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## QUATERNARY MAMMALS FROM SERRA DA BODOQUENA, MATO GROSSO DO SUL, BRAZIL <sup>1</sup>

(With 1 figure)

LEANDRO O. SALLES <sup>2,3</sup>  
CASTOR CARTELLE <sup>4</sup>  
PATRÍCIA G. GUEDES <sup>2,5</sup>  
PAULO C. BOGGIANI <sup>6</sup>  
ANWAR JANOO <sup>7</sup>  
CLAUDIA A. M. RUSSO <sup>7</sup>

**ABSTRACT:** This study is the first report on the mammalian fauna of the Quaternary of Serra da Bodoquena section, Mato Grosso do Sul, Brazil. We investigated three limestone caves for the occurrence of fossils: Nossa Senhora Aparecida, Japonês, and Nascente do Formoso, the two latter being underwater caves. For underwater caving, we developed an airlift system in order to collect small fossil fragments. We also attempted to retrieve specimens of the recent mammalian fauna. We recovered about 1650 fragments from the caves, and identified 74 species for the region (of which 34 are fossils). The paleontological results suggest that the Bodoquena region was probably characterized by an open savannah vegetation habitat rich in water patches.

**Key words:** Mammalian fauna, Quaternary, Serra da Bodoquena, Central Brazil.

**RESUMO:** Mamíferos do Quaternário da Serra da Bodoquena, Mato Grosso do Sul, Brasil. Este estudo é o primeiro relatório da fauna de mamíferos do Quaternário da região da Serra da Bodoquena, Mato Grosso do Sul, Brasil. Foram investigadas sob o ponto de vista paleontológico três cavernas calcárias: Nossa Senhora Aparecida, Japonês e Nascente do Formoso, sendo as duas últimas alagadas. Para a exploração das cavernas submersas foi desenvolvido um sistema de *airlift* para a recuperação de fragmentos fósseis de pequenas dimensões. Juntamente com as coletas dos fósseis foram realizadas coletas de mamíferos viventes. Como resultados das três expedições, foram coletados cerca de 1650 fragmentos fósseis de mamíferos e identificadas 74 espécies na região, das quais 34 são fósseis. Os resultados paleontológicos sugerem que provavelmente o final do Quaternário da Bodoquena foi

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<sup>2</sup> Museu Nacional/UFRJ, Departamento de Vertebrados. Quinta da Boa Vista, São Cristóvão, 20940-040, Rio de Janeiro, RJ, Brasil.

<sup>3</sup> E-mail: losalles@mn.ufrj.br.

<sup>4</sup> Museu de Paleontologia, Pontifícia Universidade Católica-MG. Rua Dom José Gaspar, 290, 30535-610, Belo Horizonte, MG, Brasil

<sup>5</sup> Bolsista do Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq).

<sup>6</sup> Museu de Zoologia, Universidade de São Paulo. Av. Nazaré, 481, Ipiranga, 04263-000, São Paulo, SP, Brasil.

<sup>7</sup> Universidade Federal do Rio de Janeiro/IB, Departamento de Genética. Av. Brigadeiro Trompowski, s/n, Ilha do Fundão, Rio de Janeiro, RJ, Brasil.

caracterizado por um habitat de vegetação aberta do tipo savana, rico em alagados.  
Palavras-chave: Fauna de mamíferos, Quaternário, Serra da Bodoquena, Brasil Central.

## INTRODUCTION

In attempt to contribute to a better understanding of the paleoenvironmental changes during the Quaternary of Central Brazil, a series of paleontological expeditions were organized to the Serra da Bodoquena, Mato Grosso do Sul, during the last four years. The aim was to recover the first records on the biodiversity of vertebrates from the Quaternary of the Bodoquena, the focus being on the mammalian fauna. For this, we have undertaken explorations in three limestone caves, the Nossa Senhora Aparecida, the Japonês, and the Nascente do Formoso – the two latter being underwater caves. In addition, with the intent to compare prehistoric and recent faunas, we have made collections of small terrestrial and flying mammals living in and near the caves.

Knowledge of the diversity of the vertebrates from the Quaternary of South America refers mainly to the mammalian fauna, which was subjected to large adaptive radiations during the Mid-Late Cenozoic extending to the Holocene (REIG, 1984; MARSHALL, 1985; CARTELLE, 1999). Although the elements of the megafauna received a lot of attention, the fossil records are marked by an abundance of small mammals, which are extremely important as indicators of the climatic changes in virtue of the refined and ecological interactions with their respective habitats (AVERY, 1982; KORTH, 1979).

