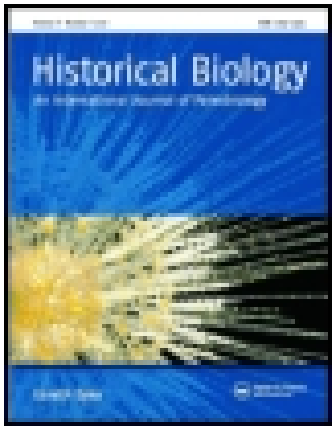

Historical Biology: An International Journal of Paleobiology

Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/ghbi20

A Quaternary very young juvenile Tapirus Brisson, 1762 (Mammalia, Perissodactyla) from a cave deposit in northern Brazil: taxonomy and taphonomy

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Published online: 29 Apr 2015.

To cite this article: Germán Mariano Gasparini, Elizete Celestino Holanda, Hermínio Ismael de Araújo-Júnior & Leonardo dos Santos Avilla (2015): A Quaternary very young juvenile Tapirus Brisson, 1762 (Mammalia, Perissodactyla) from a cave deposit in northern Brazil: taxonomy and taphonomy, Historical Biology: An International Journal of Paleobiology, DOI: 10.1080/08912963.2015.1035269

To link to this article: http://dx.doi.org/10.1080/08912963.2015.1035269

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http://dx.doi.org/10.1080/08912963.2015.1035269

A Quaternary very young juvenile *Tapirus* Brisson, 1762 (Mammalia, Perissodactyla) from a cave deposit in northern Brazil: taxonomy and taphonomy

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(*Received 11 February 2015; accepted 25 March 2015*)

During fieldworks carried out from 2009 to 2013 in Aurora do Tocantins (northern Brazil), three isolated deciduous teeth of *Tapirus* were recovered. Those fossils come from a sedimentary deposit of presumed Late Pleistocene–early Holocene age in a karstic cave. This contribution aims to present a new locality of fossil *Tapirus* from northern Brazil, describe for the first time deciduous fossil teeth for South American *Tapirus* and evaluate the taphonomic aspects of those fossils. The specimens probably belong to the same individual due to there are no repeated teeth and they have the same wear pattern. Furthermore, the crowns of those teeth show no evidence of abrasion produced by transport. However, some abrasion is observed on the borders of the pulp chamber of teeth. These polishing are probably resulting of a very short transport (parautochthonous). These specimens are the only record of Tapiridae in Gruta do Urso cave; due to correspond to isolated and deciduous teeth, its identification to species level was not possible. There is not yet clear evidence that may indicate the kind of death of the individual studied here.

Keywords: Tapiridae; Tocantins State; morphology; morphometry; age estimation; South America

1. Introduction

Fossil tapirs (Tapiridae) are known from Europe, North America, Central America, South America and South-eastern Asia, including China (e.g. Cerdeño and Ginsburg 1988; Mc Kenna and Bell 1997; Eberle 2005; Hulbert 2005; Tong 2005; Ferrero and Noriega 2007; Holanda et al. 2011; Medici 2011, Scherler et al. 2011; Holanda and Ferrero 2013). Only *Tapirus* Brisson, 1762 represents the family in South America; evidence suggests that this genus migrated to South America from North America during the Great American Biotic Interchange (GABI; David Webb 2006; Woodburne et al. 2006; GABI 2 *sensu* Woodburne 2010). The oldest reliable record of the genus *Tapirus* is from the Early Pleistocene (*ca*. 2.6–1.0 Ma) of the Pampean Region of Argentina (Tonni 1992), although there are hypotheses suggesting that tapirs entered in South America during the Late Miocene (Campbell et al. 2010).

The extant tapirs are represented by four Neotropical species – *Tapirus bairdii* (Gill, 1865); *Tapirus pinchaque* (Roulin, 1829); *Tapirus kabomani* Cozzuol, Clozato, Holanda, Rodrigues, Nienow, De Thoisy, Redondo and Santos, 2013 and *Tapirus terrestris* (Linnaeus, 1758) – and a fifth species, *Tapirus indicus* Desmarest, 1819 from the Oriental hemisphere (Nowak 1997; Cozzuol et al. 2013).

