Use of FDEM–GCM Method for Groundwater Prospecting in Crystalline

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Abstract

This work presents some results of a research project that it had as motivation to analyze Electromagnetic methods and Remote Sensory jointly used to hydro-geological investigation in crystalline geological environmental. Survey was conducted in Quixadá (Ceará / Brazil) using two-loop electromagnetic method and evaluation of the result of empirical one-dimensional modelling of two-loop electromagnetic data maps lateral variations and provides valuable depth information to locate drillings. Results also indicate that fracture zones with and without water can be traced. As a result of experimental works, a number of drilling locations were proposed.

Introduction

The geophysical applied method used in this research bases on the electromagnetic induction law treated in the frequency domain. The Two-loop EM method known as “Ground Conductivity Meter” **(**GCM) that uses the EM34 system, which is a variant of the Swedish Slingram EM induction method is common method to explore the aquifer systems in crystalline areas (e.g. Slater *et al.*, 1998; Fontes *et al.*, 1997; Monteiro Santos *et al*, 2002; Carrasquilla *et al.*, 1997; Lima e Maia, 2004; Lima *et al.*, 2007). The EM34 system is the one of the most suitable tools for a fast and more sensitive data acquisition to identify lateral variation in the conductivity in geological situations of shallow crystalline basement, in other words, close of 60 meters of depth (McNeil, 1980; 1990). The working area is in Itapiúna in Ceara State, NE Brazil (Fig. 1) and is covered with the Precambrian rocks, granite and alteration zone and/or eroded and flowed units. In terms of the geophysical parameters, crystalline rocks have larger electrical resistivity values while clay or water filled fault zones have lower value. The survey area was selected according to aerial photos and previous works. A computer code was developed to evaluate two-loop EM (TLEM) data by means of one-dimensional approach (e.g. Monteiro Santos, 2004) based on the formulas given by McNeill (1980). Interpretation of the results suggested that the use of this electromagnetic method is capable to detect the fractures in crystalline environment.

Applied Methodology and Data Process

The applied method bases on the EM induction law treated in the frequency domain. Considering two circular coils where the first is the transmitter and the second is the receiver it is then applied an alternating current in the transmitter coil. The two coils stay separate to a certain distance and they are positioned on the soil in two different configurations: (1) aligned in the same way in the vertical plan called Horizontal Dipole and (2) the two placed on the soil aligned in the horizontal plan called of Vertical Dipole.

In general the secondary magnetic field is a complicated function of the spacing *s* between the coils, of the operation frequency, *f* and of the conductivity of the soil, σ. The value measured in the receiving coil it is the ratio H_s and H_p, the field when the coils positioned on a surface of homogeneous semi space with conductivity σ and the field when the two coils in the free space, respectively. The ratio is given as over homogeneous unit,

$$\left(\frac{H_s}{H_p}\right)_V \cong \left(\frac{H_s}{H_p}\right)_H \cong \frac{iB^2}{2} = \frac{i\omega\mu_0\sigma s^2}{4} \qquad (1)$$

where $\omega = 2\pi f$, μ_0 = free space permeability, i = $\sqrt{-1}$, B is induction number and much smaller than 1, and defined in terms of the skin depth δ as:

$$B = \frac{s}{\delta} << 1, \quad \text{where} \quad \delta = \sqrt{\frac{2}{\omega\mu_0\sigma}} \qquad (2)$$

So that the reading of the instrument is carried out in terms of the apparent conductivity σ_a, defined by (e.g. McNeil 1980, Parasnis 1986):

$$\sigma_a = \frac{4}{\omega\mu_0 s^2}\left(\frac{H_s}{H_p}\right) \qquad (3)$$

Regional Geology

The study area (Folha de Itapiúna) inserted in Ceará State (northeastern Brazil) (Fig. 1) that is located in the northwestern part of a neoproterozoic erogenic belt know as the Borborema Province (BP) (Almeida *et al.*,1981) and is known as else as Borborema Province’s Northern

Tectonic Domain (Van Schmus *et al.*, 1997). The Northern Tectonic Domain is subdivided by two continental-scale shear zones, the Transbrasiliano and Senador Pompeu lineaments, into three major crustal blocks: the Northern Ceará Domain, the Central Ceará Domain and the Rio Grande do Norte Domain (Fig. 1). The Folha de Itapiúna Area includes at the most part of it the Central Ceará Domain and some of the western part of the Rio Grande do Norte Domain. The basement rocks in these blocks consist of variably metamorphosed and migmatized orthogneisses assemblages (Fetter *et al.*, 2000). Overlying parts of the basement complex are a series of supracrustal sequences ranging from Middle Paleoproterozoic to Late Neoproterozoic in age (Van Schumus *et al.*, 1995, 1997; Fetter, 1999). Both basement complex and supracrustal rocks are intruded by abundant alkaline and calcalkaline plutons and plutonic complexes that were generated during Brasiliano orogenesis (Almeida *et al.*, 1981).

