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New records and redescriptions of brazilian Scleractinia corals (Itamaracá, Maria Farinha and Pirabas Formations)

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Abstract

This work deals with the systematic study of the corals from Itamaracá, Maria Farinha and Pirabas formations (Lower Maastrichtian, Paleocene-Eocene and Lower Miocene, respectively) at Pernambuco and Pará states. Herein are presented the first records of the species *Actinastrea dickersoni* (Wells, 1941), *A. jukesbrownei* (Wells, 1945), *Caulastraea dendroidea* (Coryell and Ohlsen, 1929), *C. portoricensis* (Coryell and Ohlsen, 1929), *Ceratotrochus* (*C.*) sp., *Enallhelia* aff. *E. occidentalis* Wells, 1944, *Hydnophora latefundata* Gregory, 1895, *Stephanocoenia marylandica* (Conrad, 1841), *Trochocyathus* (*T.*) *collignoni* (Alloiteau, 1958) and *T.* (*Platycyathus*) sp. as well as redescriptions of *Cladocora* sp., *Stephanocoenia pernambucensis* Fernandes, 1978, *Stylophora silicensis* Weisbord, 1973 and *Paracyathus rugosus* Vaughan, 1900.

Keywords: Brazil, corals, Scleractinia, Maastrichtian, Tertiary.

Resumen

Especies de corales colectadas en estratos del Maastrichtiano Inferior, Paleoceno- Eoceno y Mioceno Inferior, correspondientes a las formaciones Itamaracá, Maria Farinha y Pirabas en Pernambuco y Pará provincias son identificadas y descritas. Esta fauna está representada por Actinastrea dickersoni (Wells, 1941), A. jukesbrownei (Wells, 1945), Caulastraea dendroidea (Coryell and Ohlsen, 1929), C. portoricensis (Coryell and Ohlsen, 1929), Ceratotrochus (C.) sp., Enallhelia aff. E. occidentalis Wells, 1944, Hydnophora latefundata Gregory, 1895, Stephanocoenia marylandica (Conrad, 1841), Trochocyathus (T.) collignoni (Alloiteau, 1958) y T. (Platycyathus) sp. También se presentan redescripciones de Cladocora sp., Stephanocoenia pernambucensis Fernandes, 1978, Stylophora silicensis Weisbord, 1973 y Paracyathus rugosus Vaughan, 1900.

Palabras clave: Brasil, corales, Scleractinia, Maastrichtiano, Terciario.

1. Introduction

One of the biggest gaps of Brazilian paleontological research is the systematic characterization of corals, especially the marine Post Paleozoic in sedimentary basins of the continental margin. Although coralinofauna is rare in the majority of litostratigraphic units, its definition expands the body of knowledge about the Cretaceous and Tertiary corals, helping to define detailed biogeographic patterns in the Caribbean and South America regions.

This paper deals with the systematic study of 35 specimens of Itamaracá, Maria Farinha and Pirabas formations, deposited in the collections of Departamento de Geologia, Centro de Tecnologia e Geociências da Universidade Federal de Pernambuco (DGEO-CTG-UFPE), Museu Nacional/Universidade Federal Rio de Janeiro (MN/UFRJ), and Museu de Geociências-Universidade Federal do Pará (MG/UFPa).

The records of corals of the Itamaracá Formation were only cited before by Oliveira (1957) and Moura (2007). Regarding the Maria Farinha Formation, its corals were initially mentioned by Rathbun (1875), Oliveira (1953), Kegel (1955) and Beurlen (1959), but these authors only cited their occurrences. The systematic characterization of these invertebrates was introduced by Fernandes (1978, 1984), which proposed the new species *Stephanocoenia pernambucensis* and *Madracis whitei* and recognized *Paracyathus rugosus* Vaughan and *Caryophyllidae* gen. et sp. indet. At Pirabas Formation Maury (1925), Fernandes (1979, 1981), Távora *et al*. (2002, 2015) and Lalor and Távora (2006), have described a total of 15 to date.

In Pernambuco state (Figure 1) the specimens come from the Fosforita quarry, Olinda city (8º 0' 34" S, 34º 51' 19" W), Poty quarry, Paulista city (7º 56' 24" S, 34º 52' 20" W) and Zumbi mill, Igarassu city (7º 50' 4" S, 34º 54' 23" W). Atalaia and Maçarico beaches, Salinopolis city (0º 36' 5" S, 47º 18' 48" W), Fortaleza Island, São João de Pirabas city (0º 41' 43" S, 47º 10' 23" W), and Caieira locality, Capanema city (1º 12' 19" S, 47º 9' 25" W), are the localities where specimens were collected at Pará state (Figure 2). The majority of these corals were reef-building species, lived in symbiotic relationship with zooxanthellae algae and limited their ecologic distribution to substrates in shallow, well-lit, warm marine waters.

2. Location and Stratigraphy

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

The Itamaracá Formation is a transitional unit formed during continental to marine stage, represented by an estuarine, coastal lagoon and tidal plain deposits, with marine and brackish fossils. This formation is mainly composed by siliciclastic sediments, mixed and bioelementary facies including phosphatic calciferous sandstones, shales and limestones with fossiliferous siliciclastic deposits, as well as phosphorites on the upper portion. They appear in its uppermost stratum, characterizing a maximum flood surface that separates a transgressive tract system from a high stand tract. Its fossiliferous content includes corals, bivalves, gastropods, cephalopods, polychaets, echinoids, fishes, reptiles, foraminifera, coprolites and plants that suggest Lower Maastrichtian age (Nascimento-Silva *et al*., 2011; Moura, 2007; Silva, 2014).

The Maria Farinha Formation is composed of limestones, marly limestones and thick levels of marls in its lower

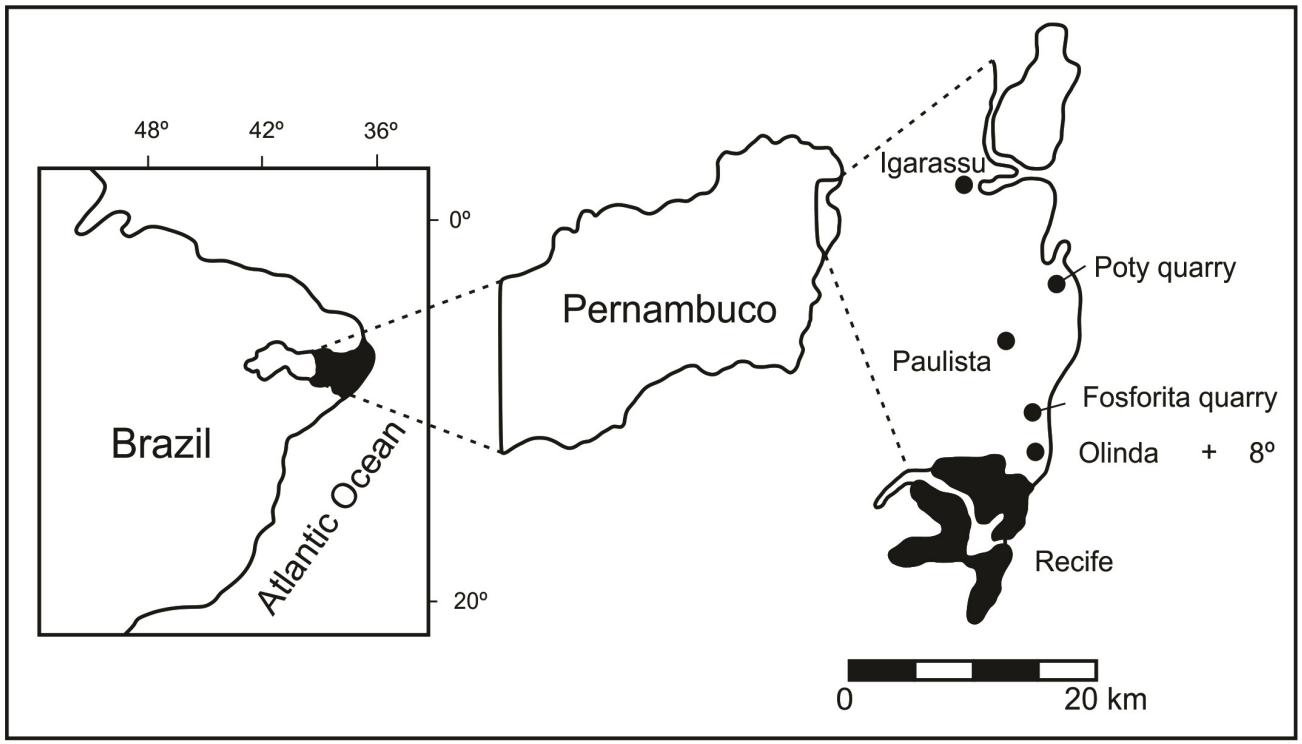

Figure 1. Map showing the study area in Pernambuco state, pointing the localities and cities where the fossil corals were collected (Távora and Miranda, 2004).

