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Oceanographic parameters in continental margin of the State of Ceará (Northeastern Brazil) deduced from C and O isotopes in foraminifers

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ABSTRACT

Specimens of Recent foraminifera of *Amphistegina radiata, Peneroplis planatus and Globigerinoides ruber*, from fifty samples of surface sediments of the continental margin of the State of Ceará, Brazil, have been analyzed for carbon and oxygen isotopes to investigate oceanographic parameters and determine the values of δ^{18}O of the oceanic water. From a comparison between values of δ^{18}O obtained for ocean water using the linear equations by (Craig and Gordon 1965) and the one by Wolff et al. (1998), it became evident that the former yielded a more reliable value ($0.2‰_{SMOW}$) than the latter. Lower values of δ^{18}O for the ocean water in this continental margin resulted from continental water influence. Values of ^{18}O ($-0.3‰$ to $-1.5‰_{PDB}$ for benthic foraminifera and $-0.6‰$ to $-2.4‰_{PDB}$ for planktic foraminifera), attest to a variation of temperatures of oceanic water masses, in average, between 20 to 22°C in deep water and 24 to 27°C, in surface water. Values of δ^{13}C from $+3.2‰$ to $-0.2‰_{PDB}$ (benthic foraminifera) reflect a variation in the apparent oxygen utilization (AOU) in the continental margin and indicate that the environments of bacteriological decomposition of organic matter are not continuous along the investigated area.

Key words: foraminifers, carbon and oxygen isotopes, continental margin, Ceará, Brazil.

INTRODUCTION

For over four decades, isotope composition of foraminifer tests, as well as quantitative distribution of species, have been regarded as a proxy for some oceanographic parameters. In addition, isotope composition of foraminifer tests has been largely used in estimating environmental parameters and in qualitative interpretation of the chemical composition of water masses as they reflect the isotopic composition and temperature in which species have developed (Niebler et al. 1999).

To examine temperature conditions, nutrients, apparent oxygen utilization (AOU), continental and seawater mixing in the continental margin of the State of Ceará, Brazil (Fig. 1) and δ^{18}O variation of seawater in the coast of the State of Ceará, C- and O-isotope of planktic (*Globigerinoides ruber*) and benthic (*Amphistegina radiata* and *Peneroplis planatus*) foraminifer tests from fifty samples of surface sediments were analyzed. These samples were collected from sectors of the continental margin of this state (Fig. 2) at depths from 14 to 1250 m, in the inner continental shelf to the continental slope.

Foraminifer tests *of Amphistegina radiata* and *Peneroplis planatus* are often observed in large amounts in sediments of the investigated area, except in the con-

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tinental slope at depths greater than 70 m and, therefore, are of fundamental importance for C and O-isotope analyses along with planktic foraminifera. Figure 2 shows sites of sampling organized in six sectors along the continental margin of the State of Ceará.

MATERIALS AND METHODS

Foraminifer tests were handpicked from fifty samples of superficial marine carbonate sediments collected during the Geomar XVIII and XXI operations (1981 and 1983) along the northeastern coast of Brazil, by the Almirante Câmara oceanographic vessel of the Brazilian Navy. The samples were collected in November and December months, dry period of the year, and the assemblage has not been affected by torrent waters of the continent. These samples were genteelly (graciously?) granted us by the Marine Geology Laboratory (LGMA) of the Federal University of Ceará (UFC). Four mg of foraminifera tests were handpicked taking care to not include the younger species, including only the older species to prevent interferences in isotopic data.

Due to the high abundance of foraminifer tests in the samples investigated (occasionally, foraminifer tests represented 90% per volume of sample) they have been easily handpicked under an optical microscope. Carbon and oxygen-isotope analyses were performed on specimens of the species *Globigerinoides ruber, Amphistegina radiata* and *Peneroplis planatus* that predominate over the other species.

Foraminifer tests were reacted with 100% orthophosphoric acid during 12 hours at 25°C. CO_2 released from this reaction was extracted in a high vacuum extraction line and cryogenically cleaned, after the Craig's method (1957). CO_2 was analyzed for C and O isotopes in a dual inlet, multiple-collector SIRA II mass spectrometer, at the stable isotope Laboratory (LABISE) of the Department of Geology of the Federal University of Pernambuco, in Recife, Brazil.

The isotopic compositions were contrasted against the in-house Borborema skarn calcite (BSC) standard. The precision of analysis was better than 0.1‰, based on multiple analyses of this internal standard. Results are reported in the international δ‰ (delta permil) notation with respect to the PDB scale.

