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SECARB FIELD TEST FOR CO_2 SEQUESTRATION IN COALBED METHANE RESERVOIRS OF THE BLACK WARRIOR BASIN, ALABAMA

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ABSTRACT

The Southeastern Regional Carbon Sequestration Partnership will be conducting a field test in the Black Warrior basin that is designed to characterize the carbon sequestration and enhanced coalbed methane recovery potential of coal. This program will help develop strategies for injection into multiple coal seams with a broad range of reservoir properties. Reservoir testing will consist of a series of production-buildup and injection-falloff tests. Deep monitoring of pressure and gas composition will be conducted through packers in observation wells. In addition, observation wells will be used for interference testing. This program will also employ a variety of reservoir simulation and shallow monitoring techniques that will be used for history matching and to ensure environmental safety.

INTRODUCTION

Significant potential exists for carbon sequestration and enhanced coalbed methane recovery in coalbed methane reservoirs of the Black Warrior basin in Alabama (Fig. 1), but this potential has yet to be tested. A conservative assessment of technical feasibility in the Black Warrior basin indicates that more than 5.9 Tcf of CO_2 can be sequestered while increasing coalbed methane reserves by more than 20 percent [1]. To begin testing the potential for carbon sequestration in coal of the Black Warrior basin, the Southeastern Regional Carbon Sequestration Partnership (SECARB) will be conducting a field test program that is scheduled to be performed from 2006 through 2009.

This paper describes the SECARB field test program in the Black Warrior basin, which incorporates a range of geological characterization, reservoir modeling, well testing, and monitoring techniques. The field test will center on a mature production well in one of the northwestern coalbed methane fields, where technical feasibility and the potential for commercial application of carbon sequestration technology are high (Fig. 2). Coal seams in the Black Warrior basin are distributed through a thick stratigraphic section and are clustered in a series of coal zones within the Lower Pennsylvanian Pottsville Formation (Fig. 3). In the area of interest (Fig. 2), coalbed methane is produced mainly from the Black Creek, Mary Lee, and Pratt coal zones (Fig. 3), and the SECARB field test will focus on determining injectivity and identifying geologic heterogeneity in these three zones.

PROJECT DESIGN

Coal is an extremely stress-sensitive rock type, and the permeability of coal in the Black Warrior basin decreases exponentially with depth as overburden stress increases [2]. Moreover, permeability can vary by more than an order of magnitude at any given depth, and mapping of production performance indicates significant reservoir heterogeneity [3, 4]. Multiple seam completion technology was developed to recover gas from numerous coal seams with variable reservoir properties [5, 6, 7], and injection

