CHARACTERIZATION OF THE ARCHITECTURE OF FLUVIAL BARS OF THE AMAZON AND TAPAJÓS RIVERS USING GPR (GROUND PENETRATING RADAR)

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Abstract

This work used GPR to study fluvial deposits in the Amazonian rivers. The radar provided information for the study of the history and evolution of fluvial bars of the Tapajós and Amazon rivers, the main tributaries of the largest watershed on the planet, the Amazon. The process was performed using the softwares REFLEX ® 6.0 and WIN GRED (IDS - Ingegneria Dei Sistemi).

Introduction

The potentiality of the radar is consolidated in sedimentological studies in academia. The high-resolution images, from reflections of electromagnetic waves, provide detailed information difficult to be observed in outcrops.

GPR has been used to determine size, thickness, stratigraphy and internal architecture of fluvial sedimentary deposits both continental and marine.

The variability and the patterns of the fluvial channels, the heterolitics characteristics of the sediments, and the large scale of the deposits sometimes with fresh water, make the fluvial deposits as an adequate environment to apply GPR (C.S.BRISTOW & H.M. JOL, 2003).

As a complementary issue in the Project *"Provenance, transport and storage of sediments in amazon river"*, the GPR was used to sandy bars imaging in the Tapajós and Amazon rivers, main tributaries of the largest hydrographic watershed of the world.

The diversity of sediment types and the difference between the rivers rendered the processing and interpretation process unique and pioneer in the Amazon watershed (Figure 1).

Adding the GPR method to study bar patterns in Amazonas made the study inovative and gave information that would be hardly observed without using geophysical techniques.

From the data acquired with GPR was possible to analyze the architecture of the reflectors based on the concepts of radar stratigraphy. The integration of sedimentary facies described in outcrops and the radar facies allowed reconstructing the geometry and suggest an evolution model for the fluvial bars in the amazon watershed.

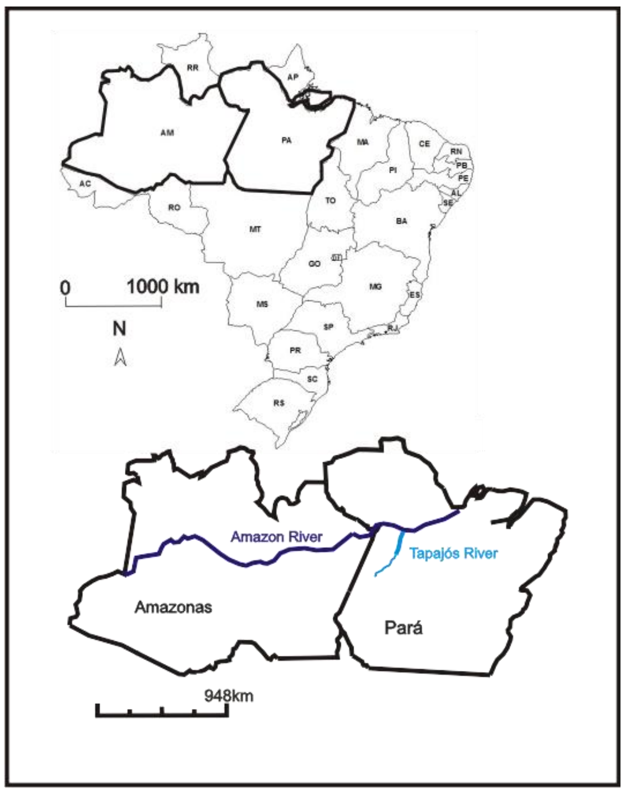

Figure 1.0 – Map of Brazil highlighting the states where the Tapajós and Amazon rivers are located.

Method

The GPR method consists in the transmission of a pulse of high-frequency electromagnetic energy (EM), usually in the 10-1000 MHz range, into the ground and is partially reflected back to the surface due to changes in the electrical properties of the materials. This allows the identification of contacts, including changes in sediment grain size (facies change), mineralogy, density, bedrock contact and water content (DAVIS & ANNAN,1989).

