Revista Brasileira de Paleontologia, 28(2):e20250446, 2025
A Journal of the Brazilian Society of Paleontology

doi:10.4072/rbp.2025.2.0446

Article

CRINOIDEA (COMATULIDA) FROM THE PIRABAS FORMATION (EARLY MIOCENE), PARÁ STATE, BRAZIL

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ABSTRACT – The Pirabas Formation, a representative geological unit of the Brazilian marine Cenozoic, assembles a rich and diverse fossil record, which includes Comatulida crinoids, components of the faunal assembly of the Pirabas Sea. Samples from the B-17 Mine outcropping, Municipality of Capanema, and the Atalaia Beach, Municipality of Salinópolis, Pará State were analyzed, and hundreds of disarticulated ossicles of crinoid comatulids were found. Centrodorsals of crinoids of the species *Sievertsella polonica* Radwanska, *Discometra rhodanica* (Fontannes), of the genus *Kiimetra* Shibata & Oji, and the family ?Zygometridae were herein identified. The taxa have affinities with those already recorded in the Miocene of the Caribbean biogeographic province and are consistent with the faunal interchange that has existed between the Tropical East Pacific and the Tropical West Atlantic regions. The material suggests the Pirabas Sea as a center of origin for some taxa, while also strengthening possible connections from the Atlantic to the Central Paratethys, the Mediterranean, and the Indian Ocean.

Keywords: Pirabas Sea, Cenozoic, Miocene, echinoderms, crinoids, paleobiogeography.

INTRODUCTION

Crinoids are represented by approximately 650 extant species, comprising 100 species of stalked crinoids (sea lilies) and another 550 species of comatulids (sea feathers), as well as about 6,000 known fossil species (Pawson, 2007). These animals constitute the most basal group of living echinoderms, and their fossil record dates from the Ordovician age. Thereafter, this taxon became abundant, reaching its climax in the Carboniferous age. After the late Permian extinction, one group survived, the Articulata, which persists to this day (Ausich *et al*., 1999; Hess, 2011).

Comatulids emerged in the Mesozoic, are typically found in shallow waters, and have an exclusively suspensivorous feeding strategy, making them common members of coral communities. During the metamorphosis, they lose their peduncle and gain greater mobility, allowing them to climb rocks, corals, and high points of the marine substrate. They can adhere to substrates with varying degrees of firmness and stability, ranging from soft to hard grounds, and some can swim short distances (Ausich *et al*., 1999; Ruppert *et al*., 2005).

The first records of the Crinoidea class for the Pirabas Formation were made by Monteiro (2013, 2017), Távora *et al*. (2015), and Manso & Souza-Lima (2017), who identified the occurrence of disarticulated ossicles, such as centrodorsals and brachials belonging to the order Comatulida. This work aims to continue the research in this order, refining the taxonomic positioning of the specimens described in previous works, describing and identifying new taxa, and expanding the known diversity of the Pirabas Formation.

GEOLOGICAL CONTEXT

The crinoids were recorded in the fossiliferous limestones of the Pirabas Formation, which crops out in the northeastern part of Pará State, more precisely in the Bragantina and Salgado zones. This lithostratigraphic unit is composed of limestones of varied composition in a Miocene marine sequence that was deposited under strong structural control in a phase of sea level variations, tectonic movements, and climatic fluctuations (Rossetti, 2000, 2001, 2006; Rossetti & Santos Junior, 2004). The limestones form a shallow marine carbonate platform, lagoon, and mangrove subenvironments that are interdigitated with cyclic sedimentation, indicating frequent sea-level oscillations and storm waves on the continental shelf. The lithofacies identified are: biocalcirrudite, stratified and unstratified calcarenite, marl, green shales, biohermite, and calcilutite (Góes *et al*., 1990).

Associated with the crinoids, there is an abundant and diverse fossil assemblage composed of vertebrate bioclasts (*e.g*., reptiles, fish, and sirenians) and diverse groups of invertebrates and microfossils (*e.g*., bivalve and gastropod mollusks, other echinoderms, micro- and macrobryozoans, porifera, corals, micro- and macroforaminifera).

STUDIED OUTCROPS

The samples studied were collected from outcrops located in the northeastern region of the Pará State. Access is made from Belém by state highway BR-316, following PA-124 to the Municipality of Capanema/PA, where the occurrence of the outcrop B-17 Mine is recorded. Continuing on PA-124 and then on PA-444, one arrives at Atalaia Beach in the Municipality of Salinópolis, PA, where the limestone outcrops of the Pirabas Formation are distributed (Figure 1).

The B-17 Mine outcrop is an open pit mineral deposit in limestone exploration activity for the manufacture of cement, under the responsibility of the company Cimentos do Brasil S/A (CIBRASA), which holds the mining rights. Its lithological composition comprises an alternation of carbonate lithofacies, including marls, calcilutites, biocalcarenites, biocalcirudites, and mudstones, as well as massive sandstones at the top of the section (Góes *et al*., 1990; Rossetti, 2006; Távora *et al*., 2007).

The outcrops at Atalaia Beach are distributed along the coastline and are most easily accessed at low tide. At certain times of the year, some layers are covered by sand and are not visible. These outcrops constitute six lithofacies exposed in their composite profile: stratified biocalcarenites, massive biocalcarenites, bicalcirudites, calcilutite, shales, biohermites, and non-fossiliferous sandstones.

