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Assessing the Feasibility of 3D Audiomagnetotelluric Modeling for Imaging Kamafugitic Rocks in the Alto Paranaíba Igneous Province, Brazil

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Abstract

This research focused on delineating kamafugitic volcanic rocks within the Alto Paranaíba Igneous Province (APIP) in Central Brazil, identified through geoelectrical contrasts by three-dimensional inversion of audiomagnetotelluric (AMT). The generated results were interpreted and revealed significant lateral geo-electrical variations that correlate with the area's geology. These variations allowed for the delineation of geo-electrical contrasts between Eocretaceous siliciclastic fluvio-deltaic and eolian rocks of the Areado Group and volcanic rocks belonging to the Mata da Corda Group, situated directly above the Neoproterozoic Bambuí Supergroup basement, within the stratigraphic context of the São Franciscana basin. It is important to note that, to complement this work, electroresistivity tomography (ERT) data will be integrated into the interpretation. The study was conducted in partnership with Sirius Pesquisas Minerais Ltda.

Introduction

The study area is located in the municipality of Presidente Olegário, in the western part of Minas Gerais State, Brazil, with an average altitude of 853 meters and a territorial extension of 3,503km². The Presidente Olegário territory is situated on the Central Brazilian Plateau, characterized by plateaus predominantly composed of sedimentary terrains with notably flattened tops, featuring open valleys bounded by abrupt escarpments. The largest existing plateau is São Pedro, encompassing the District of Ponte Firme and part of the Headquarters District. The area covered by the Presidente Olegário geological sheet is located within the São Francisco Craton, near its boundary with the Brasília Belt. Outcropping lithotypes in the region exclusively belong to the São Francisco Basin and correspond to Neoproterozoic rock associations of the Bambuí Group and thick Cretaceous coverages comprising the Areado and Mata da Corda Groups. The main objective is to delineate the three-dimensional structure of the kamafugitic rock by analyzing the geoelectrical contrasts between the volcanic manifestation in the study area and the surrounding lithotypes. For this purpose, three-dimensional audiomagnetotelluric inversion was utilized, with data distributed along two linear profiles, as shown in Figure 1.

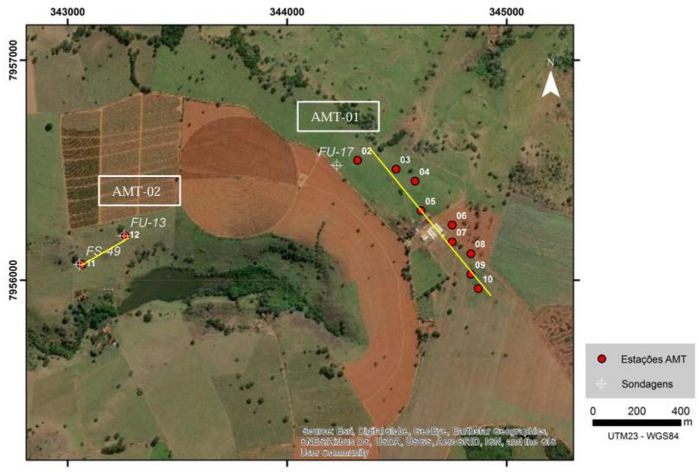

Figura 1: Location of the AMT stations, with profile AMT01 on the right and profile AMT02 on the left.

