Gravimetric and TEM prospection applied to the Quiaios Fault Structure (Serra da Boa Viagem, Central Portugal)

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ABSTRACT

The Serra da Boa Viagem (SBV) stratigraphic succession is part of the Jurassic and Cretaceous sequences of the Lusitanian Basin, located along the western Iberian margin (Figure 1). The Lusitanian Basin is an Atlantic margin rift-basin which was formed as a response to Mesozoic extension and subsequent opening of the North Atlantic Ocean. Mesozoic rifting and rotation of Iberia was followed by Cenozoic inversion movements due to Alpine collision (Rasmussen *et al.* 1998; Jabaloy *et al.* 2002). The reactivation of Hercynian basement faults has conditioned the structural evolution of the Lusitanian basin since the upper Triassic (Wilson *et al.* 1989).

The study area is characterized by a few important structural directions, essentially NE-SW, NW-SE and NS. The SBV relief is a monoclinal structure dipping south and it is part of a major anticlinal structure, faulted, slipped and vergente to north. The SBV flank extends south with the Verride anticlinal. The North scarp of the SBV relief separates the Mesozoic from the Cenozoic Gândara dune system. This contact, designated as Quiaios Fault Structure (QFS), corresponds to an inverse fault scarp striking WE to WNW-ESE (Barbosa *et al.* 1988; Cabral 1995) and include QF1 and QF2 faults (Figure 1). Both inverse faults have been only locally recognized in outcrops (Carvalho 1952 *in* Barbosa *et al.* 1988; Ribeiro 1988), being the majority of their extent mapped as inferred faults (Barbosa *et al.* 1988; Rocha 1981). A gravimetric and electromagnetic (TEM) surveys were performed in order to obtain more information about subsurface structures as well as better define the lateral continuity of the QFS.

The gravimetric data were collected using a LaCoste & Romberg gravimeter Model G (LaCoste & Romberg 1991). The gravimetric field was measured in 227 points with an irregular grid that cover an area of 22.5 km^2. All the standard gravimetric corrections were applied to the data and the gravity anomaly maps were obtained with the Surfer software.

The time domain electromagnetic method (TEM) uses loops laid on the ground as a transmitter/receiver. For a comprehensive review of the TEM method and theory, see McNeill (1994). The acquisition of the TEM data was made using the TEM-FAST 48 system, developed by AEMR Ltd (AEMR 2007). A total of 7 soundings were performed using a single loop setup with 25m side square geometry. In order to record the decay voltage we used stack 10 (130 complete cycles), time 7 (i.e. 40 time gates) and the transmitting current was 4A. Data processing is based on the solution of inverse problem in time domain electromagnetic sounding using TEM-Researcher proprietary software.

The analysis of the gravity anomalies suggest that the positive residual anomalies are possibly related with areas of uplifted basement blocks or outcropping Mesozoic formations. This is clearly the case of the positive anomaly in the SBV relief and in the NE side of the map where Cretaceous limestones outcrops (Figure 2). Negative anomalies are associated with areas of downthrown slipped blocks, where greater amounts of Mesozoic and Cenozoic sediments were accommodated. These

blocks are delimited by alignments with several directions that define the main fault systems (Machadinho 2008). The N60-70ºW alignments are the more obvious and continuous on the gravimetric map. Other alignments strike NE-SW, NW-SE, NNW-SSE and, to a minor extent, EW structures are also present. The N60-70ºW alignments delimit the major negative anomaly values located along the QFS. The NE-SW alignments seem to cross the EW and N60-70ºW directions (Figure 2). This could be related with the tectonic reactivation of the old fractures during the Cenozoic.

In order to understand the geometry of QFS, the residual gravity anomaly for one profile that crosses this structure was modelled using GM-SYS 4.9 software (Figure 3A). In this model we define three units. The Basement unit is characterized essentially by metamorphic rocks; the Mesozoic unit is formed by marls, limestones and sandstones; and the Cenozoic unit is composed by sandstones and clays. Mean density values for each block were defined based upon a table of rock densities (Telford *et al.* 1990): Basement 2.75g/cm^3, Mesozoic 2.45g/cm^3 and Cenozoic 2.10g/cm^3 (Figure 3B).

The obtained model shows that the basement deformation conditioned the fracturation pattern observed in the meso-cenozoic cover. The several blocks, well visible in our model, agreed with the main tectonic structures identified at the surface, namely the QFS, related at depth with a major downthrown block structure. This structure seems to form a foredeep basin striking N60-70ºW that could be observed in the modelled profile and accommodates a maximum of 2500m of Mesozoic and Cenozoic sediments. In this profile the geometry of the southern segment of the QF2 seems to correspond to an inverse fault dipping south.

