Exchange flow across faults

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A layered reservoir intersected by a conductive fault can have exchange flows across the fault if the upper reservoir contains denser fluid. We aim to produce reliable criteria for the exchange rate and the displacement type of fluids as a function of fault and fluid properties.

In many numerical studies of fluid behaviors in a faulted reservoir, faults appear as one-dimensional features on a two-dimensional cross-section. However, the one-dimensional fault models cannot capture unstable exchange flows that will determine the rate of leakage. Therefore, it is critical to conduct experimental and numerical studies based on three-dimensional fault models.

Our hypothesis will be addressed in two complementary ways. First, laboratory experiments will systemically explore exchange flows across permeable faults connecting upper and lower aquifers. The model consists of two source tanks which are connected by one or more bead-packed pipes representing connecting faults. The main parameters are density and viscosity ratios of the fluids, permeability of faults and number of faults. We will investigate the spatial distribution of fluid fingers using dyed solutions and measure the volumetric flux cross the fault from mass changes in the lower tank. Second, we will develop mathematical and numerical models to verify the experimental data and derive criteria for the exchange rate and the type of displacement.

This study is motivated by geological CO_2 storage, but the unstable exchange of two fluids across faults is also important in other geological and engineering applications, especially in the hydrocarbon migration and the fluid flow in sedimentary basins.