ANALYSIS OF MARMATON AND CHEROKEE GROUP CUTTINGS SAMPLES FOR GAS CONTENT
-- DART CHEROKEE BASIN OPERATING COMPANY
#A3-20 SISSON;
NW NE sec. 20-T.33S.-R.14E.; MONTGOMERY COUNTY, KANSAS

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SUMMARY

Seven cuttings samples from the Pennsylvanian Marmaton Group and Cherokee Group were collected from the Dart Cherokee Basin #A3-20 Sisson well; NW NE sec. 20-T.33S.-R.14E.; Montgomery County, KS. The samples calculate as having the following gas contents:

- Little Osage Shale at 1021' to 1025' depth (11 scf/ton)
- Excello Shale at 1051'-1056' depth (24 scf/ton)
- Bevier coal at 1072'-1074' depth (127 scf/ton)
- Croweburg coal at 1096'-1097' depth (245 scf/ton)
- "Weir-Pittsburg equivalent" at 1200' to 1201' depth (150 scf/ton)
- "Dry Wood equivalent" at 1235' to 1238' depth (91 scf/ton)
- Rowe coal at 1373' to 1374' depth (98 scf/ton)

1 no coal in sample
2 assuming accompanying dark shales in sample desorb 3 scf/ton
3 reliability of result is unclear due to small amount of coal in the sample

BACKGROUND

The Dart Cherokee Basin #A3-20 Sisson well, NW NE sec. 20-T.33S.-R.14E. in Montgomery 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 March 24, 2004, by Gary Bogue of Dart Cherokee Basin L.L.C., and turned over to K. David Newell of the Kansas Geological Survey on March 25, 2004. 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 Marmaton Group and Cherokee Group) were penetrated. The well was drilled using an air rotary rig owned by McPherson Drilling.

The samples obtained by Gary Bogue 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. Lag times for samples to reach the surface (important for assessing lost gas) were determined by using the lag times from a nearby air-drilled well (Dart Cherokee Basin #CH-1 Holder; sec. 1-T.30S.-R.14E., Wilson County, KS), which was also drilled using this drilling rig. The lag times were determined by periodically noting the time it took for cuttings to reach the surface following resumption of drilling after new pipe was added to the drill string.

Seven cuttings samples from the Pennsylvanian Marmaton and Cherokee Groups were collected:

- Little Osage Shale at 1021' to 1025' depth (798 grams dry wt.)
- Excello Shale at 1051'-1056' depth (1704 grams dry wt.)
- Bevier coal at 1072'-1074' depth (415 grams dry wt.)
- Croweburg coal at 1096'-1097' depth (539 grams dry wt.)
• "Weir-Pittsburg equivalent" at 1200'-1201' depth (531 grams dry wt.)
• "Dry Wood equivalent" at 1235' to 1238' depth (891 grams dry wt.)
• Rowe coal at 1373' to 1374' depth (1870 grams dry wt.)

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 zephrym chloride biocide was then added to the canisters, with a headspace of 1 to 2 inches being preserved at the top of the canister.

All samples were transported on March 25 to the laboratory at the Kansas Geological Survey in Lawrence, KS, and desorption measurements 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 cm³). 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, KS (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:

\[ n = \frac{PV}{RT} \]

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:

\[ (P_{\text{stp}}V_{\text{stp}})/(RT_{\text{stp}}) = (P_{\text{rig}}V_{\text{rig}})/(RT_{\text{rig}}) \]

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 \( P_{\text{stp}}, V_{\text{stp}}, \) and \( T_{\text{stp}} \), respectively, are pressure, volume, and temperature at standard temperature and pressure, where standard temperature is degrees Rankine \((^\circ R = 460 + ^\circ F)\). \( P_{\text{rig}}, V_{\text{rig}}, \) and \( T_{\text{rig}} \), 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 \( V_{\text{stp}} \) becomes:

\[ V_{\text{stp}} = (T_{\text{stp}}/T_{\text{rig}}) (P_{\text{rig}}/P_{\text{stp}}) V_{\text{rig}} \]

The conversion calculations in the spreadsheet were carried out in the English metric system, the customary measuring 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 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 an oven at 150 °F for 1 to 3 days. 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 run 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) lag time to surface for the well cuttings, 2) data tables for the desorption analyses, 3) lost-gas graphs, 4) “lithologic component sensitivity analyses” showing the interdependence of gas evolved from dark shale versus coal in each sample, 5) a summary component analysis for all samples showing relative reliability of the data from all the samples, and 6) a desorption graph for all the samples.

