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NEW RECORDS OF *TRYONIA* (GASTROPODA, COCHLIOPIDAE) FROM THE MIO–PLIOCENE SOLIMÕES FORMATION (STATE OF AMAZONAS), BRAZIL

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ABSTRACT – This paper deals with the record of gastropods of the family Cochliopidae, genus *Tryonia*, from the Mio-Pliocene Solimões Formation, from the borehole 1AS-34-AM drilled in the upper Jutaí River, Amazonas State, Brazil. We report four species, including *Tryonia scalarioides scalarioides*, *Tryonia* cf. *T. nuttalli*, besides of a new species and other kept in open nomenclature.

Keywords: Solimões Formation, Mio–Pliocene, *Tryonia*, Amazonas, Brazil.

RESUMO – Este trabalho consta de novo registro dos gastrópodes da família Cochliopidae, gênero *Tryonia*, da Formação Solimões (Mio-Plioceno), oriundos da perfuração 1AS-34-AM, às margens do Rio Jutaí, Estado do Amazonas, Brasil. Dentre os táxons identificados na unidade foram registradas as espécies *Tryonia scalarioides scalarioides* e *Tryonia* cf. *T. nuttalli*, além de outras duas espécies, uma espécie nova aqui descrita e uma mantida em nomenclatura aberta.

Palavras-chave: Formação Solimões, Mio–Plioceno, *Tryonia*, Amazonas, Brasil.

INTRODUCTION

The Solimões Formation comprises Neogene deposits of the Solimões and Acre basins covering most of western Brazilian Amazonia. This formation reaches a maximum thickness of 980 m (Maia *et al.*, 1977), and correlates with other Neogene units of Ecuador, Peru (Antoine *et al.*, 2016), Colombia (Jaramillo *et al.*, 2017) and Venezuela (Scheyer & Delfino, 2016). The unit comprises lacustrine and fluvial depositional settings, with some marginal marine intervals. They were deposited in a series of Miocene mega-wetlands spanning much of inland northern South America. These wetlands developed as a result of regional subsidence related to Andean uplift (Hoorn *et al.*, 2010).

According to Hoorn *et al.* (2010), the paleoenvironmental evolution for Neogene Amazonia is subdivided in three distinct phases: (i) a fluvio-lacustrine precursor phase (~24 to 16 Ma); (ii) Pebas phase (~16 to 11.3 Ma), represented by a wide floodplain system (mega-wetland) with episodic marine influence; and (iii) Acre phase (<11.3 to 7 Ma), with a fluvial-tidal-dominated scenario. A more recent study of the Amazon submarine fan, in the foz of Amazon Basin, based on palynology and geochemistry, indicate an age of 9.4 to 9 Ma (late Miocene) for the establishment of the actual Amazon River drainage system (Hoorn *et al.*, 2017).

A range of age estimates are proposed for the Pebas and Solimões formations: early–late Miocene (Hoorn, 1994 a,b; Muñoz-Torres *et al.*, 1998; Muñoz-Torres *et al.*, 2006; Wesselingh *et al.*, 2006b); late Miocene to Pliocene

(Leite, 2006; Silva, 2008); Pliocene (Purper, 1979) and Plio-Pleistocene (Shepard & Bate, 1980). The Solimões Formation contains late Miocene intervals that are younger than the Peruvian Pebas Formation, which today is considered to be early to early-late Miocene. Palynological zones of the Solimões Formation range from early Miocene to early Pliocene (Hoorn, 1993; Leite, 2006; Leite *et al.*, 2017; Silva-Caminha *et al.*, 2010; Silveira & Souza, 2015).

The Solimões Formation is rich in fossils, with abundant mollusks and ostracods, as well as fish, amphibians, reptiles and plant remains (Wesselingh, 2006; Ramos, 2006; Gross *et al.*, 2013; Kachniasz & Silva-Caminha, 2016). Various studies were performed on the mollusk fauna from the Solimões Formation (Etheridge, 1879; Roxo, 1924, 1935, 1937; Maury, 1937; Santos & Castro, 1967; Costa, 1979, 1980; Nuttall, 1990; Wesselingh *et al.*, 2006a,b,c; Wesselingh & Ramos, 2010). The fauna of the contemporary Pebas Formation from adjacent Peru and Colombia has been studied in detail (Wesselingh, 2006), and was found to be dominated by endemic bivalve and gastropod species.

The current paper explores new records of the genus *Tryonia*, collected from the 1AS-34-AM borehole drilled in the upper Jutaí River, State of Amazonas, Brazil. We report the occurrence of a new species here, and aim to contribute to document and understand the paleogeography and evolution of this group.

PALAEOBIOGEOGRAPHY OF THE GENUS *TRYONIA*

Tryonia is a genus of the family Cochliopidae (superfamily Truncatelloidea), whose oldest occurrences are reported from Miocene deposits in North and South America (Hershler *et al.*, 1999 a,b; Hershler, 2001; Wesselingh, 2006; Wesselingh & Macsotay, 2006; Czaja & Estrada Rodriguez, 2015). The genus was very abundant in the Amazonian Pebas System during the Miocene. Nowadays, it is mostly found in southwestern North America (Figure 1), with few additional records pointed to Central America (Hershler, 2001). Wesselingh *et al.* (1999) correlated the distribution of *Tryonia* with putative migratory routes of birds along springs, swamps, and lakes of America.

