# ANALYSIS OF CHEROKEE GROUP CUTTINGS SAMPLES FOR GAS CONTENT -- DART CHEROKEE BASIN OPERATING COMPANY
# #A2-26 TIMMONS et al.;
# NW NE NW sec. 26-T.29S.-R.14E.; WILSON COUNTY, KANSAS

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## SUMMARY

Cuttings samples from the Pennsylvanian Cherokee Group were collected from the Dart Cherokee Basin #A2-26 Timmons et al., NW NE NW 26-T.29S.-R.14E., Wilson County, KS. The samples calculate as having the following gas contents:

|  |  |
|---|---|
| • Little Osage Shale coal at 855' depth[1] | (35 scf/ton) |
| • Mineral coal at 999' depth[1] | (--- scf/ton) |
| • Riverton coal at 1162' depth[2] | (132 scf/ton) |

[1] no significant coal in sample

[2] assuming accompanying dark shales in sample desorb 3 scf/ton

## BACKGROUND

The Dart Cherokee Basin #A2-26 Timmons et al., NW NE NW 26-T.29S.-R.14E., Wilson County, KS, was selected for cuttings desorption tests in association with an on-going coalbed gas research project at the Kansas Geological Survey. The samples were gathered November 15, 2005 by personnel from Dart Cherokee Basin L.L.C., and soon turned over to LeaAnn Davidson of the Kansas Geological Survey. Samples were obtained during normal drilling of the well, with no cessation of drilling before zones of interest (i.e., coals and dark shales in the Cherokee Group) were penetrated.

The samples were canistered, with surface time and canistering times noted. These samples were collected in canisters that were supplied by Dart Cherokee Basin L.L.C. and the Kansas Geological Survey. Lag times for samples to reach the surface (important were determined by the wellsite geologist and driller.

The cuttings samples from the Pennsylvanian Cherokee Group were:

|  |  |
|---|---|
| • Little Osage Shale coal at 855' depth | (1086 grams) |
| • Mineral coal at 999' depth | (1481 grams) |
| • Riverton coal at 1162' depth | (560 grams) |

If correct wellsite procedures were followed, the cuttings were caught in kitchen strainers as they exited the air-stream pipe emptying to the mud pit. The samples were then washed in water while in the kitchen strainers to rid them of as much drilling mud as possible before the cuttings were placed in desorption canisters. Water with zephyrn chloride biocide was then added to the canisters, with a headspace of 1 to 2 inches being preserved at the top of the canister.

Desorption measurements at the Kansas Geological Survey in Lawrence, KS were continued at approximately 70 °F. Desorption measurements were periodically made until the canisters produced negligible gas with daily testing for at least two successive days.

## DESORPTION MEASUREMENTS

The equipment and method for measuring desorption gas is that prescribed by McLennan and others (1995). The volumetric displacement apparatus is a set of connected dispensing burettes, one of which measures the gas evolved from the desorption canister. The other burette compensates for the compression that occurs when the desorbed gas displaces the water in the measuring burette. This compensation is performed by adjusting the cylinders so that their water levels are identical, then figuring the amount of gas that evolved by reading the difference in water level using the volumetric scale on the side of the burette.

The desorption canisters were obtained from SSD, Inc. in Grand Junction, CO. These canisters are 12.5 inches high (32 cm), 3 1/2 inches (9 cm) in diameter, and enclose a volume of approximately 150 cubic inches (2450 $cm^3$). The desorbed gas that collected in the desorption canisters was periodically released into the volumetric displacement apparatus and measured as a function of time, temperature and atmospheric pressure.

The time and atmospheric pressure were measured in the field using a portable weather station (model BA928) marketed by Oregon Scientific (Tualatin, OR). The atmospheric pressure was displayed in millibars on this instrument, however, this measurement was not the actual barometric pressure, but rather an altitude-compensated barometric pressure automatically converted to a sea-level-equivalent pressure. In order to translate this measurement to actual atmospheric pressure, a regression correlation was determined over several weeks by comparing readings from the Oregon Scientific instrument to that from a pressure transducer in the Petrophysics Laboratory in the Kansas Geological Survey in Lawrence, Kansas (Figure 1). The regression equation shown graphically in Figure 1 was entered into a spreadsheet and was used to automatically convert the millibar measurement to barometric pressure in pounds per square inch (psi).

A spreadsheet program written by K.D. Newell (Kansas Geological Survey) was used to convert all gas volumes at standard temperature and pressure. Conversion of gas volumes to standard temperature and pressure was by application of the perfect-gas equation, obtainable from basic college chemistry texts:

$n = PV/RT$

where n is moles of gas, T is degrees Kelvin (i.e., absolute temperature), V is in liters, and R is the universal gas constant, which has a numerical value depending on the units in which it is measured (for example, in the metric system R = 0.0820 liter atmosphere per degree mole). The number of moles of gas (i.e., the value n) is constant in a volumetric conversion, therefore the conversion equation, derived from the ideal gas equation, is:

$(P_{stp}V_{stp})/(RT_{stp}) = (P_{rig}V_{rig})/(RT_{rig})$

Customarily, standard temperature and pressure for gas volumetric measurements in the oil industry are 60 °F and 14.7 psi (see Dake, 1978, p. 13), therefore $P_{stp}$, $V_{stp}$, and $T_{stp}$, respectively, are pressure, volume and temperature at standard temperature and pressure, where standard temperature is degrees Rankine (°R = 460 + °F). $P_{rig}$, $V_{rig}$, and $T_{rig}$, respectively, are ambient pressure, volume and temperature measurements taken at the rig site or in the desorption laboratory.

The universal gas constant R drops out as this equation is simplified and the determination of Vstp becomes:

$$V_{stp} = (T_{stp}/T_{rig})\ (P_{rig}/P_{stp})\ V_{rig}$$

The conversion calculations in the spreadsheet were carried out in the English metric system, as this is the customary measure system used in American coal and oil industry. V is therefore converted to cubic feet; P is psia; T is °R.

The desorbed gas was summed over the time period for which the coal samples evolved all of their gas.

Lost gas for samples (i.e., the gas lost from the sample from the time it was drilled, brought to the surface, to the time it was canistered) are normally determined using the direct method (Kissel and others, 1975; also see McLennan and others, 1995, p. 6.1-6.14) in which the cumulative gas evolved is plotted against the square root of elapsed time. Time zero is assumed to be the moment that the rock is cut and its cuttings circulated off bottom. Lost gas, however, had to be inferred for the samples collected from this well because no desorption apparatus was on site when those samples were collected. The procedure used to infer lost gas for these samples is outlined in the section below on Lost Gas.

