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Assessing Geomechanical Effects of CO_2 Injection

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Geological sequestration of CO_2 involves disposal and long-term storage of CO_2 in the depleted hydrocarbon fields, deep saline aquifers, coal measures and enhanced oil recovery. CO_2 injection will change the stress-strain field in a reservoir-seal system due to various phenomena: poro-elastic effects caused by changes to the pore fluid pressure; buoyancy effects caused by changes to the pore fluid density; thermo-elastic effects caused by changes to the pore fluid temperature; and chemical effects caused by changes to the pore fluid chemistry (water-CO_2-rock interaction). Changes in stress and associated deformation resulting from these effects may lead to damage of the top seal or re-activation of pre-existing sealed faults reducing seal integrity.

Besides the impact on seals and faults that may lead to leakage, the CO_2 injection may also induce ground movement, which can be either aseismic, in the form of ground subsidence and/or ground uplift, or seismic. Induced (micro-)seismicity is caused by a sudden slip on discontinuities and faults present in the subsurface.

In order to evaluate how the sealing integrity of top seals and faults will evolve at a given storage site, and to assess the potential for induced seismicity and ground movement, the effects of above mentioned dynamic processes must be considered. This is commonly done as a part of feasibility studies carried out by a multi-disciplinary expert team with objective to assess the storage capacity and containment characteristics of the selected candidate site.

In this paper we examine current practices for geomechanical evaluation of the potential CO_2 storage sites. In recent years we have carried out geomechanical evaluations of several currently active storage sites (e.g. Sleipner aquifer located offshore Norway; the K12-B gas field, offshore Netherlands) and future potential storage sites (e.g. the Barendrecht depleted field, onshore Netherlands; the Q8-A depleted field, offshore Netherlands). The key elements of comprehensive geomechanical evaluation of a potential CO_2 storage site are based on the following: (i) close collaboration of geomechanical engineer with other specialists; (ii) detailed geomechanical characterization of the potential site including for example derivation of elastic rock properties from available well logs; (iii) use of analytical and semi-analytical tools for caprock and fault stability assessment; (iv) use of in-house developed semi-analytical tools for forward modelling of subsidence/uplift and inversion of subsidence data; (v) use of industry-standard numerical software packages for general stress and deformation modelling from micro-to field scale, based on distinct element method, finite differences and finite element method.

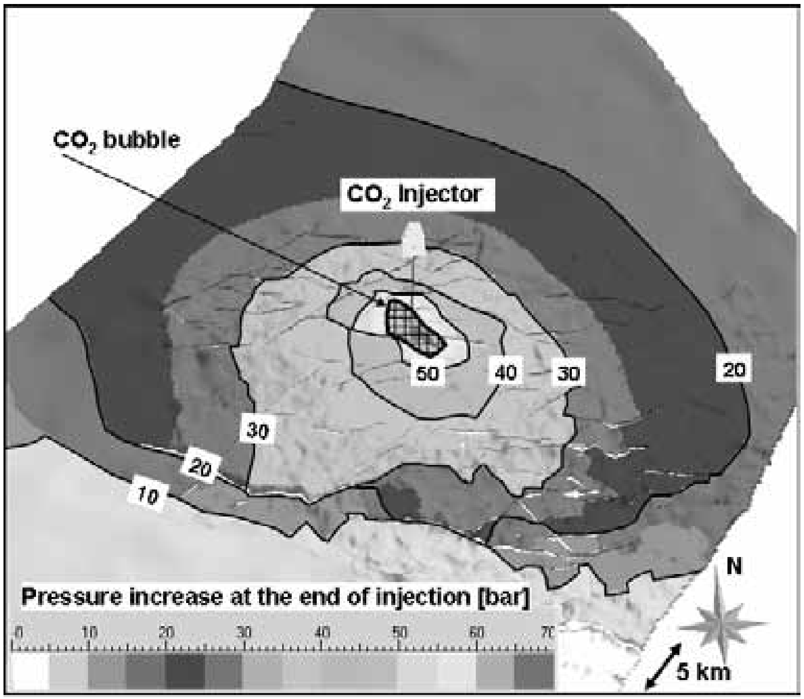

Figure 1 - Reservoir simulation results show that pressure increase in the aquifer due to CO_2 injection affects a large area (100s of km^2) beyond the CO_2 bubble. The areal extent of CO_2 accumulation is 20-30 km^2.

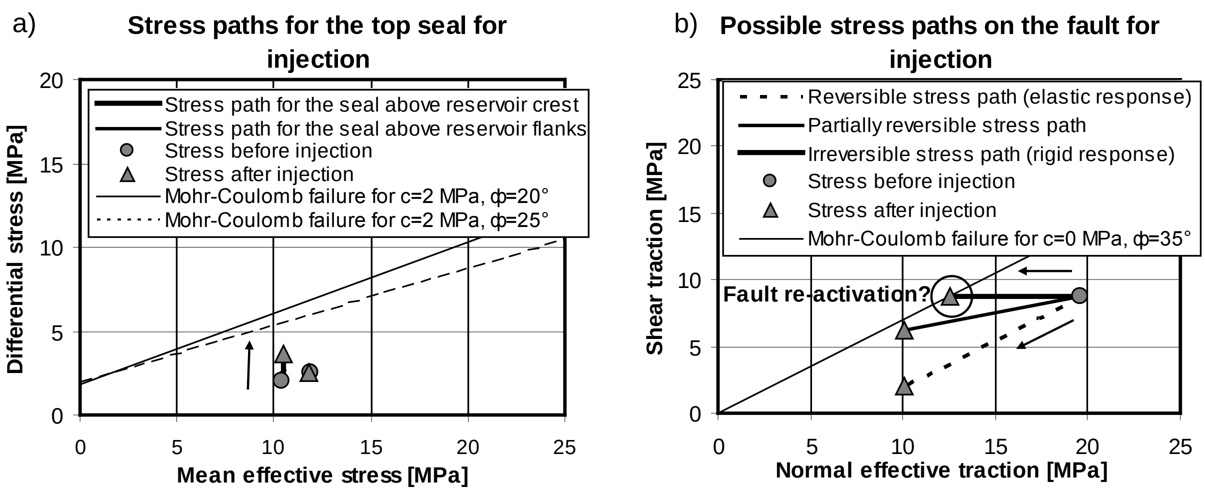

Figure 2 - Finite element modelling results showing stress evolution in top seals and on faults due to CO_2 injection into a depleted hydrocarbon field.

a) Stress changes in top seals are much smaller than in the reservoir - in many cases by one to two orders of magnitude. However, the stress development due to injection is critical as the state of stress moves towards the failure envelope.

b) Stress changes on the fault bounding the reservoir. Rigid response of the reservoir results in an irreversible critical (horizontal) stress path that may lead to slip on a fault and induced (micro-) seismicity at the storage site.