New occurrence of sirenians in the Pirabas Formation (Miocene), Pará, Brazil

Nova ocorrência de sirênios na Formação Pirabas (Mioceno), Pará, Brasil

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Abstract: This note reports a new occurrence of sirenian fossils in the Pirabas Formation, at the Praia de Fortalezinha site, in the Maracanã municipality, Pará, Brazil. The aim of this preliminary study is to corroborate the palaeobiogeography knowledge of sirenians from the Miocene of Eastern Amazon. Unlike most previous records, which consists mainly of vertebrae and ribs, the material collected from a sedimentary block chacterised as *packstone/grainstone* contains ribs and cranial parts, including a fragmented rostrum (premaxilla with incisor tooth remains), key elements for an accurate taxonomic identification. This finding broadens the fossil record of Sirenia within the Pirabas Formation. The cranial elements will enable a more detailed taxonomic identification and provide relevant data on the distribution and evolution of sirenians in South America during the Neogene.

Keywords: Sirenia. New record. Palaeobiogeography. Eastern Amazon.

Resumo: A presente nota trata de uma nova ocorrência de fósseis de sirênios na Formação Pirabas, localizada na Praia de Fortalezinha, município de Maracanã, Pará, Brasil. O objetivo deste estudo preliminar é contribuir para o conhecimento paleobiogeográfico dos sirênios no Mioceno da Amazônia oriental. Diferente da maioria dos registros anteriores, que consistem principalmente de vértebras e costelas, o material, coletado em um bloco sedimentar caracterizado como *packstone/grainstone*, contém costelas e partes cranianas, incluindo rostro (pré-maxilar com restos de dente incisivo) fragmentado, elementos-chave para uma identificação taxonômica precisa. O novo achado amplia o registro fossilífero dos sirênios na Formação Pirabas. Os elementos cranianos encontrados irão possibilitar uma identificação taxonômica mais detalhada e fornecer dados relevantes sobre a distribuição e a evolução dos sirênios na América do Sul durante o Neógeno.

Palavras-chave: Sirenia. Novo registro. Paleobiogeografia. Amazônia oriental.

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INTRODUCTION

The outcrops known as the Pirabas Formation were discovered by Domingos Soares Ferreira Penna (Penna, 1876), while on an expedition in the São João de Pirabas district, at the Primavera municipality, Pará state, Brazil. Subsequently, the formation was documented at various locations in Pará, where it is most extensive, as well as in the Maranhão and Piauí states. Due to this large extension, Távora et al. (2010) compiled information about these fossiliferous localities, including georeferenced positions as well as the macrofossil richness.

Palaeogeographically, the Pirabas Formation is the southeasternmost point in an area with several fossiliferous units from Central and South America in the western Central Atlantic Ocean, with geological ages around the Neogene period (Aguilera & Páes, 2012; Aguilera et al., 2013). During the greater part of this period, the Isthmus of Panama was not uplifted (O'Dea et al., 2016) and the connection between the Pacific and Atlantic Oceans allowed for an important input of nutrients from the west to the east (Schneider & Schmittner, 2006). In addition, the faunal composition of the Pirabas Formation is very similar to the Gatunian subprovince, which includes geological units of the region known as the "proto-Caribbean" (Aguilera & Páes, 2012). This dynamic promotes debate about the palaeobiogeographic origins of the different groups occurring in these subprovinces.

The vertebrate palaeofauna in the Pirabas Formation is very diverse, being represented by groups like sharks and rays (Santos & Travassos, 1960; Aguilera et al., 2017), bony fishes (Santos & Salgado, 1971; Aguilera et al., 2014), chelonians (Costa et al., 2004), crocodilians (Toledo et al., 1997; Moraes-Santos et al., 2011) and sirenians (Toledo & Domning, 1989). Among these, sirenians are the only aquatic mammals known from the Pirabas Formation, and their remains are abundant in this unit, found mainly as ribs and vertebrae. Despite this abundance, their occurrence is restricted to certain fossiliferous sites.

In relation to the records of sirenians, Távora et al. (2010) refer to the occurrence of *Dioplotherium* cf. *D. allisoni* (Kilmer, 1965) in Aricuru, in the Maracanã municipality, but the only reference cited for this locality is a study that reported only bryozoans (Távora & Fernandes, 1994). At the moment, the occurrence of sirenians in the Maracanã municipality has not been formally published. Therefore, this note addresses a new occurrence of sirenian fossils from the Pirabas Formation in the Pará state.

