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Paleoenvironmental Evolution of the Restinga of Jurubatiba Lagoons, Rio de Janeiro State

Evolução Paleoambiental de Lagunas da Restinga de Jurubatiba, Estado do Rio de Janeiro

Mariana Cardoso Macedo; Claudia Gutterres Vilela;
Nathalia dos Santos Labre & Mariana Christensen Lourenço

Universidade Federal do Rio de Janeiro, Instituto de Geociências, Departamento de Geologia,
MicroCentro, Avenida Athos da Silveira Ramos 274, 21941-916, Rio de Janeiro, RJ, Brasil.
E-mails: ncardosomariana@yahoo.com.br; vilela@geologia.ufrj.br; nathalia.nsl@gmail.com; marianaclgeo@gmail.com
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Abstract

This work analysed assemblages of benthic foraminifera in core samples in lagoons from the Restinga de Jurubatiba Rio de Janeiro State, to observe paleoenvironmental changes and sedimentary deposition processes. Six cores were drilled (vibra-cores) until a depth of 1,56cm, in the Garças, Maria Menina, Robalo, Visgueiro, Catingosa and Pires lagoons. It was found that cores with sandy sediments presented lower abundance and richness of foraminifera species than fine sediment cores. Through the foraminiferal assemblages, four biofacies were characterized that reflected episodes of distinct evolutionary conditions for each lagoon. For the sandy lagoons, it was recorded the biofacies *Ammonia/ Elphidium* representing moderate marine influence, and the biofacies Aglutinated/*Trochammina inflata* representing the lagoon confinement. At the muddy lagoons, occurred the biofacies *Ammonia* spp./*Elphidium* spp./*Haynesina germanica* which represents paleoenvironments with high marine influence and the biofacies *A. tepida*/ A. *parkinsoniana* with low marine influence that favor conditions to opportunistic species. Radiocarbon dating allowed to record, in the sedimentary deposition process of the lagoons, Holocene submergence phases related to the marine transgressions.
Keywords: Foraminifera; lagoons; Holocene; sea-level oscillation

Resumo

O objetivo do presente trabalho consiste em observar mudanças paleoambientais das lagunas da Restinga de Jurubatiba (RJ) através da análise de foraminíferos bentônicos. Foram coletados seis testemunhos (vibra-cores) de até 1,56cm de profundidade distribuídos nas lagunas Garças, Maria Menina, Robalo, Visgueiro, Catingosa e Pires. Os testemunhos com sedimentos predominantemente arenosos (Garças, Maria Menina e Robalo) apresentaram menor riqueza de espécies e abundância de foraminíferos do que os testemunhos com sedimentos mais finos (Catingosa, Visgueiro e Pires). Quatro biofácies de foraminíferos foram reconhecidas e refletiram episódios de condições evolutivas ambientais diferentes. Nas lagunas arenosas a biofácies *Ammonia/ Elphidium* foi associada a moderada influência marinha e a biofácies *Trochammina inflata*/ Aglutinantes representando confinamento das lagunas. Nas lagunas lamosas foi presente a biofácies *Ammonia* spp./*Elphidium* spp./*Haynesina germanica* associada a espécies calcárias marinhas sugerindo paleoambientes com alta influência marinha e a biofácies *A. tepida*/ A. *parkinsoniana* refletindo baixa influência marinha e condições propícias a espécies oportunistas. Datações radiocarbônicas permitiram registrar no processo de evolução das lagunas fases de submersão holocênica relacionadas com momentos de transgressões marinhas.
Palavras-chave: Foraminíferos; lagunas; Holoceno; oscilação do nível do mar

1 Introduction

The objective of this work was observing in different periods, paleoenvironmental changes in lagoons of Restinga of Jurubatiba, through analysis of benthic foraminiferal assemblages.

National Park (PARNA) of Restinga of Jurubatiba is an Unit of Integral Protection of Conservation. It is characterized for being a preservation area of natural eco-systems of great ecological importance, represented by 'restinga' vegetation throughout wide beach ridges and with the presence of 18 lagoons (Esteves, 1998; Caliman *et al*., 2010).

In the state of Rio de Janeiro, different works with foraminifera characterize coastal environments (Debenay *et al*., 1998, Vilela *et al*., 2004, 2011, 2014; Uehara *et al*., 2007, Eichler *et al*., 2007, Wilson *et al*., 2008; Kemp *et al*., 2011; Mamo *et al*., 2013) and its paleo-environmental evolution due to oscillations of sea level (Barbosa *et al*., 2005; Bruno, 2012; Laut *et al*., 2012). But in Restinga of Jurubatiba lagoons, few foraminiferal studies have been developed, as this pioneer work will bring contributions for the scientific investigation and for the preservation of this ecosystem.

2 Study Area

The Restinga of Jurubatiba is part of the river Paraíba do Sul paleo-delta of and it is located in Northern state of Rio de Janeiro, between the cities of Macaé, Carapebus and Quissamã, including the Restinga of Jurubatiba National Park (Caliman *et al*., 2010).

'Restingas' are Quaternary environments, formed by dunes and sand strings due to factors such as coastal adrift currents, variations of sea level and sand sources (Suguio & Tessler, 1984). The lagoons of different sizes and hundreds of small "swamps", have their formatting attributed to the maximum of the last transgression (5.100 years AP), according to Silva (1987), Dominguez *et al.* (1981) and Martin *et al*. (1997, 2003).

The Restinga of Jurubatiba belongs to an unit of Cenozoic Sedimentary Basins of Morpho-Sculptural Domain of Coastal Plains whose geo-morphological unit corresponds to Group of Sandy Strings of Jurubatiba, which is constituted by stacking groups of coastal strings of marine origin and small lagoons (Dantas, 2001). The lagoons are separated from the sea by a strip of approximately 30 m of sand, receiving marine water by percolation, in cases of undertow and occasionally by rupture of sandy bar. Caliman *et al*. (2010) through limnological analysis registered a great variation in the salinity of Jurubatiba lagoons and showed that similarities in geographic orientation of water bodies, compared to the sea, impact in large scale in the lagoons salinity values.

3 Material and Methods
3.1 Sample Collections, Treatings and Quantitative Analysis

Six vibra-cores from 76 to 156cm in length were collected in six different lagoons of Restinga of Jurubatiba to analysis of benthic foraminifera, granulometry and Total Organic Carbon (TOC). The cores were collected in the Quissamã municipality (Table 1; Figure 1).

Core	Latitude (S)	Longitude (W)	Lagoon depth (m)	Core lenght (m)
Laguna Garças	22° 12' 45.6"	041° 29' 18.7"	1.5	0,79
Laguna Maria Menina	22° 12' 23.41"	041° 28' 06.9"	1,0	1,58
Laguna Robalo	22° 12' 02.4'	041° 27' 03.0"	0.5	1,67
Laguna Visgueiro	22° 11' 47.5"	041° 25' 56.8"	0.5	1,68
Laguna Catingosa	22° 11' 29.7"	041° 24' 50.7"	0.5	1,61
Laguna Pires	22° 11' 00.9"	041° 23' 00.1"	0.2	0,83

Table 1 Lagoons data collection.