## LITHOLOGIC ANALYSIS

Upon removal from the canisters, the cuttings were washed of drilling mud, and dried in air for at least a week. After drying, the cuttings were weighed and then dry sieved into 5 size fractions: >0.0930", >0.0661", >0.0460", >0.0331", and <0.0331". For large sample sizes, the cuttings were ran through a sample splitter and a lesser portion (approximately 75 grams) were sieved and weighed, and the derived size-fraction ratios were applied to the entire sample.

The size fractions were then inspected and sorted by hand under a dissecting microscope. Three major lithologic categories were differentiated: coal, dark shales (generally Munsell rock colors N3 (dark gray), N2 (grayish black), and N1 (black) on dry surface), and lighter-colored lithologies and/or dark and light-colored carbonates. The lighter-colored lithologies are considered to be incapable of generating significant amounts of gas. After sorting, and for every size class, each of these three lithologic categories was weighed and the proportion of coal dark shale and light-colored lithologies were determined for the entire cuttings sample based on the weight percentages.

## DATA PRESENTATION

Data and analyses accompanying this report are presented in the following order: 1) data tables for the desorption analyses, 2) lost-gas graphs, 3) “lithologic component sensitivity analyses” showing the interdependence of gas evolved from dark shale versus coal in each sample, 4) a summary component analysis for all samples showing relative reliability of the data from all the samples.

### *Data Tables of the Desorption Analyses (Table 1)*

These are the basic data used for lost-gas analysis and determination of total gas desorbed from the cuttings samples. Basic temperature, volume, and barometric measurements are listed at left. Farther to the right, these are converted to standard temperature, pressure and volumes. The volumes are cumulatively summed, and converted to scf/ton based on the total weight of coal and dark shale in the sample. At the right of the table, the time of the measurements are listed and converted to hours (and square root of hours) since the sample was drilled.

### *Lost-Gas Graphs (Figure 2, 3)*

Surface and canistering times for each sample were noted by the wellsite geologist. Bottom hole time was inferred by subtracting lag time from surface time, with lag time determined from a depth-lag-time plot for a nearby well (Figure 2). To infer an approximate lost-gas value for each sample, a correlation of the total gas desorbed from a sample after it had been canistered to its rate of lost gas was developed using desorption data accumulated for 42 cuttings samples obtained from air-drilled wells in the Cherokee basin in southeastern Kansas (Figure 3). The rate of lost gas used in this correlation was that amount of gas lost by the square root of 0.6 hours (the square root of 0.36 hours). By knowing the total gas given up by the sample after canistering (i.e., the total gas desorbed) a hypothetical rate of lost-gas could be calculated using the a regression line:

lost gas rate per square root of 0.36 hours = 0.1241 X (total gas desorbed in ccs) + 48.14

Once the hypothetical lost-gas rate was calculated, the lost gas could be calculated by taking the square root of the bottom-hole to canister time (derived from subtracting the lag time from the surface time), and multiplying it times the hypothetical lost-gas rate. Analysis of the lithology of the cuttings used in this correlation revealed no consistent relationship (see Figure 2), therefore further refinement of the relationship of the rate of lost gas to the total gas desorbed after canistering is not possible at this point in time.

### *"Lithologic Component Sensitivity Analyses" (Figures 4-6)*

The rapidity of penetration of an air-drilled well makes collection of pure lithologies from relatively thin-bedded strata rather difficult. Mixed lithologies are more the norm rather than the exception. Some of this mixing is due to cavings from strata farther up hole. The mixing may also be due to collection of two or more successively drilled lithologies in the kitchen sieve at the exit line, or differential lifting of relatively less-dense coal compared to other lithologies, all of which are more dense than coal.

The total gas evolved from the sample is due to gas being desorbed from both the coal and dark shale. Both lithologies are capable of generating gas, albeit the coal will be richer in gas than the dark-colored shale. Even though dark-colored shale is less rich in sorbed gas than coal, if a sample has a large proportion of dark, organic-rich shale and only a minor amount of coal, the total volume of gas evolved from the dark-shale component may be considerable. The lighter-colored lithologies are considered to be incapable of generating significant amounts of gas.

The total amount of gas evolved from a cuttings sample can be expressed by the following equation:

$$\text{Total gas (cm}^3\text{)} = [\text{weight}_{\text{coal}} \text{ (grams) X gas content}_{\text{coal}} \text{ (cm}^3\text{/gram)}] + [\text{weight}_{\text{dark shale}} \text{ (grams) X gas content}_{\text{dark shale}} \text{ (cm}^3\text{/gram)}]$$

A unique solution for gas content$_{\text{coal}}$ in this equation is not possible because gas content$_{\text{dark shale}}$ is not known exactly. An answer can only be expressed as a linear solution to the above equation. The richer in gas the dark shales are, the poorer in gas the admixed coal has to be, and visa versa. If there is little dark shale in a sample, a relatively well constrained answer for gas content$_{\text{coal}}$ can be obtained. Conversely, if considerable dark shale is in a sample, the gas content of a coal will be hard to precisely determine.

The lithologic-component-sensitivity-analysis diagram therefore expresses the bivariant nature inherent in the determination of gas content in mixed cuttings. The gas content of dark shales in Kansas can vary greatly. Proprietary desorption analyses of dark shales in cores from southeastern Kansas have registered as much as 50 scf/ton, but can be as low as 2-4 scf/ton.

A value of 3 scf/ton for average dark shale is based on the assay of the gas content of cores of dark shales in nearby wells. However, high-gamma-ray shales (such as the Excello Shale), also colloquially known as "hot shales", typically have more organic matter and associated gas content than dark shales with no excessive gamma-ray level. Determination of gas content for a coal associated with a "hot" shale therefore carries more uncertainty than if the coal were associated with a shale without a high gamma-ray value.

In general, shale gas content does not have to be very much greater that 10 scf/ton before the associated coal starts to have a gas content less than that of the dark shale. In all the lithologic-component-sensitivity-analysis diagrams, a “break-even” point is therefore noted where the gas content of the coal is equal to that of the dark shale. This “break-even” point corresponds to the minimum gas content assignable to the coal and maximum gas content assignable to the dark shale. It can also be thought of the scf/ton gas content of the cuttings sample minus the weight of any of the lighter-colored lithologies, which are assumed to have no inherent gas content. Conversely though, to assume that all the gas evolved from a cuttings sample is derived solely from the coal would result in an erroneously high gas content for the coal.

*Summary Component Analysis for all Samples (Figure 7)*
This diagram is a summary of the individual "lithologic component sensitivity analyses" for each sample, all set at a common scale. The steeper the angle of the line for a sample, the more uncertainty is attached to the results (i.e., *gas content*$_{coal}$) for that sample. If the coal content is miniscule (i.e., < approximately 5%), the results are a better reflection of the *gas content*$_{dark\ shale}$.

## RESULTS and DISCUSSION

Samples with less that 1% coal and/or less than 5% dark shale are considered to have invalid results due to insufficient quantities of gas-generating lithologies. The best constrained data are that associated with the Riveton coal at 1162' depth'. The gas contentof the Mineral coal is difficult to assess because its sample contains so little coal.