Concerning the paleontological resources of the Brazilian caves, especially regarding the small mammalian fauna, only few explorations have brought to light their great potential. Caves frequently act as sites for the accumulation of carried material, as natural traps or furthermore as shelters for predators such as owls, which regurgitate pellets of undigested material rich in bony elements (ANDREWS, 1990). As regards the underwater cave explorations for paleontological material in Central Brazil, such attempts were formerly unrecorded until the work of SALLES *et al.* (2001).

On the dry caves of Brazil, besides the pioneering studies of LUND (1838, 1841), later extended by WINGE (1887, 1839a, 1839b), are those of VOSS & MYERS (1991) on the muroid rodents of Lagoa Santa (Minas Gerais); of CZAPLEWSKI & CARTELLE (1998) on the Chiroptera from the Quaternary of Bahia; and of SALLES *et al.* (1999) on the mammals from the Quaternary of Serra da Mesa (Goiás).

## GEOLOGICAL CONSIDERATIONS OF THE SERRA DA BODOQUENA

The Serra da Bodoquena (19°48'-22°16'S; 56°32'-57°24'W) is situated in the southwest part of the State of Mato Grosso do Sul, harbouring the municipalities of Jardim, Bonito and Bodoquena (Fig.1). In addition to its being part of the phytogeographic domain of the Cerrado, the region presents a definite influence from the adjacent biomes of the Atlantic Forest, the Pantanal, and the Chaco (see <http://www.ibama.gov.br>). The whole region has been considered as a priority area for biodiversity conservation through the MINISTÉRIO DO MEIO AMBIENTE (1999) (Ministry of Environment of Brazil), resulting in the foundation of the National Park of the Serra da Bodoquena in September 2000.

