CO_2 Sequestration Potential of Texas Low-Rank Coals

Quarterly Technical Progress Report

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By:

Duane A. McVay
Walter B. Ayers, Jr.
Jerry L. Jensen

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Texas Engineering Experiment Station
3000 TAMU
332 Wisenbaker Engineering Research Center
College Station, Texas 77843-3000

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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 (ECBM) recovery as an added benefit of sequestration. The main objectives for this reporting period were to (1) estimate the potential for CO_2 sequestration in, and methane production from, low-rank coals of the Lower Calvert Bluff Formation of the Wilcox Group in the east-central Texas region, (2) quantify uncertainty associated with these estimates, (3) conduct reservoir and economic analyses of CO_2 sequestration and ECBM production using horizontal wells, and (4) compare the results with those obtained from previous studies of vertical wells.

To estimate the total volumes of CO_2 that may be sequestered in, and total volumes of methane that can be produced from, the Wilcox Group low-rank coals in east-central Texas, we used data provided by Anadarko Petroleum Corporation, data obtained during this research, and results of probabilistic simulation modeling studies we conducted. For the analysis, we applied our base-case coal seam characteristics to a 2,930-mi^2 (1,875,200-ac) area where Calvert Bluff coal seams range between 4,000 and 6,200 ft deep.

Results of the probabilistic analysis indicate that potential CO_2 sequestration capacity of the coals ranges between 27.2 and 49.2 Tcf (1.57 and 2.69 billion tons), with a mean value of 38 Tcf (2.2 billion tons), assuming a 72.4% injection efficiency. Estimates of recoverable methane resources, assuming a 71.3% recovery factor, range between 6.3 and 13.6 Tcf, with a mean of 9.8 Tcf.

As part of the technology transfer for this project, we presented the paper SPE 100584 at the 2006 SPE Gas Technology Symposium held in Calgary, Alberta, Canada, on May 15-18, 2006. Also, we submitted an abstract to be considered for inclusion in a special volume dedicated to CO_2 sequestration in geologic media, which is planned for publication by the American Association of Petroleum Geologists.

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INTRODUCTION

The overall 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 recovery as an added benefit of sequestration. Among the objectives for this reporting period were quantification of the potential for CO_2 sequestration in, and methane production from, the Lower Calvert Bluff Formation (LCB) of the Wilcox Group coals in east-central Texas on a regional basis, and to document the uncertainty associated with these estimates. Other objectives were to conduct reservoir and economic studies of CO_2 sequestration and ECBM recovery using horizontal wells, and to compare the results with those obtained from previous studies of vertical wells.

EXPERIMENTAL

None.

RESULTS AND DISCUSSION

Coal Characterization

We continued discussions with Anadarko Petroleum regarding additional coal core acquisition and laboratory work. The objective is to better characterize CO_2 sequestration and ECBM recovery potential of Wilcox low-rank coals in the Gulf Coast Basin.

Potential Volumes of CO_2 Sequestration/ECBM Production in East-Central Texas Low-Rank Coals in the Wilcox Group

This quarter, we assessed the total volumes of CO_2 that it may be possible to sequester in, and total volumes of methane that may be producible from, Wilcox Group low-rank coals in east-central Texas. This analysis was based on (1) cost-sharing data for more than 50 coal samples provided by Anadarko Petroleum Corporation, (2) data obtained during this study (3) published reports, and (4) probabilistic simulation modeling for vertical wells, using the base-case coal seam scenario for Wilcox Group coal between 4,000-ft and 6,200-ft depth in east-central Texas.

Geologic and Coalbed Gas Systems Assessment

A major criterion in selecting a study area for this project was proximity of several power plants to coals that could be targets for CO_2 sequestration and enhanced methane production. Tertiary age coal-bearing strata of the Wilcox Group, Yegua Formation, and Jackson Group crop out in the Texas Gulf Coastal Plain, subparallel to the coast, and in the Sabine Uplift (Fig. 1).[1,2] Of these 3 formations, the Wilcox Group in

east-central Texas was selected for study, owing to presence of widespread coal deposits that, from outcrop, extend at least 50 mi into the Gulf Coast Basin. Numerous surface mines supply coal to mine-site power plants along the outcrop belt (Fig. 1).

