



Coupled numerical simulations of CO₂ injection into the carbonate aquifer of the Upper Muschelkalk, N-Switzerland

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The Triassic Trigodonus Dolomite unit of Upper Muschelkalk, a saline carbonate-hosted aquifer in Northern Switzerland, is considered a possible target for sequestering CO₂. The porosity of the aquifer ranges from 4-25 %. The porosity can be divided into macropores (mm to cm scale) and micropores (μm to nm scale). Intermittent bedding-parallel layers of macroscopic pores (cm scale) are readily visible, and originate from dissolution of anhydrite nodules and bivalve shells. The porosity of the Muschelkalk therefore exhibits a moderate layered anisotropy. Lab measurements indicate correlated permeabilities with values of 5.1 to 2.7e-18 m² for low porosity samples to larger than 1e-15 m² for samples with a large fraction of macropores.

The Upper Muschelkalk is overlain by the Gipskeuper, an anhydrite-bearing clay-rich rock of low porosity and permeability. The Gipskeuper constitutes a hydraulic barrier to the rising CO₂ plume.

We use fully coupled reactive transport simulations to assess the implications of injecting CO₂ into the Trigodonus Dolomite of the Muschelkalk aquifer. We track the movement of the plume and evaluate the efficiency of physical and chemical trapping mechanisms. Computations show that mineral trapping in the Muschelkalk aquifer is not effective. The global CO₂ mass balance indicates the release of additional CO₂ due to carbonate dissolution. However, while during and shortly after injection the dissolution of carbonate minerals dominates, after all free CO₂ has dissolved into the brine, a rebound in pH at the injection site leads to carbonate re-precipitation.

Diffusive influx of HCO₃⁻ and H⁺ from the Muschelkalk aquifer into the Gipskeuper dominates the alteration reactions in the lower part of the Gipskeuper. Clay minerals such as illite dissolve under acidic conditions and the release of cations causes carbonate minerals to precipitate. This in turn reduces the pore-space, enhancing the sealing capacity of the lower Gipskeuper.

Thus although mineral trapping, the safest form of CO₂ storage, is not effective in the Muschelkalk aquifer, this disadvantage is at least partly offset by the enhanced injectivity due to carbonate dissolution during injection and the apparent self sealing of the overlying Gipskeuper following the influx of HCO₃⁻ and acidity.