Characterization of Sedimentary and Coastal Environments in The Crispim Beach – Marudá - Pará

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Abstract

The paper focuses on analyzing the shallow stratigraphy of Crispim Beach using data obtained with the high-resolution Ground Penetrating Radar (GPR) geophysical method. The results show that GPR is sensitive to sand and can contrast sedimentary characteristics on the coast of Pará relatively well. The study suggests that the coast of Pará has a complex behavior, with many movements and deposition of sediments influenced by agents such as wind, storms, and seas.

Introduction

The coastal zone is an environment where the continent, ocean, and atmosphere interact; and it is susceptible to sea level variation, due to the astronomical and oceanographic factors mentioned above and the influence of several climatic and meteorological parameters (MARTINS et al. 2004). Due to a succession of geological processes, these extensions present a non-stable environmental system behavior (LEITE, 2010). Inserted in the coastal zone, beaches are deposits of unconsolidated material, such as sand and gravel, formed at the interface between land and sea or another large water body (SUGUIO, 1992; Voigt 1998). The study area is in Marapanim in the Northeast Paraense mesoregion and Salgado microregion (FAPESPA, 2016), with the studied beach (Crispim) not located in the municipal seat and its access is via the PA-318 highway, being in the estuary region of the Marapanim River (Figure 1).

The municipality is classified as bordering the Atlantic Ocean bathing the Salgado Paraense region, presenting ecosystems in its area mainly mangroves, as well as estuaries, tidal flats, sandy beaches, and local restingas (SANTOS, 2018). Mangroves occur in a large part of the municipality's coastal territory, as the geography full of recesses favors the installation of this ecosystem of great importance (PROST et al., 2001). The coast of Pará undergoes significant variations daily, due to the action of the tide, which is quite influential in this location (BERREDO et al., 2008). These processes, critical for the formation of different types of coasts, include dynamics of erosion and sedimentation associated with waves, tides, ocean currents and rivers, glaciers, and wind action, in addition to tectonic movements along continental margins (MARTINS, 1987).

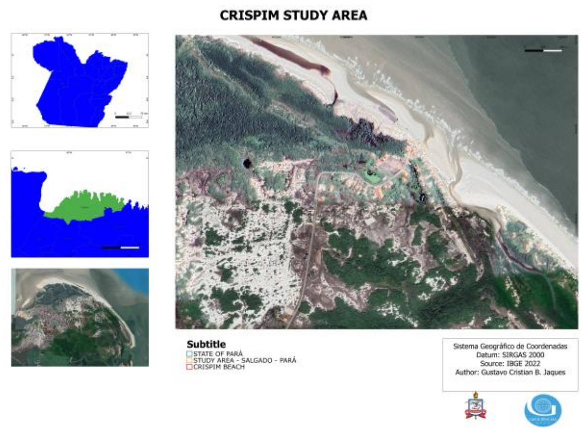

Figure 1: Location map of the study area. From the Author.

Stratigraphy aims to study, describe, interpret, and classify different layers of rock (called strata), considering the characteristics of deposition, relative and absolute age, stacking, and geometry of bodies (SIQUEIRA, 2022). Studies on sedimentology and stratigraphy on Tertiary and Quaternary age sequences in northern Brazil have been extensively carried out using strata in outcrops (Arai et al., 1997; Góes et al., 1990; Rossetti, 2000, 2001; Leite et al. al., 1997), but are often insufficient due to the lack of records in some fields, thus creating gaps that are not understood (SIQUEIRA, 2022). Therefore, the Radar Ground Penetration (GPR) method is used in research to overcome this deficiency, according to the literature (Rodriguez and Meyer, 2006; Neal and Roberts, 2000; Gandolfo et al., 2001; Barboza et al., 2014, 2018).

Ground Penetrating Radar (GPR) is the most suitable geophysical method for shallow investigations, showing excellent results in certain types of geological environments (GANDOLFO, 2001). Examples of stratigraphic mapping using GPR in various types of geological environments are found in Beres & Haeni (1991). With the achievement of excellent results in surveys on sandy deposits, a consequence of the low attenuation suffered by the electromagnetic signal in this medium (Jol & Smith, 1991; Jol et al., 1996; Van Overmeeren, 1998; Daly et al., 2002), (GANDOLFO, 2001).

