The role of land gravity data in the Neves-Corvo mine discovery and its use in present-day exploration and new target generation

Fábio Marques[1*], João Xavier Matos[1], Pedro Sousa[1], Patrícia Represas[1], Vítor Araújo[2], João Carvalho[1], Igor Morais[1], Nelson Pacheco[2], Luís Albardeiro[1] and Pedro Gonçalves[1] discuss the application of vintage land gravity data (since the 1960s) in the discovery of the first orebodies and how it is still being used to identify new targets for mineral exploration.

Introduction

Several blind massive sulphide deposits associated with the Iberian Pyrite Belt (IPB) Volcano-Sedimentary Complex (VSC) (Figure 1) were discovered in SW Iberia using joint interpretation of geological and geophysical models, such as Neves-Corvo (Albouy et al., 1981; Leca et al., 1983) and Lagoa Salgada (Oliveira et al., 1998) in Portugal, and Valverde and Las Cruces in Spain. In the IPB Portuguese sector, the former government agencies Serviço de Fomento Mineiro (SFM) and Instituto Geológico e Mineiro (IGM), as well as LNEG, fostered the acquisition of systematic geophysical surveys, in particular gravimetry, in the region during the second half of the 20th century.

Since the 1960s, the former SFM carried out detailed ground surveys over N-S for E-W grids with distances between survey stations of 200, 100 and 50 m grid size (Oliveira et al., 1998). This enabled the identification of several potential targets which attracted the interest of important international investors and led to a continuous investment in geophysical research, based on ground and airborne surveys (Matos et al., 2019).

The discovery of several massive sulphide deposits, including the world-classNeves-Corvo Cu-Zn-Sn deposit in 1977 (see location in Figure 1, Albouy et al., 1981; Carvalho et al., 1996; Carvalho et al., 1999; Oliveira et al., 2013) was a direct result of joint efforts of mining companies (a consortium formed by the Soc. Mineira e Metalúrgica de Peñarroya Portuguesa, Soc. Mineira de Santiago/Emp. Mineira e Metalúrgica do Alentejo and Societé d'Études de Recherches et d'Exploitations Minières), and former SFM exploration surveys (Albouy et al., 1981; Leca et al., 1983; Carvalho et al., 1999; Matos et al., 2019). The consortium invested significantly in exploration (Albouy, et al., 1981), namely: processing of the SFM-acquired gravity data (covering an area of 300 km^2), collection of new gravity surveys (190 km^2), more than 200 km of electric resistivity and magnetic profiles, as well as very-low-frequency (VLF) studies on several drill holes.

The Neves-Corvo deposits occur along a NW trend, with seven deposits dispersed in a large complex antiform structure (Carvalho et al., 1996; Araújo and Castelo Branco, 2010; Oliveira et al., 2013). Understanding the geometry of subsurface orebodies requires accurate geological mapping based on surface surveys and/or borehole logging (Matos et al., 2019). The accuracy of the conceived model for geology and ore deposit at Neves Corvo, however, is limited by the sparse geologic outcrops and a biased distribution of drill holes. This has driven an impetus towards

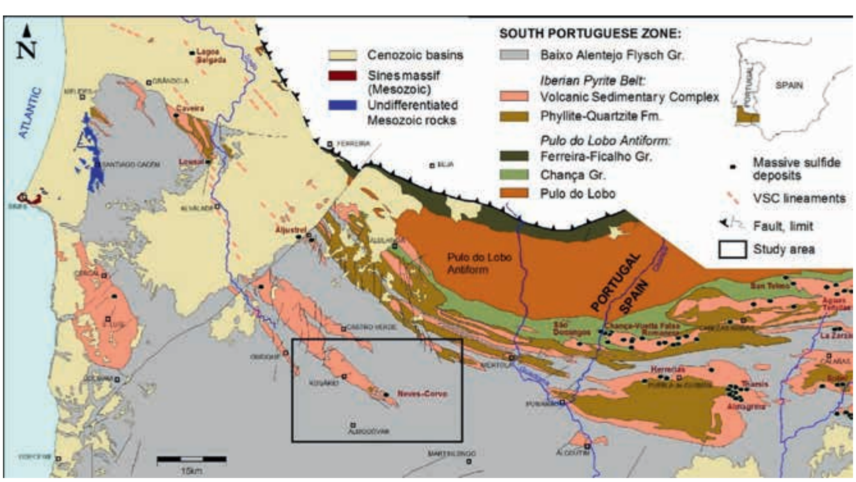

Figure 1 Location of the Iberian Pyrite Belt Portuguese sector and of the Neves-Corvo mine region used in this study.

