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Coupled hydro-mechanical modelling of seismicity induced by gas production

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Induced seismicity due to natural gas exploitation has been observed at many sites around the world. It has been suggested that the pressure drop caused by gas production leads to compaction, which affects the stress field in the reservoir and the surrounding rock formations. This in turn can reactivate pre-existing faults and hence trigger earthquakes. Although these induced seismic events are often moderate in magnitude, some of them can be felt at the ground surface causing nuisance to the population and sometimes moderate damages to structures. A well-known example is the Groningen gas field in the Netherlands, where production-induced seismicity has caused damage to buildings close to the production site. Given the high public impact, it is crucial to understand the underlying processes during natural gas exploitation.

We carried out numerical simulations to better determine the conditions leading to fault reactivation. In our numerical model, gas is produced from a permeable reservoir, cut by a normal fault and overlain by impermeable cap rock. We used a simulator that couples multiphase fluid flow and geomechanics in order to quantify the stress evolution and the reactivation of the pre-existing fault. In addition, our model considers stress-dependent permeabilities and linear poroelasticity. We performed a sensitivity analysis aimed at investigating different production scenarios and fault properties.

The 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 the compaction, as well as poroelastic effects caused by the pressure drop in the adjacent reservoir. Pore pressure stabilization occurs within the fault as a response to fluid inflow from other formations. We also analysed the case of multiple production well, and results show that simultaneous production does not prevent the fault to be reactivated. In this case, the pore pressure in the fault decreases continuously and the rupture occurs at much higher stresses. The rupture is however halted at the interface between the reservoir and the cap rock due to the even compaction on both sides of the fault.