Miocene freshwater Mollusca from western Brazilian Amazonia

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Key words – Mollusca, western Amazonia, Miocene, Solimões Formation.
Thirteen species of fossil molluscs are reported from the Solimões Formation of western Brazilian Amazonia. Based on mammalian chronology of the Solimões Formation and radiometric ages reported from coeval deposits in adjacent Peru, the age of the fauna is established as Late Miocene. The fauna includes five prosobranch gastropod species, seven pearly freshwater mussel species and one sphaeriid bivalve species. The supposed presence of *Pachydon* (Corbulidae: Bivalvia) in these deposits is rejected; *Pachydon acreanum,* whose status has long been uncertain, is transferred to the unionoid genus *Callonaia*. The Solimões mollusc fauna is entirely composed of obligate freshwater taxa, resembling species-poor modern Amazonian fluvial faunas. The presence of the fauna in outcrops covering large parts of western Amazonia indicates that by that time the preceding Pebas fauna (dominated by corbulid bivalves and cochliopid snails) must have been extinguished.

Contents

Introduction

Famous and very rich Miocene vertebrate faunas are known from deposits from southwest Brazilian Amazonia (Acre and Amazonas States) and adjacent eastern Peru, referred to as the Solimões and Madre de Dios formations (Latubresse *et al.*, 1997 and references therein). The vertebrate faunas of the region are mostly of a Huayquerian mammalian stage (Latubresse *et al.*, 1997), but some also represent the slightly younger Montehermosan stage. The Huayquerian stage is of a Late Miocene age (6.5 – 9 Ma: Flynn & Swisher III, 1995). The lower part of the coeval Madre de Dios Formation of adjacent Peru ('A' and 'B' Unit from Hermoza, 2005) yielded ages of 9.0 +/- 0.3 Ma ($^{40}Ar/^{39}Ar$; Campbell *et al.*, 2001) and 8.8 +/- 3.2 Ma (fission track) and 9.01 +/- 0.28 Ma ($^{40}Ar/^{39}Ar$; Hermoza, 2005), confirming the Late Miocene age of the Solimões Formation. During joint fieldwork of members of the Universidade Federal

do Acre, Brazil (UFAC), University of Alberta, Canada (UA) and the University of Turku, Finland (UTU) in 2000, fossil molluscs were collected in localities and areas from which previously only vertebrates had been found. The newly collected fossils, as well as part of the material described previously from the region (Roxo, 1937; Maury, 1937), are reviewed. Not included is material published by Roxo (1924) from the Peruvian locality Três Unidos on the Javarí River that is attributed to the Pebas Formation (Nuttall, 1990). This paper aims at assessing palaeoenvironmental conditions during deposition of the Solimões Formation, and to investigate faunal and stratigraphic relationships with the Miocene Pebas fauna (Wesselingh, 2006) from Colombia and Peru.

Localities

Abbreviations: DNPM = Departamento Nacional da Produção Mineral, Seção de Paleontologia, Rio de Janeiro, Brazil; DPMN = Museu Nacional, Departamento de Paleontologia, Rio de Janeiro, Brazil; RGM = Nationaal Natuurhistorisch Museum, Division of Fossil Mollusca, Leiden, The Netherlands; UFAC = Universidade Federal do Acre, Laboratório de Pesquisas Paleontológicas, Rio Branco, Brazil. A locality map is provided in Fig. 1.

Cachoeira do Bandeira – (Acre, Brazil). North bank Acre River, downriver from Assis Brasil (10°56′22″S 69°20′37″W), Solimões Formation, Late Miocene. Collected in 2000.

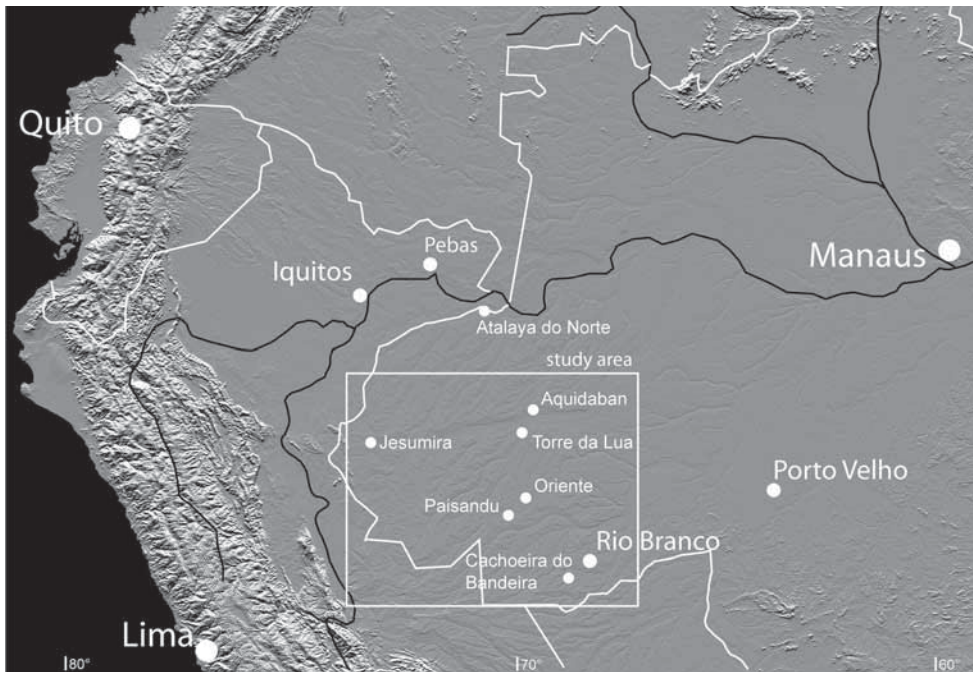


Fig. 1. Localities mentioned in this paper. Topographic background from www.photojournal.jpl.nasa.gov.

Oriente – (Acre, Brazil). North bank of Purus River, downriver from Manuel Urbano (08°49'19.2''S 69°13'40.3''W), Solimões Formation, Late Miocene. Molluscs from this locality were collected from a paleosol horizon (M. Gingras, pers. comm.). Collected in 2000.

Paisandú – (Acre, Brazil). North bank of Purus River, up river from the ferry of the BR 364 Road (08°54'18.4''S 69°17'13.0''W), Solimões Formation, Late Miocene. Collected in 2000.

Jesumira – (Acre, Brazil). A small tributary of the Moa River, which in turns flows in the Juruá River just above Cruzeiro do Sul (Nuttall, 1990) (no coordinates available), Solimões Formation(?), Late Miocene?, leg. A. Wanderley, 1936.

The locality and age of the beds of the Jesumira locality are disputed. Maury (1937) described Tertiary fossils from this locality and from nearby Porto Peter, but her localities were considered as Late Pleistocene or Holocene oxbow infills by Simpson (1961). However, Nuttall (1990, p. 359) doubted the argument leading to the assignment of fossil bivalves to the Corbiculidae instead of the Neogene genus *Pachydon*. Maury's material was studied in the DNPM in 1997 by the senior author and is discussed below under *Callonaia* sp.

