Anais da Academia Brasileira de Ciências
ISSN: 0001-3765
aabc@abc.org.br
Academia Brasileira de Ciências
Brasil

PEREIRA, NATAN S.; MANSO, VALDIR A.V.; MACEDO, RENÊ J.A.; DIAS, JOÃO M.A.; SILVA, ADRIANA M.C.
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Anais da Academia Brasileira de Ciências, vol. 85, núm. 1, marzo, 2013, pp. 57-72
Academia Brasileira de Ciências
Rio de Janeiro, Brasil

Anais da Academia Brasileira de Ciências (2013) 85(1): 57-72
(Annals of the Brazilian Academy of Sciences)
Printed version ISSN 0001-3765 / Online version ISSN 1678-2690
www.scielo.br/aabc

Detrital carbonate sedimentation of the Rocas Atoll, South Atlantic

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Manuscript received on July 19, 2011; accepted for publication on July 26, 2012

ABSTRACT

Located 266 km offshore Brazilian coast, Rocas Reef complex is the only atoll in the South Atlantic. Two scientific expeditions carried out detailed sedimentological studies of the complex. Sand texture was dominant in the sedimentary environment, although other textures such as gravel, sandy gravel and gravelly sand, were also observed. Mean size ranged from fine sand to coarse sand (-1.23 to 2.34ø), with an average value of 0.69ø (sand fraction), which from a geological perspective represents a high-energy environment. The values of mean size varied in the different geomorphologic compartments, a response to variable hydrodynamics on the reef. Sorting ranged from very well sorted to poorly sorted, with a mean value of 0.97ø (moderately sorted). The values of mean size and sorting are directly proportional (i.e. the larger the grain size, the better the sorting), a fact that might be controlled by the decreasing of organism diversity that contributes to the sedimentary environment as the mean size of the particles increase. Skewness parameter was used to correlate positive values to depositional environments. The Kurtosis parameter showed little relevance in this study. The sedimentary particles analyzed are exclusively composed of biogenic grains. In total eleven major groups were described, coralline algae being the most unusual.

Key words: biogenic particles, carbonate sediments, atoll reef, sedimentological parameters.

INTRODUCTION

The complex relationships between physical, chemical and biological processes make reef environments especially interesting (Tucker and Wright 1990). Such environments constitute some of the most studied in geobiology, linking biological activity and geological formations via the formation of carbonate, built by a huge diversity of reef organisms, such as corals, coralline algae and foraminifera.

The generation of sediments in reef environment is extremely complex, involving several processes that result from a physical, chemical and biological interaction, interfering directly with the deposition of biogenic and non-biogenic sediments.

The most important reef organisms that contribute to the generation of biogenic particles at shallow tropical reef systems are halimeda, corals, molluscs, foraminifera and coralline algae (Weber and Woodhead 1972). Sediments deposited in the interior of atoll reefs consist almost entirely of skeletal

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carbonate, and the development of sedimentary facies inside the atoll is mediated by the interplay between the sediment source supply, its physical properties and several processes that redistribute and settle the sediments (Maxwell et al. 1964 Milliman 1974).

Extensive sedimentological studies have been undertaken in recent deposits aiming to identify particular parameters that come to distinguish different types of sedimentary environment (Folk and Ward 1957, Mason and Folk 1958, Friedman 1961). Mean size, sorting, skewness and kurtosis are all common parameters in these studies. Thus, the present research aims to identify patterns in the distribution of the detrital carbonate sediments using these proxies as tools for specific assessing the generation and deposition at this very particular carbonate sedimentary environment.

STUDY AREA

The Rocas Atoll is located in the western part of the South Atlantic (3°51´S, 33°49´W), 266 km from the coastal city of Natal, Northeast Brazil (Fig. 01).

The climate is equatorial with direction and velocity of trade winds varying seasonally. During the summer 50% are from the southeasterly and 35% easterly. During winter the frequency of SE winds increases to 70%, whereas E winds decrease to 25%. The maximum wind speed is 11 m.s^{-1} (Hoflich 1984).

Rocas is located within the South Equatorial Current (SEC), which has a consistent westerly direction (JOP'S II 1996, Goes 2005). The mean speed in the 4° parallel (which cross the Rocas Atoll) is 30 cm.s^{-1} (Richardson and Walsh 1986).

The mean temperature of the sea water varies from 26°C in September to 28.3°C in April (Hoflich 1984, Servain at al. 1987), increasing to 42°C in the atoll's inner rock-pools (Soares et al. 2009). The sea surface salinity varies from 36 to 37‰ (Gherardi and Bosence 1999).

The tidal regime in Rocas is a semi-diurnal and mesotidal, with a maximum height of 3.8 m (Gherardi and Bosence 2001). Wave action is concentrated in the SE portion of the atoll although

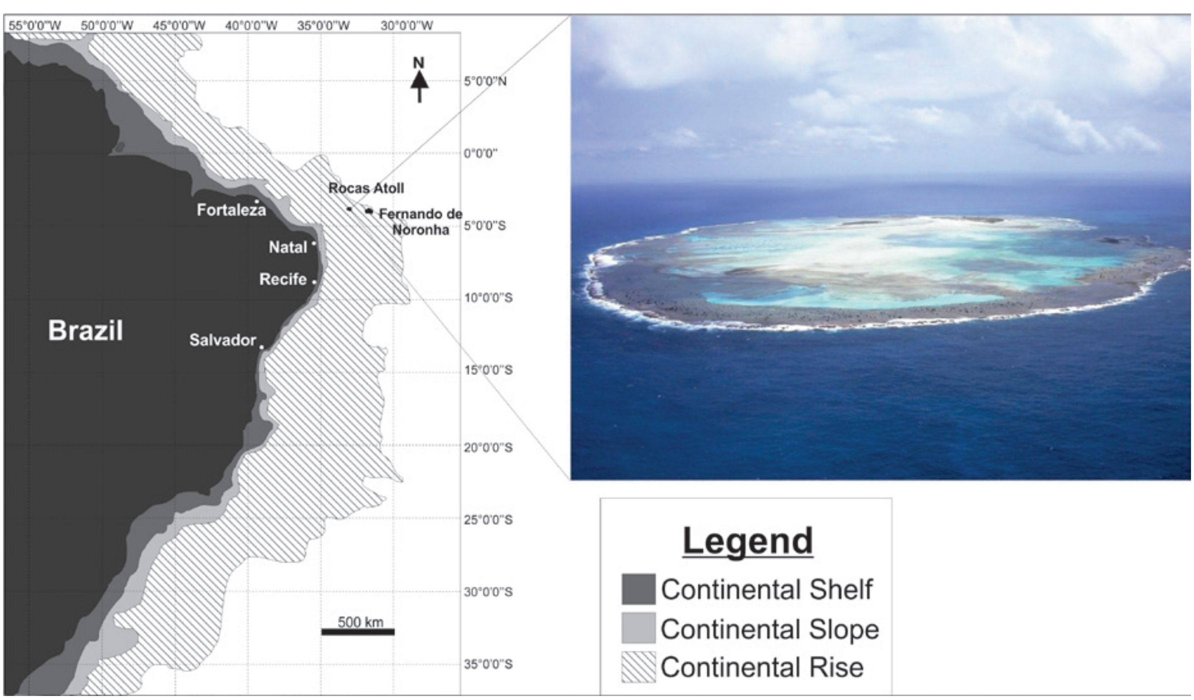

Figure 01 - Location of the Rocas Atoll. Photo: aerial picture from Rocas, viewed from southward. Source: ICMBio (2005).

the refraction of waves caused by the sea mountain that supports Rocas produce braking waves that also act in the W and SW portions (Gherardi and Bosence 2001). The mean waves heights measured in Fernando de Noronha, the closest island from the Rocas Atoll vary from 1.1 m in February and 1.6 m in June (Hoflich 1984).

