Goldschmidt 2026 Abstract
https://doi.org/10.46427/gold2026.34328

Geochemical modeling of sulfate bioreduction with implications for underground hydrogen storage

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Deep saline aquifers, mainly depleted gas reservoirs, are considered feasible geological formations for a large-scale underground hydrogen storage (UHS). Sulfate reducing bacteria (SRB) contained in the groundwater of sedimentary rock formations (e.g., limestone and sandstone) can use dissolved hydrogen to reduce aqueous sulfate to sulfide, yielding an increase in pH of the formation groundwater ($4H_{2(aq)} + SO_4^{2-} + H^+ = HS^- + 4H_2O$) that can induce the dissolution of minerals and thus alter rock properties. We have studied the overall process by conducting two series of batch experiments with different SRB. (1) Deltaproteobacteria strains contained in a biofilm sediment and (2) a single cultivated strain (Desulfovibrio desulfuricans). They both react with Na-Cl-SO_4-rich water equilibrated with $H_{2(g)}$ at 2 bar and 30 °C.

In both sets of experiments, after an initial adaptation time, SRB prompted the consumption of aqueous H_2 as evidenced by the increase in HS^- concentration and pH and the decrease in sulfate. The changes in SO_4^{2-}, HS^- and pH as a function of time are reproduced by geochemical modeling using the CrunchFlow code [1], which incorporates Monod kinetic rate laws for microbially-mediated reactions. This approach enables us to obtain the bio-kinetic parameters involved in the process, which can be used to quantify the impact of sulfate bioreduction in reactive transport systems under relevant UHS conditions.

References

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