Aquidaban – (Amazonas, Brazil). Outcrop(s) along the Juruá River (6°30'S 69°40'W), Solimões Formation, Late Miocene, leg. de Moura & Oppenheim (Roxo, 1937).

Atalaya do Norte – (Amazonas, Brazil). Unspecified outcrop in Javarí River (no coordinates), Pebas Formation, late Middle – early Late Miocene, leg. M.C. Hoorn, 1989.

Systematic palaeontology

Key: H = height; LV = left valve; RV = right valve; W = width; dimensions in mm. All illustrated specimens (Figs. 2-33) are from the Solimões Formation unless stated otherwise.

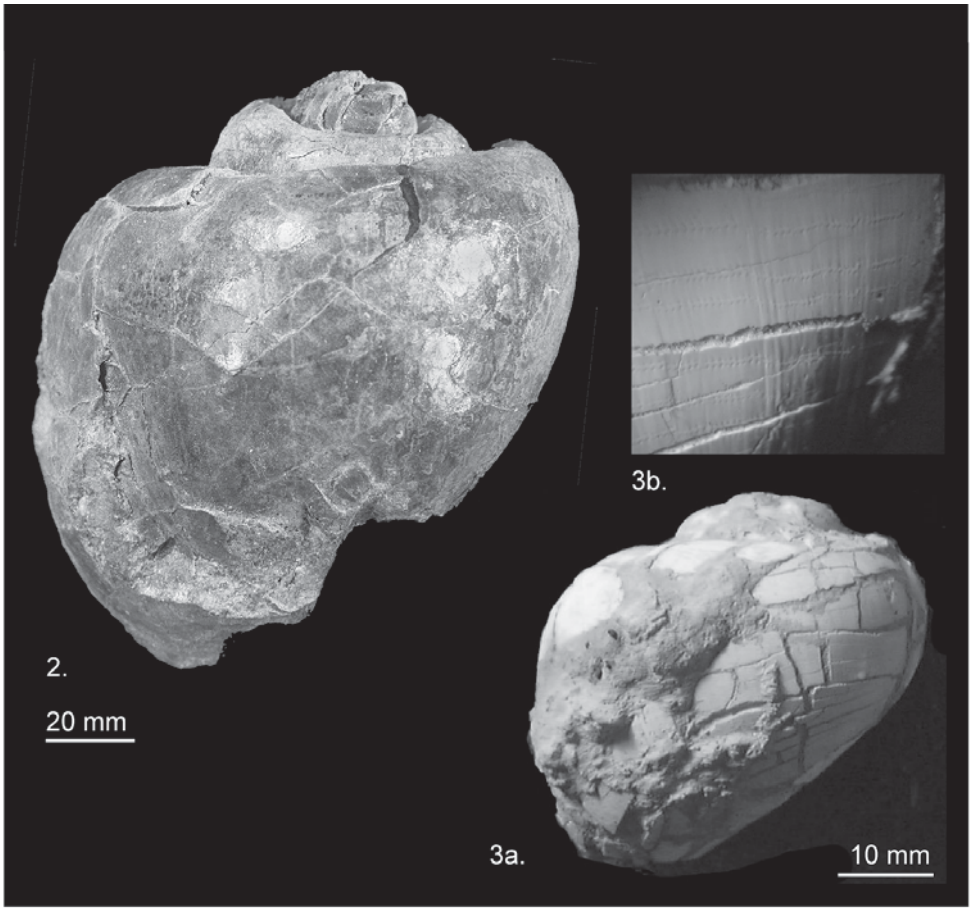
Phylum Mollusca
Class Gastropoda
Order Prosobranchia
Family Ampullariidae Gray, 1824
Ampullariidae sp. 1

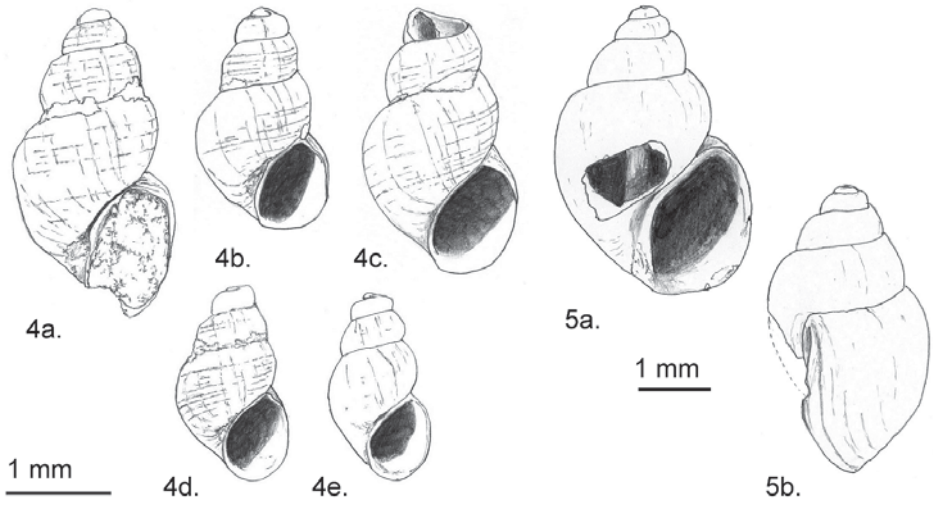
Figs. 2, 3.

1967 *Ampullarius* sp. Santos & Castro, p. 419, figs. 9, 10.
? 2006 Ampullariidae indet. Wesselingh, p. 30.

Material – UFAC-182, Cachoeira do Bandeira (Acre, Brazil), Solimões Formation, Late Miocene (1 damaged mould). RGM 456 705, Javarí River near Atalaya do Norte (Amazonas, Brazil), Pebas Formation, *Grimsdalea* interval zone, late Middle – early Late Miocene (1 damaged specimen).

Description – This is a giant (H up to *c.* 140) and globose ampullariid. The adult whorls are slightly shouldered. The shell's surface is ornamented with low, irregularly


2.
20 mm
3b.
3a.
10 mm


4a.
4b.
4c.
4d.
4e.
1 mm
5a.
1 mm
5b.

arranged spiral grooves containing mamillae (Fig. 3b). All ampullariid material from the Solimões Formation is compacted and severely damaged.

Remarks – We have not succeeded in checking a record possibly referring to this species as '*Ampularia* (?) *gigantea* Nob.' (Santos & Castro, 1967, p. 420).

Ampullariidae sp. 2

1937 *Ampullarius* sp. Roxo, p. 7.
1967 *Ampullarius* (*Effusa*) sp. Santos & Castro, p. 420, figs. 7, 8.

Material – Aquidaban (Amazonas, Brazil), DPMN-4950-1, 1 specimen; DPMN-4951-1, 1 specimen.

Description – This small (H *c.* 28) ampullariid has a thick shell. The whorl profile is very convex with a marked, deep suture. The apertural margins of the semicircular aperture are thickened. The species has a markedly erect apex.

Remarks – This species has a more convex perimeter and deeper sutures and a thicker shell than Ampullariidae sp. 1.