MATERIAL AND METHODS

The sample under study was collected during a fieldwork (in 23/03/2012) at the Praia de Fortalezinha (0° 37' 33" S, 47° 32' 30" W), Ilha de Fortalezinha, located in the northwestern part of the Maracanã municipality, Pará state, Brazil (Figure 1). The material is in a *Packstone/grainstone* rock block (Aguilera et al., 2017) found on the beach that contains several exposed segments of sirenian ribs (Figures 2A and 2B). In the laboratory, early preparation steps on the block allowed to better observe the ribs, as well as parts of a skull (Figures 2B and 2C), which will be further cleaned for a more specific identification. The assignment of the ribs and skull to the Sirenia order comes first from comparisons with previous collected material deposited into the MPEG palaeontological collection (e.g., Costa et al., 2004), abundant in some Pirabas Formation sites. Nonetheless, additional references were also used to determine the specimen (Paula-Couto, 1967; Toledo, 1989; Toledo & Domning, 1989; Domning et al., 2010), taking into consideration in this preliminary identification morphological criteria such as the rib and skull shapes. After preparation, the material was stabilised with Paraloid B72 acrylic consolidant to prevent degradation. The piece has been catalogued under the number MPEG-2427-V in the Palaeontological Collection of the Museu Paraense Emílio Goeldi (MPEG).

RESULTS AND DISCUSSION

Paula-Couto (1967) made the first formal record of sirenians in the Pirabas Formation, from material collected in the

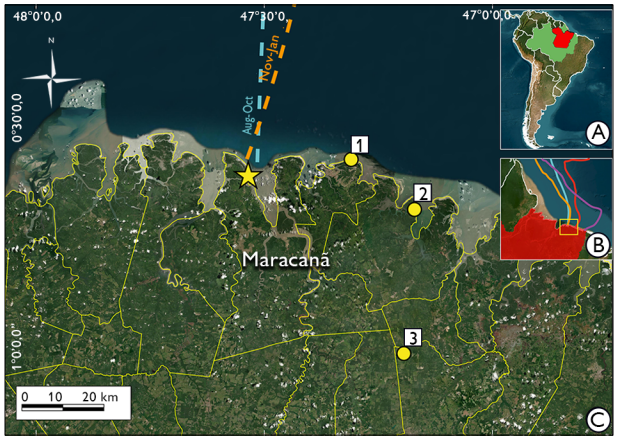

Figure 1. A) South America and in Brazil, the 'Amazônia Legal' area is given in green, with the Pará state remarked in red. The coastal zone of the Eastern Amazon is shown in (B), and the lines denote the Amazon-Tocantins delta fan oscillating intensity on the Atlantic Ocean (orange: November to January; blue: August to October; red: May to July; purple: February to April; based on Salisbury et al., 2011; Moura et al., 2016). The yellow square encloses the area shown in (C), part of the Salgado Paraense region. The Praia de Fortalezinha site (star) and other sites (circles) with sirenian occurrences are indicated: 1 = Praia do Atalaia, 2 = Ilha de Fortaleza and Ponta do Castelo, 3 = B17 mine. Map by the authors (2025).

