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## Influence of continental fraction in recent biogenic carbonate sedimentation in the oriental shelf of Northeastern Brazil

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**Abstract** The influence of continental sediments on formation of recent marine sediments, has been mineralogically and geochemically studied using shelf-floor whole sediments (WS). The studied area corresponds to the oriental shelf of Northeastern Brazil between the 10 to 80m isobaths, adjacent to a continental area dominated by semi-arid to humid tropical climate. 47 representative samples from the dominating facies in this shelf have been analyzed by X-ray diffraction (XRD) and chemical analysis and results allowed identification of two types of floor sediments of: (a) quartz-terrigenous dominance and (b) carbonate dominance, whose fraction present distinct mineralogical and geochemical characteristics. In the terrigenous facies, that occur from 10 to 25-55m depths, quartz, potassic feldspar and high Mg-calcite predominate, with Sr generally <2,200 ppm. In the carbonate facies, high Mg-calcite and aragonite coexist and predominate, with Sr concentrations up to 6,400 ppm and ranging >2,600 ppm. In both cases, low-Mg calcite is absent. Even when the terrigenous fraction is found in accessory amounts (< 3% WS), geochemical signatures, marked by strong intercorrelations SiO<sub>2</sub> - Al<sub>2</sub>O<sub>3</sub> - K<sub>2</sub>O - Rb, exhibit correlation coefficients with  $r \geq 0.9$ , reflecting a continental felsic source. The statistical analyses (co-variation between Mg/Ca and SiO<sub>2</sub>), chemistry and mineralogy of the sediments indicate that textural and mineralogical nature of the substratum is the main factor controlling the biota (dominantly benthonic in this shelf) and that, in these conditions, quartzous terrigenous facies favor species that are preserved in high Mg-calcite instead of those preserved in aragonite. This tendency showed to be independent of depth of sampling between 10 and 55 m.

**Keywords:** biogenic carbonates, Mg-calcite, Northeastern Brazil, terrigenous sediments

**Resumo** *Influência de frações continentais na sedimentação de carbonatos biogênicos recentes na porção oriental da plataforma continental nordeste brasileira.* A influência do aporte continental na formação de carbonatos biogênicos recentes é estudada a partir de dados mineralógicos e geoquímicos nos sedimentos totais do assoalho plataformal. A área estudada corresponde à plataforma do Nordeste Oriental do Brasil, entre as isóbatas de 10 e 80m, adjacente a uma porção continental dominada por clima tropical semi-árido a úmido. Foram selecionadas 47 amostras contendo, em sua maioria, sedimentos carbonáticos, que são dominantes nessa plataforma, para análises XRD e análises químicas. Os resultados definiram dois tipos de fácies, ou sedimentos de composição diferente: os de dominância terrígeno-quartzosa e os de dominância francamente carbonática. Nos sedimentos terrígenos, que ocorrem desde isóbatas de 10m, até isóbatas entre 25 e 55m, predominam quartzo, feldspato potássico e calcita de alto magnésio, com teores em Sr geralmente < 2.200 ppm. Nos sedimentos carbonáticos, predominam e coexistem calcita de alto magnésio e aragonita, com teores em Sr geralmente >2.600 ppm, chegando a mais de 6.400 ppm. Em ambos os casos, não foi identificável a presença de calcita com alto magnésio. Mesmo quando a fração terrígena é acessória (<3%), a assinatura geoquímica, marcada por fortes intercorrelações SiO<sub>2</sub> - Al<sub>2</sub>O<sub>3</sub> - K<sub>2</sub>O - Rb mantém fatores de correlação ( $r \geq 0.9$ ), refletindo a fonte félsica, de origem continental desses sedimentos terrígenos. As análises estatística (correlação Mg/Ca - SiO<sub>2</sub>), química e mineralogia dos sedimentos indicam que a natureza mineralógica do substrato é fator preponderante de controle da biota (dominantemente bentônica nessa plataforma) e que, nessas condições, as fácies mais terrígeno-quartzosas favorecem espécies preserváveis em calcita com alto magnésio em detrimento de espécies preserváveis em aragonita. Essa tendência mostrou-se independente da isóbata da amostragem desde os 10 até os 55 m.

**Palavras-chave:** carbonatos biogênicos, calcitas magnesianas, fluorescência de raiosX, sedimentos terrígenos.

**INTRODUCTION** Biogenic carbonates occur habitually in shallow marine water of tropical regions. Due to the metabolism of the species that compose them,

biogenic carbonates are chemically heterogeneous, presenting a variety of chemical elements tied to their crystalline structure (Brownlow 1996). Many factors influ-

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ence their mineralogy and spatial distribution, being the type of biota one of them. For example, the major part of the foraminifers precipitate Mg-calcite in their tests, while marine algae of the genus *Halimeda* precipitate exclusively aragonite (Bilal and Boersma 1998).

