Geomechanics of mine water heat schemes

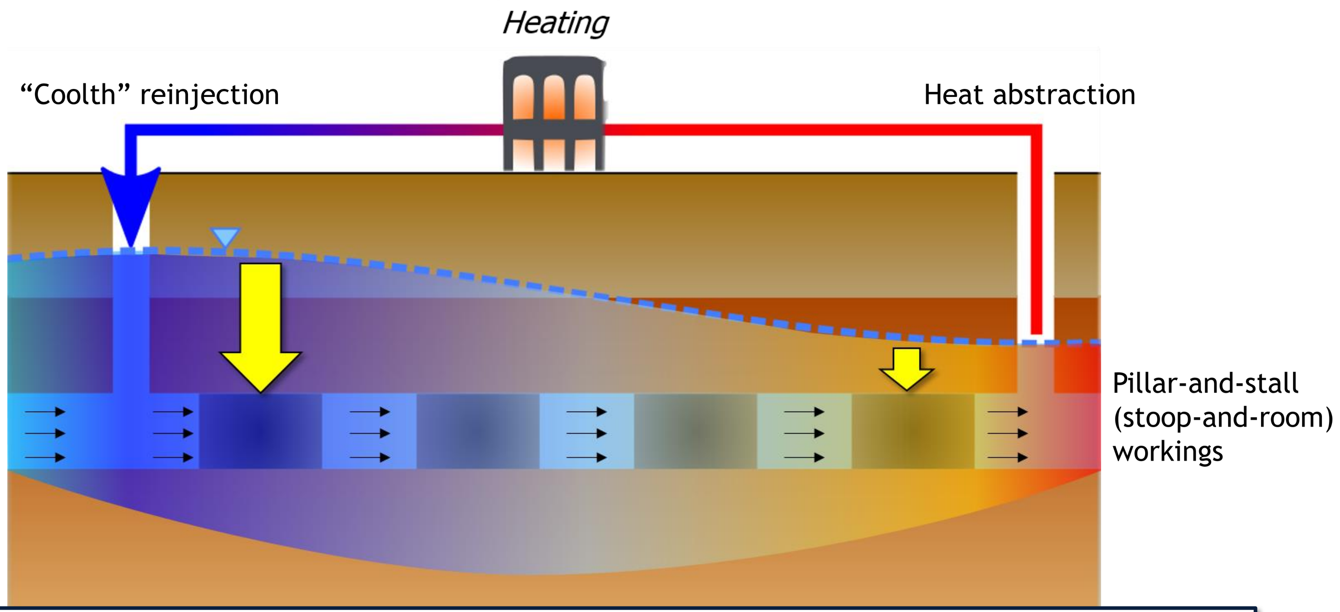
Fiona Todd fiona.todd@ed.ac.uk

Supervisors: Dr Chris McDermott, Dr Stuart Gilfillan, Dr Andrew Fraser Harris (University of Edinburgh), Dr Alex Bond (Quintessa)

@fktodd

Summary

Mine water heat schemes are potential low energy geothermal sources in the decarbonisation drive. These sources could provide **around 8% of Scotland's annual domestic heating requirement**, suggesting heat storage will also be important to make these schemes truly sustainable.

