the ENERGY lab

PROJECT FACTS

Carbon Storage – ARRA - MVA

Training Toward Advanced 3-D Seismic Methods for CO_2 Monitoring, Verification, and Accounting

Background

The overall goal of the Department of Energy's (DOE) Carbon Storage Program is to develop and advance technologies that will significantly improve the effectiveness of geologic carbon storage, reduce the cost of implementation, and prepare for widespread commercial deployment between 2020 and 2030. Research conducted to develop these technologies will ensure safe and permanent storage of carbon dioxide (CO_2) to reduce greenhouse gas (GHG) emissions without adversely affecting energy use or hindering economic growth.

Geologic carbon storage involves the injection of CO_2 into underground formations that have the ability to securely contain the CO_2 permanently. Technologies being developed for geologic carbon storage are focused on five storage types: oil and gas reservoirs, saline formations, unmineable coal seams, basalts, and organic-rich shales. Technologies being developed will work towards meeting carbon storage programmatic goals of (1) estimating CO_2 storage capacity +/- 30 percent in geologic formations; (2) ensuring 99 percent storage permanence; (3) improving efficiency of storage operations; and (4) developing Best Practices Manuals. Developing and deploying these technologies on a large scale will require a significantly expanded workforce trained in various carbon capture and storage (CCS) technical and non-technical disciplines that are currently underrepresented in the United States. Education and training activities are needed to develop a future generation of geologists, scientists, and engineers who possess the skills required for implementing and deploying CCS technologies.

The National Energy Technology Laboratory (NETL), through funding provided by the American Recovery and Reinvestment Act (ARRA) of 2009, manages 43 projects that received more than $12.7 million in funding that focus on conducting geologic storage training and support fundamental research projects for graduate and undergraduate students throughout the United States. The training and projects can be categorized under one or more of the DOE Carbon Storage Program's five Technology Areas: (1) Geologic Storage and Simulation and Risk Assessment (GSRA), (2) Monitoring, Verification, Accounting (MVA) and Assessment, (3) CO_2 Use and Re-Use, (4) Regional Carbon Sequestration Partnerships (RCSP), and (5) Focus Area for Sequestration Science. This effort is conducting research and training in seismic methods used to monitor CO_2 storage efforts.

CONTACTS

Traci Rodosta
Carbon Storage Technology Manager
National Energy Technology Laboratory
3610 Collins Ferry Road
P.O. Box 880
Morgantown, WV 26507
304-285-1345
traci.rodosta@netl.doe.gov

Karen Kluger
Project Manager
National Energy Technology Laboratory
626 Cochrans Mill Road
P.O. Box 10940
Pittsburgh, PA 15236-0940
412-386-6667
karen.kluger@netl.doe.gov

Christopher Liner
Principal Investigator
University of Houston
3010 Science & Research
4800 Calhoun Road
Houston, TX 77204-5007
713-743-9119
cliner@uh.edu

PARTNERS

Geokinetics
Fairfield

PROJECT DURATION

Start Date	End Date
12/01/2009	05/31/2012

COST

Total Project Value
$331,842

DOE/Non-DOE Share
$299,342/$32,500

PROJECT NUMBER

DE-FE0002186

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U.S. DEPARTMENT OF ENERGY

Project Description

NETL partnered with the University of Houston (Houston) to provide graduate and undergraduate student training related to improved three-dimensional (3-D) seismic technology that addresses key challenges related to monitoring movement and containment of CO_2, specifically better quantification and sensitivity for mapping of caprock integrity, fractures, and other potential leakage pathways. Specifically, the project focus was on fundamental research on (1) innovative narrow-band seismic data decomposition and interpretation, and (2) numerical simulation of advanced seismic data (multi-component, high density, full azimuth data) ideal for mapping of cap rock integrity and potential leakage pathways. Houston utilized data and results developed through previous DOE-funded CO_2 characterization project at the Dickman Field of Ness County, Kansas (Figure 1) as part of this study. In that study, conventional 3-D seismic data was exhaustively interpreted with modern volume attribute technology to detect fractures that could form potential leakage pathways for future geologic storage of CO_2 in similar geologic settings in the U.S. mid-continent. The current project assessed the added benefit of novel and rapidly evolving 3-D seismic land acquisition technology, including three-component (3C) digital sensors, acquisition design that delivers high density full azimuth data, and interpretation of narrow-band (spectral) data volumes.

