Geophysical Research Abstracts
Vol. 19, EGU2017-948, 2017
EGU General Assembly 2017

Reactive transport and mineral dissolution in fractured and porous rock: experiments, models and field observations

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We analyze the evolution of the shape of a dissolving porous body immersed in a reactive fluid. First, we consider the case of a semi-infinite body and transport-limited dissolution and show that in this case the resulting shape is parabolic. We derive the dissolution rate of such shapes depending on the contrast of permeabilities between the body and the surrounding matrix both in two and three spatial dimensions.

Next, we consider a problem of the dissolution of a finite-sized porous object in a Hele-Shaw cell. We study this system both experimentally and numerically. In the experiment, we use a microfluidic chip with a gypsum block inserted in between two parallel polycarbonate plates. By changing the flow rate and the distance between the plates we can scan a relatively wide range of Péclet and Damköhler numbers, which characterize the relative magnitude of advection, diffusion and reaction in the system. The evolving geometries are captured by a camera and then analyzed by image-processing techniques.

The experiments show a number of unexpected regularities. In particular, the upstream (trailing) edge of the dissolving object is shown to advance with a constant velocity whereas its curvature is changing in time. If the object had initially a sharp tip pointing upstream, its radius of curvature first increases and then decreases in time. Finally, we compare the obtained dissolution shapes with the natural forms such as pinnacles in a surface karst.