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## NEW MATERIALS OF *TOXODON PLATENSIS* FROM THE LATE PLEISTOCENE TAMANDUÁ DE CIMA LOCALITY, MUNICIPALITY OF SÃO BENTO DO UNA, STATE OF PERNAMBUCO, NORTHEAST BRAZIL

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### Abstract

Toxodontids were megamammals with numerous fossil records in the late Pleistocene of Northeast Brazil. However, an analysis of current literature shows that there is no consensus in taxonomy involving the genera *Toxodon*, *Trigodonops* and *Piauhitherium*. This work aims to characterize taxonomically two incomplete skulls recently collected at the Tamanduá de Cima site. DGEO-CTG-UFPE 8530 is the most complete and its identification was carried out through comparison with other materials in important fossil collections in Brazil. The description of the fossil specimens was carried out and all the material was identified as *Toxodon platensis* Owen, 1837. The record of *Toxodon platensis* at the Tamanduá de Cima site, represented by the fossils recorded here studied, as well as probable ichnofossils (footprints), indicates that these animals were also associated in the northeast of Brazil with watercourses with riparian vegetation.

**Keywords:** *Toxodon platensis*; Taxonomy; Megafauna.

NOVOS MATERIAIS DE TOXODONTÍDEOS DO PLEISTOCENO SUPERIOR DA LOCALIDADE TAMANDUÁ DE CIMA, MUNICÍPIO DE SÃO BENTO DO UNA, ESTADO DE PERNAMBUCO, NORDESTE DO BRASIL

### Resumo

Toxodontídeos foram megamamíferos com numerosos registros fósseis no final do Pleistoceno do Nordeste do Brasil. No entanto, uma análise da literatura atual mostra que não há consenso em taxonomia envolvendo os gêneros *Toxodon*, *Trigodonops* e *Piauhitherium*. Este trabalho tem como objetivo caracterizar taxonomicamente dois crânios incompletos coletados recentemente no sítio Tamanduá de Cima. DGEO-CTG-UFPE 8530 é o mais completo e sua identificação foi realizada por meio de comparação com outros materiais em importantes coleções de fósseis no Brasil. A descrição dos espécimes fósseis foi realizada e todo o material atribuído a *Toxodon platensis* Owen, 1837. O registro do *Toxodon platensis* no sítio Tamanduá de Cima, representado pelos fósseis aqui registrados, bem como por prováveis icnofósseis (pegadas), indica que esses animais também foram associados no Nordeste do Brasil a cursos d'água com mata ciliar.

**Palavras-chave:** *Toxodon platensis*; Taxonomia; Megafauna.

NUEVOS MATERIALES DE *TOXODON* DEL PLEISTOCENO SUPERIOR DE LA LOCALIDAD TAMANDUÁ DE CIMA, MUNICIPALIDAD DE SÃO BENTO DO UNA, ESTADO DE PERNAMBUCO, NORTHESTE DE BRASIL

### Resumen

Los toxodóntidos eran megamamíferos con numerosos registros fósiles en el Pleistoceno tardío del noreste de Brasil. Sin embargo, un análisis de la literatura actual muestra que no hay consenso en la taxonomía de los géneros *Toxodon*, *Trigodonops* y *Piauhitherium*. Este trabajo tiene como objetivo caracterizar taxonómicamente dos cráneos incompletos recolectados recientemente en el sitio de Tamanduá de Cima. DGEO-CTG-

UFPE 8530 es el más completo y su identificación se realizó mediante comparación con otros materiales en importantes colecciones fósiles de Brasil. Se realizó la descripción de los especímenes fósiles y todo el material atribuido a *Toxodon platensis* Owen, 1837. El registro de *Toxodon platensis* en el sitio de Tamanduá de Cima, representado por los fósiles aquí registrados, así como por probables rastros de fósiles (huellas), indica que estos animales también se han asociado en el noreste de Brasil con cursos de agua con vegetación de ribera.

