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Karst-on-a-chip: microfluidic studies of dissolution of a gypsum fracture

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Dissolution of fractured and porous media introduces a positive feedback between fluid transport and chemical reactions at mineral surfaces leading to self-focusing of the flow in pronounced wormhole-like channels [1,2].

We study the flow-induced dissolution in a simple microfluidic setup, with a gypsum block inserted in between two polycarbonate plates, which is the simplest model of a fracture [3]. This gives us a unique opportunity to observe the evolution of the dissolution patterns in-situ and in real-time. By changing the flow rate and the aperture of the fracture we can scan a relatively wide range of Peclet and Damkohler numbers, characterizing the relative magnitude of advection, diffusion and reaction in the system. Additionally, as the aperture is increased, a transition is observed between the fractal and regular dissolution patterns. For small gaps, the patterns are ramified fractals. For larger gaps, the dissolution fingers are found to have regular forms of two different kinds: either linear (for high flow rates) or parabolic (for lower flow rates). The experiments are supplemented with numerical simulations and analytical modeling which allow for a better understanding of evolving flow patterns. In particular, we find the shapes and propagation velocities of dominant fingers for different widths of the system, flow rates and reaction rates. Finally, we comment on the link between the experimentally observed patterns and the natural karst systems - both cave conduits and epikarst solution pipes.

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