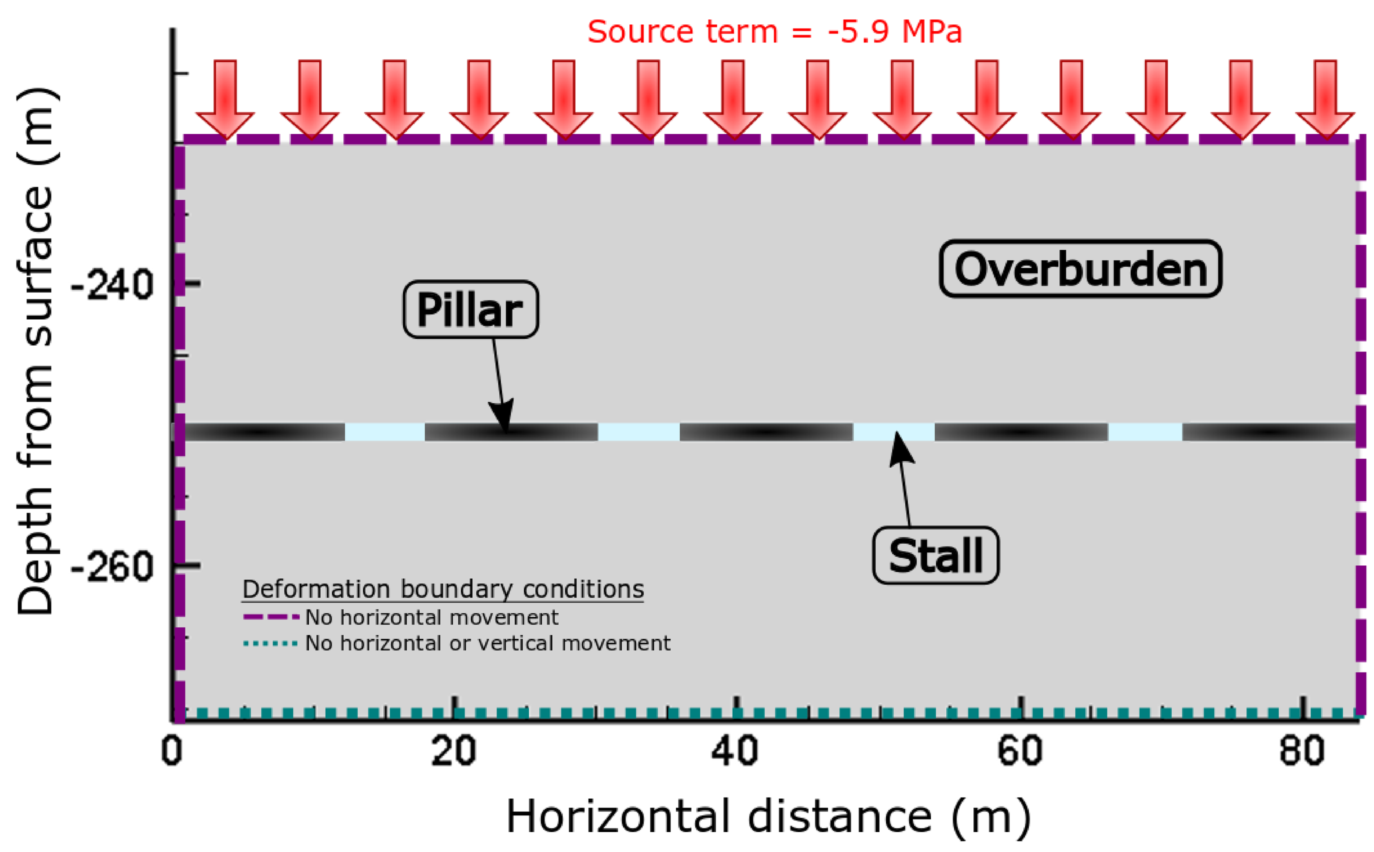


Fluctuations in pressure, temperature and flow will impact pillar integrity and potentially cause ground stability issues

Some mines rely on pillars of coal to maintain stability so it is important to understand the geomechanical response to temperature, pressure and flow fluctuations associated with mine water heat schemes. A coupled hydraulic and mechanical (HM) model has been developed for a realistic generic pillar-and-stall system to model these impacts.

Modelling

- Fully saturated 2D coupled hydro-mechanical (HM) model
- Flow controlled by Darcy's Law, no regional groundwater gradient
- Generic pillar-and-stall system with one level of workings at 250m depth



A water level rise of 40m is modelled through two equal steps of increasing pressure.

This rise is equivalent to that recorded in Midlothian between 2015 and 2017. **Mine water rebound in this area is known to cause surface uplift**[1].

