Laboratory Examinations and Numerical Modeling of Geochemical Reactions in a Reservoir Used for CO_2 and Acid Gas Storage

James A. Sorensen,* Anastasia A. Dobroskok, Steven B. Hawthorne, David J. Miller, Yevhen I. Holubnyak, Kurt Eylands, Edward N. Steadman, and John A. Harju

Energy & Environmental Research Center (EERC)
15 North 23rd Street, Stop 9018, Grand Forks, ND 58202-9018

Abstract

The injection of relatively pure supercritical carbon dioxide (CO_2) and supercritical mixtures of CO_2 and H_2S (acid gas) into geological formations has been identified as a means of annually sequestering millions of tons of greenhouse gases in North America. Geochemical reactions of reservoir and cap rocks and their associated formation fluids with CO_2 and/or acid gas can alter petrophysical and mechanical properties of rocks. Moreover, different environments can respond differently to the introduction of high concentrations of CO_2 and/or acid gas The ultimate goal of geochemical laboratory and modeling efforts conducted under the Plains CO_2 Reduction (PCOR) Partnership is to understand how the presence of supercritical CO_2 and H_2S under typical reservoir conditions influences the stability and properties of the system, how much of the injected CO_2 and H_2S remains trapped by mineralization mechanisms, and whether numerical modeling can provide a reliable tool for predicting geochemical behavior of the system. As the first steps in achieving these goals, the PCOR Partnership is conducting laboratory experiments with relatively pure minerals and with both crushed and intact cores of reservoir and cap rock from a variety of locations while, at the same time, running numerical modeling simulations. The set of experiments conducted so far has focused on choosing rocks and minerals that are expected to be reactive with the injectant and then using the modeling to scale up the results to the reservoir level. Minerals evaluated thus far include forsterite (Mg_2SiO_4), anhydrite ($CaSO_4$), magnetite (Fe_3O_4), and dolomite ($CaMg[CO_3]_2$). Rocks examined in the experiments include Madison Group limestone, Bakken Formation shale, Broom Creek Formation sandstone, and Winnipeg Group shale. Results thus far indicate that mineralogical changes may range from negligible to significant, depending on combinations of initial mineralogy, the presence or absence of water, and the nature of the injectant. For example, no conversion of magnesium silicate to magnesium carbonate in supercritical CO_2 was observed without water, but the reaction was complete in two weeks in the presence of water (80°C, 4000 psi). In contrast, in the experiments with supercritical acid gas, conversion of Fe_3O_4 to FeS_2 and FeS occurred in both wet and dry samples (2200 psi, 70°C, 50 mol% CO_2/H_2S). Experimental results will be compared to the results of numerical modeling runs which, in turn, will be used to modify and refine the model and further our understanding of the impact of geochemical reactions on the geological sequestration of CO_2.

Keywords: Geological CO_2 Sequestration, Geochemical Reactions, Geochemical Modeling