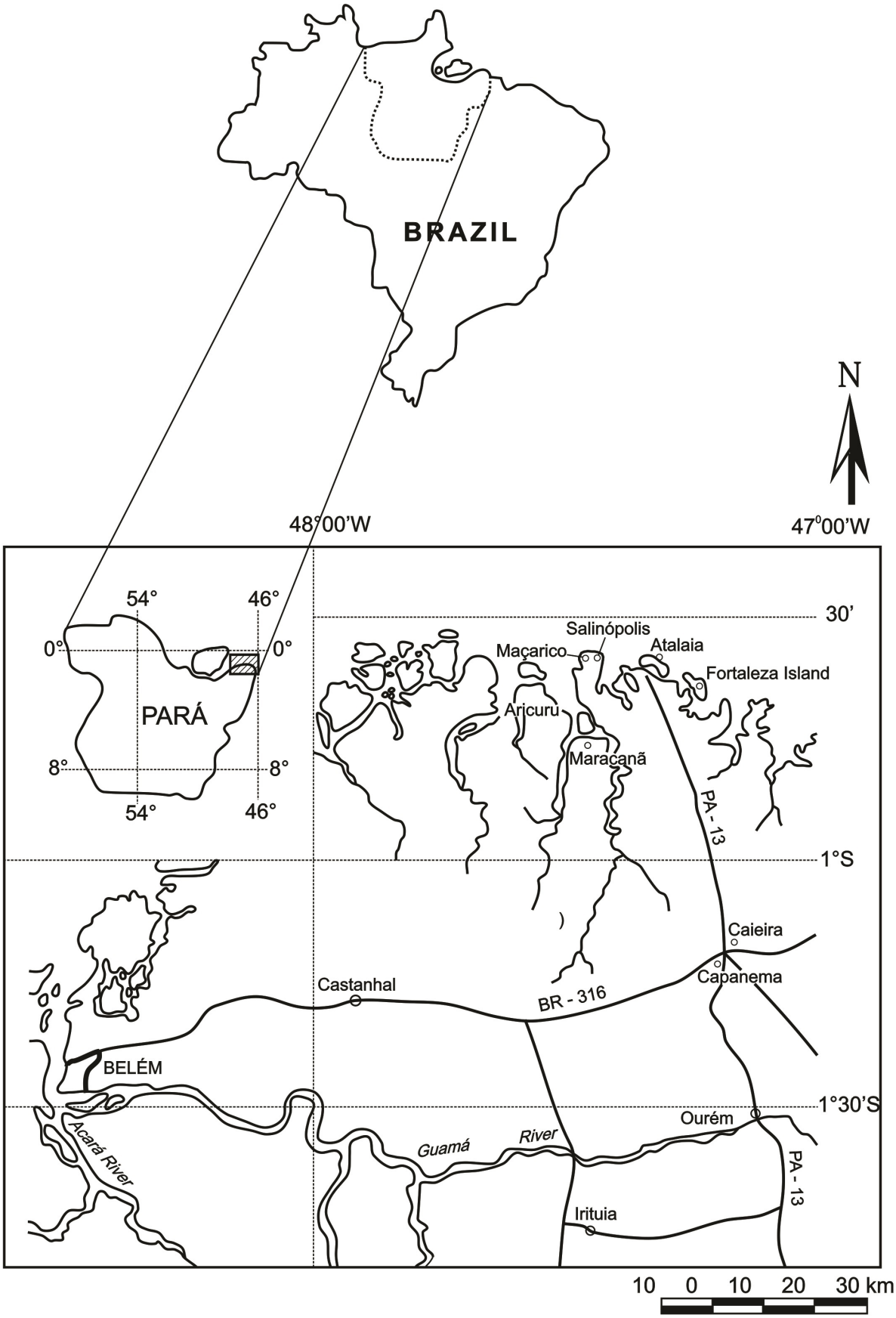

Figure 2. Map showing the study area in Pará state, pointing the localities and cities where the fossil corals were collected.

portion, while dolomitic limestones, containing fossil reefs and lagoonal reefs, characterize its upper portion. This formation exhibits the regressive profile typical 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, which displays a conglomeratic look typically associated to the Cretaceous-Paleogene transition (Nascimento-Silva *et al*., 2011). The paleontological content of this litostratigraphic unit consists of calcareous algae, foraminifera, corals, bryozoans, bivalves, 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 a manifestation of the final extensional deformation phase of the Gondwana breakup responsible for the split of the South American and African continents (Costa *et al*., 1993; Rossetti and Góes, 2004).

The Pirabas Formation (Maury, 1925), with broad outcrops along the 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 in the Pirabas River estuary, in the Bragantina platform east of Salinas County near Salinópolis city, northeastern Pará state (Rossetti and Góes, 2004). The Pirabas Formation consists of richly fossiliferous limestones that point out to a warm, shallow marine depositional environment where foraminifera, ostracods, porifera, corals, bryozoans, bivalves, gastropods, cephalopods, decapoda and cirripedia crustaceans, echinoderms, fishes, reptiles and mammals of Lower Miocene age thrived (Fernandes, 1981; Ramalho *et al*., 2015; Távora *et al*., 2010; Zagorsek *et al*., 2014).

3. Material and Methods

The samples analyzed comprise 34 specimens, all of them isolated corals, with colonial corals as dominant. The cnidaria are represented by external and internal moulds, some filled or replaced with finely crystallized calcite, displaying surface structures and fine ornamentation of partially well-preserved septal borders. The inner structures are not so well preserved due their more delicate nature. The analysis of these corals was carried out by using a Leika S6E binocular microscope, with the aid of a precision caliper for obtaining measurements. The photographs were obtained with a Sony DSC-HX1 digital camera.

The corals at the Itamaracá and Maria Farinha formations are very rare and the specimens illustrated are the best preserved. Detailed descriptions depend on the quality of the material, in cases where most diagnostic morphological structures are preserved. These structures, namely septa, pali and columella, were directly visualized with the aid of a stereomicroscope, making polished or thin sections unnecesary. In the Pirabas Formation this taxa ranges from little common to rare, excepting *Flabellum wailesi* Conrad, 1855, an abundant species.

4. Systematic Descriptions

The systematic classification and essential terminology used in this paper is mainly based on Wells (1956). The descriptions and nomenclature follow the proposal of Baron-Szabo (2006, 2008, 2014), Budd (1987), Budd and Johnson (1999), Cairns (1995), Cairns and Wells (1987), Filkorn *et al*. (2005), Roniewicz and Stolarski (1999) and Wells (1933, 1941a, 1941b, 1944, 1945, 1946). In addition, other complementary works such as Bosellini (1999), Budd *et al*. (1992), Fernandes (1978, 1979), Geyer (1954), Gregory (1895), Löser (2006), Löser *et al*. (2013) and Vaughan (1900, 1919) were considered.

The following abbreviations are used to indicate the dimensions of the corals: h: height; l: length; w: width; cd: calicular diameter; s: septa; cdp: calice's depth; c: costae's thickness and pd: pedicel's diameter. In the case of *Caulastraea dendroidea*, *C. portoricensis* and *Cladocora* sp. the size the corallites (dbc) it is also included, and *Stylophora silicensi*s and *Enallhelia* aff. *E. occidentalis* include the branch's diameter (bd) and branch's length (bl) measurements. The wt (walls' thickness) is also used to describe the cerioid and plocoid scleractinian taxa.

Order Scleractinia Bourne, 1900
Suborder Archaeocoeniina Alloiteau, 1952
Family Actinastraeidae Alloiteau, 1952

Genus *Actinastrea* d'Orbigny, 1849

Type species. *Actinastrea goldfussi* d'Orbigny, 1850

Diagnosis. Corallum colonial, massive, ramose or encrusting, cerioid to subcerioid or subplocoid. Corallites small, prismatic, directly united by septothecal walls, smooth or porous. Septa compact, radials, non-confluent and granulated laterally. Columella styliform well developed. Paliform lobes and endothecal dissepiments sparse and thin. Synapticulae situated laterally (Wells, 1956; Baron-Szabo, 2014).

Distribution. Jurassic–Recent (Geyer, 1954; Wells, 1956; Baron-Szabo, 2014).

Actinastrea dickersoni (Wells, 1941a)
Figure 3A

1941a *Astrocoenia dickersoni* Wells. Bull. Amer. Paleontology, v. 26, p. 5-6, pl. 2, fig. 4.

1984 *Madracis whitei* Fernandes. An. XXXIII Cong. Bras. Geol., v. 1, p. 312- 313, figs.1-3.

Description. Corallum colonial massive, encrusting, subplocoid to cerioid and irregularly spherical. Corallites small and numerous, cylindrical to subcylindrical, separated by thick, smooth and elevated septothecal walls. Calices monocentric and polygonal, hexagonal or pentagonal in outline, arched and moderately deep. Septa straight, equal to subequal, laminar, granulated laterally and hexamerally arranged in three incomplete to complete cycles, ranging from 16 to 24 units. Septal margins elevated, crenulated and ornamented by granules. The septa from the first cycle are thick and continuous with denticulate upper edges, and its terminations extend to the columella. The septa from the second cycle are smaller, also extending to the columella. The third cycle's septa are short, less than a half of the size of the first two cycles and do not merge to the columella. Columella well developed, small and styliform. Holotheca, trabecular structures, paliform lobes and endothecal and exothecal dissepiments absent.

Occurrence. Cuba: Perseverancia Formation, Upper Cretaceous (Wells, 1941a); Brazil: Maria Farinha Formation, Paleocene-Eocene (Fernandes, 1984); Itamaracá Formation, Lower Maastrichtian (present study).

