The role of fractures in flow partitioning during minewater geothermal energy extraction

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The UKGEOS Glasgow research field site comprises a network of 12 boreholes into flooded coal mines, and is designed to observe how warm water moves around the abandoned mine workings over time (Monaghan et al., 2018). Minewater geothermal projects involve the redevelopment of abandoned mining areas into large volume, low temperature resources and use heat pumps to drive heating for homes, industry or agriculture. This technique has proven potential as a renewable, decarbonised heat source providing reliable heating, cooling and heat storage with stable pricing to former mining areas.

Flow through minewater systems is partitioned between flow through the mine voids, through fractured media, and through porous media. This heterogeneity in flow is crucial to the development of models to predict the efficacy of minewater geothermal systems, as water flowing through the fractured material should absorb more heat than that flowing directly through the mine voids. This heat exchange then goes on to control the rate at which heat can be sustainably extracted from the minewater system.

The majority of fluid flow has generally been assumed to be through the mine voids. However, the proportion of fluid flow through the porous wallrocks is very sensitive to the fracture populations that they contain, due to the shallow nature of these mine workings leaving them under low stress. Geothermal tests at the Gaspé mines in Québec demonstrate this clearly, with high wallrock conductivities ($10^{-6}$-$10^{-4}$ m.s$^{-1}$) attributed to mine-blasting (Raymond & Therrien, 2008). Coal mining in the Glasgow area was predominantly carried out using the Pillar & Stoop or Longwall methods, which lead to very different damage states in the wallrocks, and so the effect of these fracture populations is expected to have a large effect on flow partitioning.

Here, relationships between in-situ stress, fracture population and permeability were determined from well-core samples of the Glasgow Main Coal and underlying mudstone and sandstone strata, in order to characterise how flow may be partitioned within different regions of these mine-workings.

Stress-dependent permeability and storativity were measured using the oscillating pore-pressure method, and elastic tensors were determined using an array of ultrasonic transducers. Axial fractures were then generated within these samples under low triaxial stress states, and the change in permeability with induced fractures then measured at a single stress state, with the
newly developed fracture population characterised through the changes in the elastic tensor.
