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Preliminary Results on Holocene Sea-level changes on Ceará Coast / Brazil

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ABSTRACT

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The Mid-Holocene sea-level in the East and South Brazilian coast has shown a significant rising in comparison to the current mean sea level. In Ceará State Coast, Northeastern Brazil, however, there is a lack of studies investigating sea level variation. In order to obtain information on Holocene sea-level changes, an intense survey on specific sites throughout the 573 km coast of Ceará was done and recovered more than 30 cores sampling up to 26 m of sediment profiles from the estuaries of Jaguaribe and Coreaú Rivers located in the South-east and North-west of Ceará coast, respectively. Main attention was given to the large sections well developed beach-rocks. These rocks were not found in positions higher than the current high-water line. Mangrove sediments occur in both investigated estuaries are also concentrated in places such as in Itarema. ^{14}C analysis of mangrove sediments are in progress and sea-level curves are being worked out by dating derived from mangrove horizons of different depths. Lakes have been formed during sea-level rise due to low sedimentation rates in the investigated area. This led to find the extent of the Holocene sea-level variation. This work also includes sedimentary, geochemical and mineralogical analysis as a tool to describe the Holocene history of these estuaries and to contribute to the climate history of Ceará State.

Keywords: coastal evolution, climate changes, beach rock

INTRODUCTION

Holocene sea level changes of Brazilian coast are best known along its Northeastern and Southeastern areas between Rio Grande do Norte and Rio de Janeiro (MARTIN & SUGUIO, 1996, MARTIN et al. 2003, DE OLIVEIRA CALDAS et al., 2006, ANGULO & LESSA, 1997, SUGUIO et al. 1980 & 1985). Some data are available from a location south of the mouth of the Amazon River (COHEN et al., 2005) and from Venezuela. In the area near the Amazon mouth, the sea-level in the past was significantly higher than today, up to 5m, and on the Venezuelan coast the sea-level did not reach higher level than today.

From the 1.300 km coast line between Rio Grande do Norte and the Amazon there are no available reports on sea-level changes.

The objective of this study on the coast of Ceará State is to close parts of this gap. It relies on extended field observation and on the results from sediment cores taken in the estuaries of the Jaguaribe and Coreaú Rivers. All together about half of the 573 km coast line has been studied (Figure 1).

Additionally more than 20 profiles perpendicular to the coast line towards inland have also been studied. The sampling location corresponded spacially do the cross section referred in MORAIS et al, 2006. However detailed results from the sediment core can only be reached when the ordered samples for ^{14}C analysis have been finished.

METHODS

On Ceará coast, excellent indicators of sea-level stages are beachrocks (Figure 2). They are extremely widespread, well developed and are formed between low and high tide stages (HOPELY, 1986) which ranges a bit more than 3 m. The occurrences of beachrocks have been mapped during several fieldtrips during low water stages.

As it can be seen in the above figure the occurence of beachrocks seems to be displaced. This means that the upper part of the beachrocks outcrop has faced the action of seasonal erosion, which consequences are spread along the Ceara state coastline. The samples which were taken for interpretation in this paper were collected at middle and lower parts of the beachrocks outcrops, the real representative samples. Besides beachrocks, wave cut terraces formed between high and low water stages of the tides have been studied. They are not as wide spread as beachrocks but are sufficient available for detailed studies. Wave cut terrace are formed exclusively in areas where the Plio-Pleistocene Barreiras Formation reaches the coast.

The predominantly soft Barreira Formation is consolidated through evaporation/precipitation processes when getting into the tide regime. As a third indication of sea-level, mangrove flats have been investigated. Extensive mangrove flats have been studied in the estuaries of Jaguaribe and Coreaú Rivers as well as at west of Fortim and near the border of Piaui at Bitupita.

The studied mangrove sediments are generally very fine-grained; during high tide and the majority of the mangrove flats are drowned. Higher mud flats, formed due to exceptional flooding of the river occur in the Jaguaribe estuary. In the estuarine sediments of Jaguaribe and Coreaú Rivers 31 profiles has been bored; the maximal reached depth was 26 m. For recovering of the sediment cores two methods were used. The most simple was carried out at a half open one meter iron tube, for getting initial information of the sedimentary character of estuarine sediments (Figure 3).