Material. four colony fragments (DGEO-CTG-UFPE-1537-A-C; DGEO-CTG-UFPE-2707) from the Fosforita quarry locality, Olinda city, Pernambuco state, Brazil.

Dimensions. (DGEO-CTG-UFPE-1537-A) h: 11 mm; l: 18 mm; cd: 2–2.7 mm; s: 18- 24; wt: 0.2- 0.6 mm; cdp: 0.3- 0.6 mm. (DGEO-CTG-UFPE-1537-B) h: 12 mm; l: 19 mm; cd: 1.7–2.5 mm; s: 16- 24; wt: 0.4–0.7 mm; cdp: 0.2–0.4 mm. (DGEO-CTG-UFPE-1537-C) h: 10 mm; l: 18 mm; cd: 1.8–2 mm.

Discussion. The taxonomic relationships between *Actinastrea* d'Orbigny, 1849 and *Astrocoenia* Milne Edwards and Haime, 1848 has been discussed in the past 60 years. Initially, Milne Edwards and Haime (1848) individualized the genus *Astrocoenia*, and d'Orbigny (1849) proposed *Actinastrea* based on morphologically identical copies, characterized by their small-calicular diameter colonial cerioids. Alloiteau (1954) corroborated the existence of two genus, based on the differences on the calicular extremities, septal walls, endothecal dissepiments and columella. Ever since, the characterization of the species assigned to the *Astrocoenia*-*Actinastrea* clade was confusing and insufficiently enlightening (Baron-Szabo, 2014).

Geyer (1954) considered *Astrocoenia* restricted to the Triassic, and positioned all of these clade's records from the Jurassic in *Actinastrea*. Löser (2012, 2013) proposed that Jurassic to Early Cretaceous corals assigned to *Actinastrea* belonged to the genus *Stelidioseris*. In the present research the authors follow Baron-Szabo (*op. cit.*). Thus, all species of Central and South America considered as *Astrocoenia* must be attributed in *Actinastrea*.

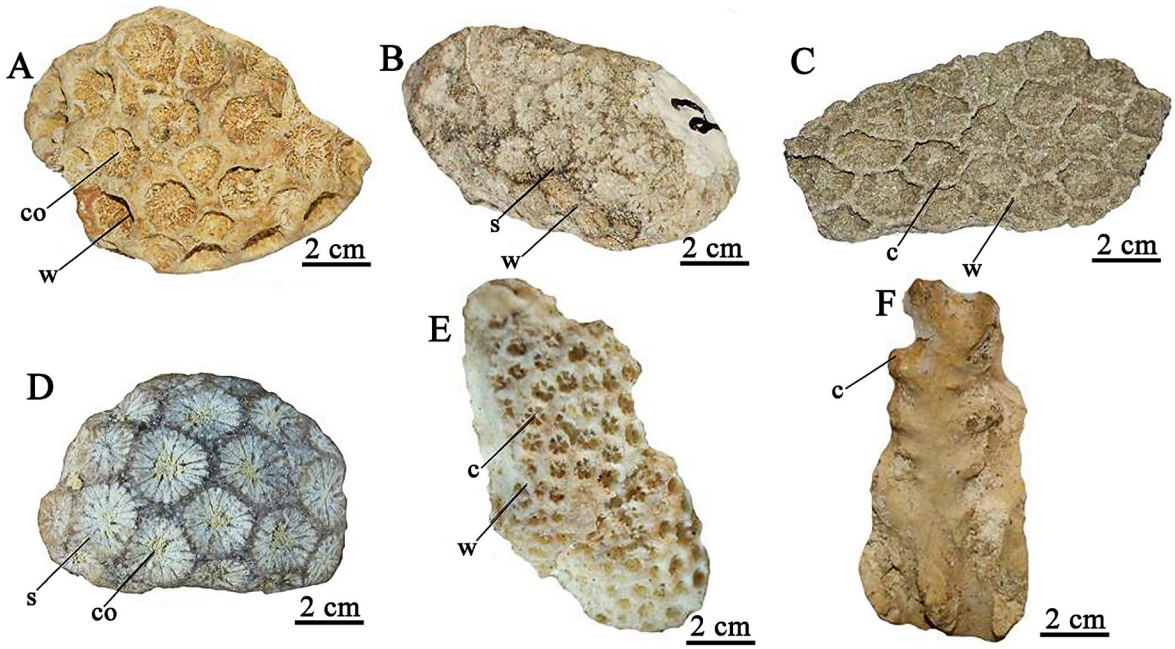

Figure 3. A) *Actinastrea dickersoni* (Wells, 1941) (DGEO-CTG-UFPE-1537-A): upper surface view of corallum subplocoid to cerioid, laminated septa, styliform columella and polygonal calices, separated by elevated walls; B) *A. jukesbrownei* (Wells, 1945) (DGEO-CTG-UFPE-2408): corallum cerioid to subcerioid and small and subcircular corallites, closely separated; C) *Stephanocoenia marylandica* (Conrad, 1841) (DGEO-CTG-UFPE-7667-A): upper surface view of corallum cerioid to subplocoid and polygonal and large calices; D) *S. pernambucensis* Ferreira, 1978 (MN-5415-I): upper surface view of corallum cerioid to subcerioid, styliform columella and polygonal calices, separated by septothecal walls; E) *Stylophora silicensis* Weisbord, 1973 (MN-5364-I): corallum plocoid to subplocoid and small and circular calices, separated by thick walls; F) *Enallhelia* aff. *E. occidentalis* Wells, 1944 (DGEO-CTG-UFPE-1540-A): upper surface view of subcylindrical branches and small and cylindrical corallites organized in one plane; (c: calice; co: columella; s: septa; w: walls).

The identifiable morphological features in *Actinastrea* sp. of the Upper Cretaceous of Mexico by Filkorn *et al*., (2005), resemble *A. dickersoni* but this species has the largest calices recorded and more numerous septa. There are also similarities in the shape of corallum, columella, calices and corallites of the *A. peruviana* (Wells, 1941b) and *A. kellumi* (Wells, 1946) recorded in the Lower Cretaceous of Peru and Upper Jurassic of Mexico, respectively. The specimens studied have more rounded and less numerous (18–24) calices and a distinct hexameral arrangement of septa. This is the first occurrence of this species on South America's Cretaceous, being previously restricted to the Cretaceous of Cuba.

The morphological review of *Madracis whitei* suggests that their diagnostic features are sufficient to consider it synonymous with *Actinastrea dickersoni*.

Actinastrea jukesbrownei (Wells, 1945)
Figure 3B

1945 *Astrocoenia jukesbrownei* Wells. Geol. Soc. America Bull., p. 3–4, figs. 4–5.

Description. Corallum colonial massive, encrusting, cerioid to subcerioid. Corallites small and prismatic, separated by porous and dentate septothecal walls. Calices monocentric, moderately deep, subcircular to polygonal, with three to six sides. Septa straight, equal to subequal, laminar, laterally smooth and octamerally arranged in two incomplete to complete cycles, ranging from 14 to 18 units. Septal margins elevated, subcrenulated and ornamented by granules. The septa from the first cycle are thicker, equal and continuous and its terminations extend to the columella, while in the second cycle are smaller, laminated and discontinuous, less than a half of the size of the first ones and doesn't merge to the columella. Columella well developed, styliform and suboval. Holotheca, trabecular structures, paliform lobes and endothecal and exothecal dissepiments absent.

Occurrence. Jamaica: Troy Formation, Middle Eocene; Barbados: Scotland Formation, Middle Eocene; Panama: Gatuncillo Formation, Upper Eocene (Wells, 1945; Budd *et al*., 1992; Stemann, 2004); Brazil: Maria Farinha Formation, Paleocene-Eocene (present study).

Material. a colony fragment (DGEO-CTG-UFPE-2408) from the Engenho Zumbi locality, Igarassu city, Pernambuco state, Brazil.

Dimensions. h: 21.5 mm; l: 19.5 mm; w: 17 mm; cd: 1–1.5 mm; s: 14–18; wt: 0.1–0.2 mm; cdp: 0.3–0.5 mm.

Discussion. This taxon is very close to *A. incrustans* (Duncan, 1873) and *A. decaturensis* (Vaughan, 1919) in the skeletal elements, but these species show bigger-diameter corallites divided by thicker separation walls.

Suborder Astrocoeniina Vaughan and Wells, 1943
Family Astrocoeniidae Koby, 1890
Subfamily Astrocoeniinae Koby, 1890

Genus *Stephanocoenia* Milne Edwards and Haime, 1848

Type species. *Astrea intersepta* Lamarck, 1816.

Diagnosis. Corallum colonial massive, plocoid to subcerioid. Corallites small to medium size, separated by septothecal to parathecal walls. Septa disposed in three cycles with denticulate outlines and composed by a 12-paliform lobes system in the first and second cycles. Columella styliform. Endothecal and exothecal dissepiments, evenly spaced (Wells, 1956; Budd, 1987).

Distribution. Cretaceous–Recent (Wells, 1956; Budd, 1987).

