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Numerical simulation of CO_2 natural convection in heterogeneous porous formations
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Geologic storage of carbon dioxide (CO_2) could be a solution to the problem of global climate change. Geologic sequestration of CO_2 is the direct injection of carbon dioxide in the compatible deep saline aquifers for long term storage. Before site scale investigations are conducted, numerical simulations play important roles to evaluate the capability of geologic disposal of CO_2. This study employed TOUGHREACT simulator with an equation of state package, called ECO2N, to simulate the migration of dissolved CO_2 plume in heterogeneous saline formations. The ECO2N module is calculated to handle two-phase (liquid, gas), three-component (water, salt and CO_2) system in the pressure- temperature regime above the critical point of CO_2. The density of dissolved supercritical CO_2 is larger than that of saline water and will lead to the migration of liquid phase CO_2 downward due to the gravitation-driven force. On the early stage of a CO_2 injection, the speed of natural convection is typically faster than diffusion of CO_2 molecules so that the convection may control the liquid CO_2 migration and then enhance the dissolution rate. This work presents a preliminary study for modeling the natural convection of CO_2 sequestration in heterogeneous saline formation in a finite two-dimensional domain. The objective of this study is to evaluate the effect of different degrees of geologic variability on the natural convection. With a minor modification of TOUGHREACT model, we can incorporate the random field generator with ECO2N module and evaluate the uncertainty influenced by the formation variability. The simulation results show that during the simulation time period, due to the heterogeneity, the liquid CO_2 was more easily pass through highly permeable region, but to be up in lower permeable region which have more carbon dioxide dissolution in this part. The convection in the heterogeneous case is sooner than in a homogeneous case with the same effective permeability for dissolved CO_2. The dissolution rate of carbon dioxide in heterogeneous media was larger and sooner than in homogeneous media, and the structure of permeability filed has different way to strongly dominate the convective effect for low, moderate and large heterogeneity, respectively. To understand the natural convection behavior of carbon dioxide, the effect of permeability is the leading condition to familiar with it.

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