PROJECT
facts

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

Carbon Sequestration

4/2008

Development of Novel Monitoring Tools for Geologic Sequestration

Background

The main goal of the U.S. Department of Energy's (DOE) Carbon Sequestration Technology Roadmap is to "develop, by 2012, fossil fuel conversion systems that offer 90 percent CO_2 capture with 99 percent storage permanence at less than a 10 percent increase in the cost of energy services." To ensure 99 percent storage permanence, the current monitoring, mitigation, and verification (MMV) technologies must be advanced to be able to locate and quantify the CO_2 within a storage reservoir. If leaks do occur, they will need to be detected from above the storage reservoir (from the reservoir to the surface). However, current methods cannot achieve these metrics. For example, although seismic imaging shows promise for detecting CO_2 plumes, conventional approaches cannot sufficiently quantify the CO_2 content in large plumes. Field experience with enhanced oil recovery (EOR) and several large sequestration efforts (e.g., Sleipner and Weyburn projects) demonstrate clearly that seismic images are sensitive to the presence of injected CO_2, allowing rough delineation of plumes. Furthermore, seismic studies at small CO_2 test injections (e.g., Frio and Hobbs) demonstrate that seismic reflection is sensitive to plumes as small as a few thousand tonnes. However, this does not mean that seismic imaging can currently quantify a large plume to a precision of a few thousand tonnes.

Primary Project Goal

The primary focus of the current effort is to address specific monitoring challenges as opposed to specific monitoring technologies. These challenges will include:

- Quantifying and attributing stored CO_2 within a reservoir
- Quantifying and attributing stored CO_2 outside the reservoir
- Detecting CO_2 movement within and through a storage reservoir
- Detecting potential CO_2 flow paths
- Improving the accuracy of CO_2 seepage detection to better than 80 percent, and
- Improving the detectability of physical or chemical changes in rock matrices to better than 60 percent.

CONTACTS

Sean Plasynski
Sequestration Technology Manager
National Energy Technology Laboratory
626 Cochrans Mill Road
P.O. Box 10940
Pittsburgh, PA 15236-0940
412-386-4867
sean.plasynski@netl.doe.gov

Darin Damiani
Project Manager
National Energy Technology Laboratory
3610 Collins Ferry Road
P.O. Box 880
Morgantown, WV 26507
304-285-4398
darin.damiani@netl.doe.gov

Melissa Fox
Program Manager
Office of Fossil Energy & the Environment
Los Alamos National Laboratory
P.O. Box 1663, MS C331
Los Alamos, NM 87545
505-665-5377 mami@lanl.gov

Objectives

The object of this research program is to quantify CO_2 within and leaking from geological storage reservoirs. The research aims to target the CO_2 storage reservoir and the soil surface to advance MMV tools to better assess CO_2 impacts to and leaking from a reservoir. Specifically, both direct and indirect CO_2 detection tools will be integrated to provide a high temporal and spatial resolution of CO_2 seepage at the soil surface and ultimately supply information regarding the mechanism of seepage. Novel seismic and acoustic imaging analyses will be performed to characterize the location of the CO_2 plume and determine any structural (caprock fracture) or chemical (mineralization or precipitation) changes to the storage reservoir. These MMV technologies will be advanced to better quantify the storage permanence of CO_2 within a storage reservoir. The research will be conducted in three phases.

Phase 1 consists of laboratory and modeling work to create in situ MMV systems. The primary objectives of this phase are to 1) create surface CO_2 detection systems that can operate and accurately detect CO_2 with high precision in varying environmental conditions (rain, snow, variable temperatures, pressures, and humidity); and 2) to create geophysical systems that can detect subsurface physical and chemical features through the coupling of P-P, P-S, S-P, and S-S waveforms.

Phase 2 consists of field deployment of MMV in situ systems and integration of data. The primary objectives of this phase are to 1) deploy the indirect and direct CO_2 analyzers collectively at a natural analog and an engineered CO_2 storage site once the in situ systems are shown to work in varying meteorological conditions; 2) determine the detection limits and sensitivity of the surface CO_2 detection tools in varying meteorological conditions; 3) accurately couple the data streams coming from the different MMV tools to temporally resolve and quantify CO_2 seepage in natural and engineered storage systems; and 4) integrate the surface and subsurface data to determine the seepage mechanism.

Phase 3 consists of expanding areas of analyses to large spatial scales. The primary objectives of this phase are to 1) use two-dimensional (2D) geologic models coupled with seismic waveforms collected from regions of known CO_2 storage to better determine CO2 plume characteristics and movement in three dimensions (3D); and 2) test and enhance laser systems to perform remote sensing of CO_2 in challenging field conditions.

