



Hyriidae and Mycetopodidae (Mollusca: Bivalvia) from Solimões formation (mio-pliocene), Amazonas, Brazil

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ABSTRACT

The Solimões Formation (late early Miocene to Pliocene, Brazil) yields an important fossiliferous content, but the mollusks have been scarcely studied. We studied 58 bivalve specimens from Aquidabã and Morada Nova, Eirunepé Municipality, southwestern Amazonas. They belong to *Castalia ambigua* (Hyriidae) and *Haasica* cf. *balzani* (Mycetopodidae). The two genera are restricted to South America. *Castalia* has its oldest occurrence in the late Cretaceous at Itapeturu Formation, Parnaíba Basin (Maranhão State, Brazil), and it presently has a wide distribution in South America. *Haasica* is currently restricted to the Paraná River Basin, and its presence in the Solimões Formation is the first in the fossil record. These strictly freshwater bivalves suggest a lacustrine environment to the upper part of the Solimões Formation.

1. Introduction

The study of fossil mollusks from western Amazonia began at the end of the XIX century with Gabb (1868), who recorded many taxa of brackish-water gastropods and bivalves in the Miocene of Ecuador. Conrad (1871), Etheridge (1879), and Roxo (1924, 1937) described the presence of Pliocene brackish-water mollusks of Pliocene age in Brazil. Subsequently, many studies were published (Woodward, 1871; Boettger, 1878; Brown, 1879; Oliveira and Carvalho, 1924; Maury, 1924; Roxo, 1924, 1935). Following several decades of interruption, important monographs revised these faunas (Nuttall, 1990; Wesselingh et al., 2002, 2006; Wesselingh, 2006a, 2006b), including material from Peruvian and Colombian Amazonia.

More recently, Guimarães et al. (2018) studied the gastropod genus *Tryonia* from a borehole drilled in the upper Jutai River, State of Amazonas, Brazil, recording a new species in the Solimões Formation and inferring a low energy (lacustrine) depositional environment. The present paper describes bivalves from the Solimões Formation (late-Miocene) outcropping close to Eirunepé town, southeastern Amazonas state.

1.1. Studied area

The Solimões Formation represents the Neogene of Solimões Basin. It has an expressive fossil content that has been used for biostratigraphic studies and paleoenvironmental reconstruction. Palynological studies have inferred an early Miocene to early Pliocene age, as it is correlated with the Pebas Formation in Peru (Antonie et al., 2016; Hoorn, 1993; Leite, 2006, 2016; Silva-Caminha et al., 2010; Hoorn and Wesselingh, 2011; Kachniasz and Silva-caminha, 2017; Jaramillo et al., 2017; Parra et al., 2020; Linhares et al., 2017, 2019; Friaes et al., 2022). The paleoenvironment is characterized as a wide megawetland of lagoons and fluvio-lacustrine system, with sporadic marine influence (Maia et al., 1977; Wesselingh et al., 2006; Hoorn et al., 2010; Silva-Caminha et al., 2010, Linhares et al., 2011, Jaramillo et al., 2017, Leandro et al., 2022). It is composed mainly of claystone interlaid by fine sand and fossil layers, the last of which includes vertebrates, invertebrates, plant fragments, and diverse microfossils, such as palynomorphs, mollusks, and ostracods (Purper, 1979, Nuttall, 1990, Muñoz-Torres et al., 1998, Wesselingh et al., 2002, 2006a; Ramos, 2006; Wesselingh and Ramos, 2010, Linhares et al., 2011, Gross et al., 2011, 2013, 2014, Antoine

