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RESEARCH PAPER

NORTHEAST GUANABARA BAY AND COASTAL PLAIN HOLOCENE SEDIMENTARY EVOLUTION (BRAZIL): A CONTRIBUTION

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Abstract

Sedimentological and radiocarbon investigations are part of an ongoing research on the Bay-head delta of northeast Guanabara Bay, Rio de Janeiro State. Sediment accumulation indicates that the Holocene infill of the bay-head delta started around 8.2 kyr BP and was not in pace with the eustatic sea-level rise. Sediment accumulation was faster during the transgressive phase (0.56 $cm.yr^{-1}$). However, during the regressive phase, progradation driven by base-level fall was predominant over vertical sediment accumulation (0.02 $cm.yr^{-1}$). Based on coring, three sedimentary units were defined: fluvial sands (U1), estuarine deposits (U2) and fluvial mud (U3).

Keywords: Guanabara Bay. Sediment Accumulation. Marine Transgression and Regression.

1. Introduction

In large protected coastal bays, such as Guanabara Bay in Rio de Janeiro, sedimentation and accumulation of silt-clay particles are enhanced by estuarine processes, specially under microtidal conditions (Kjerfve et al., 1997; Figueiredo Jr. et al., 2014; Murray-Wallace and Woodroffe, 2014).

These environments, where fine-grained sediments accumulate under low-energy estuarine conditions, are essential to a comprehensive understanding of sedimentary conditions, particularly when considering lateral changes in facies and a marked transgressive-regressive transition.

Guanabara Bay is structurally dominated by Precambrian rocks and lies in the center of a major semi-graben that developed on a passive margin setting from 58 - 20 Ma (Zalán and Oliveira, 2005; Silva et al., 2015). The origin of the current bay, rivers and coastal systems is intimately associated to the last eustatic marine transgression that flooded part of the Guanabara semi-graben.

The evolution of Guanabara Bay is an example of the role played by the last marine transgression that flooded and transformed coastlines worldwide during the late Quaternary (Rabineau et al., 2006). The start of infill over the Pleistocene substrate of Guanabara Bay was predicted by Amador (2012) to take place over 12 thousand years BP. Given the depth (over 50 meters) of the channel (Kjerfve et al., 1997) that connects the bay to the ocean and eustatic sea level observed elsewhere (Lambeck and Chappell, 2001; Muhs et al., 2003; Rabineau et al., 2006), that estimative is consistent. Sediment accumulation and supply to Guanabara Bay throughout the Holocene are quite complex and yet not fully understood (Figueiredo Jr. et al., 2014; Kirchner et al., 2015).

Guanabara Bay was extensively studied by Amador (2013, 2012, 1997, 1980a, 1980b, 1974) and Amador and Ponzi (1974a, 1974b), considering the geological evolution and historical development. Amador (1997, 2012) suggested that Guanabara Bay doubled in size during the Maximum Holocene Transgression (Angulo et al., 2006) and showed that it was drastically altered by post-colonial human induced activities.

Guanabara Bay is surrounded by the metropolitan area of Rio de Janeiro and is considered a highly impacted environment, particularly in view of industrial activities, urban and agricultural runoff, trace metals, sewage discharge, anthropogenic debris, dredging, coastal interventions and landfills (Baptista Neto et al., 2013; Fonseca et al., 2013; Abuchacra et al., 2015; Cordeiro et al., 2015; Fistarol et al., 2015; Aguiar et al., 2016; Carvalho and Baptista Neto, 2016; Silva et al., 2016; Soares-Gomes et al., 2016).

1.1 Aim of the research

The objective of the present study was to investigate the early signals of the last marine transgression, the sedimentary conditions and extent of inundation during the Maximum Holocene Transgression. The study area comprises the Bay-head delta of northeast Guanabara Bay, including the Guapimirim Environmental Protected Area (*Área de Proteção Ambiental* Guapimirim), a relatively well-preserved and largest mangrove forest around this coastal system (Fig.1).

