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Geophysical Investigation of Groundwater Flow and Hydromineral Springs in Parque das Águas de Contendas, Minas Gerais, Brazil

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Abstract

The Contendas region in Minas Gerais is home to the Parque das Águas, internationally known for the therapeutic properties of its hydromineral waters. Several previous geological, geochemical, and hydrogeological studies have been conducted to understand and characterize the hydromineral springs. This study aims to investigate the flow and pathways of groundwater in the local aquifer through geophysical methods, with emphasis on Electrical Resistivity Tomography (ERT) and Audiomagnetotellurics (AMT). The AMT data were processed using Egbert's code and inverted with the 2D algorithm of Rodi and Mackie. For the ERT data, the AGI EarthImager 2D software was used. The integrated geophysical results reveal significant lateral geo-electrical variations associated with the hydrogeological structures of the area. In the future, 3D models will be generated using the ModEM code. The project was funded by CODEMGE and carried out by UFMG, UERJ, and Observatório Nacional.

Introduction

One of the most important mineral water occurrences in Brazil is located in Contendas, in the municipality of Conceição do Rio Verde, southern Minas Gerais. This study aims to understand the processes responsible for the formation of the hydromineral springs, as well as the origin and circulation of groundwater in the Parque das Águas de Contendas and its surroundings. The local geology consists of Archaean/Paleoproterozoic gneissic rocks and Neoproterozoic metasediments of the Andrelândia Group (PACIULLO et al. 2000, RIBEIRO et al. 2013). The structural framework of the area reflects two tectonic events: deformation related to the Brasília Belt, characterized by NE-SW foliations, and tectonism associated with the Ribeira Belt, which generated strike-slip shear zones also oriented NE-SW (TROUW et al. 2007a). The geophysical investigation employed audiomagnetotelluric (AMT) and electrical resistivity tomography (ERT) methods, with two-dimensional inversions applied to two profiles with 20 AMT stations (P1 – N-S and P2 – E-W) and two ERT profiles, using 6 m electrode spacing (Fig. 1b).

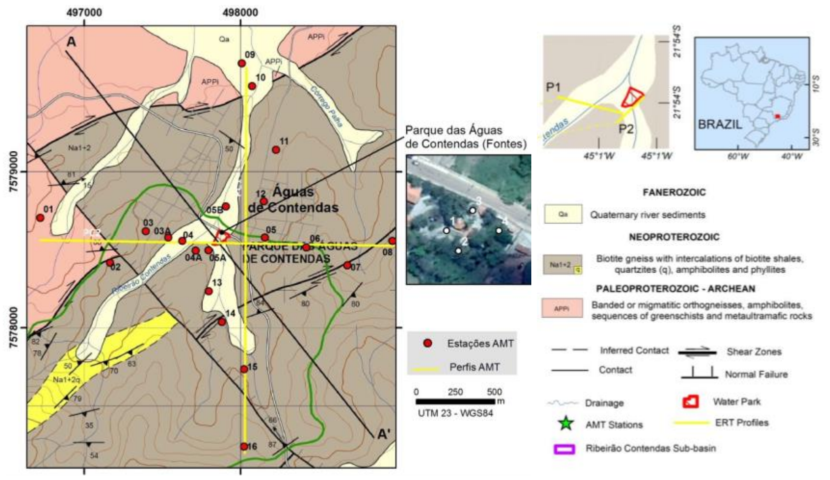

Figure 1: a) AMT stations and sections in Águas de Contendas. Na1+2, quartzites and schists of the Andrelândia Megasequence. APPi, Archean-Paleoproterozoic basement gneisses. b) Location of the ERT profiles (yellow lines) carried out in Parque das Águas de Contendas.

Method

To investigate the origin and circulation dynamics of water sources in Contendas, we applied audiomagnetotelluric (AMT) and electrical resistivity tomography (ERT) geophysical methods. By analyzing the variation of electrical conductivity with depth, we could identify potential zones of recharge, flow, and underground storage. Differences in rock conductivity allowed us to infer lithological and structural controls based on the geometric parameters of subsurface structures, such as depth, dimension, and dip direction.

Audiomagnetotelluric (AMT) Method

We acquired 20 AMT stations distributed across two intersecting profiles in the Parque das Águas de Contendas area (Figure 1). Profile P1 (N-S) is approximately 2,500 m long with 11 stations, while Profile P2 (E-W) is about 1,900 m long with 12 stations. Three of these stations (stations 5, 5A, and 5B) are shared with Profile P1. The spacing between stations varied from 100 to just over 300 meters, depending on access conditions. The data was processed using robust techniques, including noise reduction and statistical smoothing to remove outliers. 2D inversions were performed using the Rodi & Mackie code, generating sections of electrical resistivity as a function of depth and distance along the profiles.

