

Dynamics of precipitating injection fronts inside of structured medium

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Recent study on a slow earthquake elucidates that the migration of water within a mantle wedge may play relevant roles[1]. The flow inside of confined geometry, such as within a soil, is often described by the Darcy's law, where flow velocity is described by the gradient of fluid pressure. Interestingly, however, the water within a mantle wedge contains large amount of solid contents, and hence, a precipitation can be formed within the water[2]. For this reason, the dynamics of fluid flow under the effect of precipitation reaction should be explored.

Based on the above motivation, we explored the 2-dimensional confined chemical garden[3] as an analogue experiment for the fluid flow within a mantle wedge[4]. The system consists of two fluids with a quasi-two dimensional thin cell, so called a Hele-Shaw cell. The cell was filled with a fluid, and the other fluid is injected from the center of the cell. The flow in a Hele-Shaw cell can be described by the Darcy's law. Furthermore, the mixing of these fluids leads to the precipitation. Thus, the flow observed in 2-dimensional confined chemical garden system is analogous to the one of water in a mantle wedge with precipitation formation.

Our previous study[4] showed that a filamentous pattern appears when the injection speed is high enough, whereas the symmetrical circular front was formed for lower injection speed. This results indicates that the propagation radius of injection front can be drastically different depending on the injection speed. In addition, the number of moving filaments saturate whose value is proportional to the injection speed. Such tendency can be understood with our boundary model adopting the effect Laplace pressure and the conservation of precipitation at the boundary. The model further predicts existence of optimal curvature for the moving front with which the required pressure for the motion is minimum. The curvature, and the speed of the optimal boundary motion is independent of the injection speed. These experimental and theoretical study thus worked well in the 2-dimensional Hele-Shaw cell. However, actual condition in a mantle wedge should have quenched structure, which is absent in a Hele-Shaw cell.

In order to fill the gap between actual condition in a mantle wedge and our analogue experiments, we modified our Hele-Shaw cell to have periodic pillar structure. As a control parameter, we changed the pillar to pillar distance, w , as shown in attached figure. The filament pattern showed meandering motion without pillar structures ($w = \infty$). We found that the filament pattern showed straight motion especially when w agreed with the typical filament width. Our modified mathematical model adopting nonlinear response of permeability with precipitation density numerically reproduced such experimental results. This results indicates that the propagation distance of injected fluid can be modified by the locally quenched disorder within a mantle wedge.

In this paper, we show detailed setup for experiments, as well as mathematical model.

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