A New 3D Geological Model for the Neves-Corvo Mine Region, Iberian Pyrite Belt, Portugal

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Introduction

The Neves-Corvo mine, located in the Iberian Pyrite Belt in southern Portugal (**Fig. 1**) is a world-class VMS deposit and the largest operating mine in the country. Seven massive sulphide bodies and related stockwork have been discovered to date, totalling 300 Mt of sulphides. Somincor, a subsidiary of Lundin Mining, has been exploiting the mine over the last three decades and accumulated an extensive amount of geophysical and drill-hole datasets during this time. These data are used in this work to build a 3D geological model of the study area.

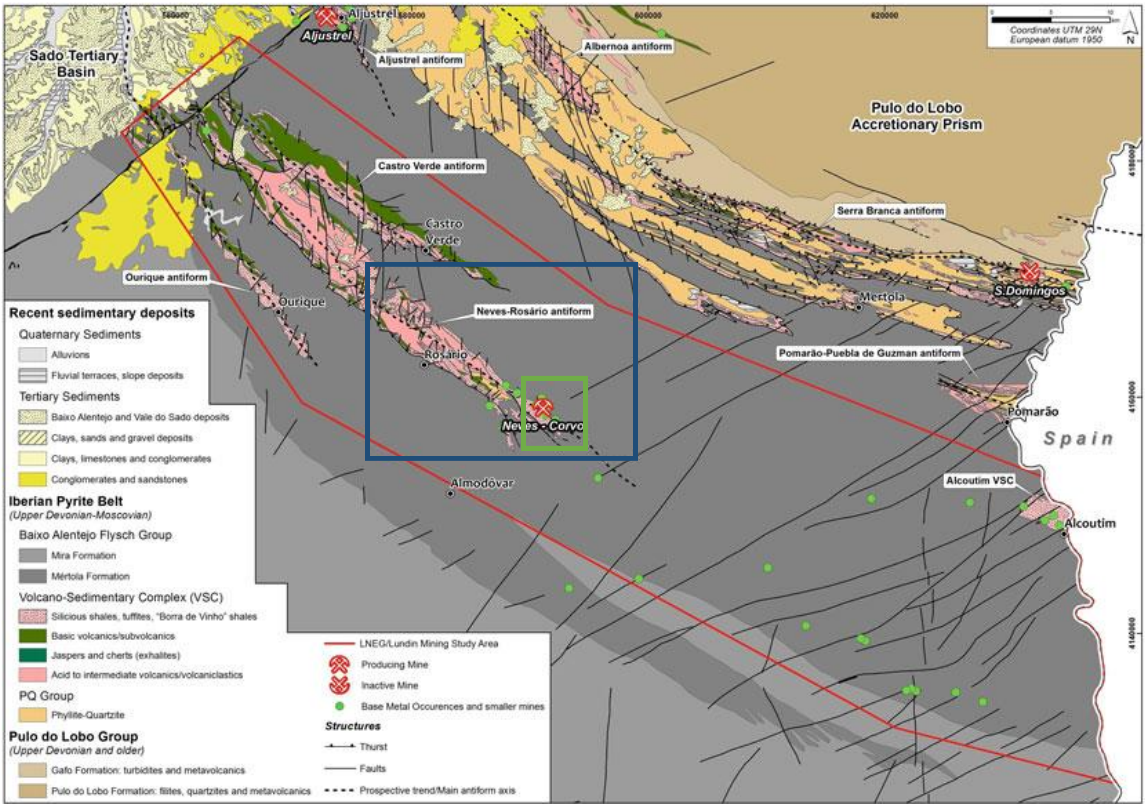

Figure 1 *Geological map showing the location of the Neves-Corvo mine (after Inverno et al., 2015) and the approximate locations of the pre-existing 3D geological modelling areas from the Promine project (red line), Lundin (green) and the one presented in this study (blue).*

During the past 15 years, Lundin Mining has reworked and updated the 3D geological model of the Neves-Corvo region using seismic and drill-hole data. Under the scope of the Promine Project, a regional 3D model was built extending from the northwest end of the Rosário-Neves-Corvo anticline to the Spanish border to investigate the possible down plunge extension of this volcanic axis to the SE, under the Flysch Group sedimentary units (Inverno et al., 2015; Carvalho et al., 2017). These geological models serve two major purposes: (1) as starting models for constrained geophysical modelling and inversions; Lundin previously attempted this approach for target generation purposes; (2) to understand the genesis and location of mineral deposits (Royer et al., 2015). Faulting, thrusting, and hydrothermal alteration provide insight regarding orebody genesis and tectonic evolution of the mineralization. Tectonic settings and identification of volcanic centres may also contribute to new findings and better targeting of mineral deposits.

