CO_2 Sequestration Potential Of Texas Low-Rank Coals

Quarterly Technical Progress Report

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ABSTRACT

The objectives of this project are to evaluate the feasibility of carbon dioxide (CO_2) sequestration in Texas low-rank coals and to determine the potential for enhanced coalbed methane (CBM) recovery as an added benefit of sequestration. The main tasks for this reporting period were to correlate well logs and refine coal property maps, evaluate methane content and gas composition of Wilcox Group coals, and initiate discussions concerning collection of additional, essential data with Anadarko.

To assess the volume of CO_2 that may be sequestered and volume of methane that can be produced in the vicinity of the proposed Sam Seymour sequestration site, we used approximately 200 additional wells logs from Anadarko Petroleum Corp. to correlate and map coal properties of the 3 coal-bearing intervals of Wilcox group. Among the maps we are making are maps of the number of coal beds, number of coal beds greater than 5 ft thick, and cumulative coal thickness for each coal interval. This stratigraphic analysis validates the presence of abundant coal for CO_2 sequestration in the Wilcox Group in the vicinity of Sam Seymour power plant. A typical wellbore in this region may penetrate 20 to 40 coal beds with cumulative coal thickness between 80 and 110 ft.

Gas desorption analyses of approximately 75 coal samples from the 3 Wilcox coal intervals indicate that average methane content of Wilcox coals in this area ranges between 216 and 276 scf/t, basinward of the freshwater boundary indicated on a regional hydrologic map. Vitrinite reflectance data indicate that Wilcox coals are thermally immature for gas generation in this area. Minor amounts of biogenic gas may be present, basinward of the freshwater line, but we infer that most of the Wilcox coalbed gas in the deep coal beds is migrated thermogenic gas. Analysis based on limited data suggest that sites for CO_2 sequestration and enhanced coalbed gas recovery should be located basinward of the Wilcox freshwater contour, where methane content is high and the freshwater aquifer can be avoided.

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INTRODUCTION

The objectives of this project are to determine the feasibility of CO_2 sequestration in Texas low-rank coals and the potential for enhanced coalbed methane (ECBM) recovery as an added benefit of sequestration. The main tasks for this reporting period were to characterize the Wilcox Groups coals in the vicinity of the Sam Seymour power plant by correlating coal intervals and making cross sections and maps of the coals. Also, we began assessing the gas content, sorptive capacity, and methane resources in the Wilcox coals, using data provided by Anadarko through a data exchange agreement. Finally, we met with Anadarko to discuss possibilities for collecting additional coal samples and performing a well test in the Wilcox coals. Among the data needed are deep Wilcox coal samples to perform isotherm analyses for methane, carbon dioxide, and nitrogen. Well tests are necessary to determine coalbed permeability.

EXPERIMENTAL

Coal Reservoir Framework

To assess the quantity of CO_2 that can be sequestered and volume of methane that can be produced, it is necessary to characterize the coal reservoir framework. The first step in reservoir characterization is to determine the number of coal beds, cumulative coal thickness, and lateral extent of coal beds or coal-bearing zones. Once the coal volume has been established, it is necessary to determine the amount of methane present in the coal and the sorptive capacity of the coal for methane, CO_2, and N_2.

Geophysical logs from approximately 200 wells are being used to update the Wilcox Group coal resource maps in the vicinity of Sam Seymour power plant (Figure 1). The types of well logs available include density, natural gamma ray, acoustic, resistivity, and caliper logs. The suite of logs available for interpretation varies greatly among the wells. Coal can be uniquely identified from log suites that include density/porosity logs, on the basis of their low density and high porosity (Figure 2). Approximately 20% of the available wells have density/porosity logs. However, caliper logs indicate that wellbore breakout is common in Wilcox coals, and where breakouts occur, density/porosity log measurements exaggerate coal thickness. In the Wilcox Group, coal can be operationally

identified in log suites that include only natural gamma ray and resistivity logs, which greatly increases the database available for coal characterization. In gamma-ray/resistivity log suites, coal is operationally defined as having a sharp, low-gamma ray response and high resistivity peak, exceeding resistivity of adjacent sandstones (Figure 2).

