Evaluation of secondary mineral precipitation by geochemical modeling at the Ketzin CO_2 storage site, Germany

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Introduction

- One of the major keys to the success of the carbon capture and storage (CCS) is understanding the geochemical effects that CO_2 has on the storage reservoir. At the Ketzin site mineral precipitation was found in observation well 202. This poster analyses the formation of these minerals and clogging potentially induced in the wellbores and the reservoir. Assessment and simulation of the interaction of the injected CO_2 with the brine and minerals is essential for proper planning of CCS.
- The large amounts of sulfate concentration cause oversaturation with respect to sulfate minerals and, therefore, an increase in sulfate concentration could result in the secondary mineral precipitating that could clog the well-bore and its surroundings, which decreases the CO_2 injectivity. This is particularly true at the Ketzin CO_2 storage site, where the formation water contains high concentration of sulfate.
- Through both, field measurement and modeling, this contribution aims to explore the observed secondary mineral precipitation, with a special focus on the sulfate minerals.

Ketzin CO2 storage site

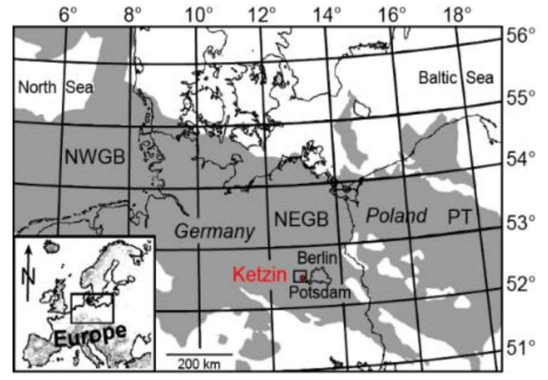


Figure 1 The CO_2 storage site at Ketzin is located in the Northeast German Basin (NEGB), about 25 km west of Berlin, Germany

Study site: Ketzin CO2 storage site

- Initiated in 2004 as the first demonstration project for geological onshore CO_2 storage in Europe
- Between 2008 and 2013, 67kt of CO_2 injected into the Upper Triassic saline aquifer reservoir at about 630 to 650m depth.

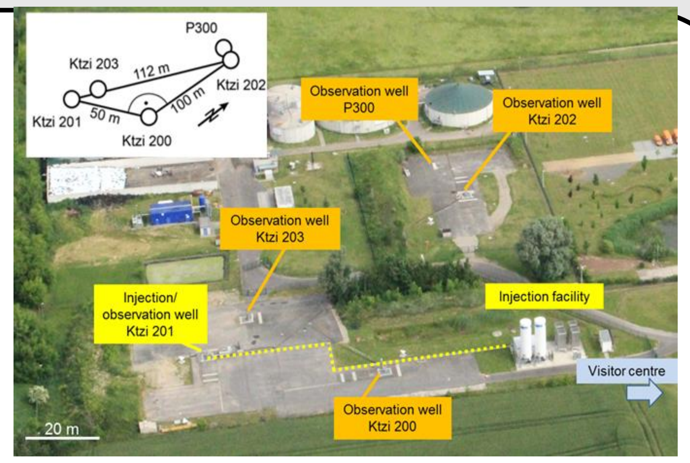


Figure 2 Aerial view of the pilot site in Ketzin. The five wells are arranged in a triangular shape with approx. 50 to 110m away from each other

Gypsum crystals from the observation well Ktzi 202

- Video camera inspection was designed for screening the inner surface of the wellbore casing as a part of the well integrity monitoring program for the Ketzin wellbores.
- Three years after start of CO_2 injection start, pure gypsum was sampled from on the inner casing surface at a depth of 650-651 m.

Figure 3 Gypsum crystals were detected at the well perforation holes with an inward growing direction (Date: Oct 2011)