The system that was used in this research (*IDS-Ingegneria dei sistemi*) is composed by two antennae (transmitter and receiver), a control unit responsible for sending pulses to the transmitting antenna and scan the signal from the receiving antenna (*DAD Control Unit*), a PC laptop (notebook), a 12V battery and a wheel-type odometer coupled to the antennas. The 100 MHz and 200MHz antennae were tested but the survey was performed using the 100MHz antenna and a offset of 1 m, configuration that presented better vertical resolution (10-15 cm). Traces were acquired every 25 cm, stacked 4 or 8 times and 512 samples per trace were recorded.

The survey comprehended about 5 km of GPR lines in the regions of Tapajós and Amazon Rivers. The system
Two softwares were used to process the GPR data: REFLEX WIN® 6.0 by Sandmeier Software e o GRED (IDS - Ingegneria Dei Sistemi). The main procedures applied were (Figure 2): time-zero-drift, dewow, background removal (filter to remove coherent noise), AGC (automatic gain control), band pass filter, manual filter (horizontal filter). The velocity of 0.1 m/ns was used to convert time to depth for all lines, which is within the range of quartz sand reported in NEAL (2004).

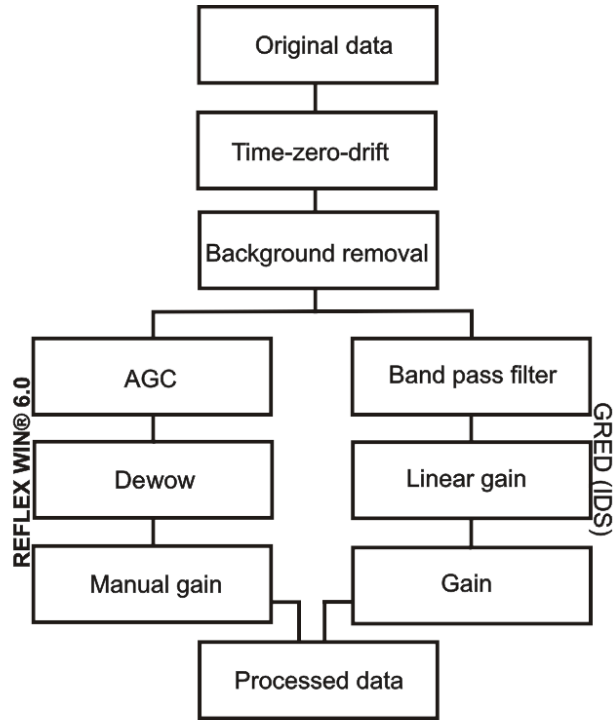

Figure 1.1 – Diagram of the data processing flow.

Similarly to seismic stratigraphy (MITCHUM *et. al.,1977;* EMERY & MEYERS,1996*),* radar stratigraphy relies on the identification of systematic reflection terminations. These terminations define radar surface. Geologically these are believed to represent significant non-depositional or erosional hiatuses. GAWTHORPE *et al.*1993 define these as the “fundamental stratigraphic units” that can be identified on radar reflection profiles. Working within the framework of surface radar it is then possible to define various radar facies.
GPR sections acquired in sandy bars are characterized by six radar facies. (Figure 1.2).

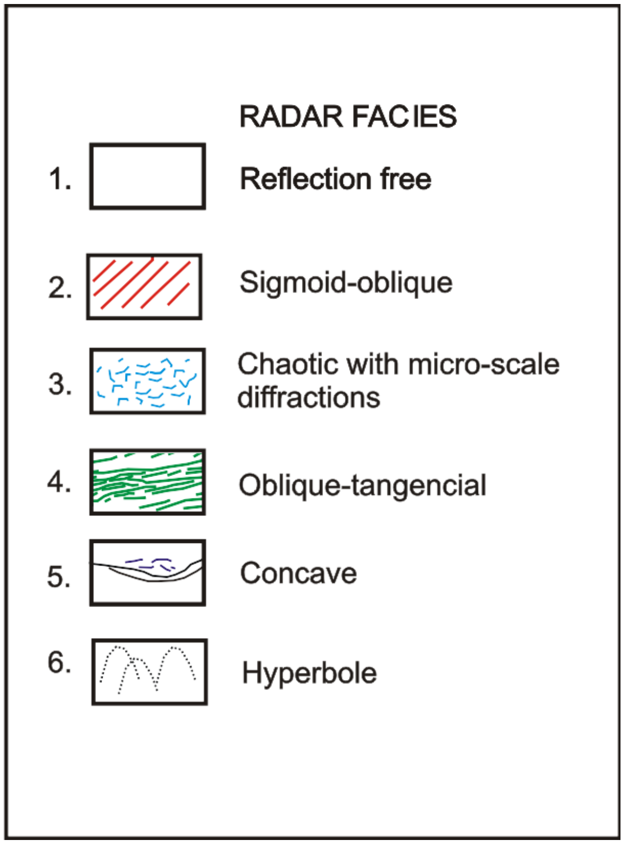

Figure 1.2 – Radar facies identified in the GPR sections.