Method

The audiomagnetotelluric (AMT) method is a passive, non-invasive, and frequency-dependent technique capable of estimating the distribution of electrical resistivity within the Earth. In this study, the frequency range utilized was between 10 Hz and 100 kHz, with signals primarily originating from atmospheric activities such as electrical storms. AMT is commonly applied in shallow subsurface investigations and has been previously used to investigate geoelectrical signatures of kimberlitic occurrences in the western region of Minas Gerais, in addition to other mineral exploration studies (La Terra et al, 2010; La Terra and Menezes, 2011) .Data acquisition was performed along two linear AMT profiles (Figure 1), both positioned close to existing boreholes. The first linear profile, AMT-01, approximately 800 m in length, comprised 09 AMT stations with an approximate spacing of 100 m between them. Station 02, located at the beginning of this profile, passed close to borehole 17. On the AMT-02 profile, only two AMT stations (11 and 12) were surveyed, with a separation of 240 m; stations 11 and 12 are situated near boreholes 49 and 13, respectively. Data processing was executed using the EMTF code (Egbert's codes for Time Series Processing) (Egbert, 1986),. The 3D inversion of the AMT data was carried out using the ModEM (Modular system for inversion of electromagnetic geophysical data) inversion package (Egbert & Kebert 2012 and Kelbert et al. 2014). It is important to note that Electrical Resistivity Tomography (ERT) data were also acquired during the survey and will be utilized to refine and enhance the generated sections. It is also important to highlight that an additional campaign was conducted, yielding a dataset arranged in a three-dimensional configuration, which allowed for the generation of a high-resolution 3D resistivity cube.

Results

3D geo-electrical sections for both profiles, displaying the subsurface resistivity distribution of volcanic and sedimentary rocks, were obtained and can be visualized in figures 02 and 03. These sections extend to approximate depths of 200 m for profile AMT02 and 600 m for profile AMT01. It is important to highlight that profile AMT02 was directly positioned over two existing boreholes, 13 and 49. This strategic placement allowed for the calibration of the method, as the lithological variations within these boreholes are known and can be seen in figure 2b. Both boreholes 13 and 49, located near AMT stations 12 and 11 respectively, exhibit a lateritic crustal soil layer from the surface down to a depth ranging from approximately 5 to 9 meters.

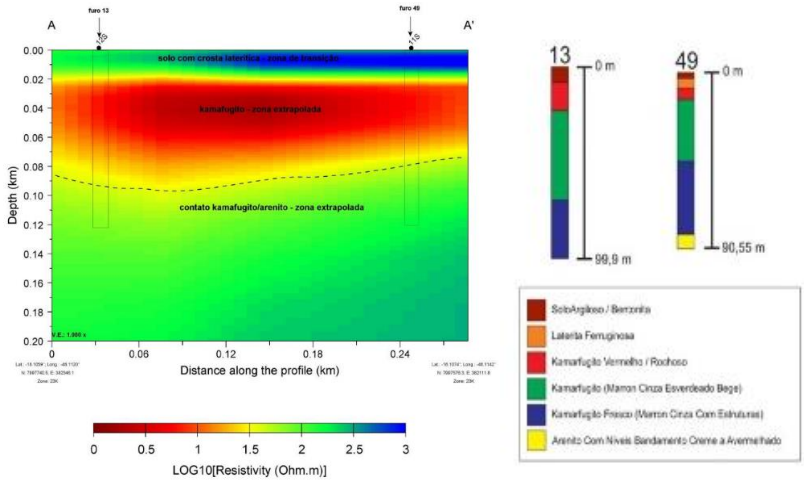

Figure 2: a) AMT-02 profile with 3D inversion results, showing two AMT stations at two pre-existing boreholes. Vertical rectangles indicate the confidence zone of the interpretation. b) Borehole descriptions (Source: Terra Brasil).

