Ancient geological structures in the middle crust of southeast brazilian portion identified by geoelectrical results with Magnetotellurics geophysical methods.

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Abstract

During the Neoproterozoic the movement, the collision and the collage of tectonic plates formed a supercontinent called Gondwana. The Ribeira Belt has originated from the formation of the supercontinent Gondwana, and extends approximately 1400 km along the Brazilian coast. It surrounds the Sao Francisco Craton in its southeastern edge, transitioning to the west to the Brasilia Belt. The Ribeira Belt comprises several tectonic lands not yet fully correlated. One can observe Proterozoic volcanic-sediments from different source sequences and Neoproterozoic-Eopaleozoic pluton´s compositions of both different ages and deformation/metamorphism degrees that have been intruded on the basement. We carried out 81 MT broad band soundings with remote reference, with acquisition frequencies of 4096 Hz, 512 Hz and 128 Hz. These soundings are distributed into two parallel profiles, approximately 30 km apart and 5 km spacing between soundings. Good quality data were collected in the period range of 0.001–100 s. Data were processed using a robust remote-reference technique. Strike and dimensionality analysis along with G-B decomposition support a general 2-D regional character of the conductivity distribution in the area, allowing us to create a 2-D inversion model. Good misfit can be observed between the measured and calculated transfer functions projected onto the profile direction. These profiles crossed Brasilia and Ribeira Belts, as well as several geosutures in the basement of the marginal basins of southeastern Brazil. The geophysical survey associated with the available geological information brought important contributions to the understanding of the main geosutures presents in the area. Results imaged the two main suture zones between the orogenics belts and allow inferences about the geographic position of their lateral limits.

Introduction and Geological Setting

Eighty-one MT broad band soundings were distributed into two NW parallel profiles of 210 km each and 30 km apart. They initiate at the southeastern Brazil coast (São Paulo State) and continue inland to the SW of the Minas Gerais State (Figure 1). The soundings were acquired with acquisition frequencies of 4096 Hz, 512 Hz and 128 Hz for 10 minutes, 30 minutes and 12 hours, respectively. They are spaced 5 km with EM field components oriented to the magnetic north and east directions. ADU07 broadband MT systems (Metronix) were used. Typically, three to four MT soundings were measured simultaneously for this study.

The geological-geophysical profiles (Figures 1 and 2) initiate in the Coastal plain with a coverture of fluvial and marine Holocene sediments and a Neoproterozoic basement with orthogneisses of the Rio Negro Complex (RNC). The 630 Ma aging RNC juvenile rocks were generated in a magmatic arc in the upper plate of an ancient subduction zone (Tupinambá et al. 2000, 2012). The suture where the two plates collided is known as the Central Tectonic Boundary (CTB). The CTB limits two terranes: the Oriental Terrane, where the magmatic arc was emplaced, and the Occidental Terrane, the passive margin of the Sao Francisco paleocontinent (Heilbron et al. 2008). The CTB suture is located at the Serra do Mar escarpment in places of difficult access in the tropical rain forest.

The sections follow along the Occidental Terrane of the Ribeira Belt. The geological substratum is predominantly formed by banded and biotic gnaisses from the Paraiba do Sul Group and the Embu Complex of yet undefined age of sedimentation, with areas containing metapelitic schist bodies and dolomitic marble. The set is cut by numerous thick granite and granitic gneiss bodies of several generations (Machado Filho et al. 1984; Perrota et al. 2005). In this area lies the Rio Paraiba do Sul Graben, in the system of the southeastern continental rifts (Zalan & Oliveira 2005), which comprehends the sedimentary basin of Taubaté.

To the west is the limit between Ribeira and Brasilia Belts, occupied by ductile shear zones with different dip angles, such as the one located along the Rio Preto. This corresponds to a geosuture evidenced by gravimetric data (Davino et al 1986). The area occupied by the Brasilia Belt is formed by Archean and Paleoproterozoic basement rocks of part of the Sao Francisco Craton, and tectonically covered by ortho and paragneisses of the Neoproterozoic Socorro Nappe (Campos et al. 1984).

2D inversion of the Broad Band MT data

Data were processed using the robust technique proposed by Egbert & Booker (1986) with remote reference (Gamble et al, 1979).

Prior to inversion, the data were decomposed following the Groom-Bailey model (GB) (Groom & Bailey, 1989; Groom et al, 1993, which assumes a 2D regional Earth distorted by 3D superficial heterogeneities.