Family Cochliopidae Tryon, 1866
***Pyrgophorus*? sp.**
Fig. 4.

1937 *Potamopyrgus* cf. *laciranus* Pilsbry & Olsson; Roxo, p. 7.

Material – DPMN-2969, Aquidaban, (label reads 'Municipio de Carauari'), Amazonas, Brazil (5 specimens).

Description – This is a small (H *c.* 3), elongate conical cochliopid. The shell is ornamented with *c.* 7-8 fine spiral ribs that are located on the lower two-thirds of the whorl. The upper spiral defines a poorly developed, smooth, steeply dipping subsutural ramp. The lower rib is visible only at the base of the body whorl. Growth lines are slightly prosocline. The ovate aperture is adnate. The shell is imperforate or has a narrowly rimate umbilicus.

◀ Figs. 2, 3. Ampullariidae sp. 1.
All specimens from the Solimões Formation unless stated otherwise. All photographs by A. t. Hooft (Leiden). 2. UFAC-182, Cachoeira do Bandeira (Acre, Brazil), rear view. 3. RGM 456 705, Javarí River, near Paumari (Pebas Formation). a, Rear view. b, Detail of sculpture.

Fig. 4. *Pyrgophorus*? sp.
All specimens from sample DGM-2969, Aquidaban (label reads 'Municipio de Carauari'), Amazonas, Brazil. Camera Lucida drawings (also of the other Figs.) by F.P.W. All front views.

Fig. 5. *Littoridina*? sp., DGM-2968, Aquidaban (Amazonas, Brazil). a, Front view. b, Lateral view.

Remarks – The attribution of this species to *Pyrgophorus* is with some hesitation. The convex whorl profile as well as the poorly defined spirals are like those of *Pyrgophorus* sp. observed in the Pebas Formation, where series exist between non-spinose and spinose specimens (Wesselingh, 2006). Roxo's specimens are non-spinose. They also might be attributed to *Lyrodus* Doering, 1884 (Parana River system, Argentina, Uruguay and Paraguay), a genus attributed by Hershler & Thompson (1992) to *Heleobia* Stimpson, 1865 (austral South America, north Africa and Europe). An attribution to the genus *Onobops*, Thompson, 1968, is also possible. Within the Pebas fauna, several *Onobops* species occur (Wesselingh, 2006) that have a similar shell as the specimens documented here. The incomplete preservation of the Solimões material precludes a convincing generic attribution for the moment. *Potamopyrgus* cf. *laciranus* Pilsbry & Olsson, 1935, to which Roxo (1937) attributed these specimens, was transferred to the genus *Dyris* by Nuttall (1990). The current specimens cannot be attributed to *Dyris* Conrad, 1871, a spirally striate genus common in the Pebas Formation, as they lack the regular onset of two or three spirals directly after the protoconch-teleoconch boundary (Wesselingh, 2000, 2006).

***Littoridina*? sp.**
Fig. 5.

Material – Aquidaban (Amazonas, Brazil): DPMN-2968, 1 specimen.

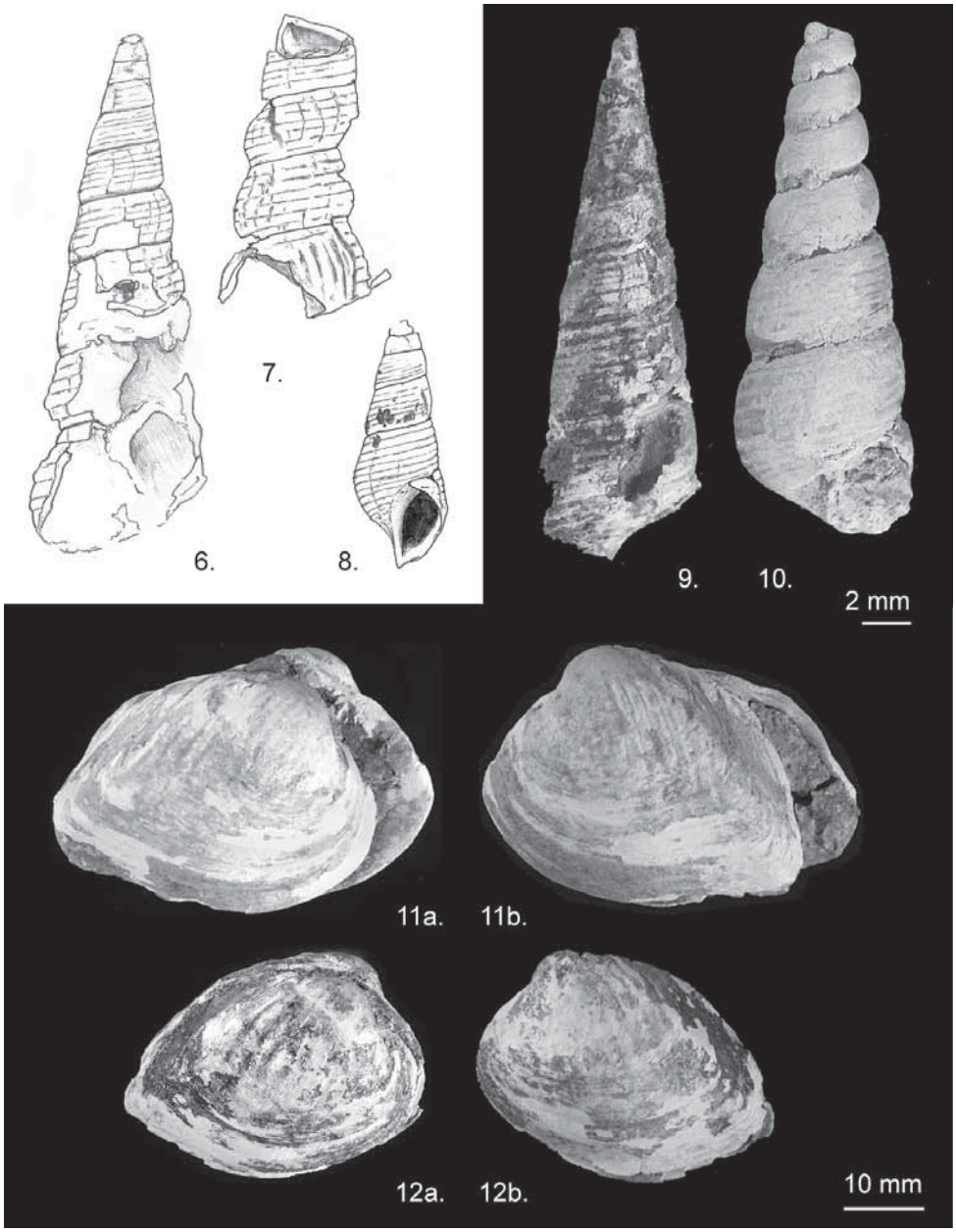
Description – Thin-shelled, smooth, ovate *Littoridina*. The whorl profiles is rather convex and the suture rather impressed for the genus. Growth lines are orthocline to slightly prosocline. The ovate aperture has slightly thickened margins. The base of the aperture is broadly retracted; H 4, W 2.5.