Accomplishments

Novel monitoring systems that can detect CO_2 seepage at the soil surface have been engineered, tested in the laboratory, and are now being fitted for field deployment. The specific tools that have been created to detect CO_2 seepage are oxygen (O_2)/CO_2 measurement systems, radon (^{222}Rn) detectors – able to measure small amounts of ^{222}Rn continuously and used as a surrogate for advective flow, and portable stable isotope detectors of CO_2 that can be used for in situ analyses (high temporal resolution at one point location) and remote analyses (large spatial coverage over a field). The project has also created seismic imaging analyses using P- and S-waveform analyses to identify faults in modeled scenarios. The research will be expanded to real case studies of fault systems and engineered storage sites that will actively pump CO_2 down hole to image CO_2 plume movement and also faults in caprock.

Current accomplishments include:

- Creation of an in situ stable isotope analysis system
- Deployment of a ^{222}Rn system into the field and meteorological impact of the ^{222}Rn background (Figure 2)
- Creation of an O_2/CO_2 concentration system and laboratory testing of this system using standards
- Creation of a remote stable isotope analysis system and laboratory testing using standards, and
- 2D and 3D analyses of P- and S-waveforms used to detect faults in the subsurface using synthetic analyses on model generated faults (Figure 3).

Benefits

If this project is successful, it should be possible to quantify the surface CO_2 leakage over large spatial (100 m this year, as high as 1 km in future years) and temporal scales (1 second resolution), detect and locate caprock fractures, and detect and locate chemical changes within the reservoir rock over large spatial scales. The use of these new tools will help enable the 99 percent storage permanence that is targeted in the 2007 DOE Carbon Sequestration Technology Roadmap.   The project will create an MMV tool set, assess multiple potential technologies or approaches, and prioritize research directions dynamically based on a specific pathway's likelihood of success.

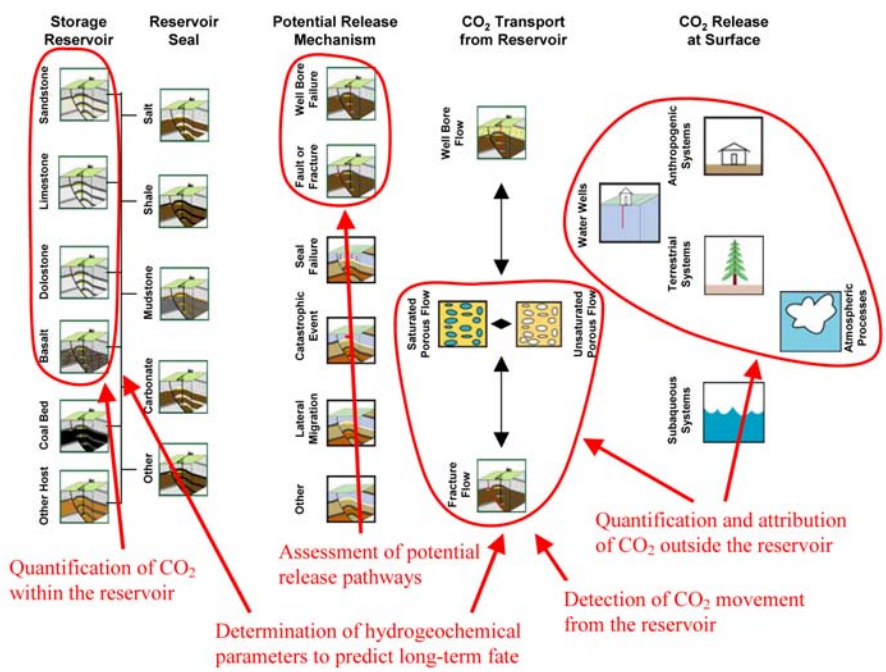

FIGURE 1. Schematic of CO_2-PENS Framework for understanding geologic storage systems and CO_2 release from these systems. Red circles and text indicate the objectives and target areas of this novel monitoring program and how these objectives can map into the DOE Carbon Sequestration Roadmap.

