



Results from coalbed methane drilling in Winn Parish, Louisiana

By Paul C. Hackley¹, Peter D. Warwick¹, F. Clayton Breland, Jr.², Troy E. Richard³, and Kirk Ross⁴

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Results from coalbed methane drilling in Winn Parish, Louisiana

By Paul C. Hackley, Peter D. Warwick, F. Clayton Breland, Jr., Troy E. Richard, and Kirk Ross

INTRODUCTION

A coalbed methane (CBM) well in Winn Parish, Louisiana, named CZ Fee A No. 114, was drilled by Vintage Petroleum, Inc., in January 2004. The CZ Fee A No. 114 CBM well was drilled to a total depth of 3,114 ft and perforated at 2,730-2,734 ft in a Wilcox Group (Paleocene-Eocene) coal bed. Analytical data from the drilling project have been released by Vintage Petroleum, Inc., and by the current well operator, Hilcorp Energy Corporation (see Appendix) to the Louisiana Geological Survey (LGS) and the U.S. Geological Survey (USGS) for publication. General information about the CZ Fee A No. 114 CBM well is compiled in Table 1, and analytical data from the well are included in following sections.

The CZ Fee A No. 114 well is located in eastern Winn Parish, approximately 30 mi east of where Wilcox Group strata crop out on the Sabine Uplift (fig. 1). In the CZ Fee A No. 114 well, lower Wilcox Paleocene coal beds targeted for CBM production occur at depths of 2,600-3,000 ft (fig. 2). Average monthly gas production for the reporting period August 1, 2004, through May 1, 2005, was 450 thousand cubic feet (Mcf) (Louisiana Department of Natural Resources, 2005).

ANALYTICAL METHODS

Coal and water samples obtained from the CZ Fee A No. 114 well were analyzed by contractors to Vintage Petroleum, Inc. Analytical methods used included canister gas desorption (Diamond and Levine, 1981;

Diamond and others, 1986), proximate, heating value, and sulfur content analyses, organic petrographic analysis, and vitrinite reflectance (American Society for Testing of Materials, 2005), adsorption isotherm analysis (Mavor and others, 1990), and produced water quality analysis (Nelson, 2003).

COAL SAMPLES

Thirteen coal samples were analyzed from three cored intervals in the Wilcox (Table 2). Samples 1 to 5 were recovered from core interval 1 (2,673.0 to 2,683.0 ft), samples 6 to 9 were recovered from core interval 2 (2,730.0 to 2,734.0 ft), and samples 10 to 13 were recovered from core interval 3 (2,937.0 to 2,941.0 ft) (fig. 2).

GAS DESORPTION ANALYSES

Results of canister desorption analyses of the 13 coal core samples are shown in Table 2. Ash yield versus bulk density and raw gas content versus bulk density are plotted in figs. 3 and 4, respectively. Gas content increases with depth and is inversely related to ash content and bulk density. Lost gas content was determined by the U.S. Bureau of Mines direct method (Diamond and Levine, 1981); plots for lost gas estimation and cumulative gas volume are shown for 8 samples in figs. 5 through 12. Total gas content was in the range 6.04 to 158.90 standard cubic feet per ton (scf/ton) (raw basis), or 91.88 to 213.49 scf/ton on a dry, ash-free basis. Residual gas measurements (Diamond and others,

1986) were performed for four samples (Table 2) and determined to range 1.93 to 5.56 scf/ton. Moisture content determined on the desorbed samples ranges from 8.45 to 19.88 weight percent (wt.%) on an as-received basis (as-rec'd) (Table 2); ash content determined on the desorbed samples ranges from 6.30 to 85.16 wt.% (as-rec'd) (Table 2).

COAL QUALITY ANALYSES

Proximate analyses, calorific value, and total sulfur content were determined for three coal samples (samples 4, 7, and 11), and are reported in Tables 3 through 5. Moisture content ranges from 12.13 to 18.65 wt.% (as-rec'd). Proximate moisture values are similar to those reported by a different laboratory as part of the gas desorption analyses (1 to 2 wt.% absolute differences between the two sets of analyses; compare as-received moisture reported in Tables 3 through 5 with Table 2). Ash yield ranges from 6.29 to 47.41 wt.% (as-rec'd). Ash yield is similar (~1 wt.% absolute differences) to that reported for the gas desorption analyses except for sample 4 where the reported ash yield for the proximate analysis is 10 wt.% greater (absolute) than that reported in the gas desorption analysis (compare as-received ash yield in Table 3 with Table 2). Calorific value ranges from 10,046 to 10,904 British thermal units per pound (Btu/lb) on a moist, mineral-matter free basis and rank according to ASTM D 388 is subbituminous B-A. Sulfur content ranges from 0.56 to 1.26 wt.% (as-rec'd).

PETROGRAPHIC ANALYSES

Maceral Analyses

The results of petrographic analyses for samples 4, 7, and 11 are shown in Tables 6 through 8. Samples contain 3.5 to 51.4 volume percent (vol.%) mineral matter, 41.6 to 60.5 vol.% vitrinite, 1.8 to 32.2 vol.% inertinite, and 2.9 to 5.2 vol.% liptinite (maceral composition on mineral-containing

basis). Samples are dominated by detrovitrinite (47.8 to 69.8 vol.%; mineral-free basis), with subordinate telovitrinite. The high inertinite sample 11 (33.3 vol.% inertinite, mineral-free basis) comes from the deepest coal core (cored interval 3; 2,937.0 to 2,941.0 ft). The high value for inertinite content in sample 11 is much higher than the range of inertinite values (2 to 15 vol.%, mineral-free) reported by Hackley and Warwick (2005) for subsurface Wilcox coals located approximately 60 mi to the north in Ouachita Parish, Louisiana.

Vitrinite Reflectance Analyses

The results of measurements of the random reflectance of vitrinite for samples 4, 7, and 11 are reported in Tables 9 through 11. Values range between 0.34 and 39 % reflectance, indicating lignite to subbituminous C rank. Rank according to the reflectance of vitrinite is slightly lower than calculated by the Parr Formula (based on ASTM D 388). Reported values for the standard deviation of measured random reflectance are 0.05 to 0.075, indicating high levels of variability in the measured vitrinite populations.

METHANE ADSORPTION ANALYSES

Methane adsorption isotherm analyses were performed on samples 4, 7, and 11. Analytical data are included in Tables 12 to 20 and isotherm plots are shown in figs. 13 through 21. Comparison of desorbed gas content with methane adsorption isotherms indicate that the samples range from undersaturated to slightly oversaturated at hydrostatic reservoir pressure (fig. 22). Reservoir pressures for the cored intervals were estimated by multiplying depth by 0.433 pounds per square inch per foot (psi/ft) (normal hydrostatic gradient; Schlumberger Limited, 2005). Equilibrium moisture values determined for the three samples as part of the isotherm analyses are 2 to 3.5 wt.% greater (absolute basis) than as-received moisture reported as part

of the desorption analyses, and 4 to 4.5 wt.% greater than as-received proximate moisture. As-received ash yield determined as part of the isotherm analyses is within 2 wt.% of ash yield reported for the proximate analyses.

PRODUCED WATER ANALYSES

Produced waters were collected in February and March, 2004. Water quality data are tabulated in Tables 21 and 22. Total dissolved solids ranged from 82,800 to 84,600 milligrams per liter (mg/l); pH ranged from 5.85 to 6.58.

GAS-IN-PLACE CALCULATIONS

Calculated gas-in-place (GIP) for the 3 cored intervals ranges from 144,515 to 208,479 Mcf for 160 acre centers (Table 23). Total GIP is 547,680 Mcf on 160 acre centers. The number of bulk density values (35) and their reported magnitude in Table 23 is inconsistent with the number of bulk density values (13) reported for gas desorption analyses (Table 2) because cored intervals were sectioned into 0.5 ft sections and bulk density was estimated using the e-log. Ash fraction in Table 23 is calculated from the estimated bulk density; average gas content and moisture values used in the GIP calculations are from the gas desorption analyses (Table 2).

ACKNOWLEDGEMENTS

The USGS and LGS thank Vintage Petroleum, Inc., and Hilcorp Energy Corporation for sharing data on coalbed methane exploration in Winn Parish, LA. TerraTek Inc. and its contractors conducted the coal analyses; Baker Petrolite conducted the water analyses. Technical reviews by Leslie Ruppert and Alex Karlsen of USGS improved the quality and clarity of this report.

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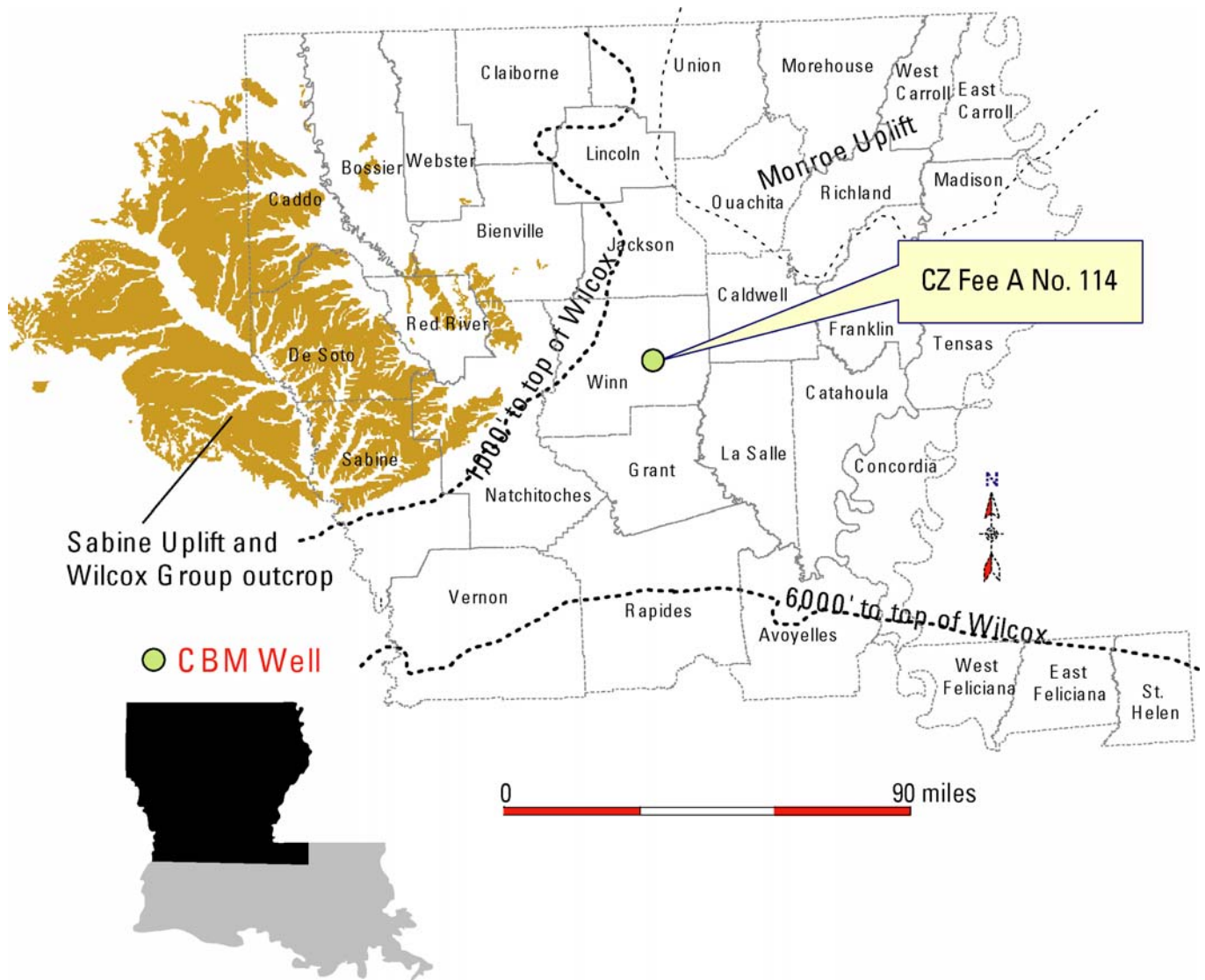


Figure 1. Location of CZ Fee A No. 114 CBM well in Winn County, Louisiana. Heavy dashed line indicates depth to the top of the Wilcox Group. Light dashed line indicates outline of the Monroe Uplift.