## REFERENCES

Dake, L.P., 1978, Fundamentals of Reservoir Engineering, Elsevier Scientific Publishing, New York, NY, 443 p.

Kissel, F.N., McCulloch, C.M., and Elder, C.H., 1975, The direct method of determining methane content of coals for ventilation design: U.S. Bureau of Mines, Report of Investigations, RI7767.

McLennan, J.D., Schafer, P.S., and Pratt, T.J., 1995, A guide to determining coalbed gas content: Gas Research Institute, Chicago, IL, Reference No. GRI-94/0396, 180 p.

## FIGURES and TABLES

FIGURE 1. Correlation of field barometer to Petrophysics Lab pressure transducer.

TABLE 1. Desorption measurements for samples.

FIGURE 2. Lag time determination for samples
FIGURE 3. Correlation of the rate of lost gas to the total gas desorbed after canistering.

FIGURE 4. Sensitivity analysis for Little Osage Shale coal at 855' depth.
FIGURE 5. Sensitivity analysis for Mineral coal at 999' depth.
FIGURE 6. Sensitivity analysis for Riverton coal at 1162' depth.

FIGURE 7. Lithologic component sensitivity analyses for all samples.

Correlation of Field Barometer to KGS Petrophysics Lab Barometer

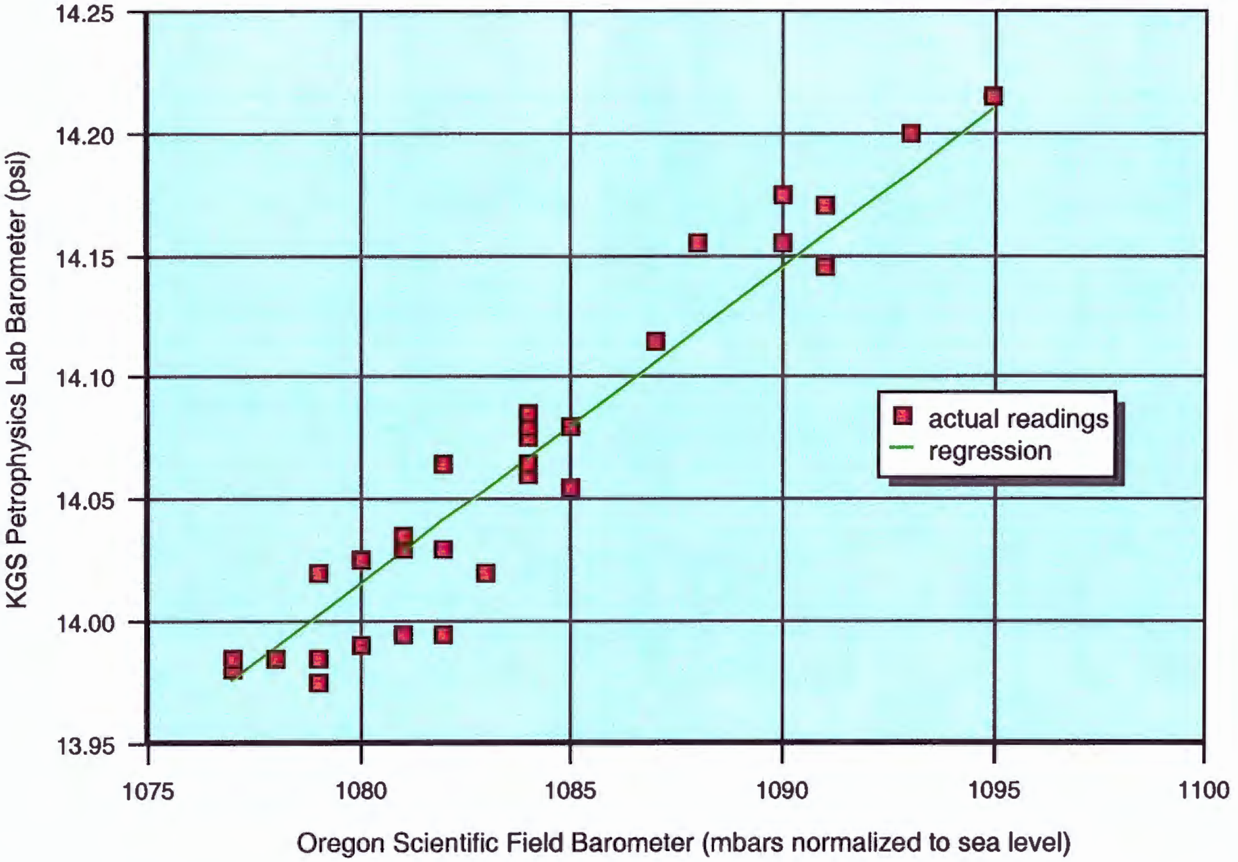


FIGURE 1.

TABLE 1 -- Desorption data for Dart Timmons et al. #A2-26 well (NW NE NW 26-T.29S.-R.14E.), Wilson Co., KS

SAMPLE: 855' to 862', Little Osage Shale, in canister MER FE

| | lbs. | grams |
|---|---|---|
| dry sample weight: | 0.5427 | 246.17 |

NOTE: los gas is estimated by time interval between at surface and canister times, and total gas evolved

| est. lost gas (cc) = | TIME 0F: | | | elapsed time (off bottom to canistering) |
|---|---|---|---|---|
| 24 | off bottom | at surface | in canister | 5.7 minutes |
| | 11/15/05 12:17 | 11/15/05 12:19 | 11/15/05 12:23 | 0.094 hours |
| | | | | 0.306865877 SQRT (hrs) |

| RIG/LAB MEASUREMENTS | | | CONVERSION OF RIG/LAB MEASUREMENTS TO STP (@60 deg F; 14.7 psi) | | | | | CUMULATIVE VOLUMES | | SCF/TON | SCF/TON | | TIME SINCE | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| measured cc | measured T (F) | measured P | cubic ft | absolute T (R) | psia | cubic ft (@STP) | cc (@STP) | cubic ft (@STP) | cc (@STP) | without lost gas | with lost gas | TIME OF MEASURE | off bottom | in canister | SQRT hrs. (since off bottom) |
| 134 | 68 | 1094 | 0.0047 | 528 | 14.200 | 0.004501854 | 127.48 | 0.004501854 | 127.48 | 16.59 | 19.71 | 11/18/05 10:46 | 70:28:39 | 70:23:00 | 8.395087849 |
| 104 | 68 | 1084 | 0.0037 | 528 | 14.070 | 0.003462039 | 98.03 | 0.007963893 | 225.51 | 29.35 | 32.47 | 11/21/05 13:53 | 145:35:39 | 145:30:00 | 12.06624078 |
| 18 | 68 | 1062 | 0.0006 | 528 | 13.784 | 0.000587038 | 16.62 | 0.008550931 | 242.13 | 31.51 | 34.64 | 11/28/05 15:09 | 314:51:39 | 314:46:00 | 17.74431834 |
| -31 | 68 | 1087 | -0.001 | 528 | 14.109 | -0.00103481 | -29.30 | 0.007516121 | 212.83 | 27.70 | 30.82 | 12/5/05 15:11 | 482:53:39 | 482:48:00 | 21.97485305 |
| -15 | 68 | 1086 | -5E-04 | 528 | 14.096 | -0.00050025 | -14.17 | 0.007015867 | 198.67 | 25.85 | 28.98 | 12/12/05 16:16 | 651:58:39 | 651:53:00 | 25.53385008 |

