Chapter Three: Coalbed Gas in the Cherokee Basin

The first test in Kansas to assess coalbed gas potential in southeastern Kansas was from several wells drilled during the late 1980's in Wilson and Montgomery counties (Stoeckinger, 1989). Desorption analyses were conducted on the Mulky, Weir-Pittsburg, and Riverton coal beds and gas contents were determined to be more than 200, 220, and 190 scf/ton, respectively (Stoeckinger, 1989). Additional testing of coalbed gas potential continues with many independent oil and gas companies operating in eastern Kansas. Detailed desorption data collected by the Kansas Geological Survey from several wells in eastern Kansas will be released during late 2003 and into mid 2004. Currently the KGS Cooper CW #1 (11-T35S-R18E, Labette County, Kansas) is the only well with desorption data available through an open-file report.

3.2 Geochemical Composition

Conventional gas from both oilfields (associated gas) and gasfields (nonassociated gas) in eastern Kansas range in origin from thermogenic, to microbial carbon dioxide reduction, and microbial origins, based on crossplots of the δD, $\delta^{13}C$ and wetness of methane (Jenden et al., 1988; Figure 3.01). In cooperation with operators, two gas samples were recovered from Cherokee Group coal samples during desorption, and sent to an outside laboratory for isotopic analysis (Isotech Laboratories, Champaign, IL). These samples have similar intermediate δD vs. $\delta^{13}C$ composition, suggesting mixed thermogenic and microbial origins (Figure 3.01). The mixed origin of coal gases in eastern Kansas is also supported by the plot of wetness versus methane $\delta^{13}C$, where the coal gas samples plot below the thermogenic arrow and in the region of mixed microbial and thermogenic gases (Figure 3.01).

Pennsylvanian rocks are mature to marginally mature in the eastern part of Kansas where Cherokee Group coals have vitrinite reflectance values of 0.5 - 0.7% (Jenden et al., 1988). Considering degree of maturation and gas geochemistry, conventional and coal natural gases in eastern Kansas are a combination of indigenous dry microbial methane, and either indigenous or migrated early thermogenic methane. An additional source of indigenous thermogenic methane is the black shale that typically overlies each coal. Also, longer distance migration of thermogenic gases into Cherokee Group reservoirs in Kansas may have occured along the regional Mississippian-Pennsylvanian unconformity from the Arkoma basin in northeastern Oklahoma (Jenden et al., 1988).

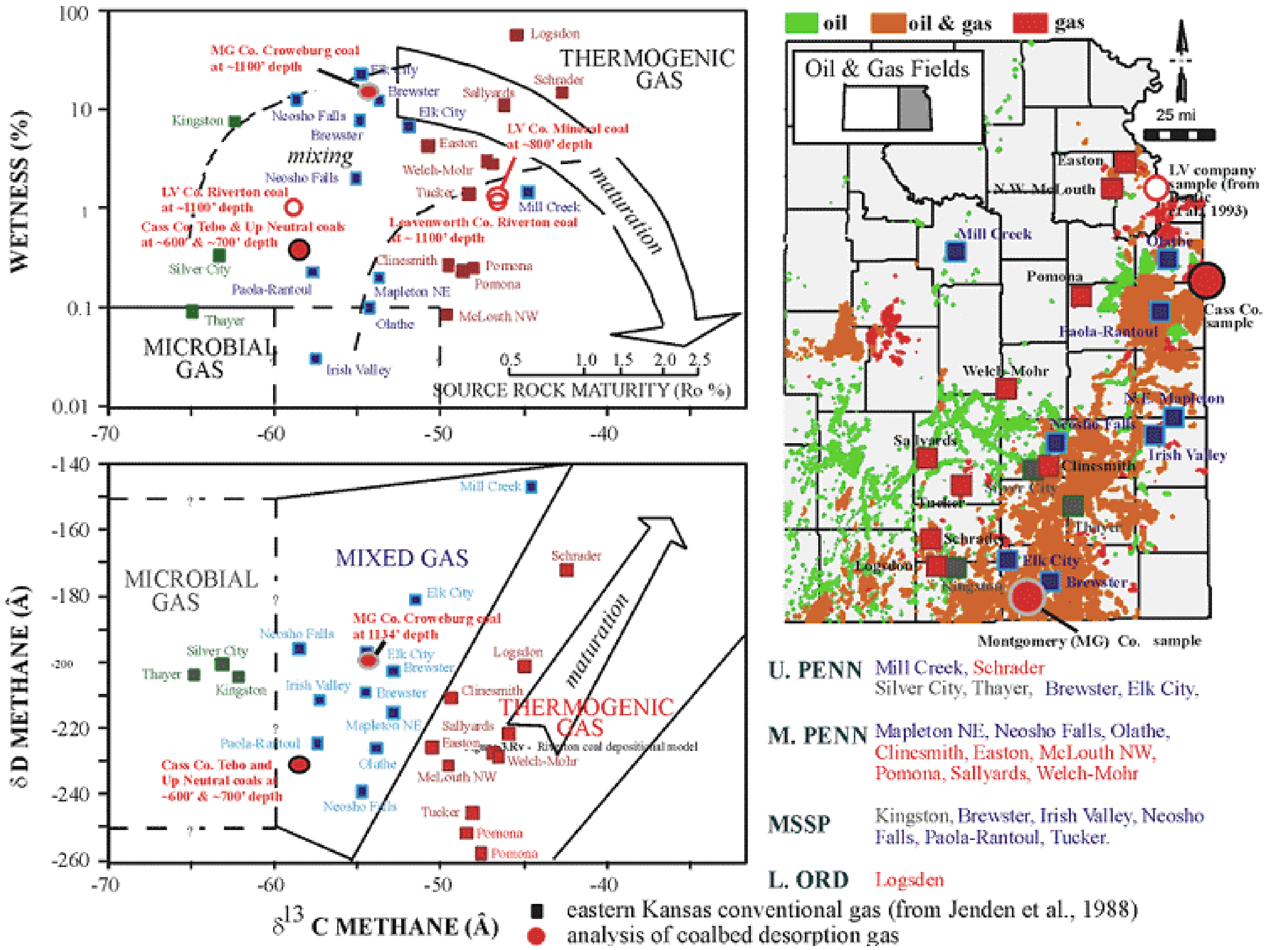


Figure 3.01 - Plots of conventional gases sampled compared to coal bed gases sampled in eastern Kansas (modified from Jenden et al., 1988).

3.3 Gas Content

Evaluation of coalbed gas potential for the Cherokee Group involves estimates of the gas content of coal samples. Gas content is based on desorption measurements of coal samples. Following catchment of cuttings or retrieval of core at the wellsite, desorption is continued under near stable conditions in the laboratory (see Chapter 1 for methodology). In the case of cuttings, lost gas is significantly greater than that of cores because the cuttings sample is pulverized before reaching the surface. However, cuttings reach the surface in a matter of seconds in air-drilled wells, whereas cores can take several minutes to reach the surface. The measured volume of desorbed gas for cuttings is commonly on the order of 25-30% lower than desorbed gas from cores (Nelson, 1999). In this study, a correction of +25% was used when calculating and comparing desorbed gas contents for cuttings samples.

Desorption analysis was conducted on core and cuttings samples from ten wells in the Cherokee basin (Figure 3.02). Desorption measurements for cores were calculated on an as-received basis (gas content calculated on whole dry weight of sample) and averaged for each coal and shale sampled and reported as standard cubic feet per ton (scf/ton; Figure 3.03). In the case of cuttings, the gas content of the coal was calculated assuming that admixed dark shales desorbed 3 scf/ton. This latter measure is consistent with the lower range of gas contents measured in dark shales from the Cherokee Group. Gas contents have a wide range from 3 scf/ton to over 300 scf/ton for coal. Black shale gas contents range from 3 scf/ton to 35 scf/ton. The highest quality coals, based on their gas content, are the Riverton, Weir-Pittsburg and Mulky (Figure 3.03). Putting all desorption values from Cherokee Group coals versus sample depth shows a slight trend of increasing gas content with depth (Figure 3.04).