The cores were opened in laboratory and sub sampled in centimetric intervals, with aliquot of 2cm. The sub samples were standardized in volumes of 20cm^3, washed using 0.500mm and 0.063mm mesh-sieves, and dried in an oven at 50ºC. The samples were splitted when necessary, and were picked with a minimum counting of 100 individuals

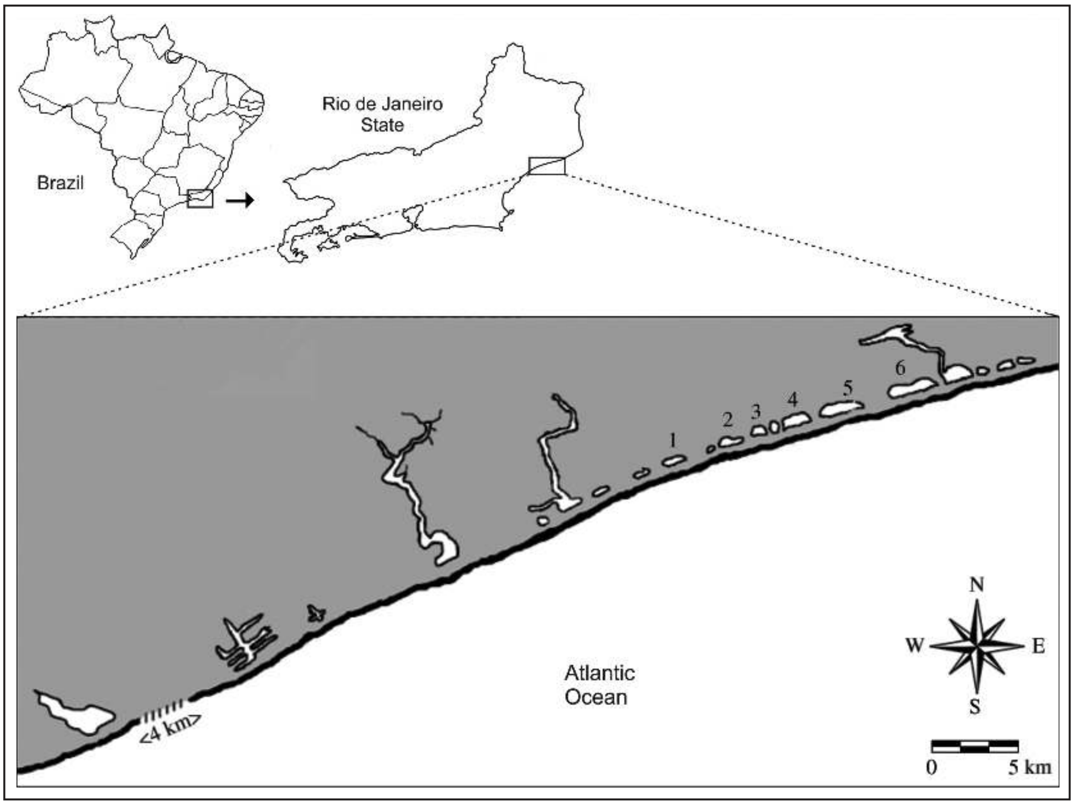

Figure 1 Illustration map of the lagoons' geographic position. Lagoons numbering: 1 – Graças, 2 – Maria Menina, 3 – Robalo, 4 – Visgueiro, 5 – Catingosa, 6 – Pires (modified from Caliman *et al*., 2010).

per sample (Fatela & Taborda, 2002). For taxonomic identification, it was used the works of Loeblich & Tappan (1988) and Ellis & Messina (1940-*et sequences*) in addition to specific bibliography (Cushman, 1929, 1930, 1932, 1939; Phleger & Parker, 1951, Boltovskoy *et al*., 1980; Debenay *et al*., 2001; among others).

The ecological studies were developed with the software PAST® (Version 2.14) and were based on Boltovskoy & Totah (1985), involving quantitative analysis of absolute abundance, relative abundance, richness of species (S), diversity and dominance. The diversity was calculated using the diversity index of Shannon, H' (Shannon, 1949), which considers the number of species and their relative abundance in the assemblage. Species with relative abundance of 10% or more were considered dominant. Biofacies were determined along the cores, based on the dominant species, foraminifera distribution and relative abundance values.

3.2 Granulometric and Geochemical Analysis

The granulometric descriptions were taken on the Laboratory of Sedimentary Geology - UFRJ (Labre & Lourenço, 2013) and Laboratory of Marine Geology of Fluminense Federal University (Prof. Dr. José Antônio Baptista Neto, written communication). Analysis of Total Organic Carbon (TOC) were made in Laboratory of Palynofacies and Organic Facies -LAFO/UFRJ by combustion through analyzer LECO SC-144DR.

Radiocarbon datings (C14) were determined by the Beta Analytics Radiocarbon Laboratory, (Miami, USA) in order to obtain an approximate date of sediment deposition in organic clay and shell samples from the base and middle samples in the Garças, Visgueiro and Pires lagoons. The measurements were taken with AMS radiometric methods, and the dates are reported as radiocarbon years before present (present = AD 1950). Calendar-calibrated results (Table 3) were calculated from the Conventional Radiocarbon Age (Talma & Vogel, 1993; Stuiver *et al*., 1998; INTCAL04, 2004) using a two sigma calibration (Variables used: C13/C12 = _3.1; 1R = _8 ± 69; Glob. Res = _200–500).

4 Results

4.1 Granulometry and TOC

The cores of Garças, Robalo and Maria Menina lagoons had sedimentologic composition predominantly sandy, while those of lagoons

Visgueiro, Catingosa and Pires had muddy composition. In the core of Marina Menina lagoon there was a loss of material during collection in the interval from 80 to 104cm. At Robalo there was average sand from the bottom to middle (160 to 120 cm) and from 96cm to top. From 120 to 60 cm there was loss of material, thus, the foraminifera were not analyzed. In core of lagoon Pires, from 8cm to top it was registered sandy sediment (Table 2).

The Total Organic Carbon (TOC) of most core samples has low values, but in the cores of Maria Menina, Robalo, Visgueiro and Catingosa it was observed high values in upper samples (Table 2).

4.2 Foraminiferal Assemblages
4.2.1 Garças, Maria Menina and Robalo lagoons (sandy cores)

The sandy cores, respectively Garças (G), Maria Menina (MM) and Robalo (RB), had similar assemblages. The core of lagoon Garças had low abundance of benthic foraminifera, only nine species, and it was barren at the bottom. The Maria Menina and Robalo lagoons (both with 17 species) were abundant in most samples. In samples MM-132, MM-136, MM-140 e MM- 148, MM- 60 to MM- 53 the abundance was low (smaller than 100 individuals), while the samples MM- 48 to MM-12cm were barren. In Robalo, most samples close to the top and bottom were barren. The remaining samples RB- 24 to RB-60 cm and 120 cm to 144 cm were abundant (Table 4).

Core	Sample	Date C^{14}
Garças	76cm	7.720 – 7.620 cal years BP
Visgueiro	80cm	6.640 – 6.450 cal years BP
Visgueiro	160cm	7.610 – 7.500 cal years BP
Pires	80cm	8.170 – 8.010 cal years BP

Table 3 Radiocarbon datings at Garças, Visgueiro and Pires cores.