Using the data described above, we assessed the occurrences and reservoir properties of Wilcox coal in east-central Texas. Among the factors evaluated were (1) coal thickness, depth, and thermal maturity, (2) regional variations of methane content, (3) CO_2 and methane sorptive capacity of coal, and (4) regional hydrology. On the basis of this evaluation, we infer presence of two coalbed gas systems in the Calvert Bluff formation of the Wilcox Group in east-central Texas. These are a shallow biogenic methane system and a deeper thermogenic methane system (Fig. 2).

The biogenic methane system occurs in the shallow Wilcox Group. It is characterized by low coal rank (Ro<0.4%), methane content of coal less than 50 scf/ton, fresh formation water, and most likely, by presence of dry gas (absence of heavier hydrocarbons). We infer that this area may be unsuitable for CO_2 sequestration and enhanced coalbed methane production, owing to protection of the Wilcox freshwater aquifer, which may disallow CO_2 injection. Also, the low methane content of the coal would adversely affect project economics.

A thermogenic methane system is inferred in the deeper Wilcox Group (Fig. 2). This system is characterized by higher rank coal (Ro = 0.4-0.67%), methane content that ranges between 150 and 400 scf/ton, wet gas (presence of heavier hydrocarbons), and higher salinity formation water. We suggest that the methane in this system is (1) early stage thermogenic or (2) migrated thermogenic gas that migrated either (a) up the basin flank from deeper, stratigraphically equivalent strata, or (b) vertically through faults, from deeper strata.

On the basis of our analysis, we tentatively conclude that the fairway for CO_2 sequestration and enhanced methane production in Calvert Bluff formation coal of east-central Texas extends from approximately 4,000-ft to 6,200 ft deep. We infer that shallower Calvert Bluff coals contain insufficient methane, and the shallow, freshwater aquifer would be protected from CO_2 injection. The east-central Texas Gulf Coastal Plain area encompassed by Calvert Bluff seams ranging between 4,000 and 6,200 ft deep is estimated to be 2,930 mi^2 (1,875,200 ac).

Gas content data are limited from the shallow, freshwater interval, and thus, this model is should be further studied to validate the concept and to correctly establish the boundary between the two coalbed methane systems.

Probabilistic Estimation of Potential Volumes

Table 1 shows the input parameters used to quantify uncertainty in our forecast of the potential volumes of CO_2 that could be sequestered in, and methane that can be produced from, the Wilcox Group low-rank coals in east-central Texas.

We estimated the original gas in place (OGIP) adsorbed in the coal reservoirs for an 80-acre, 5-spot pattern, using probabilistic input parameters in the volumetric equation. Multiplying by a probability distribution for gas recovery factor, from reservoir modeling studies described in previous quarterly reports (base-case coal seam scenarios), we obtained a range of recoverable methane resources on a pattern basis. A similar procedure was used to calculate the maximum theoretical CO_2 sequestration capacity of coal. Multiplication by an injection factor yields a range of potential CO_2 volumes that can be sequestered on a pattern basis. We used Monte Carlo simulation with 10,000 iterations to account for uncertainty in our estimates. Table 2 shows the expected values of CH_4 to be produced and CO_2 to be stored in Wilcox coals (base-case coal properties), on a pattern basis and a regional basis, assuming 80-acre, 5-spot patterns. Our analysis suggests that 38 Tcf (2.2 billion tons) of CO_2 could be sequestered, resulting in production of 9.8 Tcf of methane from the 2,930-mi^2 area (Table 2).

Fig. 3a shows cumulative distribution functions for GIP and recoverable resources for target coal reservoirs, base case, in the Calvert Bluff formation of the Wilcox Group in east-central Texas. The mean value of the OGIP is 0.59 Bcf of CH_4, and considering an average recovery factor of 71.3% (from previous modeling), the mean volume of CH_4 that can be produced from the Wilcox Group coals in east-central Texas is 0.42 Bcf per 80-acre, 5-spot pattern.

Fig. 3b shows cumulative distribution functions for the maximum theoretical sequestration capacity and potential CO_2 volumes to be stored in these coals, on an 80-ac, 5-spot pattern basis, again, using base-case reservoir properties. This analysis indicates that the mean value of the theoretical sequestration capacity is 2.24 Bcf of CO_2. Using an average injection efficiency factor of 72.4% (from previous modeling), the mean volume of CO_2 that can be sequestered in the Wilcox Group coals in east-central Texas is 1.62 Bcf per 80-acre, 5-spot pattern.

