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. There were three main objectives for this reporting period, which related to obtaining accurate parameters for reservoir model description and modeling reservoir performance of CO_2 sequestration and enhanced coalbed methane recovery. The first objective was to collect and desorb gas from 10 sidewall core coal samples from an Anadarko Petroleum Corporation well (APCL2 well) at approximately 6,200-ft depth in the Lower Calvert Bluff Formation of the Wilcox Group in east-central Texas. The second objective was to measure sorptive capacities of these Wilcox coal samples for CO_2, CH_4, and N_2. The final objective was to contract a service company to perform pressure transient testing in Wilcox coal beds in a shut-in well, to determine permeability of deep Wilcox coal.

Bulk density of the APCL2 well sidewall core samples averaged 1.332 g/cc. The 10 sidewall core samples were placed in 4 sidewall core canisters and desorbed. Total gas content of the coal (including lost gas and projected residual gas) averaged 395 scf/ton on an as-received basis. The average lost gas estimations were approximately 45% of the bulk sample total gas. Projected residual gas was 5% of in-situ gas content. Six gas samples desorbed from the sidewall cores were analyzed to determine gas composition. Average gas composition was approximately 94.3% methane, 3.0% ethane, and 0.7% propane, with traces of heavier hydrocarbon gases. Carbon dioxide averaged 1.7%. Coal from the 4 canisters was mixed to form one composite sample that was used for pure CO_2, CH_4, and N_2 isotherm analyses. The composite sample was 4.53% moisture, 37.48% volatile matter, 9.86% ash, and 48.12% fixed carbon. Mean vitrinite reflectance was 0.54%. Coal rank was high-volatile C to B bituminous.

Comparison of the desorbed gas content (395 scf/ton, as received) at reservoir pressure (2,697 psi) with the sorption isotherm indicates that Lower Calvert Bluff coal at this well site is oversaturated, but lost gas may have been overestimated. This high gas content suggests that little or no depressurization would be required to initiate methane production. Sorption isotherms results indicate that the sorptive capacity of CO_2 is about 2.5 times that of CH_4 at 1,000 psia. This ratio is similar to that of higher rank bituminous coals from other basins (e.g., Carroll, and Pashin, 2003), and it is very low in comparison to results of other low-rank coals and to the values that we used in our preliminary reservoir modeling. If this value from the APCL2 well is representative, Wilcox coals in this area will sequester less CO_2 on a per ton basis than we had earlier inferred. However, because measured methane contents are higher, enhanced coalbed methane production potential is greater than we earlier inferred.

Pressure transient testing for determining coal fracture permeability will be conducted soon by Pinnacle Technologies. The data from these analyses will be used to finalize our coal model for the reservoir simulation phase of the project.

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INTRODUCTION

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. During this reporting period, we obtained sidewall cores, measured their gas content, determined gas composition and analyzed the coal properties of Wilcox sidewall cores collected from an Anadarko Petroleum Corporation well (Well APCL2) in the vicinity of the Sam K. Seymour power plant. The actual well location is confidential. Also, we performed CO_2, CH_4, and N_2 sorption isotherm analyses to obtain input parameters for the reservoir model description and to determine parameters for reservoir simulation. Finally, we began negotiating a contract with a service company to perform pressure transient testing in coal beds in a shut-in well to determine permeability of deep Wilcox coal.

EXPERIMENTAL

This quarter, we accomplished several tasks necessary to characterize Wilcox coalbed reservoirs. This characterization included proximate analyses, measurements of vitrinite reflectance and desorbed gas content, and determination of CO_2, CH_4, and N_2 isotherms for Wilcox sidewall cores of coals penetrated in the APCL2 well.

A geologist from Hampton, Waechter & Associates (HWA) collected the 10 APCL2 sidewall core samples at the well site and placed them in 4 desorption canisters. The canisters were kept in a water bath on location at reservoir temperature for approximately 12 hours after collection while frequent desorption readings were made. Then, the samples were taken to the laboratory where desorption was completed and desorbed gas samples were collected for compositional analyses. Gas content of the core samples was calculated using both polynomial and linear fits for lost gas estimation. HWA asserts that polynomial fit usually gives the best for lost gas values, but historically, the CBM industry has used a linear fit for estimating lost gas.

