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On the physics-based processes behind production-induced seismicity in natural gas fields

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Induced seismicity due to natural gas production is observed at different sites around the world. Common understanding is that the pressure drop caused by gas production leads to compaction, which affects the stress field in the reservoir and the surrounding rock formations, hence reactivating pre-existing faults and inducing earthquakes. Previous studies have often assumed that pressure changes in the reservoir compartments and intersecting fault zones are equal, while neglecting multi-phase fluid flow.

In this study, we show that disregarding fluid flow involved in natural gas extraction activities is often inappropriate. We use a fully coupled multiphase fluid flow and geomechanics simulator, which accounts for stress-dependent permeability and linear poroelasticity, to better determine the conditions leading to fault reactivation. In our model setup, gas is produced from a porous reservoir, cut in two compartments that are offset by a normal fault, and overlain by impermeable caprock.

Results show that fluid flow plays a major role pertaining to pore pressure and stress evolution within the fault. Hydro-mechanical processes include rotation of the principal stresses due to reservoir compaction, as well as poroelastic effects caused by the pressure drop in the adjacent reservoir. Fault strength is significantly reduced due to fluid flow into the fault zone from the neighbouring reservoir compartment and other formations. We also analyze the case of production in both compartments, and results show that simultaneous production does not prevent the fault to be reactivated, but the magnitude of the induced event is smaller.

Finally, we analyze scenarios for minimizing seismicity after a period of production, such as (i) well shut-in and (ii) gas re-injection. Results show that, in the case of well shut-in, a highly stressed fault zone can still be reactivated several decades after production stop, although in average the shut-in results in reduction of seismicity. In the case of gas re-injection, fault reactivation can be avoided if gas is injected directly into the compartment under depletion. However, accounting for continuous production at a given reservoir and gas re-injection at a neighbouring compartment does not stop the fault from being reactivated.