2. Material and methods

The Holocene sedimentary evolution of the bay-head delta of northeast Guanabara Bay was investigated by coring, excavation (shallow sediment profiling) and radiocarbon age dating. Facies analyses were performed through the integration of sedimentological and radiocarbon data on several sediment cores and excavations (shallow sediment profiling). Cores were collected using a *Rammkernsonde* and Russian Peat Corer. Cores and samples were described in the field, considering lithology, compaction, laminations, bioturbations, mollusk shells and plant debris. All those cores and excavations are part of an ongoing research that allowed the determination of three sedimentary units.

However, here only preliminary results obtained in core T4 are presented. Core T4 is located on Latitude -22º 39` 37", Longitude -42º 56` 26", and was collected along the bay-head delta with a *Rammkernsonde* corer. Samples were freeze-dried and subsampled for grain-size analysis (Mastersizer Hydro 2000G and Retsch CAMSIZER P4), for organic matter (OM) content through loss-on-ignition (Schumacher, 2002) and calcium carbonate ($CaCO_3$) content (Gross, 1971).

Sedimentary facies, textural, organic matter and $CaCO_3$ results were analyzed in this core. The age model of core T4 is based on four radiocarbon data measured in three mollusk shells and one wood. The samples for radiocarbon dating were chemically prepared and measured at the Radiocarbon Laboratory of the Universidade Federal Fluminense (LAC-UFF). Samples were calibrated through OxCal software (Bronk Ramsey, 2009) using the Marine13 curve (Reimer et al., 2013) and delta R 32 ± 44 (Alves et al., 2015). The terrestrial sample was calibrated using SHCal13 (Hogg et al., 2013).

3. Results

Core T4 is 9.38 meters long and was collected on the floodplain of the Macacu river, 11.5 km from the shoreline and 1.129 meters above sea level (Fig. 2). Facies analyses allowed the determination of three sedimentary units (fluvial sands, estuarine deposits and fluvial muds) over a Pleistocene substrate, with the preservation of transgressive and regressive deposits. Based on radiocarbon data (Tab.1), sediment accumulation rates were calculated (Fig. 3).

3.1 Unit I (-938 to -890 cm)

This unit consists of a fining upward interbedded sand and mud, but predominately unimodal and bimodal, very poorly sorted sand. Reworked mollusk shell fragments were observed in this unit, which suggests a lag deposit as result of the early signals of the last marine transgression around 8 thousand years BP (Fig.2).

