the ENERGY lab

PROJECT FACTS

Carbon Storage - GSRA

Numerical Modeling of Geomechanical Processes Related to CO_2 Injection within Generic Reservoirs

Background

Fundamental and applied research on carbon capture, utilization and storage (CCUS) technologies is necessary in preparation for future commercial deployment. These technologies offer great potential for mitigating carbon dioxide (CO_2) emissions into the atmosphere without adversely influencing energy use or hindering economic growth.

Deploying these technologies in commercial-scale applications requires a significantly expanded workforce trained in various CCUS technical and non-technical disciplines that are currently under-represented 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 CCUS technologies.

The U.S. Department of Energy's (DOE) 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. The focus of these projects has been to conduct geologic storage training and support fundamental research projects for graduate and undergraduate students throughout the United States. These projects include such critical topics as simulation and risk assessment; monitoring, verification, and accounting (MVA); geological related analytical tools; methods to interpret geophysical models; well completion and integrity for long-term CO_2 storage; and CO_2 capture.

Project Description

NETL has partnered with the Missouri University of Science and Technology to conduct research and training to model potential CO_2 leakage through caprock (seal) and well penetrations by developing multi-scale models of different geological settings for geologic carbon storage sites and comparing the results with geomechanical processes. Successful CCUS depends on minimizing the risk of CO_2 leakage through caprock

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PARTNERS

None

PROJECT DURATION

Start Date
12/01/2009

End Date
05/31/2013

COST

Total Project Value
$317,938

DOE/Non-DOE Share
$299,114 / $18,824

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and fracture networks in formations above the target CO_2 storage formation. Low-permeability formations located above the target CO_2 injection zone can act as a seal and prevent the upward migration of CO_2 out of the injection zone. The effort is focusing on how fluid pressure induces rock deformation, how faults and fractures affect fluid migration, as well as on critical wellbore placement and wellbore integrity (Figure 1).

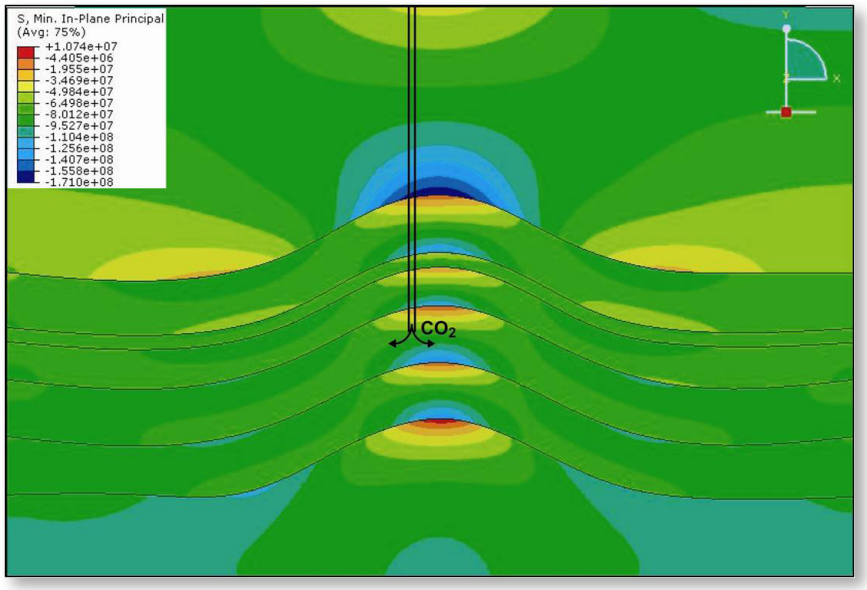

Figure 1. Principal stresses associated to an anticline structure change from compressional stresses (blue contours) to tensional stresses (red contours) within each layer. The CO_2 injection related pore pressure increase will result in different failure types for the various regions of the anticline structure.

The project is providing graduate and undergraduate students with the skills needed to develop generic, two-dimensional (2-D) and three-dimensional (3-D) finite element (FE) models of carbon storage sites based on different geological settings and boundary conditions. Students are being trained to analyze the influence of different geological settings under varying boundary conditions on induced fractures and to analyze the influence of these fractures on fluid migration. Further, 3-D models of wellbore scale size will be used to address problems related to optimal drilling sites, directions, and wellbore integrity.

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 objective of this project is to train graduate students to develop multi-scale FE models of different geological settings and study the effects of CO_2 injection related pore pressure increases on geomechanical processes. The results will demonstrate how fracture and fluid flow, as well as wellbore integrity, are dependent on a variety of changing input parameters such as geometry, loading conditions, and material properties. This aids in the overall understanding of the effects of injection and contributes to maximizing storage efficiency. The project research efforts will also help to gain an understanding of how reservoir geometry affects cap rock, fault and wellbore stability to help insure storage permanence.

Accomplishments

- As of March 2012, five students had accumulated 3,140 training related hours under the program.
- The borehole model was developed and has been advanced by completing analysis on displacement boundary conditions (analytical solution matched), completing analysis on surface pressure boundary conditions for comparison with analytical solution, and starting analysis on drilling boundary conditions for comparison with the analytical solution.
- Development of the reservoir model has advanced by establishing the setup of reservoir scale models under different stress regimes and completing sensitivity analysis on inter-layer slip, anticline amplitude, layer thickness. Results indicate that differential stress increases as reservoir thickness decreases. Higher differential stress in reservoir versus shale layers was determined. This suggests that thicker reservoirs make better injection targets, not just because of the volumetrics.
- Efforts have also begun on analyzing drilling boundary conditions for comparison with the analytical solution and the setup of an initial model to compare analytical solution for fluid injection to Finite Element code.

Benefits

The overall results of the project are making a vital contribution to the scientific, technical, and institutional knowledge necessary to establish frameworks for the development of commercial-scale CCUS. The project is helping to develop a well-trained future generation of geologists, scientists, and engineers that have the skills needed to implement commercial-scale CCUS technologies. Research results provide a numerical database for stress changes dependent on site geometry and pore pressure changes and should help increase storage efficiencies. Further, it provides a more thorough understanding of how reservoir geometry affects wellbore, formation, and caprock stability, thus facilitating future site selection efforts and ensuring storage permanence.

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