Graph of Lag-time to Surface for Well Cuttings (Figure 2)
Lag time of cuttings to surface varied, but there is a general trend of longer lag times for greater depth. The lag times accepted for cuttings were taken to be a visual average of the trend (defined by the scatter of data points on this graph) at the depth at which the samples were taken.

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 3)
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 0.6 (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:

\[
\text{lost gas rate per square root of 0.36 hours} = 0.1241 \times (\text{total gas desorbed in ccs}) + 48.14
\]

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 3), therefore further refinement of the relationship of the rate of lost gas to the total gas desorbed after canistering is not possible.

"Lithologic Component Sensitivity Analyses" (Figures 4-10)
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 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:

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

A unique solution for gas content_{coal} in this equation is not possible because gas content_{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 vice versa. If there is little dark shale in a sample, a relatively well constrained answer for gas content_{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, 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 11)
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.

Desorption Graph (Figure 12)
This is a desorption graph (gas content per weight vs. square root of time) for all the samples. The rate at which gas is evolved from the samples is thus comparable at a common scale. The final value represents the standard cubic feet of gas per ton (scf/ton) calculated for the sample, using the combined weight of the coal and dark shale in the sample.

RESULTS and DISCUSSION
Little Osage Shale at 1021' to 10256' depth and Excello Shale at 1051'-1056' depth contained no coal, thus these samples are organic-rich shales that give up adsorbed gas.
The best constrained data are those associated with the Bevier sample (1072'-1074'), which contained 8% coal. The Croweburg coal sample (1096'-1097') contained 4% coal and its result is nearly as well constrained as the Bevier sample.

However, the next three samples ("Weir-Pittsburg equivalent" at 1200'-1201' depth; "Dry Wood equivalent" at 1322' to 1324' depth; Rowe coal at 1373' to 1374' depth) contained only 1% to 2% coal, thus the calculated gas content for the coal in these samples varies greatly with whatever value is assumed for the accompanying black shales. The subsidiary amount of coal in the samples imparts some uncertainty to the desorption measurements, but an approximation of their gas content is nevertheless obtained. An estimate for gas content for the coal in these samples can be made, assuming the admixed dark shale in the sample desorb 3 scf/ton.

REFERENCES

FIGURES and TABLES
FIGURE 1. Correlation of field barometer to Petrophysics Lab pressure transducer.
FIGURE 2. Lag-time to surface for well cuttings.
TABLE 1. Desorption measurements 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 at 1021' to 1025' depth.
FIGURE 5. Sensitivity analysis for Excello Shale at 1051'-1056' depth.
FIGURE 6. Sensitivity analysis for Bevier coal at 1072'-1074' depth.
FIGURE 7. Sensitivity analysis for Croweburg coal at 1096'-1097' depth.
FIGURE 9. Sensitivity analysis for "Dry Wood equivalent" at 1235' to 1238' depth.
FIGURE 10. Sensitivity analysis for Rowe coal at 1373' to 1374' depth.
FIGURE 11. Lithologic component sensitivity analyses for all samples.
FIGURE 12. Desorption graph for all samples.
Correlation of Field Barometer to KGS Petrophysics Lab Barometer

FIGURE 1.
Dart Cherokee Basin #A3-20 Sisson, 20-T.33S.-R.14E., Montgomery 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

lag time of cutting to surface (seconds)

depth below surface (feet)

1021' to 1025' (Little Osage Shale)
1051' to 1056' (Excello Shale)
1072' to 1074' (Bevier)
1096' to 1097' (Croweburg)
1200' to 1201' ("Weir-Pittsburg equivalent")
1322 to 1324' (Dry Wood "equivalent")
1373' to 1374' (Rowe)

■ measured lag time of cuttings to surface after pipe connections

FIGURE 2.
TABLE 1 — Desorption data for DART CHEROKEE BASIN RISSON #4-30; NW NE 26 T.33S. R.14E.