According to NEAL (2004), a radar unit is characterized by its geometry, dip, continuity, amplitude and the relationship between the reflectors (Table 1).

The refection terminations present a typical superior limit of a erosion truncation marked by medium to coarse sand with granules, characteristic of radar facies 2, 3, 4 and 5. The inferior limits also present granules being downlap (radar facies 2 and 4) or subparallel (radar facies 5)

Table 1 – Classification of the radar facies according to NEAL (2004).

RadarFaceis	Shape	Dip	Relationship between reflections	Reflection continuity	Sedimentary faceis	Figure
2	saddle-shaped	inclined	oblique (non-parallel)	continuous	sand medium / thick with granules at the top and bottom	1.3
3	chaotic	chaotic	oblique: chaotic	discontinuous	sand medium / thick with granules	1.4
4	saddle-shaped	inclined	oblique: divergent	moderately continuous	sand medium / thick with granules	1.5
5	Curved: concave	horizontal	subparallel	moderately continuous	sand medium / thick at the base and granules inside	1.6

Figure 1.3

Figure 1.4

Figure 1.5

Figure 1.6

Results and Discussion

Longitudinal Bars

Rectilinear rivers, like Tapajós, present a negligible sinuosity due to the development of lateral bars. (LEOPOLD *et. al.,*1964). The GPR surveys were performed in both directions, longitudinal and transversely to the bars.

The bars of this river are formed by waves, growing in the opposite direction of the current flow.

In the GPR sections obtained in the Jamaracuá bar (Figure 1.7) is possible to see the formation of new set of bars from west to east formed by oblique stratification (radar fácies 2), with thickness of about 2 meters and low dip angle (~20°).

In the opposite margim of the fluvial channel (Figura 1.8) was possible to identify na eventual time lag when the sedimentation process was modified, presenting radar fácies 4.

Bar in the centre of the river

Different patterns of channels may be present simultaneously in a river (STEVAUX,1994). The Amazon river is the second most extensive of the world, and its morphological characteristics are modified in its way.

In the region surveyed the channel is meandering with some bars in the middle of the channel.

The processed section (Figure 1.9) shows accretions of bars from northwest to southeast, in agreement with the cross bedding present.

Conclusions

The use of GPR in the amazon region showed the potentiality of the method to study fluvial depositional systems.

The recognition of the radar facies in the GPR sections and its correlation with the sedimentary facies were fundamental to analyze the growing process of the bars.

In addition to providing the morphology of the bar was identified in this work an event in which two deposition agents acted in a single morphology, as shown in Figure 1.8.

Adding the GPR method to study bar patterns in Amazonas made the study inovative and gave information that would be hardly observed without using geophysical techniques.

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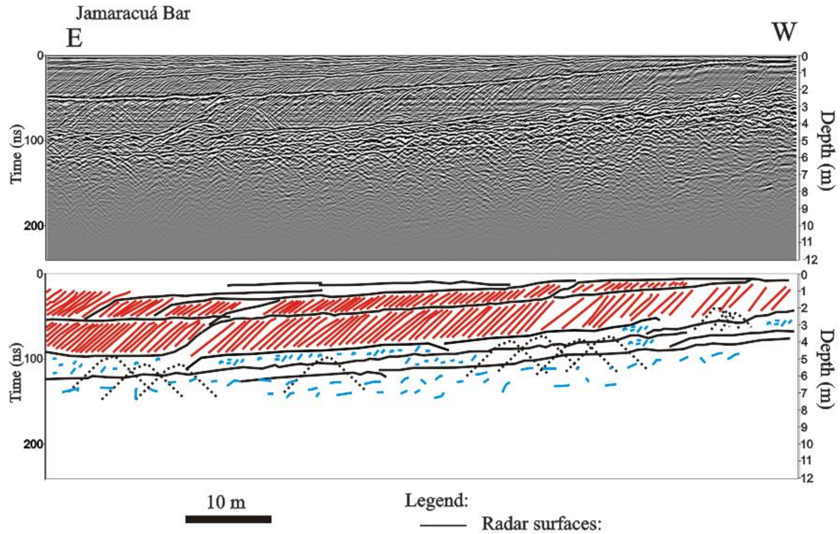

Figure 1.7 – GPR section of the Jamaracuá Bar in the Tapajós river.

