Morphology and holocene sedimentation at Flamengo Bay and Boqueirão Strait, Ubatuba, São Paulo State

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Abstract

The Holocene sedimentation on Flamengo Bay and Boqueirão Strait is investigated through comparison of sedimentological and geophysical data, both surficial and subsurficial. Since these two compartments are hydrodinamically related, their understanding can lead to increase the knowledge of oceanographic changes that occurred along the Holocene. The methodology included high-resolution seismic, sidescan sonar and bathymetry.

Introduction

The northern São Paulo State coast is deeply indented and has a diversified morphology and sediment distribution. The shoreline orientation is preferentially NNE-SSW, with very narrow or nonexistent coastal plains due the proximity of the Serra do Mar mountain range.

The studied area comprises the Flamengo Bay and Boqueirão Strait, at 23°29'42" to 23°29'30" S, 45°05' to 45°07'30" W.

Flamengo Bay is a trapezoid-shaped embayment with approximately 18 km^2, width of 2.5 km and an average depth of 14 meters. Boqueirão Strait is an elongated depression oriented WSW-ENE that separates the island Anchieta from the continent (Mahiques, 1995) and has a maximum depth of 33 meters (Figure 1)

Considering that sonographic patterns and eco-high resolution seismic characters have a close relationship

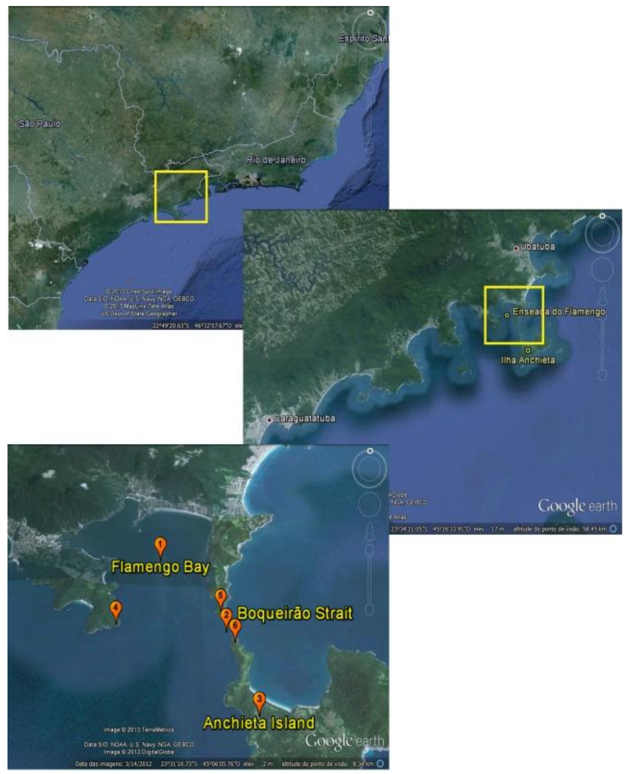


Figure 1: Location of the study area: 1- Flamengo Bay 2- Boqueirão Strait; 3- Anchieta Island; 4- Ponta Grossa; 5- Ponta do Espia; 6- Ponta da Ilha (Font: GoogleEarth)

with the distribution of the sedimentary features (Neto, 2000; Souza, 2006), this study aims the morphological and sedimentological characterization of this area.

Method

Two seismic surveys were performed to cover the whole area in 200 meters spaced lines, including control lines. (Figure 2).

The first survey included the acquisition of high resolution acoustic data with the Kongsberg-Simrad EA-400 model dual frequency (38-200 kHz) echosounder, MDCS System Meridata, operating with a Chirp frequency of 2-8 KHz, GPS and Hypack software for navigation. Softwares MDPS and Meridata Sview were used for processing and interpretation.

At the second survey, sonographic data were acquired with Marine Sonic sidescan sonar, with a 300 kHz transducer. The softwares SeaScanPC for acquisition and the SonarWiz from Chesapeake Tech were used for processing and interpretation.

To map the shoreline and construct digital elevation models (DEM), we used the Global Mapper® and Surfer® softwares.

Composition and characteristics of surface and subsurface sediments were taken from past data, presented by Mahiques (1992).

