

PROJECT facts

U.S. DEPARTMENT OF ENERGY
OFFICE OF FOSSIL ENERGY
NATIONAL ENERGY TECHNOLOGY LABORATORY



CO₂ SEQUESTRATION IN BASALT FORMATIONS

Background

There is growing concern that buildup of greenhouse gases, especially carbon dioxide (CO₂), in the atmosphere is contributing to global climate change. One option for mitigating this effect is to sequester CO₂ in geologic formations. Numerous site assessments for geologic sequestration of CO₂ have been conducted in virtually every region of the United States. For the most part, these studies have involved storing CO₂ in saline formation, deep coal seams, and depleted oil and gas reservoirs. Another option, however, is basalt formations. Basalt is a dark-colored, silica-rich, volcanic rock that contains cations—such as calcium, magnesium, and iron—that can combine with CO₂ to form carbonate minerals. Basalt formations have not received much attention with respect to their potential for permanent sequestration of anthropogenic CO₂. Major basalt formations that may be attractive for carbon sequestration occur in the Pacific Northwest, the southeastern and northeastern United States, and at several other locations around the world. Unlike sedimentary rock formations, basalt formations have unique properties that will result in chemically trapping injected CO₂, thus effectively and permanently isolating it from the atmosphere.

Because of the very limited study of basalts for carbon sequestration, basic information on injectivity, storage capacity, and rate of conversion of gaseous CO₂ to solid carbonates is not available. Experiments conducted at Pacific Northwest National Laboratory (PNNL) have confirmed that carbonate mineral formation occurs when basalts from the Columbia River Basalt Group (CRBG), Central Atlantic Mafic Province, and Newark Basin are exposed to supercritical CO₂. However, insufficient data have been generated from these experiments to permit reliable projections of CO₂ conversion rates under large-scale sequestration conditions. Information is also lacking on the ability of basalts from other parts of the world to support in situ mineralization reactions.

In this project, a hydrogeological survey will be conducted of basalt formations in the United States and India to provide a best estimate of the transmissivity of these formations and their suitability for geologic sequestration of CO₂. Similar information exists for the CRBG, which serves as a regional aquifer for the eastern portion of the state of Washington. Similar

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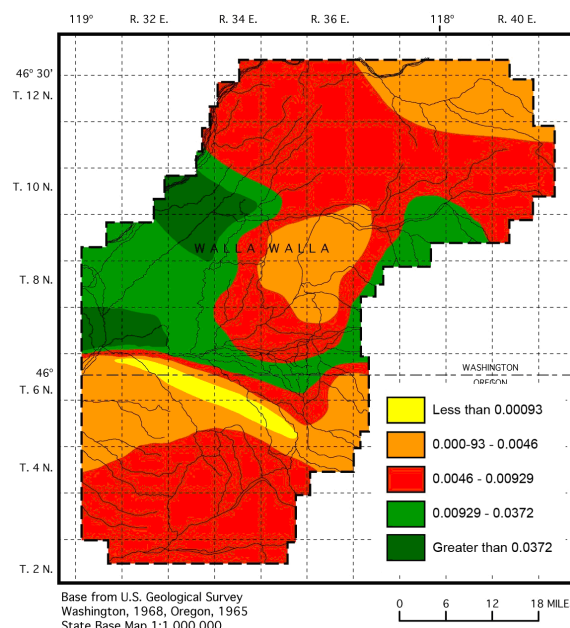
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Basalt aquifer map



PARTNER

Pacific Northwest National
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PROJECT DURATION

06/01/2003 to 09/30/2008

COST

Total Project Value
\$1,510,000

DOE/Non-DOE Share
\$1,510,000 / \$0

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hydrogeological information obtained for other flows will be used to estimate CO₂ capacity and injectivity rates.

The remaining components of this project are designed to determine the formation conditions expected to occur after the injection of CO₂ and provide the fundamental data necessary to better estimate rates of mineralization in different basalts. Dissolution rates for different basalts from around the world will be measured and compared to the CRBG. In situ pH measurements of the CO₂-saturated pore fluid in contact with basalt will be determined at formation conditions.

A specially-designed pressure cell will be used to determine the rates of CO₂ mixing and movement through actual CRBG core under realistic conditions of pressure and temperature.

Primary Project Goal

The goal of the work is to better understand the properties of basalt formations that would make them suitable for carbon storage by identifying mechanisms controlling post-CO₂ injection mixing behavior, formation pH, and mineralization rates.

Objectives

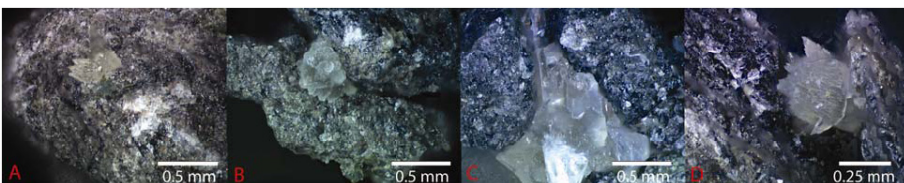
The objective of this project is to evaluate formation suitability for CO₂ storage and the rate of conversion of injected CO₂ to carbonates for basalts, with a principal focus on basalt formations in the United States and India.

Accomplishments

- A set of dissolution kinetics measurements was completed as a function of temperature and pH on basalt samples from the United States and India.
- Basalt grains from the United States, Africa, and India were reacted with supercritical CO₂ and water at 100 °C and 1500 psi for up to 1,334 days. Carbonate precipitation was identified on the post-reacted grains by optical and scanning electron microscopy, x-ray diffraction, and Raman spectroscopy. Rates of CO₂ conversion were variable based on basalt location.
- A CO₂ formation capacity assessment for the CRBG was estimated using existing geologic data obtained from prior Department of Energy studies.
- A first-order CO₂-formation capacity assessment conducted for major basalt formations in the United States conservatively estimates a CO₂ storage volume of 240 GTCO₂.
- Direct pH measurements of basalt and water mixtures reacted with supercritical CO₂ show a range of pH conditions from mildly acidic to slightly basic.

Benefits

Because of concern over the impact of greenhouse gases, particularly CO₂, on global climate change, considerable effort is being expended to evaluate the potential of CO₂ sequestration to mitigate the buildup of CO₂ in the atmosphere. Success of this project will expand the viable geologic options for CO₂ sequestration in the continental United States and provide heretofore unexplored options for CO₂ sequestration in developing countries, such as India. Basalt formations have a unique chemical makeup that could potentially convert all of the injected CO₂ to a solid mineral form, thus isolating it from the atmosphere permanently.



Columbia River Basalt and carbonate precipitates after exposure to CO₂ for a) 86 days, b) 377 days, c) 777 days, and d) 1,334 days