# Interpretation of magnetic and electromagnetic structures in the region of Samambaia-PE-Brazil, applied to groundwater reservoir

Marcos César Soares De Queiroz*, Mônica Giannoccaro Von Huelsen, Ana Luiza Carvalho Chaves and Cláudia Domingues Teixeira.



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## Abstract

The methods frequently used to locate tubular wells of groundwater in northeastern Brazil are based on the identification of permissive structures through electromagnetic (EM) induction and electrical resistivity methods. On this research, the main ideia is to emphasize the use of geotechnologies, specifically the aerogeophysical surveys, as well as the application of advanced processing techniques that can subsidize the mapping of favorable regions for groundwater. A preliminary qualitative analysis was made of the study area, located in Samambaia-PE-Brazil. Electromagnetic and magnetic structures were interpreted from the image of apparent conductivity and the map of magnetic anomalies and compared with geological structures.


## Introduction

In the Northeast of Brazil, the semi-arid climate is dominant and characterized by low and irregular rainfall, high insolation and evaporation rates, which discourages water retention over long periods in surface reservoirs.

Underground water reserves have small variation and the aquifer environment is considered strategic for the subsistence of the population in the region for its economic development.

From the hydrogeological point of view, the crystalline rocks, given to their high compactness, and absence of primary porosity, are rocks that are not favorable to confine groundwater. However, when these rocks are subjected to stresses and tensions, caused by geological events, such as the tectonic movement of crust accommodation, the percolation process and water storage along the discontinuities, geologically represented by faults , intensely weathered joints, fractures, foliations and / or geological contacts.

One of the underground water flow and storage structure models in crystalline soils for NE Brazil proposed in the literature and traditionally used for the location of deep tubular wells is based on the control of rectilinear drainage by areas of faults or fractures (*Riacho-Fenda* model*).*

Pioneering applications in the exploration of underground water resources began in 2001 with the PROASNE (Northeastern Brazil Groundwater Aerogeophysical Project), developed by the partnership between the Geological Survey of Brazil (CPRM) and the Geological Survey of Canada (GSC), where they were obtained high resolution electromagnetic and magnetic data.

Recent applications of AEM data in hydrogeology allow mapping potential lithology and aquifer geological structures (Sattel & Kgotlhang, 2003).

According to (Palacky, 1986), the interpretation of AEM data provides the location and characteristics of conductive targets, which may indicate water presence in a given region (Souza Filho *et al.,* 2010).

In this research, we intend to demonstrate and compare with other techniques the applicability of methodological approaches that aim to help the process of locate favorable structures to the groundwater storage in areas with a not very thick cover, as it is the case of the Brazilian NE Region.

## Geological Setting

The municipality of Custódia is located in the northern portion of the microregion of the Alto Vale do Rio Moxotó (Figure 1). It is geographically limited to the north with the municipalities of Iguaraci, Carnaíba, and Flores and to the south the municipalities of Ibimirim, Floresta and Betânia. To the east of Custódia are the municipalities of Sertânia and to the west are Floresta and Betânia.

In the Custódia region, two shear faults occur, Custódia and Samambaia, oriented to N15ºE. They are constituted by a great lithological variety, from rocks of the Paleoproterozoic - PF (diorites orthogneisses and granodioritic, migmatite, including gabbro, metadiorite and schist), Mesoproterozoic including orthogneisses and migmatites from the Lagoa das Contendas Complex, schist and gnaisses from the Sertânia Complex (Pmse), orthogneisses and indiscriminate migmatites (Mgi), granitic orthogneisses to tonalitic (Mgo) to Neoproterozoic with schist and intercalations of marbles and quartzites (Caroalina Complex), granitoids and orthogneiss (Ngi) and granitoids K – calcalkaline (Ngc). The Paleozoic is represented by small areas to the northwest of the municipality where sandstones of the Tacaratu Formation occur. The Cenozoic is represented by quaternary alluviums, which occur along the stretches of the main water courses that command the drainage in the municipality, such as the Moxotó rivers, Conceição, Várzea Grande, Custódia, Copiti and Maravilha streams (CPRM, 1999).