In this work, we describe and discuss the processes involved while constructing a new 3D geological model for Neves-Corvo, using a broader, regional scaled approach. The area of the model does not extend to the SE as far as the Promine model but rather, possesses a higher level of detail (Figure 1). The 3D model presented here uses an updated drill-hole database comprised of 1000 surface drill-holes and 7000 underground drill-holes. It also includes recently reprocessed legacy 2D reflection seismic profiles (Donoso et al., 2019) as well as a 3D seismic dataset from the area (Yavuz et al., 2015). Additional data used as constraints for this new model include: three (3) profiles from the Promine project (Carvalho et al., 2017), palynological studies from the EU , Explora project and over 200 line kilometres of surface TEM data acquired by Lundin Mining over the last 15 years. Gravity and airborne magnetics have also been used as a model constraint, namely through 2D forward modelling to confirm cross-sections built from drill-holes and surface geological mapping.

Geological setting

Local geology comprises the following main units, from top to bottom: the late Visean Mértola formation, a Flysch sequence composed mostly by intercalations of greywackes and dark grey shales (Oliveira et al., 2004); the Volcanic-Sedimentary Complex (VSC) of Strunian-Visean age; and the Phyllite-Quartzite (PQ) basement Formation of Frasnian age (Oliveira et al., 2004). The VSC is classically divided into an allochthonous (upper) and an autochthonous (lower) sequences separated by the so-called Neves-Corvo Main Thrust. The allochthonous, Upper VSC is composed from top to bottom by the Brancanes Formation (black shales with disseminated pyrite), Godinho Formation (tuffites and grey siliceous shales), “Borra de Vinho” Formation (purple and green shales), Grandaços Formation (black shales with carbonate lenses and nodules), Graça Formation (black graphitic shales and grey siliceous shales) with basic intrusive rocks and interbedded felsic volcanic rocks. The autochthonous, Lower VSC is composed of a jaspers and carbonates unit that represents the massive sulphide horizon´s immediate hanging wall, followed by the Neves Formation (black pyritic shales) which is ultimately underlain by the Corvo Formation (black shales with tuffs and breccias) that conformably seats on top of the PQ Basement. The area is tectonically characterized by southwest verging thrust sheets and Late Variscan near-vertical strike-slip faults.

Methodology and data used in model construction

The TEM surveys consist of in-loop, surface data acquired between 2006 and 2011 by Lundin Mining. These were acquired by a variety of Canadian EM service providers, with each transmitter loop generally 1000 m x 1000 m and approximately 13 -20 Amps of current. The data were inverted using the UBC1DEM code by Lundin at each station and later stitched together to produce 2D cross-sections of electrical resistivity. Figure 2 shows the location of the approximately 200 cross-sections used in the current work.

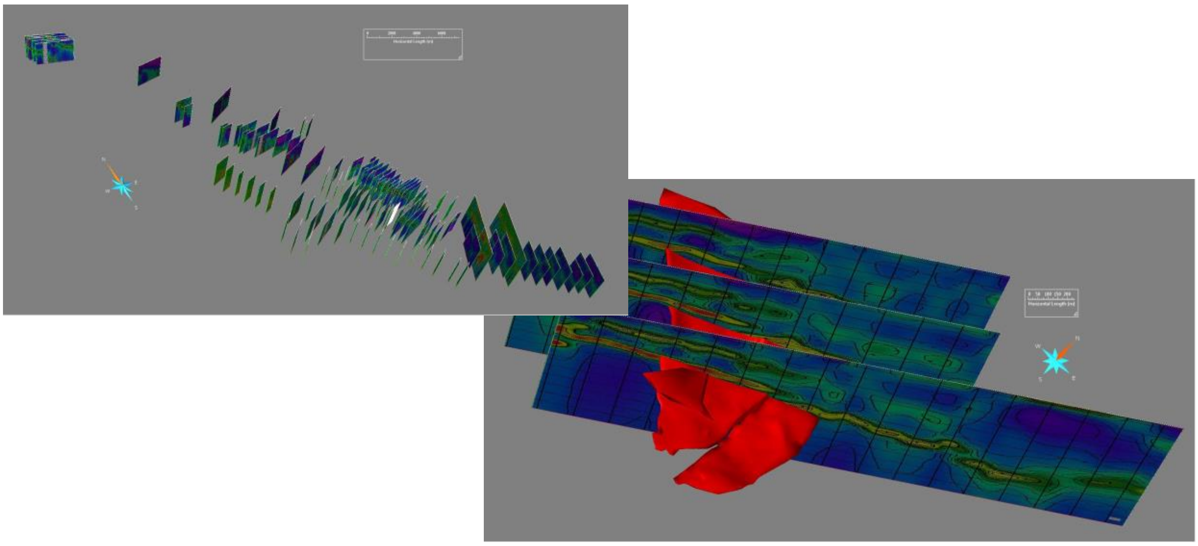

Figure 2 *Left: Distribution of the approximately 200 TEM cross-sections used in this work, obtained from 1D inversion of loop ground data stitched together to produce 2D cross-sections. Right: Detail showing TEM cross-sections crossing the Lombador deposit.*