Although remains of *Tapirus* are often fragmentary and scarce compared with other mammalian migrants that took part in the GABI, the fossil record of South American tapirs has substantially increased in quantity during the last years, and now comprises material from Argentina, Brazil, Peru, Uruguay, Bolivia and Venezuela (e.g. Rusconi 1928; Hoffstetter 1963; Takai et al. 1982, 1984; Ubilla 1983, 2004; Marshall et al. 1984; Hoffstetter 1986; Marshall and Sempere 1991; Tonni 1992; Ferrero and Noriega 2003, 2007; Holanda and Cozzuol 2006; Ferrero et al. 2007, 2009; Holanda et al. 2007, 2011; Ubilla and Rinderknech 2007; Holanda and Rincón 2009; Rincón et al. 2009, 2011; Gasparini et al. 2013; Ferrero et al. 2014).

According to Holanda and Ferrero (2013), the following extinct species of tapirs are recognised for South America: *Tapirus mesopotamicus* Ferrero and Noriega, 2007; *Tapirus greslebini* Rusconi, 1934; *Tapirus rioplatensis* Cattoi, 1957; *Tapirus tarijensis* Ameghino, 1902; *Tapirus oliverasi* Ubilla, 1983; *Tapirus cristatellus* Winge, 1906 and *Tapirus rondoniensis* Holanda, Ferigolo and Ribeiro, 2011.

During fieldworks carried out from 2009 to 2013 in the municipality of Aurora do Tocantins (State of Tocantins, northern Brazil, Figure 1), we recovered some isolated deciduous teeth of *Tapirus* from a sedimentary deposit of

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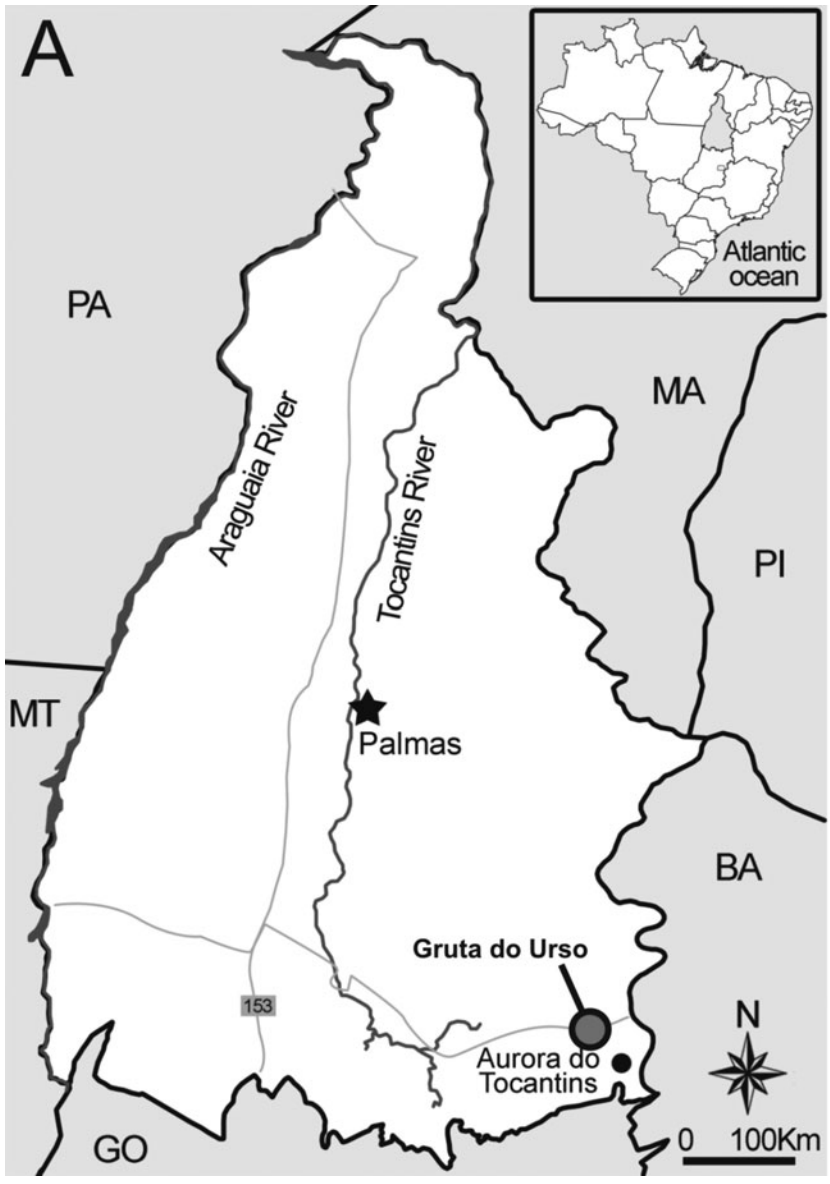