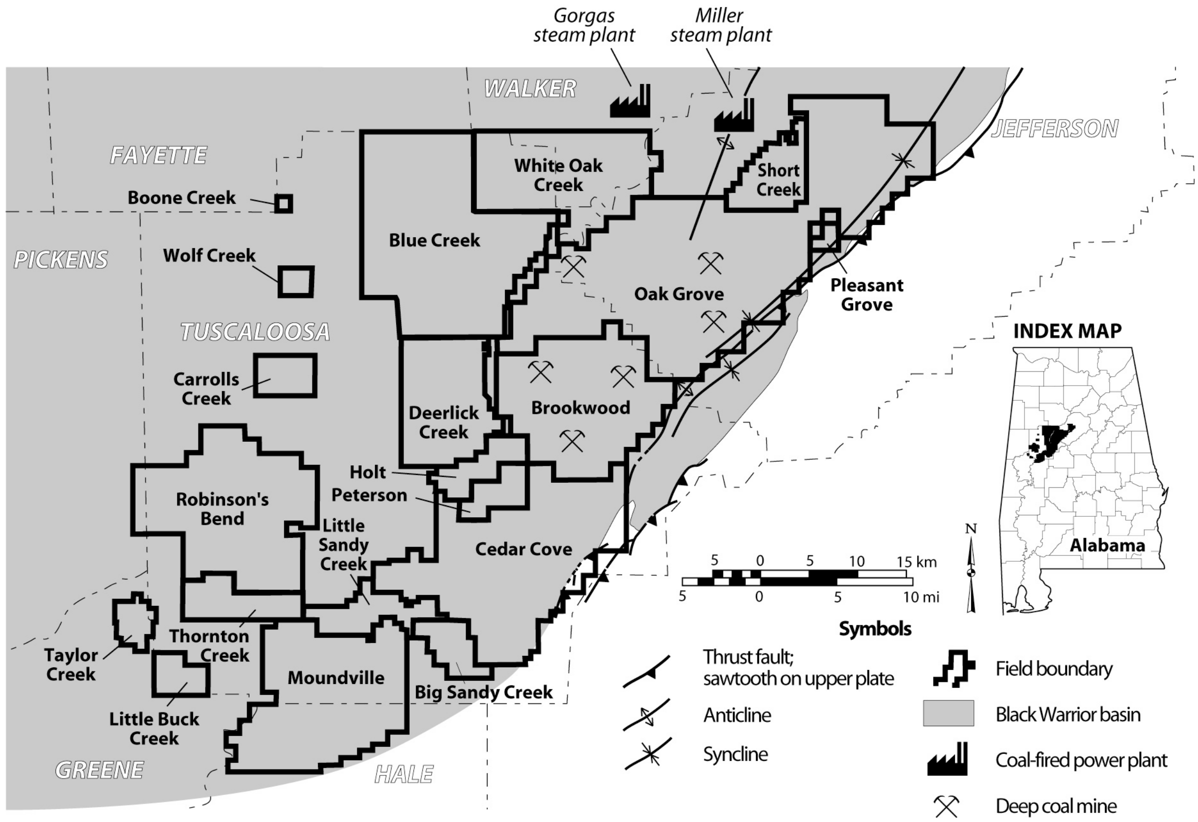

Figure 1. Coalbed methane fields of the Black Warrior basin.

procedures will need to be optimized to realize the sequestration and CO_2-enhanced recovery potential offered by multiple coal seams.

The SECARB field test will include injecting a total of 1,000 tons (17.2 MMcf) of CO_2 into the Black Creek, Mary Lee, and Pratt coal zones. In the area of interest (Fig. 2), coalbed methane wells are drilled on 40-acre units, and CO_2 capacity is estimated to be between 580 and 1,740 tons per acre (10 to 30 MMcf per acre) at an equilibrated reservoir pressure of 350 psi [1]. Therefore, the amount of CO_2 that will be injected is enough to saturate an area between 0.6 and 1.7 acres. The enhanced recovery potential in the area of interest is estimated to range from 1 to 6 MMcf/acre [1]. Commercial prices for CO_2, including delivery and injection, are currently about $100 per ton. Considering the prevailing high gas prices (> $7 per Mcf), CO_2-enhanced coalbed methane recovery is an increasingly attractive economic option.

Efforts are currently focused on selection of the production well that will be used for injection. Criteria used for site selection include coal thickness, formation water chemistry, engineering integrity, production history, and accessibility. Coal thickness is being used to verify that sufficient reservoir exists in each coal zone, and each injection zone should contain at least one coal bed thicker than 1.5 feet. Water chemistry is a critical selection criterion because Underground Injection Control Regulations prohibit injection into formations with total dissolved solids content lower than 3,000 mg/L. Cement bond logs and completion records are being used to ensure borehole integrity and to ensure that prospective injection zones have been perforated and stimulated. Production history is important because a well that has produced little water and gas may indicate low permeability or ineffective completion, whereas a well that has produced exceptional volumes of fluid may not represent common reservoir conditions. In addition, the well chosen for injection should be near depletion to minimize the economic impact of injection. Finally, the well site should be accessible in a way that facilitates the full range of injection and monitoring activities that are to be employed during the SECARB program.