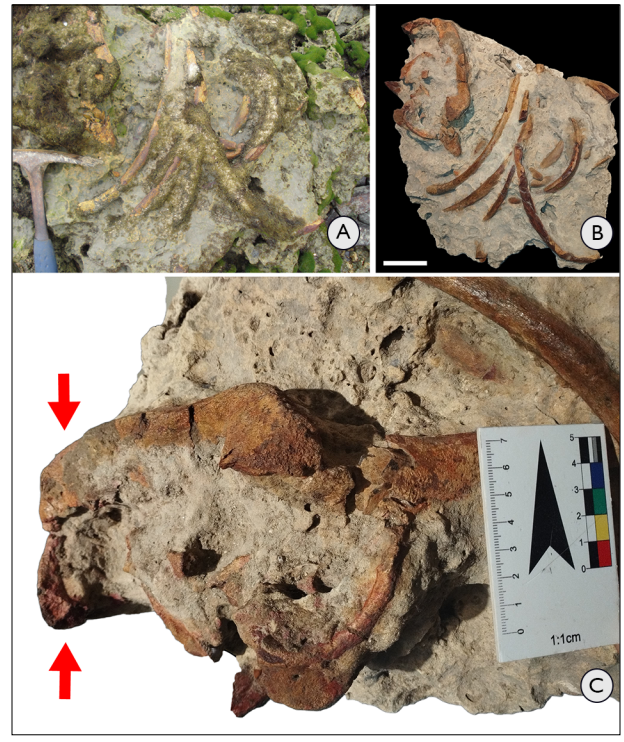

Figure 2. A) *Packstone/grainstone* block with sirenian remains, before preliminary treatment, showing only rib fragments; B) block after preliminary cleaning showing cranial remains (scale bar: 5 cm); C) detail of the cranial material, with red arrows showing the fragmented rostrum (premaxilla and incisor tooth). Images by the authors (2025).

Ilha de Fortaleza locality (type locality), at the São João de Pirabas municipality. Based on the crowns of molar teeth (one upper and one lower), he determined a new taxon named *Sirenotherium pirabense* (Paula Couto, 1967). The author also registered fragments of ribs and vertebrae from the Salinópolis municipality (cliff) and similar specimens from the Cassiano site, at the Nova Timboteua municipality, Pará.

Subsequently, Toledo (1989) collected sirenian samples from the Praia do Atalaia, at the Salinópolis municipality, including a very well preserved skull and mandible, besides vertebrae, which he attributed to *Sirenotherium pirabense*. Toledo and Domning (1989) reviewed this material and studied other cranial and post-cranial remains from this locality, and from the B5 mine of *Cimentos do Brasil* (CIBRASA), at the Capanema municipality. The authors found three taxa belonging to the same family, Dugongidae, distributed in two subfamilies: *Dioplotherium* cf. *D. allisoni* and cf. *Rytiodus*, of the Dugonginae subfamily and cf. *Metaxytherium*, Halitheriinae subfamily. *Sirenotherium pirabense* was considered by them as *nomen nudum*, since its determination does not contain diagnostic characters that justify the definition of a new taxon.

Sirenian remains are abundant in Pirabas Formation and, as in other formations, are mainly represented by vertebrae and ribs, with fragments of pachyosteoclerotic ribs being the most common fossils. However, these generally do not allow for more detailed taxonomic identification. Even teeth, which allow the determination of most fossil mammals, have limited diagnostic value in Sirenia, compared to cranial parts, particularly the cranial roof and rostrum (Domning et al., 2010). This paper records new sirenian remains to the Pirabas Formation consisting of cranial elements, a fragmented rostrum (premaxilla with upper incisor tooth, Figure 2C), which are essential for the potential taxonomic determination. An identification at least to the

genus level will contribute to knowledge of the group's diversity and geographical distribution.

The number of sirenian taxa recorded in Pirabas Formation shows the high diversity of this group in a single geological formation, compared to others in Central and North America (Costa et al., 2004). Three genera were already identified for this unit, within the Dugongidae family: cf. *Rytiodus*, *Dioplotherium*, and cf. *Metaxytherium*. Among them, cf. *Rytiodus* was first known only to the Old World, and it was documented for the first time in the Americas; and *Dioplotherium*, earlier documented in North America, had its distribution extended to South America (Toledo & Domning, 1989). Neither taxon is native, and the northeastern part of Amazon would be the southern limit of *Dioplotherium* and cf. *Metaxytherium* palaeogeographic distribution, and the western limit of *Rytiodus* (Costa et al., 2004).

CONCLUSION

The new finding of sirenians in the Pirabas Formation with cranial remains of diagnostic value could potentially contribute to the specific taxonomic identification. Consequently, this will corroborate the biodiversity of the group in the northeast of the Eastern Amazon. In addition, this suggests that the group was widely distributed on the coast of the Pará state during the Neogene, justifying the presence of large predators in the region, such as sharks of the *Otodus* genus.

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AUTHORS' CONTRIBUTION

H. M. Moraes-Santos contributed to project administration, formal analysis, acquisition of funding, conceptualisation, data curation, investigation, methodology, validation, and writing (original draft, review, and editing); Z. A. S. Luz contributed to conceptualization, data curation, investigation, methodology, validation, visualisation, and writing (original draft, review, and editing); and A. P. Linhares contributed to formal analysis, conceptualisation, data curation, investigation, methodology, validation, and writing (original draft, review, and editing).