Geophysical Research Abstracts
Vol. 14, EGU2012-13768, 2012
EGU General Assembly 2012

Simulation Studies of Effects of Flow Rate, Gravity and Sub-Core Scale Heterogeneities on CO_2/Brine Relative Permeabilities Measurements in Horizontal Corefloods

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This paper presents an assessment of the conditions under which accurate CO_2/brine relative permeability measurements can be obtained from steady-state core floods. Results are based on a combination of high resolution of 3D simulations and core-flooding experiments with X-ray CT scanning of saturation distributions. Effects of flow rate, average core permeability, interfacial tension, boundary conditions, sub-core scale heterogeneity, and gravity over a range of fractional flows of CO_2 are systematically investigated. Synthetic "data sets" are generated using TOUGH2 MP with the ECO_2N module and subsequently used to calculate relative permeability curves based on steady-state relative permeability measurement technique. This steady-state method is obtained the relative permeability data by directly using Darcy's law with measured pressure drop across the core and saturation. A comparison between the input relative permeability curves and "calculated" relative permeability is used to assess the accuracy of the "measured" values.

Results show that for modified capillary number Ncv (by Zhou et al. 1994) smaller than 10, the multiphase flow system is dominated by the viscous force. Under these conditions, saturation depends only on the fractional flow and is independent of flow rate, gravity, permeability and interfacial tension. For modified capillary numbers less than 10, accurate whole-core relative permeability measurements can be obtained regardless of the orientation of the core and for a high degree of heterogeneity under a range of relevant and practical conditions. Importantly, the transition from the viscous to gravity/capillary dominated flow regimes occurs at much higher flow rates for heterogeneous rocks. That means we need to use higher flowrates for heterogeneous cores in order to reach the viscous-dominated regime. For modified capillary numbers larger than 10, gravity effect becomes significant. Saturation gradients develop along the length of the core and accurate relative permeability measurements are not obtained using traditional steady-state methods. However, if capillary pressure measurements at the end of the core are available, or can be estimated from independently measured capillary pressure curves and the measured saturation at the inlet and outlet of the core, accurate relative permeability measurements can be obtained even when there is a saturation gradient.