Figures 3.05 - 3.08 depict the typical desorption characteristics versus time for coals from individual wells in Montgomery, Labette, Wilson and Neosho counties. In general, coals have higher gas contents in Montgomery County. This may be due to the coal deposits in Labette and Neosho counties, being up dip (i.e., shallower), the use of cuttings in Neosho and Wilson counties resulting in lower measured gas contents, or the limited sampling in Neosho, Labette and Wilson counties.

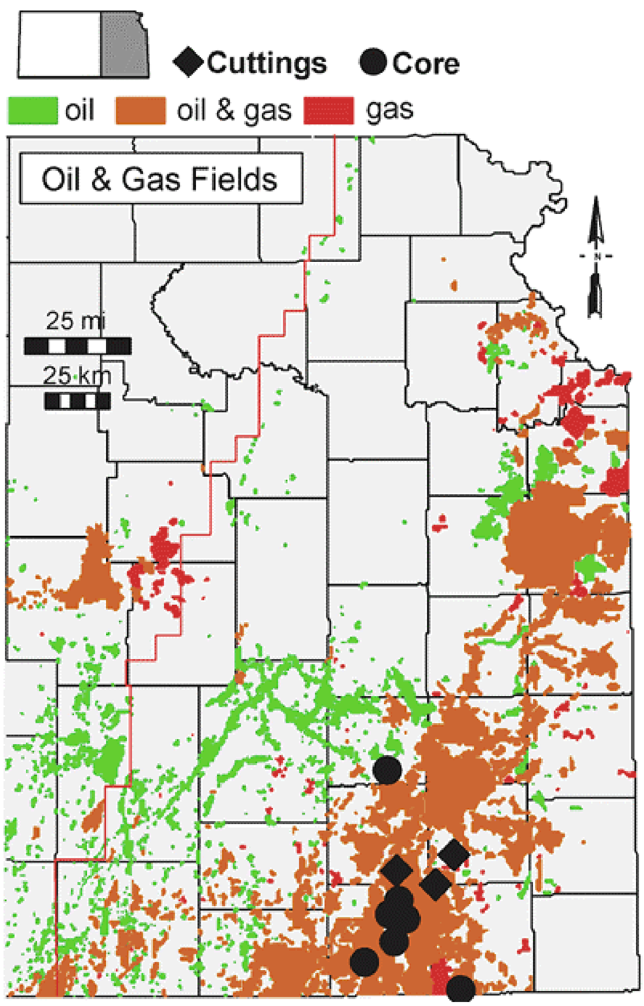


Figure 3.02 - Locations of cores and cuttings of Cherokee Group coal collected for desorption analysis.

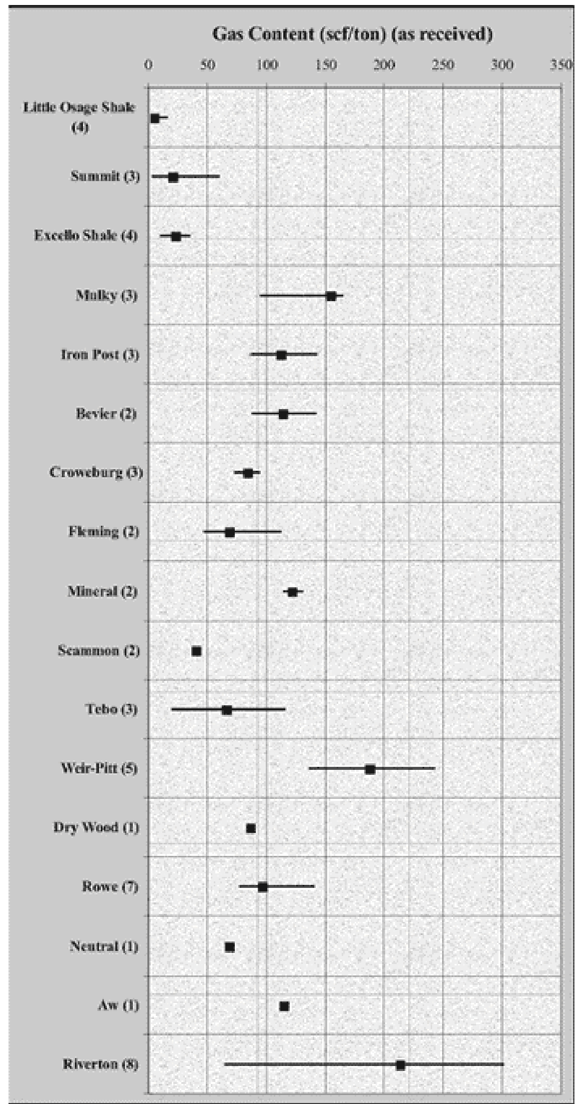


Figure 3.03 - Range and average gas content from the Cherokee basin on as received basis (see Figure 5.02 for sample locations and type). Number of samples in parentheses.

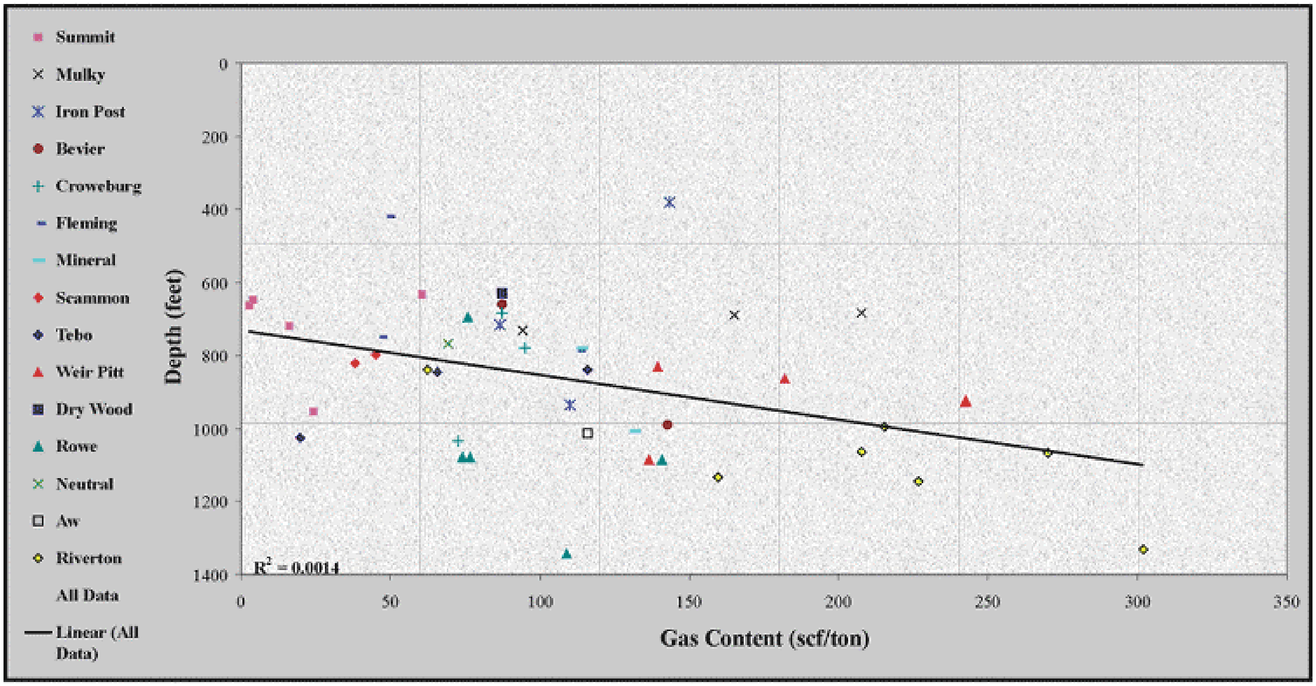


Figure 3.04 - Gas content conducted on an as received basis, plotted as a function of depth for coal samples from the Cherokee basin (see Figure 3.02 for sample location and type). Plot shows a relationship of increasing gas content with depth.