Sample air dried for approximately one week

SAMPLE: 999' to 1001', Mineral coal, in SSD canister DNA

| | lbs. | grams |
|---|---|---|
| dry sample weight: | 0.5427 | 246.17 |

NOTE: los gas is estimated by time interval between at surface and canister times, and total gas evolved

| est. lost gas (cc) = | TIME 0F: | | | elapsed time (off bottom to canistering) |
|---|---|---|---|---|
| 21 | off bottom | at surface | in canister | 5.9 minutes |
| | 11/15/05 13:42 | 11/15/05 13:44 | 11/15/05 13:48 | 0.099 hours |
| | | | | 0.314466038 SQRT (hrs) |

| RIG/LAB MEASUREMENTS | | | CONVERSION OF RIG/LAB MEASUREMENTS TO STP (@60 deg F; 14.7 psi) | | | | | CUMULATIVE VOLUMES | | SCF/TON | SCF/TON | | TIME SINCE | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| measured cc | measured T (F) | measured P | cubic ft | absolute T (R) | psia | cubic ft (@STP) | cc (@STP) | cubic ft (@STP) | cc (@STP) | without lost gas | with lost gas | TIME OF MEASURE | off bottom | in canister | SQRT hrs. (since off bottom) |
| 115 | 68 | 1094 | 0.0041 | 528 | 14.200 | 0.003863531 | 109.40 | 0.003863531 | 109.40 | 14.24 | 18.97 | 11/18/05 10:48 | 69:05:56 | 69:00:00 | 8.312574143 |
| 20 | 68 | 1084 | 0.0007 | 528 | 14.070 | 0.000665777 | 18.85 | 0.004529308 | 128.26 | 16.69 | 19.42 | 11/21/05 13:56 | 144:13:56 | 144:08:00 | 12.00967203 |
| 28 | 68 | 1062 | 0.001 | 528 | 13.784 | 0.00091317 | 25.86 | 0.005442478 | 154.11 | 20.08 | 22.79 | 11/28/05 15:10 | 313:27:56 | 313:22:00 | 17.7049585 |
| -18 | 68 | 1087 | -6E-04 | 528 | 14.109 | -0.00060086 | -17.01 | 0.004841621 | 137.10 | 17.84 | 20.58 | 12/5/05 15:12 | 481:29:56 | 481:24:00 | 21.94308294 |
| -5 | 68 | 1086 | -2E-04 | 528 | 14.096 | -0.00016675 | -4.72 | 0.00467487 | 132.38 | 17.23 | 19.96 | 12/12/05 16:17 | 650:34:56 | 650:29:00 | 25.50651333 |

Sample air dried for approximately one week

SAMPLE: 1162' to 1164', Riverton coal, in SSD canister DCB E

| | lbs. | grams |
|---|---|---|
| dry sample weight: | 0.6765 | 306.86 |

NOTE: los gas is estimated by time interval between at surface and canister times, and total gas evolved

| est. lost gas (cc) = | TIME 0F: | | | elapsed time (off bottom to canistering) |
|---|---|---|---|---|
| 21 | off bottom | at surface | in canister | 6.3 minutes |
| | 11/15/05 15:51 | 11/15/05 15:54 | 11/15/05 15:58 | 0.105 hours |
| | | | | 0.323608131 SQRT (hrs) |

| RIG/LAB MEASUREMENTS | | | CONVERSION OF RIG/LAB MEASUREMENTS TO STP (@60 deg F; 14.7 psi) | | | | | CUMULATIVE VOLUMES | | SCF/TON | SCF/TON | | TIME SINCE | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| measured cc | measured T (F) | measured P | cubic ft | absolute T (R) | psia | cubic ft (@STP) | cc (@STP) | cubic ft (@STP) | cc (@STP) | without lost gas | with lost gas | TIME OF MEASURE | off bottom | in canister | SQRT hrs. (since off bottom) |
| 118 | 68 | 1094 | 0.0042 | 528 | 14.200 | 0.003964319 | 112.26 | 0.003964319 | 112.26 | 11.72 | 13.91 | 11/18/05 10:52 | 67:00:17 | 66:54:00 | 8.185641222 |
| 22 | 68 | 1084 | 0.0008 | 528 | 14.070 | 0.000732354 | 20.74 | 0.004696673 | 132.99 | 13.88 | 18.08 | 11/21/05 13:57 | 142:05:17 | 141:59:00 | 11.92006944 |
| 12 | 68 | 1062 | 0.0004 | 528 | 13.784 | 0.000391359 | 11.08 | 0.005088032 | 144.08 | 15.04 | 17.23 | 11/28/05 15:12 | 311:20:17 | 311:14:00 | 17.64477417 |
| -21 | 68 | 1087 | -7E-04 | 528 | 14.109 | -0.000701 | -19.85 | 0.004387032 | 124.23 | 12.97 | 15.16 | 12/5/05 15:13 | 479:21:17 | 479:15:00 | 21.89417096 |
| -9 | 68 | 1086 | -3E-04 | 528 | 14.096 | -0.00030015 | -8.50 | 0.00408688 | 115.73 | 12.08 | 14.27 | 12/12/05 16:18 | 648:26:17 | 648:20:00 | 25.46444689 |

Sample air dried for approximately one week

# Dart Cherokee Basin #A2-26 Timmons et al., NW NE NW 26-T.29S.-R.14E., Wilson County, KS

(based on lag times from Dart Cherokee Basin #CH-1 Holder; sec. 1-T.30S.-R.14E., Wilson County, KS

