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Large-Scale Experiments in Microbially-Induced Calcite Precipitation (MICP): Reactive Transport Model Development and Prediction

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Design of in situ microbially-induced calcite precipitation (MICP) strategies relies on preditive tools that so far have focused on small-scale experiments and/or one-dimensional flow in porous media. Parameterizations of models in these settings may not fit at larger scales or in the case of nonuniform, transient flows. Here we test our ability to predict behavior of biostimulated MICP under controlled conditions in a meter-scale tank experiment with transient nonuniform transport in a natural soil, using independently-determined parameters. Flow in the tank was controlled by three wells, via a complex cycle of injection/withdrawals followed by no-flow intervals. Different injection solution recipes were used in sequence for transport characterization, biostimulation, cementation, and groundwater rinse phases of the 17-day experiment. Reaction kinetics were calibrated using separate column experiments designed with a similar sequence of phases. This allowed for a parsimonious modeling approach with no parameter fitting. The experimental data were simulated using PHT3-D, involving transient non-uniform flow, alternating low- and high-Damköhler reactive transport, and combined equilibrium and kinetically-controlled biogeochemical reactions. The assumption that microbes mediating the reaction were exclusively sessile, and with constant activity, in conjunction with the foregoing treatment of the reaction network, provided for efficient and accurate modeling of the entire process leading to non-uniform calcite precipitation. This analysis suggests that under the biostimulation conditions applied here the assumption of steady-state sessile biocatalyst suffices to describe the microbially-mediated calcite precipitation.