Table 3 summarizes the results for an 80-acre 5-spot pattern and extrapolation to the 2,930-mi^2 estimated target area, where the Lower Calvert Bluff formation of east-central Texas is 4,000 ft to 6,200 ft deep. The analysis assumes perfect positive correlation of volumes between patterns in the region. The results indicate that the potential CO_2 volume to be stored in LCB low rank coals in Texas ranges between 27 and 49 Tcf (1.57 and 2.69 billion tons), and the recoverable methane resources from these coals ranges between 6.3 and 13.6 Tcf.

Six major power plants are located in the east-central Texas region. These power plants and their annual CO_2 emissions (2002) are as follows: Limestone - 13 MM tons; Sam K. Seymour - 12.5 MM tons; Big Brown - 9.6 MM tons; Sandow - 4.6 MM tons; Gibbons Creek - 3.2 MM tons; and TNP One - 2.8 MM tons. Collectively, they emit 45.7 MM tons of CO_2/year. Sequestration capacity of the Lower Calvert Bluff low-rank coals in east-central Texas equates to 34 to 59 years of emissions from these six power plants.

Horizontal Well Analysis

Studies to date indicate that CO_2 sequestration and enhanced coalbed methane (ECBM) recovery using vertical wells in Texas low-rank coals is uneconomic to marginally economic. In July, we began simulation studies of Texas low-rank coals to determine if horizontal wells could improve performance and economics. We are conducting probabilistic reservoir and economic modeling studies using horizontal wells for both CO_2 injection and methane production.

Technology Transfer

As part of our technology transfer obligations for this project, we presented the paper SPE 100584 at the 2006 SPE Gas Technology Symposium held in Calgary, Alberta, Canada, on May 15-18, 2006. Also, we submitted an abstract to be considered for inclusion in a special volume dedicated to CO_2 sequestration in geologic media, which is planned for publication by the American Association of Petroleum Geologists.

Website Development

A website containing all the information relevant to this project is in development.

CONCLUSIONS

- CO_2 sequestration potential and methane resources in low-rank coals of the Lower Calvert Bluff formation in east-central Texas are significant.
- The potential CO_2 sequestration capacity of the coals ranges between 27.2 and 49.2 Tcf (1.57 and 2.69 billion tons), with a mean value of 38 Tcf (2.2 billion tons), assuming a 72.4% injection efficiency.
- Estimates of recoverable methane resources range between 6.3 and 13.6 Tcf, with a mean of 9.8 Tcf, assuming a 71.3% recovery factor.

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1. Ayers, W. B., Jr., S. K. Ruhl, M. F. Hoffmann, J. A. Rushing, D. A. McVay, and R. I. Ramazanova, 2005, Low-Rank Coals of the Wilcox Group, East-Central Texas: Potential for CO_2 Sequestration and Enhanced Methane Production: West Texas Geological Society, Fall Symposium, Midland, TX, October 25-28, 2005.

2. Kaiser, W.R.: “Texas Lignite - Status and Outlook to 2000,” The University of Texas at Austin, Bureau of Economic Geology, Mineral Resources Circular 76, 17 p., (1985).

3. Texas Environmental Profiles: “Texas Carbon Dioxide Emissions Data,” 2002. http://www.texasep.org/html/air/air_4iss_txco2.html

Table 1 - Parameters for estimating volume of CO_2 that can be sequestered and methane that can be produced from Calvert Bluff coals in east-central Texas

Parameter	Value	Fitted Distribution	Parameters Distribution
Coal Thickness	10, 20, 30 ft	Normal	$\mu = 20$, $\sigma = 4.1$
Coal Density	1591, 1644, 1704 ton/ac-ft (1.289, 1.332, 1.380 g/cm^3)	Normal	$\mu = 1646$, $\sigma = 23.25$
Gas Content	125, 250, 300 scf/ton	Beta General	$\alpha_1 = 3.78$, $\alpha_2 = 2.06$, min = 80, max = 300
CO_2 Storage (V_L, CO_2)	620, 920, 1000 scf/ton	Beta General	$\alpha_1 = 3.20$, $\alpha_2 = 1.85$, min = 590, max = 1000
Recovery Factor	60, 75, 80 %	Beta General	$\alpha_1 = 3.07$, $\alpha_2 = 2.00$, min = 0.58, max = 0.80
Injection Factor	50, 72, 75 %	Beta General	$\alpha_1 = 21.95$, $\alpha_2 = 2.50$, min = 0.50, max = 0.75
Area	80 acres		

