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Effects of mixing at pore intersections on large-scale dissolution patterns

Rishabh Prakash Sharma[1], Peter K. Kang[2], and Piotr Szymczak[1]
[1]University of Warsaw, Faculty of Physics, Institute of Theoretical Physics, Warsaw, Poland (rsharma@fuw.edu.pl)
[2]Department of Earth and Environmental Sciences, University of Minnesota, Minneapolis, USA (pkkang@umn.edu)

Dissolution of carbonate rocks is a complex process in which the interplay of flow, transport, reaction, and geometric evolution plays an important role. The nonlinear couplings between these processes may lead to the formation of intricate patterns, including spontaneously formed channels (wormholes) [1]. It has been long established that the shapes of the dissolution patterns depend on fluid flow and mineral dissolution rates [2]. Recently, it also has become increasingly clear that pore-scale processes can impact large-scale morphologies [3,4]. However, the effects of pore-scale mixing on large-scale patterns remain unclear.

In this work, we investigate the effect of pore-scale mixing processes on the evolution of dissolution channels. Pore space is represented by a network of cylindrical tubes with the diameter of each segment increasing in proportion to the local reactant consumption. The inlet concentration of each pore is controlled by local mixing rules. Two different mixing protocols are considered: full mixing, in which the incoming reactant fluxes are assumed to be completely mixed at the intersection, and streamline routing, where the tracer follows the streamlines into the outgoing pores. We found that streamline routing enhances the flow focusing particularly strongly in moderate Damköhler number regimes where relatively wide dissolution channels appear spontaneously in the system. With the same initial conditions as the full mixing case, the winning channels obtained with streamline routing not only propagate faster but also could grow at a different location in the system. The enhanced flow focusing caused by streamline routing produces thinner wormholes and leads to shorter breakthrough times. Lastly, the evolution of velocity distribution is also found to be distinctive depending on the mixing rule.

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