BEACHROCK FRACTURING AND EROSION IN NORTHEASTERN BRAZIL

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RESUMO
Dois corpos de arenitos de praia foram investigados no estado do Rio Grande do Norte, nordeste do Brasil, que apresenta um regime de mesomaré, para avaliar o papel das oscilações do nível do mar no faturamento e erosão destes corpos. As camadas sedimentares afetadas pelo fraturamento têm-se quebrado em blocos com forma de paralelepípedo que apresentam até 5 m de comprimento, 4 m de largura e 3 m de espessura. As fraturas são normais ao acamamento e formam 4 sets de juntas: um set principal de orientação N-S, paralelo ao acamamento sedimentar dos arenitos de praia e à zona costeira; um set de orientação E-W, ortogonal ao primeiro; e dois sets com orientação NE e NW, oblíquos aos dois primeiros. Os sets mais importantes que controlam o fraturamento são os de orientação N-S e E-W. O fraturamento é inicialmente induzido por erosão na base dos corpos de arenito de praia, provocando o basculamento e colapso dos blocos. O fraturamento é mais ativo em corpos cujo topo encontra-se um pouco acima do nível médio das marés. Por outro lado, este fraturamento é mais lento em corpos que se encontram abaixo do nível médio das marés, onde o crescimento de ostras, vermetídeos e algas preenchem fraturas e retardam a propagação de juntas. Os dados de campo indicam que o fraturamento e o colapso de arenitos de praia são resultantes de processos de deslizamentos gravitacionais, nos quais a variação do nível relativo do mar tem um papel fundamental.

ABSTRACT
We have investigated two Holocene beachrock in a mesotidal regime in Rio Grande do Norte State, northeastern Brazil, to assess the control on beachrock fracturing and erosion of sea-level height. The sedimentary strata affected by fractures have break up into parallelopiped shaped blocks up to 5 m long, 4 m wide and 3 m thick. Fractures are normal to bedding and form 4 joint sets: a master N-S-trending set parallel to bedding strike and the coastal zone (J1), a cross E-W-trending set perpendicular to bedding strike (J2), and two additional NE- and NW-trending sets (J3 and J4). The most important sets that control beachrock fracturing are the N-S parallel and E-W orthogonal sets. Fracturing is controlled by undercuts at beachrock base, which induce block tilting and collapse. Fracturing is active in beachrock bodies whose top is slightly above mean sea level; it is less active in beachrock bodies below mean sea level, where oyster, vermetid and algae organisms usually fill joints and, thus, delay fracture growth. Field data indicate that beachrock fracturing and collapse is a gravity-sliding process in which relative sea-level changes play a major role.

Keywords: beachrock, fracturing, holocene

1. INTRODUCTION

Beachrock is one of the most striking features of tropical coasts not only because it is an important component of their coastal system, but also because it protects the shoreline from high waves and influences coastal morphology.

Several recent works have described beachrock influence on coastal evolution in tropical coasts. In Brazil, the role of beachrock on coastal morphology was discussed by Amaral & Mendonça (1996), Coutinho and Maia (2002), and Guerra and Manso (2002). The study area provides an excellent opportunity to study beachrock fracturing and erosion. It is on the east coast of the Rio Grande do Norte State, northeastern Brazil.

2 . GEOLOGICAL SETTING

Two beachrock were chosen for study because of the extensive, excellent exposure, known age, and because of the evidence present for the factors which influence beachrock erosion and coastal morphology. They are here labeled internal and external beachrock. They occur in the intertidal zone 5 to 8 m apart and lie on sand-silty basement. Both beachrock trend roughly N-S and lie parallel to the current shoreline (Fig. 1). Their base are only exposed at low tides The external beachrock is covered by water at high tides, whereas the top of the internal beachrock is above high tide. The former is ~7.5 km long and the latter ~8 km long. Their width ranges from 1-2 m to 50 m. Both are composed of near flat-lying layers.

The two beachrocks investigated are usually coarse-grained grainstones and rudstones. The dominant detrital component is quartz that are bounded together by carbonate cement.

Ages of beachrock bodies and encrustations determined by radiocarbon dating are from Bezerra et al. (2003). The internal beachrock yielded two radiocarbon ages between 5,310 to 4,380 cal. yr BP; the external beachrock yielded three radiocarbon ages from 7,460 to 5,980 cal. yr BP. Vermetids encrusted on the external beachrock yielded ages from 460 to 270 cal. yr BP.

