Introduction

The Iberian Pirite Belt (IPB) is a 250 km long and 30-40 km wide metalogenetic province located in the SW area of the Iberian Peninsula. Included in the South Portuguese Zone, it dates from the Upper Palaeozoic and it is formed mainly by shales and volcanic rocks. More than 90 Volcanic Hosted Massive Sulfides (VHMS) deposits are known in Portugal and Spain. In the IPB sector studied in this work, the IPB basement is hidden beneath a thick sedimentary coverage, which is part of a large structure called the Sado Tertiary Basin (STB). This sedimentary layer, commonly with thickness >100 m, makes it very difficult to identify the basement structures beneath it, and it is therefore very important to define it if we are to resolve those deeper structures. Exploration borehole programs made in this area intersected the Lagoa Salgada massive sulphide deposit , whose chemical composition showed significant values of Zn, Pb, Sn, Cu, As, Hg, Sb, Cd, Au and Ag (Oliveira et. al. 1998, de Oliveira et al. 2011). Due to its economic potential, there were several studies made in the area during the 1990's by the, at the time, Instituto Geológico e Mineiro (now Laboratório Nacional de Geologia e Energia), together with a few private companies. The Lagoa Salgada discovery was directly linked to gravity and magneto-telluric surveys performed. Electrical vertical soundings and magnetic were also used. The initial geophysical data were used mainly as reference guides. A more detailed treatment of the geophysical information permits to accurate the local geophysical-geological models, essential to follow up studies and new VHMS discoveries in this IPB sector. In this work LNEG database data of the Lagoa Salgada sector were recovered and reprocessed, namely gravity and vertical electrical soundings. Several vertical structures were identified through the analysis of gravity field derivatives and profile was constructed based on a 2D density model resulting from the inversion of gravity data as well as the resistivity models resulting from 1D inversion of vertical electrical soundings, and boreholes logs.

Gelology

The area under study is a small sector of the Sado Tertiary Basin, which is a large tectonic Basin filled with Cenozoic sediments, located along the Sado River valley (western Portuguese region, south of Lisbon). The Quaternary layer is dominated by aeolian sands and fluvial sediments. Where it exists, its thickness seldom passes 10 m. The Terciary sediments are mainly from Pliocene and Miocene and consist mainly of sandstones, claystones, conglomerates and limestones. In this section, the sedimentary coverage rests unconformable over the IPB basement, formed by the Baixo Alentejo Flysch, Volcano-Sedimentary Complex (VSC) and Phyllite-Quartzite Group (Oliveira et. al. 1998, Matos et al. 2000, Oliveira et al. 2001, de Oliveira et al. 2011). The VSC is represented at Lagoa Salgada by felsic volcanics and minor sediments of Upper Devonian-Lower Carboniferous age. All these formations are affected by Variscan and late Variscan faults trending E-W, NW-SE, NE-SW and N-S. The Alpine tectonic evolution of the Sado Basin is reflected in horsts and grabens that show vertical displacements of the Paleozoic basement units. At Lagoa Salgada – Água Derramada a major

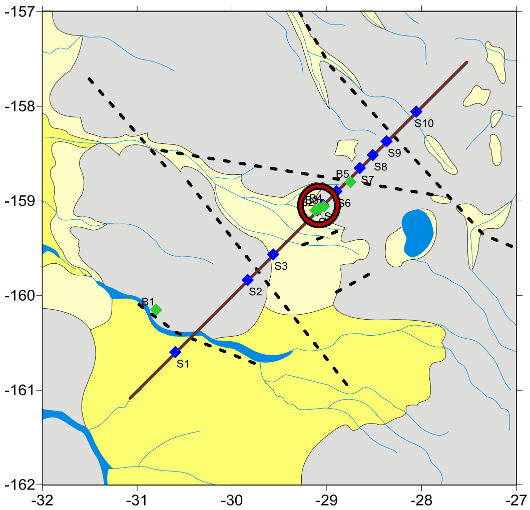

Figure 1 *Geological map of the area based on the 1:50000 39D – Torrão LNEG geological maps (Oliveira et al. 1991), grey color – aeolian Quarternary sands; yellow – Tertiary sediments. The dashed lines represent the faults identified in Oliveira et. al.(1998). The full line indicates the modeled profile. Green dots represent borehole soundings and blue dots represent VES soundings. Red circle marks the interected Lagoa Salgada VHMS deposit.*

