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Lateral growth of the fault damage zone as a result of induced seismicity

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Geo-energy applications such as geologic carbon storage, geothermal energy, and subsurface energy storage, imply fluid injection and production resulting in pressure and temperature diffusion. Changes in the initial hydraulic and thermal state may in turn induce seismicity, usually nucleated at faults that cross the injection formation or are hydraulically connected with it. We investigate fault stability as affected by fluid injection into a porous aquifer that is overlaid and underlain by low permeable clay-rich formations . We model, through fully coupled hydro-mechanical simulations, a layered sedimentary basin with alternating low-permeable and high-permeable formations and include the crystalline basement at the bottom and a fault crossing the system. The fault in composed by a fault core and a damage zone on each side of the core. While the properties of the fault core are assumed constant along the fault, the properties of the damage zone depend on the rock type it is in contact with, i.e. aquifer, low-permeable clay-rich, formation or basement. The fault has an offset equal to half of the thickness of the injection formation. We find that aquifer pressurization as a result of fluid injection causes significant stress changes around the fault that in turn affect fault stability. The lower the fault core permeability, the larger the stress changes caused by the pore pressure buildup. Simulation results show that the least stable situation occurs at the contact between the aquifer and the damage zone–unexpectedly not within the fault. Induced earthquakes are likely to nucleate on the edge of the fault damage zone, leading to a lateral growth of the damage zone and a possible spreading of the fault zone.