Lagoons	Samples	0	8	12	16	20	24	28	32	36	40	44	48	52	56	60	64	68	72	76
Garças	TOC (%)	3,1	0,3	0,4	0,4	0,4	4,4	7,7	2,1	2,2	2,3	1,3	0,6	0,9	0,3	0,6	1,2	0,4	0,4	0,5
	Sediment	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
Maria Menina	TOC (%)	28,4	6	1,3	0,9	0,7	0,4	0,4	0,4	0,4	0,4	0,4	0,5	0,6	0,6	0,5	0,4	0,2	0,5	0,4
	Sediment	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
Robalo	TOC (%)	5,6	5,3	0,6	0,6	0,3	1,3	0,9	1,3	1,2	1,3	1,3	0,9	1,1	0,8	1,2	x	x	x	x
	Sediment	S	S	S	S	S	M	M	M	M	M	M	M	M	M	M	x	x	x	x
Visgueiro	TOC (%)	6,8	4,1	2,9	3,1	3,1	1,8	1,8	1,6	1,6	1,5	1,4	1,1	1,2	1	1,1	1,1	1	0,9	1,1
	Sediment	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M
Catingosa	TOC (%)	10,6	2,1	1,6	0,6	0,9	1	0,9	0,7	0,9	1,2	0,8	1	1,2	0,8	0,8	0,9	0,8	0,7	0,9
	Sediment	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M
Pires	TOC (%)	0,8	1,2	1,2	1,2	1,1	1,2	0,8	0,8	0,8	0,9	0,9	0,9	0,8	0,9	1	0,4	1,2	1,2	1,1
	Sediment	S	S	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M

Lagoons	Samples	80	84	88	92	96	100	104	108	112	116	120	124	128	132	140	144	148	152	156
Maria Menina	TOC (%)	x	x	x	x	x	x	x	0,2	0,3	0,1	0,2	0,4	0,2	0,2	0,2	0,1	0,1	0,4	0,1
	Sediment	x	x	x	x	x	x	x	S	S	S	S	S	S	S	S	S	S	S	S
Robalo	TOC (%)	x	x	x	x	x	x	x	x	x	x	0,2	0,1	0,1	0,1	0,5	0,2	0,2	0,4	0,2
	Sediment	x	x	x	x	x	x	x	x	x	x	S	S	S	S	S	S	S	S	S
Visgueiro	TOC (%)	1,3	1	1	1,1	1,1	0,9	0,9	1	1,1	1	1,3	0,9	0,9	1,2	1,1	1	0,9	1,1	1,4
	Sediment	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M
Catingosa	TOC (%)	0,9	0,8	0,7	0,7	0,8	0,8	0,8	0,8	0,7	0,8	1,2	0,9	1,1	1	0,8	0,8	0,9	0,8	1,2
	Sediment	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M

Table 2 TOC and granulometry from the Restinga of Jurubatiba lagoons. S= Sand, M= Mud. The samples numbering correspond to the depths (cm) throughout the cores. X- Loss of material.

Samples depths (cm)	Garças	Maria Menina	Robalo	Visgueiro	Catingosa	Pires	Samples depths (cm) continuation	Maria Menina	Robalo	Visgueiro	Catingosa
	(n)	(n)	(n)	(n)	(n)	(n)		(n)	(n)	(n)	(n)
0	89	104	0	11392	32256	6144	84	x	x	4000	15488
8	5	5	6	30720	10368	3008	88	x	x	4928	59392
12	3	0	0	8000	8448	1584	92	x	x	2944	30208
16	2	0	0	10176	26624	11904	96	x	x	12544	59392
20	5	0	620	0	9920	6016	100	x	x	18816	12672
24	3	0	5504	26	26112	66560	104	x	x	1760	15232
28	0	0	15360	0	43264	159744	108	120	x	19712	12232
32	4	0	37752	3	15616	149504	112	99	x	5984	6528
36	6	0	9600	1600	36608	12992	116	268	x	11008	36608
42	9	0	50952	6592	53248	14080	120	118	7936	7104	26368
44	0	0	99840	8960	2816	12288	124	98	314	21504	17920
48	0	0	65536	3584	11520	36864	128	93	2496	3904	29696
52	0	90	108032	4544	1600	42240	132	43	5472	49152	58368
56	4	92	79872	2080	19968	5184	136	2	102	3232	54272
60	0	25	13824	3040	3872	26880	140	21	0,0	51200	39680
64	0	147	x	10752	7104	38912	144	138	101	9664	29184
68	0	110	x	9088	26880	24576	148	72	0	32256	75264
72	0	109	x	128	10240	17216	152	106	3	10240	12800
76	0	107	x	12160	29696		156	0	0	7936	58368
80			x	4832	50176						

Table 4 Absolute abundance of forminifera in the lagoons. x- loss of material.

The tests were tiny, being some of them fragmented, dissolved and pyritized. The fragmentation was most present in lagoon Garças and the pyritization was present at the bottom and middle of Maria Menina and Robalo cores.

Due to low abundance of individuals in lagoon Garças, the diversity was not measured. The richness of species was lower in lagoon Garças, with the maximum of five species while in Maria Menina and Robalo the richness varied from two to eleven species. In lagoons Maria Menina and Robalo, the diversity values were low (H’ <2), especially in samples near the top, that presented high COT values.

Through the distribution of species along the cores, it was observed the presence of two biofacies in lagoons Maria Menina and Robalo. Only one biofacies was present in the Garças lagoon:

Biofacies TA (*Trochammina*/ agglutinants) with dominance of *Trochammina inflata* associated with agglutinant species *Miliammina fusca* and *Ammotium salsum* and rare calcareous, corresponding to samples G-0, MM-0, RB-0 and RB-152 (Figures 2, 3 and 4);

Biofacies AE (*Ammonia* spp./ *Elphidium* spp.) in the other samples of cores (Figures 3 and 4).

4.2.2 Visgueiro, Catingosa and Pires Lagoons (muddy cores)

The lagoons Visgueiro (VG), Catingosa (C) and Pires (P) with muddy granulometry were abundant in foraminifera with richness of 37, 39 and 34 species, respectively, except for the samples VG-20, VG-28 and VG- 84 cm of lagoon Visgueiro that were barren. Like in the sandy lagoons, the tests of foraminifera are tiny and some tests are fragmented and dissolved. It was found pyritized tests in some samples, mainly from the bottom to the middle of cores.

The diversity of species was low in the three cores, with average values between 1 and 2, and

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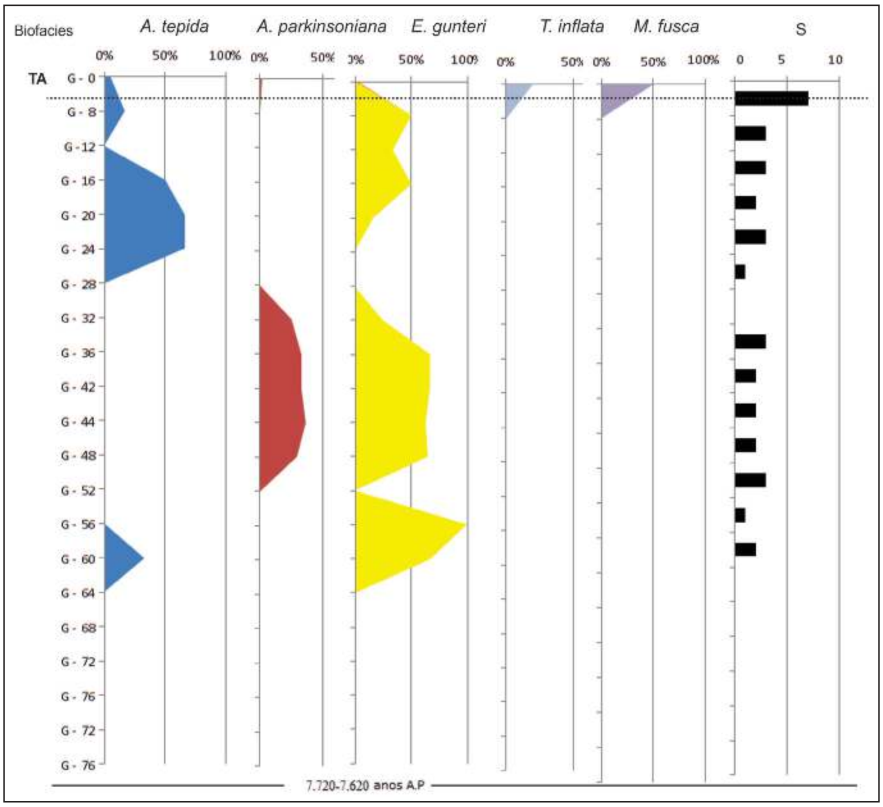