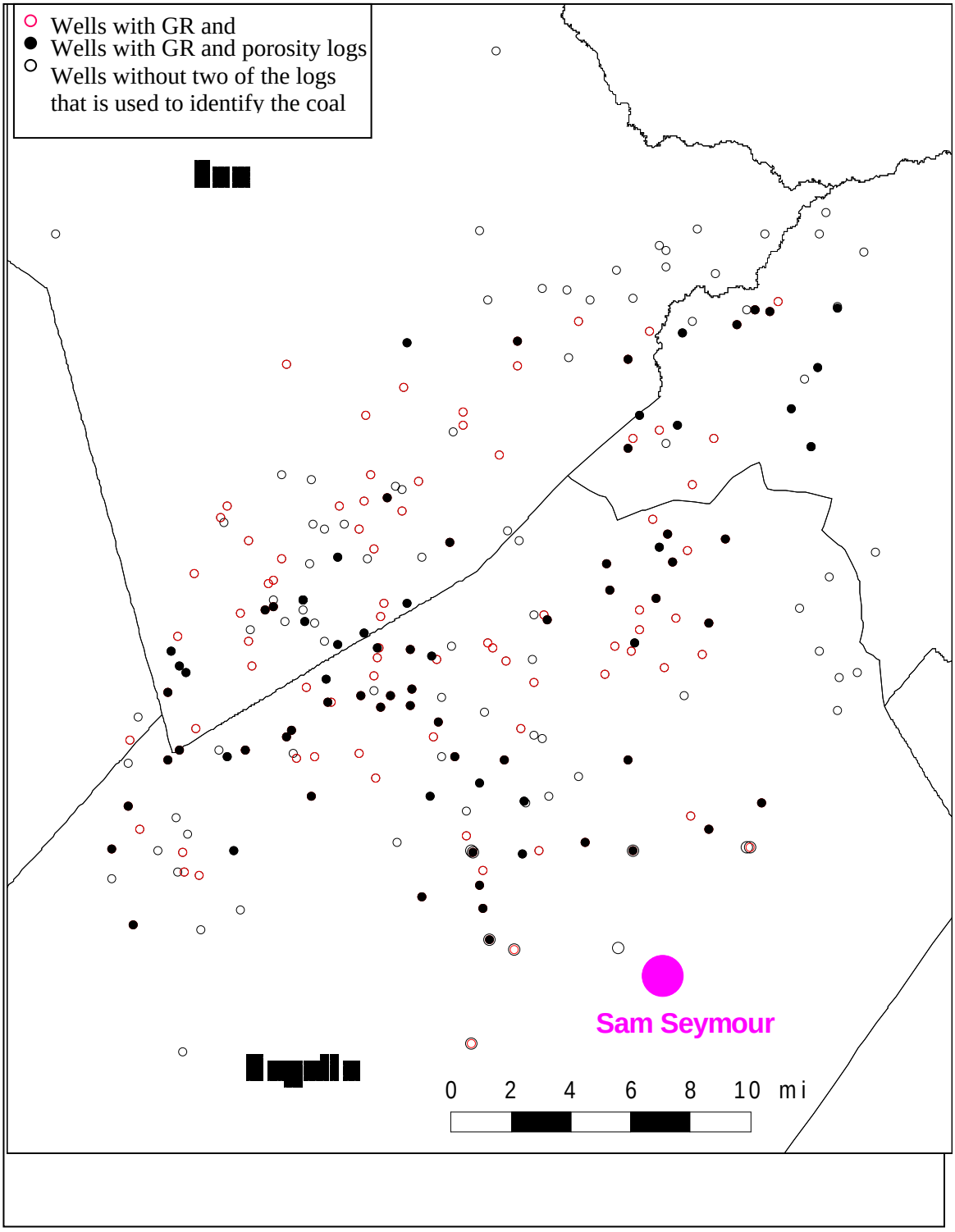

Figure 1. Location of wells used to evaluate Wilcox Group coal beds for CO_2 sequestration and enhanced coalbed methane recovery.