Geology of the Area

The reef grows in the W portion of a submarine volcanic mountain with a flattened top (Fig. 02), (a *Guyot*) rising up from depths of 4,000 m (Ottman 1963, Kikuchi and Leão 1997). This Guyot constitutes part of the submarine mountain chain located on the Fernando de Noronha Fracture Zone.

Samples from this *Guyot* have never been obtained and its composition is still unknown. However, it is possible to correlate the volcanic basement of Rocas to other sea mountains, such as samples obtained from Fernando de Noronha, which belongs to the same fracture zone.

The archipelago of Fernando de Noronha is the only part of the chain where the mineralogical composition is known. Almeida (1955) carried out a thorough geological study in Fernando de Noronha and reported three formations on the island: Remédios Formation (pyroclastic rocks, crossed by several dykes and other types of intrusive bodies); Quixaba Formation (eroded rocks from Remédios Formation, which were posteriorly buried by ankaratritc lava flow); and São José Formation (nepheline basanite spills).

Radiometric ages from the volcanic rocks in Fernando de Noronha vary from 1.7 to 12.3 Myr (Almeida 1955). It is expected that the volcanic basement upon which Rocas is located is similar in nature to those at Fernando de Noronha. That said, they would probably be older, due to the larger distance from the Atlantic's mid-oceanic ridge.

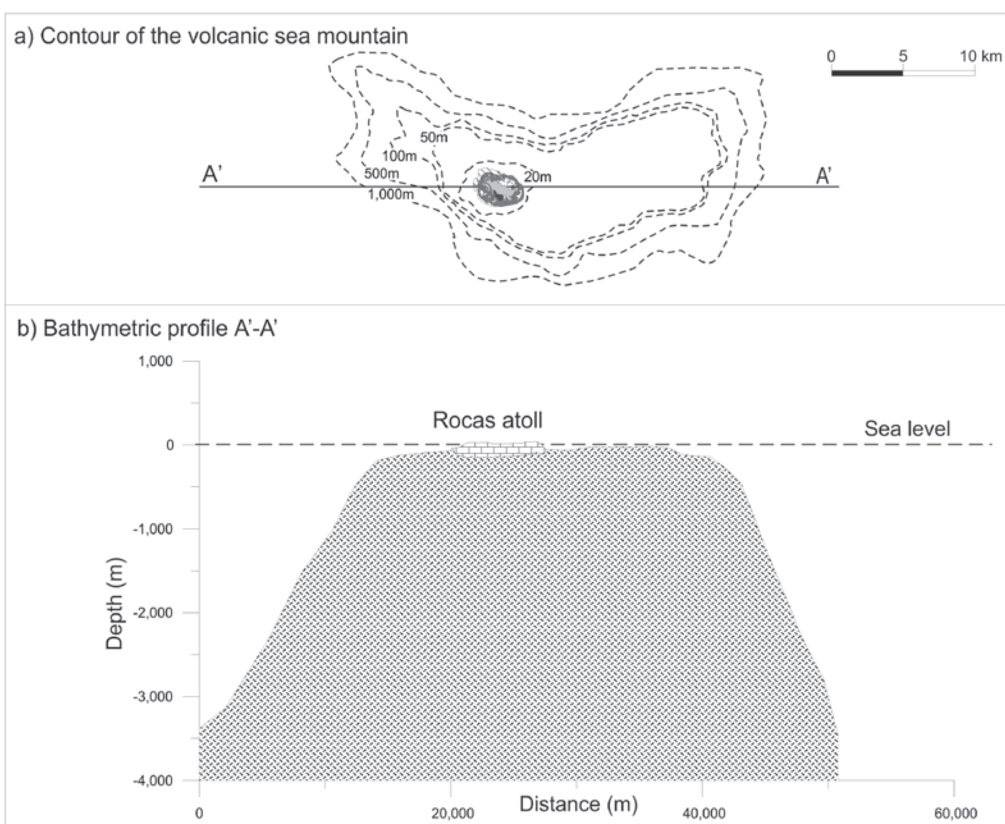

Figure 02 - Schematic illustration of the contour (a) and bathymetric profiles (b) of the Guyot that supports Rocas Atoll.

EVOLUTION OF THE ATOLL

Over time coralline algae, coral reefs, molluscs, and crustaceans colonized the guyot. The accretion of carbonate to form skeletal material provided the basis for the ring ellipsoid reef (Soares-Gomes et al. 2001, Gherardi and Bosence 2001). The reef almost attained sea-level, forming an atoll with a shallow lagoon and two islands; Farol Island and Cemitério Island (Gherardi and Bosence 2005).

Using a seismic survey and core drilling Kikuchi and Leão (1997) identified three strata at the Rocas site. The first was 12 m thick Holocene layer with seismic velocity of 0.33 m x $m.s^{-1}$. The composition of this layer is mainly composed of by encrusting coralline algae, vermetid gastropods, encrusting foraminifera (*Homotrema rubrum*), and corals. The second and third beds had seismic wave velocities of 2.50 m x $m.s^{-1}$, 4.70 m x $m.s^{-1}$ respectively, the latter corresponding to velocities typical of basaltic rocks.

The oldest radiometric ages derived from coral skeletons was 4.86 Kyr. Nevertheless, this age may not correspond to the beginning of the reef development. Thus, it is assumed that the initiation of reef growth began before 4.86 Ka, with an accretion ratio ranging from 1.5 to 3.2 m/Kyr (Kikuchi 1999).

STRUCTURE OF THE REEF

Gherardi and Bosence (2001) described the reef structure of Rocas. According to the authors, the atoll is composed by the following groups of encrusting organisms: Coralline algae, vermetid gastropods, *Homotrema rubrum* (encrusting foraminifera), acervulinids (encrusting foraminifera), polychaetes worm tubes, corals, molluscs, sponges, cemented sediments and growth cavities.

The coralline algae constitute the primary framework builders with Porolithon *cf. pachydermum* being the most significant coralline algae genus. Secondary framework builders consisted of the following five classes: vermetid gastropods, *H. Rubrum*, Acervulinids, Polychaete worm tubes and unidentified corals (Gherardi and Bosence 2001).

REEF GEOMORPHOLOGY

Geomorphological features of Rocas Atoll were previously studied by Andrade (1959), Ottman (1963) and Kikuchi and Leão (1997). The classification of the reef as an atoll has been widely debated (Vallaux 1940, Andrade 1959, Ottman 1963, Kikuchi 1994, Kikuchi and Leão 1997, Gherardi and Bosence 1999, Soares et al. 2009). Several disagreements arose from this debate. For example, Davis (1928) described Rocas as an emerged bank atoll, whereas Vallaux (1940) depicted the reef as an almost-atoll. Nevertheless, others (Kikuchi and Leão 1997, Gherardi and Bosence 2005) have reported Rocas as the only atoll in the southwestern Atlantic.

Soares et al. (2009) discussed several issues that complicate the classification of Rocas, the main issue being a dispute between genesis and morphological criteria. However, the authors argue that morphological features are sufficient to assure Rocas is a truly atoll.

Pereira et al. (2010) presented a geomorphological map of Rocas (Fig. 04) and described the atoll as one of the smallest of the world, with an axis of 3.35 km by 2.49 km, a reef area of 6.56 km^2, and a perimeter of 11 km. Compared to other atolls such as the Kwajalein Atoll (120 x 32 km), Marshall Islands, and Rangiroa Atoll (72 x 36 km), French Polynesia (Guilcher, 1988), Rocas has the smallest dimensions (Fig. 03)

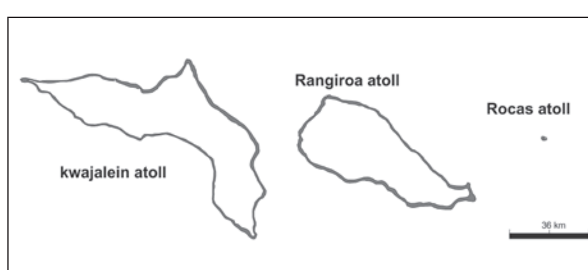

Figure 03 - Comparison between the dimensions of Kwajalein, Rangiroa and Rocas Atolls.

