Geophysical Research Abstracts
Vol. 13, EGU2011-9734, 2011
EGU General Assembly 2011

Verifying the use of Simulations of Core Flooding Experiments to Gain Insight into CO2-Brine Multiphase Flow Interactions

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Numerical simulations are an integral part of studying saline aquifers for CO2 sequestration. They are used to predict injectivity, storage capacity, plume extent, to assess leakage probability and to study geochemical interactions, among other uses. One of the main challenges in using field scale simulations to gain fundamental insight is the amount of uncertainty, particularly with respect to geological properties. One method to increase the degree of confidence in numerical simulations is to use core flooding experiments, coupled with a CT scanner, to demonstrate that numerical simulations can replicate the measured spatial and temporal distribution of CO2 over a range of conditions. After these experiments are conducted, simulations of the core flooding experiment can be used in a predictive manner, and a great deal of fundamental information can be learned about CO2 brine interactions in porous media.

In a typical experiment, pressure, temperature, salinity, injection rate and boundary conditions are all tightly controlled, and a CT scanner is used to map saturation and porosity at the sub core-scale. A low fractional flow of CO2 is introduced into a brine saturated rock core, and it is increased in steps until a fractional flow of one, or 100 percent CO2, is being injected into the core. Using a technique developed in Krause et. al. (2011), permeability is then calculated at the sub core-scale, and simulations of the core flood are conducted. To demonstrate the validity of this method however, this paper shows that the calculated permeability distribution is unique and accurate within the expected experimental error, and can be used predictively.

Two general methods are available to test uniqueness, each of which involves taking saturation measurements at different fractional flows. In the permeability calculation method of Krause et. al. (2011), the measured saturation distribution is used to calculate the permeability distribution. Theoretically, an accurate calculation would result in the same permeability distribution, independent of which saturation map was used as input. We show in this work that the resulting differences in permeability distributions are within the expected experimental error of the CT scanner measurement.

The second method for testing uniqueness is to take a permeability distribution calculated from a single saturation measurement, and show that it can be used to predict measured saturation distributions at other fractional flows. To do this test, simulations of the core flooding experiment at different fractional flows using a single permeability distribution were conducted. The results of these simulations also show that the predicted saturation distributions from simulations are accurate in comparison with the measured distributions within the expected experimental error.

To complete the work, we also conduct a sensitivity study designed to test the scale at which the core is discretized. This is done to test both the effect of scale on the accuracy of the permeability calculation and the ability of the resulting permeability distributions to predict the measured saturation distributions across a range of fractional flows. These simulations introduce some important questions regarding the upscaling of fundamental parameters such as capillary pressure curves when conducting sub core-scale simulations.

Reference:

Krause, M., Perrin, J.-C. and Benson S.M. 2011. Modeling Permeability Distributions in a Sandstone Core for History Matching Coreflood Experiments. SPE Journal, Published Online 7 January 2011.