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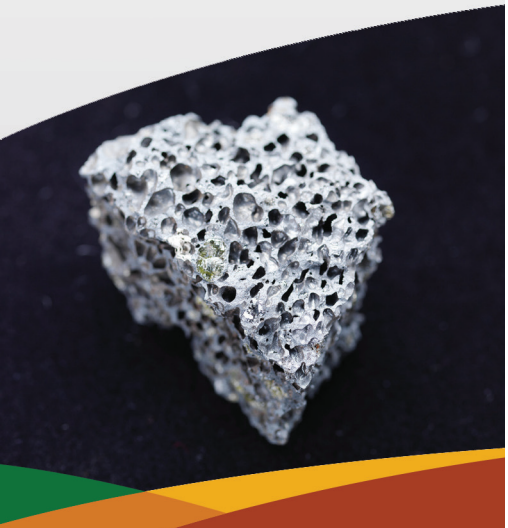
Greenhouse gas buildup in the atmosphere can be reduced by storing it deep underground. Laboratory experiments confirm that carbon dioxide is effectively trapped when injected into porous basalt (shown below) formations.



Storing CO_2 Underground: Highlights of Carbon Sequestration Research within the Geosciences Group

The Geosciences Group at Pacific Northwest National Laboratory (PNNL) is digging deep into complex subsurface challenges associated with geologic carbon sequestration. Research conducted by the Geosciences Group represents one component of a diverse set of carbon sequestration initiatives and activities currently underway at the Laboratory.

PNNL geoscientists are collaborating with other national laboratories through the U.S. Department of Energy's National Risk Assessment Partnership (NRAP) on targeted research to provide science-based methodologies to evaluate and mitigate potential risk associated with long-term storage of carbon dioxide (CO_2) in geologic formations. Carbon sequestration is the long-term storage of CO_2 in carbon sinks, such as deep underground geologic formations, saline aquifers, depleted oil and natural gas reservoirs, and basalt reservoirs. CO_2 is formed when we burn fossil fuels—such as oil, gas, and coal—that provide affordable energy for industrial and domestic use. Fossil fuel-related CO_2 emissions account for more than 80 percent of greenhouse gas emissions in the United States.

Pete McGrail, a Laboratory Fellow at Pacific Northwest National Laboratory, is part of a team studying basalts to determine how carbon dioxide can be safely and permanently stored in these massive, deep underground rock formations.

Greenhouse gases naturally occur in the Earth's atmosphere, in addition to being emitted by burning fossil fuels. Roughly one-third of CO_2 emissions in the United States come from power plants, such as coal or gas power plants. Unless properly captured at power plants and stored, CO_2 is released into the atmosphere as a greenhouse gas, which contributes to adverse global climatic changes. One of PNNL's major scientific initiatives is to advance understanding of reaction rate and mechanisms for CO_2 and gas co-contaminant mixtures injected into various geologic formations, with an emphasis on mixed greenhouse gases. "The Geosciences Group is leading research teams to develop geoscience-based methodologies to minimize potential risks associated with CO_2 storage, and advance public understanding and acceptance of safe and permanent CO_2 sequestration in deep geologic formations," said Chris Brown, the PNNL Geosciences Group Manager.

NATIONAL RISK ASSESSMENT PARTNERSHIP

Through the NRAP partnership, PNNL is leading multilaboratory research teams that are assessing CO_2 leakage via natural pathways, such as fractures and faults in geologic reservoirs and caprock; understanding corrosion and subsequent leakage through wellbore cements and casings; predicting impacts to groundwater should reservoir leakage occur; and developing innovative monitoring techniques for plume inventory and leakage assessment. This research will provide a robust, defensible, science-based approach for quantifying potential risks associated with long-term CO_2 storage.

Risk Assessment Team: This team is developing the scientific basis for a risk assessment model to address risk associated with long-term storage of CO_2. The team will study mineralogical and geochemical changes produced by rock-brine-CO_2 reactions within geologic reservoirs and overlying caprocks; determine likely geochemical reactions

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that control dissolved contaminant concentrations and their fate; and assess the impact of these reaction mechanisms on long-term risk profiles for geologic carbon sequestration projects.