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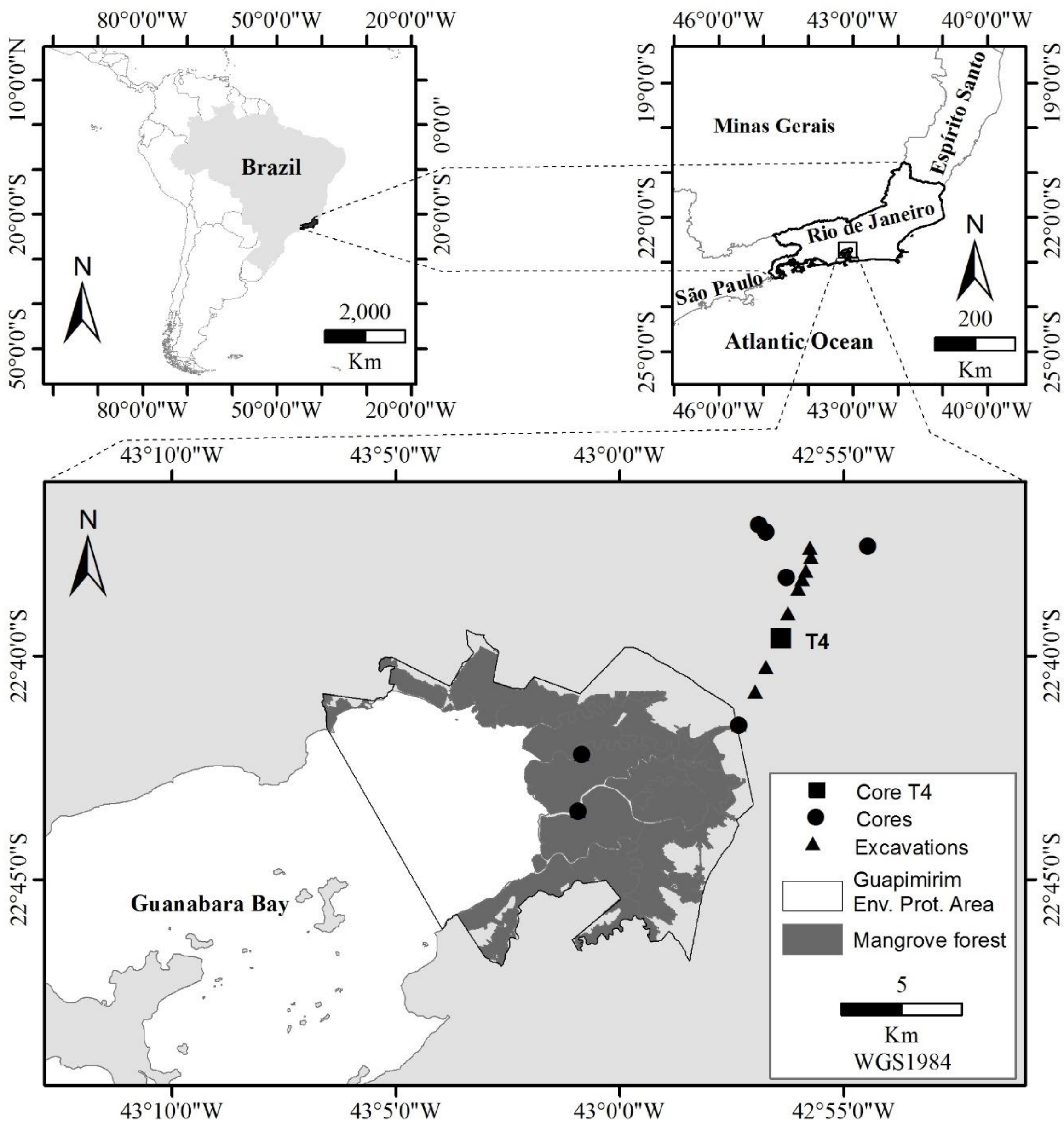

Fig. 1. Study area and sampling points. Core T4 is the focus of this study.

Tab. 1. Results of the radiocarbon data on core T4.

Sample Identification			^{14}C age (BP)		Calibrated Age			
Code	Depth (cm)	Material	Age (BP)	Uncertainty	Maximum	Minimum	Certainty (%)	Cal. year BP
150293	116	$CaCO_3$	4498	±78	4841	4411	95.4	4642
150294	138	$CaCO_3$	4574	±57	4908	4520	95.4	4726
150295	163	$CaCO_3$	4977	±68	5482	5016	95.4	5267
150265	898-908	wood	7416	±50	8331	8041	95.4	8197

