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RESEARCH ARTICLE

TAXONOMIC CONSIDERATION OF CRETACEOUS BENTHIC FORAMINIFERAL SPECIES OF THE SERGIPE STATE, BRAZIL (SOUTHERN TETHYS)

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ABSTRACT

The present study deals with the modern taxonomical consideration of the sixteen Brazilian Cretaceous smaller benthic foraminiferal species belonging to thirteen genera and represent good example of the Southern Tethyan benthic foraminiferal species. Ten out of these species are treated here as new: *Gaudryina brazilica, Textularia brazilica, Ammobaculoides brazilica, Hemirobulina brazilica, Marginulina brazilica, Citharina brazilica, Planularia brazilica, Guttulina brazilica, Bolivina brazilica* and *Valvulineria brazilensis.* The other six species have new generic name according to the modern taxonomy: *Laevidentalina mirandai, Lenticubella benderi, Coryphostoma incrassata, Valvulineria calumbiensis, V. garai,* and *V. leonardosi.* The Brazilian Southern Tethyan taxa indicate an open marine environment, which represents outer neritic environmental conditions of the identified species mainly represent warm stratigraphic interval water neritic environment (~200m). These wide paleogeographic distributions proved that the ancestral Tethys was connected with the ancestral Atlantic and Indian Oceans via Mediterranean Sea.

KEYWORDS

Foraminifera, Cretaceous, Brazil, Southern Tethys

1. INTRODUCTION

The present study deals with the taxonomic consideration of Cretaceous sixteen species belonging to thirteen genera of agglutinated and calcareous foraminiferal taxa from Sergipe State of Brazil were introduced by Petri, 1962 (Figure 1).

Figure 1: Geological map of the Sergipe area, Brazil, South Atlantic Ocean (after Petri, 1962).

This Brazilian assemblage is correlated with the other foraminiferal species from other Tethyan localities in the Southern Tethys (Egypt, Iraq and Pakistan) and also Northern Tethys (USA, France and Hungaria), Figure 2.

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Figure 2: Geographic distribution of Some North Tethyan countries: USA, France, Hungaria (H), and Southern Tethys: Brazil, Egypt (Eg), Iraq (Iq), Pakistan (P).