**Palabras-clave:** *Toxodon platensis*; Taxonomía; Megafauna.

## 1. INTRODUCTION

Northeast Brazil has numerous fossil records of the Pleistocene megafauna, collected in several types of deposits, such as lagoons, tanks, rock shelters, caves, and more recently, fluvial systems (PAULA COUTO, 1954; PAULA COUTO, 1959; ROLIM, 1971; ROLIM, 1974; SILVA et al., 2010; OLIVEIRA et al., 2019). However, many materials collected need a more accurate taxonomic determination, especially fossils collected in the State of Pernambuco.

In this paper, fossils of toxodontid mammals are studied, a group of extinct native South American herbivorous ungulates that inhabited practically the entire American continent (CARTELLE, 1994; BOND et al., 1995).

The genus *Toxodon* Owen, 1837 was the last representative of the group in the Pleistocene, with a wide fossil record in northeastern Brazil. In these region, three species of Toxodontidae are registered, including *Piauhitherium capivarae* Guérin & Faure, 2013, *Toxodon platensis* Owen, 1837 and *Trigodonops lopesi* Kraglievich, 1931.

In Pernambuco, the regions of São Bento do Una and Pesqueira are the ones with the highest number of specimens collected, all identified as *Toxodon* sp. Only Mendonça & Alvarenga (2007) made a detailed description of toxodontids, including materials collected in the Locality of São Bento do Una, Tamanduá de Cima site.

Currently, is considered that the *Toxodon* genus includes only one South American specie (*Toxodon platensis*), widely registered in the Brazilian Pleistocene (CARTELLE, 1994). In Northeastern Brazil, occurrences of toxodontidae have been recorded since the 19th century, including the state of Bahia (COPE, 1886; SOUZA CUNHA, 1979; LOBO et al., 2015), Sergipe (DANTAS et al., 2005; DANTAS & ZUCON, 2005; DANTAS, 2012), Ceará (PAULA COUTO, 1954), Rio Grande do Norte (DAMASCENO, 1973; OLIVEIRA et al., 1989), Paraíba (ROLIM, 1974; BARRETO et al., 2003), Pernambuco (PAULA COUTO, 1959; VIDAL, 1959; ROLIM, 1971; GUÉRIN et al., 1996a; SILVA et al., 2006; MENDONÇA & ALVARENGA, 2007; SILVA et al., 2010; SILVA, 2009; 2014), Piauí (GUÉRIN et al., 1990; GUÉRIN et al., 1993; GUÉRIN et al., 1996b) and Alagoas (SILVA, 2004, 2008).

Here we performed the taxonomic characterization of two incomplete skulls collected at the Tamanduá de Cima site in Pernambuco, bringing new data for their geographic distribution. Additionally, we carried out a comparative study of important materials of toxodontids deposited at FUNDHAM and MHNT,

aiming to broaden the knowledge of the taxonomy of toxodontids from the Brazilian Pleistocene.

## 2. METHODOLOGY

### 2.1. Location and Geology of the Area

Tamanduá de Cima site (Figs. 1 A-B), is located in the municipality of São Bento do Una, in the central region of the state of Pernambuco. In this site a fluvial deposit was identified, which is deposited on a sequence of metasedimentary and orthogenic rock of the Neoproterozoic (SILVA-FILHO et al., 2008; OLIVEIRA et al., 2019).

The site in question was initially prospected by a team of researchers from the Natural History Museum of Taubaté, located in the State of São Paulo, and later some specimens were studied by Mendonça (2007) and Mendonça & Alvarenga (2007). More recently, Oliveira et al. (2019) conducted a detailed study of local geology and paleontology, collecting new fossils and identifying a rare record of ichnofossils, including a possible *Toxodon* trail at the top of a thick carbonate layer. Oliveira et al. (2019) identified seven facies for the deposit, which indicate a typical river system, represented by bar and channel deposits.

