ANALYSIS OF MARMATON AND CHEROKEE GROUP CUTTINGS SAMPLES
FOR GAS CONTENT -- MERITAGE KCM #26-13 GARRISON SWD
(NE SW 26-T.19S.-R.19E.), ANDERSON COUNTY, KANSAS

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SUMMARY

Nine cuttings samples from the Pennsylvanian Marmaton and Cherokee Group were collected from the Meritage KCM #26-13 Garrison SWD well in NE SW 26-T.19S.-R.19E. in Anderson County, KS:

- Mulberry coal at 673' to 676' depth
- shale above Summit at 755' to 758' depth
- Summit "coal" at 760' to 762' depth
- Bevier coal at 853' to 855' depth
- Mineral coal at 898 to 900' depth
- Riverton "A" coal at 1108' to 1110' depth
- Riverton "A" coal (sieved coarse) at 1113' to 1115' depth
- Riverton "A" coal (sieved fine) at 1113' to 1115' depth
- Riverton "B" coal at 1120' to 1122' depth

Assuming the dark shale that is usually admixed with the coal cuttings has approximately 3 scf/ton gas content, the samples calculated as having the following gas contents:

- Mulberry coal at 673' to 676' depth (35.1 scf/ton)
- shale above Summit at 755' to 758' depth (3.3 scf/ton)
- Summit "coal" at 760' to 762' depth (5.2 scf/ton)
- Bevier coal at 853' to 855' depth (17.7 scf/ton)
- Mineral coal at 898 to 900' depth (12.2 scf/ton)
- Riverton "A" coal at 1108' to 1110' depth (82.0 scf/ton)
- Riverton "A" coal (sieved coarse) at 1113' to 1115' depth (85.1 scf/ton)
- Riverton "A" coal (sieved fine) at 1113' to 1115' depth (85.1 scf/ton)
- Riverton "B" coal at 1120' to 1122' depth (240.0 scf/ton)

1 no coal in sample
2 calculated using 4.5 scf/ton for admixed dark shale
3 results uncertain due to only small amount of coal in sample

The most reliable result, which is largely controlled by the amount of coal in the cuttings, is from the Mulberry coal sample. The least constrained results are from the Riverton "B" sample, which had only 1.3% coal. The sample of the shale above the Summit "coal" and the Summit "coal" sample had no coal in them, nevertheless, they respectively contained 69% and 59% dark shale, thus their results were reasonable good. The results for the Bevier and Mineral, samples all carry some uncertainly because they contain less than 10% coal. The Riverton "A" coarse and fine samples respectively contained 20% and 11% coal, however, both of these samples and the Riverton "A" sample from 1108' to 1110' have internally consistent results that fortify the reliability of the calculations for the gas content for this coal.
BACKGROUND

The Meritage KCM #26-13 Garrison SWD well in NE SW 26-T.19S.-R.19E. well in (Anderson County, KS) well 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 January 2, 2003 by K. David Newell and Jonathan P. Lange of the Kansas Geological Survey, with well site collection aided by Lawrence A. Weis (consultant for Meritage KCM). Samples were obtained during normal drilling of the well, with no cessation of drilling before zones of interest (i.e., coals in the Marmaton and Cherokee Group) were penetrated. The well was drilled using an air rotary rig owned by MOKAT Drilling. Lag times for samples to reach the surface (important for assessing lost gas) 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.

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

- Mulberry coal at 673' to 676' depth (275 grams dry wt.)
- shale above Summit at 755' to 758' depth (460 grams dry wt.)
- Summit "coal" at 760' to 762' depth (2421 grams dry wt.)
- Bevier coal at 853' to 855' depth (1356 grams dry wt.)
- Mineral coal at 898 to 900' depth (924 grams dry wt.)
- Riverton "A" coal at 1108' to 1110' depth (622 grams dry wt.)
- Riverton "A" coal (sieved coarse) at 1113' to 1115' depth (1101 grams dry wt.)
- Riverton "A" coal (sieved fine) at 1113' to 1115' depth (126 grams dry wt.)
- Riverton "B" coal at 1120' to 1122' depth (456 grams dry wt.)

The cuttings samples were caught in a kitchen strainer at the air stream exit by the mud pit. The samples were washed in the kitchen strainer to rid them of drilling mud before they were placed in desorption canisters. A temperature bath for the desorption canisters was on site, with temperatures ranging between 66 and 69 degrees F. The canistered samples were later that day transported to the laboratory at the Kansas Geological Survey and desorption measurements were continued at 66 to 69 degrees F ambient temperature. Desorption measurements were periodically made until the canisters produced no more gas upon 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 simply reading the difference in water level using the volumetric scale on the side of the burette.
The desorption canisters were both home-made, using PVC pipe and plumbing materials available at hardware stores, and commercial, obtained from SSD, Inc. in Grand Junction, CO. On average, the canisters were approximately 12.5 inches high (32 cm), 3 1/2 inches (9 cm) in diameter, and enclosed a volume of approximately 150 cubic inches (2450 cm$^3$). In case of small sample size (generally sample weighing less than 300 grams dry wt.), a concrete plug was placed in the desorption canister to decrease the volume of free space within the canister. This volume of this plug was 77 cubic inches (1262 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 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:

\[
\frac{P_{\text{st}}V_{\text{st}}}{RT_{\text{st}}} = \frac{P_{\text{rig}}V_{\text{rig}}}{RT_{\text{rig}}}
\]