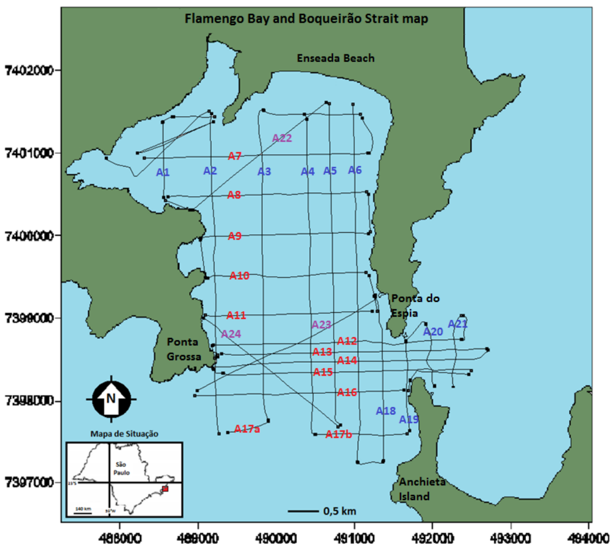


Figure 2: Map of transects conducted during the seismic and bathymetric survey

Local sedimentation

Some authors (Magliocca & Kutner, 1965; Mahiques, 1992; Mahiques & Souza, 1999) showed that the area has a restrict exchange of materials (sediments and water) with the adjacent platform and a low speed local current, preserving a natural tendency for storage of sedimentary layers deposited over time.

According to Mahiques (1992), grain-size ranges from poorly through very poorly sorted in both study areas, reflecting a complex hydrodynamic pattern and suggesting a low-energy depositional environment.

The Flamengo Bay presents a multimodal grain-size with predominance of silty terms and secondary mode in the very fine sand fraction (Mahiques, 1992). The predominance of essentially muddy sediments, mainly coarse and medium silts, occurs predominantly at the mouth of the bay and in the inner portions with highly restricted circulation.

Regarding Boqueirão Strait, Magliocca & Kutner (1965), observed a selective transport coming from the east throughout the Strait. In the eastern area there is a mixture of grain-size fractions, showing that there is no preferential sediment deposition (Mahiques, 1992), whereas the western is dominated by silty and clayey terms resulting in a tongue of sediments that juts towards WSW.

Results

Bathymetry

The image below (Figure 3) shows that the inner part of Flamengo Bay presents a homogeneous depth, mostly between 10 and 14 meters deep.

Near the mouth, depth increases slightly from the western side, getting to around 18 meters, while the eastern side shows an abrupt deepening due to the presence of Boqueirão Strait.

This depression presents a pronounced slope at both extremities. The maximum depths can be found in the smaller cross-section, between Ponta do Espia and Ponta da Ilha, reaching 35 meters.

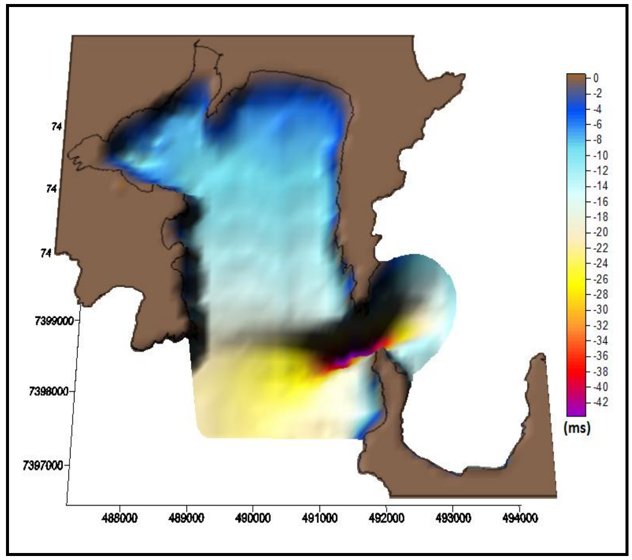


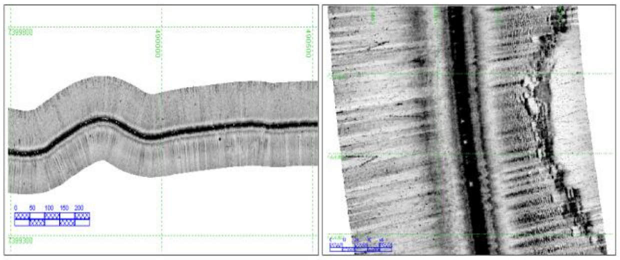
Figura 3: Bathymetry of Flamengo Bay and Boqueirão Strait

