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SECARB

Southeast Regional Carbon Sequestration Partnership (SECARB)

Black Warrior Basin Coal Seam Project

Field Test Location

Tuscaloosa County, Alabama

Amount and Sources of CO_2

1,000 Tons from Natural Source (Jackson Dome)

Primary Contacts

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Field Test Partners

Primary Sponsors
DOE/NETL
SSEB

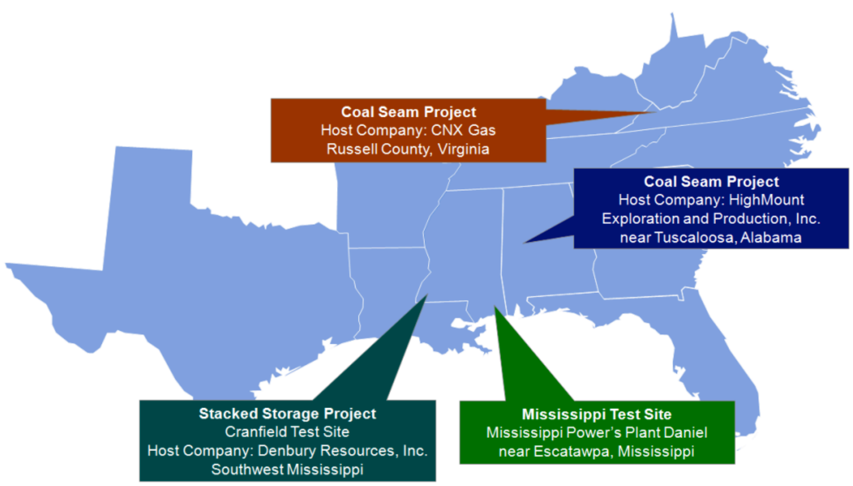
Industrial Partners
Virginia Tech
Southern Company
Electric Power Research Institute
El Paso Exploration and Production, Inc.
Denbury Resources, Inc.

Summary of Field Test Site and Operations

The Southeast Regional Carbon Sequestration Partnership's (SECARB) Black Warrior Basin Coal Seam Project injection testing was performed to provide an initial assessment of the capability of mature coalbed methane reservoirs to receive and adsorb significant volumes of carbon dioxide (CO_2) for geologic carbon sequestration and enhanced coalbed methane recovery. A coalbed methane well in Blue Creek Coal Degasification Field (Figure 1) was used for injection testing, and three deep monitoring wells were drilled and cored. Coal seams in the Black Creek, Mary Lee, and Pratt coal zones of the Pennsylvanian-age Pottsville Formation were selected for injection testing and monitoring (Figure 2).

Coal seams constitute the only viable reservoir rocks in the test area and have permeability ranging from less than 10 mD to more than 100 mD. Formation water in the target coal seams contains chloride-rich waters with total dissolved solids content greater than 20,000 mg/L. Strata between the coal seams consist of shale and sandstone with matrix permeability less than 0.001 mD and are thus effective reservoir seals. Fault zones and joint systems provide the major avenues for leakage from deep coal seams. No faults lie within the test area, thus joints are the only structures providing viable avenues for hydraulic communication between coal seams.

Three coal zones were individually through pressure-transient injection-falloff tests using a total of 278 tons of CO_2 (about 93 tons per coal zone). Coal seams at the test site can sequester more than 1,740 tons of CO_2 per acre (30 million scf/acre). Therefore, this project affected only the area immediately surrounding the coalbed methane well.



SECARB Phase II Geographic Region and Field Test Site Locations

Injection was performed through perforated casing between a retrievable bridge plug and isolation packer. Isolation packers and monitoring equipment were installed to observe the response to injection in each monitoring well. In each coal seam, slugs of 17 to 57 tons of CO_2 were injected, and reservoir pressure and fluid composition were monitored. These tests will be repeated on successively shallower coal beds and demonstrated confinement and high injectivity in each coal zone.

All injection was conducted below the formation fracture pressure and as a liquid CO_2 phase that was allowed to vaporize within the reserovir. Following these tests, the production well was pumped and vented for about 30 days to evacuate as much of the injected CO_2 as possible, and the well has been restored to production. These procedures help limit the risk of diluting natural gas produced in adjacent wells and help reduce the risk of long-term leakage of injected CO_2.

Due to the short term of this project and small injection volumes, a small-scale MVA program was established for the pilot injection. The MVA program consisted of: (1) monitoring down-hole pressure and fluid composition; and (2) monitoring soil gas for composition, CO_2 flux, and isotope analysis.