Table 2 – Expected values for coalbed methane GIP and recoverable resources, and theoretical sequestration capacity and most likely CO_2 sequestered volumes, Calvert Bluff coals, east-central Texas

Recoverable Coalbed Methane Resources		Potential Coalbed Sequestration Capacity	
Coal Thickness, ft	20	20	Coal Thickness, ft
Coal Density, ton/ac-ft	1646	1646	Coal Density, ton/ac-ft
Gas Content, scf/ton	222	850	CO_2 Storage (V_L, CO_2), scf/ton
Recovery factor, fraction	0.713	0.724	Injection Factor, fraction
Pattern Basis			
Pattern Area, ac	80	80	Pattern Area, ac
GIP (per 80 ac), Bcf	0.586	2.238	Theoretical Sequestration Capacity, Bcf
Recoverable Resources (per 80 ac), Bcf	0.418	1.621	Sequestered CO_2 Volume (per 80 ac), Bcf
East-Central Texas Region			
Region Area, ac (2,930 sq. miles)	1,875,200	1,875,200	Regional Area, ac
Number of 80-ac 5 spot patterns	23,440	23,440	Number of producer/injector wells
GIP (region area), Bcf	13,730	52,460	Theoretical Sequestration Capacity, Bcf
Potential Recoverable Resources (region area), Bcf	9,790	38,000	Potential CO_2 Seq. Volume (region area), Bcf

Table 3 - Range of uncertainty in potential volumes of CH_4 to be produced from, and CO_2 to be sequestered in, LCB low-rank coals in the Wilcox Group in east-central Texas

Area basis	Total CH_4 Volumes, Bcf			Total CO_2 Volumes, Bcf		
	P_{10}	Mean	P_{90}	P_{10}	Mean	P_{90}
Pattern area	0.270	0.418	0.580	1.160	1.621	2.100
East-central Texas area	6,330	9,790	13,600	27,190	38,000	49,220
				Total CO_2, MM tons		
				1,570	2,195	2,690

