SIDESCAN SONAR IMAGING FOR BEDFORMS MAPPING OF THE POTENGI ESTUARY, NATAL (BRAZIL).

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Abstract

This study presents the bedforms mapping of the Potengi Estuary. Located in the Natal City,eastern coast of the Rio Grande do Norte State (NE Brazil), it is inserted in the geological context of the PE-PB Basin. In this study, the identification of the estuarine bed morphology through sonographic analysis had the purpose to evaluate the influence of the superficial and bottom currents for the bottom shaping. In this way, the use of the side scan sonar showed, to be very useful in the identification of the bottom morphology and its relationship with the predominant action of the tidal currents in the Potengi estuary.

The integrated data set presented here includes hydroacoustic and sedimentological data. The hydroacoustic data were obtained with a side scan sonar system. Sediment samples from riverbed were collected with a Van Veen bottom grabber just after the sides scan sonar survey in order to calibrate the records. The integrated approach led to the identification of five main groups of bedforms: very large 2D dunes, very large 3D dunes, small ripples, flat bottom and rock outcrops. The estuarine channel is filled by Holocene sandy- to silt sediments.

Introduction

Estuaries are found along many of the world's coastlines irrespective of geological setting, energy regime and depositional environment (Perillo, 1995). They also represent one of Earth's most dynamic sedimentary environments because they lie at the interface of the terrestrial and marine spheres, and evolve in response to the interaction of fluvial, coastal (tidal) and marine (wave) processes (Knight et al., 2005).

The Potengi River Estuary is located in the easthern coast of the Rio Grande do Norte State (NE Brazil), and it is inserted in the geological context of PE-PB Basin. In order to investigate sediment bedforms of the Potengi Estuary an integrated geophysical investigation was carried out using side-scan sonar linked to surface sediment sampling. The integration between bedforms characterization and different sedimentary textures in study area allows a better knowledge of active sedimentary processes, which are responsible by formation of different bedforms, such as ripples, 2D and 3D dunes.

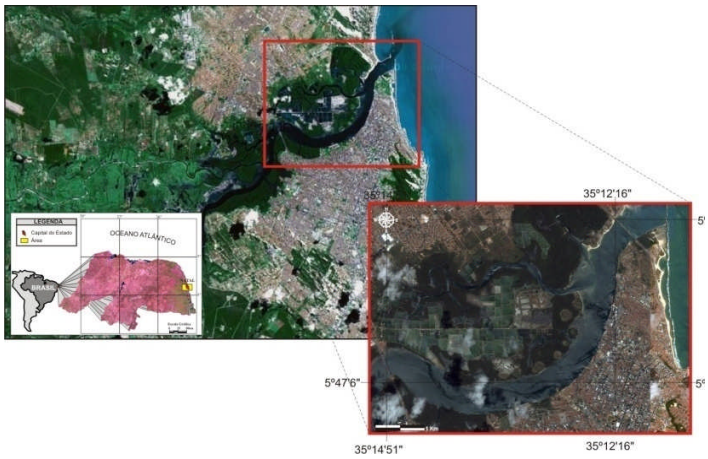

Figure 1 - Location Map of the studied area (red square) in a Google Earth Satellite image from 2009.

Method

The morphology of the river floor was mapped using a Side Scan Sonar Edgetech model 272-TD, operating at a frequency of 500 KHz and a scanning range of 50 meters. The sonographic positioning sensor was controlled from the Global Positioning System - GPS, Furuno (model GP-31), corrected with data from Global Positioning System Differential - DGPS, Furuno also brand (model GR-80). A fisher boat had been used to collect the data set. The GPS was placed on saving the vessel and the offset was calculated to correct the coordinates extracted. The navigation was based on a bathymetric chart in 1:25.000 scale produced by GGEMMA (Frazão, 2003).

The side-scan sonar dates were processed to enhance contrast and the application of a time-variable gain (TVG) to amplify the acoustic signal in specifics softwares (Discover 4100 and Sonar Wiz Map).

Five (5) sonographic longitudinal profiles were surveyed along the main navigation with approximately 5 km in length, totaling 25 km of sonography survey (Figure 2).