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 \( P_{\text{st}}, V_{\text{st}}, \) and \( T_{\text{st}} \), respectively, are pressure, volume and temperature at standard temperature and pressure, where standard temperature is degrees Rankine (°R = 460 + °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 $V_{stp}$ becomes:

$$V_{stp} = \left( \frac{T_{stp}}{T_{rig}} \right) \left( \frac{P_{rig}}{P_{stp}} \right) V_{rig}$$

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. In the case of well cuttings from Meritage KCM #26-13 Garrison SWD well, the maximum time of desorption was 33 days.

Lost gas (i.e., the gas lost from the sample from the time it was drilled, brought to the surface, to the time it was canistered) was 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 instant the cuttings sample is lifted from the bottom of the hole, or in the case of cuttings, when the drilled rock is cut and circulated off bottom. Characteristically, the cumulative gas evolved from the sample, when plotted against the square root of time, is linear for a short time period after the sample reaches ambient pressure conditions, therefore lost gas is determined by a line projected back to time zero. The period of linearity generally is about an hour for cuttings samples.

LITHOLOGIC ANALYSIS

As an experiment for comparison of desorption results, the Riverton "A" sample from 1113'-1115' depth was sieved into two size fractions before canistering at the well site. The coarser size fraction was composed of all cuttings >0.0930" in size. The finer size fraction was composed of cuttings >0.0930", but >0.0661" in size.

Upon removal from the canisters, cuttings were washed of drilling mud, and dried in an oven at 150 °F for 1 to 3 days. After drying (and with the exception of the already-sieved Riverton "A" sample from depth 1113'-1115' depth) 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. 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. The light-colored lithologies were discounted as gas-generating in the calculation of gas content.

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 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 (Figures 3-11)
Gas lost prior to the canistering of the sample was estimated by extrapolation of the first few data points after the sample was canistered. The linear characteristic of the initial desorption measurements was usually lost within the first hour after canistering, thus data are presented in the lost-gas graphs for only up to one hour after canistering. Lost-gas volumes derived from this analysis are incorporated in the data tables described above.

"Lithologic Component Sensitivity Analyses" (Figures 12-20)
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 total amount of gas evolved from a cuttings sample can be expressed by the following equation:

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

A unique solution for \(\text{gas content}_{\text{coal}}\) in this equation is not possible because \(\text{gas content}_{\text{dark shale}}\) 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 \(\text{gas content}_{\text{coal}}\) 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. For a general understanding of the lithologic-component-sensitivity-analyses diagrams, the calculated \(\text{gas content}_{\text{coal}}\) is given for assumed \(\text{gas content}_{\text{dark shale}}\) at 30 scf/ton and 50 scf/ton. For most samples gathered in east-central and northeastern Kansas, the resultant \(\text{gas content}_{\text{coal}}\) is a negative number for 30 scf/ton and 50 scf/ton \(\text{gas content}_{\text{dark shale}}\). The only conclusion is that the \(\text{gas content}_{\text{dark shale}}\) or most samples taken from this region has to be lower than 30-50 scf/ton. 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.

In all the lithologic-component-sensitivity-analysis diagrams, a “break-even” point is 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.

**Summary Component Analysis for all Samples (Figure 21)**

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., \(\text{gas content}_{\text{coal}}\)) 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 22)
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.

RESULTS and DISCUSSION

No bona fide coal was in the shale sample (755'-758') taken above the Summit "coal", or at the Summit "coal" itself (760'-762'. Gas content was calculated for a very dark shale that was present in both of these samples. Other lithologies, which are not gas generating, include light-gray shales and limestones.

The Riverton "A" sample at 1108-1110' was originally intended to sample the dark shale above the Riverton coal rather than the coal itself, however, coal constituted 7.5% of this sample and thus the linear relationship of the coal and admixed dark shale (Figure 17) could be established.

The Riverton "A" coal from 1113' to 1115' was the subject of a sieving experiment at the well site in which a coarse fraction (0.093") was canistered separately from a fine fraction (<0.093" and >0.0661"). If finer-sized cuttings desorb faster than coarser-sized cuttings, one would expect that the finer-sized fraction would calculate to having less gas per ton than the coarser-sized fraction. However, the finer-sized fraction only yields less gas per ton than the coarser-sized fraction ONLY IF shale gas-content is assumed to be less than 4.5 scf/ton. At 3 scf/ton shale gas, the fine fraction yields about 6% less gas than the coarse fraction (i.e., 88.3 vs. 93.2 scf/ton). The simultaneous solution for both size fractions is 4.5 scf/ton for shale and 85.1 scf/ton for coal (Figure 18).

