Abstract Submitted
for the DFD12 Meeting of
The American Physical Society

Nonlinear Taylor dispersion in gravity currents in porous media

MICHAEL SZULCZEWSKI, RUBEN JUANES, Massachusetts Institute of Technology — Taylor dispersion describes how a non-uniform flow can accelerate diffusive mixing between fluids by elongating the fluid-fluid interface over which diffusion acts. While Taylor dispersion has been extensively studied in simple systems such as Poiseuille and Couette flows, it is poorly understood in more complex systems such as porous-media flows. Here, we study Taylor dispersion in porous media during a gravity-driven flow using theory and simulations. We consider a simple geometry for physical insight: a horizontal, confined layer of permeable rock in which two fluids of different densities are initially separated by a vertical interface. We show that the flow exhibits a non-uniform velocity field that leads to Taylor dispersion at the aquifer scale. Unlike the classical model of Taylor dispersion, however, the diffusive mixing is coupled to the flow velocity because it reduces the lateral density gradient that drives the flow. This coupling causes the flow to continually decelerate and eventually stop completely. To model the flow, we develop a non-linear diffusion equation for the concentration of the more dense fluid, which admits an analytical similarity solution. We discuss applications of the model to CO_2 sequestration.

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Date submitted: 01 Aug 2012 Electronic form version 1.4