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Beyond the State-of-the-Art Geophysical Surveys for Mineral Exploration: Where Do We Go Next?

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As the energy transition accelerates, the mining industry faces an increasing push to produce more raw materials in more difficult and challenging mining environments prone to seismicity and characterized by complex geologic structures. Geophysical methods, seismic methods in particular, are getting more attention than ever to address these challenges because they provide high-resolution images of key subsurface geological structures and relatively retain their resolution at target depths. This paper addresses these challenges and provides several solutions. Beyond the state-of-the-art seismic solutions for deep-seated mineral deposit targeting are presented through case studies from several deep mine sites in the Witwatersrand Basin (South Africa). Firstly, we discuss the value of reprocessing legacy data using new processing algorithms for gold exploration, particularly focusing in the mining regions where no other data are available or acquisition of new data is difficult and expensive. Secondly, we showcase the state-of-the-art surface-tunnel-borehole solutions developed under the EU-funded Eramin Future project for shallow and deep-seated mineral deposit targeting. Finally, we discuss the current status and limitations of geophysical methods in difficult underground mining environments (e.g., lack of GPS signal) and present our newly developed solutions for in-mine (~ 3-km mine tunnel) seismic surveys that can be utilised to image the gold deposits and complex geologic structures several metres ahead of the mine face and metres-to-kilometres below and above the tunnel floor. Essentially, these new in-mine seismic solutions take advantage of the distributed acoustic sensing (DAS) technology that incorporates fiber-optic cables and wireless seismic recorders, which are then GPS-time synchronised using a newly developed GPS-time transmitter system developed under the Smart Exploration project. The GPS time transmitter opens up new opportunities in exploration projects as it allows the recording of seismic data in GPS-denied environments such as in-mine infrastructure (e.g., mine tunnels and underground boreholes).