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Multi-Phase Flow and Trapping of CO_2 in Saline Aquifers

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Abstract

Improved fundamental understanding of multi-phase flow and trapping in CO_2-brine systems will be needed to take advantage of the potentially large storage capacity of saline aquifers. The Global Climate and Energy Project is conducting laboratory experiments and theoretical studies of CO_2 transport and trapping in saline aquifers. Results of these studies provide the understanding needed to predict the storage capacity of saline aquifers, the spatial extent of the plume of injected CO_2, the rate of migration during the injection and post-injection periods, and the amount and timing of capillary and solubility trapping. This paper summarizes the results of this work. Taken together these studies of multi-phase flow and trapping can begin to provide a quantitative assessment of the fate and transport of injected CO_2—and how it will evolve over time and depends on the physical and chemical properties of the storage reservoir and seal.

Introduction

Saline aquifers have the largest potential capacity to store CO_2, possibly on the order of 10^4 Gt (billion metric tonnes) CO_2 (IPCC, 2005). If this large capacity is available, it could provide enough capacity for storage of hundreds of years or more of today's CO_2 emission from fossil fuel use. Taking advantage of the large potential storage capacity will require the ability to answer a number of key questions, namely:

- What fraction of the pore volume of the reservoir will be filled with CO_2?
- What will be the size of the plume of injected CO_2?
- Over the entire footprint of the plume, is the seal effective for permanent containment of CO_2?
- How quickly and to what extent will solubility trapping, capillary trapping and mineral trapping immobilize CO_2 in the storage reservoir?
- Will brine displaced by CO_2 migrate out of the storage reservoir into shallow groundwater aquifers used for drinking water?

Answering these questions will require improving fundamental understanding of the complex interplay of viscous and gravity forces, phase behavior, multiphase displacement dynamics, thermodynamic and kinetic controls on rock-brine-CO_2 interactions and basin-scale hydrogeology.

A schematic illustrating the primary processes affecting many of these issues is illustrated in Figure 1. At the pore level, viscous and capillary processes control the distribution of saturation between the wetting (brine) and non-wetting (CO_2) phases. Within the storage reservoir, geologic heterogeneity restricts the flow of both the wetting and non-wetting fluid to the higher permeability strata. Interestingly, for CO_2 storage, the presence of low permeability strata within the storage reservoir may have the beneficial effect of counteracting the effects of buoyancy flow, by locally preventing vertical flow of CO_2. The large density difference between CO_2 (~700 kg/m^3) and brine (~1000 kg/m^3) at typical storage conditions will be on the order of 300 kg/m^3. This large density difference results in strong buoyancy forces, causing the CO_2 plume to rise to the top of the storage reservoir—and bypass potential capacity in the lower portions of the storage reservoir. Finally, if the seal of the storage reservoir is not flat, CO_2 will move asymmetrically, driving CO_2 in the updip direction. The GCEP Project is evaluating all of these processes, at spatial scales from the core scale up to the reservoir scale, and time scales up to thousands of years.