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Numerical investigation of the hydro-mechanical contribution to seismic attenuation in damaged rocks

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The investigation of hydro-mechanical processes, in particular the modeling of seismic waves in fractured porous media, is essential for the physical interpretation of data obtained from seismic exploration. Here, we specifically investigate attenuation processes in fluid-saturated porous rock containing fracture networks to identify effective hydro-mechanical properties by numerical simulation. The main purpose of this work is the characterization of the overall hydro-mechanical properties by computational homogenization. We determine an effective Skempton coefficient by investigating the fluid pressure and the solid displacement of the skeleton saturated by compressible fluids. Fracture networks are stochastically generated to mimic geological in-situ situations. The fractures are approximated as ellipses with aspect ratios up to 1/100, i.e. they constitute thin and long hydraulic conduits with high permeabilities. Simulations are designed on the material scale with and without conservation of fluid mass in the control volume. Using computational homogenization approaches, we define an effective Skempton coefficient. A range of fracture networks with different characteristic properties is studied for different varieties of fractures.

On the material scale we find strongly heterogeneous pressure propagation in the fracture network and the surrounding rock, respectively. The pressure diffusion is much faster in the fracture network than in the matrix, rendering the macroscopic hydro-mechanical behavior strongly time dependent. The effective Skempton coefficient converges to an ensemble-specific instantaneous value and to 1 for long-time studies. The ultimate objective of our study is to evaluate whether constraints on the structure of fracture networks can be deduced from observations of attenuation and its frequency dependence.