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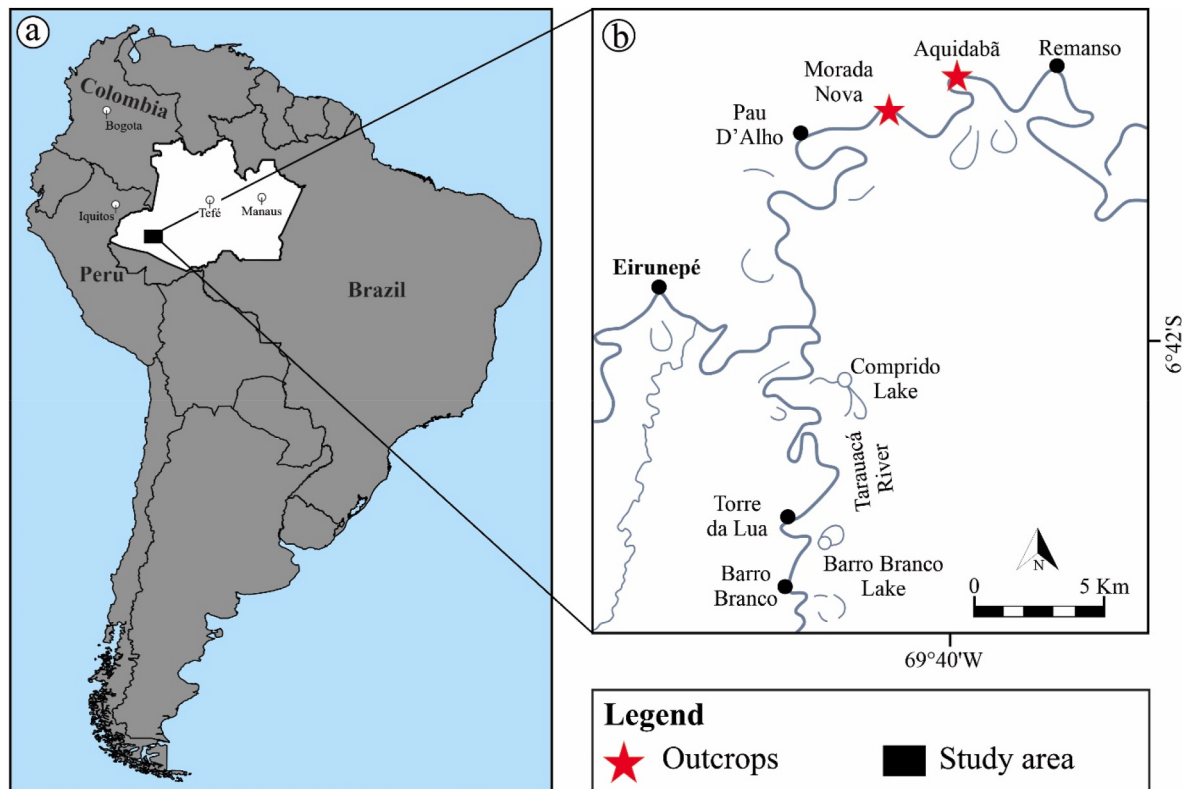


Fig. 1. Location of the studied outcrops (Modified from Gross et al., 2013).

et al., 2016, da Silveira and Souza, 2015, Sousa and Ramos, 2023, Santos and Ramos, 2023, and references therein).

The studied outcrops are located close to the town of Eirunepé, Amazonas state (Fig. 1). Gross et al. (2011, 2013) presented a detailed sedimentological description and the late Miocene microfossils of the study area. The studied bivalves are restricted to the uppermost portion of the studied section, which is related to gray and dark shales from floodplains of lakes (Fig. 2).

2. Material and methods

The studied material comprises 58 mollusk specimens collected by hand through the geological stratigraphic sections (Fig. 2). The localities are Aquidabã (06°31'40.8"S 069°39'52.0"W) and Morada Nova (06°32'51.1"S 069°42'39.4"W), right bank of Juruá River. The studied material is housed in the Paleontological collection at Museu Paraense Emílio Goeldi (MPEG).

We used a digital camera Canon, model 600D lens macro 100 mm Usm, attached to an optic microscope Leica for photographic recording (LEICA S8APO).

3. Results and Discussion

Systematic paleontology

Class Bivalvia Linnaeus, 1758
Order Unionoidea Gray, 1854
Family Hyriidae Swainson, 1840
Genus *Castalia* Lamarck, 1819

Diagnosis: *Castalia* Lamarck, 1819 [**C. Ambigua* OD] [= *Tetraplodon* Spix, 1827]. Triangular, heavy, inflated, with high sharp posterior ridge behind which margin is distinctly truncate; beaks very full and high, sculpture radial or with 1 or 2 pairs of central ribs coalescing below, whole extending over disc as strong ridges; periostracum thick, dark, dull; hinge line arched, all teeth vertically ridged; 1 strong compressed

cardinal in LV, 2 in RV, all in front of beaks, behind which lie denticles; 1 lamellar tooth in RV and 2 in LV; beak cavities deep, not compressed. Rec., S. Am (Morre, 1969).