Recorded water level in Midlothian 2015 to 2017

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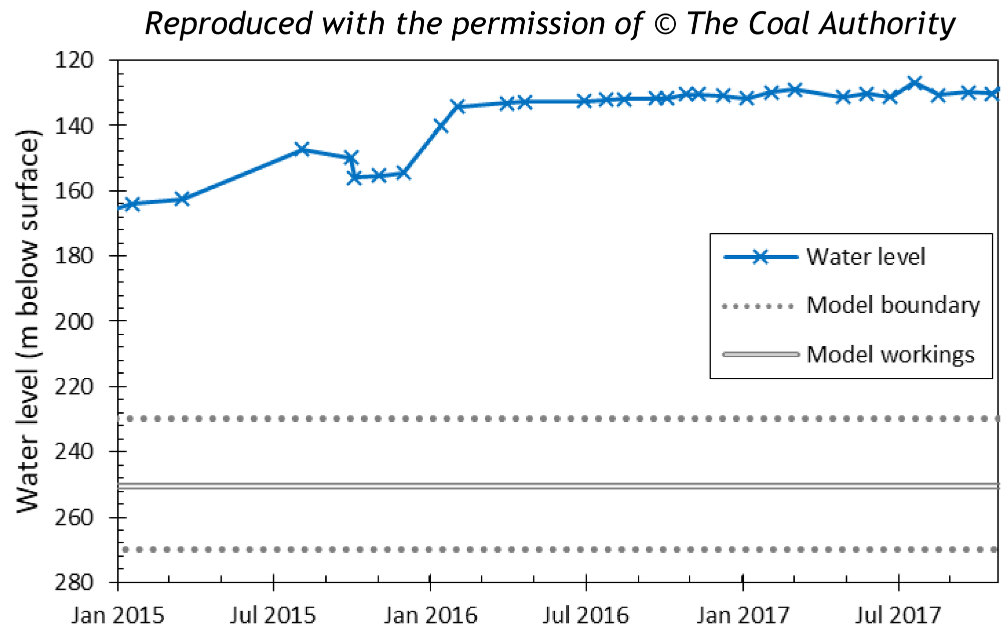


Deformation is calculated by the momentum balance equation in terms of stress which is related to strain via Hooke's law. The hydraulic and mechanical processes are coupled via poro-elasticity and the concept of effective stress for a porous media. This is determined from:

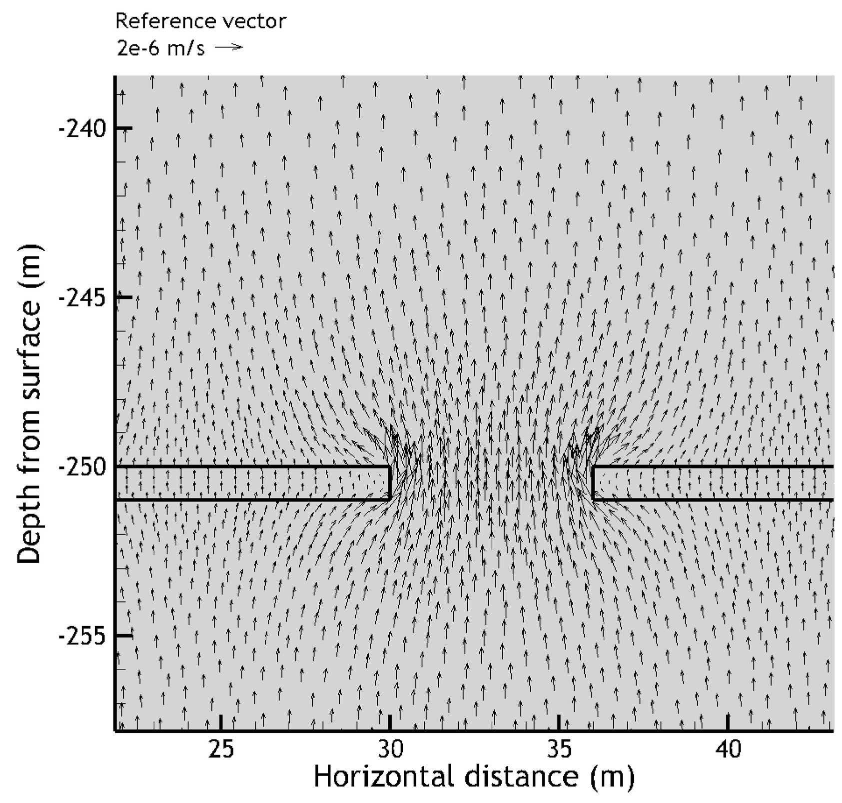
$$\sigma' = \sigma - \alpha P$$

where σ' is the effective stress (Pa), σ is the stress (Pa), P is the fluid pressure (Pa) and α is the Biot coefficient. A coupling parameter that is the ratio of fluid pressure transferred to rock pressure[2].

