the ENERGY lab

PROJECT FACTS

Carbon Storage

Geomechanical Simulation of CO_2 Leakage and Caprock Remediation

Background

Through its core research and development program administered by the National Energy Technology Laboratory (NETL), the U.S. Department of Energy (DOE) emphasizes monitoring, verification, and accounting (MVA), as well as computer simulation and risk assessment, of possible carbon dioxide (CO_2) leakage at CO_2 geologic storage sites. MVA efforts focus on the development and deployment of technologies that can provide an accurate accounting of stored CO_2, with a high level of confidence that the CO_2 will remain stored underground permanently. Effective application of these MVA technologies will ensure the safety of geologic storage projects with respect to both human health and the environment, and can provide the basis for establishing carbon credit trading markets for geologically storing CO_2. Computer simulation can be used to estimate CO_2 plume and pressure movement within the storage formation as well as aid in determining safe operational parameters; results from computer simulations can be used to refine and update a given site's MVA plan. Risk assessment research focuses on identifying and quantifying potential risks to humans and the environment associated with geologic storage of CO_2, and helping to ensure that these risks remain low.

Project Description

This three-year project—performed by Missouri University of Science and Technology in partnership with City Utilities of Springfield (Missouri)—is coupling a reservoir model with geomechanical modeling to simulate caprock leakage for the City Utilities of Springfield's geologic CO_2 storage demonstration site. Materials and methods for stopping leakage through the caprock will be examined and tested under elevated stresses to simulate in-situ conditions (Figure 1). The approach is designed to be applicable to other types of CO_2 injection sites, including deep saline aquifers. If the tests are successful, a second phase of the project will simulate the effect of fracture-filling materials on fracture flow and growth. This project is expected to help those responsible for MVA of CO_2 to identify and focus on areas of high future leakage risk potential, in order to stop possible eventual leakage through seal fractures and faults.

Goals/Objectives

The primary objective of the DOE's Carbon Storage Program is to develop technologies to safely and permanently store CO_2 and reduce Greenhouse Gas (GHG) emissions without adversely affecting energy use or hindering economic growth. The Programmatic goals of Carbon Storage research are: (1) estimating CO_2 storage capacity in geologic formations; (2) demonstrating that 99 percent of injected CO_2 remains in the injection zone(s); (3) improving efficiency of storage operations; and (4) developing Best Practices Manuals (BPMs).

The main goal of this project is to develop a novel approach to simulate caprock leakage—and simulate the success of remediation of leakage paths—for a shallow CO_2 injection site through coupled reservoir and geomechanical modeling. The simulation

CONTACTS

John Litynski
Carbon Storage Technology Manager
National Energy Technology Laboratory
626 Cochrans Mill Road
P.O. Box 10940
Pittsburgh, PA 15236-0940
412-386-4922
john.litynski@netl.doe.gov

William J. O'Dowd
Project Manager
National Energy Technology Laboratory
626 Cochrans Mill Road
P.O. Box 10940
Pittsburgh, PA 15236-0940
412-386-4778
william.odowd@netl.doe.gov

Runar Nygaard
Principal Investigator
Missouri University of Science and Technology
129 NcNutt Hall
Rolla, MO 65409
573-341-4759
nygaardr@mst.edu

PARTNERS

City Utilities of Springfield (MO)

PROJECT DURATION

Start Date	**End Date**
10/01/2009	09/30/2012

COST

Total Project Value

$1,173,374

DOE/Non-DOE Share

$917,604 / $255,770

PROJECT NUMBER

DE-FE0001132

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and remedial technology will aid in accomplishing NETL's goal of having technologies developed that can aid in accounting for 99 percent CO_2 storage permanence in the subsurface for geologic carbon storage sites. The specific objectives are to:

- Develop a detailed three-dimensional (3-D) shared-earth model, including in-situ stresses, rock, and geomechanical properties, to use as a consistent data set with coupled reservoir and mechanical simulations.
- Develop the methods to perform a more geologically correct, explicit, coupled 3-D reservoir and multiscale geomechanical simulation approach using existing commercial software, and conduct simulations on a detailed shared-earth model for the City Utilities of Springfield's CO_2 storage demonstration site.
- Develop remediation methods for sealing fractures and faults if a leak through the caprock occurs, and develop modeling capabilities for evaluating the success of fracture remediation. This work will include laboratory experiments into fracture flow and deformation characteristics after various fracture remediation techniques have been applied.

