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Influence of brittle deformation on the permeability of granite: assessing the geothermal potential of crustal fault zones

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Economically viable geothermal systems rely on the efficiency of fluid circulation and heat transfer. Permeable fault zones are therefore excellent candidates for geothermal exploitation. In crustal fault zones, hot fluids from depths that correspond to the brittle-ductile transition are brought to the surface via crustal-scale permeable fault zones and may therefore constitute a new kind of geothermal system. To assess their geothermal potential, we measured the permeability of reservoir rock during deformation to large strains (up to an axial strain of about 0.1) in the brittle regime - fault formation and sliding on the fault - by performing triaxial experiments on samples of well-characterised Lanhélin granite (France). Prior to deformation, samples were thermally-stressed to 700°C to ensure that their permeability was sufficiently high to measure on reasonable laboratory timescales. All experiments were conducted on water-saturated samples under drained conditions, at a constant pore pressure of 10 MPa and confining pressures of 20, 40, and 60 MPa (corresponding to a maximum depth of about 2 km), and at room temperature. Our data show that permeability decreases by about an order of magnitude prior to macroscopic shear failure. This decrease can be attributed to the closure of pre-existing microcracks which outweigh the formation of new microcracks during loading up to the peak stress. As the macroscopic shear fracture is formed, sample permeability increases by about a factor of two. The permeability of the sample remains almost constant during sliding on the fracture to large strains (corresponding to a fault displacement of ~7 mm), suggesting that the permeability of the fracture does not fall below the permeability of the host-rock. The permeability of the sample at the frictional sliding stress is lower at higher confining pressure (by about an order of magnitude between 20 and 60 MPa) but, overall, the evolution of sample permeability as a function of strain is qualitatively similar for confining pressures of 20−60 MPa. These experimental results will serve to inform numerical modelling designed to explore the influence of macroscopic fractures on fluid flow within a fractured geothermal reservoir.