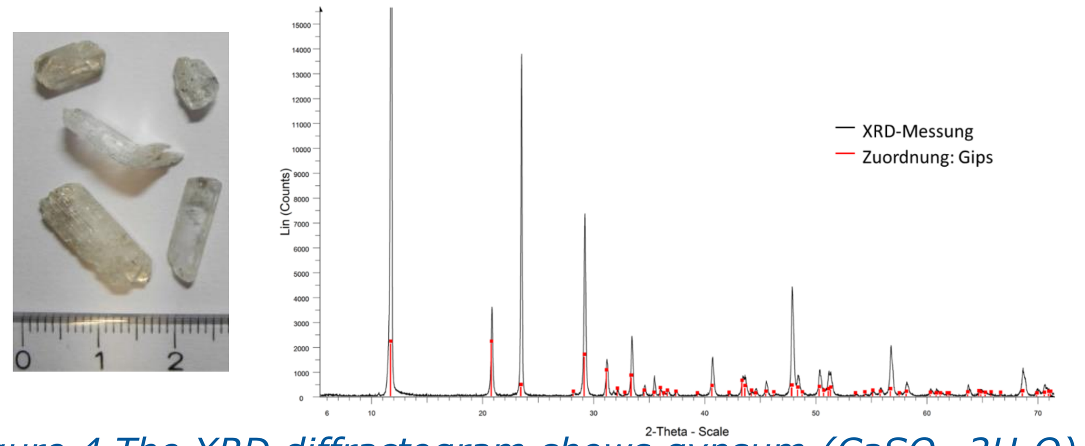


Figure 4 The XRD diffractogram shows gypsum ($CaSO_4$-$2H_2O$) as the only mineral phase (COMPLETE Final report, 2018, TIB hannover)

Geochemical batch modeling and Results

- CO_2-brine-mineral interactions are analyzed with geochemical batch modeling by PHREEQC code version 3.4 with the Pitzer database.
- Special focus is set to sulfate minerals, as field evidence exists that gypsum precipitates as a result of reservoir exposition to CO_2.
- The gypsum solubility was investigated as a function of the CO_2 partial pressure, reservoir temperature, and pressure.

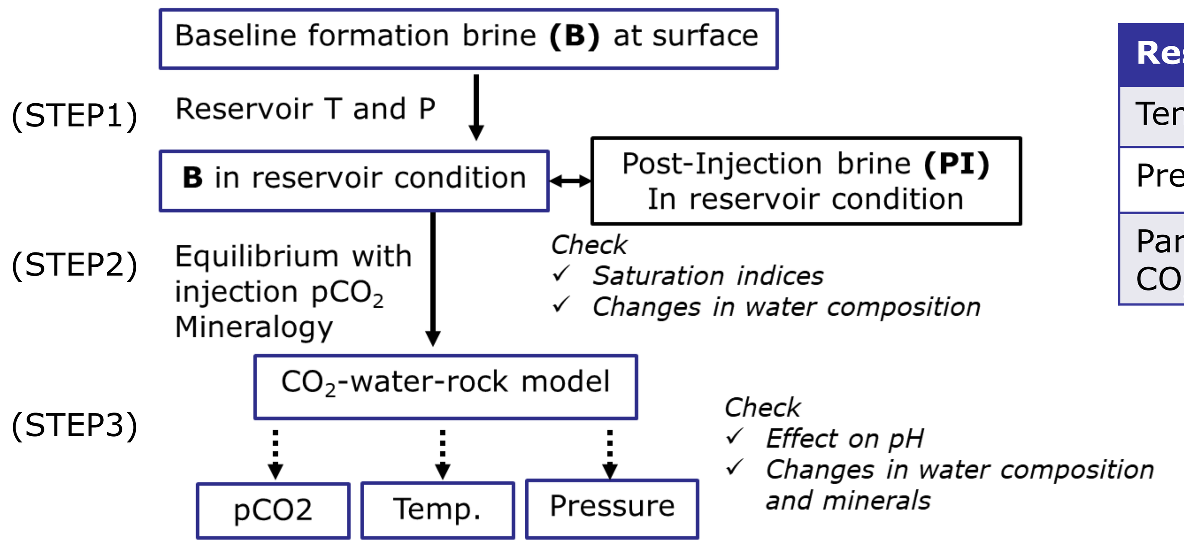


Figure 5 Workflow of the modeling approach. B: Baseline formation brine CO_2 injection, PI: Post-injection brine after six years of CO_2 injection

Reservoir condition	
Temperature [℃]	36
Pressure [bar]	70
Partial pressure of $CO_{2(g)}$ [bar]	63.79

