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# Systematic review of brazilian Nautiloidea cephalopods

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**Abstract**

This work deals with the systematic study of the nautiloid cephalopods from Brazil recorded in Manacapuru, Ponta Grossa, Maria Farinha and Pirabas formations (Silurian-Devonian, Devonian, Paleocene and Lower Miocene, respectively) at Pará, Paraná and Pernambuco states. Herein are presented the Paleozoic species *Michelinoceras* cf. *M. telamon* (Hall, 1879), *M.* sp.A, *M.* sp.B and the first record of *Trematoceras exile* (Hall, 1861) and *Spyroceras crotalum* (Hall, 1861). For Cenozoic taxa was confirmed *Nautilus pernambucensis* (Maury, 1930), *Hercoglossa lamegoi* Oliveira, 1953 and *Aturia ackermanii* Oliveira, 1958 were considered synonymous of *Hercoglossa harrisi* Miller and Thompson, 1936 and *Aturia cubanesis* (Lea, 1841) respectively.

Keywords: Brazil, Cenozoic, Nautiloidea, systematic.

***Resumen***

*Este trabajo trata sobre el estudio sistemático de los cefalópodos nautiloideos colectados en estratos del Silúrico-Devónico, Devónico, Paleoceno y Mioceno Inferior, correspondientes a las formaciones Manacapuru, Ponta Grossa, Maria Farinha y Pirabas en las provincias de Pará, Paraná y Pernambuco. En este trabajo se presentan las especies paleozoicas Michelinoceras cf. M. telamon (Hall, 1879), M. sp.A, M. sp. B, el primer registro de Trematoceras exile (Hall, 1861) y Spyroceras crotalum (Hall, 1861). Para el cenozoico se confirma la presencia de Nautilus pernambucensis (Maury, 1930), Hercoglossa lamegoi Oliveira, 1953 y Aturia ackermanii Oliveira, 1958 y las sinonimias con Hercoglossa harrisi Miller y Thompson, 1936 y Aturia cubanesis (Lea, 1841).*

*Palabras clave: Brazil, Cenozoico, Nautiloidea, sistematica.*

## 1. Introduction

The nautiloid cephalopods were highly diversified into many different orders during the Early Paleozoic and most became extinct by the end of Devonian, from these, only five species of *Nautilus* are alive today. During mid-Devonian, the ammonoids began to evolve as an offshoot of one of these extinct groups of straight-shelled nautiloids, the Bactritida, an obscure group, and regarded as a transitional stock between nautiloids and ammonoids (Miller and Thompson, 1936; Jain, 2017).

One of the biggest gaps of brazilian paleontological research is the systematic review of Nautiloidea cephalopods, specially to define its relation with the synchronous faunas and biogeographic patterns identified in the Americas. This paper deals with the systematic studies of 54 specimens of Manacapuru, Ponta Grossa, Maria Farinha and Pirabas formations, deposited in the paleoinvertebrates collection at Museu de Ciências da Terra- CPRM/RJ- Divisão de Geologia e Mineralogia (DGM), Museu Nacional/Universidade Federal Rio de Janeiro (MN/UFRJ), Museu Paraense Emílio Goeldi (MPEG), Departamento de Geologia, Centro de Tecnologia e Geociências da Universidade Federal de Pernambuco (DGEO-CTG-UFPE), Instituto de Geociências da Universidade Federal Rio de Janeiro (Cf- Cephalopoda collection, IB- Ignácio Brito collection) and Museu de Geociências- Universidade Federal do Pará (MG/UFPa).

The records of nautiloids of the Ponta Grossa Formation were formalized by Clarke (1913) and Ferreira and Cassab (1996). In other works (i.e. Lange and Petri, 1967; Bosetti *et al*., 2012; Carbonaro and Ghilardi, 2016; Cichowolski and Rustán, 2017), occurrences are restricted to citations. For the Maria Farinha Formation White (1887) introduced the systematic characterization recognizing *Nautilus sowerbyanus*, later considered as *Eutrephoceras pernambucensis* by Maury (1930). Oliveira (1953) repositioned this species at *Cimomia* genus and proposed the new species *Hercoglossa lamegoi*. At Manacapuru Formation the nautiloids were recorded by Ferreira and Cassab (1996) and only cited by Tomassi *et al*. (2015), while at the Pirabas Formation Oliveira (1958) described *Aturia ackermanii*.

The Paleozoic specimens studied in this work were collected in the Jaguariaíva site, near Jaguariaíva city, Paraná State, (24°14'S, 49°42'W) and Ribeirão do Norte locality, near Rio Bonito city, Goiás State (16° 55' 48" S, 51° 46' 48" W) as well as Tapajós river outcrop, near Itaituba city (4°17'22"S, 56°1'55"W), Vira Mundo waterfall, Trombetas river (1°3'14"S, 57°3'11"W), locality 1 (3°7'36"S, 51°47'23"W) and locality 2 (3°7'38"S, 51°47'19"W) situated at Travessão 27 site, near Altamira city, located at Pará state (figures 1, 2, 3 and 4). The Cenozoic specimens are coming from the Poty quarry, Paulista city (7º 56' 24" S, 34º 52' 20" W), Pernambuco state (Figure 5), Pedro Teixeira district (1°10'38"S, 47°13'W), near Capanerma city and Atalaia beach, Salinopolis city (0º 36' 5" S, 47º 18' 48" W), Pará state (Figure 6). The Paleozoic nautiloids identified were typical of cool to temperate regions and the Cenozoic species lived in subtropical to tropical shallow marine environments with normal salinity (Cichowolski and Rustán, 2017; Nielsen *et al*., 2009). The current contribution synthesize and update the current knowledge of Brazilian Nautiloidea and this will be allow define its relation with the synchronous faunas and biogeographic patterns identified in the Americas.

## 2. Location and stratigraphy

The Amazon Basin, with an area of approximately 500000 km$^2$ and elongated in the ENE and WSW direction, covers portions of the states of Amazonas and Pará. An initial stage of pulsating deposition of alternating glacial and marine sedimentary rocks in the basin was followed by

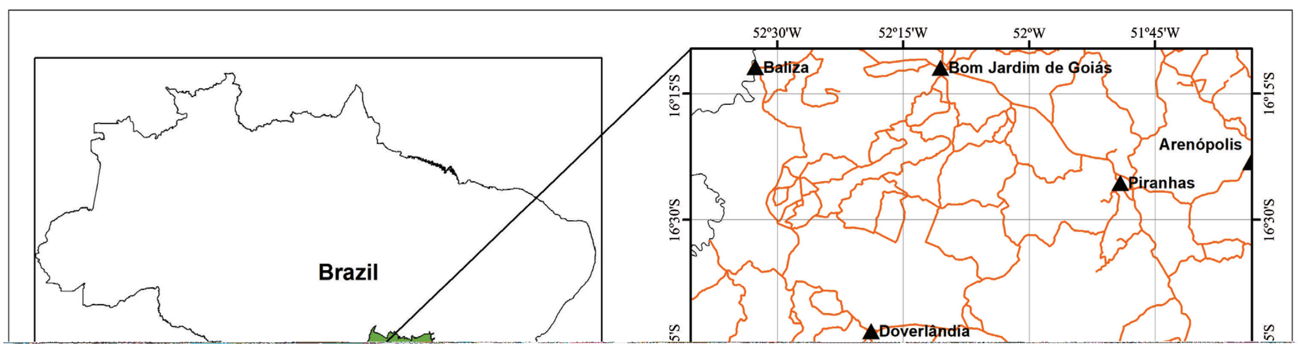


Figure 1. Map showing the localities study area in Goiás and Paraná states where the fossil nautiloids were collected.