As part of another project, three lines in the Lombador subarea were reprocessed and inverted using the Beowulf 1D ground code. (Dias et al., 2020). This allowed for a better understanding of the limitation of the data and a better interpretation. The constrained inversion carried out by Dias et al. (2020) used a larger number of drill-holes that permitted an improved understanding of the electromagnetic response of the local geological formations. The three lines chosen (Figure 2) by those authors to carry out the 1D inversion were 2 km long, spaced 300 m with a total of 60 stations separated 100 m apart. The inversion was constrained by averaged physical property data derived from approximately 300 drill-holes, but only the direct measurements from drill-holes closer than 50 m to the TEM lines were considered to avoid extreme 3D effects.

Results and conclusions

The construction of the surface representing each stratigraphic boundary was a challenging task due to the complexity of the geology in the region, with multiple stacked thrusts sheets, folds and intense faulting and deformation. Several methods of interpolation and surface creation were used to generalize the sparse data curves to the respective 3D surface.

The stratigraphic boundaries created are derived from multiple sub-surfaces extracted from several areas. The final boundaries were constructed using a time-consuming explicit modelling process with subareas merged into a single surface. Despite the extra work, explicit modelling guaranteed that the final surface properly honoured the 3D interpretations. For illustrative purposes, Figure 3 shows the example of the final surface created for the Flysch/Upper VS contact. The final step for the creation of each surface was to adjust it to fit the drill-hole markers.

