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Impact of caprock permeability on vertical ground surface displacements in geological underground utilisation

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Geological underground utilisation inducing pore pressure changes in underground reservoirs is generally accompanied by hydro-mechanical processes. Thereby, pore pressure increase due to fluid injection may trigger ground surface uplift, while a decrease in pore pressure due to reservoir fluid production is known to induce ground subsidence. Different coupled hydro-mechanical simulation studies (e.g. Klimkowski et al., 2015, Kempka et al., 2014, Tillner et al., 2014) indicate that ground surface displacements can achieve a magnitude of several decimetres, if storage or production operations are being carried out at an industrial scale. Consequently, detailed knowledge on the parameters impacting ground surface uplift or subsidence is of major interest for the success of any geological underground utilisation in order to avoid surface infrastructure damage by spatially varying deformations. Furthermore, ground subsidence may result increased groundwater levels as experienced in different underground coal mining districts.

In the present study, we carried out coupled hydro-mechanical simulations to account for the impact of caprock permeability on ground surface displacements resulting from geological underground utilisation. Thereto, different simulation scenarios were investigated using a synthetic 3D coupled numerical simulation model with varying caprock permeability and vertical location of the open well section in the target reservoir. Material property ranges were derived from available literature, while a normal faulting stress state was applied in all simulation scenarios.

Our simulation results demonstrate that caprock permeability has a significant impact on the pressure development, and thus on vertical displacements at the ground surface as well as at the reservoir top. An increase in caprock permeability from 1 x 10^{-20} m^2 by two orders of magnitude doubles vertical displacements at the ground surface, whereas vertical displacements at the reservoir top are decreased by almost 10 %. Furthermore, if the vertical location of the open well section is directly located below the caprock, vertical displacements at the ground surface are significantly higher compared to a lower open hole position.

Consequently, a focus in site characterisation in the scope of geological underground utilisation should be on detailed assessment of caprock permeability. These data may be derived by well logs and hydraulic tests as well as laboratory tests on core samples.

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