## lag-time to surface for well cuttings

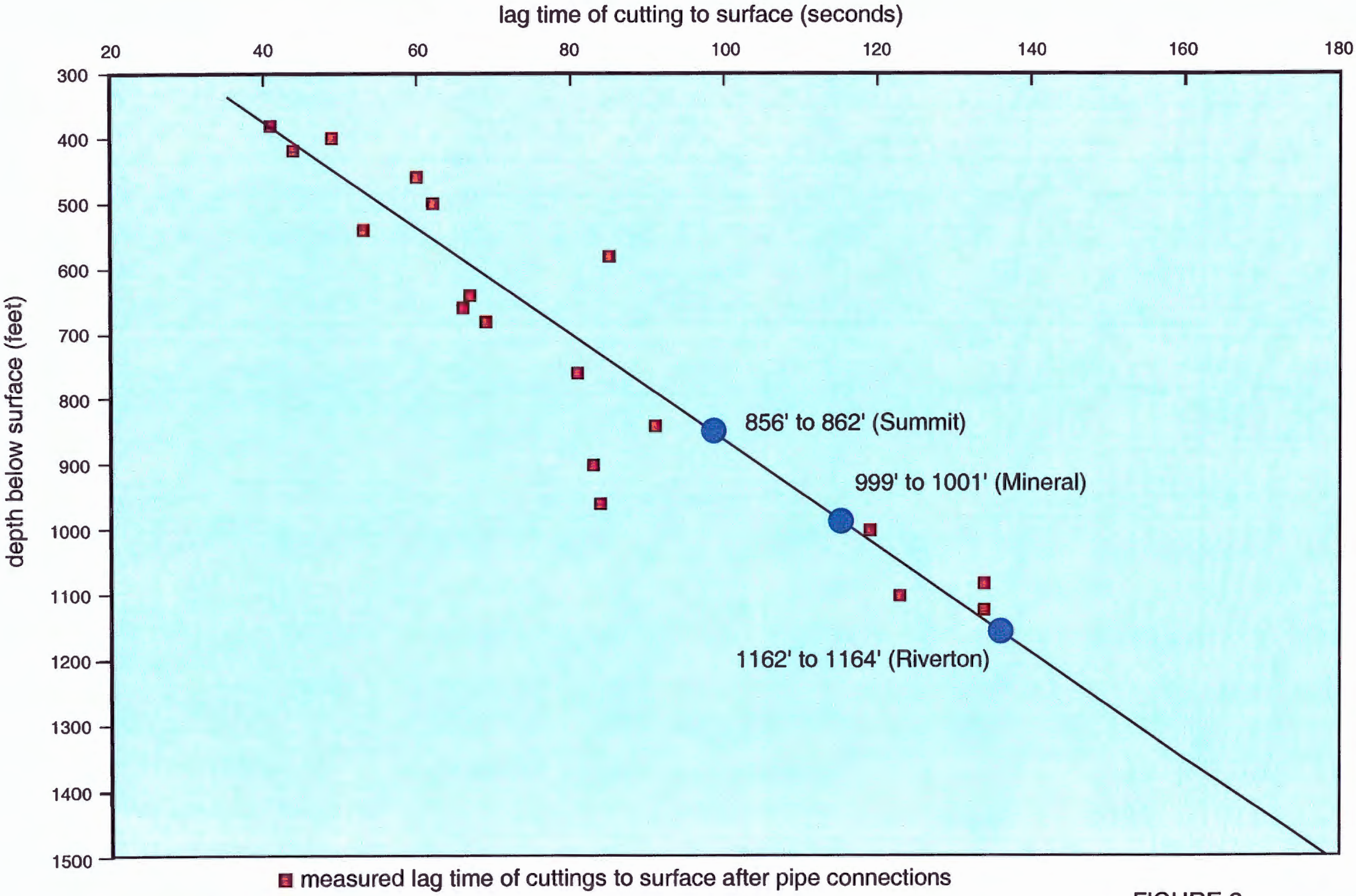
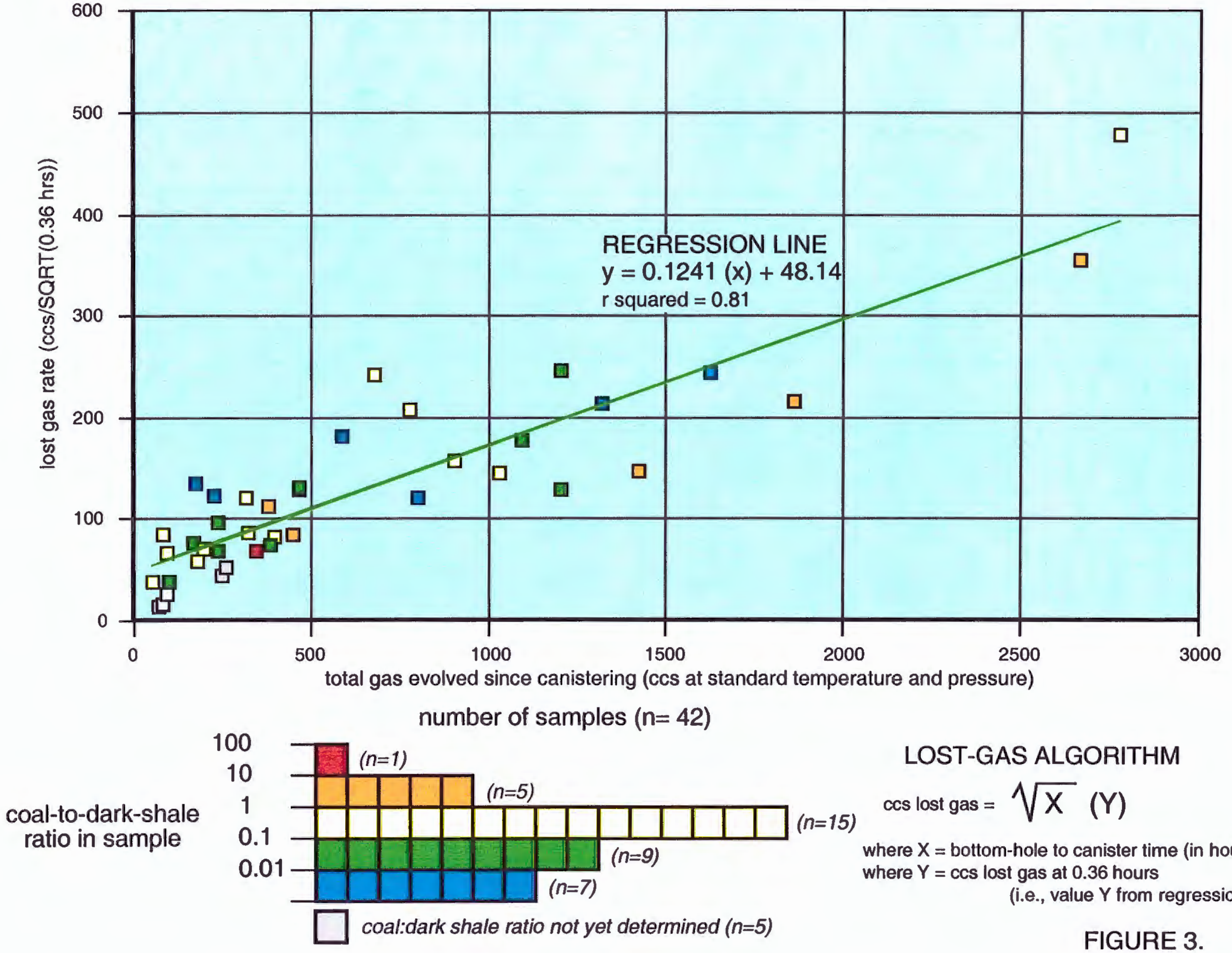


FIGURE 2.