Figure 2 Distribution of dominant foraminifera, biofacies, species richness (S), dating of Garças lagoon. The samples' numbering corresponds to the depths of them along the core.

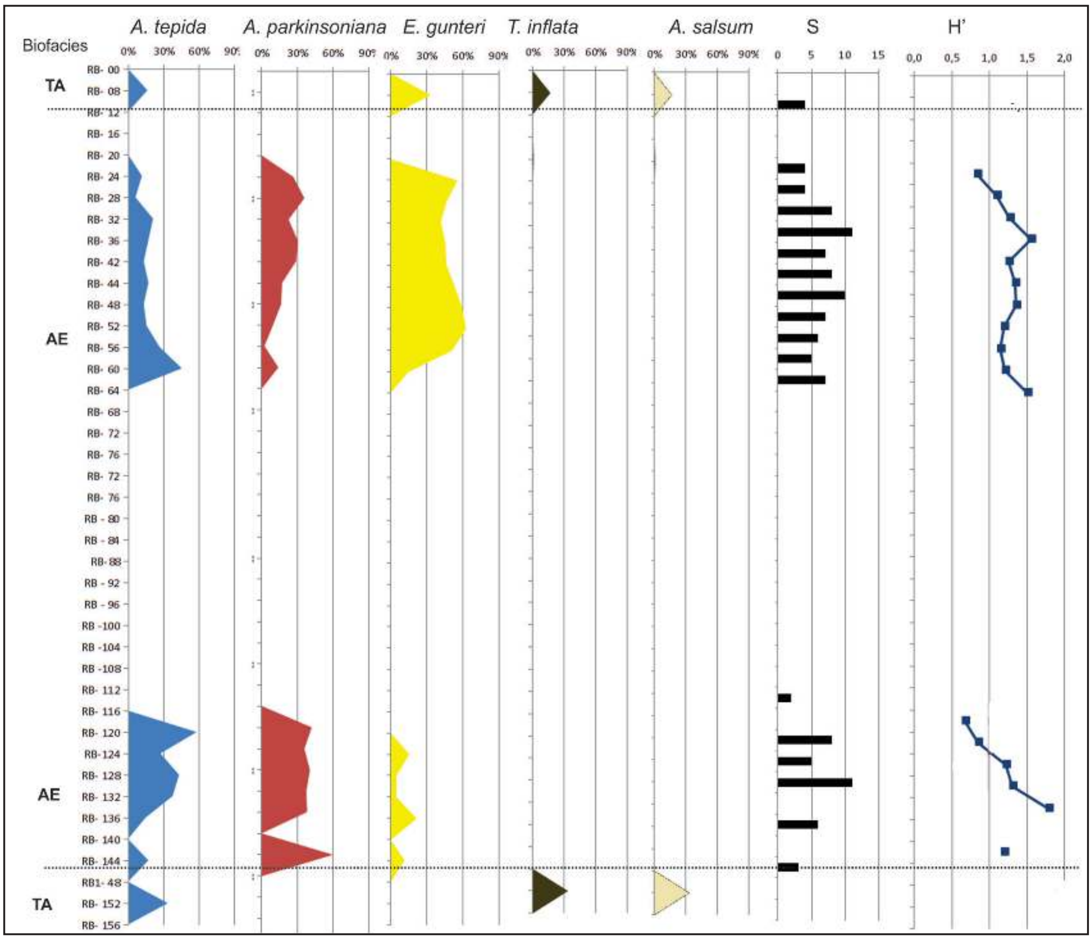

Figure 3 Distribution of dominant foraminifera, biofacies, species richness (S), diversity of Maria Menina lagoon. The samples' numbering corresponds to the depths of them along the core.

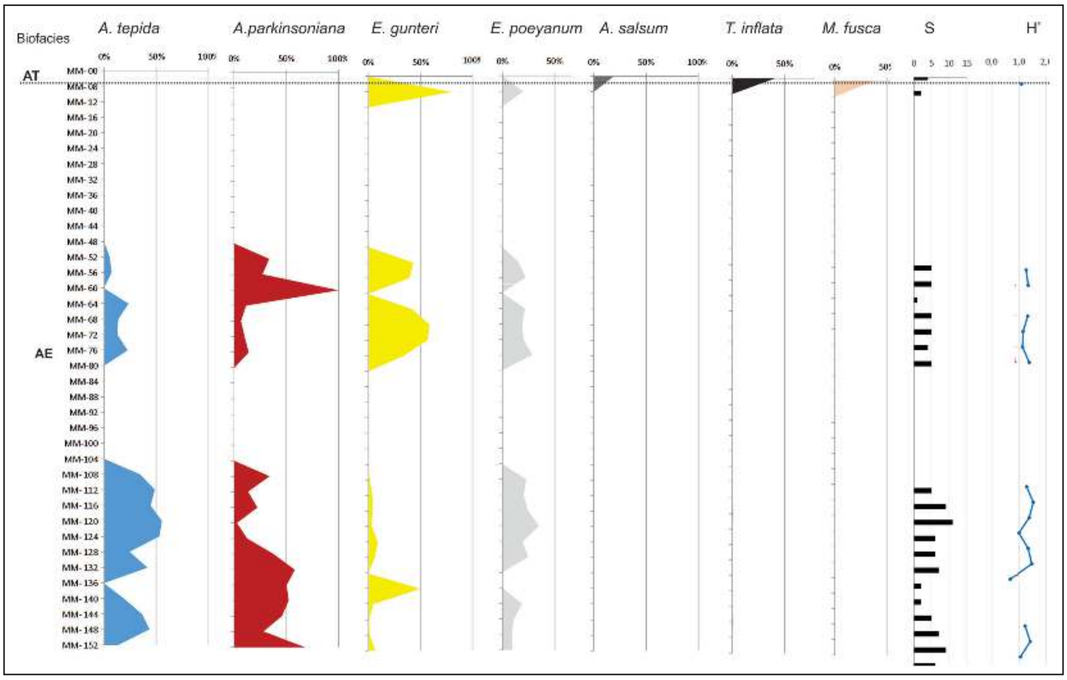

Figure 4 Distribution of dominant foraminifera, biofacies, species richness (S), divesrsity of Robalo lagoon. The samples's numbering corresponds to the depths of them along the core.

some peaks of 2.5. The richness was considered high (> 20 species), however, the diversity had a decrease from the bottom to top, with low values in samples with high content of TOC.