The objective of this work was to analyze the shallow stratigraphy of Crispim Beach based on data obtained with the high-resolution Ground Penetrating Radar (GPR) geophysical method.

Environmental Physiography

The coastal strip has a high diversity of environments present in the strip, these being (SILVA, 2009):

Coastal plain: sheltering both banks of the Marapanim River, with the presence of the coastal plateau (30 km) and is directly influenced by physical agents such as waves, winds, and tide (BAIA, 2021).

Estuarine plain: the largest of the morphological environments, reaching the upper region of the Marapanim River, composed of the estuarine channel, secondary channels, and floodplains (BAIA, 2021).

Alluvial plain: a region that suffers periodic flooding of fresh water from the Marapanim River, with morphological units called meandering channel, deposit channel, and excessive deposits being inserted in this province (BAIA, 2021).

Geology and Geomorphology

In northeastern Pará, the Upper Tertiary and Quaternary deposits refer to the Pirabas Formation, Barreiras Group, Post-Barreiras, and Recent sediments (Farias, 1992). The coastal region dating from the Holocene is composed of partially submerged river valleys. Yellow latosol, with medium texture, indiscriminate concretionary lateritic soils, alluvial soils, and indiscriminate mangrove soils (FAPESPA, 2016).
Figure 2 Using criteria from lithostratigraphy in outcrops on the Bragantina and Pará platforms, Rossetti (2001) presented a division of this sedimentary package into three depositional sequences.

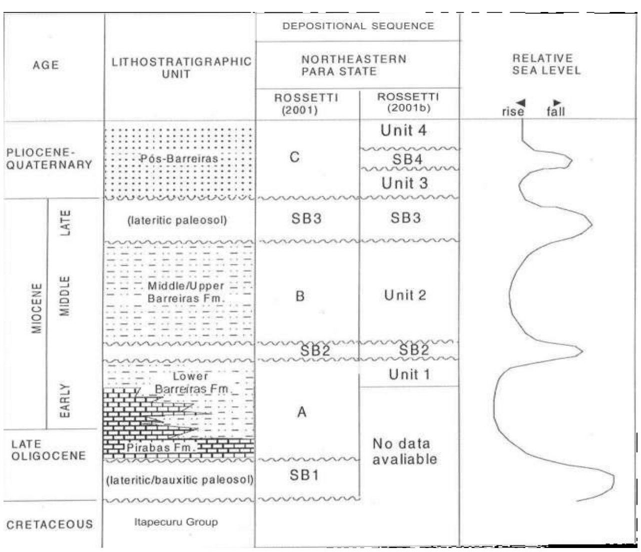

Figure 2: Stratigraphic model of the Bragantina Platform, suggesting sea fluctuations during the Cenozoic era, modified from Rosseti and Góes (2001).

The main geological formation Grupo Barreiras (Paleogeno) has sources of sand, silts, and clay - minerals, quartz, and oxy-iron hydroxides for the mangroves (BERREDO et al., 2008). The Pirabas Formation (Lower Miocene) reports deposits that are widely distributed in the area but covered by younger units. These deposits are only observed in erosional areas that have varying dimensions and thicknesses (CPRM, 2017).

The silt-clay sediments, rich in organic matter (C between 1 and 4%) are present in the mangrove environment and were deposited on sandy bars with smooth morphology and sedimentological aspects; the granulometry that determines the colonization of vegetation, the evolution of the drainage network and development of sediments, making them more consistent (BERREDO et al., 2008).

Method

Ground Penetration Radar

The Ground Penetrating Radar (GPR) method uses the propagation of electromagnetic waves from a transmitting antenna that propagates through the investigated environment, suffering reflection, reflection, and diffraction. The waves that return to the surface are detected by a receiving antenna – which can operate as a transmitting antenna – providing information about the subsurface (DANIELS, 1996).