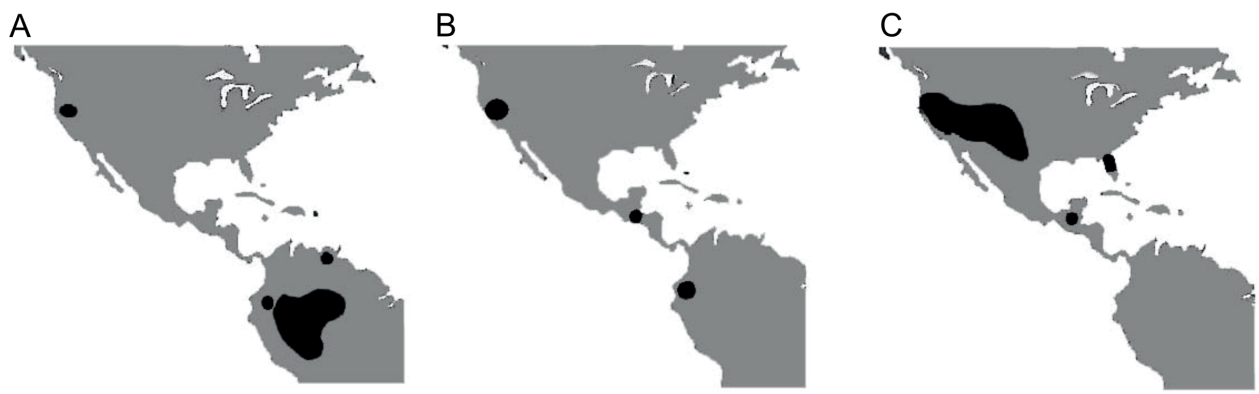

Figure 1. Distribution of *Tryonia* during Miocene (**A**), Pliocene (**B**) and Recent (**C**). Modified from Wesselingh *et al.* (1999).

MATERIAL AND METHODS

Samples were collected from 1AS-34-AM borehole (Figure 2, *c*. 05º37'S; 69º10'W) drilled at the Jutaí River bank (State of Amazonas, Brazil). The borehole is located in the southern margin of the Solimões Basin, an east-west trending intracratonic basin located in western Brazilian Amazonia.

The 1AS-34-AM borehole (05º37'S; 69º10'W), was drilled through Carvão Project, in the years 1975–76 (Figure 3). This project was executed by the Departamento Nacional de Produção Mineral/Companhia de Pesquisa de Recursos Minerais (**DNPM/CPRM**) services. Samples from sixteen fossiliferous intervals were analyzed: 169.65 m; 130.85 m; 128.82 m; 124.87 m; 122.49 m; 121.09 m; 115.0 m; 115.3 m; 113.8 m; 113.1 m; 98.6 m; 95.38 m; 91.0 m; 88.71 m; 86.72 m; and 85.29 m in depth. The samples were washed (sieve mesh 32) and the mollusk material was selected under a Zeiss SV6 stereoscopic microscope at the Earth Sciences Department of Museu Paraense Emílio Goeldi. The material was studied using Scanning Electron Microscope (**SEM**) facilities at the laboratories of Museu Paraense Emílio Goeldi. Identifications followed classifications of Nuttall (1990), Hershler (2001) and Wesselingh (2006). Each specimen was measured according to methods proposed by Hershler & Landye (1988), with the support of a Stereoscopic Microscope of CCTE-MPEG, at 1.6x magnification. Number of whorls and four measurements were included in this paper (Figure 4): height of the shell (**H**); height of the aperture (**Hap**); width of the shell (**W**); width of the aperture (**Wap**). Type material is housed in the Paleontological collection at Museu Paraense Emílio Goeldi (**MPEG**) under the numbers MPEG-2356-I to MPEG-2359-I.