Through the distribution of foraminifera along the cores, it was registered two biofacies at lagoons Visgueiro, Catingosa and Pires:

Biofacies AEH (*Ammonia* spp./ *Elphidium* spp./*Haynesina*). This biofacies was characterized by the association *Ammonia*-*Elphidium*- *Haynesina* and associated species (less abundant) such as: *Bolivina* spp., *Buliminella elegantissima, Cassidulina* spp., *Cibicides* spp., *Discorbis* spp. *Globocassidulina subglobosa*, *Nonion* spp., *Pararotalia cananeiaensis*, *Pseudononion* spp., *Rosalina* spp., present throughout the cores;

Biofacies AA, characterized by high dominance of *Ammonia tepida*/ *A. parkinsoniana* and rare calcareous species, distributed in the upper samples, in the top, 36 to 0cm, of the lagoons Visgueiro and Catingosa and at 0cm of lagoon Pires (Figures 5, 6 and 7).

5 Discussion

In sandy cores (Garças, Maria Menina and Robalo), the richness of species and abundance of foraminifera were smaller than in muddy cores (Visgueiro, Catingosa and Pires). On the top of the Garças core there were relevant abundance values for the ecological interpretations, but the abundance was very poor at deeper intervals. Considering the presence of tiny and broken tests in coarser sediment particles, it can be inferred that Garças and Maria Menina lagoons are exposed to greater hydrodynamics than the other lagoons. According to Bryant (1982), coarser sediments and incident energy are directly proportional. At Pires (0 cm) and Robalo (20 to 0cm) it has been occurred an increase in hydrodynamics toward the top, which could have been caused by washover in high tides or storms.

The inversely proportional trend of diversity versus TOC values was observed on the top of cores, with high values of TOC. Such trend was registered in other lagoons and bays, such as in Guanabara Bay and Lagoa Rodrigo de Freitas, in Rio de Janeiro city (Vilela *et al*., 2004, 2011, 2014; Santos *et al*., 2009), due to anthropogenic influence. Along the cores, that trend was not observed and the TOC values could not be compared with the diversity.

In Maria Menina and Robalo lagoons, it was observed the change of biofacies AE (*Ammonia*/ *Elphidium*) to biofacies TA (*Trochammina* / agglutinants). In the Garças lagoon, there are rare foraminiferal occurrences at the intervals

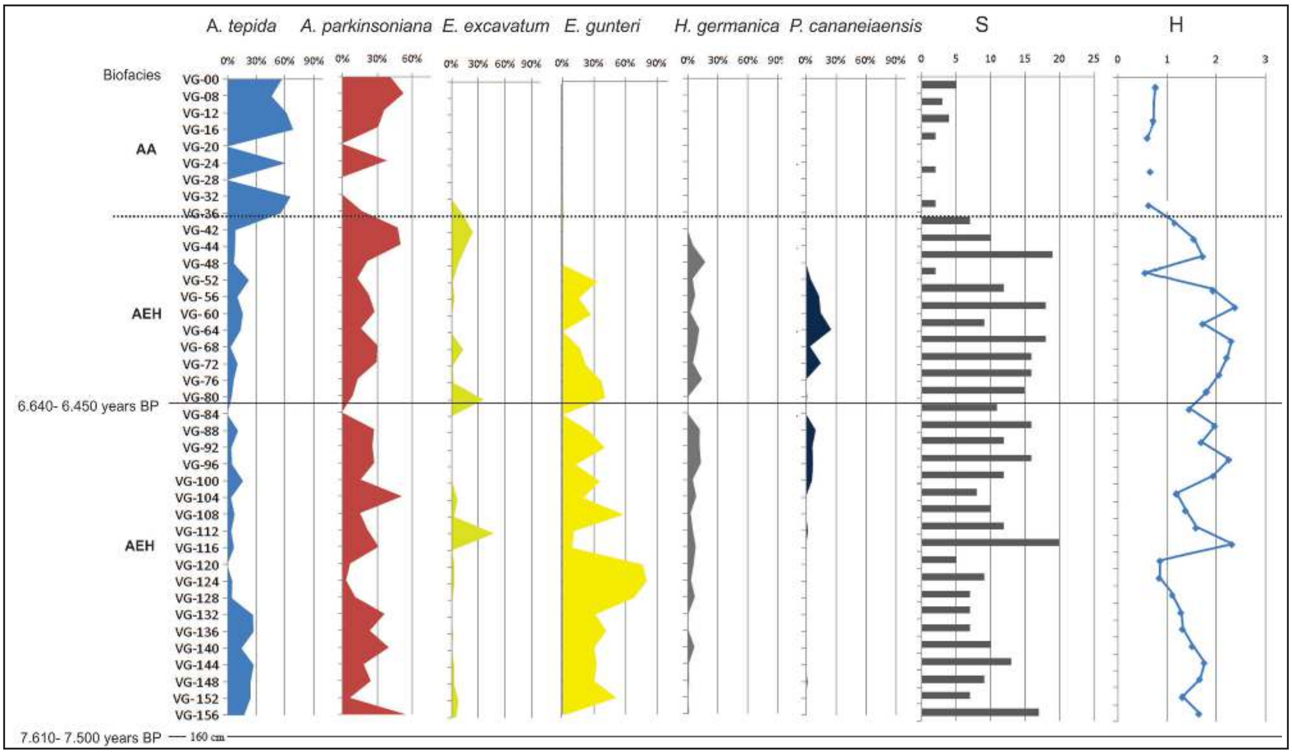

Figure 5 Distribution of dominant foraminifera, biofacies, species richness (S), diversity and datings of Visgueiro lagoon. The samples' numbering corresponds to the depths of them along the core.

