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# Three-dimensional magnetotelluric modelling of the Variça depression (NE Portugal)

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## Summary

The Variça depression is located NE Portugal astride a major late-Variscan NNE-SSW reactived strike-slip fault. The magnetotelluric (MT) method was applied to determine the electrical structure (<15 km) of the northern part of the Variça depression in NE Portugal. Thirty MT soundings were conducted on that part of the depression and the data have revealed three-dimensional features. Using two-dimensional models obtained from three profiles across the depression as preliminary models, a three-dimensional model was constructed. This model resolves a low resistivity (30 ohm m) feature in the central part of the depression up to a depth of 900 m, bounded by more resistive features. The conductor is associated with the sedimentary filling of the basin. The model reveals that deeper structure is more resistive (3500 ohm m) probably due to the presence of gneissic formations. The VFZ and the thrust faults are well displayed in the model.

## Introduction

The Variça Fault Zone (VFZ) is one of the major elements of the late Hercynian strike-slip network in the NW Iberia. Geological and geomorphological criteria reveal that the VFZ was reactived during Meso and Cenozoic times.

The Variça depression (20 km long and 2-3 km wide), which sits astride the VFZ (Figure 1), is an example of interplate neotectonic activity, since it is a pull-apart basin resulting from left-lateral strike-slip displacement of the VFZ during Quartenary times (Cabral, 1989).