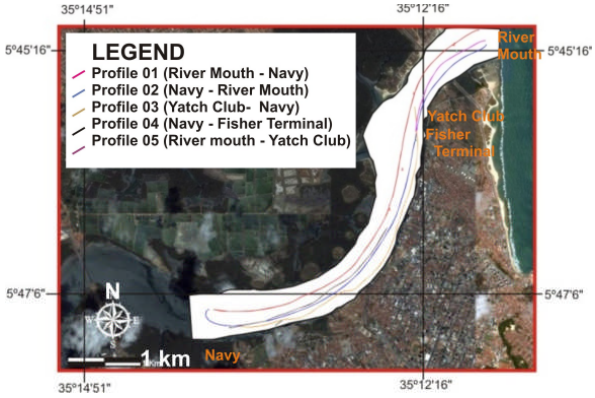

Figure 3 - Location map of sonography profiles.

General Setting

Morphology and tectonics of the Potengi Estuary

The estuary of Potengi river owns about 18 km long, located in the eastern portion of the coastline of Rio Grande do Norte state, inserted into the geological context of coastal Pernambuco-Paraíba Basin (Figure 2A), of the Cretaceous age (Mabessone 1996). A Neogene sequence (Barreiras Formation) and Quaternary sediments (fixed or mobile dunes, alluvium, river terraces and mangroves) are also recognized.

The estuary is relatively shallow, rarely exceeding 30 m depth. The geometrical configuration of the cross section has ta V shape channel. In general, the ratio width / depth is high, and related to the type of bedrock in which the river valley was excavated.

The eastern coast of Rio Grande do Norte is marked by structural valleys of NE to ENE trends, controlled by graben features. These valleys trap in your floor the sandy-clay sediments of the Barreiras Formation (Miocene-Pleistocene), capped by alluvial deposits and other Holocene deposits (Bezerra et al. 1998).

Bezerra et al. (2001), based on core and terrestrial geophysics data, concluded that the basin of the estuary Potengi river has the shape of a semi-graben, extending over at least 20km from the coast to Macaíba City, and limited by the Jundiaí fault with a preferential direction 60 ° (NE), located on the right bank of the river (Figure 2B).

Hydrology

Sediment Supply - The Potengi Basin drains an area of approximately 7.7% of the surface state, which corresponds to 4093 km². The discharge is strongly dependent on rainfall and therefore has a large seasonal and annual variability. The distribution of bottom sediments transport over the year is very irregular, with the contribution concentrated entirely in the first half, when the flows are more important. In the second half, with the decrease in flow, the contributions to the beach are very small, with negative values in August and September, which presents for this period a zero sediment budget, and even negative in years with lower rainfall when the estuary acts as a sediment trap.

Tidal Regime - tides occurring in the estuary Potengi and adjacent areas are semi-diurnal (they have two high tides and two low tides during a lunar day, with tidal period of 12 hours and 25 min), with the average changing in spring tide from nearly 2.30m and in neap tide about 0.85m with a maximum amplitude around 2.83m. These data allows to classify the tides as mesomaré type according to the classification of Davis (1977). The speeds recorded were higher during the period of flood tide.

Wind and waves conditions - The average wave height is 0.8 m with a period of 13s (Frazão, 2003). According to the UFRN Weather Station in Natal, the most frequent winds are predominantly from the East quadrant, often east-southeast, with speeds averaging monthly always around 4 and 4.5 m / s.

Estuarine Valley Stratigraphy

The estuarine valley of the Potengi River is limited by a Quaternary bedrock, mainly composed of a succession of sandstones of the Barreiras Formation, which sometimes come to surface. Above this substrate has a package of Holocene sediments, and some beachrocks. Due to the recent process of sedimentation, the bottom of the estuary is filled with mud and fine sediments in its upper part, which become thicker towards the mouth.