The sampled material was recovered from the biocalcirudite and marl levels of the Atalaia Beach outcrops and the biocalcirudite levels of B-17 Mine (Figure 2). The biocalcirudites have a whitish-gray coloration and a grain size ranging from clay to medium sand, with representative fossiliferous concentrations. The marl has a grayish color and a grain size ranging from clay to very fine sand, with a significant fossiliferous content.

MATERIAL AND METHODS

The material studied was recovered from 15 samples from the marls and biocalcirudites of the Pirabas Formation. Initially, laboratory procedures began with the separation of approximately 100 g of sediment per sample. The material from these subsamples underwent a process of manual disaggregation, followed by wet

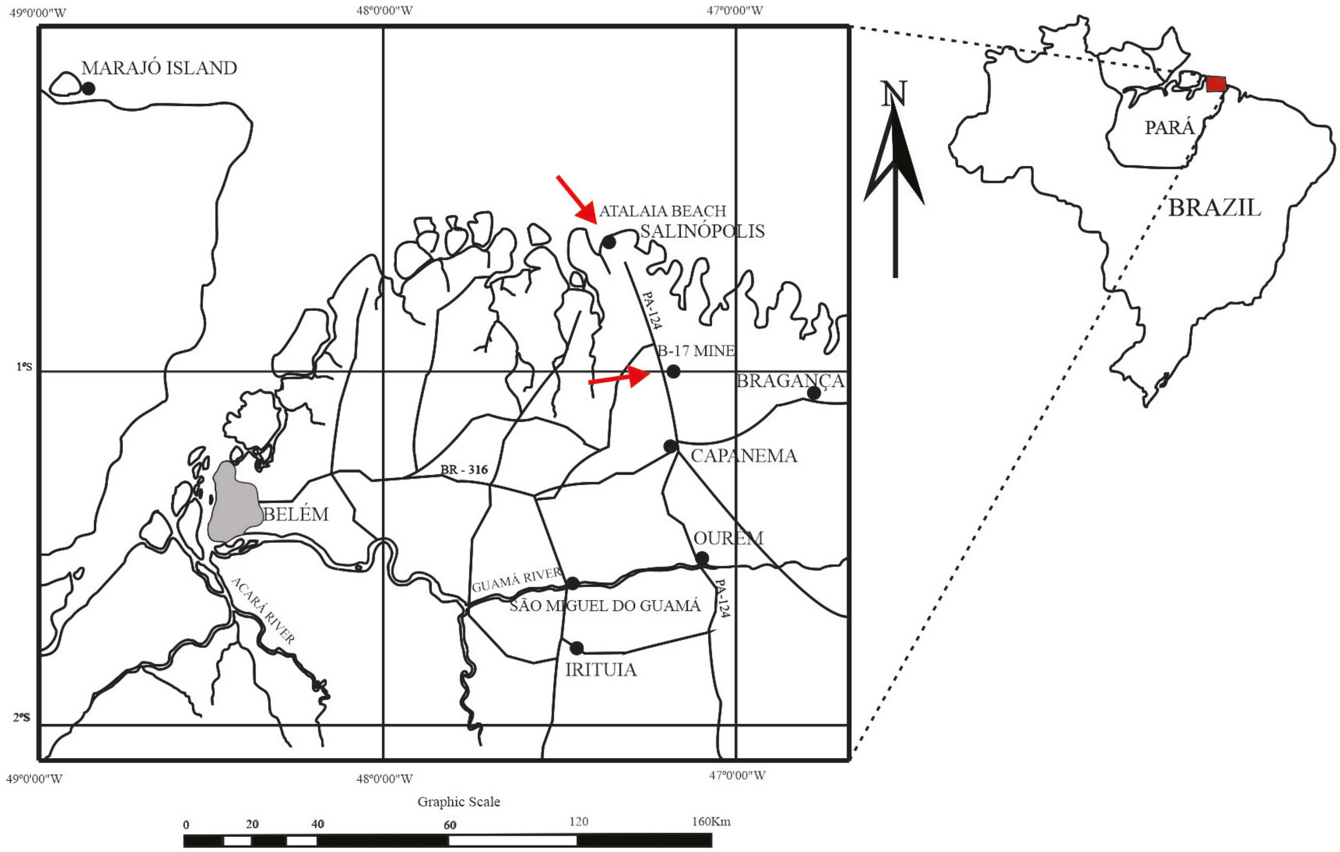

Figure 1. Location map of the outcrops: Atalaia Beach (Salinópolis Municipality) and Mine B-17 (Capanema Municipality), Pará, Brazil.

