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Indicatives of ancient conditions of sea level stability on the southern Pernambuco continental shelf

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Abstract - The continental shelf in southern Pernambuco State (Brazilian Northeast) is characteristically narrow, and breaks around 32 km from the actual coastline, in depths of 50 to 60 m. The sediments on this shelf are similar in their constitution to the rest of the Brazilian Northeastern shelf, showing a prevailing fraction of coarse carbonatic sands. There is also a significant input of terrigenous material, which may be found mainly up to 20 m deep. Regarding its geomorphology, Pernambuco's southern shelf presents a soft slope, with long and smooth surfaces, sometimes crossed by meandering channels which show more frequently next to river mouths. Indicatives of sea level change like the presence of beach rocks and paleochannels occur along the shelf. The main interest of the present work lies on the location and characterization of the submerged beachrocks on the southern portion of Pernambuco State continental shelf. The area was investigated using sonographic techniques. Data analysis allowed to identify indicatives of ancient conditions of sea level stability on the shelf. The first evidence was found at a depth of 20 m, where a beachrock of a triangular shape and rounded top with 136 m wide and 6 m height, was identified. The second evidence was registered at 40 to 50 m depth, also represented by a beachrock. Geomorphologically this second feature presents a relatively flat top, 209 m of width and 4 m height. Another structure indicative of sea level change identified was a paleochannel, which started at 30 m depth and followed the direction northwest-southeast on the shelf.

Keywords - Sea level change, Side scan sonar, Pernambuco.

INTRODUCTION

The term *beachrock* refers to calcareous deposits formed along beaches and are frequently found in tropical and sub-tropical regions. Their size and composition may vary, since they can independently derive from fine quartz sands to boulders or biogenic sediments. The grains are cemented by calcium carbonate precipitation predominantly in the form of aragonite, or occasionally calcite, just bellow the beach level, being probably induced by its shape and relief (Badyukov, 1986).

Usually it is believed that the formation of beach rocks takes place in the intertidal zone, however it is not yet known where the cementation process occurs with greater intensity. Some works suggest that the upper limit of beachrocks formation occurs within the interval between mean tide level and spring tide level (Badyukov, 1986).

Beachrocks are structures indicatives of relative sea level changes. Works developed in Brazil and abroad have reported that there are a number of these important registers of lower sea levels in the past on the continental shelf (Laborel, 1969; Santos, 1972; Dias *et al.*, 1984; Hopley, 1986; Araújo & Silva, 1996; Araújo & Freire, 1997).

On top of the studies which use beach rocks as indicatives of relative sea level changes, these features are studied for their fundamental role in the determination of present coastal morphology. Therefore, they serve as a primary tool in the reconstructing geomorphological coastal processes (Semeniuk & Searle 1987).

The main interest of the present work lies on the location and characterization of the submerged beachrocks and other features on the southern portion of Pernambuco State continental shelf through the use of a side scan sonar. By this manner we hope to identify ancient levels of coastal stability of this shelf.

Study area

The area under investigation is located on the southern half of Pernambuco State coast, in the municipality of Tamandaré, 100 km distant from its capital Recife. The western limit of the area is the continent, and the other limits of the area are on the epicontinental waters of Pernambuco's shelf, forming an elongated rectangle which corners are given by the coordinates 08° 44.221' S; 35° 03.442' W to 08° 51.155' S; 34° 47.453' W and 08° 49.325' S; 35° 05.507' W to 08° 55.533' S; 34° 48.614' W, as shown on figure 1.

Em respeito ao meio ambiente, este número foi impresso em papel branqueado por processo parcialmente isento de cloro (ECF).

Figure 1- Localization map of the study area.

Geology of the area

The continental shelf in southern Pernambuco State (Brazilian Northeast) is characteristically narrow, and breaks around 32 km from the actual coast line, in present depths of 50 to 60 m.

