Ohio's Deep CO_2 Sequestration Well

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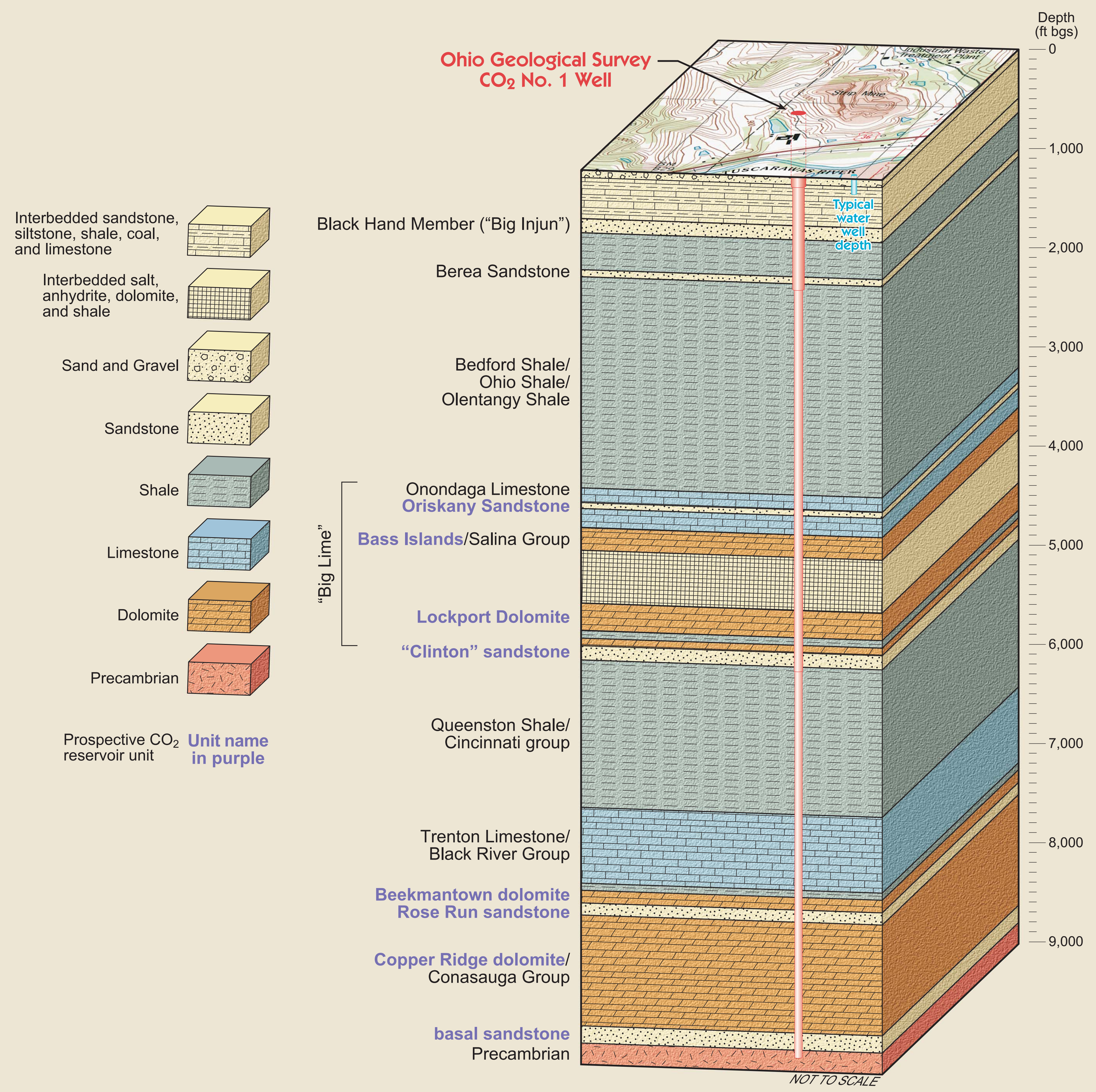
Abstract

Drilling, coring, logging, and injectivity testing of the Ohio Department of Natural Resources, Division of Geological Survey CO_2 No. 1 Well in Tuscarawas County was completed in August 2007. The well was drilled through the entire sedimentary column, reaching a total depth of 8,695 feet in Precambrian crystalline rock. This joint project between the Ohio Geological Survey and Battelle Memorial Institute was accomplished with $2.3 million from the state's general revenue fund and the Ohio Coal Development Office clean coal research funds. The stratigraphic test was conducted to evaluate the CO_2 injectivity and storage capacity of all potential reservoirs and the effectiveness of their potential confining units.