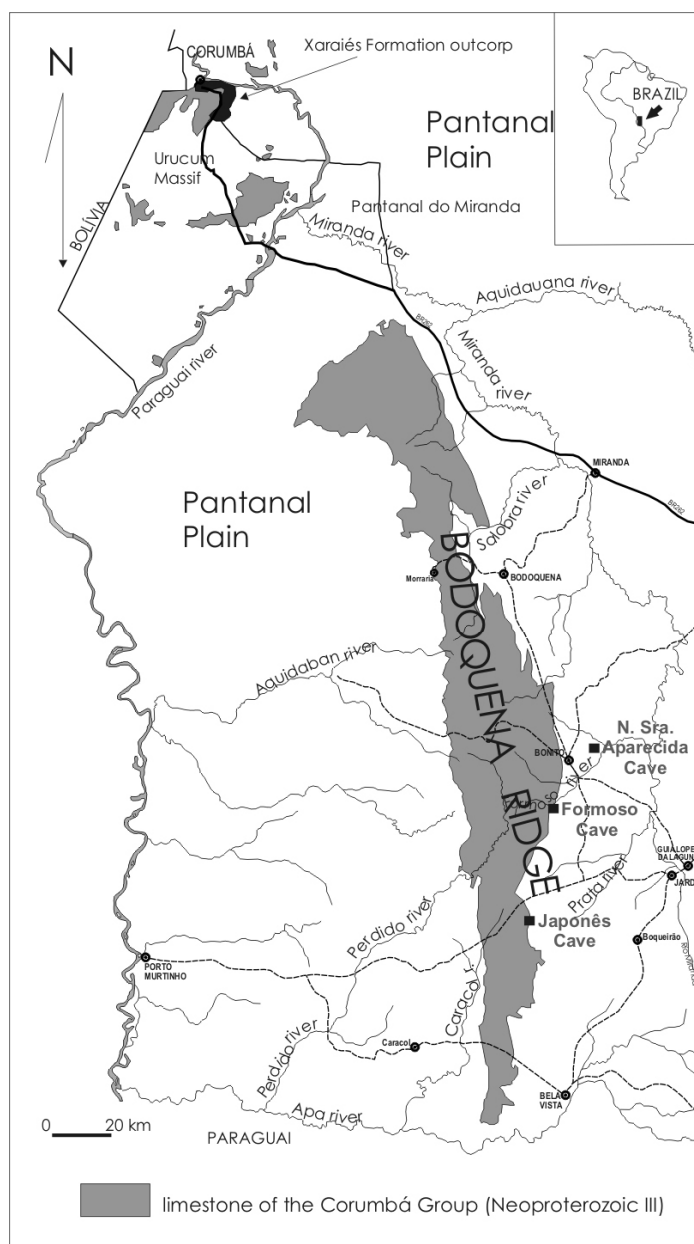


Fig.1- Map of the Serra da Bodoquena region, Mato Grosso do Sul, Central Brazil, indicating the location of the three fossiliferous limestone caves explored for fossils: Nossa Senhora Aparecida, Japonês, and Nascente do Formoso.

The Bodoquena region is in the hydrographic basin of the Paraguai River, in the sub-basin of the Miranda and Aquidauana rivers, and is carved by the rivers Peixe, Miranda, Formoso, Formosinho, Perdido, and Sucuri. These rivers developed on very pure calcareous terrain, with the total absence of agents creating turbidity of the water, thus constituting rivers with extremely clear waters (BOGGIANI *et al.*, 1999).

BOGGIANI *et al.* (1999) described the Serra da Bodoquena as a high plateau, which is steep in the West in the direction of the Plain of the Pantanal, and is gently inclined to the East, where it has a transition to the inundation plain of the Miranda River. This high plateau presents a ridge of about 300Km in length in the North-South direction with a varying width of 20 to 50km, consisting of calcareous rocks of the Corumbá Group (Neoproterozoic III). The central portion of this plateau is characterized by an elevated rocky mass where the predominantly exposed rocks are the calcites of the Tamengo Formation (Neoproterozoic III). This rock massif has an altitude varying from 450 to 650m, with very poor soil.

The limestone rocks occur in the plateau of the Bodoquena, the Urucum Massif and along the plains of the Miranda River in the Pantanal (BOGGIANI *et al.*, 1999). In these regions, deposition occurred in three distinct units: the Xaraíes Formation, the Calcareous Tuffs of the Serra da Bodoquena, and the Lenticular Calcareous rocks of the Pantanal do Rio Miranda (BOGGIANI & COIMBRA, 1995).

Meanwhile, relative to the Quaternary period, few studies have been made in this area, namely the restricted studies of ALMEIDA (1965) and the chartered speleological studies of MENDES (1957), LINO *et al.* (1984), BOGGIANI, ATENCIO & KARMANN (1986), GNASPINI, TRAJANO & SÁNCHEZ (1994), and AYUB *et al.* (1996). There are hundreds of caves in the Serra da Bodoquena karst, but no more than fifty were described and mapped (LINO *et al.*, 1984; GNASPINI, TRAJANO & SÁNCHEZ, 1994; AYUB *et al.*, 1996). Nossa Senhora Aparecida Cave is situated in the Municipality of Bonito, and has as reference point the Lago Azul Cave (21°08'224"S, 56°35'165"W). Japonês Cave (21°35'632"S, 56°39'594"W) is located in the Municipality of Bela Vista and consists of a submerged channel of crystalline waters reaching a maximal depth of 67m running for a minimal distance of 330m. The fossil material was found at a maximum depth of 43m, at a distance of 220m from the entrance of the cave. Nascente do Formoso Cave (21°15'35"S, 56°38'26"W) is located in the Formoso River spring area (Municipality of Bonito), and is also a flooded cave. Numerous fossils typical of the Quaternary of South America are encountered in the clayey sedimentary layers associated with these caves, as listed below.

#### MATERIAL AND METHODS

The classifications of WILSON & REEDER (1993) and MCKENNA & BELL (1997) were used respectively for the taxonomy of living and fossil mammals. All the collected material is currently deposited in the Mammal Collection of the Museu Nacional/UFRJ (Rio de Janeiro). Identification of the fossil fragments was done through comparative

studies based on the collections deposited in the Museu Nacional/UFRJ (Rio de Janeiro) and Museu de Ciências Naturais of the Pontifícia Universidade Católica de Minas Gerais, Belo Horizonte (Minas Gerais).

#### COLLECTING LIVE MAMMALS

The recent mammal fauna of the Bodoquena region and its vicinity is known by some isolated and scanty data. Various methods appropriate to each group were used to collect recent mammals. Here follows an outline for the collecting procedures, the details of which will be explored in future publications.