[1] Laboratório Nacional de Energia e Geologia | [2] Somincor-Lundin Mining
[*] Corresponding author, E-mail: fabio.marques@lneg.pt

acquisition of geophysical data which can be more uniformly sampled and is typically less expensive to collect.

Among the different geophysical methods employed, a strong response is expressed within the gravity data. This is the result of the large physical property contrast between high density, massive sulphide deposits and the volcano-sedimentary host rock lithologies (Neves, Corvo, Graça and Zambujal). The uppermost lenses are located in the NE flank of a gently dipping structure (10º-40º NE), at depths between 230 m (Corvo) and 350 m (Neves) (Albouy et al., 1981; Carvalho et al. 1996; Matos et al., 2019).

These were therefore the first four orebodies to be discovered, while the gravitational response of the deeper Neves-Corvo massive sulphide lenses were weaker and more difficult to recognize. With less obvious gravitational anomalies to guide exploration at such depths, rock density studies become a key issue in the geophysical characterization of Neves Corvo. In the case of the Semblana deposit (2010, ~800 m depth), ground electromagnetic surveys and extrapolation of favourable geology down dip from the Zambujal area were utilized for exploration in addition to the gravity data (Araujo and Castelo Branco, 2010).

The use of gravity for direct detection of massive sulphides in the IPB has limitations. In areas covered by thick Flysch sediments (locally >1 km) where the VSC occurs at greater depths, the gravitational response is weak and more so a function of regional geologic elements. Localized variations in density, such as those caused by high density basic rocks or black shales with disseminated pyrite, are common within the VSC sequences. Intense rock weathering, low density siliceous shales or volcanogenic sandstones also contribute to a complex and multi-layered gravity profile.

The elevated copper grades of the Neves-Corvo deposits justified more investment in exploration. The possibility of new discoveries with high metal content warranted an extension of exploration research, to explore deeper structures in the area (>>500 m depth).

Considerable efforts were exerted in areas such as the Neves-Corvo-Corte Gafo, a 600 km^2 polygon located NE of the mine site (Carvalho et al., 1996; Matos et al., 2019). With technical support of the former SFM gravity team, Somincor/Lundin implemented a multidisciplinary programme of gravity and magnetic surveys (9015 points covering an area of 314.5 km^2, as well several profiles of transient electromagnetics (TEM, 215.5 km), magnetotellurics (27.0 km) and reflection seismic data (24.0 km).

At a regional scale, a multitude of geophysical methods were deployed to characterize specific exploration targets throughout the IPB. These included: deep seismic reflection, electrical resistivity induced polarization, electromagnetic EM 37, pulse electromagnetic, transient electromagnetic, vertical transient electromagnetic, vertical electrical soundings and magnetotellurics. In structurally complex zones, such as the Semblana area (Araujo and Castelo Branco, 2010), down-hole electromagnetic surveys were essential in the identification and delineation of the primary mineralized trends. In the Neves-Corvo region, seismic profiles were used by Lundin/Somincor to define key tectonic structures (Araújo and Castelo Branco, 2010; Inverno et al., 2015; Matos et al., 2019).

The importance of gravimetric data in the search for new exploration targets

Despite the above mentioned challenges and localized exceptions, gravity continues to be one of the primary geophysical methods for massive sulphide exploration in the IPB. The effectiveness of the gravity method is related to the density contrast between the sulphide deposits (d>4 g/cm^3 in massive sulphides and d=2.9-3.9 g/cm^3 in stockwork veins, see Table 1) and the surrounding host rocks, e.g. felsic volcanic rocks, black shales of the VSC and shales and quartzites of the PQ Formation, which commonly present densities below 2.9 g/cm^3. At a local scale, sulphide stockwork and vein type structures can be identified. This, however, typically requires a reasonable degree of thickness (>50 m) and a near-surface depth (<300 m). After the gravity-assisted