Electrical Resistivity Tomography (ERT) Method

We acquired two electrical resistivity tomography (ERT) profiles in the Parque das Águas de Contendas to characterize shallow geological structures down to a depth of about 50 meters. Profile P1-ERT, measuring 336 meters long and oriented W-E, used 56 electrodes with a 6-meter spacing**.** Profile P2-ERT**,** which is 252 meters long and oriented N-S, utilized 42 electrodes with the same spacing. Both profiles employed the Schlumberger array, with a maximum current of 2.0 A and 1.2-second cycles. The instrumentation used was the SuperSting R8/IP (AGI) resistivity meter.2D inversions, performed using the finite element method, adopted a root mean square (RMS) error of up to 1%**,** with smoothing applied to remove outliers and improve data quality.

Results – AMT Profiles

The AMT sections intersect the Jesuânia Shear Zone, a fault with a normal component, and another parallel shear zone (Figure 1a). From a depth of 200 m downwards, significant lateral variations in resistivity are observed, with resistive blocks highlighted by blue-green colors**.**An extensive block of high resistivity (up to 2,500 Ω.m) appears at the far south of the N-S profile (Figure 2), bounded by the normal fault. Moving north towards Parque das Águas, two other resistive blocks are identified in the central portion, with values between 1,500 and 2,500 Ω.m**.** North of the Jesuânia Shear Zone, the basement also displays a significant resistive body.

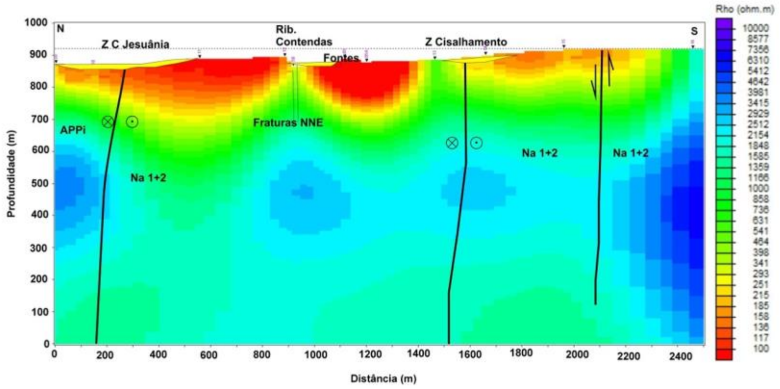

Figure 2: N-S AMT section**.** APPI, basement. Na1+2, Andrelândia Megasequence. Resistivity isolines in Ω.m.

On the E-W section (Figure 3), resistive blocks are situated between the normal fault and a secondary shear zone, while the rest of the section displays low resistivity. The intersection of the N-S and E-W sections reveals a more extensive conductive zone in the E-W direction. To the west, resistivity decreases again until it reaches another resistive domain, associated with the basement (APPi)**,** which is bounded by the normal fault. In both sections, a shallow conductor (red to yellow) stands out, with resistivities lower than 100 Ω.m. This is interpreted as a granular aquifer composed of alluvial deposits and saprolite, saturated with mineralized water. In the N-S section (Figure 2), this conductor extends for 1,400 meters, from upstream of Parque das Águas de Contendas to the Baependi River plain, potentially reaching 100 meters in depth. Below the park, resistivities between 100 and 300 Ω.m persist down to 200 meters deep**.** To the south, separated by a more resistive domain (near AMT station 13), another conductor **(**100–300 Ω.m**)** occurs. This is associated with the fractured aquifer, structurally limited by the normal fault and shear zone. In the E-W section (Figure 4), the main conductive zone is located beneath the park's springs, between 30 and 50 meters deep**,** with an irregular base and a lateral extent of approximately 1,200 meters**.** Other conductive zones extend westward, reaching the alluvial plain of a Baependi River tributary.

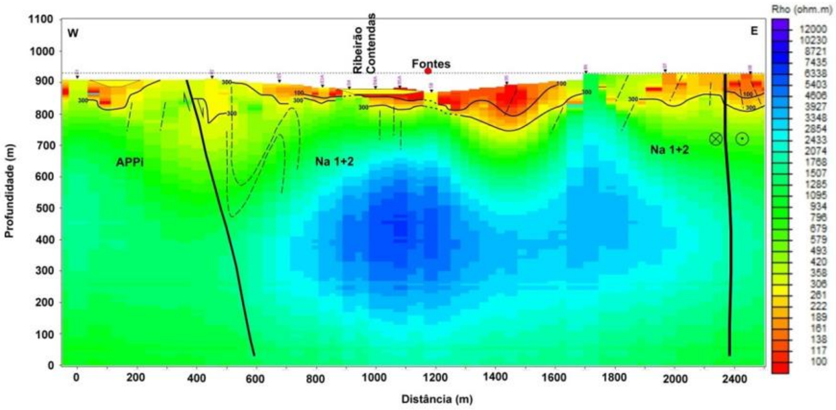

Figure 3: E-W AMT section**.** APPI, basement. Na(1+2), Andrelândia Megasequence. Resistivity isolines in Ω.m.