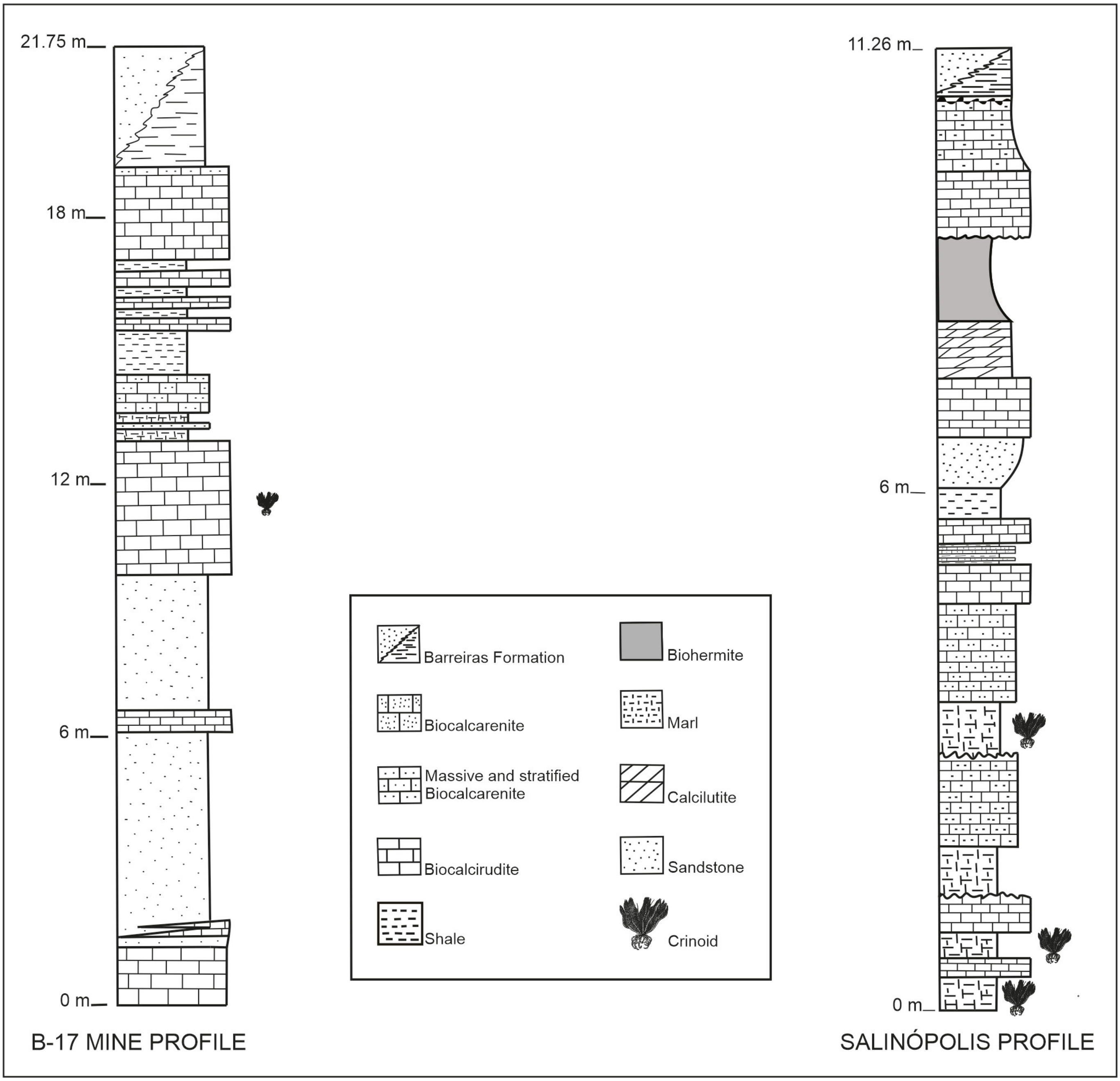

Figure 2. Profiles of the outcrops of Atalaia Beach (Salinópolis Municipality) and Mine B-17 (Capanema Municipality) showing the collection levels of the studied material. (Provided by the Paleontology Laboratory of the Universidade Federal do Pará).

sieving using sieves with mesh sizes of 0.125 mm, 0.5 mm, and 1 mm. The fractionated sediment was dried at room temperature.

The work continued by sorting samples under a Carl Zeiss Stemi SV-6 binocular lens at the Paleontology Laboratory of the Universidade Federal do Pará (**UFPA**) and an Olympus stereomicroscope in the Paleoinvertebrate Laboratory (**LAPIN**) of the Museu Nacional, Universidade Federal do Rio de Janeiro (**MN/UFRJ**).

Approximately 500 ossicles were obtained, with the largest concentration from Atalaia Beach. Those with morphological characteristics best preserved were separated for taxonomic analysis. The recovered ossicles were stored in Frank's cells and simultaneously separated by morphotypes for further taxonomic classification.

The most representative elements of the identified taxa were illustrated using a ZEISS LEO 1430 Scanning Electron Microscope (**SEM**), following the usual methods for preparing the material in *stubs* to be metalized and then photographed at the LABMEV of UFPA.

CorelDRAW software was used to create schematic drawings, which displayed and facilitated the visualization of the morphological characteristics of the identified groups.

Crinoid ossicles were described following the terminology proposed by Moore (1966), Ubaghs (1978), and Hess & Messing (2011). Taxonomic identification follows the systematics proposed by Hess & Messing (2011) and is supplemented with more recent work.

The material studied from a taxonomic point of view is deposited in the collection of the Paleontology Laboratory at UFPA, under the acronym MG, and in the paleoinvertebrate collection of the Department of Geology and Paleontology at MN/UFRJ, under the acronym MN. The samples that were deposited at the National Museum were lost in the great fire of September $2^{\nu\delta}$, 2018. However, they are adequately figured.

SYSTEMATIC PALEONTOLOGY

Class CRINOIDEA Miller, 1821
Subclass ARTICULATA Zittel, 1879
Order COMATULIDA Clark, 1908
Suborder COMATULIDINA Clark, 1908
Superfamily COMASTEROIDEA Clark, 1908
Family COMASTERIDAE Clark, 1908

Sievertsella Radwanska, 2003

Type-species. *Sievertsella seranensis* (Sieverts, 1933).

Sievertsella polonica (Radwanska, 1987)
(Figure 3A–D)

1987 *Sievertsia polonica* sp. n.: U. Radwańska, p. 117–119, figs. 2, 1–5, pl. 1, figs. 1–3, pl. 2, figs. 1–4.
2013 Comatulida indet.: Monteiro, p. 34–35, figs. 7.3–7.4.
2015 Comatulida indet.: Távora *et al*., p. 120, figs. 3.3–3.4.
2017 *Sievertsella polonica*: Monteiro, p. 53–54, pl. I, figs. 1–2.
2017 *Sievertsella polonica*: Manso & Souza-Lima, p. 430, figs. 5–6.