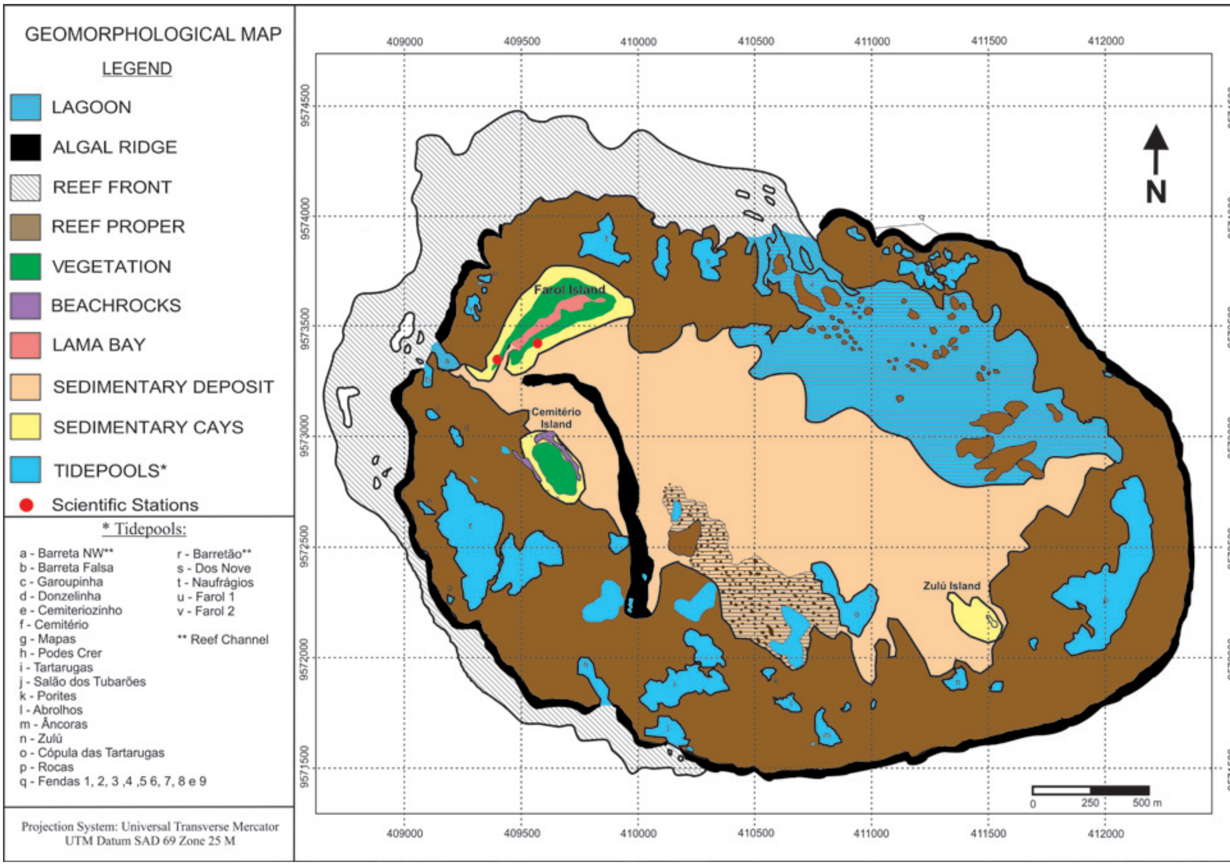

Figure 04 - Geomorphological map of Rocas Atoll. Modified from Pereira et al. (2010).

In their work, Pereira et al. (2010) described the following features: reef front, *algal ridge*, *reef proper*, *sedimentary deposit*, *tidepools*, *lagoon*, and *sedimentary cays*. The presence of *beachrocks* in the Cemitério Island were also reported (Fig. 05).

METHODOLOGY

41 sediment samples (Fig. 05) were obtained during reef top exposure at low tide. Samples came from the features including *sedimentary deposits*, *sedimentary cays* and *tidepools* at the reef complex in January and July of 2009. Cumulative frequency curves were constructed from the sieving data, and mean size, sorting, skewness and kurtosis values computed. The values of the sedimentological parameters were calculated by the software Sysgran 3.0 (Camargo 2006), and plotted on facies maps.

In order to deduce organism biodiversity, analysis of the biogenic components was undertaken in each sedimentary environment. Organisms were observed using a binocular microscope.

RESULTS AND DISCUSSION

The sedimentary environmental of the Rocas Atoll is composed entirely of carbonate skeleton derived from the reef structure, which goes through continuous degradation by physical process, such as wave action, and by the production from living carbonate secreting organisms.

Carbonate sedimentary environment composed exclusively by skeleton are greatly influenced by the local biodiversity. Differences on the biota are reflected directly on the sedimentary textures and parameters.

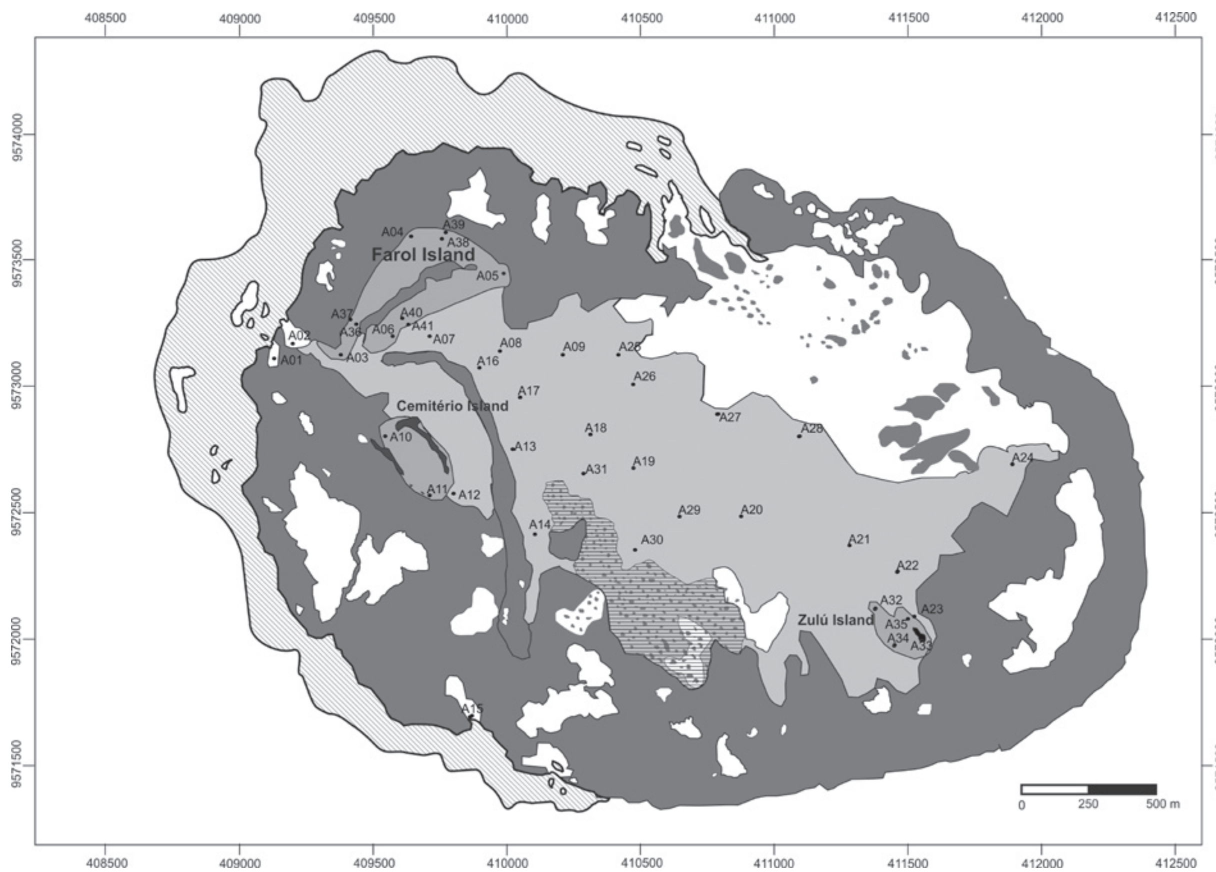

Figure 05 - Sampling distribution on the different features of Rocas Atoll.

