v. 10, n. 1, p. 1-16, 2020.
- WALDRON, T. **Palaeopathology**. New York: Cambridge University Press, 2009.