Material. A centrodorsal (MG-7155-Ib) recovered at the marl level from Atalaia beach (Salinópolis).
Description. Pentagonal centrodorsal, measuring 3.5 mm in diameter (Figure 3A); well-defined centrodorsal cavity (Figure 3B) with about 30% of the diameter of the centrodorsal; adoral surface (Figure 3D) with grooves in radial position, positioned aborally to the radial plates, appearing to be the result of fusion of the basal plates; preserved and well defined radial plates, arranged subvertically about the adoral plane, with pits of the interarticular ligaments tending to triangular; it presents about 30 cirrus sockets (Figure 3C) arranged in three irregular rings, the most peripheral cavities being wider with a slight elevation of the margin around the lumen.
Discussion. The genus *Sievertsia* was established by Radwańska (1987), and later, the name was replaced with *Sievertsella* by Radwańska (2003). This change included two species of comatulid crinoids from the Neogene: *Sievertsella seranensis* Sieverts, 1933, and *Sievertsella polonica* Radwanska, 1987. The specimen exhibits diagnostic features of the species *Sievertsella polonica* Radwanska, 1987: a 1:3 ratio of centrodorsal to cavity-Cd diameter; radials preserved in a subvertical position, exhibiting a trapezoidal-shaped contour line; interarticular ligaments of the subtriangular pits; slightly inclined articular facets and somewhat deep muscular pits; and cirrus sockets arranged in three irregular rings. This specimen can be compared with the one described by Manso & Souza-Lima (2017) also for the Pirabas Formation, showing similar features such as the pentagonal shape, the trapezoidal shape of the radials, and the subvertical position, as well as the wide centrodorsal cavity, differing in the smaller amount of cirrus sockets that are arranged in about two rows. According to Radwańska (1987), the amount of cirrus sockets is determined by the size of the centrodorsals; in this way, the centrodorsal described by Manso & Souza-Lima (2017) would be from a juvenile specimen with about 18 cirrus sockets, while the one described in this paper, presents about 30 cirrus sockets, being a large centrodorsal from an adult specimen.
Occurrence. Korytnica Basin, Poland (middle Miocene); Pirabas Formation, Pará, Brazil (early Miocene).

Superfamily TROPIOMETROIDEA Clark, 1908
Family CALOMETRIDAE Clark, 1911

Kiimetra Shibata & Oji, 2007

Type-species. *Kiimetra miocenica* Shibata & Oji, 2007.

Kiimetra sp.
(Figure 3E–H)

2007 *Kiimetra*: Shibata & Oji, p.400.
2011 *Kiimetra*: Hess & Messing, p 112.
2013 Comatulida indet.: Monteiro, p. 34–35, figs. 7.5–7.6.
2015 Comatulida indet.: Távora *et al*., p. 120, figs. 3.5–3.6.
2017 *Kiimetra* sp.: Monteiro, p. 56–58, pl. I, fig. 3.

Material. A centrodorsal (MG-7159-Ia) recovered in the biocalcirrudite of B-17 Mine.
Description. Hemispherical centrodorsal of 2.0 mm diameter (Figure 3E); well-defined centrodorsal cavity with 0.8 mm diameter, making up about 40% of the centrodorsal diameter, showing internal perforations of the axial cirrus canals (Figure 3F); on the adoral side the basal and radial plates are not preserved (Figure 3H); presence of the dorsal star on the aboral apex (Figure 3G); about 20 cirrus sockets arranged irregularly in about three rows (Figure 3G), some of the cirrus sockets showing the lumen, common to a slight elevation on the margin surrounding it.
Discussion. The specimen described here was assigned to the Calometridae family based on the arrangement of its cirrus sockets, which are distributed in irregular rows, one of the diagnostic morphological features of the family. Although Rasmussen (1978) attributes the absence of the dorsal star to this family, Shibata & Oji (2007) presented a specimen from the middle Miocene of the family Calometridae showing the dorsal star, which suggests that the loss of the dorsal star occurred throughout the family's evolution. The specimen studied here has a diameter ratio of approximately 40% between the