PERFORMANCE PERIOD

07/01/2007 to 06/30/2008

COST

Total Project Value

$900,000

DOE/Non-DOE Share

$900,000 / $0

ADDRESS

National Energy Technology Laboratory

1450 Queen Avenue SW
Albany, OR 97321-2198
541-967-5892

2175 University Avenue South
Suite 201
Fairbanks, AK 99709
907-452-2559

3610 Collins Ferry Road
P.O. Box 880
Morgantown, WV 26507-0880
304-285-4764

626 Cochrans Mill Road
P.O. Box 10940
Pittsburgh, PA 15236-0940
412-386-4687

One West Third Street,
Suite 1400
Tulsa, OK 74103-3519
918-699-2000

CUSTOMER SERVICE

1-800-553-7681

WEBSITE

www.netl.doe.gov

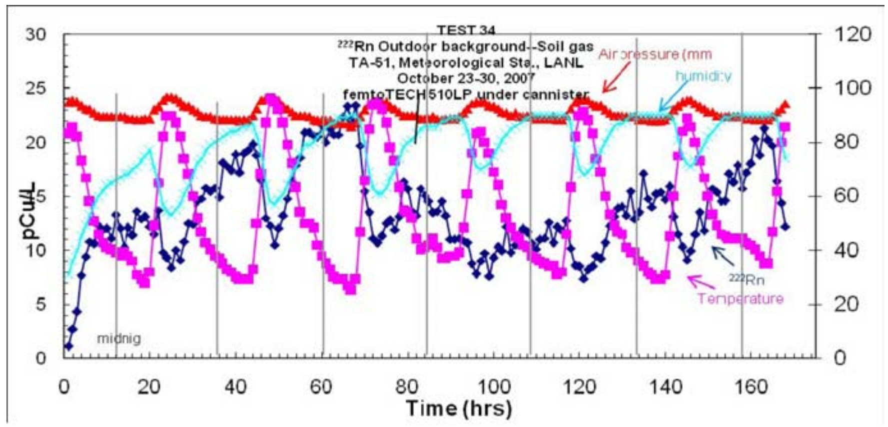

FIGURE 2. ^{222}Rn variation over 8 days in October 2007 at Los Alamos National Laboratory, Technical Area 51. Strong diurnal patterns are observed in the ^{222}Rn and the meteoric variables with highest correlations are observed between the ^{222}Rn concentration and the atmospheric pressure. This indicates that the natural background of ^{222}Rn leaving the soils is effectively pumped out of the soils due to regional winds and pressure highs.

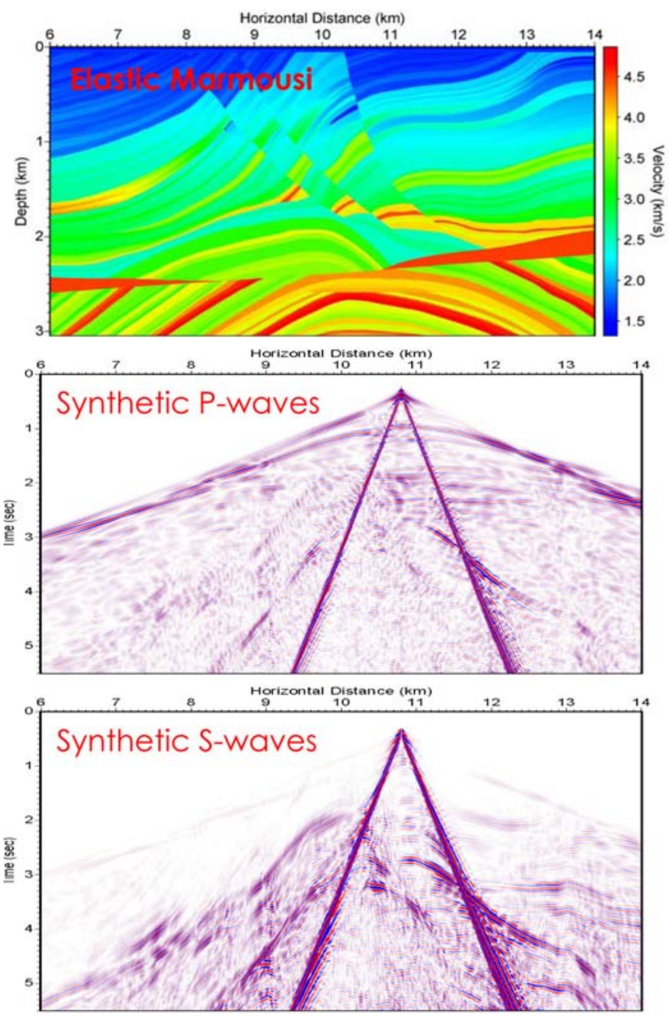

FIGURE 3. Synthetic P- and S-waveforms of the elastic Marmousi model containing three faults. These waveform analyses (P-wave, S-wave, PS-wave, SS-wave, SP-wave) will be used on known fault systems to image the faults in varying media types. Time-lapse seismic imaging of targeted fault systems will be used to identify faults and monitor potential leakage through faults over time.