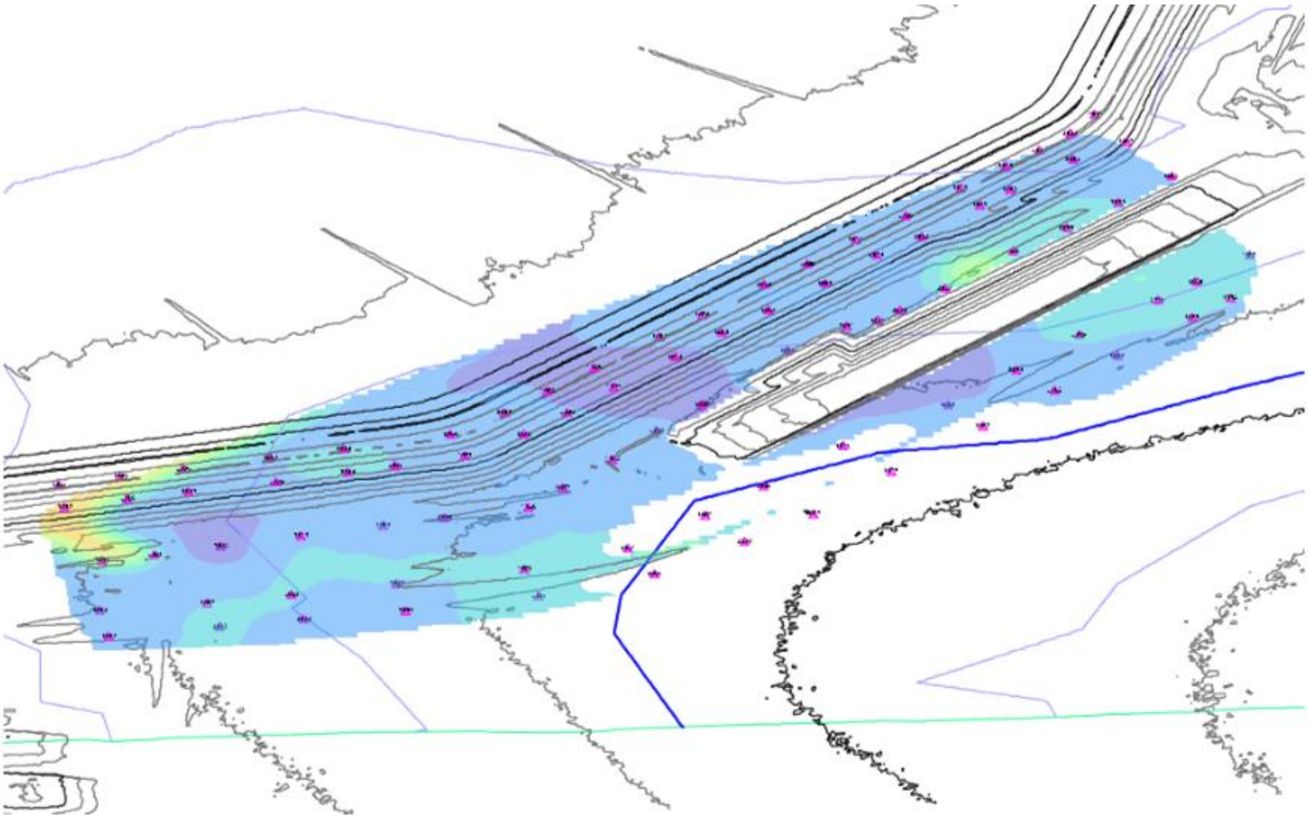
GTI-Technical Note-2	Imaging with ANT for Geotechnical Investigations



Dense surface arrays can be used to image the subsurface within TSFs. A horizontal slice through the 3D model is shown in colour scale at the level of the toe. Low velocity zones (blue) indicate seepage pathways through the structure to the seepage pond.