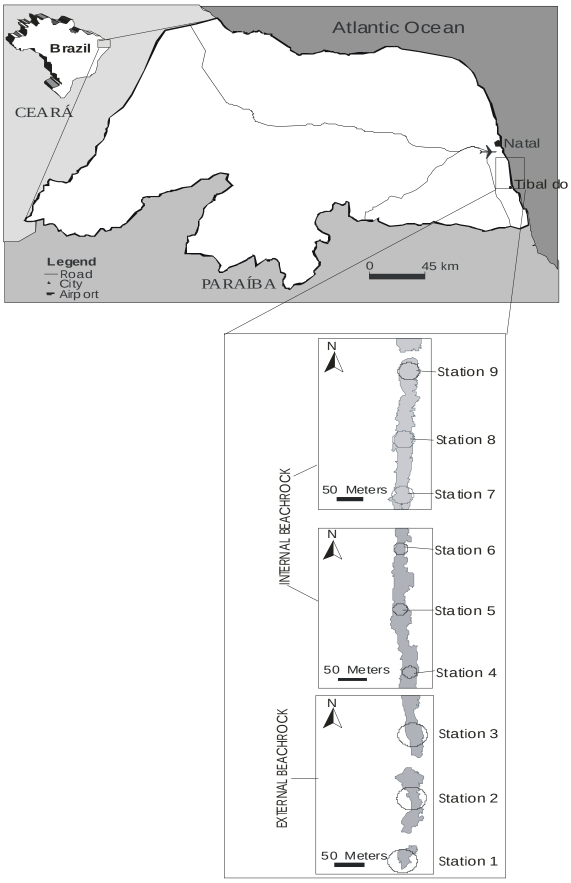

Figure 1 – Map of study area and location of beachrock bodies and stations investigated.

3. GENERAL FEATURES OF FRACTURES

Both the internal and external beachrock present three distinct zones, a central zone characterized by the main beachrock body is sandwiched between two lateral zones of beachrock that collapsed from the former. These lateral zones are the outer face, located on the sea side, and the inner face, located on the beach side (Fig. 2). Usually fracturing and erosion are more active in the former. Because these lateral zones are composed of displaces blocks, detailed investigation was carried out in the central zone of each beachrock.

No observable offset was identified along fractures in beachrock bodies, which indicates these cracks may be classified as joints. The term set is used here for parallel or subparallel joints.

Four joint sets can be distinguished on the basis of joint orientations. Joints that are parallel to the sedimentary bedding strike and trends N-S are termed J1 joint set. The general picture of this joint pattern indicates that the strikes of J1 set follow the local variation of the beachrock bedding. A second set, hereafter called J2 joint set, trends about E-W and is orthogonal to the sedimentary bedding strike. Two additional sets were also identified. They are oblique to the sedimentary bedding strike, NE and NW-oriented and termed J3 and J4 joint sets, respectively.

Joints are commonly subvertical and bedding-normal. Joints are usually planar and straight, but occasionally they wavy and hence show minor (< 10^o) variation in strike. Spacing of joints is almost similar along both beachrock bodies. J1 and J2 spacing varies from 1.9 to 4.1 m and from 2.0 to 4.3 m (J2), respectively. J3 and J4 spacing, which ranges from 2.6 to 11.5 m, has a strong dependence on spacing of the J1 and J2 sets. J1 and J2 sets are the most pervasive sets. Length of the earliest joint sets (J1 and J2) is usually greater than those of later sets (J3 and J4). According to trace of joints at the beachrock surface (Fig. 3) and rose diagrams (Fig. 4), often joints of J1 and J2 sets are larger than those of J3 and J4. In all stations, J3 and J4 joint sets are not as commonly developed as J1 and J2 joint sets. Individual J1 joints within a circle have traces 0.6 to 46 m long, J2 joints have traces 0.25 to 28 m, and J3 and J4 joints have traces 0.45 to 17 m.

The J1 and J2 joints have length of several meters to several tens of meters. They are usually greater than those of later sets (J3 and J4). J3 and J4 sets are composed of short joints whose horizontal length is usually limited by spacing of the J1 and J2 sets.

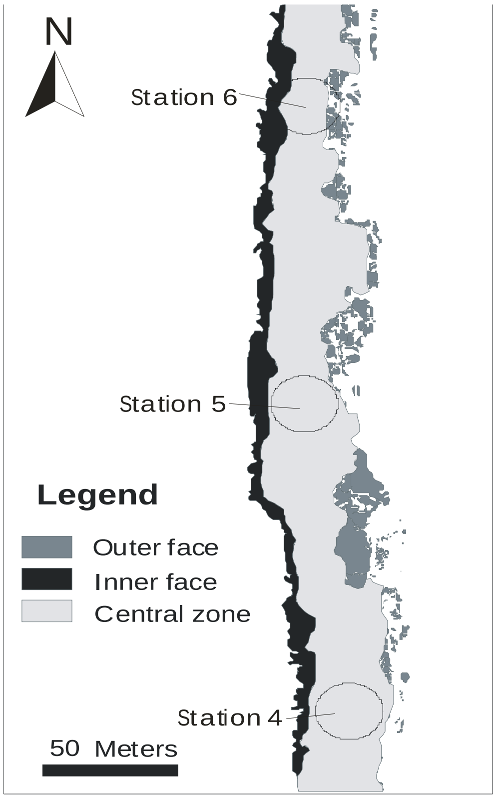

Figure 2 – Drawing of the internal beachrock showing major beachrock divisions according to degree of preservation: (a) central zone where the body is undisturbed, (b) outer face where blocks collapse towards the sea, and (c) inner face where blocks collapse towards the beach.

