Application of active and passive seismic imaging for mineral exploration: A case study from Larder Lake gold belt, Ontario

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Summary

We have conducted active and passive seismic surveys along a ~40-km transect in a world-class gold mineralization zone in Larder Lake, Ontario, Canada. Passive seismic records provided a map of surface-wave speeds by using everyday environmental seismic noise and mapping subsurface lithological boundaries using P-S wave conversions from distant earthquakes. The good correlation between the active and passive seismic results indicated that properly designed passive seismic surveys can be used as alternatives to active seismic surveys.

Data acquisition and processing

As part of the Metal Earth project an approximately 44 km long reflection seismic 2D line was acquired along a crooked profile across mafic/felsic metavolcanic and metasedimentary units of the Abitibi Greenstone Belt. The profile crosses the CLLF shear zone and the Lincoln-Nipissing Fault (LNF), about 10 km to the south. The seismic data processing flow was focused on appropriate binning of the crooked survey line, robust static solutions, detailed velocity analysis, minimal trace smoothing, and high-resolution imaging using a prestack time migration algorithm. The passive seismic survey was acquired along the same transect using 40 broadband multicomponent Guralp 3T seismometers at a nominal interstation distance of 1 km. Recorders ran continuously for 40 days and during this period 22 teleseismic events with magnitudes larger than 5 were identified and used for receiver function (RF) analysis to generate a 70 km deep P-S convertibility model. The 40-day ambient noise record also enabled Ambient Noise Surface-Wave Tomography (ANSWT) to produce a shear-wave velocity model to a depth of 10 km (Naghizadeh et al., 2022). Figure 1 shows the top 10 km of the (a) reflection seismic, (b) ambient noise surface wave tomography (ANSWT) shear-wave velocity, and (c) P-S convertibility transects.

Results

The termination of upper-crust dipping seismic reflections and the beginning of the middle-crust sub-horizontal reflections in the active seismic transect suggest that the base of the greenstone belt is located at a depth of ~12–15 km. The RF analysis identified the Moho discontinuity at ~40 km as well as the presence of a south-dipping feature penetrating into the mantle under the transect. The ANSWT method imaged a low shear-wave velocity zone (depths of 0–2 km) to the south of the Cadillac-Larder Lake Fault (CLLF) and a high shear-wave velocity zone to the north of the transect (depths of 4–10 km). To the north of the CLLF, a strong north-dipping seismic reflection (at 6 km depth) was caused by a high-velocity layer (likely a mafic intrusive/volcanic unit) at the top and a low-velocity layer (likely a felsic intrusive/volcanic unit) at the bottom. Both seismic reflection and P-S convertibility profiles imaged a south-dipping feature penetrating from the lower crust into the mantle beneath the Larder Lake transect which is interpreted to be caused by the delamination of the lower crust. The integrated interpretation of the geophysical models (reflectivity, shear-wave velocity, and P-S convertibility) revealed a detailed image of the subsurface lithological boundaries in the top 10 km with high confidence and good correlation values.

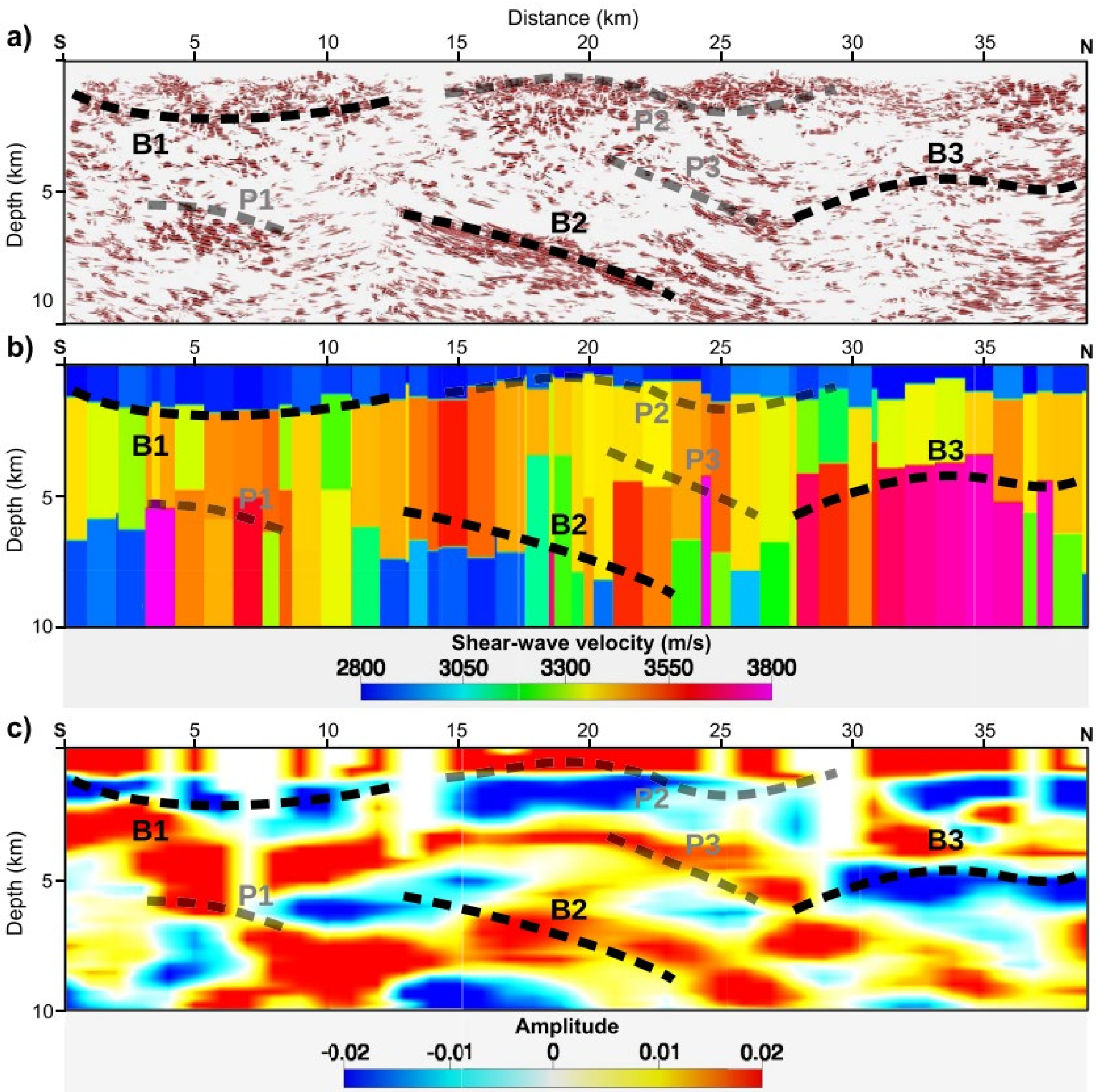

Figure 1: The top 10 km of the (a) reflection seismic, (b) ambient noise surface wave tomography (ANSWT) shear-wave velocity, and (c) P-S convertibility transects. The B1, B2, and B3 features are highly correlated between all three transects. The P1, P2, and P3 features also show noticeable correlation though with low certainty.

Conclusions

We have conducted a benchmark study to validate the effectiveness and accuracy of the images produced by passive seismic methods. Our results indicate that properly designed passive seismic surveys are viable alternatives to active seismic surveys with the added benefit of cheaper acquisition costs and fewer environmental impacts. In addition, the integrated interpretation of active and passive seismic transects reduces the uncertainties about the nature of anomalies in both methods leading to more reliable interpretations.

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References

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