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Solute transport through a fracture with significant density effects and short of the asymptotic Taylor regime

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Contaminant transport in heterogeneous fractured aquifers occurs mostly through the networks of intersecting fractures. Solute transport through individual fractures is often studied considering a continuous inflow of solute. Here we investigate the spreading and mixing of a finite amount of solute entering a fracture of constant aperture and with no significant wall roughness. The shearing induced by contact conditions at the fracture walls creates a dramatic spreading of the solute cloud, which is at the same time broadened through micro-dispersion. After a long time, this process leads to the well-known Taylor dispersion regime, in which the solute progresses along the fracture according to a one-dimensional advection-dispersion equation, at an average velocity identical to the average velocity of the fluid. In the configuration addressed by us, the observation time ranges from the injection time to the time characteristic of the asymptotic regime. We analyze solute concentration fields obtained either through two-dimensional finite element simulations, or from data recorded on an analog experimental setup, and characterize their longitudinal spreading in time, as well as the solute mixing/dilution, using horizontal centered local second moments and the corresponding horizontal effective concentration fields (following Dentz and Carrera, *Phys. Fluids*, **19**, 2007). The significant density/buoyancy effects present in the experimental data are observed to delay the evolution towards the asymptotic regime. Finite element numerical simulations in which flow- and transport- equations are coupled through the relation between fluid buoyancy and solute concentration provide an explanation to this experimental observation. Thus, buoyancy effects impact solute transport in fracture even in the absence of fracture wall roughness.