Abstract: In the early 1980s, an assemblage of extinct and extant vertebrates was collected from the Abismo Ponta de Flecha, a vertical cave in southern São Paulo, Brazil, for archaeological, geological, and paleontological analyses. While materials identified as ground sloths have been referenced in earlier publications, they have never been thoroughly described. In this study, we provide the first detailed description of a large, previously unidentified taxon found in Brazil, interpreted herein as belonging to the family Nothrotheriidae. Although direct dating of the specimen was not possible, other dated occurrences from the Ribeira de Iguape Valley suggest that it may have inhabited the region during the Late Pleistocene, coinciding with the local presence of a dense forest cover.

Keywords:
- Pleistocene;
- Quaternary;
- sloths;
- Nothrotherium;
- Xenarthra


Résumé : Un nouveau cas de paresseux terrestre dans la vallée de la Ribeira de Iguape, sud-est du Brésil. Au début des années 1980, une association de vertébrés éteints et d’autres toujours existants a été récoltée dans l’Abismo Ponta de Flecha, une grotte verticale au sud de São Paulo (Brésil), en vue d’analyses archéologique, géologique et paléontologique. Bien que les matériels identifiés comme étant des paresseux terrestres aient été mentionnés dans des publications antérieures, ils n’ont jamais été décrits adéquatement. Dans cette étude, nous fournissons la première description détaillée d’un grand taxon encore non identifié, découvert au Brésil, et interprété ici comme appartenant à la famille des Nothrotheriidae. Bien qu’il n’ait pas été possible de dater directement ce spécimen, d’autres découvertes datées de la vallée de la Ribeira de Iguape suggèrent qu’il aurait pu habiter la région à la fin du Pléistocène, ce qui coincide avec la présence locale d’un couvert forestier dense.

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1. Introduction

Brazil was once inhabited by various species of extinct sloths (Xenarthra, Pilosa) that thrived in diverse environments. In the Quaternary faunas of Brazil, ten species from four different families have been identified, the latter being Megatheriidae, Mylodontidae, Megalonychidae, and Notrotheriidae (Cartelle et al., 2008, 2009, 2019). However, recent studies by Presslee et al. (2019) and Casali et al. (2022) elevated Scelidotheriidae and Megalocnidae (Caribbean ground sloths) to the family level, with the latter being reinterpreted as a superfamily (Megalocnoidea) by Del-suc et al. (2019).

The region of the Ribeira de Iguape Valley, in the southern state of São Paulo, features a system of caves developed in Precambrian carbonate rocks. Paleontological and archaeological research in this area commenced in the late 19th century, revealing that many of these caves preserve fossil remains of extinct ground sloths (Krone, 1898; Ameghino, 1907; Paula Couto, 1973). The Abismo Ponta de Flecha Cave, a complex vertical cave in the Ribeira de Iguape Valley (Fig. 1), has yielded a fossil assemblage of extinct and extant vertebrates (Chahud, 2022a; Chahud et al., 2022, 2023a, 2023b). The first mention of sloths in this cave was by Barros Barreto et al. (1984). Subsequent references to the sloth material from Abismo Ponta de Flecha Cave were primarily found in the survey conducted by Ghilardi et al. (2011), who utilized previously published data. The present contribution aims to describe a femur belonging to a large Nothrotheriidae and provide paleoecological and paleoenvironmental insights.

2. Materials and methods

The Abismo Ponta de Flecha Cave is situated in Iporanga county, southern São Paulo state, Brazil (Fig. 1). The osteological material was collected between 1981 and 1982, and comprises 1386 elements, predominantly faunal remains, although a few archaeological remains have also been gathered (Barros Barreto et al., 1984; Chahud, 2021, 2022b). The cave, whose geographic coordinates are 24° 33'38" S, 48° 41'08" W, is largely oriented 30-40° /70-80° SE in the region of Ribeira de Iguape Valley (Barros Barreto et al., 1984). The deposits were excavated from galleries, known as 'jazidas', and the position of each element collected was meticulously recorded. The subject of this study originated from Jazida 10 (110), which preserves the greatest volume of sediments and osteological materials, primarily due to intense reworking by water (Barros Barreto et al., 1984).