Environmental factors as temperature, pH, CO<sub>2</sub> partial pressure, light penetration and availability of oxygen are also determining factors for the distribution of these sediments in the continental shelves. Morse and Mackenzie (1990) pointed to a relationship between shape and complexity of the carbonatic skeleton of different organisms and water temperature, emphasizing that aragonite-producer organisms are, many times, confined to warmer waters. These authors indicated a relationship between growth rate (or calcification) of skeletons and magnesium content in the carbonate structure.

Brownlow (1996) emphasized that organisms could precipitate calcite in either undersaturated or oversaturated in calcium carbonate waters, and that nucleation rate and crystal growth, as well as their dissolution, are delayed by the presence of Mg<sup>++</sup> in seawater. He also stated that carbonates precipitated in shallow-marine waters are formed mainly by high Mg-calcite (11 to 19% Mg) while low Mg-calcite (Mg<11%) and aragonite are usually subordinate in these facies.

X-ray diffraction analysis (XRD) is a satisfactory method of analysis for telling how much magnesium is in the structure of carbonates (Goldsmith et al. 1961) once its presence decreases the distance between the atomic planes in the crystalline structure of calcite.

Aragonite exhibits distinct behavior with respect to magnesium, because the growth of this carbonate mineral is not affected by presence of this element, since its orthorhombic structure does not admit magnesium in amount large enough to form solid solution, as it happens in calcite. On the contrary, its atomic structure favors the admission of atoms with ionic radius larger than that of calcium (e.g. strontium). In aragonite, calcium is replaced by strontium, lead and, less often, by zinc (Dana 1959).

The scope of this study is to focus on the influence of the continent derived facies in the mineralogy and geochemistry of the carbonatic sedimentation in the continental shelf of the oriental Northeastern Brazil, recognized as one of the richest shelves in biogenic carbonates in the Brazilian coast.

**STUDY AREA** The continental shelf of oriental Northeastern Brazil, particularly in the state of Ceará (Fig. 1), receives reworked sediments from the Barreiras Formation and from the crystalline basement, by means of rivers of little to intermediate importance (Freire 1985). Rocks of the crystalline basement are predominantly felsic and according to Freire (1985) this basement is covered by Neogene sediments of the Barreiras Formation along the coast. Sediments of the Barreiras Formation are constituted by red clayey sands and conglomerates. Sedimentary limestones also crop out in relatively extensive areas (e.g. Potiguar Basin) in the state of Rio Grande do Norte.

Almost all rivers that transport sediments to the continental shelf have hydrographic basins localized in the semi-arid climate domain (Meireles and Silva 2002).

According to Summerhayes et al. (1975) and Coutinho (1992), this continental shelf (Fig. 1) is relatively narrow (60-80 km), has a gentle slope (about de 1m/km, in average), warm water (25-30°C), and high salinity (30-38‰). In general, its intermediate and external domains are entirely covered by biogenic carbonatic sediments, characterized by predominating algalic rests and mollusks, small amount of corals, and total absence of ooids or other forms of carbonatic inorganic precipitation. The depth of shelf break, or the beginning of the continental slope, is between 60 and 70m isobaths. These characteristics extend along the continental shelf of other states in Northeastern Brazil, like Pernambuco, studied by Montalverne (1982).

Among the studied samples from greater depths (>80 m) carbonate nodules have been observed in dark buff color, identified by Amaral (unpublished data) as being Eocene-Oligocene phosphatic limestones of the continental margin, formed by diagenetic phosphatization of carbonate rocks, due to upwelling currents.

**METHODS** The sampling was carried out by oceanographic dredging and 47 samples have been selected between isobaths from 10 through 80 m, from the continental shelf of Ceará, Piauí, Rio Grande do Norte, Pernambuco, Paraíba and Alagoas states. This sampling includes essentially superficial Holocene sediments, composed of biogenic carbonates and subordinate terrigenous sediments. It was done during the operations of the GEOMAR XVIII (November, 1981) and GEOMAR XXI (November, 1983), on board of the *Almirante Câmara* oceanographic ship of the Brazilian Navy.

Each sample of whole sediment (WS) was washed and dried out in room temperature, put in plastic recipients and stored in the Marine Geology Laboratory (LGMA), Federal University of Ceará. The preliminary laboratory procedure consisted in homogenizing and quartering and two grams was ground down to 100 meshes in porcelain crucible and were analyzed by X-ray fluorescence, at the Stable Isotope Laboratory (LABISE), Department of Geology and by X-ray diffraction analysis, Physics Department of the Federal University of Pernambuco.

**X-ray Fluorescence Analyses** Powdered samples (WS), after dried at 110°C during 6 hours, were calcinated in a muffle at 1000°C during a couple of hours, for loss on ignition (loi) determination. Fused bead was prepared from each calcinated sample, using lithium tetraborate flux, for X-ray fluorescence analyses. These analyses were performed in a Rigaku unit model RIX 3000 equipped with Rh tube, by the calibration curve method prepared with international reference materials. Major elements are reported in weight percent and trace elements, in parts per million (ppm, Table 1).

