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A damage mechanics approach for quantifying stress changes due to brittle failure of porous rocks

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Natural fault zones or man-made injection or production of fluid impact the regional stress distribution in Earth's crust and can be responsible for localized stress discontinuities. Understanding the processes controlling fracturing of the porous rocks and mechanical behaviour of fault zones is therefore of interest for several applications including geothermal energy production.

In this contribution, we will present a thermodynamically consistent visco-poroelastic damage model which can deal with the multi-scale and multi-physics nature of the physical processes controlling the deformation of porous rocks during and after brittle failure. Deformation of a porous medium is crucially influenced by the changes in the effective stress. Considering a strain-formulated yield cap and the compaction-dilation transition, three different regimes can be identified: quasi-elastic deformation, cataclastic compaction with microcracking (damage accumulation) and macroscopic brittle failure with dilation.

The governing equations for deformation, damage accumulation/healing and fluid flow have been implemented in a fully-coupled finite-element-method based framework (MOOSE). The MOOSE framework provides a powerful and flexible platform to solve multiphysics problems implicitly and in a tightly coupled manner on unstructured meshes which is of interest for such non-linear context.
To illustrate the model, simulation of a compaction experiment of a sandstone leading to shear failure will be presented which allows to quantify the stress drop accompanying the failure. Finally, we will demonstrate that this approach can also be used at the field scale to simulate hydraulic fracturing and assess the resulting changes in the stress field.