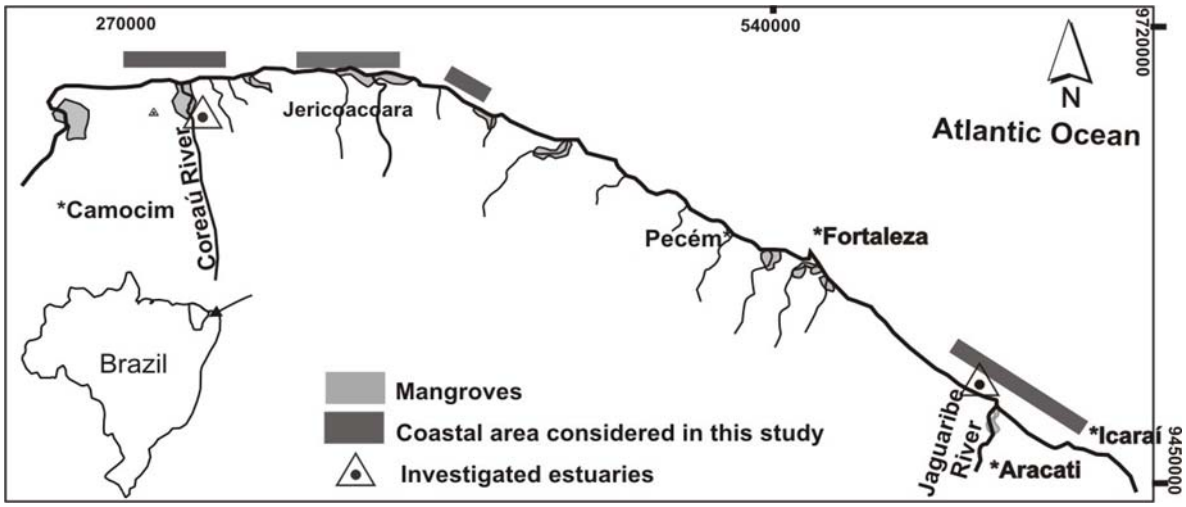

Figure 1. Location area.

Figure 2. Beachrocks located in the Jericoacoara beach

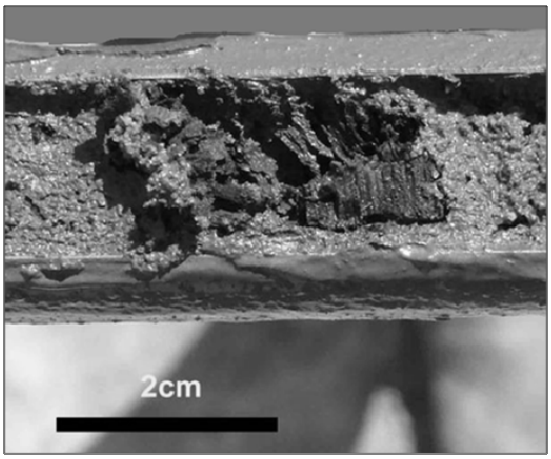

Figure 3. Half open iron bar with some mud and parts of a mangrove root.

The deepest sounding was 26 m. A second more laborious method allows, with the help of a piston, recovering sediment cores of 5 cm diameter. This method avoids contaminations from adjoining depths. Therefore, this method has been applied for further mineralogical /geochemical and isotopic (^{14}C and $\delta\ ^{13}C$) analysis.

Both Jaguaribe and Coreaú estuaries are undertaking siltation processes becoming filled up with sediments. There are only few areas at the rim of Jaguaribe estuary with some lack of sediments (Figure 4). The large majority of the sediments filling the estuaries are originated from the incoming river. As can be guessed by vertical distribution of clay minerals, smaller quantities of sediments may originate from the sea.