Side Scan Sonar

The scan sonar patterns observed were as follows: smooth, small ripple marks, rocky outcrops and isolated targets with high reflectivity (Figure 4)

Analysis of seismic profiles

The surface shows that the inner part of the bay has a homogeneous bottom. In the latitudinal direction, it is essentially flat (Figure 5) while longitudinally is possible to see a small slope (Figure 6)



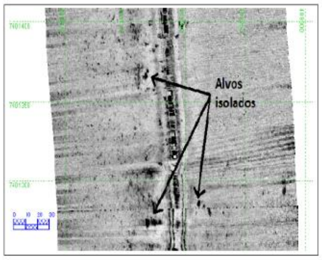


Figure 4: scan sonar patterns – (above) smooth and rocky outcrops with ripple marks; (on the left) isolated targets

The subsurface exhibits a regular a reflector (R1), also described by Mahiques and Souza (1999). It defines the upper depositional sequence and is constant throughout the region of the Bay, but is eroded near the region influenced by Boqueirão. Between the surface and R1 there is an upper depositional sequence (U1) (Figures 5 and 6). The figure 7 shows the thickness of this layer.

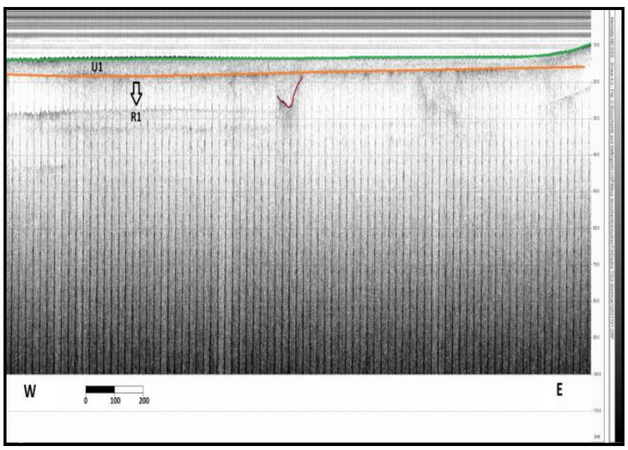


Figure 5: transect A10: latitudinal seismic profile and interpretation of reflectors and sequences found in the central region of the Bay.

Data from a core collected in the NE sector of the bay and dated by Mahiques and Souza(1999) allowed to correlate the unit 1 with the Holocene marine sedimentation, which must have started there about 7500 years BP.

This core presents a basal surface contact at 360cm. The sequence below is formed by a quartzose sand layer and above the layer is sandy mud. Its depth is consistent with which the layer R1 is found. The authors (op. cit.) also recognized it as the Holocen layer.

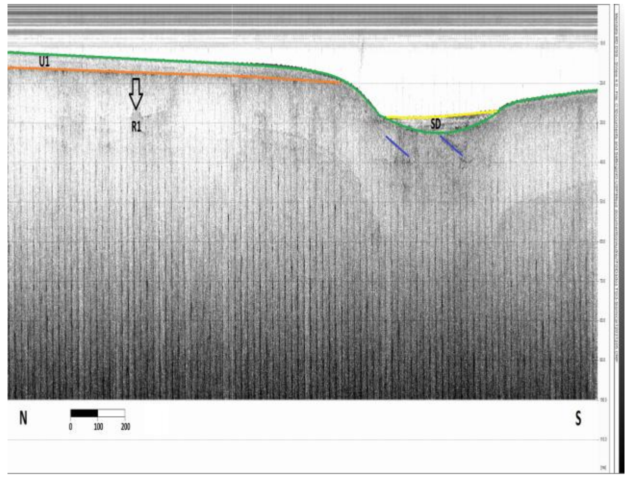


Figure 6: transect A5 - longitudinal seismic profile and interpretation of reflectors and sequences found in the inner region of the Bay.

Deposition takes place preferentially in the center-northwest side of the bay, where this sediment layer is thicker. Its thickness is less intense in the region of influence at Boqueirão Strait, when occurs a truncation of this layer with R1.