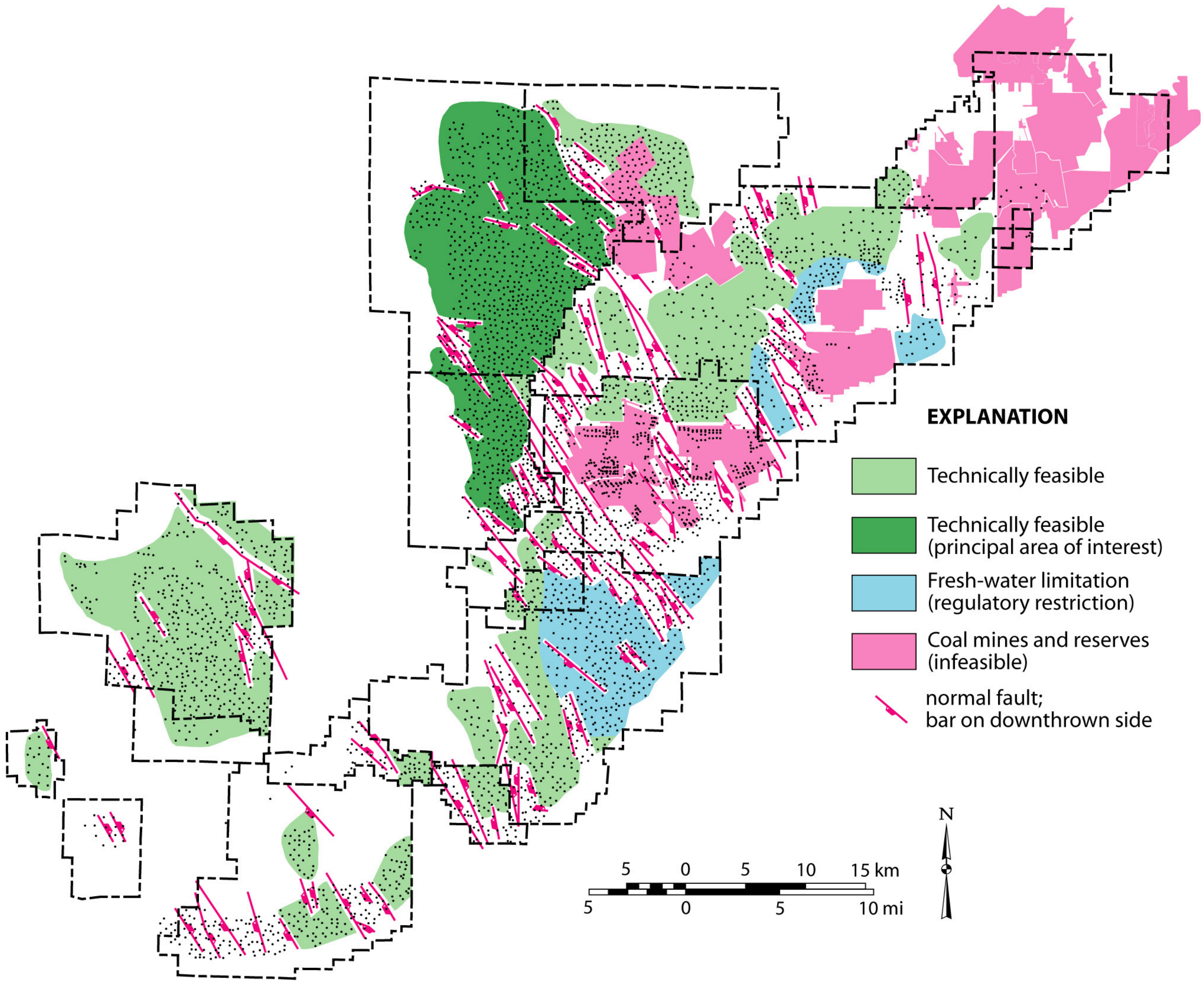

Figure 2. Map showing technical feasibility of carbon sequestration in coalbed methane fields of the Black Warrior basin [modified from 1].

The SECARB Black Warrior test site will include a mature coalbed methane well, deep observation wells, shallow monitoring wells, and surface monitoring stations (Fig. 4). Three cores will be drilled near the production well, and the core holes will be used as deep observation wells. Core analysis will focus on stratigraphic and structural analysis, proximate and ultimate analysis of coal, desorption testing to determine remaining gas (CH_4) content, and derivation of adsorption isotherms for CO_2 and CH_4. Baseline reservoir models, which will be developed by Advanced Resources International, Incorporated (ARI), using the COMET3 reservoir simulator, will be used to determine the precise location of the observation wells.

The injection and deep monitoring program will combine the production-buildup and injection-falloff testing techniques employed by the Alberta Research Council in western Canada [8] with the interference testing techniques employed at the Gas Research Institute's Rock Creek coalbed methane completion test site in the Black Warrior basin [9]. In the production well, packers will be set to isolate each injection zone, and pressure transducers will be installed to monitor the production and injection tests. Well testing in each coal zone will begin with a brief production-buildup test to provide information on pressure response prior to injection (Fig. 5). An initial injection-falloff test will constitute injection of a 33-ton slug of CO_2. Following this test, reservoir pressure will be allowed to stabilize, and then a longer term injection test will be performed during which the remaining 300 tons of CO_2 will be injected. After the pressure stabilizes, a final production test will be performed. This production test will not only provide critical