Remarks – This species was not attributed to *Aroapyrgus* Baker, 1931, because of the broadly retracted apertural base. That feature is also found in *Littoridina* species from the Pebas Formation, such as *L. crassa* (Etheridge, 1879), from which it differs by its rounded, ovate outline. *Littoridina crassa* has a clearly conical outline.

Family Pachychilidae Troschel, 1857
***Sheppardiconcha septencincta* (Roxo, 1937)**
Figs. 6-10.

1937 *Hemisinus septencinctus* Roxo, p. 9, fig. 6.
1937 ?*Hemisinus* sp. Roxo, p. 8, figs. 4, 5, 7.
2002 *Sheppardiconcha* spec. Wesselingh *et al.*, fig. 8.
2006 *Sheppardiconcha septencincta* (Roxo, 1937); Wesselingh, p. 201, fig. 250.

Material – Aquidaban (Amazonas, Brazil); DPMN-2951-1 (holotype); DPMN-2971-1, 1 poorly preserved specimen; DPMN-2954-1, 1 poorly preserved specimen; DPMN-2953-1, 1 specimen completely disintegrated; DPMN-2952, 2 incomplete specimens in matrix. Oriente (Acre, Brazil); UFAC-186/UFAC-192, 7 specimens.



Figs. 6-10. *Sheppardiconcha septencincta* (Roxo, 1937). 6. DNPM-2952, damaged specimen in matrix, Aquidaban (Amazonas, Brazil). 7. DNPM-2952, damaged specimen in matrix, Aquidaban (Amazonas, Brazil). 8. DNPM-2951, holotype of *Hemisinus septencinctus* Roxo, 1937, same locality, front view. 9. UFAC-186, Oriente (Acre, Brazil). 10. UFAC-188, same locality, front view.

Figs. 11-12. *Castalia* cf. *ambigua* Lamarck, 1819. 11a-b. UFAC-209, Oriente (Acre, Brazil). 12a-b. UFAC-208, same locality.

Description – All specimens are damaged through abrasion, breakage or dissolution and recristallization. The species is robust and straight-sided. The whorls on early teleoconch whorls are particularly tightly coiled and straight-sided. On later teleoconch whorls the perimeter becomes slightly convex and the suture marginally impressed. The shell is ornamented with five spiral grooves that become broader to form interspaces between flat spiral ribs on later teleoconch whorls. The sigmoid growth lines are obsolete. An expansion of the body whorl, often seen in other *Sheppardiconcha* species (Wesselingh, 2006), is lacking. The leftmost part of the innerlip can be located slightly to the left of the shell's axis in adult specimens. The aperture is severely damaged in all studied specimens. The base of body whorl is rounded; H 21, W 7.

Remarks – The holotype of *S. septencincta* (Fig. 13) is a subadult specimen with a damaged aperture. The outline of this specimen, with its straight sides and an apparent basal siphon, are reminiscent of the spindle-shaped *Hemisinus*, to which it was originally assigned. The apertural outline, however, is the result of breakage of the outer whorl. Close examination revealed that a basal siphon, typical of neotropical thiarids such as *Hemisinus*, is lacking. The straight-sidedness of this specimen falls within the range of morphological variation of juvenile and subadult *Sheppardiconcha* from the same locality. Therefore, all specimens referred to by Roxo (1937) as *Hemisinus septencinctus* and *Hemisinus*? sp. are here transferred to *Sheppardiconcha septencincta* (Roxo, 1937). This species also occurs in the upper parts of the Pebas Formation in assemblages typical of fluviolacustrine depositional environments (Wesselingh *et al.*, 2002).

Class Bivalvia
Order Unionoidea
Family Hyriidae Swainson, 1840
***Castalia* cf. *ambigua* Lamarck, 1819**
Figs. 11, 12.

Material – Cachoeira do Bandeira (Acre, Brazil); UFAC-nn, block of sediment with mould of ventral portion of pair. Oriente (Acre, Brazil); UFAC-207, 1 pair; UFAC-208, 1 pair; UFAC-209, 1 pair; UFAC-210, 1 pair; UFAC-211, 1 pair.

Description – Intermediate-sized (H 32, L 39) globose unionoid that is almond-shaped and has a stout posterior ridge. The upper half of the shell is decorated with a characteristic tightly chevron ornament. This ornament is usually severely damaged in the studied specimens. The umbones are located at about one-third of shell length. The posterior ridge runs to the shell's margin, where it corresponds to a rather acute boundary between posterior and ventral margins. The anterior hinge line rapidly descends into a somewhat pointed rounded anterior margin. The posterior hinge line is slightly curved. No details of the hinge are present in studied material.

Remarks – Roxo (1937) reported *Castalia ambigua* var. *inflata* from his Juruá material. That material could not be studied, but may be related to this species.

Castalia sp. 1
Figs. 13-15.

Material – Oriente (Acre, Brazil); UFAC-202, 1 juvenile pair; UFAC-203, RV; UFAC-204; 1 juvenile pair; UFAC-205, 1 juvenile LV; UFAC-206, 1 fragment.

Description – Subquadrangular (juvenile) to obliquely ovate carinate (adult) shell with a marked posterior ridge and 15-17 well developed, evenly spaced radial ribs around a poorly developed median 'V' (giving the ornament a parallel appearance). The ribs extend to the ventral margin in juveniles and to about half the shell in the adult valve. The posterior margin is smooth. The umbo is located near the anterior margin. The anterior part of the hinge descends rapidly, at an angle of approximately 80° with the straight to gently curved posterior hinge line. The shell becomes progressively inaequilateral and the posterior keel develops from rounded and insignificant to prominent and acute during growth; L 41, H 28.

Remarks – Adult *Castalia* sp. 1 shells are more inaequilateral and have more densely spaced radial ribs than *C.* cf. *ambigua*.

Castalia sp. 2
Figs. 16-18.

Material – Cachoeira do Bandeira (Acre, Brazil); UFAC-174, mould RV. Oriente (Acre, Brazil); UFAC-212, pair; UFAC-213, pair; UFAC-214, 1 RV; UFAC-228, 1 damaged pair.