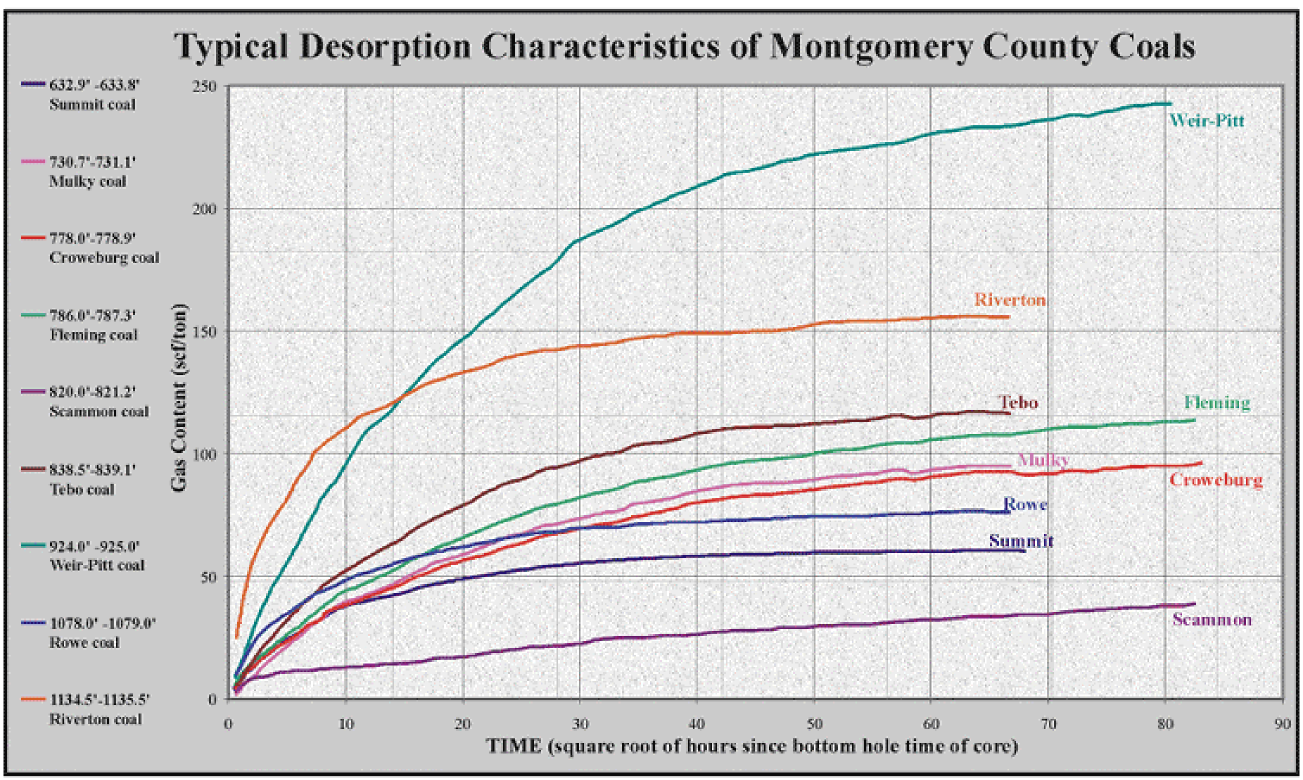


Figure 3.05 - Typical desorption characteristics for coals sampled from a single well in Montgomery County, Kansas

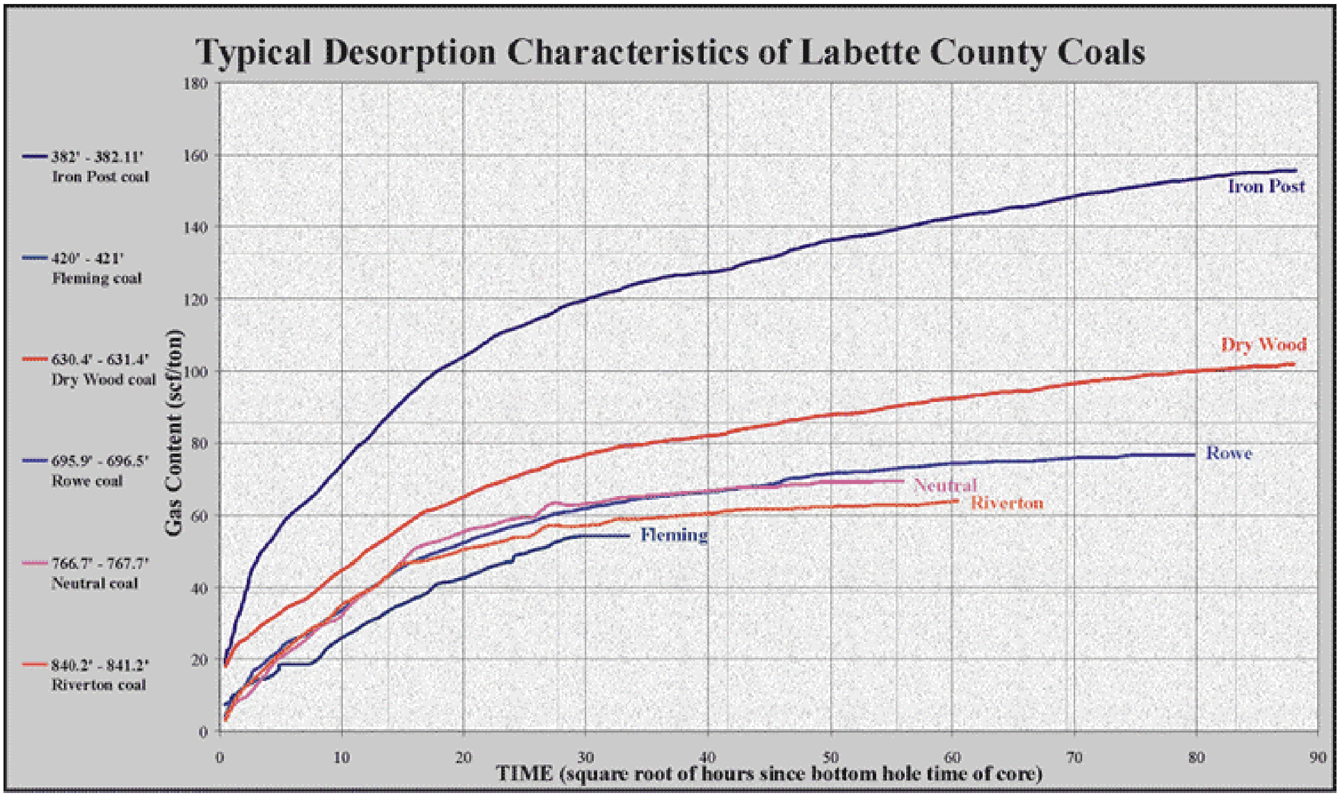


Figure 3.06 - Typical desorption characteristics for coals sampled in the Cooper CW#1 well, 11-T35S-R18E, Labette County, Kansas