# RELATIONSHIP of TOTAL GAS EVOLVED FROM a CUTTINGS SAMPLE to RATE of LOST-GAS
(from 42 cuttings samples from air-drilled wells, Cherokee basin, southeastern Kansas)



## LOST-GAS ALGORITHM

ccs lost gas = $\sqrt{X}$ (Y)

where X = bottom-hole to canister time (in hours)
where Y = ccs lost gas at 0.36 hours
(i.e., value Y from regression equation)

FIGURE 3.

# Desorption Characteristics of Cuttings Samples

## Dart Cherokee Basin #A2-26 Timmons et al., NW NE NW 26-T.29S.-R.14E., Wilson County, KS

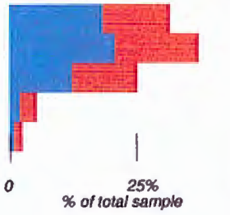
### LITHOLOGIC COMPONENT SENSITIVITY ANALYSIS for calculation of Little Osage Shale at 855'

$$\text{GAS CONTENT}_{\text{coal}} = \frac{\text{total gas desorbed} - ((\text{gas content}_{\text{dark shale}}) * (\text{weight}_{\text{dark shale}}))}{\text{weight}_{\text{coal}}}$$

total gas desorbed
(including estimated lost gas) = 266.1 ccs

TOTAL DRY WEIGHT OF SAMPLE = 1086.46 grams
$\text{weight}_{\text{light-colored lithologies}}$ = 514.39 grams (47.4%)
$\text{weight}_{\text{dark shale}}$ = 572.07 grams (52.7%)
$\text{weight}_{\text{coal}}$ = 0.00 grams (0.0%)

| *sieve size* | *grams* | *% coal* | *% dark shale* | *% light-colored liths* |
|---|---|---|---|---|
| >0.0930" | 388.41 | 0.00% | 57.44% | 42.56% |
| >0.0661" | 399.69 | 0.00% | 55.30% | 44.70% |
| >0.0460" | 269.36 | 0.00% | 48.22% | 51.78% |
| >0.0331" | 54.74 | 0.00% | 35.56% | 64.44% |
| <0.0331" | 24.26 | 0.00% | 30.00% | 70.00% |
| | **1086.46 TOTAL** | | | |



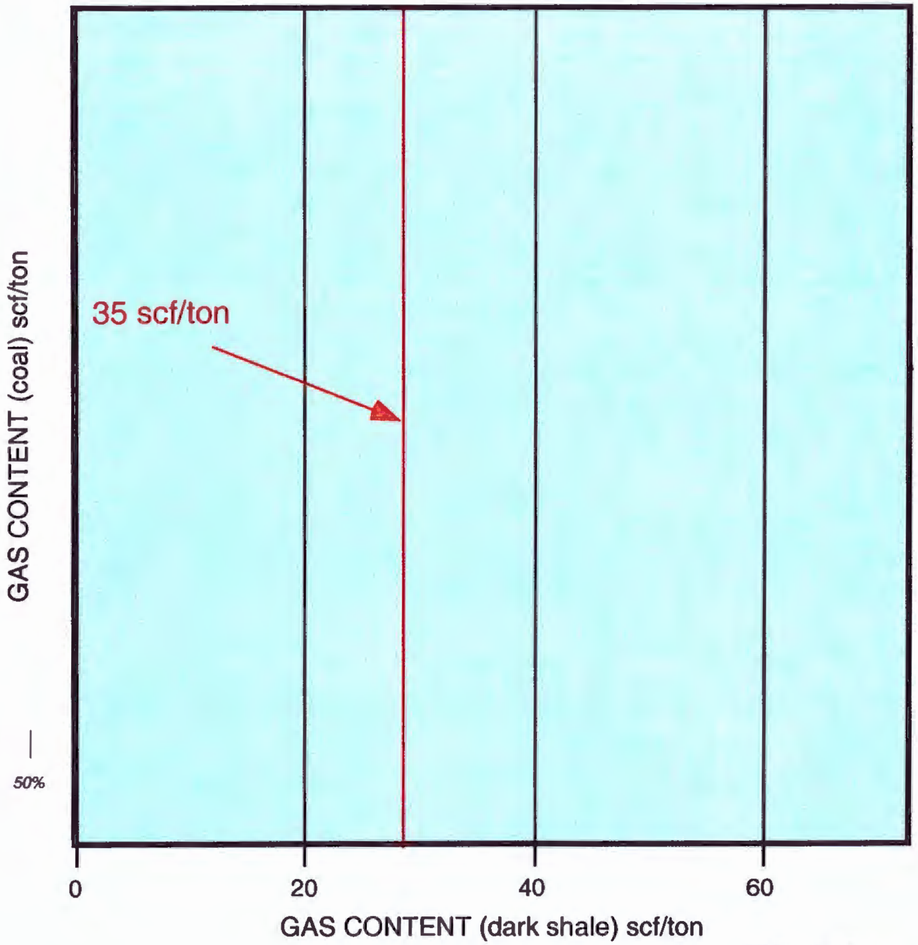


FIGURE 4.

# Desorption Characteristics of Cuttings Samples

## Dart Cherokee Basin #A2-26 Timmons et al., NW NE NW 26-T.29S.-R.14E., Wilson County, KS

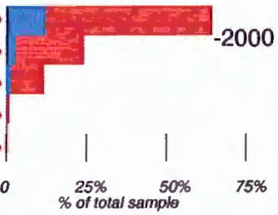
LITHOLOGIC COMPONENT SENSITIVITY ANALYSIS for calculation of Mineral coal at 999'