Figure 1. Location of the palaeontological site. At the right top corner, the map of Brazil showing Tocantins State in grey, and the larger map shows Tocantins State in white, emphasising the study area (12°35′0.08″S and 46°30′58.39″W).

presumed Late Pleistocene–early Holocene age in a karstic cave (see Section 3).

This contribution aims to present a new locality of fossil *Tapirus* from northern Brazil, describe for the first time deciduous fossil teeth for South American *Tapirus* and evaluate the taphonomic aspects of those fossils.

2. Materials and methods

Comparative materials used in morphometric analyses: *Tapirus terrestris*: MCP 1598; MCN 1315; MNRJ 1655, 64153, 64215, 71597; MZUSP 1598, 3232, 8482, 9600, 20032, 22421; UFMG 3142; UNIR-M 067, O83. *Tapirus webbi*: UF 1111, 11117, 26166, 26188, 26192, 26216, 27006, 211209, 211210, 211266; F: AMNH 37402.

Abbreviations: dpm3, deciduous third lower premolar; dpm4, deciduous fourth lower premolar; DPM4, deciduous fourth upper premolar.

Institutional abbreviations: F:AMNH, Frick fossil mammal collection, American Museum of Natural History, New York, USA; MCN, Museu de Ciências Naturais, Fundação Zoobotânica do Rio Grande do Sul, Porto Alegre, Brazil; MCP, Museu de Ciências of Pontiícia Universidade Católica do Rio Grande do Sul, Porto Alegre, Brazil; MNRJ, Museu Nacional do Rio de Janeiro, Rio de Janeiro, Brazil; MZUSP, Museu de Zoologia,

Universidade de São Paulo, São Paulo, Brazil; UF, Florida Museum of Natural History, Gainesville, USA; UFMG, Coleção de Mastozoologia, Universidade Federal de Minas Gerais, Belo Horizonte, Brazil; UNIR-M, Universidade Federal de Rondônia, Mastozoología, Porto Velho, Brazil; UNIRIO-PM, paleontological collection of Laboratório de Mastozoologia, Universidade Federal do Estado do Rio de Janeiro, Brazil.

Measurements were taken using Vernier callipers, with 0.01 mm accuracy; data are expressed in millimetres. Whenever possible, morphometric analyses were performed using version 2.17c of the Paleontological Statistics – PAST software (Hammer et al. 2001). All measurements were log10 transformed before analysis.

We have followed the taxonomical arrangement proposed by Holanda and Ferrero (2013) because this is the most current integrative review of the South American Tapiridae.

We could only compare the specimens studied here to *Tapirus terrestris* because all South American fossil species do not have deciduous teeth preserved and also there are no morphological differences in deciduous dentition among the other extant species, except in the DPM1–2 (Simpson 1945; Holanda et al. 2011).

The following taphonomic aspects were evaluated: abrasion, bone representativeness and sorting. Such aspects were identified and interpreted according to Shipman (1981), Behrensmeyer (1991), Lyman (1994) and Holz and Simões (2002). The terms autochthonous, parautochthonous and allochthonous are according to the definitions of Behrensmeyer and Hook (1992): autochthonous, a non-transported fossil assemblage; parautochthonous, a transported fossil assemblage, but preserved within its habitat area and allochthonous, fossil assemblage transported and preserved outside its habitat area.