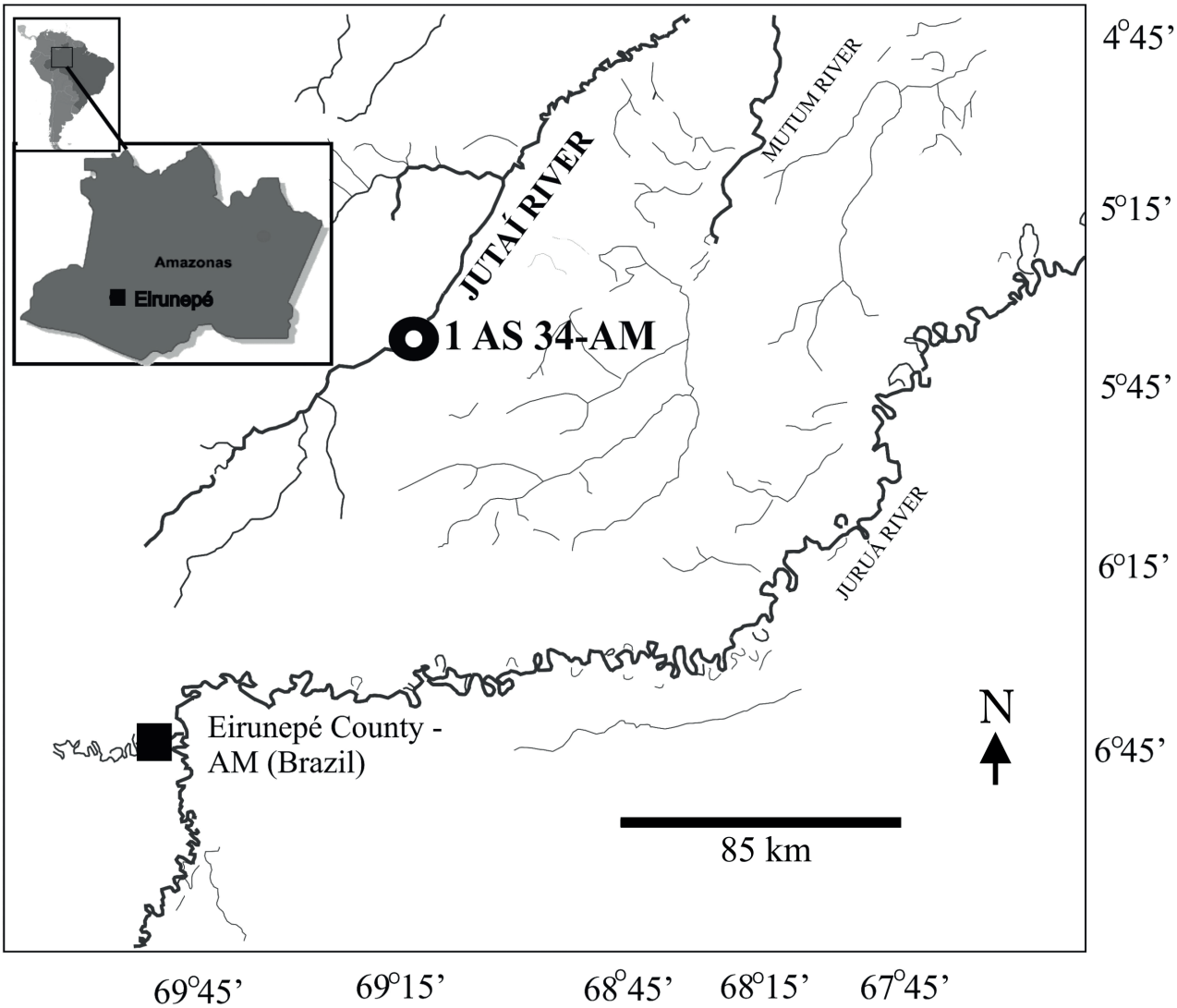

Figure 2. Geographic location of the 1AS-34-AM borehole.

RESULTS

Four species of *Tryonia* were registered in the material (Figures 5, 6). One of them concerned to *Tryonia scalarioides scalarioides* (Etheridge, 1879), other to *T. cf. T. nuttalli* Wesselingh (2006), other is the new species *T. globosa* sp. nov., and one is left in open nomenclature (*Tryonia* sp.) due to the poor quality of the material.

Tryonia Stimpson, 1865

Type species. *Tryonia clathrata* STIMPSON, 1865.

Type locality. White River drainage, Southern Nevada, USA.
Remarks. As in other *Tryonia* specimens from the Neogene of Western Amazonia (*e.g.* Wesselingh, 2006), all material here identified as *Tryonia* has well-developed axial ornamentation. Most shell characters described in earlier papers for *Tryonia* are found among specimens from the 1AS-34-AM borehole. However, we found the protoconch-teleoconch boundary in some specimens to be located at up to 2.3 whorls. This is more than previously reported, but possibly still intraspecific variation.

Tryonia scalarioides scalarioides (Etheridge, 1879)
(Figures 5D–F, 6A–C)

1879 *Melania scalarioides* Etheridge, 87 (pl. 7, fig. 8).
1990 *Liris scalarioides* Nuttall, 206–207, 354 (figs. 139–146, 456).
2006 *Tryonia scalarioides scalarioides* Wesselingh, 47 (figs. 23–25).

Extended diagnosis. transcribed of Wesselingh (2006). Robust, tuberculate *Tryonia* (SA 22–27°) with a characteristic spiral keel delimiting the base of the body whorl; robust,