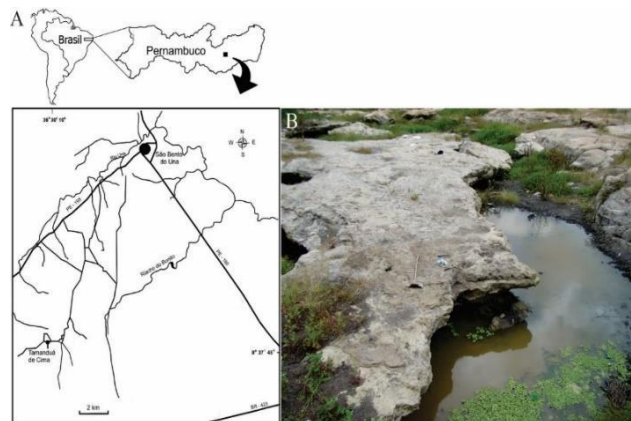


Figure 1- A) Location map of the study area, the municipality of São Bento do Una, Pernambuco. B) Paleontological site Tamanduá de Cima showing the river carbonate deposit. Source: The authors (2021).

### 2.2. Materials

For this paper, were selected two partial toxodontid skulls, deposited in the collection of macrofossils of the Department of Geology, Center for Technology and Geosciences of UFPE, registered under the acronym DGEO-CTG-UFPE.

The methodological procedures involved morphological and morphometric comparisons performed with different taxa of Toxodontidae registered in the Quaternary of Brazil, including materials from *Toxodon platensis* from the scientific collection of the Natural History Museum of Taubaté (MHNT-VT-1143, an almost complete skull), as well as the holotype of *Trigodonops lopesi* deposited in the collection of the Department of Mineral Production of Brazil (DGM-55M) and cranial materials deposited

in the FUMDHAM collection identified as *T. platensis* (n° 186001) and the type material of "*Piauhitherium capivaræ*".

The comparisons were made from direct observation of the specimens in the paleontological collections mentioned above, as well as through images in scientific literature (for example, CARTELLE, 1992, 1994; MENDONÇA & ALVARENGA, 2007 and NASCIMENTO, 2008).

Measurements were performed with the Mitutoyo caliper 0.05 x 150 mm, digital calipers (0.02 mm), and a 600 mm (24") Starret tape measure. The photos were taken with a Canon t6i digital camera. The cranial anatomical terminology adopted follows Paula Couto (1979) and Cartelle (1992).

### 2.3. Systematic Paleontology

Ordem NOTOUNGULATA Roth, 1901  
Subordem TOXODONTIA, Owen, 1858  
Família TOXODONTIDAE Owen, 1845  
Subfamília TOXODONTINAE Owen, 1845  
Gênero *Toxodon* Owen, 1837  
*Toxodon platensis* Owen, 1837  
(Figs. 2 A-D, 3A-C)

**Material:** DGEO-CTG-UFPE 8530, caudal half of skull; DGEO-CTG-UFPE 8531, incomplete skull with occipital portion on the right side.

**Fossil Locality:** Tamanduá de Cima site, São Bento do Una, Pernambuco. Upper Pleistocene.

**Description:** DGEO-CTG-UFPE 8530 (Fig. 2 A/a, B/b, C/c, D/d e E/e) is well preserved, with no signs of compression. The specimen is fractured at the top of the frontal bone, remaining preserved the posterior part showing the right and left occipital condyles, the foramen magnum, the nuchal crest, in addition to a part of the cranial roof and the sagittal crest, along with to the parietal bones, posteriorly. The bones are fused, and the sutures are not visible, except perhaps for the sphenoid-basioccipital suture (see below), indicating that it belonged to an adult animal. In the occipital region, the posterior half of the zygomatic is observed, the basilar portion, most of the basisphenoid bone, the foramen magnum and the occipital condyles. DGEO-CTG-UFPE 8531 skull (Figs. 3A, B, and C) preserved the left occipital part, including the auditory region. Although the two skulls do not diverge morphologically, the latter has the smallest measurements, mainly from the left ear.