Formation/Unit	Rock Type	N	Observed density	Density average
Mértola	Shales and greywackes	1858	2.02 - 2.86	2.72
Brancanes	pyritic black shales	231	2.57 - 2.99	2.76
Godinho	shales and volcanogenic sediments	477	2.39 - 2.83	2.71
Xistos Borra de Vinho	Green/purple shales	178	2.4 - 2.85	2.75
Grandaços	Siliceous shales and volcanogenic sediments	799	2.58 - 3.01	2.76
Graça	Black shales	11	2.72 - 2.8	2.77
Felsic volcanic rocks	Rhyolites and Rhyodacites	1970	2.57 - 3.11	2.74
Neves	Black shales	63	2.68 - 2.87	2.8
Mafic volcanic rocks	Basalts and dolerites	134	2.61 - 2.93	2.8
Spilites	Basalts	38	2.63 - 2.84	2.75
Phyllite-Quartzite Gr	shales and quartzites	428	2.56 - 3.22	2.79
Massive sulphides	Massive pyrite	42866	2.4 - 5.6	4.53
Stockwork	Felsic volcanic rocks	59200	2 - 4.97	3.07
Stockwork	black shales and quartzites	33900	2.1 - 4.89	3.08

Table 1 Measured rock densities from outcrops and drill core from exploration drilling in the Neves-Corvo region used for the gravity inversion carried out in this work. N: number of samples.

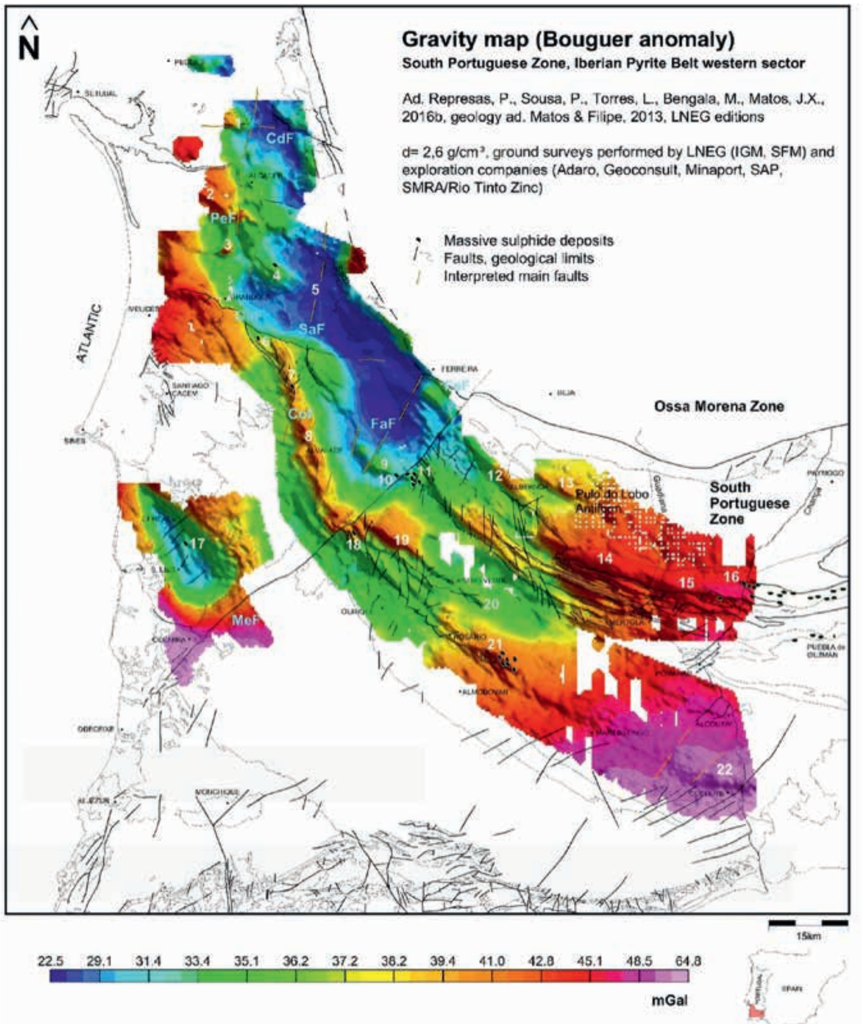

Figure 2 Bouguer anomaly map of the South Portuguese Zone and Iberian Pyrite Belt Portuguese sector (Represas et al., 2016). Interpreted main fault zones: CdF – Cordoeira-Palma, PeF – Pedrogão-Valverde-Clérigos, GaF - Grândola, SaF – Sado valley, FeF – Ferreira do Alentejo-Ficalho, CoF – Corona, FaF – Farrôbo, MeF – Messejana. Key sectors (see text): 1 – Serrinha horst, 2 – Porto de Mel horst, 3 – Pedrogão horst, 4 – Lagoa Salgada massive sulphide deposit and horst, 5 – Batão graben, 6 – Caveira old mine, 7 – Lousal old mine, 8 – Brejo/Sesmarias massive sulphide deposit, 9 – Milhouros basic volcanics rocks and horst; 10 – Morgado graben associated with the Messejana fault and Gavião massive sulphide deposit, 11 - Aljustrel mine, 12 – Albernôa, 13 – Alfarrobeira Pulo do Lobo Formation basic volcanic rocks, 14 – Corte Gafo, 15 – São Domingos old mine, 16 – Chança old mine, 17 – Salgadinho massive sulphide deposit, 18 – Montinho old mine, 19 - Casével basic volcanic rocks; 20 – São Pedro das Cabeças basic volcanic rocks, 21 – Neves-Corvo mine, 22 – Foupana-Corte São Tomé. Geology after LNEG (Oliveira et al., 1992).