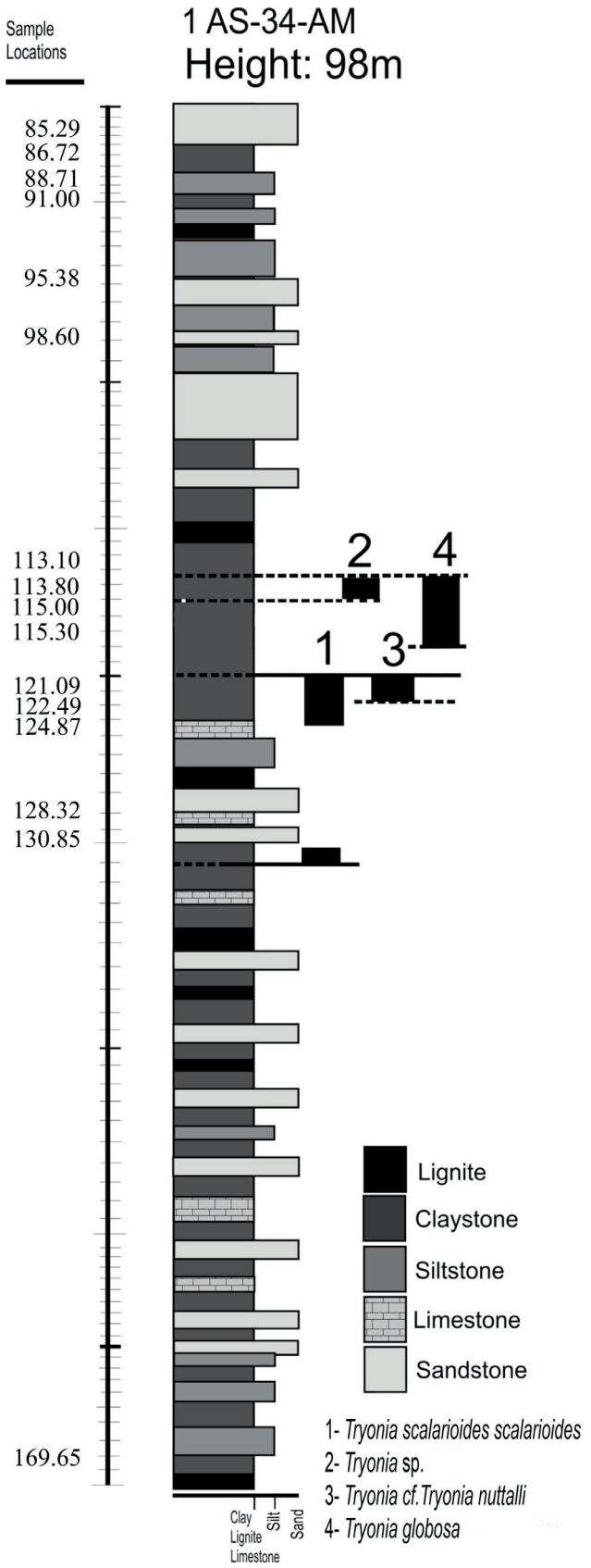

Figure 3. Vertical section of 1AS-34-AM borehole and the distribution of Tryonia´s species.

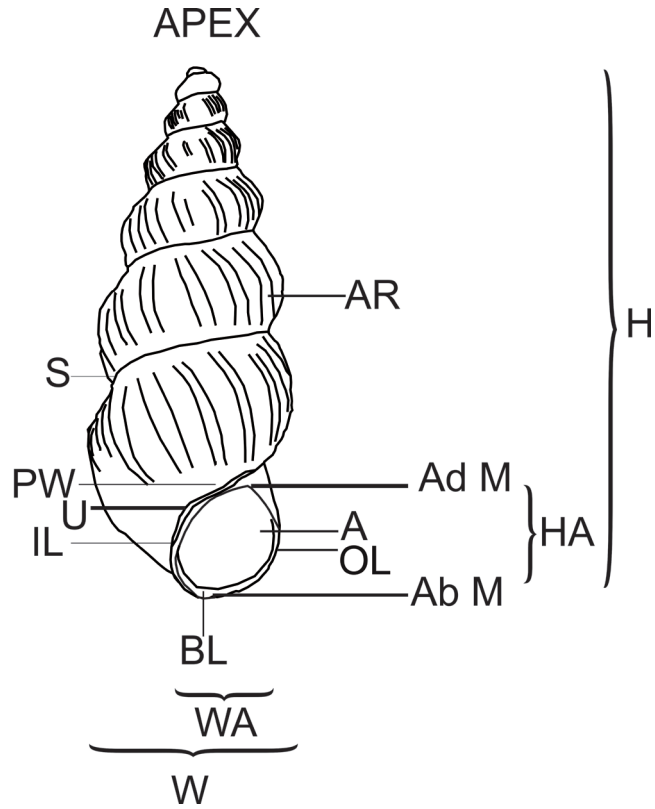

Figure 4. Morphological characters used in this paper, on a schematic drawing of a *Tryonia scalarioides scalarioides* specimen (MPEG-2359-I/4). **Abbreviations: AR**, axial ribs; **Ab M**, abapical margin of aperture; **H**, height (or length); **HA**, height of aperture; **W**, width of shell; **WA**, width of aperture; **S**, suture; **PW**, parietal wall; **U**, umbilicus; **IL**, Inner lip; **OL**, Outer lip; **BL**, basal lip; **Ad M**, adapical margin of aperture.

broad (sometimes elongate knob-like), slightly prosocline axial ribs that lower towards the sutures, reaching the largest height about medially giving the shell a shouldered appearance; median spiral rib well developed on early teleoconch whorls, becoming very thin and low on later teleoconch whorls; embryonic shell (nucleus diameter 40–70 µm) inclined with very fine low marginal wrinkles; boundary with teleoconch-2 at *c.* 0.6 whorls marked by a broad and low axial depression; remainder protoconch markedly bulbous and erect; protoconch-teleoconch boundary at 1.3–1.8 whorls poorly delimited by sudden increase of densely spaced growth lines; gradual development of spiral keel at two thirds to three fifths of the whorl height, with increasingly well-developed subsutural ramp; both fade after the third teleoconch whorl; 9–14 microscopic, regularly spaced spiral riblets may develop on the first two teleoconch whorls; at the second teleoconch whorl broad, slightly prosocline, axial undulations develop that later become clear ribs (13–17 per whorl); at the third teleoconch whorl a very fine secondary spiral may be present at two fifths of the whorl height and uncommonly a spiral rib may be visible at the lower suture; the latter becomes visible before the aperture as a marked, robust spiral that bounds the rather flat base of the body whorl; growth lines very fine and prosocline, on early teleoconch whorls crossing axial

