GPR Studies at the Cacaria Submerged Archaeological site, Maranhão State: Preliminary Results

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Abstract

In this research, the GPR (Ground Penetrating Radar) method was employed to study the Cacaria submergerd archaeological site, located in Cajari Lake, in the Penalva region, Maranhão State. The objective was to map the wooden pillars that supported the pre-colonial stilt house by indigenous people in the eastern Amazon region, as well as to map structures on the lake bottom. 270 MHz GPR results indicated the presence of sediment-covered wooden pillars on the lake bottom and suspended in the water column. A geological structure of the lake bottom could also be identified. The preliminary results can serve as a guideline for collecting ceramic materials in the vicinity of the wooden pillars, which contributes to archaeological research in the eastern Amazon region.

Introduction

Stilt houses (“Estearias”, in Portuguese) were pre-colonial indigenous settlements in aquatic environments supported by wooden pillars or tree trunks, corresponding to the prehistoric stilt houses in the lowlands of South America (Navarro, 2018). The dating of the archaeological sites was performed with carbon 14 (C14), indicating that most of the constructions occurred between 800 and 1000 AD (Navarro, 2018).

The Maranhense wetland is located in eastern Amazonia, about 200 kilometers southwest of the capital of Maranhão State, São Luís. This region covers an area of approximately 20,000 km² within an Environmental Protection Area (EPA) according to Decree No. 11,900 of June 11, 1991, reissued on October 5, 1991.

The palafitic sites are scattered in a typical area of the Amazon lowland biome, formed by a complex water system composed of rivers and lakes of varying sizes, which are determined by the seasonality of the region, with two well-defined seasons: the rainy season, from January to June, and the dry season, from July to December (Franco, 2012).

Archaeological research in the Amazon region shows that the floodplains of rivers and lakes were densely populated in the pre-colonial period (Roosevelt, 1991 and Neves, 2008). Thus, wooden pillars are archaeological remnants of these populations that inhabited the American continent, and the motivation for research is to better understand the populations of the pre-colonial Amazon.

In recent decades, there has been a significant increase in scientific publications addressing the use of the GPR (Ground Penetrating Radar) geophysical method in locating and delineating archaeological sites. The promising results obtained in recent years worldwide have aroused the interest of archaeologists and have made geophysics a fundamental methodology, both for the characterization of already known archaeological sites and for the discovery of new sites (Conyers and Goodman, 1997).

The Cacaria archaeological site (Figure 1) is located in Cajari Lake, located near the Penalva City, Maranhense wetland. This is a site that is permanently submerged. Previous work by Corrêa et al. (1991) located wooden pillars and ceramic materials, drawing attention to the fact that they were found at the bottom of the lake. In this context, the GPR method was used in this research in a pioneering way aiming to refine and map the wooden pillars on the lake bottom (Porsani et al., 2023).

In this research, the GPR method was employed to locate subsurface structures, delineate the lake bottom, and map the wooden pillars, which are the main targets of interest.

This study will contribute to the mapping of the Cacaria site located in Cajari Lake, Maranhense wetland, corroborating archaeological research in the eastern Amazon.

GPR Method

The GPR (Ground Penetrating Radar) is a non-destructive and non-invasive electromagnetic method that consists of the transmission and reflection of electromagnetic waves at high frequencies. It usually operates in the 10 MHz to 2.6 GHz range and is used to locate geological structures and objects buried by man, and has wide applications in geosciences, archaeological studies, etc. (Daniels, 1996; Porsani, 1999).

The reflected and refracted waves are recorded as a function of the double travel time, in which it is amplified, digitized and recorded on a computer hard drive for further processing (Daniels, 1996; Porsani, 1999).

GPR data acquisition and processing

GPR data acquisition followed the configuration similar to that adopted by (Porsani et al., 2005), where the antennas

were arranged inside a wooden boat. The GPR profiles were acquired by means of the constant distance reflection profiling technique using a 270 MHz shielded antenna and SIR-4000 acquisition equipment (GSSI), coupled to a GPS system (Geode). Figure 1 shows the arrangement of the GPR profiles acquired at the Cacaria archaeological site, located in Cajari Lake, in the region of the municipality of Penalva, in Maranhense wetland. In red are the profiles presented in this paper. The GPR data processing was carried out using the software RADAN (GSSI), using basic procedures such as: zero-time correction, spatial and temporal filtering, time-varying gains, background removal and time/depth conversion (water dielectric constant equal to 81).