2. Material of Study

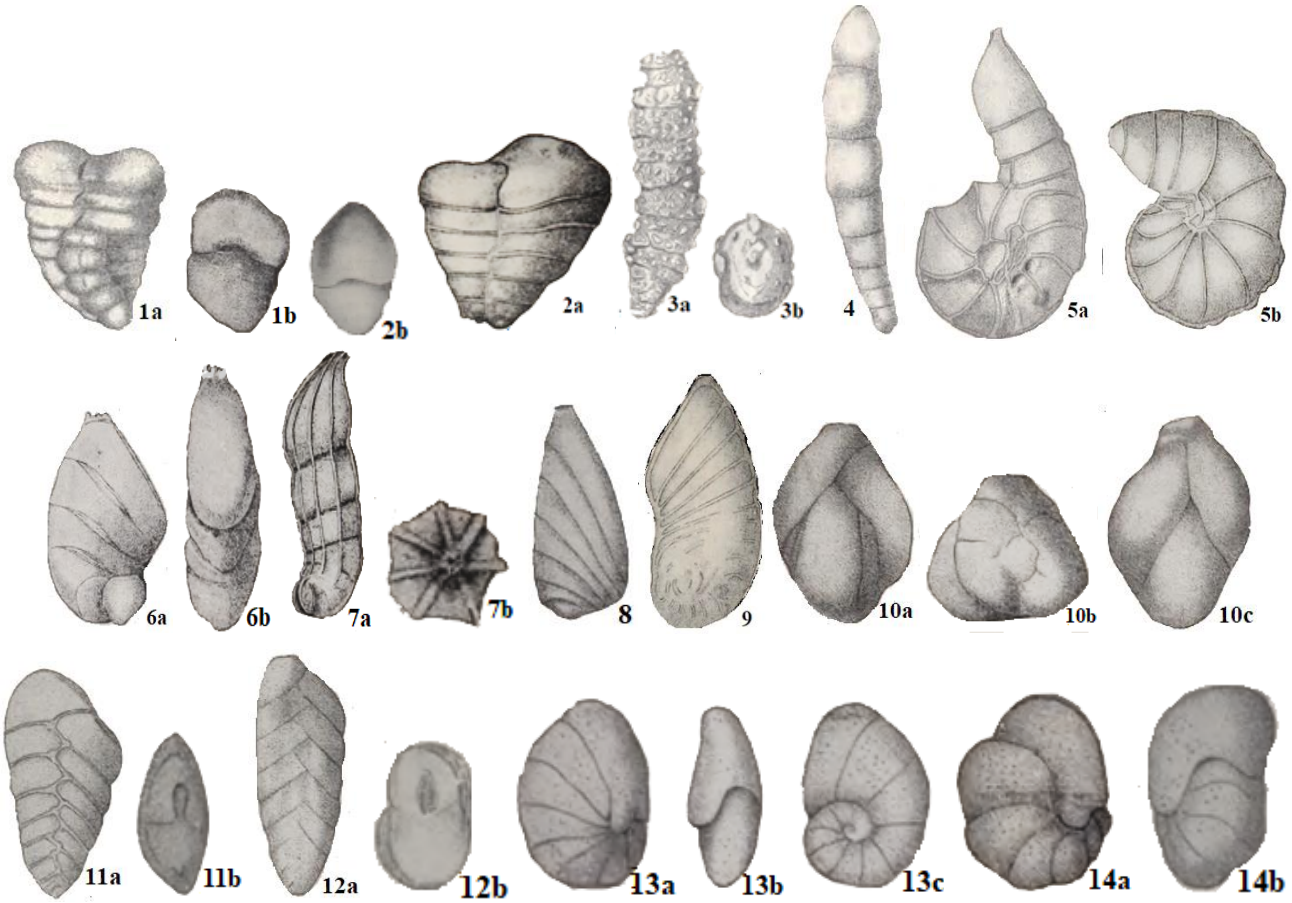
Sixteen well preserved diagnostic Cretaceous benthic foraminiferal species belong to three suborders of agglutinated and calcareous walls are recorded and illustrated from the Sergipe State of Brazil in the Southern Tethys, which are treated here with modern taxonomical consideration. These species are compared with other well-known species from some localities in the Northern and Southern Tethys.

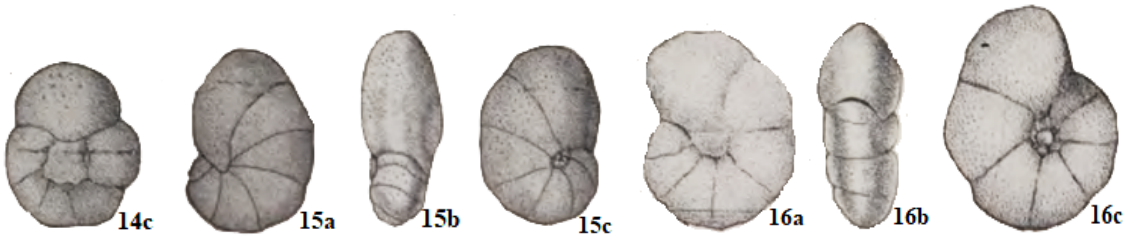
3. Systematic Paleontology

The present study deals with the taxonomic consideration of Cretaceous sixteen species belonging to thirteen genera of three foraminiferal suborders: 3 Textulariid species, 7 Lagenid species, and 6 Rotaliid species from the Sergipe State of Brazil. The taxonomy of is followed here. Ten out of this assemblage are treated here as new species (Loeblich and Tappan, 1988). The identified species is illustrated in Plate 1.

Plate 1

Fig. 1. *Gaudryina brazilica* Anan, n. sp., **2.** *Textularia brazilica* Anan n. sp., **3.** *Ammobaculoides brazilica* Anan, n. sp., **4.** *Laevidentalina mirandai* (Petri, 1962), **5.** *Lenticubella benderi* (Petri, 1962), **6.** *Hemirobulina brazilica* Anan, n. sp., **7.** *Marginulina brazilica* Anan, n. sp., **8.** *Citharina brazilica* Anan, n. sp., **9.** *Planularia brazilica* Anan, n., sp., **10.** *Guttulina brazilica* Anan, n. sp., **11.** *Bolivina brazilica* Anan, n. sp., **12.** *Coryphostoma incrassata* (Petri, 1962), **13.** *Valvulineria brazilensis* Anan, n. sp., **14.** *Valvulineria calumbiensis* (Petri, 1962), **15.** *Valvulineria garai* (Petri, 1962), **16.** *Valvulineria leonardosi* (Petri, 1962).