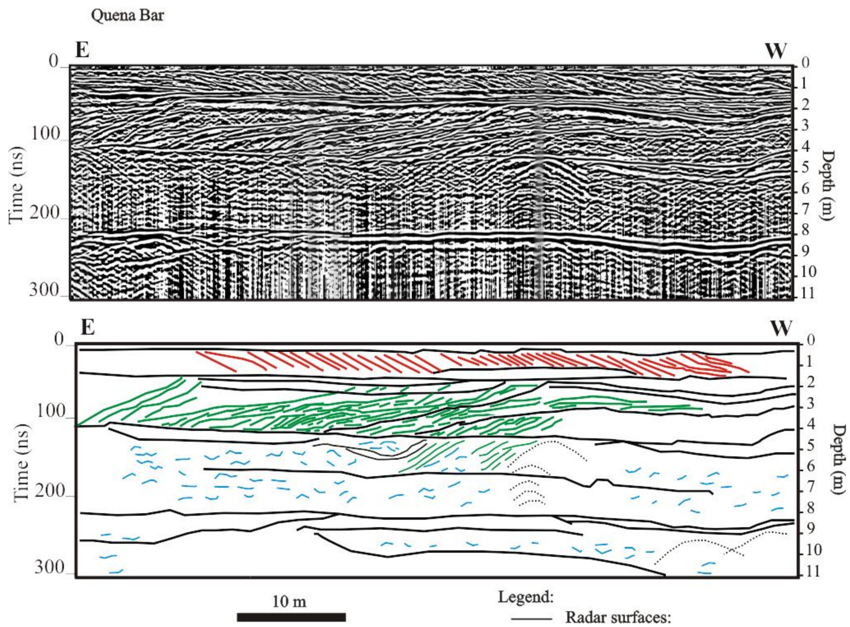

Figure 1.8 – GPR section of the Quena Bar in the Tapajós river.

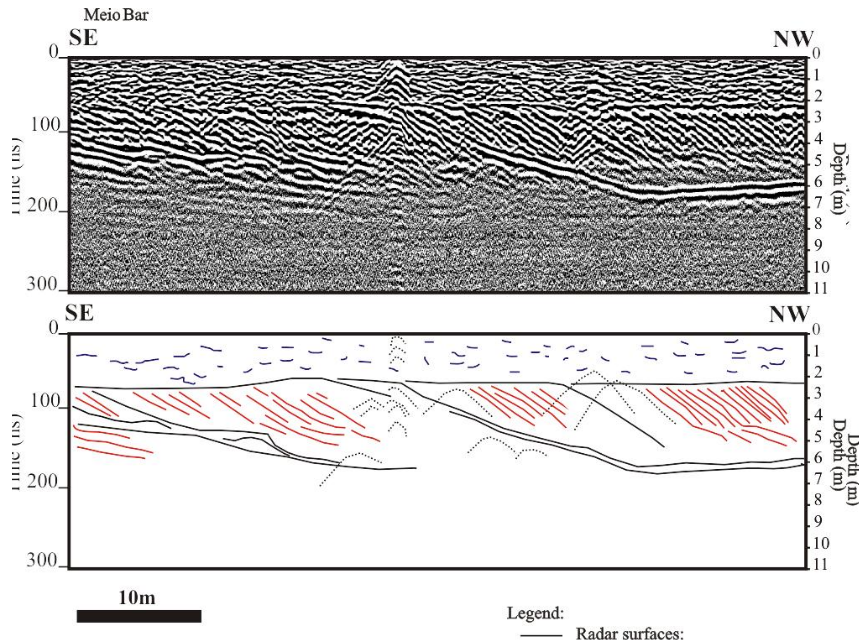

Figure 1.9 – GPR section of the Meio Bar in the Amazonas river.