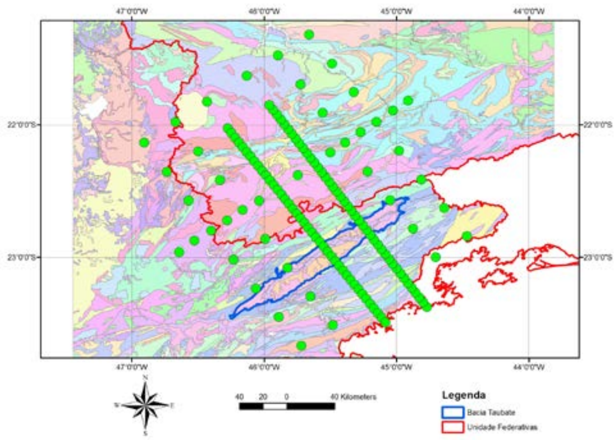

Figure 1 – Onshore broad band MT profiles.

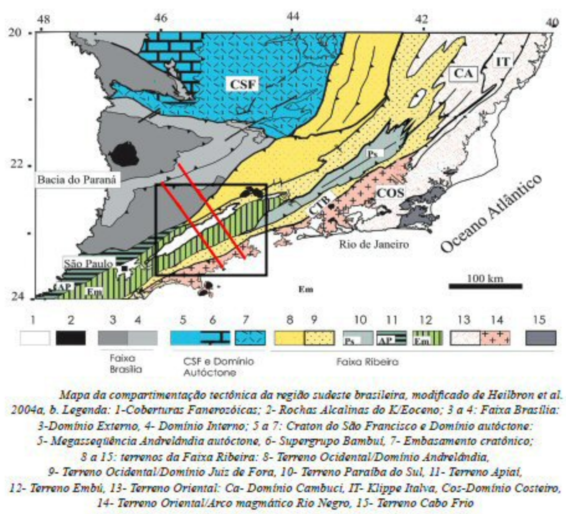

Figure 2 – Figure 2 – Geological map with both MT profiles to southwest and to the northeast an MT profile from Heibron, et al (2004) .

After the unconstrained decomposition of the impedance tensor via GB, we observed a large incidence of results around 10° for the strike angle. The procedure were repeated constraining the strike angle and allowing the twist and shear to vary freely (-45°< shear < 45°), (-60°< twist < 60°). The expectedly undistorted resulting data were then used for the 2D Inversion.

The 2D inversion were performed using the NLCG algorithm (Winglink ® software) proposed by Rodi & Mackie (2001). This routine uses the method of nonlinear conjugate gradients with Tikhonov regularization to the 2-D inverse problem for magnetotelluric data. The following parameters were used when running Winglink: a halfspace of 100 ohm.m was used as starting model and the sea bathymetry and ocean resistivity included. The inversions were unconstrained and we used the smoothed curves. The accepted deviation error was 10% for TE and TM resistivities and 5% for TE and TM phase. The regularization parameter tau for smoothing operator used was 3. Final models were obtained after 300 iterations considering the successive adjustments in the initial model. Both TE and TM modes were used simultaneously in the inversion. We assumed the regional geologic strike direction given by the gravity anomaly map as 65° (Figure 3) by Grace satellite data. The average magnetic declination of the region is about -21°, which means that in the MT set ups, the dipoles were positioned along the east-west direction, thus parallel to the strike direction.

The 2D inversion results are shown in Figures 4 and 5. The RMS for these inversions is 5.48 for the northern profile and 5.3 for the southern profile.

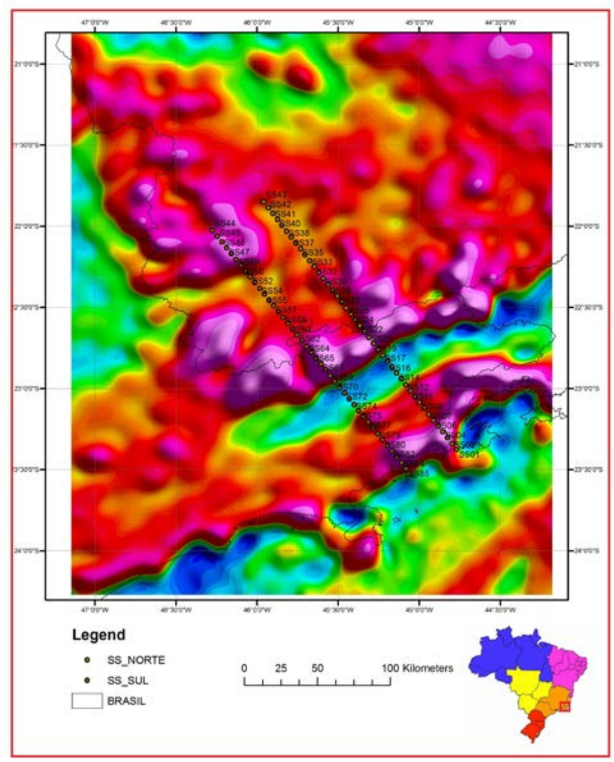

Figure 3 – Gace Satelite Gravity data of Bouguer anomalies map.

