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Modeling porous medium modification through engineered calcium carbonate precipitation at field scale

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Fluid storage in the subsurface is important to reduce climate change (sequestration of CO_2) and for energy storage (CH_4, H_2). These fluids have the potential to leak through damaged cap rocks or well bores. One method to remediate leakage is inducing calcium carbonate precipitation (ICP). Most applications of ICP rely on urea hydrolysis by microbes (MICP) promoting precipitation within the porous media. However, precipitation may also be induced by the enzyme urease (EICP) or at elevated temperatures (TICP). The applicability of a certain ICP method is largely determined by the depth below ground surface and the local geothermal gradient. MICP has been demonstrated to have immense potential to seal leakage pathways, even at field scale [1], but is only effective within a limited temperature range. As a consequence, the other ICP methods EICP and TICP have to be developed and demonstrated in the field. To assist experimental investigations on EICP and TICP, a previously developed numerical model for MICP [2] is generalized and adapted for the new precipitation-inducing processes. As the model is intended for the use in predicting the leakage mitigation for subsurface gas storage, it accounts for two-phase flow and the variety of components and processes necessary to describe ICP. The number of components and processes being dependent on the precipitation-inducing process. The model is implemented in the open-source simulator DuMu^X [3]. The primary variables solved are the aqueous-phase pressure, component mole fractions in the water phase, temperature, and, for the solid phases, the volume fractions. The mass balance equations are solved fully implicitly and are coupled through the source and sink terms due to the reactions. Process-specific kinetic rate equations for the EICP and TICP processes were fitted to experimental data obtained from batch experiments at Montana State University. The porosity and permeability reduction due to precipitation and accumulation of biomass or enzyme are accounted for by updating the porosity and permeability. Finally, the potential application of EICP and TICP approaches in the MICP field-scale scenario [1,4] is simulated using representative reservoir temperatures to assess the potential applicability and efficiency of EICP and TICP at these temperatures.

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