**X-Ray Diffraction Analysis** Analyses by XRD were

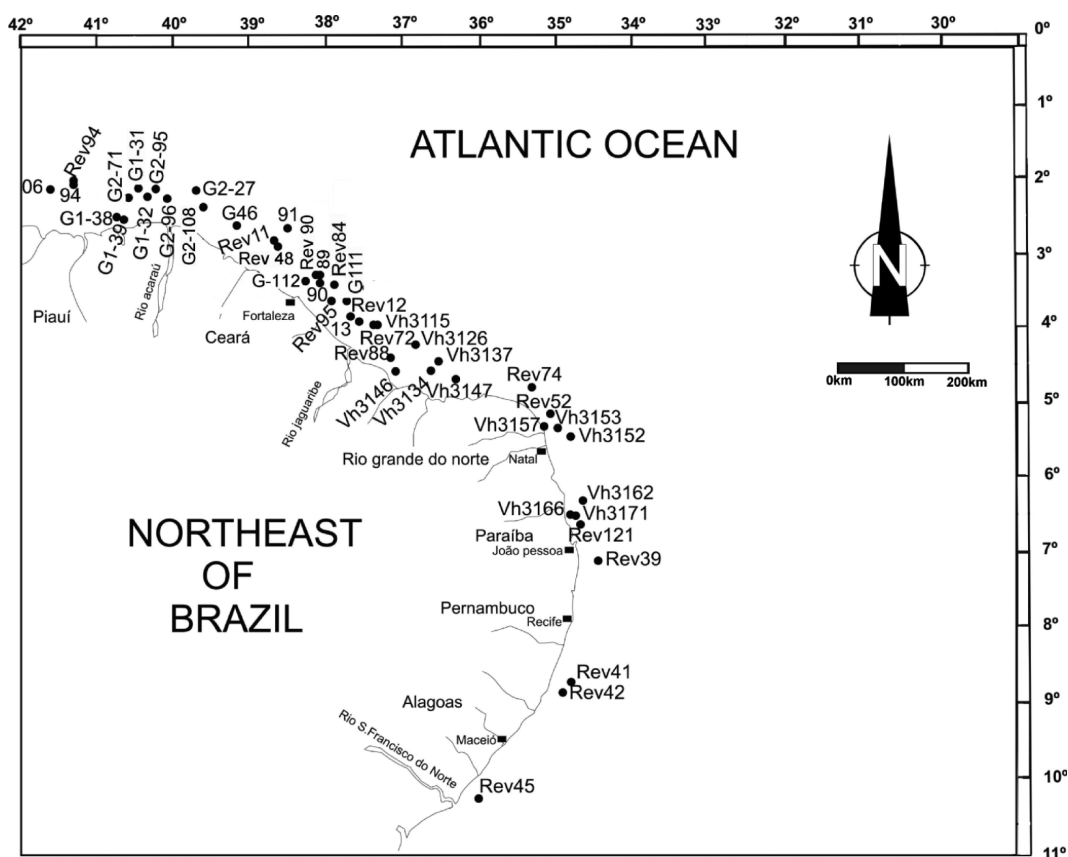


Figure 1 - Sample localities (adapted from Amaral, 1979).

performed by the powder method (Figs. 2a, b, c, d, e) using a Siemens D5000 unit, with the following standard conditions: scanning  $\theta$ /min, from 5 to 50 $\theta$ . K $\alpha$  emission, and drift correction from the peak I=100 of quartz  $\alpha$  (3.34 Å) to determining the magnesium quantity tied to the calcite structure, according to Goldsmith et al. (1961).

**Statistical Analysis** The statistical treatment of the data included a regression analysis by means of correlations among 14 variables by Spearman's correlation coefficients ( $r$ ), (Table 2), at confidence level of 95%, suitable for the type of population to be analyzed ( $n=47$ ), following suggestions in Siegel (1975).

**RESULTS AND DISCUSSION** The XRD analyses (Figs. 2a, b, c, d, e) have evidenced the predominance of the high Mg-calcite in proximal sediments of the continental shelf or in those characterized by fraction siliciclastic dominant (> 60% WS), even when they correspond to deep sediments (>25m). Quartz and subordinate quantities of potassic feldspar are the main component of this siliciclastic fraction, with muscovite and clay minerals (kaolinite) only identifiable sporadically as accessory phases. Low Sr contents (< 2,200 ppm. in general) and Mg/Ca ratios (WS)  $\geq 0.12$  (Fig. 3) characterize proximal facies, and place in evidence the reduced participation, or even absence of aragonite and of low Mg-calcite in total analyzed sediment (WS).