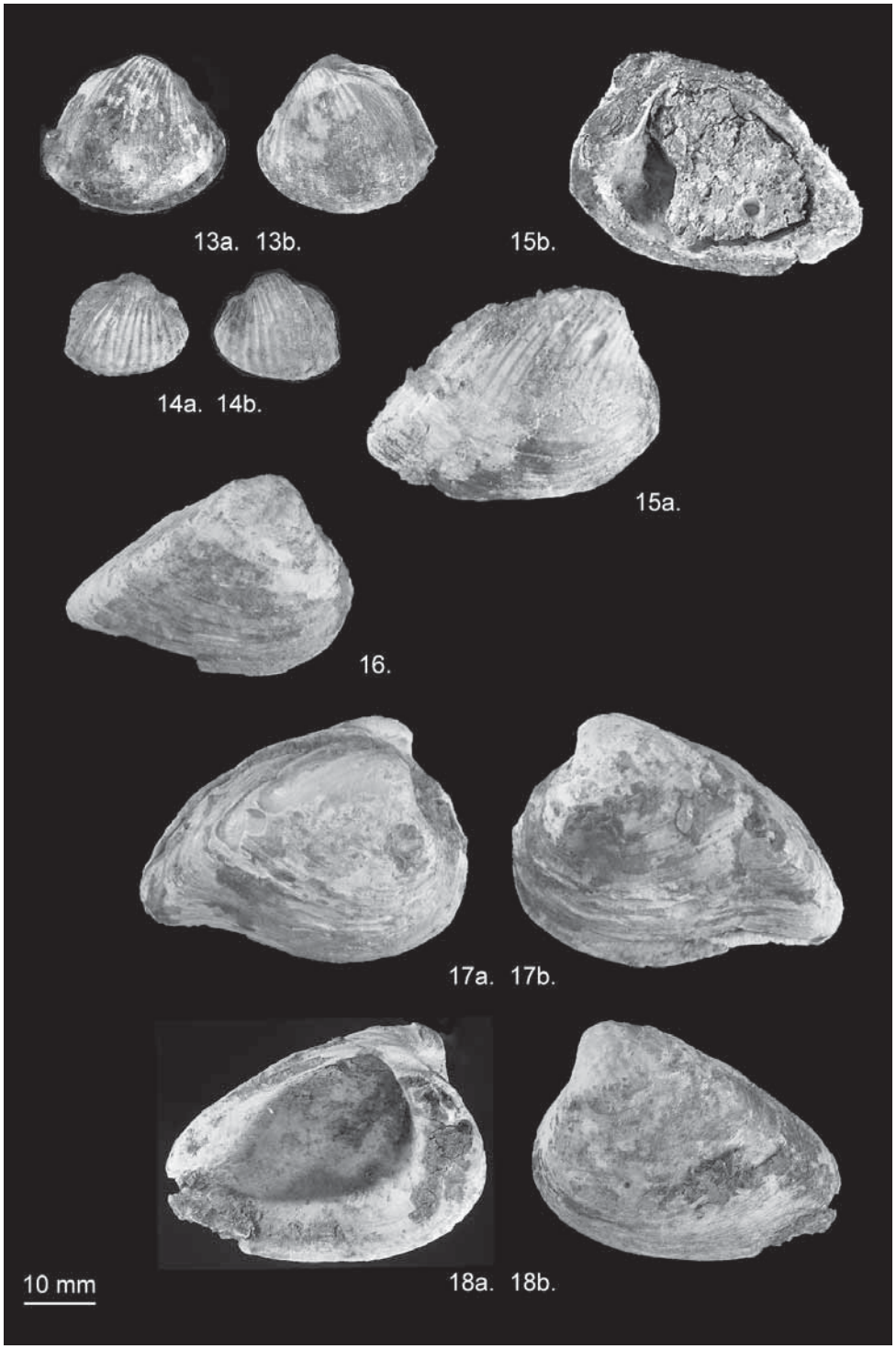
Description – Strongly inaequilateral, almost triangular, strongly carinate unionoid. The ornament is severely damaged in all specimens, but appears to consist of few (*c.* 8-10) low, robust radial ribs near the umbo. Chevron features were not observed due to poor preservation. The umbo is located at a quarter to a fifth from the anterior margin. A very prominent posterior keel is located closely to the dorsal margin of the shells and corresponds to an acute or even produced posterodorsal tip. The dorsal margin can be slightly depressed posteriorly, leading to almost rostrate outline of shell (see Figs. 17, 18); L 46, H 34.

Remarks – The trigonate outline, low shell and few radial ribs, and the tendency to develop a rostrum-like extension posteriorly distinguish this species from *C.* cf. *ambigua* and *Castalia* sp. 1.

Callonaia sp.
Figs. 19-27.

? 1937 *Anisothyris acreana* nov. spec. Maury, p. 5, figs. 1-4 (= Figs. 25-27 herein).

Material – Cachoeira do Bandeira (Acre, Brazil); UFAC-176, mould. Oriente (Acre, Brazil); UFAC-215, 1 RV; UFAC-216, pair; UFAC-217, pair; UFAC-218, damaged LV;


13a. 13b.
15b.
14a. 14b.
15a.
16.
17a. 17b.
18a. 18b.
10 mm

UFAC-219, pair; UFAC-220, damaged LV; UFAC-221, LV; UFAC-222, RV; UFAC-223, LV; UFAC-224, RV; UFAC-225, damaged juvenile RV; UFAC-226, damaged juvenile LV; UFAC-227, damaged juvenile LV. *Anisothyris acreana* Maury, 1937; DPNM-2526, mould RV; DPNM-2529, mould of pair; DPNM-2534, mould of pair; all from outer bend of the Jesumira River (Acre, Brazil).

Description – Semicircular-elongate trigonate to cuneate unionoid with rounded and gently curved posterior ridge. The ventral margin is gently curved. The posterior margin is broadly rounded to slightly tapering. The RV has a strongly developed posterior lateral tooth. The base of the hinge plate is strongly curved upward behind cardinal area in adult specimens. Juvenile specimens are distinctly cuneate. The hinge of juvenile specimens contains a very prominent *Pachydon*-like anterior cardinal tooth, but also contains a second prominent posterior cardinal separated from the former by a deep depression unlike *Pachydon*. The hinge plate of juvenile specimens is comparatively robust; L *c.* 50, H *c.* 38 (UFAC-176). No traces of ornamentation have been found on the shells that appear to have been smooth.

Remarks – We have long been uncertain about the attribution of the juvenile valves (UFAC-225/227) to this species and even to the Unionoidea. Maury (1937) assigned a number of juvenile moulds, that resemble Pebasian corbulids in size and outline, to *Anisothyris,* a *nomen nudum* introduced by Conrad (1871) as a possible replacement name for *Pachydon* Gabb, 1869. The original (aragonitic) shell material appears to have been entirely replaced by calcite or gypsum, precluding assessing the shell mineralogy, which should have made the distinction easy. The hinge features of these supposed juveniles appeared to migrate and change drastically during ontogeny. For example, the posterior cardinal in the RV must have migrated from below the umbo to a location before the umbo. The juvenile architecture of the hinge differs drastically from adult phases. The cuneate outline of the juveniles resembles *Pachydon cuneatus* Conrad, 1871, from the Pebas Formation of Peru and Colombia. However, looking at juvenile shell outlines of the adult valves (that correspond almost 1:1 with the juvenile valves), as well as the possibility of explaining most juvenile hinge features in the light of pre-migrated adult hinge features, leads us to the assignment of all specimens to *Callonaia* sp. 1.