4. FRACTURE RELATIVE CHRONOLOGY

On the assumption that the criteria valid for tectonic joints can also be used for non-tectonics joints in beachrock, no single joint set can reasonably be classified as the first or the last one to affect beachrock. All sets form a mutually cross-cutting system, which indicates episodic growth by alternating local propagation of each set. However, J1 and J2 sets usually pre-date and often perturb J3 and J4 sets. The presence of hooks and forking structures in J3 and J4 sets corroborates this timing relationship. The abutting relationships of J1 and J2 joint sets suggest an alternate development of these sets. J3 and J4 sets also show mutually cross-cutting relationships, which indicates they have been generated simultaneously. The attitude and relative age of any of the four sets is independent of the age of the beachrock in which the joints occur.

The crucial difference between joints developed in the external (stations 1-3) and internal beachrock (stations 4-9) is the occurrence of intertidal organism within open joints, mainly vermetids. At stations S1, S2, and S3, where filled joints were observed, joints can be shown to have opened in a direction normal to their walls. The aperture of filled joints varies from a few centimeters to 0.5 m. The fill is composed mainly of vermetid or coarse to fine sand cemented by calcite, which form a ‘secondary beachrock’. The infilling are vuggy, segmented, and are composed of intertidal organisms and rocks, which indicate they post-date joint opening. Bezerra et al. (2003) dated vermetids that fill open joints and yielded radiocarbon ages at 460-270 cal. yr BP in the external beachrock. The absence of joint filling from stations 4 to 9 is consistent with the internal beachrock height, which does not favored intertidal organism growth.

5. TRIGGERING PROCESSES OF BEACHROCK FRACTURING-EROSION AND CONCLUSION

The combination of chemical, biological, and mechanical erosion acts to destroy beachrock bodies. Field data indicate a few main triggering factors of beachrock fracturing and collapse. In some cases, block fracturing may be caused by severe storms that have increased wave energy. However, field data clearly indicate that the most important process in beachrock fracturing is associated with gravity-related mechanisms. The possibility that joint sets observed in the external and internal beachrock were induced by tectonic stresses or were inherited from underlying fractures can be ruled out.

We concluded that joints have been formed by gravity-sliding processes. Erosion is caused by waves and longshore currents. Undercuts at beachrock base are here suggested as the main triggering factor for beachrock tilting and jointing, which is observed today. The four joint sets, induced by block tilting, propagate in stages dominated by the formation of one or two sets. Outward tearing (extensional) processes form J1, whereas shearing (sliding) processes form J2, J3, and J4 sets. Finally, large blocks up to 60 m^3, shapes mainly by J1 and J2 joints, collapse from beachrock bodies into the sea.

It follows that beachrock ledges have been removed to improve sea bathing and sailing conditions in coastal areas. This is generally not a good practice. Since beachrock bodies act as breakwaters for adjacent beaches, they should be preserved from destruction.