Summary

It is possible note high resistivity contrast to characterize some geoelectric discontinuities in the lithosphere representing structures of the middle Crust. From the 2D imaging (Figures 4 and 5) , it is possible to infer the presence of an old magmatic arch inserted in the Ribeira Belt in the continental crust that extends up to 40 km indicated by resistor R2 in profile northern and R2, R3 profile southern . This feature has also been identified before in another MT transect shown in Figueiredo et al. (2008). These are characterized for its very high resistive values (> 15,000 ohm.m) and inverted delta shape. Past studies arose some important questions that might be answered, like the basement-cover relationship in the Ribeira-Araçuai orogen (e.g., Campos Neto and Figueiredo, 1995), depth of sutures correspondent to Cambrian collisional orogeny (Schmitt et al., 2004), Neoproterozoic magmatic arc (Campos Neto and Figueiredo, 1995). The Rio Negro Magmatic Arc was formed during one of the stages of the subduction of São Francisco Plate under the plate of the eastern terrain. The Rio Negro magmatic arc corresponds to the Neoproterozoic arc, whose rocks are fundamentally tonalitic gneisses, diorites and gabbros, and intrude the metasedimentary sequence. A first interpretation of the structures of continental crust is shown in Figure 4 and 5. It is possible note high resistivity contrast to characterize some geoelectric discontinuities in the lithosphere representing structures of the middle Crust. The mentioned geosuture is probably covered by the Socorro Nappe (structure of the superior crust that reaches 9 km) limited in the base by some conductors (C1, C2 and C3) that is ductile and deformed in this region limited by conductors C4 and C5 (profile northern). Taubaté basin is very shallow, and is marked by conductive values by contuctor C6 in southern profile.

