Going underground to monitor carbon dioxide

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A technique originally, applied to monitor the flow of contaminants into shallow groundwater supplies, has been repurposed to monitor carbon dioxide pumped deep underground for storage.

Electric Resistance Tomography (ERT) has been installed to track where a plume of injected CO2 moves underground in an oil field (Cranfield Oilfield) near Natchez, Miss. The site is part of the Southeast Regional Carbon Sequestration Partnership (SECARB), a project that eventually will store more than one million tons of CO2 in underground formations.

The ERT project at Cranfield is the deepest (10,000 feet) subsurface application of the method to date. The previous record of 2,400 feet was held by a European sequestration project near Potsdam, Germany. ERT uses vertical electrode arrays, usually in a cross-well arrangement, to perform four-electrode measurements of changes in the spatial distribution of electrical resistance within a subsurface formation. Because the Cranfield site contains CO2, which is five times as resistive as its surroundings, ERT showed that significant resistance changes occurred during plume growth and movement.

"We can image the CO2 plume as the fluid is injected," said geophysicist Charles Carrigan, the LLNL lead on the ERT project. "What we've seen is a movement of the plume outward from the injection well into the geologic formation used for storage. "

The ERT system was installed in two monitoring wells more than 10,000 feet deep and able to withstand more than 250 degrees Fahrenheit and 5,000 pounds per square inch (psi) of pressure

SECARB is a partnership involving Southern States Energy Board, regulatory agencies, geological surveys from 11 states, the Electric Power Research Institute, the Tennessee Valley Authority, southern utilities, academic institutions, a Native American enterprise and the private sector.

ERT, a technology developed for environmental and geologic applications at Livermore starting in the 1980s, is similar to a computed tomography scan. It images soil resistivity, and that gives scientists information on soil properties such as temperature, soil type and saturation. In the case of the Cranfield project, it can provide Carrigan with critical information on what happens to the CO_2 once it's stored deep underground.

Carrigan said monitoring plume characteristics requires sophisticated sensors, data acquisition devices and imaging instruments involving different measurement techniques that are capable of operating in deep boreholes. The results of the monitoring are analyzed to ensure that the site is operating as expected. Even with the proper equipment, plume movement can be difficult to reconstruct due to uncertainties in reservoir structure and unknown multiphase fluid processes.

However, ERT can convert a large number of resistance measurements into an image of electrical resistivity distribution associated with the plume. "Because changes in CO_2 concentration and saturation cause changes in resistivity, ERT is a useful monitoring tool," Carrigan said. ERT monitoring is potentially capable of signaling leakage from a sequestration reservoir possibly years before it can reach an overlying aquifer causing damage to water supplies.

"This is a great start for applying ERT to the very challenging sequestration environment," he said. "We hope we can use ERT in the future at commercial CO_2 underground storage sites."

Other researchers currently involved in the project include Abe Ramirez and Julio Friedmann at Lawrence Livermore, Doug LaBrecque at Multi-Phase Technologies and Susan Hovorka, Bureau of Economic Geology, University of Texas.

The ERT system currently takes 10,000 measurements per day that Carrigan can access remotely. So far the technology has shown that the CO_2 plume produces a strong signal and ERT has captured the basic plume details.

The advantages to power companies looking to store and monitor CO_2 movement and storage underground are very significant, according to Carrigan.

Advantages include: a robust system - no moving parts; outside-the-casing installation leaving the well open for other uses; and relatively low cost to install and continuously operate.

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