Reflection Seismic Imaging for Mineral Exploration in the Sotiel-Coronada Area, Southwest Spain

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Summary

This work explores the first results of the seismic data acquired in the Sotiel-Coronada mine as part of the SIT4ME (Seismic Imaging Techniques for Mineral Exploration) project. In this experiment, a multi-source seismic data-set was acquired at the end of 2018 in the Sotiel-Coronada area of the Iberian Pyrite Belt (IPB) (southwest Spain). In the seismic experiment presented, 653 seismic receivers were deployed distributed in a pseudo 3D grid and six crooked lines across the study area. The sensors recorded c. 900 vibration points produced by a 32 Tn vibrotruck.

Here, we present the stack results of the 2D seismic sections. Data from over 100 wells have been incorporating to aid in the structural interpretation. The preliminary interpretation reveals the complexity of this highly faulted ore-bearing area. Correlations between well log data information and 2D seismic profiles, suggest the location of a potentially mineralized area. The SIT4ME project has been funded by EIT Raw Materials (17024).

Introduction

As our society grows, larger amount of mineral resources are needed to satisfy its requirements. Since most of the shallow deposits have already been explored and exploited, the industry faces severe handicaps to identify and access new deeper ores. In order to achieve this goal, we need to develop new exploration approaches that allowed us to undertake environmentally friendly prospecting surveys that ensure the supplies of raw materials at a reduced cost.

Recent advances in seismic data acquisition and processing have increased the imaging and resolution power of this technique (Koivitso et al., 2012; Cheraghi et al., 2012). However, it is still considered an expensive prospecting tool for mineral exploration. To deal with this problem, the European Institute of Innovation and Technology (EIT) through its Raw-Materials programme funded the SIT4ME project (Seismic Imaging Techniques for Mineral Exploration). This project aims to innovate in seismic imaging protocols to improve the efficiency and thus the cost-effectiveness of seismic exploration in deep mineral resource targets.

The SIT4ME project focuses on the acquisition, processing and interpretation of seismic data in massive sulphides hosted by a shale and mafic/felsic volcanic setting near Sotiel-Coronada, in the Iberian Pyrite Belt. The latter is a Variscan metallogenic province located in SW Iberia that hosts the largest concentration of massive polymetallic sulphide deposits in the world (Gonzalez et al., 2006; Inverno et al., 2015). This complex is characterised by a simple stratigraphy made up by Devonian to Carboniferous rocks, with 3 predominating units: the Phyllite Quartzite Group, the Volcanic Sedimentary Complex, and Culm Group (alternating greywackes rocks and slate) (Schermerhorn 1971; Oliveira 1983). Nevertheless, due to some igneous intrusions and the abundance of truths faults, this stratigraphy is often disrupted and varies drastically (Boulter, 1993; Soriano & Martí, 1999).

The main objective of the SIT4ME project is to test and validate combined advanced approaches (2D and 3D acquisition geometries, travel-time tomography, pre-stack depth migration, ambient noise interferometry) that can produce robust models of the subsurface. The improvement of the capabilities of the seismic imaging technologies will have a significant effect in exploration at hard-rock environments, increasing safety, sustainability and cost-effectiveness of the mineral exploration activities.

In this presentation, we are going to show results of the integration of 2D controlled source seismic data with borehole data. Two 2D sub-perpendicular seismic lines show clear reflectors that can be correlated with the extrapolation of ore level identified at boreholes located further to the West. The image provided by seismic data is well resolved and provides the geometry of the mineralized leves at larger areas than studied by direct prospecting techniques.

Method and Results

The Sotiel mine is an underground deposit of massive polymetalic sulfides (e.g. copper, zinc, lead, silver and gold), located in the municipality of Calañas, in the province of Huelva (Southwest of the Iberian Peninsula). To conduct the seismic acquisition experiments, 653, 1C and 3C receivers were deployed in a pseudo-3D mesh defined by 6, 2D crooked lines across the c 6 km^2 study area. These sensors collected c. 900 vibration points generated by a 32t vibroseis truck making use of the available paths surrounding the target structures. Each vibration point was swept three times, with a frequency range between 10 and 100 HZ and sweep lengths of 15 seconds. The 1C and 3C components receivers were alternatively deployed with 20 m spacing along the 2D profiles. A 3D grid of 1C stations was deployed at the expected location of the target ore structure. The seismic stations also recorded environmental seismic noise during the 13 days of acquisition. In this presentation we only include 1C, 2D controlled source data. Seismic noise data will be processed, analyzed, interpreted and integrated with the controlled source seismic results in a future stage of the project. Both controlled and natural source seismic methods have proven their potential in mineral exploration at a deep subsurface (Adam et al, 2003; Cheraghi et al., 2011; Malehmir et al., 2012b). This multidisciplinary acquisition was designed based on the approximate geometry and depth (200-500 m deep) of a structure observed on a well drilling campaign carried out by MATSA. The 2D and 3D acquisition geometries ensured a good coverage around the area.

