Geoelectrical Characterization by VES/TEM Joint Inversion at Urupês Region, Paraná Basin, Brazil

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Abstract

This paper shows the results of joint inversion of VES/TEM for Urupês region, Paraná sedimentary basin, São Paulo State, Brazil. The objectives of this research were to map the Adamantina Formation (sedimentary aquifer) and to locate fractures zones in the basalt layer of the Serra Geral Formation. The results indicate the tick of the Adamantina Formation (Bauru aquifer) and the fracture zones in the basalt of the Serra Geral Formation.

Keywords: VES, TEM, Joint inversion, Parana basin, Urupês, São Paulo State, Brazil.

Introduction

In São Paulo State, Brazil, 462 cities are supplied by groundwater, covering 5.5 million people (Iritani and Ezaki, 2009). In this context, the Urupês region (Figure 1) which is located in the north-western portion of São Paulo State, approximately 450 km from São Paulo city.

In the last years, Urupês has presented some problems with the water supply in summer season. A quick solution for this is apply the geophysical methods to discovery new points to groundwater exploration. Electrical and electromagnetic methods can provide favourable locations for drilling new wells. These methods can obtain some important characteristics from aquifers such as thickness, resistivity and geometry (Fitterman and Stewart, 1986). However, in most cases, the data of both methods are interpreted by individuals 1D models which can be ambiguous and not represent the real geological medium.

The use of joint inversion of the electrical and electromagnetic methods can reduce the ambiguity of the interpretation process and the final result is better. Both methods have important advantages, the vertical electrical sounding (VES) is able to define well resistive structures, while the transient electromagnetic sounding (TEM) is very sensitive to map conductive structures. Another characteristic is that VES is more sensitive to shallow structures, while TEM soundings can reach deeper structures. The use of joint inversion is already well known in geophysics. Some papers such as Raiche et al. (1985), Albouy et al. (2001) and Schmutz et al. (2000) showed several advantages in the use of joint inversion.

In this paper we applied the joint inversion of electromagnetic (TEM) and electrical (VES) data in order to characterize the geoelectric stratigraphy of Urupês region to help the drilling of boreholes to exploitation of groundwater. The Curupira program was used (Bortolozo and Porsani, 2012). The results with the joint inversion will be used to establish the main features of the Bauru and Serra Geral Aquifers.

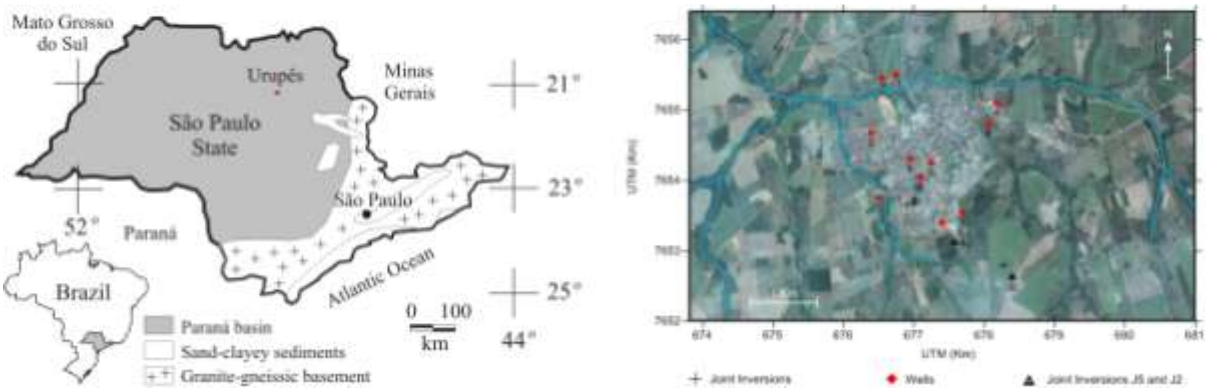

***Figure 1:** Location of VES/TEM soundings in Urupês region, São Paulo State, Brazil.*

Geological settings

The study region is over the Paraná sedimentary basin and it is constituted mainly by three formations: Adamantina, Serra Geral and Botucatu. The Adamantina formation is characterized by sand sediments with almost 90 m thickness, intercalated by clays and sands lens. Usually, this formation is associated to Bauru aquifer that is important water reservoir in São Paulo State. Below Adamatina formation, there is the Serra Geral formation that is characterized by basalt rocks. In some areas, these rocks can be fractured and filled with water (Serra Geral aquifer). According to deep wells information in the studied region, the thickness of this layer is between 400 m to 600 m (Porsani et al., 2012b). The last formation is Botucatu (Guarani aquifer) that is formed by sandstones rocks.

