PROJECT facts

Carbon Sequestration

12/2007

U.S. Department of Energy
Office of Fossil Energy
National Energy Technology Laboratory

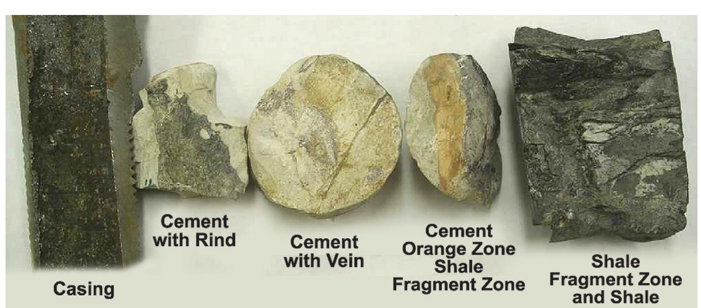
CO_2-Water-Rock Interactions and the Integrity of Hydrodynamic Seals

Background

Developing confidence in methods of sequestering carbon dioxide (CO_2) in geological formations requires an improved understanding of the long-term sealing capacity of both the new and historic wellbore systems designed to prevent fluids from escaping the sequestration reservoir. The primary concern is that the Portland cements used to seal wellbores react readily with CO_2. This has led to the recognition that the long-term integrity of the wellbore seal is a primary performance issue in the geological sequestration of CO_2. The potential effects of CO_2 on cement are varied and depend strongly on the extent of carbonation. Moderate degrees of carbonation can be beneficial to cement porosity, permeability, and strength; extensive carbonation can result in the loss of cement structural integrity. The precise effects in the wellbore environment are difficult to predict because of uncertainties about the nature and extent of CO_2-saturated fluid interaction with the cement. Moreover, there is significant experimental variability in the interpretation of cement durability in the wellbore environment.

Description

A core sample including casing, cement, and shale caprock was obtained from a 30-year old CO_2-flooding operation at the SACROC CO_2-enhanced oil recovery unit, located in West Texas (assistance from Kinder Morgan CO_2 Company, L.P., is gratefully acknowledged). The core was investigated as part of a program to evaluate the integrity of Portland-cement based wellbore systems in CO_2-sequestration environments. The core sample mineralogy and chemistry were characterized by quantitative X-ray diffraction, X-ray fluorescence, and scanning electron microscopy. Carbon and oxygen stable isotope data were obtained by phosphoric acid dissolution of solids. Computer modeling of cement degradation was conducted with the reactive transport code FLOTRAN.



Samples recovered from West Texas SACROC Unit Well 49-6

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PROJECT DURATION

02/10/2004 to 09/30/2008

COST

Total Project Value

$1,550,000

DOE/Non-DOE Share

$1,550,000 / $0

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Primary Project Goal

The key performance questions for geologic sequestration sites are centered on the fate of the CO_2 plume (i.e., whether the plume can migrate beyond the caprock seal) and on the integrity of the caprock. The objective of this project is to investigate caprock integrity issues with experimental and modeling investigations of the most obvious potential weak points: boreholes that perforate the caprock and the behavior of naturally occurring or induced fractures.

Objectives

- Determine the mode of CO_2 interaction with cement
- Develop a model of changes in effective cement permeability as a function of CO_2 reaction
- Determine the initial conditions of interfaces (width, porosity, effective permeability)
- Determine initial drive (diffusion, buoyancy, capillary, gradient)
- Calculate the changes in interface permeability
- Ultimately, couple these results with geomechanics
- Determine how the two-phase system affects reaction rates

Benefits

In order for geological carbon sequestration to be effective in mitigating atmospheric CO_2, the CO_2 must remain in the formations. This study will help determine how well the wellbore and caprock seals resist chemical degradation by supercritical and aqueous CO_2.

Accomplishments

The core sample showed that for this particular well:

- Recovered core demonstrates that Portland cement can survive decades in a CO_2 environment and continue to provide a hydrologic seal
- The most significant potential pathways for CO_2 are along the casing-cement and cement-caprock interfaces
- Experiments and observations indicate that the evolution of these interfaces is governed by competing processes of cement dissolution and carbonate precipitation with precipitation processes evident at SACROC
- Numerical models have been developed that successfully reproduce the carbonation reactions observed at SACROC and provide a preliminary basis for performance calculations
- Experiments of two-phase flow along cement-casing interfaces show potential for reduced permeability due to carbonate precipitation

Planned Activities

- Characterization studies of samples from analog sites
- Analog field samples, such as the West Texas SACROC unit core, will be studied to examine the effect of CO_2 and brine on key components of the geologic sequestration storage system. The work may include both analytical (e.g., scanning electron microscopy, stable isotope analysis, porosity, permeability) and experimental studies.
- Experimental studies of CO_2 flow and reaction under simulated wellbore conditions
- Development of 2-D numerical models of CO_2 reactive transport within wellbore systems