**Occipital view** (Figs. 2A e 2a): DGEO-CTG-UFPE 8530 has a robust and wide occipital region, showing a sub-hexagonal outline. In the dorsoventral direction, the maximum height total 32 cm, and the width (measured between the occipital condyles and the upper nuchal border) 36.10 cm. The upper portion of the skull is flattened. Between the prominent nuchal ridges, the center of the occiput becomes concave. The occipital suture is short and measures dorsoventrally 13 cm. The abaxial ridges diverge towards the occipital crest and are limited at the condylar level. The foramen magnum is circular and its transversal diameter is 4.70 cm. In the dorsoventral direction, the maximum width measurements of the occipital condyles are 6.10 cm on the right side and 6.20 cm on the left side. In DGEO-CTG-UFPE 8531

(Fig. 3A) the condyles are slightly more robust, as are the paracondylar process of exoccipital.

**Lateral view** (Figs. 2B and 2b): in DGEO-CTG-UFPE 8530 the zygomatic process is fractured, remaining only the posterior part that articulates with the bones of the temporal series. It presents itself as a tall, robust bone. The middle ear region (Figs. 2 B/b) is well preserved. The external acoustic meatus forms a vertical and long tube, enclosed by the crista meatus anteriorly, and the retrotympanic process posteriorly (Gabbert, 2004).

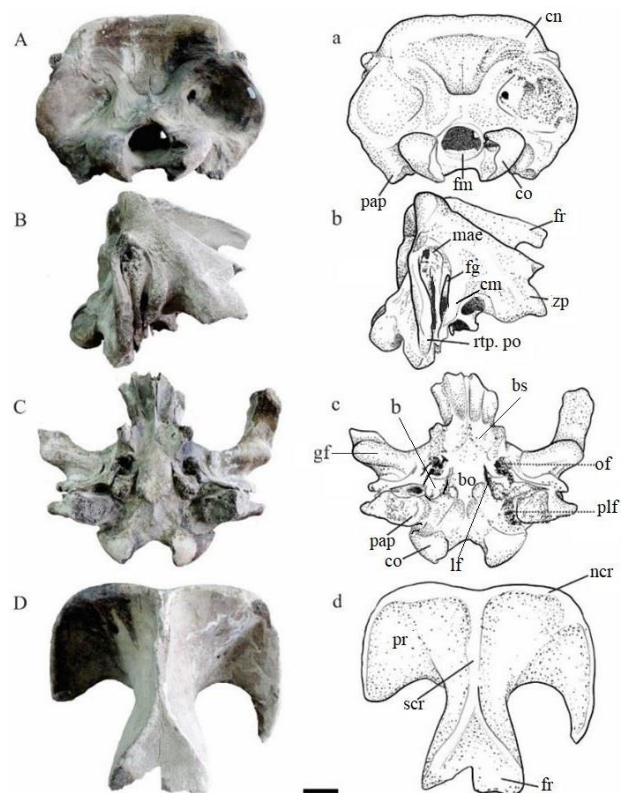


Figure 2 - *Toxodon platensis* DGEO-CTG-UFPE 8530. A/a, occipital view; B/b, right side view; C/c, ventral view; D/d, dorsal view; E/e, dorsal view. Legend: **b**, auditory bulla; **cm**, crista meatus; **bs**, basisphenoid; **bo**, basisoccipital; **co**, occipital condyle; **fg**, fissure glasseri; **fr**, frontal bone; **gf**, glenoid fossa; **lf**, lacerate foramen; **mae**, external acoustic meatus; **nrcr**, nuchal crest; **of**, foramen ovale; **rtp po**, retrotympanic process; **pap**, paracondylar process of exoccipital; **pr**, parietal bone; **plf**, posterior foramen lacerated; **scr**, sagittal crest; **zp**, zygomatic process. Scale bar: 5 cm. Source: Authors (2021).