RESULTS AND DISCUSSION

δ^{18}O FOR THE WATER OF ALONG THE COAST OF CEARÁ

It has been kept that δ^{18}O and δD of the ocean water are close to zero or show narrow interval of variation around zero and that oxygen fractionation during evaporation of the ocean water not only affects its isotopic composition but also affects its salinity (e.g. Faure 1986).

The salinity of surface, intermediate and deep waters of the Red Sea vary from 36 to 41‰ while seawater δ^{18}O varies from 0.6 to 0.9‰ $_{SMOW}$ (Craig 1966). (Craig and Gordon 1965) studied δ^{18}O values and salinity of the North Atlantic waters and proposed a linear equation showing the co-variation of δ^{18}O and water salinity: $\delta^{18}O_w = -21.2 + 0.61S$; where S is the salinity in permil units.

Wolff et al. (1998) analyzed *Globigerinoides sacculifer* in samples of sediments of the Ceará Rise, in the northeastern coast of Brazil, and proposed that temperature, salinity and δ^{18}O are mainly controlled by the inflow of continental water and local rains and adopted the equation: $\delta^{18}O_w = 0.182 * S - 5.6$ to calculate δ^{18}O of the seawater and found a value of $+0.92$‰ $_{SMOW}$ for δ^{18}O of the surface seawater. To calculate the δ^{18}O for the seawater, they used the salinity value of 35.8‰ of (Levitus et al. 1994).

The Ceará Rise, located relatively far from the coast of Ceará in the northeastern coast of Brazil, is a seamount that rises from the abyssal plane to 4300 m. (G.S.S. Freire, unpublished data) measured a water salinity of 35‰ for the ocean water along this coast, next to Fortaleza town, a value which has to do with the influence of continental waters.

There is a co-variation between salinity and seawater δ^{18}O as depicted from (Wolff et al. 1998) and (Craig and Gordon 1965) equations. In the attempt to verify which of these two equations would yield salinity values closer to the 35‰ value reported by (G.S.S. Freire, unpublished data) for the continental shelf of the State of Ceará (Table I) we have used the planktic foraminifer δ^{18}O data from this study, with vital effect correction.

As shown in Table I, values for salinity calculated by (Craig and Gordon 1965) equation are closer to 35‰. Thus, it seems that seawater δ^{18}O in a shallow

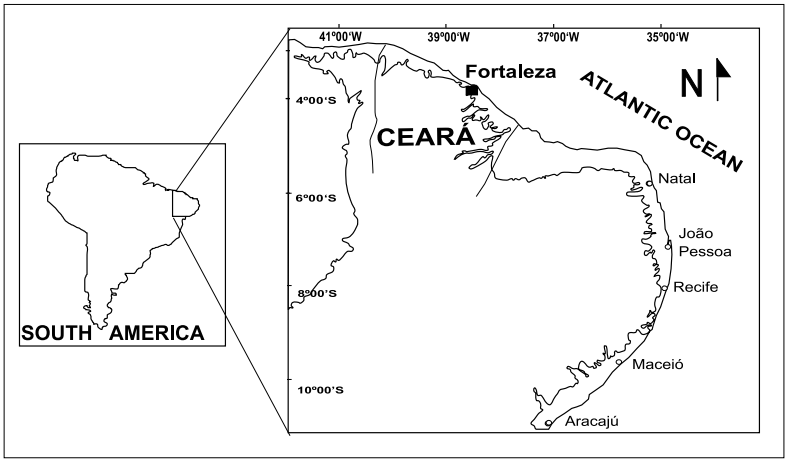

Fig. 1 – Localization of study area.

