ANALYSIS OF KANSAS CITY, MARMATON, AND CHEROKEE GROUP
CUTTINGS AND CORE SAMPLES FOR GAS CONTENT
-- PETROL OIL & GAS #7-1 TRULOVE
NW NW SE, sec. 7-T.21S.-R.14E., COFFEY COUNTY, KANSAS

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SUMMARY

Four cuttings and six core samples from the Pennsylvanian Kansas City, Marmaton, and Cherokee Groups were collected from the Petrol Oil & Gas #7-1 Trulove, NW NW SE, sec. 7-T.21S.-R.14E., in Coffey Co., KS. The samples calculate as having the following gas contents:

- CORE -- shale seam in Bethany Falls Ls.; 1051.0'-1051.6' (3.4 scf/ton)
- CORE -- Hushpuckney Shale; 1057.0'-1057.6' (3.1 scf/ton)
- CUTTINGS -- Lake Neosho Shale; 1264' to 1268' (8 scf/ton)
- CUTTINGS -- Anna Shale; 1324' to 1326' (8 scf/ton)
- CORE -- "V shale"; 1482.7' to 1483.6' (25.6 scf/ton)
- CORE -- Croweburg coal; 1483.6' to 1484.5' (101.8 scf/ton)
- CORE -- shale above Tebo coal; 1552.7' to 1553.5' (3.3 scf/ton)
- CORE -- Tebo coal; 1556.1' to 1556.8' (68.0 scf/ton)
- CUTTINGS -- Riverton coal; 1728' to 1731' (large sample) \(^1\) (125 scf/ton)
- CUTTINGS -- Riverton coal; 1728' to 1731' (small sample) \(^1\) (135 scf/ton)

\(^1\) assuming accompanying dark shales in sample desorb 3 scf/ton

The Riverton coal assays to be a high-volatile B bituminous coal. Chemical analysis of the gas indicates that it is a low-BTU gas, with mixed-biogenic-and-thermogenic origin.

BACKGROUND

The Petrol Oil & Gas Trulove well, NW NW SE, sec. 7-T.21S.-R.14E., in Coffey Co., KS, was selected for cuttings desorption tests in association with an ongoing coalbed gas research project at the Kansas Geological Survey. The samples were gathered January 8, 9, and 10, 2004, by K. David Newell and Troy Johnson of the Kansas Geological Survey. Cuttings samples were obtained during normal drilling of the well, with brief cessation of drilling before zones of interest (i.e., coals and dark shales in the Pennsylvanian Kansas City, Marmaton, and Cherokee Groups) were penetrated. The well was drilled using a mud rotary rig ("Rig #9") owned by Coconut Drilling.

Lag times for samples to reach the surface (important for assessing lost gas) were determined by periodic carbide tests.

Four cuttings samples were collected:
- Lake Neosho Shale; 1264' to 1268' (459 grams dry wt.)
- Anna Shale; 1324' to 1326' (422 grams dry wt.)
- Riverton coal; 1728' to 1731' (large sample) (920 grams dry wt.)
- Riverton coal; 1728' to 1731' (small sample) (311 grams dry wt.)

Six core samples were also collected:
- shale seam in Bethany Falls Ls.; 1051.0'-1051.6' (741.2 grams dry wt.)
- Hushpuckney Shale; 1057.0'-1057.6' (2625.6 grams dry wt.)
• "V shale"; 1482.7' to 1483.6' (3241.3 grams dry wt.)
• Croweburg coal; 1483.6' to 1484.5' (1107.5 grams dry wt.)
• shale above Tebo coal; 1552.7' to 1553.5' (3973.2 grams dry wt.)
• Tebo coal; 1556.1' to 1556.8' (1968.6 grams dry wt.)

The cuttings were placed in kitchen strainers after they were shoveled from a settling box in the mud stream situated immediately before the mud emptied into the mud pit. After catching the cuttings samples, the samples were washed in water while in the kitchen strainers to rid them of as much drilling mud as possible. The cuttings were then placed in desorption canisters.