Fig. D50, 4 **C. ambigua*; 4°-d, RV ext., LV int., both valves dorsal, hinges.

***Castalia ambigua* Lamarck, 1819**

Fig. 3 A-L *Castalia ambigua*: Roxo (1924): 45p; Sousa (2018), 76–77p, Fig. 3 A-C; 79p, Fig. 4-D.

Castalia cf. *ambigua*: Simone and Mezzalana (1994): 165p, Fig. 740; Wesselingh et al., 2006: 425–426, Figs. 11–12.

Material: 36 specimens.

Figured material (Dimensions - High/length in cm): MPEG-2810-I; MPEG-3574-I; MPEG-3575-I; MPEG-3236-I; MPEG-2709a-I; MPEG-2709b-I.

Dimensions: MPEG-2810-I (1.5/1.7); MPEG-3574-I (fragmented; 1.7/1.9); MPEG-3575-I (fragmented; 2.0/2.3); MPEG-3236-I (1.7/2.0); MPEG-2709a-I (2.3/2.5); MPEG-2709b-I (2.4/2.8); MPEG-2709-I (2.4/3.0); MPEG-2784-I (2.7/3.0); MPEG-3241-I (0.8/1.2); MPEG-3564-I (1.4/1.8); MPEG-3235-I (2.2/2.5); MPEG-3573-I (1.7/1.9).

Remarks. *Castalia ambigua* has morphological variations mainly in size (Average: 2.05), outline, and ornamentation pattern observed in the analyzed specimens and the literature (Wesselingh et al., 2006). Related to the ornamentation, the radial ridges, when present, are larger and sparse (Fig. 3 C and E), extending along the entire surface, from the umbo to the ventral region, sometimes with a nitid “V” shape ridge close to the umbo (Fig. 3A–C), in other specimens the ridges are thinner (Fig. 3 A, I, K), or they seem to fade in middle level of the valves in larger specimens, intercepted by evident deep grooves (Fig. 3 G). The growth lines are visible in the ventral region, convergent to the anterior and posterior margins crossing the radial ridges; some are more evident (Fig. 3 C, E, G). In rare specimens, some discrete tubercles over the ridges in the anterior margin can be seen (Fig. 3 A, G). In the internal view, it has strong hinge with median ridge and low cardinal and lateral teeth (Fig. 3B, F); the adductor muscle is pronounced in the anterior