Order Foraminiferida Eichwald, 1830

Suborder Textulariina Delage and Hérouard, 1896

1. ***Gaudryina brazilica* Anan, n. sp. (**=*Gaudryina* sp. Petri, 1962, p. 52, pl. 1, fig. 8)

   Etymology: From State of Brazil.

   Diagnosis: Test somewhat longer than broad with finely smooth arenaceous wall, greatest breadth near the apertural end, tapering initial portion, triangular to biserial arrangement with inflated nearly discoidal chambers, chambers increasing gradually in length and height, rounded periphery, sutures depressed, aperture low basal slit near the inner margin of the last-formed chamber.

   Remarks: This species is characterized by its nearly discoidal chambers with rounded edges, inclined triserial portion with tapering triangular inflated initial portion.

2. ***Textularia brazilica* Anan n. sp.** (=*Textularia*? sp. Petri, 1962, p. 49, pl. 3, fig. 1).

   Diagnosis: Finely agglutinated wall with inflated biserial chambers, about equal as long as broad, periphery broadly rounded, sutures straight slightly depressed, low basal slit aperture near inner margin of last-formed chamber.

   Remarks: It is characterized by equal broad finely agglutinated test, chambers increasing gradually in length and height, rounded periphery, sutures nearly straight depressed, aperture basal rounded-shaped of last-formed chamber.

3. ***Ammobaculoides brazilica* Anan, n. sp.** (=*Ammobaculoides* sp. Petri, 1962, p. 49, pl. 1, fig. 7).

   Diagnosis: Elongate coarsely-grained roughly finished test, small-size planispiral portion, later biserial, and finally elongate uniserial portion, slightly depressed sutures, rounded periphery, terminal crescent aperture.

   Remarks: This species differs from the type species *Ammobaculoides navarroensis* Plummer (1932) by smaller planispiral initial portion, longer uniserial portion, crescentic than discoidal aperture (Table 1).

4. ***Laevidentalina mirandai* (Petri, 1962)**(=*Dentalina mirandai* Petri, 1962, p. 72, pl. 8, fig. 6)

   Remarks: This species belongs here to the genus *Laevidentalina* Loeblich and Tappan (1986) due to its rounded proloculus in the arcuate elongate test.

   5. *Lenticubella benderi* (Petri, 1962) (=*Lenticulina benderi* Petri, 1962, p. 60, pl. 5, figs. 1-4)**.**

   Remarks: The new genus *Lenticubella* Anan, 2022 (with large closed coiled early portion, followed by uncoiled many chambers) differs from the genus *Lenticulina* Lamarck, 1804 (with symmetrical planispirally enrolled test). This species belongs here to the genus *Lenticubella* Anan (2022). This species is closely with *Lenticubella misrensis*, but differs by raised sutures in the coiled and uncoiled stages.

6. ***Hemirobulina brazilica* Anan, n. sp. (=***Marginulina gardnerae* Petri, 1962, p. 66, pl. 8, fig. 3).

   Diagnosis: Smooth slight curve and later become rectilinear test and elongated in lateral view and also in section, chambers gradually increasing in size as added, oblique flush limbate sutures, terminal radiate aperture at dorsal edge.

   Remarks: The genus *Hemirobulina* Stache differs from *Marginulina* d'Orbigny (1826) in having a smooth surfaces rather than longitudinally costate wall. The Brazilian species differs from the Hungarian *Hemirobulina ornata* by more globular proloculus and limbate flush than depressed sutures (Hantken, 1875).

7. ***Marginulina brazilica* Anan, n. sp.** (=*Marginulina tenuissima* – Petri, 1962, p. 68, pl. 6, fig. 5).