Wellbore Integrity Team: Geologic reservoirs near industrial sites are typically populated by several cement based wellbores. Wellbores are industrial wells capped with cement for sealing purposes. Despite the impermeability of an overlying caprock in a geologic reservoir, its sealing integrity may be compromised by wellbores. Wellbores thus represent a likely route for leakage of CO_2 from geologic reservoirs. This team is developing the parameters for a multiphase-flow model that will predict how CO_2 will react with wellbore cement and rock, and interfaces between metal and cement or cement and rock in a reservoir. By studying these interactions through laboratory experiments and computer tomography scanning, scientists are assessing acidic corrosion and subsequent CO_2 leakage rates through wellbores over time, and how cracks or fractures in the wellbore can create potential pathways for CO_2 leakage. The team is also experimenting with various combinations to make cement more stable and chemically resistant to CO_2.

Natural Leakage Pathways Team: This team is researching how to better predict the performance of caprocks covering carbon sequestration geologic reservoirs, and the potential for supercritical CO_2 leakage through faults and fractures. Using data from numerous geologic formations, the team is developing three-dimensional numerical models to help quantify the amount of CO_2 leakage, potential pathways, and absorption into the caprock. Scientists are exploring various caprock factors, including how the type, strength, and thickness of a caprock can effectively resist CO_2 leakage. For example, marine shale caprock usually has low permeability and would naturally resist CO_2 leakage if it is more than 10 to 20 meters thick.

Groundwater Team: Injection of CO_2 into geologic reservoirs can result in significant geomechanical stresses to the reservoir, caprock seals, faults and fractures, and wellbores in the region. These stresses can cause CO_2 and brine leakage, which can potentially impact groundwater and surface water. This team is studying long-term effects of CO_2 leakage and how to protect natural water resources by using laboratory and computational tools to understand the impact of CO_2 and brine leakage on groundwater chemistry.

How Much CO_2 Storage Potential Do We Have?

The U.S. Department of Energy estimates there are more than 3500 billion metric tons and over 1100 years of CO_2 storage potential in the United States and Canada.

-Carbon Sequestration Atlas, published by the U.S. Department of Energy National Energy Technology Laboratory

WALLULA BASALT CO_2 SEQUESTRATION PILOT STUDY

This team is investigating whether geologic basalt formations can be used to safely store CO_2 permanently. In 2009, the team completed drilling a CO_2 injection borehole approximately 4000 feet deep near Wallula, Washington. The team conducted a combination of field and laboratory tests, including rock and geochemical sampling, hydrologic testing, and geophysical surveys and computer modeling to determine the most appropriate zone for CO_2 injection. PNNL also conducted numerous public outreach activities to address public concerns about the proposed project and obtain community support. Through these efforts and research, PNNL successfully obtained the world's first permit to inject up to 1000 tons of CO_2 to a depth of 2900 feet in a continental flood basalt region. PNNL will monitor and measure the long-term effects of CO_2 on the basalt reservoir, the surrounding soil, and groundwater.

FUTUREGEN 2.0

FutureGen 2.0 is a U.S. Department of Energy funded project that is developing the world's first near-zero emissions coal-fueled power plant. In support of this multi-agency project, Geosciences Group scientists characterized several potential sites before selecting Morgan County, Illinois, as the preferred storage site for CO_2 captured from the power plant. The CO_2 will be transported from the power plant at Meredosia, Illinois, via pipeline to the storage site, and injected into a saline geologic reservoir at a depth of approximately 1500 meters. Characterization of the CO_2 injection zone and subsurface is ongoing, and is based on analysis of wellbore data, including cores, geophysical logs, and hydrologic well testing, along with other geophysical and structural data. State-of-the-art multicomponent seismic surface imaging technology will be an important component to develop vertical and horizontal profiles to define the geometry of the reservoir, with an emphasis on the thickness and character of the injection reservoir. The FutureGen power plant is expected to begin operation in 2017.

Geosciences Group

PNNL's Geosciences Group's primary goal is to solve complex environmental challenges with earth-science solutions. We apply technical expertise in geosciences to develop, deliver, and deploy transformational science and technology solutions for our clients.

To learn more about the Geosciences Group, please contact **Chris Brown**, Geosciences Group Manager, at (509) 371-7381 or visit our website at http://geosciences.pnnl.gov/.

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