Stress Distribution in the Rotokawa Geothermal Field, New Zealand and implications for fluid flow through brittle crust

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Quantifying the stress field is a vital tool for mapping and determining how to maintain the pathways that hydrothermal fluids follow in a naturally fractured geothermal system. Permeability in the Rotokawa Geothermal Reservoir, located in the Taupo Volcanic Zone (TVZ), is primarily fracture hosted and is influenced by the activity of large faults. Thus permeability preservation in the reservoir relies on cyclical reactivation of these structures. The magnitude and orientation of the principal stress axes will influence fault mechanics and how fracture-hosted permeability operates in geothermal reservoirs. Slip on faults and fractures can depend heavily on their orientation relative to that of the stress field and the relative magnitude of the principal stresses.

Leak-off Tests (LOTs), density models and borehole images are used to constrain stress magnitudes at depth in the Rotokawa Geothermal Reservoir. In the extensional tectonic setting of the TVZ, the vertical stress axis coincides with the maximum principal stress. As this is dependent on the weight of the overburden, we employed extensive lab-based density measurements that have been performed on core from Rotokawa and other geothermal fields to derive a vertical stress model. Using this data, the vertical stress across the Rotokawa Field has been modeled taking into account the variable lateral thicknesses of different lithologies. Data from LOTs and the observation of drilling induced tensile fractures (DITFs) on borehole acoustic images are used to quantify the minimum and maximum horizontal stresses respectively.

The differential between the vertical and minimum horizontal stresses corresponds to a crust in frictional equilibrium. Results of this study indicate that spatial variation in the vertical stress magnitude due to lateral variation in the thickness of the overlying stratigraphy may be an important factor in maintaining permeable fractures. For example, the presence of a young andesitic cone in the strata causes a local increase in the vertical stress. This may have a local effect on the permeability of the underlying rocks.

Another key outcome of this study is that a portion of the fractures imaged in boreholes is exploiting weaknesses in an otherwise strong rock. The range of fractures observed suggest that the fractures were activated under compressional shear conditions, yet the strength of the rock measured suggest that is difficult to initiate such fractures. It is likely that the rock is weaker due to the presence of primary fractures (i.e., created when the rock was emplaced) or fractures due to subsequent volcanic activity. It is therefore crucial to have a good grasp on the volcano-tectonic history of the region in order to understand the pathways that fluids take to reach the surface.