Invariantly propagating dissolution fingers in finite-width systems

Filip Dutka* and Piotr Szymczak

Institute of Theoretical Physics, Faculty of Physics, University of Warsaw,
Pasteura 5, 02-093, Warsaw, Poland
* fdutka@fuw.edu.pl

ABSTRACT

Dissolution fingers are formed in porous medium due to positive feedback between transport of reactant and chemical reactions [1-4]. We investigate two-dimensional semi-infinite systems, with constant width W in one direction. In numerical simulations we solve the Darcy flow problem combined with advection-dispersion-reaction equation for the solute transport to track the evolving shapes of the fingers.

We find the stationary, invariantly propagating finger shapes for different widths of the system W, flow rates and reaction rates. Shape of the reaction front, turns out to be controlled by two dimensionless numbers – the (width-based) Péclet number $Pe_W = \frac{v\,W}{D\,\phi_0}$ and Damköhler number $Da_W = \frac{ksW}{v}$, where k is the reaction rate, s – specific reactive surface area, v - characteristic flow rate, D – diffusion coefficient of the solute, and ϕ_0 – initial porosity of the rock matrix. Length of the stationary finger L turns out to be proportional to $Pe_W W$. Velocity of propagating front in initial stages of finger formation as a function of system parameters is also calculated.

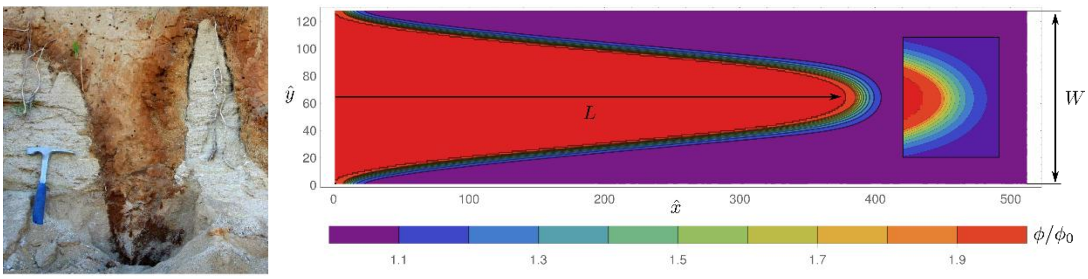

Fig. 1 Dissolution finger in the limestone quarry in Smerdyna (left) and porosity ϕ/ϕ_0 obtained in simulation for Péclet number $Pe_W = 128$ and Damköhler number $Da_W = 25.6$ (right). Inset shows close-up of the dissolution front.

References

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