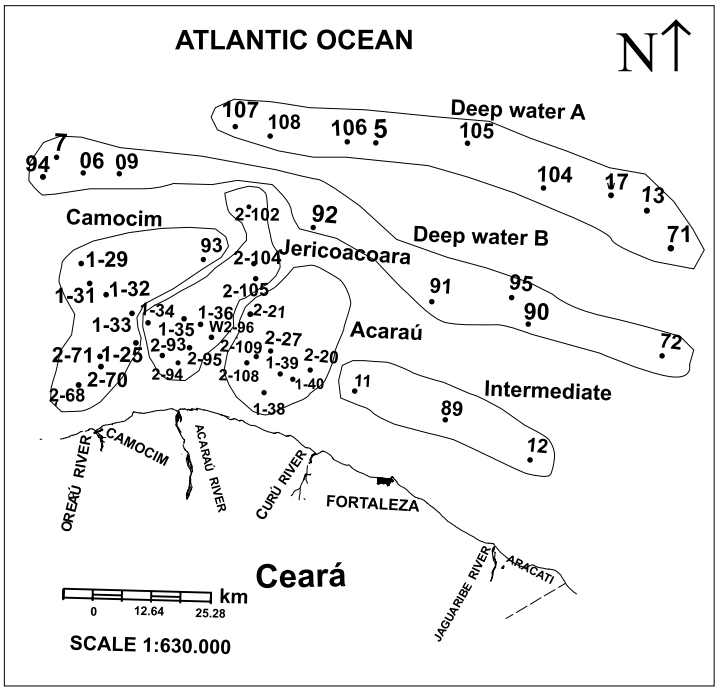

Fig. 2 – Cores and sectors along the coast of Ceará.

and narrow tropical continental shelf, influenced by continental waters like the Ceará coast, (Craig and Gordon 1965) equation seems to be the most appropriate. From then on, this equation ($\delta^{18}O_w = -21.2 + 0.61S$) has been used assuming the salinity of 35‰ to calculate the $\delta^{18}O$ of the seawater in the continental shelf of the State of Ceará, and a value of 0.2‰ $_{SMOW}$ was obtained.

A $\delta^{18}O$ value of 0.9‰ $_{SMOW}$ for the seawater calculated by (Wolff et al. 1998) probably reflects a more saline ambient of the Ceará Rise, while the value of 0.2‰ $_{SMOW}$ determined here, portrays a large conti-

TABLE I
Salinity calculation by equations of (Craig and Gordon 1965) and (Wolff et al. 1998) and values of $\delta^{18}O‰_{PDB}$ correct of vital effect.

Sample	$\delta^{18}O‰_{PDB}$	sal (‰) Craig and Gordon 1965	sal (‰) Wolff et al. 1998
w 11	−0.6	33	27
w2 102	0.0	34	31
w 05	−0.5	33	28
w 92	0.0	34	31
w 06	−0.6	33	27
w 107	1.8	37	41
w 91	−0.4	34	29
w 13	−0.5	33	28
w 09	−0.8	33	26
w 90	−0.4	34	29

nental-water influence. Perhaps the ambient studied by (Wolff et al. 1998) does not receive a large influence of continental water as anticipated, but it is mainly influenced by oceanic currents and by the precipitation/evaporation rate.

PLANKTIC FORAMINIFERS

Globigerinoides ruber lives at depths from 0 to 50 m in seawater and compared to other planktic species, carbonate tests of this species form in oxygen isotope disequilibrium of 0.0‰ to −1.0‰ compared to seawater (Niebler et al. 1999). (Costa et al. 2003) evaluated oxygen isotopic disequilibrium in foraminifer tests from the equatorial Atlantic and for that they used (Kim and O'Neil 1997) equation to calculate $\delta^{18}O$ values of calcite precipitated in isotopic equilibrium with seawater.

$$\delta^{18}O_{PDB}\text{calcite equil.} = \left(\delta^{18}O_{W\ SMOW}\right) - 0.27 + 3.25 - (0.2 \times T) \quad \text{(A)}$$

(Kim and O'Neil 1997)

In this equation $\delta^{18}Ow_{SMOW}$ is 0.92‰ from (Wolff et al. 1998) and was considered as a regional value to northeastern coast of Brazil.

Apparent temperatures of seawater (without vital-effect correction of measured $\delta^{18}O$ foraminifer tests to measure the oxygen isotopic disequilibrium caused by species) in this study were calculated using (Epstein et al. 1953) equation. Here the temperatures were used for the calculation of $\delta^{18}O$ differences in calcite precipitated from foraminífera tests. In plugging the obtained temperature values in equation (A), assuming a value of $\delta^{18}O$ of 0.92‰ $_{SMOW}$ for the seawater of the northeastern coast of Brazil in (Wolff et al. 1998), a decrease of about −0.5 to −0.6‰ $_{PDB}$ for $\delta^{18}O$ values was observed for all samples of *Globigerinoides ruber*.

Thus all samples which contained *Globigerinoides ruber* were regarded as in oxygen-isotope disequilibrium of −0.6‰ and their $\delta^{18}O$ values, after correction, were used to calculate temperatures for surface waters. In this study, (Epstein et al. 1953) equation modified by (Craig 1965) was used: $T°C = 16.9 - 4.2\ (\delta c - \delta w) + 0.13\ (\delta c - \delta w)^2$.