The Riverton "B" sample at 1120-1122' only contained 1.5% coal. Due to this small amount of coal and the minuscule amount of gas evolved, the solution to the linear relationship of the coal and its admixed dark shale carries much uncertainty (Figure 19). When the 1120-1122' line is plotted against the linear solutions for the 1108-1110' and 1113-1115' samples (Figure 20), the solutions to these simultaneous equations (i.e., expressed as the points of intersection of these lines with the 1120-1122' line) are:

9.0 scf/ton (dark shale), 53.9 scf/ton (coal) for the 1108-1110' sample
8.7 scf/ton (dark shale), 64.7 scf/ton (coal) for the 1113-1115' sample

These unique solutions, however, are not necessarily valid though, due to the depth differences for the samples, and uncertainty inherent with small gas yield and low coal content in the 1120-1122' sample. One reasonable conclusion though is that the shale sampled with the Riverton "B" at 1120-1122' is capable of desorbing around 8 scf/ton,
whereas shale higher up in around the Riverton "A" at 1108-1115' depth desorb less—likely 4.5 scf/ton.

The Bevier and Mineral coal samples higher in the well desorbed only minor amounts of gas, respectively 17.7 and 12.2 scf/ton, assuming admixed shales desorb at 3 scf/ton (see Figure 21). The Mulberry had slightly greater gas content, assaying at 35.1 scf/ton. This sample had the least uncertainty associated with it (Figure 21), since it had the greatest amount of coal (60%) of all the samples obtained from this well.

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. Lost-gas graph for Mulberry coal at 673'-676' depth.
FIGURE 4. Lost-gas graph for shale above Summit "coal" at 755'-758' depth.
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FIGURE 7. Lost-gas graph for Mineral coal at 898-900'.
FIGURE 8. Lost-gas graph for Riverton "A" coal at 1108'-1110' depth.
FIGURE 9. Lost-gas graph for Riverton "A" coal (coarse fraction) at 1113'-1115' depth.
FIGURE 10. Lost-gas graph for Riverton "A" coal (fine fraction) at 1113'-1115' depth.
FIGURE 11. Lost-gas graph for Riverton "B" coal at 1120'-1122' depth.
FIGURE 12. Sensitivity analysis for Mulberry coal at 673'-676' depth.
FIGURE 13. Sensitivity analysis for shale above Summit "coal" at 755'-758' depth.
FIGURE 15. Sensitivity analysis for Bevier coal at 853'-855' depth.
FIGURE 17. Sensitivity analysis for Riverton "A" coal at 1108'-1110' depth.
FIGURE 18. Sensitivity analysis for Riverton "A" coal (coarse and fine fractions) at 1113'-1115' depth.
FIGURE 19. Sensitivity analysis for Riverton "B" coal at 1120'-1122' depth.
FIGURE 20. Sensitivity analysis for all Riverton coal samples.

FIGURE 21. Lithologic component sensitivity analyses for all samples.

FIGURE 22. Desorption graph for all samples.
Correlation of Field Barometer to KGS Petrophysics Lab Barometer

FIGURE 1.
Meritage KCM #26-13 Garrison SWD; NE NW sec. 26-T.19S.-R.19E., Anderson County, KS
lag-time to surface for well cuttings

lag time of cutting to surface (seconds)

depth below surface (ft)

-400
-500
-600
-700
-800
-900
-1000
-1100
-1200

673' to 676' (Mulberry coal)
755' to 758' (sh. above Summit) & 760' to 762' (Summit "coal")
853' to 855' (Bevier coal)
898' to 900' (Mineral coal)
1108'-1110' (Riverton "A") & 1113'-1115' (Riverton "A")
1120'-1122' (Riverton "B")

measured lag time of cuttings to surface after pipe connections

FIGURE 2.
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DECANISTERED 10/03

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DECANISTERED 10/03

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<td>8.945E-05</td>
<td>0.0145</td>
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</table>

SORT hrs (since off bottom)

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<tr>
<th>Time</th>
<th>Measured Volume</th>
<th>Measured Weight</th>
<th>Total Weight</th>
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<td>0.0145</td>
</tr>
<tr>
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<td>8.945E-05</td>
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SORT hrs (since off bottom)

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<th>Time</th>
<th>Measured Volume</th>
<th>Measured Weight</th>
<th>Total Weight</th>
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<tr>
<td>7/5/03</td>
<td>13:50</td>
<td>8.945E-05</td>
<td>0.0145</td>
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<tr>
<td>7/5/03</td>
<td>13:53</td>
<td>8.945E-05</td>
<td>0.0145</td>
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<tr>
<td>7/5/03</td>
<td>13:56</td>
<td>8.945E-05</td>
<td>0.0145</td>
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<tr>
<td>7/5/03</td>
<td>13:59</td>
<td>8.945E-05</td>
<td>0.0145</td>
</tr>
</tbody>
</table>
### Section 1