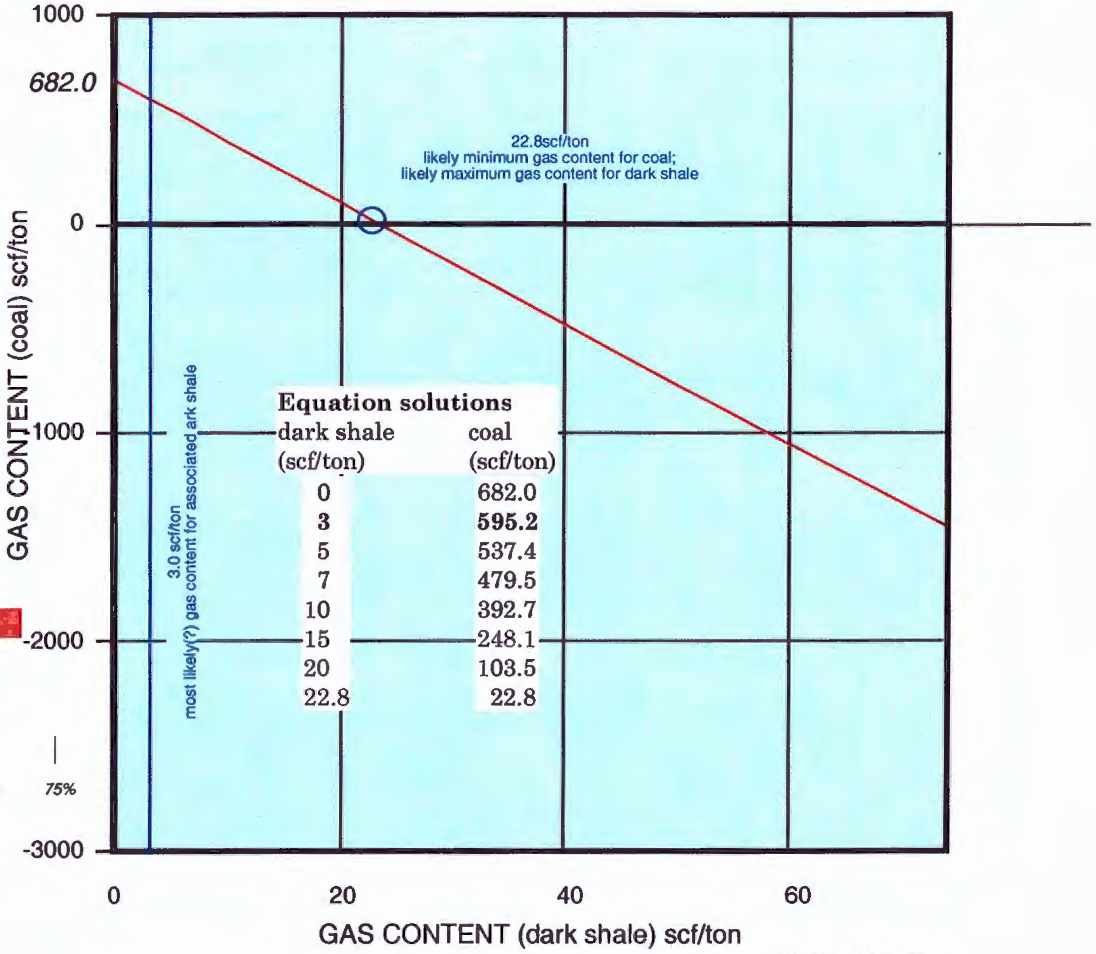
$$\text{GAS CONTENT}_{\text{coal}} = \frac{\text{total gas desorbed} - ((\text{gas content}_{\text{dark shale}}) * (\text{weight}_{\text{dark shale}}))}{\text{weight}_{\text{coal}}}$$

total gas desorbed
(including estimated lost gas) = 175.1 ccs

TOTAL DRY WEIGHT OF SAMPLE = 1481.21 grams
$\text{weight}_{\text{light-colored lithologies}}$ = 1235.04 grams (83.4%)
$\text{weight}_{\text{dark shale}}$ = 237.94 grams (16.1%)
$\text{weight}_{\text{coal}}$ = 8.23 grams (0.6%)

| *sieve size* | *grams* | *% coal / % dark shale / % light-colored liths* |
|---|---|---|
| >0.0930" | 944.00 | 0.50% / 18.64% / 80.87% |
| >0.0661" | 352.10 | 0.13% / 11.76% / 88.11% |
| >0.0460" | 169.91 | 1.71% / 11.45% / 86.84% |
| >0.0331" | 11.70 | 1.30% / 7.79% / 90.91% |
| <0.0331" | 3.51 | 1.50% / 6.00% / 92.50% |
| | **1481.21 TOTAL** | |





**Equation solutions**

| dark shale (scf/ton) | coal (scf/ton) |
|---|---|
| 0 | 682.0 |
| **3** | **595.2** |
| 5 | 537.4 |
| 7 | 479.5 |
| 10 | 392.7 |
| 15 | 248.1 |
| 20 | 103.5 |
| 22.8 | 22.8 |

FIGURE 5.

# Desorption Characteristics of Cuttings Samples

## Dart Cherokee Basin #A2-26 Timmons et al., NW NE NW 26-T.29S.-R.14E., Wilson County, KS

LITHOLOGIC COMPONENT SENSITIVITY ANALYSIS for calculation of Riverton coal at 1162'

$$\text{GAS CONTENT}_{\text{coal}} = \frac{\text{total gas desorbed} - ((\text{gas content}_{\text{dark shale}}) * (\text{weight}_{\text{dark shale}}))}{\text{weight}_{\text{coal}}}$$

total gas desorbed
(including estimated lost gas) = 165.1 ccs

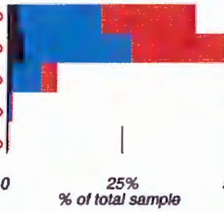
TOTAL DRY WEIGHT OF SAMPLE = 559.76 grams

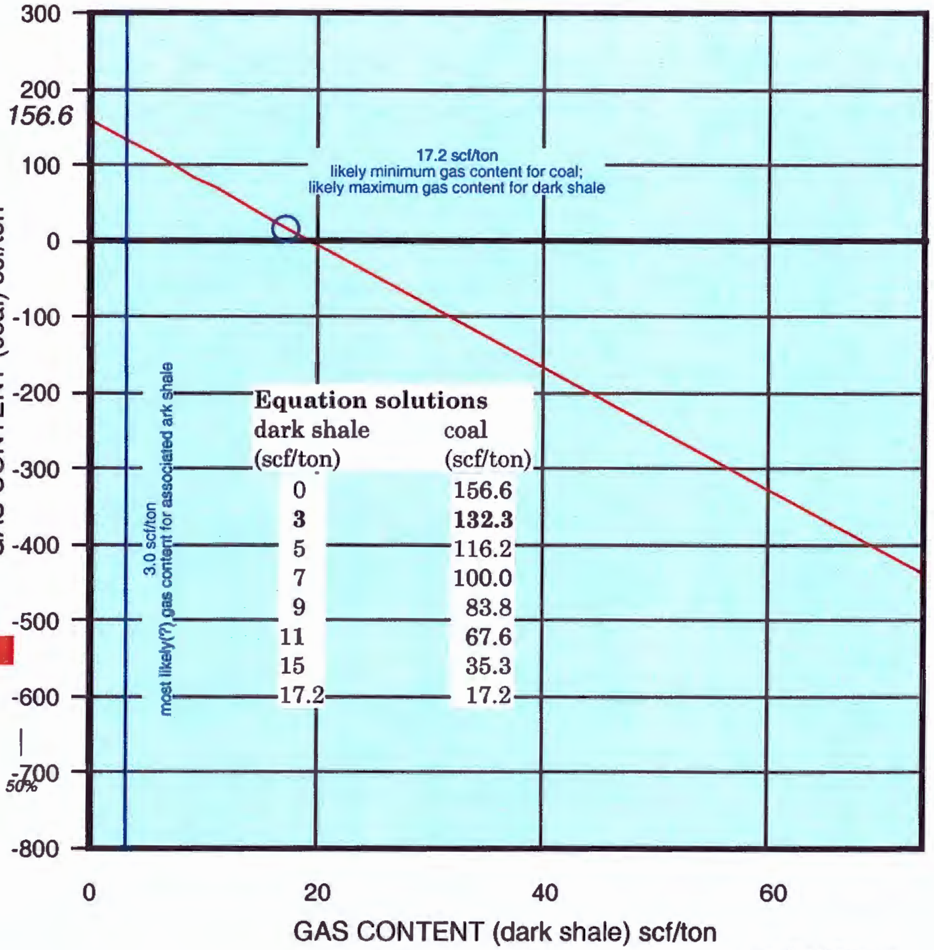
$\text{weight}_{\text{light-colored lithologies}}$ = 252.90 grams (45.2%)