BENTHIC FORAMINIFERS

Foraminifer tests of the *Amphistegina radiata* and *Peneroplis planatus* species were selected among the benthic foraminifers because they are present in the majority of the studied samples, even in those from the continental slope, although in small amount (except in the site 5, at 1000 m depth), assuring co-existence between them in same conditions of temperature and salinity.

Saraswati et al. (2004) studied, among other species, *Peneroplis planatus*, Akajima Sea, Japan, that lives in conditions similar to those of tropical environments and they found an enrichment of 0.8‰ for $\delta^{18}O$ values

in foraminifer tests of this species. The same authors argued that the genus *Amphistegina* calcify their tests in close isotope equilibrium to the seawater and some species reach a maximum enrichment of 0.3‰ of their δ^{18}O values.

Applying the same procedure used for the planktic species to verify the vital effect in the *Peneroplis planatus* species, an isotopic enrichment of δ^{18}O from 0.3 to 2.1‰ was observed and an average correction of 0.95‰ was applied to all δ^{18}O values of this species before calculating the final temperatures for bottom water in the studied region. For the species *Amphistegina radiata,* the same procedure point to small enrichment reaching 0.1 to 0.2‰. This variation not strongly influenced the temperature calculation, giving differences in decimal. Therefore, vital effect was not considered for *Amphistegina radiata.*

CARBON AND OXYGEN ISOTOPES

To investigate possible changes of oceanographic parameters with depth and to facilitate the interpretation of experiments, we chose adjacent sectors containing the samples along the coast of Ceará (Fig. 2), extending from the inner shelf to the continental slope. Carbon and oxygen-isotope values, a list of the analyzed foraminifer samples and temperatures for water of the continental margin of the State of Ceará are found in Tables II through III.

The Jericoacoara sector displays δ^{18}O values of foraminifer tests from -1.1‰ to -0.3‰ $_{\text{PDB}}$ (Table I) while the Acaraú sector exhibits values from -0.4 to -1.2‰ $_{\text{PDB}}$ in sample 2-27a collected from 25 m depth, being this sector the one which receives more influence from continental waters. In the Camocim sector, δ^{18}O varies from -0.3 to -1.4‰ $_{\text{PDB}}$. The intermediate sector has δ^{18}O values from -0.5‰ to -1.1‰ while the deep-water sectors display δ^{18}O values from -0.4 to -1.0‰ $_{\text{PDB}}$.

A significant variation of δ^{18}O is observed in shallow-water sectors (continental shelf) where values almost double from one sample to another in one same sector. This variation could be associated to the large influence of continental waters since along this area, there are rivers with variable size and fluvial discharge such as the Jaguaribe, Acaraú, Curu and Coreaú rivers. In deep-water sectors, variations are accounted by the influence of oceanic streams.

The Acaraú sector shows lower δ^{18}O values in the environment of calcification of species compared to other shallow-water sectors in the continental shelf. This sector is the one which receives more influence of continental waters and, based on δ^{18}O values around -1.5‰ (at 2-21, 25 m depth) and -1.2‰ (at 2-27, 25 m depth), we suggest that continental-water influence reaches at least 25 m depth, regarding that oceanic water along the coast of the State of Ceará has high-wave energy allowing an intense mixing of continental and oceanic waters. This does not imply, however, that other sectors share the same features since the influence they receive is exerted by smaller rivers and also there is no sample from near larger rivers. Besides, it is difficult to estimate how much continental waters influence the ocean surface due to the fact that cores with planktic foraminifers were collected far from the coast.

δ^{13}C AND APPARENT OXYGEN UTILIZATION (AOU)

The δ^{13}C of foraminifer shells is usually not influenced by the temperature but is largely influenced by photosynthesis in the oceanic surface and by bacteriological decomposition of organic matter in the oceanic floor. During the photosynthesis of seaweeds, carbon dioxide-fixing enzymes have strong affinity for the lighter CO_2 molecule. As a result, the photic zone of the oceanic water that is characterized by a high primary productivity is ^{13}C enriched since ^{12}C remains tied to the organic-matter structure. Simultaneously, carbon fixed by the organic matter is released during bacteriological decomposition of the organic matter in deep waters, resulting in a ^{13}C-depleted environment.

Considering the oxygen behavior in the water of the oceans, (Hemleben and Bijma 1994) suggested an empirical relationship between $\delta\ 13C_{(\sum CO2)}$ and AOU in this environment. They explained that the oceanic surface is enriched in oxygen produced during the photosynthesis and enriched in ^{13}C as a result of ^{12}C fixation by the organic matter produced. In deep water, oxygen is consumed by the bacteriological decomposition of organic matter and the ^{13}C level is lowered by the release of ^{12}C to the environment. This implies a direct relationship between δ^{13}C and dissolved oxygen in the marine environment.