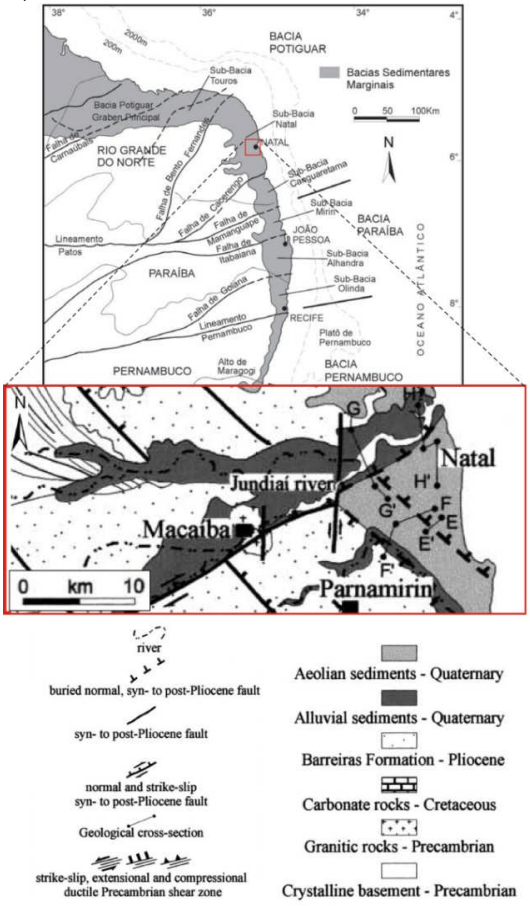

Figure 2 - (A) Location map of the PE-PB-RN basin (B) Geological Map of the coastal plain between Natal and Parnamirim.Modified from Bezerra et al. (2001).

Results

Classification of Bed Forms

The bedforms result from the interaction between wind and water or sediment substrate. Thus, the development of these forms is related to three main parameters: size of sedimentary material, depth and velocity of the flow, where the extent and characteristics of the surface are a direct product of the balance between erosion and deposition in different parts the bed (Della Fávera, 2001). The classification of bedforms follow the directions from Ashley (1990), including revisions of Dalrymple& Rhodes (1995) based on morphology. According to this classification, all forms of large-scale cross-bed (excluding the ripples and antidunas) occupy a similar position in the sequence of lower flow regime, which is subsequently modified by data such as size, shape and overlap. The wide variety of forms reflects the different hydrodynamic conditions, as well as the type of sediment.

The flow regimes were classified according to the Froude number corresponding to each generated form of bed, being characterized as higher or lower flow regime(Figure 4).

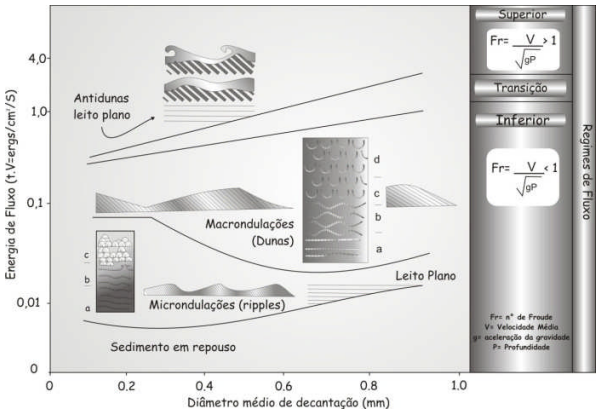

Figure 4 - Diagram showing the different bedforms in sand beds and their relationship with grain size for different flow regimes (a = straight ridge, wave crests b = c = d = ridge crests linguóides half-moon) (In Rocha, 2008 modified from Harms & Fahnestock 1965; Simons et al 1965 e Allen 1968).

Identification of the bed forms in the Potengi Estuary

In the estuary of the Potengi river were identified three main bedforms, that are mostly framed in a lower flow regime: a flat bottom, ripples (ripples) and Dunes ranging from small to large dunes (lengths wave ranging from 2.4 to 90m and heights up to 4.2m).

Changes in morphology of bedforms varied in size over short distances, e.g. in Figure 5 it is possible to observe small dunes close to medium dunes and flat bottom. These abrupt changes are related to depth variation.

