Use of Ambient Noise Surface Wave Tomography in Mineral Resource Exploration and Evaluation

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Summary

Passive seismic imaging is a low-impact, low-cost technique that can be used to explore for and evaluate mineral deposits. The recent development of autonomous seismic recorders ("nodes") allows for reliable, low-cost, continuous recording of seismic data for weeks or months at a time. In addition to improving field operations connected with traditional 3D active-source reflection surveys, nodes greatly increase the flexibility of seismic survey design and, most importantly, permit low-cost collection of dense passive seismic data with minimal impact on the local environment.

The technique uses ambient seismic noise from natural and anthropogenic sources for subsurface imagining and monitoring. Cross-correlation between receiver pairs is used to extract the Green function and analysis of dispersion of surface wave from the cross-correlated data generates a near-surface velocity model. This model is then used to establish the structure, lithology, and physical characteristics of materials in the subsurface. The results can be used alone or jointly with other geophysical or geological data, or employed to improve imagining of active source data.

The scales of passive seismic imaging range from the entire crust and upper mantle to near-surface geotechnical or civil engineering surveys, spanning depths from 100s of kilometers to few meters. Most current applications are in the petroleum, geothermal, groundwater and geo-engineering sectors but the technique is finding increasing employment in mine security and mineral exploration.

Introduction

In this paper, we first describe two applications of the passive seismic method (called ambient noise surface wave tomography) in mineral exploration and mining. In the first, we imaged old workings of an old Australian gold mine and showed that the method could be used to identify old mine workings, mineral deposits, faults or shears and determine the thickness of the slag-heap. In the second we demonstrated how the method can be used to define the geological setting of a magmatic Cu-PGE deposit.

Method

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The scales of passive seismic imaging range from the entire crust and upper mantle to near-surface geotechnical or civil engineering surveys, spanning depths from many kilometers to few meters. Most current applications are in the petroleum, geothermal, groundwater and geo-engineering sectors but the technique is finding increasing employment in mine security and mineral exploration.

Application 1: imaging old mine workings

In September 2016, 100 seismic sensor nodes were installed above an old mine and seismogram data was recorded for 2 days. The nodes were buried 5-10 cm below the surface and positioned partly above the old mine workings. as shown in Figure 1.

Figure 1: Locations of the seismic sensors relative to the suspected locations of the old workings.

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Tomographic results

Figure 2 shows all the tomographic maps assigned to a related depth. Even though a complete depth inversion was not performed, we estimated the depths for the tomographic results at 1/3 of the associated wavelength. The meshes show that the tomographic images are able to delineate the slag-heap and old workings. We also created iso-surfaces of the low velocity areas to aid in interpreting the velocity anomalies. The iso-surfaces for one low velocity zone are shown in Figure 3.

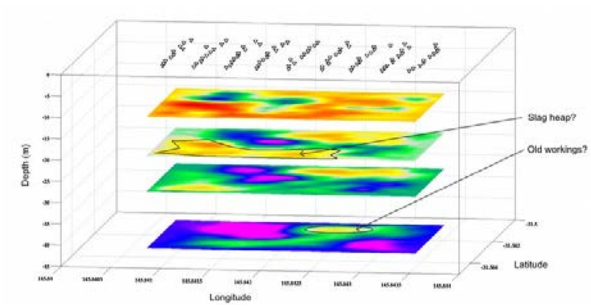

Figure 2: Tomographic maps represented in 3D. The vertical axis is depth in meters.

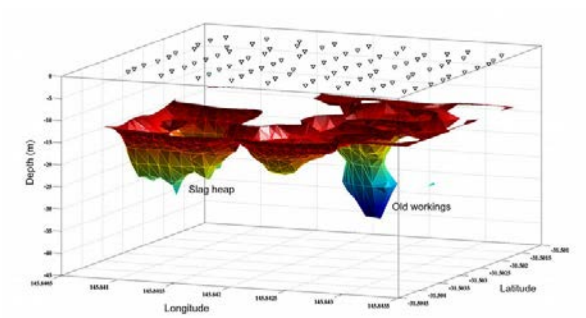

Figure 3: Isosurfaces of low velocity anomalies. The anomaly in the South West is interpreted as being the slag heap, while the deeper anomaly in the North is interpreted as the old workings.