TABLE II

Values of $\delta^{18}O‰_{PDB}$, $\delta^{13}C‰_{PDB}$, temperature and species in Jericoacara, Araraú and Camocim sectors.

Sample	depth (m)	$\delta^{13}C‰_{PDB}$	$\delta^{18}O‰_{PDB}$	species	temp.°C
Jericoacoara					
2–93	16	3.2	−0.3	*Peneroplis planatus*	23
2–94	17	2.7	−0.5	*Peneroplis planatus*	23
2–96	17	3.1	−0.4	*Peneroplis planatus*	23
1–35	18	3.1	−0.4	*Peneroplis planatus*	23
1–36	18	2.7	−0.6	*Peneroplis planatus*	22
1–34	19	2.4	−0.5	*Peneroplis planatus*	21
2–105	30	0.7	−1.5	*Amphistegina radiata*	25
Acaraú					
1–39	15	1.8	−0.9	*Amphistegina radiata*	22
1–40	18	2.3	−0.7	*Peneroplis planatus*	24
2–109	16	2.1	−1.7	*Amphistegina radiata*	22
2–20	21	2.6	−0.6	*Peneroplis planatus*	24
2–27b	22	2.9	−0.4	*Peneroplis planatus*	23
2–27[a]	25	1.9	−1.2	*Peneroplis planatus*	26
2–21	25	0.9	−1.5	*Amphistegina radiata*	25
Camocim					
2–70	17	3.1	−0.4	*Peneroplis planatus*	24
1–25	28	2.8	−0.5	*Peneroplis planatus*	23
1–33	28	3.3	−0.3	*Peneroplis planatus*	23
93	45	0.6	−1.4	*Amphistegina radiata*	22
1–32	45	3.0	−0.5	*Peneroplis planatus*	24
1–31	50	2.3	−0.5	*Peneroplis planatus*	23

TABLE III

Results of $\delta^{18}O‰_{PDB}$, $\delta^{13}C‰_{PDB}$ and temperature in planktic foraminifer in samples along study area.

Sample	depth (m)	$\delta^{13}C‰_{PDB}$	$\delta^{18}O‰_{PDB}$	species	temp.°C
11	45	2.4	−1.2	*Globigerinoide ruber*	27
2–102	75	2.4	−0.6	*Globigerinoide ruber*	24
05	1000	2.3	−1.1	*Globigerinoide ruber*	27
92	800	2.3	−0.6	*Globigerinoide ruber*	24
06	900	2.3	−1.2	*Globigerinoide ruber*	27
107	1250	2.3	+2.4	*Globigerinoide ruber*	28
91	800	2.3	−1.0	*Globigerinoide ruber*	26
13	1150	1.6	−1.0	*Globigerinoide ruber*	26
09	1050	2.6	−1.4	*Globigerinoide ruber*	28
90	1070	2.4	−0.9	*Globigerinoide ruber*	26

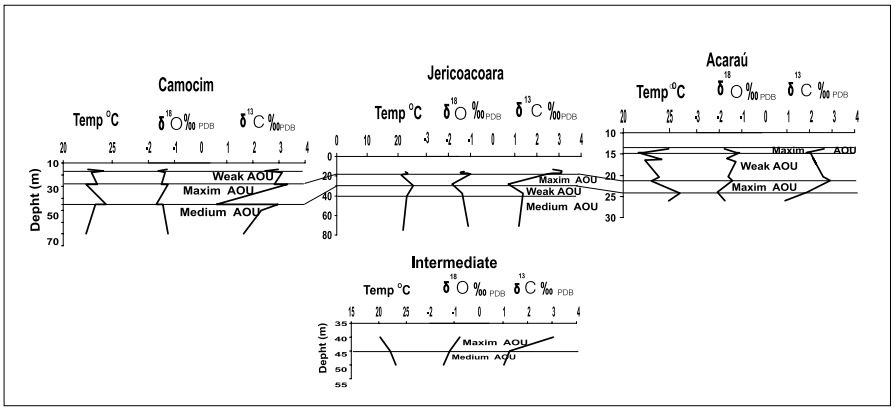

Fig. 3 – Temperature and isotopic values in shallow waters sectors.

