GPR investigation on a beach ridge coastal plain, Paraíba do Sul River delta

Alberto Garcia de Figueiredo Jr.*[1], Cleverson Guizan Silva[1], Sidney Luiz de Mattos Mello[1], Lucia Artusi[2], Suzana Hinds Ferreira da Silva[1], Valdenira Ferreira dos Santos[3], Cláudia Zetune Gonçalves[1], Lázaro Matos Laut[1], Valterlene de Oliveira[1], Carlos Manoel Vargas de Figueiredo[4].1- UFF; 2- IEAPM; 3- IEPA; 4- INB

This paper was prepared for presentation at the 8th International Congress of The Brazilian Geophysical Society held in Rio de Janeiro, Brazil, 14-18 September 2003.

Abstract

Paper is related to use of GPR in a coastal plain dominated by beach ridge in order to understand stratigraphy, sedimentary units thickness and geometry to be applied on heavy mineral research.

Results allowed identification of three main radar facies. The upper one related to washover deposits and beach ridge crest degradation. Intermediate unit has characteristic sigmoidal radar surfaces and is related to beach face deposits. Lower radar facies can be related to pro-delta deposits or river flood plain deposits.

Introduction

Heavy minerals have density higher than quartz (2.6) and are disseminated in sediment. And due to their density, they can be selected and concentrated during transportation by wind and currents. Most common heavy minerals are ilmenite, pyroxene, amphibolites, garnet, zircon, staurolite, monazite, rutile, cassiterite, apatite, gold and diamond.

Concentrations of heavy minerals by wave action on sand beaches are very common and they can form extensive deposits depending on sediment source and wave characteristics. In the Paraiba do Sul River delta, because sediment supply and sea-level fluctuation during the last 5,000 years, a series of beach ridges have formed a wide progradational coastal plain as much as 20 km wide (Fig. 1). The heavy minerals mineralogy is predominantly amphibolites and pyroxene, secondarily garnets. Ilmenite and magnetite appears as the third most common mineral with relative mean concentration less than 10% (Figueiredo Jr. *et al.*, 2002). Other heavy minerals of economic interest are zircon, rutile, leucoxene and monazite. Not all beach ridges are mineralized and the most prone are those formed during high wave energy periods. Once formed the beach ridges can be superimposed by over wash deposits and also degraded by erosion with time. Both factors contribute for transforming the beach-ridges into a field of gentle undulations after thousands of years.

In order to better characterize the beach-ridges, a ground-penetrating radar (GPR) was used to identify the sedimentary units, to determine the depth and geometry of each unit and locate targets to be cored.

Because monazite is radioactive heavy mineral and it is always present and associated with other heavy minerals in the study area, survey with a Geiger counter was very useful to locate the GPR profiles in the most prone areas.

The study area is located in the south portion of the Paraiba do Sul River delta, Rio de Janeiro State

Method

Prior to GPR survey, 1,048 measurements points were taken with a Geiger counter along several cross sections (Fig. 1). The areas with most expressive values were chosen to be surveyed with GPR. Seven profiles of GPR were run perpendicular to beach-ridges crests totaling 9 km. Each profile was subdivided into 100 meters sections marked by wood sticks with notation of profile and section number.

The equipment used was a Ramac with two antennas of 200 MHz set 60 cm apart in a fiberglass boat towed by hand. Electromagnetic pulses were controlled by a spinning wheel set to be fired every 0,20 m and data was acquired with a note book computer. Horizontal position and elevation of shot points were controlled with a Differential Global Positioning System (DGPS) on cinematic mode and within cent metric precision.

The techniques used on GPR acquisition and interpretation are very similar to seismic reflection. In GPR an electromagnetic high frequency pulse of 10 to 1000 MHz is transmitted by an antenna to the ground. The pulse propagates with a finite velocity depending on soil properties and is reflected and diffracted accordingly to changes in sediment composition, water content grain-size and compaction (Davis & Annan, 1989; Baker, 1991; Pestana & Botelho, 1997; van Dam & Schlager, 2000). As in seismic, continuous systematic reflection signals are denominated “radar surfaces”. A set of radar surfaces with characteristic configuration, continuity, frequency can then be used to define “radar facies” (Neal *et al.*, 2002).

