The Johnson County Enhanced Natural Gas Recovery Well Test

Name: Crossrock Drilling No. SS-#1
Interstate Drilling

Purpose: To perform a transient pressure test in a Devonian shale well to assess the possibility for enhanced natural gas recovery with CO_2 storage in eastern Kentucky

Funding source: Incentives for Energy Independence Act 2007 (IEIA)

Cost: $790,000 (approximately);
IEIA=$425,000,
Matching funds=$365,000

Well type: Existing shale gas well

Total depth: 1,910 ft

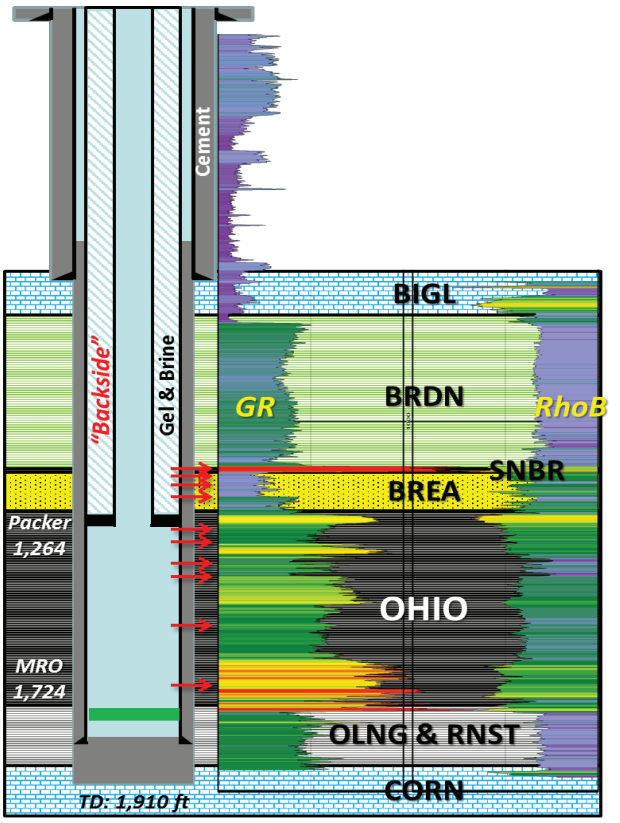
Primary target: Devonian Ohio Shale from 1,227 to 1,714 ft

Data collected:

- Pre- and post-test data
  - ☐ Well flow profiles
  - ☐ Produced gas compositions
  - ☐ Pulsed neutron logs
- Pressure and temperature
- CO_2 injection rate, pressure, and temperature

Additional data collected from two Ohio Shale gas wells in Burk Branch, Pike County

- Rotary sidewall cores and advance logs
- Standard and advanced laboratory analyses
- Reservoir modeling and simulation



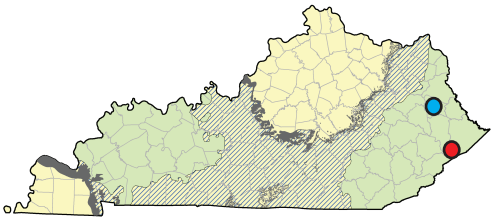
Rock units and test configuration for the Ohio Shale enhanced natural gas recovery test with the gamma ray (GR) and density (RhoB) logs. Red arrows indicate perforations and "MRO" is the downhole equipment for monitoring pressure and temperature.

Subsurface testing:

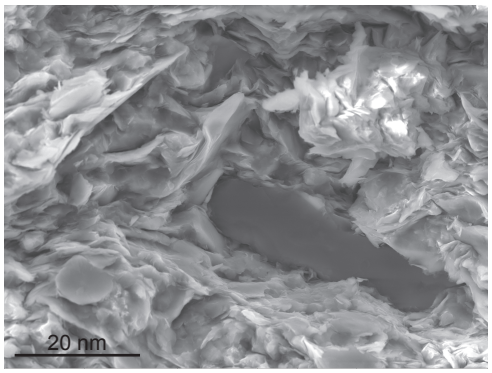
- Injected 87 tons of CO_2 into the shale in three stages through perforations in the well casing below an inflatable packer set at 1,264 ft (to isolate the test interval)
- Pre- and post-test pulsed neutron log data compared to identify CO_2 retained in the shale

Results:

- → First test of concept of CO_2 enhanced natural gas recovery in gas shales in the nation
- → CO_2 can be delivered at pressure downhole using standard nitrogen fracture stimulation
- → CO_2 was retained in the shale



Location of the Crossrock No. SS-#1 well (blue circle) and the Burk Branch wells (red circle).



Scanning electron microscope image of organic matter (dark gray) in clay matrix from the K-2605 well at 4,319 ft depth. The width of the image is a little more than the width of a human hair.

Installing tubing and packer in the Crossrock No. SS-#1 test well.

Discussion: The Devonian Ohio Shale is a major natural gas shale in Kentucky. Isotherm data for the shale indicate that CO_2 is preferentially adsorbed with respect to CH_4 (methane). CO_2 should stay in the shale and expel CH_4, which would enhance natural gas production. An initial test site was proposed at Burk Branch in Pike County, and data to characterize the shale were acquired, including scanning electron microscope imaging of shale microstructure. These data were combined with other data to construct a reservoir model of the shale and simulate scenarios for conducting a pilot test of the enhanced natural gas recovery concept with CO_2.

The original site was withdrawn from testing by the site owner, and a new test site was identified in Johnson County: the Crossrock No. SS-#1 well. The SS-#1 well is an existing gas well completed in the Devonian Berea Sandstone through the Lower Huron Member of the Ohio Shale. The well was shut in and never produced. After background data including pulsed neutron well logs were collected, a packer was set at a depth of 1,264 ft to isolate the injection zone. CO_2 was pumped at pressures up to 1,000 psi (below pressures required for fracture stimulation) in three stages. During the third stage, an increase in pressure in the casing/tubing annulus indicated some of the injected CO_2 was migrating around the packer through fractures in the formation into the overlying Berea Sandstone; the test was terminated with 87 tons of an initial planned 300 tons of CO_2 injected.

A post-test pulsed neutron log and other data were acquired. Analysis of the well logs indicated CO_2 was retained in the shale. The short duration of the test precluded determining whether or not CO_2 was adsorbed by the shale. Analysis of the transient pressure test data was inclusive as a result of the CO_2 migration into the Berea Sandstone.

Data acquired during this test will help develop a better understanding of shale gas reservoirs and enhanced natural gas recovery with CO_2 possibilities. Data will also be valuable for designing future tests of the concept of enhanced natural gas recovery with CO_2. Uncontrolled factors associated with the well used in the test affected the outcome. Future tests should use a well drilled for that purpose.