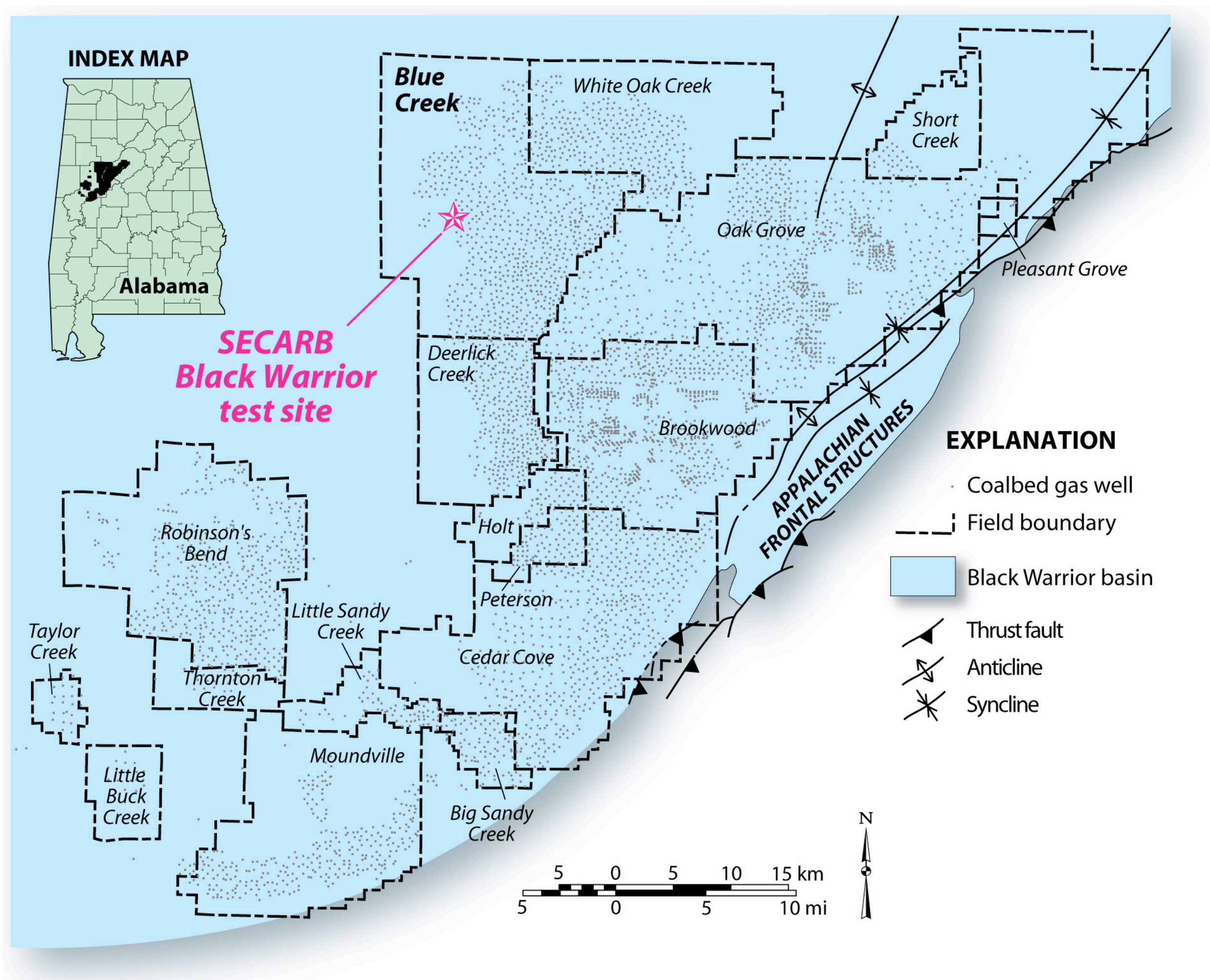


Figure 1. Coalbed methane fields of the Black Warrior Basin in Alabama and location of SECARB Black Warrior Basin Coal Seam Field Test Site