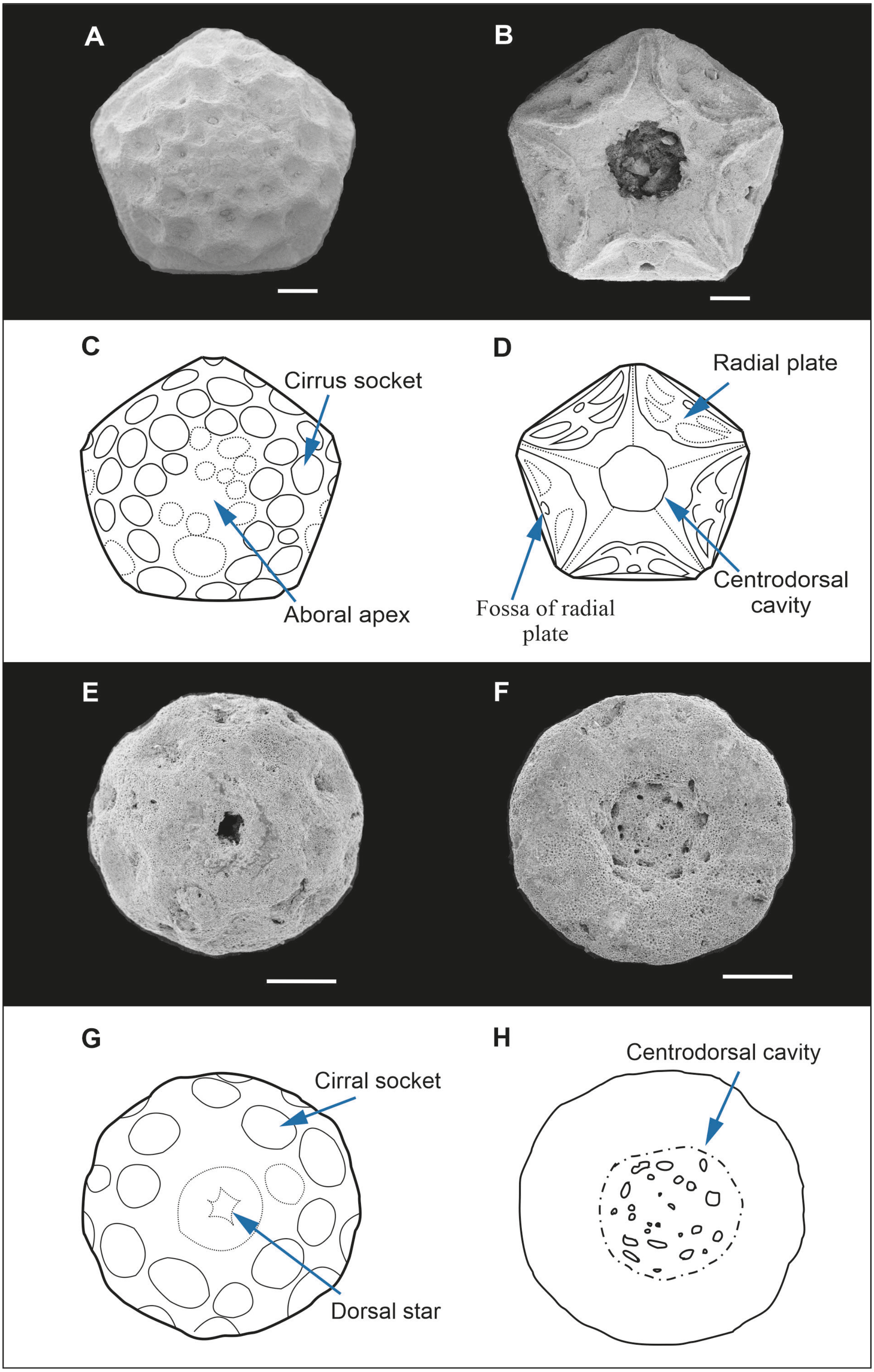

Figure 3. *Sievertsella polonica*; **A**, **C**, aboral view; **B**, **D**, adoral view. *Kiimetra* sp.; **E**, **G**, aboral view; **F**, **H**, adoral view. Scale bars = 200 µm.

centrodorsal and the centrodorsal cavity, a characteristic found in very small specimens within the superfamily (Hess, 2011). The still incipient presence of the dorsal star, which may have been eroded by taphonomic processes, as well as the arrangement of its cirrus sockets, allows this specimen to be classified in the genus *Kiimetra*. The specimen under study exhibits some features in common with *Kiimetra miocenica*. Among these, the most notable are the presence of the dorsal star, the hemispherical shape, and the distribution of the cirrus sockets. However, the centrodorsal is smaller in diameter than the specimens found in the Sirahama Formation, where 30 centrodorsals, ranging mainly from 3.0 mm to 4.0 mm in diameter, were recovered.

Additionally, the number of cirrus sockets in these centrodorsals is significantly larger, ranging from 30 to 40. This may be related to their larger size, the Brazilian specimen being a juvenile, or it could indicate that the specimen studied here represents a new species. Still, the absence of radials in the Brazilian specimen prevents a more refined identification.

Occurrence. Sirahama Formation, Tanabe Group, Japan (early–middle Miocene); Pirabas Formation, Pará, Brazil (early Miocene).

Family ZIGOMETRIDAE Clark, 1908

?Zygometridae indet.
(Figure 4A–D)

1908h Zygometridae: Clark.
2011 Zygometridae: Hess & Messing, p.105.
2017 ?Zygometridae indet.: Monteiro, p. 55–56, pl. I, figs. 6–7.

Material. A centrodorsal (MN 10191-I) recovered at the marl level of Atalaia Beach.

Description. Low hemispherical centrodorsal; aboral apex broad, flattened and with some concavity (Figure 4A), without cirrus marks, measuring three millimeters in diameter; centrodorsal cavity about 30% of centrodorsal diameter; adoral surface (Figure 4B) with impressions of V-shaped radials and rod-shaped basals (Figure 4D); cirrus sockets large and well defined, distributed in two irregular series (Figure 4C); some cavities show a slight ridge positioned transversely, close to the lumen, this surrounded by a slightly elevated ring.

Discussion. This specimen presents an incomplete centrodorsal; however, it was possible to describe morphological characteristics that allowed for its positioning, although with some doubts regarding the family Zygometridae. Among these characteristics, it is worth highlighting the V-shaped radial impression, the very wide aboral apex, free of cirri and flattened with a slight concavity, as well as the distribution of the cirri cavities in two lines. However, some issues need to be discussed; this family was previously recorded only for the Holocene, thus extending its stratigraphic distribution. Furthermore, in the studied specimen, the basals are apparently visible externally, whereas in the current genera, this does not occur, which would possibly represent a plesiomorphic characteristic in the family. Thus, the specimen may represent a new genus. It is worth highlighting the absence of radials, which would be necessary for this taxonomic refinement. The occurrence of this specimen seems to represent the first fossil record of the family Zygometridae and extends its stratigraphic distribution by more than 20 million years.