Stephanocoenia marylandica (Conrad, 1841)
Figure 3C

1841 *Astrea marylandica* Conrad. Proceed. Acad. Nat. Sci. Philadelphia, v. 1, p. 28–33.
1904 *Septastraea marylandica* (Conrad). Vaughan, Maryland Geol. Sur., Miocene, Syst. Paleont., p. 444-447, pl. 126, figs. 1a, 1b; pl. 127, figs. 1–3; pl. 128, figs. 1–2; pl. 129.
1942 *Astrangia marylandica* (Conrad). Richards and Harbison, Acad. Nat. Sci. Priladelphia Proc., v. 94, p. 178, 224.
1971 *Septastraea marylandica* (Conrad). Weisbord, St. Florida, Dept. Nat. Res. Bureau Geol., Geol. Bull., n. 53, p. 47–52, pl. 12, figs. 1–7 (see complete synonymy in Weisbord, 1971).

Description. Corallum colonial massive, encrusting, cerioid to subplocoid. Corallites larger and prismatic, separated by dentate and delicate septothecal walls. Calices monocentric, polygonal, hexagonal, pentagonal and quadrangular in outline, broad and moderately deep. Septa straight, equal to subequal, thick, equidistant, laterally granulated and hexamerally arranged in three incomplete cycles, averaging from 12 to 18 units. Septal margins elevated, dentated and ornamented by granules. The septa from the first and second cycles are thicker, equal, and continuous, merged internally in a ring-shaped system of six pali around the columella. The third cycle's septa are short and laminated, less than a quarter of the size of the first two cycles and do not merge to the paliform system. Columella well developed, thick and styliform to papillose. Holotheca, trabecular structures and endothecal and exothecal dissepiments absent.

Occurrence. United States of America: Jackson Bluff Formation, Upper Miocene; Mary Formation, Miocene-Pliocene; Yorktown Formation, Miocene-Pliocene (Conrad, 1841; Richard and Harbison, 1942; Weisbord, 1971); Brazil: Maria Farinha Formation, Paleocene-Eocene (present study).

Material. two colony fragments (DGEO-CTG-UFPE-7667-A and DGEO-CTG-UFPE-7667-B) from the Poty quarry locality, Paulista city, Pernambuco state, Brazil.

Dimensions. (DGEO-CTG-UFPE-7667-A) h: 5 mm; l: 32.5 mm; w: 17 mm; cd: 3.5–5.5 mm; s: 12–18; wt: 0.3- 0.6 mm; cdp: 0.3–0.5 mm. (DGEO-CTG-UFPE-7667-I-B) h: 6.5 mm; l: 26.5 mm; w: 13 mm; cd: 3.5–4.5 mm; s: 12–18; wt: 0.2–0.4 mm; cdp: 0.2–0.3 mm.

Discussion. *Stephanocoenia marylandica* (Conrad, 1841) is similar to *S. pernambucensis* Fernandes, 1978, also recorded at the Maria Farinha Formation. The distinction between them is in the shape and arrangement of corallites and septa as well as separation walls and diameter of calices. In addition, the species herein described include affinities with *S. storrsi* Wells, 1941b recognized from the Eocene of Peru. However, the characters related to the corallites (diameter and separation walls), calice, septa, columella and paliform structures are different between these taxa.

Stephanocoenia pernambucensis Fernandes, 1978
Figure 3D

1978 *Stephanocoenia pernambucensis* Fernandes. An. XXX Cong. Bras. Geol., v. 2, p. 961, pl. I, figs.1–4.

Description. Corallum colonial massive, encrusting, cerioid to subcerioid and irregularly spherical. Corallites prismatic to subcylindrical, separated by smooth septothecal walls. Calices broad, shallow and monocentric, subcircular to polygonal (hexagonal and pentagonal) in outline. Septa straight, equal to subequal, thick, equidistant, laterally smooth and hexamerally arranged in three complete cycles with 24 units. The septa from the first cycle are thicker, equal and continuous, merged internally in a ring-shaped system of six pali around the columella. The septa from the second cycle are laminated and do not merge to the paliform system. The third cycle's septa are smaller and discontinuous, less than a quarter of the size of the first two cycles and do not merge to the paliform system. Columella well developed, central, thick and styliform. Holotheca, trabecular structures and endothecal and exothecal dissepiments absent.

Occcurrence. Brazil: Maria Farinha Formation, Paleocene-Eocene (Fernandes, 1978).

Material. Five colony fragments (MN-5415-I; MN-5416-I; MN-5417-I; MN-5418-I and MN-5419-I) from the Maria Farinha river, Maria Farinha district, Paulista city, Pernambuco state, Brazil, deposited on the paleoinvertebrates collection at the Museu Nacional/UFRJ.

Dimensions. (MN-5415-I, holotype) h: 6 mm; l: 11 mm; w: 8 mm; cd: 2–3 mm; s: 24; wt: 0.1–0.4 mm; cdp: 0.2–0.3 mm.

Discussion. This taxon is similar to *S. intersepta* (Esper, 1795) and *S. marylandica* (Conrad, 1841) in the corallum, coralites, calice and columella (Fernandes, 1978) but it is different in the size and arrangement of secondary septa, separation walls and paliform system.

Family Pocilloporidae Gray, 1842

Genus *Stylophora* Schweigger, 1819

Type species. *Madrepora pistillata* Esper, 1797 emend. Milne Edwards and Haime, 1850.

Diagnosis. Corallum plocoid, ramose to submassive in shape, separated by compact walls. Corallites tending to spiral irregularly around branches. Septa compact with the first cycle attached to styliform columella. Endothecal dissepiments delicate and vesicular (Wells, 1956; Baron-Szabo, 2006).

Distribution. Eocene-Recent (Wells, 1956).

Stylophora silicensis Weisbord, 1973
Figure 3E

1973 *Stylophora silicensis* Weisbord. Bull. State Florida Dept. Nat. Res. Div. Int., Res. Bureau Geol., v. 53, p. 20–22, pl. 2, figs. 1–4.

1979 *Stylophora* cf. *S. silicensis* Weisbord. Fernandes, Bol. Mus. Par. Emílio Goeldi, n. ser. Geol., 22, p. 16–19, est. I, figs. 1–4.

Description. Corallum colonial massive to branching, plocoid to subplocoid, with subcircular branches in cross section. Corallites cylindrical, small and numerous, disposed obliquely in longitudinal section and separated by thick and smooth walls. Calices circular to subcircular disposed irregularly or regularly in transverse rows, monocentric, moderately deep and elevated in their superior edges. Septa straight, equal to subequal, laminar, equidistant and hexamerally arranged in three incomplete to complete cycles, averaging from 20 to 24 units. Septal margins slightly concave and smooth. The septa from the first cycle are thicker, equal and continuous, merged internally to the columella. The septa from the second and third cycles are smaller, discontinuous, rudimentary and do not merge to the columella. Columella well developed, circular, central and styliform. Holotheca, trabecular structures, paliform lobes and endothecal and exothecal dissepiments absent.

Occurrence. United States of America: Tampa Formation, Lower Miocene (Weisbord, 1973); Brazil: Pirabas Formation, Lower Miocene (Fernandes 1979).

Material: Three colony fragments (MN- 5364-I; MN-5365-I and MN-5366-I) from Atalaia beach locality, Salinopolis city, Pará state, Brazil, reposited on the paleoinvertebrates collection at the Museu Nacional/UFRJ.

Dimensions. (MN- 5364-I) h: 20 mm; l: 40 mm; cd: 1–1.2 mm; bd: 0.6–9 mm; wt: 0.2–0.6 mm; cdp: 0.2–0.3 mm. (MN- 5365-I) l: 45 mm; cd: 1–1.2 mm; wt: 0.4–0.7 mm.

Discussion. Fernandes (1979) recognized similarities in branches, corallites, calice and septa with the species of the Lower Miocene of Florida, *S. minutissima* Vaughan, 1900 and *S. imperatoris* Vaughan, 1919 (Weisbord, 1971; 1973). Moreover, they are similar with *S. affinis* Duncan, 1863 (Pleistocene of Sudan) in corallum, corallites and columella, but very different in diameter of calices and number of septa (Hamed, 2015).

Suborder Stylinina Alloiteau, 1952
Family Stylinidae d'Orbigny, 1851
Subfamily Euheliinae de Fromentel, 1861

Genus *Enallhelia* Milne Edwards and Haime, 1849

Type species. *Lithodendron compressum* Goldfuss, 1829 emend. Milne Edwards and Haime, 1851.

Diagnosis. Corallum colonial branching to dendroid. Corallites and calice may anastomose, lying in one plane. Costae thin, recovered by stereome. Columella styliform well developed (Wells, 1956).

Distribution. Middle Jurassic-Lower Cretaceous (Wells, 1956).

Enallhelia aff. *E. occidentalis* Wells, 1944
Figure 3F

1944 *Enallhelia occidentalis* Wells. Journ. Paleont., v. 18, n. 5, p. 437, pl. 70, figs. 4–6.

Description. Corallum colonial branching to dendroid with anastomosed and subcylindrical branches. Corallites small and cylindrical, organized in one plane, separated by smooth and compact parathecal walls. Calices circular to elliptical, monocentric and shallow. Septa equidistant and laminar, averaging from 10 to 12 units. Columella poorly preserved, small and styliform. Trabecular structures, paliform lobes and endothecal and exothecal dissepiments absent.