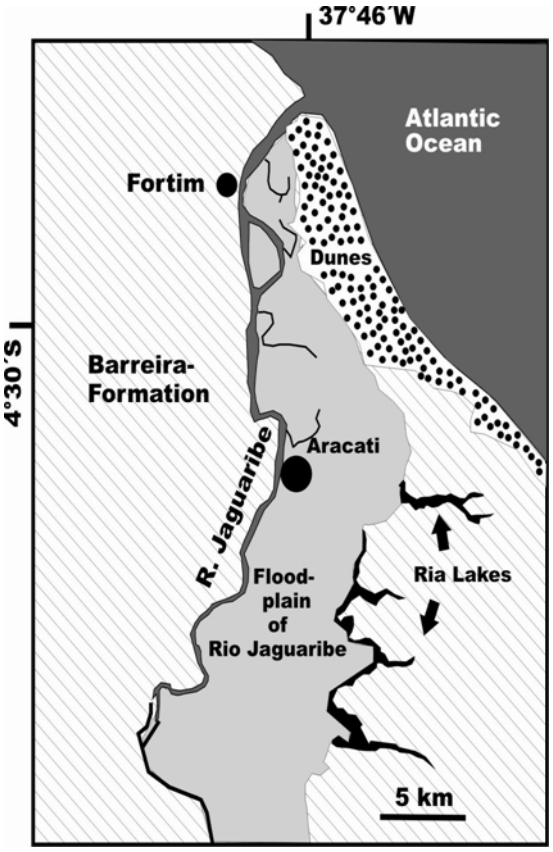

Figure 4. Environmental map of the Jaguaribe river (Dunes, mangrove, fluvial plain and Barreiras Formation).

DISCUSSION

The great advantage of sea-level studies along the Ceará coast is the generally well distribution of beachrocks. Previous discussions were taken on the position of the beachrocks and pointed out for meter higher than today. However this is here considered as simple displacement of the outcrops upper part broden by seasonal very intense waves. Other indicators such as wave cut terrace and mangrove sediments also occur in many places along the coast. It can be supposed that at least during the entire Holocene, the condition for the development of these indicators were similar to that of today.

That means that when sea-level would have been significantly higher (higher than 1 m) beachrocks, wave cut terrace and mangrove mud flats would have formed in those levels. Their distribution would not be restricted only to some isolated places, because beachrocks occur along larger sections of the coast. In contrast, during the present survey, no beach rock could be found in places where formation could not be explained by the today's sea level. Sea-level indicators are in general not restricted to some isolated locations. This is the case in Huon Peninsula/Papua New Guinea where paleo-sea-levels could be observed continuously on a distance of at least 50 km. On the Southeastern North Sea coast, Holocene sea level can be studied nearly constantly in old tidal flat sediments on a distance of more than 500km. Similar distributions of beachrocks should be expected on the Ceará coast on higher elevation when sea-level would have been higher during Holocene times. Beachrocks exposed to atmospheric conditions since mid Holocene (5.000years), would not have disintegrated. That was e.g. noticed in anthropogenic carbonate shells mounts in Pantanal (IRION et al., 2009) and shell accomulations in the dunes North of the city of Aracati, which shows only minor dissolution. Since the shells are several hundred to more than one thousand (Pantanal) exposed to atmospheric conditions it can be excluded that beach rock which are cemented by calcium carbonate would have undergone a far going disintegration during the last 5.000 years. Therefore it can be stated that sea-level during Holocene never reached levels above the current one.

The padding of the estuaries is made up as mentioned above predominantly by the incoming rivers. Clay mineralogical investigations of the recovered sediment cores will show in what degree landward transported marine sediments contribute to the filling of the estuaries. The landward sediment transport is well known from rivers on the USA East coast (MEADE, 1969) and from rivers of the South-eastern corner of the North Sea (IRION et al., 1987, 2007). It seems probable that both studied estuaries have undergone stages of rias during their development. Rias are still widespread on the East coast of South America. Examples are the mouth of de la Plata and Pará (Belém) rivers but there are also rias far inland in the Amazon basin where the lower 150 km of Negro and Tapajós Rivers form lakes. Yet there are still smaller Rias at the rim of Jaguaribe estuary. Those rias show that the sedimentary processes are still not finished and due to human activity less and less sediments will reach the estuary. Jaguaribe River is characterized by many dams, the last one crosses the river 30 km from its entrance into the Atlantic Ocean. Similarly, at Careaú River, the last barrage was constructed at the city of Granja some 30 km from the sea. Only a very small proportion of the river sediments reach today the estuary. Sea-level rise which has been compensated – during the last few thousand years – predominantly by river sediments will not be compensated in future. Additionally in both estuaries there are large shrimp farms and during construction of these farms, large masses of sediments had to be moved. All together the sediment balance in the area of the estuaries is expected to be negative in the future decades. When sea-level rises a few decimeters, the estuarine sediments drown and extended wetlands will form with increasing water depth. The situation will be similar to that which may be supposed for the time of the faster sea-level rise of Mid-Holocene time.

CONCLUSION

This present study of Ceará coast shows that sea-level during Holocene was never significantly higher on this coast than it is today. That means a constant sea level is to be supposed for the last 6.000 years which corresponds to sea-level development on any stable continental rims. The most important change may occur in the estuaries when the sea-level rises,as predicted, some decimeters during the following 100 years and the lack of sediments caused by man action will produce an increasing flooding.

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