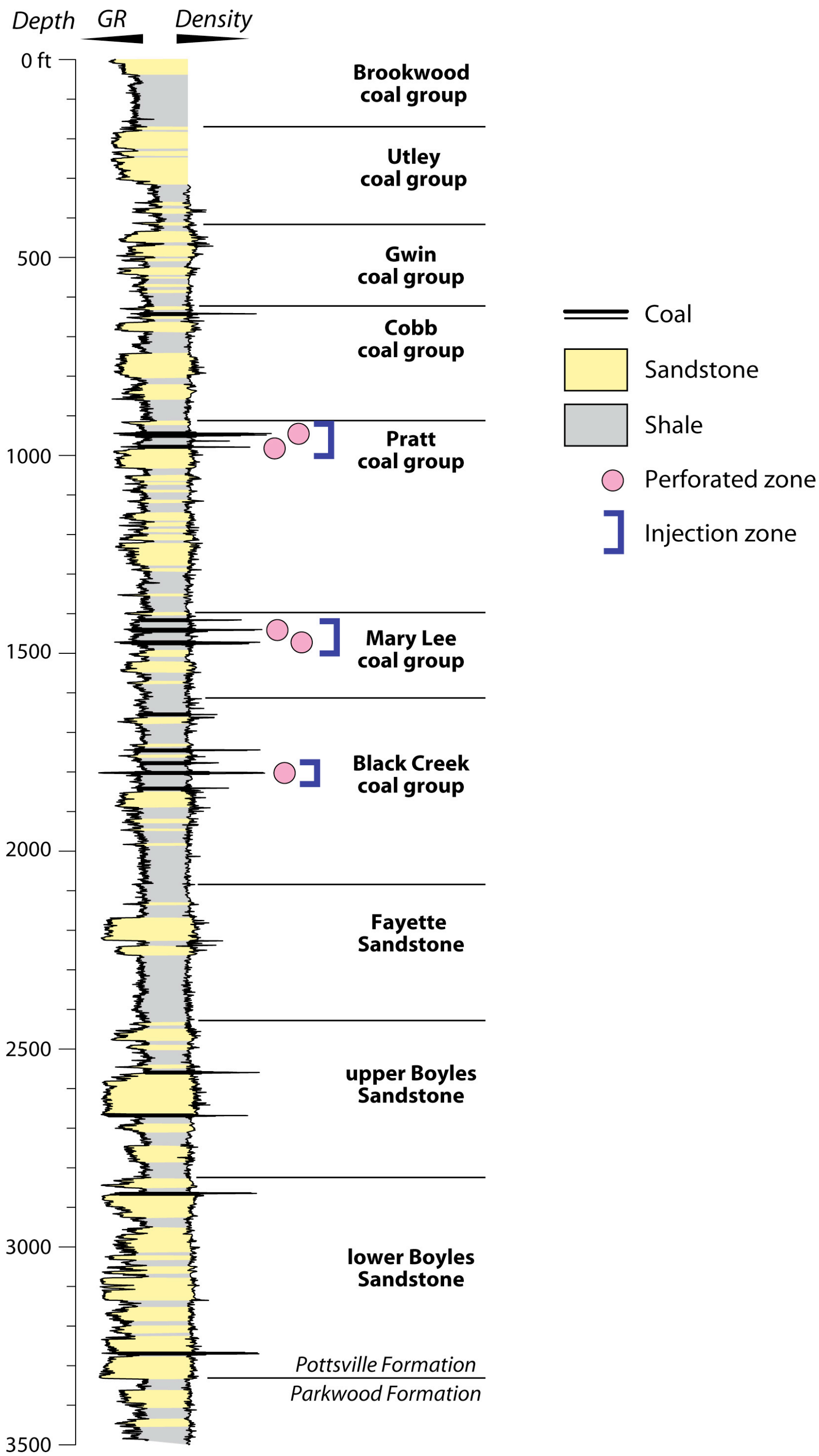


Figure 2. Well log showing stratigraphic section and injection zones in the test area

Research Objectives

The principal objectives of the SECARB Black Warrior coal test are (1) to determine if sequestration of carbon dioxide in mature coalbed methane reservoirs is a safe and effective method to mitigate greenhouse gas emissions and (2) to determine if sufficient injectivity exists to efficiently drive CO_2-enhanced coalbed methane recovery.

Coalbed methane is produced from multiple thin coal seams (0.3 to 2.0 m) distributed through more than 300 m of section in the Black Warrior basin (Figure 1). Coal is an extremely stress-sensitive rock type, and permeability can decrease by as much as four orders of magnitude from the surface to depths as shallow as 700 m. Coal, moreover, is an extremely heterogeneous reservoir, and permeability can vary by more than an order of magnitude at a given depth. Accordingly, procedures and technologies need to be developed to manage reservoirs with properties that vary greatly from seam to seam, This field test is intended to be the first step in this process.

The reservoir properties of coal also can change over time. During primary production, permeability can increase by an order of magnitude as gas desorbs and coal matrix shrinks. Injection of CO_2 will reverse this process, and injectivity is predicted to decrease over time. Therefore, another important objective of this test is to quantify the effect of changing matrix properties on the performance of sequestration and enhanced gas recovery operations.