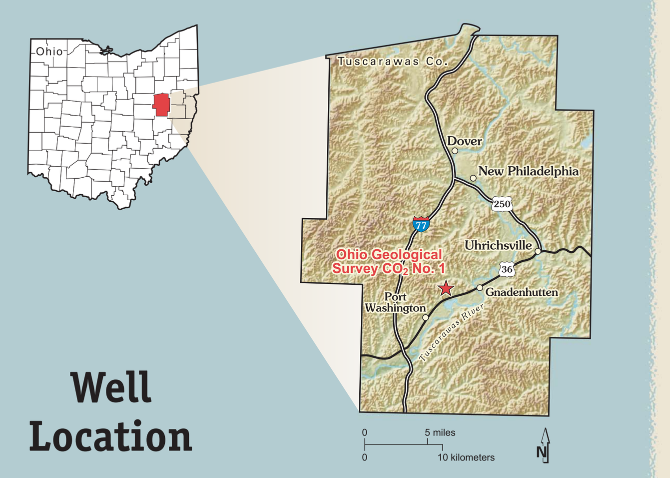
Primary reservoirs for evaluation of CO_2 sequestration are the Cambrian basal sandstone and the Rose Run sandstone. Preliminary log analyses from this well indicate that the basal Cambrian sandstone contains 56 feet of net sandstone (greater than 6 percent porosity) with an average porosity of 10 percent. The Rose Run sandstone has 24 feet of net sandstone with an average porosity of 9.0 percent (13.5 percent maximum). Core analyses on 82 sidewall cores include porosity and permeability, geochemistry, thin section petrography, SEM, X-Ray diffraction, and rock mechanics. Slug and constant-pressure injectivity testing was conducted for two zones within the Cambrian basal sandstone and three zones within the Rose Run sandstone. Approximately 3,950 gallons of treated brine were injected. Maximum downhole pressures were 4,355 psi for the basal Cambrian sandstone and 3,825 psi for the Rose Run interval. Analyses of all data are being finalized and will allow us to better assess the sequestration potential of target reservoir zones and to generate detailed models for CO_2 sequestration simulations.

Geology and Well Construction of the Tuscarawas County Stratigraphic Test



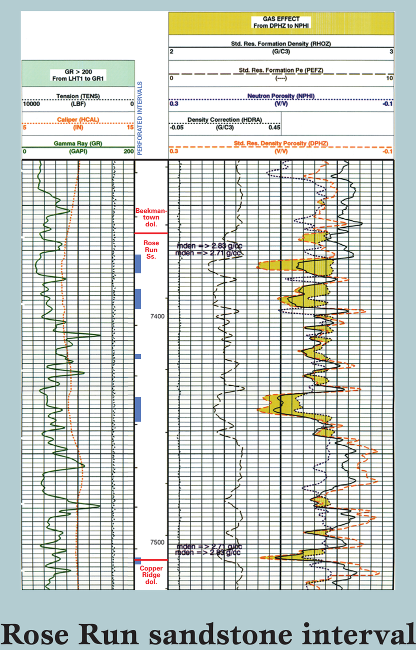
Ohio Geological Survey CO_2 No. 1 Well Goals

- Verify existence, depth, and thickness of key potential injection formations.
- Obtain detailed formation data from logs and sidewall cores for both potential reservoirs and caprocks.
- Perform injection rate tests.
- Correlate results with existing data to provide a larger understanding of Ohio's CO_2 injection capability.