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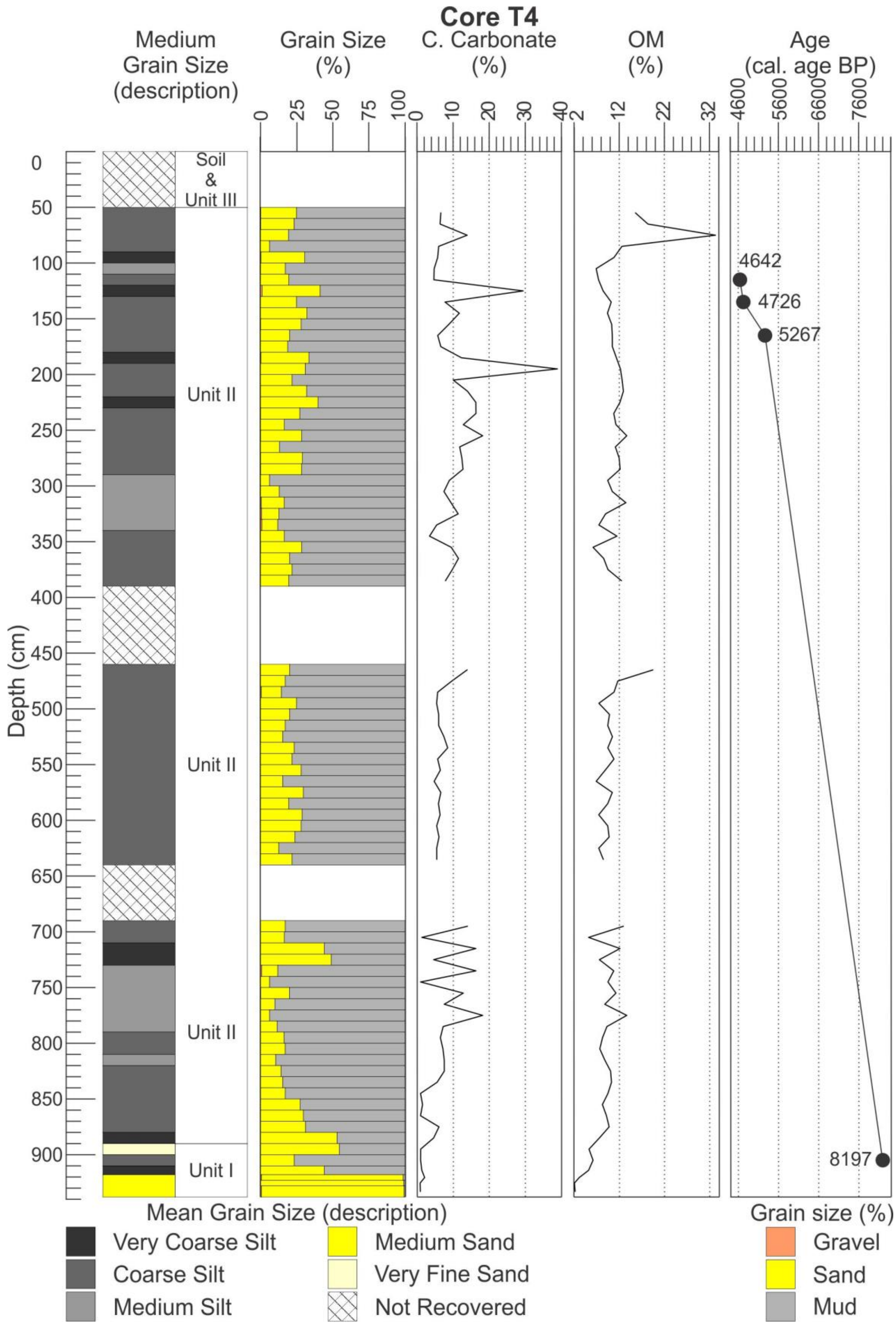

Fig. 2. Results of medium grain size, sedimentary units, calcium carbonate (%) and organic matter (%) content in 10 cm intervals and calibrated radiocarbon data (cal. age BP). Unit III on core T4 was only described in the field.

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3.2 Unit II (-890 to -50 cm)

Unit II displayed an overall fast fining upward estuarine infilling from 8197 to 4642 years BP (Fig.2), which is indicative of hydrodynamic energy decreasing as a result of sea level rise. Calibrated radiocarbon age in 163 cm, 138 cm and 116 cm, was respectively 5267 cal. years BP, 4726 cal. years BP and 4642 cal. years BP, interpreted here, based on the sea level curve from Angulo et al. (2006), as a period of transition between the transgressive and highstand phases. From 8197 to 4642 cal. years BP, sediment accumulation rate of 0.56 $cm.yr^{-1}$ (Fig. 3) that resulted in a 7.89 meters thick deposit (Fig. 2) suggests that sediment supply and vertical accumulation under estuarine conditions were intense, regardless of sea level rise and the continuous increase in accommodation space. From 4642 cal. years BP at 116 cm down core to present, an overall very slow sediment accumulation of 0.02 $cm.yr^{-1}$ was observed.

3.3 Unit III (-50 to 0 cm)

Unit III, comprised between 4642 cal. years BP (116 cm) and present time (0 cm), is placed in a very slow sediment accumulation phase (0.02 $cm.yr^{-1}$). This unit was only described in the field and consisted of an orange tinted fluvial mud and soil that is usually flooded during rainy season.