The material were analyzed using identified specimens from the Cuvieri Cave, curated at the Laboratory of Human Evolutionary Studies (LEEH) of the Biosciences Institute at the University of São Paulo (IB-USP). Additionally, the following references were consulted: Ameghino (1907), Krakilevich (1926), Lund (1950), Paula Couto (1954, 1979, 1980), Cartelle and Fonseca (1982), Cartelle and Bohórquez (1986), De Iulis (1994), Toledo (1998), Pujos (2001), Cartelle et al. (2008, 2009), Ghilardi et al. (2011), Brandoni and Vezzosi (2019), Vezzosi et al. (2019), McDonald (2023), Pujos et al. (2023), and Varela et al. (2023a, 2023b).

The specimen described in this study is curated at the Laboratory of Systematic Paleontology within the Department of Sedimentary and Environmental Geology at the Institute of Geosciences of the University of São Paulo. The specimen has been assigned two numbers for the current study: the first, associated with field collection, bears the prefix "PF-", and the second is designated "GP/2C-", indicating its occurrence in the collection, IGC-USP.

3. Chronology

The Abismo Ponta de Flecha Cave presents a diverse array of macrovertebrates typical of the present-day fauna, with a few specimens attributed to extinct species of the Quaternary megafauna (Chahud, 2022a, 2022b; Chahud et al., 2023b).

To date, only one such specimen has undergone dating. The initial dating, conducted by Baffa et al. (2000), employed electron spin resonance (ESR) to date a premolar of Toxodon platensis (PF-997/GP/2C-533E), resulting in an age of 6,700 ± 1,300 BP from dentine and 5,000 ± 1,600 BP from dental enamel. Later, a 14C AMS date for the same specimen produced ages of 11,380 ± 40 BP (13,150-13,770 cal BP) and 11,090 ± 40 BP (12,900-13,180 cal BP). These 14C data suggest that the specimen probably lived around the Pleistocene/Holocene boundary (Neves et al., 2007). Other dates attributed to extinct Quaternary large mammals from the Ribeira de Iguape Valley are mostly less than 20,000 years, with specimens of Catonyx cuvieri and Toxodon platensis displaying ages younger than 14,000 years (Table 1).
Table 1: Ages of specimens of the megafauna from the Ribeira de Iguape Valley (Neves et al., 2007; Husse et al., 2011, 2013). * curated in the Institute of Geosciences of the University of São Paulo, ** curated in the Museum of Zoology of the University of São Paulo.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Taxon</th>
<th>Cave name</th>
<th>Conventional age (14C yr BP)</th>
<th>2σ calibration (cal yr BP)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PF-997/GP/2C-533E*</td>
<td>Toxodon platensis</td>
<td>Abismo Ponta de Flecha</td>
<td>11,380 ± 40</td>
<td>13,150-13,770</td>
</tr>
<tr>
<td>PF-997/GP/2C-533E*</td>
<td>Toxodon platensis</td>
<td>Abismo Ponta de Flecha</td>
<td>11,090 ± 40</td>
<td>12,900-13,180</td>
</tr>
<tr>
<td>GP/2E-706*</td>
<td>Catonyx cuvieri</td>
<td>Abismo Iguatemi</td>
<td>10,800±60</td>
<td>12,860-12,580</td>
</tr>
<tr>
<td>GP/2E-716*</td>
<td>Smilodon populator</td>
<td>Abismo Iguatemi</td>
<td>14,580±90</td>
<td>18,030-17,260</td>
</tr>
<tr>
<td>MZSP-PV454**</td>
<td>Toxodon platensis</td>
<td>Abismo do Fóssil</td>
<td>11,850±70</td>
<td>13,860-13,460</td>
</tr>
<tr>
<td>MZSP-PV610**</td>
<td>Eremotherium laurillardi</td>
<td>Abismo do Fóssil</td>
<td>12,550±60</td>
<td>15,130-14,240</td>
</tr>
<tr>
<td>MZSP-PV773**</td>
<td>Indeterminate Ground Sloth</td>
<td>Abismo do Fóssil</td>
<td>15,230±70</td>
<td>18,680-18,060</td>
</tr>
<tr>
<td>MZSP-PV642**</td>
<td>Scelidotheriinae</td>
<td>Abismo do Fóssil</td>
<td>17,800±80</td>
<td>20,680-21,370</td>
</tr>
<tr>
<td>MZSP-PV660**</td>
<td>Glyptodon sp.</td>
<td>Abismo do Fóssil</td>
<td>17,800 ± 70</td>
<td>20,680-21,370</td>
</tr>
</tbody>
</table>

4. Systematic paleontology

Superorder Xenarthra Cope, 1889
Order Pilosa Flower, 1883
Family Nothrotheriidae Ameghino, 1920
Subfamily Nothrotheriinae Ameghino, 1920
Genus Nothrotherium Lydekker, 1889
Nothrotherium sp. (Fig. 2)

Material and occurrence: The specimen is represented by a left femur, PF-990/GP/2C-559 (Fig. 2), which lacks the distal part; found in Jazida 10 of Abismo Ponta de Flecha cave.