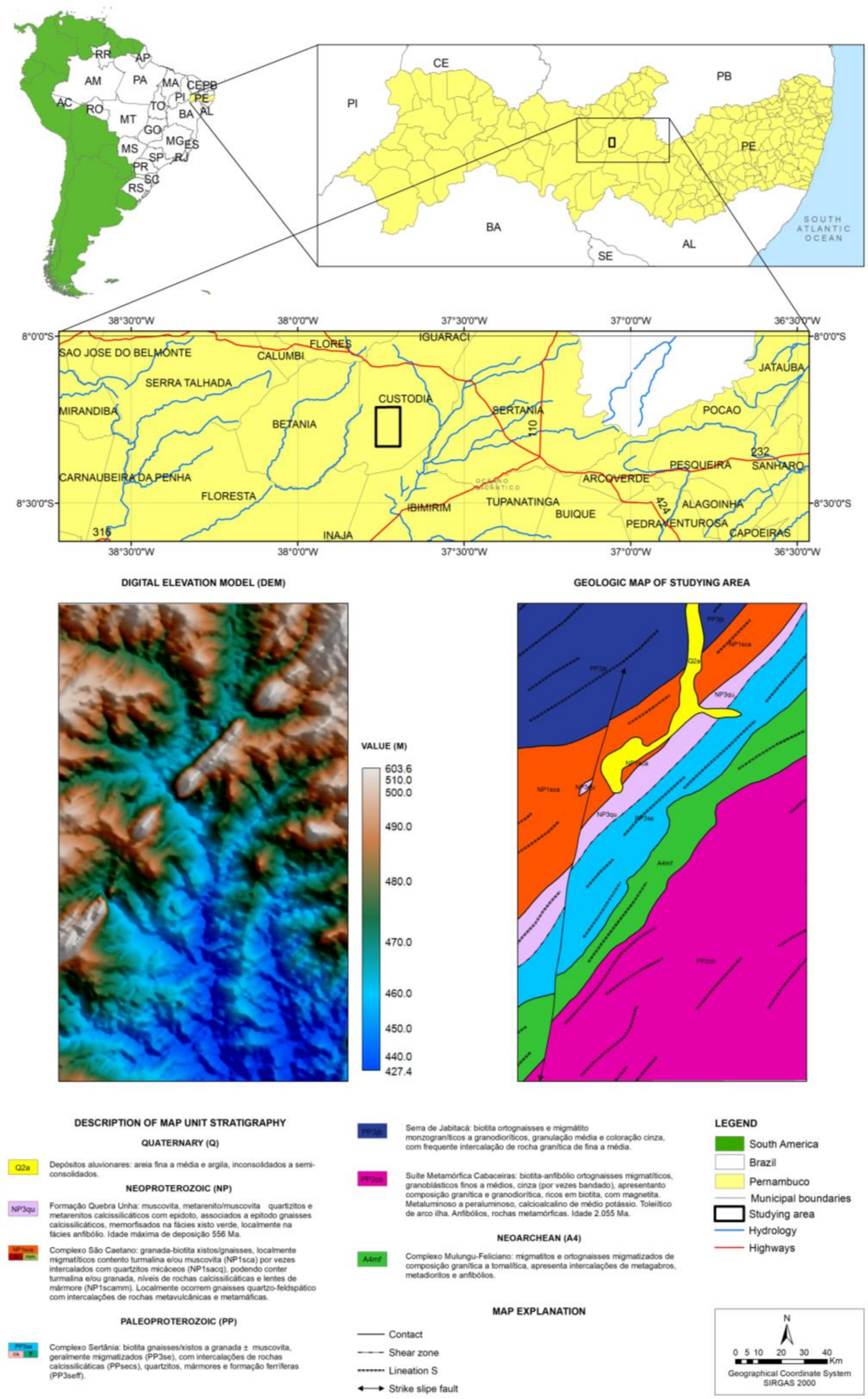


***Figure 1** - Location map and geological map of the study area.*

## Method

The geophysical date has been surveyed between March and May 2001.

The main parameters of data acquisition were:

Flight line direction: E-W, with 13 km of extension;

Control line direction: N-S, with 8 km of extension;

Flight line spacing: 0.1 km;

Control line spacing: 0.5 km;

Average flight height: 60 m.

The interval between the geophysical measurements was 0.1 s. The height of the magnetometer and electromagnetometer sensors on the ground was 30 m at an approximate flight speed of 144 km/h (LASA Eng., 2001).

Data processing included removal of IGRF calculated (International Geomagnetic Reference Field). The final available product is the Total Magnetic Intensity (TMI). It was calculated the Vertical (Dz) and Horizontal Derivatives (Dx and Dy), Analytical Signal Amplitude (ASA), Tilt-Derivative (TDR), Total Horizontal Gradient Amplitude (THDR) and Analytical Signal Phase (ASP). Applications of these techniques help to infer the geometry of the magnetic fonts.