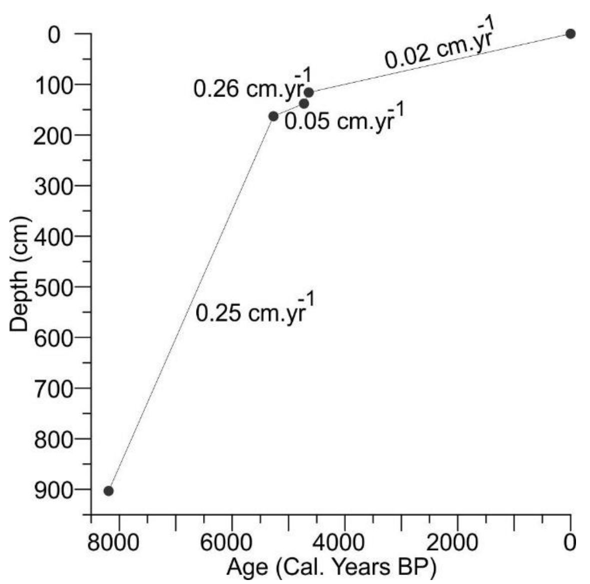

Fig. 3. Calibrated radiocarbon age (cal. age BP) and sediment accumulation ($cm.yr^{-1}$).

4. Discussion

The marine transgression and accumulation of estuarine sediments on the bay-head delta of northeast of Guanabara Bay occurred around 8200 years BP, with the predominant fining-upward deposition of silt particles until ~4500 cal. years BP. On the bay-head delta, it was observed a much faster sediment accumulation rate in the transgressive phase. This sedimentological setting suggests that northeast Guanabara Bay infilling since ~8200 cal. years BP developed as a sheltered environment bellow base-level with abundant sediment supply. During the regressive phase, shoreline progradation driven by base-level fall on a reduced accommodation space was predominant over vertical aggradation.

Following Catuneanu et al. (2009) sequence stratigraphy definitions, we argue that faster sediment accumulation rates observed during the transgressive phase since 8200 cal. years BP are probably the result of abundant sediment discharge due to significant climate change and sea level elevation, as shown by Kirchner et al. (2015) and Figueiredo Jr. et al. (2014). Facies analysis and radiocarbon dating on core T4 indicate that the transgressive infilling of the outer part of the bay started before 8200 cal. years BP, as observed in coastal bays and estuaries around the globe (Woodroffe et al., 1993; Maddox et al., 2008; Rodriguez et al., 2008; Weschenfelder et al., 2014; Boski et al., 2008, 2015; Kostecki et al., 2015; Masuda and Itomoto, 2015; Borges and Nittrouer, 2016). of the Bay-head delta as a result of previous sediment infilling during the transgressive phase along the study area.

The identification of thick transgressive estuarine deposits 11.5 km away from the present shoreline indicates that the Guanabara Bay was wider as predicted by Amador (2012, 1997). The predominant accumulation of silts and the preservation of three sedimentary units (fluvial sands, thick estuarine deposits and fluvial muds) indicate a constant supply of fine sediment particles by rivers and the development of a low energy environment of northeast Guanabara Bay since 8200 cal. years BP. This setting shows that the bay acts as a sink, especially for fine sediment particles. Nowadays, considering the alarming environmental quality of Guanabara Bay (Baptista Neto et al., 2013, 2016; Fonseca et al., 2013; Abuchacra et al., 2015; Cordeiro et al., 2015; Fistarol et al., 2015; Abreu et al., 2016; Aguiar et al., 2016; Carvalho and Baptista Neto, 2016; Silva et al., 2016; Soares-Gomes et al., 2016), we assume that the bay acts as a sink not only for sediments but also for pollutants.

5. Conclusion

Transgressive sedimentation on Guanabara Bay occurred prior to 8200 cal. years BP. In the northeast region of Guanabara Bay, an extensive bay-head delta developed as result of an intensive sediment accumulation in low energy transgressive conditions followed by rapid shoreline progradation (~11.5 km) in regressive conditions. Abundant sediment supply throughout the Holocene under estuarine conditions played a major role on the development of the extensive bay-head delta. The northeast portion of the bay showed a high potential for the preservation of the sedimentary strata.

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