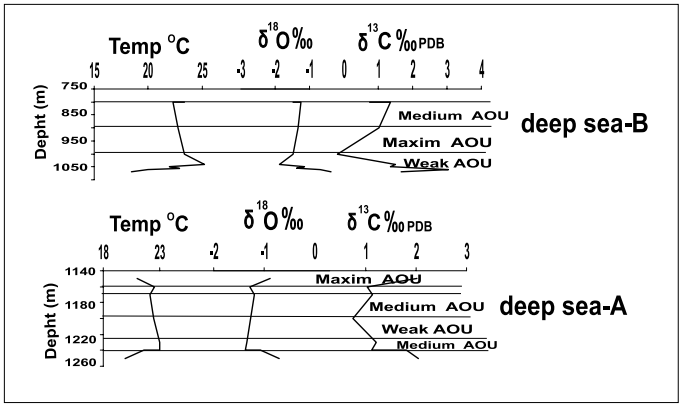

Fig. 4 – Temperature and isotopic values in deep waters and intermediate sectors.

In the present study, one established empirical relationships between δ^{13}C of benthic foraminifer tests and AOU for each sector of the studied area, determining possible sites of maximum and minimum AOU and release of ^{12}C to the environment (Figs. 3 and 4).

A large variation of δ^{13}C has been observed in the environment of each sector: values vary from 0.7 to 3.2‰ in the Jericoacoara sector, 0.9 to 2.9‰ in the Acaraú sector, 0.6 to 3.3‰ in the Camocim sector, 0.8 to 2.0‰ in deep waters A, −0.2 to 1.4‰ in deep waters B. If it is taken into account that nutrients are used in the photic zone for the animal metabolism and released during the bacteriological decomposition of the organic matter, a strong negative relationship is seen between $\delta^{13}C\Sigma_{CO2}$ and the amount of nutrients of the environment.

In the Jericoacoara sector, from 20 to 30 m deep there is a decrease in the δ^{13}C values from 3.2‰ to 0.5‰ (Fig. 3). In this depth range, probably more ^{12}C is released to the environment; there is a larger nutrient concentration and decomposition of organic matter, and more AOU. From 20 to 40 m deep, the AOU decreases as well as δ^{13}C values. At depths greater than 40 m there is little variation.

The Acaraú sector shows two zones of AOU: (1) a narrow one between depths of 14 to 15 m with progressively lower δ^{13}C. Between 15 and 22 m deep there is an intermediate section with increase of δ^{13}C values from 1.7 to 3.0‰; (2) a second zone of maximum AOU between depths of 22 to 25 m with a large decrease of the δ^{13}C values (3.0 to 1.0‰).

TABLE IV

Number of observed species in samples.

Jericoacoara		Acaraú		Camocim	
sample	n species	sample	n species	sample	n species
2–93	12	1–38	13	2–71	15
2–94	14	1–39	20	2–68	11
2–96	13	2–108	14	2–70	16
1–35	11	1–40	18	1–25	10
1–36	11	2–109	17	1–33	14
1–34	12	2–20	20	93	7
2–105	10	2–27[b]	11	1–32	15
2–104	20	2–27[a]	8	1–31	13
2–102	11	2–21	11	1–29	18
deep water A		deep water B		Intermediary	
sample	n species	sample	n species	sample	n species
13	20	91	15	12	10
105	15	92	20	11	35
104	10	06	20	89	6
17	15	94	5		
108	10	07	20		
05	20	09	11		
106	10	72	10		
71	20	2–95[a]	10		
107	20	90	25		

The Camocim sector has three different zones of AOU: (1) the first one between 15 and 26 m depths, with small variations of δ^{13}C and slight increase in AOU; (2) a second zone between 26 to 42 m depths, characterized by a large decrease in the δ^{13}C values (3.4 to 0.6‰) and consequently increase in AOU; and (3) a third zone at depths between 45 to 75 m, characterized by strong variations in δ^{13}C, but smaller than in the second zone.

One important factor that influences the δ^{13}C values, among several ones available in the environment to construction of foraminifer test, is the species respiration. In a given environment, in surface or in deep water, the larger the quantity of nutrients available, the larger the productivity of species that inhabit this site and, consequently, the larger the amount of CO_2 released to the environment due to species respiration. In this case, the CO_2 is ^{13}C enriched since organisms have the preference for the ^{12}C for their metabolism. This way, one can observe an empirical relationship between the δ^{13}C values and the quantities of living species.

Species observed under an optical microscope have been counted (Table IV) and compared with the δ^{13}C values in each sample (Fig. 5). It was verified that in deep water A and B, Acaraú and Jericoacoara sectors the δ^{13}C does not seem to be influenced by the species respiration and, therefore, there are other important factors in the environment playing this role. However, in the Camocim and Intermediate sectors, the influence of the respiration over the δ^{13}C is remarkable.