The core samples was also obtained by a conventional coring technique, with time off bottom and at the surface noted.

Two samples (Lake Neosho Shale, Anna Shale) were placed in "Stoeckinger" desorption canisters, which average 38 cubic inches internal volume (620 cm$^3$). The other samples were placed in canisters with approximately 153 cubic inches internal volume (2985 cm$^3$).

The "Stoeckinger" desorption canisters were obtained from Bill Stoeckinger, consulting geologist to Petrol Oil and Gas. The other canisters were obtained from SSD, Inc., in Grand Junction, CO., or Pel-I-Cans in Dallas, TX.

Temperature baths for the desorption canisters were on site, with temperature kept at approximately 75 °F for the Croweburg and shallower samples. The Tebo and Riverton samples were placed in an 80 °F temperature bath. The canistered samples were transported to the laboratory at the Kansas Geological Survey in Lawrence, KS on January 10, 2004, and desorption measurements were continued at approximately the same temperature. 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 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. 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:

\[ \left( \frac{P_{\text{stp}}V_{\text{stp}}}{RT_{\text{stp}}} \right) = \left( \frac{P_{\text{rig}}V_{\text{rig}}}{RT_{\text{rig}}} \right) \]

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:

\[ V_{\text{stp}} = \left( \frac{T_{\text{stp}}}{T_{\text{rig}}} \right) \left( \frac{P_{\text{rig}}}{P_{\text{stp}}} \right) V_{\text{rig}} \]

The conversion calculations in the spreadsheet were carried out in the English metric system, 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 (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 the moment that the rock is cut and its cuttings 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 surface 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

Upon removal from the canisters, the cuttings were washed of drilling mud and dried in air for several 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) 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 cuttings sample, 4) a summary component analysis for all samples showing relative reliability of the data from all the samples, and 5) a desorption graph for 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.

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Lost-Gas Graphs (Figures 2-11)
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 is usually lost within the first hour after the cuttings leave the bottom of the hole, thus data for cuttings are presented in the lost-gas graphs for only up to one hour after cuttings were off bottom. Lost-gas for the core samples were posted for a 9-hour period after the core was pulled off bottom. The lost-gas volumes derived from these graphs are incorporated in the data tables described above.

"Lithologic Component Sensitivity Analyses" (Figures 12-14)
Collection of pure lithologies from relatively thin-bedded strata is rather difficult using cuttings. 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:

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

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 vice 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.
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 wells in southeastern Kansas. 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 displaying 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, the assumed shale gas content does not have to be very much greater than 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.

Desorption Graphs (Figures 15, 16)
These are desorption graphs (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. Core and cuttings data are presented on separate graphs.

Gas Chemistry (Figure 17)
Gas isotopic chemistry is compared to similar analyses on other nearby conventional and coalbed gases.

ASHING and DENSITY EXPERIMENTS

Simple ashing of the samples was carried out in a muffle furnace at the Kansas Geological Survey. The samples were first weighed and then subjected to 110 °C until their weight stabilized. This first firing approximates moisture content. A second firing at 750 °C for three to four days essentially ashed the sample. Two crucibles of sample were utilized for both the 110 °C and 750 °C firings. Each crucible was filled with approximately 1.5 grams of pulverized coal (i.e., < 0.0460" sieve size). Results were accepted if the difference in weight loss for each sample was less than 2%.

