the ENERGY lab

PROJECT FACTS

Carbon Sequestration

Geomechanical Simulation of Fluid-Driven Fractures

Background

Increased attention is being placed on research into technologies that capture and store carbon dioxide (CO_2). Carbon capture and storage (CCS) technologies offer great potential for reducing CO_2 emissions and, in turn, mitigating global climate change without adversely influencing energy use or hindering economic growth.

Deploying these technologies in commercial-scale applications requires a significantly expanded workforce trained in various CCS specialties 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 CCS technologies.

The U.S. Department of Energy's (DOE) National Energy Technology Laboratory (NETL) has selected 43 projects to receive more than $12.7 million in funding, the majority of which is provided by the American Recovery and Reinvestment Act (ARRA) of 2009, to conduct geologic sequestration training and support fundamental research projects for graduate and undergraduate students throughout the United States. These projects will 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 is partnering with the University of Minnesota to provide graduate and undergraduate students the opportunity to participate in cutting-edge research related to the modeling of fluid-driven fractures, a challenging problem in geomechanics related to geologic carbon storage. An understanding of fracturing physics provides researchers with the insight to help them maintain the reservoir and caprock integrity critical to any CO_2 geologic storage project. Modeling studies indicate that fractures in the caprock formation (low permeability formation above the target injection formation) can lead to potential CO_2 leakage into other formations, including drinking water sources.

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U.S. DEPARTMENT OF ENERGY

PROJECT DURATION

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12/01/2009

End Date
11/30/2012

COST

Total Project Value
$299,568

DOE/Non-DOE Share
$299,568 / $0

Government funding for this project is provided in whole or in part through the American Recovery and Reinvestment Act.

The difficulties in fracture simulation stem from a number of interacting factors including (1) the strong nonlinearity in the lubrication equation (which takes into account fluid density, fluid velocity, and normal and shear stress) that governs the flow of fluid inside the fracture; (2) the moving boundary nature of these factors as the crack edge and the possibly distinct fracturing fluid front evolve; and (3) the deterioration of the lubrication equations near the crack front caused by the disappearance of the channel aperture, which is itself responsible for a large fluid pressure gradient in the tip region. In particular, the unrealistic effort to accurately capture the near tip pressure gradient (ultimately needed to calculate the velocity of the fracture front) is the major disadvantage of most computational algorithms for hydraulic fracture. It translates into long calculation times and irreversible errors in the predicted evolution of the fracture footprint.

The research approach includes numerical analyses with discrete element and boundary element methods, and physical experiments for material estimation and predictive model testing. The discrete element method is used to compute the stresses and displacements in a volume containing a large number of particles, such as grains of sand. The boundary element method attempts to use the given boundary conditions to fit values into an integral equation, rather than values throughout the entire defined space. Two doctoral students will be funded by this effort. One of the students will concentrate on experimental studies and the other will focus on numerical modeling. Specific project research includes:

1. Testing of fluid-saturated rock under plane-strain (two-dimensional) compression. Rock hardening and contractant softening will also be investigated from undrained experiments, where pore pressure will be measured throughout the failure process. Drained tests will be monitored with the acoustic emission technique and the sources will be characterized by moment tensor analysis (mathematical representation of the movement). Acoustic emissions are the stress waves produced by the sudden internal stress redistribution caused by changes in the internal structure (e.g., crack initiation and growth and crack opening and closure) of the materials.

2. Using the numerical modeling approach to implement the multi-scale nature of the particular crack tip asymptotics (approaching infinity) that arise in a fluid-driven fracture as a result of the competing physical processes that manifest themselves at different length and time scales. A comprehensive library of these asymptotics for a variety of situations encountered in the field will enhance reservoir modeling. Other issues that will be recognized and addressed are the possible non-linear hydraulic-thermal response of the rock mass linked to flow in deformable fractures.

Goals/Objectives

The goal of project is to support graduate students working on the geomechanical simulation of fluid-driven fractures. The project has the following objectives:

- Devise rock characterization techniques related to laboratory testing of fluid-saturated rock.
- Develop predictive models for the simulation of fluid-driven fractures.
- Establish educational frameworks for geologic sequestration issues.

These objectives will be achieved by (1) using a novel apparatus to produce faulting in a fluid-saturated rock (Figure 1); (2) modeling fluid-driven fractures with a boundary element method; and (3) developing curricula for training geoengineers.

Benefits

Given the anticipated timeframe associated with the lifetime of geologic sequestration, modeling of fluid-driven fractures will be an essential tool for predicting the effectiveness of a reservoir, and modeling will provide assurance of the long-term storage security. Additionally, the project will provide CCS research opportunities for two graduate students. Besides becoming familiar with CO_2 sequestration challenges, the students will be able to join the geologic sequestration community upon graduation, and become an integral part of the CCS technology transfer effort. Lastly, important CCS technology transfer information will be disseminated through reports, refereed publications, and technical conferences.

Figure 1. A novel apparatus will be used to produce faulting of fluid-saturated rock to devise rock characterization techniques and develop predictive models for the simulation of fluid-driven fractures.

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