In more distal conditions of the continental

shelf, deeper sediments (>25m) where there is absolute predominance of the carbonatic fraction, high Mg-calcite (sometimes more than one type) coexist with large amount of aragonite. The siliciclastic fraction, frequently accessory in this environment, sometimes is not identifiable by X-ray diffraction of whole sediment (WS). High Mg-calcite with Ca:Mg ratios of 85:15 to 80:20 predominate but at deeper isobath (> 35m), Ca:Mg ratios of 70:30 can occur associated. High Sr contents (>2,500 ppm) and Mg/Ca (WS) ratios <0.12 (Fig. 2) characterize this paragenesis.

The predominance of high Mg-calcites is ratified by strong contents of MgO (2.78 a 6.89%) for WS with  $\text{CaCO}_3_{\text{total}} > 95\%$ . Low Mg-calcites have not been identified. Samples with high Sr contents (>3,000 ppm) had the presence of aragonite systematically confirmed in XRD analyses.

The results of statistical analyses attest, at a first instance, to the anticipated geochemical duality of shelf sedimentary systems, that is, the opposition between chemical species related to the supply of continental terrigenous sediments and those associated to carbonate precipitations that occur in situ. In this sense, it is aligned with terrigenous continental source the strong inter-correlations among  $\text{SiO}_2$  -  $\text{Al}_2\text{O}_3$  -  $\text{K}_2\text{O}$  - Rb (Table 2), generally with correlation coefficients ( $r$ )  $\geq 0.9$  to which somehow are also associated the set of inter-correlations  $\text{Fe}_2\text{O}_3$ -Mn-TiO<sub>2</sub> ( $r = 0.4$  a  $0.8$ ). The set of inter-correlations between  $\text{SiO}_2$ - $\text{Al}_2\text{O}_3$ - $\text{K}_2\text{O}$ -Rb marks the main siliciclastic constitution, composed by quartz

Table 1 - Chemical analyses for bulk sediments collected at different depths (major elements in wt. % and trace elements in ppm).

Sample	Depth (m)	Lat (S)	Long(W)	SiO <sub>2</sub>	Al <sub>2</sub> O <sub>3</sub>	Fe <sub>2</sub> O <sub>3t</sub>	MgO	CaO	Na <sub>2</sub> O	K <sub>2</sub> O	TiO <sub>2</sub>	P <sub>2</sub> O <sub>5</sub>	PF	Mn	Sr	Rb	Mg/Ca
Vh03157	10	05°45'12"	35°11'12"	68.68	3.00	2.62	1.61	8.46	0.13	0.23	2.81	0.04	10.98	549	820	15	0.22
Vh03146	15	04°52'06"	36°22'48"	1.05	0.31	0.16	6.89	43.30	0.37	0.04	0.19	0.06	45.77	46	2629	5	0.13
Rev88	18	04°36'00"	37°14'24"	0.00	0.00	0.03	5.97	48.39	0.41	0.01	0.03	0.07	46.92	16	3052	5	0.10
Vh03147	20	04°44'30"	36°19'12"	88.31	1.88	0.62	1.02	2.87	0.08	0.17	0.56	0.00	3.10	158	183	12	0.48
Rev74	20	04°56'24"	35°19'30"	25.61	0.65	0.05	3.90	34.56	0.48	0.18	0.04	0.05	35.14	16	3287	5	0.10
Vh03166	20	06°45'12"	34°54'30"	5.79	0.36	0.07	3.26	45.52	0.99	0.10	0.03	0.07	43.58	5	5301	5	0.06
G2 96	21	02°29'05"	40°04'00"	3.20	0.33	0.31	5.90	46.63	0.11	0.05	0.01	0.11	43.57	30	2940	5	0.10
Vh03171	23	06°51'48"	34°46'30"	14.63	0.38	0.08	3.90	41.11	0.48	0.04	0.02	0.07	39.51	18	3588	5	0.08
G2 95	25	02°30'06"	40°07'00"	9.27	0.60	0.37	5.50	42.85	0.30	0.23	0.01	0.10	40.95	31	2626	5	0.11
G1 32	25	02°17'00"	40°27'30"	70.18	3.17	0.47	1.74	12.11	0.11	0.90	0.23	0.03	13.09	90	1318	31	0.16
G2 71	25	02°31'05"	40°35'00"	8.53	0.50	0.29	5.42	43.85	0.10	0.14	0.02	0.10	41.40	36	2611	5	0.10
G2 27	25	02°33'05"	39°47'03"	12.43	1.39	0.33	4.31	40.56	0.32	0.35	0.08	0.09	40.52	40	3717	5	0.09
Rev12	25	03°52'48"	37°43'12"	87.78	1.97	0.25	1.04	3.52	0.18	0.22	0.28	0.00	4.85	51	217	15	0.40
G1 12	25	03°36'30"	38°17'30"	7.61	0.25	0.05	3.67	45.38	0.58	0.07	0.02	0.10	42.51	17	4086	5	0.07
G2 108	28	02°35'09"	39°52'00"	1.23	0.31	0.34	5.54	48.48	0.20	0.03	0.01	0.12	44.60	29	2689	5	0.09
Rev95	30	03°17'24"	38°00'00"	0.12	0.00	0.01	2.78	50.62	0.69	0.03	0.01	0.07	45.93	5	6482	0	0.04
Vh03134	30	04°48'30"	36°37'42"	0.67	0.21	0.07	3.86	49.17	0.76	0.04	0.02	0.08	45.70	14	5200	0	0.06
06	35	02°18'00"	41°39'36"	0.00	0.00	0.03	5.44	49.13	0.23	0.00	0.00	0.08	45.34	11	3611	5	0.09
90	35	03°28'48"	38°04'48"	0.00	0.00	0.02	4.52	50.88	0.13	0.00	0.03	0.08	45.41	18	4349	0	0.07
G1 31	35	02°15'00"	40°30'30"	61.05	2.32	0.96	2.21	16.55	0.08	0.56	0.12	0.06	18.03	111	1550	20	0.13
13	35	04°15'00"	36°39'36"	61.41	2.81	1.83	2.29	15.69	0.13	0.75	0.18	0.06	16.73	98	1226	25	0.15
Rev42	35	09°06'00"	34°33'36"	66.86	2.21	0.18	1.09	14.53	0.63	0.68	0.13	0.01	16.19	50	3326	25	0.09
89	35	03°28'48"	38°04'48"	0.39	0.01	0.02	2.78	50.13	0.66	0.05	0.01	0.08	45.94	16	6060	5	0.04
Rev90	35	03°28'48"	38°04'48"	0.05	0.05	0.04	3.52	50.58	0.62	0.00	0.00	0.08	45.45	12	4735	5	0.06
Rev121	35	06°48'00"	34°39'36"	16.83	1.83	1.55	3.41	36.59	1.27	0.28	0.11	0.12	38.67	71	3063	10	0.08
Rev72	35	03°49'48"	37°22'12"	63.70	2.9	0.59	1.58	14.97	0.69	0.76	0.08	0.01	16.16	53	2981	23	0.12
G 111	38	03°54'30"	37°35'00"	7.60	0.41	0.15	4.04	42.07	0.77	0.11	0.23	0.11	42.49	51	3174	5	0.08