discovery of the Neves-Corvo deposit (Albouy et al., 1981; Leca et al., 1983) collecting density measurements of key lithologies and mineralized intersections became common-practice for exploration work across the IPB.

Although gravity interpretation is relied upon to guide exploration in the IPB, potential-field modelling suffers from the phenomenon of non-uniqueness; multiple solutions exist that may satisfy the observed data. In structurally complex areas like Neves-Corvo, this ambiguity can be significant. In cases such as this, structural information provided through seismic reflection surveying can be used to help constrain and supplement interpretation of gravity data. This technique has been used with success by Lundin Mining in the Neves-Corvo region, mapping known massive sulphide lenses (e.g. Lombador and Semblana), assisting with development of an updated geological and structural model, and defining new exploration targets (Araujo and Castelo Branco, 2010; Lundin Mining website, Feb. 2016, http://www.lundinmining.com/).

The current-LNEG gravity database is a compilation of legacy data and more recent airborne gravity surveys performed by AGC/Lundin (Araujo and Castelo Branco, 2010; Nobre, 2013). The ground data was acquired over multiple survey generations beginning in the 1960s with Billiton, Minaport-EDM, SFM/IGM/LNEG, SMRA and Somincor. In total, more than ~388 000 gravity measurements have been collected in the IPB Portuguese sector. Depending on the survey parameters, the distance between points varied from 50 m to 500 m. The Portuguese Geological Survey, LNEG, was responsible for the storage and maintenance of this database. The data was compiled and levelled using common data points. It was then gridded, using a kriging algorithm to 500 m cells to achieve a uniformly distributed surface. The LNEG gravity database allowed for the production of the first regional IPB Portuguese sector Bouguer anomaly map (Represas et al., 2016). The regional Bouguer anomaly was determined using a crustal density of 2.6 g/cm^3, which is similar to the one used in the IPB Spanish sector gravity surveys (Garcia et al., 1998).

The gravity database. 3D inversion: still needed?

Although 3D geological models incorporating drillhole, underground and surface geological data have been built and used to constrain geophysical inversions at Neves-Corvo (e.g. Inverno et al., 2015), new data continues to be collected. Over several years, Somincor/Lundin performed surface TEM surveys over a large portion of their mineral claims. These have been inverted in 1D and stitched together to image the conductive layers/bodies to depths as great as 2 km. The majority of drillholes within the area do not exceed 2 km depth and most are well above that depth.

Information below this depth is still required to constrain the 3D gravity inversion, as it may influence long wavelength anomalies. Refined and improved geophysical inversion models offer great value to a dynamic and continually evolving exploration strategy.

To identify new targets in the Neves-Corvo region, the vintage gravity dataset has been revisited to enable a solid 3D gravity inversion constrained by recent drill hole and seismic reflection data. To achieve this goal, several steps were needed. Firstly, to check the accuracy of the existing gravity database. This database is a Bouguer anomaly map produced from the levelling of tens of surveys carried out by LNEG and private companies since the 1960s.

Figure 2 shows the resulting Bouguer anomaly map (Represas et al., 2016). The map shows a large regional southwest trend, throughout the gravity data linked to deep and large-scale sources. Studies developed at Iberian scale (Portugal and Spain) define large E-W anomalies related with the geometry of Moho and with deep alkaline plutonic structures with main W-E direction along the Algarve region (González-Castillo et al., 2014).

The IPB Portuguese sector gravity map reflects the main structures of the South Portuguese Zone and, in particular, the different IPB sectors (Represas et al., 2016; Matos et al., 2019). The gravity anomaly values drop considerably in areas were the Paleozoic basement is covered by Cenozoic age sediments and are conditioned by local basement geology and paleorelief/Cenozoic sediments thickness. This is a result of graben and horst structures developed during the late Variscan and Alpine periods (e.g. Alvalade/Sado Cenozoic Basin, Oliveira et al., 1998; Represas and Matos, 2012), positioning lower density Cenozoic overburden adjacent to the crystalline basement. This produces the strong gravity gradients which delineate the main late Variscan subvertical fault zones.