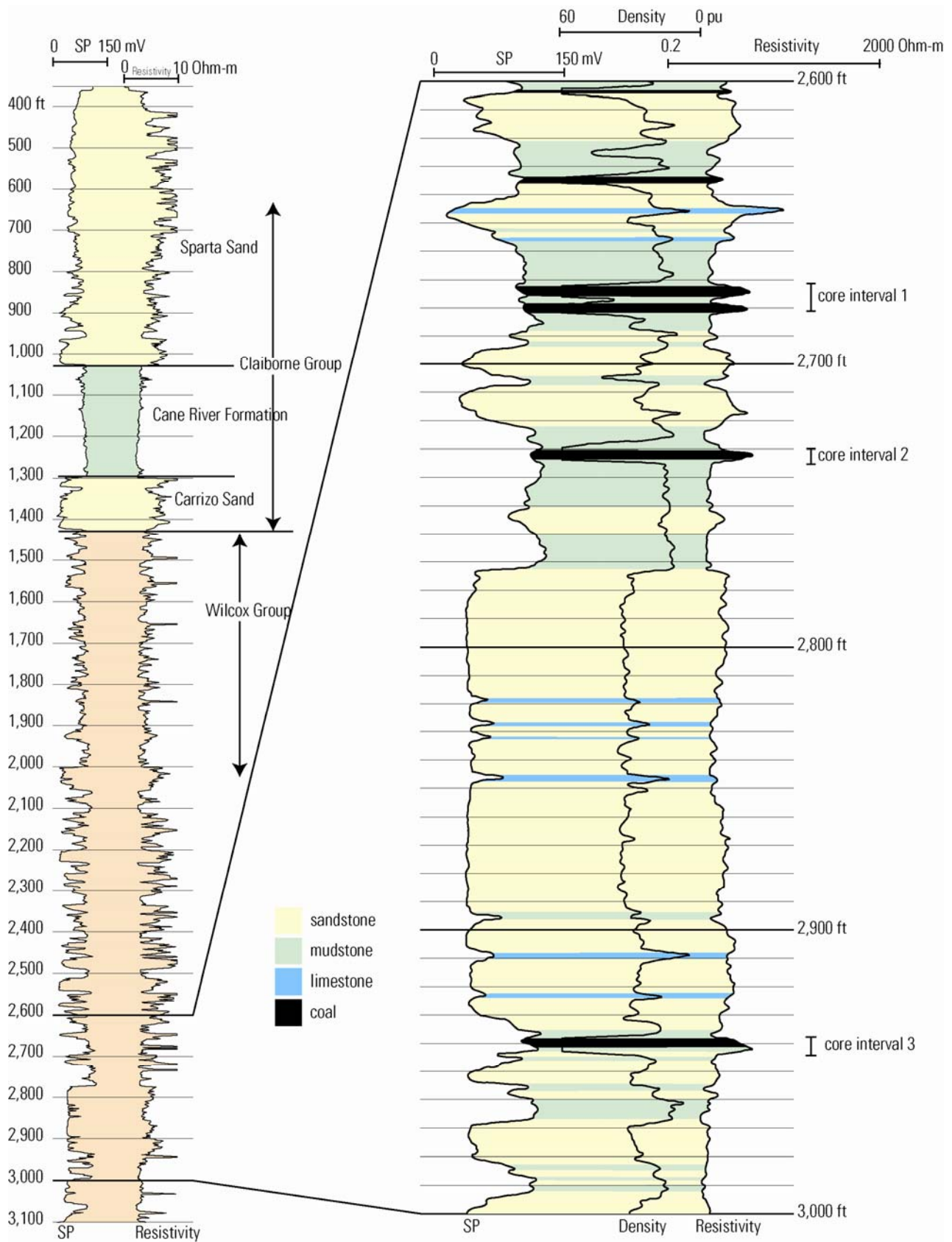


Figure 2. E-logs and interpreted stratigraphy of CZ Fee A No. 114 CBM well.

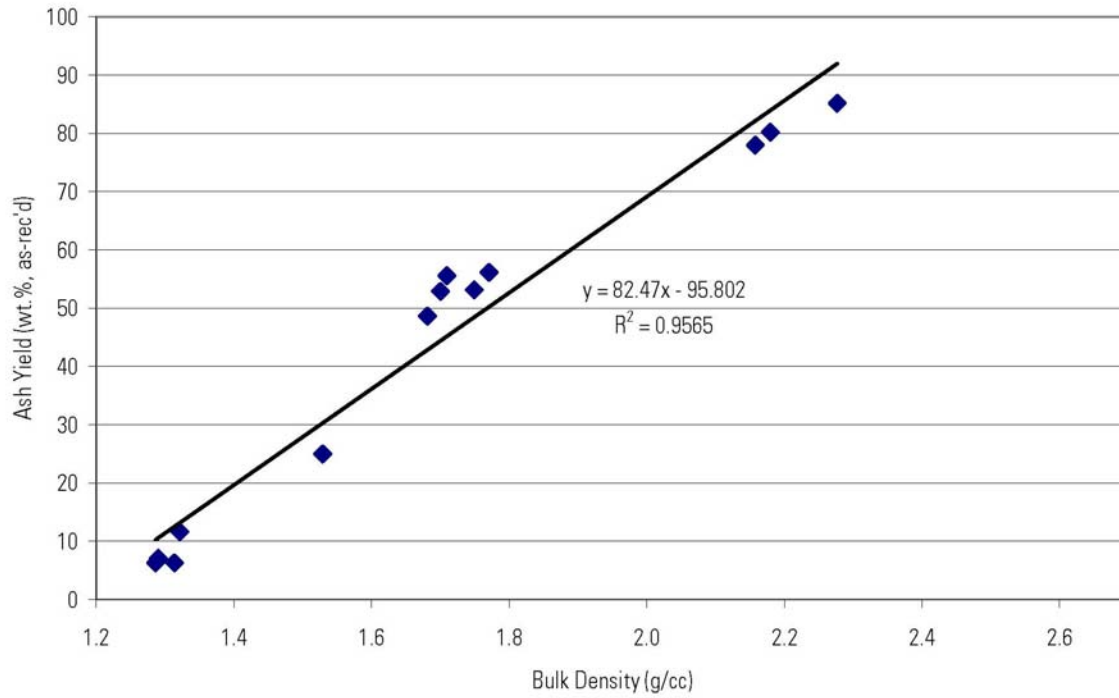


Figure 3. Ash yield (as-received) versus bulk density, CZ Fee A No. 114 CBM well samples. Abbreviations: % = percent; as-rec'd = as-received; g/cc = grams per cubic centimeter.

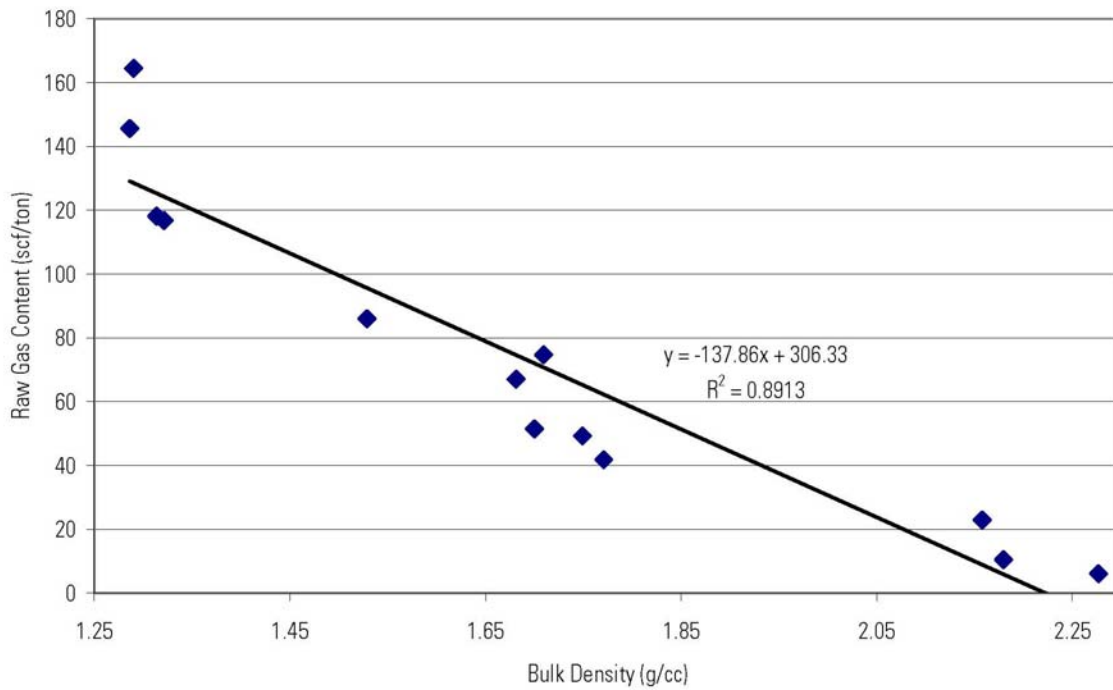


Figure 4. Raw gas content versus bulk density, CZ Fee A No. 114 CBM well samples. Abbreviations: scf/ton = standard cubic feet per ton; g/cc = grams per cubic centimeter.

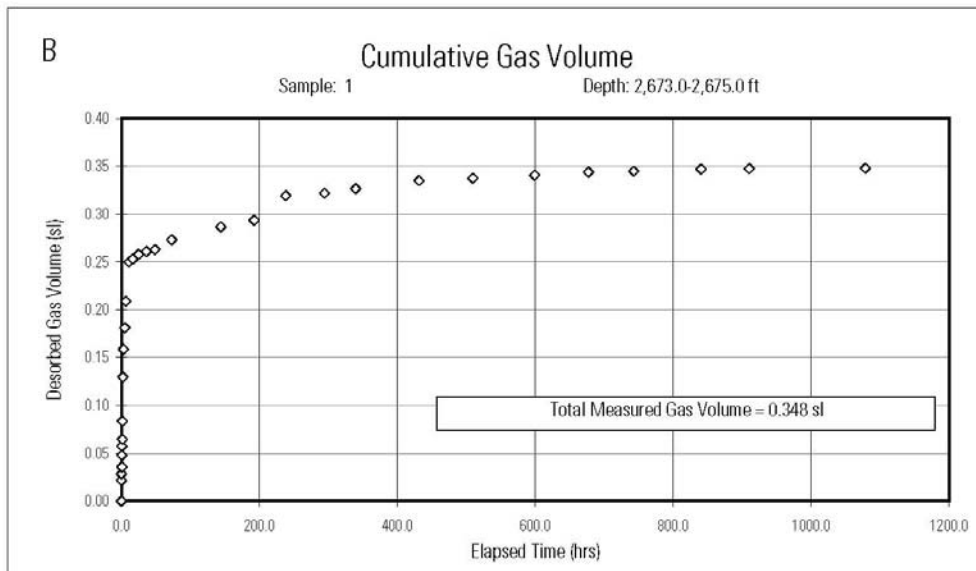
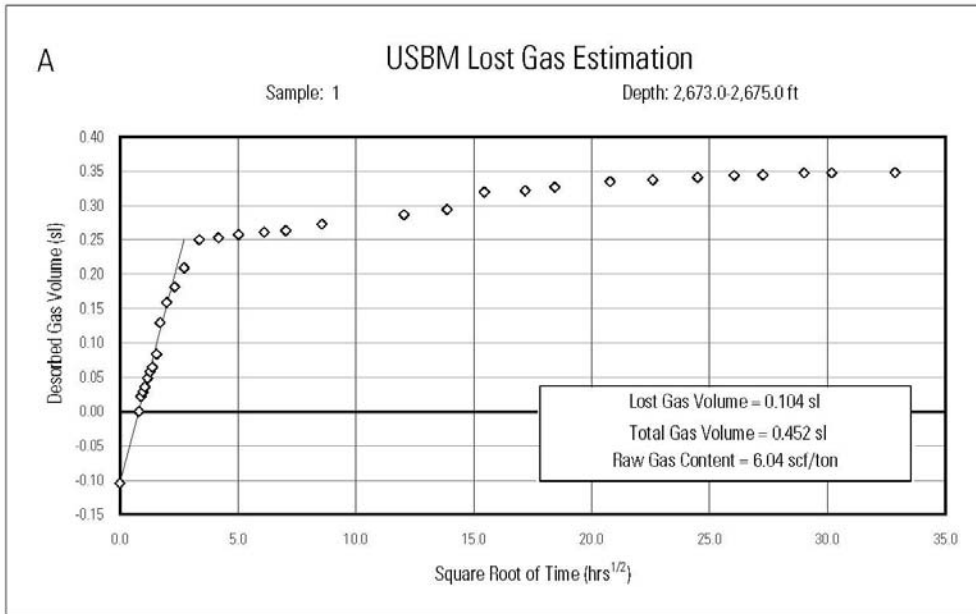


Figure 5. A. Lost gas estimation, and B. Cumulative gas volume for CZ Fee A No. 114 CBM well, sample 1. Abbreviations: sl = standard liter; scf/ton = standard cubic foot per ton; hrs = hours. Desorbed gas volume on abscissa ranges 0.00-0.40 sl.

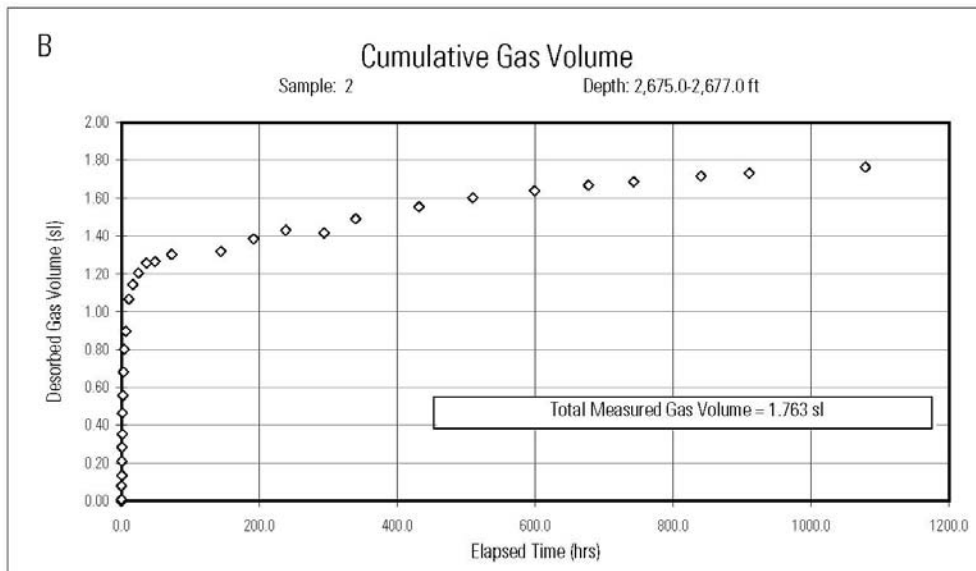
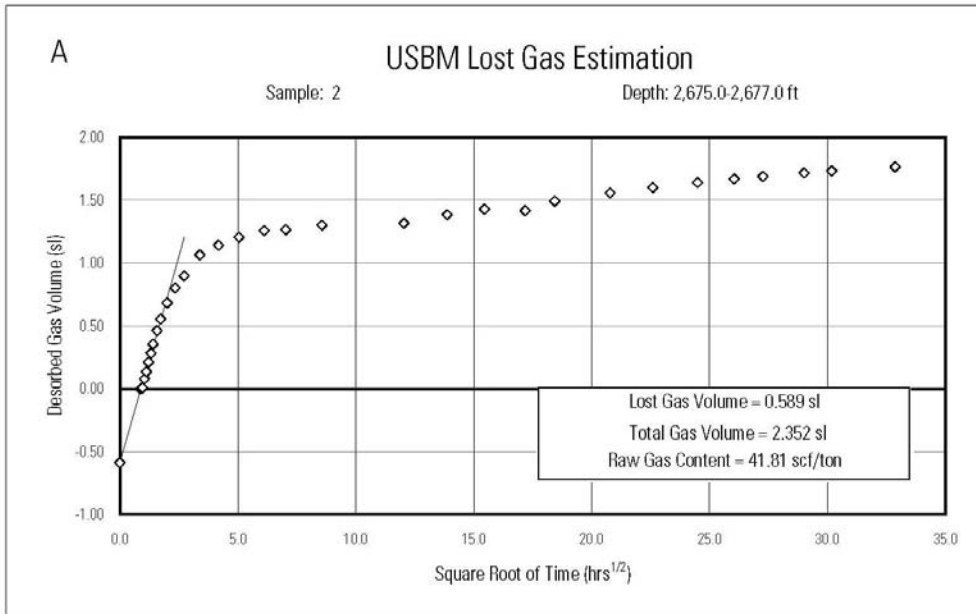


Figure 6. A. Lost gas estimation, and B. Cumulative gas volume for CZ Fee A No. 114 CBM well, sample 2. Abbreviations: sl = standard liter; scf/ton = standard cubic foot per ton; hrs = hours. Desorbed gas volume on abscissa ranges 0.00-2.00 sl.