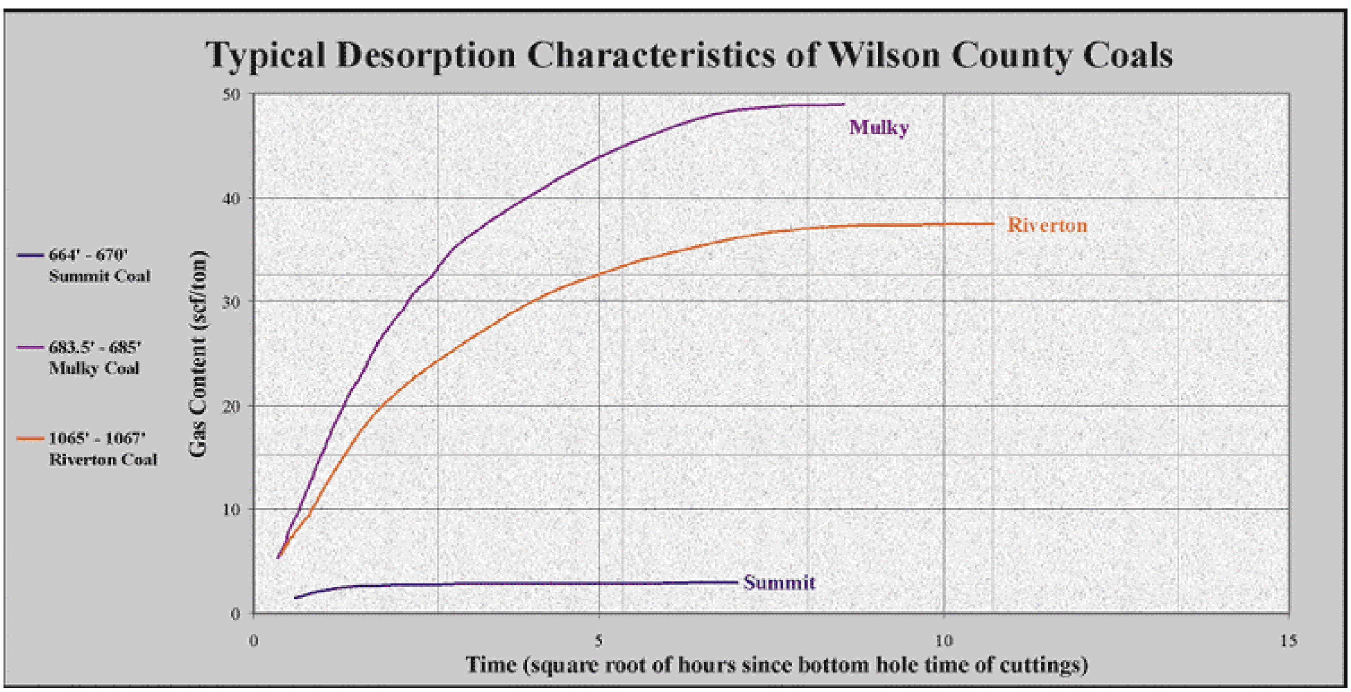


Figure 3.07 - Typical desorption characteristics for coal cuttings from a single well sampled in Wilson County, Kansas. A correction of +25% was used when calculating desorbed gas contents of cutting samples.

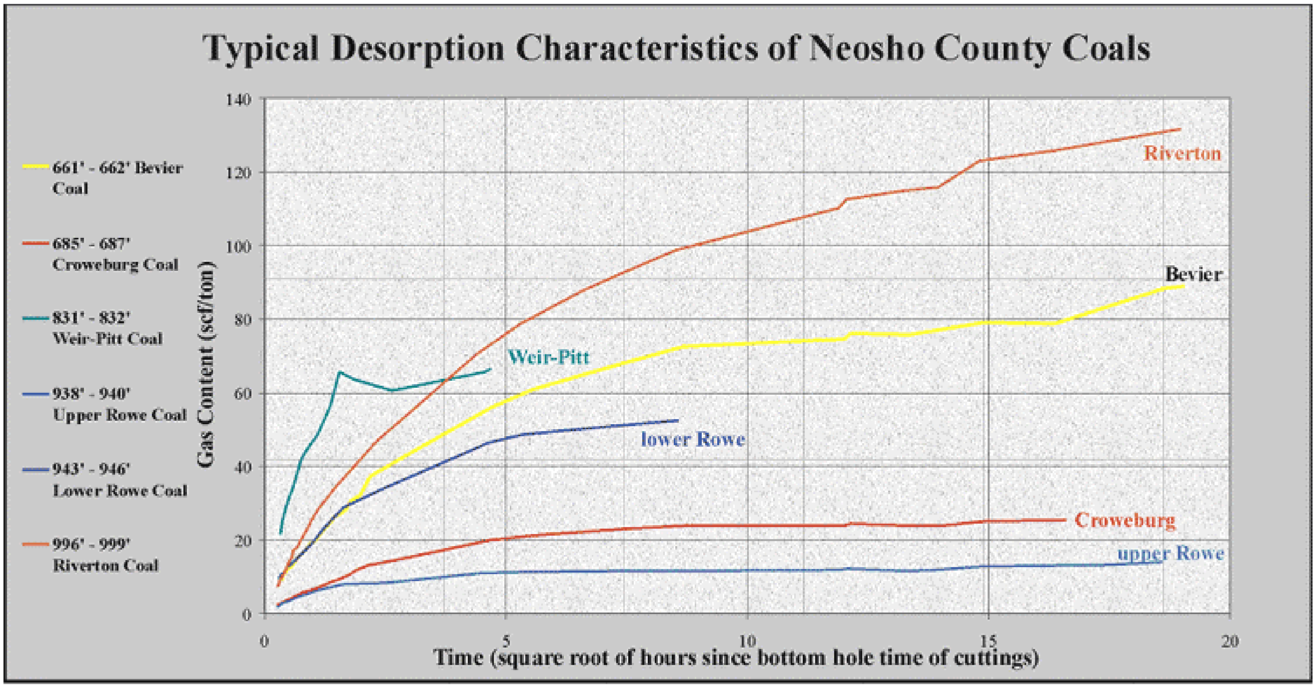


Figure 3.08 - Typical desorption characteristics for coal cuttings from a single well sampled in Neosho County, Kansas. A correction of +25% was used when calculating desorbed gas contents of cutting samples.

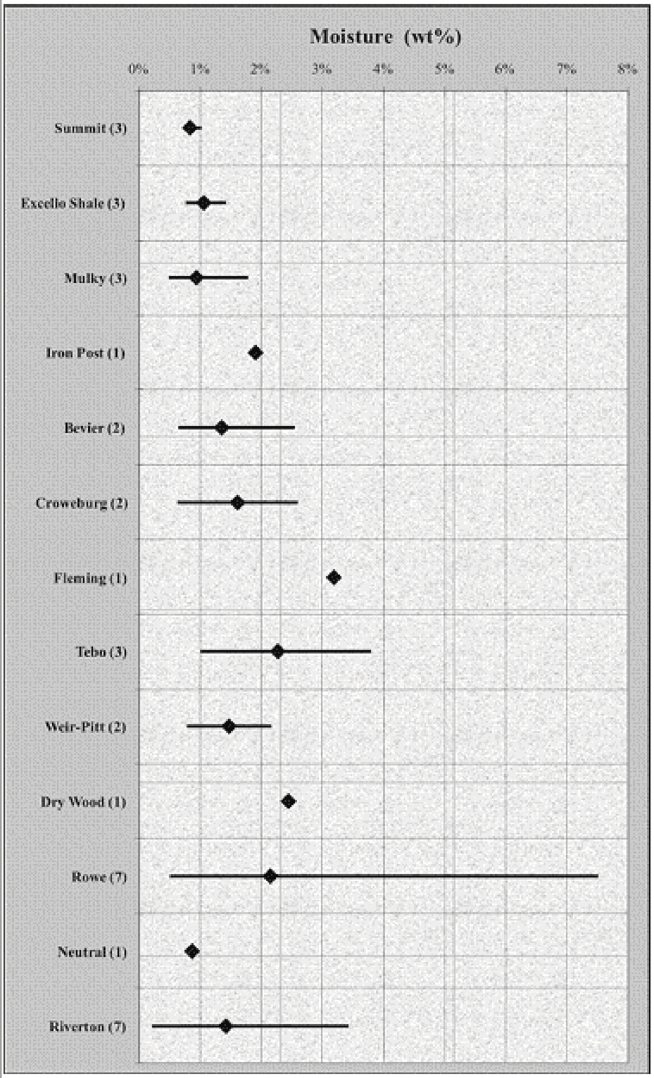
3.4 Proximate Analysis

The ASTM Book of Standards (2002) describes the process of proximal analysis on coals. Proximal analysis of coal samples used in this study was conducted at Luman's Lab (Chetopa, KS). To report analytical results including desorbed gas on a dry (moisture free) basis, moisture content must be determined (Figure 3.09). Testing for moisture entails calculating the weight loss of a sample when heated. Moisture ranges from 0.1 to 7.5 % for Cherokee Group coals (Figure 3.09).
Determining ash content involves burning the sample and weighing the residue. Ash is an important indicator of clastic input, likely derived from marine or fluvial deposition of clay, silt and sand during peat development. The moisture-free weight percentage of ash ranges from 7 to 90 % for Cherokee Group coals and carbonaceous shales (Figure 3.10). The Summit, Tebo, and Rowe coals have ash contents that are significantly higher than other coals. When comparing ash contents of subsurface samples with outcrop samples, ash content on average appears to be lower for outcrop samples (Allen 1925; Schoewe, 1959; Brady and Hatch, 1997; also see Figure 3.10). Lower ash contents of outcrop samples may be due to coal deposits being up dip and further away from a marine influence than samples down-dip.