#### Sample 1: 450 to 455 (Bever coal) in container Maggy 3

**Dry Weight**
- lbs: 0.04
- grams: 0.00014126

**Measurements**
- Measured T (F): 14.079
- Approximate Absolute T (F): 13.970

**Humidity**
- Sample Measured: 0.901258
- Measured T (F): 13.719
- Approximate Absolute T (F): 13.518

**Volume**
- Cubic ft (F): 0.00102309
- Estimated Volume at 0.00102309: 0.00102309

**Temperature**
- C: 14.079
- F: 13.719

**Mean**
- 14.079

**Sample Time**
- 14:03 elapsed time (off bottom)

**Data**
- TIME: 14:03
- Delta Time: 0.0014126
- Mean Deviation: 0.0014126

**Decanistered**
- 1/2/03

**Conclusion**
- The sample is concluded.

### Section 2

#### Sample 2: 456 to 458 (Mineral coal) in container Maggy 4

**Dry Weight**
- lbs: 0.04
- grams: 0.00014126

**Measurements**
- Measured T (F): 14.079
- Approximate Absolute T (F): 13.970

**Humidity**
- Sample Measured: 0.901258
- Measured T (F): 13.719
- Approximate Absolute T (F): 13.518

**Volume**
- Cubic ft (F): 0.00102309
- Estimated Volume at 0.00102309: 0.00102309

**Temperature**
- C: 14.079
- F: 13.719

**Mean**
- 14.079

**Sample Time**
- 14:03 elapsed time (off bottom)

**Data**
- TIME: 14:03
- Delta Time: 0.0014126
- Mean Deviation: 0.0014126

**Decanistered**
- 1/2/03

**Conclusion**
- The sample is concluded.
<table>
<thead>
<tr>
<th>TIME OF MEASURE</th>
<th>TIME SINCE</th>
<th>TIME OF</th>
<th>SOFTN</th>
<th>SOFTN</th>
<th>est. lost gas (cc)</th>
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</thead>
<tbody>
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<td>1/2/03 19:10</td>
<td>1/2/03 19:10</td>
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<tr>
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<td>1/2/03 19:35</td>
<td>1/2/03 19:35</td>
<td>1/2/03 19:35</td>
</tr>
</tbody>
</table>

**Sample: 110F to 115F (Riverton 'A' coal) in canister 10**

**Sample: 1110F to 1115F (Riverton 'A' sieved sample -- >0.006") in canister 9**

**Sample: 1110F to 1115F (Riverton 'A' sieved sample -- >0.006") in canister 5**
<table>
<thead>
<tr>
<th>RIG MEASUREMENTS</th>
<th>CONVERSION OF RIG MEASUREMENTS TO STP (cubic ft, °F degrees, ft•sec², °F • ft³)</th>
<th>CUMULATIVE VOLUMES</th>
<th>SCRFON/STTON WITH/OUT LOST GAS</th>
<th>TIME SINCE DECANISTERED</th>
<th>TIME SINCE DEGRAS</th>
<th>DRYWEIGHT</th>
<th>DCANISTERED</th>
</tr>
</thead>
<tbody>
<tr>
<td>measured cc</td>
<td>measured F</td>
<td>measured P</td>
<td>measured (F) (ABSOLUTE T (F))</td>
<td>measured (F) (ORIG) P</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>0.5</td>
<td>1087 1.7856E+05</td>
<td>529 14.109</td>
<td>6.68357E-05</td>
<td>529 14.109</td>
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<tr>
<td>1</td>
<td>1087 0.00081224</td>
<td>529 14.109</td>
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<tr>
<td>1</td>
<td>1087 0.00081224</td>
<td>529 14.109</td>
<td>6.68357E-05</td>
<td>529 14.109</td>
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</tbody>
</table>

DECANISTERED 1/09/03
673' to 676' (Mulberry Coal) in canister Brady 27
Meritage KCM Garrison #26-13 SWD; NE SW sec. 26-T.19S.-R.19E., Anderson County, KS

Elapsed time (off-bottom to canister)
= 0.175
= \sqrt{0.031 \text{ hrs.}}
= 1.8 \text{ min.}

25cc estimated lost gas

FIGURE 3.
755' to 758' (shale above Summit "coal") in canister Maggy 1
Meritage KCM Garrison #26-13 SWD; NE SW sec. 26-T.19S.-R.19E., Anderson County, KS

elapsed time (off-bottom to canister)
= 0.219
= SQRT(0.048 hrs.)
= 2.9 min.