The desorbed, moist coal samples were placed in double-sealed plastic bags and sent to RBM Earth Science Consultants (RBM) for isotherm measurements and for vitrinite reflectance and proximate analyses. The sidewall cores were crushed to -60 mesh, and as-received moisture and ash were determined. All sidewall samples were then mixed to form one composite sample. A 1-gram split was used for vitrinite reflectance and a 10-gram split was used for proximate analysis. The remaining sample was placed in an equilibrium moisture bath for 25 days. The sample was then loaded into high pressure bombs and isotherms were determined.

RESULTS AND DISCUSSION

Analyses of the composite sample of the 10 sidewall cores from well APCL2 indicate average values of 4.53% moisture, 37.48% volatile matter, 9.86% ash, 48.12% fixed carbon, and a heating value of 12,405 BTU/lb, as received. Sulfur content was 1.31%. Vitrinite reflectance of the composite coal sample, which was measured over a 148-ft depth interval (6,118 – 6,262 ft), ranged between 0.47% and 0.61%; mean value was 0.54%. Coal rank is borderline between high-volatile C and high-volatile B bituminous. Bulk density measurements of the APCL2 sidewall core samples averaged 1.33 g/cc, whereas average coal density from well logs was 1.35 g/cc.

Total gas desorbed from cores included measured, lost, and projected residual gas. The total gas content of coals from the 4 APCL2 canisters, based on a polynomial fit for lost gas, ranged from 365 to 429 scf/ton, with an average total gas content of 395 scf/ton (as-received basis) (Table 1). The lost gas estimations for the samples were 43% to 47% of the total gas and averaged approximately 45% of the total gas. HWA concluded that estimated values of lost gas may be inaccurate owing to the long retrieval time (49 minutes), fluctuation of ambient temperature, and/or high diffusivity of the coal. Projected residual gas was approximately 5% of in-situ gas content. These measured gas values corroborate previous Anadarko test results and indicate significant methane resources in deep Wilcox coals.

Six samples of gas desorbed from the Anadarko sidewall cores retrieved from the APCL2 well were analyzed for gas composition by Empact Analytical Laboratories. Average gas composition was 94.3% methane, 3.0% ethane, and 0.7% propane, with traces of the heavier hydrocarbons. Carbon dioxide averaged 1.7% in the coalbed gas (Table 2).

Sorption isotherms for pure CO_2, CH_4, and N_2 were run to pressures of 595, 3142, and 2767 psia, respectively, at 168° F (Figs. 1 and 6) (RMB Earth Science Consultants, 2005). Ideally, isotherms would have been run from 0 psia to pressures greater than reservoir pressure, which is approximately 2,697 psi, assuming a freshwater hydrostatic gradient of 0.435 psi/ft and average depth of 6,200 ft. However, the limitations of laboratory equipment restricted CO_2 adsorption analysis to below the critical point.

At 1,000 psia (projecting the CO_2 curve), the ratio of CO_2:CH_4 sorptive capacity is about 2.5:1. This ratio is low in comparison to laboratory results for Wilcox coals from Sandow surface mine and from the U.S. Geological Survey's (USGS) Panola County well (Warwick *et al.*, 2000, sample PA/CN2) (Figs. 2 and 3). In the Sandow and PA/CN2 cases, as with other adsorption studies of low-rank coal by the USGS, the CO_2:CH_4 ratio was approximately 10:1. Based on the USGS and Sandow mine analyses, we had used a 10:1 ratio of CO_2:CH_4 when setting up the preliminary reservoir model for this study. The 2.5:1 ratio obtained for the APCL2 samples is similar to results from bituminous coals in other basins (e.g., Carroll and Pashin, 2003, Black Warrior Basin). However, those results were for much higher rank coals than those of the Wilcox Group in the APCL2 well. This result (2.5:1 storage capacity), based on only the APCL2 well, suggests that Wilcox coals in this area will sequester less CO_2 per ton of coal than anticipated on the basis of earlier studies (10:1 storage capacity). However, because measured methane contents are higher, enhanced coalbed methane production potential is greater than we earlier predicted.