The map also indicates important anomalies at a local scale, most of them with a good correlation with the geology. At this scale, the massive sulphide deposits appear as oval-shaped anomalies, e.g. Feitais (Aljustrel) (11 in Fig. 2, Matos et al., 2019), Neves-Corvo (21 in Fig. 2, Albouy et al., 1981; Leca et al., 1983; Carvalho et al., 1996) and Lagoa Salgada (4 in Fig. 2, Oliveira et al., 1998; Represas and Matos, 2012), with amplitudes of > 0.5 mGal.

These anomalies are oriented parallel to the regional strike of the VSC host rocks (NW-SE to NNW-SSE) and correspond to the main areas of historic exploration (Carvalho, 1996; Matos et al., 2019).

From the regional gravity map for the IPB Portuguese sector, a grid was extracted for the Neves-Corvo region. The extracted, levelled grid was compared to the original overlapping datasets for quality assurance purposes and to assess the presence of any artefacts as a result of the levelling/gridding process. Some surveys, which were only available as paper maps, were digitized and the entire gravity survey relevelled (Marques et al., 2019).

The resulting Bouguer anomaly map is shown in Figure 3, in a 3D perspective view. Beyond the main anomaly, directly related with the Neves-Corvo VMS deposit (massive and stockwork ores), other geological features can be correlated with elements of the gravity map including VSC/PQ, NW-SE lineament and tectonic structures.

The main thrust zones of the SW Neves-Corvo sector are represented by important gradients. Subvertical late-Variscan strike-slip faults of E-W, N-S and NE-SW orientations are also apparent with the residual anomaly map (e.g N-S Lombador fault). In several areas, strong correlations exist between the gravity and seismic datasets. This is especially pronounced in the main NE-SW trending thrust fault zones.

To improve the 2D and 3D gravity modelling constraints, the existing density database (LNEG and Somincor/Lundin Mining data) was updated to more than 30,000 density measurements. The Lower VSC units have recently been the subject of focus as these were poorly sampled in the past. Table 1 presents rock densities, measured from drill core and outcrop in the Neves-Corvo region. These were the values used for the gravity inversion carried out in this study.

Rock density is affected by several factors such as porosity, fracturing, mineral distribution, weathering alteration and depth. Considering the same geological formation, the presence of metallic minerals (e.g. sulphide or magnetite veins/disseminations) will increase its average density, while low-density minerals (e.g. clays, silica, sericite, carbonates) will have the opposite effect.

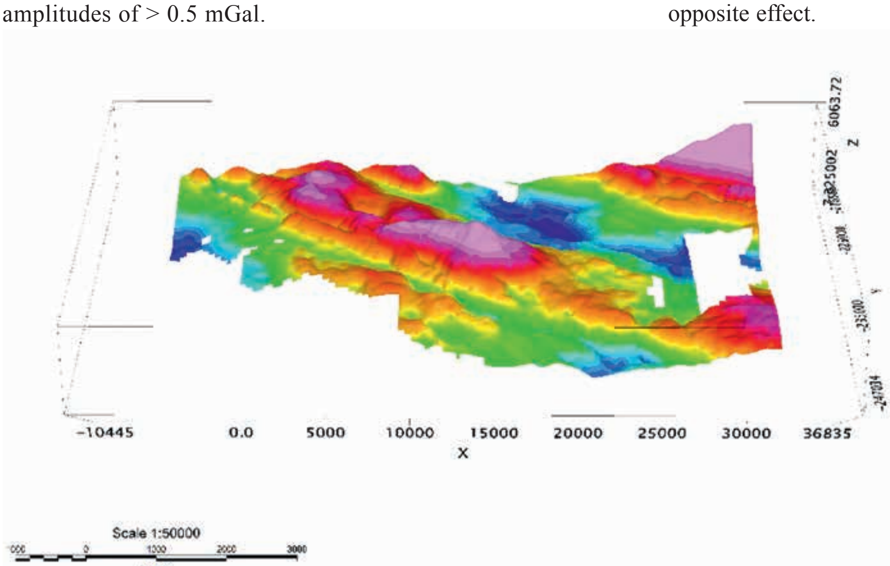

Figure 3 3D view of the residual Bouguer anomaly map used for the study area, extracted and relevelled from the IPB Portuguese sector gravity map shown in Figure 2. Reference density of 2.6 g/cm3 for the Bouguer anomaly calculation and a second degree polynomial was used to produce the residual (Marques et al., 2019).

