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Numerical Generation of Dense Plume Fingers in Saturated Homogeneous Porous Media

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In nature, the migration of dense plumes typically results in the formation of vertical plume fingers. Flow direction in fingers is downwards, which is counterbalanced by upwards flow of less dense fluid between fingers. In heterogeneous media, heterogeneity itself is known to trigger the formation of fingers. In homogeneous media, however, fingers are also created even if all grains had the same diameter. The reason is that pore-scale heterogeneity leading to different flow velocities also exists in homogeneous media due to two effects: (i) Grains of identical size may randomly arrange differently, e.g. forming tetrahedrons, hexahedrons or octahedrons. Each arrangement creates pores of varying diameter, thus resulting in different average flow velocities. (ii) Random variations of solute concentration lead to varying buoyancy effects, thus also resulting in different velocities.

The objective of the present paper is to introduce and evaluate methods that incorporate pore-scale heterogeneity into homogeneous systems such that dense fingers are generated realistically. Each method is evaluated by numerically re-simulating a laboratory-scale experiment of plume transport in homogeneous saturated sand (Simmons et al., Transp. Porous Media, 2002). The following 6 methods are being discussed: (i) homogeneous sand, (ii) initial perturbation of solute concentration, (iii) spatially random, time-constant perturbation of solute source, (iv) spatially and temporally random perturbation of solute source, (v) spatially and temporally random noise of simulated solute concentration, and (vi) random K-field that introduces physically insignificant but numerically significant heterogeneity.

Results show that methods (iii) to (vi) realistically reproduce the number of fingers observed in the laboratory experiment. Future work will focus on the numerical generation of dense fingers in unsaturated homogeneous sand.