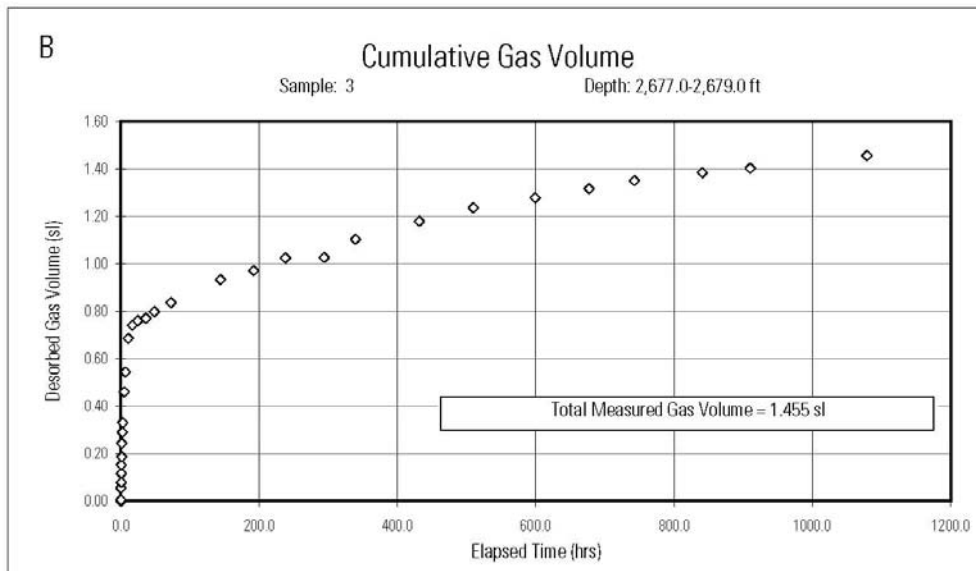
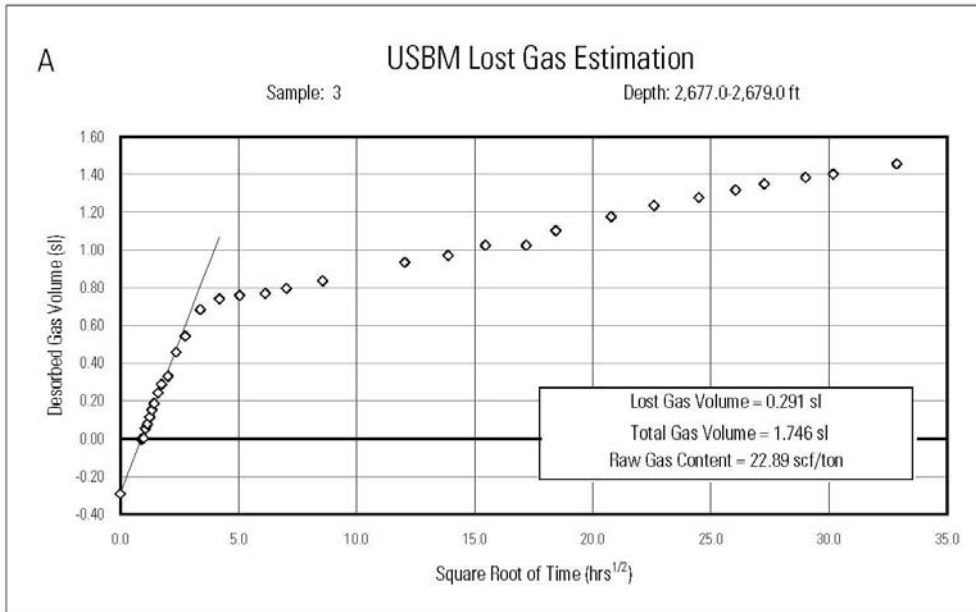


Figure 7. A. Lost gas estimation, and B. Cumulative gas volume for CZ Fee A No. 114 CBM well, sample 3. Abbreviations: sl = standard liter; scf/ton = standard cubic foot per ton; hrs = hours. Desorbed gas volume on abscissa ranges 0.00-1.60 sl.

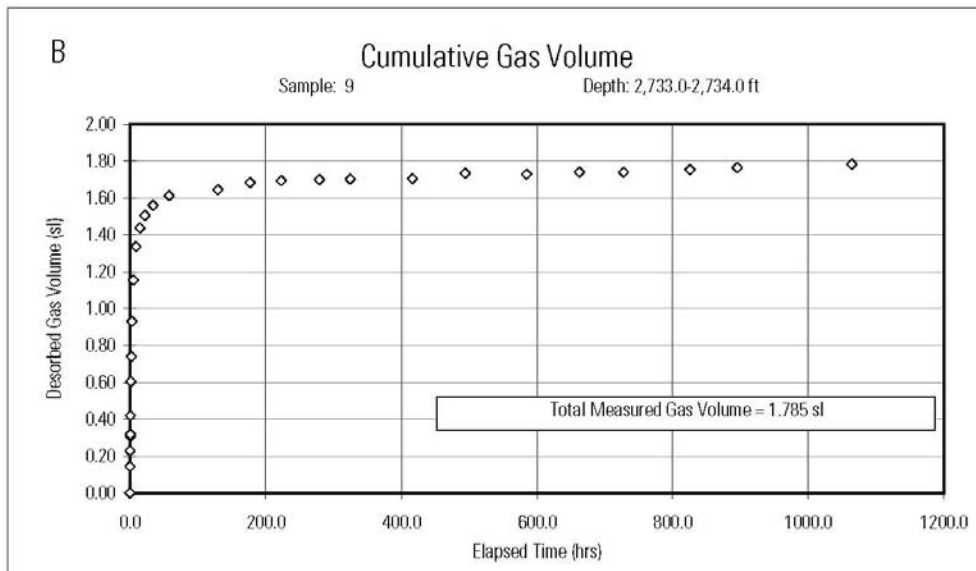
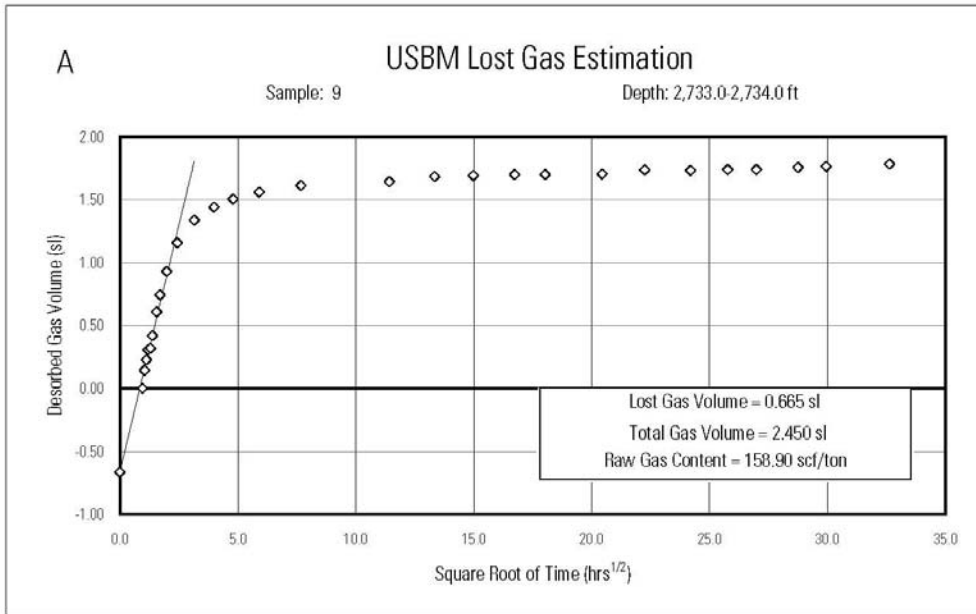


Figure 8. A. Lost gas estimation, and B. Cumulative gas volume for CZ Fee A No. 114 CBM well, sample 9. Abbreviations: sl = standard liter; scf/ton = standard cubic foot per ton; hrs = hours. Desorbed gas volume on abscissa ranges 0.00-2.00 sl.

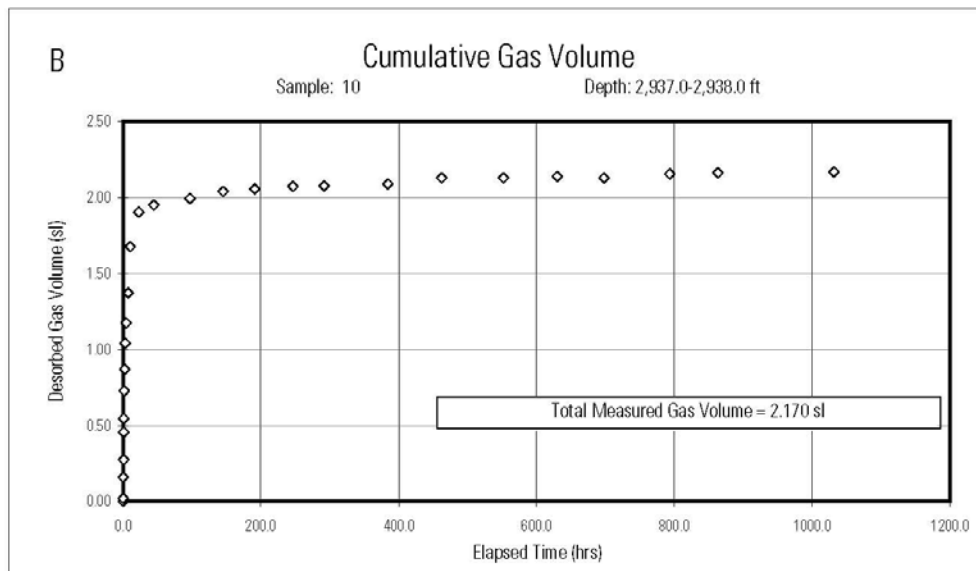
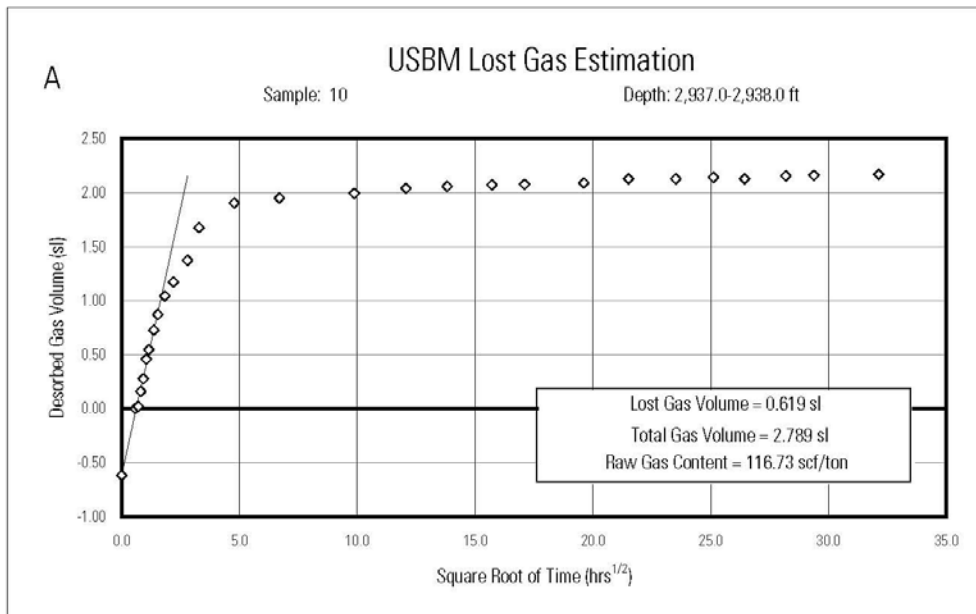


Figure 9. A. Lost gas estimation, and B. Cumulative gas volume for CZ Fee A No. 114 CBM well, sample 10. Abbreviations: sl = standard liter; scf/ton = standard cubic foot per ton; hrs = hours. Desorbed gas volume on abscissa ranges 0.00-2.50 sl.