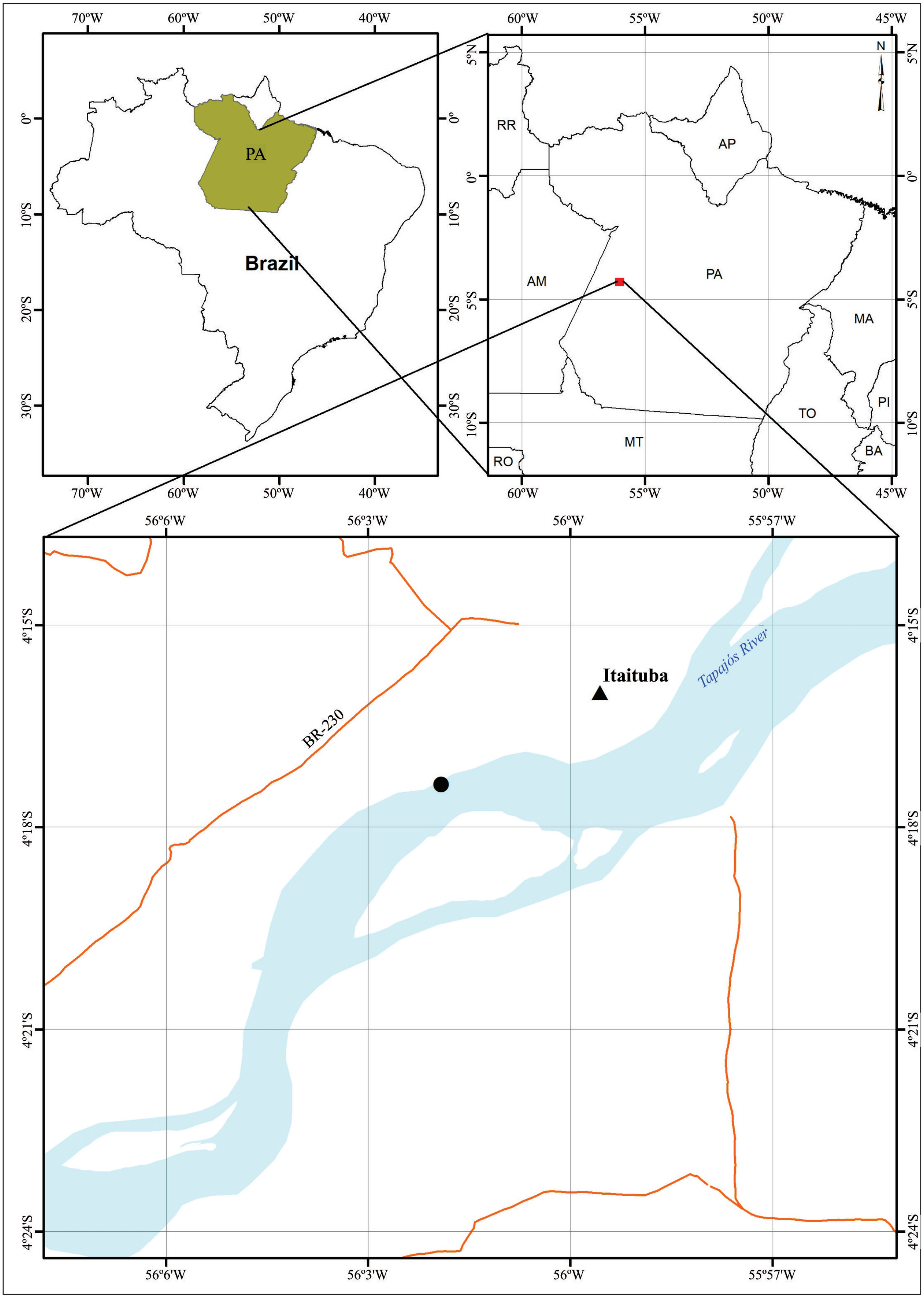


Figure 2. Map showing the locality study area in Pará state and Itaituba city where the fossil nautiloids were collected.

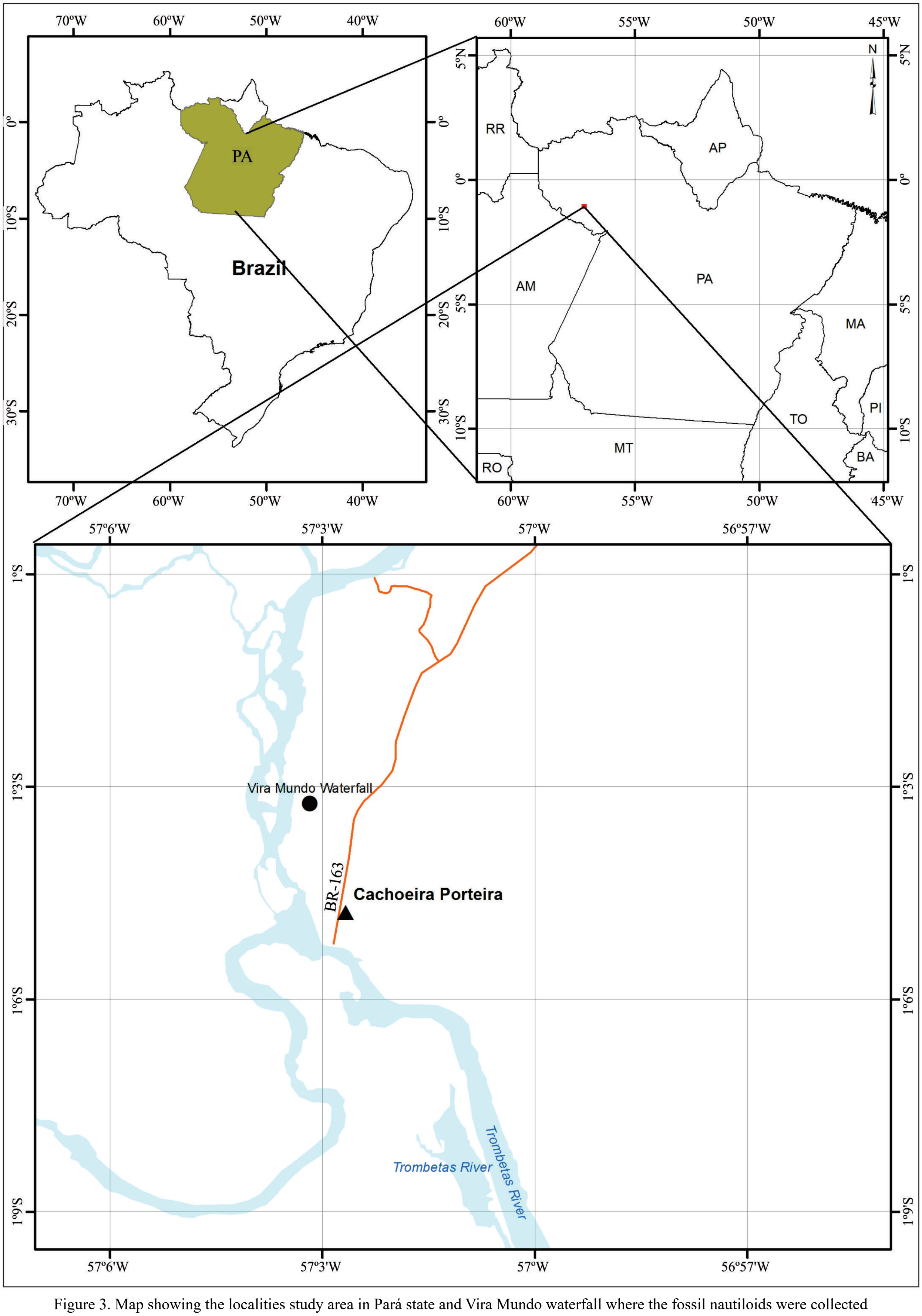


Figure 3. Map showing the localities study area in Pará state and Vira Mundo waterfall where the fossil nautiloids were collected