associated to potassic feldspar, apparently with absence (or in non-detectable amounts) of sodic plagioclase in XRD analysis. The set Fe<sub>2</sub>O<sub>3</sub>-Mn-TiO<sub>2</sub> ( $r = 0.7$  to  $1.0$ ) point to the presence of a residual fraction of pedogenic origin, composed of Fe and Mn oxides, besides heavy minerals containing Ti (e.g. ilmenite and/or rutile). Although in non-systematic way, the highest contents of Fe<sub>2</sub>O<sub>3</sub>, TiO<sub>2</sub> and Mn, use to occur in more terrigenous facies, independently of the depth of sampling.

On the contrary, biogeochemical sedimentation, marked by integrated inter-correlations CaO-MgO-P<sub>2</sub>O<sub>5</sub> ( $r = 0.7$ , systematically), is invariably opposed (negative  $r$ ) to the terrigenous set as a whole. The diadochy of Ca<sup>++</sup> for Mg<sup>++</sup> in the Mg-calcites composition and partition of Ca<sup>++</sup> in the composition of aragonite and Ca phosphates (probably apatite group) explain why the integrated correlations of the biochemical set are not so strong. An essentially benthonic bioclastic association, composed mainly by algae, mollusks, echinoids and corals, besides sporadic presence of scales, spines and fecal pellets. support the geochemical signatures of this set. The

diversity of this biota and its corresponding mineralogical preservation allow a reasonable correlation between CaO-MgO ( $r = 0.7$ ), but weak between Sr-MgO ( $r = 0.2$ ) on account of the competition between Sr and Mg ( $r = -0.8$  for Ca/Mg-Sr) in the carbonate composition.

The Mg/Ca-SiO<sub>2</sub> correlation ( $r = 0.8$ ) evidence the geochemical competition between Sr and Mg in the integration to the crystallographic structure of the carbonates. By itself, it could indicate the influence of the depth in the Mg content of calcites, that is, the preferential formation of high Mg-calcites occur in facies proximal to the shelf, where the terrigenous fraction use to be stronger. However, in the studied sampling there are quartzous siliciclastic sediments (SiO<sub>2</sub> > 60% and Al<sub>2</sub>O<sub>3</sub> < 3%) from 10 to 55 m, and the Mg/Ca-SiO<sub>2</sub> correlation is more sensitive where the quartzous siliciclastic fraction is greater (Fig. 4), independently on depth of sampling. This way, it seems more evident that the mineralogical and chemical compositions of these sediments are directly related to the nature of the benthonic biota and this one with the type of substratum

Table 1 - continued.