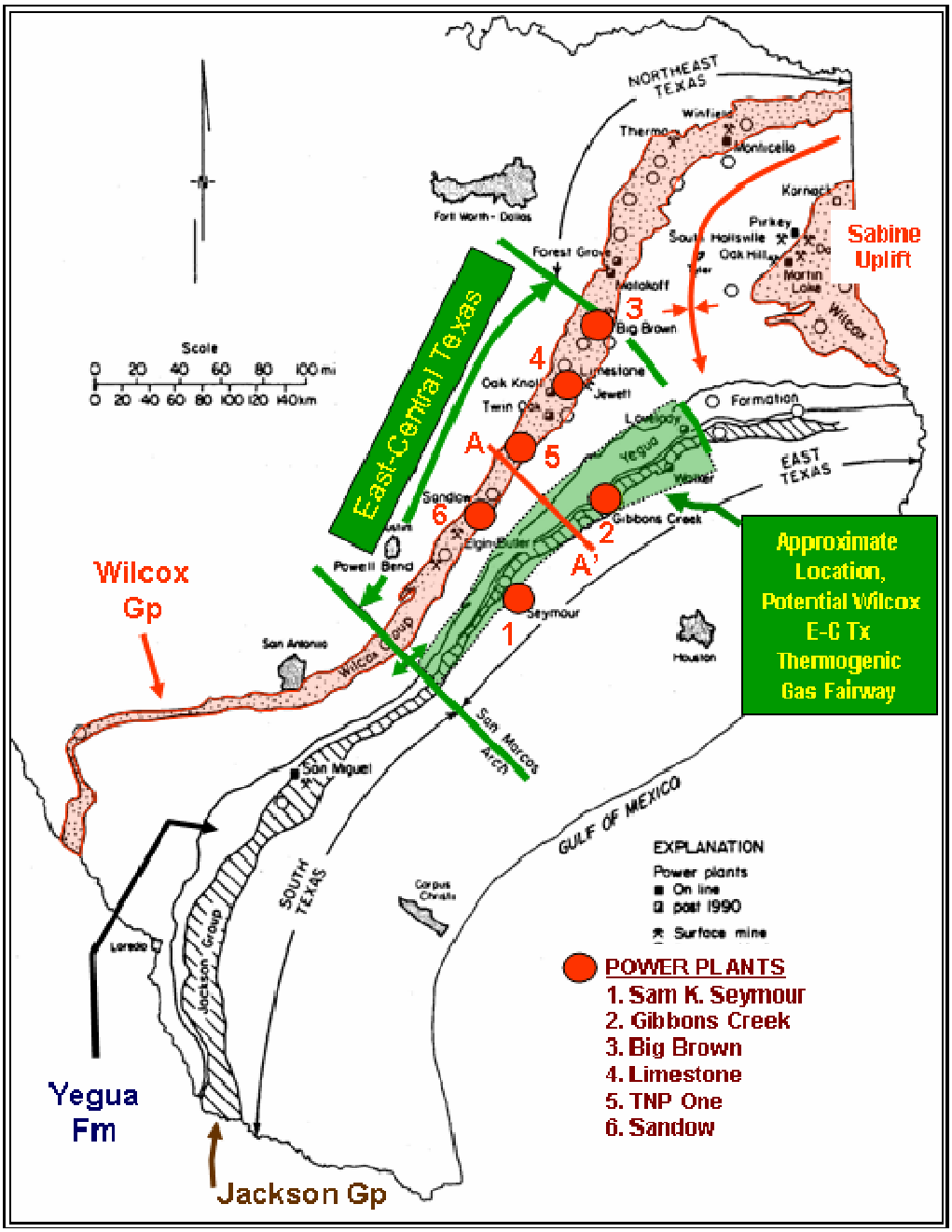


Fig. 1. Map of Texas showing the Wilcox outcrop, location of the east-central Texas area, cross section A-A' (Fig. 2), and locations of the six electrical generating plants in the region (modified from Ayers *et al.*, 2005; after Kaiser, 1985).