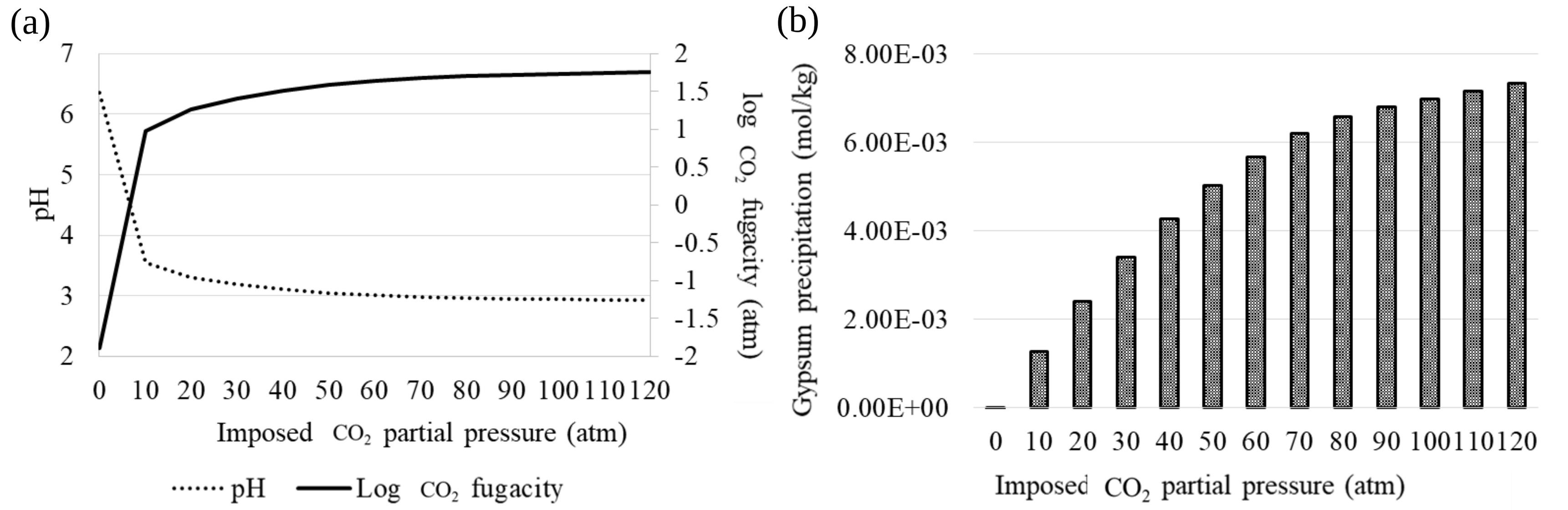
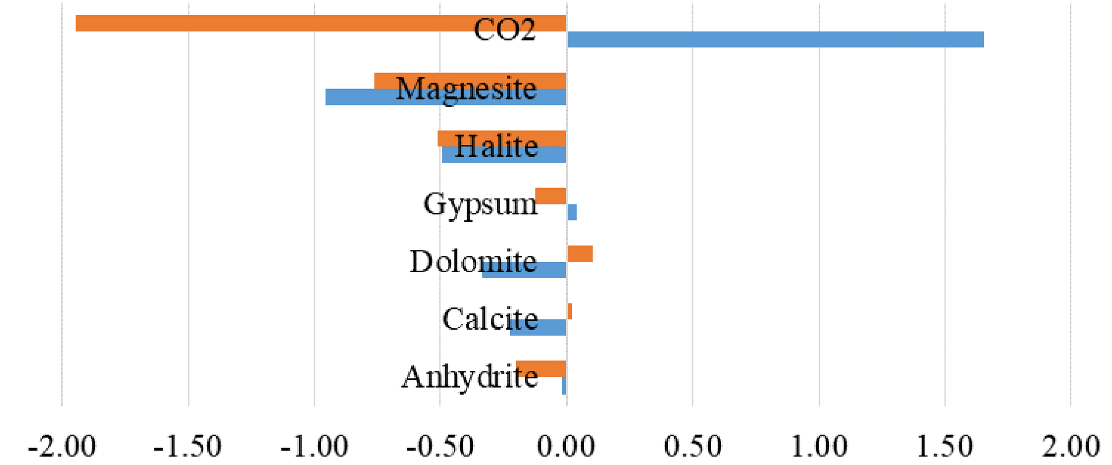


Figure 7 (a) pH and CO_2 fugacity changes and (b) amount of gypsum precipitation as a function of the imposed CO_2 partial pressure (STEP3). Note that it is assumed that dissolved CO_2 is in equilibrium with a constant pressure of the CO_2 gas phase in contact with the solution.



	Anhydrite	Calcite	Dolomite	Gypsum	Halite	Magnesite	CO2
B	-0.20	0.02	0.10	-0.13	-0.51	-0.76	-1.95
PI	-0.02	-0.22	-0.34	0.04	-0.50	-0.96	1.66

Figure 6 Calculated mineral saturation index and CO_2 fugacity for baseline (B) and Post-injection (PI) in the reservoir condition (STEP1)