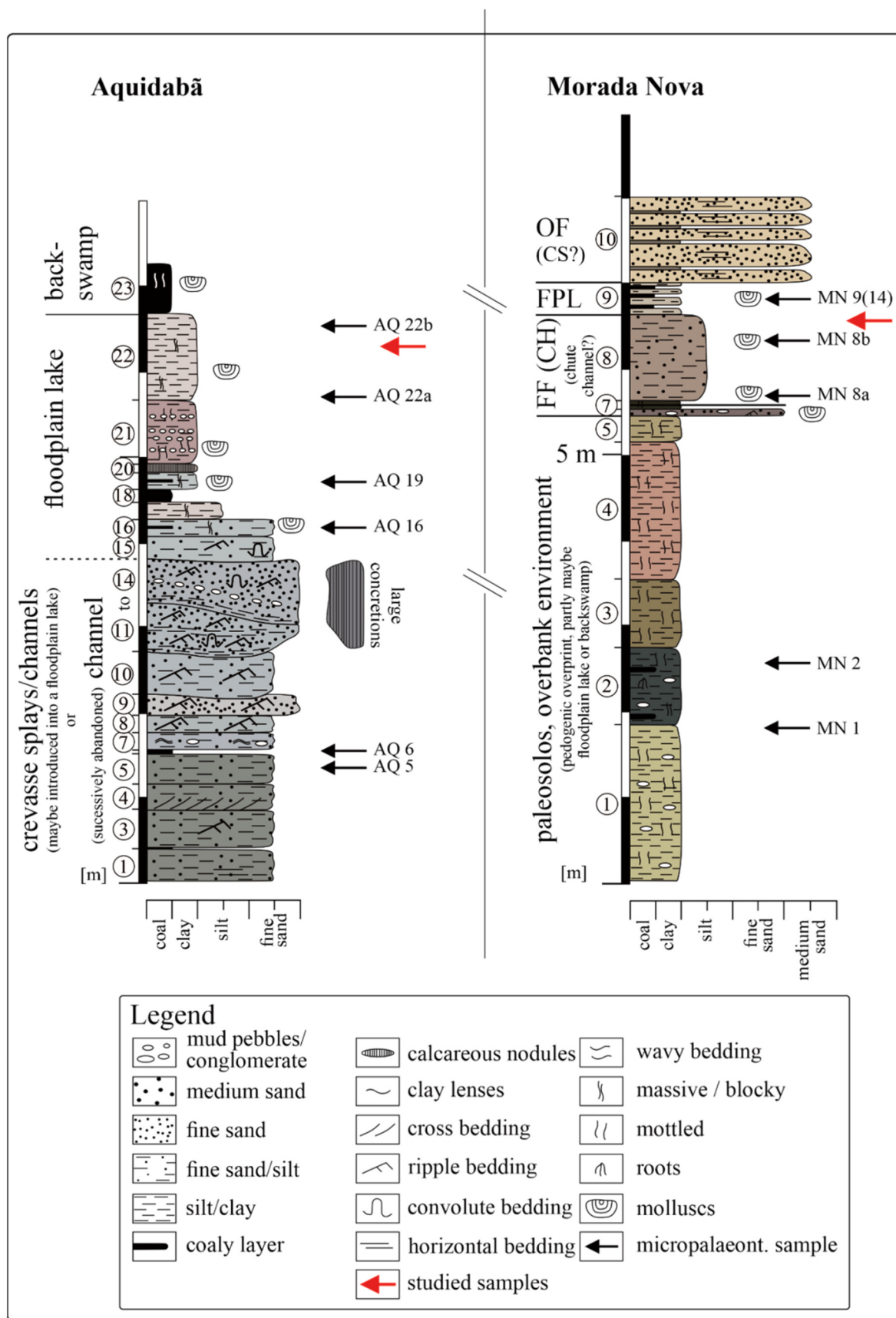


Fig. 2. Stratigraphic sections of the studied outcrops with the collected samples (Modified from Gross et al., 2011).