Result from Electrical Resistivity (ER) Profiles

The ERT sections were acquired in the interfluvial region south of Parque das Águas de Contendas (Figure 1b) and processed with a Schlumberger array**,** normalized to 900 Ω.m (Figure 4). The P1 section (E-W) (Figure 4a) traverses, from west to east, the left bank slope of the Contendas Stream, its main channel, and the alluvial plain. East of the channel, we observe a conductive domain within the quartzites and schists of the Andrelândia Megasequence. This is linked to the presence of mineralized water in mylonitic foliation**.** The basement here is covered by alluvial sediments up to 15 m thick, which reflect the electrical properties of the underlying bedrock. The P2 section (N-S) (Figure 4b) begins on the colluvial ramp located at the divide between the Contendas Stream and its right-bank tributary, crossing the alluvial plain to the opposite bank of the stream. A highly conductive basement domain (low resistivity) extends from the divide to the stream channel, suggesting salinized water is present in the mylonitic quartzite of the Andrelândia Megasequence. Overlying this basement are resistive colluvial ramps and low-conductivity alluvial deposits. The P2 section indicates that, near the Park, the basement's conductivity does not extend into the alluvial deposits**,** suggesting a lack of hydraulic connection between deep and shallow aquifers**.** Furthermore, the high resistivity of the colluvial ramps indicates low vertical recharge through direct infiltration**.**

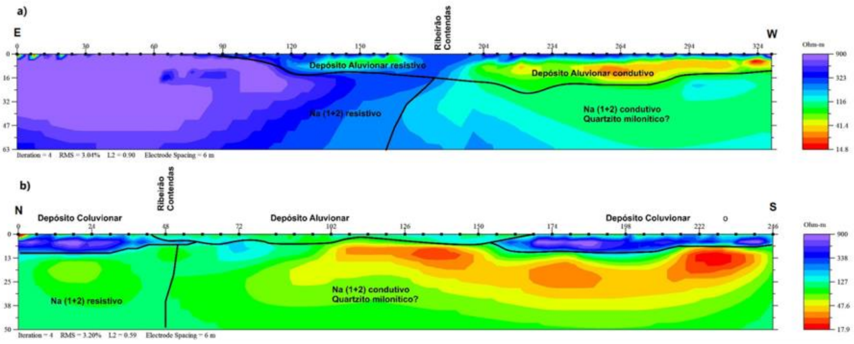

Figure 4: Electrical resistivity sections of Águas de Contendas, Schlumberger array, normalized to 900 Ωm. a) P1-E-W section; b) P2-N-S section.

Conclusions

The AMT P1 (N-S) and P2 (E-W) sections cut through basement rocks and the Andrelândia Megasequence, both influenced by tectonic features like the Jesuânia Shear Zone, a southeastern shear zone, and a normal fault. The Contendas Stream and Córrego da Palha follow N-S lineaments, with alluvial deposits found between 880–890 m elevations. A prominent wide conductive zone (≤100 Ω.m) stands out in the AMT sections beneath the Parque das Águas de Contendas, interpreted as a fractured aquifer**.** This zone reaches depths of 30–50 m (P2) and up to 200 m (P1), extending approximately 1,200 m in the E-W direction and 1,400 m in the S-N direction, from upstream of the Park to the alluvial plain of the Baependi River. The conductive anomaly's geometry and orientation suggest structural control by regional folds and shear zones**,** particularly a NE-oriented fractured zone parallel to the foliation, which concentrates under the right bank of the Contendas Stream. The ERT sections**,** acquired south of the Park, show a deep conductive domain within the basement**.** This is linked to the presence of mineralized water in the mylonitic foliation of the quartzite**.** Above this, alluvial sediments up to 15 m thick exhibit varying resistivity: low over the conductive basement and high in colluvial areas. This arrangement indicates no hydraulic interaction between the deep and shallow aquifers. Additionally, the colluvial ramps, due to their high resistivity, do not contribute to the vertical recharge of the fractured aquifer**.**

References

Paciullo, F.V.P.; Ribeiro, A.; Andreis, R.R., Trouw, R.A.J. 2000, The Andrelândia basin, a Neoproterozoic intraplate continental margin, southern Brasília: Revista Brasileira de Geociências, 30(1), 200-202.

Pedrosa-Soares, A.C., Jeber, A., Alkmim, F.F., Scudino, P., La Terra, E.F., Voll, E., Siga: Circuito das Águas: Caracterização Geoambiental, Geológica, Geofísica, Hdrogeológica e Hidrogeoquímica do Circuito das Águas de Minas Gerais, com Ênfase nos Parques Hidrominerais de Caxambu, Cambuquira, Marimbeiro, Contendas e Lambari 1. ed. Belo Horizonte: CODEMGE - Companhia de Desenvolvimento de Minas Gerais, 2018. v. online. 512p

Ribeiro, A, 2003, Relatório da Folha São João del Rei: COMIG.

Rodi, W. and Mackie, R.L., 2001, Nonlinear conjugate gradients algorithm for 2-D magnetotelluric inversion: Geophysics, 66, 174-187

Trouw, C.C., Medeiros, F.F.F, Trouw, R.A.J., 2007, Evolução tectônica da Zona de Cisalhamento Caxambu, MG: Revista Brasileira de Geociências, 37(4), 767-776.