Occurrence. Venezuela: Barranquin Formation, Lower Cretaceous (Wells, 1944); Brazil: Itamaracá Formation, Lower Maastrichtian (present study).

Material. eight colony fragments (DGEO-CTG-UFPE-1540-A-H) from the Fosforita quarry locality, Olinda city, Pernambuco state, Brazil.

Dimensions. (DGEO-CTG-UFPE-1540-A) h: 15 mm; l: 30 mm; cd: 1.3–1.5 mm; bd: 3.5–4.5 mm; bl: 10–13mm; s: 10. (DGEO-CTG-UFPE-1540-B) h: 19 mm; l: 38 mm; cd: 1.2–1.3 mm; bd: 3.5–5.5 mm; bl: 10–16 mm; s: 12. (DGEO-CTG-UFPE-1540-C) h: 25 mm; l: 40 mm; bd: 5–5.5 mm; bl: 18 mm. (DGEO-CTG-UFPE-1540-D) h: 20 mm; l: 40 mm; bd: 5 mm. (DGEO-CTG-UFPE-1540-E) h: 29 mm; l: 21 mm; bd: 5 mm. (DGEO-CTG-UFPE-1540-F) h: 16 mm; l: 28 mm. (DGEO-CTG-UFPE-1540-G) h: 14 mm; l: 20 mm. (DGEO-CTG-UFPE-1540-H) h: 19 mm; l: 22 mm.

Discussion. The Stylinidae family is rare in the Occidental Atlantic (Löser *et al*., 2013) probably due to environmental or taphonomic peculiarities. The genus *Enallhelia* Milne Edwards and Haime, 1849 and Oculina Lamarck, 1816 are very similar in the shape of corallum and calice but distinct in the size of corallum and calice, arrangement of corallites and septa (Wells, 1956). Furthermore the Lamarck genus is cenozoic and *Enallhelia* is restricted to the Cretaceous. *Enallhelia occidentalis* Wells, 1944 was proposed and recognized only in the Lower Cretaceous of Venezuela. The specimens studied herein show similarities but their skeletal elements calice and septa are obliterated due the preservation setting, preventing the undoubted systematic characterization of the species of the Barranquin Formation. Likewise there are resemblance with *E. anomalos* (Felix, 1891) and *E. somaensis* Eguchi, 1942, both found in the Cretaceous of Mexico (Löser, 2006; Löser *et al*., 2013) in the corallum, columela, corallites and separation walls, but the calice, septa and arrangement of branches are dissimilar.

Suborder Faviina Vaughan and Wells, 1943
Superfamily Faviicae Gregory, 1900
Family Faviidae Gregory, 1900
Subfamily Faviinae Gregory, 1900

Genus *Caulastraea* Dana, 1846

Type species. *Caulastraea furcata* Dana, 1846.

Diagnosis. Corallum colonial phaceloid with intracalicular budding. Corallites circular to elliptical, with up to three distinct centers. Costae well developed. Columella trabecular to spongy, without paliform lobes. Endotheca vesicular and epitheca absent (Wells, 1956; Budd and Johnson, 1999).

Distribution. Eocene–Recent (Wells, 1956; Budd and Johnson, 1999).

Remarks. The species from genus *Caulastraea* herein studied were considered originally by Coryell and Ohlsen (1929) as belonging to the genus *Calamophyllia* Blainville, 1830.

Caulastraea dendroidea (Coryell and Ohlsen, 1929)
Figures 4A, 4B

1929 *Calamophyllia dendroidea* Coryel and Ohlsen. Scient. Sur. Porto Rico Virgin Island, v. 3, n. 3, pl. XXX, figs. 2–3.
1999 *Caulastraea dendroidea* (Coryell and Ohlsen, 1929). Bull. Amer. Paleont., v. 356, p. 39.

Description. Corallum colonial, dendroid, phaceloid and constituted by recurved and random arrangement branches, whose bifurcation angles are unequal and averaging from 25º to 30º between the three corallites. Epitheca thick, smooth, incomplete and rudimentary. Corallites monocentric and subcylindrical, with mid-lower segments united by a basal extremity. Calices subelliptical, shallow and laterally compressed. Septa arranged in five incomplete cycles (61 to 65 units), equal to subequal, recurved, continuous, laterally granulated, moderately thick, spaced on smaller cycles, compressed on the bigger ones and merged to the columella on the first three cycles. Costae well developed and straight, uninterrupted in the primary and secondary septa. Columella sublamellar and elongated. Exothecal dissepiments delicate and locally preserved on the lower third of the samples. Trabecular structures, paliform lobes and endothecal dissepiments absent.

Occurrence. Puerto Rico: Ponce Formation, Middle Miocene (Coryell and Ohlsen, 1929); Brazil: Pirabas Formation, Lower Miocene (present study).

Material. A colony fragment (MG-7151-I) from the Ponta do Castelo locality, Fortaleza island, São João de Pirabas city, Pará state, Brazil.

Dimensions. h: 56 mm; l: 43 mm; cd: 27–29 mm; dbc: 4 mm; s: 61–65; c: 1–1.5 mm.

Discussion. *Caulastraea dendroidea* (Coryell and Ohlsen, 1929) resembles *Retiophyllia dawsoni* (Clapp and Shimer, 1911) in some features of the corallum, corallites, calices and septa. However, *R. dawsoni* has thin epitheca, smaller number of septa, more reduced calicular diameter and common endothecal dissepiments. Also the species *C. dendroidea* is very similar to the *C. portoricensis* (Coryell and Ohlsen, 1929) in corallum, calice, septa and columella, but are distinct the epitheca thickness, size and bifurcation angle of corallites as well as the origin of branch points.

Caulastraea portoricensis (Coryell and Ohlsen, 1929)
Figures 4C, 4D

1929 *Calamophyllia portoricensis* Coryel and Ohlsen. Scient. Survey Porto Rico Virgin Island, v. 3, n. 3, p. 199–200, pl. 30, fig. 4.

1999 *Caulastraea portoricensis* (Coryell and Ohlsen, 1929). Budd and Johnson, Bull. Amer. Paleont., v. 356, p. 38–39, pl. 2, figs. 1-10, text-figures 4, 6, 21, 22.

Description. Corallum colonial, dendroid, phaceloid, branching and recurved. Branches multidirectional and characterized by unequal bifurcations varying from 35º to 45º between the five corallites. Epitheca delicate, smooth, incomplete and rudimentary. Corallites monocentric, subcylindrical and spaced, with lower segments united by a basal extremity. Calices shallow and laterally compressed, elliptical to subeliptical. Septa disposed in five incomplete cycles (48 to 52 units), equal to subequal, recurved, continuous, laterally granulated, moderately thick, spaced on smaller cycles, compressed on the bigger ones and merged to the columella on the first three cycles. Costae well developed and recurved, continuing from the primary and secondary septa. Columella sublamellar and elongated to styliform. Trabecular structures, paliform lobes and endothecal and exothecal dissepiments absent.

Occurrence. Puerto Rico: Lares de Calcário, Lower Miocene; Los Puertos and Ponce Formations, Middle Miocene; Mona Island, Upper Miocene; Dominican Republic: Mao Formation, Lower Pliocene; Bahamas: Upper Pliocene; Jamaica: Manchioneal and Hope Gate Formation, Plio-Pleistocene; Costa Rica: Moín Formation, Plio-Pleistocene (Coryell and Ohlsen, 1929; Budd and Johnson, 1999); Brazil: Pirabas Formation, Lower Miocene (present study).

Material. A colony fragment (MG-7152-I) from the Ponta do Castelo locality, Fortaleza island, São João de Pirabas city, Pará state, Brazil.

Dimensions. h: 46 mm; l: 62 mm; cd: 19–25 mm; dbc: 6 mm; s: 48–52; c: 1–1.5 mm.

Discussion. *Caulastraea portoricensis* (Coryell and Ohlsen, 1929) is like *Dermosmilia cretacica* Turnsek 1974 in corallum, calices, arrangement and thickness of septa, columella and costae. But *D. cretacica* is different in calices' shape and bifurcation angles, as well as having distinct biogeographic and biocronologic patterns. With *C. dendroidea* the differences are in the thickness of the epiteca, corallum's size, number of septa, bifurcation angles and branching points of corallites.

Subfamily Montastreinae Vaughan and Wells, 1943

Genus *Cladocora* Ehrenberg, 1834

Type species. *Madrepora flexuosa* Pallas, 1766.

Diagnosis. Corallum phaceloid-dendroid to subflabelloid. Wall septothecal and septoparathecal. Costosepta compact, finely granulated laterally and dentated marginally. Paliform lobes opposite all but last cycle of septa. Pseudo-columella formed by trabecular extensions of axial septal ends, irregularly parietal, spongy to papillose, sublamellar deeper in corallum. Endothecal dissepiments delicate (Wells, 1956; Baron-Szabo, 2006).

Distribution. Upper Cretaceous-Recent (Wells, 1956).

Remarks. According to Wells (1956), based on fossil and recent occurrence, the genus *Cladocora* is divided in *C.* (*Cladocora*) Ehrenberg, 1834 fossil and *C.* (*Dendrocora*) Duncan, 1876 recent subgenus, proposal not cited nor adopted in subsequent studies, (Eguchi, 1974; Baron-Szabo, 2006; Baron-Szabo *et al*., 2006) including this work.