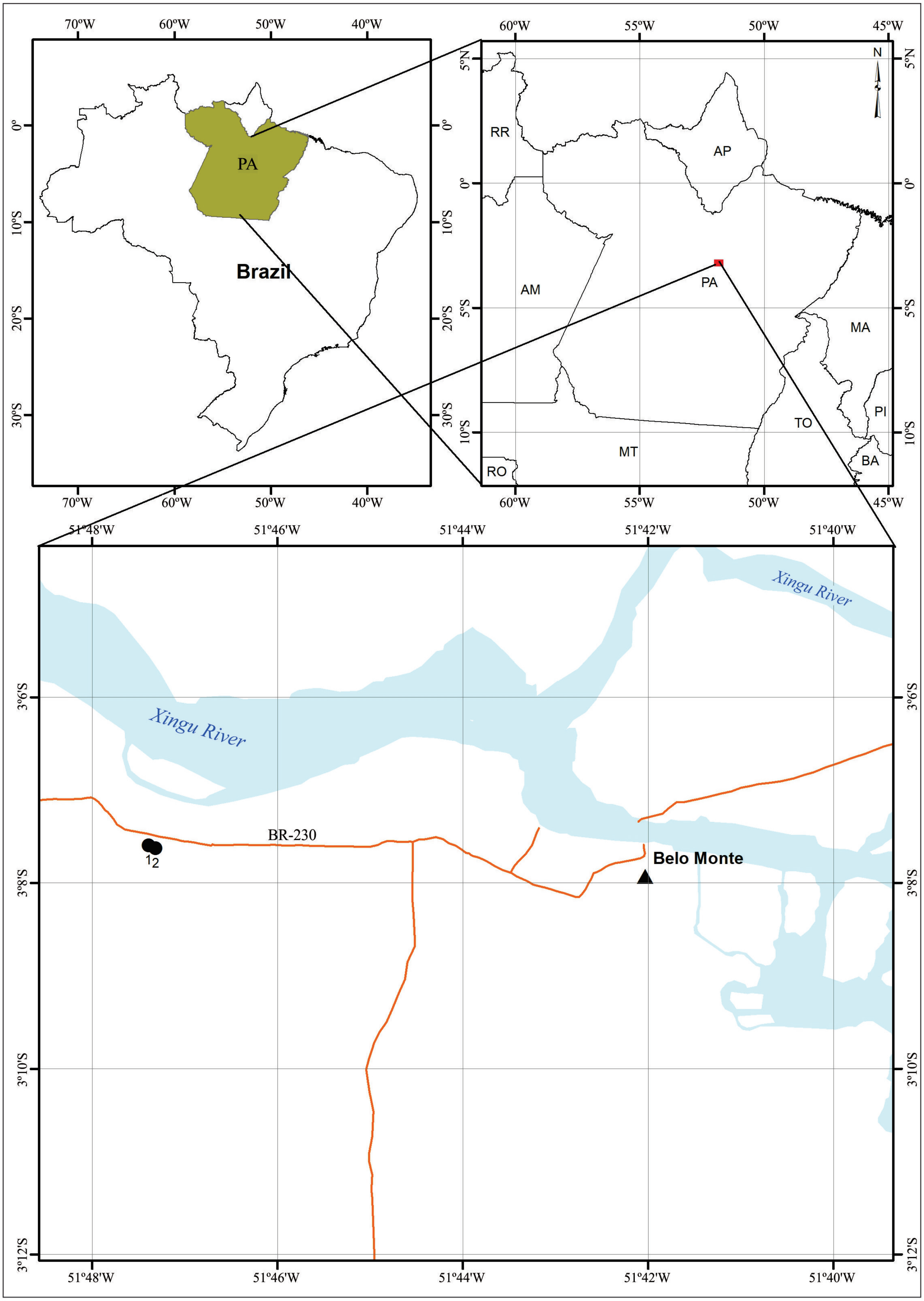


Figure 4. Map showing the localities study area in Pará state and Belo Monte Site where the fossil nautiloids were collected.

a transgressive-regressive cycle (Devonian and Tournasian Sequence) of deposition of marine and glacial sedimentary rocks of the Urupadi and Curuá groups, which extended to the northwestern African basins, without connection to the Solimões Basin to the west (Scheffler *et al*., 2014).

The Manacapuru Formation is composed by fine to medium sandstones, shales and laminated siltstones interbedded, deposited in shallow marine environment with coastal influence and normal to low salinity, in times of marine ingression/regression which occurred during the sineclise stage of the Amazonas Basin evolution. The paleontological content of this formation presents linguloid and rhynchonelid brachiopods, tentaculitoids, conularids, rare orthoconic cephalopods, acritarcha, chitinozoans and ichnofossils (Cunha *et al*., 1994, 2007; Tomassi *et al*., 2015).

The Paraná Basin is a huge intracratonic basin on the South-American platform, with NE-SW elongated shape located in southernmost Brazil and northwestern Uruguay, parts of Paraguay and Argentina, occupies a surface area of about 1700000 km$^2$, where the sedimentary fill was conditioned by tectonic-eustatic cycles linked to the evolution of West Gondwana during Palaeozoic and Mesozoic times (Holz *et al*., 2010).

The Ponta Grossa Formation is dominated by mudstones, siltstones, black shales, and fine sandstones in its lower portion (Jaguariaíva Member), deposited in shallow marine shelf environment while the middle portion is composed by sandstone-dominated (Tibagi Member). Finally, siltstones, fine- to medium-grained sandstones and subordinate black shales characterize its upper portion (São Domingos Member). This formation exhibits three major (3$^{rd}$-order) depositional sequences containing a record of three to seven higher-order relative sea-level cycles regressive profile of high- to low- energy oscillations (Sedorko *et al*., 2018). The paleontological content of this litostratigraphic unit presents brachiopods, trilobites, bryozoans, conularids, bivalves, gastropods, cephalopods, tentaculitoids, annelids, echinoderms, fishes and plants of middle Emsian (Devonian) age (Milani *et al*., 2007; Holz *et al*., 2010).

The Paraíba Basin in northeastern Brazil occupies a continental area of about 7600 km$^2$ and oceanic area about 31400 km$^2$, extending along continental shelf deeper than 3000 m, where a complete carbonate sequence of Cretaceous-Paleogene rocks is present. The depositional history of these rocks started with the Beberibe Formation, followed by the Itamaracá, Gramame and Maria Farinha formations, deposited on a carbonate distal steepened ramp (Nascimento-Silva *et al*., 2011).

The Maria Farinha Formation is composed of limestones, marly limestones and thick levels of marls in its lower portion, while dolomitic limestones, containing fossil reefs and lagoonal reefs, characterize its upper portion. This formation exhibits regressive profile of high- to low-energy oscillations. At the contact between the Gramame and Maria Farinha formations, there is an erosional unconformity characterized by a carbonate sequence with intraclasts, displaying conglomeratic aspect associated to the Cretaceous-Paleogene transition (Nascimento-Silva *et al*.,

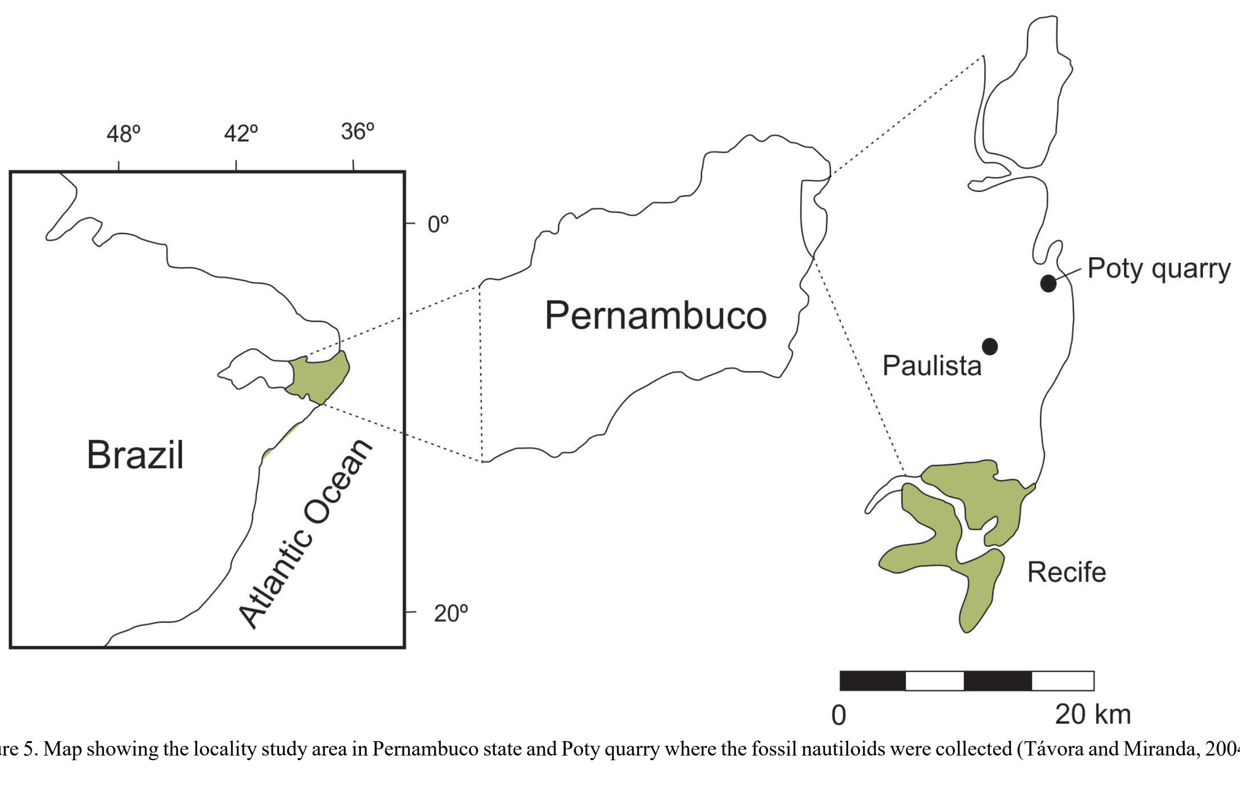


Figure 5. Map showing the locality study area in Pernambuco state and Poty quarry where the fossil nautiloids were collected (Távora and Miranda, 2004)

