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Stress change and fault slip in produced gas reservoirs used for storage of natural gas and carbon-dioxide

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Gas extraction and subsequent storage of natural gas or CO_2 in produced gas reservoirs will change the state of stress in a reservoir-seal system due to poro-mechanical, thermal and possibly chemical effects. Depletion- and injection-induced stresses can mechanically damage top- and side-seals, re-activate pre-existing sealing faults and create new fractures, allowing fluid migration out of the storage reservoir and causing induced seismicity.

The first case study describes a field scale three-dimensional geomechanical numerical modelling of a depleted gas field in the Netherlands, which will be used for underground gas storage (UGS). The field experienced induced seismicity associated with gas production in the past and concerns were raised regarding the risk of future injection-related seismicity. The numerical modelling study aimed at investigating the potential of major faults for reactivation during UGS operations. The geomechanical model was calibrated to match the location and timing of the fault slip on the main central fault, which has most likely caused past seismic events during gas production. Simulation results showed that the part of the central fault most sensitive to slip during reservoir depletion is located at partial juxtaposition of the two main reservoir blocks across the central fault, which is in agreement with the seismological localization of the recorded seismic events. UGS operations with annual cycles of gas injection and production will largely have stabilizing effects on fault stability. The potential for fault slip on the central fault will therefore be low throughout annual operational cycles of this storage facility.

The second case study describes a field scale two-dimensional geomechanical modelling of an offshore depleted gas field in the Netherlands, which is being considered for CO_2 storage. The geomechanical modelling study aimed at investigating the mechanical impact of induced stress changes, resulting from past gas extraction and future CO_2 injection, on the reservoir rock, top- and side-seals as well as faults. The study focused in particular on the potential for induced hydro-fracturing of the reservoir rock and top seals and re-activation of existing faults. In contrast to the first case study of UGS where good calibration data were available, in this case calibration data were largely missing as the field has not experienced (felt) induced seismicity during production period and subsidence of the seabed was not measured. Numerical simulations of CO_2 injection into compartmentalized reservoir structures showed that the side seal and boundary faults at the edges of reservoir compartments represent weak spots where production-induced mechanical damage and fault re-activation will first occur. Possible permeability enhancement resulting from local seal damage and fault slip can provide initial pathways for CO_2 penetration into the seal enhancing fluid-rock chemical interactions.