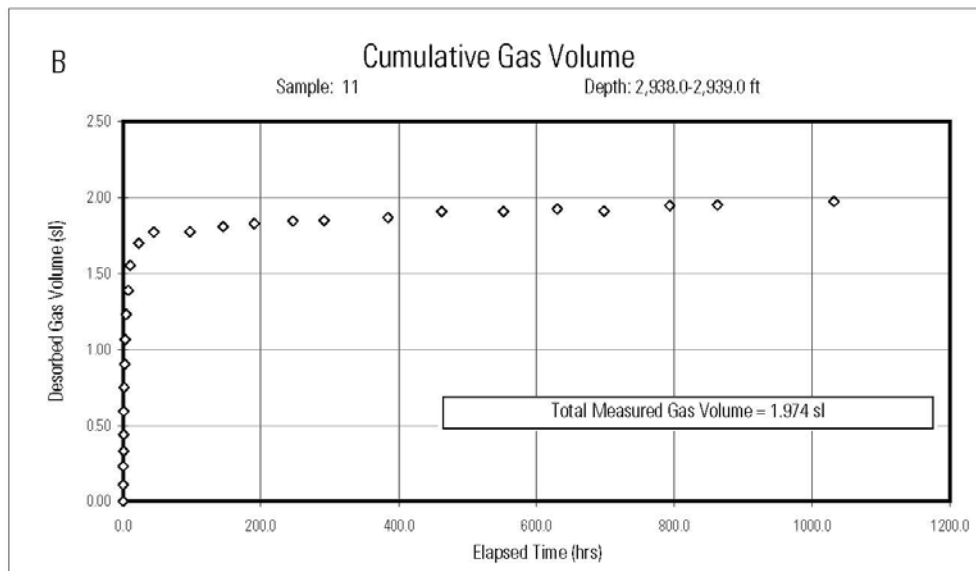
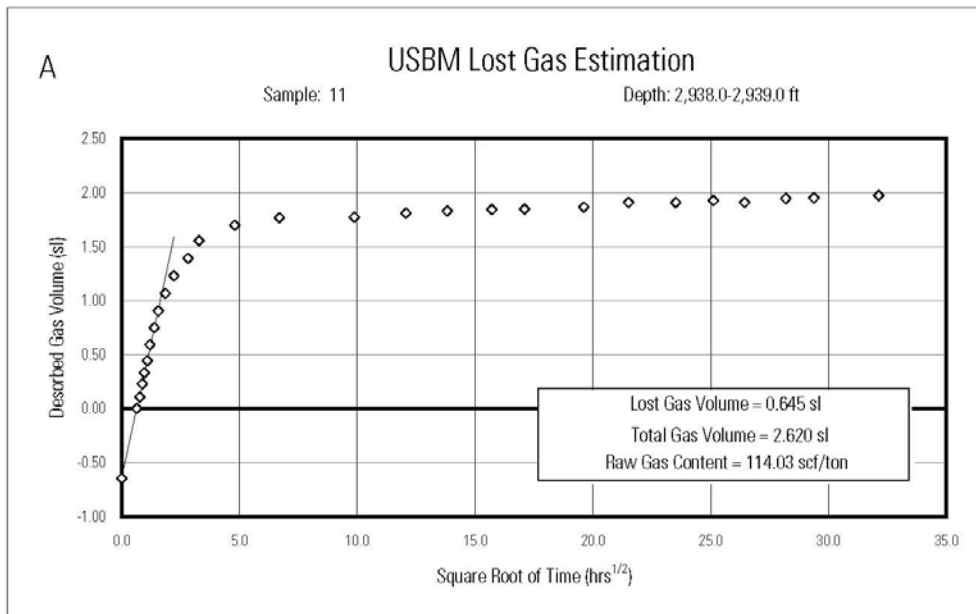


Figure 10. A. Lost gas estimation, and B. Cumulative gas volume for CZ Fee A No. 114 CBM well, sample 11. Abbreviations: sl = standard liter; scf/ton = standard cubic foot per ton; hrs = hours. Desorbed gas volume on abscissa ranges 0.00-2.50 sl.

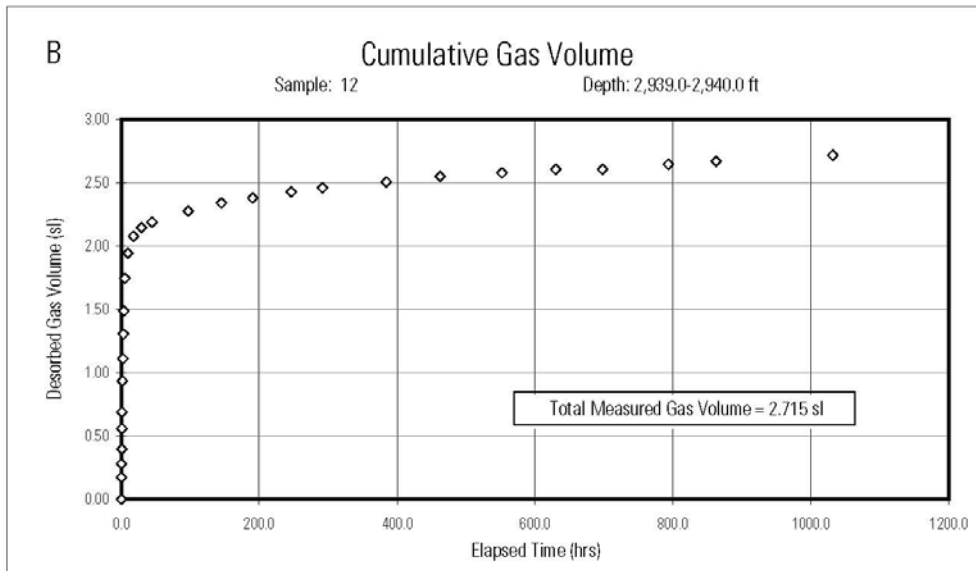
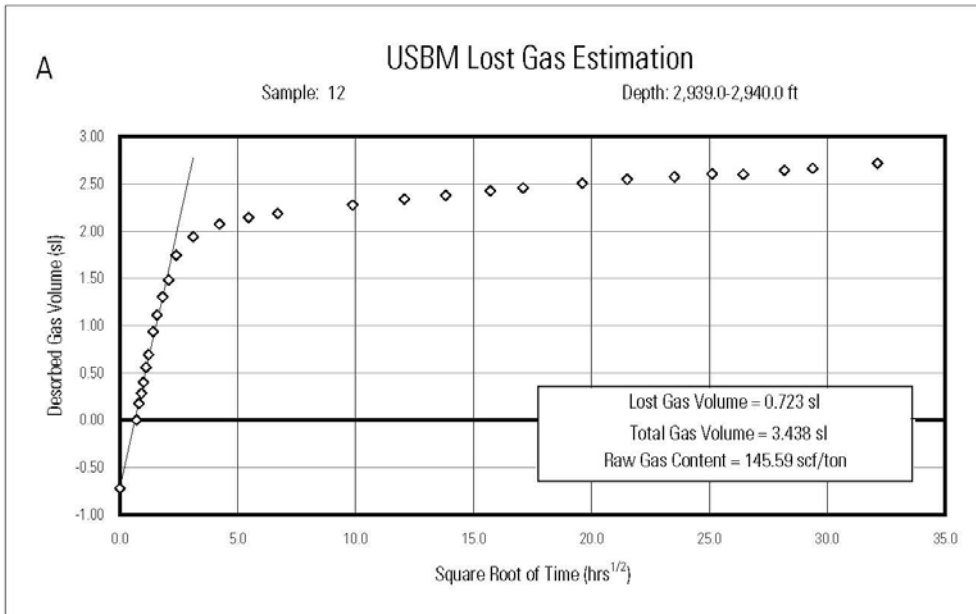


Figure 11. A. Lost gas estimation, and B. Cumulative gas volume for CZ Fee A No. 114 CBM well, sample 12. Abbreviations: sl = standard liter; scf/ton = standard cubic foot per ton; hrs = hours. Desorbed gas volume on abscissa ranges 0.00-3.00 sl.

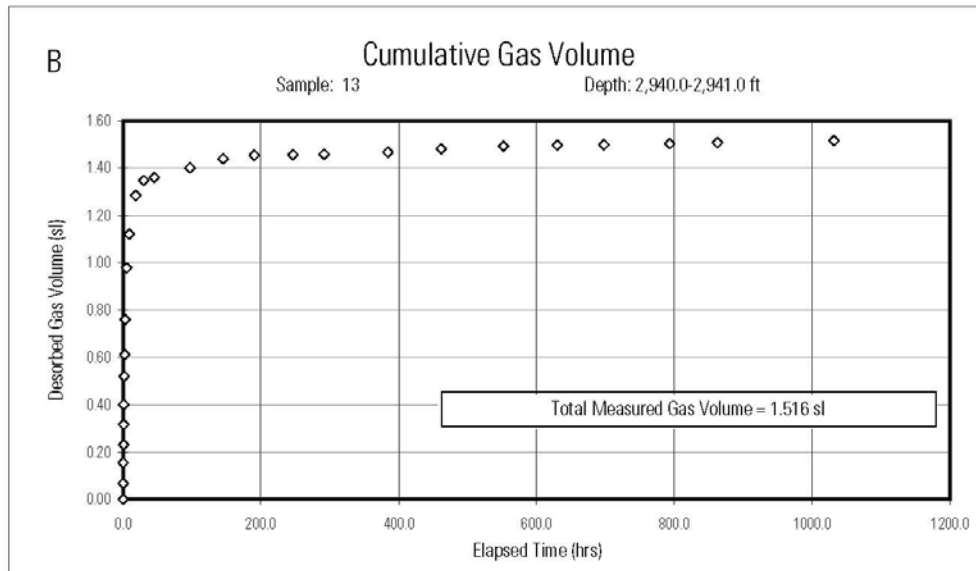
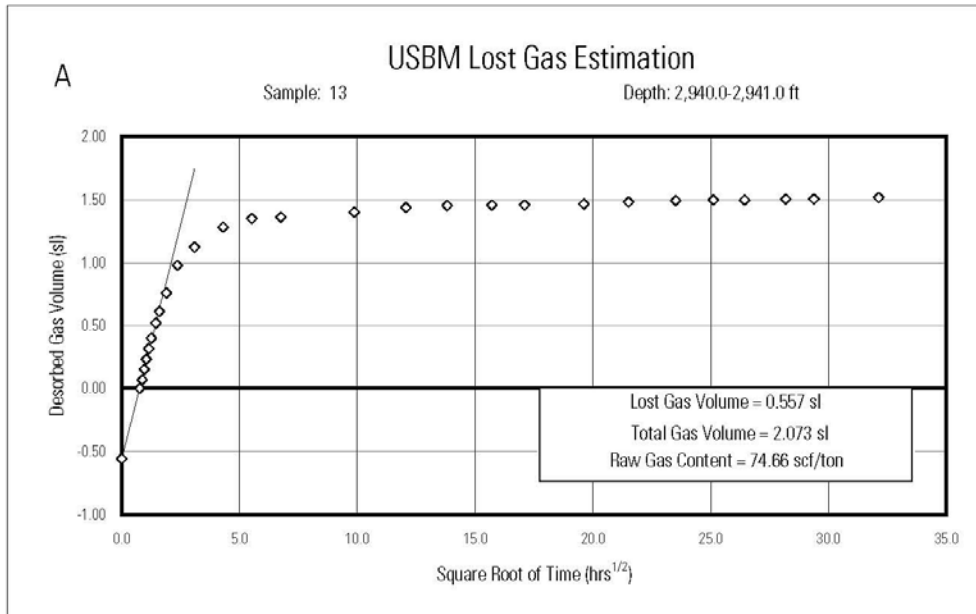


Figure 12. A. Lost gas estimation, and B. Cumulative gas volume for CZ Fee A No. 114 CBM well, sample 13. Abbreviations: sl = standard liter; scf/ton = standard cubic foot per ton; hrs = hours. Desorbed gas volume on abscissa ranges 0.00-1.60 sl.

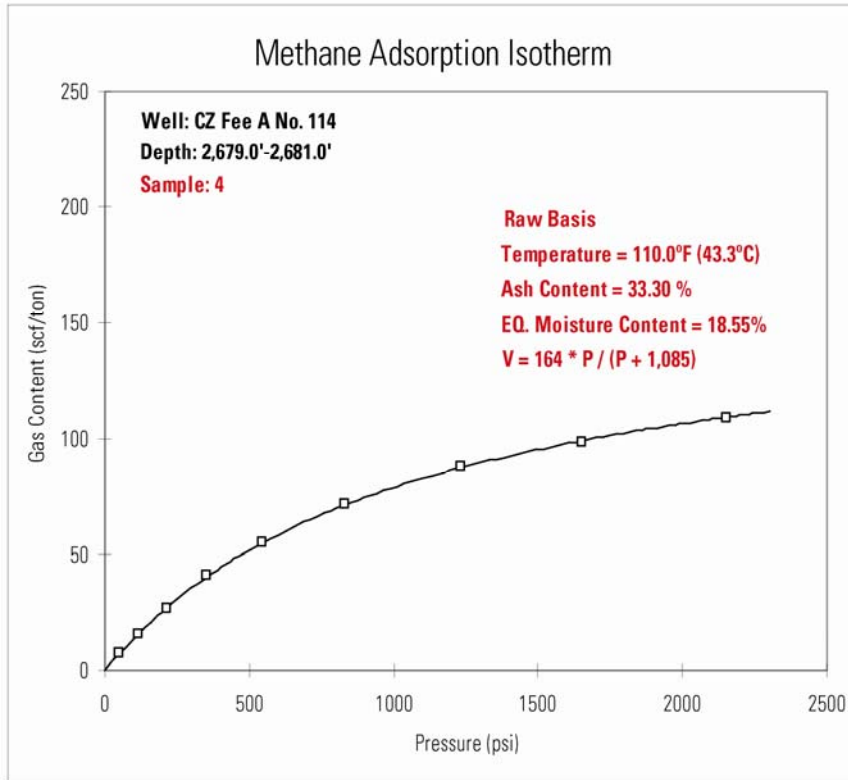


Figure 13. Methane adsorption isotherm, CZ Fee A No. 114 CBM well, sample 4, raw basis. Abbreviations: EQ. = equilibrium; V = volume; P = pressure; scf/ton = standard cubic feet per ton; psi = pounds per square inch.