Preliminary Results

Figure 2 presents a section of the GPR profile 2 (Figure 1), in which it is possible to observe a strong horizontal reflector at a depth ranging from ~2.8 m to ~0.7 m, interpreted as the Cajari lake bottom. In this image, it is not possible to observe other structures more clearly, e.g., the wooden pillars. Figure 3 presents a zoom related to the 20 to 56 m section of the profile, in which it is possible to identify hyperbolic diffraction signatures below the lake bottom at ~3 m depth, which indicates that these structures are covered by sediment, and may be related to the wooden pillars. The diffraction hyperbolas come from point targets, such as the wooden pillars, which are the objects of this research.

Figure 4 shows a section of the GPR profile 1 (Figure 1), between the positions of ~96 m and 138 m in length. At ~3.2 m depth, it is possible to observe a clear subhorizontal reflector, corresponding to the lake bottom. At this depth, and at the 112 m position in the profile, a diffraction hyperbola can be observed above the lake bottom, which can be interpreted as a wooden pillar fixed to the sediment at the lake bottom. At 115 m of the profile, a sharp change in the slope of the lake bottom is observed, which makes another strong reflector, also interpreted as the lake bottom at ~1.8m depth. This change in the lake bottom feature is associated with the geological structure at the bottom of Cajari Lake in the municipality of Penalva.

Figure 5 shows a section of the GPR profile 3 (Figure 1), between the positions 173 m and 192 m. At ~2.4 m depth, a strong subhorizontal reflector interpreted as the Cajari lake bottom is observed. At the position of ~184 m a clear hyperbolic diffraction is observed suspended in the water sheet. It is likely that this anomaly, can be related as being due to the presence of a wooden pillar into the lake bottom, whose top is above the lake bottom. However, for its proof, a numerical modeling study is necessary, and this activity will be a task to be carried out in due course.

Preliminary Conclusions

The GPR geophysical method proved useful for the mapping of the Cacaria submerged archaeological site, located in Cajari Lake, municipality of Penalva, Maranhão State.

270 MHz GPR results allowed us to determine the depth of the lake bottom, changes in its geological feature and, mainly, to locate targets that can be interpreted as wooden pillars which are used to support stilt house, i.e., the dwellings of pre-colonial peoples of eastern Amazonia.

The results, although preliminary, can serve as a guide for the collection of ceramic materials in the vicinity of the wooden pillars, which contributes to archaeological research in the eastern Amazon region.

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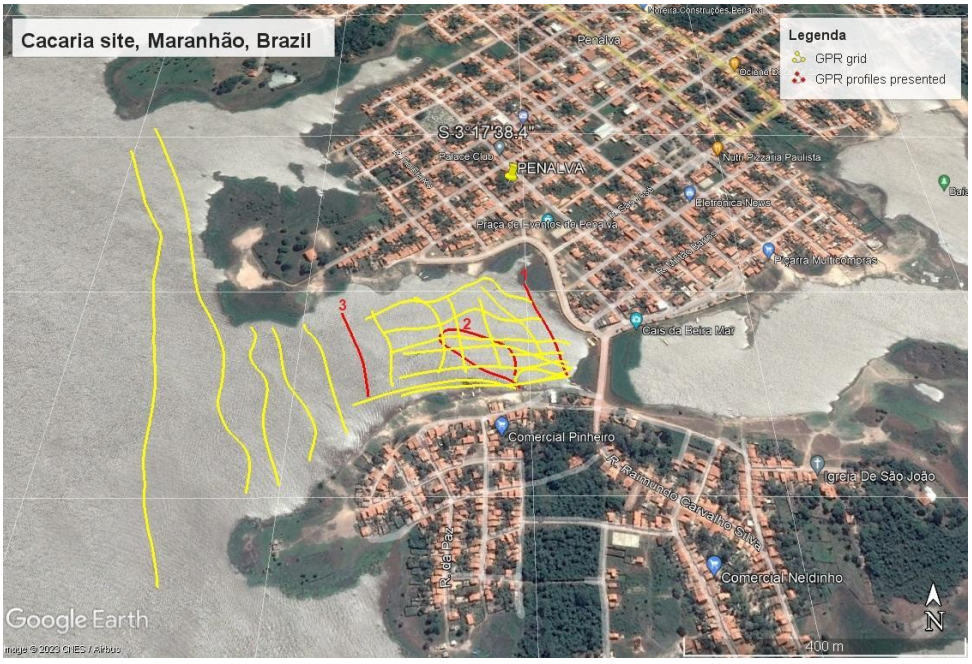

