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Modeling the dynamical interaction between fracture development, stress transfer, fluid flow, and chemical precipitation

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Increasing evidence suggests substantial high pressure fluid reservoirs reside at the base of seismogenic zones. These trapped reservoirs evolve and grow as input from devolization below provides a continuous source of fluids. Late in the earthquake cycle, when the reservoir has reached its capacity, pore-elastic stresses and breakdown of the competent overlying brittle crust set into motion a dynamical interaction between crack growth and fluid flow into this network, with important consequences on the initiation process preceding large earthquakes. Modeling these processes is challenging because of the timescales involved and many interacting feedbacks. We have developed a 3-dimensional model that addresses many of these feedbacks, using the FLAC algorithm to simulate a pore-elastic visco-plastic rheology coupled to a non-linear pressure diffusion, where permeability is a function of either the effective normal stress or alternatively as a function of the accumulated plastic strain. Fractures, in either tensile or in shear, develop in the model in response to the far-field boundary conditions, and to stress perturbations arising from the linking and growing fracture network. These numerical models are used to investigate pre-,co-, and post-seismic fluid flow to establish potential links between hydro-mechanical interactions, foreshocks, and aftershocks. These models also have direct application to geothermal systems, particularly enhanced geothermal systems where a crack network is stimulated via injection of high pressure fluids in low-permeability rocks. The aim of these models is to develop insight into the complex interactions and timescales between fracture, fluid flow, and subsequent precipitation that ultimately seals up the hydraulic pathways. We discuss the hydromechanical consequences of hypothesized high pressured fluid reservoirs at depth, and show through modeling that the spatio-temporal behavior of these reservoirs has important implications on the earthquake cycle.