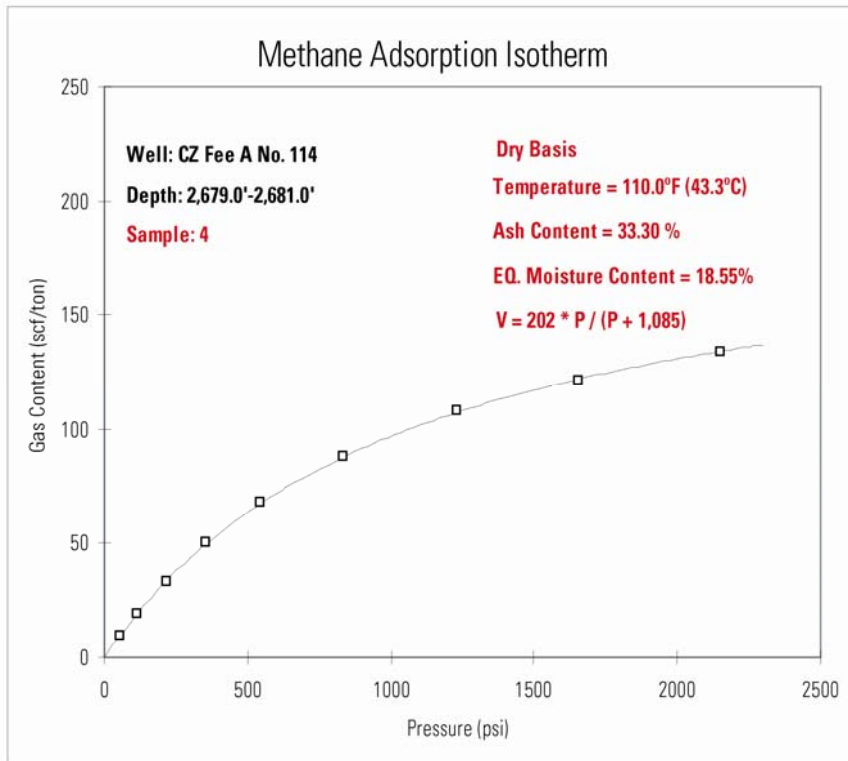


Figure 14. Methane adsorption isotherm, CZ Fee A No. 114 CBM well, sample 4, dry basis. Abbreviations: EQ. = equilibrium; V = volume; P = pressure; scf/ton = standard cubic feet per ton; psi = pounds per square inch.

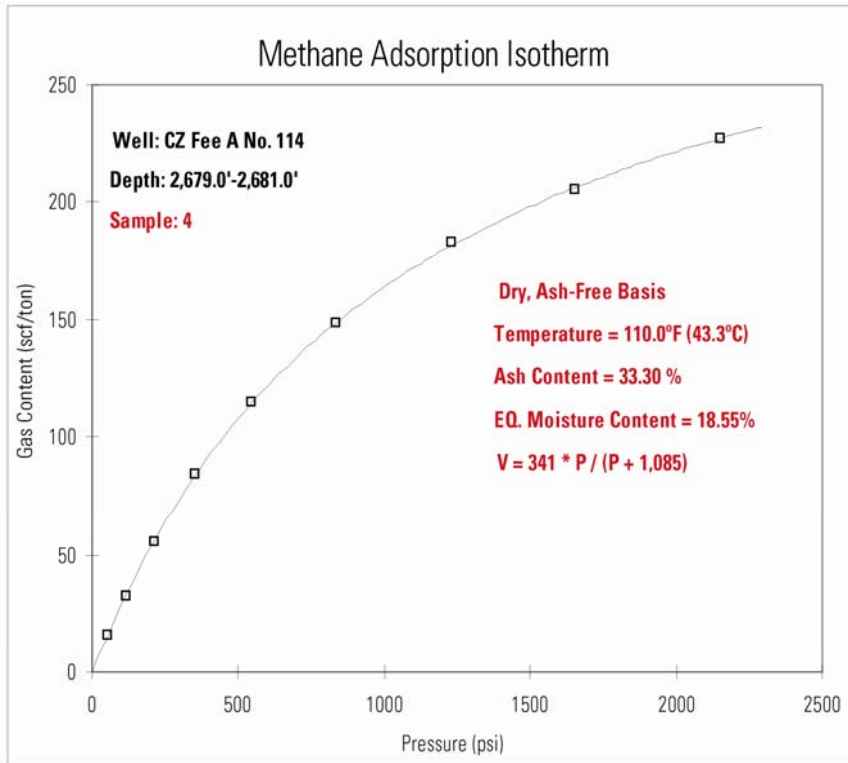


Figure 15. Methane adsorption isotherm, CZ Fee A No. 114 CBM well, sample 4, dry, ash-free basis. Abbreviations: EQ. = equilibrium; V = volume; P = pressure; scf/ton = standard cubic feet per ton; psi = pounds per square inch.

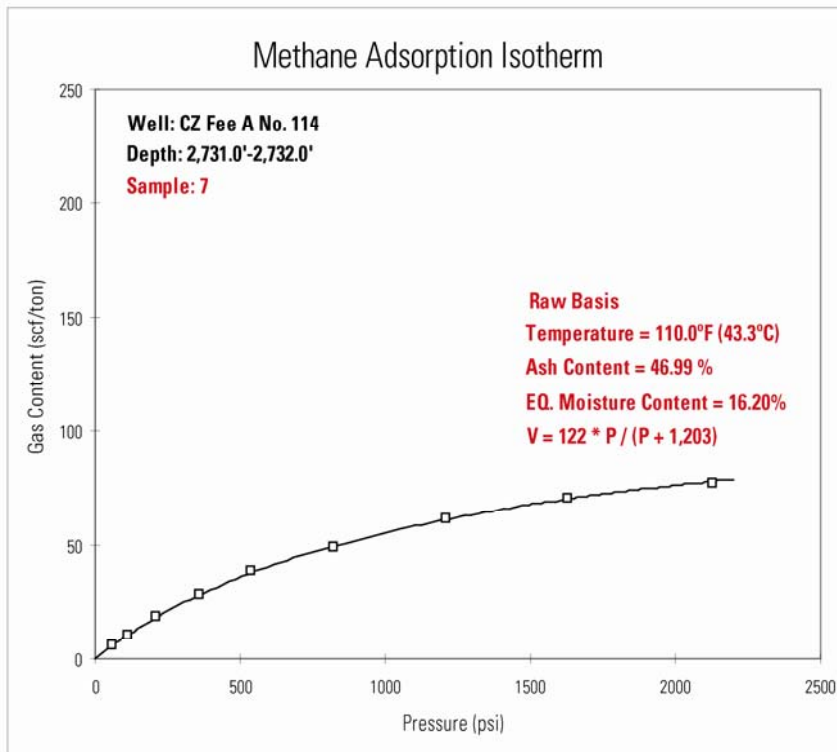


Figure 16. Methane adsorption isotherm, CZ Fee A No. 114 CBM well, sample 7, raw basis. Abbreviations: EQ. = equilibrium; V = volume; P = pressure; scf/ton = standard cubic feet per ton; psi = pounds per square inch.

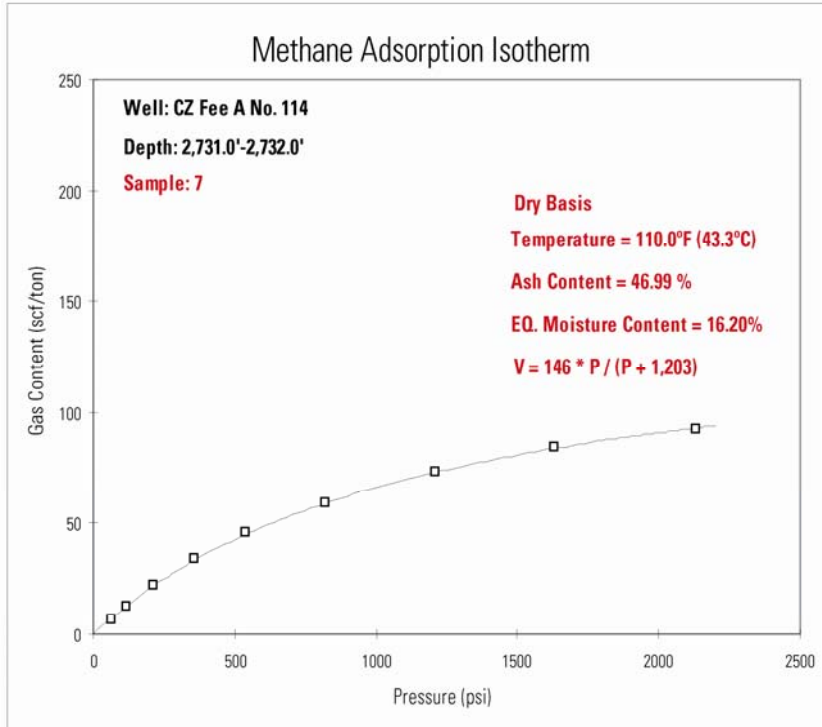


Figure 17. Methane adsorption isotherm, CZ Fee A No. 114 CBM well, sample 7, dry basis. Abbreviations: EQ. = equilibrium; V = volume; P = pressure; scf/ton = standard cubic feet per ton; psi = pounds per square inch.

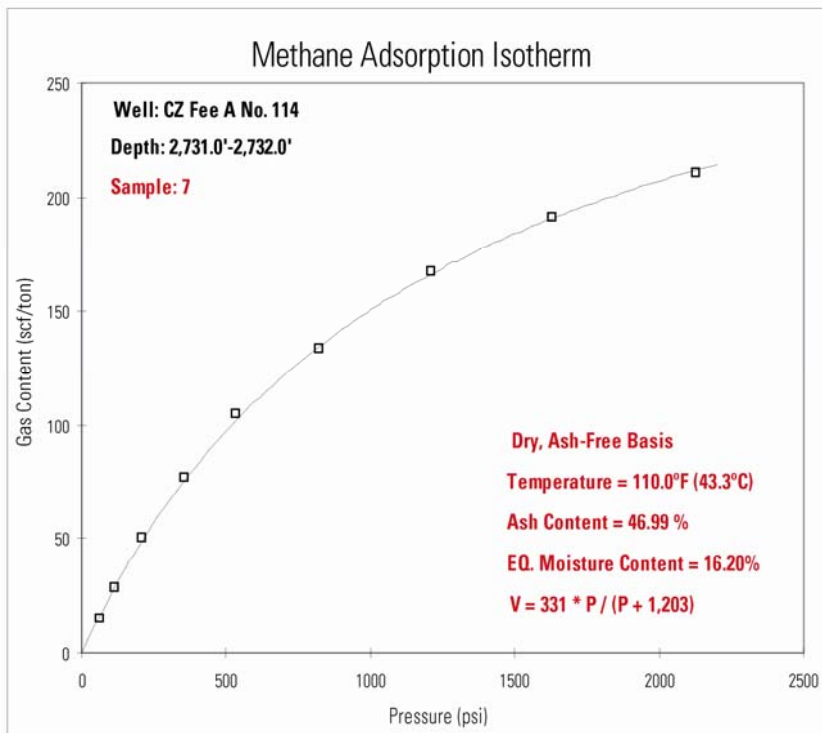


Figure 18. Methane adsorption isotherm, CZ Fee A No. 114 CBM well, sample 7, dry, ash-free basis. Abbreviations: EQ. = equilibrium; V = volume; P = pressure; scf/ton = standard cubic feet per ton; psi = pounds per square inch.

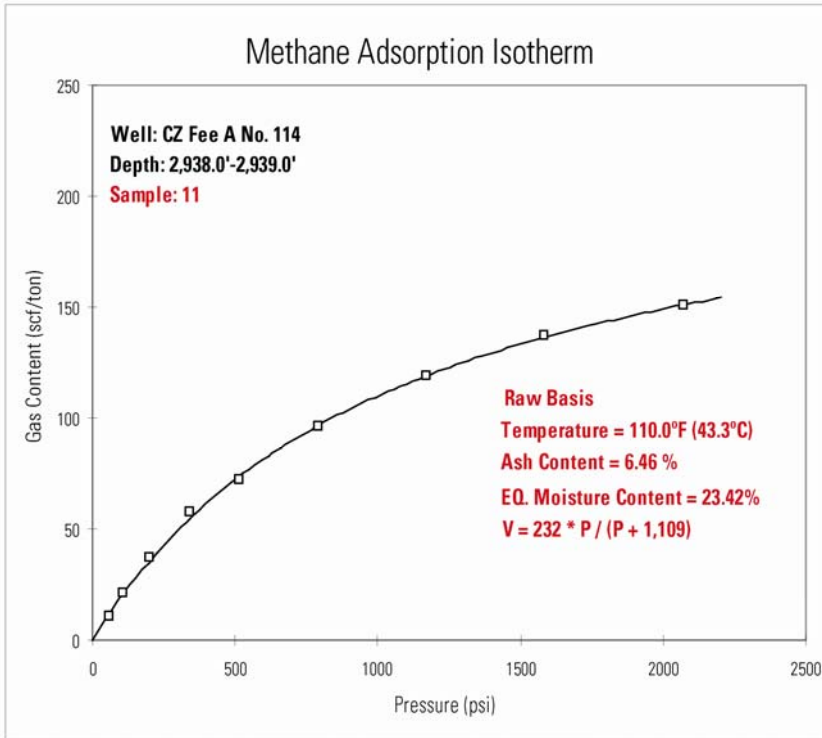


Figure 19. Methane adsorption isotherm, CZ Fee A No. 114 CBM well, sample 11, raw-basis. Abbreviations: EQ. = equilibrium; V = volume; P = pressure; scf/ton = standard cubic feet per ton; psi = pounds per square inch.