***Diplodon* cf. *longulus* Conrad, 1874**

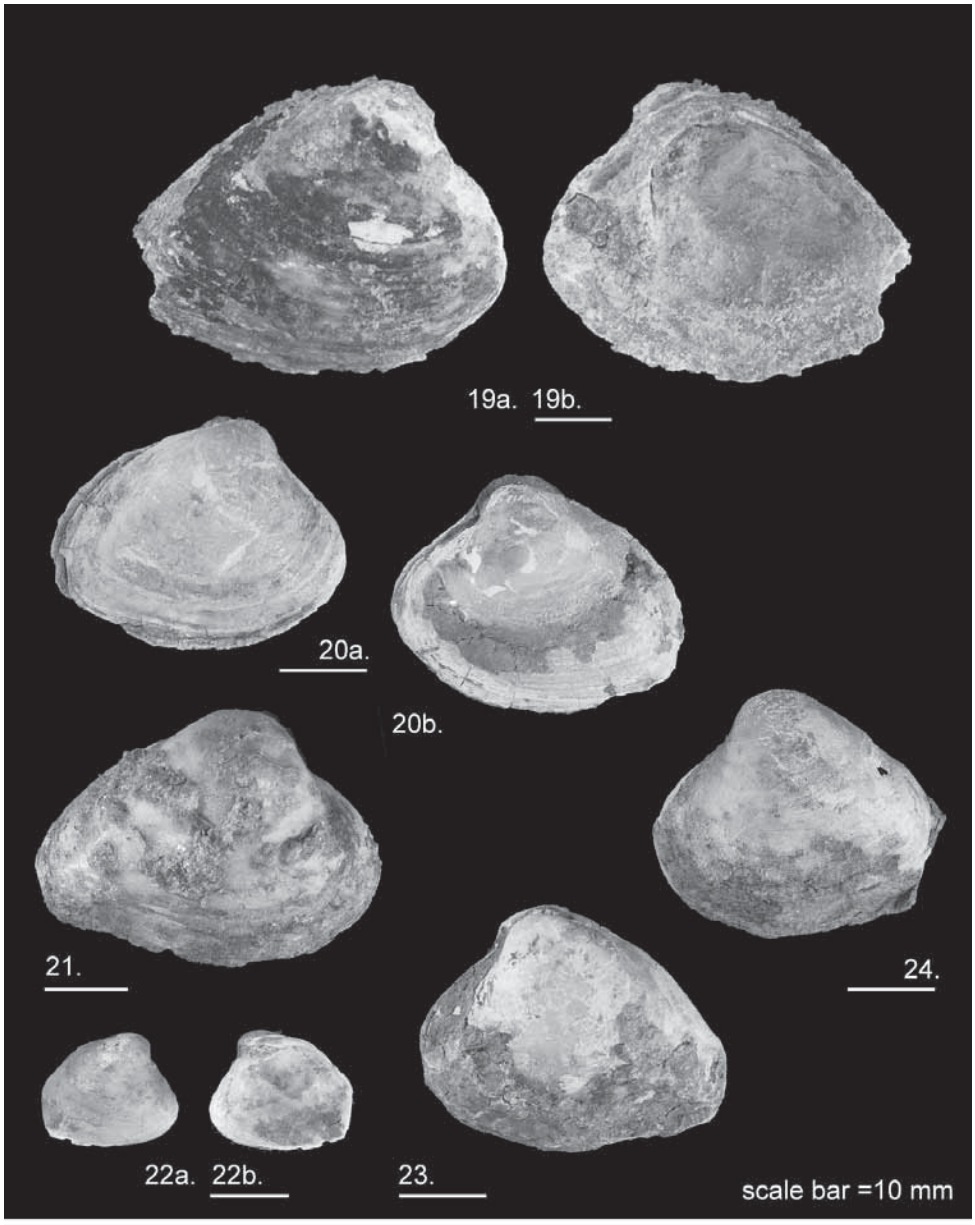
Figs. 28, 29.

1937 *Ecuadorea bibliana* Marshall; Roxo, p. 6, figs. 2, 3?

Material – Cachoeira do Bandeira (Acre, Brazil); UFAC-nn, cast. Oriente (Acre, Brazil); UFAC-195, 1 pair; UFAC-196, 1 pair; UFAC-197, 1 pair; UFAC-198, LV. Aqui-

◀ Figs. 13-15. *Castalia* sp. 1. 13, UFAC-204, Oriente (Acre, Brazil). 14, UFAC-202, same locality. 15, UFAC-203, same locality.

Figs. 16-18. *Castalia* sp. 2. 16, UFAC-214, Oriente (Acre, Brazil). 17, UFAC-213, same locality. 18, UFAC-212, same locality.


19a. 19b.
20a.
20b.
21.
24.
22a. 22b.
23.
scale bar =10 mm


25.
26a. 26b.
27a. 27b.
27c.
5 mm

daban (Amazonas, Brazil); DPMN-2960-1, 1 fragment; DPMN-2958-1, 2 valves of a juvenile pair.

Description – Flat, strongly inaequilateral *Diplodon*, with umbones located at about one eighth lenght from the anterior margin. The anterior and posterior hinge are located on a straight line near the umbo. The anterior tip of the hinge is alate, pointing upwards. The posterior half of the posterior hinge line is gently curving downward. A low and poorly defined posterior ridge is present. The characteristic chevron-like ornamentation is damaged or entirely abraded in studied specimens, but judging from remains possibly corrugate (e.g., non-continuous ribs) and limited to umbonal region; L 78, H 54.

Remarks – An extensive synonymy exists for Pebasian *Diplodon longulus* (Nuttall, 1990; Wesselingh, 2006). Material collected by the senior author in the Pebas Formation justifies Nuttall's synonymy; there is a large variation in outlines and intermediates between these extremes. The Solimões Formation material cannot be attributed with certainty to this species, since details of the external ornament are too poorly preserved. In general these shells are flatter and thinner-shelled then the Pebasian *D. longulus.*

Family Mycetopodidae Gray, 1840
***Mycetopoda pittieri*? Marshall, 1927**
Fig. 30.

1927 *Mycetopoda pittieri* Marshall, p. 1.