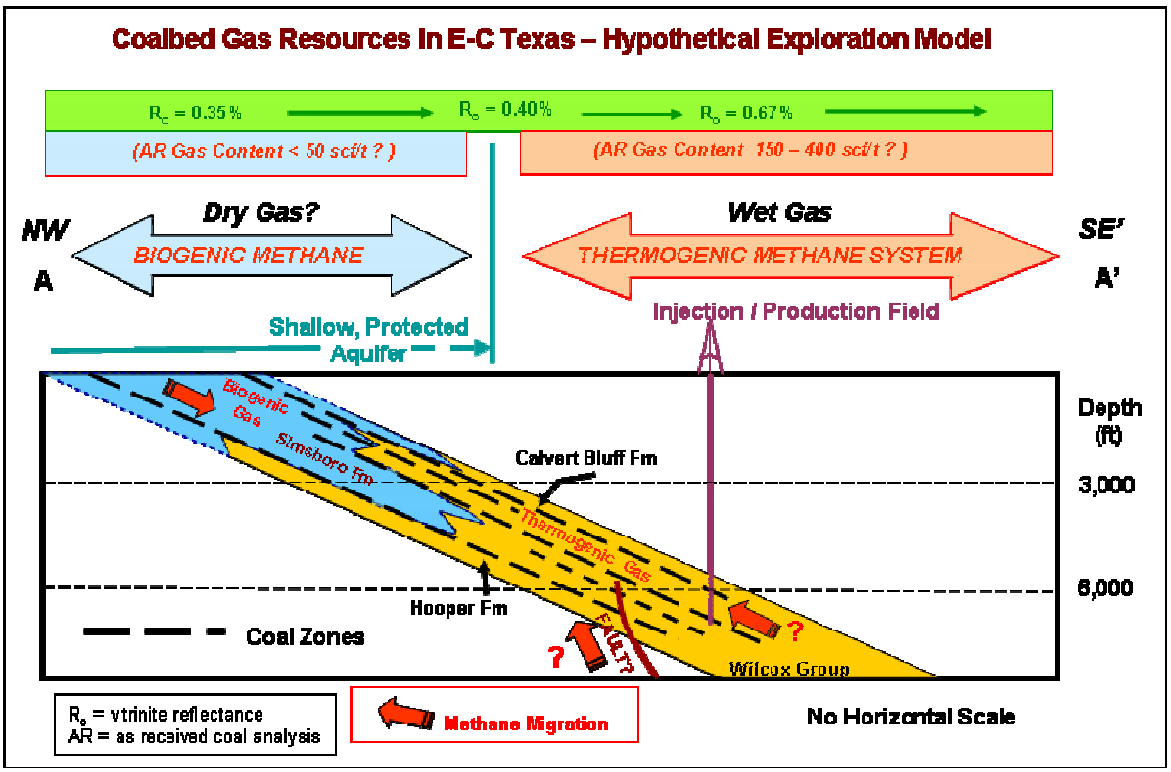
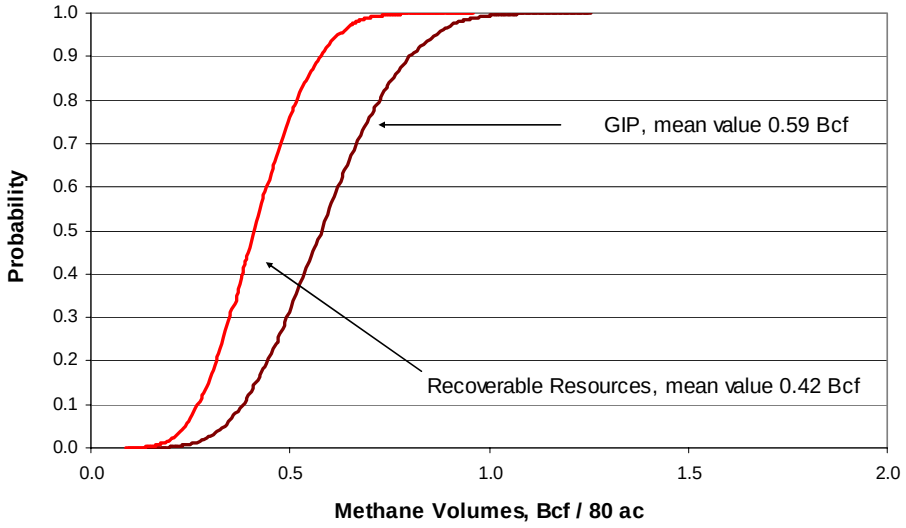
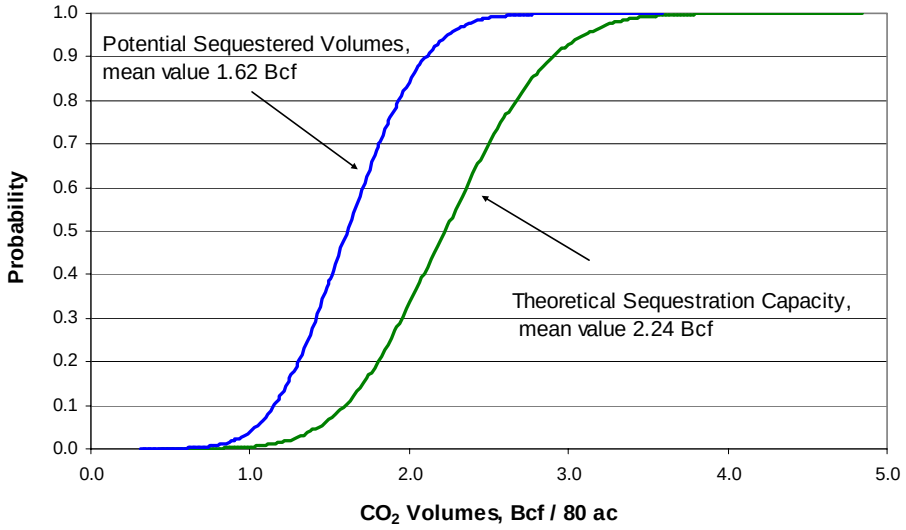


Fig. 2. Schematic cross section showing two coalbed gas systems in the Wilcox Group in east-central Texas (see Fig. 1 for location of cross section A-A') (from Ayers *et al.*, 2005). The deeper, thermogenic gas field was evaluated in this study.



(a)



(b)

Fig. 3. Cumulative distribution functions for: (a) OGIP and recoverable methane resources, and (b) theoretical sequestration capacity and potential CO_2 sequestration volumes, for target coal reservoirs in the Wilcox Group in east-central Texas. Volumes are for an 80-acre, 5-spot pattern (40-acre well spacing).