Description: The specimen exhibits a fragmentary femoral head, with incrustations and several superficial fractures (Fig. 2). The greater trochanter region is elongated, is slightly inclined downward with respect to the femoral head, and exhibits a small natural cavity on the posterior face (trochanteric fossa). The third trochanter is not prominent, and a slight curvature exists between it and the greater trochanter. Distal to the femoral head, the lesser trochanter displays evidence of abrasion. The diaphysis is elongated, straight and flat, and decreases in width towards the distal region.

Measurements of the femur, as well as those of other specimens taken from the literature, are presented in Table 2.
Figure 2: Femur of *Nothrotherium* sp. from the Abismo Ponta de Flecha Cave (PF-990/GP/2C-559). A) Anterior view, B) Posterior view, C, Ci and Cii) Lateral views, D) Proximal view. Scale bar = 100 mm.

Table 2: Measurements of proximal femora from species of Notrotheriini. Data taken from CARTELLE and FONSECA (1982), BRANDONI and VEZZOSI (2019), and VEZZOSI et al. (2019). The number of specimens used to estimate measurement is presented in parentheses.

<table>
<thead>
<tr>
<th>Specimen</th>
<th>Maximum width of proximal part</th>
<th>Diameter of femoral head</th>
<th>Minimum width of diaphysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>PF 990/GP/2C-559</td>
<td>150</td>
<td>~76.5</td>
<td>94.5</td>
</tr>
<tr>
<td><em>Nothrotherium</em> torresi</td>
<td>194</td>
<td>88</td>
<td>---</td>
</tr>
<tr>
<td><em>Nothrotherium</em> cf. torresi</td>
<td>179.81</td>
<td>89.08</td>
<td>---</td>
</tr>
<tr>
<td><em>Nothrotheriops</em> sp. MCRS 199</td>
<td>149</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td><em>Nothrotheriops</em> shastensis</td>
<td>145.6-182.1 (6)</td>
<td>77.5-86.2 (6)</td>
<td>112</td>
</tr>
<tr>
<td><em>Nothrotheriops</em> texanus</td>
<td>156.8-175.2 (9)</td>
<td>73.3-86 (10)</td>
<td>---</td>
</tr>
<tr>
<td><em>Nothrotherium</em> maquinense</td>
<td>87-105.4 (7)</td>
<td>50</td>
<td>54-55 (2)</td>
</tr>
<tr>
<td>Pronothrotherium typicum</td>
<td>146.7</td>
<td>67</td>
<td>---</td>
</tr>
<tr>
<td>Monothropus cartellei</td>
<td>131</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td><em>Nothrotheriinae</em> indet. MACN Pv 14148</td>
<td>190</td>
<td>98</td>
<td>---</td>
</tr>
<tr>
<td><em>Nothrotheriinae</em> indet. MACN Pv 14172</td>
<td>206</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td><em>Nothrotheriinae</em> indet. MACN Pv 14149</td>
<td>180</td>
<td>85</td>
<td>---</td>
</tr>
</tbody>
</table>

Discussion: The external morphology of the proximal part of the femur and the fully fused epiphysis preclude this specimen’s being from a young sloth of the Mylodontidea or Megatheriidae (CARTELLE & DE JUILLIS, 1995; CARTELLE et al., 2008, 2009). The angle formed by the greater trochanter and the femoral head differs from that observed in previously described Brazilian Megalonychidae (CARTELLE et al., 2008). When compared to the known forms of Notrotheriini (Table 2), the specimen displays a maximum proximal femoral width greater than that of *Nothrotherium maquinense* and specimens of *Nothrotheriops texanus*, being similar in size to *Nothrotheriops shastensis*, while smaller than the femora attributed to *Nothrotherium torresi* and the indeterminate *Nothrotheriinae* studied by BRANDONI and MCDONALD (2015), BRANDONI and VEZZOSI (2019), and VEZZOSI et al. (2019). Although the femoral head is fragmented, it can be inferred that it was approximately the size of that of *Nothrotheriops texanus* and much larger than that of the only Notrotheriinae ever described from the region, *Nothrotherium maquinense*.