The sediments on this shelf are similar in their constitution to the rest of the Brazilian Northeastern shelf. The prevailing fractions are of coarse biogenic carbonatic sands, which main origin are *Halimeda* and other reef-building algal species (França, 1976). There is also a significant input of terrigenous material, which may be found mainly up to 20 m of depth, and originated from fluvial contribution to the region.

Regarding its geomorphology, Pernambuco's southern shelf presents a soft slope, with long and smooth surfaces, sometimes crossed by meandering channels which show more frequently next to river mouths.

In respect to the bathymetric features, from the coastline down to 20 m depth, there is an abrupt slope, and after this depth the shelf presents a much smoother slope, which follows all the way to the its break.

METHODOLOGY

Sampling took place from February 12th to 16th 2001, on board of the *R/V Velella*, a research boat operated by the "Projeto Recifes Costeiros" (BID/FMM).

During the work the area was covered by 8 profiles distant 2 to 3 km from each other. The profiles were taken perpendicular to the coastline. Profiles 1 and 8 reached the shelf break; 2, 3, 4 and 7 covered the inner shelf, and; profiles 5 and 6 stretched down to the 45 m depth line, as shown on figure 2.

Navigation during data acquisition was set at 4.5 knots, which was determined as the best speed for maximum resolution of the register. Positioning was orientated by a hand-held GPS and each sampling point also registered by a hand-GPS every 3 minutes.

The hardware used during field work was an echo-sounder of the bathymetric type, with the possibility of coupling with a side scan sonar. The sonar model HYDROTRAC Echo Sounder of 200 kHz frequency, has signal emission capacity only on one side of the fish and a maximum recovery of 80 m. The incoming signal was registered on an analogical register which uses fax paper. This type of sonar may be deployed on the side of a small boat from where the

depth of the fish was set at 1 m below the water surface. Due to the rocking of the boat there was the risk of errors in the register of the depth data, therefore requiring correction.

To evaluate the real need to correct the depth data registered by the side scan sonar, a comparison with the echobathymeter was made along the same profile (profile number 8). The line was occupied in one direction with one equipment and vice-versa. The results from this experiment were T-tested and showed a relative mean difference of 3% between both equipments. This difference was found to be non significative ($p < 0,0001$) and the correction of the depth data acquired using the side scan sonar was not considered necessary. In this way, all the depth data used in the present work are derived from the side scan sonar registers.

In order to plot the profiles a vertical plan was defined from the points stored in the GPS. The distance between each two of these points in the same profile was determined according to Equation 1:

$$d^2 = (DLat)^2 + (DLon)^2 \quad (1)$$

where d is the distance in meters between the two points; **DLat** is the variation in latitude between the two points and; **DLon** is the variation in longitude between the two points.

The sonographic registers were interpreted according to the usual methodology to the reading of data from analogical registers of side scan sonars, which is based on the principle of the sound waves reflectance. Structures of higher reflectance, as rocks, are represented by darker signals, and those of lower reflectance, as mud which absorb more efficiently the sound, are represented by lighter signals, sometimes not being registered at all (Johnson & Helferty, 1990).

The bathymetric profiles were plotted using Microsoft Excel 2000 and the figures edited on Adobe Photoshop 4.0.

RESULTS

The interpretation of the sonographic registers allowed the identification of a number of bottom features, such as beachrocks, channels and others.

The first feature to be identified as a beachrock was detected at a depth of approximately 20 m, in a flat region recovered by terrigenous and carbonatic sediments, characterized in the register by shades of gray which indicate a medium level of bottom reflectance (Fig. 3).

Figure 2- Map showing the profiles covered in the study area. The numbering indicates the order in which the profiles were occupied.

In regard to its geomorphology, this beachrock presented a triangular shape with rounded top, stretching parallel to the coastline. The dimensions of the detected structure were determined as being around 163 m wide and 6 m height.

The second occurrence of a beachrock was found in depths between 40 and 50 m. Geomorphologically, this feature showed a flatter top and dimensions about 209 m of width to 4 m of height.