From the electromagnetic signal, images of the Quadrature (Q) and in-phase (I) componentes in - Frequency Domain (FDEM) were obtained, with three pairs of coplanar horizontal coils and two pairs of coaxial vertical coils, spaced 6.4 m apart. The coaxial coils are in the vertical position, with frequencies of 900 and 4500 *Hz* and the axis aligned with the direction off light, and the coplanar coils are horizontal, with frequencies of 900, 4500 and 33.000 *Hz*.

Stacked conductivity profiles were generated for diferente frequencies, low, médium and high, considering the coaxial and coplanar arrangements.

## Results

Figure 2 shows the image of the Amplitude of the Analytical Signal (ASA), where it is noted that the region with the highest magnetic values predominates in the southeast of the area. In general, the magnetic structures have a preferred NE / SW direction.

According to the power spectrum of the magnetic signal, shown in figure 3, the deeper anomalous sources reach values below 2 km. The shallow sources are 0.5 km deep.

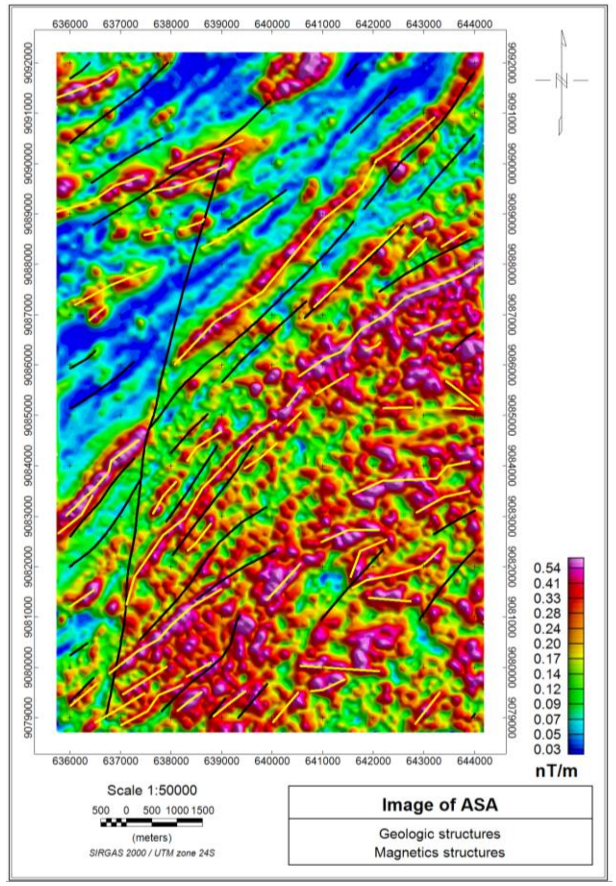


***Figura 2*** *- Image of the Analytic Signal Amplitude (ASA) of the Total Magnetic Intensity (TMI). Interpreted magnetic structures (—) and geological structures (—).*

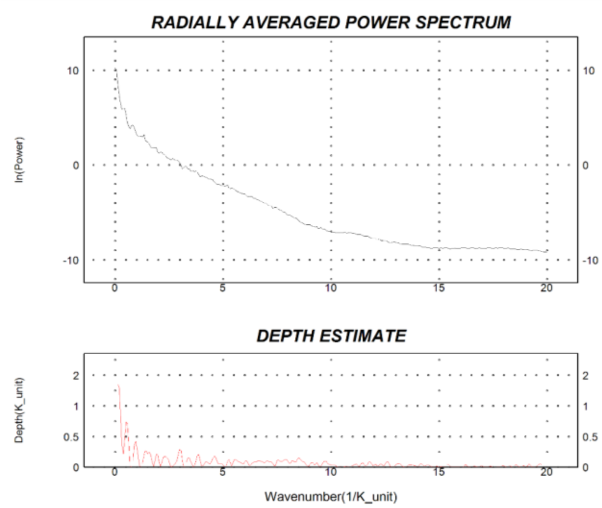


***Figure 3*** ***–*** *Power spectrum of the Total Magnetic Intensity (TMI) data showing the estimated depths of the magnetic sources.*

The image of the apparent conductivity (Figure 4) shows high conductivity in the northwest direction, with predominance structures in the NE / SW practically in the whole area. This extensive conductive area to NW was interpreted as a probable conductive cover due to the existing rocks in the region or even may be related to the presence of groundwater that is in that part. The stacked profiles (Figure 5) indicate shallow southeast structures characterized with high frequency electromagnetic signal in NW / SE directions and an NE / SW. Most of the electromagnetic structures do not present displacement with the increase of the depth, indicating that these structures are arranged vertical to subvertical. It is evident that the sinistral NE / SW transcurrent faults and N / S extension, which cuts the area, caused the displacement of the electromagnetic anomaly (Figure 4, 5 and 6).