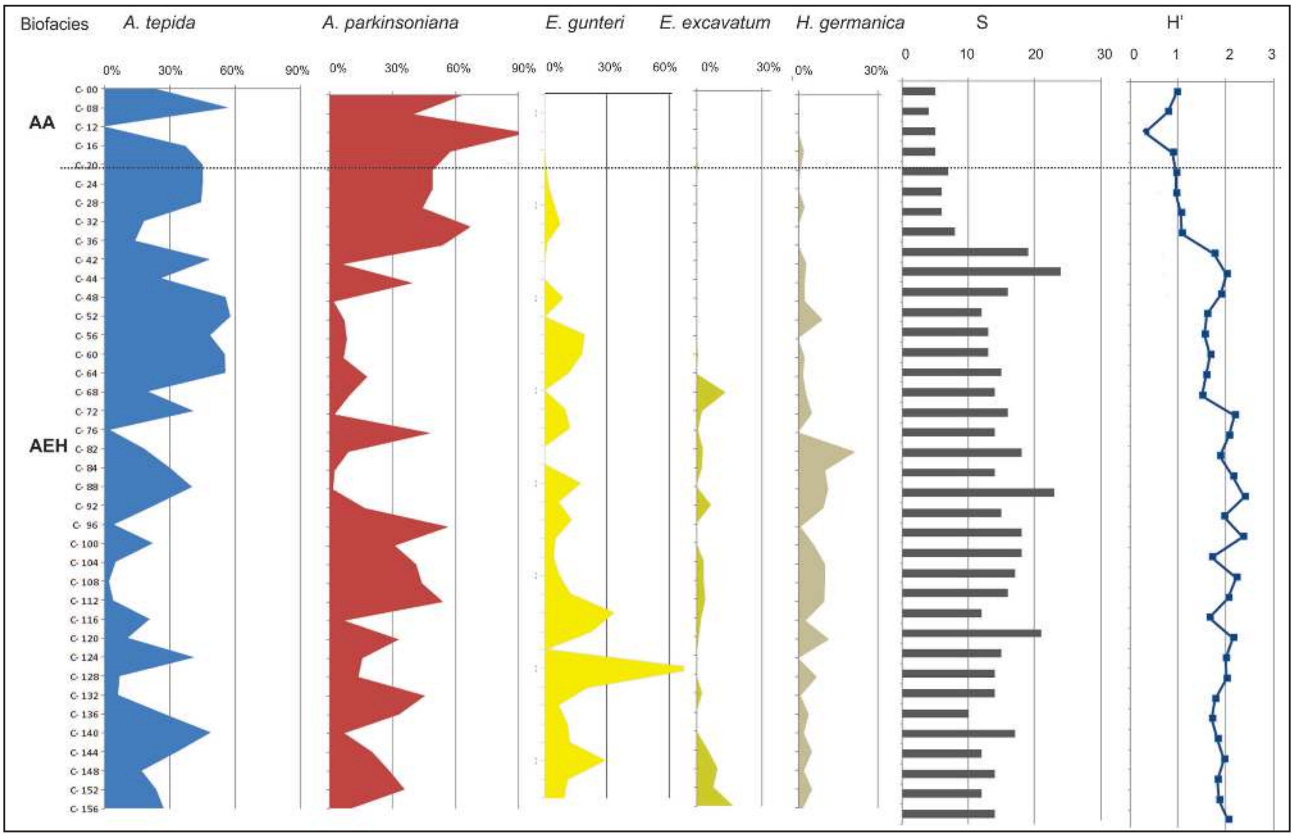

Figure 6 Distribution of dominant foraminifera, biofacies, species richness (S), diversity of Catingosa lagoon. The samples' numbering corresponds to the depths of them along the core.

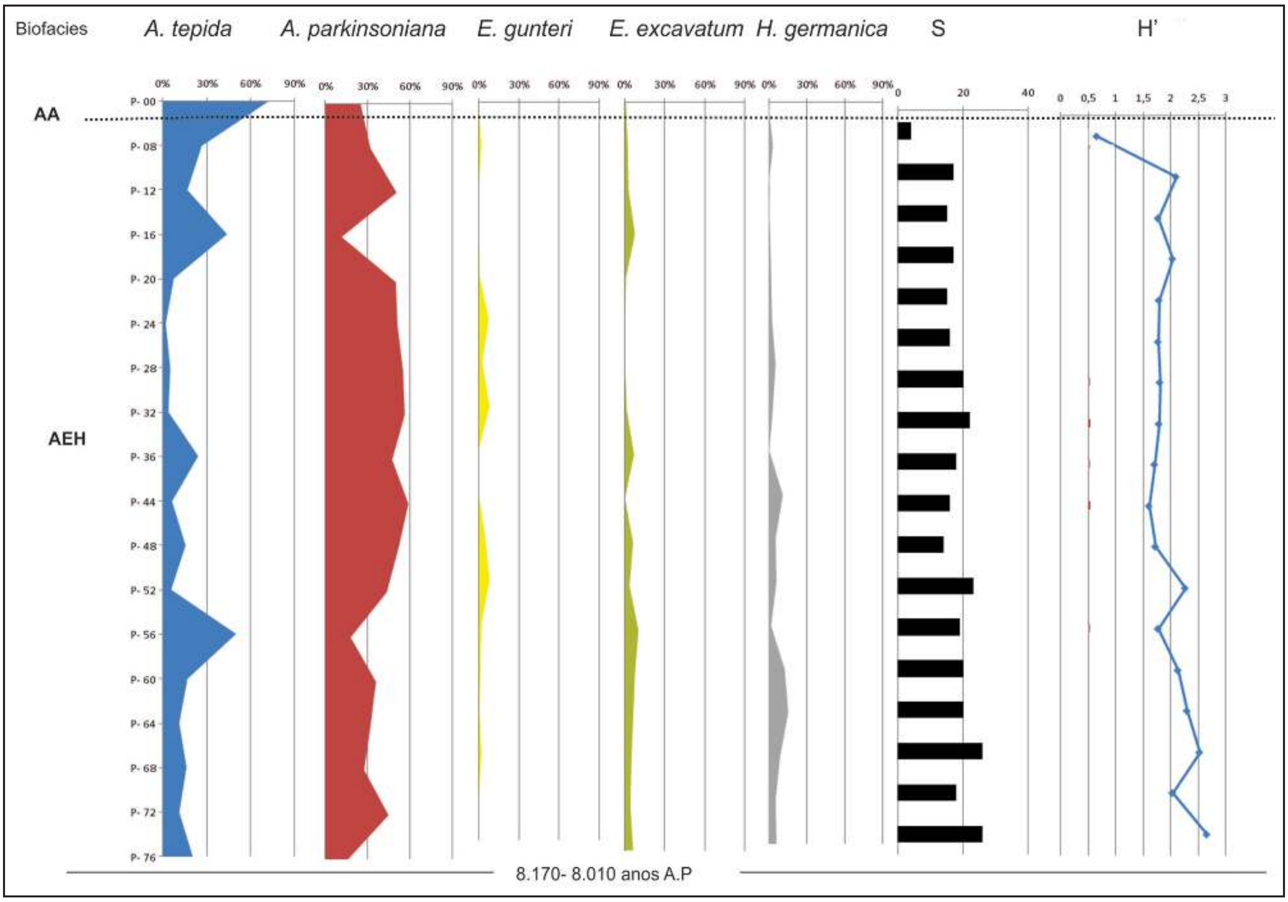

Figure 7 Distribution of dominant foraminifera, biofacies, species richness (S), diversity and datings of Pires lagoon. The samples' numbering corresponds to the depths of them along the core.

excepted for the top, where biofacies TA is present. *Ammonia* and *Elphidium* are common in coastal marine environments (Sen Gupta and Machain-Castillo, 1993). *Ammonia tepida* is an opportunistic cosmopolitan species, tolerant to environmental changes that another species does not resist (Yanko *et al*., 1994; Alve, 1995; Culver & Buzas, 1995; Sen Gupta *et al*., 1996). According to Sen Gupta *et al*. (1996), *Ammonia parkinsoniana* tolerates oxygen low contents *Elphidium* is observed in coastal environments, and it is commlonly registered in Brazilian bays and lagoons (Laut *et al*., 2010; Vilela *et al*., 2014; Bruno, 2012, among others). Agglutinant species in coastal regions indicate a more confined environment and are related to low salinity found in mangroves, estuaries, bays and lagoons (Debenay, 2000; Scott *et al*., 2001; Bomfim *et al.*, 2010; Laut *et al.*, 2010; Semensatto *et al*., 2009). Thus, probably the biofacies AE reflects the phase of open lagoon, with the assemblage *Ammonia*/*Elphidium*. The presence of agglutinant species (Biofacies TA) at the top of Garças, Maria Menina and Robalo cores reflects confinement and low salinity that can be related to moments of closure of the lagoons (Figure 8).

