SEISMIC METHODS IN MINERAL EXPLORATION: WHAT WE LEARNED FROM THE COGITO-MIN PROJECT?

Michał MALINOWSKI[1], Emilia KOIVISTO[2], Suvi HEINONEN[3], Calin COSMA[4], Marek WOJDYŁA[5] and Sanna JUURELA[6]

[1]*Institute of Geophysics PAS, Ks.Janusza 64, 01-452 Warsaw; michalm@igf.edu.pl*
[2]*University of Helsinki, P.O. Box 64, FI-00014 Helsinki*
[3]*Geological Survey of Finland, P.O. Box 96, FI-02151 Espoo*
[4]*Vibrometric Oy, Taipaleentie 127, FI-01860 Perttula*
[5]*Geopartner Sp. z o.o., Skośna 39B, 30-383 Krakow*
[6]*Boliden FinnEx Oy, Polvijärventie 22, FI-83700 Polvijärvi*

Introduction

The COGITO-MIN (COst-effective Geophysical Imaging Techniques for supporting Ongoing MINeral exploration in Europe) project joined the forces of research institutions and industry partners from Finland and Poland. It aimed at methodological advances in the use of seismic imaging for deep mineral exploration and resource delineation, considering the cost-effectiveness of the methods. Our test site was the polymetallic Kylylahti mine operated by Boliden (Fig. 1). It is located at the NE side of the famous Outokumpu mining and exploration district that hosts Cu–Co–Zn–Ni–Ag–Au semi-massive to massive sulphide deposits. It is a good site for seismic exploration because the ophiolite-derived rock assemblage hosting the sulphide mineralizations, as well as the sulphide mineralizations themselves, are strongly reflective within their background rocks, turbiditic mica schists with black schist intercalations. Yet, the complexity of the structure (see Fig. 1) was very challenging for surface seismic methods. Here we report on the main outcomes of the various components of the project.

Seismic experiments and their results

A very comprehensive dataset was acquired during the COGITO-MIN field work in 2016 (Fig. 1): (i) a 3D passive seismic survey in which ~1000 seismic receivers in a 3.5 x 3 km grid were left to record ambient noise sources for 30 days, (ii) two approximately 6-km long high-resolution seismic reflection 2D profiles, (iii) an active 3D seismic reflection survey utilizing the passive seismic grid and a “random” distribution of Vibroseis and explosive sources, (iv) a multi-azimuth walk-away three-component VSP survey in three boreholes starting from the mine tunnels, with one borehole instrumented also with the fibre-optic cable (DAS technology). Chamarczuk et al. (2018) have developed a new workflow for reflection seismic imaging using ambient noise data from a 3D passive survey using seismic interferometry (SI). Sections retrieved with SI exhibit abundant reflectivity, consistent with some geological features and correlating to some extent with reflectors observed in the active-source images. High-resolution 2D reflection profiles confirmed the depth-extend of the Outukumpu assemblage rocks, manifesting themselves in form of increased, yet not coherent, reflectivity, providing an interesting target for further investigations (Heinonen et al. 2018). Specialized pre-stack depth imaging (Hlousek et al. 2015) turned out to outperform more traditional time imaging approach, especially in the shallower section for imaging steeply dipping contacts. Sparse and irregular active-source 3D survey has provided new details about the architecture of the Kylylahti area, in particular about the spatial extent of the Outokumpu assemblage rocks. Similarly to 2D imaging, a significant uplift in imaging the ore-hosting lithologies, were brought by the pre-stack depth imaging (Singh et al. 2019). VSP results, corroborated by the detailed forward modelling, led to successful interpretation of key geological contacts including the target sulphide mineralization (Riedel et al. 2018). It demonstrates the value of in-mine VSP measurements for detailed resource delineation in a complex geological setting, especially when coupled with the fiber-optic DAS technology, which provide reflection data at sufficient quality with less logistical efforts.

