Geomorphological and paleogeographic characterization of continental shelf of the Apodi-Mossoró river, RN/Brazil

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Abstract

The Brazilian marginal basins have a huge potential to generate and accumulate petroleum. Incised valleys which are eroded in response to a fall of relative sea levels are related to a potential reservoir. Also, modern drowned-valley estuaries serve as harbors to petroleum and salt industries, fisheries, waste-disposal sites and recreational areas for a significant fraction of the world's population. The combined influence of these factors has produced a dramatic increase in research on modern and ancient incised-valley systems. This paper is one expression of this interest. The integrated use of satellites images and seismic, bathymetry and sides scan sonar was used on the Apodi-Mossoró River mouth to characterizes incised valley system. Through bathymetric data processing, a digital terrain model was developed, and a detailed morpho-estratigraphyc analysis was performed. In this way it was possible to recognize a geomorphologic framework quantification and structures, which may influence this area. Understanding the geomorphic response of these now submerged regions to rapid sea-level rise is crucial to understanding how future climate change is likely to affect modern coastal landscapes. A channel extending from the Apodi river mouth to the shelf dominates the investigated area. This structure can be correlated with the former river valley developed during the late Pleistocene sea level fall.
Keywords: petroleum site, incised-valley system, bathymetry, side scan sonar, shallow seismic, morpho-estratigraphyc analysis, digital terrain model, Brazilian margin, Apodi river, Rio Grande do Norte State.

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1 Introduction

The Brazilian coast concentrates many industries of exploration of sea researches (for example, fishing, salt industry and petroleum industry), also there is the tourism service. However, there is a deficit in the knowledge of the acting in the Brazilian continental shelf.

The portion of the continental shelf under study is adjacent to Areia Branca City (fig. 1), and located in the northern litoral of the Rio Grande do Norte state (Brazil), inserted on the Potiguar Basin. The geologic context become this area propitious to the petroleum exploration, and with the salt industry, these are the main sector of the industry there.

The Potiguar Basin, together with the Recôncavo-Tucano, Jatobá and the Sergipe-Alagoa Basins, are part of the NE Brazilian Rift System [1]. The sedimentation of this basin occurred in different moments, corresponding to the last regressive sequence of the drift phase [2]. That include coastal sandstones (Barreiras and Tibau formations), carbonatic rocks of continental shelf (Guamaré formation) and shallow and deep marine mudstone intercalated by turbidites (Ubarana formation).

The studied area (fig. 1) is located in the extreme west of the Rio Grande do Norte state, bounded by latitudes 4°30´S-5°00´S and longitudes 36°55´W-37°15´W and the depth of 35 m. This area features an open, wave dominated, mesotidal coast with a tidal range of 3m during the spring tide and 0.8 m during the neap tides [3]. Sediment supply to the coastal area is influenced by the river discharge in the ocean. And that discharge has been harmed to the long of the last thirty years because of the barrages contructed in that rivers and the salt industry located in the estuaries [4].

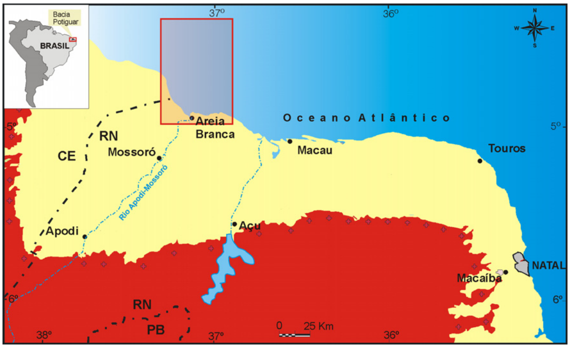

Figure 1: Localization map from Rio Grande do Norte state, showing the Potiguar Basin área.

In the research area there are some structures sculptured along the last sea level falls, during the last glacial maximum (LGM), ~20.000 cal. (B.P), lowering the sea level to 107 m deeper than nowadays [4, 5].

The main focus of this paper are the submarine geomorphology, as well as the influences factors of this geomorphology, the paleogeographic evolution of this area since the Pleistocene until the recent, through integration of satellites images, bathymetric, side scan sonar and shallow seismic, and hydrodynamics data from the area.

2 Methods

The satellites images used in this research was a LANDSAT 7 ETM+, path-row 216_063 (13/08/1999 and 20/07/2002) and 215_063 (13/06/2000). They were georeferenced in the UTM coordinates system and processed by RGB 123 colors composition.