VES and TEM methods

In this work the electrical (VES) and electromagnetic (TEM) methods were used to acquire data. Both methods show the resistivity variation with depth after the inversion; with obtained results is possible to correlate the geological data with resistivities data. The TEM technique uses a square transmitter loop as transmitting source and a DC electrical current is injected by a generator. This current is ceased, causing the time variation of the primary magnetic field associated with the current in the transmitter loop. According to the Faraday's law, an electromotive force is induced in subsurface, generating eddy currents in the soil. These induced currents are attenuated, causing the time variation of the secondary magnetic field. This time variation induces more electromotive force and more eddy currents, such that this effect diffuses in depth like a smoke ring effect. The measurements of electromotive force associated with time variation of the secondary magnetic field are done with a receiver coil on surface, being related with apparent resistivity. More information about the application of TEM method in hidrogeology studies can be found in literature (Christiansen et al., 2006; Porsani et al., 2012a, 2012b; Bortolozo et al., 2012). In the electric method, electric currents are injected direct in the earth´s surface by fixed electrodes on the soil. So, the voltage is measured and converted to apparent resistivity (Kearey et al., 2002).

Acquisition and treatment of data

Fifteen TEM soundings and twelve VES soundings were acquired in three field campaigns conducted in 2009, 2011 and 2012. Each TEM sounding was obtained with PROTEM-57-MK2 (Geonics) that allow working in three different frequencies (30 Hz, 7.5 Hz and 3.0 Hz). In field, it was used a square central loop of 100 m side, current of 28 A and a number of tree curves by each frequency. So, the total time for each frequency was 360 s, this way, it is possible to obtain a good signal/noise ratio.

The VES data was acquired with SYSCAL-R2 (Iris Instruments) in Schlumberger mode and AB/2 length of 200 m. All VES soundings were acquired in the same point of TEM receive coil. After all data have been obtained, they were treated and inverted in Curupira program (Bortolozo and Porsani, 2012), for a total of ten joint inversions. This program permits to correct the static-shift present in the VES data using the TEM data. More details about the static-shift formulations can be found in Meju (2005).

Interpretation of results

Figures 2 and 3 show results of joint inversion of soundings J2 and J5 (Figure 1). In "a" and "b" can be seen the adjust curve to VES and TEM soundings, respectively. Observe that the adjust error was below 5 % in both soundings. The geoelectric model is in "c" and the geological profile interpreted is shown in "d". The Figure 2d show four geological layers interpreted from five geoelectric layers. The two first layers in the geoelectric model corresponds the soil and its thickness is 4m. The third and fourth layer in the geoelectric model can be associated to sediments of Adamantina formation (Bauru aquifer). The resistivities of 90 ohm.m and 10 ohm.m are similar with results obtained by Porsani et al. (2012b) in Bebedouro city, located ~120 km from Urupês. Observe in this case, the joint inversion can solve the saturated portion that is showed by the thirst layer (57 m thick and resistivity 10 ohm.m) in geological profile. The last geological layer (109 m depth) is interpreted as the basalt layer being characterized by high resistivity (120 ohm.m).