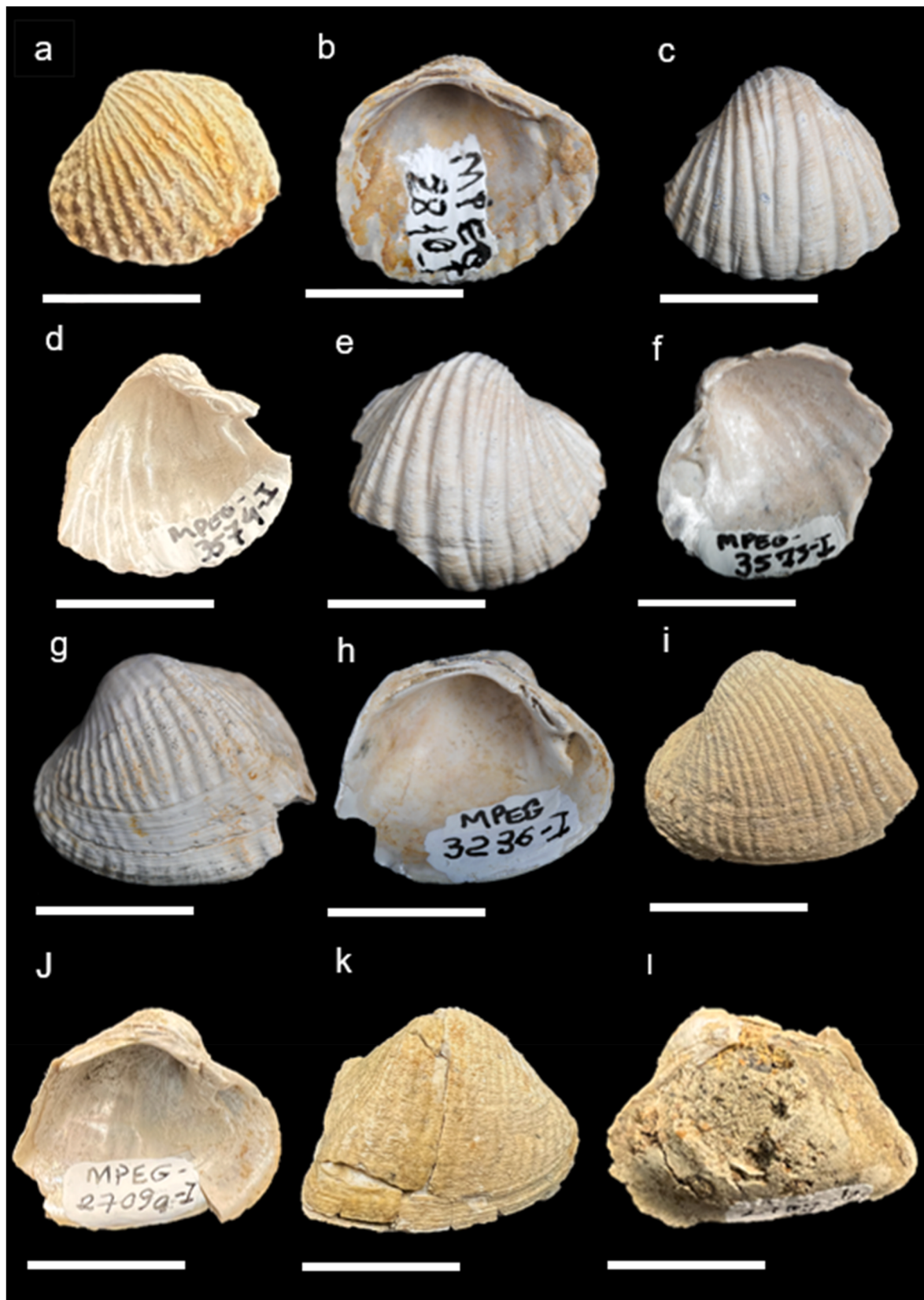


Fig. 3. *Castalia ambigua*; A-B, MPEG- 2810-I, A-external view, left valve; B- interior view, left valve, ring detail; C-D, MPEG-3574-I, C- external view, left valve; D- interior view, left valve, ring detail; E-F, MPEG-3575-I, E-external view, left valve; F- interior view, left valve, ring detail; G-H, MPEG-3236-I, G-external view, left valve; H- interior view, left valve, ring detail; MPEG-2709A-I, I- external view, left valve; J-interior view, left valve, ring detail; MPEG-2709B-I, K- exterior view, left valve; L-interior view, left valve, ring detail. (Scale 2 cm).

