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Characterising Geological Repository Host Rock Properties Using Novel Seismic Surveys and 3D Acoustic and Anisotropic Full-Waveform Inversion

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The UK has a large volume of higher activity radioactive waste and government policy is to contain and isolate the waste in a geological repository. The facility will be highly-engineered, with multiple protective barriers to ensure that no harmful quantities of radioactivity ever reach the surface. Currently no specific UK disposal site has been chosen, but granite is one of the candidate host rocks, given its high strength and low groundwater permeability. After the construction of the facility and during its operational period, regular monitoring will be required to ensure that barrier integrity is maintained.

In this study, we have built workflows involving sophisticated computational methods and numerical simulations that produce time-lapse rock-property models of the host rock of a hypothetical repository. We have designed novel seismic surveys to characterise geological models of granite with natural and engineered fracturing at a disposal depth of 1000 m (the UK repository might be shallower). By using effective-medium-models, the increased fracture density around the tunnels produces a reduction in seismic velocity and alterations in anisotropic parameters. Next, we simulated the seismic surveys and applied 3D Acoustic and Anisotropic Full-Waveform Inversion (FWI) to evaluate the quality of the recovered low-velocity tunnel damage and disturbed zones. Furthermore, we assessed the effectiveness of using a survey design consisting of surface and tunnel receivers (a combined survey) to resolve the target.

After applying Acoustic FWI we find that the velocity anomaly within the disturbed zone can be resolved to within 2 m/s (3%). Using the combined survey, we have been able to resolve the anomaly strength and shape more completely, and are able to recover the fracture properties through applying Anisotropic FWI. When we add further complexity to the model by including facility tunnels, we discover that the combined survey is essential for recovering the velocity structure around the tunnels.

We conclude that it is beneficial to use 3D FWI and novel survey designs for characterising subtle structural variations as may be present in granite. This information is important for the disposal site selection process and facility design.