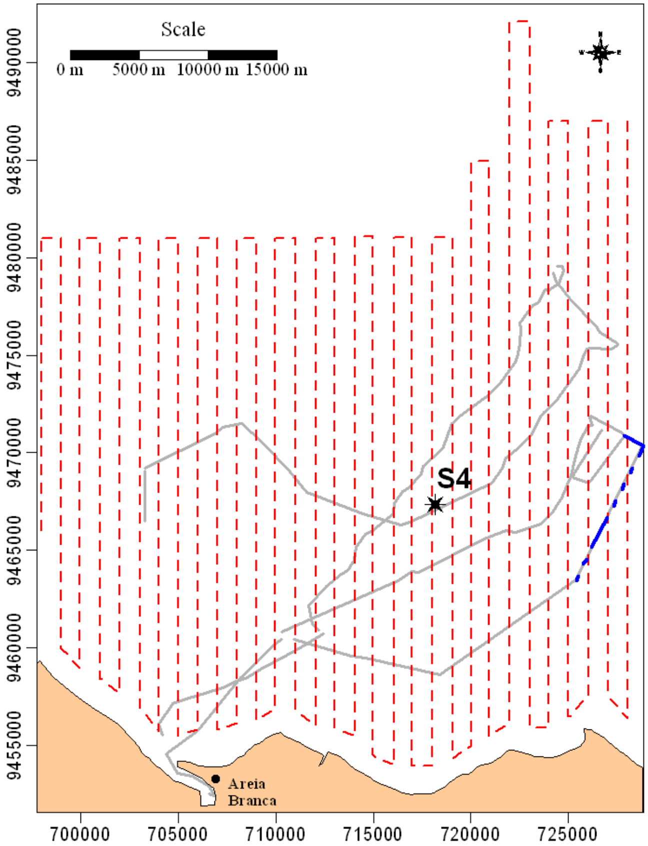

Figure 2: Location of the bathymetric (red lines), seismic (grey lines) and side scan sonar (blue lines) profiles and S4 location.

The hydroacustic data were collected (fig. 2) perpendicular to the coast, totalizing 31 profiles (~ 850 km) and distance of 1 km. They were collected using an HYDROTRAC echosounder from Odom Hidrographic Systems, operating in the 200 kHz frequencies. Post-collection processing of data consisted of the filtering and making the digital terrain model, using the kriging as interpotation method.

The hydrodynamic data were collected at the same time of the bathymetric data. The used equipment was an *InterOcean* current meter model S4. It was installed in the westward of the main channel, at the half-water (~8 m) to measure the current intensity and direction in the region. The average level of the tides recorded by the current meter was used in the bathymetric data correction.

The seismic and sonographyc data (fig 2) was collected using an *EdgeTech subbottom discover type* X-Star 3200-XS (bandwidth 0.5 – 6 Hz) and a side scan sonar type 272-TD respectively. The seismic profiles were distributed in the main channel and the margins, totalizing 9 profiles (~136 km). The sonographyc data was collected in a main line (~9 km). The post-collection processing of the seismic and sonographyc data consisted of contrast enhancement, filtering and application of time variable gain (TVG).

3 Results

The integration of all data allows the visualization of a complex geologic evolution from this part of the continental margin of the Rio Grande do Norte state, since the Pleistocene until the recent days.

3.1 Bottom geomorphology

Through satellite images analysis it was possible to identify well-marked structures in this portion of continental shelf. This structure was classified according to Ashley [6]. Correlating the processed images with the bathymetrical model (fig. 3), it was possible to see several geomorphologics features: submarine channel, flat bottom, reefs, and subaquous dunes.

3.1.1 Submarine channel

The submarine channel from the Apodi-Mossoro river is located in its mouth, measuring about 30 km in length. The channel has two main directions: NW-SE in the shallow part (5 km - maximum wide and 3km - medium wide), and NE-SE in the deep part (1.4 km- medium wide) (fig. 4a). The channel directions are the same one of the structural features present in the continent, according to Costa Neto [7]. The southward flank of the NW-SE channel direction is abrupt, and it probably represents a residual scarp of neotectonics reativation [8], with gradient of 1:150 (fig. 4a). And the northward flank is softer, in different step levels with gradient of 1:400 (fig. 4a) in each one. In the NE-SW channel direction the flanks are symmetrical with gradient of 1:30 (fig. 4b). The channel incision is strong, with a difference of altitude to 20m.

3.1.2 Flat bottom

There is a gentle slope with gradient varying from 1:1.700 at the coastal proximal portions, to 1:20.000 in the distal portions of the margin (gig. 4c). Because the inner shelf extremely plane, the depth varying is gentle.