Figure 1- *Location and layout of the GPR profiles at the Cacaria submerged archaeological site, Cajari Lake, Maranhão State.*

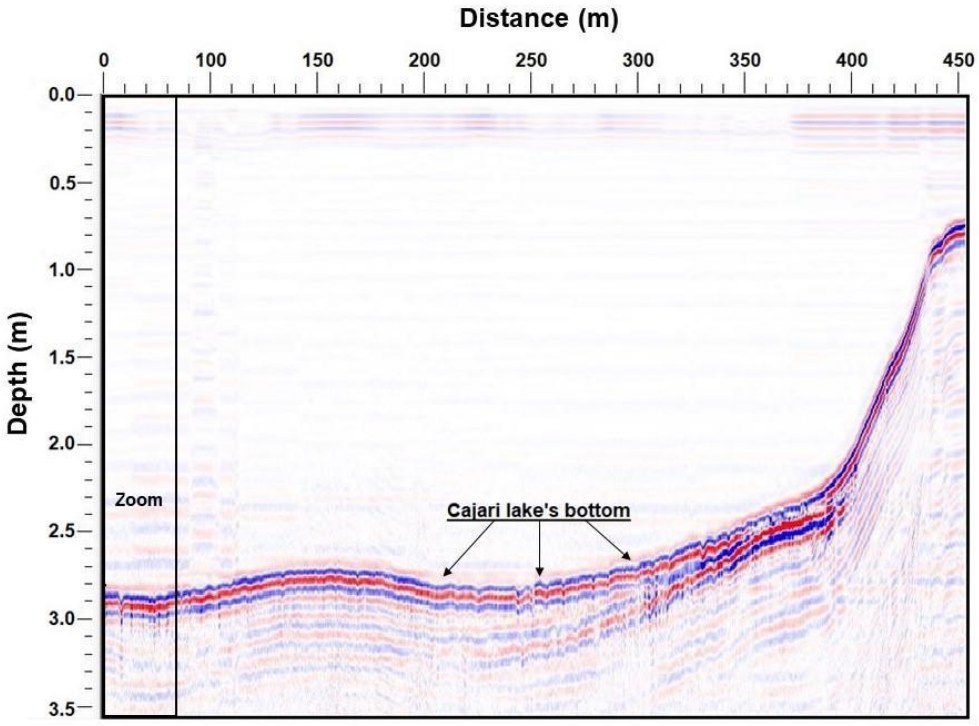

Figure 2- *GPR 2 profile of 270 MHz in the S-N direction in the Cacaria submerged site, Cajari Lake, Penalva City, Maranhão State.*