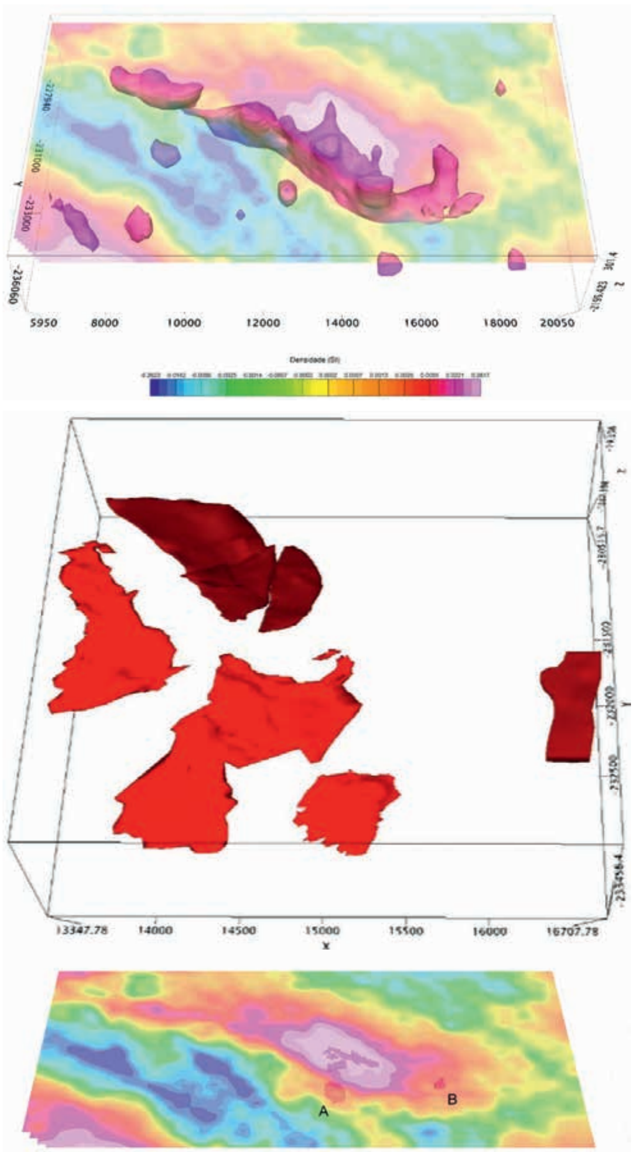

Figure 4 Top: Density model produced in the unconstrained inversion (density differences in g/cm³), overlaid to the Bouguer anomaly map. Middle: 3D model of the massive sulphide lenses based on drill-hole data used to constrain the 3D gravimetric inversion. Bottom: Density model produced using the 3D geological model above as a constraint (density differences in g/cm³) overplotted on the Bouguer anomaly map.

Preliminary results from 3D gravity inversion

After careful checking of the gravity database, generation of the revised Bouguer anomaly map and update of the density database, an unconstrained 3D gravity inversion was produced using commercial software (VOXI). This preliminary inversion is shown in Figure 4. The unconstrained inversion was unable to accurately locate the known orebodies, represented in the Figure 4 (middle image). As is typical with an unconstrained inversion, smoothly varying bodies are produced to most efficiently (and easily) satisfy the data.

To more accurately reflect the known distribution of the orebodies, a 3D geological model built from drill holes performed up to 2012 was used to constrain the 3D inversion. Although this model includes the base of the flysch/top of VSC contact, the base of the VSC/top of basement (PQ Fm.), only the massive sulphide lenses discovered up to date were used to constrain the gravity inversion. As the average densities obtained from Table 1, VSC host rocks and the PQ Fm. present similar densities and the major contrasts contributing to the gravity response are associated with the massive sulphides. This model and the constrained 3D inversion results are also shown in Figure 4 (middle and bottom images).

We can see using the massive sulphide lenses as an initial model leads to an inverted density model that better resembles the known lenses. However, this preliminary inversion also produces other high-density bodies, either beneath or to the side (marked A and B in Figure 4, respectively) of the known lenses. These were not a component of the constraint but are nevertheless required to satisfy the data. If substantiated by additional geophysical or geologic information, they may represent legitimate targets for future exploration. Presently, a new 3D geological model is being built to further constrain the inversion. This model will include the stratigraphic interface between Upper and Lower VSC refined by the interpretation of reprocessed 2D and 3D seismic reflection data, updated drill-hole data, a revised surface geologic map, (Donoso et al., 2018) and additional TEM data inverted in 1D.