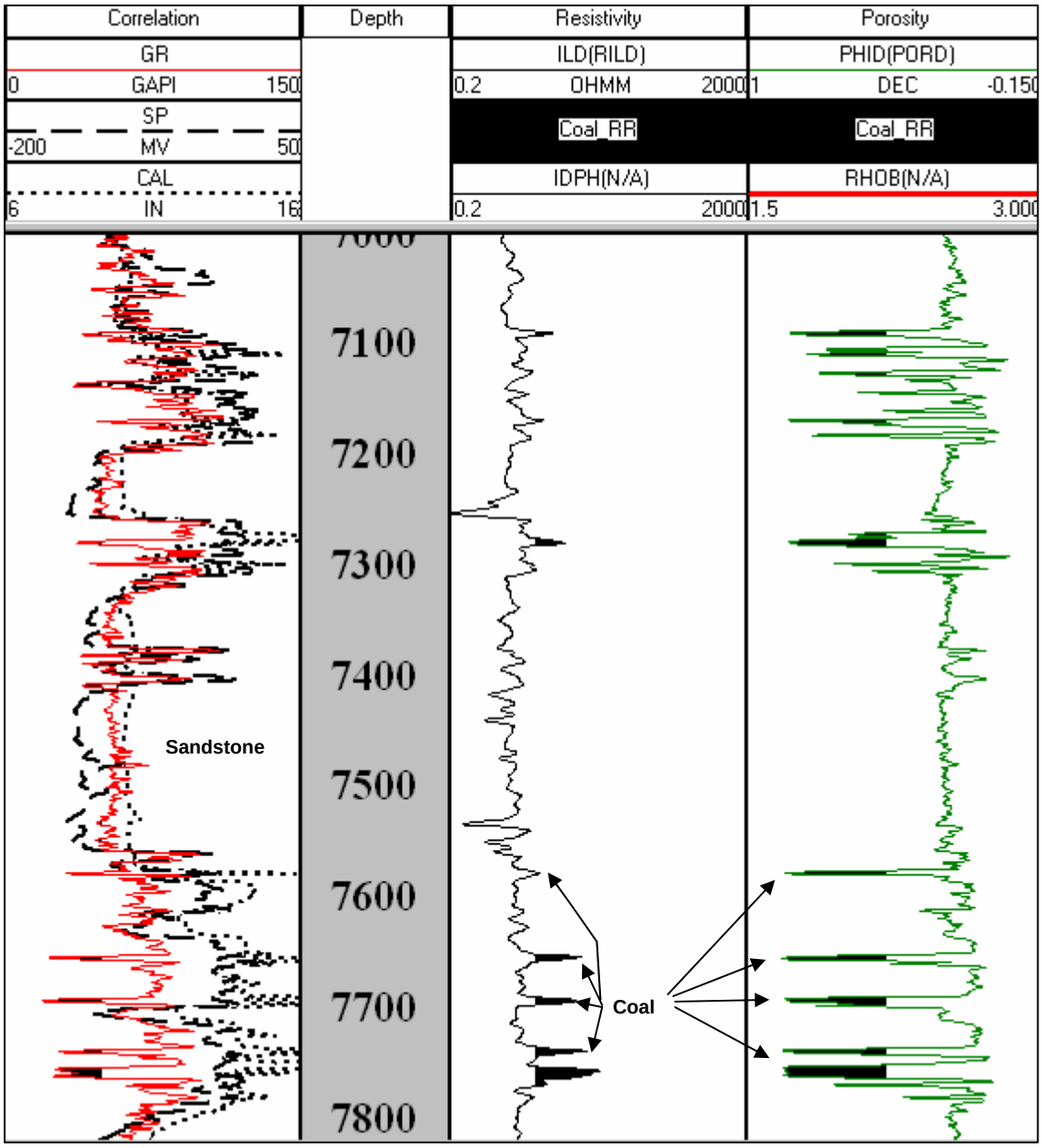

Figure 2. Geophysical well log showing interpretation of coal in the Wilcox Group. Cutoffs for shading of coal on the curves are: PHID > 0.45; ILD > 4 ohm-m; GR < 50 API units. Coal is uniquely identified by high density porosity (PHID). In the absence of density/porosity logs, an operational definition can be used to identify coal in the Wilcox on the basis of high resistivity (ILD) peaks and low gamma ray (GR) readings. Washouts are common in the coals (see caliper (CAL).