Textural Classes

Using the Shepard diagram (1954) four textural classes (Fig. 06) were identified in Rocas' carbonate sediments: Sand (78%), Gravelly sand (15%), Sandy gravel (2%), and Gravel (5%).

Although the classification of Shepard is merely descriptive, it is be possible to deduce, using textural maps, information on the local hydrodynamics, mirroring the energetic level according to the distribution of fine and coarse particles (Dias 2004). In this way the environmental energy level reflects the sediment mobilization capability of the environment. Coarse particles are thereby associated to high-energy environments, that decrease proportionally with decreasing mean size (Folk and Ward 1957).

Sandy deposits dominate the Rocas textural map. Others textures were distributed on the areas surrounding cays (Fig. 07).

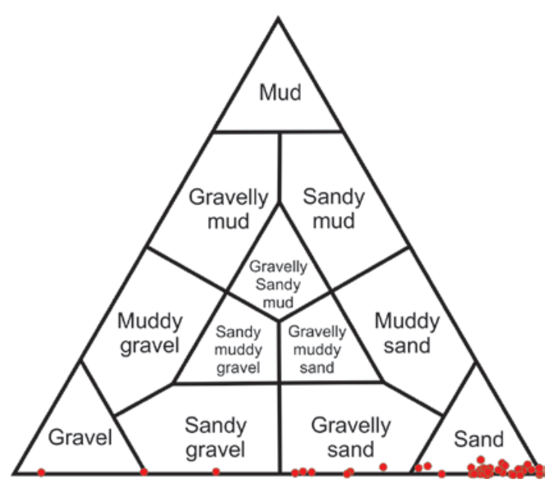

Figure 06 - Distribution of the samples in a Shepard diagram.

The lack of fine particles is probably related to low production of fine fraction and/or hydrodynamics process. The latter may be depositing the fine sediment on the outer atoll, which could be

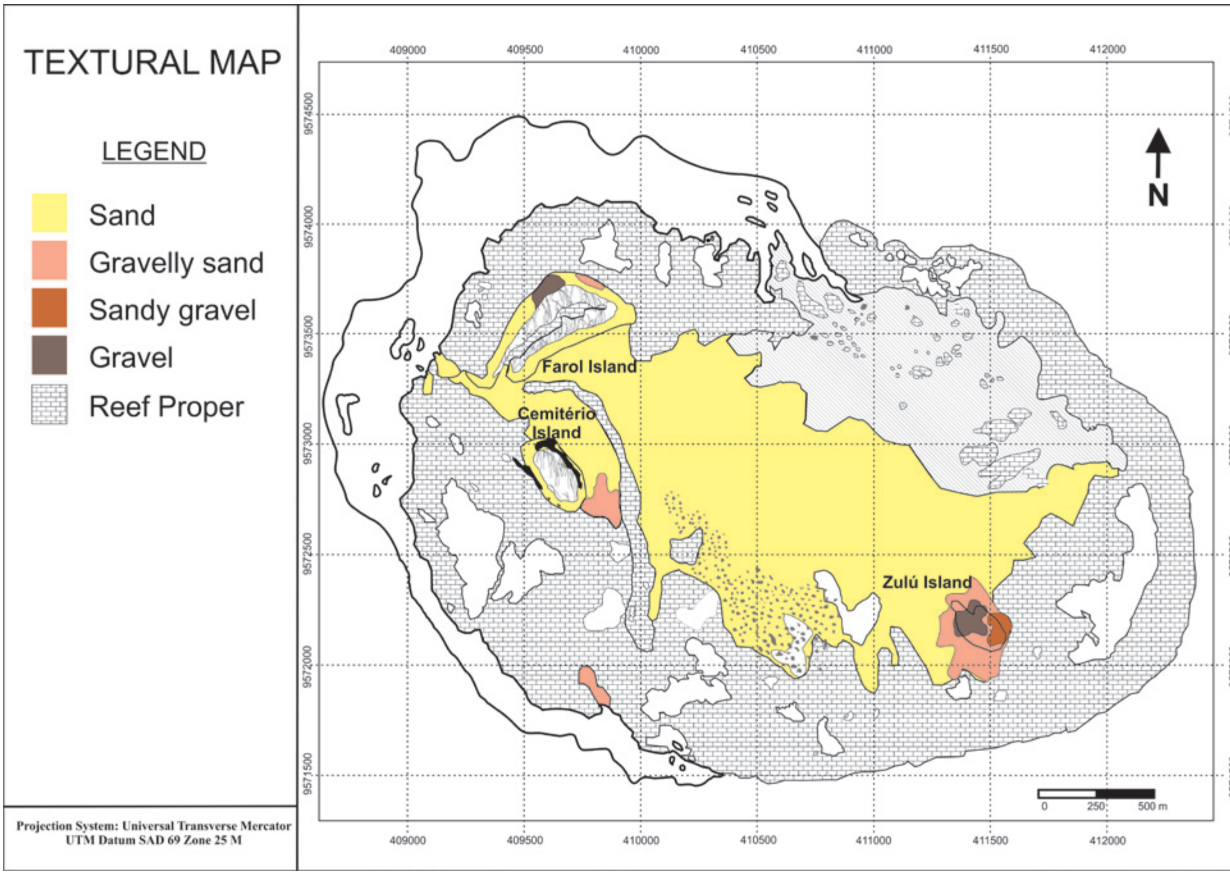

Figure 07 - Textural map of the Rocas Atoll.

investigated by direct sampling in this area. Weber and Woodhead (1972) pointed out that inner reef environments are much richer in carbonate sands than carbonate muds. Mud rarely yielded percentage above 2% at Capricorn reef complex, Australia (Maiklem 1970), which correspond to the results published by Maxwell et al. (1961) in the Great Barrier of Australia. The mud present in that system had a terrigenous origin. The explanation frequently pointed out by researchers to explain the lack of fine inner-reef material is its hydrodynamic removal through suspension (Thorp 1936), or its deposition in a deeper area of the reef, like a lagoon, as was found at Kure and Midway Atoll (Gross et al. 1969).

In Rocas, the *sedimentary deposits* are constantly influence by the tide, and this seems to be the most determinant factor on the distribution of the textural classes of this feature, where the hydrodynamism of the tidal currents shifted sediments during high tide, removing finer sediment from the inner part of the atoll.

Mean Size

The mean size reflects one of the most important parameters in sedimentological studies. In a geological view, the mean size represents the mean kinetic energy of the transport agent, although it is also dependent on the size distribution of the available source (Sahu 1964).

Mean size *phi* values ranged from -1.23 to 2.34ø, straddling five classifications: fine sand, medium sand, coarse sand, very coarse sand and granule. Constituting 37% of samples, coarse sand was the most dominant, followed by medium sand and very coarse sand, yielding 32% and 22%, respectively. Fine sand and granule represented only 7% and 2%, respectively.

It is possible to analyse the sedimentary environment of Rocas in two ways. As a whole, including samples from *sedimentary deposits*, *sedimentary cays* and *tidepools*. Alternatively, each of these features can be assessed separately. Verifying all samples together, the mean grain size value is 0.69ø (coarse sand), suggesting that geological agents are acting favourably to deposit coarser particles. In other words, the local hydrodynamic situation can be considered high. The few samples that presented finer particles are associated with specific features of the reef that might diminish the hydrodynamic action, such as the fine sand next to the *algal ridge* and in the Eastern part of the *sedimentary deposit*, which seems to be protected by the *reef proper* (Fig. 08).