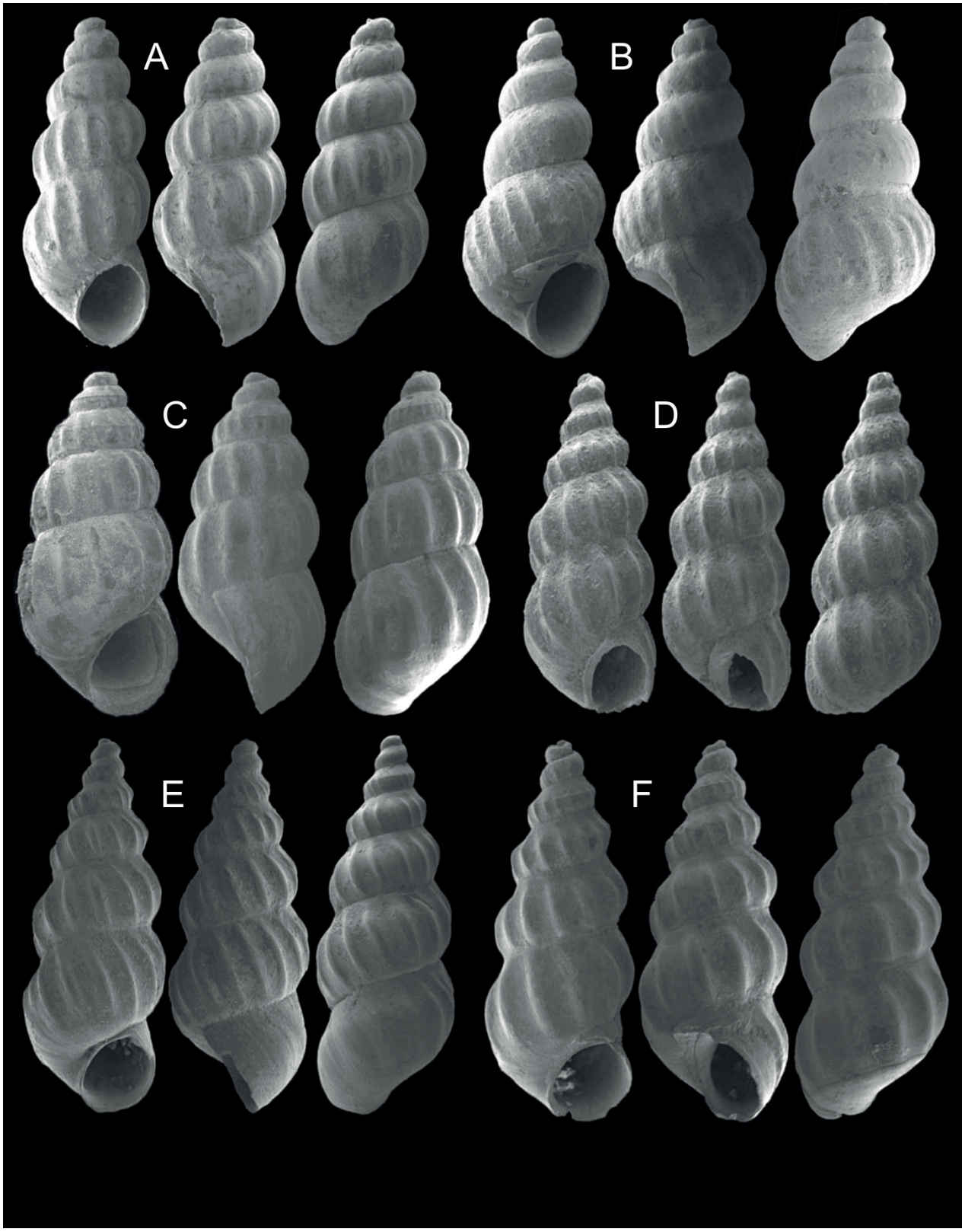

Figure 5. Species of *Tryonia* identified in this paper. **A**, *Tryonia* sp. (MPEG-2356-I, H = 3.06 mm); **B**, *Tryonia cf. T. nuttalli* (MPEG-2358-I/1, H = 3.00 mm); **C**, *Tryonia globosa* sp. nov. (holotype, MPEG-2357-I/1, H = 3.48 mm); **D–F**, *Tryonia scalarioides scalarioides*; **D**, MPEG-2359-I/3 (H = 2.64 mm); **E**, MPEG-2359-I/1(H = 4.08 mm); **F**, MPEG-2359-I/2 (H = 3.42 mm).

ribs; on latter whorls becoming less prosocline; axials with broad, concave interspaces; aperture adnate or very rimately detached, subovate; margins thin; columellar lip can be slightly erect; shell imperforate or with rimate umbilicus.