The training effort was based on the numerical simulation of improved seismic technology that included elastic wavefield simulation. Elastic wave simulation requires compressional wave velocity (Vp), shear wave velocity (Vs) and density to compute elastic response for a layered earth model. Conventional sonic logs provide Vp, and these data were acquired as part of the original Dickman Field Project. The shear wave velocities can be obtained using a full wave sonic log, but no well in the study area has such a log. Therefore, Vs was estimated in order to perform the seismic simulation using local Vp and interpreted gamma ray and electrical potential well logging.

With Vp, Vs, and density models available, elastic simulation can be performed to generate multi-component seismic data. Seismic elastic wavefield simulation for the selected project site was completed by developing earth models, generating seismic simulations, and completing analyses of these data. Sonic and density logs acquired at the project site were also used to build the elastic earth model. The study also focused on the development and simulation of a new 3-D seismic survey. Interpretation of the new seismic data set was completed, including generation and mapping of horizon

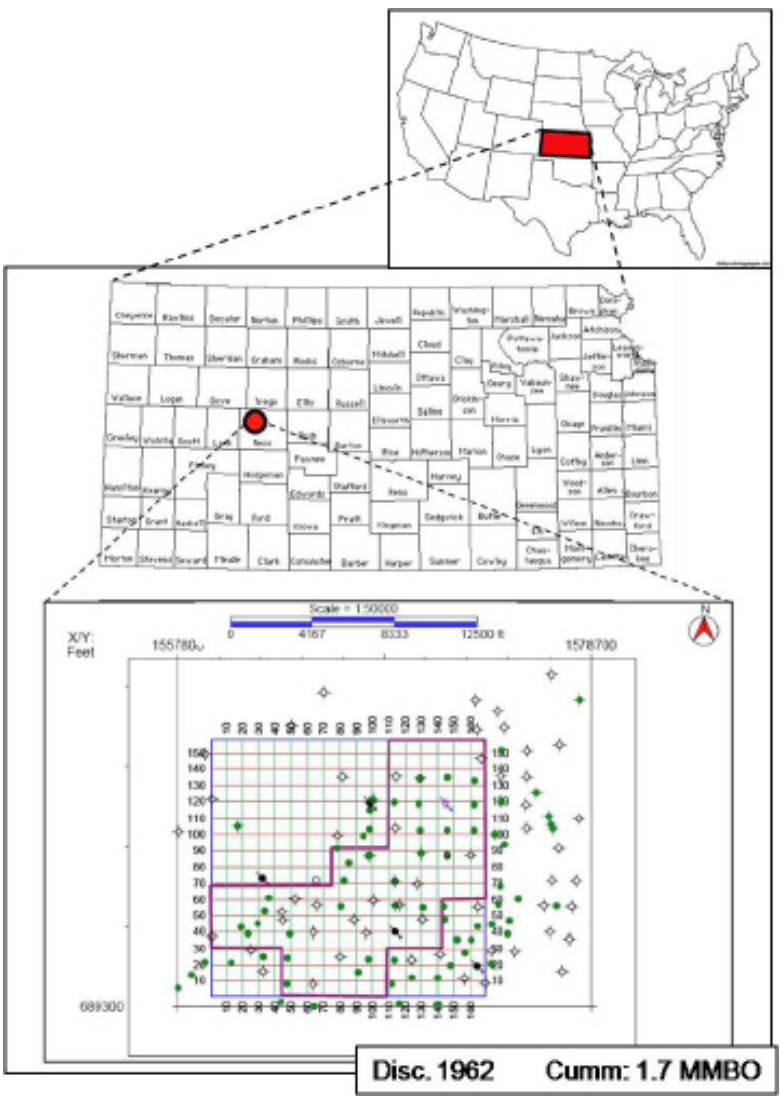

Figure 1. Simplified map depicting the location of the study site, Dickman field, Ness County, Kansas.

sections in the simulation migrated data volumes. From this study, a comprehensive workflow was built for simulation of simultaneous source seismic data for CO_2 storage operations (Figure 2).

Goals/Objectives

The overall goal of this project was to provide a numerical simulation of improved seismic technology that addresses key challenges, such as:

- Monitoring the movement and containment of CO_2.
- Quantification and sensitivity for mapping of caprock integrity and potential leakage pathways.
- Fundamental research aimed at low cost, high density, full azimuth, and vector seismic data.

These objectives contribute to the Carbon Storage Program efforts to ensure CO_2 storage permanence and enhance storage capacity estimates.

