Magnetotelluric investigation on the onshore Campos Basin.

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Abstract

The understanding of sedimentary terrains is crucial to developing their exploratory potentials. The Campos Basin is a marginal basin with an emerged portion associated. The offshore portion is yet the main hydrocarbon production site in Brazil, while the emerged portion has been studied for groundwater prospecting. We have performed a magnetotelluric (MT) survey crossing over the basin from the sedimentary terrain reaching the basement. We analyzed data from three profiles with 39 MT stations in total. Two profiles are located over the sedimentary floor and one profile is crossing the limit with the basement. The results from the profiles within the basin evidenced a two-dimensional behavior and the third profile provided more information about the position and location of the basement.

Introduction

Campos Basin is a sedimentary basin located at the southeast coast of Brazilian territory (Figure 1). The basin has approximately 120,000 km^2 until bathymetry 3500 m and of which 500 km^2 are located at the onshore portion. The offshore region of the basin has a huge density of data (especially the number of well drilled) because of great potentiality of the area. The onshore part also has a great amount of data including gravimetric, airborne magnetic and gamma spectrometric, magnetotelluric and TEM (transient electromagnetics) besides LANDSAT 7 images (Pavie, 2004). Despite this amount of data the emerged basin has basically groundwater exploration activities.

The data were acquired along three profiles R01, R02 and R03, named line 1, line 2 and line 3, respectively. The profiles are not parallel to each other; the R01 profile is in the NE-SW direction while R02 and R03 profiles are in the NW-SE direction following the same trend (Figure 2). The line 1 has approximately 50 km and 23 MT stations, the line 2 has about 23 km and 10 MT stations and the line 3 has approximately 17 km and 6 MT stations. The R02 and R03 profiles are separated by a distance of about 20 km.

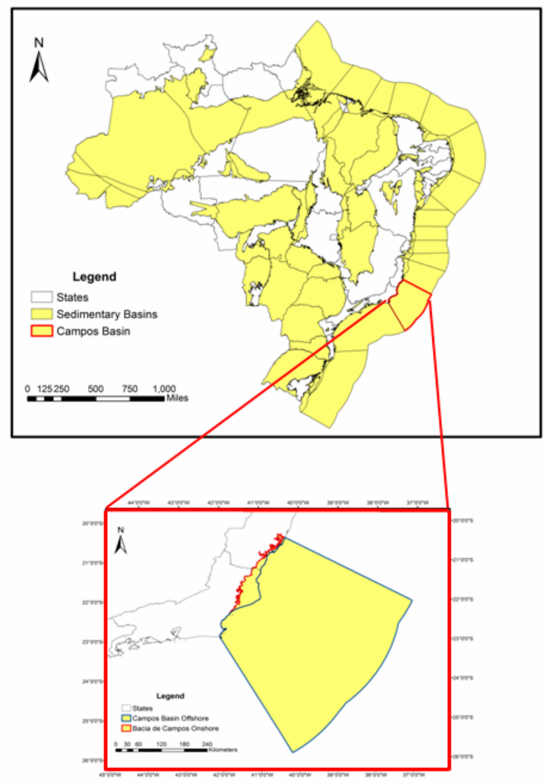

Figure 1: Location map of research area – Campos Basin. The basin is divided into two portions, onshore and offshore.

The basin belongs to a group of basins formed by the rift process occurred in the Atlantic Ocean. The basin has synthetic and antithetic faults forming grabens, half-grabens and horsts. The strike of the basin is approximately NE-SW which represents the direction of amalgamation after Gondwana's rifting (Bizzi et all, 2003). The geologic map presented in figure 2 shows smoothly this two-dimensional situation. The three profiles were chosen particularly in these directions in order to characterize the sedimentary package and the position of the basement in a situation of the basin edge.

The main objective of this work is to obtain an electrical signature of the onshore basin computing a 2D geoelectric model of the subsurface. The results and further interpretations of this research project are shown below.

Methodology

We realized an electromagnetic study using the magnetotelluric method introduced by Tikhonov (1950) and Cagniard (1953) and reviewed by Vozzof (1972). The method consists in take some measures simultaneously of both electric and magnetic fields and then obtains information about electrically distribution of the local subsurface. The measures are usually made by electrodes and magnetic coils working in the frequency range of 10^{-4} to 10^{3} Hz, this interval is called "MT Broad Band". The source of the magnetotelluric field is divided in two main phenomena: for frequencies higher than 1 Hz the sources are the lightning storms (called "*sferics*") and for frequencies lower than 1 Hz, the source is basically the interaction of the solar wind with the earth magnetosphere (called *ULF pulsations*). From these electric and magnetic field values is possible, after some processing steps, to evaluate the impedance tensor. The impedance tensor is described for a linear relation that connects the magnetic field **H** and electric field **E** (Equation 1).

$$\vec{E}(\omega) = \vec{\vec{Z}}(\omega) \bullet \vec{H}(\omega) \qquad (1)$$

The ***H*** field is the input signal and the ***E*** field is the output signal of this circuit represented by the earth and represented by the tensor ***Z*.** The impedance tensor is a complex value and then described for amplitude and phase. From this tensor we can reach the two more important parameters of the method, i.e., resistivity and phase in function of frequency or period.