We evaluated depth relations between vitrinite reflectance and methane storage capacity determined from isotherms, using Wilcox coal data from the Sandow surface mine and from the PA/CN2 (365 ft deep), another Anadarko well in this area, APCWAL (2,300 ft deep), and APCL2 (average 6,200 ft) wells, on a dry ash-free basis (Figs. 4 and 5). As expected, vitrinite reflectance and methane sorptive capacity increases with depth and thermal maturity.

Comparison of the desorbed gas content values with the methane isotherm (as received) for the APCL2 well indicates that the Wilcox coals tested from this well are saturated with methane (Fig. 6) and should require no depressurization to initiate gas production. However, the fact that estimated total methane content at reservoir temperature and pressure plots above the isotherm suggests that, as noted by HWA, the lost gas component may have been overestimated. Therefore, we also plotted measured and calculated residual gas content only on for comparison (Fig. 6).

Pressure transient testing for determining coal fracture permeability will be conducted in the 1st quarter of 2005 by Pinnacle Technologies. These data, along with the newly acquired gas compositional analyses and sorption capacities of CO_2, CH_4, and N_2 from the APCL2 well, will be used to finalize our coal model for the reservoir simulation phase of the project.

As part of our technology transfer obligations for this project, an abstract was accepted for presentation at the American Association of Petroleum Geologists Annual Meeting to be held in Calgary, Canada in June 2005, and a preliminary abstract for the ATCE 2005 meeting was submitted to the Society of Petroleum Engineers.

CONCLUSIONS

Laboratory desorption results from sidewall core coal samples from an Anadarko Petroleum Corporation well at average depth of approximately 6,200-ft depth and total thickness of 33.5 ft in the Lower Calvert Bluff Formation of the Wilcox Group in east-central Texas indicated that these Wilcox coals have gas content values of around 395 scf/ton of stored methane, which is considered high for high-volatile C-B bituminous coals. Also sorption isotherms results indicated that the sorptive capacity ratio of CO_2:CH_4 is about 2.5 at 1,000 psia. This value is similar to that of higher rank bituminous coals from other basins, and low in comparison to results of other low-rank coals and to the values that we used in our preliminary reservoir modeling, which means that Wilcox coals in this area will sequester less CO_2 on a per ton basis than we had earlier inferred. However, because methane contents measured in Wilcox coals are higher than anticipated, enhanced coalbed methane production potential is greater than we earlier inferred.

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2) Carroll, R.E., and Pashin, J.C.: Relationship of sorption capacity to coal quality: CO_2 sequestration potential of coalbed methane reservoirs in the Black Warrior Basin, The University of Alabama, 2003 International Coalbed Methane Symposium, Paper 0317, 11 p.

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5) Warwick, P.D., Barker, C.E., SanFilipo, J.R., and Biewick, L.R.H.: Preliminary evaluation of the coalbed methane resources of the Gulf Coastal Plain, U.S. Geological Survey Open-File Report 00-142, 2000, 43 slides, USGS_GULF_COAST_CBM_of00-143.pdf.

Table 1 - Gas content of 10 sidewall cores coal samples from the Lower Calvert Bluff Formation of the Wilcox Group in the region of Sam K. Seymour power plant. The 10 samples from Well APCL2 were desorbed in 4 canisters. All measurements are on an as-received basis.

Canister #	Coal Bed		(1) Lost Gas (scf/ton)	(2) Lost + Measured Gas (scf/ton)	(3) Total Gas (scf/ton)
	Top (MD, ft)	Bottom (MD,ft)			
1	6112	6114	195.2	411.3	429.3
2	6116	6118	161.6	362.7	365.0
3	6148	6152	174.5	392.1	407.5
4	6264	6274	179.8	359.0	382.1
Sidewall Core Averages			**177.2**	**375.6**	**394.8**

(1) Lost Gas content using polynomial fit
(2) Without Residual Gas
(3) Lost + Measured + Projected Residual Gas

Table 2 – Wilcox coalbed gas composition; 2 samples from each of 3 canisters.