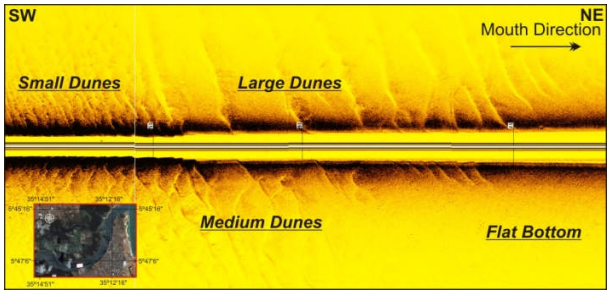

Figure 5 - Sonogram along the estuary of the Potengi river, showing the abrupt change of bedforms.

Field of subaqueous dunes

The bedforms classified as "dunes" are divided into two groups: two-dimensional forms (2-D), which occur at lower speeds, and three-dimensional forms (3-D) at higher speeds for a given size grain (Middleton & Southard, 1986) (Figure 6).

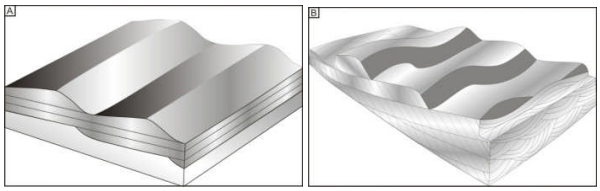

Figure 6 - Schematic figure showing tabular cross-stratification formed by migration of 2-D dunes (A) and trough cross-stratification formed by 3-D dunes (B), modified from Della Favera (2001).

Two-dimensional dunes (2D) and three-dimensional dunes (3D)

The two dimensional dunes were observed along most of the area changing from small to medium sizes (Figure 7). Next to the river mouth, where the river receives significant influence of tidal currents, they are generally superimposed by large two dimensional dunes (Figure 8). In some parts (upstream river portion) of the estuary was observed symetrical dune fields, indicating the deposition of sediments by the action of tidal currents (Figure 9).

2D and 3D dunes were found with small wavelengths between 2 and 3 m, followed by 2D medium dunes with wavelengths of about 6 m and heights ranging from 0.4 to 1.6 m

The 2D large dunes wavelengths ranging from 65 to 90 m, with heights of 2 to 2.8 m.

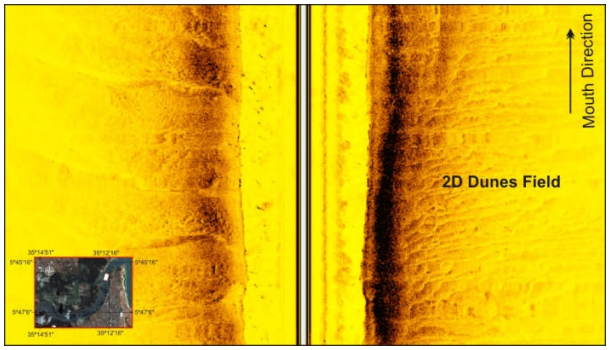

Figure 7 - Sonogram showing a straight crests dune field (2D).

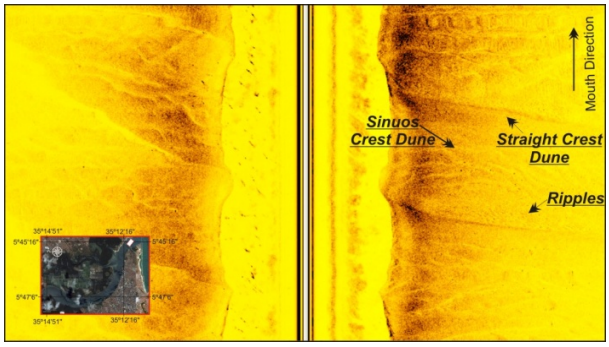

Figure 8 - The presence of large 2D dunes overlying sinuous crest dune at the mouth of the estuary of the Potengi river. Also view a ripples.

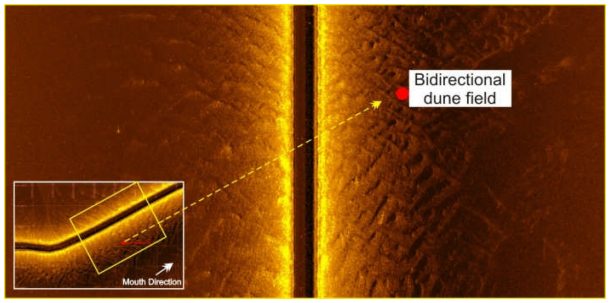

Figure 9 - Extensive bidirectional dune field ranging from small to medium wavelengths.