Thermal Maturity of Coal, and Content and Composition of Gas in Wilcox Coalbeds

As part of a Data Exchange Agreement (DEA) with Anadarko Petroleum Corporation, we received analyses of thermal maturity and the content and chemical composition of Wilcox Group coalbed gas in the area of Lee, Fayette and Washington Counties. These data were from the Lower Calvert Bluff, Hooper, and Barracuda coal intervals in five east-central Texas wells. Under the terms of the DEA with Anadarko,

exact locations of these wells will not be released until the DEA expires. Included in the data are more than 75 gas desorption analyses from sidewall cores and cuttings, rather than from whole-core samples. Sample depths ranged between 1,800 and 7,300 ft. Most samples were acquired from wells drilled to deeper Austin Chalk or other targets. Other gas data included 3 sorption isotherms and 14 analyses of gas chemical and/or isotopic composition. This database of gas analyses is being used to build the coalbed reservoir simulation model that will be used to evaluate the amount of CO_2 that can be sequestered and the coalbed methane resources that may be recoverable. Also included in the Anadarko data were 8 vitrinite reflectance values.

Gas desorption data and chemical and isotopic analyses are being used to (1) determine the volume of methane resources in the coal, (2) evaluate the presence and quantities of other gas species, and (3) assess the origin and distribution of gases in the coal. All of these factors must be considered when assessing the CO_2 sequestration potential of the coal beds and the most favorable sites for sequestration.

RESULTS AND DISCUSSION

Correlation and Mapping

This quarter, we began making expanded well log cross sections to correlate the Lower Calvert Bluff, Hooper, and Barracuda coal intervals in the Wilcox Group (Figure 3) of parts of Fayette, Lee, and Washington Counties, near the Sam Seymour power plant (Figure 1). Also, we began recording the coal occurrence data and revising existing regional coal-occurrence maps to better characterize reservoir properties of Wilcox coal groups in the vicinity of Sam Seymour power plant.