   Diagnosis: Elongate test with semi-circular in section, early stage slightly curved but not completely enrolled, later chambers rectilinear, raised oblique sutures, surface with prominent seven longitudinal costae, aperture radiate, terminal produced on a neck at the dorsal angle.

   Remarks: It differs from *Marginulina tenuissima* (Heron-Allen and Earland) by lesser numbers of chambers, distinct seven straight raised longitudinal costae.

8. ***Citharina brazilica* Anan, n. sp.** (=*Citharina*? sp. a, Petri, 1962, p. 79, pl. 9, fig. 11).

   Diagnosis: This species is characterized by its triangular test in section, strongly angled chambers back toward the base, sutures oblique and curved, aperture terminal radiate and slightly produced.

   Remarks: This species is closed related with the Paleocene *Citharina plumoides* (Plummer, 1927), but differs mainly by less number of chambers.

9. ***Planularia brazilica* Anan, n., sp.** (=*Planularia derbyi* Petri, 1962, p. 63, pl. 7, fig. 4).

   Diagnosis: Large broadly ovate strongly compressed test, stage planispirally coil early large, chambers increasing gradually in breadth and somewhat more in height on the dorsal margin than ventrally, raised thickened sutures, periphery partially carinate with faint keel, surface have a prominent longitudinal shorter ribs covering the coiled portion and crossing the central part of the early chambers, uncoiled chambers smooth, aperture at the dorsal angle.

   Remarks: This species has compressed test, large coiled portion covered with longitudinal shorter ribs, but small in the later uniserial chambers, raised thickened sutures.

10. ***Guttulina brazilica* Anan, n. sp.** (=*Guttulina* sp. Petri, 1962, p. 86, pl. 10, fig. 8).

    Diagnosis: Smooth ovate test, chambers inflated successive chambers 144° apart added spirally in five planes, depressed sutures, and terminal radiate aperture.

    Remarks: This species differs from the type species *Guttulina communis* d'Orbigny by thicker chambers in width, lesser elongated, and gradually increased as added.

11. ***Bolivina brazilica* Anan, n. sp.** (=*Bolivina* cf. *incrassata* Petri, 1962, p. 86, pl. 11, fig. 15).

    Diagnosis: Elongate somewhat compressed and triangular in length but fusiform in outline test, chambers biserial increase gradually as added, sutures limbate slightly depressed, aperture narrow loop at the base of the apertural face.

    Remarks: This species is characterized by limbate slightly depressed sutures, and fusiform test in outline.

12. ***Coryphostoma incrassata* (Petri, 1962)** (=*Bolivina incrassata* - Petri, 1962, p. 86, pl. 11, fig. 14).

    Remarks: This species belongs to the genus *Coryphostoma* Loeblich and Tappan (1962) due to its mainly biserial test with a tendency to become uniserial arrangement.

13. ***Valvulineria brazilensis* Anan, n. sp.** (=*Nonionella leonardosi* Petri, 1962, p. 87, pl. 10, fig. 11a-c).

Diagnosis: This species belongs here to the genus *Valvulineria* Cushman (1926) due to its unequally evolute biconvex low trochospiral test, and aperture an interiomarginal umbilical-extraumbilical arch with broad thin imperforate apertural flap projecting over the umbilicus and generally covering those from previous chambers but rarely only partially covering them. This species has 9-10 elongated chambers in the last whorl of the ventral side, partly evolute dorsal side with two whorls, the last-formed chamber extends to cover the umbilical area by broad thin imperforate apertural flap.

Remarks: This species resembles the Campanian *Valvulineria iraqensis* Anan (2023), but differs by its more elongated test and numbers of chambers, and narrower apertural flap.

14. ***Valvulineria calumbiensis*** **(Petri, 1962)** (=*Anomalina calumbiensis* Petri, 1962, p. , pl. 17, fig. 5 a-c)

Diagnosis: According to the modern taxonomic consideration this species belongs here to the genus *Valvulineria* Cushman (1926). 7-8 inflated chambers in the last whorl, the last chamber consists about ⅓ of the test, whorls, the last-formed chamber extends to cover the umbilical area by broad thin imperforate apertural flap.

Remarks: It resembles the Ypresian *Valvulineria critchetti* (LeRoy, 1953), but differs by more rounded test, less lobulated periphery, less numbers of chambers, and larger apertural flap.