At the Central Ceará Domain the basement complex of the Central Ceará domain is dominated by high-grade felsic orthogneisses and migmatites that are primarily tonalitic to granodioritic in composition (Fetter *et al.*, 2000).

At the Rio Grande do Norte Domain the basement complex of the Rio Grande do Norte domain in Ceará is dominated by paragneisses and schists, but some tonalitic to granodioritic orthogneisses are present locally. Most of these basement gneisses show variable degrees of migmatization, from small degrees of partial melting to almost complete remelting in some locales (Fetter *et al.*, 2000).

Local Geology

The Lithologie is represented in the Folha de Itapiúna as geological units belonging to Precambrian, Palaeozoic, Mesozoic and Cenozoic Ages. The Precambrian crystalline rocks recover most of the study area mapped surface, embracing entities of Inferior, Medium and Superior Proterozoic Ages. There are too Jurassic basic dikes, tertialy/quartenary sandy/muddy colluviums sediments and recent alluvium deposits (Fig. 2).

Results

In the field survey the FDEM-GCM EM34 system was used to collect the data in vertical and horizontal dipole configurations with intercoil spacing of 10, 20 and 40m. Six data were obtained for each station. The graphics illustrated the results are used for qualitative interpretation curves obtained from ideal geologic model (figures 5 and 6). In these graphics is possible to suggest well locations sites.

The 1D modelling scheme for each GCM reading point produces quasi-2D models along the profiles. Inversion process was performed with smoothness criteria and using predefined depth values: 1, 2, 5, 10, 15, 20, 25, 30, 45, 60, 75m. The graphics obtained for quasi-2D block models and quasi-2D interpolated models are used for hidrogeological interpretation. In these graphics is possible to infer fractured zones occurrences (figures 5 and 6). Geoelectrical models obtained from both interpretation methods present fractured structure under the profile.

Conclusions

Fault zones can be imaged clearly by using densely gathered data and quasi-2D modelling scheme using 1D modelling code for two-loop electromagnetic data. Locations of existing wells are also in accord with our models.

The groundwater prospecting surveys require fast and efficient data gathering systems. The results of this study show that FDEM-CGM method is the one of the most suitable tools for a fast and more sensitive data acquisition to identify lateral variation in the conductivity in geological situations of shallow crystalline basement.

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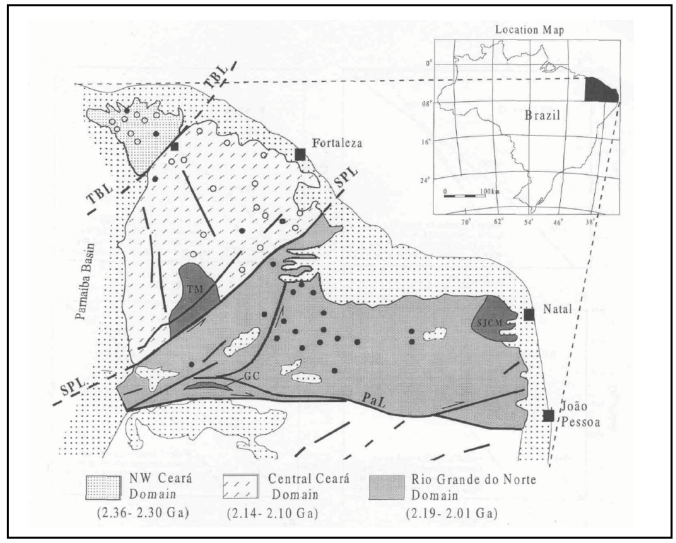
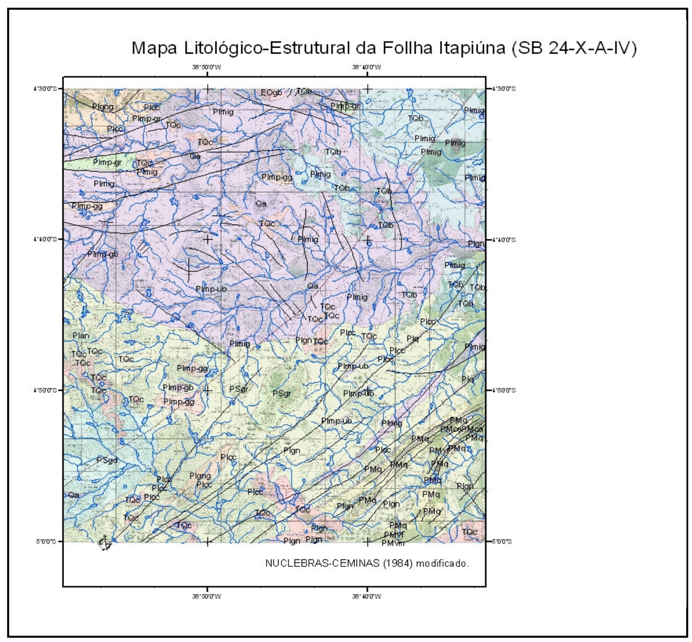


Fetter *et al*., 2000. Modified.