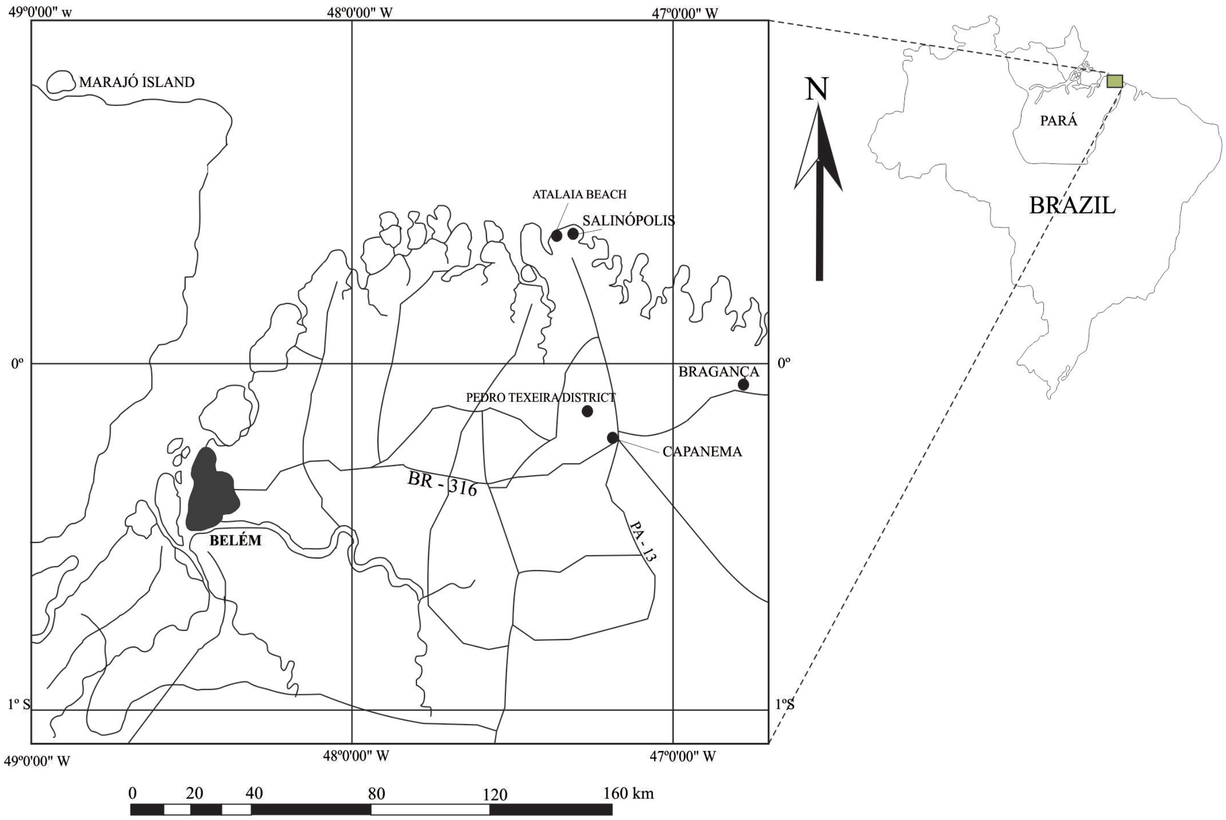


Figure 6. Map showing the localities study area in Pará state and Atalaia Beach and Pedro Teixeira District where the fossil nautiloids were collected.

2011). The paleontological content of this litostratigraphic unit presents calcareous algae, foraminifera, corals, bryozoans, bivalvs, gastropods, cephalopods, decapods crustaceans, echinoderms, fishes, reptiles and plants of Paleocene-Eocene age (Távora and Miranda, 2004).

The sedimentary evolution in western Amazonia region, during the Miocene was mostly influenced by NW-SE normal faults dipping northeasterly and also sets of NE-SW strike-slip and transfer faults. This geometry is related a manifestation of the final extensional deformation phase of to the Gondwana breakup responsible for the split of South American and African continents (Costa *et al*., 1993; Rossetti and Góes, 2004).

The Pirabas Formation (Maury, 1925), with broadly outcrops along northeastern region of the Pará, Maranhão, and Piauí states, provides some of the best marine Cenozoic paleontological occurrences in Brazil. The Pirabas Formation-type location is the Pirabas River estuary, near the Salinópolis city, northeastern of Pará state in the Bragantina platform east of Salinas County in Pará state (Rossetti and Góes, 2004). The Pirabas Formation consists of richly fossiliferous limestones that indicate a warm, shallow marine depositional environment where lived foraminifera, ostracods, porifera, corals, bryozoans, bivalves, gastropods, cephalopods, decapoda and cirripedia crustaceans, echinoderms, fishes, reptiles and mammals all of Lower Miocene age (Fernandes, 1981; Távora *et al*., 2010; Zagorsek *et al*., 2014; Ramalho *et al*., 2015).

## 3. Systematic descriptions

The descriptions, systematic classification, essential terminology and nomenclature used in this paper is mainly based on Flower (1945), Miller (1947), Teichert *et al*. (1964) and Dzik (1984). In addition, other complementary works such as Clarke (1913), Miller and Thompson (1936), Oliveira (1953, 1958), Nielsen *et al*. (2009), Wilson (2014) and Laurito and Mora (2018) were considered.

The following abbreviations are used to indicate the dimensions of the Orthoceratida, h: height; l: length; ml: maximum length; mw: maximum width; bs: basal septa; cd: camerae distance; si: septa interspace and st: suture thickness. For Nautilida, fd: full diameter; mh: maximum height; mw: maximum width; sd: siphuncle diameter and ud: umbilical diameter.

Subclass Nautiloidea Agassiz, 1847

Order Orthoceratida Kühn, 1940

Family Orthoceratidae Kühn, 1940

Genus *Michelinoceras* Foerste, 1932

*Michelinoceras* cf. *M. telamon* (Hall, 1879)
Figure 7A

1879 *Orthoceras telamon* Hall. pt. 2, pl. 85, figs. 3–4.
1899 *Michelinoceras telamon* (Hall). Hall, p. 289, fig. 223.
1903 *Orthoceras telamon* Hall. Clarke and Ruedmann, p. 642.
1939 ?*Michelinoceras telamon* (Hall). Kindle and Miller, p. 87.
1996 "*Orthoceras*" sp. Ferreira and Cassab, p. 316.
2014 *Michelinoceras telamon* (Hall). Wilson, p. 190–191.

**Description:** Straight, narrow, subcylindrical, regularly and gradually enlarging orthoconic shell, with smooth chambers, concave and regularly spaced septa. Apical angle four degrees, concavity of septa about 100 degrees.

**Occurrence:** United States of America: Hamilton Group, Middle Devonian (Hall, 1879; Grabau, 1899; Kindle and Miller, 1939; Wilson, 2014); Brazil: Manacapuru Formation, Silurian-Devonian (Ferreira and Cassab, 1996).

**Material:** one shell fragment (MN 2448-I) from the Tapajós river outcrop, near Itaituba city, Pará State, Brazil.

**Dimensions:** l: 35 mm; mw: 9 mm; cd: 4 mm.

**Discussion:** The preservational features of this specimen suggests that is belong to the *Michelinoceras* genus, but the diagnostic morphological elements for species classification are obliterated, not allowing systematic characterization as *M. telamon*.

*Michelinoceras* sp. A
Figure 7B

1913 *Orthoceras* cf. *O. gamkaense* Reed. Clarke, p. 159, pl. 8, fig. 10.
1996 *Michelinoceras gamkaense* (Reed). Ferreira and Cassab, p. 313–314.
1996 "*Orthoceras*" sp. A. Ferreira and Cassab, p. 314–315.