3. Location, geological setting and age

The fossils described here were collected in 2009 and 2013 from the Gruta do Urso limestone cave in the municipality of Aurora do Tocantins (12°35′0.08″S and 46°30′58.39″W), State of Tocantins, northern Brazil (Figure 1). The geological context of the study area is still poorly understood. Online notes of Companhia de Pesquisa de Recursos Minerais (2006) on the geology of this municipality report carbonate and terrigenous deposits of the Bambuí Group, which is Neoproterozoic in age. In order to recognise stratigraphic aspects, a controlled excavation in the cave was conducted and three levels were recognised. A superficial carbonated layer cemented the top of the cave deposit, and this limited the top of the fossil bearing layer. This fossiliferous level has a thickness of around 180–220 mm, and it is composed of laminated reddish-grey loess-like sediments of granulometry from very thin to thin. The bottom of the fossil bed is limited by a non-fossiliferous yellowish layer with thicker granulometry.

Although there is no absolute dating for the fossils described here, their age can be discussed based on dates from the bottom and top of the fossiliferous level and also by the faunistic assemblage found associated at that same level. Nevertheless, fossils of *Panthera onca* (Linnaeus, 1758) found at the bottom and *Morenelaphus* Carette, 1922 from the top of the fossiliferous level gave dates of around 22,000 and 3800 electron spin resonance years BP, respectively (Pegô et al., in prep.; Rodrigues et al. 2014). In addition, the *Tapirus* fossils from Gruta do Urso cave were found in association with the armadillo *Propraopus sulcatus* (Lund, 1842), which is restricted to the Early Pleistocene–Late Pleistocene (Castro et al. 2013) and, also to the equid *Equus* (*Amerhippus*) *neogeus* Lund, 1840, which is a fossil guide for the Lujanian (Late Pleistocene–early Holocene; Cione and Tonni 1999, 2005). Meanwhile, the Tapiridae fossils here studied can be attributed to the Late Pleistocene-early Holocene.

4. Systematic palaeontology

Class **Mammalia** Linnaeus, 1758

Order **Perissodactyla** Owen, 1848

Family **Tapiridae** Burnett, 1830

Genus *Tapirus* Brisson, 1762

Tapirus sp

4.1 Chronological and geographic distribution in South America

Currently, it is found from Rio Grande do Sul, Brazil, and the Gran Chaco of Argentina and Paraguay, until the west of the Andes, from the northern portion of Colombia to the Gulf of Guayaquil in Ecuador (Brooks et al. 1997). However, in the Late Pleistocene, it is recorded until Uruguay (Ubilla 1996) and the Province of Entre Ríos, Argentina (Tonni 1992; Ferrero et al. 2007), about 32°S (Arroyo Perucho Verna paleontological site, Colón Department; Figure 2).

The oldest assured record of the genus *Tapirus* in South America is from the Early Pleistocene of Argentina (Tonni 1992).

4.2 Studied material

Isolated teeth: DPM4 left (UNIRIO-PM 1340), dpm3 right (UNIRIO-PM 1342) and dpm4 right (UNIRIO-PM 1341), all deciduous teeth (Figure 3).

4.3 Geographical and stratigraphical provenance

The fossil material comes from the Gruta do Urso cave, State of Tocantins, Brazil (Figure 1). Age: Late Pleistocene/early Holocene.

Figure 2. Geographical distribution of fossil species of the genus *Tapirus* for the Quaternary of South America. Distribution of extant *Tapirus.*

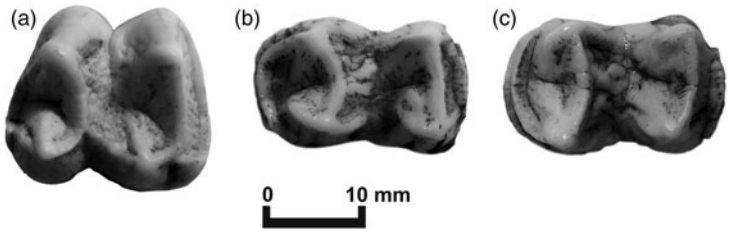

Figure 3. Occlusal view of studied material. (a) DPM4 left (UNIRIO-PM 1340), (b) dpm3 right (UNIRIO-PM 1342) and (c) dpm4 right (UNIRIO-PM 1341). Scale bar = 10 mm.