Conclusions

In order to locate IPB VMS deposits different geophysical methods must be employed and integrated with geologic, geochemical and drill hole data. Vintage land gravity data, acquired by multiple private companies and government institutions in the second half of the 20th century led to the discovery of Neves-Corvo in 1977. Strong density contrasts between massive sulphides and their host rocks makes gravity one of the most useful tools for exploration in the Neves-Corvo IPB area. Ground gravity data played a significant role in the discovery of mineralization at Neves-Corvo (Neves, Corvo, Graça and Zambjual) and contributed to the overall geologic framework by which later exploration discoveries were based (Lombador and Semblana).

Drill hole data interpretation is of crucial importance in defining high-resolution local scale models of the geological structures, and should consider sulphide ore type and zonation, hydrothermal alteration events, geological units and overall tectonic setting. In this and petrophysically appropriate environments, gravity data, complemented with electromagnetic surveys, seismic reflection profiles and drill-hole logging can produce more realistic 3D geological models to constrain 3D gravimetric inversion models to help provide new targets to explore. In this work, gravity data was revisted, checked and a new Bouguer anomaly map was produced. From this data, both 3D gravimetric unconstrained inversion and a constrained inversion using a 3D drill hole-based geological model were undertaken. A new 3D gravity inversion using a more detailed 3D geological model is currently being carried out.

An iterative approach, incorporating new or reworked geologic and geophysical datasets as a constraint to the inversion process is the best solution to the problem of non-uniqueness. This is not only true of gravity, but all other potential fields geophysical datasets. Adopting this type of adaptive methodology will lead to the better results and the potential to reveal small and/or deeper orebodies previously undetected.

Acknowledgments

The authors would like to thank the projects EXPLORA, Op ALT20-03-0145-FEDER-000025, funded by Alentejo 2020, Portugal 2020 and European Union (European Regional Development Fund (ERDF) and Smart Exploration project, supported by the EU H2020 research and innovation programme under grant agreement No. 775971. This work is also dedicated to all SFM/IGM/LNEG field work teams that permitted the production of thousands of geophysical maps,co-ordinated by José Marcos Bengala, Manuel Nolasco Silva, Vitor Alvoeiro and Luís Torres. The authors are also grateful to Matt Penney and Bill Spicer from Lundin Mining for their valuable comments.

References

Albouy, L., Conde, L.N., Foglierinni, F., Leca, X., Morikis, A., Callier, L., Carvalho, P., Songy, J.C. [1981]. Le gisement de sulfures massifs polymétalliques de Neves Corvo, Baixo Alentejo, Portugal. *Chronique de La Recherche Minière*, nº 460, BRGM: 5-27.

Albardeiro, L., Solá, R., Salgueiro, R., Morais, I., Matos, J.X., Mendes, M., Pereira, Z., Batista, M. J., Inverno, C., Oliveira, D., Rosa, D., Pacheco, N. [2017]. Insights into timing of mineralization in the Neves-Corvo VMS deposit (Iberian Pyrite Belt). Proceedings of the 14th SGA Biennial Meeting – Mineral Deposits to Discover, V. 3, Québec City, Canada, 989-992.

Andrade R., Schermerhorn, L., [1971]. Aljustrel and Gavião. In: Carvalho, D., Goinhas, J., Schermerhorn, L.J.S., (Eds.,). *Livro guia da excursão 4. I Congresso Hipano-Luso-Americano de Geol. Económica*, 32-59.

Araujo, V., Castelo Branco, J.M. [2010]. Área de Mértola, relatório 1º Semestre 2010. *AGC Minas de Portugal, Lda*, Arquivo LNEG ID 10810.

Carvalho, P., Pacheco, N., Beliz, A., Ferreira, A. [1996]. Últimos desenvolvimentos em prospeção realizados pela Somincor. *Bol. Geologico y Minero ITGE*, **107** (5-6), Madrid, 39-54.

Carvalho, D., Barriga, F. J. A. S., Munhá, J. [1999]. Bimodal-siliciclastic systems – the case of the Iberian Pyrite Belt. *Reviews in Economic Geology*, **8**, 375-408.