Outcrops, Flat Bottom and Ripples

It was possible to identify large submerged rock outcrops (Figure 10), related to the Barreiras Formation, showing a considerable control on deposition of sediments.

The flat bottoms were generally near the river bank, composed of fine sandy sediments, probably deposited in low flow velocities, or cohesive mud. However, in some parts of the main channel, the bedforms are absent, probably due to changes in currents that did not allow the preservation of these features in the background. Usually on these flat portions were identified depressions point probably related to eddies (Figure 11).

Ripples were also recognized over dunes of medium wavelength, asymmetric dunes and sinuous dunes (Fig. 12).

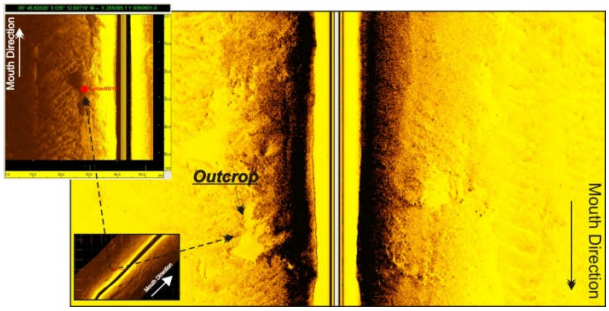

Figure 10 - Outcrop, probably from Barreiras Formation.

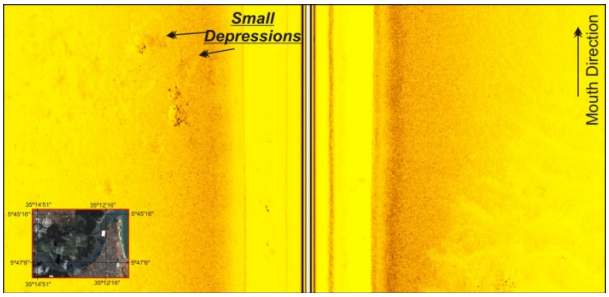

Figure 11 - Form of bed flat especially for small depressions usually generated by eddies.

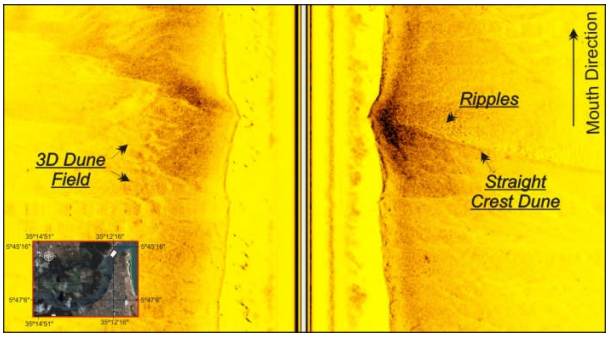

Figure 12 - Overlapping ripples (Ripples) on dunes of straight crest, also view a 3D dune field.

Conclusions

Side Scan Sonar image profiles provided new significant details for the bedforms in the estuary of the Potengi river. Different bedforms were identified: flat bottom, ripples, outcrops, 2D and 3D dunes.

The flat bottom is related to terrigenous mud on the margin of estuary with high content of organic material, and under lower currents. The ripples are formed by siliciclastic sands with gravels that find in 3D dunes near to the river mouth. Most of the dunes are observed in the main channel and are composed by siliciclastic sands. The 2D straight dune crests are present in most on the area ranging between small and medium size.

The sinuous crests dunes (3D) present small and large size forming a complex field dunes. They are larger near the river mouth.

Acknowledgments

This work was funded by Grant PQ-CNPq No 303481/09-9, PROBRAL (CAPES/DAAD) and by REDE RECIFES (CAPES/CGPE/ CII/ Ciências do Mar 207-Edital 09 2009). Thanks are also due to the UFRN (GGEMMA/PPGG) by the logistic support, to CAPES by the scholarship to first author, and to the students participating in field and lab work.

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