Figured specimens. MPEG-2359-I/1 H: 4.08 mm; W: 1.62 mm; HA: 0.84 mm; WA: 0.72 mm; 6.6 whorls. MPEG-2359-I/2 L24: H: 3.42 mm; W: 1.38 mm; HA: 0.72 mm; WA: 0.6 mm; 6.3 whorls. MPEG-2359-I/3: H: 2.64 mm; W: 1.2 mm; HA: n.a. (aperture damaged).

Other material. MPEG-2359-I/4 and others 39 additional specimens.

Remarks. The specimens here described are quite similar to the material reported by Nuttall (1990) as *Liris scalarioides*, with a few differences. MPEG-2359-I/1 has spiral ornament over the entire shell, while it is restricted in the material figured by Nuttall (1990) to the intermediate teleoconch whorls. In Nuttall's specimens 14 to 25 axial ribs per whorl are present; in the material studied here the range is between 14 to 32 ribs. Moreover, specimen MPEG-2359-I/1 of this paper is suchlike Nuttall's specimens, despite the shoulders observed in some of his shells (*e.g.* GG21561, GG21563 and GG21562). Specimen MPEG-2359-I/1 has more prominent subsutural ramps. Furthermore, in our material the axial ribs are closer set and more numerous on intermediate teleoconch whorls than in Nuttall's material.

The specimens described in this study, especially MPEG-2359-I/2, also resemble *Tryonia scalarioides scalarioides* as reported by Wesselingh (2006) from Macedonia (Colombia) and Santa Elena (Peru) outcrops. Wesselingh's material contains fewer axials per whorl than our Jutai material. The Jutai specimens also resemble specimens described by Costa (1980) as *Liris minuscula*, particularly her MP-I-6279/32 specimen. Both share a marked spiral ornament ("keeler belt" according to Costa, 1980, 1981) in the middle of the shell. However, this keel covers more whorls (two to four whorls) in MP-I-6279/32 than in our material (two to three whorls), and are located on early teleoconch whorls only. There are also differences in the aperture shape. MP-I-6279/32 has subangulate to angulate adapical and abapical edges, whereas the specimens described here are more circular. In addition, the descriptions of Costa (1979, 1980) lack reference to a spiral sculpture under the keels, differing of the specimens here identified.

Occurrence. 1AS-34-AM borehole (5°37'00"S;69°10'00"W) at 121.49 and 130.85 m of depth, east of Jutaí River, State of Amazonas, Brazil.

Distribution. Late Cenozoic, Pebasian, Canamá, Peru (Etheridge, 1879); Iquitos, Peru (de Greeve, 1938); Três Unidos, Peru (Roxo, 1924; Costa, 1981); Cachoeira das Tracoas, Brazil (Roxo, 1924); Atalaia do Norte and São Paulo de Olivença, Brazil (Costa, 1980); Puerto Nariño, Colombia (Nuttal, 1990); Santa Elena (Loreto, Peru), Pebas Formation, MZ8 (upper middle–lower upper Miocene); Macedonia (Amazonas, Colombia), Pebas Formation, MZ11 (upper middle–lower upper Miocene) (Wesselingh, 2006).

Tryonia cf. Tryonia nuttalli Wesselingh, 2006
(Figures 5B, 6E)

Figured specimens. MPEG-2358-I/1: H: 3.0 mm; W: 1.32 mm; HA: 0.84 mm; WA: 0.6 mm; 5.75 whorls.

Other material. MPEG-2358-I/2 to MPEG-2358-I/8.

Diagnosis. Small, elongated-conic shells. Axial sculpture moderately to strongly marked and slightly prosocline, with slight spiral line crossing axial ribs at intermediate whorls. Outline slightly convex.

Remarks. Our specimens are similar to *Tryonia nuttalli* Wesselingh (2006), however differ in its smoother ornamentation pattern. *T. nuttalli* is a highly variable taxa but we could not attest herein its synonymy with the present species. In its diagnosis, Wesselingh (2006) attends to deep sutures, flattened whorl profile and rounded marked axial ornament such species exhibits. Nevertheless, samples described in this paper lack the same pattern. It is observed their axial ribs are not as curved or prominent as in reported specimens of *T. nuttalli*. Besides, and as previously stated, materials figured by Wesselingh (2006) reveal deeper sutures and more flattened whorls, raising doubts for a precise identification. *Tryonia cf. T. nuttalli* resembles also in shape and outline to specimens of *Liris scalarioides* (GG21561, GG21563 and GG21562) illustrated by Nuttall (1990). However, the axial sculpture of the latter specimens tends to be more marked comparing to *Tryonia cf. T. nuttalli.* Furthermore, the shell outline of Nuttall's three specimens is more convex and the suture is slightly deeper. Specimens of *Tryonia cf. T. nuttalli* are also similar to *Tryonia minuscula* (Gabb, 1869) as illustrated by Wesselingh (2006), though the axial ribs of the former are more widely spaced and less numerous.

Occurrence. 1AS-34-AM borehole (5° 37'00"S; 69° 10'00"W) at 121.09 m of depth, east of Jutaí River, State of Amazonas, Brazil.

Tryonia globosa sp. nov.
(Figures 5C, 6F)

1990? *Liris* sp. Nuttall, 208–210 (figs. 149–153).