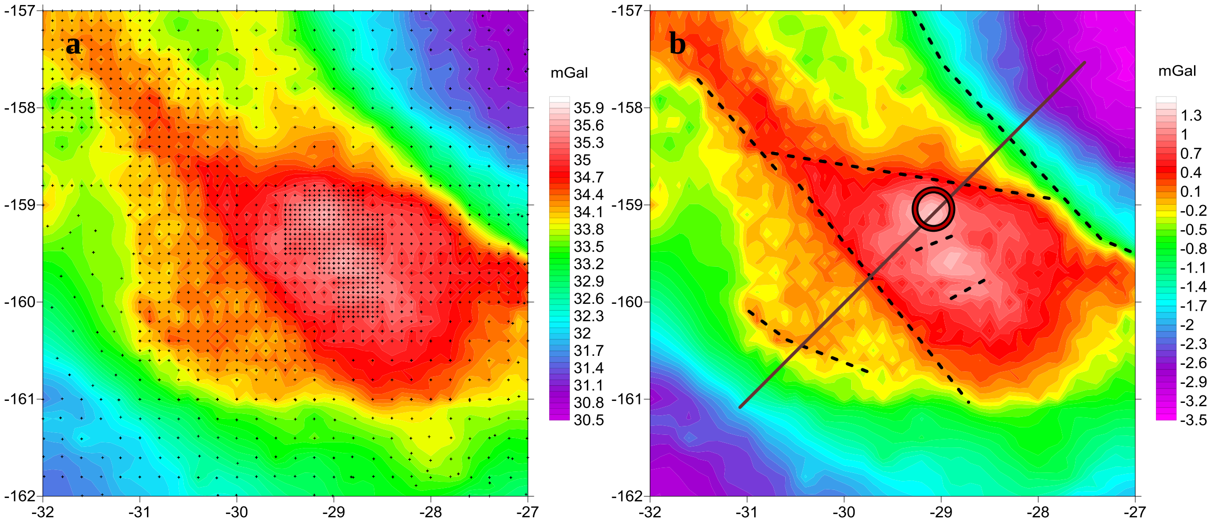

***Figure 2 a** Complete Bouguer anomaly. The dots represent gravity stations. **b** Residual Bouguer anomaly considering the regional gravity field as a first degree polynomial surface that increases from NE to SW. The dashed lines are the faults identified in Oliveira et. al.(1998). The full line indicates the modelled profile.* Red circle marks the Lagoa Salgada VHMS deposit

horst is present were felsic rock are dominant (Oliveira et al. 2001, 1998). This volcanic unit hosts the Lagoa Salgada VHMS deposit formed by massive sulphide lenses and associated stockworks (de Oliveira et al. 2011, Matos et al. 2000). The geological map of the area is shown in Figure 1. This figure also shows the location of boreholes made in the area which allowed the constraining of the determined model.

Gravity data and derivatives

The data used in this work is part of a regional exploration survey which was made over several stages, covering a total area of 655 km^2 (Oliveira et al. 1998). This survey comprised gravity profiles with distances varying from 2.6 to 4.0 km as well as grids with spacing of 200 m x 200 m, 100 m x 100 m and 50 m x 50 m, according to the complexity and size of local structures. Here, we selected an area of 25 km^2 that includes the VHMS mineralizations intersected by boreholes. The location of the