$\text{weight}_{\text{dark shale}}$ = 273.08 grams (48.8%)

$\text{weight}_{\text{coal}}$ = 33.78 grams (6.0%)

| *sieve size* | *grams* | *% coal / % dark shale / % light-colored liths* |
|---|---|---|
| >0.0930" | 226.03 | 5.22% / 44.61% / 50.17% |
| >0.0661" | 267.97 | 6.87% / 48.58% / 44.56% |
| >0.0460" | 59.16 | 5.46% / 63.54% / 31.00% |
| >0.0331" | 5.31 | 5.41% / 67.57% / 27.03% |
| <0.0331" | 1.29 | 5.00% / 70.00% / 25.00% |
| | **306.86 TOTAL** | |





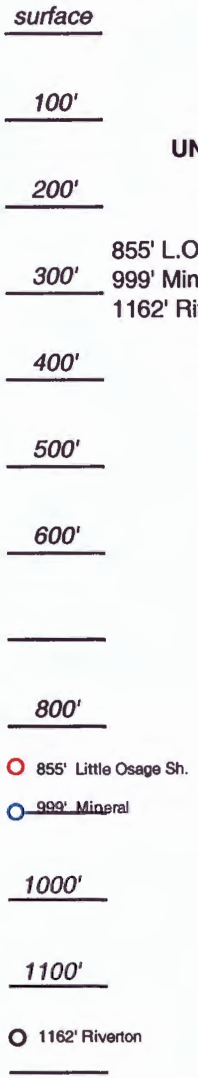
**Equation solutions**

| dark shale (scf/ton) | coal (scf/ton) |
|---|---|
| 0 | 156.6 |
| **3** | **132.3** |
| 5 | 116.2 |
| 7 | 100.0 |
| 9 | 83.8 |
| 11 | 67.6 |
| 15 | 35.3 |
| 17.2 | 17.2 |

FIGURE 6.

# Desorption Characteristics of Cuttings Samples

## Dart Cherokee Basin #A2-26 Timmons et al., NW NE NW 26-T.29S.-R.14E., Wilson County, KS



### LITHOLOGIC COMPONENT SENSITIVITY ANALYSIS for all samples

| UNIT | coal in sample | dk sh in sample | scf/ton w/ shale @ 3 scf/ton | maximum scf/ton | minimum scf/ton |
|---|---|---|---|---|---|
| 855' L.O.S. | ---- | 53% | ---- | ---- | 34.6 |
| 999' Mineral | <1% | 45% | | *no valid data* | |
| 1162' Riverton | 2% | 89% | 132.3 | 156.6 | 17.2 |

**scf/ton w/ shale @ 20 scf/ton**

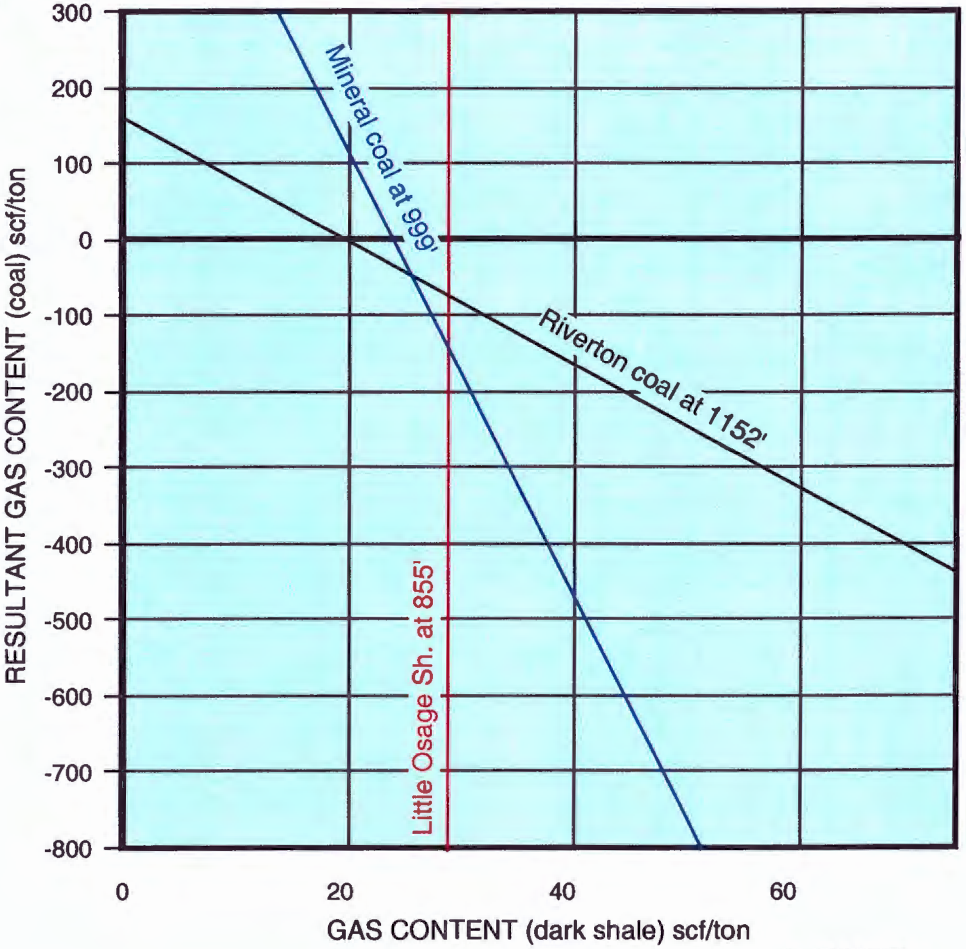


FIGURE 7.