4.4 Description

The crown morphology of the material herein studied is lophodont and the crown height is taller than a typical brachyodont.

DPM4 (*UNIRIO-PM 1340*): The outline of this tooth is quadrangular in occlusal view (Figure 3(a)). This tooth has a strong parastyle developed; parastyle height is more than 50% of paracone height, but the parastyle is smaller than paracone. The parastyle is separated from the paracone by a buccal ridge. The protocone and hypocone are widely separated, but the paracone and metacone are united forming a pronounced longitudinal crest (ectoloph). The protoloph is wider than the metaloph; they are separated lingually by a transverse groove, and both are oriented transversely. The mesial and distal cingula are well developed; the labial one on the posterior half and lingual cingulum are absent.

dpm3 (*UNIRIO-PM 1342*): The outline of this deciduous tooth is rectangular in occlusal view (Figure 3 (b)). The protolophid and hypolophid are approximately equal in height and are well separated each other. Mesial and distal cingula are well developed, but no labial or lingual cingulids are present.

dpm4 (*UNIRIO-PM 1341*): The outline of this deciduous tooth is rectangular in occlusal view (Figure 3 (c)). The protolophid and hypolophid are approximately equal in height and are well separated each other. Mesial and distal cingula are well developed, but no labial or lingual cingulids are present. Both dpm3 and dpm4 lacking accessory cuspids and metastylids.

Measurements: DPM4: length 21.46 mm × width 19.29 mm; dpm3: length 22.54 mm × width 14.93 mm; dpm4: length 23.43 mm × width 14.81 mm.

4.5 Remarks: age estimation

All teeth recovered from Gruta do Urso cave are deciduous premolars. A detailed analysis of crown enamel of those *Tapirus* sp. teeth in a stereomicroscope shows that all have no wear. Hulbert et al. (2009) proposed an age group classification for *Tapirus* based on gross dental wear, and accordingly, all fossils recovered from Gruta do Urso cave representing very young juveniles. Moreover, dental wear keys developed by Maffei (2003) and Hitchins (1978) were used to attribute 'calendar' ages to individuals of *Tapirus polkensis* (a North American fossil tapir) that exhibit similar amounts of wear. Therefore, all *Tapirus* fossils studied here are classified in group 0 (zero), deciduous premolars with little to no wear. Furthermore, Gibson (2011) combined the age group of Hulbert et al. (2009), the 'calendar' age of Maffei (2003) and Hitchins (1978) and direct analysis of *Tapirus bairdii* (the extant Central American Tapir) specimens in US zoos, and proposed a dental wear key for placing tapirs into rough age groups. Based on that, the *Tapirus* specimens from Gruta do Urso cave were under 1 year old when they died. Furthermore, the absence of dental wear on the specimens suggests that the individual died around a few days from its birth because around 10 days the calf actively follows the mother through the forest (Wilson and Mittermeier 2011) experiencing solid foods (abrasive) other than milk. Thus, we consider the *Tapirus* fossils recovered from Gruta do Urso cave as belonging to a very young individual.

4.6 Taphonomy

The three specimens were found isolated, but they were found very close to each other. Furthermore, as there are no repeated teeth, the value of minimum number of individuals is one, and the three specimens have the same wear pattern (no wear). For all those reasons, we assume that the three specimens belong to the same individual.

The crowns of the teeth show no evidence of abrasion produced by transport or trampling. However, some abrasion is observed on the borders of the pulp chamber of teeth. These polishing can indicate a very short-distance transport of the specimens towards the cave, allowing the classification of the assemblage as parautochthonous (sensu Behrensmeyer and Hook 1992).