Sample #	Sidewall Canister Gas Samples, Normalized Mole% (with air subtracted)						
	N_2	CO_2	C_1	C_2	C_3	$iC_4 + nC_4$	Heavy Hydrocarbons C_5^+
A	0.00	1.16	96.05	2.13	0.46	0.17	0.03
B	0.00	1.68	93.59	3.55	0.82	0.31	0.05
C	0.00	1.70	94.64	2.69	0.67	0.26	0.04
D	0.00	1.89	94.39	2.81	0.62	0.24	0.05
E	0.00	1.59	93.53	3.54	0.85	0.37	0.12
F	0.00	1.91	93.53	3.38	0.82	0.31	0.05
Averages	**0.00**	**1.655**	**94.288**	**3.017**	**0.707**	**0.277**	**0.057**

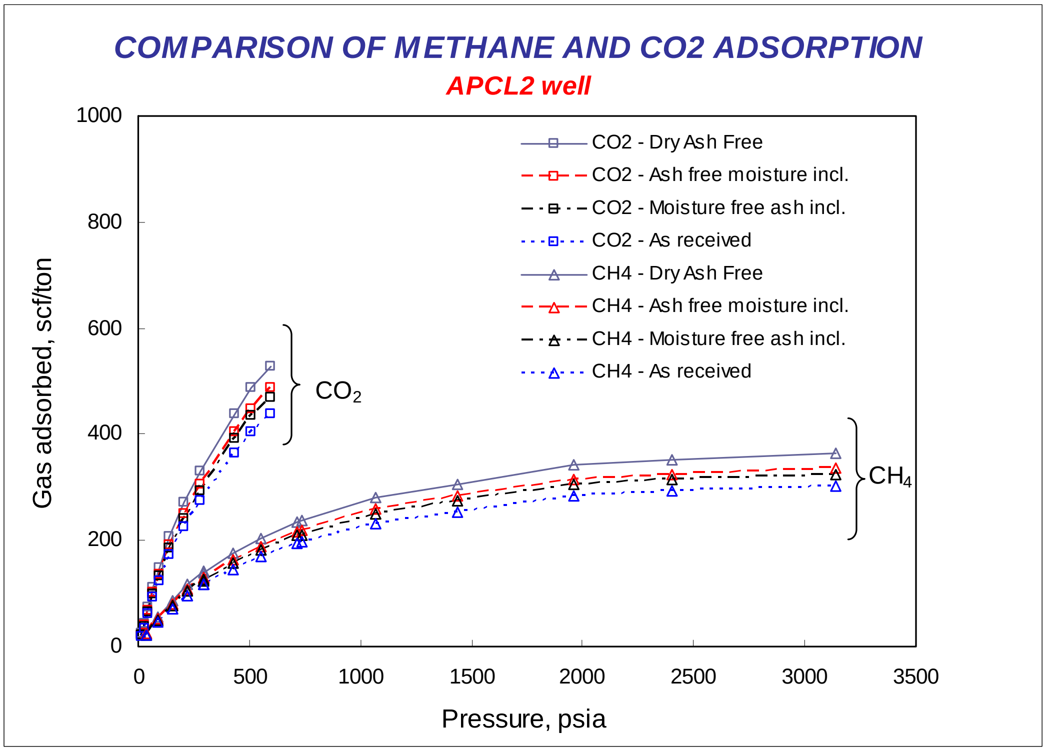

Fig. 1- Comparison of methane and carbon dioxide adsorption isotherms for the Calvert Bluff Formation, APCL2 well.