8 cc estimated lost gas

square root of hours since cuttings were off bottom

FIGURE 4.
$760' \text{ to } 762' \text{ (Summit "coal") in canister Maggy 2}$

Meritage KCM Garrison #26-13 SWD; NE SW sec. 26-T.19S.-R.19E., Anderson County, KS

elapsed time (off-bottom to canister) 
$= 0.254$
$= \sqrt{0.065 \text{ hrs.}}$
$= 3.9 \text{ min.}$

$24\text{ cc estimated lost gas}$

FIGURE 5.
853' to 855' (Bevier coal) in canister Maggy 3
Meritage KCM Garrison #26-13 SWD; NE SW sec. 26-T.19S.-R.19E., Anderson County, KS

elapsed time (off-bottom to canister)
= 0.240
= SQRT(0.057 hrs.)
= 3.4 min.

45cc estimated lost gas

FIGURE 6.
898' to 900' (Mineral coal) in canister Maggy 4
Meritage KCM Garrison #26-13 SWD; NE SW sec. 26-T.19S.-R.19E., Anderson County, KS

elapsed time (off-bottom to canister) = 0.249
= SQRT(0.062 hrs.) = 3.7 min.

13cc estimated lost gas

FIGURE 7.
1108' to 1110' (Riverton "A") in canister 10
Meritage KCM Garrison #26-13 SWD; NE SW sec. 26-T.19S.-R.19E., Anderson County, KS

Elapsed time (off-bottom to canister)
= 0.246
= SQRT(0.061 hrs.)
= 3.6 min.

11cc estimated lost gas

FIGURE 8.
1113' to 1115' (Riverton "A" sieved sample -- >0.090") in canister 9
Meritage KCM Garrison #26-13 SWD; NE SW sec. 26-T.19S.-R.19E., Anderson County, KS.

Elapsed time (off-bottom to canister) = 0.379
= SQRT(0.144 hrs.)
= 8.6 min.

34cc estimated lost gas

FIGURE 9.
1113' to 1115' (Riverton "A" sieved sample -- <0.090"; >0.0661") in canister 5
Meritage KCM Garrison #26-13 SWD; NE SW sec. 26-T.19S.-R.19E., Anderson County, KS

elapsed time (off-bottom to canister)
= 0.454
= SQRT(0.206 hrs.)
= 12.4 min.

square root of hours since cuttings were off bottom

FIGURE 10.
1120' to 1122' (Riverton "B" coal) in canister A
Meritage KCM Garrison #26-13 SWD; NE SW sec. 26-T.19S.-R.19E., Anderson County, KS

Graph:
- Volume of desorbed gas (cc @ STP) vs. square root of hours since cuttings were off bottom
- Elapsed time (off-bottom to canister) = 0.220 = SQRT(0.049 hrs.) = 2.9 min.
- 14cc estimated lost gas

FIGURE 11.
Desorption Characteristics of Cuttings Samples
Meritage KCM #26-13 Garrison SWD; sec. NE NW 26-T.19S.-R.19E.; Anderson Co., KS

LITHOLOGIC COMPONENT SENSITIVITY ANALYSIS for calculation of gas content of Mulberry coal from 673-676'

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

\[
\text{total gas desorbed} = 181 \text{ ccs}
\]

TOTAL DRY WEIGHT OF SAMPLE = 275.08 grams

weight_{light-colored lithologies} = 96.68 grams (35.2%)
weight_{dark shale} = 14.37 grams (5.2%)
weight_{coal} = 164.03 grams (59.6%)

\[
\begin{array}{c|c|c|c|c}
\text{sieve size} & \text{grams} & \% \text{coal} / \% \text{dark shale} / \% \text{light-colored liths} \\
\hline
>0.0930" & 182.66 & 58.97% / 4.86% / 36.17% \\
>0.0661" & 63.21 & 63.01% / 6.51% / 30.48% \\
>0.0460" & 25.86 & 58.45% / 4.73% / 36.82% \\
>0.0331" & 2.68 & 37.65% / 4.71% / 57.65% \\
<0.0331" & 0.68 & 54.52% / 5.20% / 40.28% \\
\hline
\text{TOTAL} & 275.08 & & &
\end{array}
\]

Equation solutions

\[
\begin{array}{c|c|c}
\text{dark shale} & \text{coal} \\
\text{(scf/ton)} & \text{(scf/ton)} \\
0 & 35.3 \\
3 & 35.1 \\
5 & 34.8 \\
10 & 34.4 \\
15 & 34.0 \\
20 & 33.6 \\
30 & 32.7 \\
32.5 & 32.5 \\
\hline
\end{array}
\]

most likely gas content for dark shales?