The acquisition was performed using the TerraSIRch (Subsurface Interface Radar) System-3000 equipment from Geophysical Survey System Inc with a 200 MHz shielded antenna. Fourteen lines of measurements were taken in the research area (Figure 3). The radargrams were processed using the Sandmeier Scientific Software ReflexW version 9.5, following the steps below:

- **Header gain removal** – the device itself, at the time of acquisition, adds a gain to the profiles.
- **Dewow filter** – is a high pass filter, which serves to remove the low-frequency noise generated by the equipment itself.
- **Gain ACG** – abbreviation for Automatic Gain Control, system to automatically control the gain or increase of the amplitude of a signal.
- **Static correction** – acts to remove the space present between the antennas and the ground, establishing a zero level of the section.
- **Band-Pass Filter** – where the user chooses the bandwidth, he thinks is necessary, reducing noise that is outside the central frequency range.
- **Equalizer Trace Gain** – for the purpose of normalizing the amplitude of all traces.

Results

For a better understanding. The selected radar profiles were analyzed separately.

- Profile 05:

With approximately 103 meters in length, with a cut being made, obtaining a final size of 60 meters, profile 05 starts in the sea–continent direction (Figure 3).

The acquisition out in the sand strip shows a complex sedimentary architecture, making possible separation of units in the data difficult. Using singular recognition, it is possible to locate two archetypes (Figure 4).

When we observe a bedding pattern, we associate the behavior of the yellow Rdf-I dune frame, with its pattern deposited on the paleo mangrove, its appearance is probably due to the rise in sea level and winds on the mangrove coast. In Rdf-II we defined its behavior as a product of wind deposits, in Rdf-III we defined it as a paleo mangrove, as we identified an advance of the sand strip over the characteristic mangrove of the region (See Figure 4).

- Profile 08:

Approximately 132 meters long, this profile was created parallel sand strip, in a West-East direction (Figure 4).

In this radarfacie, we identified several deposits of marine sedimentation (Rdf-IV), as well as a sequence boundary (SL-1) with the line occurring between 10 and 40 meters and about 5 meters, separating two moments of marine deposition (see Figure 5)

- Profile 13:

This profile, in turn, is approximately 104 meters long, being carried out in a parking lot located a few meters from the sand strip, with the survey in a South-North direction (Figure 3).

We again observed the presence of Rdf-IV deposition of marine sediments, which was expected since the same line is close to the previous one, however in this one we were able to identify two sequence limits SL 1 and SL 2, with SL 1 having a good continuity and delimiting the basaltic environment and the SL 2 parallel to it, marking a new moment of successive marine depositions over time, high and low tides (See Figure 6).

- Profile 14:

Measuring about 270 meters, it is carried out on the access road to the sand strip, its measurement direction is North-South (Figure 3).

In this radarfacie, we observed the existence of a paleolake, which, due to changes in tidal levels, and deposition of marine sediments over time, had its depth attenuated, with the sequence limits SL 1 and SL 2 well marked and contrasted.

SL 1 has its continuity interrupted by the river path with a series of marked depositions and SL 2 is interrupted not appearing on the other side of the river, probably the result of aeolian or marine depositions.

Conclusions

We found that the GPR, with its sensitivity to sand, manages to contrast relatively well with the sedimentary characteristics of the coast of Pará, we focused only on some data and a basic interpretation of the information available in the radarfacies. If successful, the research can be deepened with new ways of interpreting and delimiting the deposition layers of the environments.

Each radarfacies shows the complex behavior of the coast of Pará, showing much more than just a few basement layers, with many sediment movements and depositions, all in a short period of time, probably influenced by a series of agents, such as wind, storms, and seas.

The beach data show and validate the existence of aeolian deposits, dunes and marine deposition on the coast, produced by changes in sea level, enabling the correlation with the units found in the model suggested by Rosseti and Góes (2001).

The present summary used the literature of other authors to base their interpretations, thus, we recommend in future projects in the area the use of other methods, with the intention of increasing the foundation, being able to use antennas of higher frequencies, in the intention for detailing shallower and deeper areas and layers.

We hope to carry out new in-depth studies to better understand the erosion movements that affect the beach, and try to understand the possible cause, whether it is natural or anthropic.

