UltraGround Penetrating Radar (UltraGPR) Inputs for Bauxite Geological Modelling with Accuracy Improvements

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Abstract

The Ultra-ground penetrating radar (UltraGPR) is a geophysical surveying technique based on transmitting pulsed electromagnetic (EM) energy into the subsurface and measuring the strength of the reflected energy. The reflected energy depends of petrophysical characteristics of each rock type with different porosity, permeability, humidity and crystallinity degree. For geological applications, in particular Amazonian lateritic bauxite deposits, the challenges were always the depth of penetration as well as the ability to discern bauxite from clays at significant depths, where traditional GPR would not penetrate. Therefore, this study aimed to evaluate the efficiency of UltraGPR methodology to determine lateritic horizon and the ore zone thickness and geometry, since these are probably the most challenge aspects to well understand in bauxite deposits and also considering the more recent technology innovations and developments. The study area is located at Paragominas Bauxite Province (PBP), northeastern of Pará State (Brazil). The UltraGPR data were processed from specific algorithms in a similar scheme to what has been applied to others lateritic deposits worldwide using custom low-pass frequency filters to subdue unwanted interference caused by the conductive clay overburden and thereby enhance the underlying bauxite layers. The data were interpreted and crosschecked with boreholes and then were incorporated in the 3D geological modelling workflow in Leapfrog Geo® environment. The results showed nearly perfect correlation with boreholes and a clearer geometry definition among lithological contacts, confirming that UltraGPR is a suitable method for bauxite exploration since it leads to improvements on geological models' accuracy. During mineral exploration in regional targets, the UltraGPR survey can be used to obtain a preliminary information regarding ore thickness and its potential, supporting the drilling plan and a more assertive and agile decision making. Similarly, mine planning and operation may benefit from better control and precision of geometry in the short-term models.

Keywords: Geological modelling, Paragominas Bauxite Province, UltraGPR, Geophysics.

1. Introduction

Ground Penetrating Radar (GPR) has a long history with the first commercial equipment release during the 1960's. Early works were done with standard military radar systems and radio echo sounders to map the thickness of ice sheets in the Arctic and Antarctic, pioneering research conducted by the British Antarctic Survey [1]. In the 1970's, work with GPR in non-polar environments began focus on civil engineering and mineral explorations for coal beds purposes [2] and as the strengths and limitations of the technique became more apparent, the possible applications dramatically broadened together with the technology advances involving the advent of the high-speed laptop computer and the ability to capture, digitize, and store large volumes of radar data in the early 1990's.

Today, modern GPR systems have fast data processors and data transfer circuitry, and are easily mounted within small boats, aboard sleds, or within backpacks. Typical commercial applications of GPR include engineering and environmental site evaluations, fracture mapping, stratigraphic mapping, void detection, forensic studies, glaciology and permafrost engineering, archaeological studies as well as mineral exploration [3, 4].

The operational concept of GPR is very simple. At a total weight of less than 4 kg, UltraGPR is highly transportable and easy to deploy in the most challenging terrain and environments. The entire GPR is designed to be enclosed within two small cylinders, a generator and receiver connected by a hose. No control unit, laptop and no fiber optics are used, it has been replaced by wireless protocols, including Bluetooth and Wi-Fi which transmitter the data to a palmtop (Figure 1a).

The UltraGPR is a geophysical surveying technique based on transmitting pulsed electromagnetic (EM) energy, usually 10 MHz – 1 GHz range, which radiates ultra-wideband radio waves into the subsurface. The radar receiver measures and digitizes the subtle voltage fluctuations in the antenna, storing the values for later processing on computer (Figure 1b). The reflected energy depends mainly on differences in electrical conductivity and permittivity that are a function of the water content, soil moisture and others petrophysical characteristics of each rock type such porosity, permeability and crystallinity degree. Due to physics of EM wave propagation in dielectrics environments (subsurface) the radar energy penetration is optimized in highly electrically resistive soils and rocks such sands and gavels in dry conditions and limited in saturated clays [5, 6].

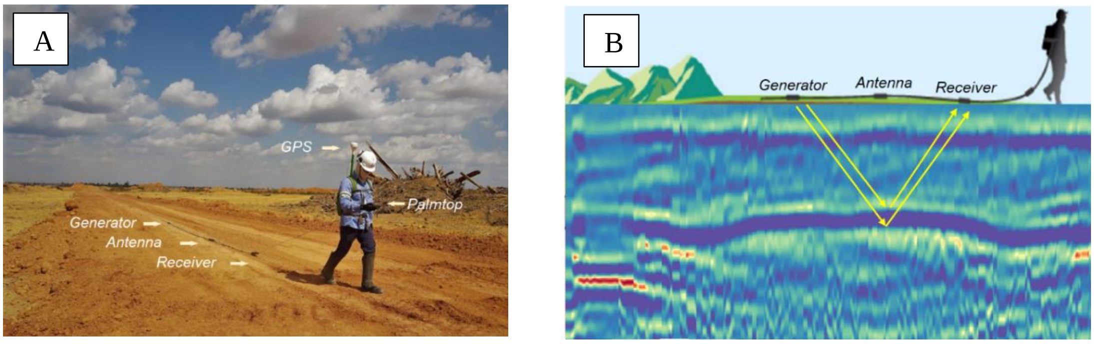

Figure 1. UltraGPR's components (a) and operational concepts (b).