(30 - 50 scf/ton)

FIGURE 12.
Desorption Characteristics of Cuttings Samples
Meritage KCM #26-13 Garrison SWD; sec. NE NW 26-T.19S.-R.19E.; Anderson Co., KS

LITHOLOGIC COMPONENT SENSITIVITY ANALYSIS for calculation of gas content of shale above Summit "coal" at 755-758'

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

Total gas desorbed = 32 ccs

TOTAL DRY WEIGHT OF SAMPLE = 459.87 grams
\[\begin{align*}
\text{weight}_{\text{light-colored lithologies}} &= 143.90 \text{ grams (31.3\%)} \\
\text{weight}_{\text{dark shale}} &= 315.97 \text{ grams (68.7\%)} \\
\text{weight}_{\text{coal}} &= 0.00 \text{ grams (0.0\%)}
\end{align*}\]

<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>334.12</td>
<td>0.00% / 74.28% / 25.72%</td>
</tr>
<tr>
<td>&gt;0.0661&quot;</td>
<td>72.43</td>
<td>0.00% / 48.84% / 51.16%</td>
</tr>
<tr>
<td>&gt;0.0460&quot;</td>
<td>26.60</td>
<td>0.00% / 58.27% / 41.73%</td>
</tr>
<tr>
<td>&gt;0.0331&quot;</td>
<td>8.36</td>
<td>0.00% / 66.22% / 33.78%</td>
</tr>
<tr>
<td>&lt;0.0331&quot;</td>
<td>18.36</td>
<td>0.00% / 61.90% / 38.10%</td>
</tr>
</tbody>
</table>

459.87 TOTAL

3.29 scf/ton ASSUMED GAS CONTENT (dark shale) scf/ton

FIGURE 13.
Desorption Characteristics of Cuttings Samples
Meritage KCM #26-13 Garrison SWD; sec. NE NW 26-T.19S.-R.19E.; Anderson Co., KS

LITHOLOGIC COMPONENT SENSITIVITY ANALYSIS for calculation of gas content of Summit "coal" at 760-762'

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

\[
\text{total gas desorbed} = 233 \text{ ccs}
\]

TOTAL DRY WEIGHT OF SAMPLE = 2420.65 grams
\[
\text{weight}_{\text{light-colored lithologies}} = 992.17 \text{ grams (41.0%)}
\]
\[
\text{weight}_{\text{dark shale}} = 1428.48 \text{ grams (59.0%)}
\]
\[
\text{weight}_{\text{coal}} = 0.00 \text{ grams (0.0%)}
\]

<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>1741.00</td>
<td>0.00% / 66.44% / 33.56%</td>
</tr>
<tr>
<td>&gt;0.0661&quot;</td>
<td>498.45</td>
<td>0.00% / 43.80% / 56.20%</td>
</tr>
<tr>
<td>&gt;0.0460&quot;</td>
<td>146.45</td>
<td>0.00% / 28.72% / 71.28%</td>
</tr>
<tr>
<td>&gt;0.0331&quot;</td>
<td>15.45</td>
<td>0.00% / 23.08% / 76.92%</td>
</tr>
<tr>
<td>&lt;0.0331&quot;</td>
<td>19.31</td>
<td>0.00% / 40.51% / 59.49%</td>
</tr>
</tbody>
</table>

\[
2420.65 \text{ TOTAL}
\]

5.23 scf/ton

FIGURE 14.
Desorption Characteristics of Cuttings Samples
Meritage KCM #26-13 Garrison SWD; sec. NE NW 26-T.19S.-R.19E.; Anderson Co., KS

LITHOLOGIC COMPONENT SENSITIVITY ANALYSIS for calculation of gas content of Bevier coal from 853-855'

GAS CONTENT$_{coal}$ =

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

\[
\text{total gas desorbed} = 109 \text{ ccs}
\]

TOTAL DRY WEIGHT OF SAMPLE = 1356.35 grams

\[
\text{weight}_{\text{light-colored lithologies}} = 808.80 \text{ grams (59.6%)}
\]

\[
\text{weight}_{\text{dark shale}} = 421.78 \text{ grams (31.1%)}
\]

\[
\text{weight}_{\text{coal}} = 125.77 \text{ grams (9.3%)}
\]

<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>1018.83</td>
<td>8.97% / 31.84% / 59.18%</td>
</tr>
<tr>
<td>&gt;0.0661&quot;</td>
<td>178.93</td>
<td>13.07% / 34.24% / 52.68%</td>
</tr>
<tr>
<td>&gt;0.0460&quot;</td>
<td>74.43</td>
<td>7.53% / 24.00% / 68.47%</td>
</tr>
<tr>
<td>&gt;0.0331&quot;</td>
<td>26.43</td>
<td>2.68% / 12.75% / 84.56%</td>
</tr>
<tr>
<td>&lt;0.0331&quot;</td>
<td>38.23</td>
<td>8.06% / 25.71% / 66.23%</td>
</tr>
</tbody>
</table>

1356.35 TOTAL

Equation solutions

\[
\begin{array}{cccc}
\text{dark shale} & \text{coal} \\
\text{(scf/ton)} & \text{(scf/ton)} \\
0 & 27.8 \\
1 & 24.4 \\
2 & 21.1 \\
3 & 17.7 \\
4 & 14.4 \\
5 & 11.0 \\
6 & 7.7 \\
6.4 & 6.4 \\
\end{array}
\]

FIGURE 15.
Desorption Characteristics of Cuttings Samples
Meritage KCM #26-13 Garrison SWD; sec. NE NW 26-T.19S.-R.19E.; Anderson Co., KS