Cladocora sp.
Figure 4E

Description. Corallum colonial phaceloid to dendroid, occupying a hollow cavity. Corallites branching, cylindrical and subparallel, without lateral connections. Calices circular to subcircular, monocentric and shallow. Septa subequal, continuous and thick, hexamerally arranged with 16 to 20 units. The septa from first cycle are thicker and merged internally to the center. Septal margins gently elevated, forming costae upwards the calicular margins. Columella apparently papillose, developed from the union of septa. Epitheca, paliform lobes, trabecular structures, endothecal and exothecal dissepiments absent.

Occurrence. Brazil: Pirabas Formation, Lower Miocene (Fernandes, 1979).

Material. One colony fragment (MN- 5363-I) from the Caieira locality, Capanema city, Pará state, Brazil, deposited on the paleoinvertebrates collection at the Museu Nacional/ UFRJ.

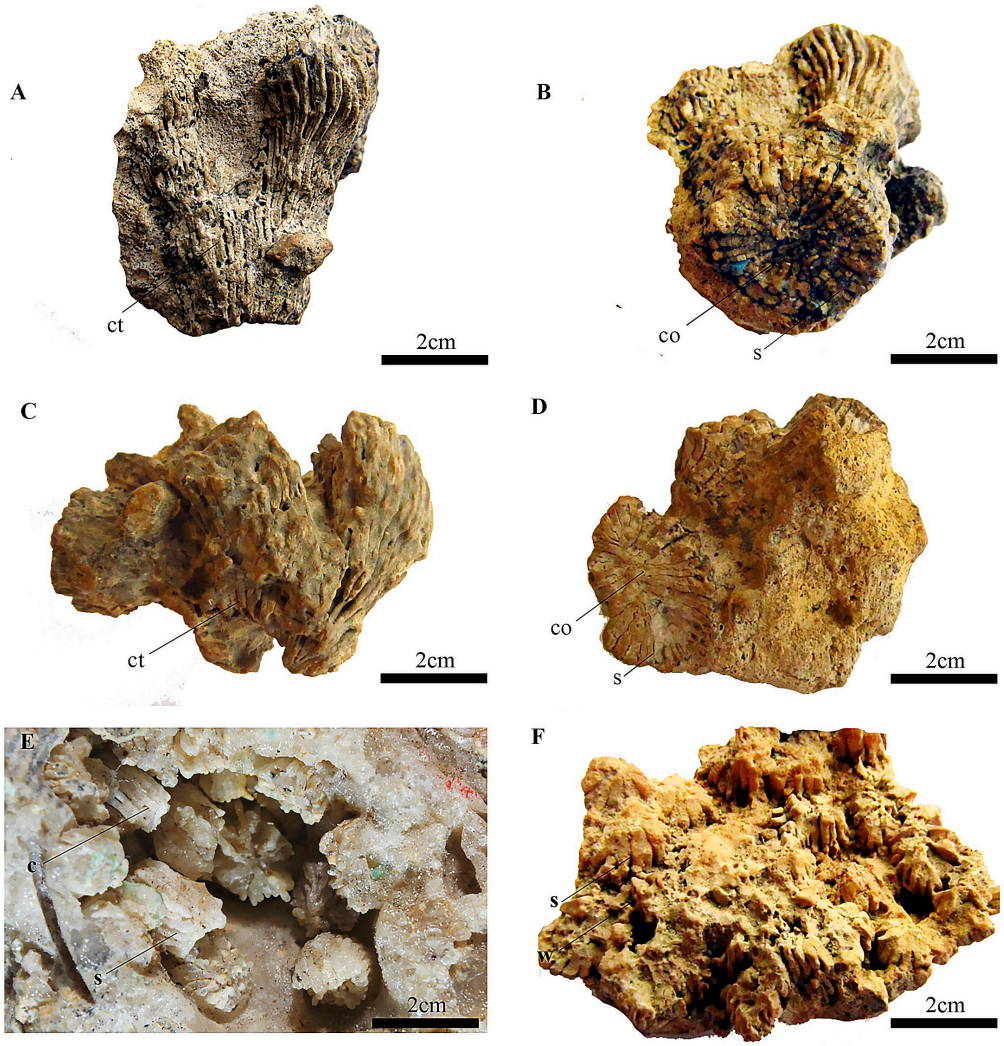

Figure 4. A) *Caulastraea dendroidea* (Coryell and Ohlsen, 1929) (MG-7151-I): lateral view of corallum phaceloid, subcylindrical corallites and a well-developed costae; B) *Caulastraea dendroidea* (Coryell and Ohlsen, 1929) (MG-7151-I): upper surface view of subelliptical calice, thick septa and sublamellar columella; C) *C. portoricensis* (Coryell and Ohlsen, 1929) (MG-7152-I): lateral view of corallum phaceloid, recurved, spaced corallites and a well-developed costae; D) *C. portoricensis* (Coryell and Ohlsen, 1929) (MG-7152-I): upper surface view of elliptical calice, thick septa and an elongated columella; E) *Cladocora* sp. (MN-5363-I): upper surface view of branching and cylindrical corallites and circular calices; F) *Hydnophora latefundata* Gregory, 1895 (MG-7153-I): upper surface view of conical and flat monticules, elevated calices and a discontinuous and lamellar columella; (c: calice; co: columella; ct: costae; s: septa; w: walls).

Dimensions. h: 10 mm; l: 40 mm; cd: 1–3 mm; dbc: 2–3 mm; s: 16–20; c: 0.1 mm.

Discussion. The morphology of corallum, corallites, costae and septa are diagnostic of the genus *Cladocora* (Wells, 1956; Baron-Szabo, 2006). The specimen is similar to *C. arbuscula* Lesueur, 1821 from the Plesistocene of Panamá and *C. johnsoni* Gane, 1895 from the Pliocene of United States of America in corallum, calice and columella, but is distinct in the septa, corallites and branches arrangement. The species definition is not possible to be stablished due to a lack of recognition of diagnostic morphological details from the calice and septa (Weisbord, 1974).

Family Merulinidae Verrill, 1866

Genus *Hydnophora* Fischer, 1807

Type species. *Hydnophora demidovii* Fischer, 1807.

Diagnosis. Corallum colonial massive, encrusting and hydnophoroid. Monticules conical to cylindrical, short and discontinuous, separated by septoparathecal walls. Septa compact, finely granulated laterally. Columella irregularly trabecular to lamellar, discontinuous. Endothecal dissepiments delicated and vesicular (Wells, 1956; Baron-Szabo, 2006).

Distribution. Cretaceous–Recent (Wells, 1956).

Hydnophora latefundata Gregory, 1895
Figure 4F

1895 *Hydnophora latefundata* Gregory. Quart. Journ. Geol. Soc. London, 51, p. 267–268. Pl. 11, fig. 1.
1901 *Hydnophora latefundata* Gregory. Vaughan, Samml. Geolog. Reichs-Museums in Leiden, v. 2, n. 1. p. 7.
1999 *Hydnophora latefundata* Gregory. Bosellini, Paläontologische Zeitschrift, v. 73, n. 3/4, p. 235–236.

Description. Corallum colonial, massive, encrusting, subplocoid to plocoid, The lateral fusion of corallites walls constitute special structures named monticules, that are numerous, with a shape varying between conical, flat, elongated, straight or slightly sinuous. Calices elevated, monocentric, irregularly distributed and subcircular to elliptical in outline. Septa straight, equal to subequal, thick, equidistant, laterally smooth and hexamerally arranged in three incomplete cycles, averaging from 18 to 23 units. The septa from the first cycle are thicker, equal and continuous, limited to the upper section of the monticules. The second and third cycle's septa are subequal and laminated, limited to the lower section of the monticules, near to the columella. Septal margins elevated, dentated and smooth. Columella lamellar and discontinuous. Holotheca, trabecular structures, paliform lobes and endothecal and exothecal dissepiments absent.

Occurrence. Barbados: Miocene; Saint Croix: Miocene; Trinidad: Miocene (Gregory, 1895); Brazil, Pirabas Formation, Lower Miocene (present study).

Material. A colony fragment (MG-7153-I) from the Maçarico beach locality, Salinópolis city, Pará state, Brazil.

Dimensions. h: 13 mm; l: 49 mm; w: 44mm; cd: 5–8 mm; s: 18–23; wt: 0.8–1.4 mm.

Discussion. The genus *Hydnophora* is very similar to *Polyphylloseris* Fromentel 1857 in the corallum, septa and calices features (Wells, 1956) and has a distinct morphology between corallites and columella. *H. latefundata* Gregory, 1895 seems similar to *Agaricia agaricites* Linnaeus, 1758, in the septa and interseptal furrows (Vaughan, 1901). Also, the corallum and septa arrangement resembles *H. variabilis* (Duncan, 1873) from the Eocene of Saint Bartholomew and *H. reussi* (Duncan, 1868) from the Oligocene of Antigua. Meanwhile in *H. variabilis* the shape of calices and number of septa are different, and *H. reussi* possesses thicker separation walls of corallites and septotecate. Until now *H. latefundata* Gregory, 1895 is the only occurrence of this genus in the Miocene of the Caribbean region (Bosellini, 1999) and this research recognized it in the brazilian Miocene.