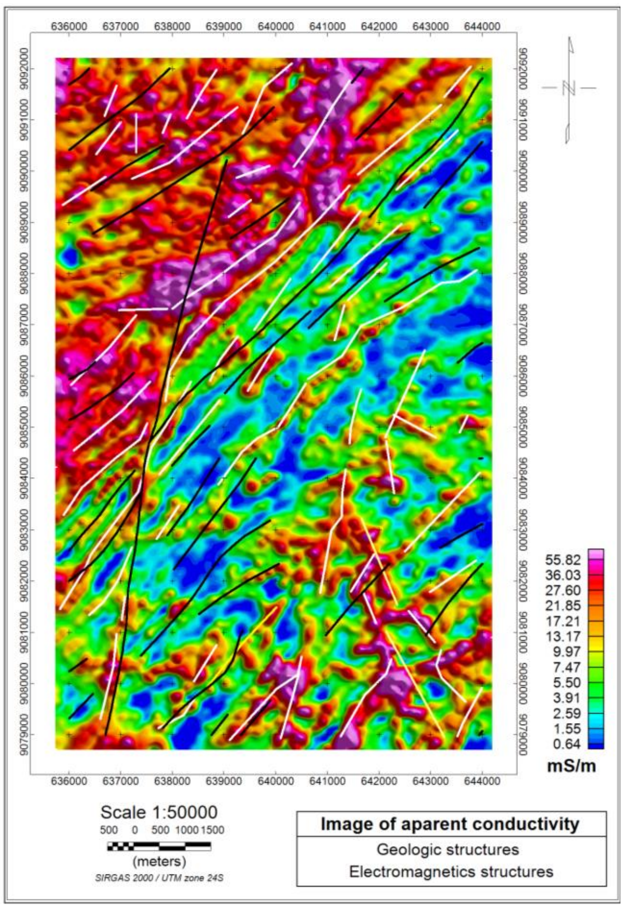


***Figure 4*** *- Image of Apparent Conductivity in a low-frequency coplanar configuration. Interpreted shallow electromagnetics structures (—), electromagnetics structures (▭) and geological structures (—).*

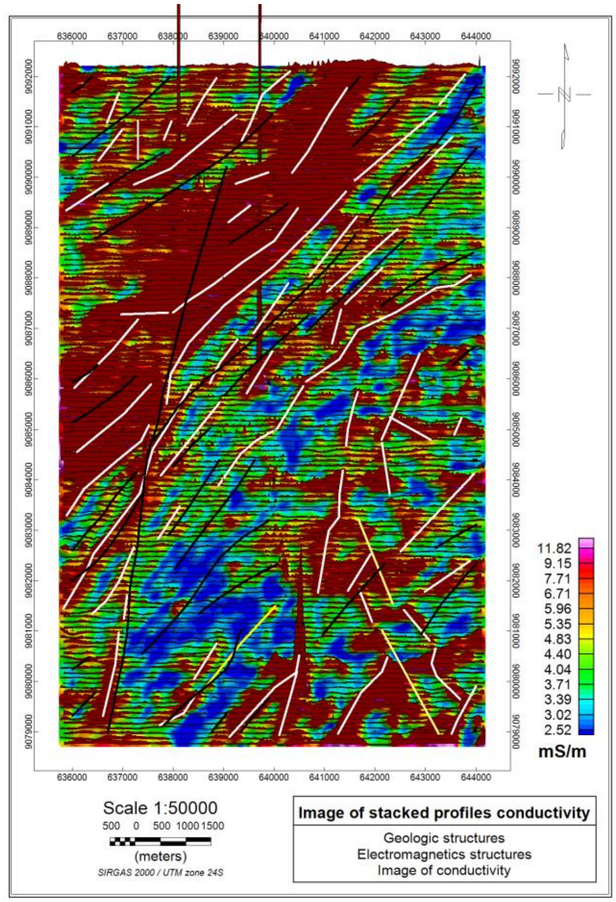


***Figure 5*** *- Image of stacked profiles conductivity, both with low-frequency coplanar configuration. Interpreted shallow electromagnetics structures (—), electromagnetics structures (▭) and geological structures (—)*

Figure 6 shows a composition of the conductivity images and the Amplitude of the Analytical Signal (ASA). This composition has demonstrated excellent indicative of areas with higher conductivity and also those areas with well-defined magnetic structures. Areas with warm colors represent the high responses for both geophysical data, magnetic and electromagnetic, whereas cold colors represent magnetic or exclusively conductive bodies.