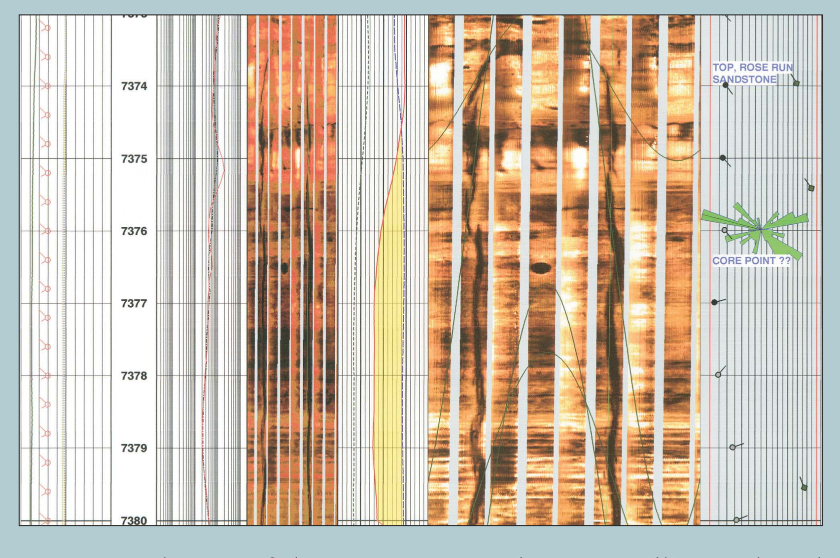
Well Location

Reservoir Characterization



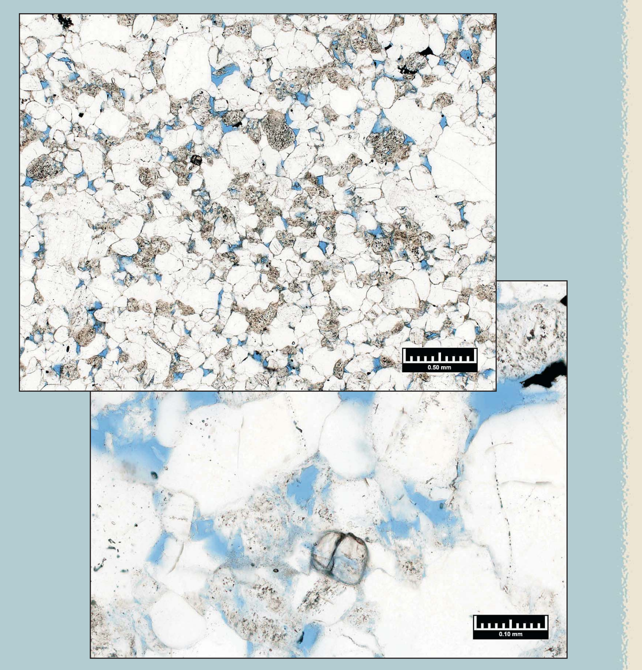
Rose Run sandstone interval

Net sandstone (> 6 % porosity) is 24 ft
Maximum porosity is 13.5 %
Average porosity is 9.5 %
Maximum permeability is 26.6 md (core analyses)

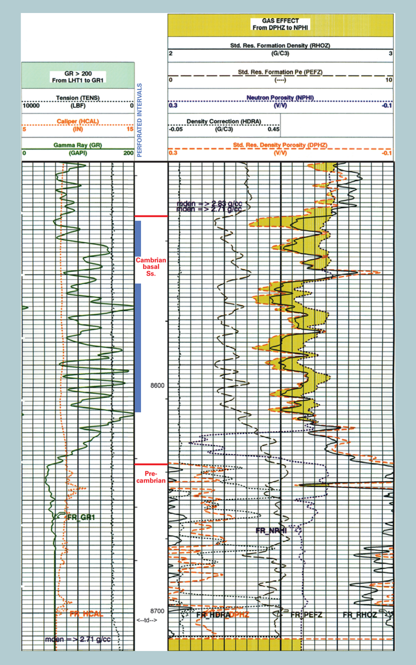


FMI near the top of the Rose Run sandstone. Drilling-induced vertical fractures are displayed. Note the location of a sidewall core.

Sidewall core photos of the Rose Run sandstone at 7,441 feet (end trim and longitudinal view).

