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A Darcy-Brinkman-Stokes Approach to Modeling Microbially Induced Calcium Carbonate Precipitation in Porous and Fractured Media

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Microbially induced calcium carbonate precipitation (MICP) is an eco-friendly solution in geotechnical engineering, particularly for applications in bioremediation and CO_2 sequestration. Mathematical models have been developed to describe coupled biochemical processes in geological media. However, there is a lack of numerical methods capable of modeling MICP directly from a single set of equations, which poses challenges on practical engineering applications. In this paper, we developed a pore-scale numerical solver, MICPFOAM, using a unified framework based on the Darcy-Brinkman-Stokes equation for simulating MICP in both porous and fractured media. The solver is implemented based on the OpenFOAM environment. We then validated our model in two systems, i.e., a flow system and a reaction system. Results demonstrated that MICP was significantly slower in fractured media than in porous media because of the preferential flow. In the reaction-diffusion system, strong diffusion ($D = 10^{-6}$) drove MICP far from equilibrium, while fast precipitation ($K_p = 10^{-2}$) combined with low ureolysis ($K_u = 10^{-5}$) promoted MICP to reach equilibrium. The initial biomass distribution is able to determine the occurrence of MICP, while biomass density only affects the amount of $CaCO_3$ after reaching equilibrium. Our model facilitates the coupling of biogeochemical properties in typical porous and fractured media, offering an applicable framework to model versatile processes and providing optimal conditions for potential MICP applications.

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