The flat bottom was probably formed by the bioclastic sediments, or because the absence of enough energy (hydrodynamic conditions) which could form other structures.

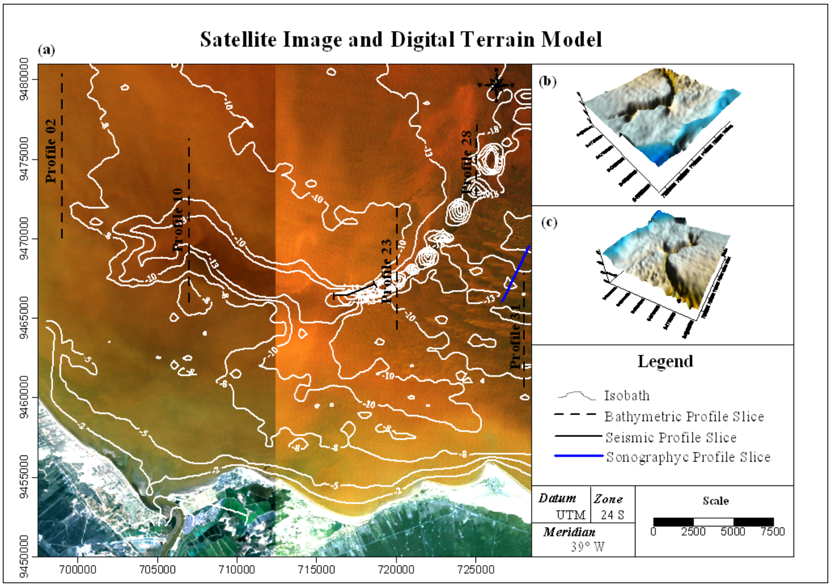

Figure 3: Main geomorphological framework finding in the study area: submarine channel, subaquous dunes and reefs. (a) Map with the satellite images composition RGB 123; (b) and (c) TDM in different angles. The bathymetric, seismic and side scan sonar profiles showing in this paper are located in the map.

3.1.3 Reefs

They appear as abrupt raised features in the sea bottom (fig. 4d). We can find them in the east portion of the area, next to the channel margin. Costa Neto [7] classified these in linear or isolated, and after that, Santos *et al* [9] nominated them as organic and inorganic.

3.1.3.1 Linear reef They are located in the depth in 15 and 20m. The bathymetric records (fig. 4d) shows the walls shape, with difference in the relief varying from 8 to 12 m, and 100 to 300m wide. The flanks are vertical and abrupt. They are present in the submarine channel margin (fig. 3).

3.1.3.2 Isolated reef. These structures are located in the east portion of the area, as the linear reefs. They have a convex and plane top, with a relief amplitude of 8 m and width from 30 to 60 m. They occur between 8 and 20m of depth.

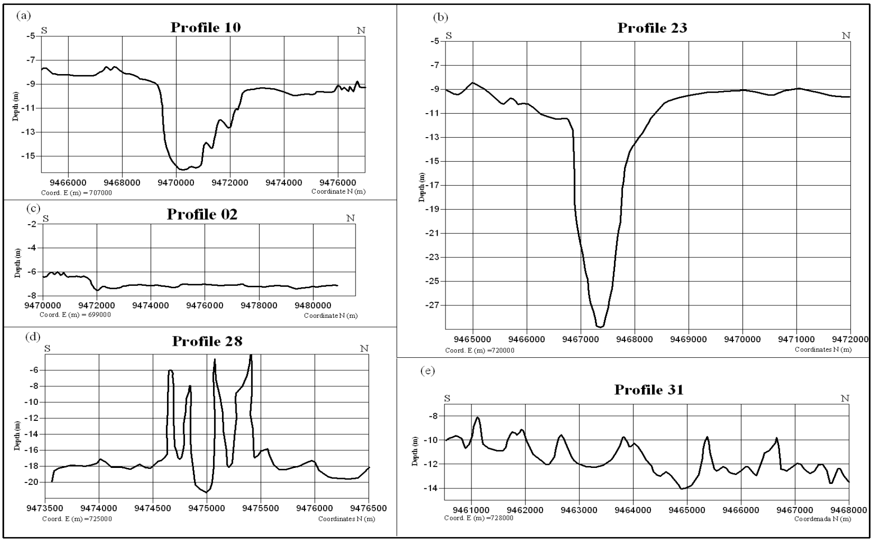

Figure 4: Part of bathymetric profiles (for location see fig. 03). (a) part of the NW-SE channel direction, showing a gentle incision; (b) NE-SW channel direction with deep incision; (c) flat bottom in the westward of the area; (d) linear reefs showing in the satellites images, and (e) subaquous dunes located in the eastside of the submarine channel.