In general, clays are highly absorptive of radar energy, and standard GPR instrument signals cannot penetrate through more than 50 cm of clay. However, GPR has proven effective at imaging partially weathered rocks and the underlying parent bedrock to depths of over 30 m [7], a challenge for mineral exploration purposes in laterite regions that generally contain a high clay fraction. UltraGPR has been designed to be able to penetrate though up to 20 m of overburden clay by using real-time sampling receivers coupled with a ultra-wide band antenna system whereby data in the range of 10 MHz – 20 MHz can be used to map bauxite horizons through thick clay [3].

For geological applications, in particular Amazonian lateritic bauxite deposits, the challenges were always the depth of penetration as well as the ability to discern bauxite from clays at significant depths, where traditional GPR would not penetrate. Therefore, this study aimed to evaluate the efficiency of UltraGPR methodology to determine lateritic horizon and the ore zone thickness and geometry, since these are probably the most challenge aspects to well understand in bauxite deposits and also considering the more recent technology innovations and developments.

drillholes and geophysics, and the mined ore, even allowing the identification of areas where ore loss and contamination have occurred.

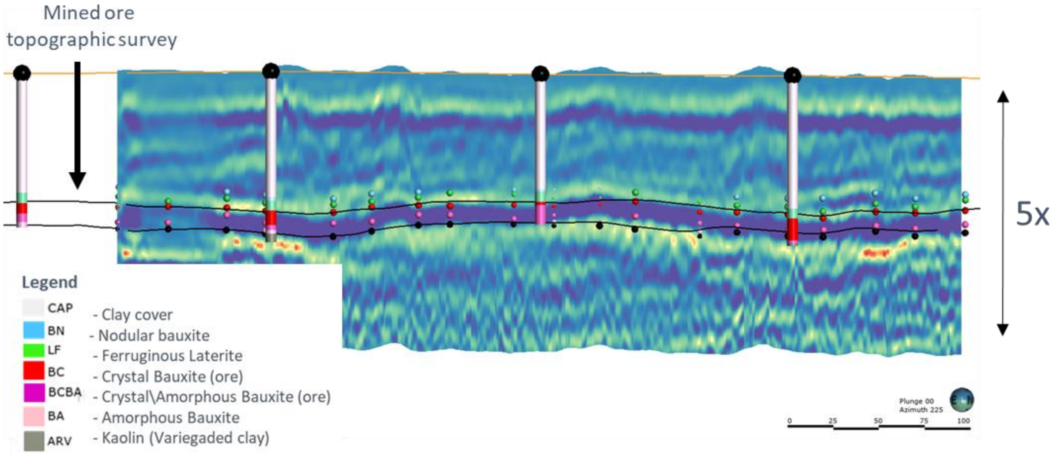

Figure 14. Geophysical section showing the correlation between boreholes, the contacts of the layers surveyed during geological mapping (colored dots) and the bottom and top mined ore survey (continuous black line).

4. Conclusions

Due to clay cover of approximately 10m to 15m, the radar signal is absorbed by the environment and instead of rebounding, it is retained, generating interference, loss of analytical capacity and masking more detailed information. In this way, 20 MHz UltraGPR instrumentation which was developed specifically for use in bauxitic and other lateritic weathering sequences was chosen, trying to filter characteristic noise signals and also to emphasize abrupt lithological changes, with thicknesses over 50 cm, in this way, being able to map the top and base contacts between lateritic and clayey layers.

The processed data appears to map the top and base of the bauxitic layer. Therefore, interstitial layers within the bauxite did not have a clear distinction between the crystallized bauxite (BC) and crystallized/amorphous bauxite (BCBA) lithotypes.

The results showed nearly perfect correlation with boreholes and a clearer geometry definition among lithological contacts, confirming that UltraGPR is a suitable method for bauxite exploration since it leads to improvements on geological models' accuracy. During mineral exploration in regional targets, the UltraGPR survey can be used to obtain a preliminary information regarding ore thickness and its potential, supporting the drilling plan and a more assertive and agile decision making. Similarly, mine planning and operation may benefit from better control and precision of geometry in the short-term models and represents an opportunity for operational savings through the optimization of financial resources from the drilling grids.

5. References

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