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High-frequency ambient noise surface wave tomography at the Marathon PGE-Cu deposit (Ontario, Canada)

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Ambient noise surface wave tomography (ANSWT) is an environmentally friendly and cost-effective technique for subsurface imaging. In this study, we used natural (low-frequency) and anthropogenic (high-frequency) noise sources to map the velocity structure of the Marathon Cu-PGE deposit (Ontario, Canada) to a depth of 1 km. The Marathon deposit is a circular (ø = 25 km) alkaline intrusion comprising gabbros at the rim and an overlying series of syenites in the centre. Cu-PGE mineralisation is hosted by gabbros close to the inward-dipping footwall of the intrusion. The country rocks are Archaean volcanic breccias that are seismically slower than the gabbros, and similar in velocity to the syenites. We used ANSWT to image the footwall contact that controls the location of the mineralisation.

An array of 1024 vertical-component receivers were deployed for 30 days to record ambient noise required for surface wave analysis. Two overlapping grids were used: a 200 m x 6040 m dense array with node spacing of 50 m, and a 2500 m x 4000 m sparse array with node spacing of 150 m. The signal was down-sampled to 50 Hz, divided into segments of 30 minutes, cross-correlated and stacked. Surface wave analysis was conducted over the dense array and the sparse array data. We considered the fundamental mode of Rayleigh wave propagation for our frequency-wavenumber (F-K) analysis and focused on the phase velocity variation in the high-frequency ambient noise signal (up to 22 Hz). We reconstructed the shallow structure with progressively increased resolution using surface wave dispersion curves extracted from receiver arrays divided into segments of variable lengths. Several average dispersion curves were computed from individual dispersion curves belonging to different seismic lines. Each average dispersion curve was inverted to obtain S-wave velocity models using an McMC transdimensional Bayesian approach.

The tomographic images reveal a shallow high-velocity anomaly, which we interpret as being related to the gabbro intrusion that hosts the mineralization. The large-wavelength structures in the S-wave velocity models are relatively consistent with the geological structures inferred from surface mapping and drill core data. These results show that the ANSWT, focused on the high-frequency signal provided by anthropogenic noise sources, is an efficient technique for imaging “shallow" (1 km depth) geological structures in a mineral exploration context.