Flying mammals - Chiroptera: we used mist-nets at ground level in sites that are representative of the diverse landscapes of the region and at the entrance of caves, constituting a capture effort of approximately 11,875 sq.m. per hour encompassing about 15 days of work. After exposure to inhalation of sulphurous ether the specimens were assessed biometrically and preserved in fluid after fixation in 10% formalin for 24 hours before final conservation in 70% alcohol.

Small terrestrial mammals - marsupials and rodents: we used Tomahawk and Sherman traps disposed in different alignments mostly at ground level and in trees at a height of about 3m above ground. As bait, we used various vegetable or industrial products, amounting to a capture force up to 2,000 traps.nights (referred to approximately 20 days of work). The collected animals were killed by inhalation of sulphurous ether and either prepared as skins and skeletons or in fluid conditions. We registered the biometric data that seemed pertinent for each animal and the viscera were fixed for preservation.

No methodology for sampling was implemented for medium to large mammals. The cataloguing was done through gathering of carcasses during the trips and excursions and direct observations and indirect evidences such as footprints and faeces in the field.

We retrieved tissue samples mainly from the digestive tract for further morphological and molecular studies, and material for cytogenetic and parasitological studies.

#### DRY CAVE EXPLORATIONS

The paleontological studies in Nossa Senhora Aparecida cave were primarily focused on the small mammal faunal remains which probably originated from owl pellets. An area of about 4m<sup>2</sup> of the cave was selected where the fossil material could have accumulated by deposition *in situ* by predators or carried there by water, aiming thus for a maximal possibility of fossil occurrence. This area was then divided into quadrats of 1m<sup>2</sup> for the excavation.

The investigation is in agreement with the excavation protocol: primarily by taking samples from the superficial layer, and subsequent sampling up to a depth of 25cm so as to ensure a proper stratigraphic screening of the selected area. The separation of material is done by successive screen-washing using a system of sieves with different mesh sizes: 10.0mm, 5.0mm, and 2.5mm. The evident bone

material was separated during the washing and the remaining sediment was dried up in the field and then saved for later refined sorting in the lab.

#### UNDERWATER CAVES EXPLORATION

Regarding the submerged caves of Japonês and Nascente do Formoso, there is no speleological evidence yet indicating that they were dry for any long period due to phreatic level changes. Given that these caves present adverse diving conditions, modern human impact is presumed to be virtually absent, thus giving a great opportunity for paleontological and taphonomical studies. Sophisticated techniques were required in order to collect fossil material under those conditions.

For the sampling of these caves, we manually collected the large fossils deposited on the cave floor. We adapted an air lift aspiration system in order to excavate and collect small sized and fragmented fossil material embedded in the sediments from submerged caves (SALLES *et al.*, 2001), and the system is currently being improved for better performance. Areas selected for air lifting were encountered at different distances from the entrance of the cave, reaching a maximal depth of 43m.

The aspirated material was channeled through a tube up to the surface, at the extremity of which was laid a system of sieves with different mesh sizes, same as used in the excavation of the dry caves for sorting the material. All the accumulated material in the fine sieves was dried and saved for later sorting in the camp lab.

#### RESULTS

The material extracted from the Nascente do Formoso Cave amounts to approximately 200 pieces, from the Nossa Senhora Aparecida Cave we registered around 450 fragments, and from the Japonês Cave we recovered around 1,000 fragments. This material includes other vertebrate groups such as amphibians, snakes, and crocodiles, as well as invertebrates. In spite of the fact that most of the material is fragmentary, the state of preservation is exceptional. The collected material contain fragments of the scapular and the pelvic girdles, vertebrae, long bones, osteoderms, cranial fragments, maxillae, mandibulae, and teeth from a diverse mammalian megafauna from the Pleistocene of South America.

From the sorted material, we have identified up to now 74 mammal species, which are distributed into 30 families. Table 1 gives the list of extant and fossil mammal species identified and their respective localities. Note that the paleofauna found at Nossa Senhora Aparecida is exclusively represented by small mammals (summing up 15 species) whereas the Japonês (18 species) and Formoso (4 species) faunas consist mostly of medium and large sized mammals. Comparisons between the faunas found in these two caves require further investigations.

Table 1. Diversity of mammals from the Quaternary of Serra da Bodoquena (30 families and 74 species).