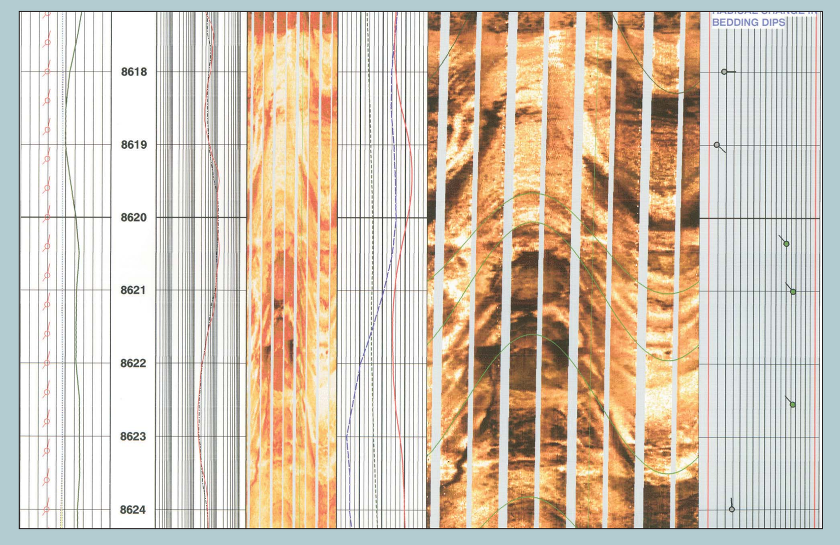


Thin-section photomicrographs of the Rose Run sandstone at 7,441 feet (magnification: 40X in upper photo; 200X in lower photo). This is a subarkose composed dominantly of quartz and feldspar. Pore types include intergranular, grain-moldic, and intragranular (leached feldspar). Cementation includes quartz and feldspar overgrowths.



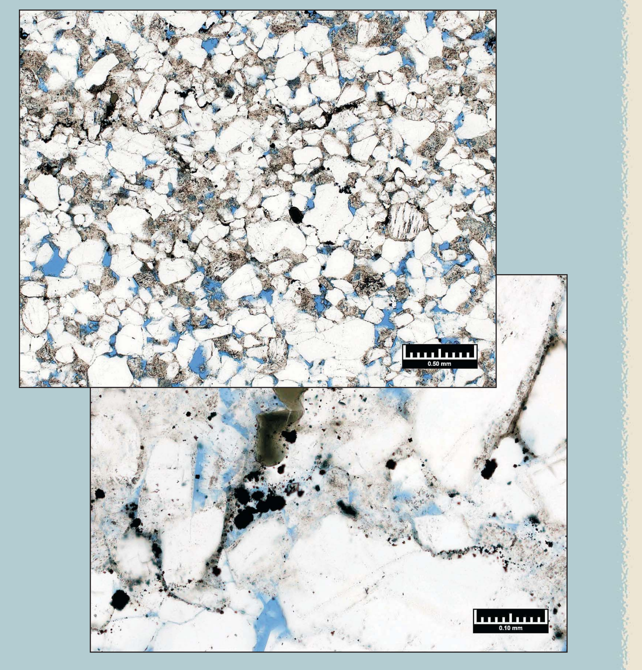
Cambrian basal sandstone interval

Net sandstone (> 6 %) is 56 ft
Maximum porosity is 15 %
Average porosity is 10 %
Maximum permeability is 1.0 md (core analyses)



Precambrian contact with overlying Cambrian basal sandstone is marked by sharp change in dip on FMI log.

Sidewall core photos of the Cambrian basal sandstone at 8,561 feet (end trim and longitudinal view).



Thin-section photomicrographs of the Cambrian basal sandstone at 8,561 feet (magnification: 40X in upper photo; 200X in lower photo). This arkose consists dominantly of quartz, K-feldspar, and lithic fragments. Authigenic cements include pore-lining clay, quartz overgrowths, feldspar overgrowths, and pyrite.