During the last 5 years, a great amount of mammalian fossils has been recovered from Gruta do Urso cave. Several mammalian groups were already identified in this assemblage (Avilla et al. 2013; Castro et al. 2013; Rodriguez et al. 2013; Rodrigues et al. 2014); however, the three isolated teeth presented here are the only record of

tapirs. This intriguing representation of specimens can be associated to a sorting towards the more resistant specimens (teeth) face to destructive taphonomic processes, such as transport and weathering (Lyman 1994). Furthermore, if our estimative of age of the individual is correct, a very young animal would have most of its skeleton very fragile with lots of non-fused bones and cartilage components. In consequence, even if there was a very-short transport, most of the very young tapir carcass can have been destroyed before its deposition in the Gruta do Urso cave; otherwise we would find other cranial and post-cranial elements inside the cave.

According to Wilson and Mittermeier (2011), mortality in tapirs may be heavy during the first year of life due to predation. However, starvation or diseases can also be erected as causes of death of young individuals (Holz and Simões 2002). The assignment to the type of death could be made if post-cranial specimens of *Tapirus* had been found in Gruta do Urso cave because evidence of predation, disease or starvation is often observed in post-cranial bones. Thus, only new findings including post-cranial elements of *Tapirus* in Gruta do Urso cave will allow an assignment for the type of death more decisively.

4.7 Morphology and morphometry

Recently, studies have supported the high degree of morphological resemblance of the teeth of different species of *Tapirus* from South America (Perini et al. 2011; Holanda and Ferrero 2013; Ferrero et al. 2014). This morphological homogeneity has posed considerable problems for the definition of diagnostic characters, and thus also the assignment of fossil specimens to any particular species. On the other hand, tooth size differences have been used to distinguish between fossil species similar in size to *Tapirus terrestris* and larger than *Tapirus terrestris*, like *Tapirus tarijensis*, *Tapirus greslebini*, *Tapirus oliverasi*, *Tapirus rioplatensis* and, in some cases, *Tapirus cristatellus* (Holanda and Ferrero 2013; Ferrero et al. 2014).

The species *Tapirus mesopotamicus* and *Tapirus rondoniensis* were established based on cranial and upper teeth characters. Despite *Tapirus oliverasi* has been described based on a fragmented dentary, this species has larger size and robustness than *Tapirus terrestris* (Holanda and Ferrero 2013). In addition, *Tapirus cristatellus* was founded based on cranial characters, but taking into account its size, it is revealed an overlapping in some dimensions with *Tapirus terrestris*, but also it is larger than *Tapirus terrestris* in other measurements (Holanda et al. 2012; Holanda and Rincón 2012).

The specimens of Gruta do Urso cave share the common deciduous teeth characters with *Tapirus terrestris* (Simpson, 1945). However, differences in deciduous teeth to the other South American fossil species are unknown, except for the dpm2 from *Tapirus tarijensis* (Ferrero et al. 2014). Regarding the size, the measurements of Gruta do Urso cave specimens were compared with *Tapirus terrrestris* and *Tapirus webbi* (large North American fossil tapir). The results were controversial. The principal component analyses of dpm3 and dpm4 measurements (Figure 4(a)) show a distinction between *Tapirus terrestris* and *Tapirus webbi* and also a slight overlap along PC2. UNIRIO-PM 1342 and UNIRIO-PM 1341 fell within the larger size range of *Tapirus webbi* in this case. However, the length and width ratio of UNIRIO-PM 1340 (Figure 4 (b)) showed the width of DMP4 is less than *Tapirus terrestris* and *Tapirus webbi*, and the length of DPM4 is within size range of *Tapirus terrestris*. Because the ontogenetic and taphonomic analysis suggest that the teeth belong to the same individual, this variation in size do not