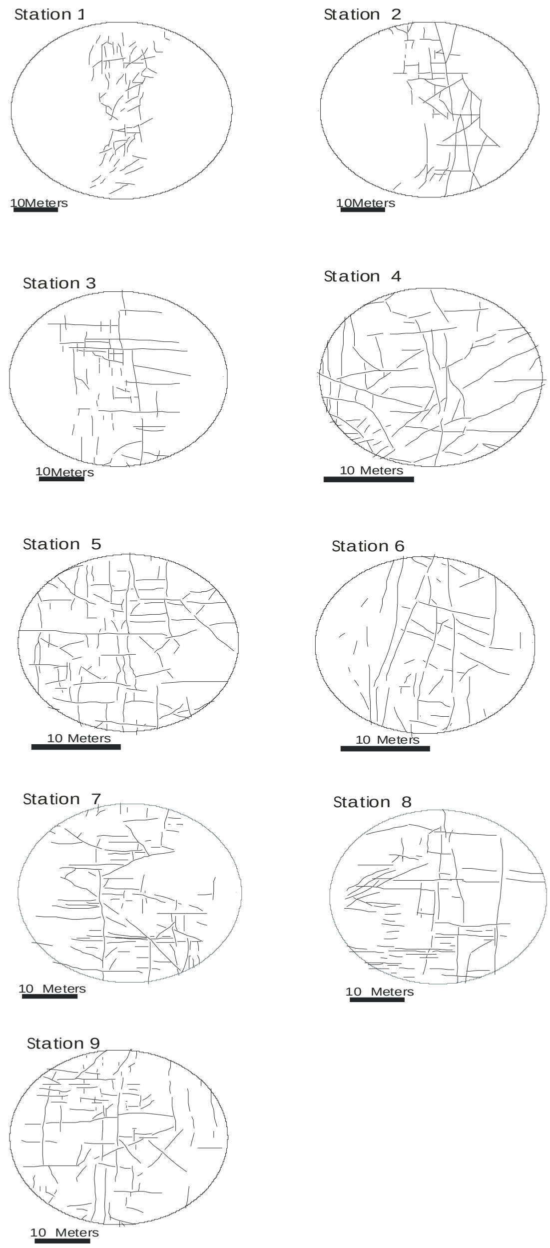

Figure 3 – Maps of joint sets as traces on bedding in the middle zones from the external and internal beachrocks.

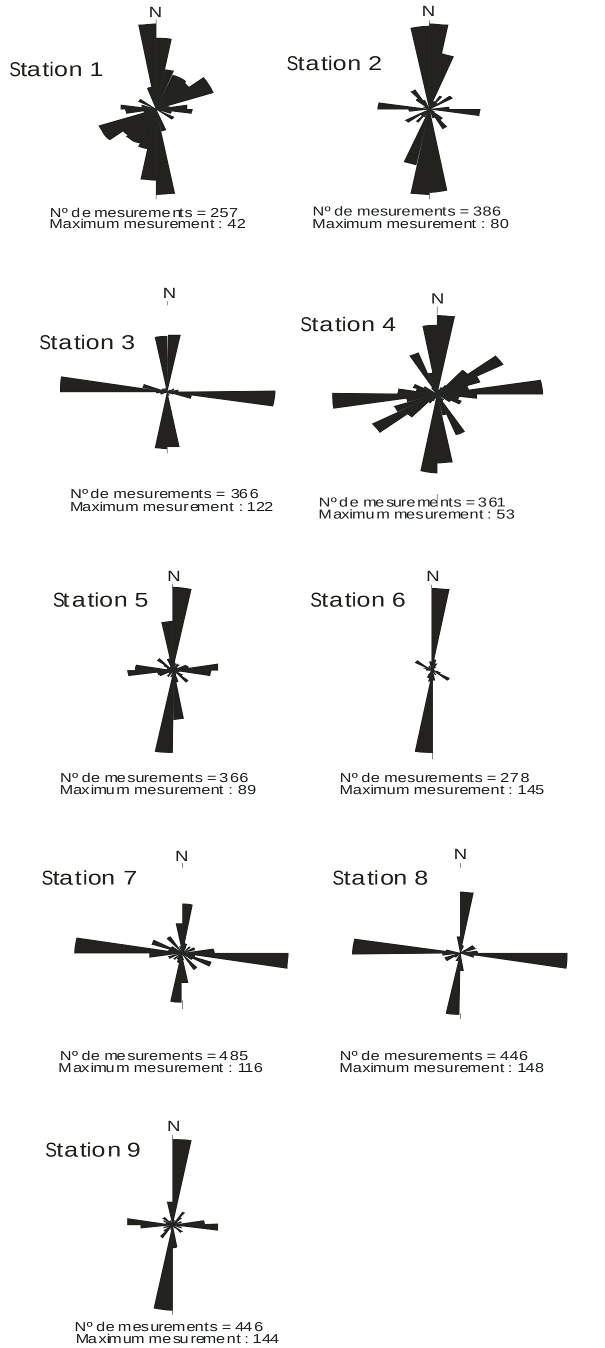

Figure 4 – Rose diagrams of joint frequency. Each 1m of joint trace is equal to 1 unit (measurement) in the diagrams.

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REFERENCES

AMARAL, R.F. & MENDONÇA, F.B. 1996. Mapeamento de feições físicas na zona costeira a partir de fotografias aéreas de pequeno formato – Praia de Barreta, litoral oriental do Rio Grande do Norte. Anais do Congresso Brasileiro de Engenharia e Agrimensura, 7, 463-470.

BEZERRA, F.H.R., BARRETO, A.M. & SUGUIO, K. 2003. Holocene sea-level history on the Rio Grande do Norte State coast, Brazil. Marine Geology, 196, 73-89.

COUTINHO, P.N. AND MAIA, L.P. 2002. Influência da morfologia dos recifes na definição de obras costeiras. Proceedings of the XLI Brazilian Geological Congress, abstract vol. P. 83. João pessoa, Brazil.

GUERRA, N.C. AND MANSO, V.A.V. 2002. Os beachrocks como controle ambiental. Proceedings of the XLI Brazilian Geological Congress, abstract vol. P. 96. João Pessoa, Brazil.