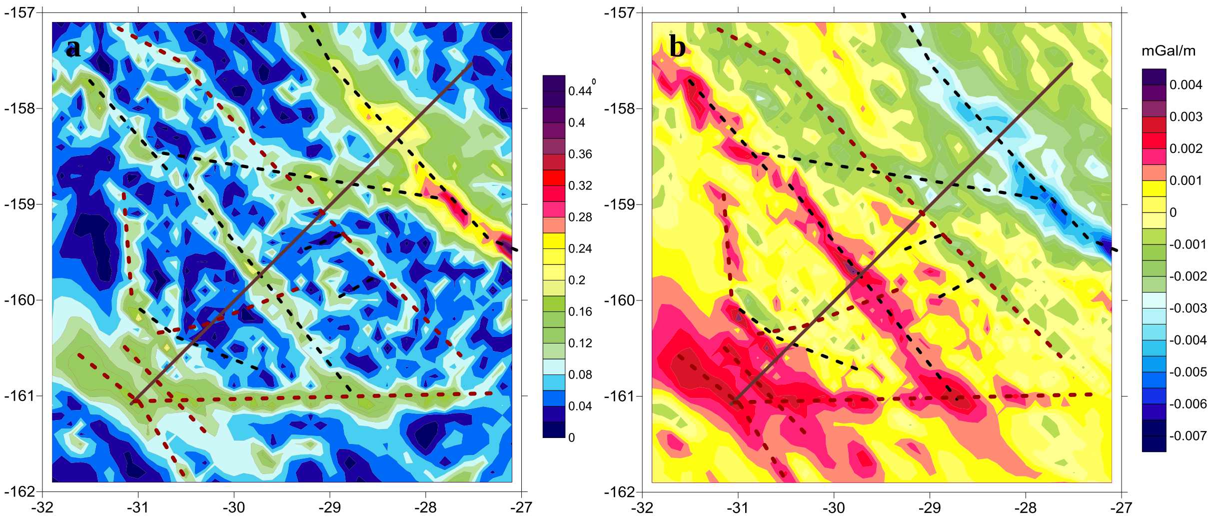

***Figure 3 a** Inclination of the steepest slope of the gravity field at any given point. **b** First derivatives of the gravity field along direction N45°W. Dashed black lines represent the faults identified in Oliveira et. al. (1998). Dashed brown lines are faults marked using the derivative maps. The full lines indicate the modeled profile.*

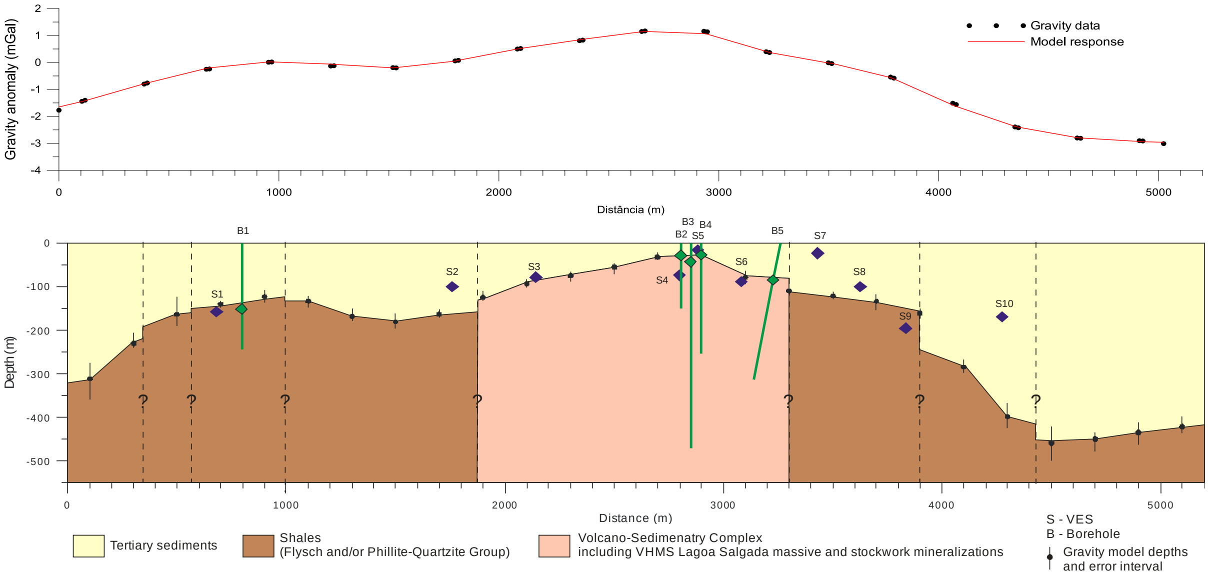

***Figure 4 a** Gravity data and density model response. **b** Geological profile made using a combination of 2D gravity inversion density model, 1D inversion of vertical electrical soundings and exploration borehole logs. Faults (dashed lines) were placed according to gravity derivative analysis. Green lines represent borehole soundings that intersect the basement at depths represented by the green dots. Dark blue dots mark the places were 1D VES models reveal a more resistive layer.*

gravity stations, as well as the Bouguer gravity map, can be seen in Figure 2a. This Bouguer map resulted from the common corrections using a Bouguer density of 2.65 g/cm^3. At Lagoa Salgada a large positive anomaly trending NW-SE can be observed, which coincides with the places where mineralization was intersected by drill holes. The orientation of this anomaly, sub parallel to the basement structures is favourable in the VHMS exploration programs planning.