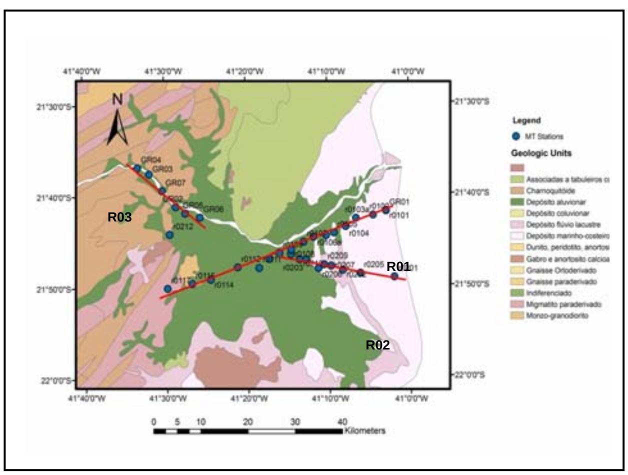

Figure 2: Geologic map from Campos basin showing the locations of the three MT profiles studied in this work.

Discussion

The resistivity and phase curves obtained by classical processing (Sims et al., 1971) did not present critical outliers (Figure 3). This point is especially important because the presence of noise on the data can lead to models not too accurate.

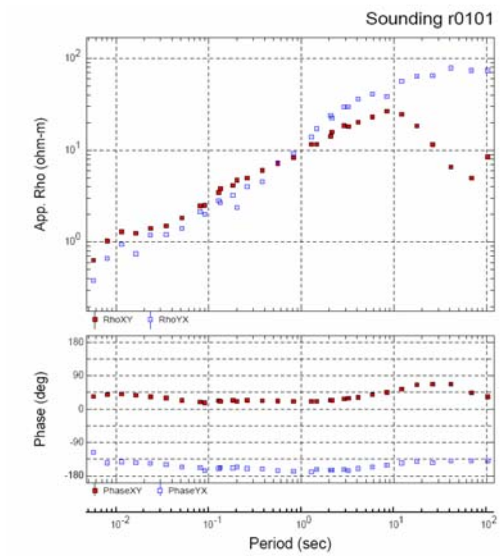

Figure 3: Apparent resistivity and phase curve for station r0101 of line 1. No outliers were observed on this sounding.

Further, the data were submitted to 2D inversions based on technique of Rodi & Mackie (2001). The inversion was calculated using the algorithm Nonlinear Conjugate Gradients (NLCG) that finds regularized solutions that explain the magnetotelluric data inside of a determined misfit. The technique consists in minimize the objective function:

$$\psi(\vec{m}) = (\vec{d} - F(\vec{m}))^T V^{-1} (\vec{d} - F(\vec{m})) + \lambda \vec{m}^T \vec{L}^T \vec{L}m \qquad (2)$$

Where *V* is a positive matrix, *L* and *Lm* are second difference matrices and l is a positive number called regularization parameter. This parameter controls the tradeoff between fitting the data and adhering to the model constraint. Larger values causes smoother models however worse data fit are obtained. This is a parameter that must be find in several inversion procedures. There is not default value to be used in any inversion. The inversions are computed from forward model constrained using finite difference equations. The algorithm inverts for a user-defined 2D mesh of resistivity blocks and incorporating topography.

Results

We discuss on the conclusions below the results for the three 2-D inversion models carried out in this project, shown in Figures 3, 4 and 5 for R01, R02 and R03 profiles.

Conclusions

The 2D inversion results showed clearly the geoelectric structures of the onshore portion of Campos

The MT results identified some geoelectrical horizons associated with the basement structures or sediments. The basement extends laterally between all profiles and approaching the coast it reaches a depth of about 2000 m.

The sedimentary layers of the basin are expressed by two conductive markers which represent the quaternary deposition of deltaic sandstones from Rio Paraíba do Sul.

Model R03 is located near the basin edge and presents a different colour range to better show the resistivity distribution and contrasts along the profile. The high resistivity values show that in this region we reached the crystalline rocks of the basement.

References

Bizzi, L. A., et al., 2003. Geologia, tectônica e recursos minerais do Brasil: textos, mapas & SIG. CPRM - Serviço Geológico do Brasil, Brasília, 692 pp.

Cagniard, L., 1953 Basic theory of the magneto-telluric method of geophysical prospecting, Geophysics, 18, 605–635.

Pavie, G. F. S. , 2004. Análise Geofísica - Geológica da Porção Emersa da Bacia de Campos através de uma Metodologia Integrada. M.Sc. Dissertation, UENF-RJ.

Rodi, W. & Mackie, R. L., 2001. Nonlinear conjugate gradients algorithm for 2D magnetotelluric inversion. Geophysics, vol. 66, no. 1, p. 174-187.