Suborder Caryophylliina Vaughan and Wells, 1943
Superfamily Caryophylliicae Gray, 1847
Family Caryophyllidae Gray, 1847
Subfamily Caryophylliinae Gray, 1847

Genus *Trochocyathus* Milne Edwards and Haime, 1848

Type species. *Turbinolia mitrata* Goldfuss, 1826 Milne Edwards and Haime, 1848.

Diagnosis. Corallum solitary fixed or free, variably conical, turbinate, ceratoid or discoidal. Costosepta compact finely granulated laterally. Pali opposite all but last cycle in two crowns. Columella fascicular or spongy. Endothecal dissepiments vesicular (Wells, 1958; Baron-Szabo, 2008).

Distribution. Middle Jurassic-Recent (Wells, 1956).

Subgenus *Trochocyathus* (*Trochocyathus*) Milne Edwards and Haime, 1848

Type species. *Trochocyathus* (*Trochocyathus*) *uber* Vaughan and Popenoe, 1935.

Diagnosis. Corallum turbinate to ceratoid. Calices' contour subelliptical to elliptical (Wells, 1956).

Distribution. Middle Jurassic-Recent (Wells, 1956).

Trochocyathus (*Trochocyathus*) *collignoni* (Alloiteau, 1958)
Figure 5A, 5B

1958 Paratrochocyathus collignoni Alloiteau. Ann. Géol. Madagascar, 25, p. 135-136, pl. 31, figs. 3–4.
1984 Paratrochocyathus collignoni Alloiteau. Turnsek *et al*., Palaeont. Am., n. 54, p. 475.
2000 Paratrochocyathus collignoni Alloiteau. Baron-Szabo, Bull. Nat. Hist. Mus., 56, p. 126.
2000 Paratrochocyathus collignoni Alloiteau. Looser, Cat. Cret. Corals, v. 1, p. 60.
2003 Paratrochocyathus collignoni Alloiteau. Turnsek *et al*., Gulf Coast Sec. Found. Spec. Publ. Geol., 1, p. 172, figs. 9j–9k.

Description. Corallum solitary small, turbinated, ceratoid to trochoid and elliptical transversally. Calice monocentric and slightly depressed, elliptical to subelliptical on the upper edge and fixed by a recurved and subcircular pedicel. Costosepta well defined on the calicular margin, continuous, irregularly to regularly spaced and separated by shallow and planed furrows. Septa hexamerally arranged in five incomplete to complete cycles with 48 to 55 units, equal to subequal, laterally smooth and irregularly spaced. The septa from the first and second cycle are thicker, equal, elongated and merged internally in a ring-shaped system of pali around the columella. The third and fourth cycle's septa are laminated and apparently do not merge to the paliform system. The septa from the fifth cycle are smaller, incomplete and delicate. Fosseta subcircular and moderately deep. Columella spongy, delimited by the paliform system. Epitheca, trabecular structures, endothecal and exothecal dissepiments absent.

Occurrence. Madagascar: Ambarimaninga, Albian; United States of America: Finlay and Del Norte Formations,

Middle-Upper Albian (Alloiteau, 1958; Turnsek *et al*., 2003); Brazil: Itamaracá Formation, Lower Mastrichtian (present study).

Material. two specimens (DGEO-CTG-UFPE-1541-A-B) from the Fosforita quarry locality, Olinda City, Pernambuco state, Brazil.

Dimensions. (DGEO-CTG-UFPE-1541-A) h: 22 mm; l: 14 mm; w: 12 mm; cd: 14 mm; s: 55; c: 0.1–0.3 mm; pd: 0.7 mm. (DGEO-CTG-UFPE-I541-B) h: 14 mm; l: 13 mm; w: 0.6 mm; cd: 13 mm; s: 48; c: 0.1 mm.

Discussion. This species that occurs in the Cretaceous of Madagascar and United States of America was originally described in the genus *Paratrochocyathus* Alloiteau, 1958 and was later confirmed by Turnsek *et al*. (2003). According to Baron-Szabo (2000) it is synonymous to the genus *Paratrochocyathus* and *Trochocyathus*, due the similar morphological features of pali and columella, assignment adopted in this work. The specimen studied is similar to *T. woolmani* Vaughan, 1900 from the Cretaceous of United States of America but *T*. (*T*.) *collignoni* possess bigger corallum, ovalate calice and numerous septa (Wells, 1933).

Subgenus *Trochocyathus* (*Platycyathus*) Fromentel, 1863

Type species. *Trochocyathus* (*Platycyathus*) *terquemi* Milne Edwards and Haime, 1857 emend. Wells, 1933.

Diagnosis. Like *T*. (*Trochocyathus*) but corallum discoidal and free (Wells, 1956; Baron-Szabo, 2008).

Distribution. Cretaceous-Recent (Wells, 1956).

Trochocyathus (*Platycyathus*) sp.
Figure 5C

Description. Corallum solitary small, ceratoid to trochoid, transversally discoid. Calice circular, monocentric and shallow. Costosepta straight to sinuous, continuous, irregularly spaced and separated by deep and rounded furrows. Septa hexamerally arranged in four incomplete to complete cycles with 40 to 48 units, equal to subequal, laterally granulated and irregularly spaced. The septa from the first cycle are thicker and more elongated than others. Columella, epitheca, trabecular structures, paliform lobes and endothecal and exothecal dissepiments absent.

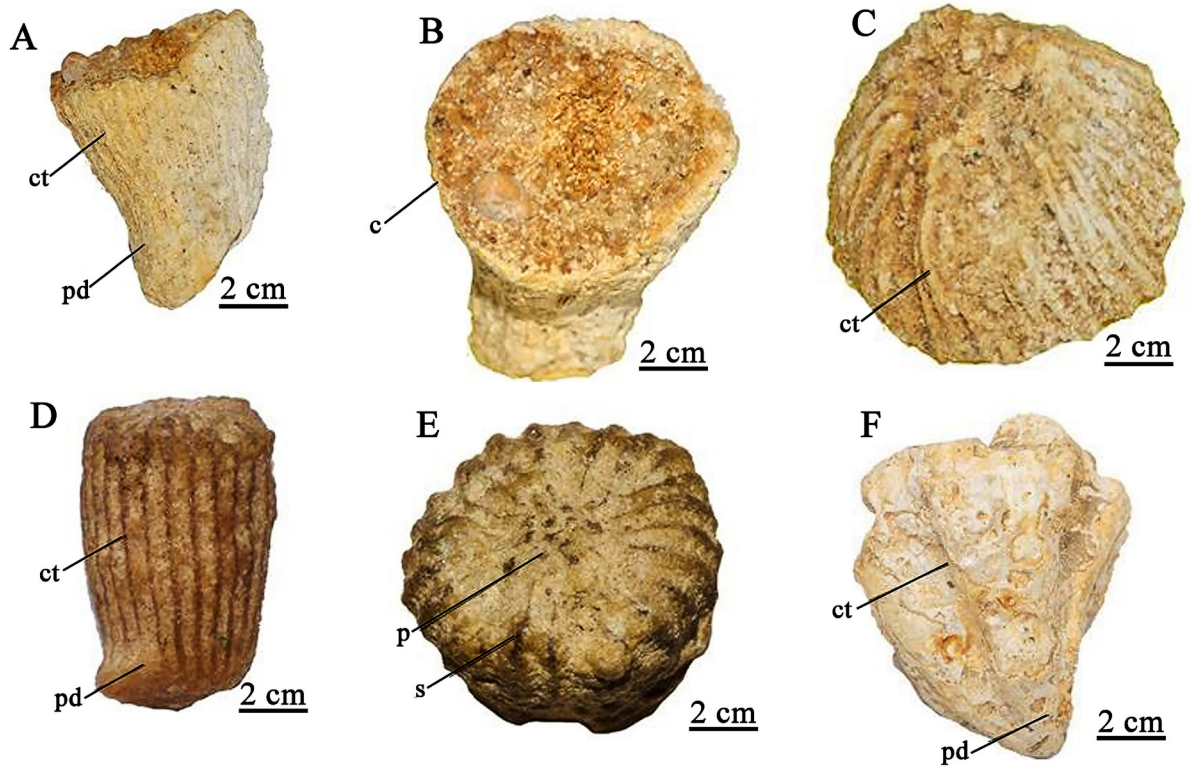

Figure 5. A) *Trochocyathus* (*Trochocyathus*) *collignoni* (Alloiteau, 1958) (DGEO-CTG-UFPE-1541-A): lateral view of corallum ceratoid to trochoid, equidistant costosepta and recurved pedicel; B) *Trochocyathus* (*Trochocyathus*) *collignoni* (Alloiteau, 1958) (DGEO-CTG-UFPE-1541-A): upper surface view of subelliptical calice; C) *T.* (*Platycyathus*) sp. (DGEO-CTG-UFPE-1541-C): lower surface view of discoid corallum and straight to sinuous costosepta; D) *Paracyathus rugosus* Vaughan, 1900 (MN-5421-I): lateral view of corallum cylindrical to trochoid, equidistant costosepta and a well-developed pedicel; E) *Paracyathus rugosus* Vaughan, 1900 (MN-5422-I): upper surface view of discoid calice and a rudimentary pali around the columella; F) *Ceratotrochus* (*Ceratotrochus*) sp. (DGEO-CTG-UFPE-5501): lateral view of corallum ceratoid to trochoid and recurved pedicel; (c: calice; ct: costae; p: pali; pd: pedicel; s: septa).

