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Effect of pore structure on gas trapping in porous media

Sadjad Mohammadian, Helmut Geistlinger, and Hans-Jörg Vogel
Helmholtz Centre for Environmental Research, Department of Soil Physics, Halle (Saale), Germany

Capillary trapping of nonwetting phase in porous media plays an important role in many geological processes. For example, large portions of hydrocarbons cannot be extracted from reservoirs due to capillary forces, while in carbon sequestration processes; capillary trapping might improve the storage efficiency. An important case is when the wetting phase (mostly water) displaces a low-viscosity low-density fluid. In such cases, like water encroachment into gas reservoirs or rising of water table in soils, competition of gravity, viscous, and capillary forces determines the final configuration of the fluids in invaded zone. The trapped nonwetting phase and its distribution within the porous media will affect many other processes such as flow of the other fluids and mass transfer phenomena. Thus, investigating the parameters affecting phase trapping and distribution, especially their relation to pore structure, which controls the capillary action, is required. The aim is to predict gas trapping from structural properties of the material.
We conducted a series of column experiments, in which water displaces air at a range of flow rates in different glass-bead packs. The final 3D configuration and morphology of fluids was observed using X-Ray Computed Tomography (CT). We extracted 3D structure of porous media as well as of the trapped gas phase, and quantified them in terms of volume ratios, interfacial area, and morphology. Then we investigated the relations of the trapped phase to capillary forces (pore structure) and viscous forces (front velocity). The results give us new insights to explore the flow and dissolution processes: We found no systematic dependency of the front velocity of the invading water phase in the velocity range from 0.1 to 0.6 cm/min what corresponds to capillary numbers from 2 to 12 $\times 10^{-6}$. Our experimental results indicate that the capillary trapping mechanism is controlled by the local pore structure and local connectivity and not by thermodynamics, i.e. large pores are occupied first by the gas phase.