GPR data processing initiated with electronic noise filtering using De Wow routine with Gradix from Interpex Ltda. A high-pass filter was applied after spectral analysis of each record in order to determine the best cutoff frequencies found between 80 and 260 MHz and a residual mean frequency of seven filtered points. Next a Gaussian pass-band filter of 120 MHz was applied in order to remove reflectors attenuation and to promote a spectral balance along the record. Because there were not many diffractions patterns, data migration was not applied so dipping reflectors could be slightly out of their true horizontal and vertical position. Depth conversion of travel time (ns) to meters was based on previous experiment in the area using estimated velocity of 0.085 m ns^{-1}. Maximum depth penetration was 8 meters.

Results

GPR profiling allowed definition of 3 radar fácies, each one with distinct radar surfaces (Fig. 2). The top radar facies is characterized by short, sporadic, horizontal radar surfaces and it can up to 3 meters thick. This facies could be associated with washover deposits and also sediments eroded from the beach ridge crests and spread in lower areas in the inter-ridges. There is no radar surface separating this upper facies from the underlying facies. The intermediate radar facies is characterized by a set of several sigmoid radar surfaces deeping toward ocean. The deep angle varies from 3° to 5° degrees. Some radar surfaces have higher signal strength indicating lithological changes. The intermediate radar facies is the most expressive unit and it can reach up to 5 meters in thickness. This facies is attributed to correspond to the beach face where heavy minerals are deposited. The causes of radar surfaces with higher strength are still to be determined, if related to heavy mineral deposit or coarser grain-size. The deeper radar facies has horizontal, undulating not so continuous radar surface. Because of radar surfaces characteristics and predictable geology, this facies could be associated with prodelta deposits or river flood plain deposits.

Conclusions

The use of GPR on beach ridges allowed determination of a radar stratigraphy, thickness and geometry of radar facies and their relation to sedimentary units.

This information associated with radiometric data will help define the targets to be cored in the next faze of the research.

Acknowledgments

Development of this research was only possible with research funds from the “Indústrias Nucleares do Brasil” (INB) to whom we are grateful. We are also thankful to the Department of Geology, Lagemar at “Universidade Federal Fluminense” (UFF), for support to this research. To Mr. Rinaldo M. Marques and Mr. André P. Dias from “Geopesquisas Ltda.” for their help during GPR profiling and data processing assistance. To Mr. Alexandre Benevento and Mr. Raul C.M. Aguiar from GNSS for assistance during DGPS data collection.

References

Baker, P.L. – **1991** – Response of ground-penetrating radar to bounding surfaces and lithofacies variations in sand barrier sequences. Explo. Geophys., vol. 22, p. 19-22.

Davis, J.L. & Annan, A.P. - **1989** – Ground-penetrating radar for high-resolution mapping of soil and rock stratigraphy. Geophys. Prospect., vol. 3, p. 531-551.

Figueiredo Jr, A.G., Silva, C.G., Mello, S.L.M., Figueiredo, C.M.V., Esteves, M.G.P., Pessanha, I.B.M. e Molinari, L. - **2002** - Minerais Pesados do Delta do Rio Paraíba do Sul, RJ, XLI Congresso Brasileiro de Geologia, João Pessoa, resumos, vol. 1, p. 21.

Neal, A., Pontee, N.I., Pye, K. and Richards, J. – **2002** – Internal structure of mixed-sand-and-gravel beach deposits revealed using ground-penetrating radar. Sedimntology, vol. 49, p. 789-804.

Pestana, R. da Cruz & Botelho, M.A.B. – **1997** – Migração de dados (GPR) com correção topográfica simultânea. Rev. Bras. Geof., vol. 15, no. 1, p. 3-10.

Van Dam, R.L. & Schlager, W. – **2000** – Identifying causes of ground-penetrating radar reflections using time-domain reflectometry and sedimentological analyses. Sedimentology, vol. 47, p. 435-449.

