Depositional sequences in the central coast of Maricá (RJ) identified through ground penetrating radar (GPR) investigation

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This paper was prepared for presentation during the 11th International Congress of the Brazilian Geophysical Society held in Salvador, Brazil, August 24-28, 2009.

Abstract (Font: Arial Bold, 9)

The integration of data obtained from ground penetrating radar (GPR) images and borehole's cores and samples collected at the central coast of Marica (RJ) provided information about the evolution of this coastal plain. The results indicated the existence of several depositional units above weathered basement rock, these units being mostly related to the dynamics of a barrier-lagoon system. The data also presents evidence of an important sea transgression over the basement giving rise to an earlier barrier-lagoon system which gradually retrograded; this was followed by a regression of the sea forcing progradation of this coastal system; another transgression occurred forming a new barrier-lagoon system that still today is undergoing retrogradation. There are several examples in the world of formations which represent ancient barrier-lagoon models that contain oil or gas, and this work aims to contribute to the improvement of the current knowledge of modern analogs of such geological systems and its exploration.

Introduction

The coastal plain geomorphology of Maricá is characterized by presence of the large Maricá Lagoon and by two sandy barriers which confine a series of small isolated lagoons (figures 1 and 2 A and B). This is considered an environmental protection area (APA) by the government and as such is well preserved except for the illegal sand extraction that locally destroy the vegetation and changes the landscape.

Several studies have aimed to understand the geological and geomorphological history of the Maricá coast (Muehe, 1975; Muehe, 1984; Muehe, et al., 1984; Muehe, 1989; Perrin, 1984; Ireland, 1987; Turcq, et al., 1999; Santos & Silva, 2000; Pereira, 2001; Pereira et al., 2003; Lins-de-Barros, 2005; Silva, 2006; Silva et al., 2008; Silva et al. in press). However, the stratigraphy and depositional sequences are not well understood. These provide clues for the dynamics and evolution of the barrier-lagoon system, age relationships and sea level changes. Such is the objective of this work, a contribution to the understanding of the Maricá barrier system and the processes related to its migration through the Quaternary.

Figure 1: Location of study area, central coastal plain of Maricá (RJ, Brazil). www.cdbrasil.cnpm.embrapa.br.

Ground penetrating radar (GPR) provides high-resolution images of the shallow stratigraphy with much more detail and continuity than conventional methods. The application of GPR in studies in many parts of the world became a common practice from the 70's onwards (Neal, 2004). In Brazil the methodology has been applied from the last decade on in different types of environments such as sandy barriers, aeolian dunes, fluvial deposits, karst topography, and on the Barreiras Formation (Madeira, 2001; Pereira, 2001; Pereira et al., 2003; Moutinho et al., 2005; Neto, 2006; Santos et al., 2006; and others). In this work, GPR was used to map the poorly known sedimentary sequences and internal geometry of the quaternary barrier – lagoon system of Maricá. Boreholes helped to make data integration in order to achieve the objectives. Several formations, of different ages, and in different parts of the world, regarded as paleo barrier-lagoon systems, are oil and/or gas reservoirs, and so modern analogs are increasingly used as models in the oil industry. This work hopes to bring more information about the basic characteristics of the barrier systems.