Derivation name. From the globose shape of the shell.

Holotype. MPEG 2357-I/1. H: 3.48 mm; W: 1.68 mm; HA: 1.02 mm; WA: 0.84 mm; 5.6 whorls.

Paratype. MPEG-2357-I/2 H: 1.38 mm; W: 0.96 mm; HA: 0.54 mm; WA: 0.42 mm; 3.6 whorls.

Type locality. 1AS-34-AM borehole (5°37'00"S;69°10'00"W) at 115.3 m of depth, east of Jutaí River, State of Amazonas, Brazil.

Other material. MPEG-2357-I/3 severely fragmented across aperture, growth lines damaged.

Diagnosis. Shell small, ovate-conic. Relatively broad and with high whorls. Axial ribs prominent, orthocline to slightly prosocline, with a fine spiral line delimitating axial ribs at intermediate whorls. Whorl profile rounded. Suture deeply impressed. Aperture relatively large and ovate.

Description. Small, outline ovate conical. Whorls relatively rounded; suture deeply impressed. Protoconch bulbous, smooth, consisting of 1.5 whorls. Protoconch-teleoconch boundary marked by the onset of spiral line forming upper

limit of axial ribs at subsequent (intermediate teleoconch) whorls. Axial ribs are orthocline to slightly prosocline, continue prominently accross the entire teleoconch; from 14 to 22 per whorl. Ribs become more widely spaced on the body whrol, with relatively wide concave interspaces. Growth lines are extremely fine and prosocline. Body whorl slightly globose comparing to spire whorls. Aperture ovate, base broadly rounded. Outer lip slightly thickened, basal part slightly projecting. Shell imperforate.

Remarks. *Tryonia globosa* sp. nov. is more inflated and with a marked axial ornamentation, whose ribs are more spaced, specially at the bodywhorl, compared to other *Tryonia* species described from the Solimões/Pebas Formation. Another remarkable trace regards to thickness of basal lip, well developed and downward prominent for the holotype.
Occurrence. 1AS-34-AM borehole (5°37'00"S; 69°10'00"W) at 113.8 and 115.3 m of depth, east of Jutaí River, State of Amazonas, Brazil.