Figure 1 - Schematic map showing the subdivision of major crustal blocks in the Northern Tectonic Domain of the Borborema Province, TBL - Transbrasiliano Lineament, SPL = Senador Pompeu Lineament, PaL = Patos Lineament..



Lima *et al*., 2007.

Figure 2 – Geological-Estructural Map of Folha de Itapiúna.

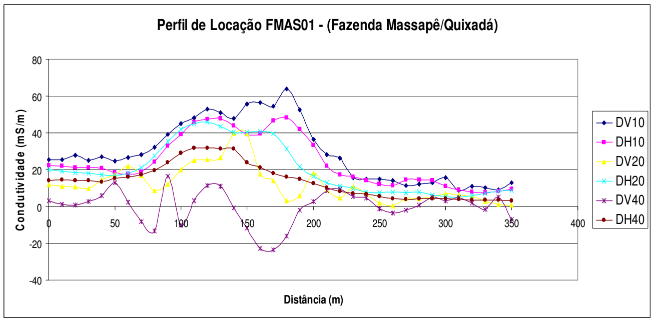


Figure 3 – EM34 Survey – Profile 01 with all Dipole modes.

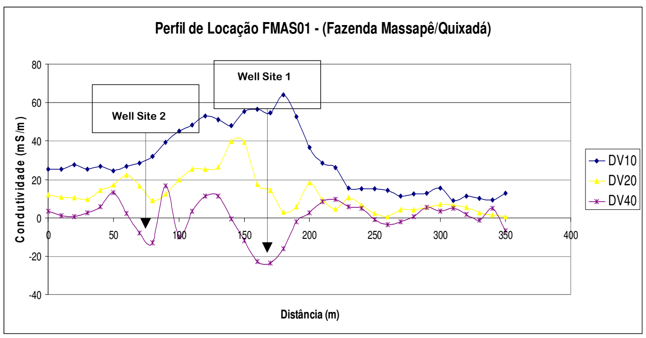


Figure 4 – EM34 Survey – Profile 01 with Vertical Dipole mode and Well Location sugested.

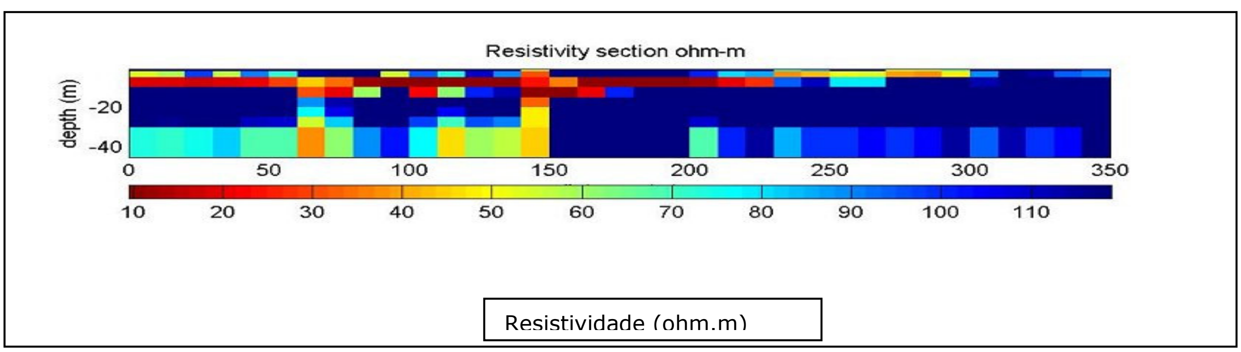


Figure 5 – Quasi-2D Geoelectrical Model.

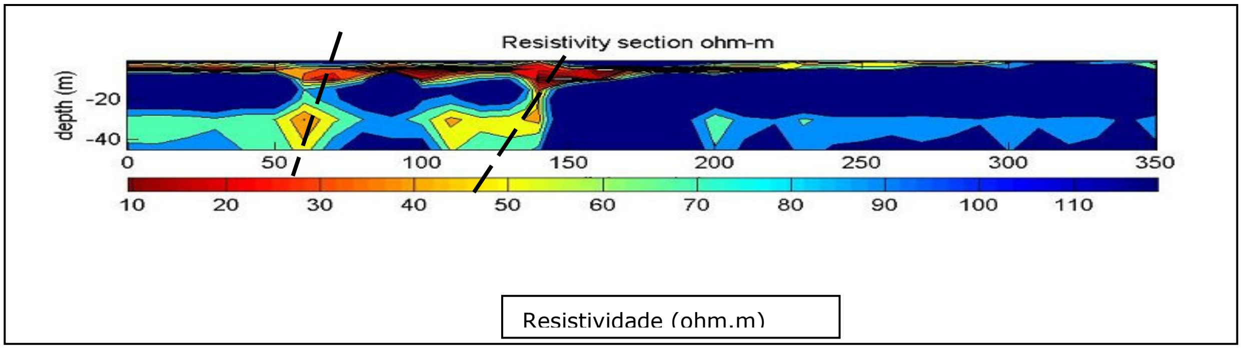


Figure 6 – Interpretation of Interpolated Quasi-2D Geoelectrical Model.