The assemblage *Ammonia/ Elphidium/ Haynesina* (biofacies AEH), in Visgueiro, Catingosa and Pires lagoons (muddy cores) is characteristic of shallow coastal marine environments. *Haynesina germanica* is typical of transitional environments (Debenay *et al*., 1998; Murray, 2006). According to Ruiz *et al.* (2005) this species commonly occupy coastal regions where salinity values are not inferior to 25.8%. The occurrence of species of *Bolivina*, *Buliminella*, *Elphidium* confirmed the coastal environment. Species such as *Pararotalia cananeiaensis* and *Discorbis williamsoni* indicate marine influence in coastal environments (Debenay, *et al*., 2001; Eichler *et al*., 2012), and *Globocassidulina subglobosa* is related to marine environments of high energy (Mackensen *et al*., 1995). *G. subglobosa* is associated to the Current of Brazil (Boltovskoy *et al*., 1980) or Subtropical current - STSW (Eichler *et al*., 2012). There is a tendency of reduction of those species towards the top (Figure 9).

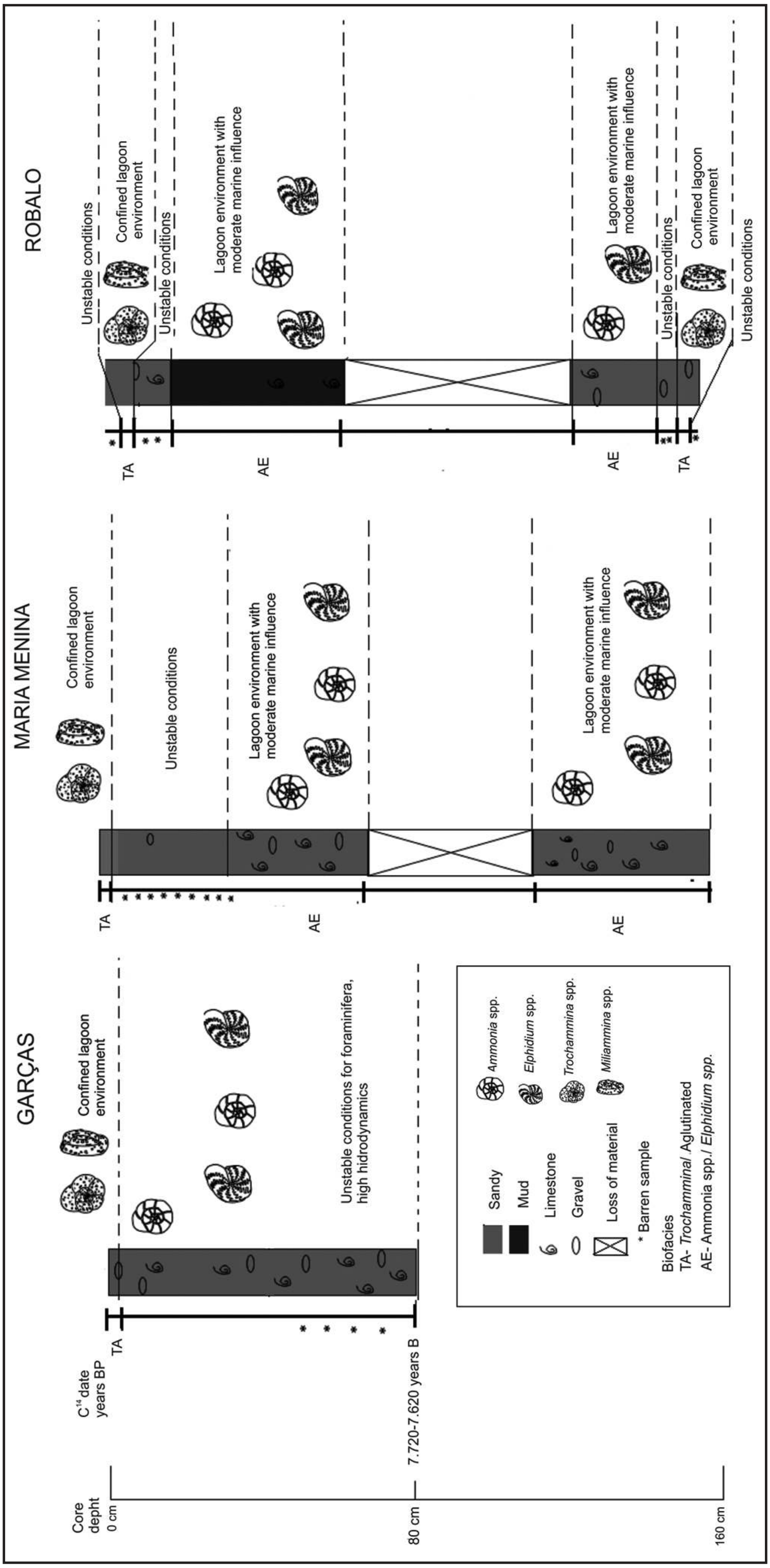

Figure 8 Integrated results of lithology and biofacies in Garças, Maria Menina and Robalo lagoons.