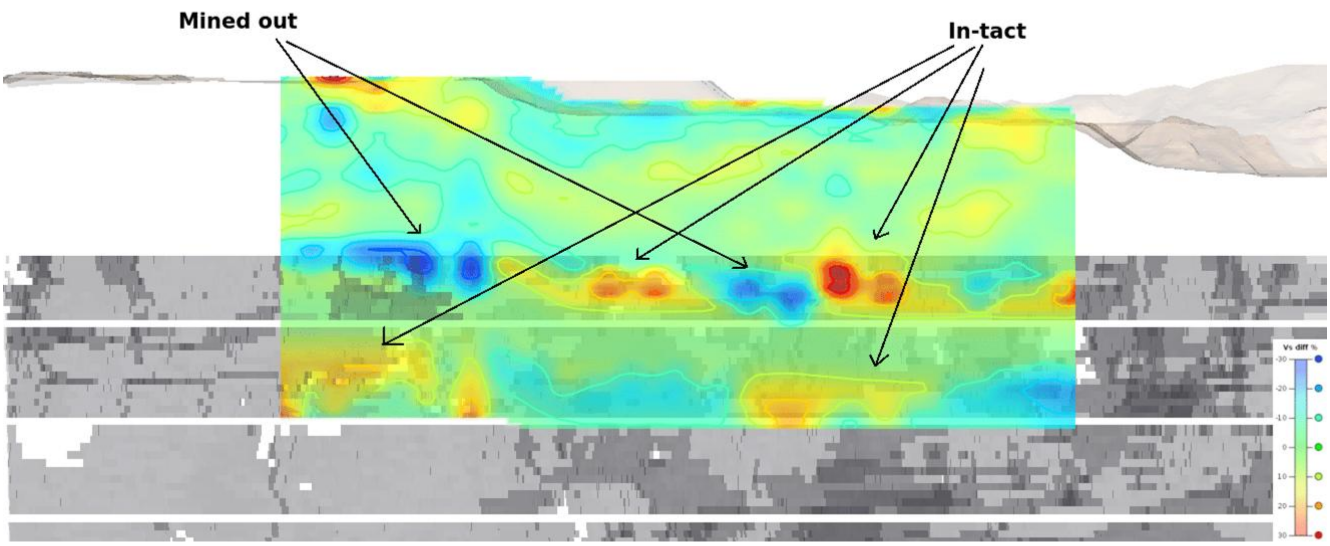
In recent years, passive seismic imaging using ambient noise has emerged as a novel, low-cost and environmentally sensitive approach to exploring the sub-surface. This technique has been used to image the sub-surface on a crustal scale (e.g. Shapiro et al., 2005; Sabra et al., 2005; Moschetti et al., 2007; Young et al., 2011; Poli et al., 2012; Lin et al., 2013) and industrial scale (e.g. Gouedard et al., 2008; Nakata et al., 2011; Olivier et al., 2015) and can even be used to image reflectors (Draganov et al., 2009). This technique dispenses with active seismic sources, and instead uses ambient seismic noise, from passive sources such as ocean waves, traffic or minor earthquakes. ANT is, in theory, fully scalable. Practical considerations are nevertheless important for meeting imaging goals. In particular, the seismic wavelengths used for imaging need to be appropriate in relation to the size of the imaging target. For a seismic imaging project to be successful the desired wavelengths need to be present in the ambient noise field, the sensor spacing must be appropriate for their reliable detection, and the sensor response must be sensitive to the frequencies associated with them.

At the smaller end of the scale of ANT deployments are surveys for geotechnical applications. These arrays are typically deployed over a scale of 1 km or less, with sensor spacing of 100 m or less, and the depth of interest is typically 50 m or less. Accordingly, the frequency range of interest is typically above 5 Hz which makes this class of surveys heavily dependent on nearby anthropogenic sources of noise (factories, mines, roads and railways) and often unfeasible in remote locations.

IMS, Institute of Mine Seismology, has pioneered the use of ANT for imaging of **Tailings Storage Facilities (TSFs)**[1]. Both line and 2D array deployments are possible with the former resulting in a 2D depth-velocity map and the latter resulting in a full 3D subsurface model. In this context the imaging goals are typically related to water: imaging the phreatic surface and seepage pathways as well as internal zones of relative strength or weakness. The method also excels at imaging the pre-construction surface, where often this is unknown due to change of ownership of the TSF. The method can also be used to identify geological structure below the TSF, with the presence of near-surface faults a particular concern for long term stability of the structure. Seismic wavelengths typically allow for deeper imaging than Induced Polarization and Electro-resisitivity methods. TSF imaging projects are by far the most numerous of surveys conducted by IMS that fall in the geotechnical category.

However these surveys have also been deployed for the following applications:

- Void detection: identification of location, size and growth of cavities that pose a safety risk to surface operations
- Near-surface characterization for planned construction projects
- Cave-front tracking: particularly for previously open cast mines that have switched to underground operations
- Aquifer imaging: same value proposition i.e. reduced drilling costs for developing urban water resources but typically on smaller scale than mineral exploration



Other applications of ANT in a geotechnical context typically involve the detection of voids or cavities. Where in-mine seismic systems exist, the resolution of the model can be enhanced using travel-time tomography.

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