the ENERGY lab

PROJECT FACTS

Carbon Sequestration

Simulation of Coupled Processes of Flow, Transport, and Storage of CO_2 in Saline Aquifers

Description

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, of possible carbon dioxide (CO_2) leakage at CO_2 sequestration sites, along with risk assessment of those 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 permanently sequestered. Effective application of these MVA technologies will ensure the safety of sequestration projects with respect to both human health and the environment, and provide the basis for establishing carbon credit trading markets for sequestered CO_2. Risk assessment research focuses on identifying and quantifying potential risks to humans and the environment associated with CO_2 sequestration, and helping to ensure that these risks remain low.

This four-year project — performed by the Colorado School of Mines in partnership with Lawrence Berkeley National Laboratory (LBNL) — will develop a comprehensive reservoir simulator for modeling non-isothermal multiphase flow and transport of CO_2 in saline aquifers under varying temperature and pressure conditions. The project focuses on saline aquifers because these formations have the largest potential capacity for CO_2 storage. The simulator will model the complex geology of these formations, including heterogeneity, anisotropy, fractures, and faults. The simulator will also model geochemical and geomechanical processes that would occur during CO_2 geologic sequestration (GS). It will use parallel computation methods to allow rapid and efficient modeling assessment of GS injection strategies and long-term prediction of GS system behavior and safety.

Primary Project Goal

The primary goal of this project is to develop a state-of-the-art, comprehensive reservoir simulator for quantitative investigations of CO_2 non-isothermal, multiphase flow and long-term storage in saline aquifers. The simulator will model the complex and coupled physical and chemical processes in CO_2-brine systems, and will demonstrate (1) multiphase flow, dissolution, diffusion, and dispersion of CO_2 in the aquifer; (2) the effect of temperature on fluid and rock properties, solution and phase

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COST

Total Project Value
$2,000,000

DOE/Non-DOE Share
$1,600,000 / $400,000

PARTNERS

Lawrence Berkeley National Laboratory

behaviors, local heat transfer between fluids and the rock, and global heat transfer both within the aquifer and between the aquifer and surrounding seals; (3) the effect of geochemical processes on long-term dynamics of the aquifer; (4) elevated, pressure-induced rock deformation; (5) proper handling of fractures and faults of various scales; (6) proper treatment of dissolution-driven instability in the brine phase below horizontally placed CO_2-brine interfaces; and (7) an efficient, robust numerical solution that will be computed implicitly in parallel for rapid assessment of various injection strategies and storage system performance.

Accomplishments

This project was awarded on October 1, 2009. To achieve the overall goal, the project team will complete the following phases: (1) develop a three-phase, non-isothermal flow module to handle CO_2-brine multiphase flow and mutual dissolution, over a full range of temperature and pressure conditions, from injection wellhead to deep storage reservoir to leakage to shallower depths and all the way to the land surface; (2) develop a physically based module to compute rock mechanical deformation and an improved modeling tool for quantitative evaluation of GS systems for CO_2 injection, its potential leakage through caprocks, leakage prevention, and long-term storage performance; (3) incorporate representative geochemical reactions in the model containing selected compositions of brine, rock, and CO_2; (4) characterize and model the instability due to dissolution-driven density inversion in the brine phase near phase boundaries; (5) implement efficient parallel computing technologies, including grid partitioning, grid block reordering, assembly of the Jacobian matrix, and solving the linear system; (6) incorporate general fracture conceptual models, emphasizing flow through faults and rock mechanical coupling; and (7) verify the model against existing simulators or models, validate it using available laboratory testing data and results, and demonstrate its application to field-scale CO_2 injection test sites.

Benefits

The proposed research will make significant contributions to the design, modeling, and monitoring of CO_2 GS systems by producing a comprehensive simulator that can fully couple the complex hydro-thermal-mechanical-chemical processes in CO_2 sequestration. In particular, the proposed development provides a practical approach to evaluate long-term performance of CO_2 GS systems, and to assess risks associated with a particular GS system by consideration of fully coupled processes of thermal, geochemical, and rock deformation effects. This research is strategically important to DOE's mission in CO_2 geologic sequestration and management. Furthermore, once the research goals are achieved, the developed simulator will substantially enhance the ability to predict long-term performance of CO_2 GS systems, from sound engineering design to long-term monitoring.

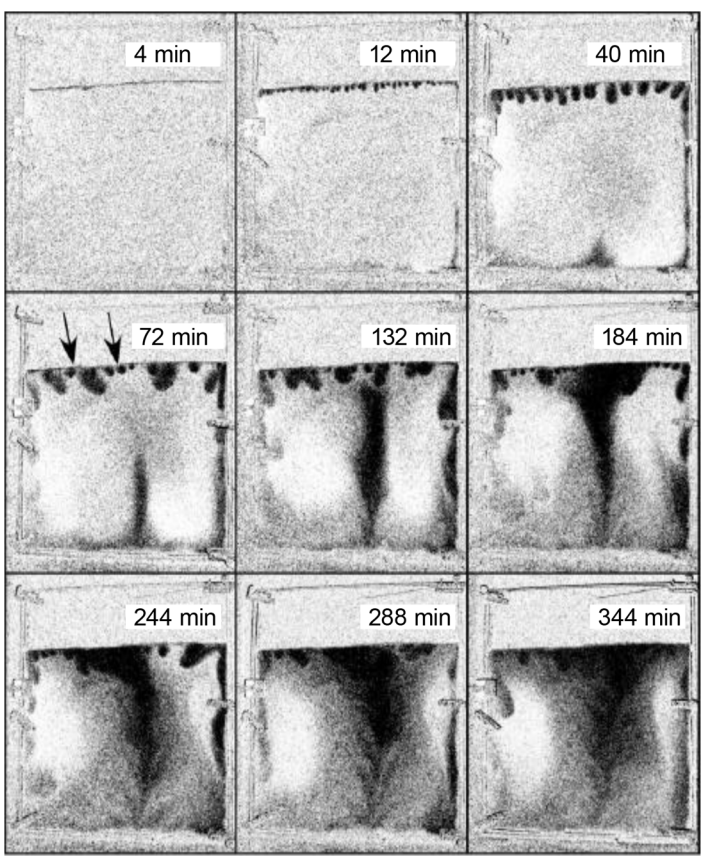

Figure 1: Dissolution of CO_2 into brine phase generates density inversion with resulting flow fingering that suggests future directions for multiphase flow modeling of enhanced CO_2 dissolution rate.