15. ***Valvulineria garai*** **(Petri, 1962)** (=*Nonionella garai* Petri, 1962, p. 86, pl. 10, fig. 9 a-c).

Diagnosis: This species belongs here to the genus *Valvulineria* Cushman (1926) due to its unequally evolute biconvex low trochospiral test, umbilical side more convex than dorsal side, 7-8 elongate chambers in the last whorl, low arched and elliptical last chamber covered largely the umbilical area, broadly rounded periphery.

Remarks: This species is closed to the Paleocene Pakistanian *V. ranikotensis* (Haque, 1956) but differs by its more chambers numbers, and more lobulated periphery.

16. ***Valvulineria leonardosi*** **(Petri, 1962)** (=*Nonionella leonardosi* Petri, 1962, p. 87, pl. 10, fig. 10a-c).

Diagnosis: This species belongs here to the genus *Valvulineria* as the main characters of *V. garai* (Cushman, 1926).

Remarks: This species differs from *V. garai* by more elongated test, the last formed chamber, and more rounded periphery (Petri, 1962).

4. PALEOGEOGRAPHY

The Cretaceous Period was a time of major tectonic activity during which North and South America, and Eurasia, which were separated from Gondwana, which the Neo-Tethys evolved into a global EW-oriented seaway, and the South Atlantic and North Atlantic basins opened. The recorded sixteen benthic foraminiferal species of Brazil were originally recorded from Sergipe State of Brazil, which were introduced by (Petri, 1962). Notice relationship observed between Brazil fauna and other localities in the North and South Tethys (Table 1), and between Cretaceous Brazil, Ypresian Argentina, and Miocene Chile (Table 2). Some taxa are recorded:

1. *Ammobaculoides brazilica* Anan, n. sp. and the American *Ammobaculoides navarroensis* Plummer (1932) by smaller planispiral initial portion, longer uniserial portion, crescentic than discoidal aperture.
2. *Lenticubella benderi* (Petri, 1962) and the Egyptian *Lenticubella misrensis* Anan (2022) by raised sutures in the coiled and uncoiled stages.
3. *Hemirobulina brazilica* Anan, n. sp. and the Hungarian *Hemirobulina ornata* (Hantken, 1875) by more globular proloculus and limbate flush than depressed sutures.
4. *Citharina brazilica* Anan, n. sp. and the American Paleocene *Citharina plumoides* (Plummer, 1927) by mainly less number of chambers.
5. *Guttulina brazilica* Anan, n. sp. and the French *Guttulina communis* d'Orbigny (1826) by thicker chambers in width, lesser elongated, and gradually increased as added.
6. *Valvulineria brazilensis* and the Campanian Iraqi *Valvulineria iraqensis* Anan (2023) by more elongated test and numbers of chambers, and narrower apertural flap.
7. *V. calumbiensis* (Petri, 1962) and the Egyptian Ypresian *Valvulineria critchetti* (LeRoy, 1953) by more rounded test, less lobulated periphery, less numbers of chambers, and larger apertural flap.

Table 1: The distribution of the Cretaceous benthic foraminiferal species in **1**. Brazil (South America) and other Tethyan localities in **2.** USA (North America), **3.** France, **4.** Hungaria (Europe), **5.** Egypt (Africa), **6.** Iraq, **7.** Pakistan (Asia).

sp. no.	Cretaceous Brazil benthic foraminifera and other Tethyan localities	Tethyan localities							Cretaceous Brazil benthic foraminifera and other Tethyan localities	Tethyan localities							sp. no.
		1	2	3	4	5	6	7		1	2	3	4	5	6	7	
1	*Gaudryina brazilica*	x							*Planularia brazilica*	x							13
2	*Textularia brazilica*	x							*Guttulina brazilica*	x							14
3	*Ammobaculoides brazilica*	x							*G. communis*			x					15
4	*A. navarroensis*		x						*Bolivina brazilica*	x							16
5	*Laevidentalina mirandai*	x							*Coryphostoma incrassata*	x	x						17
6	*Lenticubella benderi*	x							*Valvulineria brazilensis*	x							18
7	*Hemirobulina brazilica*	x							*V. iraqensis*						x		19
8	*H. ornata*			..	x				*V. calumbiensis*	x							20
9	*Marginulina brazilica*	x		..					*V. critchetti*					x			21
10	*M. tenuissima*			x					*V. garai*	x							22
11	*Citharina brazilica*	x							*V. ranikotensis*							x	23
12	*C. plumoides*		x						*V. leonardosi*	x							24

Table 2: Comparative identified benthic foraminiferal species of Anan in three countries in the South America: Brazil Cretaceous fauna, Argentine Ypresian fauna and Chile Miocene fauna. See also figure 3.