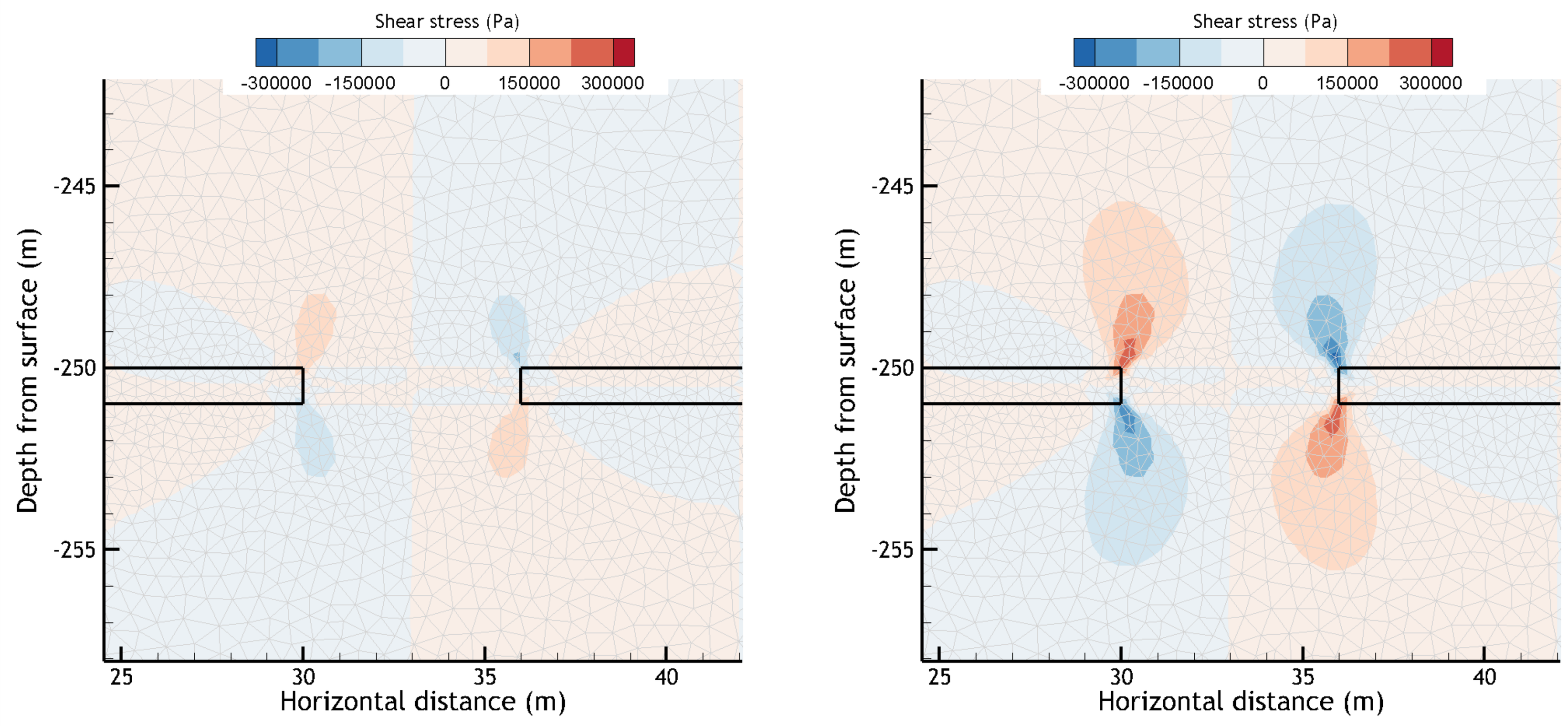
Results

The modelled velocity profile between two pillars is shown. This indicates flow is from the base of the model to the top, simulating rising groundwater and no regional gradient which is anticipated from the conceptual model.

The fluid preferentially flows through the stalls which is as expected. These results give **confidence the model is running correctly.**