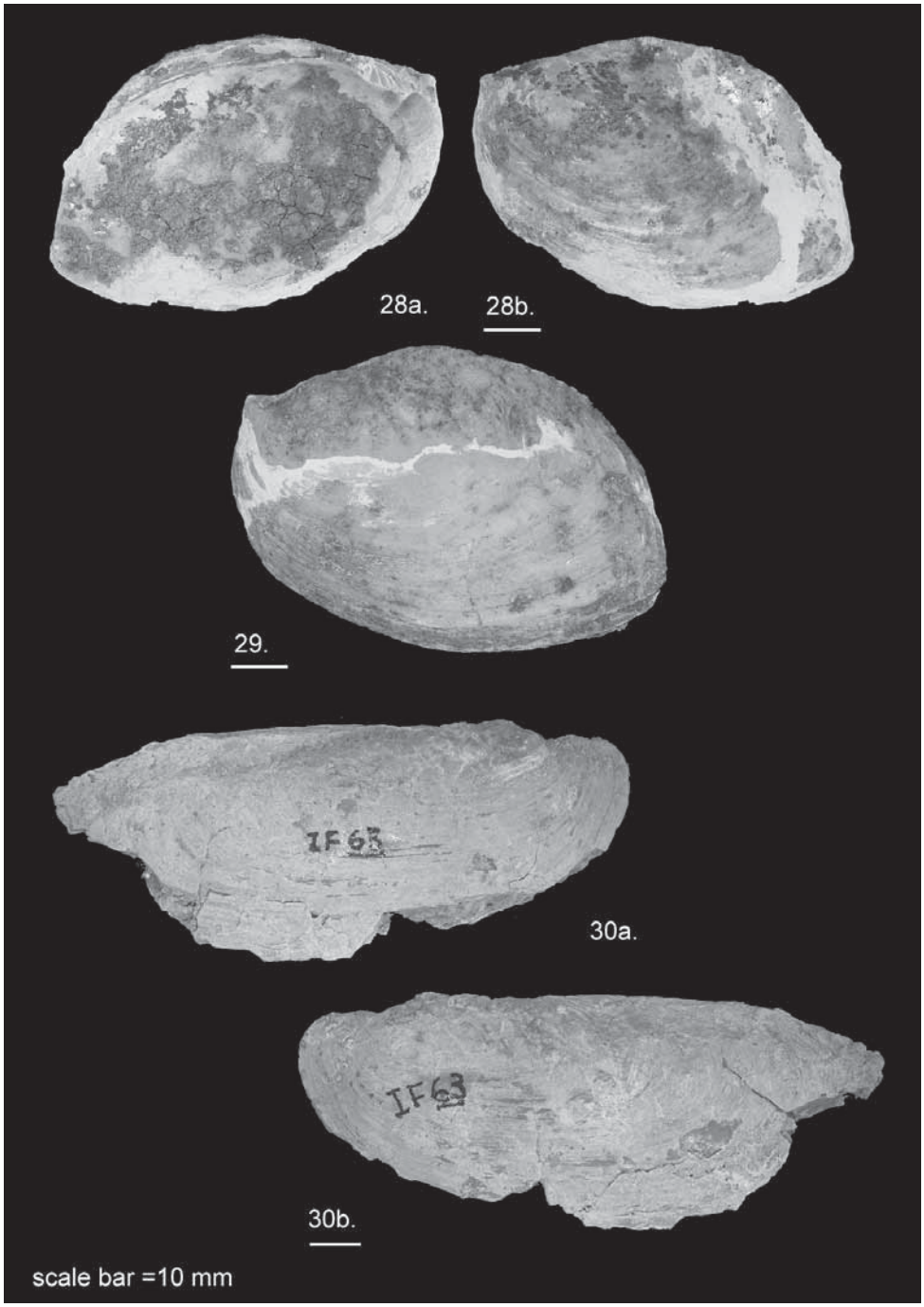
Material – Cachoeira do Bandeira (Acre, Brazil); UFAC-63, 1 damaged pair.

Description – Elongately ovate to strongly inaequilateral shell. The beak is located at about one eighth length from the anterior margin. The shell is tapering anteriorly. The straight posterior hinge line is slightly elevated compared to the anterior hinge line. The shell is rather flat; it is slightly more convex in the anterior half; L 113, H 48.

Remarks – Of the extant *Mycetopoda* species, the Acre species resembles most *M. pittieri* Marshall, 1927. Both have the notched nature of the anterodorsal margin, the gradual down curving of the posterodorsal margin and the slightly different elevation of the anterior and posterior hinge line. However, *M. pittieri* lives nowadays in northern Venezuela (Orinoco drainage and Maracaibo area; data from http://www.inhs.uiuc.edu/), and we have little insight as to the range of morphological variation in other extant *Mycetopoda* species, so the attribution of the fossil material to *M. pittieri* is uncertain.

◀ Figs. 19-24. *Callonaia* sp. 19, UFAC-222, Oriente (Acre, Brazil). 20, UFAC-217, same locality. 21, UFAC-215, same locality. 22, UFAC-226, same locality. 23, UFAC-223, same locality. 24, UFAC-216, same locality.

Figs. 25-27. *Callonaia* sp. Material published as *Anisothyris acreana* by Maury (1937). 25, DNPM-2526, mould RV, outer bend of the Jesumira River (Acre, Brazil). 26, DNPM-2529, mould of pair, same locality. 27, DNPM-2534, mould of pair, same locality.



Figs. 28, 29. *Diplodon* cf. *longulus* Conrad, 1874. Both UFAC-198, Oriente (Acre, Brazil).

Fig. 30. *Mycetopoda pittieri*? Marshall, 1927. UFAC-63, Cachoeira do Bandeira (Acre, Brazil).

Anodontites cf. *trapesialus* (Lamarck, 1819)

Figs. 31, 32.

? 1967 *Anodontites* sp., Santos & Castro, p. 418, fig. 11.

Material – Cachoeira do Bandeira (Acre, Brazil); UFAC-183, mould of pair; UFAC-177, mould of LV. Oriente (Acre, Brazil); UFAC-185, pair; UFAC-199, pair; UFAC-200, 1 valve.

Description – Very large (W 210 for IF185), ovate-trapezoid to cuneate, inaequilateral robust shell. The umbones are located at about one quarter length from the anterior margin. The semidiameter runs from the umbo to one sixth (juvenile) to one-third (adult) of the shell length at the ventral margin. The posterior end of the hinge line is slightly curved downwards. The anterior hinge line is located lower than the posterior hinge line, rather straight, but descending in juvenile specimens. It is tending to become alate in the adult specimen. Details from hinge in all specimens are obscured by cemented carbonate.

Remarks – Roxo (1937, p. 6) mentioned fragments of indeterminate *Anodontites* from Aquidaban that might be attributed to this species. *Anodontites capax* (Conrad, 1874) from the Pebas Formation has posterior and anterior hinge lines in a straight line, lacks a clearly defined semidiameter, and is flatter and more aquilateral then *A.* cf. *trapesialis.* The *Anodontites* sp. reported from the Chandless River (Acre, Brazil) in Santos & Castro (1967) is attributed with a query to *A.* cf. *trapesialis*, since the specimen appears to be more elongate than the material seen during the present study.

Order Sphaerioidea
Family Sphaeriidae Deshayes, 1854

Eupera sp.

Fig. 33.

