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Pore-scale modelling of non-linear rock deformation under low- stress ranges

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Under increasing compressive stress, intrinsic micro cracks and pores in rock samples close, leading to non-linear deformation at low-stress ranges. This intrinsic non-linearity significantly affects rock geophysical properties under confinement, such as rock stiffness and transport properties. Many studies have reported this low-stress inelastic behaviour in experiments, and some analytical models have been established to predict this phenomenon. However, in the perspective of pore-scale numerical modelling, this non-linear deformation was completely ignored, and the rock was treated as elastic in simulations until rock failure. As a result, the modelled rock geophysical properties in the non-linear part are quite different from the experimental results. To address this issue, we proposed a method to predict the rock geophysical properties at the low-stress non-linear range through numerical simulations. A crucial aspect of this approach involves dividing the transition phase between macro pores and the solid phase into several sub-phases with varying porosities, all treated with zero elastic moduli. These sub-phases deform and transition to other phases based on the extent of deformation under the applied strain conditions in the Finite-Element method. The ability to interchange between different phases in the rock model enables the modelling of non-linear behaviour within the low-stress range. We validated this method on various rock samples, and the results align well with experimental measurements.

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