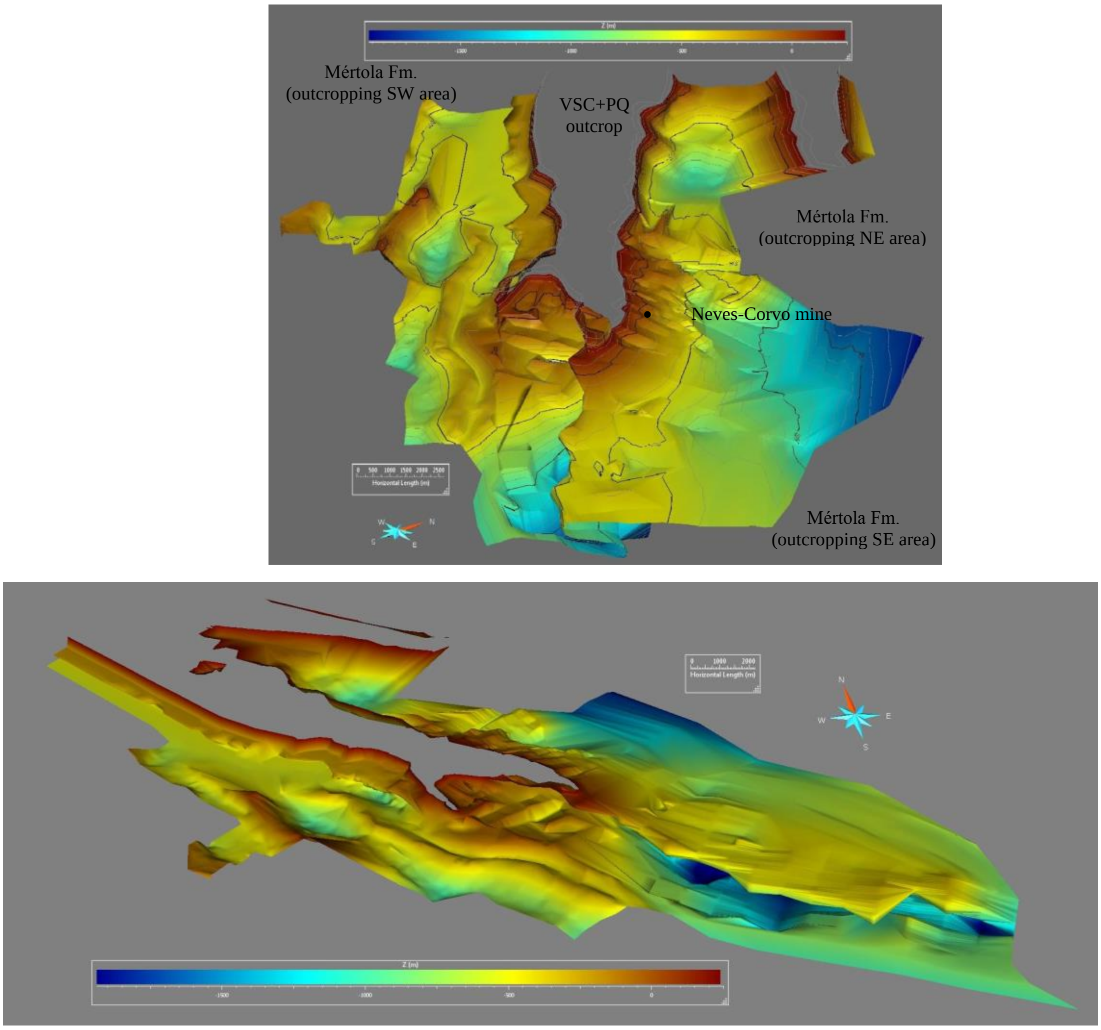

***Figure 3**: Two distinct 3D views of the base of Mértola formation surface, built in this work.*

Explicit 3D geological modelling constrained by a suite of geoscience data constraints, although time-consuming, provides a significant level of detail relative to the more commonly implemented implicit modelling practices. This new model allows for a better understanding of the geological and tectonic history of the study area and simultaneously promotes a more efficient and reliable exploration targeting process. This may in turn be used as input to constrain or refine pre-existing geophysical inversion models as well. In the scope of this work, we have built a constrained 3D geological model within a portion of the Iberian Pyrite Belt that hosts the world-class Neves-Corvo mine. This was achieved through the integration of reprocessed TEM and 2D-3D seismic data, over 8000 drill-holes, updated geological outcrop data and reprocessed gravity and aeromagnetic data. A first use of the 3D geological model built in the scope of this work has been through 3D constrained gravity inversion, where a few areas of interest have been outlined from an exploration perspective, which will be further investigated.

Acknowledgements

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References

Carvalho, J., Inverno, C., Matos, J., Rosa, C., Granado, I., Branch, T., Represas, P., Carabaneanu, L., Matias, L., Sousa, P. [2017]. Subsurface Mapping in the Iberian Pyrite Belt Using Seismic Reflection Profiling and Potential Field Data, International Journal of Earth Sciences, 106, 899–915. DOI: 10.1007/s00531-016-1340-1.

Dias, P., Represas, P., Pacheco, N., Thunehed, H., Carvalho, J., Ramalho, E., Donoso, G., Inverno, C., Marques, F., Araújo, V. [2020]. 3D TEM and Gravity Modeling over the Lombador Deposit, Neves-Corvo, Portugal, Extended Abstract of the 82nd EAGE Conference & Exhibition 2020, Amsterdam, 6-9 December.

Donoso, G. A., Malehmir, A., Pacheco, N., Araujo, V., Penney, M., Carvalho, J., Spicer, B. and Beach S. [2020]. Potential of legacy 2D seismic data for deep-targeting and structural imaging at the Neves-Corvo massive sulphide-bearing deposit, Portugal. Geophysical Prospecting.

Inverno, C., A. Díez, Montes, C. Rosa, J. García-Crespo, J. Matos, J.L. García-Lobón, J. Carvalho, F. Bellido, J.M. Castello-Branco, C. Ayala, M. J. Batista, F. Rubio, I. Granado, F. Tornos, J. T. Oliveira, Rey, C., Araújo, V., Sánchez-García, T., Pereira, Z., Represas P., Solá, A. R., Sousa, P. [2015]. Introduction and geological settings (chapter 9), In: 3D, 4D and Predictive Modelling of Major Mineral Belts in Europe, Part IV: The Iberian Pyrite Belt and Ossa-Morena Zones (Ed. P. Weihed), Springer, Berlin.

Oliveira, J. T., Pereira, Z., Carvalho, P., Pacheco, N., Korn, D. [2004]. Stratigraphy of the tectonically imbricated lithological succession of the Neves Corvo mine area, Iberian Pyrite Belt, Portugal, Mineralium Deposita, 39, 422-436.

Raiche, A., Wilson, G. and Sugeng, F. [2007]. Practical 3D inversion –The P223F Software Suite. 19th Geophysical Conference and Exhibition Abstracts, ASEG, 68-69.

Royer, J. J., Mejia, P., Caumon, G., Collon, P. [2015]. 3D and 4D Geomodelling Applied to Mineral Resources Exploration—An Introduction. In: Weihed P. (eds) 3D, 4D and Predictive Modelling of Major Mineral Belts in Europe. Mineral Resource Reviews. Springer, Cham. DOI https://doi.org/10.1007/978-3-319-.

Yavuz, S, Kinkela, J., Dzunic, A., Penney, M., Neto. R., Araújo, V., Ziramov, S., Pevzner, R., Urosevic, M. [2015]. Physical property analysis and preserved relative amplitude processed seismic imaging of volcanogenic massive sulfides—a case study from Neves-Corvo, Portugal Geophysical Prospecting, 63, 798-812. DOI: 10.1111/1365-2478.12269.