In the electromagnetic results it is possible to identify higher values of resistivity corresponding to the Jurassic marls and limestones. Lower values are related with sands and clays of the Cenozoic units. The data were modelled until a maximum investigation deep of 110m. The TEM section analysis shows the two main faults. QF1 fault is clearly visible between the TEM soundings 2 and 3 and QF2 at TEM sounding 5 (Figure 3C). Both geophysical methods allow the recognition of the fault planes that form the QFS and that are responsible for the SBV relief. The gravimetric method proved to be a useful method to identify deep structures and the time domain electromagnetic method is complementary allowing a better understanding of the shallow structures not always visible in outcrops.

Two episodes of deformation associated with the formation of the SBV structure have been recognized. Upper Cretaceous transcurrent deformation trending EW was followed by the Cenozoic inversion of some of the pre-existent structures (Machadinho 2008). The QFS in the analysed area testify the presence of structures associated with the Cenozoic tectonic inversion of the Lusitanian Basin as a result of the formation of the Pyrenees and Alpine compression (NS to NNW-SSE).

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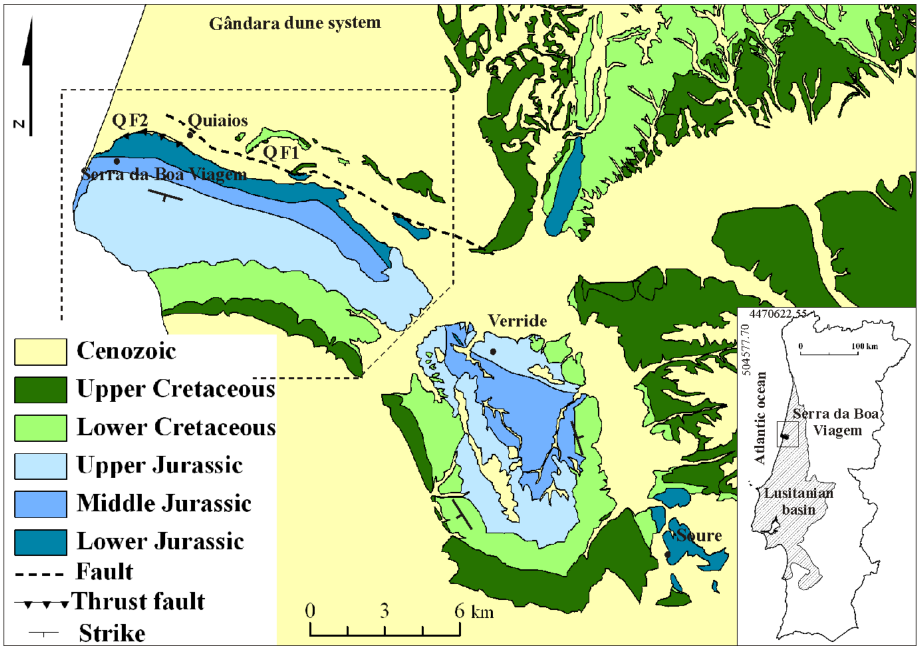

Figure 1. Geological setting and location of the study area. Adapted from 1:50000 geological maps (Barbosa *et al*. 1988 and Rocha *et al*. 1981).

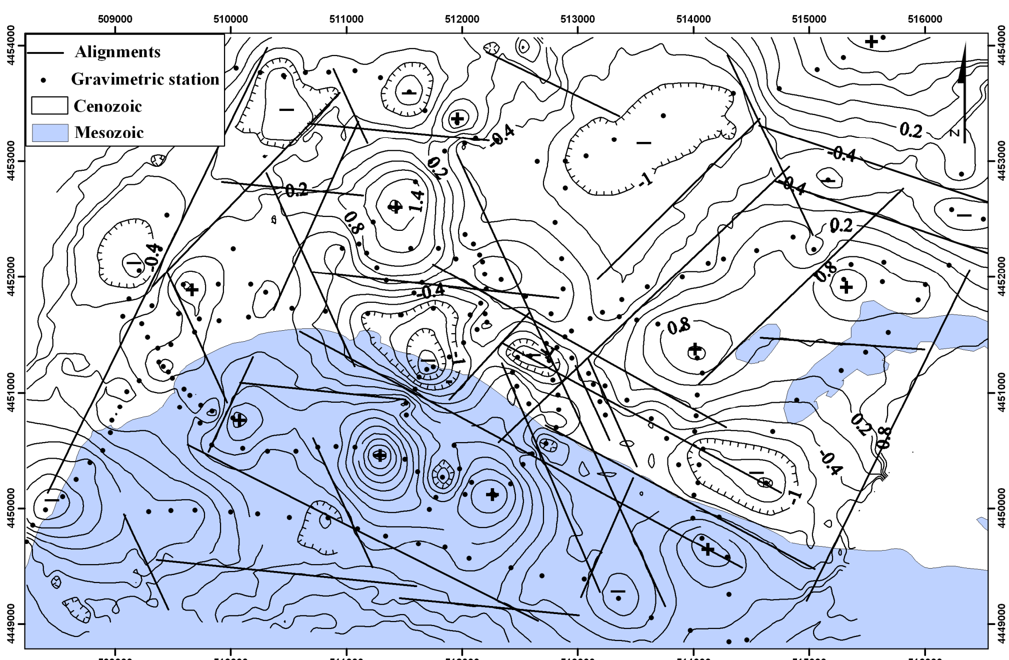

Figure 2. Residual gravity anomaly map and fault alignments analysis.