Application 2: exploring an ore deposit

The Marathon deposit is one of several gabbroic to ultramafic-hosted disseminated Cu-PGE sulfide deposits located around the outer gabbroic boundary of the (1108-1105Ma) Coldwell Complex near the town of Marathon in Ontario, Canada. In late 2017 two passive seismic surveys were conducted to image the lower contact of the intrusion to better define the structures that control the mineralization. Two surveys were conducted. The first aimed to test the characteristics of ambient seismic noise in the region, which were found to be adequate (mainly from nearby Lake Superior).

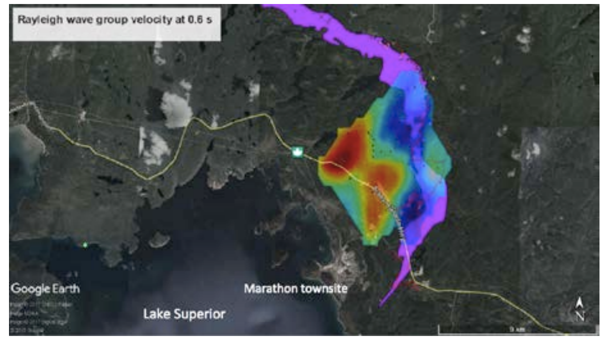

Figure 4: Rayleigh group seismic velocity map of the Marathon test site superimposed on a Google Earth photo and a geological map showing gabbros (purple) at the eastern margin of the Coldwell Complex. These gabbros host the PGE mineralization.

In the second survey an array of 90 nodes collected data for a period of 30 days. The results shown in Figures 5 and 6 demonstrate that that method was capable of delineating the lower contact of the intrusion and defining structures that influenced the ore zones. A high-velocity zone at 700 m depth, which was not identified in earlier geological and geophysical surveys, could represent ultramafic rock of the type that hosts the mineralization.

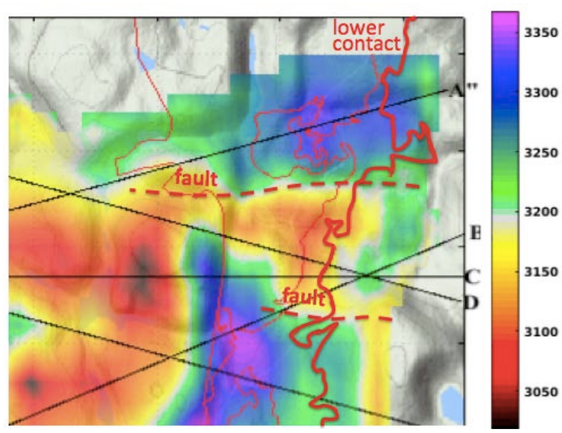

Figure 5: Slice at 250 m depth through the velocity model. The lower contact from geological mapping (in red) is defined, as are two faults that displaced the contact.

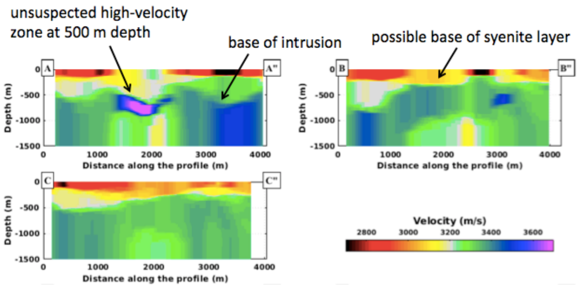

Figure 6: Sections across the velocity model and interpreted geological features.

Conclusions

The results from the project suggest that the method is well suited towards imaging old mine workings and mined out areas and has applications for mineral exploration.

Acknowledgments

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