Injection Testing Results in the Cambrian Basal Sandstone and the Rose Run Sandstone

Ohio Borehole Test Summary/ Activity Log: basal sand

Formation	Perforated Test Interval Depth, ft bKB[a]	Borehole Test Activity	Test Date/Time[b]	Comments*
Basal Sand	8,526 - 8,531 8,536 - 8,542 8,554 - 8,566 8,566 - 8,576	Swab Development of Basal Sand Perforated Zones	7/19/07 (15:30 - 18:30) 7/20/07 (08:00 - 11:30)	Total volume of fluid ***removed*** from interval? 3,970 gallons (94.5 barrels); pH increased from 1 to 6 and fluid weight density from 8.5 to 10.3 lb/gal during the course of fluid removal
		Aborted Injection Test	7/20/07 (17:18 - 20:52)	Injection rate at ~2 gpm and then test aborted due to inadvertent closing of downhole shut-in tool; Injection Vol.: 430 gal Max. Surface Inj. Pressure: < 0 psi Max. Downhole Obs. Pressure: 3,405 psi Avg. Fluid Weight Density: ~9.8 lb/gal
		Constant-Pressure Injection Test	7/22/07 (10:08 - 19:01)	Injection rates varied from 2.42 to 0.61 gpm during the course of the test; Injection Vol.: 555 gal Max. Surface Inj. Pressure: 3 psi Max. Downhole Obs. Pressure: 4,355 psi Avg. Fluid Weight Density: ~9.8 lb/gal
		Slug Injection Test	7/23/07 07:03 - 09:56	Injection Vol.: 85 gal Max. Surface Inj. Pressure: < 0 psi Max. Downhole Obs. Pressure: 4,340 psi Avg. Fluid Weight Density: ~9.8 lb/gal
		Basal Sand Test Interval Summary: Total Injection Volume: 1,070 gallons Total Injection Period: 15.3 hours (1.1gal/min_RAR) Maximum Surface Injection Pressure: 3 psi Maximum Observed Downhole Pressure: 4,355 psi		

Ohio Borehole Test Summary/ Activity Log: Rose Run #1

Formation	Perforated Test Interval Depth, ft bKB[a]	Borehole Test Activity	Test Date/Time[b]	Comments*
Rose Run #1	7,506 - 7,509	Constant-Pressure Injection Test	7/26/07 (18:10) - 7/27/07 (08:42)	After test system fill-up, the test was maintained at a constant surface pressure of 50 psi. Injection rates varied from 0.2 to 0.07 gpm during the course of the constant-pressure injection test: Injection Vol.: 245 gal Max. Surface Inj. Pressure: 50 psi Max. Downhole Obs. Pressure: 3,680 psi Avg. Fluid Weight Density: ~9.8 lb/gal
		Slug Injection Test	7/28/07 (07:22 - 10:01)	Injection Vol.: 5 gal Max. Surface Inj. Pressure: < 0 psi Max. Downhole Obs. Pressure: 3,635 psi Avg. Fluid Weight Density: ~9.8 lb/gal
		Rose Run #1 Test Interval Summary: Total Injection Volume: 250 gallons Total Injection Period: 17.2 hours Maximum Surface Injection Pressure: 50 psi Maximum Observed Downhole Pressure: 3,680 psi		

Ohio Borehole Test Summary/ Activity Log: Rose Run #2

Formation	Perforated Test Interval Depth, ft bKB[a]	Borehole Test Activity	Test Date/Time[b]	Comments*
Rose Run #2	7,416 - 7,418 7,435 - 7,446	Constant-Pressure Injection Test #1	7/29/07 (14:00) - 7/30/07 (10:00)	After test system fill-up, the test was maintained at a constant surface pressure of 50 psi. Injection rates varied from 3.2 to 1.0 gpm during the course of the constant-pressure injection test: Injection Vol.: 245 gal Max. Surface Inj. Pressure: 50 psi Max. Downhole Obs. Pressure: 3,825 psi Avg. Fluid Weight Density: ~9.8 lb/gal
		Slug Injection Test	7/31/07 (09:25 - 10:15)	Injection Vol.: 45 gal Max. Surface Inj. Pressure: < 0 psi Max. Downhole Obs. Pressure: 3,785 psi Avg. Fluid Weight Density: ~9.8 lb/gal
		Constant-Pressure Injection Test #2	7/31/07 (12:17 - 20:03)	After test system fill-up, the test was maintained at a constant surface pressure of 50 psi. Injection rates varied from 1.2 to 1.0 gpm during the course of the constant-pressure injection test: Injection Vol.: 530 gal Max. Surface Inj. Pressure: 50 psi Max. Downhole Obs. Pressure: 3,825 psi Avg. Fluid Weight Density: ~9.8 lb/gal
		Rose Run #2 Test Interval Summary: Total Injection Volume: 820 gallons Total Injection Period: 28.6 hours Maximum Surface Injection Pressure: 50 psi Maximum Observed Downhole Pressure: 3,825 psi		