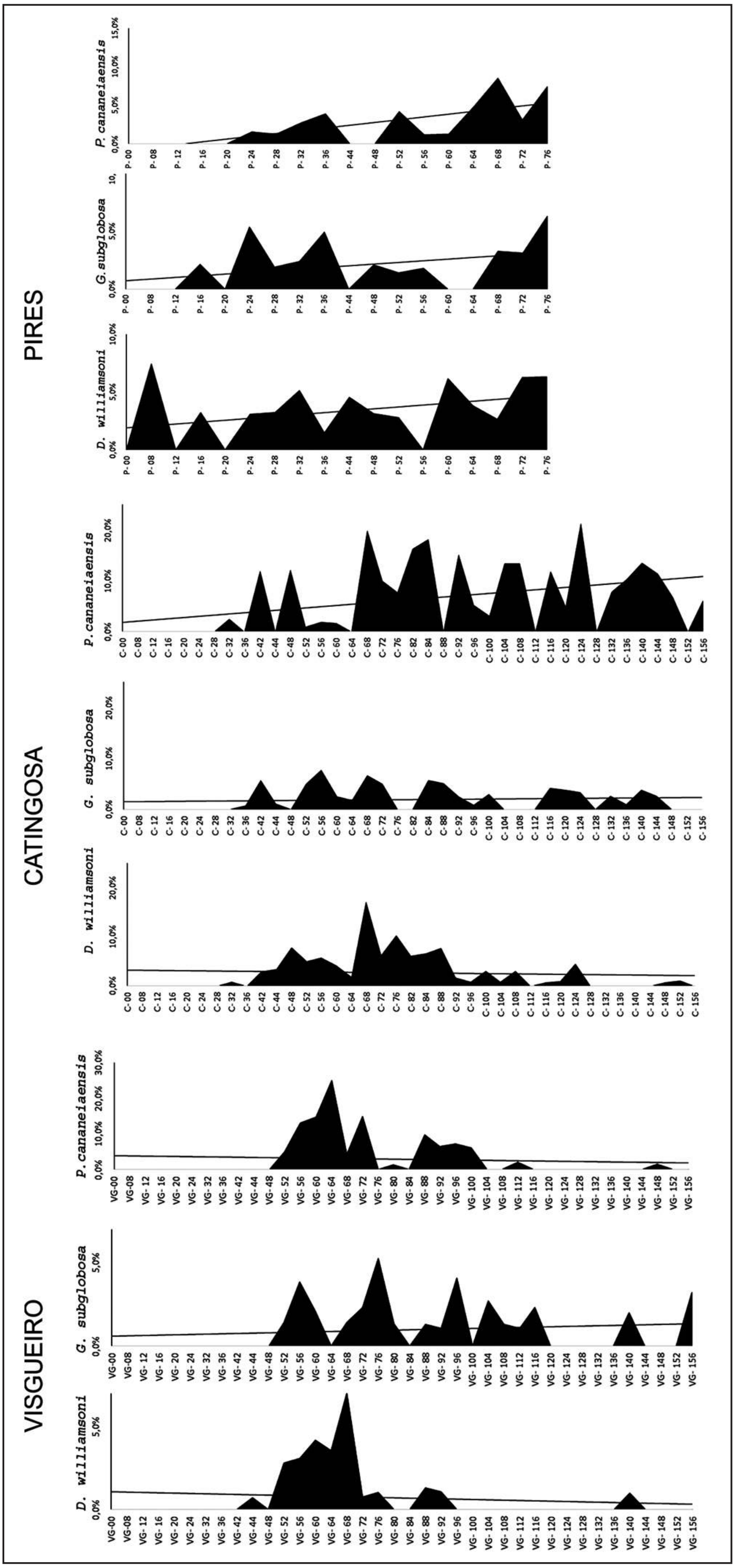

Figure 9 Distribution of *Discorbis williamsoni*, *Globocassidulina subglobosa* and *Pararotalia cananeiaensis* in the cores of Visgueiro, Catingosa and Pires lagoons.

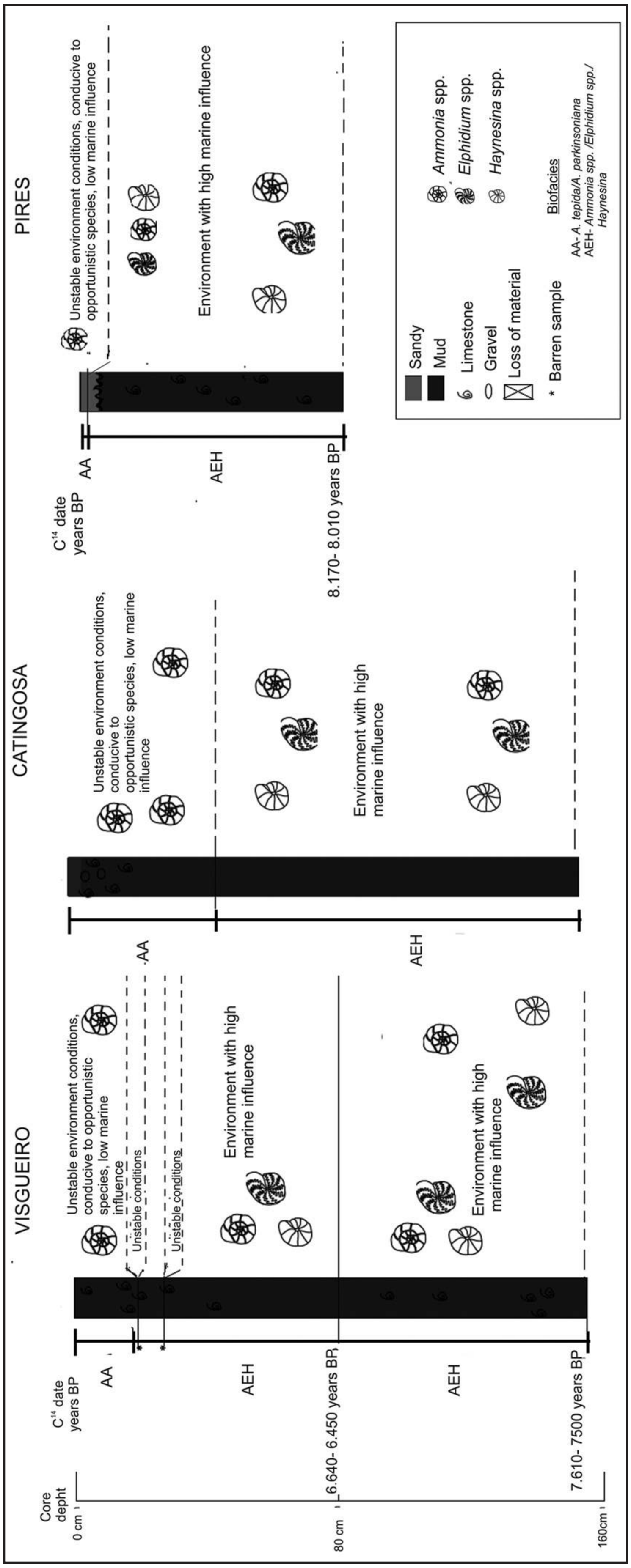

Figure 10 Integrated results of lithology, biofacies and dates of the Visgueiro, Catingosa and Pires lagoons.

Results of dates at the bottom of Garças, Pires and Visgueiro lagoons correspond to a period of marine regression, according to Martin *et al*. (1997) and Castro *et al*. (2014). Such authors interpreted a regression period for over 7,000 yr BP, after a period of high sea level. Biofacies AEH along the cores of Visgueiro, Catingosa and Pires lagoons represents high marine influence in coastal environments. Biofacies AA, in the upper part of the cores inferred unstable conditions that favored opportunistic species. Biofacies AE, in Garças, Maria Menina and Robalo, characteristic of more restrict coastal environment in the past, evolved to a confinement (biofacies TA), to the present (top of the core).

At the bottom of Garças lagoon core (~7,750 yr. BP) it could be observed a period of instability with high hydrodynamics and absence of foraminifera in sandy sediments with shell fragments probably reworked. At Pires lagoon, at the bottom of core (~8,000 yr BP) the biofacies AEH indicated higher marine influence, in this phase.

It was possible a connectivity in Visgueiro, Catingosa and Pires lagoons in the past, considering the highest sea level inferred by the high occurrence of marine species. Carbon dates indicated that in Garças and Visgueiro lagoons, at the bottom and middle of the cores, sediments include in was deposited in the Holocene, during a marine transgression period (Martin *et al*., 1997). The same was also observed at the bottom of a core in the Comprida lagoon (147-149 cm), also at Restinga of Jurubatiba (Pires, 2015; Pires *et al*., 2015).

The reduction of richness and diversity of species and high dominance of *Ammonia* spp. (biofacies AA), in Catingosa (20 to 0cm) and Visgueiro (36 to 0cm) indicate unstable conditions, favorable to opportunistic species and probably recorded moments of closure of the lagoons until the present (Figure 10).

6 Conclusions

The granulometric composition was determinant to foraminifera distribution, with a greater environmental stability in muddy lagoons, reflected by the abundance and richness of foraminifera.

In lagoons Maria Menina and Robalo the foraminifera demonstrated the evolution from an environment with moderate marine influence (biofacies AE) to the closure of lagoons (biofacies AT).

In the Garças lagoon it was registered a higher dynamic in the past and the lagoon's closing at the top (biofacies AT).

In lagoons Visgueiro and Catingosa the foraminiferal assemblages reflected the past conditions of high marine influence (biofacies AEH) followed by low influence and closure of lagoons (biofacies AA). The radiocarbon dates in the bottom of cores in Visgueiro and Pires lagoons corresponded to holocenic transgression periods.

In lagoon Pires, the biofacies AEH suggest a constant marine influence throughout all core, except for the top (0cm).

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