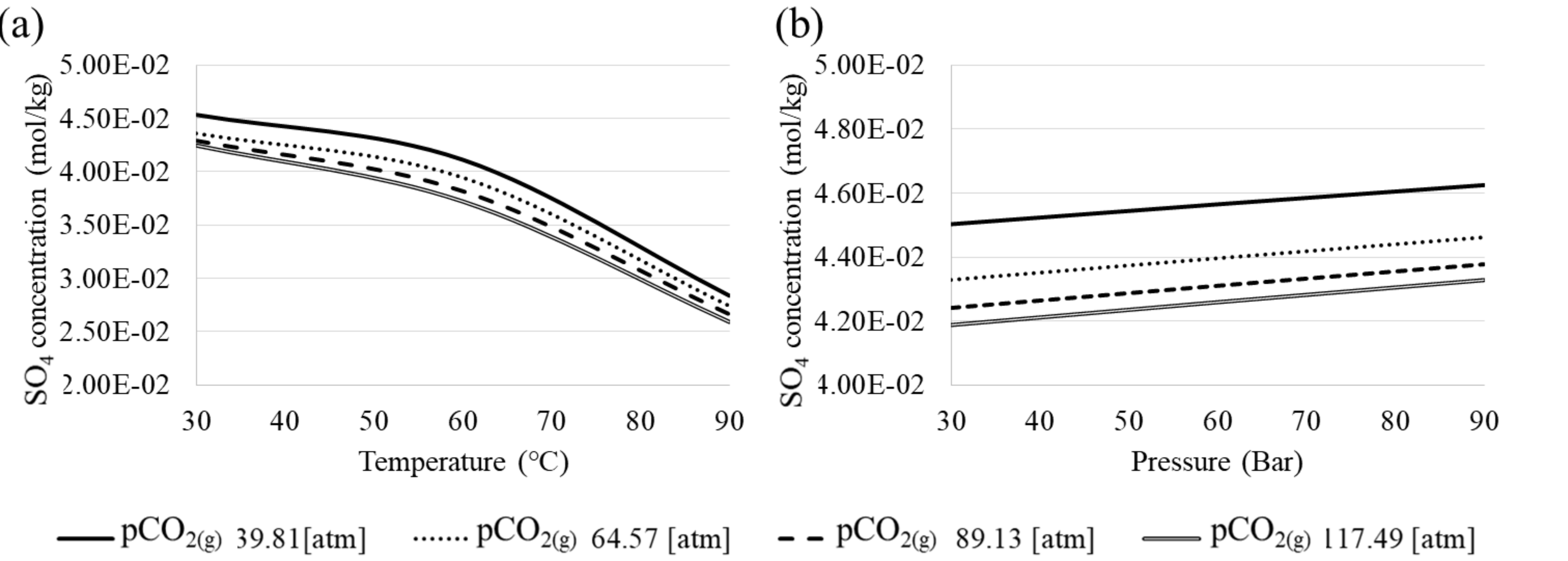
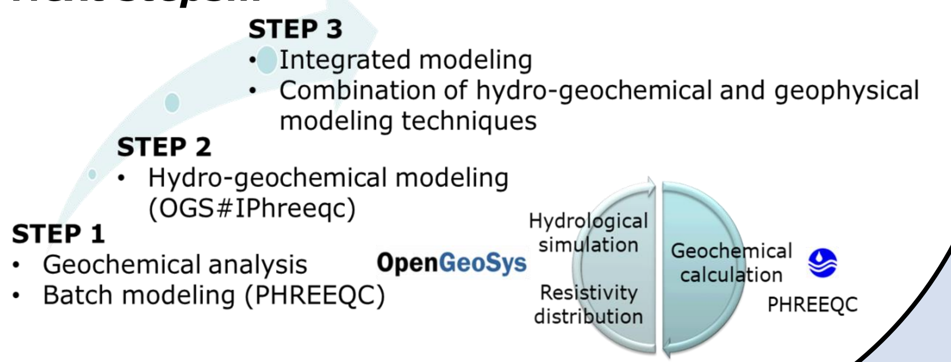


Figure 8 SO_4 concentration, assumed to represent sulfate mineral solubility, under a range of (a) temperature (from 30 to 90 ℃) and (b) pressure variations (from 30 to 90 bar) with varying imposed CO_2 partial pressure ($pCO_{2(g)}$ = 39.81, 64.57, 90.13, and 117.49 atm) (STEP3)

- Gypsum formed in response to interaction with the CO_2-charged brine at the observation well Ktzi 202, at the Ketzin CO_2 storage site (Fig. 3 and Fig. 4), and Post-injection brine show dissolution of carbonates and precipitation of gypsum (Fig. 6).
- As the gypsum solubility decreases with increasing CO_2 concentration, high permeability zones may show a more growing sulfate mineral precipitation (Fig. 7).
- A large amount of gypsum precipitation can be expected due to the temperature ascends (Fig. 8).

Next steps…



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