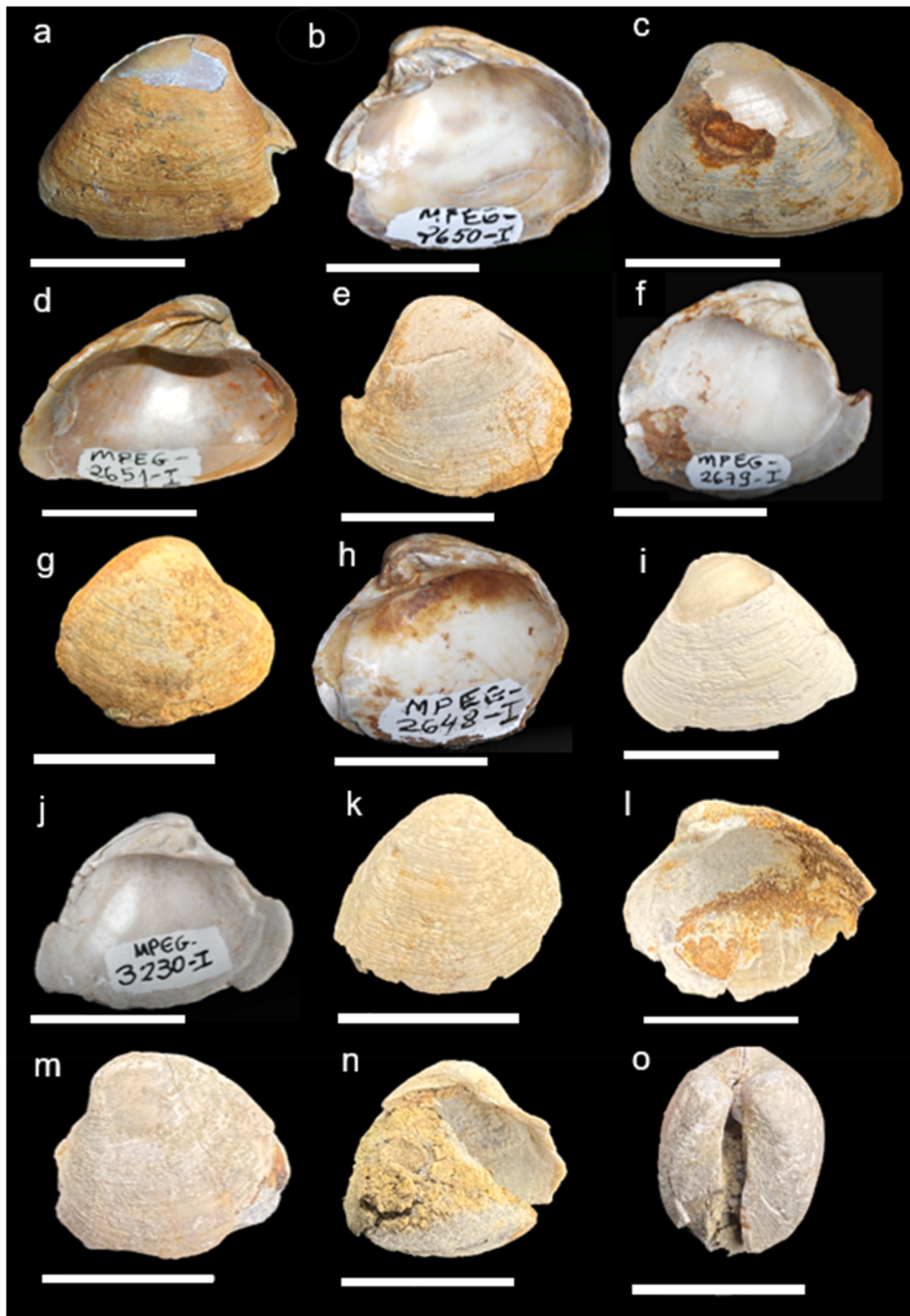


Fig. 4. *Haasica* cf. *balzani*; A-B, MPEG-2650-I, A-external view, right valve; B- interior view, right valve, hinge detail; C-D, MPEG- 2651-I, C- external view, right valve; D-interior view, right valve, hinge detail; E-F, MPEG-2679-I, E-external view, right valve; F- interior view, right valve, hinge detail, G-H, MPEG- 2648-I, G – exterior view, left valve; H- interior view, left valve, hinge detail; MPEG- 3230-I, I – exterior view, left valve; J-interior view, left valve, hinge detail; MPEG- 2796A-I, K – external view, left valve; L-interior view, left valve, hinge detail; MPEG- 2796B-I, M- exterior view, left valve; N- interior view, left valve, hinge detail. O-view of the two valves. (Scale 2 cm).

region (Fig. 3 B, F; H). Some specimens are not well preserved, with the ornamentation eroded, but the hinge line is typical of the genus, the length is longer than their height. (Fig. 3 J, L).

Occurrence: The collected specimens occur in the uppermost portion of the studied sections, of the Aquidabã and Morada Nova outcrops, on the right bank of the Juruá River, Eirunepé town, Amazonas state, Brazil; the layers are constituted by gray and dark shales related to floodplain lakes (Fig. 2) Solimões Formation, late Miocene.

Stratigraphic and geographic distribution: *Castalia ambigua* has a wide Recent and fossil record throughout South America. It was previously recorded in the Late Miocene and Pliocene Solimões Formation in the Acre and Amazonas states (Brazil) (Wesselingh et al., 2006a; Sousa, 2018), and in the Pebas Formation, Perú (Roxo, 1924, 1937). Presently, it is widespread along South America, from Guyanas to Uruguay (Roxo, 1924, 1937; Wesselingh et al., 2006a; Sousa, 2018).

Family mycetopodidae

Genus *Haasica* Strand, 1932

Diagnosis: *Haasica* Strand, 1932 [* *Plagiodon balzani* Ihering, 1893; OD] [= *Marshalliella* Haas, 1932 (non Kiefer, 1913; nec Poppius, 1914). Externally like *Monocondylaea*; hinge plate with high narrow cardinal in RV, separated from low denticle behind by cuneiform groove; preumbonal callosity in RV, divided from high narrow tooth by narrow, deep furrow which extends under beak; beak cavities deep, somewhat compressed. Rec., S. Am (Morre, 1969).

Fig. D54, 11. **H. balzani* (Ihering); 11°-d, RV int., both valves dorsal.