Analyzed separately, the *sedimentary cays* showed a predominance of coarse sand. The Farol Island samples ranged from -0.96 to 1.37ø, with an average of 0.44ø (coarse sand), as did the Cemitério Island (average, 0.70ø). The Zulú Island exhibited a diameter size varying from coarse sand to gravel (average, 0.31ø).

The *sedimentary deposit* presented extreme values ranging form 2.34 and -0.29ø (average 1.16ø, medium sand). The *tidepools* ranged from coarse sand to very coarse sand with a mean value of 0.008ø (coarse sand).

The wide range of the *phi* values in the Rocas sediments may be explained by the influence of the different geomorphological features on the distribution of the particles size. This can be observed on the beach face of the cays, where combined wave action and tidal currents remove fine sediments and the deposition of finer particles are found next to the *algal rigde*, caused by the low hydrodynamics in this area. Even so, coarse sand samples in the middle part of the *sedimentary deposit* might reflect the tidal current during high tide.

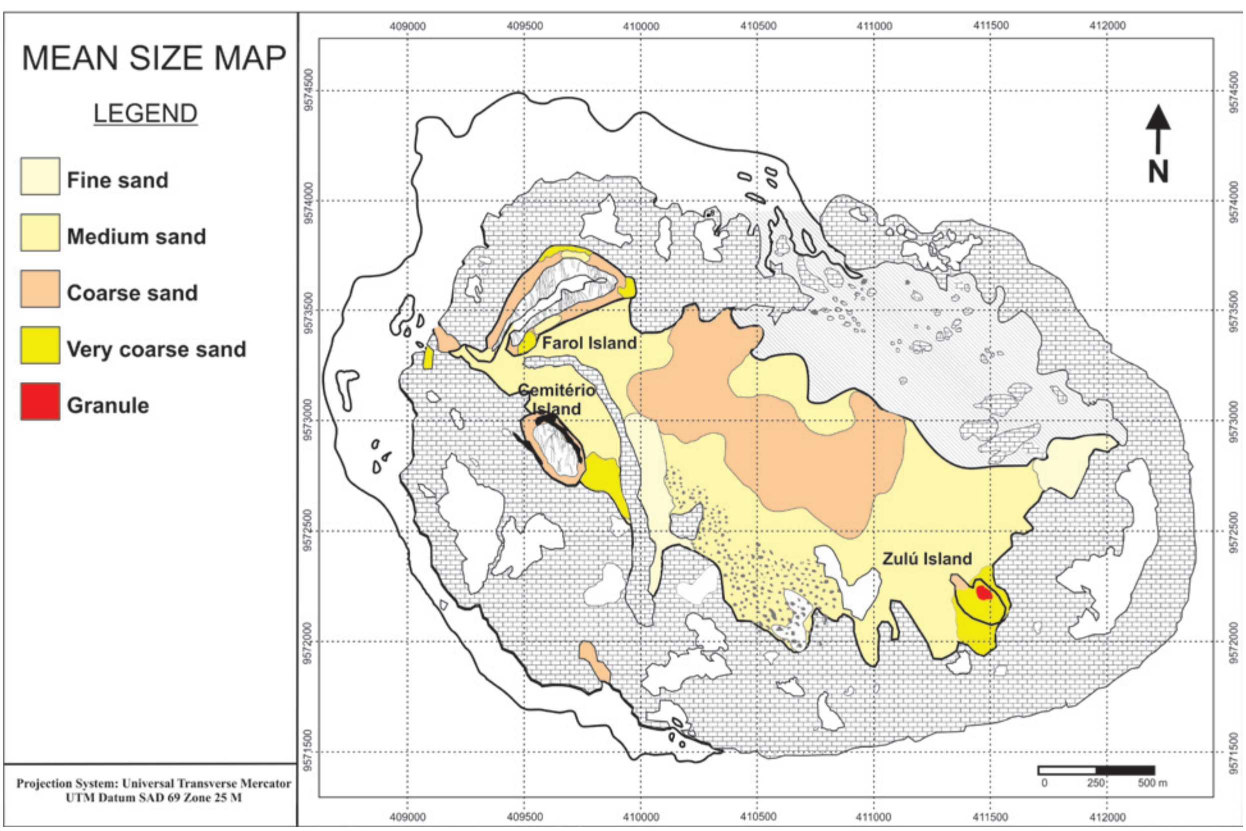

Figure 08 - Mean grain size map of Rocas Atoll.

SORTING

Sedimentological parameters such as mean size and sorting are not normally used in carbonate sediments. However, Gerhard and Cross (2005) assert that these statistical measurements have shown reliability in describing carbonate sedimentary environments, which are subject to mechanical transportation through extensive bioturbation, waves, and currents.

At Rocas, sorting (σI) ranged from 0.23 to 1.72ø; 48% of samples were clustered in the interval of 1.0 - 2.0ø, classifying them as poorly sorted; 41% were grouped fairly tightly between 0.5 - 1.0ø, equivalent to being moderately sorted. The average sorting was 0.97ø (moderately sorted).

The sorting map (Fig. 09) shows clearly the predominance of poorly sorted sediments. Sorting increases on the central and eastern part of the *sedimentary deposit*, on Farol and Cemitério islands, and on the leeward *tidepool*.

Two conditions might be influencing sorting values: first, wave and tidal current action, working mainly on the beach face and areas subject to these processes (for example the central part of Rocas, which may be providing a better sorting); second, the effect of the biogenic source has a direct influence on the sedimentological measurements, where dominance of a single source can lead to improved sorting and thus, a noticeable enrichment biogenic carbonate sediments (Folk et al. 1962, Folk and Robles 1964, Stoddart 1964, Gerhard and Cross 2005).

Pereira et al. (2008) described ten major groups of organisms that contribute to the sedimentation of the reef complex. Although coralline red algae dominates the reef structure (Gherard and Bosence 2001, Kikuchi and Leão 1997), this fact is clearly insufficient to create sediment homogenity given that most sediments are poorly sorted, and better sorting samples seems to occur due to wave and current action. Poorly sorted

