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Numerical simulation of fluid injection in faulted and fractured rocks based on a fully-coupled hydro-mechanical model

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We present a fully-coupled hydro-mechanical simulation of fluid injection-induced activation of pre-existing discontinuities, propagation of new damages, development of seismic activities, and alteration of network connectivity in naturally faulted and fractured rocks, which are represented using the discrete fracture network approach. We use the finite element method to compute the multiphysical fields including stress, strain, damage, displacement, and pressure by solving governing and constitutive equations of coupled solid and fluid domains. Essential hydro-mechanical coupling mechanisms are honoured such as pore pressure-induced shear slip of natural discontinuities, poro-elastic response of rock matrix, and stress-dependent permeability/storativity of both fractures and rocks. We use the numerical model developed to investigate the hydro-mechanical behaviour of deeply buried fractured rocks and fault zones in response to high-pressure fluid injection, with a specific focus on the system either below or above the percolation threshold. We observe a strong control of fracture network connectivity on the damage emergence, seismicity occurrence and connectivity change in the rock mass subject to hydraulic stimulation. We highlight the strong poro-elastic effect that tends to drive heterogeneous connectivity evolution of fracture systems during fluid injection. The results of our research and insights obtained have important implications for injection-related geoengineering activities such as the development of enhanced geothermal systems and extraction of hydrocarbon resources.