Occurrence. Pirabas Formation, Brazil (early Miocene); western Pacific Ocean and eastern Indian Ocean (Holocene).

Superfamily HIMEROMETROIDEA Clark, 1909
Family HIMEROMETRIDAE Clark, 1908

Discometra Gislén, 1924

Type-species. *Eugeniacrinus*? *rhodanicus* Fontannes, 1877.

Discometra cf. *D. rhodanica* (Fontannes, 1877)
(Figure 4E–H)

1877 *Eugeniacrinus? rhodanicus*: Fontannes, p. 669.
1880 *Antedon rhodanicus*: Fontannes, p. 410–412, pl. 2, fig. 10a–c.
1897 *Antedon rhodanicus*: de Loriol, p. 121–124, pl. 4, fig. 8 (non 9–10).
1897 *Antedon rhodanicus*: Nicolas, p. 131–132, fig. 6; 1898. p. 398–399, 402–404, fig. 1.
1904 *Antedon rhodanicus*: Airaghi, p. 44–45, figs. 14–15.
1904 *Antedon rhodanicus*: Schütze, p.156–162, pl. 2, figs. 4–5.
1930 *Antedon rhodanicus*: Albus, p. 291–292, pl. 11, figs. 5, 7.
1924 *Discometra rhodanica*: Gislèn, p. 180–182.
1939 *Discometra rhodanica*: Biese & Sieverts-Doreck, p. 106–107.
1961 *Discometra rhodanica*: Sieverts-Doreck, p. 110–117, 124, text fig. 2.
1978 *Discometra rhodanica*: Rasmussen, T890, fig. 593-4a.
1928 *Antedon* cf. *rhodanicus*: Valette, p. 31–34, fig. 5.
2017 ?*Discometra sp.*: Monteiro, p. 54–55, pl. I, figs. 4–5.

Material. A centrodorsal (MN 10190-I) recovered at the marl level from Atalaia beach (Salinópolis).

Description. Low discoidal centrodorsal, with a diameter of 1.75 cm and a small centrodorsal cavity, with 0.22 cm, making up less than 20% of the centrodorsal diameter (Figure 4F). On the adoral side, rod-shaped basal impressions were preserved as well as interradial ridges from the centrodorsal cavity (Figure 4F, H). The radials were not preserved. Aboral apex slightly depressed and rough; small, round, cirrus sockets near the aboral apex and larger ones towards the centrodorsal ends, arranged in about three irregular lines tending to helicoidal (Figure 4E); some cirral cavities exhibiting raised margin around the axial canal, slight crenulation.

Discussion. This specimen exhibits morphological characteristics, such as the shape of its centrodorsal, its aboral apex being free of cirrus and slightly depressed, the arrangement of the cirrus sockets, as well as grooves and ridges radiating from the center, that enable its classification within the family Himerometridae (*sensu* Hess & Messing, 2011). These characteristics associated with the remarkable difference in the size of its centrodorsal cavity, which makes up less than 20% of the diameter of the