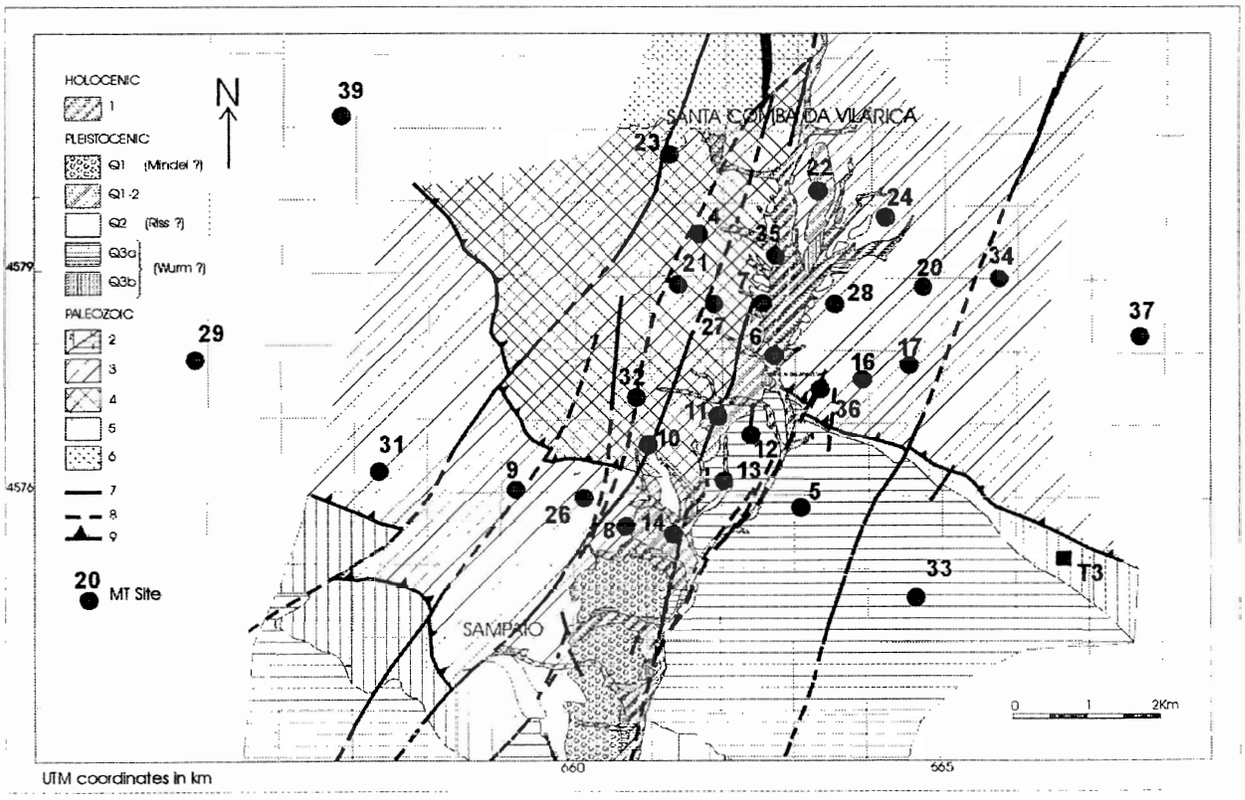


Figure 1: Geological setting of the Variça Fault Zone (courtesy of A. Mateus and J. Cabral,) and MT sites location.

Thirty MT soundings were carried out in the northern sector of the VFZ, in order to provide a first approach to the three-dimensional electrical resistivity distribution associated with the main geological structures. The aim of this paper is to present the three-dimensional modelling of the large tectonic features represented in the MT data.

There are two main different families of tectonic structures in the region under study. The first one, comprises segments of the regional thrusts of NW Iberia generated during the earlier Variscan deformation phases and subsidiary structures related to their late reactivation. These structures put in contact the metasedimentary formations belonging to the Autochthon, Parautochthon and Allochthon domains of NW Iberia (Ribeiro et al., 1990); generally, they correspond to severely crushed corridors with a general strike ranging from NW-SE to WNW-ESE and strong dip (>60°) towards NE or NNE. The second family comprises mainly subvertical, NNE-SSW to NE-SW structures that bound the Vilariça depression and define one important segment of the VFZ northern branch.

**MT data analysis**

The MT data was acquired in four bands of frequency ranging from 180 to 1/125 Hz. The time series has been processed, after visual inspection, using the cascade decimation and a robust method based on Egbert and Booker (1986). The horizontal fields measurement directions were N26°E and N116°E, in accordance with the main strike of the geological structures. Figure 2, shows the field apparent resistivity and the three-dimensional model responses at 4 sites.

The impedance distortion analysis carried out using the Groom-Bailey method (Groom & Bailey, 1991) indicated that the distortion of the data is not strong in the 0.1 to 100 s period range. Also, the N26°E strike was confirmed as the