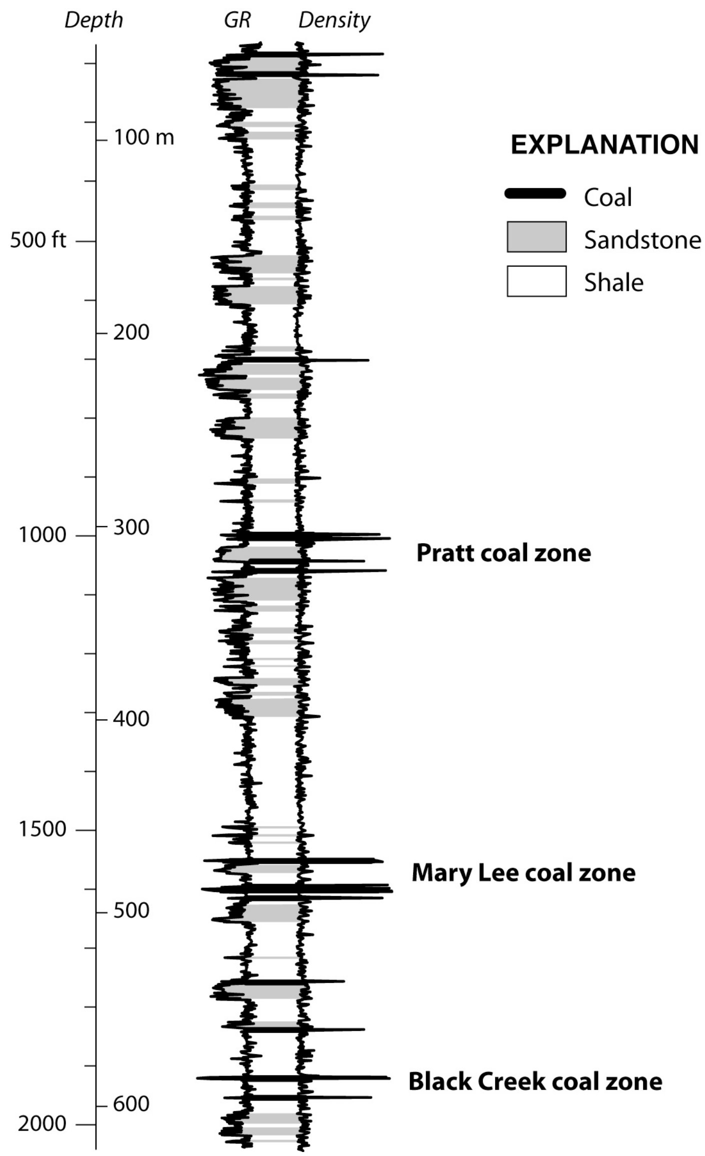

Figure 3. Geophysical well log from the primary area of interest (Fig. 2) showing Pottsville coal zones to be used for reservoir testing.

information on the post-injection response of the reservoir but will also help minimize the risk of long-term breakthrough of injectate to nearby coalbed methane wells.

Deep monitoring in the three observation wells will include monitoring of reservoir pressure and fluid composition. Prior to injection, packers will be set to isolate each coal zone, and pressure transducers, slim-hole chromatographs, and fluid sampling apparatus will be set between the packers in the stratigraphic intervals where gas will be injected. The results of monitoring will be instrumental for determining the effectiveness of CO_2 injection and for characterizing the combined effects of geologic heterogeneity and the hydraulic fracture system at the test site. For example, interference testing using a similar monitoring design at the Rock Creek site indicated that differences in fracture architecture had a strong influence on permeability anisotropy in the Black Creek, Mary Lee, and Pratt coal zones [9].

To help ensure environmental safety during the well testing, the Southern Company will employ surface and shallow subsurface monitoring techniques, which are described in detail by Esposito and Tinsley [10]. Li-COR equipment will be used to monitor soil gases at the test site. However, surface

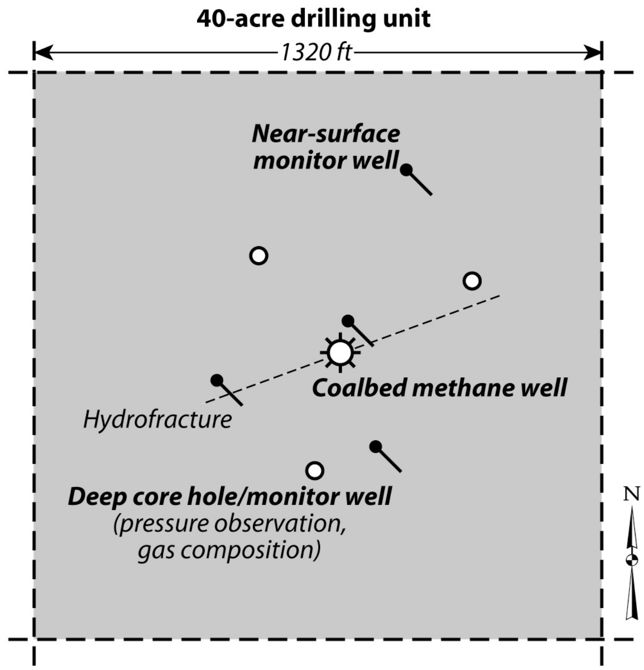

Figure 4. Schematic plan view of the SECARB Black Warrior test site.