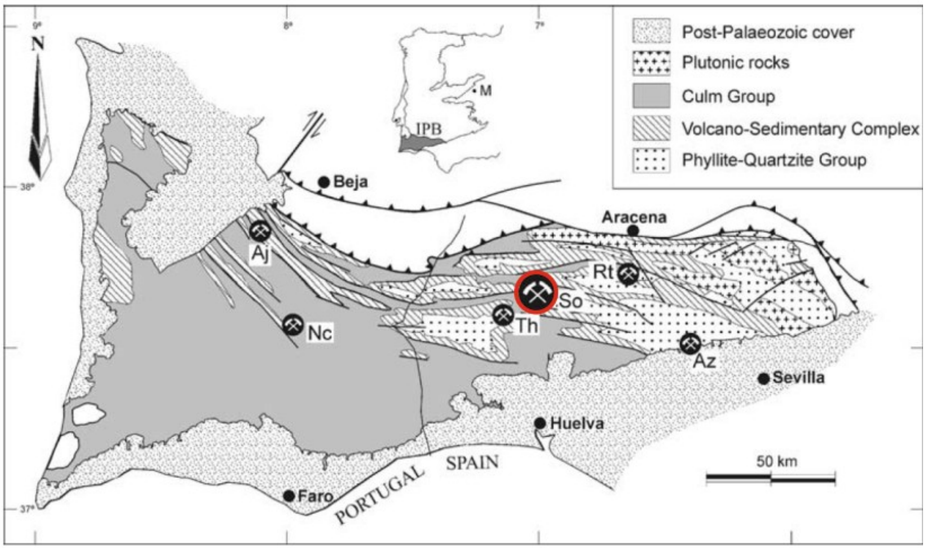

Figure 1 *Geological map of the Iberian Pyrite Belt showing the location of the Sotiel-Coronada Mine and the main mining districts. González et al., 2006.*

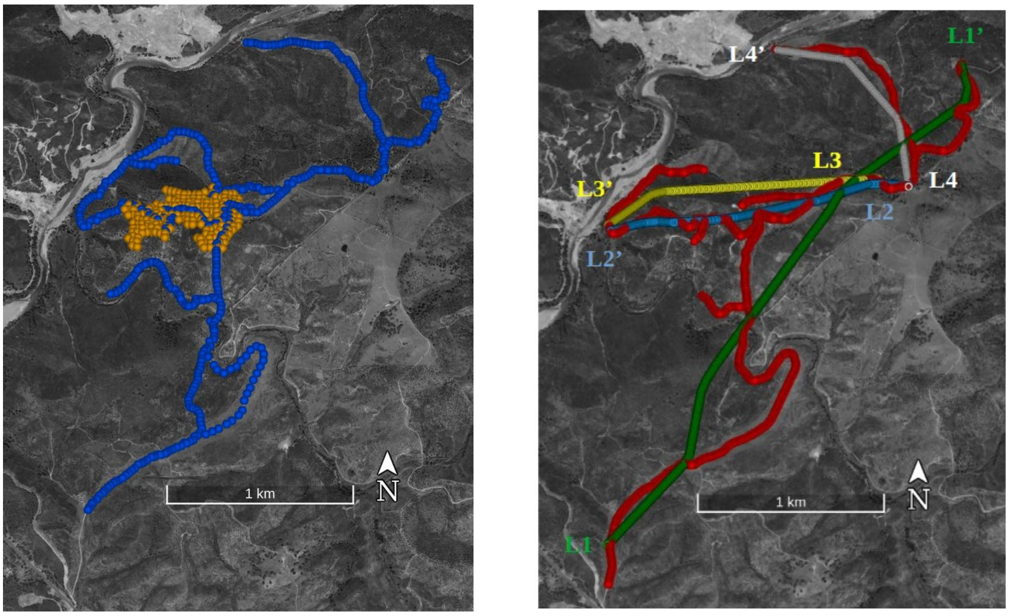

Figure 2 *Geometry of the acquisition in Sotiel. (a) Distribution of receivers along the 2D lines (in blue) and the 3D area (in orange). (b) Distribution of the vibration points in the study area along the accessible and unpaved roads (in red) and seismic lines (in light blue) analysed in this study.*

The 2D seismic data processing flow started editing noisy traces to avoid contamination in our data set. The geometry of the midpoints CMP was calculated based on the location of the vibration and receiver locations, assuming a linear bin size of 5 m. First arrivals were carefully picked in all traces to calculate the static corrections. Other steps, e.g., notch filter, mute, amplitude equalization, frequency filters, deconvolution and velocity analysis were applied to obtain the processed stack profile.