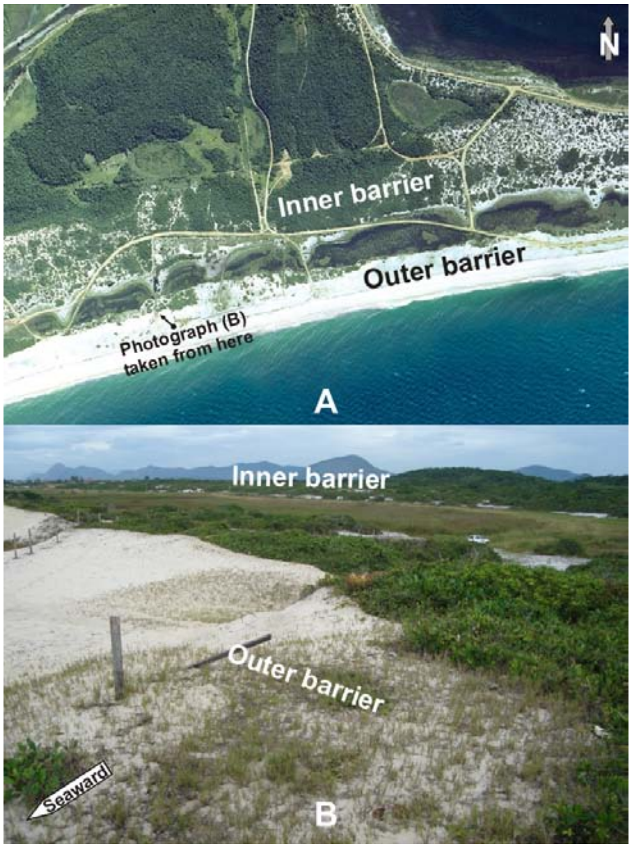

Figure 2- (A) Aerial photograph of the barrier system discussed in this paper showing the two barriers and the lagoonal plain in between; the Maricá lagoon is visible at the upper right of the photo; (B) a panoramic view of the local coastal geomorphology (2007).

Method

The GPR profiles were collected oriented both parallel and perpendicular to the coastline (profile 1 – parallel; profiles 2, 3, 4, 5, 6 and 7 – perpendiculars) (figure3). GPR data was collected using a Georadar GSSI (Geophysical Survey Systems Incorporated), SIR-2000 model. 200 MHz shielded antennae provided the best arrangement between resolution and depth of penetration, about 25 m below the surface in this area. Processing was conducted using RADAN (Radar Data Analysis) software and included application of gains and filters, deconvolution, topographic correction and migration. For the topographic correction of GPR data, a topographic survey was carried out along the same profiles. Velocities were determined from CMP (common mid-point) surveys in nearby areas of Maricá as 0,10 mns-1 (Pereira, 2001). This is the medium velocity calculated from other CMP surveys in lagoonal and unsaturated and saturated sands below the water table (Neal and Roberts, 2000, apud Neal, 2004). Three boreholes, using percussion, were carried on along line 2, in the inner and outer barriers and in the lagoonal plain. One-meter long cores and grab samples were described and correlated to main GPR reflectors.

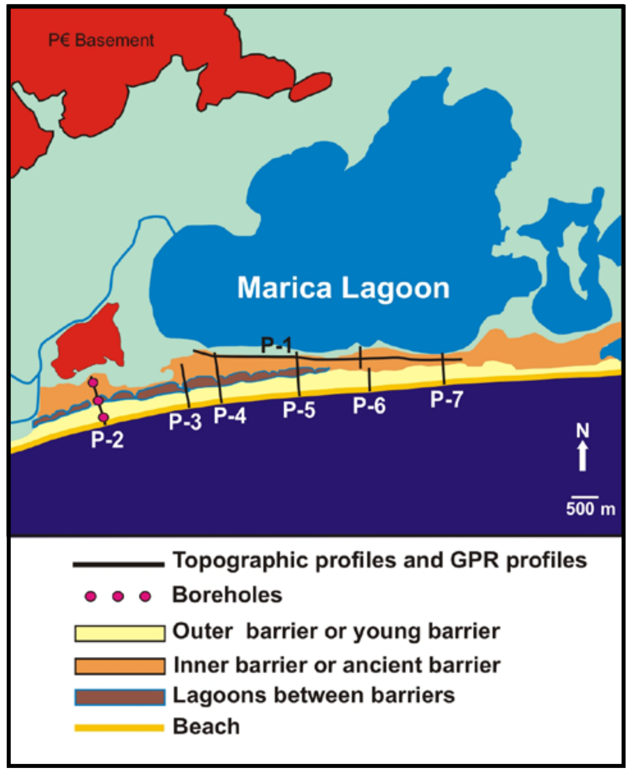

Figure 3: Location of GPR and topographic profiles, and boreholes.

Results

Results are here discussed based on line 2 and 3 boreholes obtained along this 750 meters long profile (figure 3). The more prominent reflectors were identified and they allow a preliminary definition of these coastal depositional sequences (figure 4). The base of this coastal package appears as reflector A, a strong continuous seaward dipping reflector, which represents the top of weathered basement rocks (borehole S2-IB), here named unity I (figure 4). This reflector is best defined at the inner barrier region where it lies at the depth of about 20 meters. Reflector A progressively diminish intensity towards the sea, and at the outer barrier region it is not seen. Here, the weathered basement lies at about 25 meters indicating that the basement gentle dips towards the sea along this profile. Basement (unity I) appears as a reflector free unity, regarded as typical for basement rocks (Switzer et al, 2006).

In the area of the inner barrier, a second reflector (B) is present for an extension of about 400 m reaching the lagoonal plain, where it lies directly on the basement (figure 4). There is a sharp increase in grain size of the sediments as observed in borehole S2-IB, at about 10 m depth. Reflectors A and B define a lithologic unity, approximately lenticular in shape, composed of coarse sand and gravel (unity II). Reflections within this unity are semi parallel to chaotic. Unity II geometry and composition suggest a sedimentary deposition coming from inland resting upon the basement.