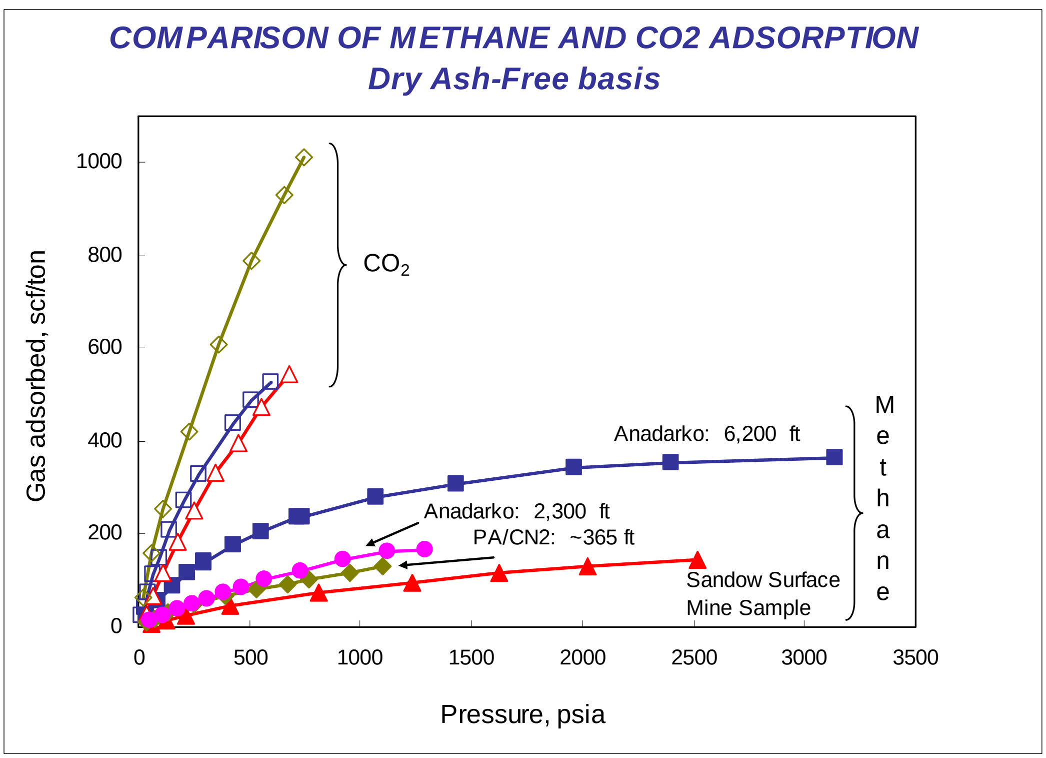

Fig. 2- Comparison of methane (4 samples) and carbon dioxide (3 samples) adsorption isotherms for Wilcox coal samples from one surface mine and 3 east-central Texas wells. Approximate or average sample depths are shown for each sample. Values for carbon dioxide are plotted as open versions of the symbols used for methane for the same well.

