CO_2 Sequestration and Enhanced Gas Recovery in Depleted Gas Reservoirs: Quantification of Fundamental Chemical and Mechanical Processes Affecting Flow and Injectivity

Final Report

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13. ABSTRACT (Maximum 200 words)

Apparent global temperature increases associated with increased atmospheric concentration of carbon dioxide has generated tremendous interest in deliberate CO_2 sequestration. Depleted gas reservoirs are a primary candidate for sequestration, because these reservoirs already demonstrate characteristics necessary for long-term gas storage. The primary purpose of this project was to evaluate the possible effects during and after injection of CO_2 in a reservoir. We contend that the primary processes that will affect reservoir injectivity and storage-capacity are (1) chemical precipitation (mineralization) and dissolution processes, and (2) mechanical deformation or rock strain processes, and thus we focused this research project on these two major themes. Results from experimental analyses served to parameterize state-of-the-art coupled reactive flow and deformation/strain numerical model simulations. Interpretations of simulation results provide a foundation for gas-reservoir pilot injection test design. Specifically, model results demonstrate that injected CO_2 plume migration rates are influenced significantly by concomitant mineralization and associated porosity/permeability evolution. Uncertainties in chemical kinetic parameters and heterogeneities in rock and brine composition are significant. Additionally, simulations demonstrate that overpressures induced by high CO_2 injection rates can cause significant rock strain that may severely reduce injectivity and seal integrity. These results and conclusions are being used to develop designs and provide engineering constraints for a pilot CO_2 injection test in a natural gas reservoir.

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Introduction

Many natural gas reservoirs that are considered depleted are possible candidates for carbon storage. Specifically, sequestration of power-plant-produced carbon dioxide (CO_2) in natural gas reservoirs and other geologic formations is one proposed method for isolating anthropogenic CO_2 from the atmosphere. This approach to power-plant emissions management is especially attractive because of in-tandem opportunities for value-added enhanced natural gas recovery.

Both industry and the federal government are interested in determining the viability, risks, and optimal sites for sequestering CO_2 in the subsurface. Depleted gas reservoirs are especially appealing sites because they are otherwise relatively useless, and the value-added opportunity for enhanced gas recovery makes it economically attractive. A primary objective of this project was to evaluate the possible effects during and after injection of CO_2 in a reservoir. Results of the project provide critical information needed for design and engineering of future pilot CO_2 injection tests and long-term sequestration projects.

Work Plan

Major tasks and results of this study include
(1) design and deployment of a new (expanded) laboratory for high pressure and temperature multiphase CO_2-brine flow testing and mechanical testing,
(2) CO_2 reactive flow, transport, and mechanical experimental data and results,
(3) associated simulation results and interpretations,
(4) an analysis of two reservoirs suitable for pilot testing, and
(5) critical physical and chemical process information and recommendations regarding design and engineering of a reservoir pilot test of carbon dioxide injection and sequestration.
These products are currently being integrated into
(6) a multi-institutional proposal to be submitted to the U.S. Department of Energy (DOE). Specifically, during the course of this RPSEA project, the PI developed, submitted, and was awarded a "Phase I" project in the DOE Regional Partnerships for Carbon Sequestration program. In the Phase I Partnership proposal, this RPSEA project was cited as a "seed" project providing necessary research/development information required for the Regional Partnerships Program. Thus, the PI of this RPSEA project is also PI of the Southwest Regional Partnership for Carbon Sequestration, a consortium of 40 entities from industry, government organizations, non-government organizations, and academic institutions. The Phase I proposal gleaned vital support from this RPSEA seed project, and project results are also critical for the Phase II proposal.

Following laboratory equipment acquisition and development, three case-studies were carried out for this project. The first was fundamental in nature, focusing on experimental testing of prototype or standard rock formations with established rock properties, including the Berea sandstone. The purpose of this first case study was to test and calibrate the expanded laboratory system. The other two case studies were site-specific, focusing on two candidate sites for possible long-term sequestration: the Permian Basin of New Mexico, site of a previous CO_2 injection pilot, and the Uinta basin, Utah, site of a potential future pilot. Given the dual chemical – mechanical focus of this project, we focused the Permian Basin case study on chemical processes that may affect long-term storage of the plume injected in that reservoir, and focused the Uinta basin study on possible mechanical processes that may affect CO_2 injectivity and reservoir seal veracity. We originally intended to focus on the San Juan Basin of New Mexico, but core availability information obtained was inaccurate; cores that were available were not suitable for our analyses.