LITHOLOGIC COMPONENT SENSITIVITY ANALYSIS for calculation of gas content of Mineral coal from 898-900'

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

total gas desorbed = 40 ccs

TOTAL DRY WEIGHT OF SAMPLE = 924.47 grams

\text{weight}_{\text{light-colored lithologies}} = 620.57 grams (67.1%)
\text{weight}_{\text{dark shale}} = 262.61 grams (28.4%)
\text{weight}_{\text{coal}} = 41.29 grams (4.5%)

<table>
<thead>
<tr>
<th>sieve size (mm)</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>543.28</td>
<td>4.60%</td>
<td>33.65%</td>
<td>61.76%</td>
</tr>
<tr>
<td>&gt;0.0661&quot;</td>
<td>237.99</td>
<td>4.58%</td>
<td>21.23%</td>
<td>74.19%</td>
</tr>
<tr>
<td>&gt;0.0460&quot;</td>
<td>107.79</td>
<td>3.76%</td>
<td>20.45%</td>
<td>75.79%</td>
</tr>
<tr>
<td>&gt;0.0331&quot;</td>
<td>16.31</td>
<td>3.64%</td>
<td>17.27%</td>
<td>79.09%</td>
</tr>
<tr>
<td>&lt;0.0331&quot;</td>
<td>19.10</td>
<td>4.14%</td>
<td>23.15%</td>
<td>72.71%</td>
</tr>
</tbody>
</table>

924.47 TOTAL

FIGURE 16.
Desorption Characteristics of Cuttings Samples
Meritage KCM #26-13 Garrison SWD; sec. NE NW 26-T.19S.-R.19E.; Anderson Co., KS

LITHOLOGIC COMPONENT SENSITIVITY ANALYSIS for calculation of gas content of Riverton "A" coal from 1108-1110'

GAS CONTENT\textsubscript{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 = 141 ccs

TOTAL DRY WEIGHT OF SAMPLE = 622.35 grams
weight\textsubscript{light-colored lithologies} = 352.41 grams (56.6%)
weight\textsubscript{dark shale} = 223.22 grams (35.9%)
weight\textsubscript{coal} = 46.73 grams (7.5%)

sieve size | grams | % coal / % dark shale / % light-colored liths
---|---|---
>0.0930" | 425.50 | 4.85% / 36.37% / 58.78%
>0.0661" | 135.67 | 13.79% / 36.08% / 50.13%
>0.0460" | 51.11 | 12.24% / 32.05% / 55.72%
>0.0331" | 8.84 | 11.21% / 30.84% / 57.94%
<0.0331" | 1.24 | 10.52% / 33.83% / 55.64%

622.35 TOTAL

FIGURE 17.
Desorption Characteristics of Cuttings Samples  
Meritage KCM #26-13 Garrison SWD; sec. NE NW 26-T.19S.-R.19E.; Anderson Co., KS

LITHOLOGIC COMPONENT SENSITIVITY ANALYSIS for calculation of gas content of sieved Riverton coal from 1113-1115'

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

SIEVED CUTTINGS (COARSE FRACTION)  
>0.0930‘’  
(total gas desorbed = 393 ccs  
TOTAL DRY WEIGHT OF SAMPLE = 1011.36 grams  
weight$_{\text{light-colored lithologies}}$ = 267.89 grams (26.5%)  
weight$_{\text{dark shale}}$ = 628.67 grams (62.2%)  
weight$_{\text{coal}}$ = 114.81 grams (11.4%)  

SIEVED CUTTINGS (FINE FRACTION)  
<0.0930’’ and >0.0661’’  
(total gas desorbed = 73 ccs  
TOTAL DRY WEIGHT OF SAMPLE = 126.07 grams  
weight$_{\text{light-colored lithologies}}$ = 48.60 grams (38.6%)  
weight$_{\text{dark shale}}$ = 52.80 grams (41.9%)  
weight$_{\text{coal}}$ = 24.67 grams (19.6%)  

FIGURE 18.
Desorption Characteristics of Cuttings Samples
Meritage KCM #26-13 Garrison SWD; sec. NE NW 26-T.19S.-R.19E.; Anderson Co., KS

LITHOLOGIC COMPONENT SENSITIVITY ANALYSIS for calculation of gas content of Riverton coal from 1120-1122'