Sample	Depth (m)	lat ( S)	long (W)	SiO <sub>2</sub>	Al <sub>2</sub> O <sub>3</sub>	Fe <sub>2</sub> O <sub>3t</sub>	MgO	CaO	Na <sub>2</sub> O	K <sub>2</sub> O	TiO <sub>2</sub>	P <sub>2</sub> O <sub>5</sub>	PF	Mn	Sr	Rb	Mg/Ca
Rev52	40	05°18'00"	35°24'24"	0.00	0.00	0.00	4.48	50.06	0.43	0.01	0.00	0.06	45.72	5	5133	0	0.07
G 46	40	02°57'30"	39°16'30"	0.60	0.16	0.16	5.68	49.08	0.31	0.00	0.00	0.11	44.86	14	2801	0	0.09
Rev75	40	03°16'30"	35°06'00"	0.15	0.01	0.04	5.47	46.21	0.73	0.30	0.00	0.07	47.27	15	3839	5	0.10
Rev41	43	09°04'48"	35°01'12"	0.33	0.03	0.02	3.11	50.42	0.47	0.01	0.00	0.07	44.87	16	4710	5	0.05
Rev39	55	07°28'48"	34°46'48"	70.31	2.75	0.15	1.72	12.20	0.50	0.73	0.04	0.02	13.83	29	2161	24	0.16
Rev48	60	03°20'24"	38°40'12"	0.03	0.00	0.03	3.19	51.19	0.63	0.00	0.00	0.08	45.46	18	3165	5	0.05
Rev94	60	02°18'00"	41°27'36"	0.15	0.00	0.07	4.98	48.19	0.90	0.12	0.03	0.12	47.74	16	3936	5	0.08
VH3115	60	04°15'00"	37°24'30"	4.60	0.35	0.05	4.78	46.21	0.57	0.14	0.01	0.08	43.65	9	3200	5	0.08
94	60	02°18'00"	41°27'36"	0.58	0.06	0.05	4.45	46.28	0.65	0.12	0.02	0.10	47.43	30	4314	5	0.08
VH3137	60	04°40'00"	36°34'42"	2.50	0.45	0.14	3.81	48.13	0.82	0.09	0.03	0.10	44.80	20	4051	5	0.06
Rev45	60	10°36'00"	36°24'00"	6.59	0.46	0.32	5.18	44.00	0.48	0.09	0.04	0.09	43.44	43	2882	5	0.09
VH3153	60	05°46'00"	35°00'30"	7.83	1.07	1.17	3.85	43.57	0.66	0.19	0.06	0.17	41.52	76	3063	5	0.07
Rev84	80	03°39'36"	38°00'00"	0.37	0.02	0.02	5.72	48.26	0.44	0.00	0.00	0.08	45.79	10	3120	5	0.10
Rev11	80	03°01'48"	38°46'12"	0.05	0.00	0.03	4.78	49.20	0.41	0.00	0.02	0.10	46.78	18	3890	5	0.08
VH3126	80	04°34'42"	36°53'24"	3.46	0.62	0.15	3.11	46.20	0.70	0.12	0.03	0.08	43.85	22	3888	5	0.06
VH3162	80	06°39'42"	34°43'18"	3.90	1.76	0.79	4.33	44.26	0.79	0.13	0.08	0.10	44.03	73	3816	5	0.08

Table 2 - Correlation matrix for major elements (wt.% oxides) and trace elements (ppm).

SiO <sub>2</sub>																	
SiO <sub>2</sub>	1.0																
Al <sub>2</sub> O <sub>3</sub>	0.9	1.0															
Fe <sub>2</sub> O <sub>3t</sub>	0.5	0.7	1.0														
MgO	-0.8	-0.7	-0.3	1.0													
CaO	-1.0	-0.9	-0.5	0.7	1.0												
Na <sub>2</sub> O	-0.3	-0.2	-0.1	-0.1	0.3	1.0											
K <sub>2</sub> O	0.8	0.9	0.4	-0.6	-0.8	-0.1	1.0										
TiO <sub>2</sub>	0.4	0.5	0.7	-0.3	-0.5	-0.2	0.1	1.0									
P <sub>2</sub> O <sub>5</sub>	-0.8	-0.5	0.0	0.7	0.7	0.2	-0.5	-0.3	1.0								
PF	-1.0	-0.9	-0.5	0.8	1.0	0.4	-0.7	-0.5	0.8	1.0							
Mn	0.5	0.6	0.8	-0.4	-0.6	-0.3	0.2	1.0	-0.3	-0.5	1.0						
Sr	-0.7	-0.7	-0.5	0.2	0.7	0.6	-0.5	-0.4	0.3	0.7	-0.5	1.0					
Rb	0.9	0.9	0.4	-0.7	-0.9	-0.2	0.9	0.3	-0.6	-0.8	0.4	-0.6	1.0				
Mg/Ca	0.8	0.5	0.3	-0.4	-0.8	-0.5	0.3	0.4	-0.6	-0.8	0.4	-0.8	0.4	1.0			

they are tied to.