We emphasize that the specimens of *N. maquinense* described from Brazil include subadults and young adults, with a previously reported instance of a young female with a fetus (CARTELLE, 1994; PUJOS et al., 2023). The specimen discovered at the Abismo Ponta de Flecha cave is larger than previously described representatives of *N.*
maquinense (Cartelle & Fonseca, 1982; Brandoni & Vezzosi, 2019; Vezzosi et al., 2019), and morphological differences in the proximal and medial part of the femur suggest that it represents a distinct species. While the external morphology of the specimen is indistinguishable from the femur of Nothrotherium torresi described by Kruglievich (1926), the measurements indicate that it represents a small individual. The key feature that makes this specimen similar to Kruglievich’s (1926) is the slight curvature between the lesser third trochanter and the greater trochanter. In contrast, another specimen identified as Nothrotherium cf. torresi by Vezzosi et al. (2019) displays a much more robust greater trochanter and a prominent third trochanter.

The specimens of large Nothrotheriinae and Nothrotheriops studied by Brandoni and McDonald (2015) and Brandoni and Vezzosi (2019) are considerably more robust than the Abismo Ponta de Flecha Cave specimen. Additionally, a curvature is observed between the greater trochanter and the third trochanter.

Nothrotherium torresi was described on the basis of a single femur, a practice that may be considered dubious. Therefore, we have opted to designate the specimen studied herein as belonging to Nothrotherium sp. Multiple nothrotheres, including N. torresi, have been reported from the Upper Pleistocene of Argentina based on a few bones, and McDonald (2023) suggested that many of these taxa may eventually become junior synonyms. However, the systematic content of the genus Nothrotherium needs further clarification, as several of these specimens, such as those presented by Brandoni and McDonald (2015) and Vezzosi et al. (2019), display different dimensions and morphologies, necessitating a review of the genus.

Last but not least, we emphasize that the classification of our specimen within the genus Nothrotherium is based on its anatomical similarities with those described by Kruglievich (1926), Brandoni and McDonald (2015), and Vezzosi et al. (2019). It is important to note that the specimen from the Abismo Ponta de Flecha cave, along with those found in Argentina, also bears resemblance to some ancient species of Megalonichidae (Brandoni, 2009). Therefore, the family-level assignment of these materials remains an open question, and they may represent a yet-to-be-described genus.

5. Paleoeological comments

The paleoeology of several species of extinct sloths was examined by Dantas and Santos (2022) who suggested that Nothrotherium maquinense probably had a diet very similar to that of extant sloths. Vezzosi et al. (2019) proposed that Nothrotherium torresi inhabited humid environments, and that the genus Nothrotherium tolerated a variety of environments, from cold and arid to warm and humid.

In the last 14,000 years, the region of Ribeira de Iguape Valley, where the Abismo Ponta de Flecha Cave is located, experienced very few environmental and paleoclimatic changes. It has been proposed that the modern forest was established after this period (Saia, 2006). Unfortunately, it has not been possible to date our specimen, and the absence of organized stratigraphy thwarted attempts to formulate a reliable chronological inference. Nevertheless, given (1) the presence of some megafaunal species after the proposed period of forest establishment (e.g., Catonyx cuvieri, recorded in the Ribeira Valley around the Pleistocene/Holocene boundary; Hubbe et al., 2013) and (2) the likelihood that Nothrotherium inhabited humid environments (Vezzosi et al., 2019), we cannot rule out the possibility that our specimen lived at a time when dense forest cover had already been established.

6. Conclusions

The presence of a large species of Nothrotheriinae has been observed for the first time in Brazil. Originating from the Abismo Ponta de Flecha Cave, the individual is known only from a femur and shares a similar shape with Nothrotherium torresi from Argentina. However, it differs from the latter species in its smaller size, leading us to classify it as belonging to Nothrotherium sp. We believe that the classification of this species, along with other large Nothrotheriinae, would greatly benefit from a detailed systematic revision, which should include the study of better preserved specimens. It should then be possible to confirm the validity of several species that have been described within the group of large Nothrotheriinae.

While we lack specific dates for the specimen from Abismo Ponta de Flecha Cave, it is reasonable to suggest that it inhabited the region during the Late Pleistocene, if not the Early Holocene, corresponding to a period when the modern dense forest was expanding over the Ribeira de Iguape Valley region.

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