DISSOLUTION IN POROUS MEDIA: UPSCALING, INSTABILITIES, AND HETEROGENEITY EFFECTS

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Extended Abstract

Dissolution mechanisms in porous media are of paramount importance in many practical situations. This is the case, for instance, when considering acid injection in reservoirs, or NAPL (Non-Aqueous Phase Liquid) pollutant dissolution in aquifers, salt formation dissolution, …. When trying to model those phenomena, several important theoretical questions must be answered. The major question concerns the possibility of representing by macro-scale equations mass and momentum transfer in such systems. Because dissolution patterns are greatly affected by heterogeneity effects at all scales (pore-scale and small-scale heterogeneities leading to wormholing, large-scale heterogeneities, …) , and because the dissolution process itself leads to transient evolution of the geometrical characteristics of the system, there is a great potential for non-local behavior in space and time.
These questions are reviewed on the basis of recent theoretical, experimental, and numerical evidence. The status of Darcy-Scale and Core-Scale models is discussed based on:

- theoretical arguments using averaging techniques,
- direct numerical simulation of pore-scale and Darcy-scale problems,
- experimental evidence (acid injection, salt dissolution, NAPL dissolution).

Darcy-Scale Model

Darcy-scale models involve most often a dispersion equation with a mass exchange term. The theoretical status of such a macroscopic model is reviewed based on results obtained for the asymptotic regime in a simple case, namely the tube problem, and in a more general case for periodic arrays of particles.

It is shown that Darcy-Scale models have a sufficient potential for reproducing unstable dissolution patterns in porous media (see an example Fig. 1, for heterogeneous porous media), as well as some quantitative characteristics such as the *optimum flow rate* leading to the longest wormhole for a minimum acid consumption. Stability diagrams for the different dissolution patterns (stable front dissolution, conical wormhole, wormhole, ramified wormhole, stable uniform dissolution) have been obtained numerically using the Darcy-scale model, in the case of homogeneous media.

Core-Scale Models

Core-scale models are built through cross-section averages of numerically obtained dissolution patterns. Based on numerical results and theoretical arguments, the possible features of large-scale models is investigated. In particular, one-equation and two-equation models are considered, and effective properties estimated from numerical experiments. The discussion shows that “intrinsic properties” may be expected to some extent for some dissolution regimes, but that historical effects might be important for other regimes.

Impact of heterogeneities

Finally, a weak solution to the problem of the impact of large-scale heterogeneities on dissolution models is presented in the case of NAPL dissolution.

Figure 1. Example of dissolution structures in heterogeneous porous media

References

Golfier, F., C. Zarcone, B. Bazin, R. Lenormand, D. Lasseux, and M. Quintard. 2002. On the ability of a Darcy-scale model to capture wormhole formation during the dissolution of a porous medium. Journal of Fluid Mechanics **457**:213-254.

Golfier, F., M. Quintard, and S. Whitaker. 2002. Heat and mass transfer in tubes: An analysis using the method of volume averaging. Journal of Porous Media **5**:169-185.