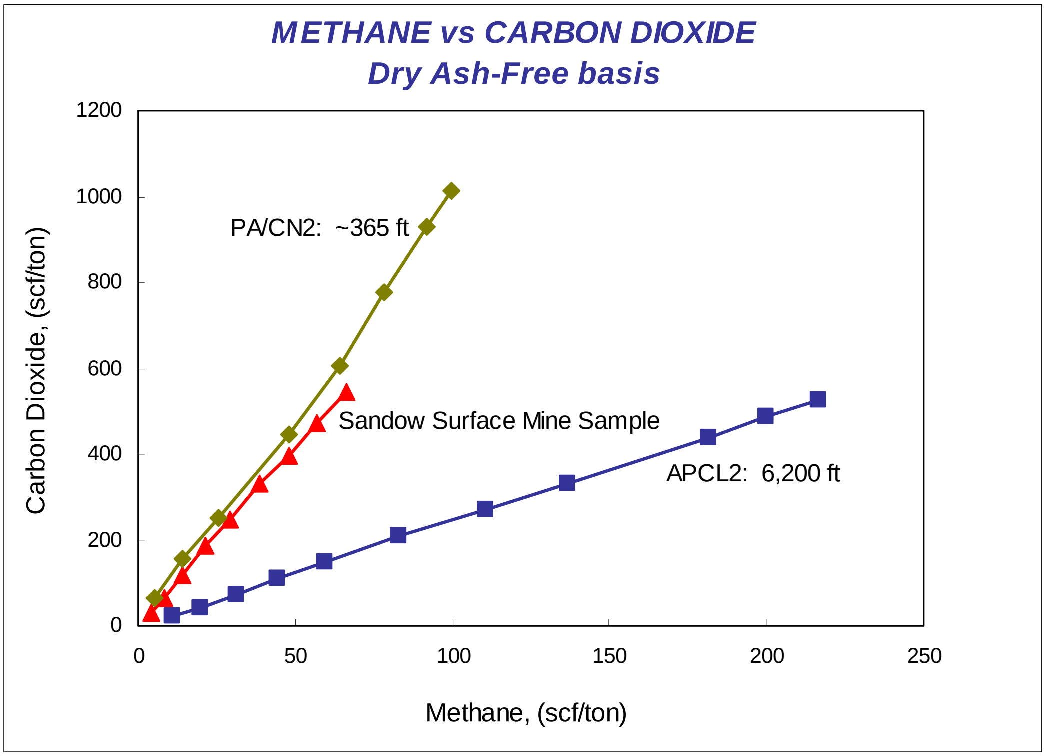

Fig. 3- Comparison of methane and carbon dioxide adsorption isotherms for Wilcox coal samples from one surface mine and 3 east-central Texas wells (dry, ash-free basis). The ration of carbon dioxide to methane is much lower for Wilcox coals in the APCL2 well than in the other wells.

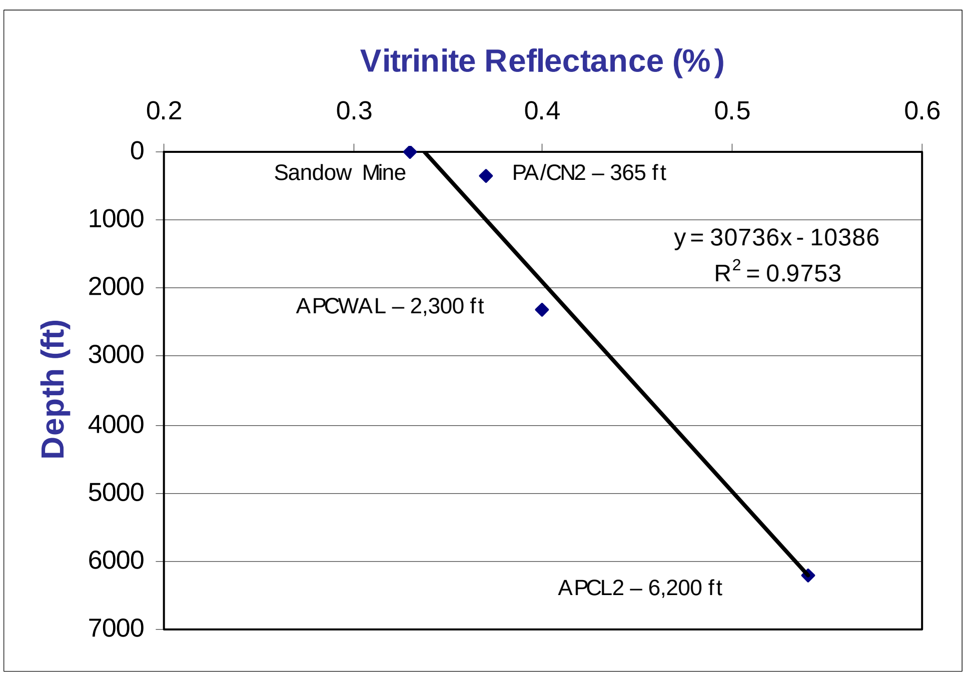

Fig. 4- Vitrinite reflectance of Wilcox coals increases with depth in east-central Texas.