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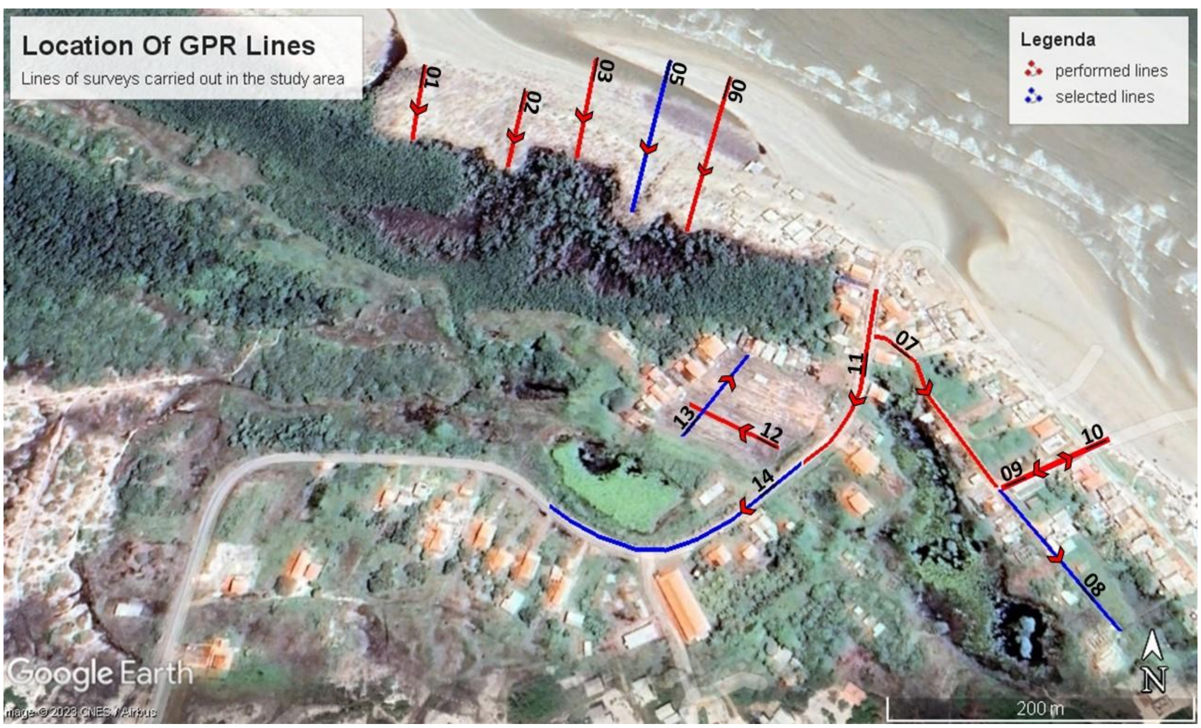

Figure 3: Location of study lines performed. From the author.