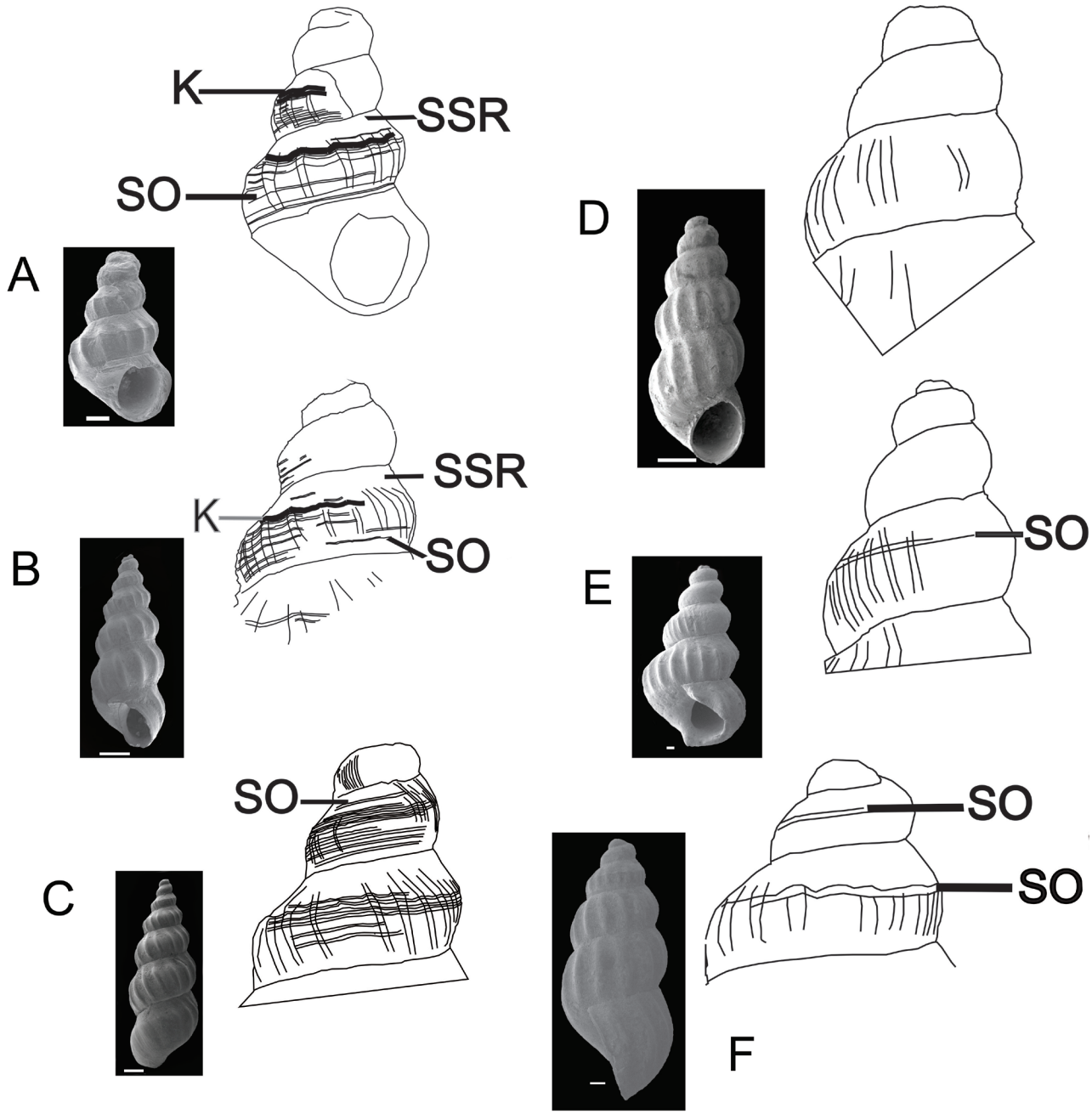

Figure 6. Diagnostic characters defined for *Tryonia* species. **A–C**, *Tryonia scalarioides scalarioides*. Dark line in A and B indicates presence of keel (**K**) forming base of subsutural ramp (**SSR**). **D**, *Tryonia* sp.; **E**, *Tryonia cf. T. nuttalli*, with spiral ornament (**SO**) crossing axial ribs on early teleoconch whorls. **F**, *Tryonia globosa* sp. nov. with well defined axial ribs on early teleoconch whorls bounding spiral ridge forming poorly delimited shoulder. Height: A = 1.479 mm; B = 3.42 mm; C = 4.08 mm; D = 3.06 mm; E = 2.316 mm; F = 3.48 mm.

Tryonia sp.
(Figures 5A, 6D)

Figured specimen. MPEG-2356-I.
Material. One specimen. Damaged, available only through photographic register.
Dimensions. MPEG-2356-I. H: 3.06 mm; W: 1.2 mm; HA: 0.72 mm; WA: 0.66 mm; 5.25 mm whorls.
Description. Shell small, elongate-conic. Convex outline. Suture slightly to strongly impressed. Protoconch bulbous, smooth, of 2.3 whorls. Protoconch-teleoconch boundary delimitated by slight-marked axial ribs, becoming stronger at body whorl. Axial sculpture consists of orthocline to slightly prosocline ribs, from 10 to 20 ribs per whorl. Ribs of spire slighter and closer to each other comparing to those of body whorl, separated by concave inter-spaces. Aperture subcircular, abapical edge of peristome circular, adapical edge slightly subangulated. Outer and basal lips thin. Shell imperforate.
Remarks. MP-I-6279/30 specimen of Costa (1980) resembles our MPEG-2356-I, except for the axial ribs, which are more numerous in the latter. *Tryonia* sp. is also similar to *Tryonia nuttalli* Wesselingh (2006), from Michana (Peru), but that species contains more pronounced subsutural ramps. Besides, *T. nuttalli* has two or three spirals at intermediate whorls, whilst *Tryonia* sp. has no spiral ornament at all. Furthermore, the protoconch of *T. nuttalli* presents up to 1.7 whorls, whereas in *Tryonia* sp. the protoconch can reach up to 2.3 whorls. Finally, *T. nuttalli* of Wesselingh (2006) has an aperture with thin margins, which differs from the reinforced apertural margins of *Tryonia* sp. *T. scalarioides* specimens of Wesselingh (2006a) and Nuttall (1990) are more aciculate towards the apex, and the whorls are separated by deeper sutures, conferring a more flattened morphology. Moreover, spiral lines of *T. scalarioides* are more numerous and evident.
Occurrence. 1AS-34-AM borehole (5º37'00"S;69°10'00"W) at 113.8 m of depth, east of Jutaí River, State of Amazonas, Brazil.

DISCUSSION AND CONCLUSIONS

We only observed *Tryonia* specimens in clay layers, indicating low energy depositional environments, consistent with a lacustrine origin. Modern *Tryonia* are known mostly from springs and lakes with low salinity, and fossil species have been reported almost exclusively into lake deposits (Hershler, 2001; Wesselingh *et al.*, 2002).

Fossil occurrences of *Tryonia* in Amazonia comprise five species: *T. nuttalli* Wesselingh, 2006, *T. semituberculata* (Nuttall, 1990), *T. scalarioides* (Etheridge, 1879), *T. acicularis* (Nuttall, 1990) and *T. minuscula* (Gabb, 1869). These species are typical for the Pebas Formation of Peruvian and Colombian Amazonia, but several have been reported before also from the Brazilian border zone, Ecuador (as *Liris*: see Nuttall, 1990 for reference), and Venezuela (Wesselingh & Mactosay, 2006).

With the exception of *Tryonia scalaroides scalaroides* specimens, other individuals from 1AS-34-ASM borehole here identified and described differ considerably in morphology from other *Tryonia* species from the literature. One new species could be registered and nominated as *Tryonia globosa* sp. nov. Other two lack enough preserved material for a more accurate identification, and were attributed to *Tryonia* sp. and *Tryonia cf. Tryonia nuttalli*. Our records contribute to the knowledge of gastropod diversity from the Miocene of Amazonia, and extends the record of the genus *Tryonia* further south of State of Amazonas.

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