Calculation of sulfur entails mixing part of the sample with Eschka mixture that dissolves with the sulfur in hot water and precipitates it as barium sulfate. The barium sulfate is then filtered, ashed, and weighed. Sulfur and ash content are traditional indicators of coal quality. Coals with a lower ash and sulfur content are generally regarded as higher quality. Coals with higher sulfur contents (> 2.5%) reflect a marine influence (Brady and Hatch, 1997). For Cherokee Group coals, the moisture-free weight percentage of sulfur ranges from 2 to 12.5 % (Figure 3.11). The Mulky, Iron Post, Dry Wood, Rowe, and Riverton coals have sulfur contents that suggest strong marine influence. When comparing sulfur contents of subsurface samples with outcrop samples, sulfur content on average appears to be slightly higher for the outcrop samples (Allen 1925; Schoewe, 1959; Brady and Hatch, 1997; Figure 3.11).

Once calculations for moisture and ash content are obtained, the calorific value (Btu/lb) can be determined on a moist, ash-free basis. Calculating the calorific value involves burning a sample in an adiabatic oxygen bomb calorimeter. Observation of temperature before and after combustion represents the calorific value. The calorific value provides a basis to determine coal rank. Most Cherokee Group coals on a moist, ash-free basis have calorific values greater or equal to 14,000 Btu/lb and are classified as high-volatile A bituminous (Figure 3.12). Cherokee coals with calorific values ranging between 13,000 and 14,000 are classified as high-volatile B bituminous (Figure 3.12). When comparing the calorific value of subsurface samples with outcrop samples, the calorific values for subsurface and outcrop samples are fairly consistent with each other (Allen 1925; Brady and Hatch, 1997; Schoewe, 1959).

Once moisture and ash content are obtained, desorption measurements can be calculated on a moisture ash-free basis (MAF) and averaged for each coal and shale sampled (Figure 3.13). Gas contents on a MAF basis range widely from 28 scf/ton to over 360 scf/ton for coals, and 64 scf/ton to 115 scf/ton for black shales. Gas content may be a reflection of several factors such as coal quality, rank, depth, association with adjacent source rock, and the amount and type of organic matter. As shown in Figure 3.14, there is an indication that gas contents generally increase with decreasing weight percentages of moisture-free ash. Figure 3.15 supports a relationship between increasing Btu/lb and gas content. Slight evidence for increasing gas content (MAF) with depth can be seen in the combined desorption data as well as in the data for individual wells (Figure. 3.16). Results presented in the previous graphs are from whole samples rather than multiple samples through each sampled coal. Individual coals may significantly vary laterally.



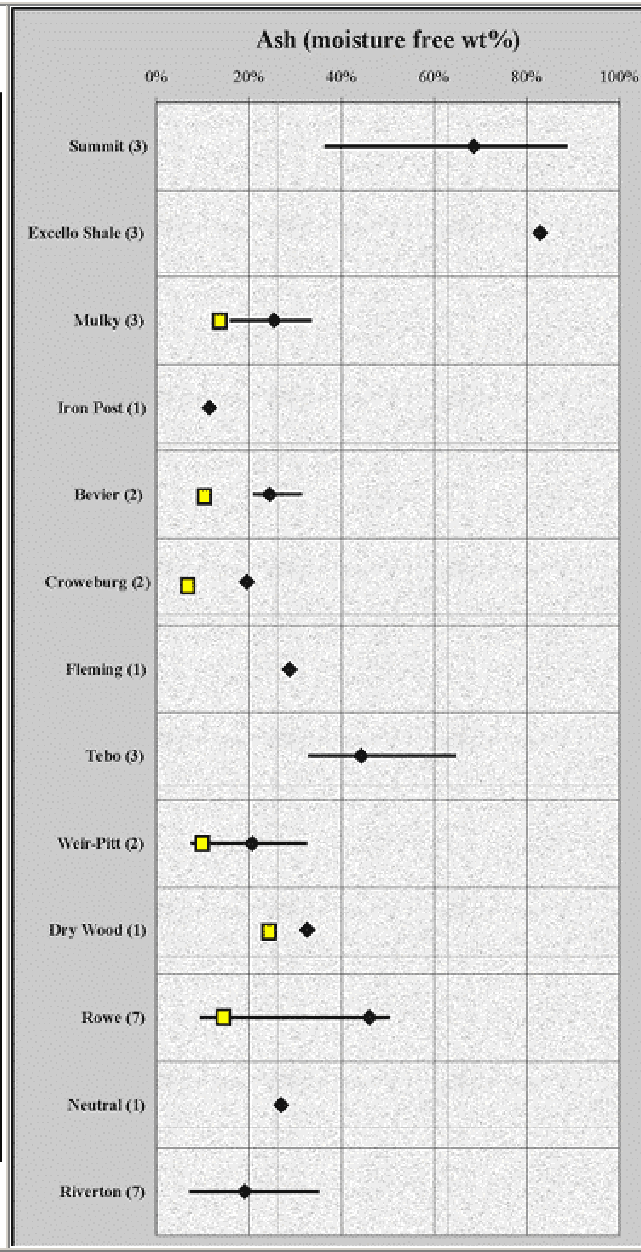
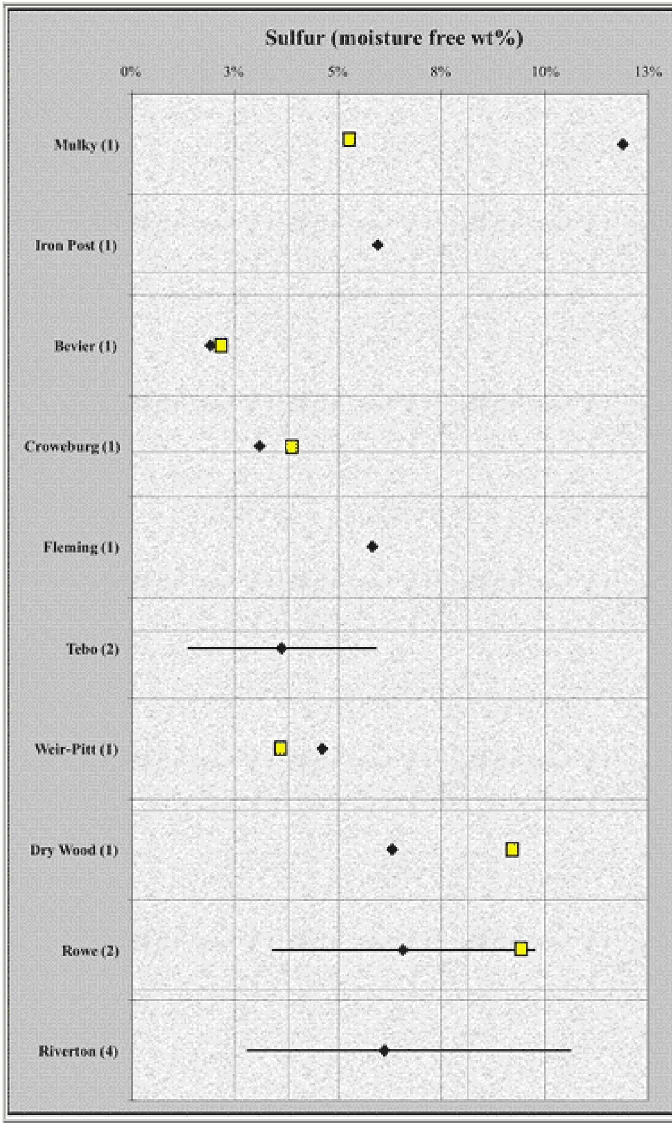


Figure 3.09 - Range and average moisture (weight percentage for coal samples from the Cherokee basin (see Figure 3.02 for sample locations and type). Number of samples indicated in parentheses.