Ohio Borehole Test Summary/ Activity Log: Rose Run #3

Formation	Perforated Test Interval Depth, ft bKB[a]	Borehole Test Activity	Test Date/Time[b]	Comments*
Rose Run #3	7,377 - 7,380 7,387 - 7,396	Constant-Pressure Injection Test	8/1/0 (11:36)- 8/2/07 (07:36)	After test system fill-up, the test was maintained at a constant surface pressure of 50 psi. Injection rates varied from 0.55 to 0.17 gpm during the course of the constant-pressure injection test: Injection Vol.: 265 gal Max. Surface Inj. Pressure: 50 psi Max. Downhole Obs. Pressure: 3,780 psi Avg. Fluid Weight Density: ~9.8 lb/gal
		Slug Injection Test	8/3/07 (07:46 - 9:47)	Injection Vol.: 30 gal Max. Surface Inj. Pressure: < 0 psi Max. Downhole Obs. Pressure: 3,745 psi Avg. Fluid Weight Density: ~9.8 lb/gal
		Rose Run #3 Test Interval Summary: Total Injection Volume: 295 gallons Total Injection Period: 22.0 hours Maximum Surface Injection Pressure: 50 psi Maximum Observed Downhole Pressure: 3,780 psi		

Ohio Borehole Test Summary/ Activity Log: Composite Rose Run

Formation	Perforated Test Interval Depth, ft bKB[a]	Borehole Test Activity	Test Date/Time[b]	Comments*
Composite Rose Run	7,377 - 7,380 7,387 - 7,396 7,416 - 7,418 7,435 - 7,446 7,506 - 7,509	Swab Development of Composite Rose Run Perforated Zone	7/24/07 (16:00 - 18:15) - 7/25/07 (07:00 - 13:05)	Set bridge plug at 7,530 ft and initiated development of composite Rose Run perforated interval. Total volume of fluid ***removed*** from interval?10,330 gallons (246 barrels); pH increased from 1 to 5 and weight from 8.6 to 10.1 lb/gal during the course of fluid removal
		Constant-Pressure Injection Test	8/3/07 (17:25) - 8/4/07 (17:34)	After test system fill-up, the test was maintained at a constant surface pressure of 50 psi. Injection rates varied from 2.12 to 0.82 gpm during the course of the constant-pressure injection test: Injection Vol.: 1,450 gal Max. Surface Inj. Pressure: 50 psi Max. Downhole Obs. Pressure: 3,790 psi Avg. Fluid Weight Density: ~9.8 lb/gal
		Slug Injection Test	8/6/07 (06:33 - 8:33)	Injection Vol.: 65 gal Max. Surface Inj. Pressure: < 0 psi Max. Downhole Obs. Pressure: 3,740 psi Avg. Fluid Weight Density: ~9.8 lb/gal
		Composite Rose Run Test Interval Summary: Total Injection Volume: 1,515 gallons Total Injection Period: 26.2 hours Maximum Surface Injection Pressure: 50 psi Maximum Observed Downhole Pressure: 3,790 psi		