**Ventral view, basicranium:** The middle ear region (Figs. 2 C/c) is well preserved on the right side of the skull. DGEO-CTG-UFPE 8530: between the paraoccipital processes is located the basisphenoid, in the middle of the bone. Anteroposteriorly, the basilar portion is concave and diverges in "V". The structure of the basisphenoid bone is very robust and tapers posteriorly, forming a short and sharp crest. The occipital condyles are strong, and salient distally. DGEO-CTG-UFPE 8531 also



presents the basisphenoid also tapering anteriorly. The glenoid fossa in the ventral squamosal region is located anterior to the tympanic bulla. The fossa is poorly excavated and expanded laterally. The sphenoid-basioccipital suture is located well anterior to the tympanic bulla.

**Dorsal view** (Figs. 2D and 2d): DGEO-CTG-UFPE 8530 skull is broad at the back and tapered in the anterior face. The sagittal crest measured in the median portion is 1.80 cm wide, ending at a point equivalent to the posterior edge of the orbit. The temporal lines are sharper and separate from the sagittal crest in two parts forming an acute angle.

### 3. RESULTS AND DISCUSSION

#### 3.1. Comparative analysis with *Toxodon platensis*

We did not find differential characters in relation to the *T. platensis* material described for Argentina by Owen (1837), a point of view also defended by Cartelle (1992, 1999). In dorsal view, in the intertropical specimens, only the sagittal crest appears to be somewhat longer with the temporal lines separating more anteriorly. The sagittal crest of DGEO-CTG-UFPE 8530 is 11.80 cm long, slightly smaller than that presented by the specimen FUMDHAM 186001, which is 12.70 cm long, indicating a smaller variation. The specimen studied here has measurements similar to those observed in *T. platensis* (MHNT-VT-1143), in which the crest measures 0.84 cm in width and 11.20 cm in length.

In occipital view, the posterior region of DGEO-CTG-UFPE 8530 is wider than it is tall, similar to specimen FUMDHAM 186001 (Fig. 3D). The occipital condyles are similar in size and shape in all specimens studied, ranging up to one centimeter in width. In both specimens from Pernambuco and Piauí, this variation is related to age development, as well as the width in the foramen magnum, which presents the same variation. In lateral view, the zygomatic process of DGEO-CTG-UFPE 8530 presents an anteroventral orientation, similar to that observed in MHNT-VT-1143 and FUMDHAM 186001 (Figs. 2B, 3E), being more robust and wider in the anterior portion. The auditory region is well preserved in DGEO-CTG-UFPE 8530, which is proportionally smaller than the other specimens analyzed.

#### 3.2. Comparison with *Trigodonops lopesi*

**Dorsal view:** the frontal bone of *Tr. lopesi* (FUMDHAM 188265) is wider (Fig. 3G), convex, with the temporal lines directed transversely, unlike *T. platensis*, which has a flat triangular frontal and with temporal lines oblique to the sagittal plane. The nuchal crest of *Tr. lopesi* is rounded, forming a semicircle that projects strongly posteriorly, as in the juvenile specimens analyzed by Cartelle, 1992 (Fig. 222). This shape is also visible, mainly in MCL 5191. The sagittal crest of DGEO-CTG UFPE 8530 is shorter and narrower, while the same crest in *Tr. lopesi* is wider, measuring 3.20 cm in the posterior portion, where the parietals meet. Mesially, the sagittal crest of *Tr. lopesi* is 1.50 cm wide and 15 cm long, while in the specimen of *T. platensis* this crest does not exceed 12 cm in length. In lateral view, the cranial roof of *T. platensis* in DGEO-CTG-UFPE 8530 (Fig. 2D) presents an almost straight and flat angle, very different

from the caudal portion of the skull of *Tr. lopesi* (FUMDHAM 188265), which has a very wide and arched nuchal crest, forming a semicircle at the top of the parietal portion. The zygomatic process (Fig. 3 I) in FUMDHAM 188265 is markedly higher in the anterior and median portion, and more inclined than in *T. platensis*.

However, the maximum width of the zygomatic process is almost the same in both species. In occipital view, *T. platensis* (DGEO-CTG-UFPE 8530), the maximum height (32 cm) is smaller than the width (36.1 cm).