Figure 3.10 - Range and average ash content on a moisture free basis for coal and shale samples from the Cherokee basin (see Figure 5.02 for sample locations and type). Samples are compared against the average ash content of coals along the outcrop belt (). Higher ash contents reflect a closer relationship with fluvial or marine processes. Number of samples indicated in parentheses.



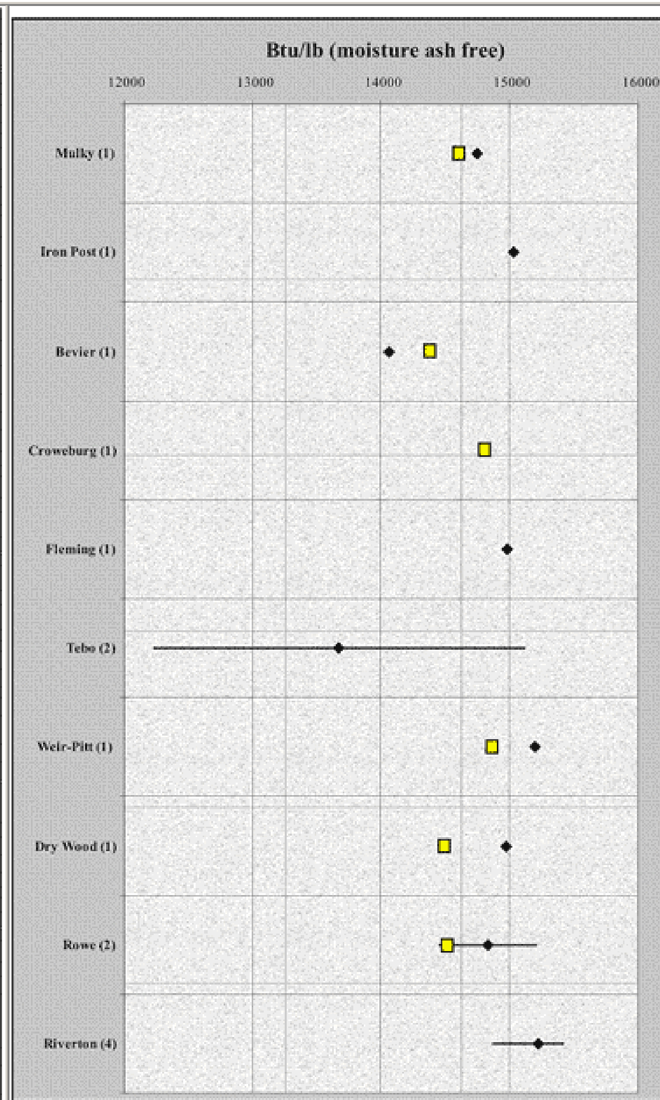


Figure 3.11 - Range and average sulfur content on a moisture free basis for coal and shale samples from the Cherokee basin (see Figure 5.02 for sample locations and type). Samples are compared against the average ash content of coals along the outcrop belt. Higher sulfur contents reflect a closer relationship with marine processes. Number of samples indicated in parentheses.

Figure 3.12 - Range and average calorific value (Btu/lb) on a moist, ash free basis. Most Cherokee Group coal have calorific values greater than 14,000 Btu/lb and would be classified as high-volatile A. Samples are compared against the average calorific values of coals along the outcrop belt. Number of samples indicated in parentheses.

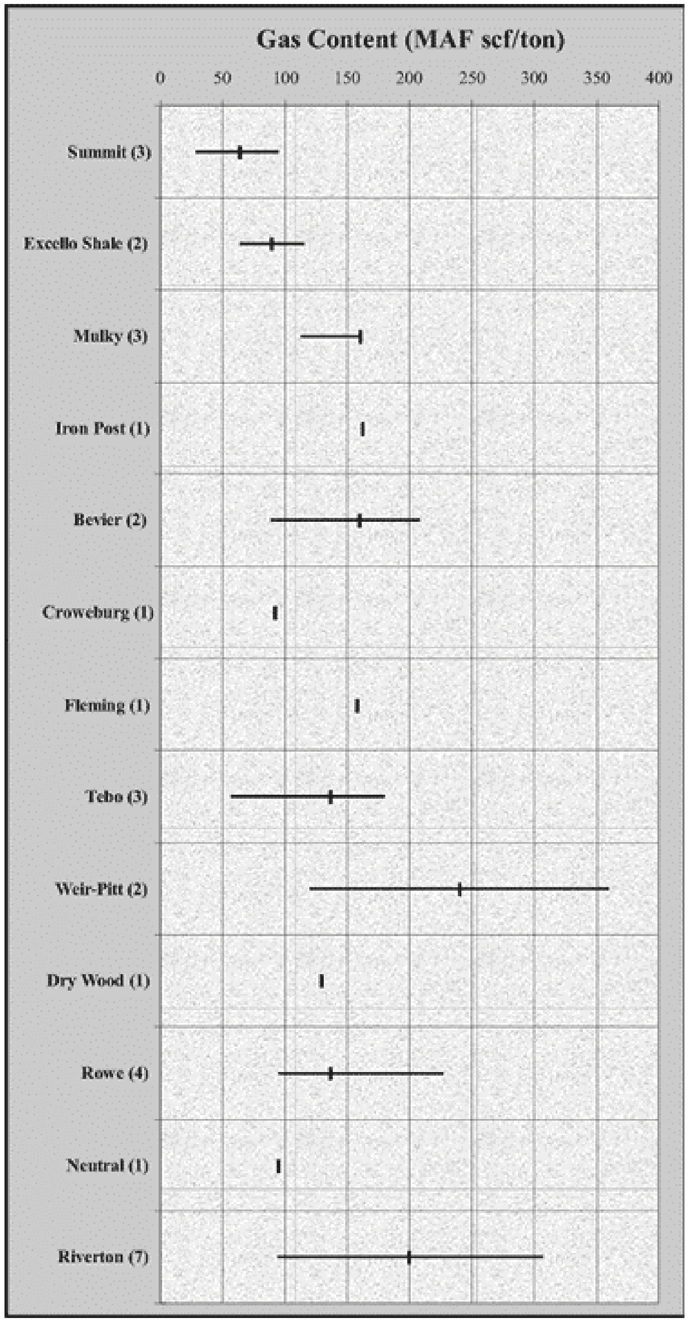


Figure 3.13 - Range and average gas content on a moisture ash free basis for coal and shale samples from the Cherokee basin (see Figure 3.02 for locations and type). Number of samples indicated in parentheses.

3.5 Discussion

Based on averaged desorbed gas content data from ten wells, estimates of original gas in place (OGIP) can be made for a portion of the Cherokee basin. Since the outcrop belt of the Cherokee Group follows a northeast trend throughout Cherokee and Crawford counties, all volumetric calculations include only coal contained within Chautauqua, Elk, Montgomery, Labette, Wilson, and Neosho counties. An estimate of coal mass for each individual coal must first be determined by using equation 1:

$$C_m = C_{A\text{-}F} * T/A\text{-}F \qquad (1)$$

where C_m is coal mass (short tons); $C_{A\text{-}F}$ is the volume of coal (acre-feet); and T/A-F is tons per acre-foot. In this study a value of 1800 tons per acre-foot for coal, and 2850 tons per acre-foot for shale was applied in the equation. Total coal mass (C_m) for an individual coal is estimated by determining the amount of acre-feet for coal greater than 1.5 feet (0.46 m). Estimates of OGIP are derived using equation 2:

$$OGIP = G_c * C_m \qquad (2)$$

where OGIP is original gas in place (scf); G_c is the average gas content (scf/ton), on an as received basis; and C_m (short tons) is the total coal mass. Using the above equation, volumetrics for twelve coals and two black shales found within the Fort Scott Limestone and Cherokee Group were determined (Table 3.1).