Cleating can give rise to significant permeability anisotropy in coal, and anisotropy ratios exceeding 15:1 are common. All coalbed methane wells in the Black Warrior Basin have been hydraulically fractured to improve communication between the natural cleat system and the wellbore. Multiple deep monitoring wells will be used to perform interference tests that will quantify the effects of permeability anisotropy and induced hydraulic fractures in different coal seams.

Another objective was to begin developing MVA protocols that can be applied effectively to commercial-scale operations. Monitoring pressure simultaneously in multiple coal zones helped quantify the degree of hydraulic communication between coal zones. Carbon isotopes were be analyzed to determine if isotopically heavy injectate is mixing with isotopically light soil gas. Soil flux monitoring for CO_2 was performed to evaluate seepage monitoring protocols.

Summary of Modeling and MMV Efforts

Modeling activities being conducted in conjunction with this test include a broad range of geologic and reservoir modeling techniques. Highlights include advanced reservoir modeling to simulate the performance of the field test using COMET software. The University of British Columbia and Oak Ridge National Laboratory will be developing models of gas adsorption for Pottsville coal and will include work on the kinetics of adsorption under wet and dry reservoir conditions. The Geological Survey of Alabama and the University of Alabama are developing discrete fracture network models of coalbed methane reservoirs and will develop simulations of the SECARB test site. A summary table of MVA activities is provided below.

Technique	Equipment	Parameters	Application
Reservoir Pressure & Fluid Composition	Pressure detectons and sampling tubes in injection wells and deep monitoring wells	Formation and injection pressure, gas composition, water composition	Injectivity & reservoir heterogeneity; tracking CO2 movement in and above formation (multi-zone monitoring)
Site Reconnaissance	Visual reconnaissance	Detect vegetative stress from CO2 flux	Evaluate ecosystem impacts
Soil gas flux	Real-time infrared gas analyzer with accumulation chamber (Li-Cor CO2 flux monitor)	CO2 flux	Determine soil dynamics and develop protocols for leak detection
Isotopic analysis	Mass spectrometer gas analyzer	Analyze composition of 13C in soil gas, produced coalbed gas, and injected CO2	Analysis of soil dynamics, reservoir dynamics, and utility of major gas isotopes as tracers
Mechanical integrity testing	Hydrostatic pressure gauge, wireline well logger	Hydrostatic pressure test and cement bond log	Examine integrity of well casing and cement and verify ability of well to hold pressure in accordance with UIC guidelines

Accomplishments to Date

1. Sequestration opportunities in coal of the Black Warrior Basin and southern Appalachian thrust belt have been assessed.
2. A pilot test site, hosted by El Paso Exploration and Production, Incorporated, was developed in Blue Creek Field.
3. Injection and monitoring activities have been completed and demonstrated significant injectivity in all coal seams test and that the injected CO_2 remained in zone.
4. Site closure has been completed, and the well used for injection testing has been returned to coalbed methane production.
5. A vigorous technology transfer and outreach program has been conducted through the internet, publications, and presentations at technical and non-technical meetings.

Target Sink Storage Opportunities and Benefits to the Region

Coal is among the most attractive potential CO_2 sinks in SECARB region, and the prolific coalbed methane industry in the Black Warrior basin is approaching maturity. Coal in the Black Warrior basin has potential to sequester 1.12 to 2.32 Gt of CO_2, and CO_2-enhanced coalbed methane recovery has the potential to prolong the life of the reservoirs and increase reserves by 20 to 40 percent. Technically feasible sequestration capacity in established fields is estimated conservatively to be 468 MMt, and enhanced coalbed methane recovery potential is estimated to be between 0.8 and 1.6 Tcf. Two coal-fired power plants with combined CO_2 emissions exceeding 31 Mmt/yr are immediately north of the coalbed methane fields (Figure 1). The proximity of mature coalbed methane reservoirs to these plants provides substantial economic incentive for sequestration, and the numerous conventional hydrocarbon reservoirs and saline aquifers in the basin can help facilitate longer-term sequestration.

Cost

Total Field Project Cost: **$2,381,440**

DOE Share: **$1,875,465** **78.8%**

Non-DOE Share: **$505,975** **21.2%**

Field Project Key Dates

Baseline Completed: Q3, FY09
Drilling Operations Begin: Q4, FY09
Injection Operations Begin: Q1 FY10
MMV Events:
- **Pre-injection baseline:** Q3, FY09
- **Injection monitoring:** Q1 FY10
- **Post-injection monitoring:** Q2, FY 10

Tasks	FY2006				FY2007				FY2008				FY2009				FY2010			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
2.1 Project Definition	■	■																		
2.2 Design			■	■	■	■	■	■	■	■	■	■	■	■						
2.3 Implementation															■	■	■			
2.4 Operations																	■	■	■	
2.5 Closeout/Reporting		■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■

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