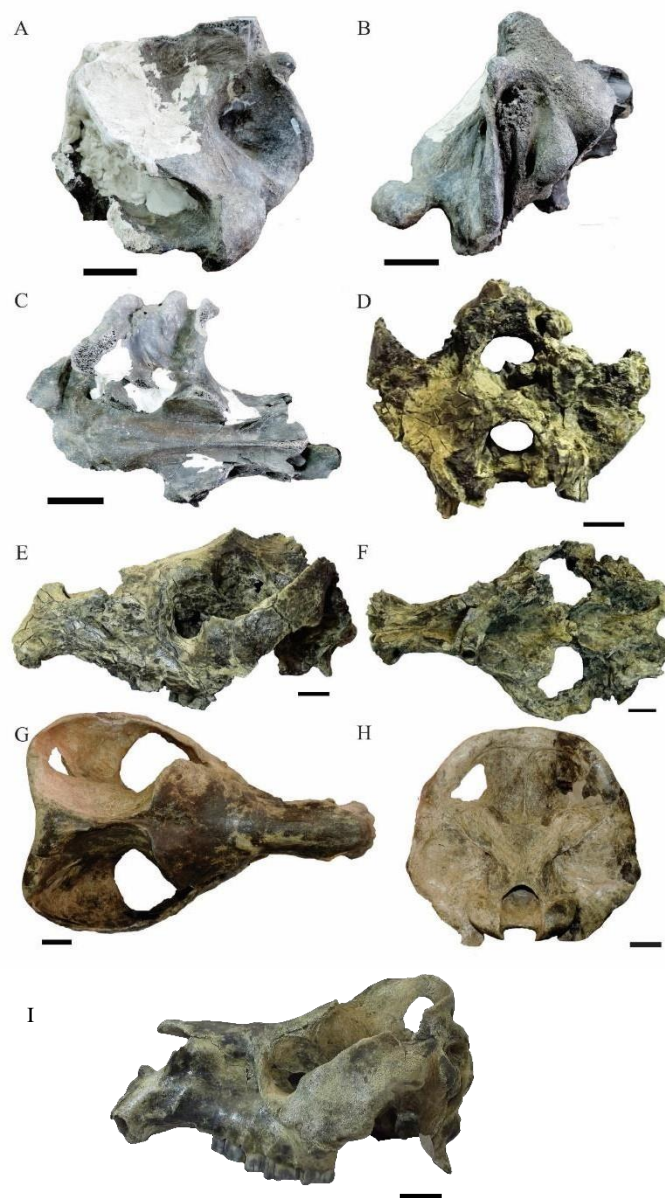


Figure 3 - A. *Toxodon platensis*. DGEO-CTG-UFPE 8531, occipital view; B, left lateral view; C, dorsal view. D, *Toxodon platensis* FUMDHAM 186001, occipital view; E, right lateral view; F, ventral view. G, *Trigodonops lopesi* (Piauihytherium)

*capivarae*) FUMDHAM 188265, dorsal view; H, occipital view, I, right lateral view. Scale: 5 cm. Source: Authors (2021).

In *Tr. lopesi* the transverse diameter of the skull is equivalent in height and length (48 cm), and its configuration is circular. Furthermore, the parietal concavity is strongly accentuated in FUMDHAM 188265 (Fig. 3H), and the external occipital bulge presents the same configuration, that is, markedly concave and rough as the parietal bone. The condylar portion in both species is very similar.