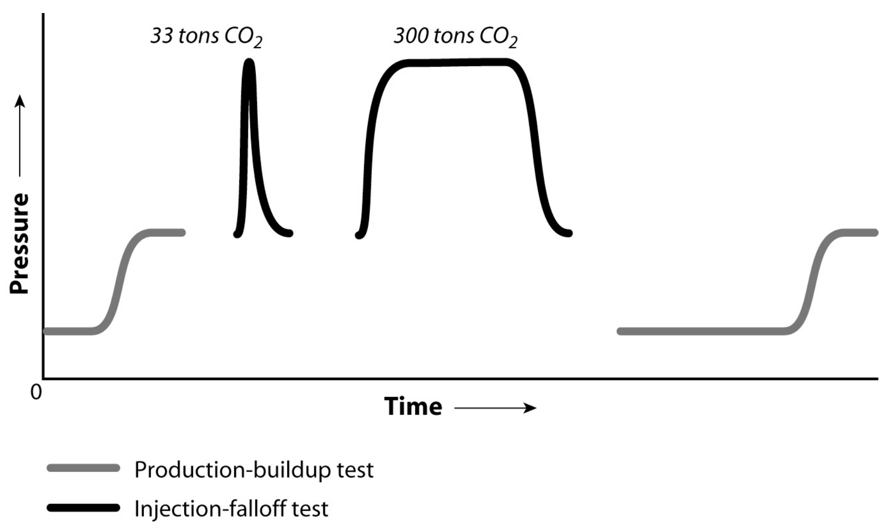

Figure 5. Schematic graph showing the plan for production-buildup and injection-falloff testing to be conducted in each coal zone at the SECARB Black Warrior test site.

monitoring has a high probability of detecting CO_2 emissions associated with bacterial action in the soil profile, as well as fugitive CO_2 released at the surface during injection operations. Shallow subsurface monitoring will be conducted in shallow slant holes that are designed to intersect fracture systems in bedrock below the soil profile to test for leakage of injectate and minimize false CO_2 readings related to soil bacteria. Surface and shallow subsurface monitoring will commence about 6 months prior to the first injection-falloff test to establish baseline conditions. Monitoring will continue throughout the injection testing and will be completed at least 6 months after the last injection-falloff test as the SECARB field program concludes.

As results of the production-buildup and injection-falloff tests are obtained, ARI will develop reservoir models using COMET3 software. These models will aid in the visualization of project results and in history matching. The shale and sandstone units between Pottsville coal beds are effectively impermeable, thus the principal avenues for leakage of injected CO_2 are natural fractures. Discrete fracture network models have been useful for characterizing the potential for cross-formational flow in the Pottsville Formation [11]. For this reason, computer models of fracture networks and flow in the Pottsville Formation are being developed to assess potential environmental risks associated with sequestration and enhanced coalbed methane recovery.

SUMMARY

Assessment of the CO_2 sequestration and enhanced recovery potential of coalbed methane reservoirs in the Black Warrior basin of Alabama indicates that more than 5.9 Tcf of CO_2 can be sequestered while increasing coalbed methane reserves by more than 20 percent. The Black Warrior coalbed methane fields are approaching maturity, and CO_2-enhanced coalbed methane recovery has potential to add decades of life to these fields.

SECARB will be conducting a field test in the Black Warrior basin, where multiple coal seams are dispersed through a thick stratigraphic section. The permeability of coal decreases exponentially with depth; thus, strategies need to be developed to manage injection into multiple coal seams with a broad range of reservoir properties. Reservoir testing will consist of a series of production and injection-falloff tests in three coal zones, and deep monitoring of pressure and gas composition will be conducted through packer and interference tests in three observation wells. Baseline reservoir simulations will aid in the design of the testing program, and follow-up simulations will be performed for history matching of the results.

Monitoring of gas composition in shallow boreholes and in the soil profile will be used to determine if seepage of injected gas occurs and to facilitate the development of monitoring protocols that will ensure the safe conduct of CO_2 injection activities. In addition, discrete fracture network models are being developed to characterize multi-phase flow in fracture networks and to assess environmental risks associated with CO_2 injection and enhanced coalbed methane recovery.

ACKNOWLEDGMENTS

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