Stanford scientists subject rocks to hellish conditions to combat global warming

December 1 2011

To test the effectiveness of carbon sequestration, scientists in Sally Benson's Stanford University lab subject rock core samples to high temperatures and pressures similar to those found a half-mile or more underground. Credit: Courtesy Global Climate & Energy Program/Stanford University

A team of Earth scientists at Stanford University is subjecting chunks of rock to hellish conditions in the laboratory – all in the name of curbing climate change.

By exposing a handful of rocks to high temperatures and pressures, the scientists have obtained critical new data about the large-scale underground storage of carbon dioxide, a potent greenhouse gas and leading cause of global warming.

"About 60 percent of the world's carbon dioxide emissions come from power plants, refineries and other industries," said Sally Benson, professor (research) of energy resources engineering at Stanford. "One way to significantly curb global warming is to capture carbon dioxide from industrial smokestacks and store the emissions in geologic formations thousands of feet below the surface."

Benson and her colleagues have conducted numerous experiments on rock core samples and analyzed the results in microscopic detail. The goal is to predict how minute grains and pores in rock will affect the flow of vast quantities of carbon dioxide pumped deep into the ground.

"We want to see where the carbon dioxide moves, how fast, how much gets dissolved and how much gets trapped," said Benson, director of Stanford's Global Climate and Energy Project.

On Dec. 6 and 7, she and members of her lab will present their findings at the 2011 fall meeting of the American Geophysical Union (AGU) in San Francisco.

Experimental rocks

Over the past five years, Benson's team has collected cylinder-shaped core samples of sandstone and other rocks from various sites in North America. Each core – roughly the size of a beer can – is placed in a special chamber and subjected to high temperatures and pressures similar to those found a half-mile or more underground.

"We then inject carbon dioxide and water into the rock cores and take X-ray CT scan – just like the CT scan you'd get if you had a back injury," Benson explained.

This technique has allowed Benson's team to generate detailed, threedimensional maps showing the real-time movement of carbon dioxide through tiny pore spaces between individual grains of rock.

"We're making observations on a spatial scale that people have ignored in the past," Benson said. "Before, you could only estimate the average properties of a rock. Now we can tell you the precise carbon dioxide saturation and relate that to other rock properties in a quantitative way. "

Among the most important properties for large-scale carbon storage is permeability – a measurement of how easily fluids flow through a porous rock formation. The higher the permeability, the more carbon dioxide can be pumped into the rock.

"We developed a new imaging technique that allows you to determine the permeability and capillary pressure down to the individual pixel," Benson said. "Nobody has done that before. Because we can observe the rocks so carefully and control the amount of CO2 in them by the experiments we do, we've been able to learn a huge amount about what happens in a real CO2 sequestration project at a much larger scale."

Leakage potential

A major focus of Benson's research is leakage potential: Will stored carbon dioxide gas eventually escape its underground prison and return to the atmosphere?

Because carbon dioxide is soluble in water, scientists worry about the consequences of water leaking from an underground reservoir. Will dissolved carbon dioxide gas be released and eventually reach the surface?

"It's like when you open a bottle of Perrier water," Benson said. "You release the pressure and little bubbles of carbon dioxide come out. But is there a big risk of that happening underground? Do we have to not only worry about carbon dioxide getting out of the reservoir, but also about water containing carbon dioxide escaping?"

To address the problem, Stanford graduate student Lin Zuo focused on a property known as relative permeability – a measure of the ability of water and carbon dioxide to through the pore spaces between grains of rock. "CO2 and water basically have to compete," Benson explained. "Which one gets the big pores, and which one gets the small spaces?"

In his lab experiments, Zuo discovered that carbon dioxide has an incredibly low the relative permeability when it's released from water. "This is good news," Benson said. "It means that it's not really a problem if water with dissolved carbon dioxide gets out of the storage reservoir, because when the bubbles come out of solution, they actually plug up the rock formation."

But will the released carbon dioxide bubbles eventually escape? "Lin's study predicts that the rock formation will stay plugged up for a really, really long time. His research shows that one thing people worry about is not really a big risk after all. This kind of work helps us prepare for scale-up, so that we can accurately predict where the carbon dioxide will go when we put it underground."

Norwegian example

Despite the enormous potential of carbon capture and storage to significantly reduce global greenhouse gas emissions, the technology has only been adopted by a handful of commercial operators, including the Sleipner natural gas project in Norway's North Sea.

Since 1996, nearly 12 million metric tons of carbon dioxide have been captured from natural gas production at Sleipner and stored in a sandstone aquifer filled with saline water about 2,600 feet below the seabed, according to the company website. "The carbon dioxide will probably remain stored in the geological layer for thousands of years," the website predicts.

So why hasn't the Sleipner example been adopted worldwide?

"We can do it today," Benson said. "It's really just a matter of money. If we had a price on carbon that was $50 a metric ton, carbon capture and storage would take off. But with no price on carbon in sight, companies can only sustain a certain amount of investment. So really the impediment is creating the incentive where people will pay that price for capturing carbon."

The Norwegian government created an incentive 20 years ago. "To combat global warming, Norway imposed a carbon tax of $50 per metric ton for offshore carbon dioxide emissions in 1991," Benson said. "Companies were faced with a choice – either pay the tax or stop emitting carbon dioxide into the atmosphere. They soon realized it would cost them a lot less to inject it under the seabed."

The biggest expense Sleipner and other companies face is separating and capturing the carbon dioxide emissions. "Separating is quite costly, $50 to $100 per metric ton," Benson said. "That's the big cost. The underground storage is less than 20 percent of the total cost."

The natural gas produced at the Sleipner site contains about 10 percent carbon dioxide, which has to be separated and removed before the company can sell the natural gas. The additional cost of storing it in the seabed is relatively nominal, Benson said. Perhaps one day the United States and other major fossil fuel consumers will follow Norway's lead, she added.

"Fundamentally, carbon capture and storage is not such a challenging thing to do," she said. "If we were really serious about dealing with climate change, we would be deploying this technology today."

Provided by Stanford University

Citation: Stanford scientists subject rocks to hellish conditions to combat global warming (2011, December 1) retrieved 25 April 2024 from https://phys.org/news/2011-12-stanford-scientists-subject-hellish-conditions.html