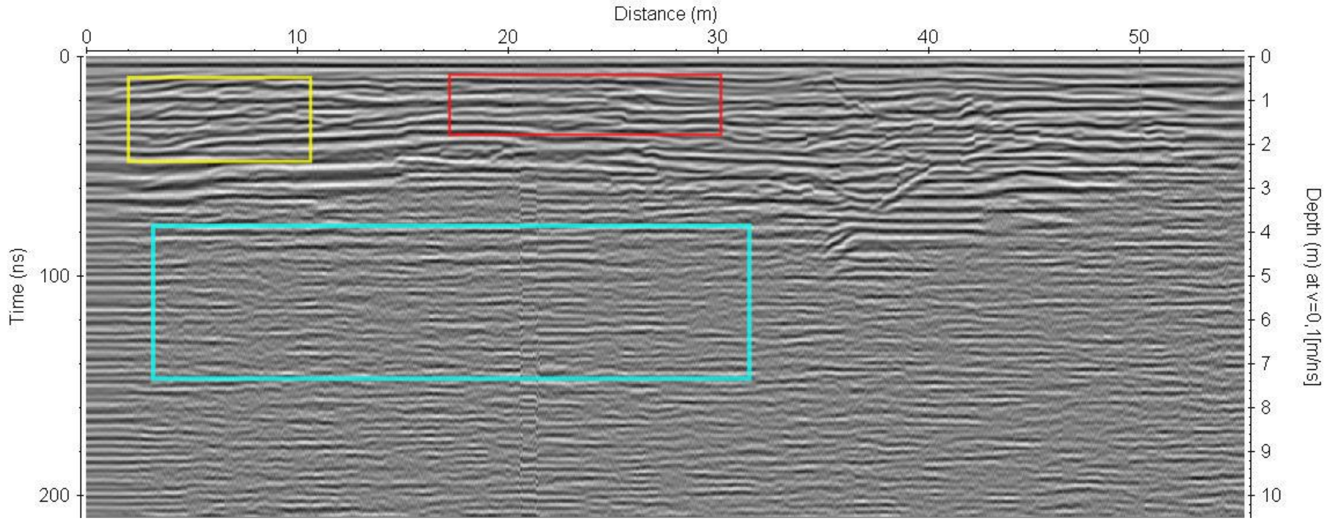

Figure 4: Radargram referring to acquisition 05. Rdf-I: Dune (Yellow); Rdf-II: Paleomagrove (Light Blue); Rdf-III: Eolian Deposits (Red).

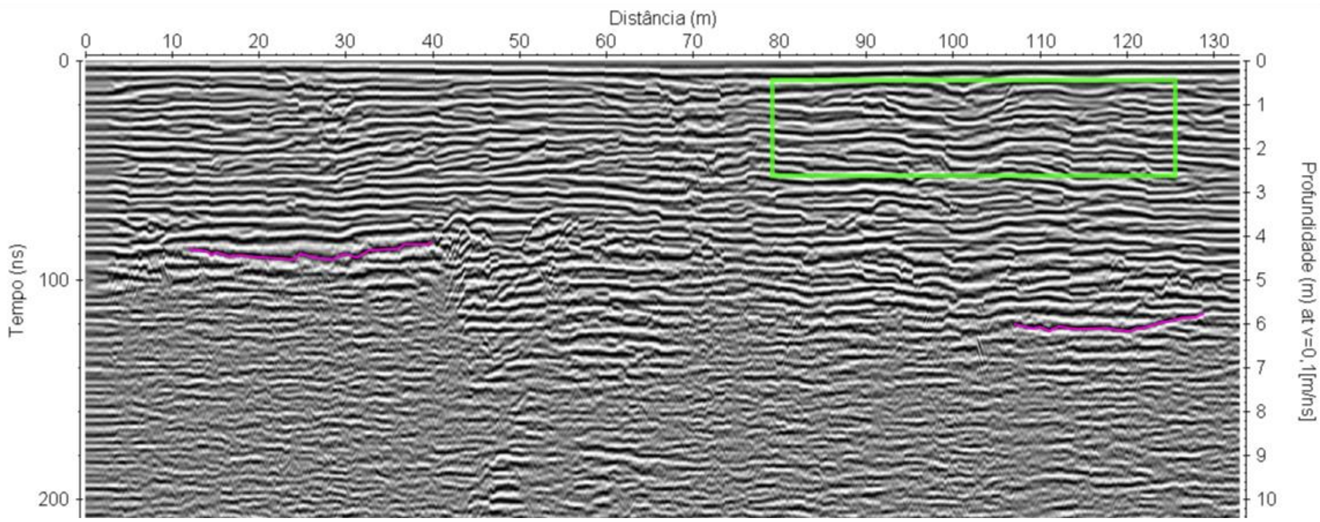

Figure 5: Radargram referring to acquisition 08. Rdf-IV: Marine Sediments (Green); SL-1 (Sequence Limit 1 - Purple); SL-2 (Sequence Limit 2 - Purple).

