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Hydro-mechanical behaviour of fractures under hydrostatic and deviatoric stresses

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Joints, fractures, and fault zones are ubiquitous on all scales in the brittle upper crust. The presence of these features significantly alters the effective mechanical and hydraulic behaviour relative to intact rocks. In hydraulic fracturing for example, this relation between physical properties and damage structure is exploited and high fluid pressures are used to create new fractures in order to enhance a rock formation's hydraulic properties. Increasing the fluid pressure in the subsurface may also lead to shear failure of pre-existing fractures which might promote further enhancement of hydraulic properties. Our goal is to further investigate the relation between shearing and modification in hydraulic properties. We used a method that allows for the continuous measurement of hydraulic properties of cylindrical sandstone samples cut at an angle of 35° from the cylinder axis to model a fracture. A central borehole drilled through the upper sample half provides a hydraulic connection to the fracture. To determine hydraulic properties, we apply a periodic pore pressure variation. The phase shift and amplitude ratio between the fluid flow and the pressure oscillation are representative of the effective hydraulic properties from a comparison to known analytical solutions. The samples containing the artificial fractures were prepared from two adjacent sandstone formations from the triassic Buntsandstein Unit of Central Germany with high and low matrix permeabilities, respectively. The large permeability contrast between the samples enabled us to study fracture flow with and without matrix leak-off. Our results for hydrostatic conditions match previous findings that normal stress on the fracture surface controls hydraulic properties. By changing the frequency of the pressure oscillation we identified a pronounced frequency dependence of the resulting effective hydraulic properties. We suggest that tests at higher frequencies yield properties of highly conductive features (i.e. the fracture) and the influence of less conductive features (i.e. the surrounding rock) increases with decreasing frequencies. Depending on frequency we therefore probe different subsets of the sample. For both host rocks we found that shear displacement and associated surface processes reduce effective hydraulic properties compared to hydrostatic measurements at similar stress conditions.