Donoso, J., Malehmir, A., Pacheco, N., Araujo, V., Penney, M., Carvalho, J., Beach, S., Spicer, B. [2018]. Potential of Legacy 2D Seismic Data for Deep-Targeting and Structural Imaging at the Neves-Corvo Mining Site, Portugal. *EAGE Near Surface Geoscience*, Extended Abstracts.

García, J., Plata, J., Rubio, F., Navas, J. [1998]. Cartografia geofisica regional del ITGE en la Faja Pirítica. *IV Simp. Int. dos Sulfuretos Polimetálicos da Faixa Piritosa Ibérica*. APIMINERAL, Lisboa, A.1.1-A.1.20.

González-Castillo, L., Galindo-Zaldívara, J., Ruiz-Constánc, A., Pedrerab, A. [2014]. Magnetic evidence of a crustal fault affecting a linear laccolith: The Guadiana Fault and the Monchique Alkaline Complex (SW Iberian Peninsula). *Journal of Geodynamics*, **77**, 149-157, doi:10.1016/j.jog.2013.10.007.

Inverno, C., Rosa, C., Matos, J., Carvalho, J., Castello-Branco, J.M., Batista, M.J., Granado, I., Oliveira, J.T., Araújo, V., Pereira, Z., Represas, P., Solá, A.R., Sousa, P. [2015]. Chap. 11 - Modelling of the Neves Corvo Areation and Geological Setting of the Iberian Pyrite Belt. P. Weihed (ed.), *3D, 4D and Predictive Modelling of Major Mineral Belts in Europe*, Springler Verlag, Mineral Resource Reviews, 231-261, Doi:10.1007/978-3-319-17428-0_9.

Laboratório Nacional de Energia e Geologia, Lisboa [2010]. *Geological map of Portugal*, 500k scale.

Leca, X., Ribeiro, A., Oliveira, J.T., Silva, J.B., Albouy, L., Carvalho. P., Merino, H. [1983]. Cadre géologique des minéralisations de Neves Corvo (Baixo-Alentejo, Portugal) – Lithostratigraphie, paléogéographie et tectonique. *Mémoire du BRGM*, 121. Orléans, France.

Matos, J.X., Carvalho, J., Represas, P., Batista, M.J., Sousa, P., Ramalho, E.C., Marques, F., Morais, I., Albardeiro, L., Gonçalves, P. [2019] (Submitted). Geophysical surveys in the Portuguese sector of the Iberian Pyrite Belt: a global overview focused on the massive sulphide exploration and geologic interpretation. *Comunicações Geológicas*, T. 2019.

Matos, J.X., Pereira, Z., Rosa, C.J.P., Rosa, D.R.N., Oliveira, J.T., Relvas, J.M.R.S. [2011]. Late Strunian age: a key time frame for VMS deposit exploration in the Iberian Pyrite Belt. *11TH SGA Biennial Meeting*, Autofagasta, Chile, 790-792.

Nobre, F. [2013]. Área de Almodôvar, Relatório Final. *AGC Minas de Portugal*. LNEG ID 15964.

Oliveira, J. T., coord. [1992]. Notícia Explicativa Carta Geológica de Portugal, esc. 1/200 000, fl. 8, Serv. Geológicos de Portugal.

Oliveira, V., Matos J. X., Bengala, M., Silva, M. N., Sousa, P., Torres, L. [1998]. Geology and Geophysics as Successful Tools in the Discovery of the Lagoa Salgada Orebody (Sado Tertiary Basin - Iberian Pyrite Belt), Grândola, Portugal. *Mineralium Deposita*, **33**, 170-187.

Oliveira, J.T., Rosa, C., Rosa, D., Pereira, Z., Matos, J.X., Inverno, C., Andersen, T. [2013]. Geology of the Neves-Corvo antiform, Iberian Pyrite Belt, Portugal: New insights from physical volcanology, palynostratigraphy and isotope geochronology studies. *Mineralium Deposita*, **48**, DOI 10.1007/s00126-012-0453-0, 749–766.

Represas, P., Matos, J.X. [2012]. New Approach on the Gravity Data of the Lagoa Salgada Structure, Iberian Pyrite Belt, Portugal. *Near Surface Geoscience 2012*, 18th European Meeting of Environmental and Engineering Geophysics, Abstracts, P65.

Represas, P., Sousa, P., Torres, L., Bengala, M., Matos, J.X. [2016]. Gravimetric Map (Bouguer anomaly, density 2.6) of the South Portuguese Zone, Iberian Pyrite Belt, scale 1/400 000, LNEG/URMG, Lisboa.