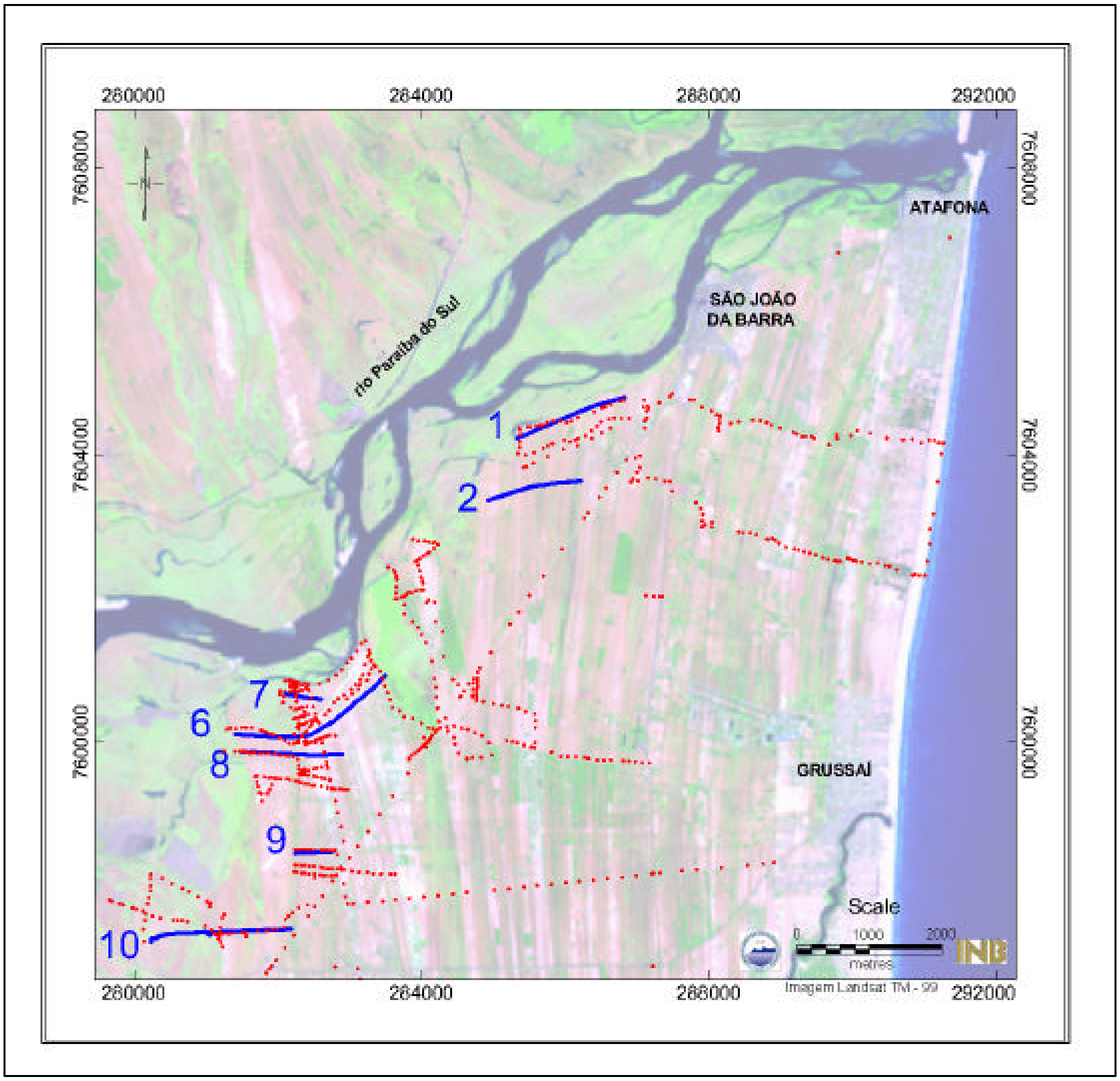

Figure 1 – Landsat TM image of study area in the Paraiba do Sul River delta. Beach ridges are seen as alternating pink and white ribbons. GPR profiles are represented as blue lines and points of radiometric measurements as red dots .