<table>
<thead>
<tr>
<th>unit</th>
<th>depth</th>
<th>moisture</th>
<th>ash</th>
<th>moisture-free ash</th>
</tr>
</thead>
<tbody>
<tr>
<td>shale in B. Falls Ls.</td>
<td>1051'</td>
<td>0.73%</td>
<td>83.37%</td>
<td>83.98%</td>
</tr>
<tr>
<td>Hushpuckney Shale</td>
<td>1057'</td>
<td>1.04%</td>
<td>91.03%</td>
<td>91.98%</td>
</tr>
<tr>
<td>Lake Neosho Shale</td>
<td>1264'</td>
<td>0.88%</td>
<td>79.96%</td>
<td>80.67%</td>
</tr>
<tr>
<td>Anna Shale</td>
<td>1324'</td>
<td>0.94%</td>
<td>77.37%</td>
<td>78.10%</td>
</tr>
<tr>
<td>&quot;V shale&quot;</td>
<td>1483'</td>
<td>1.1%</td>
<td>77.6%</td>
<td>78.4%</td>
</tr>
<tr>
<td>Croweburg coal</td>
<td>1484'</td>
<td>1.02%</td>
<td>7.67%</td>
<td>7.75%</td>
</tr>
</tbody>
</table>
shale over Tebo coal 1553' 1.44% 90.00% 91.31%
Tebo coal 1556' 2.70% 35.75% 36.74%
Riverton large smpl 1728' 2.23% 7.59% 7.76%
Riverton small smpl 1728' 1.91% 6.35% 6.47%

1 source of data for ashing and moisture are proximate analyses from Luman's Laboratories, Chetopa, KS

Using the equation from McLennan and others (1995):

\[ G_e = G_{pc} (1-a_d) \]

where:
- \( G_e \) = gas content, scf/ton
- \( G_{pc} \) = "pure coal", gas content, scf/ton
- \( a_d \) = dry ash content, weight fraction

the gas content of the samples converts to:

<table>
<thead>
<tr>
<th>unit</th>
<th>depth</th>
<th>moisture-free ash</th>
<th>( G_e )</th>
<th>( G_{pc} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>shale in B. Falls Ls.</td>
<td>1051'</td>
<td>83.98%</td>
<td>4.0 scf/ton</td>
<td>21.2 scf/ton</td>
</tr>
<tr>
<td>Hushpuckney Shale</td>
<td>1057'</td>
<td>91.98%</td>
<td>3.1 scf/ton</td>
<td>38.7 scf/ton</td>
</tr>
<tr>
<td>Lake Neosho Shale</td>
<td>1264'</td>
<td>80.67%</td>
<td>8 scf/ton</td>
<td>42 scf/ton</td>
</tr>
<tr>
<td>Anna Shale</td>
<td>1324'</td>
<td>78.10%</td>
<td>8 scf/ton</td>
<td>37 scf/ton</td>
</tr>
<tr>
<td>&quot;V shale&quot;</td>
<td>1483'</td>
<td>78.4%</td>
<td>25.6 scf/ton</td>
<td>118.5 scf/ton</td>
</tr>
<tr>
<td>Croweburg coal</td>
<td>1484'</td>
<td>7.75%</td>
<td>101.8 scf/ton</td>
<td>110.4 scf/ton</td>
</tr>
<tr>
<td>shale over Tebo coal</td>
<td>1553'</td>
<td>91.31%</td>
<td>3.3 scf/ton</td>
<td>26.4 scf/ton</td>
</tr>
<tr>
<td>Tebo coal</td>
<td>1556'</td>
<td>36.74%</td>
<td>68.0 scf/ton</td>
<td>107.5 scf/ton</td>
</tr>
<tr>
<td>Riverton large smpl</td>
<td>1728'</td>
<td>7.59%</td>
<td>125 scf/ton</td>
<td>136 scf/ton</td>
</tr>
<tr>
<td>Riverton small smpl</td>
<td>1728'</td>
<td>6.47%</td>
<td>135 scf/ton</td>
<td>145 scf/ton</td>
</tr>
</tbody>
</table>

Coal samples were also tested for their density. Cuttings samples (4 to 5 grams) were weighed and then placed in water in a 10-cc graduated cylinder to determine the volume of the sample. The core samples were weighed and immersed in water in a beaker filled to its brim. With placing the sample in the beaker, the displaced water was spilled from the beaker and subsequently weighed. The volume of the sample is thus easily converted to volume using 1 gram/cc for the density of the water. The following density measurements were calculated:

<table>
<thead>
<tr>
<th>unit</th>
<th>depth</th>
<th>density and uncertainty</th>
</tr>
</thead>
<tbody>
<tr>
<td>shale in Bethany Falls Ls.</td>
<td>1051'</td>
<td>2.50 g/cc ± 0.06</td>
</tr>
<tr>
<td>Hushpuckney Shale</td>
<td>1057'</td>
<td>2.44 g/cc ± 0.01</td>
</tr>
<tr>
<td>Lake Neosho Shale</td>
<td>1264'</td>
<td>2.38 g/cc ± 0.07</td>
</tr>
<tr>
<td>Anna Shale</td>
<td>1324'</td>
<td>2.39 g/cc ± 0.07</td>
</tr>
<tr>
<td>&quot;V shale&quot;</td>
<td>1483'</td>
<td>2.08 g/cc ± 0.05</td>
</tr>
<tr>
<td>Croweburg coal</td>
<td>1484'</td>
<td>1.36 g/cc ± 0.03</td>
</tr>
</tbody>
</table>
I

shale over Tebo coal 1553' 2.49 g/cc ± 0.24
Tebo coal 1556' 1.67 g/cc ± 0.07
Riverton large smpl 1728' 1.26 g/cc ± 0.07
Riverton small smpl 1728' 1.26 g/cc ± 0.07

Compositional and isotopic chemistry were performed on a gas sample from the "large sample" of the Riverton coal. This analysis was performed by Isotech Laboratories in Champaign, IL. The sample was taken after desorption ceased and consisted of headspace gas in the canister.

**Isotopic Analyses**

<table>
<thead>
<tr>
<th>Analysis</th>
<th>Riverton (1728')</th>
</tr>
</thead>
<tbody>
<tr>
<td>δ¹³CO₂</td>
<td>2.27</td>
</tr>
<tr>
<td>δ¹³C_methane</td>
<td>-55.29</td>
</tr>
<tr>
<td>δDC_methane</td>
<td>-247.7</td>
</tr>
<tr>
<td>δ¹³C_ethane</td>
<td>-19.00</td>
</tr>
</tbody>
</table>

**Chemical Analyses (as reported; red = hydrocarbons; blue = non hydrocarbons, green = oxygen)**

<table>
<thead>
<tr>
<th>Component</th>
<th>(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methane</td>
<td>67.38</td>
</tr>
<tr>
<td>Ethane</td>
<td>0.452</td>
</tr>
<tr>
<td>Propane</td>
<td>0.0482</td>
</tr>
<tr>
<td>n-Butane</td>
<td>0.0055</td>
</tr>
<tr>
<td>iso-Butane</td>
<td>0.0134</td>
</tr>
<tr>
<td>n-Pentane</td>
<td>0.0000</td>
</tr>
<tr>
<td>iso-Pentane</td>
<td>0.0000</td>
</tr>
<tr>
<td>Hexane+</td>
<td>0.0039</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>29.00</td>
</tr>
<tr>
<td>Oxygen</td>
<td>0.488</td>
</tr>
<tr>
<td>Argon</td>
<td>0.272</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>0.0000</td>
</tr>
<tr>
<td>Carbon Dioxide</td>
<td>2.33</td>
</tr>
<tr>
<td>Helium</td>
<td>0.0027</td>
</tr>
</tbody>
</table>

**Chemical Analyses (recalculated after removing atmospheric contamination; red = hydrocarbons; blue = non hydrocarbons)**

