Mineral prospect imaging and mining environment monitoring using innovative seismological deployments and data processing

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Project Highlights:

- Development of new mining-focussed seismology acquisition and processing techniques.
- Data processing workflows to deliver a range of mine seismology deliverables including imaging, monitoring, and hazards.
- Fieldwork deployment of seismometers and seismic nodes at UK/international case study mines, quarries, and/or mineral prospects.

Overview:

Seismology techniques used in mines resemble those employed across a range of scales, from crustal structure imaging to volcano monitoring and earthquake hazard analysis, for example. This project will harness the latest technologies in passive seismology acquisition and processing, adapt and improve them for mining environments, and demonstrate their effectiveness across a range of mining applications and scenarios.

Mine seismology is a common but underutilised branch of geoscience that involves recording active (e.g. blast) and passive (e.g. rock crusher, microearthquake, environmental, vehicles) signals within and surrounding open-pit and subsurface mining environments and mineral prospects. Its applications are numerous and include: i) real-time seismic monitoring of the rock mass; ii) regional seismicity monitoring; iii) monitoring tailings and water storage facilities; and iv) static and time-lapse imaging.

This project will utilise the latest technology in SmartSolo seismic nodes and broadband seismometer deployments, develop new techniques and workflows in seismological imaging and monitoring, and apply them to specific mining challenges to improve the exploration, feasibility, construction, operation, and remediation stages of the mine life cycle. Through delivering enhanced real-time monitoring tools, it will also benefit mine health and safety and provide information useful for public and outreach activities.

As global mining activities increase, cost-effective monitoring and imaging will become more important and therefore this project, through its extensive training and focussed research programme will equip the PhD researcher with the skills to be at the forefront of mine seismology in industry or academia.

The researcher will join the vibrant geosciences and geophysics research groups at Aberdeen and enjoy access to TARGET and industry partners and through collaborative training and research events.

In addition to dedicated TARGET training, additional training is available via modules from Aberdeen's MSc Geophysics programmes.

Figure 1: Schematic image of a working quarry with example SmartSolo node deployment that provide continuous vibration monitoring and (time-lapse) velocity imaging (superimposed colour tomography velocity variation image). Photo by Kurt Bouda from Pixabay.

Alt text: Photograph of a working open quarry with exposed rock faces. Superimposed are several seismic node sensors and a tomographic velocity model with red and blue regions showing low and high velocity subsurface rocks.

Methodology:

SmartSolo seismic nodes (https://smartsolo.com) and Güralp seismometers will be deployed by the candidate for specific subsurface imaging and monitoring goals at different mining and mineral prospect sites across the UK and internationally in collaboration with industrial partners.

The project will adapt passive seismological methodologies for optimal use in mining environments. It will focus on ambient seismic noise monitoring and imaging, principally by recording and analysing environmental and mine-related noise sources. Seismological monitoring and imaging techniques could include (depending on case study mine and field dataset(s) required):

- Daily, weekly, yearly, …, seismic noise analysis reporting and analysis (e.g. Lecocq. et al, 2020).
- Peak ground velocity (PGV), acceleration (PGA) and displacement (PGD) (e.g. Mendecki, et al., 1999).
- Microseismic event identification and analysis (e.g. Wilkins et al., 2020).
- Coda wave interferometry tracking of tailings dam integrity (e.g. Olivier et al., 2017; Ouellet et al., 2022).

- Ambient noise velocity tomography to map geological variability, fractures, and fluids (e.g. Lynch et al., 2019)

Possible Timeline

Year 1: Familiarisation of current mine seismology and other relevant passive seismological techniques and recent developments. Skills building in coding, field deployment, data processing and interpretation, with existing and new passive seismological datasets. Building network links with CASE and other industrial partners and case study mines and/or quarries. TARGET, University, and other training. UK conference. Test deployments and write up for publication.

Year 2: Background research first mine/quarry case study location. Deploy equipment and process results. Publish results in an internationally leading journal. European conference attendance.