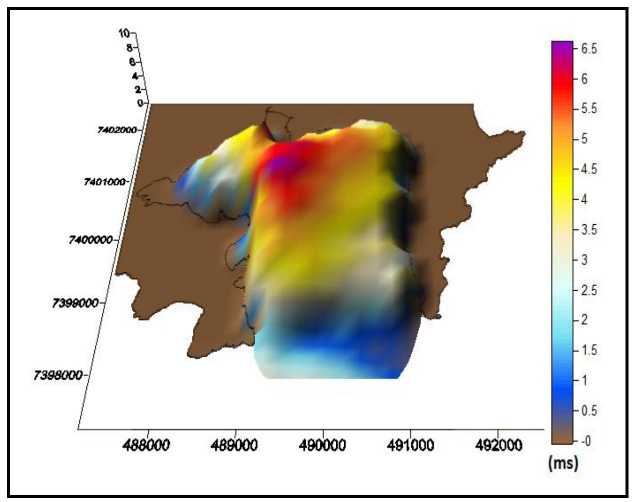


Figure 7: Unit U1 – thickness model

Boqueirão region has much more pronounced slopes in both side flanks as well as regarding its length. The subsurface reflectors in this region are also more complex (Figure 8 and 9), and the unit U1 has been completely eroded due to local higher flow speed.

Another important feature is the formation of a depositional sequence (SD) towards WSW-ENE, indicated by filled divergent facies, which ranges from inside the depression to Ponta Grossa (Figure 10)

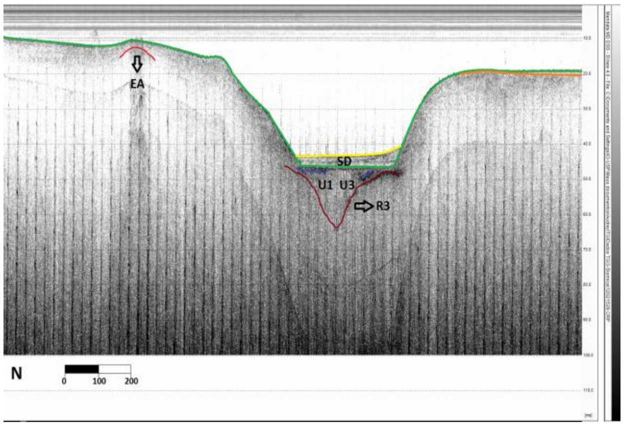


Figure 8: transect A18 – seismic profile and interpretation of sequences and reflectors perpendicular to Boqueirão.

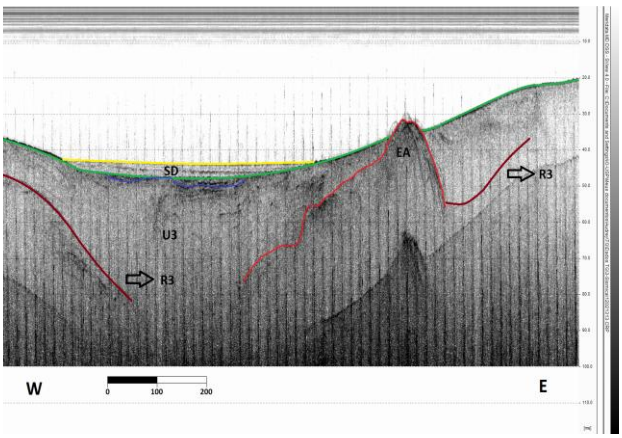


Figure 9: Transect A14 - seismic profile and interpretation of sequences and reflectors along Boqueirão Strait.

The particle size of SD indicates essentially silty terms and its the location agrees with the aforementioned selective transport throughout Boqueirão Strait.

In addition, the reflector R3 and the Acoustic Basement (EA) can also be identified.

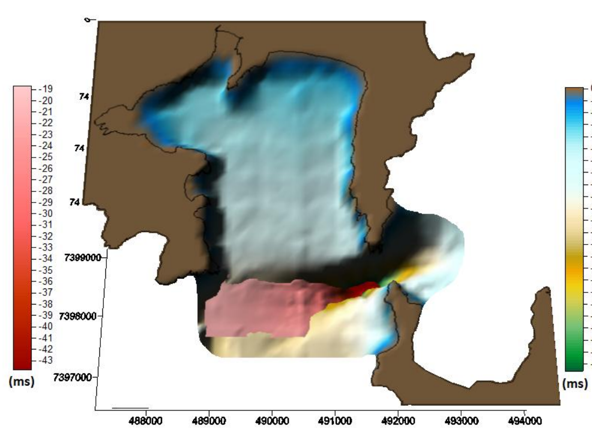


Figure 10: Model of depositional sequence (SD) formed in Boqueirão Strait.