To strip the data of long wave regional signals a regional-residual separation was made. Because the area is mostly dominated by the Lagoa Salgada central anomaly, we chose to consider the regional field as a first degree polynomial surface. The residual field is shown in Figure 2b. Then, we did a few operations on these data, and for that we generated a regular grid over a mesh with 100 m x 100 m spacing. First, we calculated the inclination of the steepest slope of the gravity field at any given point (Figure 3a). This allowed for a first recognition of the major vertical structures found in this area, as it depicts the inclination of the slope independently of its orientation. Considering the alignment of the structures found, we calculated the directional derivatives that would enhance these structures, like the one in Figure 3b.

2D model

From the borehole data we knew that the Paleozoic basement shales and the volcanic rocks have very similar densities (average 2.75 and 2.73 g/cm^3, respectively), whereas the Tertiary sediments have a much lower density (average 2.35 g/cm^3). So we just considered a single interface representing the interface Tertiary sediments/Paleozoic basement. This interface was then adjusted to fit the observed gravity data using a simulated annealing inversion algorithm (Represas, 2009). It was tested and verified that density values of 2.7 g/cm^3 for the basement and 2.4 g/cm^3 for the sediments were the ones that provided the best model, considering all the information available. The obtained model was validated using the borehole logs, and the fitting was verified (see Figure 4).

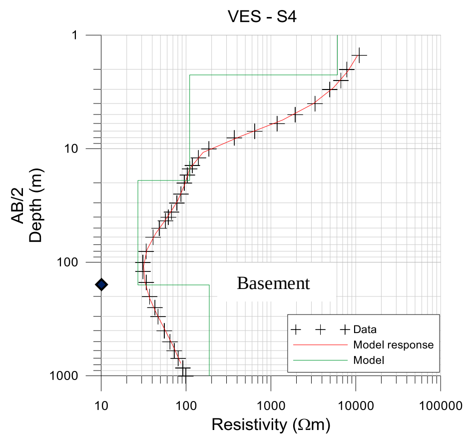

***Figure 5**Example of a VES model.*

Also the discontinuities identified on the gravity derivative maps were placed. Because we do not know the attitude of those faults they were placed vertically, however this is only a representation. Moreover, the fact that some of the boreholes intersected shales while others intersected volcanic rocks led us to position a volcanic rock block in the centre of the profile. The knowledge of the exact location of the shales/volcanic rocks interfaces is conditioned by the limited borehole data. Resistivity models (e.g. Figure 5) were also used to validate the model. These models were calculated using software IPI2win (Bobatchev et.al, 2001). The agreement is verified, however, there are some places where it is not so evident, probably due to the presence of water in the tertiary sediments.

Discussion

The gravity field observed at the Lagoa Salgada IPB sector is conditioned by several factors: i) – strong density contrast between the Tertiary cover and the Palaezoic basement; ii) – the presence of a regional NW-SE Volcano Sedimentary Complex structure, where felsic rocks are present with hydrothermal systems, massive sulphide and stockwork mineralizations (Lagoa Salgada deposit). This structure is surrounded by shale basement units; iii) – Variscan (NW-SE dominant direction) and Late-Variscan fault zones (E-W dominant direction), with significant vertical movements, during the Alpine orogeny; iv) – Different Paleo weathering zones, more developed in the shale basement units than in the volcanic units. The knowledge of the main fault structures and of the variation of the interface Tertiary cover/Paleozoic basement is essential to the correct understanding of the gravity field. More work will be done considering the different density of the rocks intersected in the > 50 exploration boreholes done in this IPB sector. This work will contribute to a better refinement of the gravity data and a more accurate geological-geophysical model. In consequence it will permit the selection of new targets favourable to the present of VHMS deposits.

Acknowledgements

The authors thank the gravity data compilation to Pedro Sousa (LNEG/UI. Recursos Minerais e Geofísica). First author supported by FCT grant SFRH/BPD/62894/2009. Work partially supported by Pest-OE/CTE/LA0019/2011 – IDL.

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