Tikhonov, A. N., **1950** On determining electrical characteristics of the deep layers of the Earth's crust, Dokl. Akad. Nauk. SSSR, 73, 295–297

Sims, W.E., Bostick, F.X. and Smith, H.W., 1971, The estimation of magnetotelluric impedance tensor elements from measured data: Geophysics, 36, 938-942.

Vozzof, K., 1972, The magnetotelluric method in the exploration of sedimentary basin, Geophys., v. 37, p. 98-141.

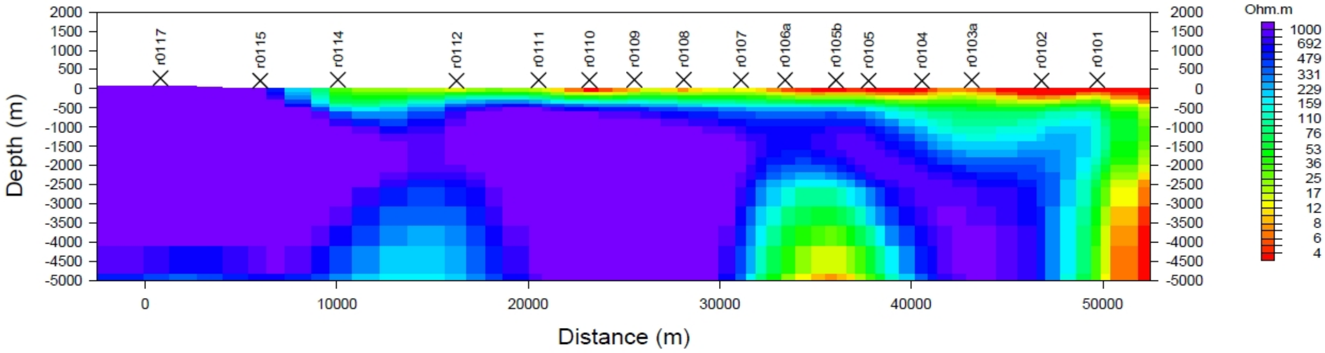

Figure 3: Geoelectric section R01

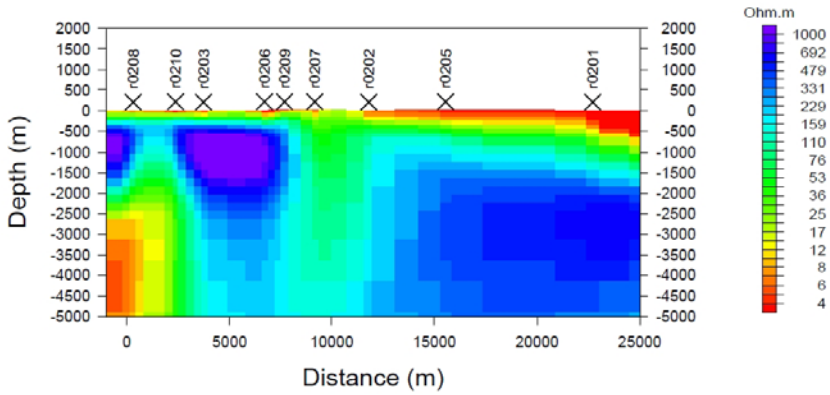

Figure 4: Geoelectric section R02

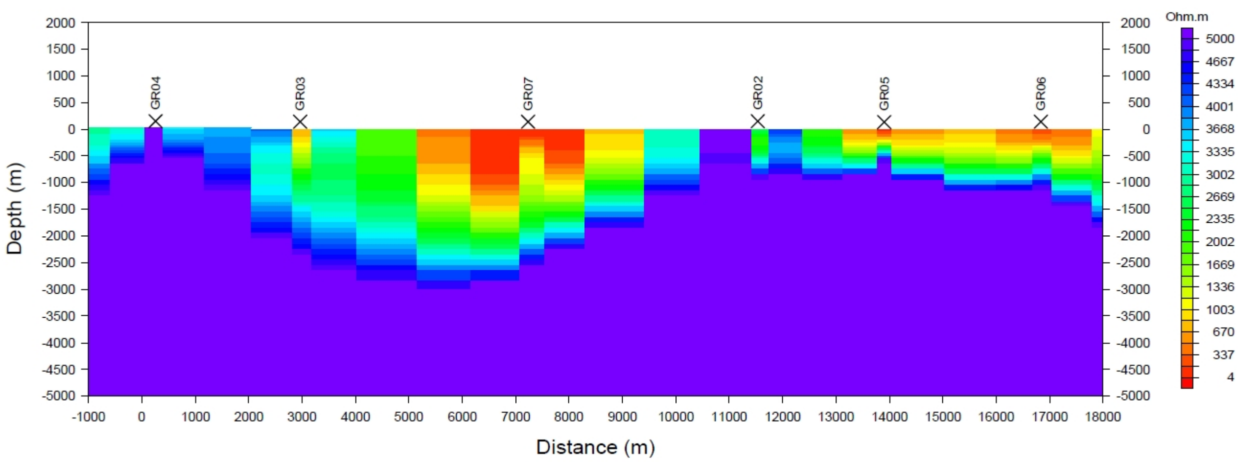

Figure 5: Geoelectric section R03