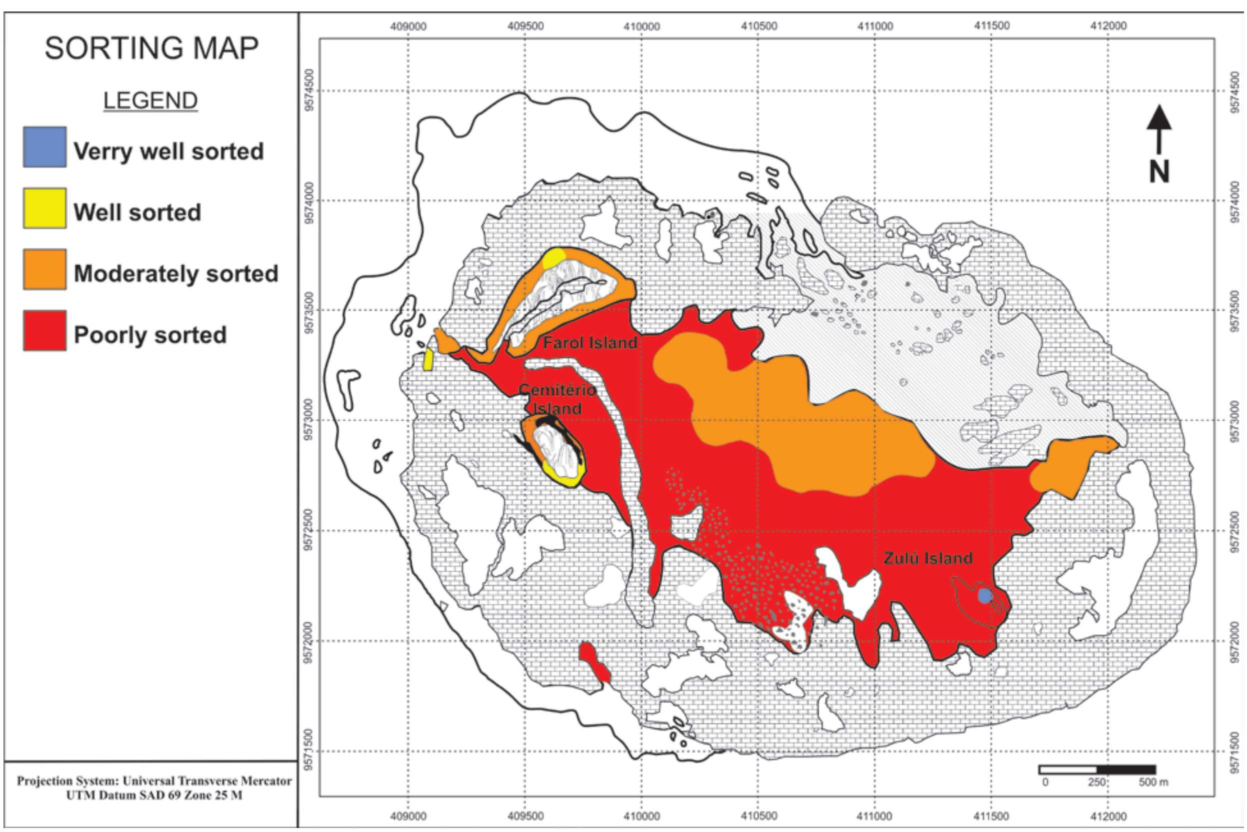

Figure 09 - Sorting map of Rocas Atoll.

carbonate sediments are frequently reported and their cause is usually attributed to the high biodiversity of organisms that release their carbonate skeletons into the system (Folk et al. 1962, Folk and Robles 1964, Stoddart 1964).

Mean Size x Sorting

The geological significance of sedimentological measurements can be easily perceived by plotting mean size versus sorting (Folk and Cotera 1971). In Rocas, we noted that coarse sand tends to be better sorted (mean size = -1.2ø, sorting σ_I = 0.2). Stoddart (1964) at Half Moon Cay, Belize, described the same correlation. However, Folk and Cotera (1971), studying carbonate sediments in Alacran Reef at Yucatán, Mexico, showed the opposite trend, with better sorting attributed to finer sediment.

In Rocas, there is a slightly tendency for better sorting with increasing grain size (Fig. 10). Stoddart (1964) explain that this trend is partly due to the narrowing in range of organisms that contribute to the sedimentary environment as size increases.

Sedimentary deposit can easily be distinguished from the other facies types in figure 10. The former is characterized by smaller diameters and poorer sorting. This may be explained by the major influence of organism source on the deposit, whereas, the others present coarser sediments and better sorting, which could be ascribed to wave and tidal action, during high tide.

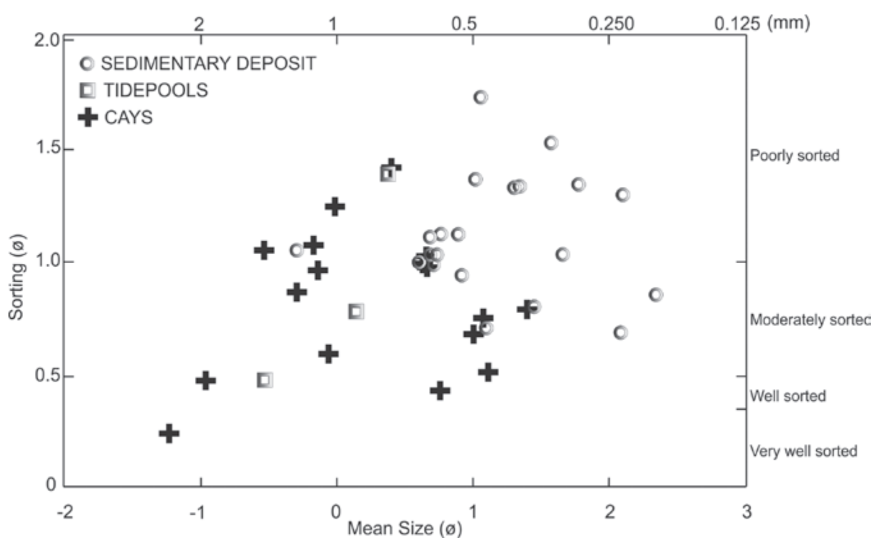

Figure 10 - Plotting of mean grain size and sorting values of samples from *sedimentary deposit*, *tidepools* and *cays* of Rocas Atoll.

Studies on carbonate sediments in the Caribbean (Folk and Robles 1964 in Alacran and Isla Mujeres; Stoddart 1964 at Half Moon Cay, Belize) concluded that mean size and sorting are more dependent on the type of biogenic source than the wave energy. The latter effectively controls the mean size and the former has major influence on the sorting.

Skewness

Several investigations have applied skewness sedimentological measurements, although the geological meaning of this parameter is almost never mentioned (Martins 1965). This parameter is controlled more by depositional processes than transport pattern (Suguio 1973).

In Rocas, the samples yielded skewness values ranging from -0.581 to 0.764, (strongly negatively to strongly positively skewed) in the atoll; 46% of samples fell into the range of negative skewness, whereas, positive skewness was represented by

34% of the samples. Symmetrically skewed samples made up 20% of the whole.

Negative values of skewness dominate the *sedimentary deposit*, with some restricted samples of positive and nearly symmetrical skewness (Fig. 11). Folk and Robles (1964) showed that carbonate sediments of the Isla Perez in Alacran Reef Complex are predominantly negatively skewed, hinting that this was probably caused by the addition of coarse sand, provided by corals and coralline algae.

Positive skewness prevail on the cays (Farol and Zulú Islands). Duane (1964) explained that positively skewed signatures could be related to the influx of particles. Pereira et al. (2010) noticed an increase in the volume of sediments on the Farol and Zulú Islands. Thus, we conclude that the positively skewed signature probably indicates a tendency towards the deposition of biogenic carbonate in the reef system.

The dominance of negatively skewed values on the *sedimentary deposit* can be explained in two ways: one, intense action of depositional agents, sparked by the tidal regime, could be removing finer particles; or two, by the addition of coarse sand, mainly by the fragmentation of coralline algae, corals and molluscs created in the reef complex.

In Rocas, medium and finer sand show tendency to be negatively skewed and vice versa (Fig. 12). Folk and Ward (1957) found a similar pattern in Brazos River, Texas.

This observation leads to another correlation; the comparison between the texture of the sediments of some areas of the atoll to the skewness. Areas with gravel, sandy gravel and gravelly sand textures are overwhelmingly positively skewed. Cronan (1972) found similar trends in Irish Sea sediments, where gravelly sand