TAXA		REC	NSA	JAP	FOR
MARSUPIALIA					
Didelphidae	<i>Didelphis albiventris</i> Lund, 1840	x			
	<i>Gracilinanus</i> sp.		x		x
	<i>Marmosa</i> sp.				x
	<i>Monodelphis domestica</i> (Wagner, 1842)	x	x		
	<i>Thylamys macrura</i> (Olfers, 1818)	x	x		
	<i>Thylamys</i> sp.		x		
XENARTHRA					
Myrmecophagidae	<i>Myrmecophaga tridactyla</i> Linnaeus, 1758	x			
	<i>Tamandua tetradactyla</i> (Linnaeus, 1758)	x			
Dasypodidae	<i>Cabassous unicinctus</i> (Linnaeus, 1758)	x			
	<i>Dasypus</i> sp.	x		x	
	<i>Euphractus sexcinctus</i> (Linnaeus, 1758)	x		x	
	<i>Propraopus</i> sp. <sup>†</sup>			x	
	<i>Pampatherium</i> sp. <sup>†</sup>			x	
Mylodontidae	<i>Glossotherium</i> sp. <sup>†</sup>			x	
	<i>Mylodonopsis ibseni</i> Cartelle, 1991			x	
Megatheriidae	<i>Eremotherium</i> sp. <sup>†</sup>			x	
Glyptodontidae	<i>Glyptodon</i> sp. <sup>†</sup>			x	
CHIROPTERA					
Emballonuridae	<i>Rhynchonycteris naso</i> (Wied-Neuwied, 1820)	x			
Noctilionidae	<i>Noctilio leporinus</i> (Linnaeus, 1758)	x			
Phyllostomidae	<i>Chrotopterus auritus</i> (Peters, 1856)	x			
Phyllostominae	<i>Micronycteris megalotis</i> (Gray, 1842)	x			
	<i>Phyllostomus hastatus</i> (Pallas, 1767)	x			
Glossophaginae	<i>Anoura caudifera</i> (E. Geoffroy, 1818)	x			
	<i>Anoura geoffroyi</i> Gray, 1838	x			
	<i>Glossophaga soricina</i> (Pallas, 1766)	x			
Carollinae	<i>Carollia perspicillata</i> (Linnaeus, 1758)	x			
Sternodermatinae	<i>Artibeus jamaicensis</i> Leach, 1821	x			

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TAXA		REC	NSA	JAP	FOR
Sternodematinae	<i>Artibeus lituratus</i> (Olfers, 1818)	x			
	<i>Artibeus obscurus</i> Schinz, 1821	x			
	<i>Artibeus planirostris</i> (Spix, 1823)	x			
	<i>Platyrrhinus helleri</i> (Peters, 1866)	x			
	<i>Platyrrhinus lineatus</i> (E. Geoffroy, 1810)	x			
	<i>Sturnira lilium</i> (E. Geoffroy, 1810)	x			
Desmodontinae	<i>Desmodus rotundus</i> (E. Geoffroy, 1810)	x			
Natalidae	<i>Natalus stramineus</i> Gray, 1838	x			
Furipteridae	<i>Furipterus horrens</i> (F. Cuvier, 1828)	x			
Vespertilionidae	<i>Eptesicus fuscus</i> (Beauvois, 1796)	x			
	<i>Myotis nigricans</i> (Schinz, 1821)	x			
PRIMATES					
Cebidae	<i>Cebus apella</i> (Linnaeus, 1758)	x			
CARNIVORA					
Procyonidae	<i>Nasua nasua</i> (Linnaeus, 1766)	x			
	<i>Procyon cancrivorus</i> (G. Cuvier, 1798)				
Canidae	<i>Cerdocyon thous</i> (Linnaeus, 1766)	x			
Felidae	<i>Leopardus pardalis</i> (Linnaeus, 1758)	x			
	<i>Puma concolor</i> (Linnaeus, 1771)	x			
	<i>Smilodon populator</i> Lund, 1842†			x	
PERISSODACTYLA					
Equidae	<i>Equus</i> sp.†			x	
Tapiridae	<i>Tapirus terrestris</i> (Linnaeus, 1758)	x			
	<i>Tapirus</i> sp.†			x	x
LITOPTERNA					
Macraucheniidae	<i>Xenorhinotherium</i> sp.†			x	
PROBOSCIDEA					
Gomophoteriidae	<i>Haplomastodon</i> / <i>Stegomastodon</i> sp.†			x	x
ARTIODACTYLA					
Tayassuidae	<i>Tayassu</i> sp.	x		x	
Cervidae	<i>Mazama</i> sp.	x		x	

continued...