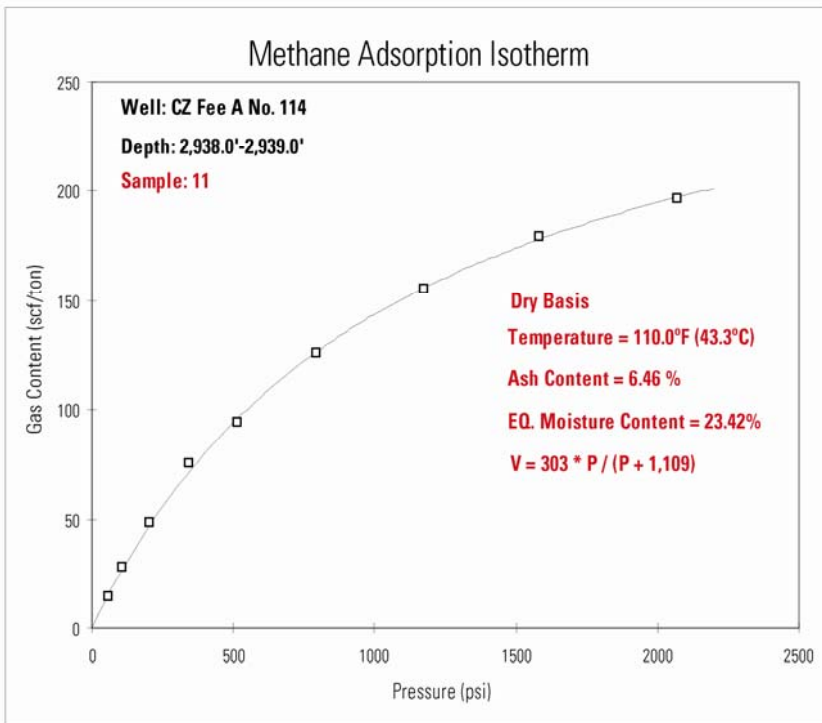


Figure 20. Methane adsorption isotherm, CZ Fee A No. 114 CBM well, sample 11, dry basis. Abbreviations: EQ. = equilibrium; V = volume; P = pressure; scf/ton = standard cubic feet per ton; psi = pounds per square inch.

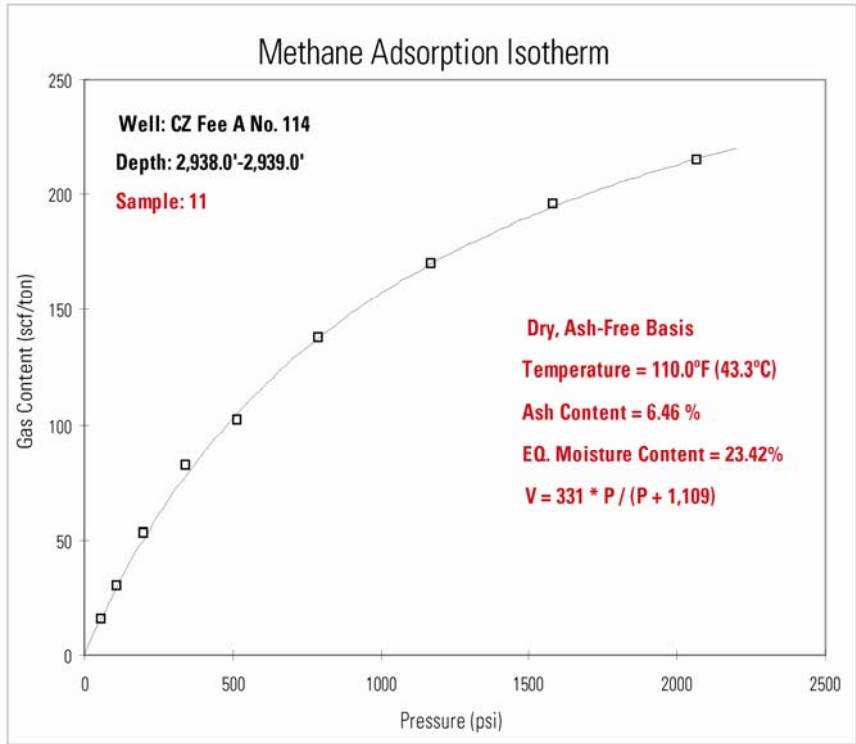


Figure 21. Methane adsorption isotherm, CZ Fee A No. 114 CBM well, sample 11, dry, ash-free basis. Abbreviations: EQ. = equilibrium; V = volume; P = pressure; scf/ton = standard cubic feet per ton; psi = pounds per square inch.

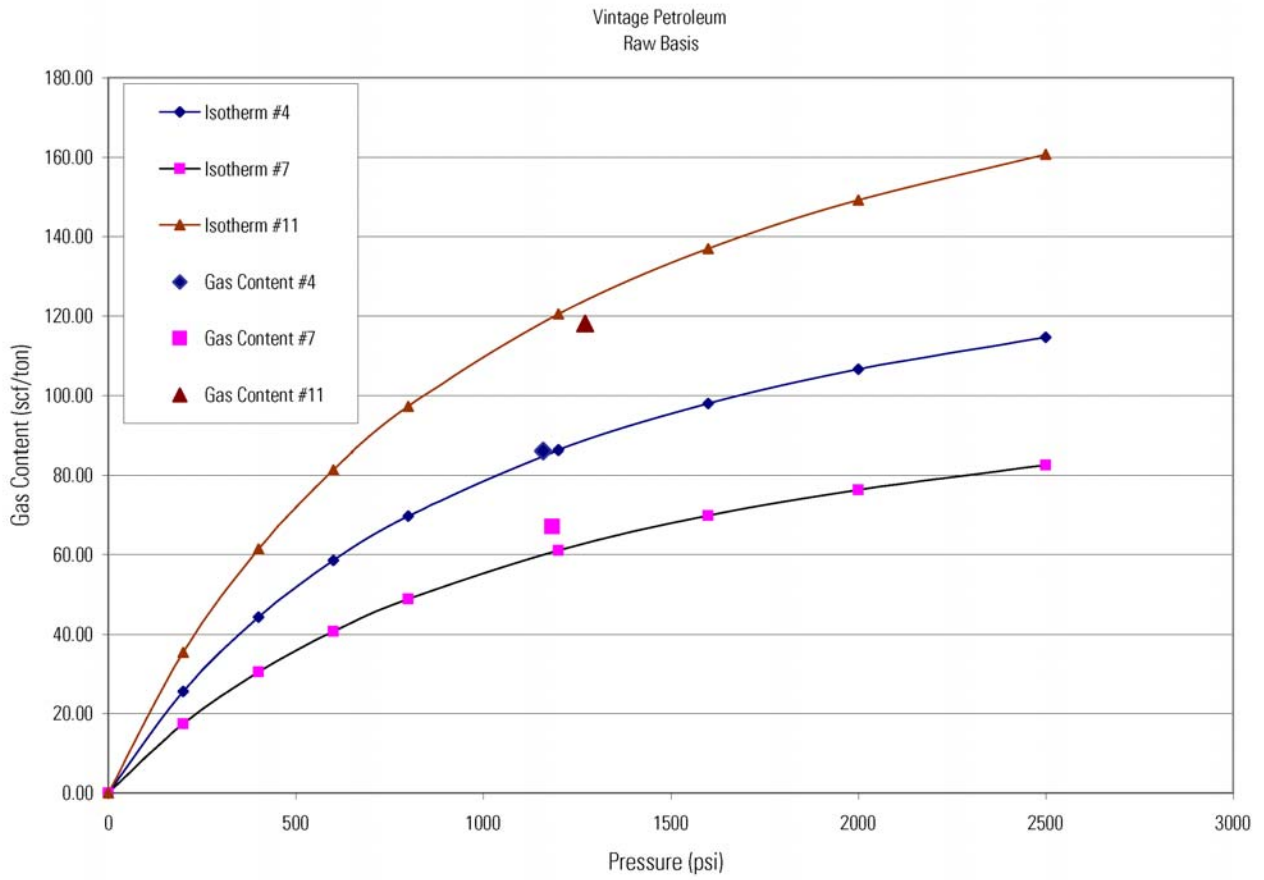


Figure 22. Methane adsorption isotherms and measured gas content, CZ Fee A No. 114 CBM well, as-analyzed basis. Abbreviations: scf/ton = standard cubic feet per ton; psi = pounds per square inch.

Table 1. General information for CZ Fee A No. 114 CBM well, Winn Parish, LA.

Hole name: CZ Fee A No. 114
API number: 17127223830000
Louisiana serial number:
228951
Spud Date: 1/8/2004
Completion Date: 4/12/2004
Operator: Vintage Petroleum,
Inc.
Parish: Winn
Latitude: 31°54'28"
Longitude: 92°29'19"
Township, Range, Section: 11N, 01W,
029
Perforation Interval: 2,730-2,734
ft
Total depth of hole:
3,114 ft
Cored Intervals: 2,673-2,683 ft, 2,730-2,734 ft, 2,937-2,941 ft, all in Wilcox Group (Paleocene-Eocene).

Table 2. Gas desorption data for CZ Fee A No. 114 CBM well.

CORE	SAMPLE	DEPTH (ft)	SAMPLE WEIGHT (g)	TOTAL	USBM LOST GAS (scc)	USBM TOTAL GAS (scc)	USBM TOTAL GAS (scf/ton)		BULK DENSITY (g/cc)	MOISTURE	ASH	RESIDUAL GAS (scf/ton)	RAW	DAF
				MEASURED GAS (scc)			RAW DATA	DAF BASIS		CONTENT (wt.%, as-rec'd)	CONTENT (wt.%, as-rec'd)		TOTAL GAS (scf/ton)	TOTAL GAS (scf/ton)
1	1	2,673.0-75.0	2,399.1	348	104	452	6.04	109.82	2.277	9.34	85.16			
	2	2,675.0-77.0	1,802.3	1,763	589	2,352	41.81	140.11	1.771	14.02	56.14			
	3	2,677.0-79.0	2,444.2	1,455	291	1,746	22.89	192.84	2.158	10.16	77.97			
	4	2,679.0-81.0	1,540.3	2,802	1,239	4,041	84.05	142.36	1.529	15.98	24.98	1.93	12.34	108.91
	5	2,681.0-83.0	2,428.8	381	408	789	10.41	91.88	2.180	8.45	80.22			
2	6	2,730.0-31.0	1,040.3	1,096	501	1,597	49.19	150.29	1.749	14.13	53.14			
	7	2,731.0-32.0	985.8	1,335	651	1,986	64.55	168.27	1.681	13.00	48.64	2.49	53.93	161.95
	8	2,732.0-33.0	982.4	961	616	1,577	51.44	154.47	1.700	13.81	52.89			
	9	2,733.0-34.0	494.0	1,785	665	2,450	158.90	213.49	1.290	18.50	7.07	5.56	122.29	175.68
3	10	2,937.0-38.0	765.5	2,170	619	2,789	116.73	167.69	1.321	18.77	11.62			
	11	2,938.0-39.0	736.0	1,974	646	2,620	114.03	154.47	1.314	19.88	6.30	4.04	149.63	198.42
	12	2,939.0-40.0	756.6	2,715	723	3,438	145.59	193.06	1.286	18.28	6.31			
	13	2,940.0-41.0	889.4	1,516	557	2,073	74.66	230.29	1.709	12.01	55.57			

Abbreviations: ft = feet, g = grams, scc = standard cubic centimeters, scf/ton = standard cubic feet per ton, g/cc = grams per cubic centimeter, wt.% = weight percent, as-rec'd = as-received, DAF = dry, ash-free, USBM = U.S. Bureau of Mines (Diamond and Levine, 1981).

Table 3. Coal quality data for CZ Fee A No. 114 CBM well, sample 4 (2,679.0-2,681.0 ft).

ANALYSIS	As- Received (wt. %)	Moisture- Free (wt. %)	Moisture & Ash-Free (wt. %)
PROXIMATE ANALYSIS			
Moisture	13.88		
Ash	35.25	40.93	
Volatile Matter	26.02	30.21	51.15
Fixed Carbon	24.85	28.86	48.85
Total	100.00	100.00	100.00
HEATING VALUE (Btu/lb)	6,624	7,692	13,021
SULFUR	0.99	1.15	1.95
COAL RANKING DATA -- BASED ON PARR FORMULAS (ASTM D 388)			
Dry, Mm-free FC		52.00	
Dry, Mm-free VM		48.00	
Moist, Mm-free Btu		10,710	
Agglomerating Characteristics		Not Determined	
Coal Rank		Sub Bituminous	A

Abbreviations: ft = feet, wt.% = weight percent, Btu/lb = British thermal units per pound, FC = fixed carbon, VM = volatile matter, Mm = mineral matter, ASTM = American Society for Testing and Materials (ASTM, 2005).

Table 4. Coal quality data for CZ Fee A No. 114 CBM well, sample 7 (2,731.0-2,732.0 ft).

ANALYSIS	As- Received (wt. %)	Moisture- Free (wt. %)	Moisture & Ash-Free (wt. %)
PROXIMATE ANALYSIS			
Moisture	12.13		
Ash	47.41	53.95	
Volatile Matter	22.99	26.16	56.82
Fixed Carbon	17.47	19.88	43.18
Total	100.00	100.00	100.00
HEATING VALUE (Btu/lb)	4,899	5,575	12,108
SULFUR	0.56	0.64	1.38
COAL RANKING DATA -- BASED ON PARR FORMULAS (ASTM D 388)			
Dry, Mm-free FC		47.82	
Dry, Mm-free VM		52.18	
Moist, Mm-free Btu		10,046	
Agglomerating Characteristics		Not Determined	
Coal Rank		Sub Bituminous	B

Abbreviations: ft = feet, wt.% = weight percent, Btu/lb = British thermal units per pound, FC = fixed carbon, VM = volatile matter, Mm = mineral matter, ASTM = American Society for Testing and Materials (ASTM, 2005).