Accomplishments

- Shared earth models for four potential Missouri injection sites have been developed and populated with geological, petro-physical and geomechanical data. The injection horizon considered is the Lamotte sandstone formation which is directly overlaying the basement rocks. Results from reservoir simulations show that well placement and brine withdrawal is imperative to consider for shallow storage sites to obtain required injection volumes.
- A coupled fluid flow and geomechanical modeling approach has been developed. The model is capable of mapping different grid geometries, populating finite difference and finite element models with corresponding data, detecting plastic deformations, and modeling formed/reactivated fractures in cap rock.
- The coupled simulation includes a sealant fracture permeability model which expands the simulation approach to include the fracture leakage remediation methods for sealing fractures and faults. Two main remediation approaches were investigated. In the first, the sealant material is delivered directly by drilling a well into the failed area (created by the CO_2 injection causing faults or fractures to occur). In the second approach the delivery of the sealant material is with the CO_2 injection stream. In this scenario the sealant will follow the CO_2 flow into the leakage zone and seal off the fracture at arrival. The modeling indicates that the sealant arrival time is highly dependent on the reservoir boundaries. A change of reservoir boundaries from closed to semi-open boundaries (that would occur when brine is produced to reduce pressure buildup in the formation) decreased the sealant arrival time several orders of magnitude.
- The stability evaluation of the fracture sealing materials showed that a polymer gel remains stable when exposed to CO_2 but not micro cement where carbonation will occur. Investigation of four sealant materials (paraffin wax, silica based gel, polymer based gel, and micro-cement) indicated that all four materials significantly reduce fracture permeability. However gels and paraffin wax developed worm holes when large differential pressures were applied. Based upon the experimental results micro-cement is recommended for fractures over 0.5 mm. A better approach to seal off fractures could be to inject micro-cement as a primary fracture filling material with polymer gel injected as a secondary fracture filling material to avoid CO_2 getting in contact with the cement.

Benefits

As carbon capture, utilization, and storage (CCUS) capacity increases and projects become commercial beyond 2020, the importance of accurate geologic models and robust risk assessment protocols will become increasingly important to project developers, regulators, and other stakeholders. NETL's Carbon Storage Program aims to continue improvements to the models and risk assessment protocols. Specific goals within the Simulation and Risk Assessment Focus Area that will enable the Carbon Storage Program to meet current programmatic goals are to (1) validate and improve existing simulation codes which will enhance the prediction and accuracy of CO_2 movement in deep geologic formations to within ± 30 percent accuracy, (2) validate risk assessment process models using results from large-scale storage projects to develop risk assessment profiles for specific projects, and (3) develop basin-scale models to support the management of pressure, CO_2 plume, and saline plume impacts from multiple injections for long-term stewardship in major basins of the United States.

This project pursues a novel simulation approach that will improve leakage detection by developing a better predictive tool for where and when leakage might occur. This tool will enable those responsible for MVA of CO_2 to identify and focus on areas of high leakage risk potential. The project also addresses another important issue: how to stop possible leakage through seal fractures and faults. This will help to meet NETL Storage Division's goal to ensure storage permanence in the subsurface.

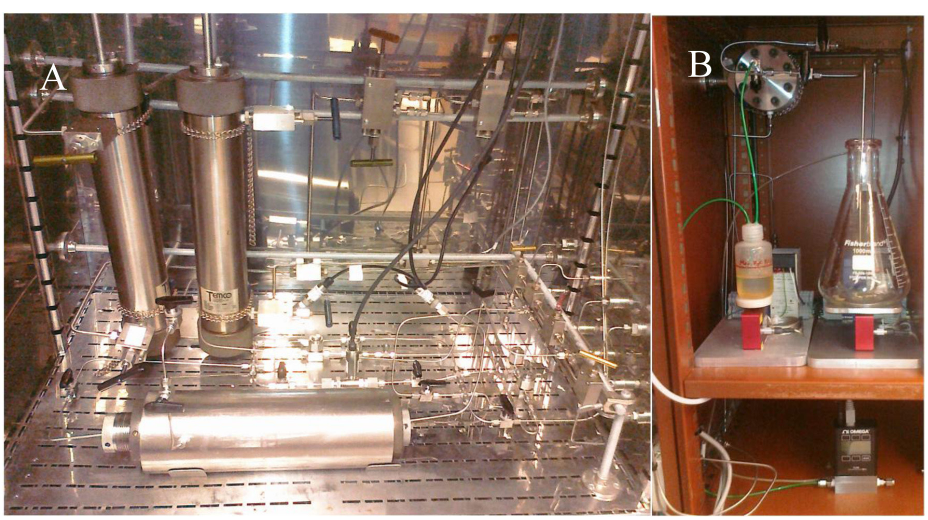

Figure 1. High pressure and high temperature fractured core flow apparatus developed for simulating sealing of fractures. A) The core holder and injection fluid accumulators are mounted inside a constant temperature air bath. B) Liquid and gas separation beaker and flow measurement devices are shown.