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Insights into the reactive transport of impure CO_2 through cap rock

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Understanding the long-term risks associated with geological Carbon Capture and Storage (CCS) demands an investigation of the impacts of dissolved CO2 and accompanying gas impurities on the caprock integrity. We employ PHREEQC software to conduct geochemical modelling, focusing on the diffusive transport of CO2 and main reactive impurities (e.g., H2S, SO2, NO2) through the cap rock over a span of 10,000 years. We aim to identify potential diffusion-driven leakage risks by assessing diffusion extension and mineral reaction fronts stemming from the relevant gas-fluid-rock interactions. Our study focuses on Nini West depleted setting in the Danish North Sea as the potential storage site for which detailed lithological composition has been determined previously [1]. To evaluate the potential of securely storing less purified CO2 stream, the concentration of the gas impurities is chosen to be 0.1 vol% and 1 vol%, which is significantly higher than the values stated in the relevant documents. The reactive transport model involves dissolution of impure CO2 stream in the reservoir brine followed by its diffusion through the caprock**.** The results show that the involved reactions can retard the CO2 propagation (by diffusion) front dramatically (~7-8 times), which reduces the chance of diffusion-induced leakage in the system. This retardation is more prominent for CO2 reaction since impurities have much lower portion in the stream and are consumed (through reactions that form sulfate/sulfide and ammonium/nitrogen minerals or aqueous species) greatly when dissolved in the aqueous phase. Although increasing the concentration of impurities shows negative impacts on the integrity of seal close to its interface with reservoir, mineral precipitation at further distances reduces the diffusive flux to some extent. The dissolution/precipitation extent is mainly determined by the mineralogy and condition of the system, and the results obtained are specific to comparable systems.

References:

[1] H.I. Petersen, N. Springer, R. Weibel, N.H. Schovsbo, Sealing capability of the Eocene–Miocene Horda and Lark formations of the Nini West depleted oil field – implications for safe CO2 storage in the North Sea, International Journal of Greenhouse Gas Control 118 (2022) 103675. https://doi.org/10.1016/j.ijggc.2022.103675.