**Description:** Straight, elongate, narrow, long, subcylindrical, gradually tapering orthoconic shell. Inflated embryonic area, long and simple living chamber, circular cross section and septal necks straight. External surface crossed by delicate, contiguous and regularly convex transverse lines. A rounded and central cavity at posterior end suggest the position of siphuncle. Inflated and broadly rounded apical end resembling a septum and septal neck.

**Occurrence:** Brazil: Ponta Grossa Formation, Devonian (Clarke, 1913; Ferreira and Cassab, 1996).

**Material:** two shell fragments, from the Jaguariaíva site, near Jaguariaíva city, Paraná State, Brazil (DGM 87-I) and Ribeirão do Norte locality, near Rio Bonito city, Goiás State, Brazil (DGM 2001-I).

**Dimensions:** (DGM 87-I): l: 80 mm; mw: 25 mm; bs: 15 mm; si: 17 mm; (DGM 2001-I): l: 40 mm; mw: 10 mm; bs: 8 mm.

**Discussion:** The preservational setting of this specimen suggests that belongs to the *Michelinoceras* genus. Others diagnostic morphological elements for species classification are obliterated due the preservation, causing doubted systematic characterization at specific status.

*Michelinoceras* sp.B
Figure 7C

1996 "*Orthoceras*" sp. B. Ferreira and Cassab, p. 315.
1996 "*Orthoceras*" sp. C. Ferreira and Cassab, p. 315.

**Description:** Straight conical orthocone shell with narrow and probably smooth chambers; straight traverse sutures with a concave, delicate and slightly ondulated striae at each suture.

**Occurrence:** Brazil: Manacapuru Formation, Silurian-Devonain (Ferreira and Cassab, 1996).

**Material:** three shell fragments (MN 3306-I) and ten shell fragments (MN 2700-I), from the Vira Mundo waterfall, Trombetas river, Pará State, Brazil.

**Dimensions:** (MN 3306-I) l: 20 mm; mw: 9 mm; (MN 2700-I) ml: 21 mm; mw: 17 mm, on average.

**Discussion:** The specific diagnostic morphological elements are obliterated by fossilization state, preventing systematic characterization at specific status.

Family Pseudorthoceratidae Flower and Caster, 1935
Genus *Trematoceras* Eichwald, 1851

*Trematoceras exile* (Hall, 1861)
Figures 7D, 7E

1861 *Orthoceras exile* Hall, p. 78, pl. 8, fig. 5.
1903 *Orthoceras exile* Hall. Clarke and Ruedmann, p. 625.
1939 *Michelinoceras*? *exile* (Hall). Kindle and Miller, p. 101.
1996 "*Orthoceras*" cf. *O. gamkaense* (Reed). Ferreira and Cassab, p. 315–316.
2014 *Dolorthoceras exile* (Hall). Wilson, p. 191.

**Description:** Elongate, straight, slender, depressed, cylindrical, very gradually tapering, swelling in the first third, with circular cross-section and probably thick orthocone shell. Septa distant and convex. Straight traverse sutures, parabolically ending apical. Transverse striae in the external surface no visible.

**Occurrence:** United States of America: Hamilton Group, Middle Devonian (Hall, 1861; Kindle and Miller, 1939; Wilson, 2014); Brazil: Manacapuru Formation, Silurian- Devonian (Tomassi *et al*., 2015) and Ponta Grossa Formation, Devonian (Ferreira and Cassab, 1996).

**Material:** one shell fragment (DGM 1573-I) from the Jaguariaíva site, near Jaguariaíva city, Paraná State, four shell fragments (MPEG 3089-I, MPEG 3090-I, MPEG

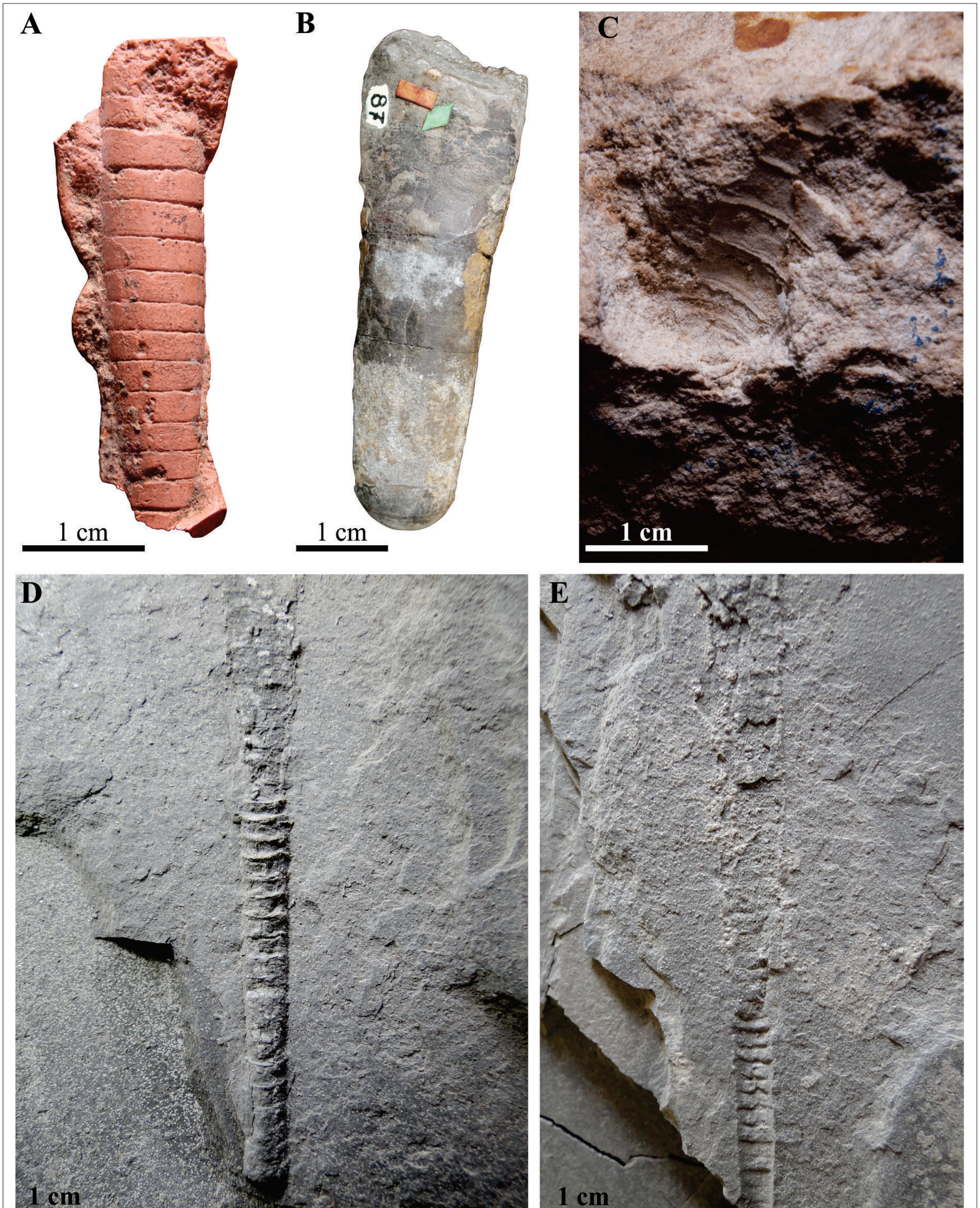


Figure 7. Longitudinal view: A: *Michelinoceras* cf. *M. telamon* (Hall, 1879) (MN-2448-I); B: *M*. sp. A (DGM-87-I); C: *M*. sp. B (MN-3306-I); D: *Trematoceras exile* (Hall, 1861) (MPEG-3089-I); E: *Trematoceras exile* (Hall, 1861) (MPEG-3090-I).