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TAXA		REC	NSA	JAP	FOR
Cervidae	<i>Ozotoceros</i> sp. †				x
Camelidae	<i>Paleolama major</i> (Liais, 1872)†				x
NOTOUNGULATA					
Toxodontidae	<i>Toxodon platensis</i> Owen, 1840†				x
RODENTIA					
Muridae	<i>Akodon</i> sp.				x
Sigmodontinae	<i>Bolomys</i> sp.	x	x		
	<i>Calomys</i> sp.	x	x		
	<i>Holochilus brasiliensis</i> (Desmarest, 1819)				x
	<i>Kunsia tomentosus</i> (Lichtenstein, 1830)				x
	<i>Nectomys squamipes</i> (Brants, 1827)	x			
	<i>Oligoryzomys</i> sp.	x		x	
	<i>Rhipidomys</i> sp.	x			
	<i>Scapteromys tumidus</i> (Waterhouse, 1837)				x
	<i>Oryzomys</i> sp.	x			
Echimyidae	<i>Carterodon sulcidens</i> (Lund, 1841)				x
	<i>Clyomys</i> sp.				x
	<i>Thrichomys apereoides</i> (Lund, 1839)	x		x	
Caviidae	<i>Cavia</i> sp.				x
Hydrochaeridae	<i>Hydrochaeris hydrochaeris</i> (Linnaeus, 1766)	x			
Dasyproctidae	<i>Dasyprocta</i> sp.	x			
LAGOMORPHA					
Leporidae	<i>Sylvilagus brasiliensis</i> (Linnaeus, 1758)	x			

(REC) extant taxa, (NSA) Nossa Senhora Aparecida Cave, (JAP) Japonês Cave, (FOR) Nascente do Formoso Cave.

## DISCUSSION

The interpretation of the factors that have influenced South American mammalian faunal changes during the Late Cenozoic is still an ongoing debate as is reflected by an abundant literature, and recently reviewed by DE VIVO & CARMIGNOTTO (2004) and commented by ARAUJO, NEVES & PILÓ (2004). The first insights based on the megafauna assemblages of the Japonês and the Formoso caves as well as some of the small mammals found at Nossa Senhora Aparecida cave (such as *Kunsia tomentosus*, *Holochilus brasiliensis*, *Cavia* sp., *Carterodon sulcidens*, and *Scapteromys tumidus*) indicate that the Holocene-Pleistocene conditions in the

region may have been characterized by open vegetation (savannas) with inundated areas, rich in elements typical of the South American megafauna from that period, probably associated with medium to small sized mammal communities. However, it is premature at this stage to embark on the possible paleontological scenarios of the Quaternary for the Bodoquena region. It will be developed in forthcoming publications as we reach a more detailed understanding of the fossil material sampled, including dating. Lack of previous inventory data from the Serra da Bodoquena and nearby regions inevitably renders comparative analyses difficult at this stage and such gaps can only be filled in by accruing the collecting efforts.

It is important to point out that concerning small mammals, some fossil species encountered in the Nossa Senhora Aparecida cave were not registered among the living species captured: *Akodon* sp., *Holochilus brasiliensis*, *Kunsia tormentosus*, *Scapteromys timidus*, *Carterodon sulcidens*, and *Cavia* sp. This could be due to non-exhaustive sampling of living species, because the collecting efforts were oriented towards the paleontological aspect. Assuredly our results on the recent mammalian fauna from the Serra da Bodoquena region will probably be amplified with increased sampling.

Diverse research developments are envisaged regarding this project, including the detailed comparative studies of fossil mammals, the dating of the material, as well as the molecular analysis of taxa through the extraction and sequencing of DNA from extant and fossil samples. These morpho-molecular data will have to be considered within the context of phylogenetic reconstructions and the formulation of eco-historical essays regarding the Quaternary of Brazil.

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MUSEU NACIONAL  
Universidade Federal do Rio de Janeiro  
Quinta da Boa Vista, São Cristóvão  
20940-040 – Rio de Janeiro, RJ, Brasil

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