TEMPERATURE

Temperatures obtained in this study (Figs. 4 and 5) show that in the Jericoacoara sector, at depths between 20 and 30 m, there is an increase from 21 to 25°C. At depths between 20 and 40 m, there is a decrease in temperature from 25 to 22.5°C and beyond the depth of 40 m,

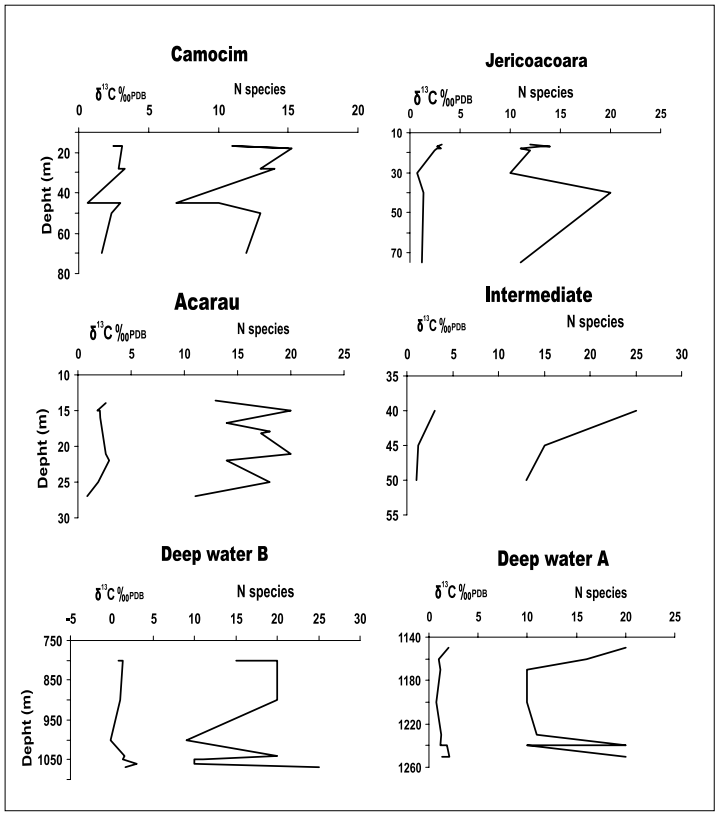

Fig. 5 – Number of observed species and δ^{13}C values with depth.

variations are little. The Acaraú sector shows, at depths between 14 and 15 m, a relatively large decrease of temperature and a small increase at depths from 15 to 22 m.

The Camocim sector is characterized, at depths between 15 to 26 m, by small variation in temperature (23 to 24°C), and between 26 to 42 m there is an increase from 21 to 25°C. The deep currents that come cross the sectors Jericoacoara and Acaraú, at depths between 15 to 20, have a minimum and maximum of 20 and 22°C respectively (cores 1-34, 1-36 and 2-108; Fig. 6). Water with similar temperature is found in the Intermediate sector, at depths between 40 to 50 m (cores 11 and 12). In shallower areas (14 m deep or less), the temperature of deep currents is from 24 to 25°C (core 1-38, Acaraú sector). Similar temperature was observed in the core 7 in surface water of the Camocim sector.

The estimated temperatures for surface water represent values from the surface down to 50 m depth due to the habitat of the species *Globigerinoides ruber*. The surface currents, generally warmer than deep waters, show temperature of 26°C in cores 13, 90 and 91 (Table III). Surface temperatures of 28°C occur in core 9.

Figure 6 shows water mass distribution with different temperatures, along the coast of Ceará. Therefore, examining this figure, one verifies the behavior of water masses in continental shelf of the State of Ceará varying between currents with different temperatures along the coast.

CONCLUSIONS

From the comparison between Craig and Gordon (1965) and Wolff et al. (1998) linear equations, one suggests that to calculate the δ^{18}O of the seawater in a continental margin like that of the State of Ceará, narrow, shallow and influenced by continental waters, the Craig and Gordon (1965) equation seems to be more appropriate.