<table>
<thead>
<tr>
<th>Component (%)</th>
<th>Riverton</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methane</td>
<td>69.00</td>
</tr>
<tr>
<td>Ethane</td>
<td>0.463</td>
</tr>
<tr>
<td>Propane</td>
<td>0.0494</td>
</tr>
<tr>
<td>n-Butane</td>
<td>0.0060</td>
</tr>
<tr>
<td>iso-Butane</td>
<td>0.0140</td>
</tr>
<tr>
<td>n-Pentane</td>
<td>0.0000</td>
</tr>
<tr>
<td>iso-Pentane</td>
<td>0.0000</td>
</tr>
<tr>
<td>Chemical</td>
<td>Percentage</td>
</tr>
<tr>
<td>----------------</td>
<td>------------</td>
</tr>
<tr>
<td>Hexane+</td>
<td>0.0040</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>27.83</td>
</tr>
<tr>
<td>Argon</td>
<td>0.260</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>0.0000</td>
</tr>
<tr>
<td>Carbon Dioxide</td>
<td>2.38</td>
</tr>
<tr>
<td>Helium</td>
<td>0.0028</td>
</tr>
</tbody>
</table>

'atmospheric component (based on oxygen content and atmospheric ratio of other gases to oxygen) subtracted from the analysis, with components recalculated to 100%.

### Other Chemical Data

<table>
<thead>
<tr>
<th>Component</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Riverton</td>
<td></td>
</tr>
<tr>
<td>Calculated BTU</td>
<td>740</td>
</tr>
<tr>
<td>Total % non-HCs</td>
<td>30.48</td>
</tr>
<tr>
<td>HC Wetness (%)</td>
<td>0.77</td>
</tr>
</tbody>
</table>

Plotting of the isotopes and gas wetness (Figure 17) indicates that the gas is of mixed biogenic and thermogenic origin. The large quantity of admixed non-hydrocarbon gases indicates that the gas produced will be a low-BTU gas (<950 BTU).

### RESULTS and DISCUSSION

Proximate analyses were made for the Riverton coal samples. The proximate analyses were performed on the following samples by Luman's Laboratory (see Appendix 1):

<table>
<thead>
<tr>
<th>Unit</th>
<th>Moisture</th>
<th>Ash</th>
<th>Moisture-free Ash</th>
</tr>
</thead>
<tbody>
<tr>
<td>Riverton large smpl</td>
<td>2.23%</td>
<td>7.59%</td>
<td>7.76%</td>
</tr>
<tr>
<td>Riverton small smpl</td>
<td>1.91%</td>
<td>6.35%</td>
<td>6.47%</td>
</tr>
</tbody>
</table>

According to the BTU/lb. (dry, ash-free) determinations, all the samples can be classified as high-volatile B bituminous coal.

The Riverton samples, even though they were from cuttings, registered good gas content. Two samples of cuttings, designated the "large" and "small" samples, were taken from this zone. The "small sample" had a markedly greater gas content (scf/ton) than the "large sample" 157.3 scf/ton vs. 125.8 scf/ton, based on the weight of coal calculated in the sample, even though the physical attributes of the samples were virtually identical. Upon examination of the desorption curves (Figure 15) the "small sample" shows an increase in gas generation in its later stages of desorption. This indicates a late-stage biogenic gas being produced in the desorption process. Using a curve based on the larger of the two samples, the gas content of the "small sample" (not counting residual) is likely closer to 136 scf/ton rather than 157 scf/ton.

### REFERENCES

FIGURES and TABLES

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

TABLE 1. Desorption measurements for samples.

FIGURE 2. Lost-gas graph for shale seam in Bethany Falls Ls.; 1051.0'-1051.6'.
FIGURE 3. Lost-gas graph for Hushpuckney Shale; 1057.0'-1057.6'.
FIGURE 4. Lost-gas graph for Lake Neosho Shale; 1264' to 1268'.
FIGURE 5. Lost-gas graph for Anna Shale; 1324' to 1326'.
FIGURE 6. Lost-gas graph for "V shale"; 1482.7' to 1483.6'.
FIGURE 7. Lost-gas graph for Croweburg coal; 1483.6' to 1484.5'.
FIGURE 8. Lost-gas graph for shale above Tebo coal; 1552.7' to 1553.5'.
FIGURE 9. Lost-gas graph for Tebo coal; 1556.1' to 1556.8'.
FIGURE 10. Lost-gas graph for Riverton coal; 1728' to 1731' (large sample).
FIGURE 11. Lost-gas graph for Riverton coal; 1728' to 1731' (small sample).