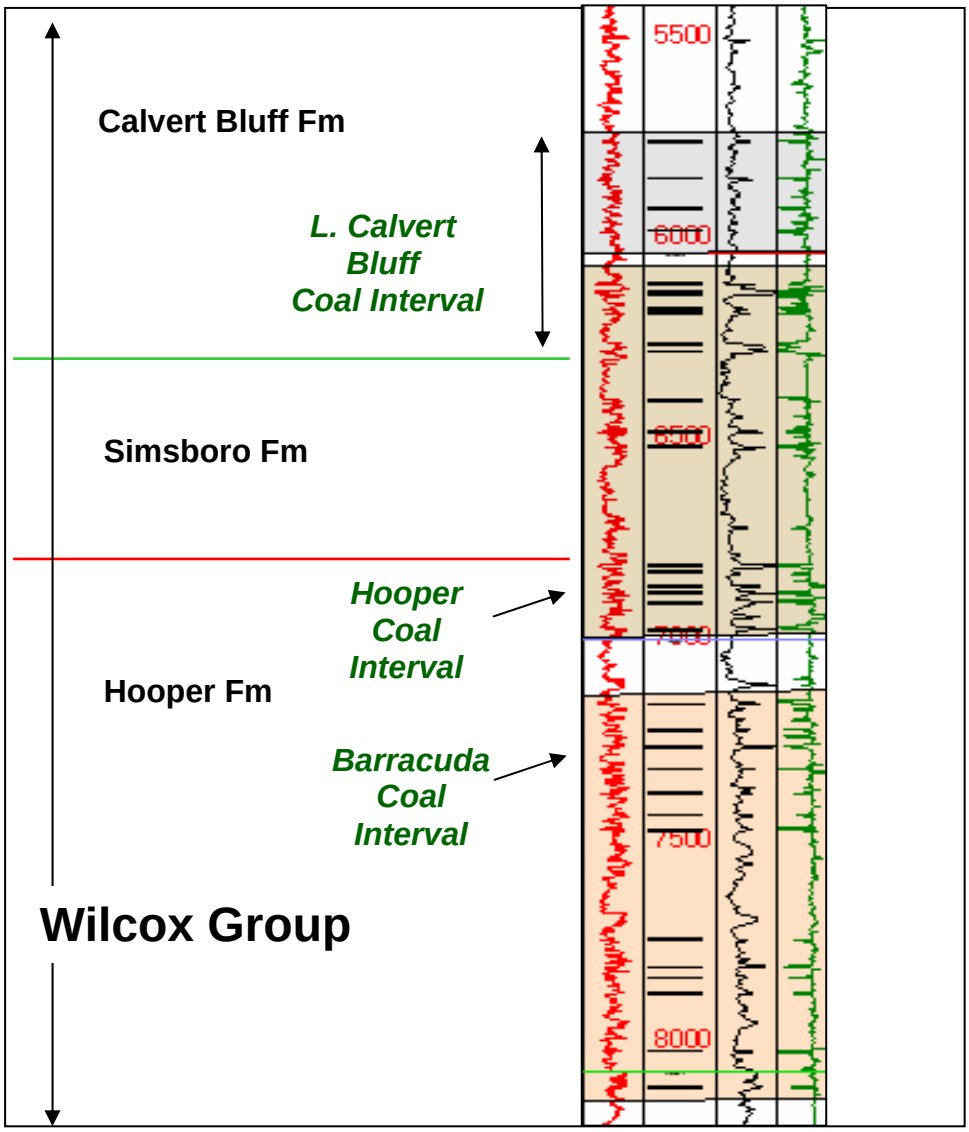

Figure 3. There are 3 major coal-bearing intervals in the Wilcox Group in this area. They occur in the Lower Calvert Bluff and Hooper Formations. Other coals occur in the Simsboro Formation and the Upper Calvert Bluff Formation. Coals are indicated by the heavy black lines in the middle column.

Preliminary results from the stratigraphic analysis shows that total Wilcox coal thickness ranges between 25 and 90 ft in the Lower Calvert Bluff interval, between 15 and 90 ft in the combined Hooper and Barracuda coal intervals. The number of coal beds ranges between 4-25 in the Lower Calvert Bluff and 4-30 in the combined Hooper and Barracuda intervals. The number of individual coal beds greater than 5 ft thick ranges from 0 to 8 with a maximum individual seam thickness of 15 ft in the Lower Calvert Bluff. There are 0 to 6 coal beds greater than 5 ft thick in the combined Hooper and Barracuda intervals; maximum individual seam thickness is 22 ft.

Gas Content and Gas Compositional Analyses

Anadarko provided coalbed gas desorption data (as received) for approximately 75 samples, which will allow us to determine the volume of methane in place in the coals. For some samples, they also provided proximate analyses of the coal, which will be used to calculate gas content on a dry, ash-free (DAF) basis in the future. DAF values normalize for variable contents of inorganic matter (ash) in coals, and thus, they allow better stratigraphic and areal comparison of gas content variability.

In 4 of the 5 wells having desorption data, average coalbed gas content (as received; AR) in the 3 coal-bearing intervals (Lower Calvert Bluff, Hooper, and Barracuda) ranges between 190 and 330 scf/t. Generally, Wilcox average gas content increases with depth, as is indicated by the increase from 216 scf/t in the Lower Calvert Bluff to 276 scf/t in the Barracuda interval (Table 1).

Table 1. Preliminary assessment of average gas content from 3 Wilcox coal-bearing intervals in 5 wells, based on approximately 75 desorption samples. Well C data are not included in the Interval averages of the last column. Overall average gas content is greatest (276 scf/t) in the Barracuda, which is the deepest interval in each well. Data provided by Anadarko Petroleum Corporation.

Coal Interval	Average Gas Content (scf/t, as received), by Well (A-E)					
	A	B	C	D	E	AVERAGE
L. Cal. Bluff	271	252	14	152	190	***216***
Hooper	273	251	18	176	206	***226***
Barracuda	330	292			206	***276***
AVERAGE	***291***	***265***	***16***	***164***	***201***	***239***

In Well C, the Wilcox coal intervals are relatively shallow and the gas content is low. Interpretation of the low gas content in Well C is discussed below. The Calvert Bluff and Hooper coals samples in this well were from depths between 1,800 and 2,600 ft, whereas in the other wells Calvert Bluff, Hooper, and Barracuda samples were from depths ranging between 3,950 and 7,300 ft.