Unit	avg. scf/ton	acre-feet	Tons (short)	OGIP (bcf)
Little Osage Shale	6.4	13,097,227	37,327,097,378	239
Summit coal	22	875,520	1,575,935,694	35
Excello Shale	24	12,080,067	34,428,192,005	826
Mulky coal	156	511,071	919,928,556	144
Iron Post coal	113	1,195,535	2,151,963,324	243
Bevier coal	115	3,137,264	5,647,075,056	649
Croweburg coal	85	1,271,683	2,289,029,292	195
Fleming coal	70	878,086	1,580,553,918	111
Mineral coal	123	2,238,127	4,028,628,492	496
Scammon coal	42	1,087,171	1,956,907,044	82
Tebo coal	70	800,868	1,441,561,644	101
Weir-Pittsburg coal	190	3,028,844	5,451,919,740	1,036
Aw coal	116	3,832,218	6,897,992,742	800
Riverton coal	214	4,295,402	7,731,723,078	1,655
			Total OGIP	**6,612**

Table 3.1 – Volumetric calculations for the Fort Scott Limestone shales and Cherokee Group coals (avg. scf/ton is reported on an as received basis).

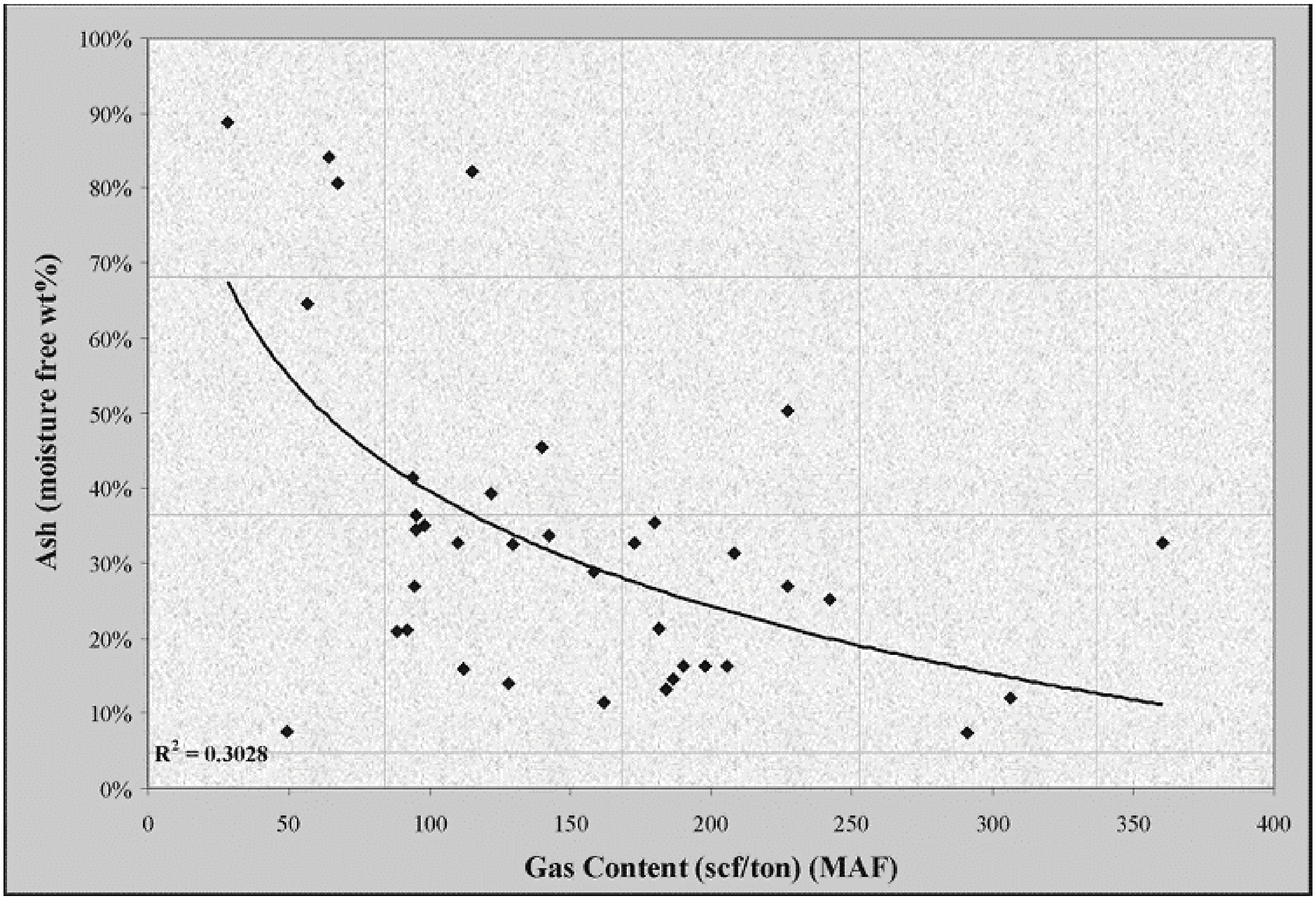


Figure 3.14 - Gas content conducted on an moisture ash free basis (MAF), plotted as a function of moisture free ash content. Plot shows a general relationship of increasing gas content (MAF) with decreasing ash content (MF).

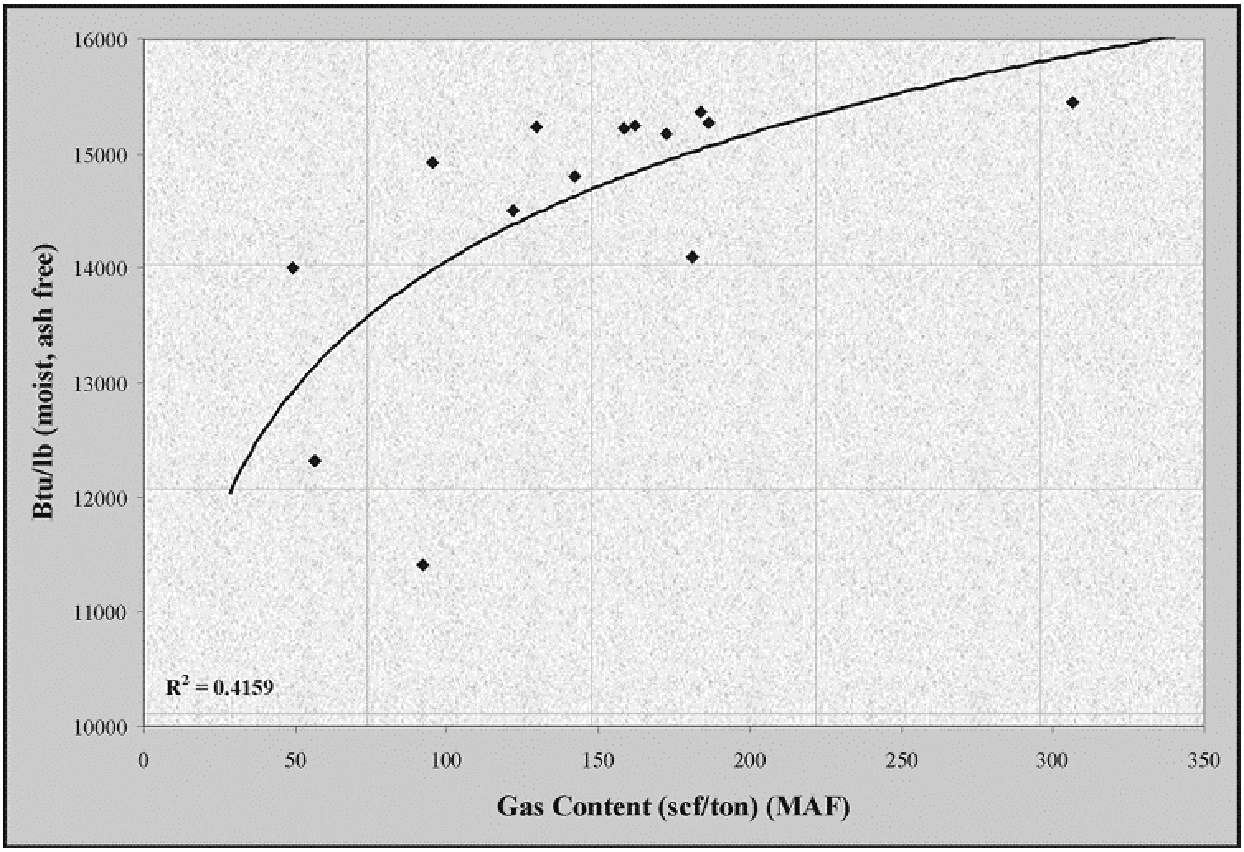


Figure 3.15 - Gas content conducted on an moist, ash free basis, plotted as a function of Btu/lb (moisture as free). Plot shows a general relationship of increasing gas content (MAF) with increasing Btu/lb (MAF).