The reflector R3 may also be related to the homonym reflector described by Mahiques & Souza (1999), which shows patterns similar to those of R1, revealing the presence of two major erosional events indicated by the present shape of the bottom surface and R3.

These similar patterns allows to conclude that the same dynamic processes that maintains the shape of the bottom of Boqueirão as it is nowadays are comparable to those responsible for developing R3, which may possibly be related to the Cananéia transgression, which occurred about 120,000 years BP, when sea level reached 8 meters high above the current level.

The seismic records revealed distinct patterns of eco-character along the surveyed area and, for the classification of such patterns, a classification guide proposed by Baptista Neto (1993) with four distinct types of echo characters were adopted with adaptations (Figure 10):

- Echo-character type1: highly reflective surface with little or no penetration of the acoustic signal and presence of sandy sediments mostly medium to fine;
- Echo-character type 2: highly reflective surface, more signal penetration, allowing visualization to the acoustic basement;
- Echo-character type 3: little reflective surface, showing subsurface reflectors and presence of finer sediments like silt;
- Echo-character type 4: Strongly reflective, with extremely irregular background corresponding to rocky outcrops.

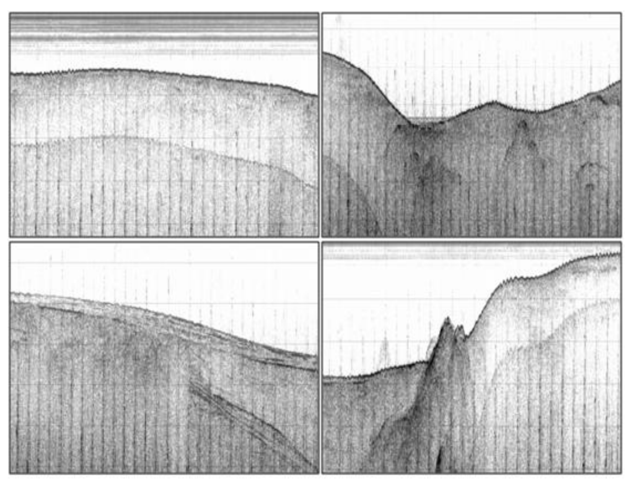


Figure 10: clockwise – echo-character types 1, 2, 3 e 4

Generally, near rocky shores it is common to find echo type 1 while type 2 is found primarily in the sheltered regions of the Bay. However, types 3 and 4 are preferentially found in Boqueirão area.

There are also regions with more than one type of eco-characters due to the variability of sediment types, generating gradations that can be smooth or abrupt.

Conclusions

The two studied compartments are clearly separated by both background morphology and sedimentary processes that govern them.

The inner part of the bay presents relevant homogeneity of parameters, unlike the complex environment formed by Boqueirão Strait and adjacencies.

The sonographic records reflect this homogeneity that is interrupted only by the appearance of high isolated reflection targets and features with alternating intensity reflection near the rocky shores, which is characteristic of rocky outcrops accompanied by small ripple marks

The geophysical methods allowed the recognition of an irregular subsurface reflector, R1, which marks the depositional unit (U1) between it and the surface. It also allowed for modeling the thickness of this layer that has its depositional center in the northwest center of the Bay. This layer was identified as a representative of the Holocene deposition. Both R1 and U1 are absent in Boqueirão and in the region of its influence.

The second compartment analyzed, Boqueirão Strait, has the greatest depths of the study area, reaching 33 meters deep. The seismic records show the absence of R1, which was totally eroded, and the presence of a local modern depositional sequence (SD).

The reflector R3 found in Boqueirão can be correlated with the Cananéia Transgression and has the same conformation of the present surface, suggesting that the processes that led to the current form of Boqueirão were the same as it was 120,000 years ago.

Acknowledgments

The authors wish to express their gratitude to the Oceanographic Institute of the University of São Paulo for financial e technical support. We also thank IPT - Institute for Technological Research, especially Dr. Luiz Antônio Pereira de Souza, for all transmitted knowledge and assistance provided.

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