SAMPLE 1051' to 1065' (Little Osage Shale) cuttings in Dart SSD cantsite

| sample dry sample weight: | 1.5896 | 72.42 |

RIGLAB MEASUREMENTS

<table>
<thead>
<tr>
<th>CONVERSION OF RIGLAB MEASUREMENTS TO STP (060 deg F; 14 psi)</th>
<th>CUMULATIVE VOLUMES</th>
<th>SCF/TON</th>
</tr>
</thead>
<tbody>
<tr>
<td>cubic ft (STP)</td>
<td>cubic ft (STP)</td>
<td>cubic ft (STP)</td>
</tr>
<tr>
<td>WITHOUT lost gas</td>
<td>WITH lost gas</td>
<td>WITH lost gas</td>
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</tbody>
</table>

NOTE: gas is estimated by time interval between surface and cantister times, and total gas evolved est. lost gas (cc) TIME: 00. 3.07 minutes

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</thead>
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<td>SCF/TON</td>
<td></td>
</tr>
<tr>
<td>24 OFF bottom at surface in cantister</td>
<td>11:58, 12:04, 12:04</td>
<td>SCF/TON</td>
<td></td>
</tr>
</tbody>
</table>

SAMPLE 1051' to 1065' (Excelsior Shale) cuttings in Dart SSD cantsite

| sample dry sample weight: | 3.6216 | 145.42 |

RIGLAB MEASUREMENTS

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<th>CONVERSION OF RIGLAB MEASUREMENTS TO STP (060 deg F; 14 psi)</th>
<th>CUMULATIVE VOLUMES</th>
<th>SCF/TON</th>
</tr>
</thead>
<tbody>
<tr>
<td>cubic ft (STP)</td>
<td>cubic ft (STP)</td>
<td>cubic ft (STP)</td>
</tr>
<tr>
<td>WITHOUT lost gas</td>
<td>WITH lost gas</td>
<td>WITH lost gas</td>
</tr>
</tbody>
</table>

NOTE: gas is estimated by time interval between surface and cantister times, and total gas evolved est. lost gas (cc) TIME: 00. 0.97 hours

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<td>SCF/TON</td>
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<td>24 OFF bottom at surface in cantister</td>
<td>11:58, 12:04, 12:04</td>
<td>SCF/TON</td>
<td></td>
</tr>
</tbody>
</table>
NOTE: loss gas is estimated by time interval between at surface and canister times, and total gas evolved

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| Sample Decanistered: 4/12/2004 DUE TO NO MORE GAS BEING EVOLVED; sampled air dried for 18 days |
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)

**REGRESSION LINE**
\[ y = 0.1241 \times (x) + 48.14 \]
\[ r \text{ squared} = 0.81 \]

**LOST-GAS ALGORITHM**
\[ \text{ccs lost gas} = \sqrt{X} (Y) \]
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 #A3-20 Sisson, 20-T.33S.-R.14E., Montgomery County, KS

LITHOLOGIC COMPONENT SENSITIVITY ANALYSIS for calculation of Little Osage Shale from 1021' to 1025'

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

- total gas desorbed (including estimated lost gas) = 257.7 ccs
- TOTAL DRY WEIGHT OF SAMPLE = 798.20 grams
  - weight_{light-colored lithologies} = 73.99 grams (9.3%)
  - weight_{dark shale} = 724.21 grams (90.7%)
  - weight_{coal} = 0.00 grams (0.0%)

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<tr>
<th>sieve size</th>
<th>grams</th>
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<th>% dark shale</th>
<th>% light-colored liths</th>
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<td>&gt;0.0930&quot;</td>
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<td>7.58%</td>
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<td>115.86</td>
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<td>9.30%</td>
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<td>&gt;0.0460&quot;</td>
<td>81.71</td>
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<td>92.28%</td>
<td>7.72%</td>
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<td>&gt;0.0331&quot;</td>
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<td>0.00%</td>
<td>83.06%</td>
<td>16.94%</td>
</tr>
<tr>
<td>&lt;0.0331&quot;</td>
<td>21.92</td>
<td>0.00%</td>
<td>55.00%</td>
<td>45.00%</td>
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<tr>
<td>798.20 TOTAL</td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

**FIGURE 4.**

11.4 scf/ton

GAS CONTENT (dark shale) scf/ton

% of total sample

GAS CONTENT (coal) scf/ton
Desorption Characteristics of Cuttings Samples
Dart Cherokee Basin #A3-20 Sisson, 20-T.33S.-R.14E., Montgomery County, KS

LITHOLOGIC COMPONENT SENSITIVITY ANALYSIS for calculation of Excello Shale from 1051' to 1056'