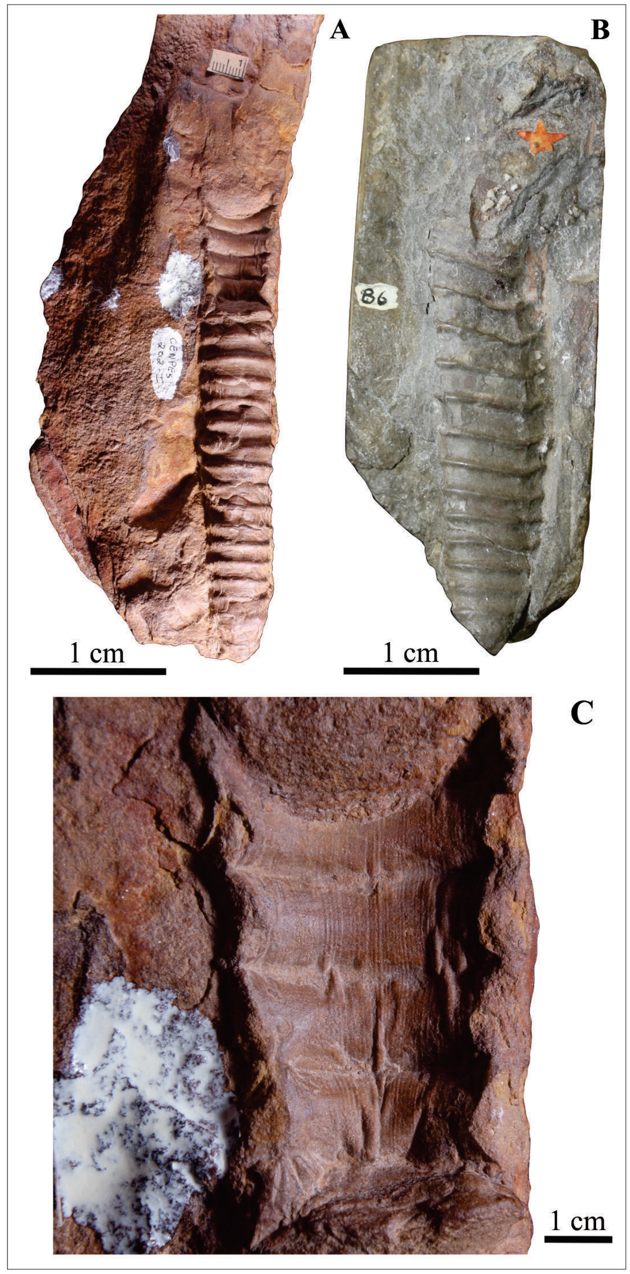


Figure 8. Longitudinal view: A: *Spyroceras crotalum* (Hall, 1861) (MN-6082-I); B: *Spyroceras crotalum* (Hall, 1861) (DGM-86-I); C: Details of external surface showing transverse annulations, and the longitudinal striae of *Spyroceras crotalum* (Hall, 1861) (MN-6082-I).

3091-I, MPEG 3092-I) from localities 1 and 2, Travessão 27 site, near Altamira city, Pará State, Brazil.

**Dimensions:** (DGM 1573-I) l: 145 mm; mw: 12 mm; (MPEG 3089-I): l: 65 mm; mw: 7 mm; (MPEG 3090-I): l: 63 mm; mw: 7 mm; (MPEG 3091-I): l: 27 mm; mw: 5 mm; (MPEG 3092-I) l: 34 mm; mw: 4 mm.

**Discussion:** Although the preservation of these specimens is not all that could be desired, the above description presents the main diagnostic characters that allows recognize *T. exile*.

Family Kionoceratidae Hyatt, 1900
Genus *Spyroceras* Hyatt, 1884

*Spyroceras crotalum* (Hall, 1861)
Figures 8A, 8B, 8C

1861 *Orthoceras crotalum* Hall, p. 78–79, pl. 8, figs. 1–2.
1903 *Orthoceras* (*Spyroceras*) *crotalum* Hall. Clarke and Ruedmann, 622.
1913 *Spyroceras zoilus* Clarke, p. 159–160, pl. 8, fig. 11.
1939 *Spyroceras crotalum* (Hall). Kindle and Miller, p. 101.
1996 *Spyroceras meloi* Ferreira and Cassab, p. 311–312, figs. 1, 3–4.

**Description:** Narrow, straight, cylindrical and very gradually tapering orthocone shell. Straight transverse sutures. Septa numerous, moderately convex, more visible toward the apical end, at intervals equal to those of the rings. External surface marked by strong, high and rounded transverse annulations, little undulating or bent backwards on one side not corresponding with the line of septa, become more conspicuous toward the aperture and the outline of latter annulations may become oblique (Figure 8B). Other important and well marked morphological character are delicate, longitudinal and contiguous striae sometimes slightly undulated, in passing over the annulations, more elevated near the outer chamber.

**Occurrence:** United States of America: Hamilton Group, Middle Devonian (Hall, 1861; Kindle and Miller, 1939; Wilson, 2014); Brazil: Manacapuru (Silurian-Devonian) and Ponta Grossa (Devonian) formations (Clarke, 1913; Ferreira and Cassab, 1996).

**Material:** one shell fragment (DGM 86-I) from the Ponta Grossa city, Paraná State, Brazil and one shell fragment (MN 6082-I), from the Tapajós river outcrop, near Itaituba city, Pará State, Brazil.

**Dimensions:** (DGM 86-I): l: 145 mm; mw: 20 mm; bs: 6 mm; si: 7 mm; st: 4 mm; (MN 6082-I): l: 140 mm; mw: 25 mm; bs: 8 mm; si: 7.5 mm; st: 3 mm.

**Discussion:** The species *Orthoceras crotalum* was included in *Spyroceras* genus since Kindle and Miller (1939). The morphological features of *S. meloi*, including shape and size of orthoconic shell, septa numbers, annulated surface and longitudinal striae patterns are diagnostic of *S. crotalum*. Also, the morphological review of *Kionoceras zoilus* is sufficient to consider it synonymous with *S. crotalum* considering that the differences, including the oblique pattern of the annulations represents taphonomic signatures or intraspecific variation.

Order Nautilida Agassiz, 1847
Suborder Nautilina Agassiz, 1847
Family Nautilidae Blainville, 1825
Genus *Hercoglossa* Conrad, 1866

*Hercoglossa harrisi* Miller and Thompson, 1936
Figure 9A–E; Figure 10A

1936 *Hercoglossa harrisi* Miller and Thompson, p. 62–64, pl. 7, figs. 1–2.
1947 *Hercoglossa harrisi* Miller and Thompson, p. 51–53, pl. 35, figs. 1–4, pl. 53, figs. 1–2.
1953 *Hercoglossa lamegoi* Oliveira, p. 27–30, est. 3, figs. 1–3, est. 4, figs. 1–2.
1993 *Hercoglossa harrisi* Miller and Thompson. Schmidt and Jung, p. 349, fig. 4–3.

**Description:** Nautiliconic, involute, sublenticular to subglobose shell, rapidly expanded oral and large, consisting of at least four or five whorls. Early whorls wider than high and broadly rounded laterally and rather deep dorsally. Living chamber compressed laterally and gently rounded ventrally, length longer than half of the one complete whorl. Septa concave transversely, curved ventrally and dorsally, defining a sigmoidal outline; septal necks cylindrical, a third as long as the camerae. In mature specimens there are at least 10 camerae in phragmocone. Each suture is formed by a large broadly ventral saddle and narrower dorsally with shallow and rounded lateral lobe, followed by a rounded dorsolateral saddle and lobe. Ending with a broader lower rounded asymmetrical saddle and a broad rounded dorsal lobe. Umbilicus small, inconspicuous, closed and low ends. Rounded and gently distinct umbilical flanges. Siphuncle small, circular in cross section, located nearer the venter than the dorsum (Figure 10A).

**Occurrence:** United States of America: Midway Group, Paleocene (Miller and Thompson, 1936; Miller, 1947); Trinidad: Soldado Rock, Paleocene (Miller and Thompson, 1936; Miller, 1947); Venezuela: Misoa-Trujillo Formation, Paleocene (Miller and Thompson, 1936; Miller, 1947); Brazil: Maria Farinha Formation, Paleocene (Oliveira, 1953).

**Material:** 13 shells (DGEO-CTG-UFPE-2435, DGEO-CTG-UFPE-2436, DGEO-CTG-UFPE-2439, DGEO-CTG-UFPE-2446, DGEO-CTG-UFPE-2448, DGEO-CTG-UFPE-2450, DGEO-CTG-UFPE-2452, DGEO-CTG-UFPE-2453, DGEO-CTG-UFPE-2455, DGM 4097-I, DGM 4306-I, 033-Cf, 144-IB) from Poty quarry, Paulista city, Pernambuco State, Brazil.