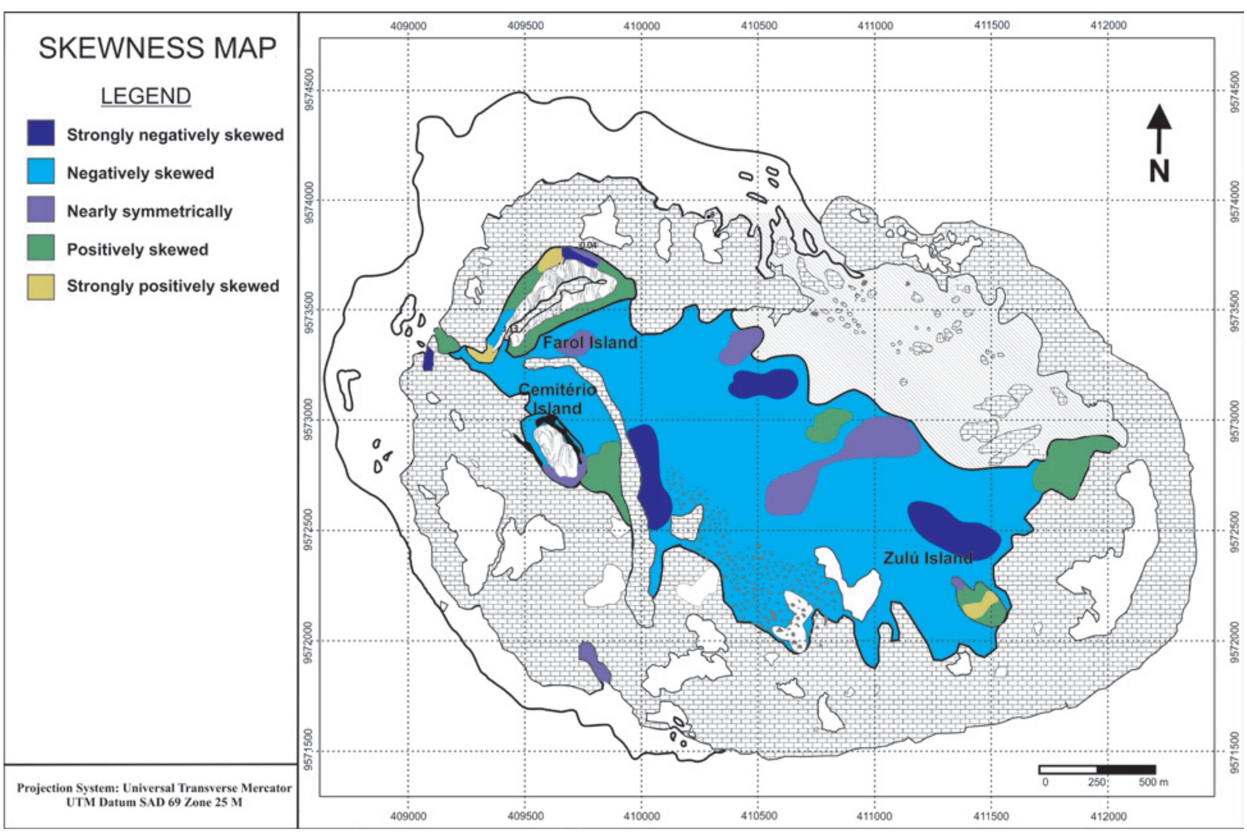

Figure 11 - Skewness map of Rocas Atoll.

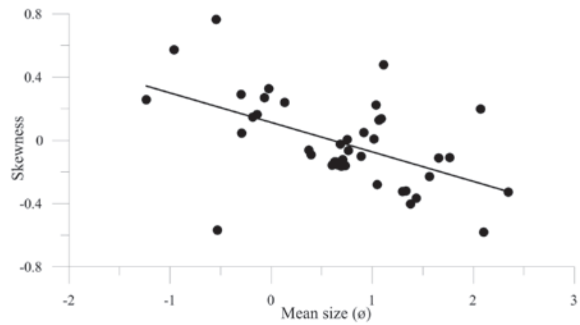

Figure 12 - Plotting of the mean size and skewness.

texture was strongly linked to positive values of skewness due to depositional process.

Skewness signatures are sensitive to environmental parameters crucial in distinguishing sedimentary environments such as beaches, dunes, estuaries and tidal deltas (Mason and Folk 1958, Friedman 1961, Duane 1964). At Rocas Atoll, skewness values effectively separated out depositional environments, as was seen in the case of the cays (Farol and Zulú Islands), which exhibited positively skewed values relative to the *sedimentary deposit*, that presented negatively skewed values.

Kurtosis

Kurtosis parameters show values consistent with leptokurtic and extremely leptokurtic (43.89%), platykurtic and extremely platykurtic (41.45%) and mesokurtic (14.63%). Indeed, kurtosis signatures are complex showing only ambiguous patterns on the sedimentary body of Rocas (Fig. 13). This is with the exception of the dominance of leptokurtic sediments on the Farol and Cemitério islands, which signifies the dominance of one population in determining the total fraction, leading to better sorting, which can be seen on the islands.

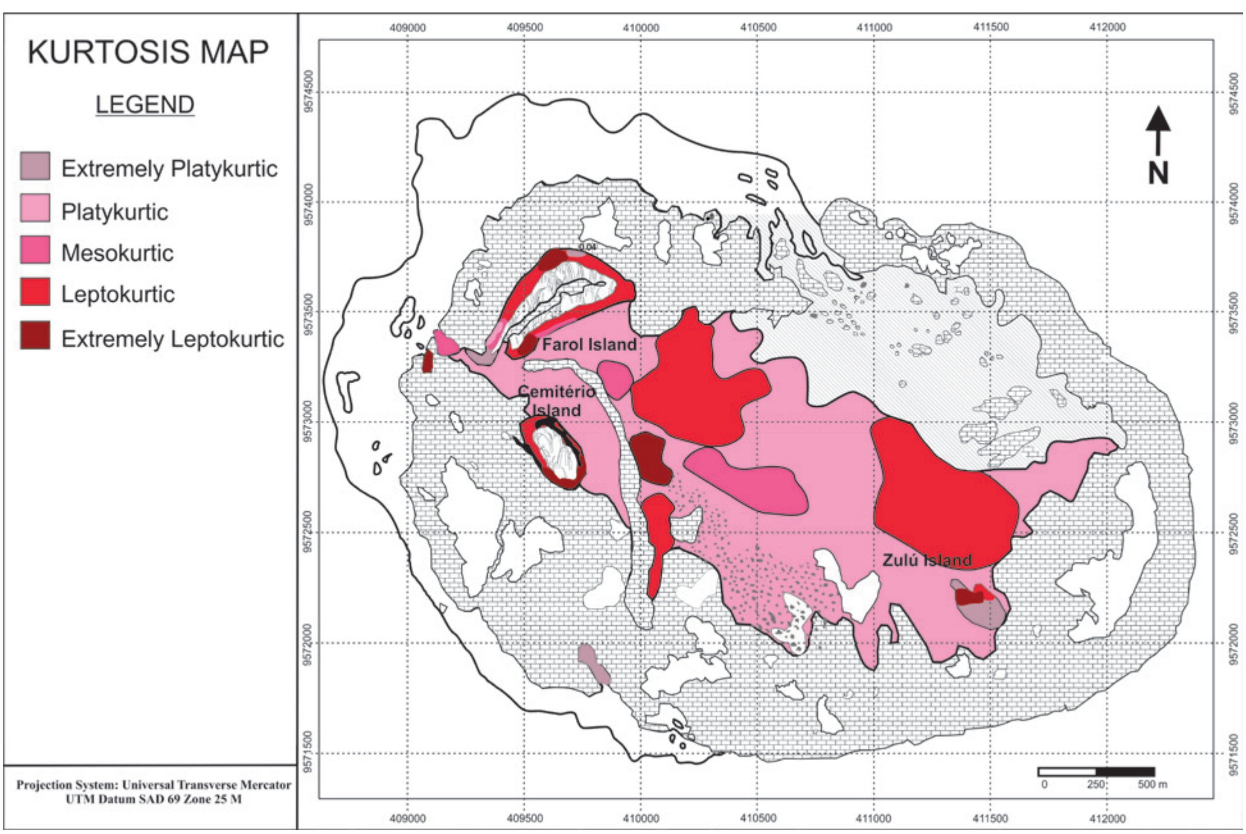

Figure 13 - Skewness map of Rocas Atoll.

Sediments from the beach face of these islands are under breaking wave action during high tide. This phenomenon will likely select a certain type of particle size, leading to predominance of one size population. For reasons not immediately obvious this process favours the prevalence of leptokurtic curves.

Folk and Robles (1964) pointed out a dominance of leptokurtic values in the carbonate sediments of Isla Perez, Alacran Reef complex, ascribing the main cause as the prevalence of coarse sand. With the exception of Farol and Cemitério islands, the kurtosis signature seems not to carry any significant implications on the carbonate sediments at Rocas.

BIOGENIC PARTICLES

Biogenic particles of Rocas were previously studied by Soares et al. (2009) who shed light on the origin and distribution of the carbonate particles in the atoll's reef complex. Thus, although biogenic composition is of great importance, it is treated briefly here.