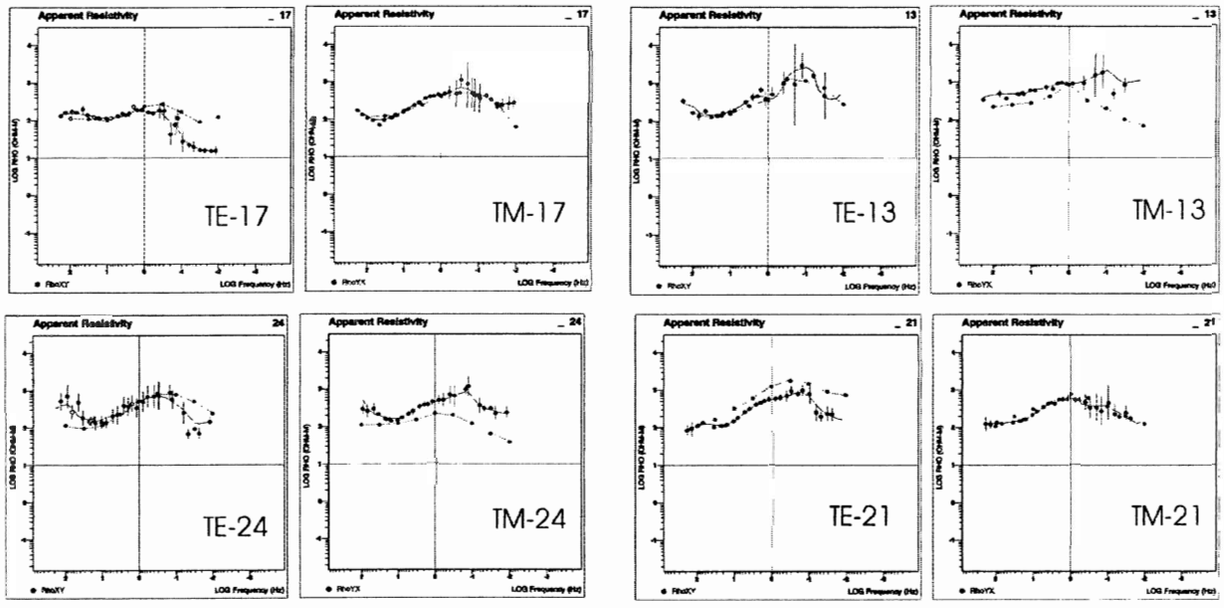


Figure 2: Observed apparent resistivity (dots) and three-dimensional model's response (dashed lines) at four sites inside the depression.