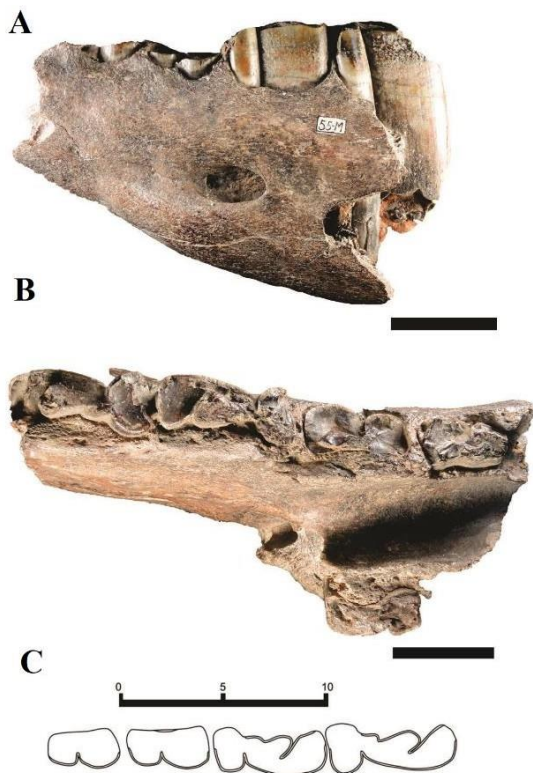


Figure 4 - Holotype of *Trigodonops lopesi* (DGM 55M), lower jaw of a juvenile specimen in lateral view (A), ventral (B) and outlines of occlusal surfaces of molar teeth p2-3 and m1-2 (C). Scale bar: 10 cm. Illustration C by Kraglievich, 1931.

### 3.3. Paleocological Considerations

The record of these new remains of *Toxodon platensis* at the Tamanduá de Cima site, where two other skulls had already been recorded (MENDONÇA, 2007; MENDONÇA & ALVARENGA, 2007) confirms the presence of this species, whose geographic distribution includes a large part of South America. The other Pleistocene toxodontid species have a more restricted geographic distribution. *Mixotoxodon laevis*, for example, was limited to northern South America, while *Trigodonops lopesi* occurred in northern and northeastern regions of Brazil.

Oliveira et al. (2019) discussed the probable paleovegetation of the Tamanduá de Cima site. The chronology of the site and isotopic data, positioned at the last glacial maximum (or at its limit), suggested the presence of a typically open vegetation as indicated by megaherbivores (e.g. *Notiomastodon platensis*), but with the presence of arboreal elements indicative of riparian vegetation. The isotopic data, taken from the carbonate cement of river sandstones, presented  $\delta^{13}\text{C}$  values between -4.73 and 0.15 ‰, with a mean of -2.83 ‰ (N = 11) and  $\delta^{18}\text{O}$  values ranging from -4 ‰ to +5.85 ‰ with an average of 0.46 ‰, suggested a floodplain physiognomy more compatible with C4 vegetation (see also DUPONT et al., 2010).

$\delta^{18}\text{O}$  values were also interpreted as expected variation for paleochannel/fluvial environments, such as springs (see OLIVEIRA et al., 2017 and OLIVEIRA et al., 2019). These data are supported by the paleoecology of *Toxodon platensis*, which has been considered as a generalist megaherbivore, with cranial and dental morphology compatible with an abrasive diet, but with seasonal/regional dietary variation or mixed-feeders (DANTAS et al., 2017). The ecological role of this species will be situated between grazing and browsing feeders, as suggested by recent studies using stable isotopes of  $\delta^{13}\text{C}$  (mean - 5.74 ± 4.80), from tooth enamel samples from Northeastern Brazil (VIANA et al., 2011; DANTAS et al., 2017). Thus, the material from *T. platensis* described here, stratigraphically associated with an assemblage of herbivorous mammals suggestive of open and arboreal environments associated with river systems, corroborate these studies.

### 4. FINAL CONSIDERATIONS

The materials described in this work representing cranial elements of *Toxodon platensis* confirm the presence of this species in the Upper Pleistocene of the State of Pernambuco.

The record of *Toxodon platensis* at the Tamanduá de Cima site, represented by the fossils described here, as well as by probable footprints, indicates that these animals were also associated with watercourses with riparian vegetation.

The associated fossil assemblage, including *Notiomastodon*, *Eremotherium*, *Glyptotherium*, *?Hippidion*, llamas, and deer suggests a Cerrado environment with arboreal elements associated with the fluvial environment.

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