3.1.4 Subaquous dunes

These features have amplitude from 1 to 5 m related to the bottom (fig. 4e), the main direction is parallel to the coastal line and the crests directions are NE-SW. They occur in the inner shelf, in the east side of the area. These dunes has 200m to 1.5km-length in the distal portion of the shelf, and in some cases, there is an abrupt flank in the west direction, which indicates a sediment remobilization by the ebb tide currents.

In the side scan sonar profile, the subaquous dunes are represented by different color bands (fig. 5). These bands correspond to the dunes crests and valley, respectively, and length about 1 km. The color and the reflection coefficient indicates that, probably, the crest are composed mainly by siliciclastic sediment, and the valleys are formed by carbonatic ones. We believe that the carbonatic sediment deposition has occurred during the sea level rise in the Holocene. These buildings are located next to the channel edge. The continuous occurrence of these two features, is interpreted as the strong energy resulting inside the channel, which canalize the clastic influx basinward, giving conditions to the development of lateral bioconstructions [10].

3.2 Hydrodynamic parameters

The S4 current meter was installed on the 4º49,27´S-37°01,90´W coordinate (fig. 2), in the west margin of the channel, and at 8 m depth, to recorded the local hydrodynamics. The anchor period corresponds to half neap tide cycle and half spring tide cycle.

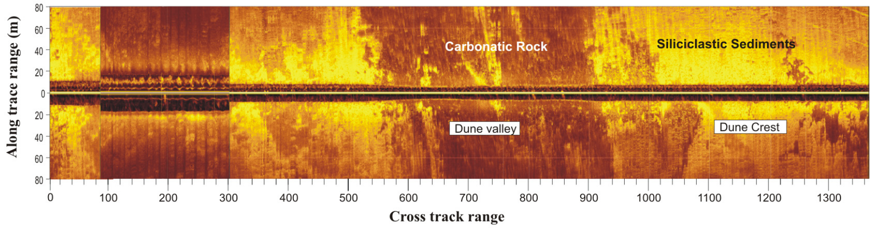

Figure 5: Part of the side scan sonar profile showing the difference in litology between valley and crests (bandwidth 500kHz and 80m range).

The diagrams in fig. 6 indicate the presence of ESE-WNW currents directions, with the main ebb current instead of flow current.

The current stick (fig. 6(a)) gives a good idea of the flow (in direction and velocity), recorded here at 8m depth. However, it is difficult to see the E-W component of the flow since it disappears within the time axis itself, and it necessary look at them individually. The fig. 6(b) and 6(c) represent direction with compass bearing and magnitude of velocity (east + north components) respectively. It shows clearly that the direction of the flow has an ESE-NWN component associated with the regime of the tides. During flow tide, the current propagates in a <300 degree compass bearing, with a magnitude varying from 20 cm/s. During ebb tide, the flow changes direction to >100 degree compass bearing, with strongest velocities reaching 30 cm/s and the temperature falls cause of the water river arriving (fig, 6(d)). This difference in speed current is probably because of the cycle changing from neap to spring tides. That is noticed for the sea level increasing in 1 m (fig. 6(e)).

The maximum intensity of the currents (36.72 cm/s) observed during the period recorded, is not capable to transport great amounts of sediments, and the hypothesis of that currents had formed these dunes by sediment transport is discarded. However, they can justify the possible remobilization of these sediments and a low transport in the ESE-WNW direction, like the longshore drift direction. Frazão [11], attributed the remobilization of the subaquous dunes near Açu river submarine channel (located eastwards from this area) to the ebb tide. The same idea is used here to the Apodi-Mossoro river submarine channel. The knowledge of the currents direction and intensity in the area is very important to understand the sediment transport, as well to foresee the migration of the contaminate plume, in case of a possible hydrocarbons spilling.

3.3 Seismostratigraphic analysis

The seismic profile show the presence of incised valley in all area (fig. 7) probably cut in the last sea level fall during the late Pleistocene. This sea level fall resulted in the horizontal I unit showed in the fig. 7. This horizontal is present in all profiles. Schwarzer *et al* [4], using high resolution seismic also observed this same horizontal in the continental shelf in front of the Açu river, and attributed it to the Pleistocene/Holocene limit.