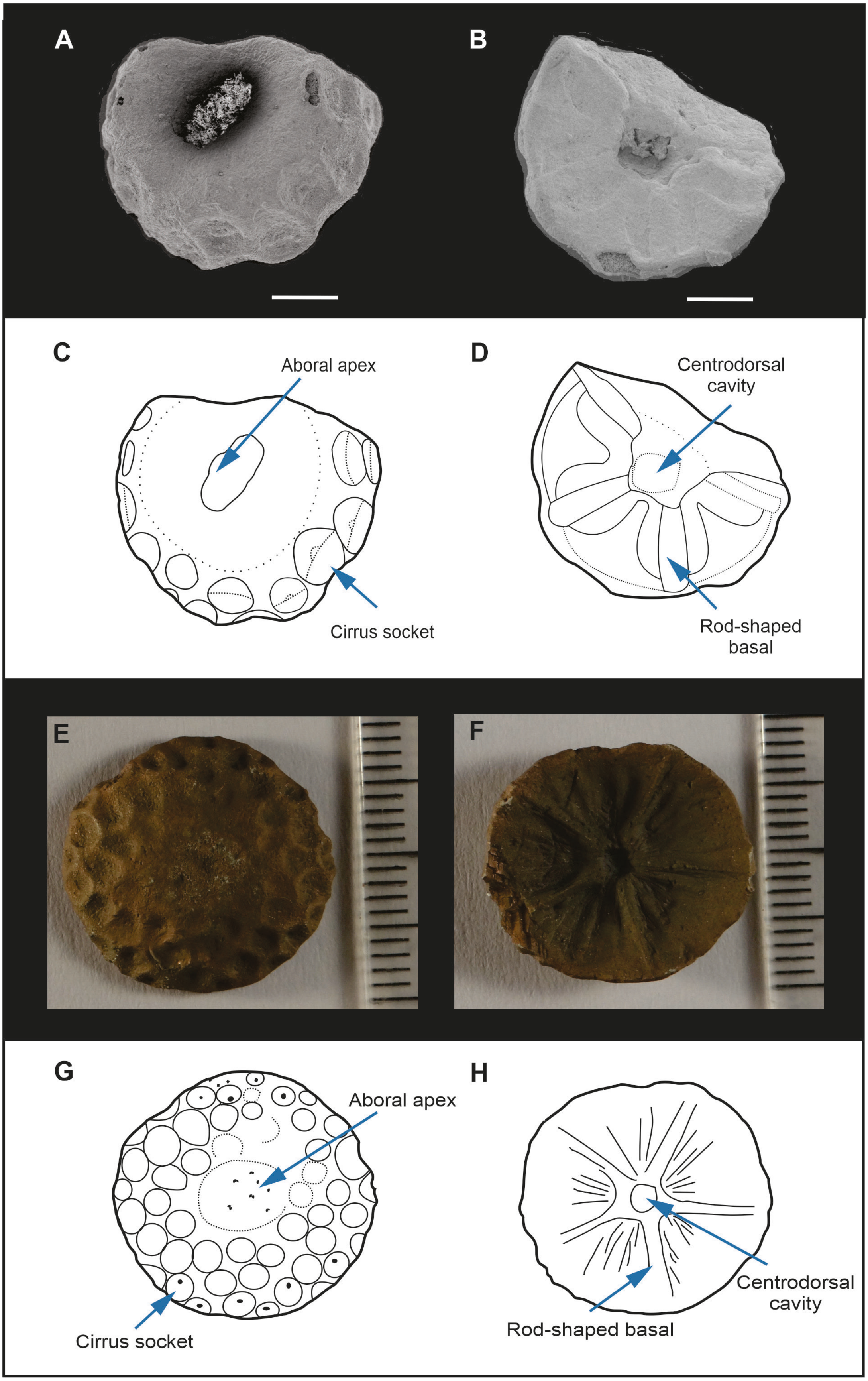

Figure 4. Zigometridae sp.; **A**, **C**, aboral view; **B**, **D**, adoral view. *Discometra* cf. *D. rhodanica*; **E**, **G**, aboral view; **F**, **H**, adoral view. Scale bars = 200 µm.

centrodorsal, the arrangement of the cirrus sockets, and the presence of the rod-shaped basal rods, bring this specimen closer to the genus *Discometra*, more specifically to *D. rhodanica* from the Miocene of France, according to the morphological characteristics redescribed by Eléaume *et al*. (2020). The presence of the rod-shaped basal is still debated, as the genus *Discometra* is placed in the family Himerometridae, which is part of the superfamily Himerometroidea, where rod-shaped basals are absent (*sensu* Hess & Messing, 2011). For the specimen studied herein, the absence of radials makes identification at the genus level difficult.

Occurrence. Eggenburg Burdigalian and Zogeisdorf, Austria (early Miocene); Burdigalian of the basin Rhône-Provence, France; Pirabas Formation, Brazil (early Miocene).

PALEONTOLOGICAL CONSIDERATIONS

Among the crinoid ossicles studied, hundreds of brachial elements and four centrodorsal elements were used for identification: *Sievertsella polonica*, *Kiimetra* sp., *Discometra* cf. *D. rhodanica*, and ?Zygometridae indet. The taxonomic framework of the brachials became limited due to the absence of morphological characteristics of these ossicles and the lack of specific classification studies using those characters.

The record of these new taxa enriches the biotic diversity of the Pirabas Sea and its forms of interaction, both harmonic and disharmonic, including homotypic and heterotypic relationships. These taxa did not live in isolation, resulting in a complexity of ecological relationships that should be studied in greater detail in the future.

The comparative analysis of the life patterns of recent crinoids and their relationships in the environment recapitulates the taxa that inhabited a shallow platform environment, characterized by a substrate that was sometimes sandy and poorly consolidated, and occasionally muddy, serving as a base for both sessile and weak epibenthic forms, as well as endobenthic ones. This substrate variation is well demonstrated stratigraphically, with thinner levels like marls and shales and sandier levels like biocalcirrudites, resulting from sea level variations.

According to environmental preferences, the new taxa recorded for the outcrops of Atalaia Beach can be classified within the fossil associations of paleoecological units I and II of Távora *et al*. (2013), which are adapted to inner platform and reef environments. B-17 Mine configures a lagoonal paleoenvironment, not consistent with the environmental preferences of these taxa, denoting the transportation of this material by storm events out of their natural habitat, which is corroborated by the presence of other marine organisms in the fossil content of the paleo-lagoon (Távora *et al*., 2007).

Based on criteria of morphological similarity, mode of life, and feeding strategy, crinoids remain most of the time on substrate, mooring themselves through cirrus, but they are not fixed forms; they are vagile and have a suspensivorous feeding strategy. Therefore, they would be part of the G1 guild (epibenthic sessile/suspensivorous) of Távora *et al*. (2013), which assembles epibenthic elements and a suspensivorous feeding strategy, although sessile. Thus, it is necessary to add a new guild that assembles the vagile epibenthic suspensivorous organisms or even expand the feeding strategies of the G2 guild of Távora *et al*. (2013) by incorporating suspensivorous organisms.

PALEOBIOGEOGRAPHIC CONSIDERATIONS

During the Cenozoic, there were several changes in the circulation of ocean water currents (Wright, 1998; Rögl, 1999; Potter & Szatmari, 2009), which affected the Pirabas Formation's biota, including a rich and varied echinoderm fauna represented by the classes Echinoidea, Asteroidea, Ophiuroidea, and Crinoidea.