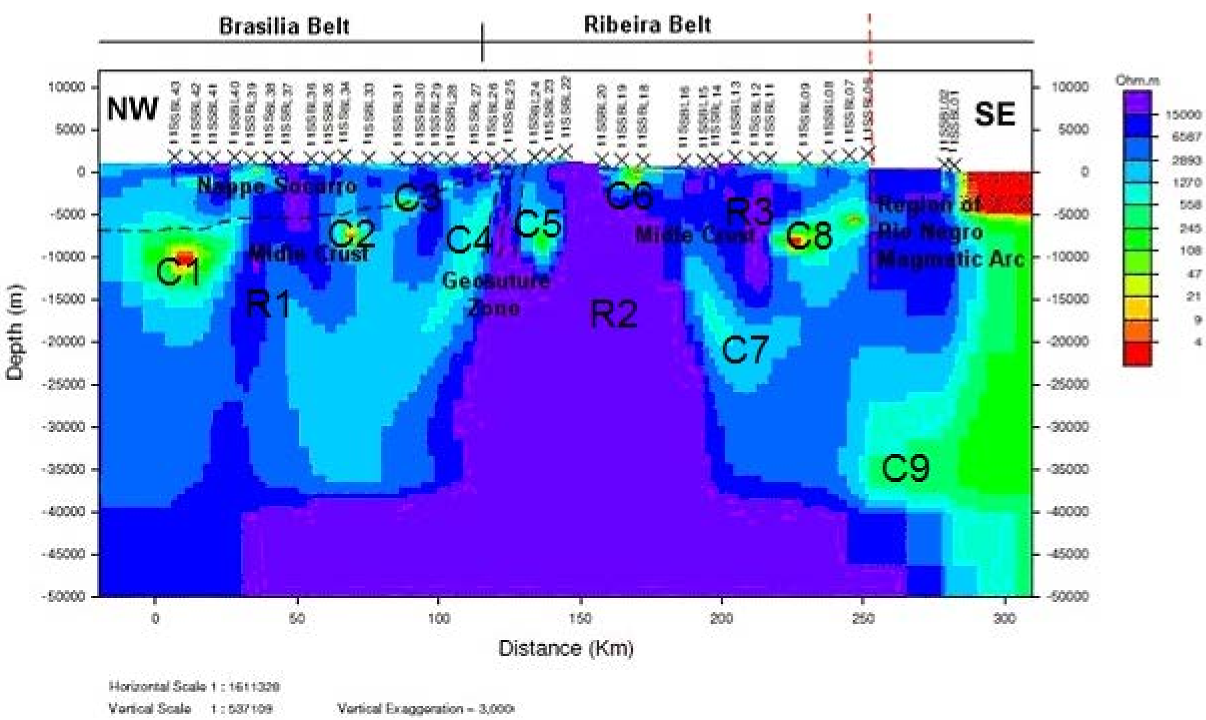

Figure 4 – 2D inversion of GB decomposed data with geologic interpretation for the northern profile

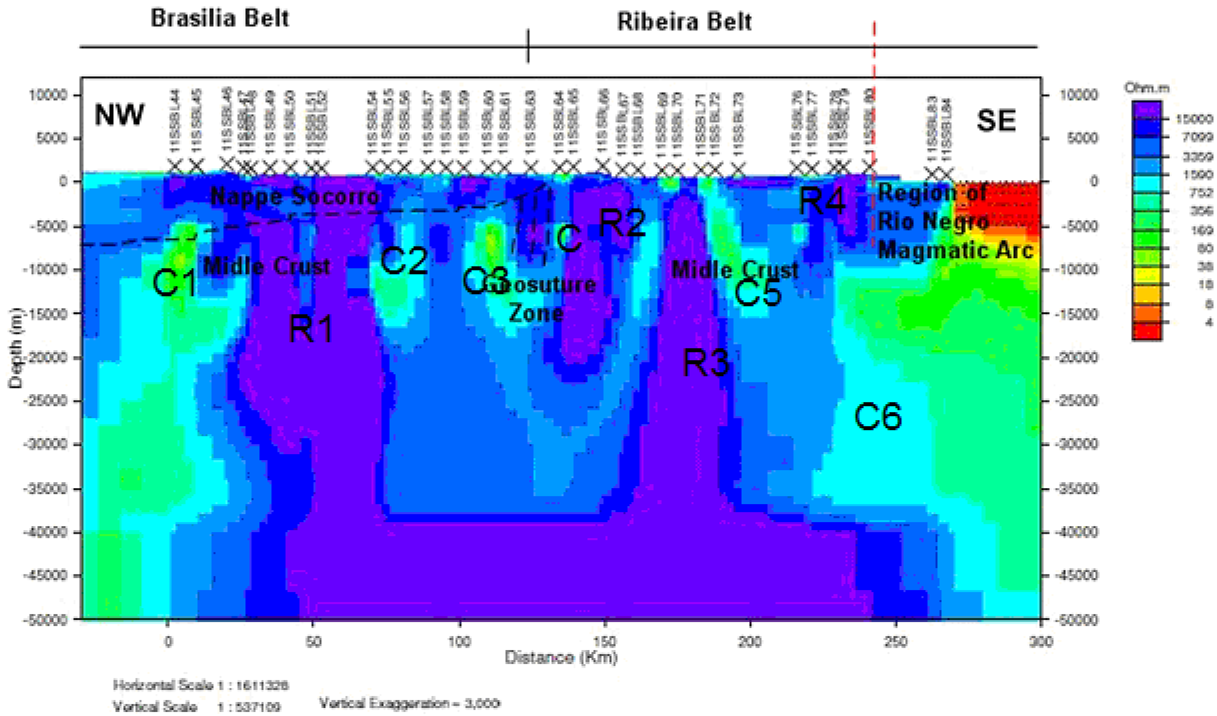

Figure 5 - 2D inversion of GB decomposed data for the southern profile

Future Perspectives

The acquisition of broadband MT data is part of a broader 3D array project involving gravity, magnetic, long period MT and seismic interferometry data, along with geological surveys.

Further work involves a meticulous full MT dimensionality analysis for both broadband and long period data using the WALDIM code (Marti et al, 2009).

The futures analysis of deep geological structures will corroborated by magnetic and gravity data applied 3D inversion algorithm developed by authors Li & Oldenburg, (1998)

Next steps will involve 3D inversion using the ModEM code (Kelbert & Egbert, 2012) and 2D joint inversion of multiple geophysical data using the cross-gradient technique as structural constraints (Gallardo & Meju 2003, 2004, 2007, Gallardo et al., 2012).

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