**Dimensions:** The specimens have on average fd: 150 mm; mh: 87 mm; mw: 105 mm; sd: 3 mm; ud: 12 mm.

**Discussion:** Miller (1947) reported that *H. harrisi* is a rather primitive member of the genus, and it most distinctive character is the shape of suture, including the low ventral saddle, narrow lateral lobes and narrow dorsolateral saddles. Accordingly Oliveira (1953) the differences between *H. harrisi* and *H. lamegoi* are the shape and outline of lateral saddles and dorsal lobe. In this research is considered that the differences pointed out by Oliveira (1953) are a result of ontogenetic or intraspecific variations, and that the same shape of suture is sufficient for to consider *H. lamegoi* as synonymous of *H. harrisi*.

Genus Nautilus Linnaeus, 1758

*Nautilus pernambucensis* (Maury, 1930)
Figure 9F-J; Figure 10B

1887 *Nautilus sowerbyanus* White, p. 230–231, est. 25, figs. 1-4.
1930 *Eutrephoceras pernambucense* Maury, p. 249–250.
1947 *Cimomia pernambucense* (Maury). Miller, p. 45–46, pl. 30, figs. 1–4.
1953 *Cimomia pernambucensis* (Maury). Oliveira, p. 27–30, est. 3, figs. 1–3, est. 4, figs. 1–2.

**Description:** Planispiral, involute, subglobose and smooth shell; rounded transversely, convex ventrally and gently curved at contact with lateral lobes, transverse section reniform. Whorls increasing rapidly, ovate whorl section. The whorls enveloping form a well marked concave zone. Undulate to nearly direct line septal suture defined by shallow lobes and absence of ventral lobe (Figure 10B). This suture crossing the periphery and great part of each side, sometimes forward curve near umbilicus. Umbilicus very small and narrow with rounded ends.

**Occurrence:** Brazil: Maria Farinha Formation, Paleocene (Oliveira, 1953).

**Material:** 14 shells (DGEO-CTG-UFPE-1220, DGEO-CTG-UFPE-2438, DGEO-CTG-UFPE-2439, DGEO-CTG-UFPE-2443, DGEO-CTG-UFPE-2444, DGEO-CTG-UFPE-2445, DGEO-CTG-UFPE-2449, DGEO-CTG-UFPE-2451, DGEO-CTG-UFPE-2454, DGEO-CTG-UFPE-2456, DGEO-CTG-UFPE-4755, DGM 4106-I, MN 3057-I, 287-IB) from Poty quarry, Paulista city, Pernambuco State, Brazil.

**Dimensions:** The specimens have on average fd: 175 mm; mh: 31 mm; mw: 98 mm; sd: 5 mm; ud: 32 mm.

**Discussion:** The specimens described by White (1887) at Maria Farinha Formation as *Nautilus sowerbyanus*, typical species of the Cretaceous of Europe were once again studied by Maury (1930), that pointed out resemblance of these specimens with tertiary species of Texas and Peru. Accordingly she proposed the new name *Eutrephoceras pernambucense* for this brazilian species. Miller (1947) repositioned the taxon and Oliveira (1953) it confirms at *Cimomia* genus. Finally Dzik (1984) considered *Cimomia* as a variety and synonymous with *Nautilus*.

Family Aturidae Chapman, 1857
Genus *Aturia* Bronn, 1838

*Aturia cubaensis* (Lea, 1841)
Figures 9K-M; Figure 10C

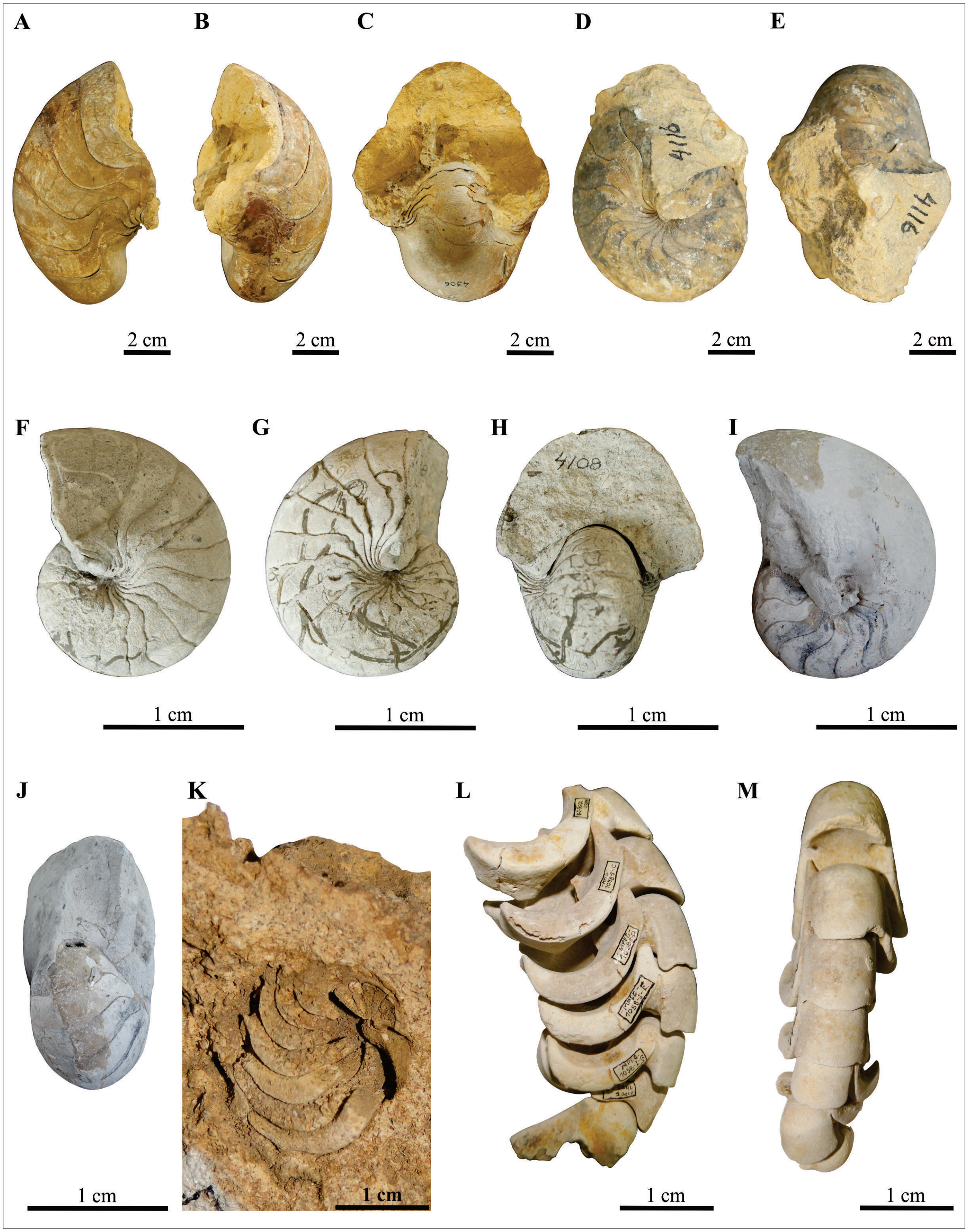


Figure 9. *Hercoglossa harrisi* Miller and Thompson, 1936. A, B: Lateral views (DGM-4306-I); C: Dorsal view of *Hercoglossa harrisi* Miller and Thompson, 1936 (DGM-4306-I); D: Lateral view of *Hercoglossa harrisi* Miller and Thompson, 1936 (DGM-4116-I); E: Dorsal view of *Hercoglossa harrisi* Miller and Thompson, 1936 (DGM-4116-I); F- G: Lateral views of *Nautilus pernambucensis* (Maury, 1930) (DGM-4108-I); H: Dorsal view of *Nautilus pernambucensis* (Maury, 1930) (DGM-4108-I); I: Lateral view of *Nautilus pernambucensis* (Maury, 1930) (DGEO-CTG-UFPE-P12); J: Dorsal view of *Nautilus pernambucensis* (Maury, 1930) (DGEO-CTG-UFPE-P12); K: Lateral view of *Aturia cubaensis* (Lea, 1841) (MG-807-I); L: Lateral view of *Aturia cubaensis* (Lea, 1841) (MPEG-1058-I); M: Ventral view of *Aturia cubaensis* (Lea, 1841) (MPEG-1058-I).