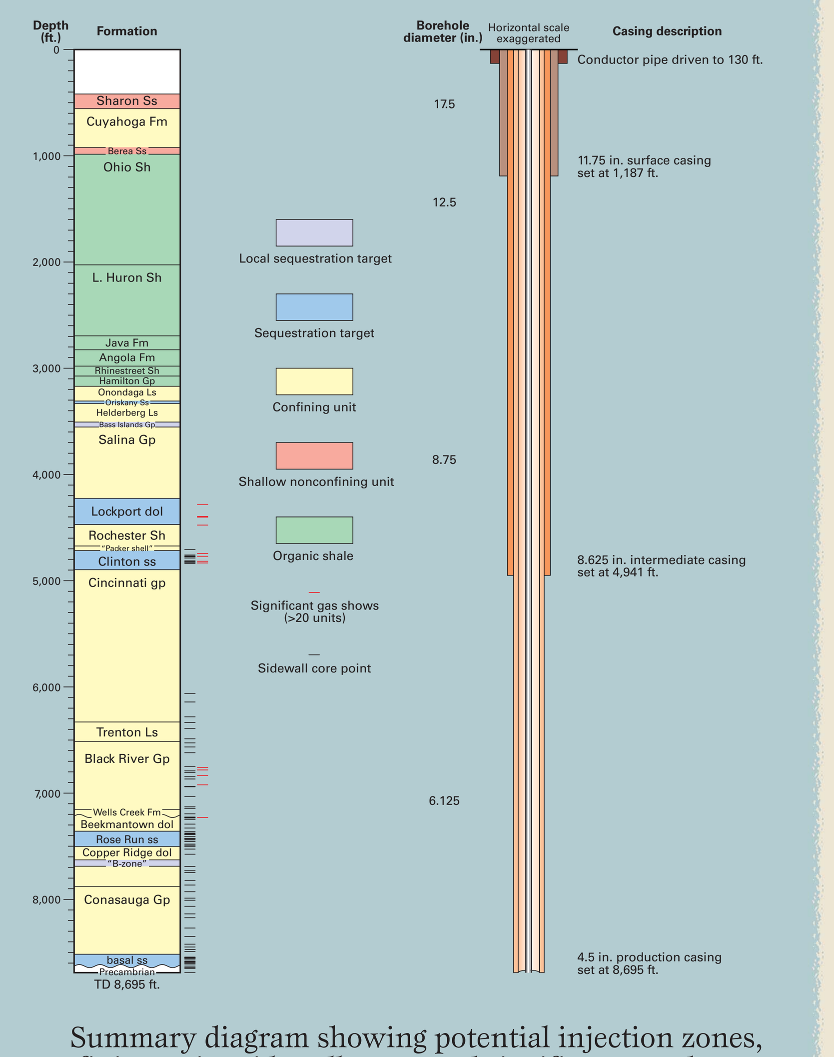
Summary

Wireline Logs and Coring Conducted on the Ohio Geological Survey CO_2 No. 1 Well

- Gamma Ray, Lithodensity Compensated Neutron, PEF
- Laterolog
- CMR (Combinable Magnetic Resonance)
- Sonic Porosity
- Pressure Express
- Sidewall Cores (82)
- Perf Log
- Cement Bond Log
- FMI (Formation Micro Imager—processed interpretation)
- FracCADE Advisor (processed interpretation)
- Dipole Sonic (processed interpretation)
- Injection tests were performed in the Cambrian basal sandstone and the Rose Run sandstone

Results

- At this site, reservoir quality for the Cambrian basal sandstone was less than expected. Wireline logs indicated 56 feet of net sandstone (> 6 %). The average porosity was 10 % with a maximum of 15 %. However, core analyses indicated relatively low permeabilities with a maximum permeability of 1.0 md, and most were < 0.1 md. Results form this well will be correlated to other wells to identify areas of better reservoir quality.
- Reservoir quality of the Rose Run sandstone was more promising in regards to permeability. Logs indicated a net sandstone thickness of 24 feet (> 6 % porosity). The average porosity was 9.5 % with a maximum of 13.5 %. Core analyses indicated permeability values with measurements of 1.40, 13.8 and 26.6 md in selected zones.
- Log, core, and injectivity tests from this well will be correlated to other wells in the region and used to provide models for regional and site specific injection potential.
- Issues involving sequestration in oil and gas producing areas are being examined. This well was turned over to the operator who controlled the lease, which resulted in significant production from the Beekmantown dolomite. This well will provide additional data for exploration of this and other producing reservoirs.
- Other states are now attempting to fund similar research wells for CO_2 sequestration research.
- Efforts such as this are keeping Ohio at the forefront of carbon sequestration research in the U.S.



Summary diagram showing potential injection zones, confining units, sidewall cores, and significant gas shows.