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

total gas desorbed (including estimated lost gas) = 1237.1 ccs

TOTAL DRY WEIGHT OF SAMPLE = 1703.88 grams

- weight_{light-colored lithologies} = 61.13 grams (3.6%)
- weight_{dark shale} = 1642.75 grams (96.4%)
- weight_{coal} = 0.00 grams (0.0%)

<table>
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<th>grams</th>
<th>% coal</th>
<th>% dark shale</th>
<th>% light-colored liths</th>
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<td>&gt;0.0930&quot;</td>
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<td>98.16%</td>
<td>1.84%</td>
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<td>&gt;0.0661&quot;</td>
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<td>&gt;0.0460&quot;</td>
<td>225.35</td>
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<td>5.32%</td>
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<td>&gt;0.0331&quot;</td>
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<td>&lt;0.0331&quot;</td>
<td>60.96</td>
<td>0.00%</td>
<td>80.00%</td>
<td>20.00%</td>
</tr>
</tbody>
</table>

1703.88 TOTAL

FIGURE 5.
Desorption Characteristics of Cuttings Samples
Dart Cherokee Basin #A3-20 Sisson, 20-T.33S.-R.14E., Montgomery County, KS

LITHOLOGIC COMPONENT SENSITIVITY ANALYSIS for calculation of gas content of Bevier coal from 1072' to 1074'

GAS CONTENT \( c_{\text{coal}} \) =

\[
total \text{ gas desorbed} - \left( \left( \text{gas content}_{\text{dark shale}} \right) \times \left( \text{weight}_{\text{dark shale}} \right) \right)
\]

\[
\text{weight}_{\text{coal}}
\]

total gas desorbed (including estimated lost gas) = 161.1 ccs

TOTAL DRY WEIGHT OF SAMPLE = 415.18 grams

\[
\text{weight}_{\text{light-colored lithologies}} = 101.68 \text{ grams (24.5%)}
\]

\[
\text{weight}_{\text{dark shale}} = 90.29 \text{ grams (67.3%)}
\]

\[
\text{weight}_{\text{coal}} = 33.99 \text{ grams (8.2%)}
\]

<table>
<thead>
<tr>
<th>sieve size</th>
<th>grams</th>
<th>% coal</th>
<th>% dark shale</th>
<th>% light-colored liths</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;0.0930&quot;</td>
<td>260.34</td>
<td>4.42%</td>
<td>73.30%</td>
<td>22.28%</td>
</tr>
<tr>
<td>&gt;0.0661&quot;</td>
<td>75.90</td>
<td>10.91%</td>
<td>62.58%</td>
<td>26.50%</td>
</tr>
<tr>
<td>&gt;0.0460&quot;</td>
<td>40.87</td>
<td>15.28%</td>
<td>53.28%</td>
<td>31.44%</td>
</tr>
<tr>
<td>&gt;0.0331&quot;</td>
<td>19.16</td>
<td>16.84%</td>
<td>56.84%</td>
<td>26.32%</td>
</tr>
<tr>
<td>&lt;0.0331&quot;</td>
<td>18.91</td>
<td>25.00%</td>
<td>45.00%</td>
<td>30.00%</td>
</tr>
</tbody>
</table>

415.18 TOTAL

FIGURE 6.
Desorption Characteristics of Cuttings Samples
Dart Cherokee Basin #A3-20 Sisson, 20-T.33S.-R.14E., Montgomery County, KS

LITHOLOGIC COMPONENT SENSITIVITY ANALYSIS for calculation of gas content of Croweburg coal from 1096' to 1097'

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

Total gas desorbed (including estimated lost gas) = 182.7 ccs

TOTAL DRY WEIGHT OF SAMPLE = 538.98 grams
- weight_{light-colored lithologies} = 181.58 grams (33.7%)
- weight_{dark shale} = 337.65 grams (62.7%)
- weight_{coal} = 19.75 grams (3.7%)