It is possible that such distal siliciclastic sediments observed in these deep isobaths (> 25m) correspond to ancient reworked coastal zones, not covered by more recent sediments, marking periods of stabilizations of coastline during the rising of sea level from the peak of the latest glacial period.

Original records should be certainly covered by subsequent process of sedimentation. In this sense, regarding the gentle gradient of the shelf and the order of magnitude of the sedimentation rates of the shallow carbonatic platforms (0.5-1.5 m 1000 yr<sup>-1</sup>, Tucker and

Wright 1990) in few thousand years these deposit could be sufficiently covered by more recent sediments precluding their sampling by oceanic dredgers. Alternatively, these deeper quartzous terrigenous facies could correspond to active axes of currently submerse paleochannels still receiving continental detritic materials by means of plumes of the present-day drainage systems. In any of these alternatives, the siliciclastic nature of these substrata seem as important as the hydrodynamic conditions or temperature of the water to the mineralogy and geochemistry of the associated carbonates. Therefore, among the possibilities pointed out by Morse and

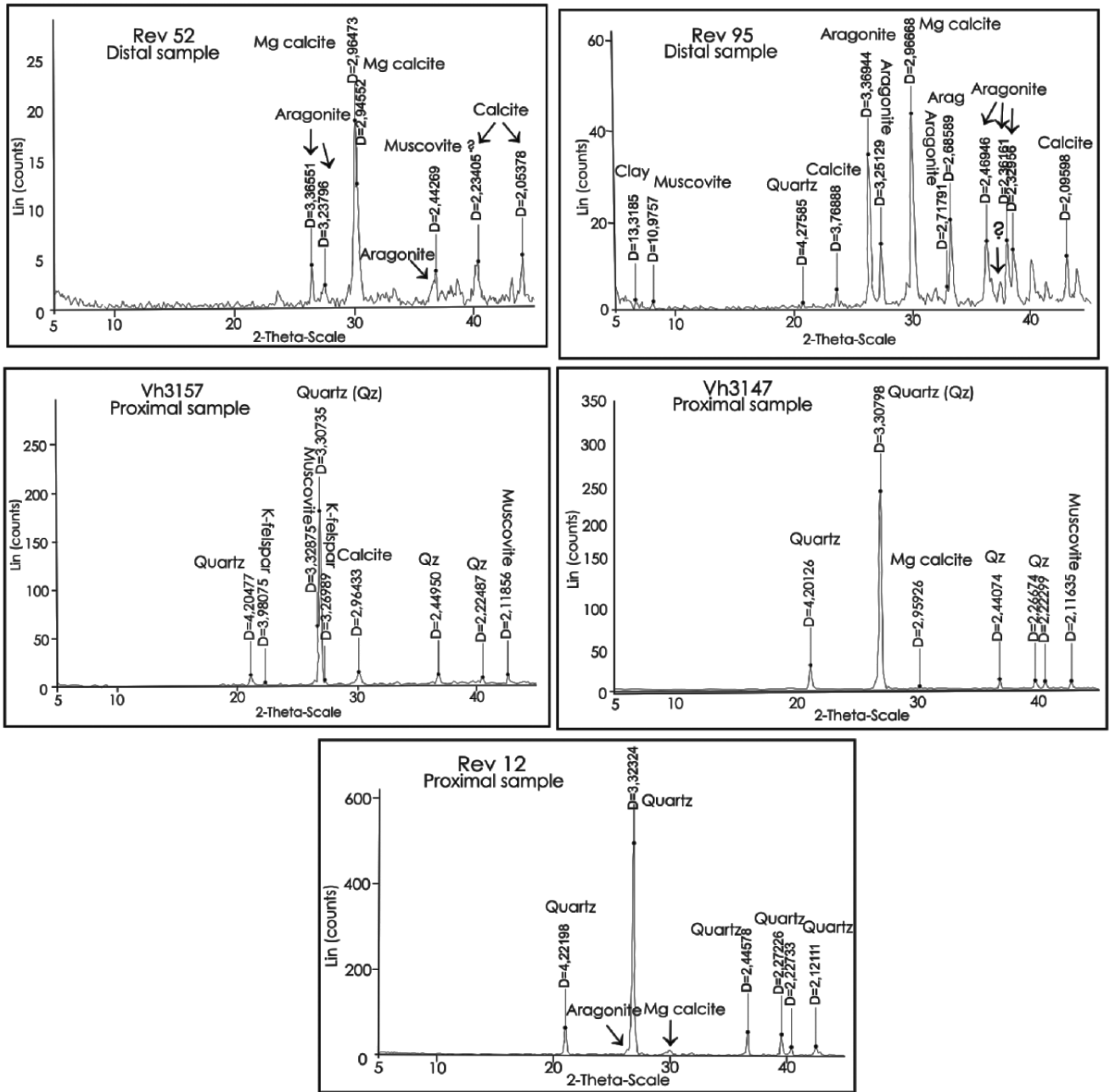


Figure 2 - Diffractograms of samples collected at different depths. (a) sample rev52, collected from 40 m depth; (b) sample rev95, from 30 m depth; (c) sample vh3157, from 10 m deep; (d) sample vh3147, from 20 m deep; (e) sample rev 12, from 25m deep.