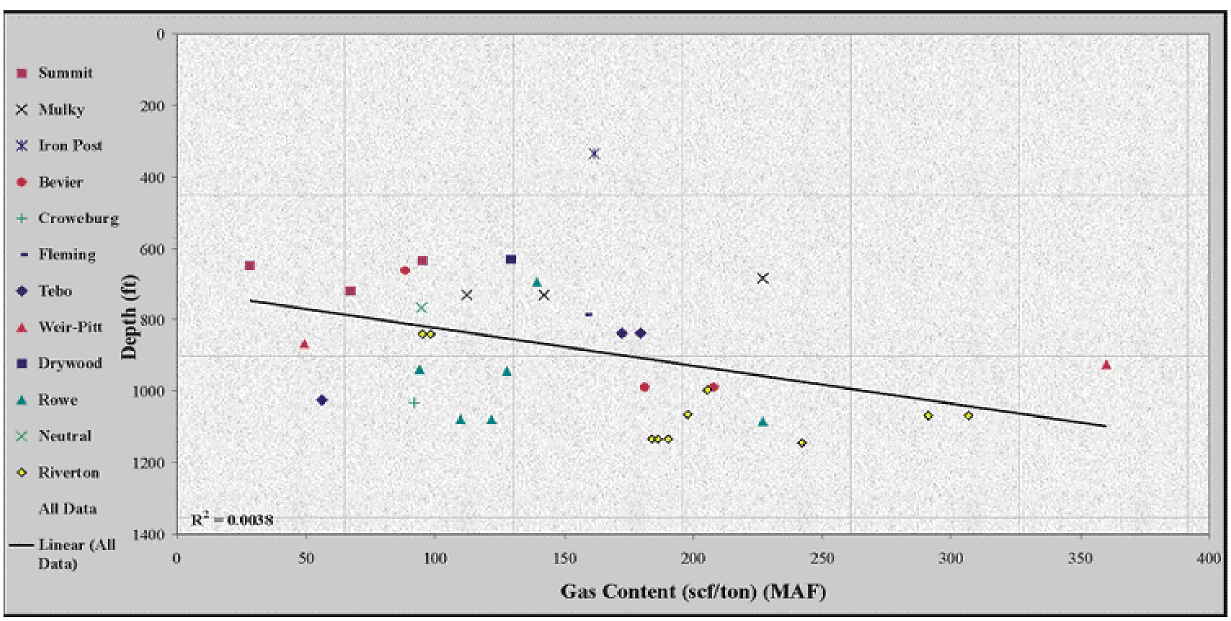


Figure 3.16 - Gas content conducted on a moisture ash free basis, plotted as a function of depth for coal samples from the Cherokee basin (see Figure 3.02 for sample location and type). Plot shows a relationship of increasing gas content with depth.

Values for total gas in place for individual coals range from 35 to 1,655 billion cubic feet (bcf). Exploration cutoffs for individual coal seams based on gas content (MAF) versus depth can be made using Figure 3.16. For example, when considering the Riverton coal as an exploration target, gas saturations less than 100 scf/ton (MAF) are found at depths shallower than 800 feet (244 m). If coal is thin (less than 1.5 ft; 0.5 m) it may have insufficient gas content to be a viable exploration target. Figure 3.17 indicates the ranges in gas in place for each coal over an area of one square mile (one section), assuming a constant thickness. Combined coal gas resource estimates for Chautauqua, Elk, Montgomery, Labette, Wilson, and Neosho counties area are more than 6,600 bcf. Several moderately gas-saturated coals such as the Neutral, Rowe and Dry Wood and miscellaneous informally known coals are not included in the above estimate.

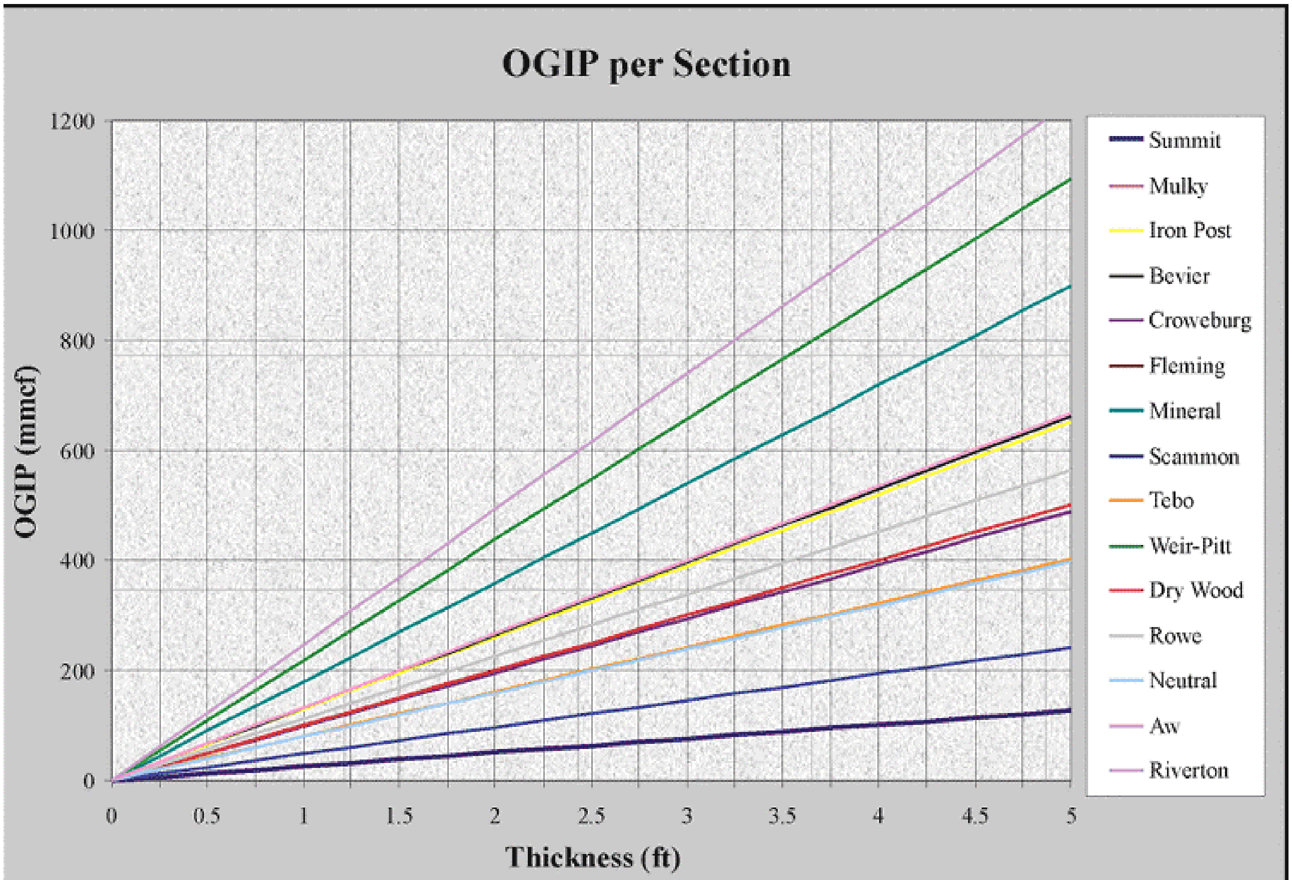


Figure 3.17 - Range of gas in place for each coal per section (one square mile) assuming a constant thickness.