Benefits

- At the end of this project two students had accumulated 3,164 training-related hours under the program.
- Approximately 3.3 square miles of previously shot 3-D seismic data was acquired and reprocessed through pre-stack time migration. Seismic attributes including amplitude, curvature, and several others were used to identify possible faults, fractures, and other discontinuities to demonstrate an improved understanding of the study area. Geological and seismic data were integrated to create a geological property model and a flow simulation grid. Integrated depth maps were made of the formation tops and the deep saline aquifer.
- Multi-scale data integration conducted in this study improved the confidence of fault and fracture interpretation based on seismic attributes. These interpretations helped in the reconstruction of multi-episode deformation history of the area. Interpretations also indicated that several major northwest-trending faults and associated fractured zones are a likely fluid conduit, and a northeast-trending fault served as the sealing fault for the hydrocarbon-producing structure.

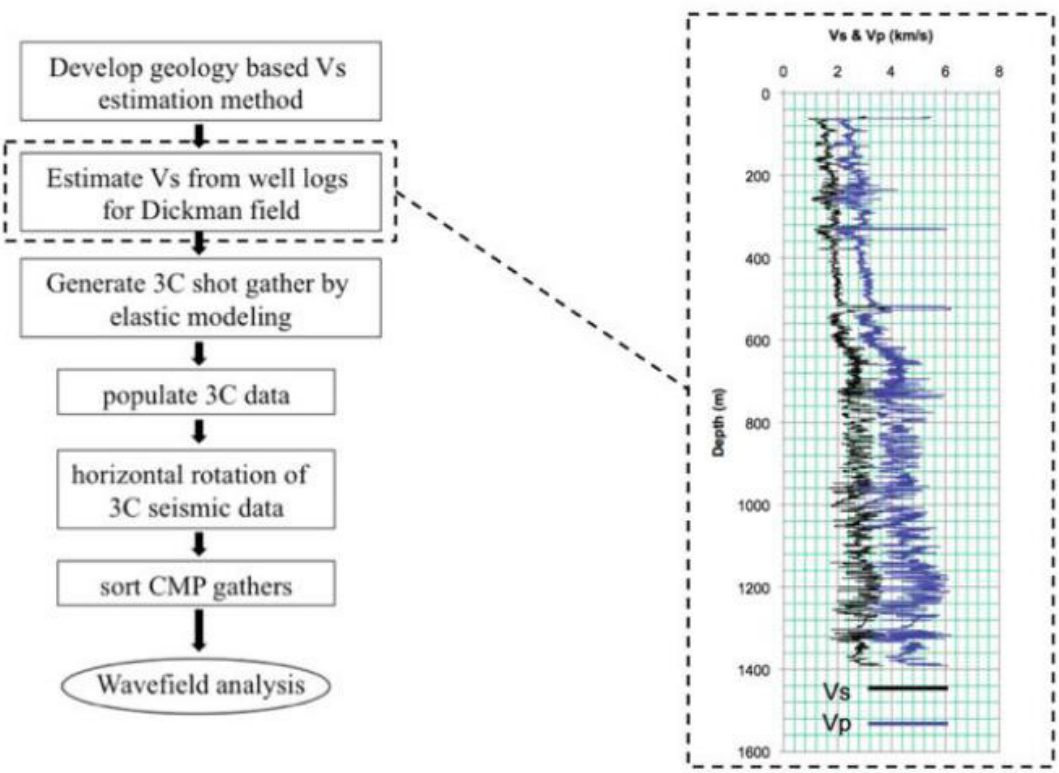

Figure 2. 3-D 3C elastic simulation workflow for the Dickman Field.

- An estimate of the deep saline aquifer carbon storage potential was made. It indicated a value of approximately 527,000 metric tons of CO_2 per square mile. The deep saline aquifer at the study site is part of the Western Interior Plains and Ozark Plateau aquifers that cover several hundred thousand square miles. The aquifer system is stable with water flow velocity of only about 40 feet per million years, which excludes the possibility that injected CO_2 will be migrated to the surface through the aquifer water flow. The aquifer system studied at the Dickman Field is an ideal CO_2 storage target.

A final report has been completed and is now available.

Benefits

The project developed an elastic earth model of the Kansas Dickman Field, which furthered the understanding for new seismic interpretation techniques. These simulated seismic interpretations provided a new suite of attributes of the study site, leading to an improved image of CO_2 migrated volumes. This research effort will help NETL's efforts to develop technologies that ensure 99 percent storage permanence of CO_2 within the injection zone and estimate storage capacity within geologic formations. Additionally, this research is preparing students to take on new challenges in seismic modeling for carbon storage. This helps to cultivate the skills needed to implement CCS technologies on a commercial scale.

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