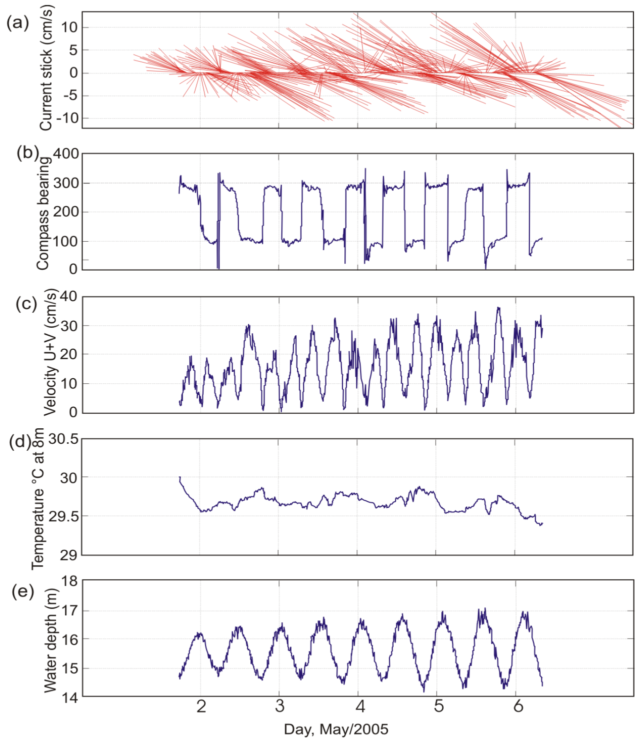

Figure 6: Hydrodynamic graphics obtained with the S4. (a) current stick; (b) direction with compass bearing; (c) magnitude of velocity; (d) temperature and (e) water depth showing the tide flux. The ebb tide predominance in the region is clearly observed.

The fig. 7 shows part of a seismic profile inside the channel. The horizon I limits pleistocenic/holocenic sediment. The holocenic sediment has the sub-horizontal layers (12 m thickness), or they are filling the incised valley by sigmoidal structures (5 m thickness). In the last case, low impedance contrast impedes exact differentiation between top and downlapping structures.

A tableau-like structure (fig.7), characterised by strong reflections, has 100m length and 8 m. Structures like this ware interpretated by Schwarzer *et al* [4] as pebble beds or consolidated sediments of the Barreiras and Tibau formation. These author affirms that tableau-like structure indicates the existence of a recent neotectonic activity resulting in the uplift occurred during the Pleistocene or early Holocene because of the horizontal I presence above this structure.

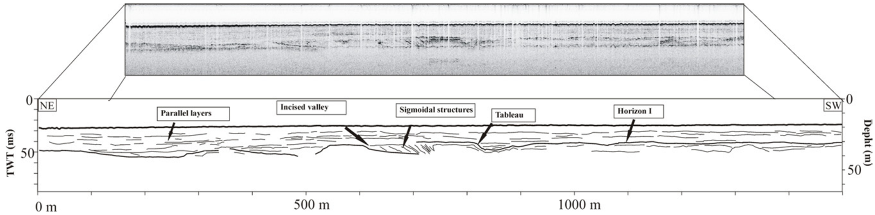

Figure 7: Part of a seismic profile inside of the channel, showing the main sedimentary structures present in the study area (for location see fig. 03).

4 Conclusions

The integrated use of satellite images and bathymetric profiles show a good response to identify some geomorphological features, as subaquous dunes, channel margins and reefs. The different tones recorded in the sonographyc profiles shown the dune valley and the crest, probably constituted by carbonatic and siliciclastic sediments respectively. The wavelength of these dunes is about 1 km. The hydrodynamics data give the main current ESE-WN direction with speed higher than 30 cm/s, probably caused by longshore drift, forming crests in the NE-SW direction. This current has no competence to build this subaquous dunes finding in the area, but they can justify the possible migration and a low transport of the sediment.

The paleogeographyc evolution at Pleistocene/Holocene of this area is related to the last glaciation, when, in the Pleistocene, the continental shelf was exposed and also the clastic sediments of Barreira and Tibau formations, sculpturing many channels, including the Apodi-Mossoró. This channels was buried during the sea level rise (during the Holocene), and there was sedimentation above the horizon I, represented by the parallel layers. Tectonic activities were evidenced in the Latest Pleistocene/Earlier Holocene, suggesting the uplift of this shelf portion.

This area has a huge economic value to this region, which becomes essential the knowledge about local geology and the influence factors in the geomorphological features.

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