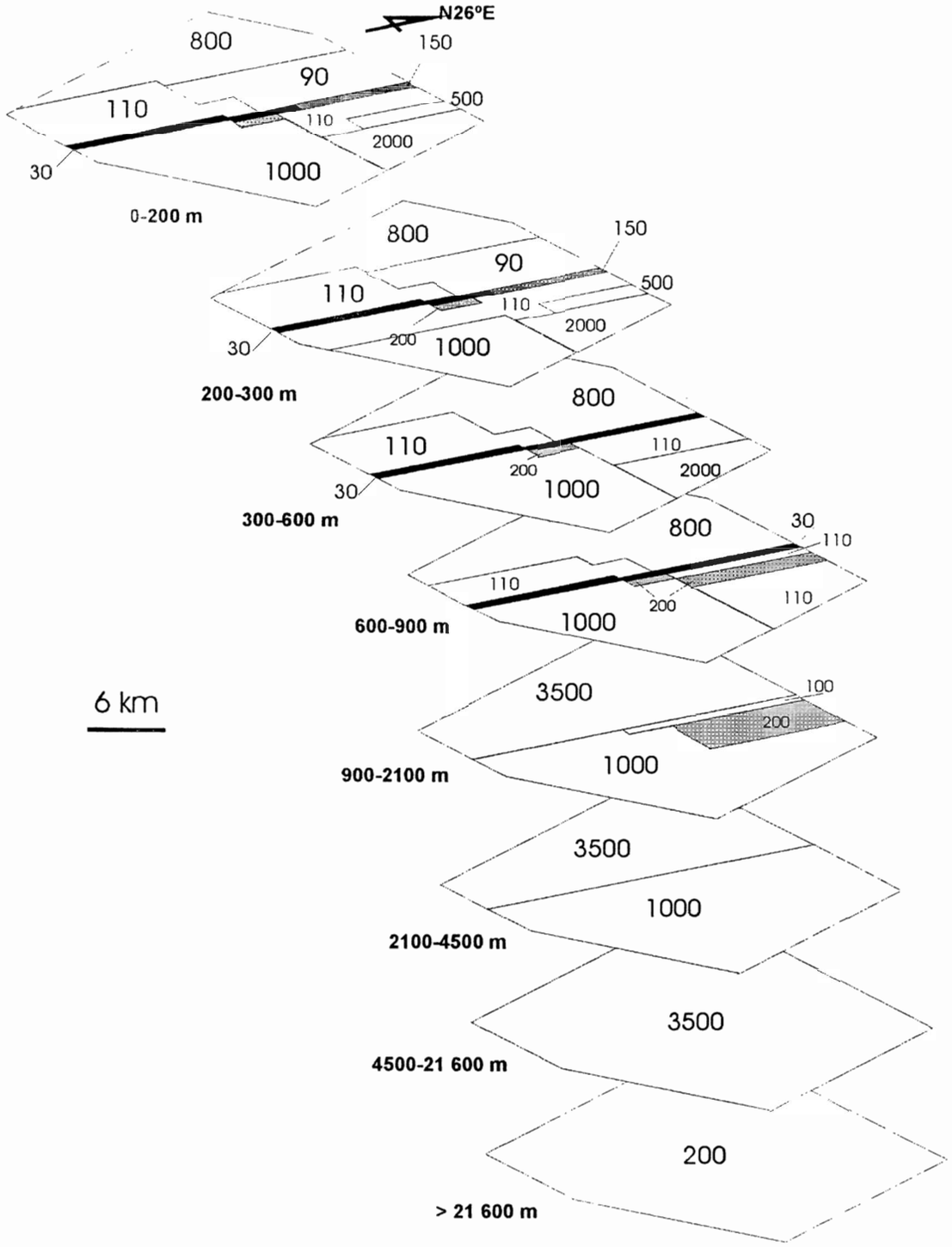


Figure 3: Three-dimensional resistivity model for the north sector of the Vilariça depression. Values on the model are in ohm m.

dominant direction of the main geological structures. The static shift effect was corrected according to the methodology described by Jones and Dumas (1993). The mean value of the TE mode (N26°E) apparent resistivities at 1.3 s is about 500 ohm m. This value, which is associated with deep structures (>5 km), was taken as representing the regional level for the TE mode. The static-shift correction was performed shifting both apparent resistivity curves, at each site, simultaneously until the TE curve reaches the 500 ohm m level at 1.3 s.

**Three-dimensional modelling**

The 3D regional MT model was constructed using the Mackie et al. (1993) program. The central part of the model represents to an area of approximately 6x6 km involving the main geological and tectonic features. The depression region and its surroundings were discretized into 40 blocks in the N26°E direction, 40 blocks in the N116°E direction, and 22 earth layers. The model was more finely discretized near zones of strong resistivity contrast, mainly inside the depression. The outer boundaries of the model are 150 km far from the origin at the center of the depression zone. The initial model was constructed on the basis of the geology of the region and two-dimensional previous models. However, no attempt was made to model the details suggested by the data.

Figure 3, shows horizontal slices of the final model obtained by trial and error. According to this model the following observations can be made:

- The sedimentary fill of the depression comprises low resistive bodies (30-200 ohm m) at a depth between 300 and 900 m.
- Surrounding the sediments we find more resistive bodies (200-1000 ohm m) associated with the metasedimentary formations.
- The main tectonic structures, represented by the segment of the Vilariça fault, are well displayed in the model.
- The model puts in evidence the thrusts with the lateral displacement: the first between sites 12 and 16, at east of the basin and the second between sites 9 and 10 at west.
- The Lower Allochthon domain is represented by the body located NW, with resistivity of 90 ohm m and a thickness of 300 m. Underlying this formation is the Parautochthon, with a thickness of 600 m and resistivity of 800 ohm m.. The Allochthon should be below these two structures, however, its resistivity in this area might be very close to the gneissic basement being very difficult to distinguish both formations.
- The Parautochthon domain at NE and SW is represented by bodies with resistivity of 110 ohm m and thickness of 900 m.
- At SE it is not possible to distinguish the Autochthon from the gneissic basement.
- Underlying all those formations is the gneissic basement at a depth of 4500 m and resistivity of 3500 ohm m.

Figure 2, compares the model's response with the data. The fit between both is acceptable but not perfect, specially at long periods. It means that, even in depth the geoelectric structure of the VFZ is three-dimensional. Therefore, a more complex model for deeper parts of the model is needed in order to explain all data features.

**Conclusions**

The region under study, the northern sector of the Vilariça depression, presents three-dimensional geoelectric features. The 3D modelling of thirty MT soundings puts in evidence the complex geometry of the VFZ, and the general behaviour of the structure overlying the gneissic basement.

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