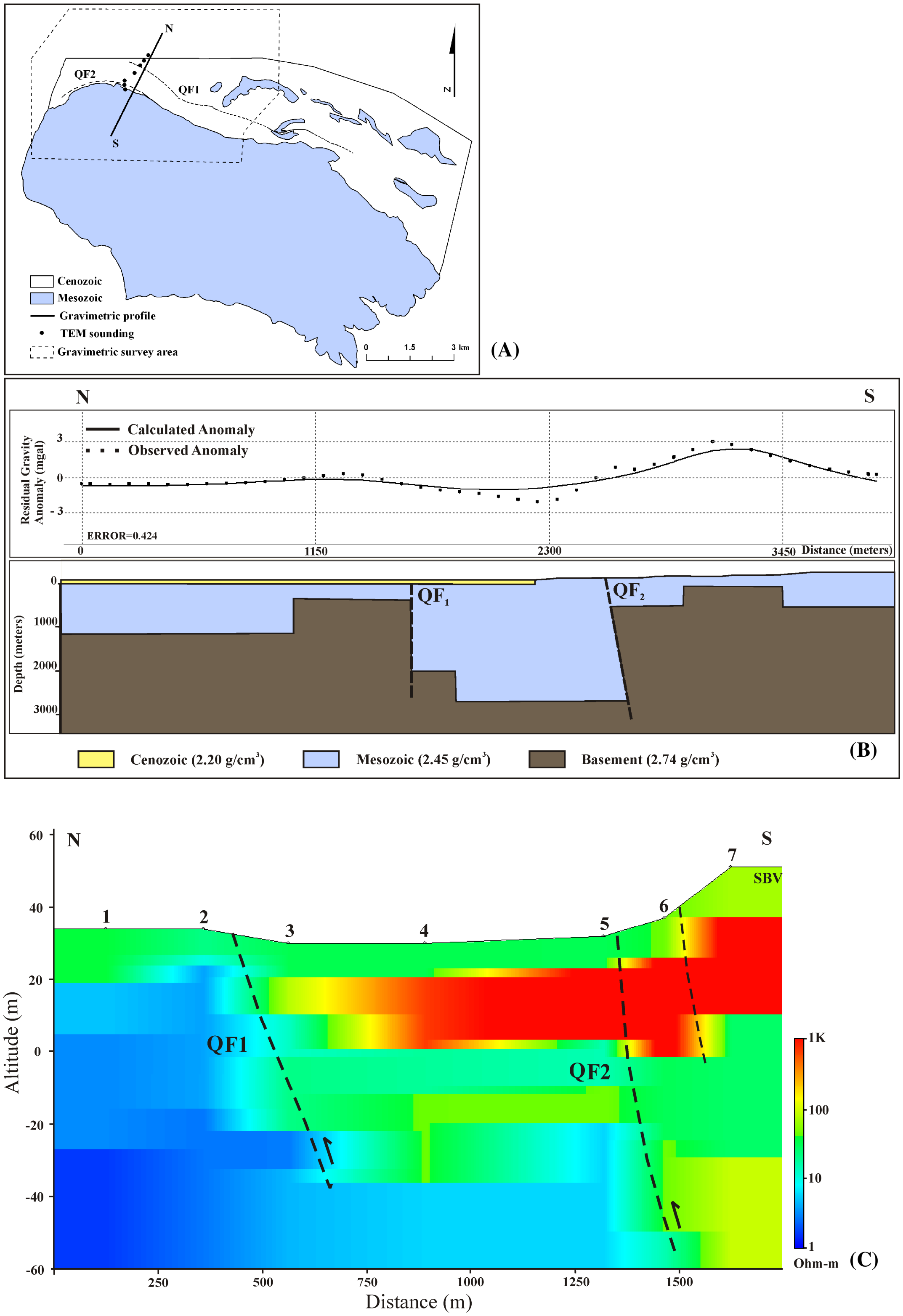

Figure 3. **(A)** Location of the geophysical data modelling. **(B)** Cross section of the gravity model generated with GM-SYS (QF1 and QF2 faults strike N60-70ºW). **(C)** Geoelectric section (TEM-FAST 48 system) and inferred inverse fault planes.