It is proposed here that $0.2‰_{\text{SMOW}}$ is the δ^{18}O

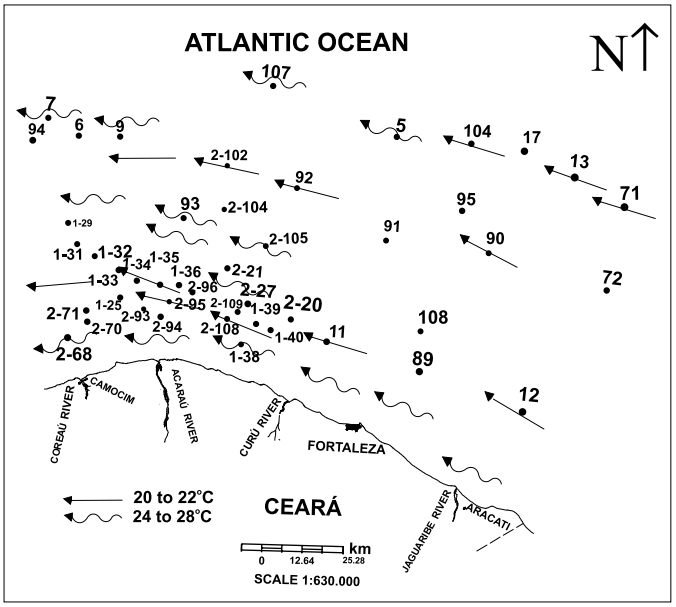

Fig. 6 – Temperatures and possible behavior of water currents along of coast of Ceará.

value for the water of the continental shelf of Ceará, a value relatively lower when contrasted with $0.92‰_{\text{SMOW}}$ obtained by Wolff et al. (1998), reflecting a major influence of continental water to the environment. Perhaps the environment of Ceará Rise is being more influenced by oceanic currents and by the precipitation/evaporation rate than continental influence.

From the estimated temperatures, one assumes that the behavior of the water masses in the continental shelf of the State of Ceará result from the interaction of a variety of currents along the coast, with different temperatures, and that this behavior can extend beyond the continental shelf.

The cores with lower δ^{18}O values of foraminifer test is associated with the proximity of the mouth of rivers being the cores of the Acaraú sector the most affected, next to the Acaraú river mouth, regarded as an important river in the coast of Ceará. Based on δ^{18}O values of $-1.5‰_{\text{PDB}}$ (core 2-21, 25 m depth) and $-1.2‰_{\text{PDB}}$ (core 2-27a, 25 m depth), both in the Acaraú sector, it is supposed that the influence of the continental waters reaches at least a depth of 25 m, considering the wave energy, and not implying, however, that other sectors display same characteristics, due to the influence of smaller rivers. Regarding distribution of apparent oxygen utilization (AOU) in deep waters of the continental shelf of the State of Ceará obeys the following pattern: (a) in the western portion of the continental shelf (Camocim sector), the maximum AOU zone is between depths of 30 to 45 m, while the minimum AOU zone is between 15 to 30 m; (b) in the eastern portion (Jericoacoara sector), the maximum AOU zone is situated between the depths of 18 to 30 m and the minimum AOU zone is between 30 and 40 m. In the Acaraú sector, west of Fortaleza, a small maximum AOU zone is between 13 and 15 m. Between depths of 15 to 22 m, there is an intermediate zone and other maximum AOU zone between 22 and 25 m. Apparently, the AOU zones are not continuous along the inner and outer continental shelves of the State of Ceará.

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RESUMO

Amphistegina radiata, Peneroplis planatus e *Globigerinoides ruber*, presentes em cinqüenta amostras de sedimentos superficiais da margem continental do Estado do Ceará, Brasil, foram analisados quanto à composição isotópica do Oxigênio e Carbono para investigar parâmetros oceanográficos, e um possível valor de δ^{18}O do oceano. Foi feita uma comparação entre as equações lineares de Craig e Gordon (1965) e de Wolff et al. (1998), e verificou-se que a primeira equação foi mais apropriada para o cálculo de δ^{18}O do oceano, na área estudada, encontrando-se um valor de $0{,}2‰_{\text{SMOW}}$. Os menores valores de δ^{18}O estão associados à desembocadura dos rios, refletindo a influência continental. Valores de δ^{18}O de $-0{,}3‰$ a $-1{,}5‰_{\text{PDB}}$ (bentônicos) e $-0{,}6‰$ a $-2{,}4‰_{\text{PDB}}$ (planctônicos), em toda a área, indicam variação na temperatura das massas de água entre 20 a 22°C, nas águas de fundo, e entre 24 a 27°C nas águas de superfície em média. Valores de δ^{13}C de +3,2‰ a $-0{,}2‰_{\text{PDB}}$ (bentônicos), em toda a área, indicam variação na distribuição da Utilização Aparente do Oxigênio (AOU) na margem continental, e indicam que os ambientes de decomposição bacteriológica da matéria orgânica não são contínuos ao longo da área de estudo.

Palavras-chave: foraminíferos, isótopos de carbono e oxigênio, margem continental, Ceará, Brasil.

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