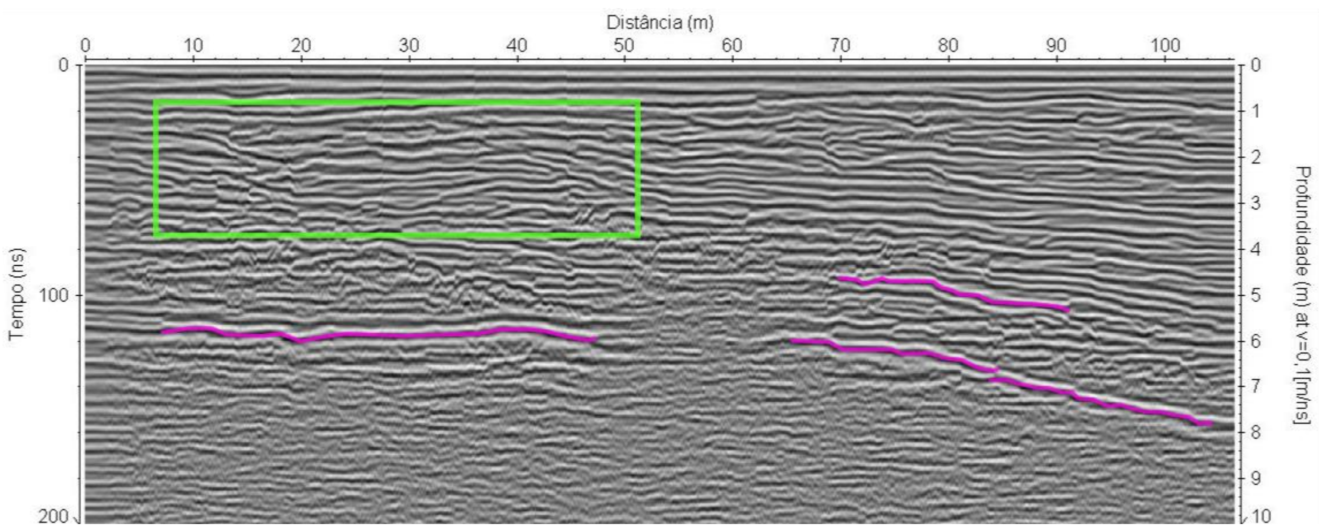

Figure 6: Radargram referring to the acquisition 13. Rdf-IV: Marine Sediments (Green); SL-1 (Sequence Limits 1 - Purple); SL-2 (Sequence Limits 2 - Purple).

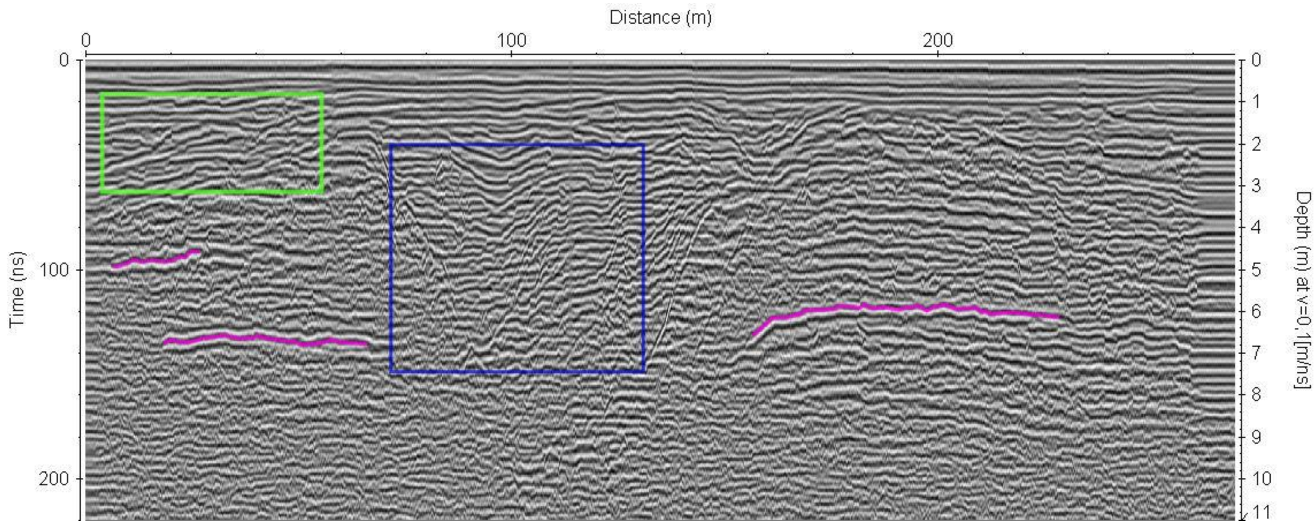

Figure 7: Radargram referring to the acquisition 14. Rdf-IV: Marine Sediments (Green); Rdf-V: Paleolake (Blue); SL-1 (Sequence Limits 1 - Purple); SL-2 (Sequence Limits 2 - Purple).