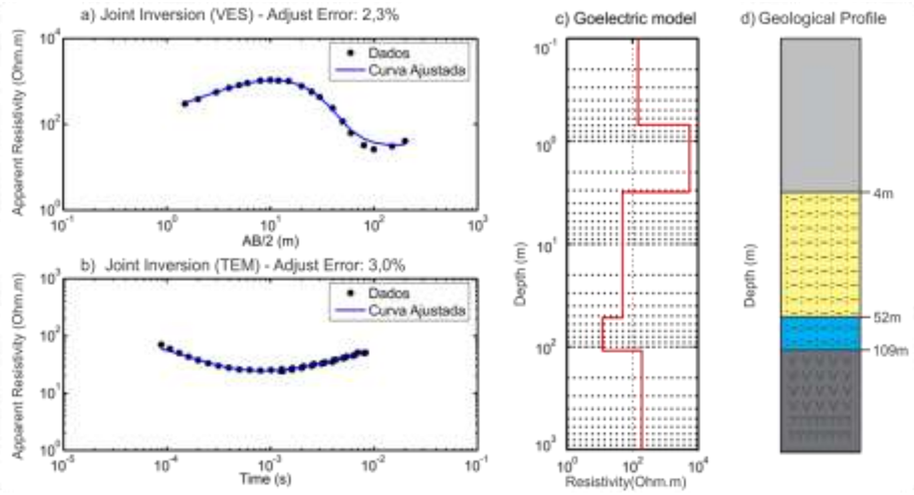

Figure 2: *Joint inversion J2. a) apparent resistivity curve by AB/2 to the VES sounding. b) apparent resistivity curve by time to the TEM sounding. c) geoelectric model. d) geological profile.*

Figure 3 shows the results from joint inversion J5 that is located near well W10 (Figure 1). Figure 3d shows four geological layers interpreted from five geoelectric layers. The soil is interpreted by two first layers in the geoelectric model. The third geoelectric layer is very well determined asa conductive layer (20 ohm.m and ~110 m thick), being interpreted as sediments of Adamantina formation (Bauru aquifer). The third geological layer (115 m depth) is interpreted as the basalt layer with high resistivity. Observe that the presence of a conductive layer (17 ohm.m) inside the basalt layer (~310 m depth). In the study region Serra Geral formation has 400 - 600 m thick basalts (Porsani et al., 2012a). So, probably this low conductivity inside of the basalt layer could be related with fractures filled with water or clay.

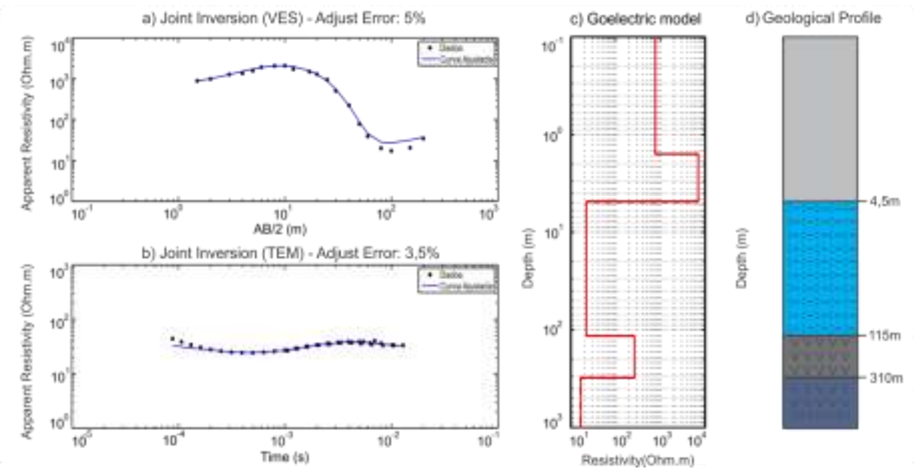

Figure 3: *Joint inversion J5. a) apparent resistivity curve by AB/2 to the VES sounding. b) apparent resistivity curve by time to the TEM sounding. c) geoelectric model. d) geological profile.*

Conclusions

Results from joint inversion in Urupês region showed interesting features from aquifers. The sedimentary aquifer was well characterized as a conductive layer in both results, having a thick more than 100 m. The conductive layer inside of the basalt layer (310 m depth) was also well determined and can be related with fractured zone filled with water (or clay). These structures can help to define a new location to drilling wells to groundwater exploitation.

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