This feature was also surrounded by a muddy type of bottom, characterized by the absense of signal on the register, and therefore indicating the total absorbance of the sound waves from the sonar by the bottom (Fig. 4).

The interpretation of the registers has also revealed the occurrence of a long channel with a mud bottom. This channel was detected for the first time in profile 4, around 30 m depth, where it showed 41.2 m of maximum depth from the water surface (Fig. 5). In this region the channel is 10 m deeper than the surrounding bottom and 1629 m wide.

This channel was also registered on profile 1, starting at around 30 m depth and showing a maximum depth of 52 m from the water surface. In average, at this profile, the channel has 19 m of depth and 2847 m width (Fig. 6). It is interesting to observe that, in this region where the channel was detected again, it was also registered the presence of the second beachrock previously described.

Profile 6 was the region where the channel occurred for the last time within the sampling area. In this register the channel presents a large elevation which does not seems to be a beachrock. Here the channel has a depth of 50.4 m from the water surface and is 4000 m wide. The main depth of the channel is around 13.6 m, as shown in figure 7.

DISCUSSION AND CONCLUSIONS

Features as beachrocks can serve as indicatives of abandoned levels of shoreline stability. Based on the evidences pointed out in the present work it was possible to observe the existence of at least two points of past sea level stability.

The first point of sea level stability for the Pernambuco southern shelf occurred at a depth of 20 m as can be seen on the map in figure 8. This evidence is in perfect agreement with another description of a sea level stability evidence, at the same depth, found on the Ceará shelf and deccribed by Araújo & Freire (1997).

The sedimentary characteristics described for the 20 m depth region, where the first beachrock was registered, are of a mixture of terrigenous and carbonatic material. The first may be derived from some nearby conduct of continental sources of material, and the second from local sources of carbonatic material represented in this region by Halimeda and other calcareous algae.

The second submerged evidence of sea level stability on Pernambuco's continetal shelf was mapped between depths of 40 to 50 m (Fig. 8).

This second point correlates well with other occurrences already reported for the Rio de Janeiro continental shelf (Araújo & Silva, 1996) and for the Ceará continental shelf (Araújo & Freire, 1997) as well.

This second point of abandoned sea level stability is characterized by a mud channel which surrounds it. This sort of arrangement has no previous register in the available literature. The origin of this mud deposit may be attributed to the formation of a low energy depositional environment, protected by the steep borders of the channel.

Figure 3- Representation of the submerged beachrock found in profile 1 around 20 m depth.

Figure 4 - Beachrock found in profile 1 at 40 m depth. Note the lack of signal in the register, representing the occurrence of a mud bottom.

Figure 5 - Bathymetric profile 4 presenting a sharp increase in depth from 30 m reaching a maximum at 41.6 m indicating the presence of a channel 1629 m wide.

Figure 6 - Bathymetric profile 1 presenting another feature similar to a channel which starts at 32 m depth, reaching maximum depth of 51 m and 2847 m of width.

Figure 7 - Bathymetric profile 6, where the third evidence of a channel can be seen. The channel starts at 36 m depth and reaches maximum depth of 51 m and 4000 m of width.

Based on the registers presented, there is the confirmation of the existence of a channel starting around 30 m depth, on the middle shelf, which extends to the outer shelf at depths of 35 to 40 m.

Regarding its geomorphology the channel stretches along the shelf in the northwest-southeast direction (Fig. 8). It is important to be observed that where

the channel starts, near the coast, it is narrower than in its two other registers along the shelf, strongly suggesting the shape of a river bed, as shown in figure 8.

According to the characteristics described above this channel may be a paleochannel, which associates with the Formoso River during periods of sea level transgression and regression. Other authors

Figure 8 - Map showing the points where evidence for the presence of the geological features indicative of sea level change and the points of detection of the submerged channel.

have also described paleochannels on the Brazilian Northeast continental shelf in the states of Sergipe, Alagoas (Summerhayes *et al.*, 1976) and Paraíba (Zembruski *et al.*, 1972).

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