Cenozoic marine faunas have typical Cretaceous ancestors from the Tethys Sea, the primary source of faunal elements for the Caribbean Biogeographic Province. Their westward dispersion enabled their diversification and adaptation to different substrates and neritic bathymetries through shallow ocean currents, combined with their ecological tolerance, which allowed for a successful occupation of the current Central American and Mexican region, the Central American marine corridor (Távora *et al*., 2010b). Migrations occurred from this area to the North and South Atlantic, and also extended to the North and Central Pacific via the Strait of Panama. The Tropical East Pacific (TEP) region has a paleofauna that appears to be a product of multiple derivations of elements from the possibly older Tropical West Atlantic (TWA) region. The uplift of the Isthmus of Panama caused regional bioevents of extinction, primarily affecting mollusks, corals, and bryozoans. (Beu, 2001; Marko & Jackson, 2001).

The Caribbean Biogeographic Province (CBP) is characterized by a rich and varied endemic fauna of mollusks, decapod crustaceans, corals, foraminifera, ostracods, bryozoans, and echinoderms, all typical of marine environments of shallow, warm, agitated, clear, and normal salinity waters (Cecca, 2002). The fauna of the Pirabas Formation records taxa correlated with the Caribbean Biogeographic Province, as evidenced by the Echinoidea, represented by 17 taxa, including the orders Cassiduloidea, Cidaroidea, Clypeasteroidea, and Spatangoidea, which maintain affinities with the CBP (Brito, 1981).

Schweitzer (2001) proposed two possible migration routes: one westward from southern Europe and the Tethys Sea, reaching the coasts of the United States and South America through the Central American corridor; and the other eastward from Europe, the Tethys Sea, and Japan, along the east coast of the United States. This second route would be less common; however, it is represented in the Brazilian Cenozoic malacostracans (Távora *et al*., 2010a).

The taxa studied in this paper seem to corroborate connections and migration routes established during the Neogene, among them the communication from the Atlantic with the Parathetys that has already been studied and recognized, as is the case of the simultaneous appearance of 26 species of bivalves in the

Atlantic, Mediterranean and Central Parathetys and the similar occurrences of echinoids in this same period (Studencka *et al*., 1998; Kroh, 2007).

Comatulida is a cosmopolitan order, and its fossil occurrences have corroborated the exchange of taxa in the CBP and communication between the TEP and TWA regions, as well as possible Atlantic communication with Paratethys.

Within this context, the *Discometra* cf. *D. rhodanica* occurring in Pirabas is also recorded for the early Miocene of Austria, corroborating the communication from the Atlantic to the central Parathetys. *Sievertsella polonica*, recorded in the middle Miocene of Poland, may have radiated from the sea of Pirabas in the early Miocene. The presence of *Kiimetra* in the middle Miocene of Japan and the early Miocene of the Pirabas Formation indicates a probable radiation of this taxon from the Pirabas Sea during the marine transgression event, which was related to the connection between the Atlantic Ocean and the Mediterranean and Indian Oceans.

Similarly, the presence of fossils of the family Zigometridae in the Pirabas Formation, along with its current distribution in the western Indian Ocean and eastern Pacific, also suggests the emergence of the family in the CBP and its subsequent radiation into the Indian Ocean.

CONCLUSIONS

The disarticulated crinoid remains recorded for the Pirabas Formation were herein identified as: *Sievertsella polonica*, *Discometra* cf. *rhodanica*, *Kiimetra* sp., and ? Zygometridae indet. The presence of comatulid crinoids records affinities with the synchronic units from Jamaica, reaffirming the faunal exchange between the TEP and TWA regions. The presence of *Discometra* cf. *rhodanica* in the early Miocene of Brazil and Austria highlights the Atlantic communication with Paratethys. The records of *Sievertsella polonica* and the genus *Kiimetra*, which occur in the middle Miocene of Poland and Japan, respectively, have their earliest occurrences in the Pirabas Formation. This suggests a probable radiation of these taxa from the Pirabas Sea, with the CBP as their point of origin. This is supported by the only fossil record of the family Zigometridae in the Pirabas Formation, which extends the temporal record by more than 20 Ma, and which currently occurs only in the Pacific and Indian Oceans.

DATA AVAILABILITY STATEMENT

Data will be available upon request.

ACKNOWLEDGEMENTS

The authors acknowledge the Fundação de Amparo à Pesquisa do Estado do Rio de Janeiro - FAPERJ for supporting the development of this research (processes E-26/201924/2015 and E-26/200.110/2019); the Laboratório de Microscopia Eletrônica de Varredura (Instituto de Geociências da Universidade Federal do Pará) as its coordinator, Prof. Dr. Cláudio Nery Lamarão and his technical team; the Departamento de Geologia e Paleontologia do Museu Nacional da Universidade Federal do Rio de Janeiro, and Laboratório de Paleontologia da Universidade Federal do Pará, for enabling the physical space for the execution of part of the research activities.

FUNDING

The authors thank financial support provided by Fundação de Amparo à Pesquisa do Estado do Rio de Janeiro - FAPERJ for supporting the development of this research (processes E-26/201924/2015 and E-26/200.110/2019) and CNPq (processes 407.614/2022-2, 311057/2022-5).

AUTHOR CONTRIBUTIONS

Débora Barroso Monteiro: writing – original draft; conceptualizations; investigation; taxonomic analysis; formatting. Sandro Marcelo Scheffler: writing – review; editing; conceptualization. All authors gave final approval for publication and agreed to be held accountable for the work performed therein.

DECLARATION OF AI USE

We have not used AI-assisted technologies to create, review, or any part of this article.

ETHICS

This work fulfills collecting authorizations.

CONFLICT OF INTEREST

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

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Received: 15 January 2024. Accepted: 16 June 2025.

Associated editor: Sergio Martinez
Editor-in-chief: Matias do Nascimento Ritter