Vitrinite reflectance (R_o) values from 8 samples range between 0.38% and 0.67%. Thermal maturity of the Wilcox coals increases with depth; the lowest vitrinite reflectance was from the shallowest sample (R_o = 0.38% at 1,826 ft in Well C), and the highest value was from deepest sample analyzed (R_o = 0.67, at 6,282 ft in Well A). Thermal maturity is greater than suggested by present burial depths, because the region has undergone structural inversion and erosional unroofing. The deeper coals have passed into the oil-generation window (R_o = 0.50%) but are thermally immature for gas generation (R_o = 0.78%).

Anadarko provided 13 analyses of gas chemical composition and 1 analysis of isotopic composition. Chemical composition of the gas is quite variable, and there is some uncertainty concerning the quality of the analyses. However, methane () appears to range between 93 and 100% (mole%); ethane and heavier hydrocarbons (C_{2+}) range between 0 and 6%, and CO_2 ranges between 0 and 5%. In one well having gas compositional analyses from 7 depths, gas wetness, as determined by the percentage of C_{2+} hydrocarbons, increases with depth. In this well, the shallowest gas sample is 99.61% C_1 and 0.37% C_{2+} at 3,957 ft; at 4,856 ft. In contrast, at 4,856 ft, C_1 = 94.94% and C_{2+} = 5.09% of the total gas. For the only sample having isotopic analyses of the gas, $\delta^{13}C$ methane = -47.9‰.

Origin of Wilcox Coalbed Gas

We tentatively conclude that most of the gas in the deeper Wilcox coals of this area is early stage thermogenic gas or, more likely, migrated thermogenic gas that either moved vertically up faults from deeper source rocks or migrated laterally up the basin flank to the Wilcox Group, where it was captured by adsorption in the coal matrix; biogenic methane is a minor constituent of the coalbed gas in the deeper coals that have high gas content. This interpretation is supported by: (1) the abundance of heavy hydrocarbon (C_{2+} as much as 6%) in the coalbed gas; (2) isotopic composition of the methane ($\delta^{13}C$ methane = -47.9‰), which is heavy for pure biogenic gas, (3) low thermal maturity of the coal (R_o < 0.78%), less than the primary gas-generation window; (4) regional hydrology; and (5) low gas content in Well C (Table 1). We infer that thermogenic gas is migrating westward up the flank basin, while fresh water is moving into the basin from meteoric recharge zones at outcrop (Figure 4). The basinward limit of Wilcox fresh water in Figure 4 is defined by the 20-ohm-m contour, which is approximately equivalent to 1,000 mg/L of total dissolved solids. The low Wilcox coalbed gas content in Well C can be explained by position of the well (in northern Burleson county; exact location is confidential until the DEA expires) near the 20-ohm-m, freshwater contour (Figure 4). At this location, Wilcox fluids are moving into the basin, as is evidenced by the resistivity contours (Figure 4). Freshwater moving into the basin has supplied microbes that have generated the small amounts of biogenic methane gas present in Well C. Unfortunately, gas compositional or isotopic analyses were not available for Well C.