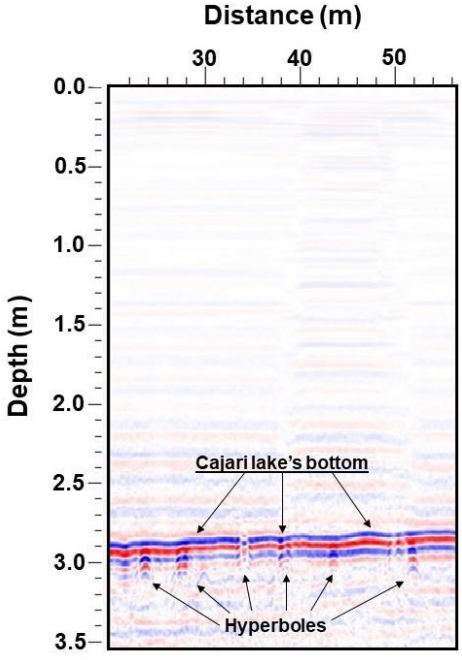

Figure 3- *Zoom in GPR 2 profile (Figure 2).*

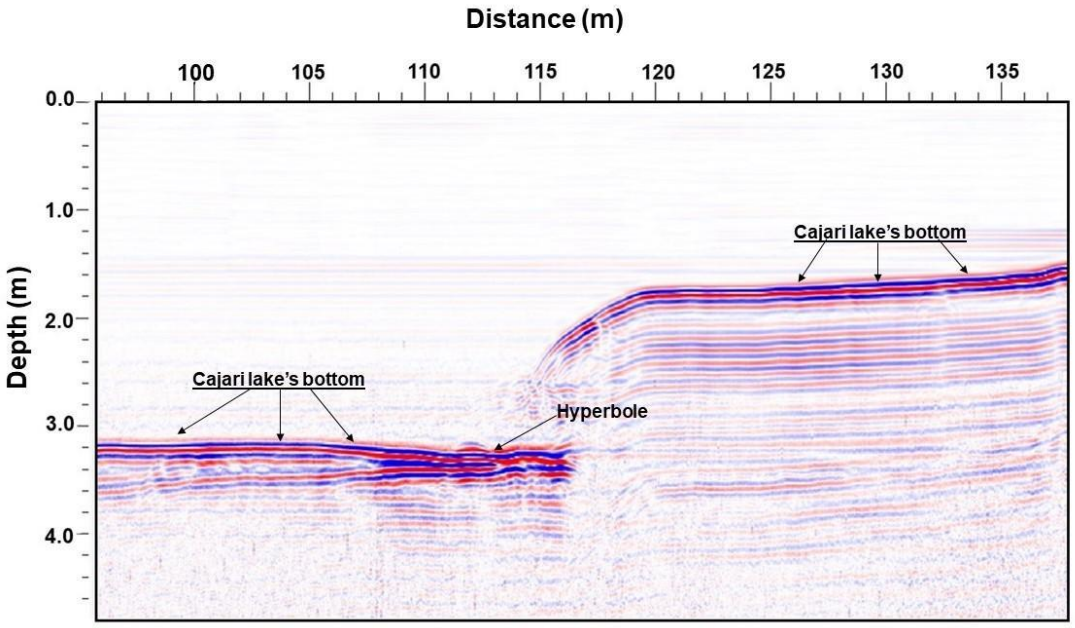

Figure 4- *GPR 1 profile between the positions of ~96 m and 138 m in length, obtained in the S-N direction, at the Cacaria submerged site, Cajari Lake, Penalva City, Maranhão State.*

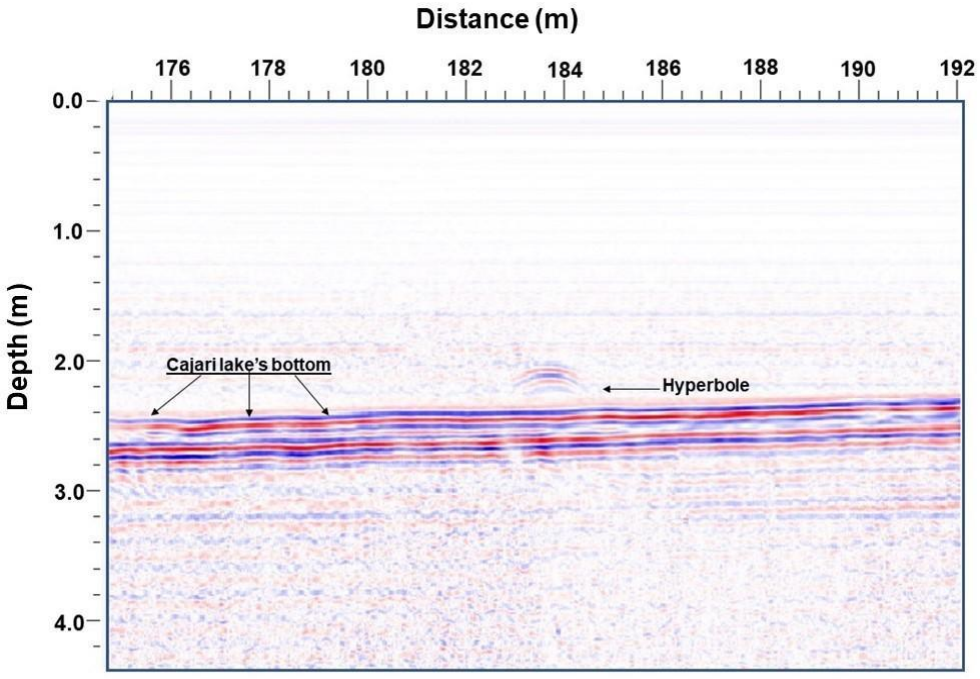

Figure 5- *GPR 3 profile between the positions 173 m and 192 m, S-N direction, at the Cacaria submerged site, Cajari Lake, Penalva City, Maranhão State.*