Table 5. Coal quality data for CZ Fee A No. 114 CBM well, sample 11 (2,938.0-2,939.0 ft).

ANALYSIS	As- Received (wt. %)	Moisture- Free (wt. %)	Moisture & Ash-Free (wt. %)
PROXIMATE ANALYSIS			
Moisture	18.65		
Ash	6.29	7.73	
Volatile Matter	33.21	40.82	44.24
Fixed Carbon	41.85	51.44	55.76
Total	100.00	100.00	100.00
HEATING VALUE (Btu/lb)	10,151	12,478	13,524
SULFUR	1.26	1.55	1.68
COAL RANKING DATA -- BASED ON PARR FORMULAS (ASTM D 388)			
	Dry, Mm-free FC (wt.%)	56.40	
	Dry, Mm-free VM (wt.%)	43.60	
	Moist, Mm-free Btu/lb	10,904	
	Agglomerating Characteristics	Not Determined	
		Sub Bituminous	
	Coal Rank	A	

Abbreviations: ft = feet, wt.% = weight percent, Btu/lb = British thermal units per pound, FC = fixed carbon, VM = volatile matter, Mm = mineral matter, ASTM = American Society for Testing and Materials (ASTM, 2005).

Table 6. Petrographic data for CZ Fee A No. 114 CBM well, sample 4 (2,679.0-2,681.0 ft).

Maceral Type	Counts	Maceral % with Mineral Matter	Maceral % without Mineral Matter
Detrovitrinite	344	34.57%	69.49%
Telovitrinite	78	7.84%	15.76%
Total Vitrinite		42.41%	85.25%
Sporinite	11	1.11%	2.22%
Cutinite	7	0.70%	1.41%
Resinite	11	1.11%	2.22%
Exsudanite (bitumen)		0.00%	0.00%
Total Liptinite		2.91%	5.86%
Detroinertinite	25	2.51%	5.05%
Fusinite	5	0.50%	1.01%
Semifusinite	7	0.70%	1.41%
Macrinite	6	0.60%	1.21%
Funginite	1	0.10%	0.20%
Total Inertinite		4.42%	8.89%
clay/other	500	50.25%	
quartz		0.00%	
carbonate		0.00%	
pyrite		0.00%	
Total Minerals		50.25%	
Total Sum	995	100.00%	100.00%

Table 7. Petrographic data for CZ Fee A No. 114 CBM well, sample 7 (2,731.0-2,732.0 ft).

Maceral Type	Counts	Maceral % with Mineral Matter	Maceral % without Mineral Matter
Detrovitrinite	330	33.92%	69.77%
Telovitrinite	75	7.71%	15.86%
Total Vitrinite		41.62%	85.62%
Sporinite	8	0.82%	1.69%
Cutinite	1	0.10%	0.21%
Resinite	42	4.32%	8.88%
Exsudanite (bitumen)	0	0.00%	0.00%
Total Liptinite		5.24%	10.78%
Detroinertinite	11	1.13%	2.33%
Fusinite	1	0.10%	0.21%
Semifusinite	1	0.10%	0.21%
Macrinite	4	0.41%	0.85%
Funginite	0	0.00%	0.00%
Total Inertinite		1.75%	3.59%
clay/other	500	51.39%	
quartz	0	0.00%	
carbonate	0	0.00%	
pyrite	0	0.00%	
Total Minerals		51.39%	
Total Sum	973	100.00%	100.00%

Table 8. Petrographic data for CZ Fee A No. 114 CBM well, sample 11 (2,938.0-2,939.0 ft).

Maceral Type	Counts	Maceral % with Mineral Matter	Maceral % without Mineral Matter
Detrovitrinite	251	46.14%	47.81%
Telovitrinite	78	14.34%	14.86%
Total Vitrinite		60.48%	62.67%
Sporinite	15	2.76%	2.86%
Cutinite	2	0.37%	0.38%
Resinite	4	0.74%	0.76%
Exsudanite (bitumen)	0	0.00%	0.00%
Total Liptinite		3.86%	4.00%
Detroinertinite	104	19.12%	19.81%
Fusinite	23	4.23%	4.38%
Semifusinite	33	6.07%	6.29%
Macrinite	15	2.76%	2.86%
Funginite	0	0.00%	0.00%
Total Inertinite		32.17%	33.33%
clay/other	17	3.13%	
quartz	2	0.37%	
carbonate	0	0.00%	
pyrite	0	0.00%	
Total Minerals		3.49%	
Total Sum	544	100.00%	100.00%

Table 9. Vitrinite reflectance data for CZ Fee A No. 114 CBM well, sample 4 (2,679.0-2,681.0 ft).

Readings					
0.26	0.28	0.28	0.29	0.30	0.31
0.33	0.34	0.34	0.34	0.35	0.35
0.37	0.38	0.38	0.38	0.38	0.38
0.40	0.41	0.41	0.42	0.42	0.42
0.44	0.45	0.45	0.47	0.67	0.68
0.32	0.32	0.32	0.33	0.33	0.33
0.35	0.35	0.35	0.35	0.36	0.36
0.38	0.38	0.39	0.39	0.39	0.40
0.42	0.43	0.43	0.43	0.43	0.43
Total Readings	Minimum Reflectance	Maximum Reflectance	Mean Reflectance	Standard Deviation	Coal Rank
54	0.26 %	0.68 %	0.38 %	0.075 %	Subbituminous C

Table 10. Vitrinite reflectance data for CZ Fee A No. 114 CBM well, sample 7 (2,731.0-2,732.0 ft).

Readings					
0.26	0.27	0.29	0.31	0.32	0.33
0.35	0.36	0.36	0.36	0.37	0.37
0.39	0.39	0.39	0.39	0.39	0.39
0.41	0.42	0.42	0.42	0.42	0.42
0.46	0.46	0.46	0.48	0.49	0.55
0.33	0.33	0.33	0.34	0.34	0.35
0.38	0.38	0.38	0.38	0.38	0.39
0.39	0.40	0.40	0.40	0.40	0.41
0.43	0.43	0.44	0.44	0.44	0.46
Total Readings	Minimum Reflectance	Maximum Reflectance	Mean Reflectance	Standard Deviation	Coal Rank
54	0.26 %	0.55 %	0.39 %	0.05 %	Subbituminous C

Table 11. Vitrinite reflectance data for CZ Fee A No. 114 CBM well, sample 11 (2,938.0-2,939.0 ft).

Readings					
0.26	0.27	0.28	0.28	0.29	0.29
0.30	0.31	0.31	0.31	0.31	0.32
0.33	0.33	0.33	0.34	0.34	0.34
0.36	0.37	0.37	0.37	0.38	0.38
0.43	0.45	0.47	0.50	0.30	0.30
0.29	0.29	0.29	0.29	0.33	0.33
0.32	0.32	0.33	0.33	0.36	0.36
0.35	0.35	0.35	0.36	0.41	0.41
0.39	0.39	0.40	0.40		
Total Readings	Minimum Reflectance	Maximum Reflectance	Mean Reflectance	Standard Deviation	Coal Rank
52	0.26 %	0.5 %	0.34 %	0.05 %	Lignite

Table 12. Methane adsorption isotherm analytical data (as-analyzed basis) for CZ Fee A No. 114 CBM well, sample 4 (2,679.0-2,681.0 ft). Abbreviations: g = grams; % = percent; °F = degrees Fahrenheit; °C = degrees Celsius; psi = pounds per square inch; MPa = Mega Pascal; scf/ton = standard cubic feet per ton; scc/gm = standard cubic centimeters per gram; V = volume; P = pressure.

Methane Adsorption Isotherm
Vintage Petroleum
Sample: 4
As-Analyzed Basis

Well: CZ Fee A No. 114
Depth: 2,679.0'-81.0'

Sample Weight = 131.36 g	Ash Content = 33.30 %
Particle Size = < 20 Mesh	Equilibrium Moisture Content = 18.55%
Temperature = 110.0°F (43.3°C)	

Methane Adsorption

<u>Pressure</u>		<u>Gas Content (Raw Basis)</u>	
(psi)	(MPa)	(scf/ton)	(scc/gm)
52	0.36	7.7	0.24
117	0.81	15.8	0.49
215	1.48	26.9	0.84
354	2.44	40.7	1.27
544	3.75	55.2	1.72
833	5.74	71.4	2.23
1,232	8.49	88.1	2.75
1,655	11.41	98.9	3.09
2,151	14.83	109.2	3.41

Langmuir Coefficients **$V = 164.4 * P / (P + 1,085.0)$**

<u>PL</u>		<u>VL (Raw Basis)</u>	
(psi)	(MPa)	(scf/ton)	(scc/gm)
1,085.0	7.48	164.4	5.1

Table 13. Methane adsorption isotherm analytical data (dry basis) for CZ Fee A No. 114 CBM well, sample 4 (2,679.0-2,681.0 ft). Abbreviations: g = grams; % = percent; °F = degrees Fahrenheit; °C = degrees Celsius; psi = pounds per square inch; MPa = Mega Pascal; scf/ton = standard cubic feet per ton; scc/gm = standard cubic centimeters per gram; V = volume; P = pressure.

Methane Adsorption Isotherm
Vintage Petroleum
Sample: 4
Dry Basis

Well: CZ Fee A No. 114
Depth: 2,679.0'-81.0'

Sample Weight = 131.36 g	Ash Content = 33.30 %
Particle Size = < 20 Mesh	Equilibrium Moisture Content = 18.55%
Temperature = 110.0°F (43.3°C)	

Methane Adsorption

<u>Pressure</u>		<u>Gas Content (Dry Basis)</u>	
(psi)	(MPa)	(scf/ton)	(scc/gm)
52	0.36	9.4	0.29
117	0.81	19.4	0.61
215	1.48	33.0	1.03
354	2.44	50.0	1.56
544	3.75	67.8	2.12
833	5.74	87.7	2.74
1,232	8.49	108.2	3.38
1,655	11.41	121.4	3.79
2,151	14.83	134.1	4.19

Langmuir Coefficients **$V = 201.9 * P / (P + 1,085.0)$**

<u>PL</u>		<u>VL (Dry Basis)</u>	
(psi)	(MPa)	(scf/ton)	(scc/gm)
1,085.0	7.48	201.9	6.3

Table 14. Methane adsorption isotherm analytical data (dry, ash-free basis) for CZ Fee A No. 114 CBM well, sample 4 (2,679.0-2,681.0 ft). Abbreviations: g = grams; % = percent; °F = degrees Fahrenheit; °C = degrees Celsius; psi = pounds per square inch; MPa = Mega Pascal; scf/ton = standard cubic feet per ton; scc/gm = standard cubic centimeters per gram; V = volume; P = pressure.

Methane Adsorption Isotherm
Vintage Petroleum
Sample: 4
Dry, Ash-Free Basis

Well: CZ Fee A No. 114
Depth: 2,679.0'-81.0'

Sample Weight = 131.36 g	Ash Content = 33.30 %
Particle Size = < 20 Mesh	Equilibrium Moisture Content = 18.55%
Temperature = 110.0°F (43.3°C)	

Methane Adsorption

<u>Pressure</u>		<u>Gas Content (Dry, Ash-Free Basis)</u>	
(psi)	(MPa)	(scf/ton)	(scc/gm)
52	0.36	15.9	0.50
117	0.81	32.8	1.02
215	1.48	55.8	1.74
354	2.44	84.6	2.64
544	3.75	114.7	3.58
833	5.74	148.3	4.63
1,232	8.49	183.0	5.71
1,655	11.41	205.3	6.41
2,151	14.83	226.8	7.08

Langmuir Coefficients **$V = 341.5 * P / (P + 1,085.0)$**

<u>PL</u>		<u>VL (Dry, Ash-Free Basis)</u>	
(psi)	(MPa)	(scf/ton)	(scc/gm)
1,085.0	7.48	341.5	10.6

Table 15. Methane adsorption isotherm analytical data (as-analyzed basis) for CZ Fee A No. 114 CBM well, sample 7 (2,731.0-2,732.0 ft). Abbreviations: g = grams; % = percent; °F = degrees Fahrenheit; °C = degrees Celsius; psi = pounds per square inch; MPa = Mega Pascal; scf/ton = standard cubic feet per ton; scc/gm = standard cubic centimeters per gram; V = volume; P = pressure.

Methane Adsorption Isotherm
Vintage Petroleum
Sample: 7
As-Analyzed Basis

Well: CZ Fee A No. 114
Depth: 2,731.0'-32.0'

Sample Weight = 134.03 g	Ash Content = 46.99 %
Particle Size = < 20 Mesh	Equilibrium Moisture Content = 16.20%
Temperature = 110.0°F (43.3°C)	

Methane Adsorption

<u>Pressure</u>		<u>Gas Content (Raw Basis)</u>	
(psi)	(MPa)	(scf/ton)	(scc/gm)
62	0.43	5.7	0.18
115	0.79	10.6	0.33
212	1.46	18.5	0.58
359	2.48	28.4	0.89
536	3.70	38.5	1.20
821	5.66	49.4	1.54
1,211	8.35	61.6	1.92
1,630	11.24	70.4	2.20
2,130	14.69	77.4	2.42

Langmuir Coefficients **$V = 122.0 * P / (P + 1,202.5)$**

<u>PL</u>		<u>VL (Raw Basis)</u>	
(psi)	(MPa)	(scf/ton)	(scc/gm)
1,202.5	8.29	122.0	3.8

Table 16. Methane adsorption isotherm analytical data (dry basis) for CZ Fee A No. 114 CBM well, sample 7 (2,731.0-2,732.0 ft). Abbreviations: g = grams; % = percent; °F = degrees Fahrenheit; °C = degrees Celsius; psi = pounds per square inch; MPa = Mega Pascal; scf/ton = standard cubic feet per ton; scc/gm = standard cubic centimeters per gram; V = volume; P = pressure.