A total of 11 major groups are described: coralline algae, foraminifera, bryozoans, sponges, corals, bivalve, gastropod, ostracodes, crustaceans, echinoderms and vertebrates (Fig. 14 and 15).

Coralline algae are a major contributor to the sedimentary body. This was expected due to

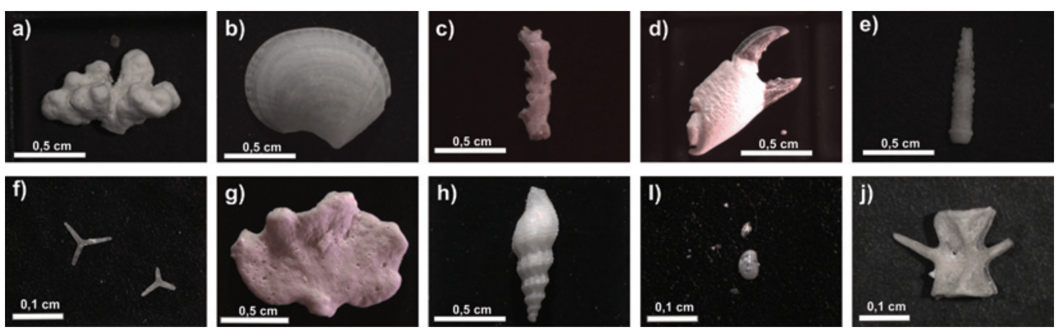

Figure 14 - Diversity of biogenic carbonate particles of Rocas Atoll. **a)** Coralline algae; **b)** Bivalve; **c)** Bryozoans; **d)** Crustacean; **e)** Echinoderm; **f)** Sponge spicules; **g)** Halimeda; **h)** Gastropod; **i)** Ostracode; and **j)** Vertebrate bones.

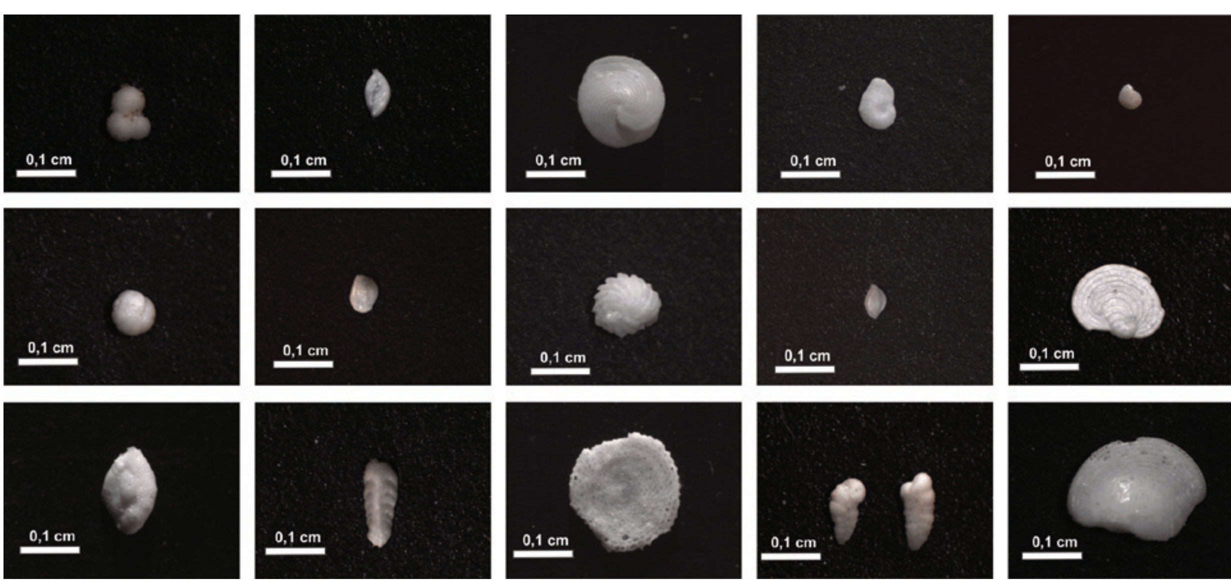

Figure 15 - Diversity of the foraminifera observed in the sediment samples collected inside the atoll.

the reef structure of Rocas, which is primarily composed by these organisms (Kikuchi and Leão 1997, Gherardi and Bosence 2001). Foraminifera (Fig. 15), bivalve and gastropods, which comprise the secondary framework builders (Gherardi and Bosence 2001), were also noteworthy components in the sediments samples.

CONCLUSIONS

Sedimentological signatures have long been applied to diagnose particular environmental conditions in a variety of environments. Such parameters have shown specific values inherent to the sedimentary setting, distinguishing, for example, dune, beach and river systems. The sedimentary body of the Rocas Atoll is characterized by a low percentage of fine particles, which we conclude is due to the high local hydrodynamism and/or the insufficient production of mud (finer material). Mean size varies according to the different geomorphological features of the reef environment, where distributions of coarser sand are primarily located on *cays* and *tidepools*, and medium sand on the *sedimentary deposit*, clearly showing differential hydrodynamic action on the geological agents at Rocas. The environment is characterized by poorly sorted sediments, probably due to the wide variety of biogenic sediment components, typical of a reef system. The few cases where sediment is well-sorted (Farol and Cemitério islands) can be attributed to breaking wave and tidal action. Regarding plotting mean size and sorting values, we notice that sorting is positively correlated with mean grain size. This seems to occur due to decreasing organism diversity as size increases. Positive skewness signatures on the Farol and Zulú islands were strongly associated with the deposition of material, a conclusion corroborated by the growth of these two cays over the past few years. The kurtosis parameter did not yield any significant pattern on Rocas, except for leptokurtic particles on Farol and Cemitério islands, assumed to correspond with breaking wave action on the beach face of these islands. The biogenic composition of the carbonate sediments comprises eleven major groups, coralline algae being the most important. In conclusion, sedimentological signatures (mean size, sorting, skewness and kurtosis) were, to differing degrees, useful in diagnosing the sedimentological features of this biogenic carbonate sedimentary environment. The research presented in this article extends beyond the Rocas Atoll, contributing to a wider understanding of the sedimentary processes and characterizations of reef systems.

ACKNOWLEDGMENTS

We thank the staff from the Instituto Chico Mendes de Conservação e Biodiversidade for the logistical support provided in the scientific expeditions, specially to Maurizélia de Brito Silva, for helping in the fieldwork.

RESUMO

Localizada 266 km da costa brasileira, o complexo recifal de Rocas representa o único atol do Atlântico Sul. Duas expedições científicas foram realizadas para um detalhado estudo sedimentológico do ambiente. No ambiente sedimentar predominou a textura areia, embora outras texturas, como cascalho, cascalho arenoso, areia cascalhosa também foram observadas. O tamanho médio do grão variou de areia fina a areia grossa para (2.34 - 1,23 ø), com um valor médio de 0.69ø (fração areia), que em uma perspectiva geológica representa um ambiente de alta energia. Os valores de tamanho médio variou nos diferentes compartimentos geomorfológicos, uma resposta à hidrodinâmica variáveis sobre o recife.O grau de selecionamento variou de muito bem selecionado a pobremente selecionado, com um valor médio de 0.97ø (moderadamente selecionado). Os valores de diâmetro médio e de selecionamento são diretamente proporcionais (ou seja, quanto maior o tamanho do grão, melhor será a separação), um fato que pode ser controlada pela diminuição da diversidade de organismo que contribuem para o ambiente de sedimentação com o aumento do tamanho médio das partículas. Parâmetro de assimetria

foi utilizado para correlacionar valores positivos para ambientes deposicionais. O parâmetro Curtose mostrou pouca relevância neste estudo. As partículas sedimentares analisadas são exclusivamente compostas de grãos biogênicos. No total, 11 grupos principais foram descritos, sendo as algas coralinas o mais incomum.

Palavras-chave: partículas biogênicas, sedimentos carbonáticos, atóis, parâmetros sedimentológicos.

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