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Deep Geothermal: The Role of Creep Fractures for deep Fluid Transfer

K.Regenauer-Lieb[2,3], M. Veveakis [3] , A. Karrech [2], T. Poulet [3] and C Schrank [1,2]

[1]Queensland University of Technology,

[2]The University of Western Australia

[3]CSIRO Earth Science and Resource Engineering,

Klaus.Regenauer-Lieb@csiro.au

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ABSTRACT

We present results of a pilot study investigating the hypothesis of ductile shear deformation in deep geothermal prospects. Geothermal energy is pushing the boundaries of current geomaterial models through going deeper and hotter than ever reached before. A characteristic of material behaviour at such conditions is that the material parameters develop a distinct dependence on the temperature conditions in addition to their well-known pressure dependence. Although this is commonly neglected, the process already starts at relatively shallow depth for clay rich rocks (like in unconventional shale gas plays), which can behave in a ductile manner. In addition they display dewatering reactions at a critical temperature where the clay minerals dehydrate. The same style of temperature dependence is repeated for different lithologies at greater depth. The presence of water has the effect of lowering this critical boundary. In the Soultz-sous-Forets geothermal project in Europe for instance the interaction of the hydrothermal activity with the granite produces clay rich shear zones which lower the realm of ductile deformation to relatively low temperature levels. The role of such ductile deformation is traditionally understood as a local reduction of the frictional coefficient with little insight into the processes that cause such an apparent weakening. We postulate here that it is exactly this weakening effect that creates and sustains geothermal reservoirs. It is important to explicitly consider these important thermally activated processes in geothermal energy. Thinking outside the box of linear elastic fracture mechanics is required for understanding the mechanisms of geothermal reservoirs.

We present a fresh approach where we interpret deep geothermal reservoirs as a product of localization phenomena occurring on longer time-scales than previously thought. The truncation at a particular depth/temperature can be interpreted as a strong indication for thermally activated creep processes, which require a critical temperature to cause a localization phenomenon known as creep fracture. We present and test the creep fracture hypothesis using microtomographic observations [1] and a forward numerical model [2] of the nucleation of creep fractures during the past 5 Myrs of collision of the Australian Continent with the Papua New Guinean archipelago.

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