<table>
<thead>
<tr>
<th>sieve size</th>
<th>grams</th>
<th>% coal</th>
<th>% dark shale</th>
<th>% light-colored liths</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;0.0930&quot;</td>
<td>365.62</td>
<td>2.55%</td>
<td>63.09%</td>
<td>34.37%</td>
</tr>
<tr>
<td>&gt;0.0661&quot;</td>
<td>91.34</td>
<td>5.25%</td>
<td>62.17%</td>
<td>32.57%</td>
</tr>
<tr>
<td>&gt;0.0460&quot;</td>
<td>46.48</td>
<td>4.51%</td>
<td>63.93%</td>
<td>31.56%</td>
</tr>
<tr>
<td>&gt;0.0331&quot;</td>
<td>20.77</td>
<td>6.42%</td>
<td>55.96%</td>
<td>37.61%</td>
</tr>
<tr>
<td>&lt;0.0331&quot;</td>
<td>14.76</td>
<td>15.00%</td>
<td>60.00%</td>
<td>25.00%</td>
</tr>
</tbody>
</table>

538.98 TOTAL

\[\text{GAS CONTENT}_{\text{dark shale}} = \text{total gas desorbed} - (\text{gas content}_{\text{coal}}) \times (\text{weight}_{\text{coal}})\]

\[\text{TOTAL DRY WEIGHT OF SAMPLE} = 538.98 \text{ grams}\]
- \text{weight}_{\text{light-colored lithologies}} = 181.58 \text{ grams (33.7\%)}
- \text{weight}_{\text{dark shale}} = 337.65 \text{ grams (62.7\%)}
- \text{weight}_{\text{coal}} = 19.75 \text{ grams (3.7\%)}

\[\text{Equation solutions}\]
- dark shale: \(16.4 \text{ scf/ton}\)
- coal: \(296.3 \text{ scf/ton}\)

FIGURE 7.
Desorption Characteristics of Cuttings Samples
Dart Cherokee Basin #A3-20 Sisson, 20-T.33S.-R.14E., Montgomery County, KS

LITHOLOGIC COMPONENT SENSITIVITY ANALYSIS for calculation of gas content of Weir-Pittsburg "equivalent" interval from 1200' to 1201'

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

total gas desorbed
(including estimated lost gas) = 69.6 cc

TOTAL DRY WEIGHT OF SAMPLE = 530.94 grams
\[ \text{weight}_{\text{light-colored lithologies}} = 55.04 \text{ grams (10.4%)} \]
\[ \text{weight}_{\text{dark shale}} = 470.46 \text{ grams (88.6%)} \]
\[ \text{weight}_{\text{coal}} = 5.44 \text{ grams (1.0%)} \]

sieve size | grams | % coal / % dark shale / % light-colored liths
--- | --- | ---
>0.0930" | 305.64 | 0.53% / 91.03% / 8.43%
>0.0661" | 90.99 | 1.07% / 85.45% / 13.48%
>0.0460" | 45.76 | 2.60% / 82.29% / 15.10%
>0.0331" | 16.03 | 4.69% / 81.25% / 14.06%
<0.0331" | 12.03 | 1.00% / 90.00% / 9.00%
530.94 TOTAL

\[ \begin{align*}
4.7 \text{ scf/ton} & \quad \text{likely minimum gas content for coal; likely maximum gas content for dark shale} \\
\end{align*} \]

Equation solutions:
- dark shale (scf/ton): 0, 1, 2, 3, 4
- coal (scf/ton): 409.8, 323.3, 236.8, 150.3, 63.7

FIGURE 8.
Desorption Characteristics of Cuttings Samples
Dart Cherokee Basin #A3-20 Sisson, 20-T.33S.-R.14E., Montgomery County, KS

LITHOLOGIC COMPONENT SENSITIVITY ANALYSIS for calculation of gas content of Dry Wood coal from 1322' to 1324'

GAS CONTENT$_{\text{coal}}$ =
\[
\text{total gas desorbed} - (\text{gas content}_{\text{dark shale}} \times \text{weight}_{\text{dark shale}}) / \text{weight}_{\text{coal}}
\]

Total gas desorbed (including estimated lost gas) = 94.3 ccs

TOTAL DRY WEIGHT OF SAMPLE = 890.71 grams

weight$_{\text{light-colored lithologies}}$ = 262.50 grams (29.5%)

weight$_{\text{dark shale}}$ = 615.31 grams (69.1%)

weight$_{\text{coal}}$ = 12.90 grams (1.5%)