Cretaceous Brazil foraminiferal species of Anan		Ypresian Argentina foraminiferal species of Anan		Miocene Chile foraminiferal species of Anan	
1	*Ammobaculoides brazilica*	1	*Reticulophragmium argentinica*	1	*Parvigenerina chileana*
2	*Gaudryina brazilica*	2	*Tritaxia argentinica*	2	*Siphogaudryina chileana*
3	*Textularia brazilica*	3	*Siphotextularia argentinica*	3	*Lagena chileana*
4	*Hemirobulina brazilica*	4	*Patellina argentinica*	4	*Lagena mainayefae*
5	*Marginulina brazilica*	5	*Spiroloculina argentinica*	5	*Lagena samarae*
6	*Citharina brazilica*	6	*Quinqueloculina argentinica*	6	*Reussoolina rustomi*
7	*Planularia brazilica*	7	*Lagenoglandulina argentinica*	7	*Vaginulinoides fingeri*
8	*Guttulina brazilica*	8	*Tollmannia fingeri*	8	*Vaginulinella fingeri*
9	*Bolivina brazilica*	9	*Leticuzonaria argentinica*	9	*Vaginulina chilensis*
10	*Valvulineria brazilensis*	10	*Hemirobulina yehiai*	10	*Ramulina fatemae*
11		11	*Marginulina argentinica*	11	*Planulina chileana*
12		12	*Leroyia argentinica*	12	*Cibicides chileana*
13		13	*Vaginulinopsis argentinica*	13	*Falsocibicides chileana*
14		14	*Ramulina morsii*	14	*Gyroidina chileana*
15		15	*Ramulina subornata*	15	
16		16	*Brizalina argentinica*	16	
17		17	*Orthokarstenia striata*	17	
18		18	*Rectuvigerina argentinica*	18	
19		19	*Buliminelloides argentinica*	19	
20		20	*Ellipsoglandulina argentinica*	20	
21		21	*Orthokarstenia striata*	21	
22		22	*Valvulineria nabilae*	22	
23		23	*Woodella jawdati*	23	
24		24	*Pullenia argentinica*	24	
25		25	*Buccella argentinica*	25	

Figure 3: Location map of Brazil, Argentina and Chile in South America.

5. Paleoenvironment

The Mediterranean Sea was part of the southern epicontinental shelf of the Neo-Tethys Ocean, and the seaway was connected westward to the Pacific Ocean via the Caribbean Tethys, and a uniform and strong W-trending Tethyan Circumglobal Current (TCC) flowing throughout the Neo-Tethys Ocean was driven by winds blowing from the same direction (Abed, 2013). Tectonics and sea-level changes played an important role in the depositional history of this area during the Cretaceous. Circulation in the South Atlantic was, and still is, anticlockwise; the northerly flowing current joined the TCC in the Caribbean Tethys near the Equator and then flowed westward into the Pacific Ocean (Fig. 4). The environmental conditions of the identified species mainly represent warm stratigraphic interval water neritic environment (~200m).

Figure 4: Paleogeography of the Neo-Tethys Ocean during the Maastrichtian showing the flow direction of the Tethyan Circum global Current (TCC) from east to west (after Abed, 2013).

6. Conclusion

The present study deals with the recording of sixteen identified species of the Cretaceous foraminiferal species were originally erected from Sergipe State of Brazil. The Tethyan realm had been connected with the Atlantic Ocean from west to the Indo-Pacific Ocean in the east, via Mediterranean Sea. Environmental conditions of the identified species mainly represent warm stratigraphic interval water neritic environment (~200m).

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