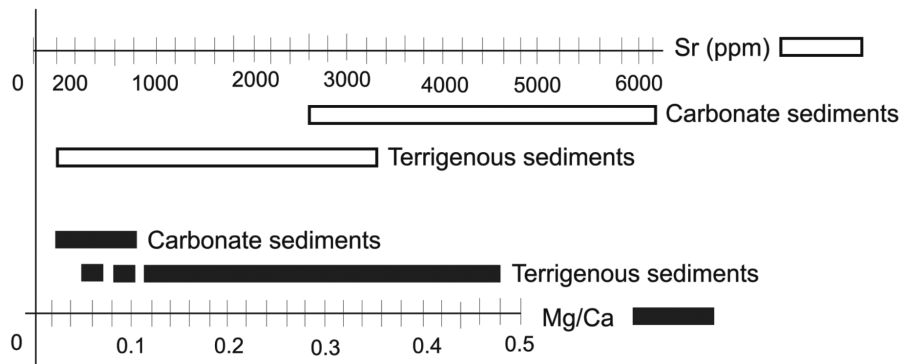


Figure 3 - Sr (ppm) and Mg/Ca ratios, respectively for terrigenous and carbonatic sediments, in the continental shelf in the oriental Northeastern Brazil.

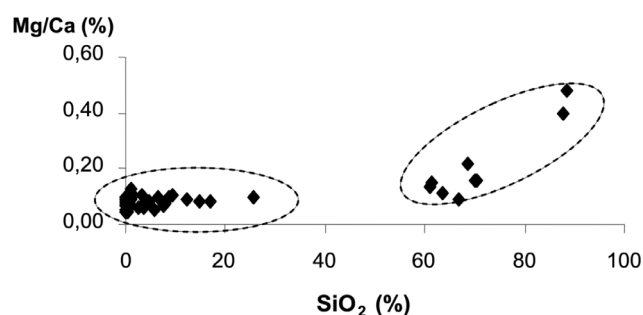


Figure 4 - Scattering diagram ( $\text{SiO}_2$  versus  $\text{Mg/Ca}$ ) for samples collected among 10 and 80m depth. The correlation  $\text{Mg/Ca}$  is high in samples with more quartz, independent of depth.

Mackenzie (1990) it is suggested to discard the temperature effect, since the expected difference between 10 and 55 meters of depth would be of the order of a few degrees centigrades, retaining the conception of "biota differences".

In the case of  $\text{Na}_2\text{O}$ , there is an undefined behavior with weak negative correlations with all of the terrigenous set, in concordance with the absence of sodic plagioclase. Its co-variance with  $\text{CaO}$  ( $r = 0.3$ ) and mainly that with  $\text{Sr}$  ( $r = 0.6$ ) suggest that, as already pointed out by Okamura and Kitano (1986) and Tucker and Wright (1990) that sodium can be tied to the crystallographic structure of carbonates.

**CONCLUSIONS** The analytical results revealed two types of bottom sediments:

(a) Terrigenous sediments: with predominance of quartz and residual quantities of potassic feldspars

and heavy minerals (probably: ilmenite, goethite and Mn oxides). In these sediments the terrigenous fraction is stoichiometrically, superior to 65% WS, and the carbonatic fraction (<35%) uses to be represented predominantly by high Mg-calcites being in general, observed  $\text{Mg/Ca}$  ratios  $\geq 0.12$  and  $\text{Sr} < 2,200$  ppm;

b) Carbonatic sediments: with predominance shared by high Mg-calcite and aragonite and even dominance of aragonite, accompanied of accessory quantities of terrigenous fraction (generally < 5%). In these sediments, it is usually observed  $\text{Mg/Ca}$  ratios  $< 0.12$  and  $\text{Sr} > 2,600$  ppm.

Even with low amounts of  $\text{Al}_2\text{O}_3$  (<3% in 95.5% of the cases; average of 0.8%) strong integrated correlations among  $\text{SiO}_2$  -  $\text{Al}_2\text{O}_3$  -  $\text{K}_2\text{O}$  - Rb have shown to be preserved confirming the quartz and potassic feldspar paragenesis in accordance with the felsic nature of the crystalline basement on which the costal drainage system has been established.

The quantity of Mg inserted in crystallographic structures of calcite in the studied shelf is statistically associated to a greater participation of the quartzous-terrigenous fraction in the bulk sediments of the substratum that govern the development of the benthonic biota kept in high Mg-calcite instead of the biota kept in aragonite. This tendency has proven to be independent on the depth of sampling from 10 to 55 m.

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