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Multiphase flow of CO$_{2}$ and water in reservoir rocks at reservoir conditions

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A firm understanding of the multiphase flow properties of CO_2 and water in porous media is essential to predicting the long-term fate of CO_2 in geologic storage. Recently, pilot-scale and simulation based studies have highlighted the importance that properties of relative permeability, residual saturation, and rock heterogeneity will play in determining the long-term distribution of CO_2 in the subsurface[1−3]. There is a clear need for more observations to expand the current dataset of experimental work, as well as an in-depth discussion of these results in the context of the multiphase flow theory that is used in reservoir-scale predictions of subsurface flow.

In this paper we present the results of an experimental investigation into the flow properties of CO_2 and water in 5 distinct rock lithologies: a Berea sandstone and 4 reservoir rocks from formations into which CO_2 injection is either currently taking place or is planned. Drainage and imbibition relative permeability, as well as end-point saturations were measured using the steady-state method in a high pressure and temperature core-flooding apparatus with fluid distributions observed using X-ray computed tomography. In addition, absolute permeability, capillary pressure curves, and petrological studies were performed on each sample to fully characterize the rocks.

The results are discussed in terms of their potential impact on basin-scale modeling of industrial CO_2 injection projects. Theoretical explanations for generally low end-point CO_2 relative permeabilities are discussed as well as its relevance for reservoir simulations. It is shown that small-scale heterogeneity plays an important role in both the overall saturations of CO_2 in a rock as well as the saturation distribution within the rock. Clear evidence of heterogenous flow-properties are observed even in rocks of homogeneous rock lithology. Observations of residual CO_2 saturation are discussed in the context of the long-term stability of CO_2 injected in the subsurface. The experiments are compared with results reported by other laboratories[4]; Similarities are highlighted and differences are discussed in the context of rock types, experimental conditions, and laboratory procedures. Finally, the treatment of parameter inputs used in previous modeling studies is evaluated in the context of these results and some suggestions for making decisions about model inputs in the future are provided.

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