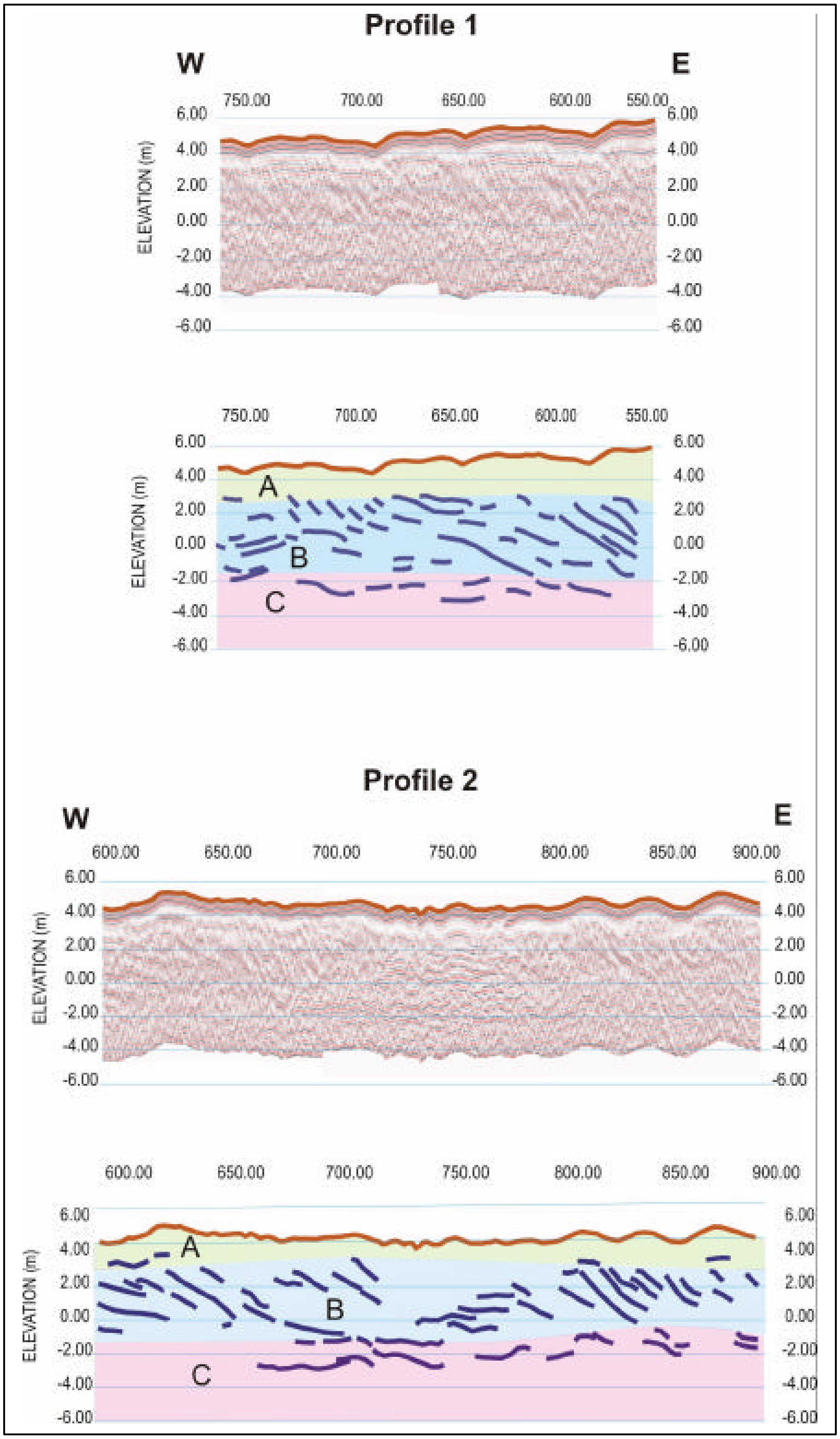

Figure 2 – Example of GPR records showing the three main radar facies. The top radar facies (A) is characterized by short, sporadic, horizontal radar surfaces. The intermediate radar facies (B) is characterized by a set of several sigmoid radar surfaces deeping toward ocean. The deeper radar facies (C) has horizontal, undulating and not so continuous radar surfaces.