the ENERGY lab

PROJECT FACTS

Carbon Sequestration

CO_2 at the Interface: Nature and Dynamics of the Reservoir/Caprock Contact and Implications for Carbon Storage Performance

Background

The U.S. Department of Energy (DOE) National Energy Technology Laboratory (NETL) is currently funding research aimed to advance state-of-the-art technologies that address geologic storage of carbon dioxide (CO_2) in multiple formation types and across all phases of CO_2 geologic storage operations.

Geologic storage involves the injection of CO_2 into underground formations that have the ability to securely contain it over long periods of time. Research efforts are currently focused on several geologic storage formation types: deltaic, coal/shale, fluvial, alluvial, strandplain, turbidite, eolian, lacustrine, clastic shelf, carbonate shallow shelf, and reef. Basaltic interflow zones are also being considered as potential reservoirs. These formations contain different fluids such as saline water, oil and natural gas. A principal element of the DOE's Carbon Sequestration Program is Core Research and Development (R&D), and one of the R&D focus areas—geologic storage—is aimed at addressing the challenges of CO_2 storage in these formations.

Critical challenges identified in the geologic storage focus area include CO_2 well bore integrity, geochemical and mechanical responses, fluid flow and containment, and development of mitigation technologies. Obtaining a better knowledge base of the characteristics of the interface between the caprock above the formation and the formation rock itself will improve the ability to effectively contain CO_2 in the formation.

Figure 1: Outcrop analog of a formation/caprock interface in the eastern San Rafael Swell, UT. The Carmel Formation (red upper unit) is a low-permeability sealing lithology, whereas the Navajo Sandstone (tan lower unit) is a high-permeability formation lithology. Deformation band faults cut the Navajo and intersect the interface at a high angle. Outcrop is approximately 5 meters high.

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PROJECT DURATION

Start Date

10/01/2010

End Date

09/30/2013

COST

Total Project Value

$552,806

DOE/Non-DOE Share

$452,763 / $100,043

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U.S. DEPARTMENT OF ENERGY

Project Description

The purpose of this study is to analyze and assess the zone comprised of the top of the formation rock and bottom of the overlying caprock (known as the caprock/formation interface, Figure 1) surrounding CO_2 injection wells. Effective caprock formations are typically low-permeability rock units that are relatively thick and serve as a seal above the storage formation rock that prevents any injected CO_2 from migrating out of the formation. The study is using information obtained from rock outcropings and core samples of proposed CO_2 clastic formations and overlying mudstone caprock to determine the characteristics of this zone, and is using these data to develop conceptual models of the behavior of formation-caprock interfaces and, in particular, sandstone/mudstone contacts.

The New Mexico Institute of Mining and Technology (NMIMT), in collaboration with Utah State University and Sandia National Laboratories, is examining the primary depositional texture of the sediment at the interface, the structural characteristics of the rock within this zone, and the changes that the sediment underwent as it transformed into rock and following rock formation (diagenesis). These elements will affect how the rock responds physically and chemically to CO_2 injection. Of concern is the possibility that mesoscale (centimeters to several meters) features at the interface—such as zones where the rock interfaces are preferentially cemented (diagenetic), or is deformed (e.g., fractures)—may greatly influence the degree that the formation and caprock are connected. High connectivity may in some cases provide leakage pathways into the caprock, compromising its ability to provide a long- term seal for sequestered CO_2.

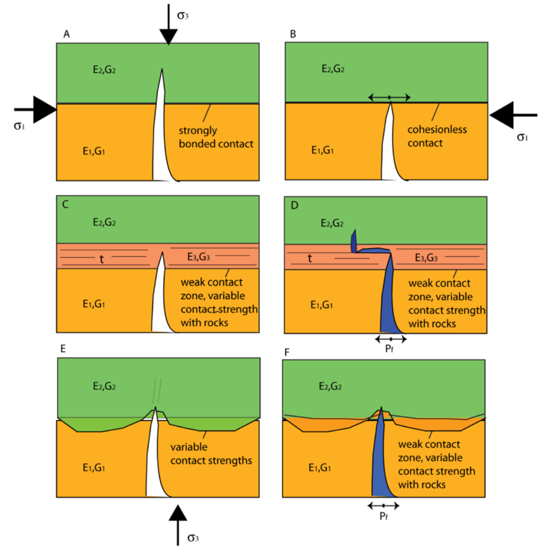

Figure 2: NMIMT will use numerical mechanical models to examine the nature of rock fracture and its interplay with the mechanical nature of a variety of sedimentological contacts. The general conditions for the model domain are: E = Young's Modulus, G = Fracture modulus, where E1>E2>E3, and G1<G2<G3 - strong, stiff rocks are actually easier to fracture. NMIMT will examine a range of conditions loaded by far-field stresses, and local stresses at crack tips, including: A – bonded simple contact, B – narrow cohesionless contact, C – contact zone of thickness t, D – fluid pressurized system [this can be applied to all contact geometries with pore pressure Pf], E – irregular narrow contact, and F – irregular contact zone.

Goals/Objectives

The purpose of this study is to assess depositional, structural, and diagenetic characteristics of caprock/formation interfaces of proposed CO_2 injection sites, and how insight gained from observation linked to coupled modeling can guide inferences into best modeling practices. NMIMT is examining outcrop analogs and core samples of proposed CO_2 clastic formations and overlying mudstone caprock and performing laboratory testing to properly characterize the thermal, hydrological, chemical, and mechanical properties of sandstone-mudrock interfaces. Some of the specific topics addressed in this study include:

- How physical properties of sand/mudstone interfaces influence CO_2 storage and transport.
- How geochemical perturbations induced by CO_2 emplacement influence leakage of CO_2 across the interface.
- How the physical/chemical properties at the interface affect brine migration into caprock (which could mitigate pressure issues that result from injecting CO_2 into the brine saturated formation).
- How fractures at the interface respond to increased pressures resulting from CO_2 injection into the formation rock.

NMIMT plans to investigate interfaces in three different formation/seal pairs. The first stage of the project will involve a brief field campaign to perform basic description of the interfaces and conduct detailed sampling. The second stage will involve laboratory analysis of the samples to identify their key petrographic, geochemical, mechanical, and petrophysical properties. Finally, the descriptive information acquired in the first two steps will be used as input data for a detailed coupled thermal, hydrologic, mechanical, and chemical modeling investigation of the implication for transmission of fluids across the interface. The modeling effort includes generating a range of numerical experiments that will test how stresses, and fractures, are transmitted across the sedimentary interface. NMIMT will examine a range of conditions for fracture propagation across a range of boundaries, including narrow bonded, narrow contact with free slip, and an interface with a finite width.

The success of this project will depend heavily on successfully classifying field work observations into usable objective functions in terms of how observed sandstone-mudrock interfaces are expected to behave during CO_2 injection and storage, and the ability to integrate this understanding in terms of coupled thermal, hydrological, mechanical, and chemical (THMC) models.

Benefits

This work will benefit the carbon capture and storage community by advancing the understanding of dynamics specific to the caprock/formation interface and improving models used by the carbon capture and storage community to predict and characterize potential storage formations. Additionally, training of future carbon capture and storage professionals will be enhanced through opportunities for interaction between personnel at Sandia National Laboratories and students and faculty at Utah State University and New Mexico Institute of Mining and Technology.