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Characterizing Subcore Heterogeneity: A New Analytical Model and Technique to Observe the Spatial Variation of Transverse Dispersion

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Transverse dispersion, the lateral spread of chemical components in an aqueous solution caused by small heterogeneities in a rock, plays an important role in spreading, mixing and reaction during flow through porous media. Conventionally, transverse dispersion has been determined with the use of an annular core device and concentration measurements of the effluent (Blackwell, 1962; Hassinger and Von Rosenberg, 1968) or concentration measurements at probe locations along the core (Han et al, 1985; Harleman and Rumer, 1963). Both methods were designed around an analytical model of the transport equations assuming a single constant for the transverse dispersion coefficient, which is used to analyse the experimental data. We have developed a new core flood test with the aim of characterising chemical transport and dispersion directly in three dimensions to (1) produce higher precision observations of transverse dispersion than has been possible before and (2) so that the effects of rock heterogeneity on transport can also be observed and summarised using statistical descriptions allowing for a more nuanced picture of transport than allowed by description with a single transverse dispersion coefficient.

The dispersion of a NaI aqueous solution injected into a Berea sandstone rock core was visualised in 3D with the use of a medical x-ray CT scanner. A device consisting out of three annular regions was used for injection. Water was injected into the centre and outer annular region and a NaI aqueous solution was injected in the middle annular region. An analytical solution to the flow and transport equations for this new inlet configuration was derived to design the tests. The Berea sandstone core was 20 cm long and had a diameter of 7.62cm. The core flood experiments were carried out for Peclet nr 0.5 and Peclet nr 2. At steady state, x-ray images were taken every 0.2 cm along the core. This resulted in a high quality 3D digital data set of the concentration distribution of the NaI aqueous solution at steady state for the different Peclet numbers. The average transverse dispersion coefficient (Dt) was calculated from the change in variance of the transverse distance travelled by the NaI solution along the core. A Dt of 2.396e-04 cm2/min was obtained for Peclet nr 0.5 and a Dt of 4.771e-04 cm2/min for Peclet nr 2. These values coincide precisely with the Dt calculated from the pore scale modelling on Berea sandstone of Bijeljic and Blunt, 2007, and serves as a benchmark demonstrating the utility and repeatability of the technique.

This new technique shows promise for use in characterising average transport characteristics and analysing the impacts of natural rock heterogeneity.

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