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Numerical modelling of hydraulic fracturing, damage and microseismicity in 2D

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We present a numerical approach for the modelling of hydraulic fracturing and damage of low-permeable rock by fluid injection. It computes the intermittent propagation of rock damage, microseismic event locations, microseismic frequency–magnitude distributions, stimulated rock volume and the injection pressure. The model is based on concepts from invasion percolation theory by using a regular grid, where the cells are either intact or fractured (damaged). The percolation grid is extended with an equation for fluid pressure. All cells are connected to their nearest neighbours by hydraulic transmissibilities (also called bonds), and the pressure equation is solved with a finite volume method. Fluid injection takes place at the center of the grid at a constant rate. Fluid injection builds-up the pressure in the zone of damaged cells. The bonds are also assigned strength and they may break. Only bonds between damaged cells and intact cells can break. A bond breaks when the fluid pressure exceeds the least compressive stress plus the rock strength. Breaking a bond implies that the intact cell connected to the damaged cell also breaks and damage propagates into the rock. The fluid invades a new cell when it is damaged, which leads to a pressure decrease. The rock strength is uniformly distributed between zero and a max-value. All damaged and connected cells during a time step constitute a microseismic event, where the size of the event is the number of cells in the cluster. The magnitude of the event is the log10 of the event size. The model produces events with a magnitude–frequency distribution having a b-value that is approximately 0.8. The model is studied with respect to the physical parameters: permeability of damaged rock and the rock strength. "High" permeabilities of the damaged rock give the same b-value 0.8, but "moderate" permeabilities give higher b-values. Another difference is that "high" permeabilities produce a percolation-like fracture network, while "moderate" permeabilities result in damage zones that expand circularly away from the injection point. In the latter case of "moderate" permeabilities, the injection pressure increases substantially beyond the fracturing level. The rock strength and the time step do not change the observed b-value of the model for moderate changes.