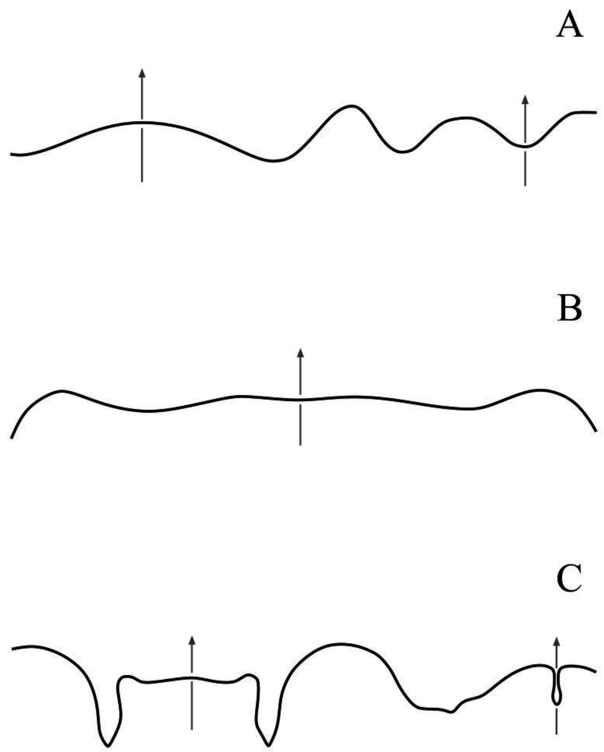


Figure 10. Suture line of (A) *Hercoglossa harrisi* Miller and Thompson, 1936; (B) *Nautilus pernambucensis* (Maury, 1930); and (C) *Aturia cubaensis* (Lea, 1841).

1841 *Nautilus cubaensis* Lea, p. 259, pl. 10, fig. 15.
1936 *Aturia curvilineata* Miller and Thompson, p. 69–70, pl. 9, figs. 1–4, pl. 10, figs. 1–2.
1947 *Aturia curvilineata* Miller and Thompson. Miller, p. 93–94, pl. 73, figs.3–4, pl. 84,figs. 1–2, 5–8, pl. 85, figs. 4–6.
1956 *Aturia cubaensis* (Lea). Miller and Furnish, p. 1154, pl. 121, figs. 1–4.
1958 *Aturia ackermanii* Oliveira, p. 3–5, est. 1, fig. 1, est. 2, figs. 1–2.
1966 *Aturia cubaensis* (Lea). Jung, p. 489–491, pl. 1, figs. 2–7, pl. 2, figs. 2–6.
1982 *Aturia curvilineata* Miller and Thompson. Woodring, p. 725–726, pl. 120, figs.5–6.
1982 *Aturia cubaensis* (Lea). Woodring, p. 726.
1990 *Aturia cubensis* (Lea). Beu and Maxwell, p. 239, pl. 26, fig. Q.
2009 *Aturia cubaensis* (Lea). Nielsen *et al*., p. 76–81, figs. 3–4.
2018 *Aturia cubaensis* (Lea). Laurito and Mora, p. 172–173, figs. 2–3.

**Description:** Nautiliconic, planispiral, involute and subdiscoidal shell ornamented by delicate growth lines or smooth. Whorls laterally compressed, flattened laterally, rounded ventrally and impressed dorsally; last whorl enveloping the previous and a center with a small and pocket-like umbilicus on each side. Lateral lobes pointed to gently convex, acute and deep dorsally, compressed laterally and with narrow ends. Septa closely spaced increasing the space as it moves away from the adaptical zone. Septal face with a narrow and deep hollow in mid-dorsal position, and 15 short camerae at last whorl. Undulated and broadly rounded suture at dorsal and umbilical areas with pointed lateral lobe without ventral lobe. The median saddle is wide, moderately convex and the lateral saddle is curve with ends no attached to the umbilical seam. It forms a deep arch forward from umbilicus and a deep, narrow and pointed lateral lobe on septal face backwards from umbilicus (Figure 10C). Siphuncle subdorsal, moderate, circular in cross-section, located close to the dorsum in an adaptical flexure of the septa. Umbilicus small and narrow; umbilical shoulders rounded.

**Occurrence:** United States of America: Chipola Formation, Miocene (Laurito and Mora, 2018); Venezuela: Cantaure and Falcón formations, Miocene (Miller and Thompson, 1936; Miller, 1947; Laurito and Mora, 2018); Colombia: La Guajira peninsula, Miocene (Laurito and Mora, 2018); Trinidad: Brasso Formation, Middle Miocene (Miller and Thompson, 1936; Miller, 1947); Panama: Gatun Formation, Miocene (Woodring, 1982); Costa Rica: Río Banano and Punta Carballo formations, Miocene (Laurito and Mora, 2018); Cuba: Nipe Series, Oligocene to Miocene (Miller and Furnish, 1956; Laurito and Mora, 2018); Argentina: San Julián Formation, Upper Miocene (Laurito and Mora, 2018); Chile: Navidad, Ranquil and Lacui formations, Upper Eocene to Upper Miocene (Nielsen *et al*., 2009); Brazil: Pirabas Formation, Lower Miocene (Oliveira, 1958).

**Material:** one fragment shell (MG-807-I) from the Atalaia beach, Salinópolis city, and three shell fragments (MPEG 264-I, MPEG 1058-I, DGM 4546-I) from Pedro Teixeira district, near Capanema city, Pará State, Brazil.

**Dimensions:** The specimens have on average fd: 74 mm; mh: 45 mm; mw: 31 mm; sd: 2 mm; ud: 3 mm.

**Discussion:** Oliveira (1958) pointed out that the *Aturia ackermanii* are not closely similar to *A. curvilineata* due the differences in the size of the camerae in last whorl specially at adaptical area, which can be attributed to intraspecifical variation. Jung (1966) did regards the type lot of *A. curvilineata* represents juvenile stages of *A. cubaensis*, and so proposed both as synonyms. Since then all subsequent research, including this one has followed this proposal.

## 4. Considerations of the brazilian nautiloid faunas

Some studies on Upper Silurian-Early Devonian deposits of the northern margin on Gondwana suggest the presence of cosmopolitan faunas (Gnoli, 2003). The records of bactritids, orthoceratoids, bivalves, corals and ostracods in seas of the southwestern Gondwana indicate that cool waters from the extreme southern paleolatitudes were not an effective biogeographic barrier that affected the dispersal ability of marine invertebrates (Bosetti *et al*., 2012; Cichowolski and Rustán, 2017).

The fauna of Paraná Basin is related with the Malvinokaffric Realm and the fauna of Amazonas Basin appear to be transitional between Malvinokaffric and Eastern Americas Realm. The nature of barriers separating these two faunal realms was probably a combination of temperature gradients and narrow intermittent marine connections limiting faunal dispersal (Barrett and Isaacson, 1988).

The Devonian nautiloids identified in this research at Manacapuru and Ponta Grossa formations confirms the complex paleobiogeographic affinities between the American faunas. *Michelinoceras* spp., *Trematoceras exile* (Hall) and *Spyroceras crotalum* (Hall) attest the influence from Eastern American Realm in South America, existence of marine connections and consequent faunal dispersal that explain the achievement of same nautiloid taxa at Eastern American and Malvinokaffric realms.

During the Cenozoic, a large-scale northeastward movement following by an eastward one of the east-pacific-Caribbean plate allowed considerable displacements of the fossil biota of the Caribbean region until the Miocene (Galácz, 1988). In this time, the nautiloids were fairly abundant with eight genera in Paleocene and Eocene at Atlantic Gulf Coast Plain and Tropical America where in South America *Hercoglossa* genus seems to be limited to the Early Tertiary.

The nautiloids undergo a decline throughout the rest of Tertiary, only *Aturia* was well represented until Miocene (Miller and Thompson, 1936). This genera *Aturia* is considered as typical of tropical and subtropical regions, and *A. cubaensis* (Lea) reached wide paleobiogeographical occurrence, until USA, Central and South America to New Zealand, Australia, India, Japan and Europe due the unique morphology and position of the siphuncular tube as well as your multi-layered nature (Jung, 1966; Nielsen *et al*., 2009; Laurito and Mora, 2018). The large septal necks suggest great adaptation to an energy efficient buoyancy regulation, great vertical migration and resistance to transport of dead shells through ocean currents explain their notorious distribution (Chirat, 2000; Nielsen *et al*., 2009). The populations achieved on south of South America presents taphonomic features that suggest they are autochthonous, as well as several gastropods genera associated such as *Xenophora*, *Strombus*, *Ficus* and *Terebra* that attest a relative warm environment in the region, reinforcing the paleobiogeographic and paleoceanographic connection in this area during the Cenozoic times (Nielsen *et al*., 2009). This context justifies the occurrence of *A. cubaensis* at Pirabas Formation.

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