FIGURE 12. Sensitivity analysis for Lake Neosho Shale; 1264' to 1268'.
FIGURE 13. Sensitivity analysis for Anna Shale; 1324' to 1326'.
FIGURE 14. Sensitivity analysis for Riverton coal; 1728' to 1731'.

FIGURE 15. Desorption graph for cuttings samples.
FIGURE 16. Desorption graph for core samples.

FIGURE 17. Crossplot of isotopes and wetness for the Riverton gas.

APPENDIX 1. Float/sink and proximate analyses for the two Riverton samples.
Correlation of Field Barometer to KGS Petrophysics Lab Barometer

Oregon Scientific Field Barometer (mbars normalized to sea level)

FIGURE 1.
<table>
<thead>
<tr>
<th>SAMPLE</th>
<th>Description measurements for Petrol Oil &amp; Gas #1-19 Trulove, NW NW SE15-14E, Coffey Co., KS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Table 1</td>
<td>---</td>
</tr>
</tbody>
</table>

**Gas #7-1 Trulove, NW NW SE 7-21S-14E, Coffey canister MER 3**

- **Percent moisture:** 0.5
- **Gas lost (cc):** 0.0

**Notes:**
- **Dry gas:** 2217
- **Absolute T (°F):** 1079
- **Relative T (°F):** 1057
- **Time:** 0.49
- **Volume:** 0.316

**DECANISTERED 6/5/2004, sample dried 8 days in air**

---

**Table:**

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>Description measurements for Petrol Oil &amp; Gas #1-19 Trulove, NW NW SE15-14E, Coffey Co., KS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Table 1</td>
<td>---</td>
</tr>
</tbody>
</table>

**DECANISTERED 6/5/2004, sample dried 8 days in air**

---

**Table:**

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>Description measurements for Petrol Oil &amp; Gas #1-19 Trulove, NW NW SE15-14E, Coffey Co., KS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Table 1</td>
<td>---</td>
</tr>
<tr>
<td>Sample</td>
<td>Date</td>
</tr>
<tr>
<td>--------</td>
<td>------</td>
</tr>
<tr>
<td>1280 ft</td>
<td>12/30</td>
</tr>
<tr>
<td>1283 ft</td>
<td>12/30</td>
</tr>
<tr>
<td>1286 ft</td>
<td>12/30</td>
</tr>
<tr>
<td>1289 ft</td>
<td>12/30</td>
</tr>
</tbody>
</table>

**Note:**
- The measurements are taken at the surface and converted to standard temperature and pressure (STP) conditions.
- The correction factor is applied to correct for the volume at surface conditions to STP conditions.

**Additional Observations:**
- The gas is estimated to be lost at the rate of 0.001% per hour.
- The elapsed time to reach the STP condition is calculated based on the time elapsed since the start of the measurement.

**Sample Preparation:**
- The samples are prepared by cutting them from the shale formation.
- The shale is cut into canisters for further analysis.

**Conversion Factors:**
- The volume measurements are converted from cubic feet (ft³) to cubic meters (m³) and cubic inches (in³) as needed.

**Data Source:**
- The data is sourced from the field observations and recorded in the field notes.

**References:**
- Additional references are provided in the documents for further reading.

**Table:**
- The table includes columns for sample number, date, time, temperature, pressure, volume, and correction factor.
- The data is presented in a clear and organized manner to facilitate easy reading and analysis.

**Additional Notes:**
- The data is subject to further analysis and may require additional corrections.
- The results are presented in a format that is easy to interpret and use in further studies.

**Conclusion:**
- The data provides valuable insights into the properties of the shale formation and can be used to inform decisions regarding further exploration and extraction.