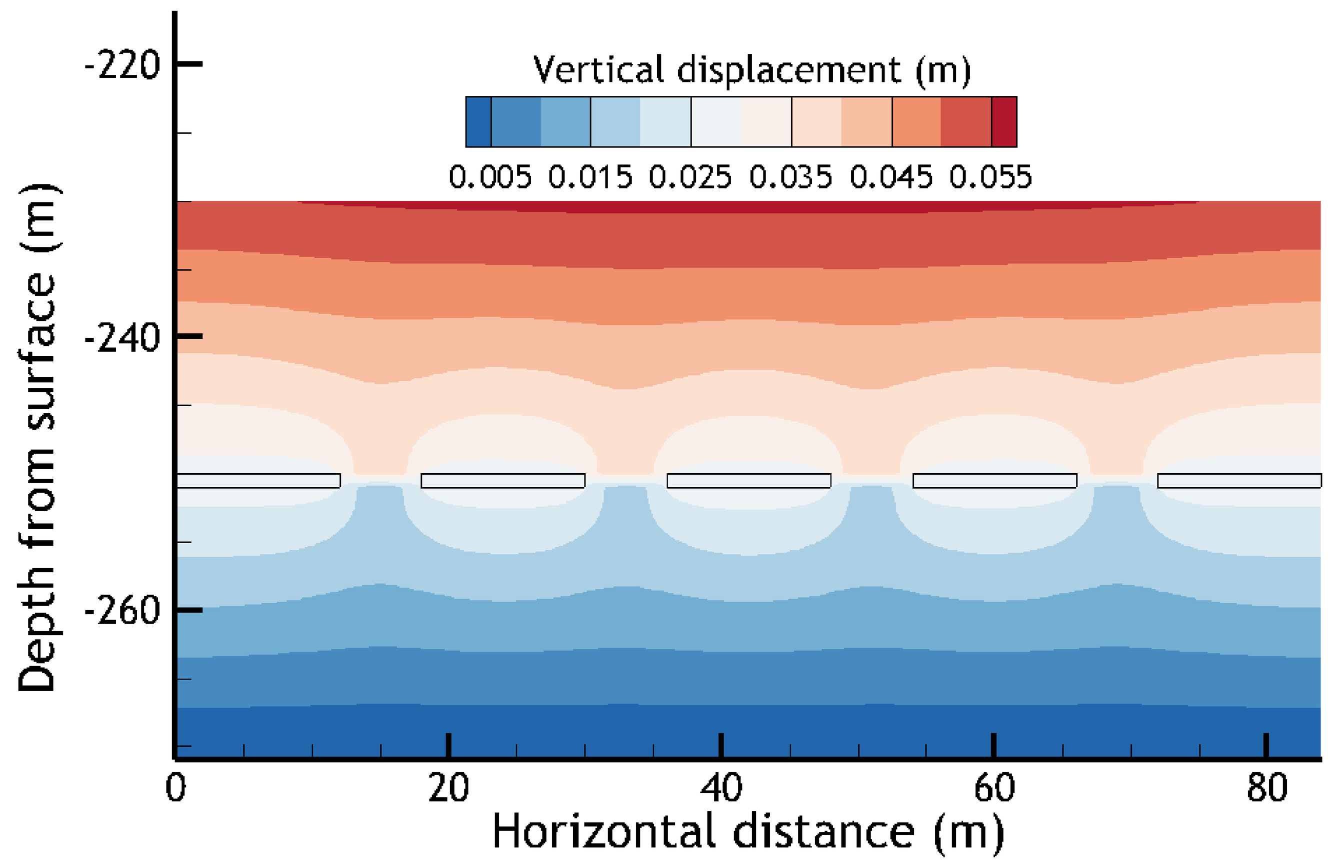
The **displacement around the pillar edges is of interest** as this is where stress is likely to build up and cause weakening over time. The differential shear stress for 20m and 40m water level rise is shown below. This shows the stress is highest at the pillar corners. The magnitude is approximately doubled from 0.15MPa to 0.30MPa for a doubling of water level rise.



20m water level rise

40m water level rise

The modelled vertical displacement of 55mm for a water level rise of 40m is shown below. This is the same order of magnitude to that seen in reality; abandoned collieries in Midlothian[3] show a surface uplift of 24mm for a mine water level rebound of 26m. **The modelled uplift rate is 1.4mm/m of water level rise compared to 0.9mm/m in reality.** This generic model doesn't take site specific factors into account. Nevertheless the comparable results provide confidence in the methodology.



Next steps

The next steps of this research are to:

- Include heat coupling
- Investigate the impact of cyclical heating/cooling
- Investigate the impact of overburden heterogeneity
- Identify key processes

References

1. *GVL. 2018. Relative land motion map of the UK 2015 - 2017. https://www.geomaticventures.com/uk-map*
2. *McDermott, C., Williams, J., et al. 2016. Screening the geomechanical stability (thermal and mechanical) of shared multi-user CO2 storage assets: A simple effective tool applied to the Captain Sandstone Aquifer. International Journal of Greenhouse Gas Control, 45, 43-61*
3. *Sowter, A., Athab, A., Novellino, A., Grebby, S. & Gee, D. 2017. Supporting energy regulation by monitoring land motion on a regional and national scale: A case study of Scotland. Proceedings of the Institution of Mechanical Engineers, Part A: Journal of Power & Energy, 232*

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