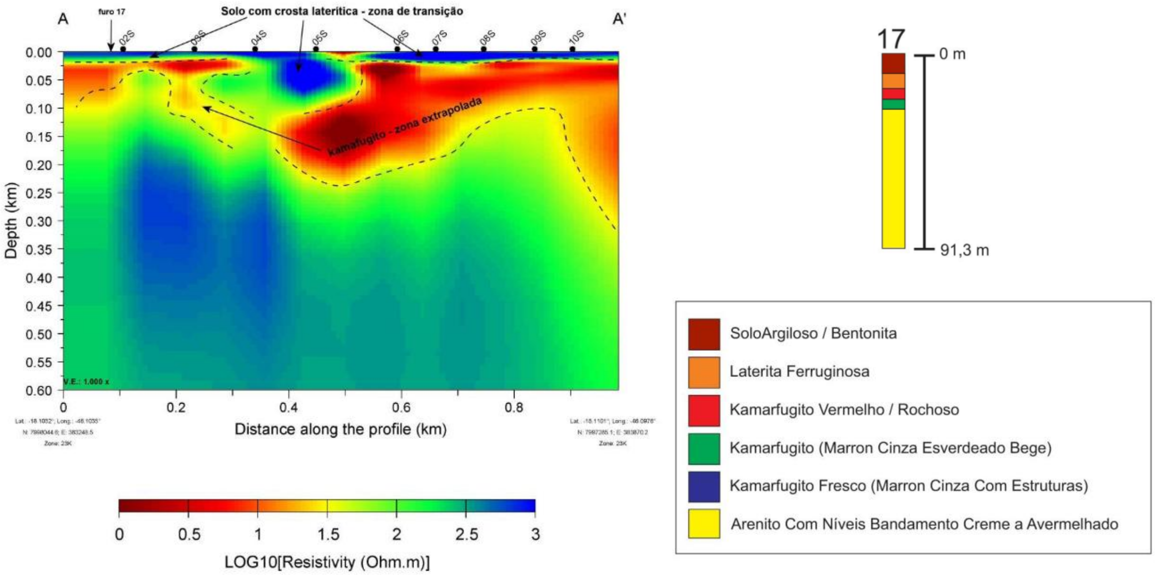

Figure 3: AMT-01 Profile with 3D Inversion Results, showing 09 AMT stations at one pre-existing boreholes.

AMT profile 02, particularly between stations 11 and 12, reveals a correlation with poorly defined boundaries at depth. The strongest correlation is observed within the layer corresponding to kamafugite variants (Figure 2), which appears in reddish-to-yellow hues, indicating low resistivity values (<30 Ωm). These low values for an igneous rock like kamafugite may be associated with metallic mineralization and secondary porosity. This kamafugite interval at both AMT stations is clearly delineated by the geophysical method. The basal contact between the kamafugite and sandstone is also visible as a dashed line in Figure 2. Based on the AMT results over the boreholes, the presence of kamafugite, the soil and laterite crust, and the kamafugite/sandstone contact were all identified. Following the method's calibration using the results from AMT profile 02, the presence of possible kamafugite (dashed lines) can be inferred along the entire AMT profile 01, where a strong red coloration is observed (Figure 3). This prominent conductive zone, occurring between AMT stations 05 and 10, exhibits an apparent NW dip, reaching a depth of 250 m, and shows lateral discontinuity between stations 04 and 05. This discontinuity is attributed to an oval-shaped resistive body, which we interpret as partially lateritic, with values exceeding 100 Ωm and potentially reaching 1000 Ωm. The continuity of the possible kamafugite in the left portion of the profile, showing a shallower trend, is corroborated by data from borehole 17 (Figure 3), approximately 50 m from AMT station 02. A lateritic soil horizon is present throughout the entire profile. Below the interpreted lower boundary of the kamafugitic zone lies the contact with sandstone. Resistive bodies approaching 1000 Ωm are visible at greater depths, though no association with other lithotypes has been made in this interpretation yet.

Conclusions

3D audiomagnetotelluric (AMT) inversion was successfully performed. The results effectively delineated the kamafugitic levels and their basal contact with underlying sandstone formations. The co-location of boreholes with two AMT stations provided crucial data for method comparison and calibration. The 3D AMT method proved highly effective for the outlined objective, enabling clear observation of the kamafugite's upper and lower boundaries, including its contact with the sandstone. A significant advantage of this method is its ability to acquire measurements from the surface down to considerable depths, reaching up to 1000 m. The regional clayey soil and lateritic crust were also discernable through this method. Consequently, the results are highly relevant, providing valuable insights into the subsurface geology of the area. Acquisition of measurements along profiles allowed for the observation of the lateral continuity of structures and lithotypes. However, for a comprehensive three-dimensional visualization, future work will involve modeling a 3D resistivity cube. This will be achieved by integrating a grid-like array of AMT measurements collected across the entire study area. This detailed 3D model will highlight the upper and lower boundaries (thickness) of the kamafugitic body and surrounding rocks, as well as their lateral discontinuities.

Acknowledgments

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