Methane Adsorption Isotherm
Vintage Petroleum
Sample: 7
Dry Basis

Well: CZ Fee A No. 114
Depth: 2,731.0'-32.0'

Sample Weight = 134.03 g	Ash Content = 46.99 %
Particle Size = < 20 Mesh	Equilibrium Moisture Content = 16.20%
Temperature = 110.0°F (43.3°C)	

Methane Adsorption

<u>Pressure</u>		<u>Gas Content (Dry Basis)</u>	
(psi)	(MPa)	(scf/ton)	(scc/gm)
62	0.43	6.8	0.21
115	0.79	12.6	0.39
212	1.46	22.1	0.69
359	2.48	33.9	1.06
536	3.70	46.0	1.44
821	5.66	58.9	1.84
1,211	8.35	73.5	2.29
1,630	11.24	84.0	2.62
2,130	14.69	92.4	2.88

Langmuir Coefficients **$V = 145.6 * P / (P + 1,202.5)$**

<u>PL</u>		<u>VL (Dry Basis)</u>	
(psi)	(MPa)	(scf/ton)	(scc/gm)
1,202.5	8.29	145.6	4.5

Table 17. Methane adsorption isotherm analytical data (dry, ash-free basis) for CZ Fee A No. 114 CBM well, sample 7 (2,731.0-2,732.0 ft). Abbreviations: g = grams; % = percent; °F = degrees Fahrenheit; °C = degrees Celsius; psi = pounds per square inch; MPa = Mega Pascal; scf/ton = standard cubic feet per ton; scc/gm = standard cubic centimeters per gram; V = volume; P = pressure.

Methane Adsorption Isotherm
Vintage Petroleum
Sample: 7
Dry, Ash-Free Basis

Well: CZ Fee A No. 114
Depth: 2,731.0'-32.0'

Sample Weight = 134.03 g	Ash Content = 46.99 %
Particle Size = < 20 Mesh	Equilibrium Moisture Content = 16.20%
Temperature = 110.0°F (43.3°C)	

Methane Adsorption

<u>Pressure</u>		<u>Gas Content (Dry, Ash-Free Basis)</u>	
(psi)	(MPa)	(scf/ton)	(scc/gm)
62	0.43	15.5	0.48
115	0.79	28.7	0.90
212	1.46	50.3	1.57
359	2.48	77.2	2.41
536	3.70	104.7	3.27
821	5.66	134.1	4.19
1,211	8.35	167.3	5.22
1,630	11.24	191.2	5.97
2,130	14.69	210.3	6.56

Langmuir Coefficients **$V = 331.4 * P / (P + 1,202.5)$**

<u>PL</u>		<u>VL (Dry, Ash-Free Basis)</u>	
(psi)	(MPa)	(scf/ton)	(scc/gm)
1,202.5	8.29	331.4	10.3

Table 18. Methane adsorption isotherm analytical data (as-analyzed basis) for CZ Fee A No. 114 CBM well, sample 11 (2,938.0-2,939.0 ft). Abbreviations: g = grams; % = percent; °F = degrees Fahrenheit; °C = degrees Celsius; psi = pounds per square inch; MPa = Mega Pascal; scf/ton = standard cubic feet per ton; scc/gm = standard cubic centimeters per gram; V = volume; P = pressure.

Methane Adsorption Isotherm
Vintage Petroleum
Sample: 11
As-Analyzed Basis

Well: CZ Fee A No. 114
Depth: 2,938.0'-39.0'

Sample Weight = 87.03 g	Ash Content = 6.46 %
Particle Size = < 20 Mesh	Equilibrium Moisture Content = 23.42%
Temperature = 110.0°F (43.3°C)	

Methane Adsorption

<u>Pressure</u>		<u>Gas Content (Raw Basis)</u>	
(psi)	(MPa)	(scf/ton)	(scc/gm)
58	0.40	10.8	0.34
110	0.76	21.1	0.66
202	1.39	36.9	1.15
343	2.36	57.5	1.79
517	3.56	71.8	2.24
792	5.46	96.5	3.01
1,173	8.09	118.9	3.71
1,581	10.90	137.2	4.28
2,070	14.27	150.4	4.69

Langmuir Coefficients **$V = 231.9 * P / (P + 1,109.1)$**

<u>PL</u>		<u>VL (Raw Basis)</u>	
(psi)	(MPa)	(scf/ton)	(scc/gm)
1,109.1	7.65	231.9	7.2

Table 19. Methane adsorption isotherm analytical data (dry basis) for CZ Fee A No. 114 CBM well, sample 11 (2,938.0-2,939.0 ft). Abbreviations: g = grams; % = percent; °F = degrees Fahrenheit; °C = degrees Celsius; psi = pounds per square inch; MPa = Mega Pascal; scf/ton = standard cubic feet per ton; scc/gm = standard cubic centimeters per gram; V = volume; P = pressure.

Methane Adsorption Isotherm
Vintage Petroleum
Sample: 11
Dry Basis

Well: CZ Fee A No. 114
Depth: 2,938.0'-39.0'

Sample Weight = 87.03 g	Ash Content = 6.46 %
Particle Size = < 20 Mesh	Equilibrium Moisture Content = 23.42%
Temperature = 110.0°F (43.3°C)	

Methane Adsorption

<u>Pressure</u>		<u>Gas Content (Dry Basis)</u>	
(psi)	(MPa)	(scf/ton)	(scc/gm)
58	0.40	14.1	0.44
110	0.76	27.5	0.86
202	1.39	48.2	1.50
343	2.36	75.1	2.34
517	3.56	93.8	2.93
792	5.46	126.0	3.93
1,173	8.09	155.3	4.85
1,581	10.90	179.1	5.59
2,070	14.27	196.4	6.13

Langmuir Coefficients **$V = 302.8 * P / (P + 1,109.1)$**

<u>PL</u>		<u>VL (Dry Basis)</u>	
(psi)	(MPa)	(scf/ton)	(scc/gm)
1,109.1	7.65	302.8	9.4

Table 20. Methane adsorption isotherm analytical data (dry, ash-free basis) for CZ Fee A No. 114 CBM well, sample 11 (2,938.0-2,939.0 ft). Abbreviations: g = grams; % = percent; °F = degrees Fahrenheit; °C = degrees Celsius; psi = pounds per square inch; MPa = Mega Pascal; scf/ton = standard cubic feet per ton; scc/gm = standard cubic centimeters per gram; V = volume; P = pressure.

Methane Adsorption Isotherm
Vintage Petroleum
Sample: 11
Dry, Ash-Free Basis

Well: CZ Fee A No. 114
Depth: 2,938.0'-39.0'

Sample Weight = 87.03 g	Ash Content = 6.46 %
Particle Size = < 20 Mesh	Equilibrium Moisture Content = 23.42%
Temperature = 110.0°F (43.3°C)	

Methane Adsorption

<u>Pressure</u>		<u>Gas Content (Dry, Ash-Free Basis)</u>	
(psi)	(MPa)	(scf/ton)	(scc/gm)
58	0.40	15.4	0.48
110	0.76	30.0	0.94
202	1.39	52.6	1.64
343	2.36	82.0	2.56
517	3.56	102.4	3.20
792	5.46	137.6	4.30
1,173	8.09	169.6	5.29
1,581	10.90	195.6	6.11
2,070	14.27	214.5	6.70

Langmuir Coefficients **$V = 330.7 * P / (P + 1,109.1)$**

<u>PL</u>		<u>VL (Dry, Ash-Free Basis)</u>	
(psi)	(MPa)	(scf/ton)	(scc/gm)
1,109.1	7.65	330.7	10.3

Table 21. Produced water data for CZ Fee A No. 114 CBM well, February 2004. Abbreviations: TDS = total dissolved solids; mg/l = milligrams per liter; g/cm³ = grams per cubic centimeter; °F = degrees Fahrenheit; meq/l = milliequivalents per liter.

Summary

Sampling Date	25-Feb-04
Analysis Date	4-Mar-04
TDS (mg/l)	82,819.6
Density (g/cm ³)	1.061
Anion/Cation Ratio	1.00

Anions (75° F)	mg/l	meq/l
Chloride	50,100	1,413
Bicarbonate	226	3.70
Sulfate	44.8	0.93

pH at time of sampling	5.85
pH at time of analysis	5.85
pH used in calculations	5.85

Cations (75° F)	mg/l	meq/l
Sodium	29,133	1,267
Magnesium	171	14.1
Calcium	2,520	126
Barium	549	8.00
Iron	75.3	2.70
Manganese	0.96	0.03

Table 22. Produced water data for CZ Fee A No. 114 CBM well, March 2004. Abbreviations: TDS = total dissolved solids; mg/l = milligrams per liter; g/cm³ = grams per cubic centimeter; °F = degrees Fahrenheit; meq/l = milliequivalents per liter.

Summary

Sampling Date 25-Mar-04

Analysis Date 6-Apr-04

TDS (mg/l) 84,598.4

Density (g/cm³) 1.063

Anion/Cation Ratio 1.00

Anions (75° F)	mg/l	meq/l
Chloride	51,100	1,441
Bicarbonate	372	6.10
Sulfate	0.39	0.01

pH at time of sampling 6.58

pH at time of analysis 6.58

pH used in calculations 6.58

Cations (75° F)	mg/l	meq/l
Sodium	29,696	1,292
Magnesium	97.6	8.03
Calcium	2,800	140
Barium	521	7.59
Iron	10.9	0.39
Manganese	0.34	0.01

Table 23. Gas-in-place (GIP) calculations for CZ Fee A No. 114 CBM well.

Assumptions:

Drainage		160 Acres		Core #1				
Depth (ft)	C _{gi} (scf/ton)	ρ _c (g/cm ³)	f _a	f _m	A (acres)	h (ft)	GIP (Mcf)	
2,672	135.4	1.65	0.403	0.116	160	0.5	11,690	
2,672.5	135.4	1.35	0.155	0.116	160	0.5	14,481	
2,673	135.4	1.3	0.114	0.116	160	0.5	14,734	
2,673.5	135.4	1.25	0.073	0.116	160	0.5	14,926	
2,674	135.4	1.26	0.081	0.116	160	0.5	14,892	
2,674.5	135.4	1.27	0.089	0.116	160	0.5	14,856	
2,675	135.4	1.3	0.114	0.116	160	0.5	14,734	
2,675.5	135.4	1.27	0.089	0.116	160	0.5	14,856	
2,676	135.4	1.45	0.238	0.116	160	0.5	13,793	
2,679	135.4	1.7	0.444	0.116	160	0.5	11,012	
2,679.5	135.4	1.4	0.197	0.116	160	0.5	14,167	
2,680	135.4	1.33	0.139	0.116	160	0.5	14,589	
2,680.5	135.4	1.32	0.131	0.116	160	0.5	14,640	
2,681	135.4	1.41	0.205	0.116	160	0.5	14,097	
2,681.5	135.4	1.7	0.444	0.116	160	0.5	11,012	
Total core 1							208,479	
		Core #2						
Depth (ft)	C _{gi} (scf/ton)	ρ _c (g/cm ³)	f _a	f _m	A (acres)	h (ft)	GIP (Mcf)	
2,730	171.6	1.55	0.320	0.148	160	0.5	15,376	
2,730.5	171.6	1.57	0.337	0.148	160	0.5	15,092	
2,731	171.6	1.41	0.205	0.148	160	0.5	17,025	
2,731.5	171.6	1.29	0.106	0.148	160	0.5	17,958	
2,732	171.6	1.25	0.073	0.148	160	0.5	18,170	
2,732.5	171.6	1.3	0.114	0.148	160	0.5	17,897	
2,733	171.6	1.32	0.131	0.148	160	0.5	17,766	
2,733.5	171.6	1.45	0.238	0.148	160	0.5	16,615	
2,734	171.6	1.9	0.609	0.148	160	0.5	8,617	
Total core 2							144,515	
		Core #3						
Depth (ft)	C _{gi} (scf/ton)	ρ _c (g/cm ³)	f _a	f _m	A (acres)	h (ft)	GIP (Mcf)	
2,938	186.4	1.78	0.510	0.1723	160	0.5	14,462	
2,938.5	186.4	1.38	0.180	0.1723	160	0.5	18,112	
2,939	186.4	1.3	0.114	0.1723	160	0.5	18,800	
2,939.5	186.4	1.35	0.155	0.1723	160	0.5	18,395	
2,940	186.4	1.3	0.114	0.1723	160	0.5	18,800	
2,940.5	186.4	1.3	0.114	0.1723	160	0.5	18,800	
2,941	186.4	1.3	0.114	0.1723	160	0.5	18,800	
2,941.5	186.4	1.3	0.114	0.1723	160	0.5	18,800	
2,942	186.4	1.3	0.114	0.1723	160	0.5	18,800	
2,942.5	186.4	1.3	0.114	0.1723	160	0.5	18,800	
2,943	186.4	1.6	0.362	0.1723	160	0.5	15,116	
Total core 3							194,686	
GIP Total of all 3 seams							547,680	
							Mcf	

Explanation: Depth = top of 0.5 ft sample interval, C_{gi} = average measured desorbed gas content for entire cored interval (see Table 2), dry ash-free, ρ_c = bulk density, f_a = ash fraction of 0.5 ft sample interval (calculated from bulk density), f_m = moisture fraction of 0.5 ft interval, A = area, h = height, GIP = gas in place = A·h·[1.359·C_{gi}·ρ_c·(1-f_a-f_m)]. Abbreviations: scf/ton = standard cubic feet per ton; g/cm³ = grams per cubic centimeter; ft = feet; Mcf = thousand cubic feet

APPENDIX: Permission to publish coalbed methane analytical data from operator

"Troy Richard"
<trichard@hilcorp.com>

06/26/2007 08:42 AM

To "Paul C Hackley" <phackley@usgs.gov>

cc

Subject: RE: Release of Colgrade CZ "A" #114 cbm data
t

Mr. Hackley,

On May 9, 2007, I obtain approval from Hilcorp's Executive Vice President – Exploitation. You have Hilcorp's permission to publish the information as written.

Troy E. Richard, CPL
Senior Landman
Hilcorp Energy Company, General Partner
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