Year 3: Background research second mine/quarry case study location. Deploy equipment and process results. Publish results in an internationally leading journal. International conference attendance.

We anticipate that the project will deliver world-leading research in designing novel ways of collecting, applying and developing existing passive seismological acquisition and processing techniques to mining environments and mineral prospects. Publications in internationally leading journals are anticipated in the broad areas of deployment best practice, methodology development, monitoring, and imaging. Case study sites will be chosen to represent a broad range of applications, geological settings, and mining-related research problems, but the researcher will be able to push research boundaries in the areas most attractive to them.

Training and skills:

TARGET researchers will participate in a minimum of 40 days training over the 3.5 years of study composed of:

- an annual one-week workshop dedicated to their year group, and tailored to that cohort's needs in terms of skills development – *for the first three years of their study*;
- an annual all-TARGET workshop with cross-year interactions, advanced training and opportunities to specialise in particular areas – *all years of study*;
- a number of one-day workshops;
- additional online events and in-person workshops attached to relevant conferences.

The researcher will additionally benefit from relevant training in scientific coding, passive seismology, machine-learning, seismometer/node/DAS deployment, and general geophysical fieldwork and health and safety. If appropriate, the researcher will attend specific workshops for training in open-source codes for data handling and processing.

All PhD students at the University of Aberdeen benefit from mandatory training in "Research Integrity". "Research Ethics and Governance", "Equality, Diversity and Inclusion" and "Health, Safety and Wellbeing" and have access to a multitude of optional transferable skills courses. The researcher will also have access to the University of Aberdeen's Centre for Energy Transition training courses and events.

Partners and collaboration (including CASE):

The successful applicant will be supervised by an interdisciplinary team spanning seismology, fieldwork, geophysical data processing, and structural geology. The supervisor team will discuss with the researcher the optimum meeting schedule, typically alternating individual and group meetings on a weekly basis, with the external TARGET partners joining at least monthly. Regular visits to meet with the TARGET co-supervisors in Leicester and Leeds will be facilitated.

A CASE partnership with SmartSolo Scientific seismic sensor will provide direct insights into industry and sensor technology, sales, software, and user experience via an industrial placement and supervision.

Further reading:

Lynch, R., Hollis, D., McBride, J., Arndt, N., Brenguier, F., Mordret, A., Boué, P., Beaupretre, S., Santaguida, F. and Chisolm, D., 2019. Passive seismic ambient noise surface wave tomography applied to two exploration targets in Ontario, Canada. In *SEG Technical Program Expanded Abstracts 2019*(pp. 5390-5392). Society of Exploration Geophysicists.

Mendecki, A.J., Van Aswegen, G. and Mountfort, P., 1999. A guide to routine seismic monitoring in mines. *A handbook on rock engineering practice for tabular hard rock mines*, p.35.

Olivier, G., Brenguier, F., Campillo, M., Lynch, R. and Roux, P., 2015. Body-wave reconstruction from ambient seismic noise correlations in an underground mine. *Geophysics*, *80*(3), pp.KS11-KS25.

Olivier, G., Brenguier, F., de Wit, T. and Lynch, R., 2017. Monitoring the stability of tailings dam walls with ambient seismic noise. *The Leading Edge*, *36*(4), pp.350a1-350a6.

Ouellet, S.M., Dettmer, J., Olivier, G., DeWit, T. and Lato, M., 2022. Advanced monitoring of tailings dam performance using seismic noise and stress models. *Communications Earth & Environment*, *3*(1), p.301.

Wilkins, A.H., Strange, A., Duan, Y. and Luo, X., 2020. Identifying microseismic events in a mining scenario using a convolutional neural network. *Computers & Geosciences*, *137*, p.104418.

Further details:

Please visit https://target.le.ac.uk/ for additional details on how to apply.

Direct any queries about this project to Dr. David Cornwell (d.cornwell@abdn.ac.uk) at the School of Geosciences, University of Aberdeen.