Farther south, reflector C dips gently seawards for an extension of about 300 meters. It represents a sharp lithological change from mud (below) to sand (borehole S2-LP). Unity III is bounded by reflectors A and C and it is 8 meters thick under the lagoonal plain area; it shows seaward dipping strata (20-22°) towards the inner barrier (figure 4), but they disappear in the more central area of unity III. Geometry and lithology are suggestive of a paleolagoon environment.

Reflector D is a continuous reflector between the area of the lagoonal plain and the outer barrier (figure 4). It has a concave up shape that changes to a flat horizontal surface towards the outer barrier. Borehole S2-OB showed the presence of sand and gravel on top of a thick sandy unit (unity IV). Unity IV is mostly a sand layer that can reach 15 meters of thickness, and is homogeneously distributed throughout the profile. It's main characteristic is a variety of internal reflectors representing strata either dipping towards the continent as well as strata dipping to sea (downlaps). Such behaviour is typical of an earlier retrograding barrier, which cover the paleolagoon (unity III) and reaching the position of the inner barrier, where the sand of this unity IV outcrops and characterize the present day landform of the inner barrier. The barrier later prograded, and the progradation sets can be traced down to underneath the present lagoonal plain (around 550m along the profile). So, this unity IV has a remarkable evidence of a retrogradation of the barrier-lagoon system followed by a progradation of the earlier coastline.

Associated with the reflector D, under the lagoonal plain, there is a set of plane parallel strata representing mud with organic matter, muddy sand and sand (unity V; borehole S2-LP). This unity is here interpreted as a second lagoon which was filled up with sand and forms the present day lagoonal plain. The same geological configuration was confirmed by Pereira (2001) and Pereira et al. (2003) that indicated the age of 5.900-6.040 years before present for such lagoonal environment. It can be separated into unity VI which corresponds to the modern outer barrier. It is 5 meters thick and the sand presents the same texture and composition of the modern barrier form bottom to top. On the barrier front (facing the beach) this unity VI is characterized by reflectors dipping 25 to 45° to the sea (figure 4) which may represent old beach storm scarps, like the ones seen today at the inner limit of the beach. The face of the barrier to the continent also has steep dipping layers which continue all the way to the surface where today there is a small dune field.

Extensive mining of sand created a topographic depression on the outer barrier measuring 3 m of depth/ 120 m wide/ 300 m length (figure 4). The illegal extraction retrieved around 100.000 m³ of sand destroying the landscape and the sand barrier ecosystem, even inside an environmental protection area.

One last strong and very continuous reflector E is the expression of the water table, and can be observed along the entire profile at very shallow depths (3 to 4 meters) or even reaching near the surface giving rise to the wet plain between the barriers (figure 2 A & B). The present-day morphology of the barriers and lagoon appears as reflector F.

Conclusions

The association of GPR images, samples and cores from boreholes collected at the Maricá coastal plain allows a preliminary discussion about the depositional sequences and order of events. On top of weathered Precambrian basement rocks there is a 20-25 meters (maximum along the profile here presented) sedimentary deposit relative to a previous barrier-lagoon system. This deposit contains evidences of relative sea level fluctuations during the time interval of sedimentation. At the base, a mud layer (unity III) here interpreted as a paleolagoon deposit points out to a former barrier-lagoon system (the barrier itself was farther south). This coastal environment underwent transgression and so a retrogradation sequence developed with barrier sands (unity IV) on top of lagoonal muds. As a result of this important transgression, the retrogradation of the barrier reached very far inland giving rise to the inner barrier (as seen today). Afterwards, the barrier prograded as shown by the several reflectors with downlaps almost troughout the entire cross section, which indicates a sea level fall. On top of that, another barrier-lagoon system was established as consequence of a sea level rise: the lagoonal muds (unity V) were covered by barrier sands (unity VI) as a consequence of this continuing transgression, which is still happening today. So, the data presents evidence of (1) an important transgression of the sea over pre-existing rocks (basement) giving rise to an earlier barrier-lagoon system which gradually retrograded; (2) followed by a regression of the sea forcing progradation of this coastal system; (3) another transgression forming a new barrier-lagoon system, the expression of today's lagoonal plain and outer barrier system, that it is still continuing to retrograde, as pointed out by Lins-de-Barros, 2005; Silva, 2006 and Silva et al., In press. This research will continue and new boreholes are planned as well as the further interpretation of the collected GPR lines.