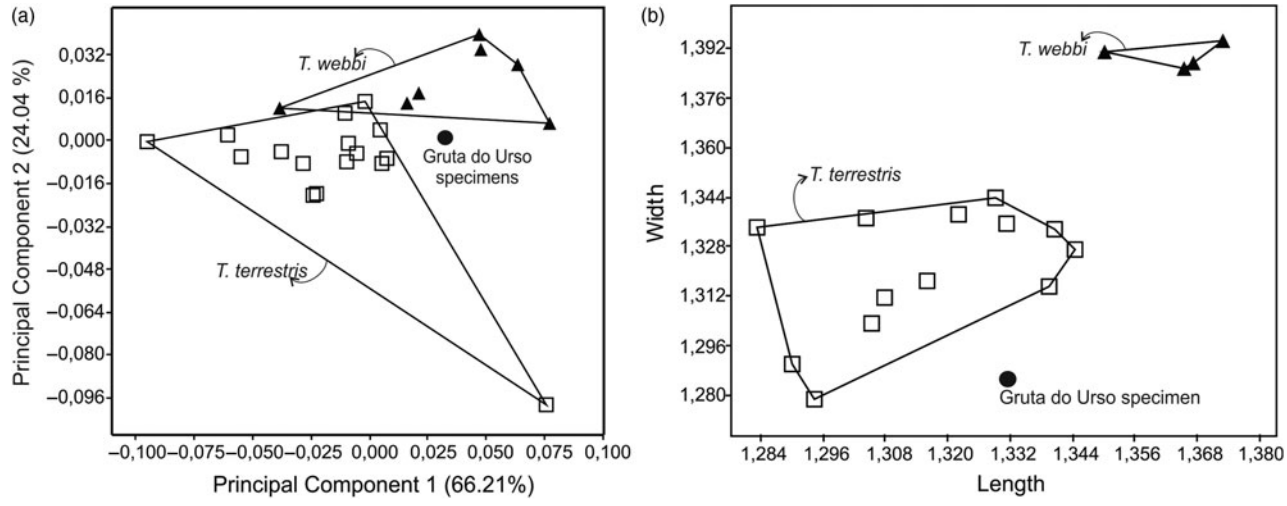

Figure 4. Morphometric analysis. (a) Scatter plot of the first two principal component scores arising from the PCA of de dpm3 and dpm4 measurements and (b) Scatter plot of the width and length of DPM4. Percentage (%) of variation explained.

allow us to assign them to a particular species. Perini et al. (2011) verified that size and proportions of lower molars are insufficient parameters to describe and identify fossil species of *Tapirus*. For those deciduous teeth from Gruta do Urso cave, the sample size also did not allow us to make a statistically significant analysis.

5. Conclusion

The three specimens belonging to the same individual of *Tapirus* sp. are described for Gruta do Urso cave fossil assemblage. Some minor evidence of abrasion was observed on the borders of the pulp chamber of teeth, allowing us to infer that the specimens were transported through a short distance and, therefore, represent parautochthonous elements.

These specimens are the only record of Tapiridae in Gruta do Urso cave; due to correspond to isolated and deciduous teeth, its identification to species level is not possible. If our estimative of age of the individual represented by the three deciduous teeth is correct, a very young animal would have most of its skeleton very fragile with lots of non-fused bones and cartilage components. In consequence, even if there was a very short transport, most of the very young tapir carcass should be destroyed before its deposition in the Gruta do Urso cave. Only new findings including post-cranial elements of *Tapirus* in Gruta do Urso cave will allow an assignment of the type of death more decisively.

Acknowledgements

The authors thank Alejandro G. Kramarz (MACN), C. Cartelle (PUC-Minas), I. Olivares (MLP) for access to material under their care. We extend our acknowledgements to W. de Moura and the Municipality of Aurora do Tocantins for supporting logistically all the fieldtrips. Anonymous referees and Editor (G. Dyke) helped to improve the manuscript.

Disclosure statement

No potential conflict of interest was reported by the authors.

Funding

The field trips, which resulted in the collection of the specimen, were made possible by the financial support of the Universidade Federal do Estado do Rio de Janeiro (UNIRIO), Conselho Nacional de Desenvolvimento Científico e Tecnológico [grant number 401812/2010-3] (Edital MCT/CNPq no. 32/2010 – Fortalecimento da Paleontologia Nacional/Edital 32/2010) and the UNIRIO. Also, this study was partially funded by the Fundação Carlos Chagas de Amparo à Pesquisa do Estado do Rio de Janeiro and Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq), Brazil, and by the Consejo Nacional de Investigaciones Científicas y Técnicas and the PICT 2010-0804.

Notes

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