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Permeability evoluation at the brittle to ductile transition in newberry volcano basalt

Marie Violay and **Gabriel Meyer**
EPFL, IIC, LEMR, Lausanne, Switzerland (marie.violay@epfl.ch)

Superhot Rock (SHR) geothermal projects (e.g., Japan Beyond-Brittle Project, Iceland Deep Drilling Project, and Newberry Volcano) seek to extract heat from geothermal reservoirs where water reaches a supercritical state (≥ 400 °C). Exploiting such a resource could multiply the electrical power delivered by geothermal wells by almost an order of magnitude. However, SHR reservoirs are hosted in semi-brittle to ductile rocks where fluid flow, porosity, permeability, and rock mechanics are still poorly understood. We conduct experiments in a newly designed, internally heated, gas-confining triaxial apparatus (located at EPFL, CH) where we deform reservoir-type samples under realistic SHR temperature, pressure, and strain rate conditions. Deep well core samples (40 x 20 mm) of andesitic basalts (porosities of 8–10%) from Newberry Volcano (US), were subjected to increasing confinement pressure (25–100 MPa) and temperature (20–500 °C) while continuously recording gas permeability via harmonic permeability. Additionally, triaxial deformation experiments were done at strain rates of 10^{-6} s^{-1}, confinement up to 100 MPa, temperature up to 500 °C, and up to 8% strain while recording permeability. Results were compared with granite samples from Lanhelin (Fr.). Samples were ductile (e.g., no localization of strain) at relatively low pressure–low temperature conditions (100 MPa, 200 °C). Moreover, permeability in samples subjected to hydrostatic conditions rapidly decreased several orders of magnitude from an initial value of 5.10^{-20} m^2 to less than 10^{-22} m^2 at 50 MPa and 200 °C, effectively impermeable. Thus, permeability decreases rapidly in the ductile regime with strain to reach below measurable values at around 3% strain, and it remains so during subsequent semi-brittle flow up to 8% strain. We interpret this rapid decay of permeability as a result of the conjoined effect of ductile pore collapse and plastic deformation of the poorly crystalline matrix present in the sample. These insights further underline the need for advanced, sustainable reservoir engineering techniques in order to extract heat from high enthalpy geothermal reservoirs.