This processing flow was applied to the main 2D seismic sections, one N-S (L1) and tree E-W (L2, L3 and L4) profiles (Figure 1.b). L1 is the longest (3400 m) profile (Figure 2). A coherent reflectivity can be observed down to ~2000 ms two-way traveltime (TWT). A highly reflective N-dipping band of approximately 380 m length is observed at the center of the L1 profile, between 0 and 300 ms TWT (Figure 3). This reflectivity has been preliminarily interpreted as a mineralized zone. An antiform-synform structure dominates in profiles L2 and L3, and their image is hindered by noise as the seismic lines get closer to L4, towards the north of the study area.

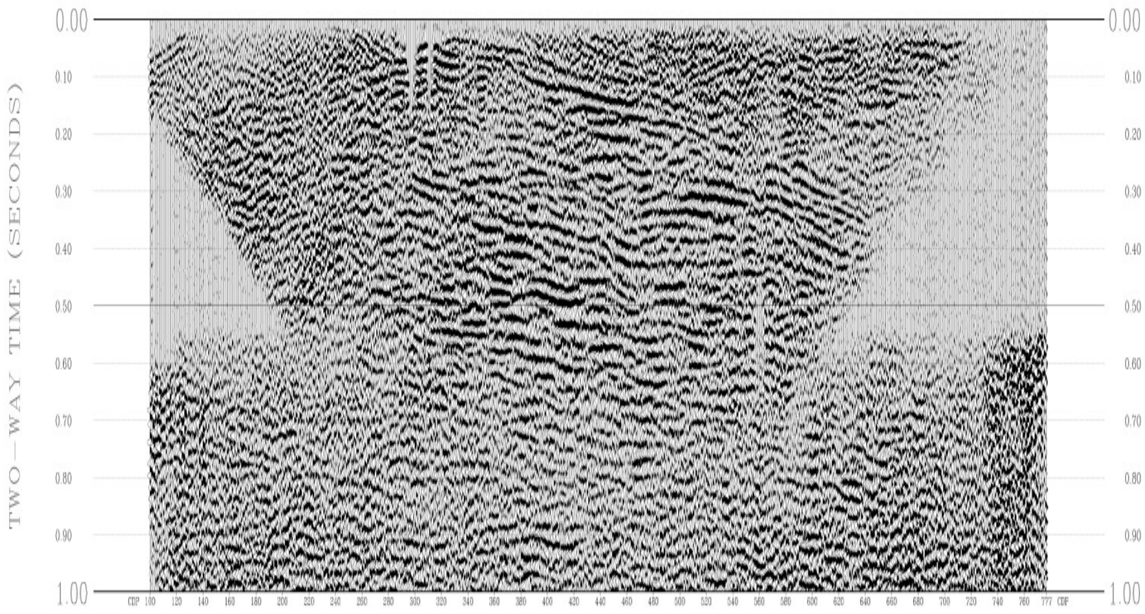

Figure 3 *2D processing stack L1 of the Sotiel-coronada data. Surgical mute was apply to reduce surface noise. L1 profile location on figure 2 right.*

The reflector observed in figure 3 and described above coincides with the eastern prolongation of a level of mineralized rocks identified in a logging survey undertaken further to the W. However, due to the complex geology, rough topography and the 3D effect of the crooked line acquisition, some of the reflections observed will probably have an out–of-plane origin. Different techniques have been combined to unravel the depth and geometry of the main structures: 2D processing seismic data, surface geology and existing drill cores to increase the accuracy. Further analysis, including travel time tomography, processing and interpretation of 3D data and analysis of the seismic noise will be necessary to prove right the identifications of new mineralized layers.

Conclusions

At the end of 2018 a multidisciplinary seismic data acquisition experiment was carried out in the Sotiel-Coronada area. 2D seismic data shows valuable information of the subsurface structures. The main profile (N-S Line 1) presents conspicuous N-dipping reflectivity probably related to a mineralized zone. Results were contrasted with the surface geology and existing drill cores with good correlation between the data acquired.

Future work will involve the use of conventional and non-conventional processing algorithms (pre-stack depth migration, CRS, processing of 3D seismic data, first arrivals tomography) and integration with new datasets (e.g.,gravity and magnetic anomalies) to design a low cost method that allow us to obtain a high resolution image of the subsurface in the Sotiel study area. This experiment will assess the potential and capability of reflection seismic methods for mining exploration in combination with surface geology and other techniques.

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