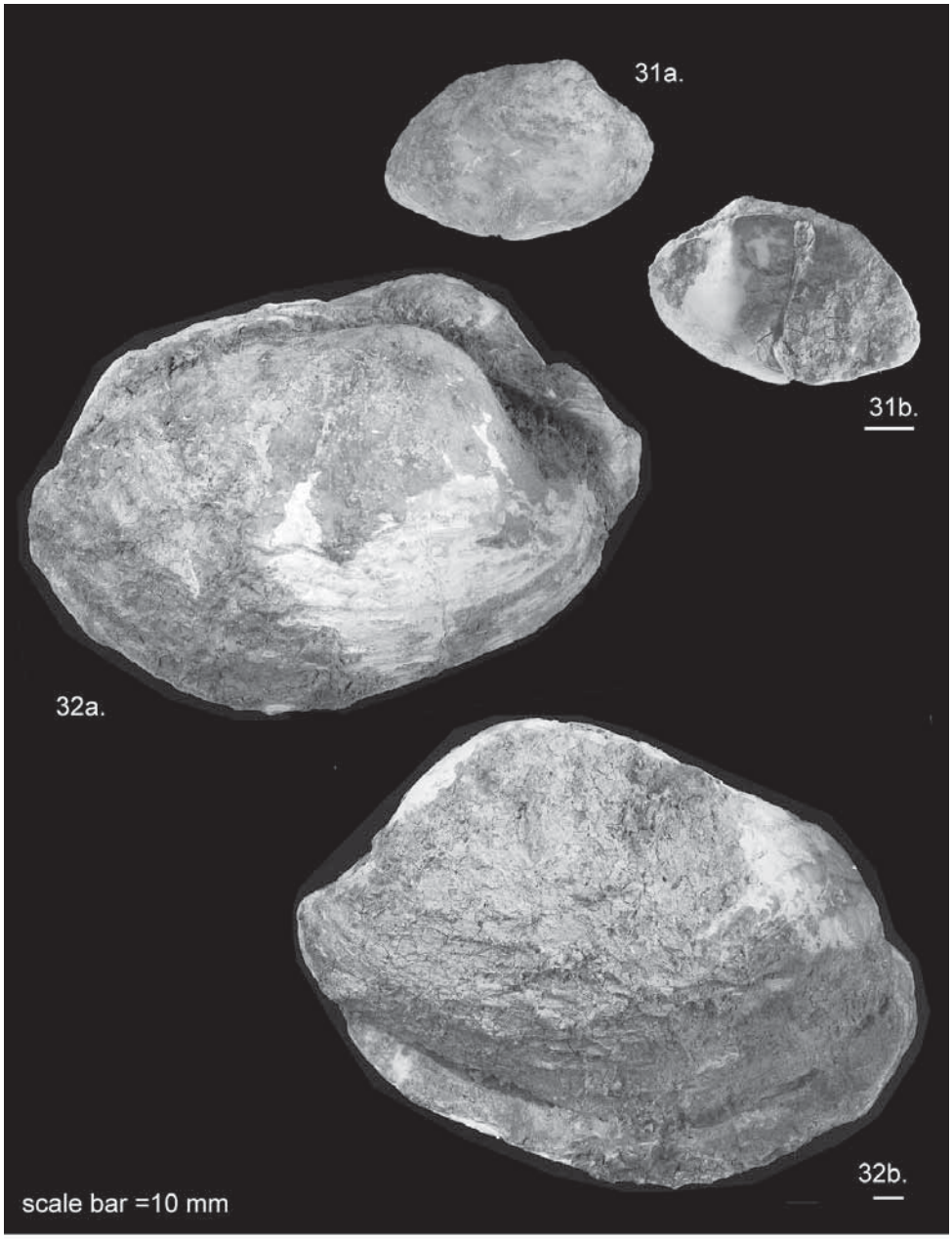
1937 *Sphaerium bahiaensis* Spix; Roxo, p. 7, fig. 1.
2006 *Eupera* sp. Wesselingh, p. 231, figs. 300, 301

Material – Aquidaban (Amazonas, Brazil); DPMN-2961-1, 2 valves. Additional material from the Pebas Formation in Wesselingh (2006, p. 231).

Description – Rather large (W up to 8 mm), comparatively broad, ovate-trapezoid *Eupera*. The posterior margin is higher then the anterior margin; the former can be almost straight, the latter is rounded. The umbo is located at one third distance from anterior margin. The shell contains numerous fine, rather well-defined growth lines; W 8, H 6.

Discussion

Two species reported by Roxo (1937) could not be studied. *Helix* sp. was not recovered in the DPMN collections. '*Stenogyra maritima* Spix' was recovered in the collections of the DPMN, but the material was completely disintegrated (destroyed due to pyrite oxidation).


31a.
31b.
32a.
32b.
scale bar =10 mm


2 mm
33a. 33b.
33c.
33d.

The Solimões fauna studied is dominated by pearly freshwater mussel species. The composition of the fauna (including unionoids, ampullariids and sphaeriids) is very similar to the present day mollusc faunas found in floodplain lakes, and smaller and larger rivers in Amazonia, with the exception of smaller and fragile species, such as planorbiids, that are absent from the newly collected fossil material. The fossil material is poorly preserved (with common dissolution and replacement of the original aragonite by calcite and/or anhydrite), which presumably led to the disappearance of fragile and small species, such as planorbid snails and (most of the) sphaeriid bivalves. The entire fossil fauna is composed of taxa that are incapable of surviving saline conditions.

The newly studied fauna has four species in common with the Pebas fauna. Three of these, Ampullariidae sp. 1, *Sheppardiconcha septencincta* and *Eupera* sp. occur in the Thiaridae-Pulmonata assemblage of Wesselingh *et al.* (2002), the only Pebasian assemblage that is dominated by non-endemics and considered to represent mainly fluvial depositional settings. The fourth species that the Solimões Formation and the Pebas Formation may bear in common, *Diplodon longulus*, is found in lacustrine and fluviolacustrine associations in the latter. Many of the newly studied fossil bivalves, despite their poor preservation, are paired, indicating that they fossilised *in situ.*

Recently, ostracods from Solimões Formation deposits of the Torre da Lua locality near Eirunepé (Amazonas, Brazil), not far from the Aquidaban localities from which Roxo (1937) described his molluscs, have been investigated by Ramos (2006). She described a fauna of eight species from floodplain deposits. Six out of eight species are typical of freshwater environments and Ramos (2006, p. 8) argued that the two *Cyprideis* species, considered by other workers of the Pebas fauna as an indicator of brackish conditions, could represent equally well freshwater settings. Six ostracod species are shared between the Solimões Formation and the Pebas Formation. Two of these species belong to the Pebasian *Cyprideis* flock, the other four are considered to be typical fluviolacustrine taxa.

Combined evidence from mammalian chronology and radiometric age estimates from coeval deposits in adjacent Peru indicate that the Solimões fauna is slightly younger then the Pebas fauna. The predominance of unionoid taxa in the Solimões fauna, added with sphaeriids and ampullariids, are indicative of its fluviolacustrine character, which is corroborated by the ostracod fauna. The geographic widespread occurrence of the faunas in western Brazilian Amazonia indicates that the Pebas fauna must have vanished by the Late Miocene (about 9 Ma) in western Amazonia.

Conclusions

Molluscan faunas from the vertebrate-bearing Solimões Formation of Brazilian Acre and Amazonas states are mainly made up of pearly freshwater mussels. The Solimões

◀ Figs. 31, 32. *Anodontites* cf. *trapesialis* Lamarck, 1819. 31, UFAC-200, Oriente (Acre, Brazil). 32, UFAC-185, same locality.

Fig. 33. *Eupera* sp. DGM-2961-1, Aquidaban (Amazonas, Brazil).

Formation faunas slightly post-date the Pebas fauna of adjacent Peruvian and Colombian Amazonia. The shells were fossilized *in situ* in a floodplain environment. The geographic widespread occurrence of mollusc faunas lacking Pebasian endemic species in Late Miocene deposits of western Amazonia indicate that the Pebas fauna probably was extinguished by that time.

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