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Towards adapting seismic interferometry to retrieve body-wave reflections for mineral exploration: the passive seismic experiment in the Kylylahti Cu-Au-Zn mine area, Finland

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Over the past twenty years, reflection seismology has been progressively used for mineral-exploration purposes. However, acquisition of active-source seismic data in the mining camps is challenging and costly. Recently, passive seismic imagery, using noise sources and utilizing seismic interferometry (SI), has developed as a promising tool to image the Earth's interiors without the requirement of having active sources.

Here, we propose to use SI as a cost-effective method to support mineral exploration at a mining-camp scale. To investigate the feasibility of SI to image hard-rock environments hosting mineralizations, a 3D passive seismic experiment was conducted over the Kylylahti Cu-Au-Zn mining area, eastern Finland, as a part of the ERA-MIN COGITO-MIN project. A dense seismic array recorded continuously for 30 days; it consisted of 1000 receivers that were placed with 200-m line spacing and 50-m inline receiver interval. We present a methodology to retrieve body-wave reflections in the setting dominated by ambient noise generated by underground mine activities and urban sources. First, we investigate the spectral content of our data and show the results of array-processing techniques to understand the spatio-temporal distribution of the dominant noise sources. Power spectral-density plots and beam-forming analysis indicate the broad frequency content (5-150 Hz) and diverse spatial distribution of the recorded noise sources. Surface waves constitute the bulk part of our recordings; however, by the means of visual inspection we found some noise panels containing high-velocity (>5km/s) seismic events likely related to routine underground mine activity. To employ seismic energy generated below Kylylahti array, we propose mineral-exploration seismic interferometry (MESI) robust processing workflow. The key steps of our method involve detection of body-wave sources, evaluating their locations, and selective stacking over stationary-phase areas. We create virtual-shot gathers following two approaches – by summing all noise and by using approximately 1000 body-wave sources detected and processed with our workflow. We further test different selective-stacking schemes for captured body-wave events. We demonstrate comprehensive comparison of the stacked seismic sections retrieved using SI and 3D active seismics. Sections retrieved with SI exhibit high reflectivity, consistent with some geological features and correlating to some extent with reflectors observed in the active seismics. We show that discrepancies in reflectivity patterns between the passive and active seismic results might be attributed to using sources that illuminate the target bodies from different angles. Our results are supported with extensive numerical-modelling study which confirms the fidelity of reflections obtained using SI.

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