Haasica cf. *balzani* (Ihering, 1893).

Fig. 4: A-O.

Non *Fossula balzani matogrosensis* Ihering, 1915

Callonaia sp: Wesselingh et al., 2006: 427–430, Figs. 19–27

Callonaia duprei: Sousa 2018: 84–85, Fig. 7 A–B (non Récluz, 1842)

Material: 22 specimens.

Figured material (Dimensions - High/length in cm): MPEG-2650-I; MPEG-2651-I; MPEG- 2679- I; MPEG-2648- I; MPEG-3230-I; MPEG-2796a-I; MPEG-2796b-I.

Dimensions (High/length in cm): MPEG- 2650- I (2.4/2.8); MPEG-2651- I (2.5/3.5); MPEG- 2679- I (fragmented; 3.4/3.4); MPEG-2648- I (2.4/2.9); MPEG-3230- I (fragmented; 2.3/2.9); MPEG-2796a- I (2.2/2.5); MPEG-2796b- I (2.4/2.5); MPEG-3232- I (2.2/2.4); MPEG-2785- I (2.5/3.5); MPEG-2680- I (2.5/2.9); MPEG-2691- I (2.0/2.2); MPEG-2677- I (2.6/2.9); MPEG-3578- I (1.5/1.8).

Remarks. Specimens of *Haasica* cf. *balzani* from the studied material have external morphological patterns typical of the genus; the surface is smooth, and the right valve has evident fine and concentric growth lines that are close to each other, extending from the dorsal to the ventral portion of the shell; umbo acute sometimes more angulated and well projected (Fig. 4A–C), lower in the left valve (Fig. 4 G, H). Internal view typical of the genus; the hinge is evident, with cardinal teeth high and elongated; lateral teeth absent (Fig. 4 B). (Average: 2.58).

A typical *Haasica balzani* has a slightly more rounded outline (Simone, 2006: Fig. 1028) than the specimens studied herein. The studied valves are slightly more triangular and with taller umbo. Because these differences have been found in some extreme variation specimens of *H. balzani*, the suggestive identification is presented herein. The hinge leaves no doubt about its generic attribution, but the available material still needs to allow a more specific, accurate identification. Therefore, we preferred a more conservative approach; however, a new species is possible.

This species has already been recorded in the Solimões Formation as belonging to *Callonaia* (*Callonaia duprei*). Morphological analysis of the specimens allowed us to verify that they are very different from the genus *Callonaia*, which belongs to the Hyriidae family. This genus has valves with a much more angular anterior region and without wing projections. In addition, it differs in the hinge from *Haasica*, which has a hinge with higher and more curved cardinal teeth without lateral teeth.

Occurrence: *Haasica* cf. *balzani* was found in the Aquidabã locality, on the right bank of the Juruá River, Eirunepé town, Amazonas state,

Brazil, in the uppermost portion of the section, related to gray and dark shales, and floodplain lakes (Fig. 2). Solimões Formation, Late Miocene.

Stratigraphic and geographic distribution: It is the first fossil record for the genus. The species was known for the late Miocene Solimões Formation in Acre state, Brazil (Wesselingh et al., 2006; Sousa, 2018), (see synonymy list). *Haasica balzani* is an endemic species with a restricted Recent distribution in the Alto Paraguay Basin (Paraguay River, São Paulo and Mato Grosso states, Brazil), (Simone, 2006; Graf and Cummings, 2019).

4. Conclusions

The genus *Haasica* was found for the first time in the fossil record (Solimões Formation, Late Miocene), and the geographic distribution of the species *Haasica* cf. *balzani* is restricted to Brazil, so this was the first record for the state of Amazonas, Brazil. *Castalia ambigua* was found in new localities in the State of Amazonas, Brazil. These two genera, which are typical of freshwater environments, suggest a lacustrine environment to the upper portion (Upper Miocene) of the Solimões Formation.

CRedit authorship contribution statement

Lorena Lisboa Araujo: Writing – review & editing, Writing – original draft, Supervision, Project administration, Methodology. **Maria Inês Feijó Ramos:** Writing – review & editing, Writing – original draft, Supervision, Project administration, Investigation. **Luiz Ricardo Lopes De Simone:** Writing – review & editing. **Sergio Martínez:** Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

No data was used for the research described in the article.

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