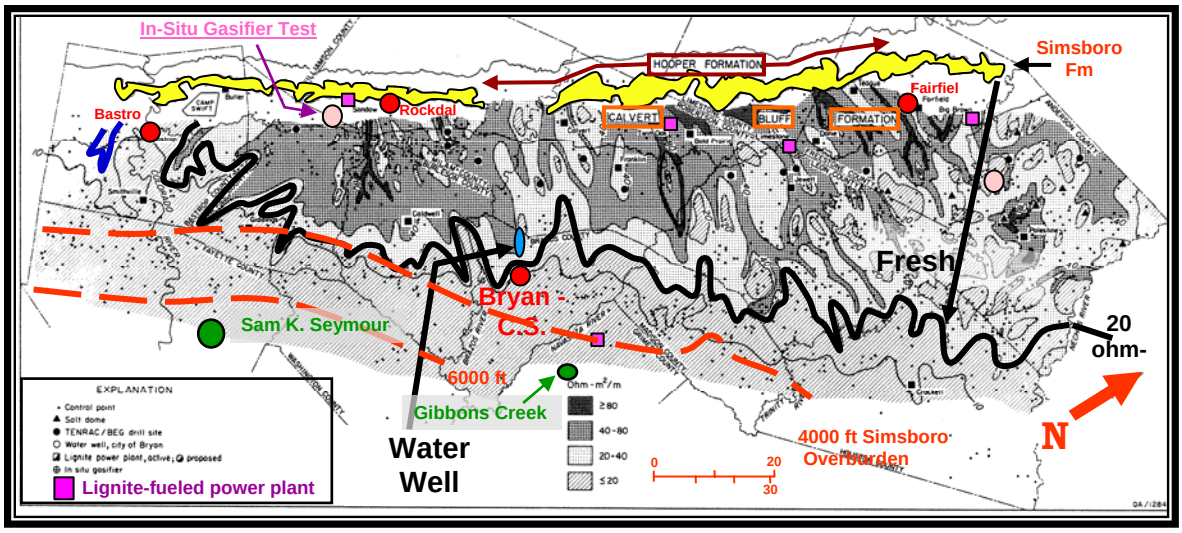

Figure 4. Resistivity of the maximum (thickest) sandstone in the Simsboro Fm. Total dissolved solids content of Simsboro ground water varies inversely with resistivity. Fresh, meteoric water enters the Wilcox Formation at outcrops. Simsboro outcrop is yellow. The 20-ohm-m line approximates the basinward (southeast) limit of fresh water. Modified from Ayers and Lewis, 1985.

The above model of coalbed gas origin has implications for CO_2 sequestration and for primary and enhanced production of coalbed gas in Wilcox coal beds. The model suggests that coalbed methane resources are greatest basinward of the freshwater contour. This occurrence of higher gas content in coals is favorable for CO_2 sequestration and enhanced coalbed gas production, because it focuses these activities outside (basinward of) the freshwater, protected Wilcox aquifer.

Discussions with Anadarko Concerning Collection of Additional Critical Data

As a result of several meetings and conferences calls with Anadarko we are proceeding with plans to collect additional Wilcox coal samples. Among the most critical data needed for the project are deep Wilcox coal samples to perform isotherm analyses for methane, carbon dioxide, and nitrogen so that we can model CO_2 sequestration and enhanced coalbed gas recovery. Anadarko is planning to spud a well in September and has agreed allow us to collect coal samples for isotherm analyses. It is equally important to perform well tests in the Wilcox coals to determine coalbed permeability. We are evaluating suitability of a shut-in Anadarko well for coalbed permeability testing in mid-September.

CONCLUSIONS

1. Ongoing stratigraphic analysis validates the presence of abundant coal for CO_2 sequestration in the Wilcox Group in the vicinity of Sam Seymour power plant.
2. Evaluation of gas desorption of approximately 75 coal samples indicates that average methane content of Wilcox coals in this area ranges between 216 and 276 scf/t basinward of the freshwater boundary.
3. Wilcox coals are thermally immature for gas generation in this area.
4. Although minor amounts of biogenic gas may be present, we infer that most of the Wilcox coalbed gas in the deep coal beds is migrated thermogenic gas.
5. Sites for CO_2 sequestration and enhanced coalbed gas recovery should be located basinward of the Wilcox freshwater contour, where methane content is high and the freshwater aquifer can be avoided. Regional hydrologic maps may be useful for determining an updip boundary for CO_2 sequestration and enhanced coalbed gas recovery.
6. Data acquisition planned with Anadarko should provide the remaining critical data for the reservoir model.

REFERENCE

Ayers, W.B., Jr., and Lewis, A.H., 1985, The Wilcox Group and Carrizo Sand (Paleogene) in East-Central Texas: depositional systems and deep-basin lignite: The University of Texas at Austin, Bureau of Economic Geology Special Publication, 19 p., 4 figs., 30 pls.