Equation solutions

<table>
<thead>
<tr>
<th>sieve size</th>
<th>grams</th>
<th>% coal / % dark shale / % light-colored liths</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;0.0930&quot;</td>
<td>575.25</td>
<td>1.21% / 71.92% / 26.87%</td>
</tr>
<tr>
<td>&gt;0.0681&quot;</td>
<td>171.93</td>
<td>1.43% / 67.08% / 31.48%</td>
</tr>
<tr>
<td>&gt;0.0460&quot;</td>
<td>82.97</td>
<td>2.96% / 61.58% / 35.47%</td>
</tr>
<tr>
<td>&gt;0.0331&quot;</td>
<td>34.70</td>
<td>2.27% / 64.77% / 32.95%</td>
</tr>
<tr>
<td>&lt;0.0331&quot;</td>
<td>25.87</td>
<td>1.00% / 49.00% / 50.00%</td>
</tr>
</tbody>
</table>

890.71 TOTAL

FIGURE 9.
Desorption Characteristics of Cuttings Samples
Dart Cherokee Basin #A3-20 Sisson, 20-T.33S., R.14E., Montgomery County, KS

LITHOLOGIC COMPONENT SENSITIVITY ANALYSIS for calculation of gas content of Rowe coal from 1373' to 1374'

GAS CONTENT_{\text{coal}} = \frac{\text{total gas desorbed} - ((\text{gas content}_{\text{dark shale}}) \times (\text{weight}_{\text{dark shale}}))}{\text{weight}_{\text{coal}}}

\text{total gas desorbed (including estimated lost gas)} = 257.9 \text{ ccs}

\text{TOTAL DRY WEIGHT OF SAMPLE} = 1870.46 \text{ grams}
\begin{align*}
\text{weight}_{\text{light-colored lithologies}} &= 342.60 \text{ grams (18.3\%)} \\
\text{weight}_{\text{dark shale}} &= 1488.96 \text{ grams (79.6\%)} \\
\text{weight}_{\text{coal}} &= 38.90 \text{ grams (2.1\%)}
\end{align*}

\begin{array}{c|c|c|c|c}
\text{sieve size} & \text{grams} & \% \text{coal} & \% \text{dark shale} & \% \text{light-colored liths} \\
\hline
>0.0930'' & 907.48 & 1.43\% & 82.89\% & 15.68\% \\
>0.0661'' & 416.50 & 3.54\% & 77.81\% & 18.65\% \\
>0.0460'' & 331.45 & 1.49\% & 75.62\% & 22.89\% \\
>0.0331'' & 134.21 & 2.88\% & 75.54\% & 21.58\% \\
<0.0331'' & 80.83 & 3.00\% & 60.00\% & 22.00\% \\
\hline
\end{array}

\text{TOTAL} = 1870.46 \text{ grams}

Equation solutions
\begin{align*}
\text{dark shale (scf/ton)} & = 212.3 \\
\text{coal (scf/ton)} & = 97.5
\end{align*}

FIGURE 10.
Desorption Characteristics of Cuttings Samples
Dart Cherokee Basin #A3-20 Sisson, 20-T.33S.-R.14E., Montgomery County, KS

LITHOLOGIC COMPONENT SENSITIVITY ANALYSIS for all samples

<table>
<thead>
<tr>
<th>UNIT</th>
<th>scf/ton</th>
<th>maximum scf/ton</th>
<th>minimum scf/ton</th>
</tr>
</thead>
<tbody>
<tr>
<td>300' Little Osage Sh.</td>
<td>0%</td>
<td>----</td>
<td>11.4</td>
</tr>
<tr>
<td>300' Excello Shale</td>
<td>0%</td>
<td>----</td>
<td>24.4</td>
</tr>
<tr>
<td>300' Bevier Shale</td>
<td>8%</td>
<td>127.1</td>
<td>151.8</td>
</tr>
<tr>
<td>300' Croweburg coal</td>
<td>4%</td>
<td>245.0</td>
<td>296.3</td>
</tr>
<tr>
<td>300' &quot;Weir-Pitt. equiv.&quot;</td>
<td>1%</td>
<td>150.3</td>
<td>409.8</td>
</tr>
<tr>
<td>300' &quot;Dry Wood equiv.&quot;</td>
<td>2%</td>
<td>91.1</td>
<td>234.2</td>
</tr>
<tr>
<td>300' Rowe coal</td>
<td>2%</td>
<td>97.5</td>
<td>212.3</td>
</tr>
</tbody>
</table>

FIGURE 11.
Desorption Characteristics of Cuttings Samples

based on total weight of gas-generating lithologies (i.e., coal and dark shale) in sample


FIGURE 12.