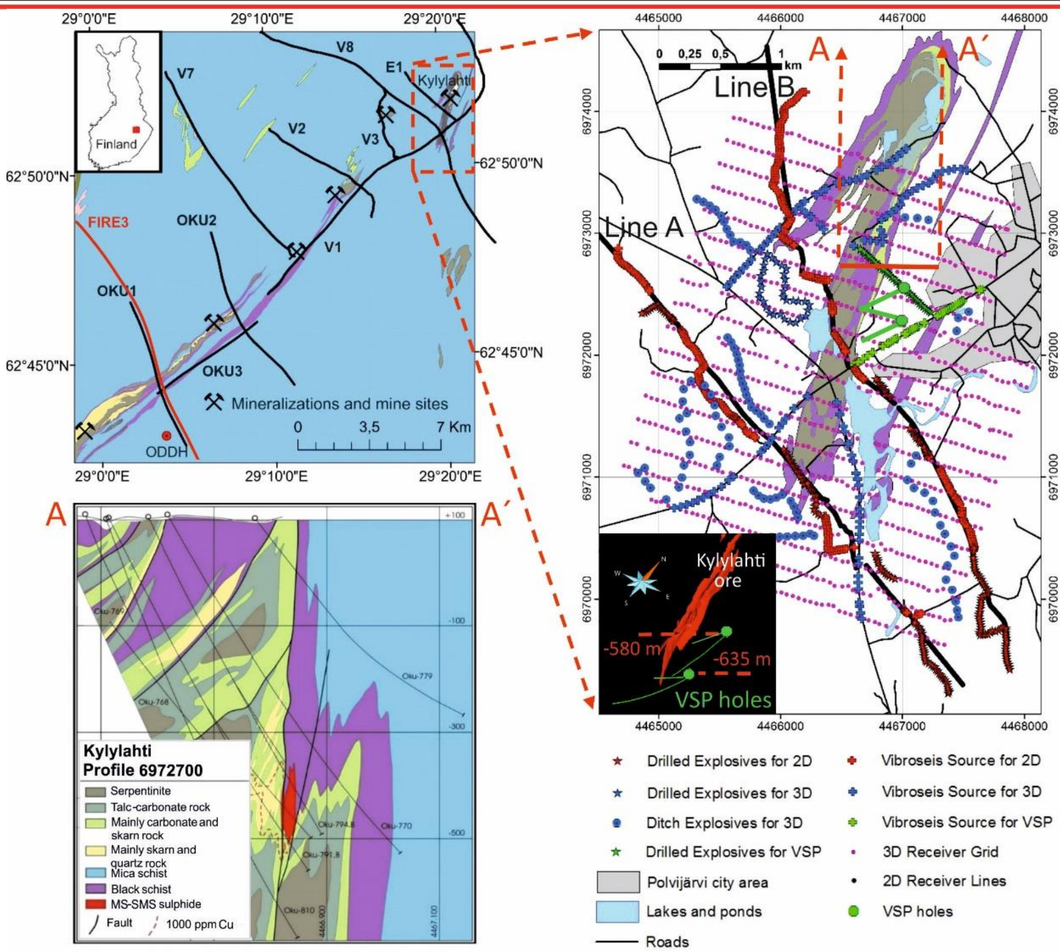

Figure 1. *Location of the Kylylahti mine on the geological map (Bedrock of Finland –DigiKP). Geological cross-section A-A´ from Peltonen et al. (2008) across the Kylylahti deposit. Right: Survey layout of the COGITO-MIN project.*

Acknowledgements

COGITO-MIN has been funded through ERA-MIN. The funding for the Finnish COGITO-MIN project partners comes from TEKES (Business Finland) and for the Polish project partners from the NCBR.

References

Chamarczuk M. et al., 2018. Seismic Interferometry for Mineral Exploration: Passive Seismic Experiment over Kylylahti Mine Area, Finland. 2nd Conference on Geophysics for Mineral Exploration and Mining.

Heinonen S. et al., 2018. Seismic Exploration in The Kylylahti Cu-Au-Zn Mining Area: Comparison of Time and Depth Imaging Approaches. 2nd Conference on Geophysics for Mineral Exploration and Mining.

Hloušek F., Hellwig O. and Buske, S., 2015. Improved structural characterization of the Earth's crust at the German Continental Deep Drilling Site using advanced seismic imaging techniques. Journal of Geophysical Research: Solid Earth, 120(10), 6943-6959.

Peltonen P., Kontinen A., Huhma H. and Kuronen U., 2008. Outokumpu revisited: New mineral deposit model for the mantle peridotite-associated Cu–Co–Zn–Ni–Ag–Au sulphide deposits. Ore Geology Reviews, 33, 559–617.

Riedel M. et al., 2018. Underground Vertical Seismic Profiling with Conventional and Fiber-Optic Systems for Exploration in the Kylylahti Polymetallic Mine, Eastern Finland. Minerals, 8, 538.

Singh B. et al., 2019. Benefits of depth imaging in hardrock seismic exploration: case study from the Kylylahti mine, Finland. 81st EAGE Annual Meeting and Exhibition.