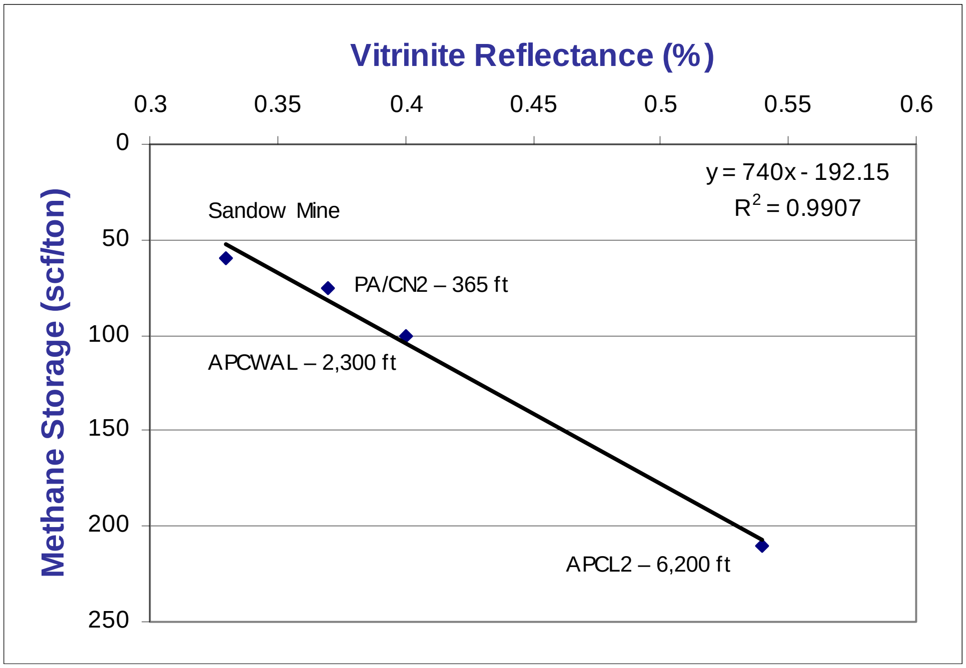

Fig. 5- In east-central Texas, methane storage capacity of Wilcox coals is related to vitrinite reflectance.

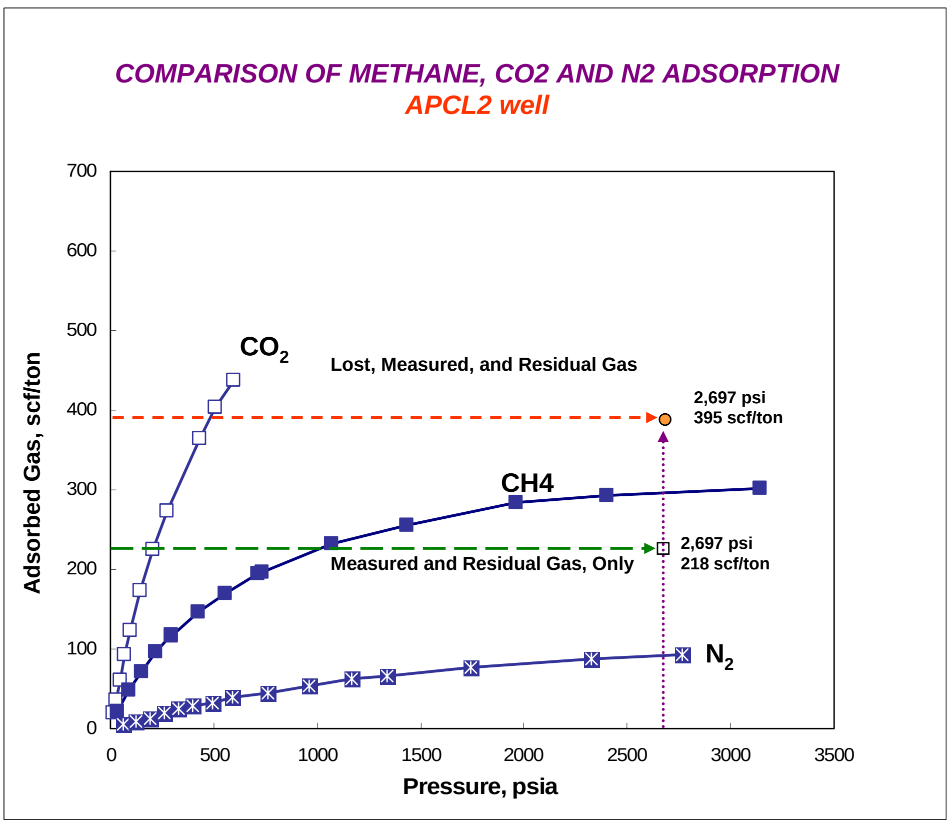

Fig. 6- In the APCL2 well, total gas (lost, measured, and residual gas) determined for Wilcox coals exceeds storage capacity measured from isotherm analysis (as received basis).