GCEP
Global Climate & Energy Project
STANFORD UNIVERSITY

Linking Chemical and Physical Effects of CO_2 Injection to Geophysical Parameters

Investigators

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Objective

The proposed research examines how geochemical reactions change the physical properties of rocks which result in changes to its seismic attributes. These mineral reactions must be incorporated into conventional models and simulations to enhance the characterization of reservoirs while monitoring fluid flow. Quantifying these chemical-physical links will be a major step forward for managing and monitoring CO_2 plumes.

Background and Approach

The standard practice to modeling of fluid effects on seismic data has been based almost exclusively on Gassmann's equations which describe the interaction of fluid compressibility with the elastic rock frame to determine the overall rock elastic behavior. This approach has been successful under conditions of pure fluid saturations and in relatively inert systems in which the pore fluids and minerals are at, or close to, chemical equilibrium. However, it oversimplifies the complex rock-fluid interaction during CO_2 underground injection. As a consequence, treating the properties of the rock pore space and frame as constants and basing the computation on homogeneous saturation distributions leads to incorrectly mapping the fate of CO_2. This program will use an alternative approach that taps experimental data and models from geochemistry and rock physics that will:

(i) provide a better understanding of the reaction kinetics of CO_2-bearing reactive fluids with rock-forming minerals, and
(ii) quantify how the resulting long-term, CO_2-injection induced changes to the rock pore space and frame (e.g. porosity, permeability, mineral dissolution, and cementation) affect seismic parameters in the reservoir.

This pioneering, comprehensive study integrates the physiochemical impact of CO_2 on seismic properties and contributes to the field by improving estimates, reducing uncertainty and long-term risks.

Activities

To identify and distinguish among signatures and possible mechanisms occurring during CO_2 injection, the research will be divided among three main tasks: laboratory, theoretical, and numerical simulation work.

Laboratory Measurements—This task encompasses several activities, the first of which is to prepare and organize a set of carbonate rocks, calcite-cemented sandstones, and sandstones for the systemic laboratory study. Samples will then undergo testing, analysis, and measurements to characterize the hydraulic transport properties and the microtexture. Acoustic measurements on core plugs will be performed under controlled overburdren pressure while flooding CO_2 into bring saturated samples (Figure 1). And the mineral dissolution kinetics will be determined in three stages under standard temperature and pressure conditions. The schematic of the apparatus is shown in Figure 2. These results will be used for theoretical modeling and simulations in subsequent tasks.

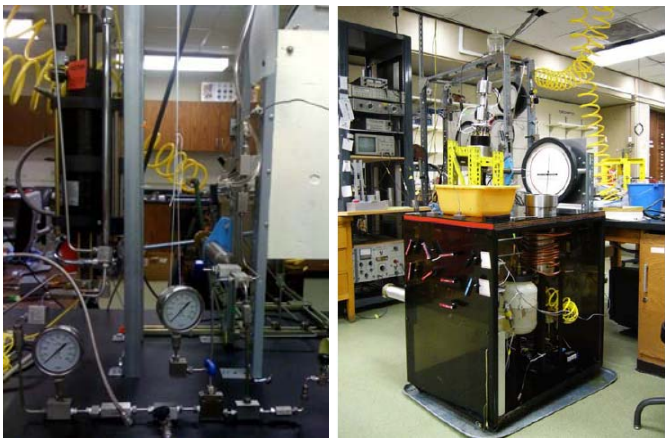

Figure 1: System to measure the P- and S- wave velocity under confining and multiphase pore fluid pressure.

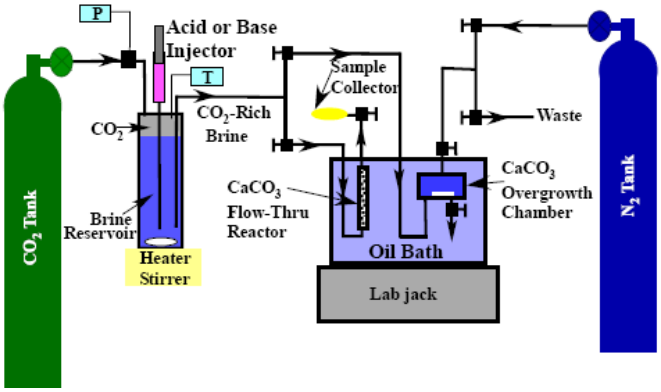

Figure 2: Schematic diagram of the reactor system

Data Modeling—The data modeling will establish new relations and systematic patterns linking properties controlling the elastic-wave velocities (i.e. porosity, pore geometry, and microstructure) to dissolution rates. It is anticipated that a better understanding of the fundamental physicochemical principles controlling the relationship between chemical reactivity, intrinsic physical rock properties, and geophysical observations will result. And the relationships will be used to modify the existing classical fluid substitution schemes. Data modeling will involve statistical regressions and uncertainty analysis, and a new modeling strategy will include both P-wave and S-wave information.

Numerical Simulations—Detailed descriptions of the pore microstructures will be based on Lattice Boltzmann methods. The images taken from lab measurements will be used as inputs for multifluid simulations and for mathematically characterizing the microstructure to quantify changes in the porosity and permeability due to induced dissolution. This exercise will develop pore-scare simulation techniques and extend existing single-and two-phase flow simulations and diffuse simulations to handle more rigorous gas/liquid multifluid systems. Results will be compared to lab measurements to improve algorithms for robustness accuracy and speed.