Acknowledgments

This project was funded by FAPERJ (E-26/170 452/07). The authors would like to thank CENPES-PETROBRAS for the GPR equipment and for processing of the GPR data. Thanks also to the responsibles for the Maricá APA for permiting access study area. We are very grateful to friends and students who helped during field work.

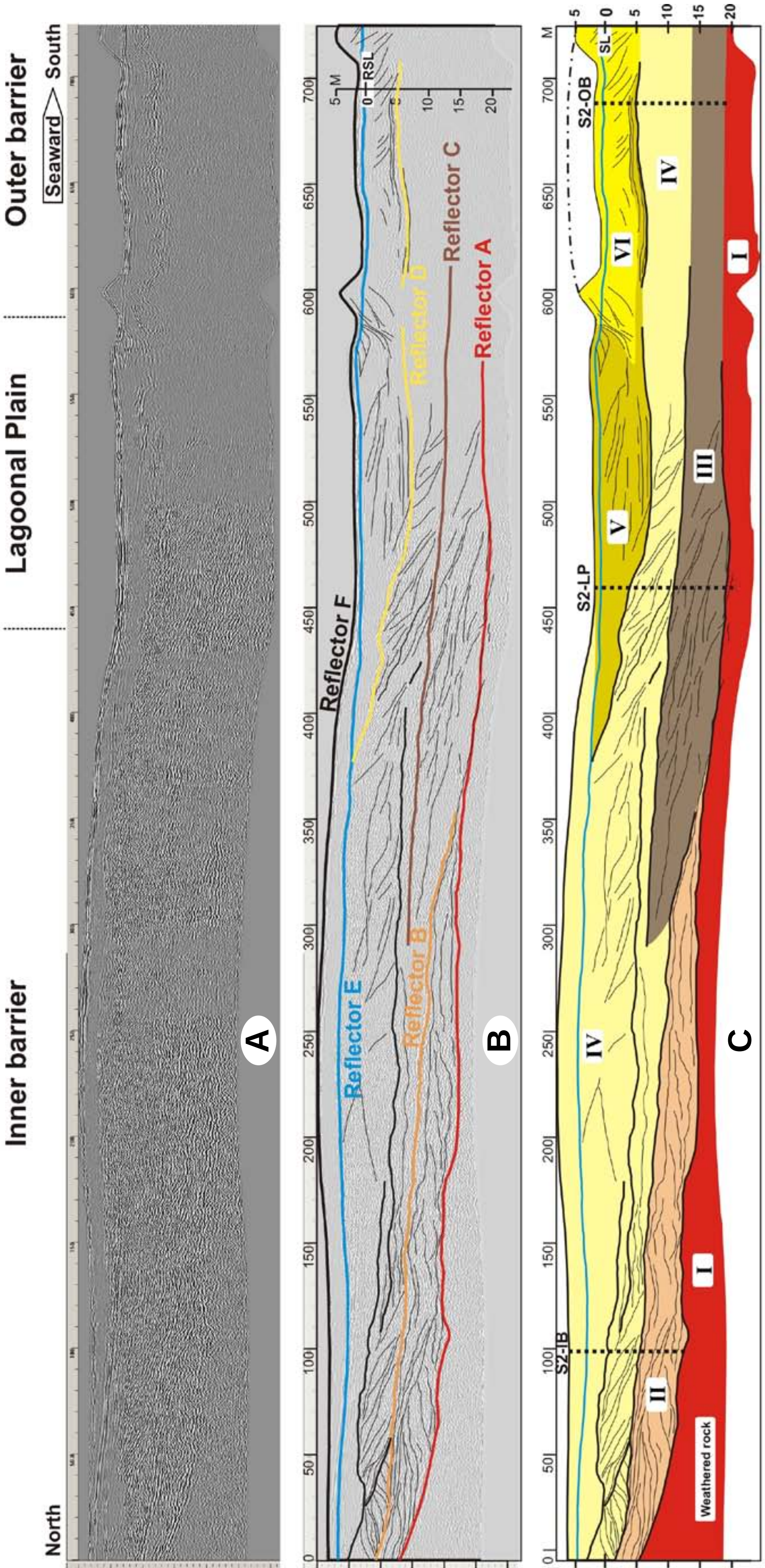

Figure 4 : A – GPR profile 2 collected perpendicularly to the coastline. B – GPR interpretation. C – Stratigraphy and deposition units of the barrier-lagoonal system in the Maricá coastal plain.

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