Occurrence. Brazil: Itamaracá Formation, Lower Maastrichtian (present study).

Material. one juvenile specimen (DGEO-CTG-UFPE-1541-C) from the Fosforita quarry locality, Olinda city, Pernambuco state, Brazil.

Dimensions. h: 7 mm; l: 14 mm; cd: 14 mm; s: 40–48; c: 0.1 mm.

Discussion. The morphological features related to corallum, costae, septa and calice allow us to consider it belonging to the *Trochocyathus* genus and *T*. (*Platycyathus*) subgenus (Wells, 1956; Baron-Szabo, 2008). However, the conservation quality of this specimen precludes its classification into a specific level.

Genus *Paracyathus* Milne Edwards and Haime, 1848

Type species. *Paracyathus procumbens* Milne Edwards and Haime, 1848.

Diagnosis. Corallum solitary fixed of free, turbinate, tympanoid, ceratoid or trochoid. Septotheca costate, shallow to deep. Paliform lobes often bi- or trilobated, developed in all cycles but the last one. Columella papillose often indistinguishable from the inner paliform lobes (Wells, 1956; Cairns and Wells, 1987; Cairns, 1995; Baron-Szabo, 2008).

Distribution. Eocene–Recent (Wells, 1956; Cairns and Wells, 1987; Cairns, 1995).

Paracyathus rugosus Vaughan, 1900
Figures 5D, 5E

1900 *Paracyathus rugosus* Vaughan. U. S. Geol. Surv. Mon. 39, p. 109, pl. VIII, figs. 21–21b.

1978 *Paracyathus rugosus* Vaughan. Fernandes, An. XXX Cong. Bras. Geol., 2, p.962, est. I, figs. 5–6.

Description. Corallum solitary small, cylindrical to trochoid with thick and flat base. Calice discoid, monocentric and shallow, subcircular to circular in outline, fixed by a well-developed and rounded pedicel. Costosepta gradually thicker toward the oral extremity, straight to sinuous, equidistant, continuous, and separated by shallow and flat furrows. Septa hexamerally arranged in three complete cycles with 24 units, straight, equal to subequal, equidistant, thicker, moderately spaced and laterally granulated. The septa from the first and second cycle are thicker and continuous, merged internally in a ring-shaped system of six pali around the columella. The third cycle's septa are smaller, laminated and apparently do not merge to the paliform system. Fosseta subcircular and shallow. Columella subtrabecular and continuous, confined to paliform system. Epitheca, trabecular structures and endothecal and exothecal dissepiments absent.

Occurrence. United States of America: Woods Bluff Formation, Lower Eocene (Vaughan, 1900); Brazil: Maria Farinha Formation, Paleocene- Eocene (Fernandes, 1978).

Material. four juvenile specimens (MN 5421-I, MN 5422-I, MN 5423-I e MN 5424-I), from the Maria Farinha river, Maria Farinha district, Paulista city, Pernambuco state, Brazil deposited on the paleoinvertebrates collection at the Museu Nacional/UFRJ.

Dimensions. (MN-5421-I) h: 9 mm; cd: 4.5 mm; pd: 3 mm. (MN-5422-I) h: 6.5 mm; cd: 3.5 mm; pd: 3 mm. (MN-5423-I) h: 7 mm; cd: 4 mm; pd: 2 mm. (MN-5424-I) h: 5 mm; cd: 4 mm; pd: 3 mm.

Discussion. The species *Paracyathus rugosus* Vaughan, 1900 is similar to *P. bellus* Vaughan, 1900, *P. sinuosus* Cairns and Wells, 1987 and *P. vaughani* Gane, 1895 concerning the shape of calice and columella, number and arrangement of septa and paliform lobes, costae, intercostal furrows and tapering of the apical end.

Genus *Ceratotrochus* Milne Edwards and Haime, 1848

Type species. *Turbinolia multiserialis* Michelotti, 1838 emend. Milne Edwards and Haime, 1850.

Diagnosis. Corallum solitary trochoid, fixed or free. Costosepta compact, shallow to deep. Paliform lobes developed in all cycles but the last one. Columella papillose to fascicular. Endothecal dissepiments sparse (Wells, 1956; Cairns and Wells, 1987; Baron-Szabo, 2008).

Distribution. Middle Cretaceous- Recent (Wells, 1956).

Subgenus *Ceratotrochus* (*Ceratotrochus*) Milne Edwards and Haime, 1848

Type species. *Ceratotrochus* (*Ceratotrochus*) *multispinosus* Michelotti, 1838.

Diagnosis. Costosepta extended above the surface of the calices. Columella fascicular (Wells, 1956; Cairns and Wells, 1987).

Distribution. Middle Cretaceous-Recent (Wells, 1956).

Ceratotrochus (*Ceratotrochus*) sp.
Figure 5F

Description. Corallum solitary small, ceratoid to trochoid, transversally elliptical. Calice subelliptical, monocentric and shallow, fixed by a gentle and subcircular pedicel. Costae gradually thicker toward the oral extremity, continuous, straight to sinuous, equidistant and separated by deep and planed furrows. Septa hexamerally arranged, straight, thick, equidistant and dentated. Columella, epitheca, trabecular structures, paliform lobes and endothecal and exothecal dissepiments absent.

Occurrence. Brazil: Itamaracá Formation, Lower Maastrichtian (present study).

Material. one juvenile specimen (DGEO-CTG-UFPE-5501) from the Fosforita quarry locality, Olinda city, Pernambuco state, Brazil.

Dimensions. h: 18 mm; l: 16 mm; w: 11 mm; s: 6; c: 1–2 mm; pd: 2.5 mm.

Discussion. The morphological features of corallum, costae and pedicel were marked by the generic characteristics recognized in the specimen, and also the septa and columella display a close resemblance to the subgenus *C.* (*Ceratotrochus*) (Wells, 1956; Chevalier, 1961; Cairns and Wells, 1987). The poor conservation quality of the samples, especially on their calice and septal details, justifies its designation as an undefined species.

5. Conclusions

The taxonomy of Upper Cretaceous shallow marine corals from the Itamaracá Formation (Paraíba Basin), the Cenozoic Maria Farinha Formation (Paraíba Basin) and the Pirabas Formation (Bragantina platform) are compared to coral associations of the same age in others areas of the world.

Regarding the Itamaracá Formation, *Actinastrea dickersoni* (Wells, 1941), *Enallhelia* aff. *E. occidentalis* Wells, 1944 and *Trochocyathus* (*Trochocyathus*) *collignoni* (Alloiteau, 1958) are recorded in Cretaceous rocks from Cuba, Venezuela and the United States of America. The indeterminate *Ceratotrochus* (*Ceratotrochus*) sp. and *T.* (*Platycyathus*) sp. belong to European and cosmopolite subgenus respectively. This coralinofauna has affinities with Mexico, southern USA, central Tethys, Central America and Venezuela, reinforcing the view of Filkorn and Pantoja-Alor (2009) of the existence of other possible intermediate biogeographic connecting areas in the Caribbean and South America regions.

The center of origin and diversity of the Cenozoic scleractinian corals is the Caribbean region, with direct ancestors in Europe (Távora *et al*., 2010). The Paleocene-Oligocene is marked by bioevents of radiation and biogeographic expansion of hermatipic species, resulting in an important development pulse of reefs. During the Miocene the coralinofauna were reduced and tending to endemic. The study of mollusks and decapod crustaceans shows that paleoinvertebrates from the Maria Farinha and Pirabas Formations are related to the Caribbean Biogeographic Province, with well-marked phylogenetic affinity (Távora and Miranda, 2004; Távora *et al*., 2010).

The coral association of the Maria Farinha Formation is composed by *Actinastrea jukesbrownei* (Wells, 1945), *Stephanocoenia marylandica* (Conrad, 1841), *S. pernambucensis* Fernandes, 1978, colonials and *Paracyathus rugosus* Vaughan, 1900, solitaire. According to Távora and Miranda (2004) and Távora *et al*. (2005) the decapod crustaceans and mollusks fauna are closely related to the Paleocene and Eocene of the Mexico, Trinidad and to the Midway Group (Paleocene) and Castle Haynes Formation (Eocene) of the United States of America.

The fossil reefs and lagoon-environment reefs in the upper rocks of the Maria Farinha Formation present regressive characteristics of high- to low-energy oscillations that may not have favored the great development of a coral fauna or its preservation history.

The scleractinian Flabellidae family from the Pirabas Formation is observed to be more abundant in spite of the other elements that are uncommon to rare. The five taxa cited in this work occur in the synchronous litostratigraphic units of the Caribbean region, in particular from Puerto Rico, Costa Rica, Trinidad, Barbados and Saint Croix, as well as Pliocene-Pleistocene from Bahamas, Dominican Republic and Costa Rica. The continuous temporal distribution of *Caulastraea portoricensis* (Coryell and Ohlsen, 1929) between the Miocene and Pleistocene, and the restricted occurrence of *Stylophora silicensis* Weisbord, 1973 from the Tampa Formation (Florida state, USA) and the cosmopolitan aspect of *Cladocora* sp. are relevant aspects to the biogeographic analysis.

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