Abstract

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Density-driven convection and reactive solute transport in saturated porous media are present in many hydrogeological processes. Typical examples include the groundwater salinization in carbonate-rock aquifers and the acid treatment of oil wells in petroleum drilling industry. In this thesis, the classical Elder problem of density-driven flow in a two-dimensional porous medium is extended to include the local chemical interactions between the solute in the liquid phase and the solid mineral structure of the porous medium. Effects of the geochemical processes on the flow and mass transport are investigated. In the weakly reactive and convective case, analytical solutions for the streamfunction and concentrations of the solute, minerals and products are derived using Fourier and Laplace transforms. For the reactive and strongly density-driven case in the regime dominated by the diffusive mass transport, a decrease in the net solute concentration is found as compared to the non-reactive case. This decrease is pronounced at higher values of the Damköhler number when the solute reaction rate becomes larger than the solute diffusion rate. Furthermore, the flow structure is affected by products generated by the chemical reaction when the Rayleigh number for the products is sufficiently high. In this case, numerical simulations show the formation of diluted fluid tongues exhibiting damped periodic oscillations. The numerical results are obtained using the pseudospectral method, verified against the analytical solution for the non-reactive and purely diffusive case.

Keywords: Elder problem, density-driven convection, porous medium, reactive infiltration, oscillatory convection