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Evolution of self-propping fracture permeability in sandstone with a large pre-offset under hydrothermal conditions

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The permeability of rock mass plays a significant role in the success and sustainability of geothermal energy exploitation. For most of the deep geothermal reservoirs, rock fractures determine the productivity due to the impermeable rock matrix. During geothermal energy production, the injection of cold water and variations of pore pressure within the reservoir will change the temperature and in-situ stress conditions, which may result in the change of fracture permeability. Previous studies indicated the general relationships between fracture permeability and THM conditions, only limited studies highlighted a comprehensive investigation on fracture permeability combined geometry analysis and thermo-hydro-mechanical properties. Therefore, we present a study combined the methods of photo scan and micro-CT scan and drained compression experiments to investigate the evolution of self-propping fracture permeability in sandstone.
Two representative sediments with the matrix permeability below 0.15 mD were selected for the experiments, namely Fontainebleau sandstone, a pure quartz sandstone contained more than 99.5% quartz and Flechtinger sandstone, a clay-bearing sandstone with complex compositions. A single tensile fracture was generated by a Brazilian setup, 750 microns of a pre-offset along the axial direction of the rock sample was assembled with spacers, and then a visible self-propping fracture was prepared.
Drained experiments were performed at room temperature. Confining pressure was changed stepwise or continuously. Volumetric fluid content in the aperture was calculated based on the drained bulk modulus, indicating the change of the aperture volume. The initial and final aperture volumes prior to and after experiments were obtained from the extracted 3d mode by micro-CT scan. Then we got the full curve of mechanical aperture volume. The results indicated that permeability showed a small degradation with increasing of the effective pressure for both samples, an irreversible permeability damage appeared after the first confining pressure cycle. For Fontainebleau sandstone, permeability maintained constant during further two confining pressure cycles between 100 bars and 300 bars. It shows that there is no significant correlation between hydraulic aperture and mechanical aperture under such stress conditions. The increase of temperature from 28°C to 140°C led to the decrease of permeability from 850 mD to 252 mD for Fontainebleau sandstone and from 670 mD to 244 mD for Flechtinger sandstone, respectively. This permeability decrease of both samples can be fully restored by temperature decreasing. Based on the 3d model analysis of contacted fracture surfaces, the pre-offset of 750 microns can separate two surfaces drastically, increasing fracture aperture and decreasing contact points. Wide channels appear due to the unfit-surface geometry. The main channels won't be sensitive to a certain range of effective stress on account of the mechanical properties of contact areas, while the expansion of rock matrix can compress main channels causing permeability decrease. The results can be considered as the reference for further chemical and time-dependent behaviours of fracture rock permeability.