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

\begin{align*}
\text{total gas desorbed} & = 64 \text{ ccs} \\
\text{TOTAL DRY WEIGHT OF SAMPLE} & = 456.21 \text{ grams} \\
\text{weight}\text{\textsubscript{light-colored lithologies}} & = 257.54 \text{ grams (56.5\%)} \\
\text{weight}\text{\textsubscript{dark shale}} & = 192.87 \text{ grams (42.3\%)} \\
\text{weight}\text{\textsubscript{coal}} & = 5.80 \text{ grams (1.3\%)}
\end{align*}

\begin{tabular}{|c|c|c|c|c|}
\hline
\text{sieve size} & \text{grams} & \% \text{coal} / \% \text{dark shale} / \% \text{light-colored liths} \\
\hline
>0.0930" & 322.58 & 0.78\% / 41.04\% / 58.18\% \\
>0.0661" & 93.30 & 1.68\% / 45.31\% / 53.02\% \\
>0.0460" & 33.27 & 3.49\% / 46.51\% / 50.00\% \\
>0.0331" & 5.34 & 7.35\% / 38.24\% / 54.41\% \\
<0.0331" & 1.73 & 10.00\% / 40.00\% / 50.00\% \\
\hline
\text{456.21 TOTAL} & & & & \\
\end{tabular}

\begin{align*}
\text{Equation solutions} & \\
\text{dark shale} & \text{coal} \\
0 & 353.8 \\
1 & 320.5 \\
3 & 240.0 \\
5 & 187.5 \\
7 & 120.9 \\
9 & 54.4 \\
10 & 21.1 \\
10.3 & 10.3
\end{align*}

\text{FIGURE 19.}

\text{likely minimum gas content for coal; likely maximum gas content for dark shale}
\text{calculated gas-content range for coals (-644 to -1309 scf/ton)}
\text{assuming most likely(?) gas content for dark shales? (30 - 50 scf/ton)}
\text{most likely gas content for dark shales? (30 - 50 scf/ton)}
Desorption Characteristics of Cuttings Samples
Meritage KCM #26-13 Garrison SWD; sec. NE NW 26-T.19S.-R.19E.; Anderson Co., KS

LITHOLOGIC COMPONENT SENSITIVITY ANALYSIS for gas content of Riverton cuttings samples at 1108-1110', 1113-1150', & 1120-1122'

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

1108-1110' Riverton cuttings sample
- total gas desorbed = 141 ccs
- TOTAL DRY WEIGHT OF SAMPLE = 622.35 grams
- weight_{light-colored lithologies} = 352.41 grams (56.6%)
- weight_{dark shale} = 223.22 grams (35.9%)
- weight_{coal} = 46.73 grams (7.5%)

1113-1115' Riverton cuttings samples
- total gas desorbed = 466 ccs
- TOTAL DRY WEIGHT OF SAMPLE = 456.21 grams
- weight_{light-colored lithologies} = 316.49 grams (27.8%)
- weight_{dark shale} = 681.47 grams (59.9%)
- weight_{coal} = 139.48 grams (12.3%)

1120-1122' Riverton cuttings sample
- total gas desorbed = 64 ccs
- TOTAL DRY WEIGHT OF SAMPLE = 456.21 grams
- weight_{light-colored lithologies} = 257.80 grams (56.5%)
- weight_{dark shale} = 192.87 grams (42.3%)
- weight_{coal} = 5.80 grams (1.3%)

FIGURE 20.
Desorption Characteristics of Cuttings Samples
Meritage KCM #26-13 Garrison SWD; sec. NE NW 26-T.19S.-R.19E.; Anderson Co., KS

LITHOLOGIC COMPONENT SENSITIVITY ANALYSIS for all samples

<table>
<thead>
<tr>
<th>UNIT</th>
<th>coal in sample</th>
<th>scf/ton w/ shale @ 3 scf/ton</th>
<th>maximum scf/ton</th>
<th>minimum scf/ton</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mulberry</td>
<td>60%</td>
<td>35.1</td>
<td>35.3</td>
<td>32.5</td>
</tr>
<tr>
<td>shale</td>
<td>0%</td>
<td>---</td>
<td>3.3</td>
<td>3.3</td>
</tr>
<tr>
<td>Summit</td>
<td>0%</td>
<td>---</td>
<td>5.2</td>
<td>5.2</td>
</tr>
<tr>
<td>Bevier</td>
<td>9%</td>
<td>17.7</td>
<td>27.8</td>
<td>16.7</td>
</tr>
<tr>
<td>Mineral</td>
<td>5%</td>
<td>12.2</td>
<td>31.3</td>
<td>4.2</td>
</tr>
<tr>
<td>Riverton &quot;A&quot;</td>
<td>8%</td>
<td>82.0</td>
<td>96.4</td>
<td>16.7</td>
</tr>
<tr>
<td>Riverton &quot;A&quot; (cs)</td>
<td>20%</td>
<td>88.3</td>
<td>94.7</td>
<td>30.2</td>
</tr>
<tr>
<td>Riverton &quot;A&quot; (ln)</td>
<td>11%</td>
<td>93.2</td>
<td>109.7</td>
<td>16.9</td>
</tr>
<tr>
<td>Riverton &quot;B&quot;</td>
<td>1%</td>
<td>240.0</td>
<td>353.8</td>
<td>10.3</td>
</tr>
</tbody>
</table>

FIGURE 21.
Desorption Characteristics of Cuttings Samples (ie., coal & dark shale)
Meritage KCM #26-13 Garrison SWD; NE SW sec. 26-T.19S.-R.19E., Anderson County, KS

FIGURE 22.