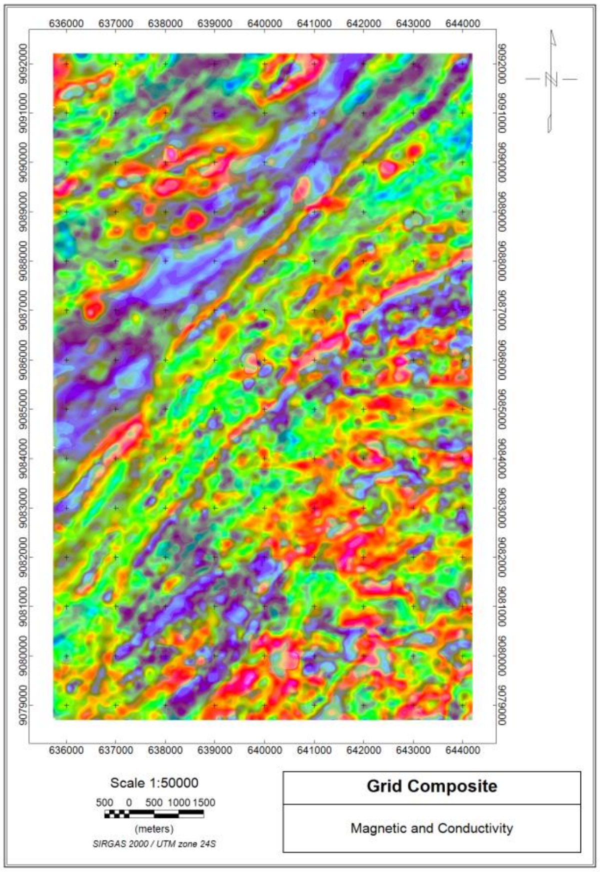


***Figure 6*** *- Composite image of the Amplitude of the Analytical Signal (ASA) and the Apparent Conductivity in a low-frequency coplanar configuration.*

## Conclusions

In general, magnetic anomalies are predominant in the southeast portion of the area. The magnetic sources mostly reach shallow depths of up to 500 m. The conductive sources are present mainly in the northwest portion and are shallower than the magnetic sources. The magnetic and conductive features indicate that the structures present in the area have a preferred NE / SW direction (Figure 4). It is observed that the magnetic and conductive bodies simultaneously dominate in the southeast region.

This research follows, with the proposal of a better characterization of the region, in which it predicts the integration with gravimetric data with the purpose of generating a 2D model representative of the area, besides the seismic study of the region.

## Acknowledgments

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- Geological Survey of Brazil – CPRM.

## References

LASA ENGENHARIA e PROSPECÇÕES S/A, 2001, Projeto Aerogeofísico Água Subterrânea no Nordeste do Brasil, Blocos Samambaia (PE). Relatório final do levantamento e processamento dos dados magnetométricos e eletromagnetométricos e seleção das anomalias eletromagnéticas. Texto técnico. Cooperação Canadá-Brasil / PROASNE. Brasília.

MORAIS, FRANKLIN DE. Produtividade e qualidade da água dos poços no meio fissural do Alto Vale do rio Moxotó. Dissertação de Mestrado - Universidade Federal de Pernambuco, 1999.

NABIGHIAN, M.N., 1991a, Eletromagnetic Methods in Applied Geophysics. In: Investigations in Geophysics, No. 3, Vol. 1 – Theory. Ed. Misac N. Nabighian, SEG, Tulsa, U.S., 505 p. il.

PALACKY, G. J. (1986). Geological Background to resistivity mapping. Ed., Palacky, GJ, Airborne resistivity mapping. GSC Paper, 86(22), 19-27.

SATTEL, D.; KGOTLHAND, L., 2003, Modelling Aquifer Structures with Airborne EM in the Boteti Area, Botswana. Proceedings of Symposium on the Application of Geophysics to Engineering and Environmental Problems, San Antonio, Tx, U.S.A.

SOUZA FILHO, O. A. de; REMACRE, A. Z.; SILVA, A. M.; SANCEVERO, S. S.; McCAFFERTY, A. E.; PERROTTA, M. M. 2006b. Airborne Electromagnetic Data as External Variable to Predict Groundwater Electrical Conductivity in the Crystalline Domain of Irauçuba Region – Ceará, Brazil. 2006b Hydrogeophysics Symposium, Vancouver. Society of Exploration Geophysicists, Tulsa, abstracts.