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The role of temperature on non-Darcian flows in engineered clay barriers

PI: Cheng Chen, Virginia Tech

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Collaborators: Rui Qiao, Virginia Tech

Yifeng Wang, Sandia National Lab

ABSTRACT:

In low-permeability porous media, such as clay and shale, a certain hydraulic gradient is required to overcome the binding energy between water molecules and solid surface to trigger water flow, which leads to a nonlinear relationship between water flux and pressure gradient. This behavior is referred to as non-Darcian flow. Non-Darcian flows have important implications to geologic disposal of high-level nuclear waste, because shale has been proposed as a disposal medium with compacted bentonite as a buffer material. Non-Darcian flows can occur in both geologic barrier (shale) and engineered barrier (bentonite clay) systems. Consideration of the impact of temperature on non-Darcian flow in an engineered clay barrier is necessary, because the clay barrier can be subject to significant temperature changes resulting from the heat-releasing nuclear waste package. Unfortunately, experimental data with respect to the role of temperature on non-Darcian flows are extremely rare. The proposed project aims to develop a predictive continuum-scale flow model to facilitate experimental data interpretation and provide mechanistic insights into the role of temperature on non-Darcian flows in low-permeability engineered clay barriers (Aim R1), conduct experiments over a wide range of temperatures to unravel the role of temperature on the threshold gradient of non-Darcian flow in both saturated and unsaturated bentonite (Aim R2), and use molecular dynamics (MD) simulations to obtain fundamental understanding of non-Darcian flow and its dependence on temperature and mineral-water interfacial chemistry (Aim R3). The experimental data, associated with the MD simulation, will provide valuable information to improve fundamental understanding and scientific knowledge with respect to the temperature dependence of threshold gradient in non-Darcian flows, because very limited experimental data are available for saturated flow and no experimental data are available for unsaturated flow. They are also able to support the exploration and characterization of the predictive continuum-scale model, which can provide reliable model inputs for coupled thermal-hydrological-mechanical (THM) simulations for bentonite clay buffers.