---

<table>
<thead>
<tr>
<th>Sample</th>
<th>Date</th>
<th>Time</th>
<th>Temperature</th>
<th>Pressure</th>
<th>Volume</th>
<th>Correction Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>1280 ft</td>
<td>12/30</td>
<td>8:18</td>
<td>310°F</td>
<td>14.2 psia</td>
<td>11.1 ft³</td>
<td>0.995</td>
</tr>
<tr>
<td>1283 ft</td>
<td>12/30</td>
<td>8:18</td>
<td>315°F</td>
<td>14.2 psia</td>
<td>11.1 ft³</td>
<td>0.995</td>
</tr>
<tr>
<td>1286 ft</td>
<td>12/30</td>
<td>8:18</td>
<td>320°F</td>
<td>14.2 psia</td>
<td>11.1 ft³</td>
<td>0.995</td>
</tr>
<tr>
<td>1289 ft</td>
<td>12/30</td>
<td>8:18</td>
<td>325°F</td>
<td>14.2 psia</td>
<td>11.1 ft³</td>
<td>0.995</td>
</tr>
</tbody>
</table>

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- The results are presented in a format that is easy to interpret and use in further studies.

**Conclusion:**
- The data provides valuable insights into the properties of the shale formation and can be used to inform decisions regarding further exploration and extraction.
<table>
<thead>
<tr>
<th>Sample</th>
<th>1555 T to 1555.5 °C (Tabo schist) core in canister 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>dry sample weight:</td>
<td>3.430</td>
</tr>
<tr>
<td>wet sample weight:</td>
<td>3.430</td>
</tr>
<tr>
<td>water weight:</td>
<td>3.430</td>
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</tbody>
</table>

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<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>dry sample weight:</td>
<td>8.759</td>
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<tr>
<td>wet sample weight:</td>
<td>8.759</td>
</tr>
<tr>
<td>water weight:</td>
<td>8.759</td>
</tr>
</tbody>
</table>

**OIL SAMPLES**

- **Sample A**: 5.41 g of sample A was placed in a canister and dried at 110°C for 24 hours. The sample was then placed in a 50°C oven for 1 hour and stored at room temperature until analyzed.
- **Sample B**: 5.42 g of sample B was placed in a canister and dried at 110°C for 24 hours. The sample was then placed in a 50°C oven for 1 hour and stored at room temperature until analyzed.

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<thead>
<tr>
<th>Sample</th>
<th>Dry Sample Weight</th>
<th>Sample Height</th>
<th>Seed Loss (ac)</th>
<th>0.450</th>
<th>Time (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decanistea Sed 7/12/2004</td>
<td>1.035</td>
<td>97.89</td>
<td>0.450</td>
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<td></td>
</tr>
</tbody>
</table>

### Table: Conversion of Roland Measurements to SPOM (180 deg F, 1.75 psi)

<table>
<thead>
<tr>
<th>Conversion of Roland Measurements to SPOM (180 deg F, 1.75 psi)</th>
<th>Cumulative Volumes (in^3)</th>
<th>Seed Loss (ac)</th>
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<tr>
<td>---------------------------------------------------------------</td>
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<tr>
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<td>97.89</td>
<td>0.450</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
1051.0'-1051.6' (shale seam in Bethany Falls Ls.) core in canister MER 3
Petrol Oil & Gas #7-1 Trulove; NW NW SE 7-T.21S.-R.14E., Coffey County, KS

Figure 2.
1057.0'-1057.6' (Hushpuckney Shale) core in canister 4
Petrol Oil & Gas #7-1 Trulove; NW NW SE 7-T.21S.-R.14E., Coffey County, KS

elapsed time (cutting to canister)
= 1.439
= SQRT(2.071 hrs.)
= 124.3 min.

135cc (?) estimated lost gas

Figure 3.
1264' to 1268' (Lake Neosho Shale) cuttings in canister Stoeckinger #5
Petrol Oil & Gas #7-1 Trulove; NW NW SE 7-T.21S.-R.14E., Coffey County, KS

Figure 4.

20cc estimated lost gas

elapsed time (cutting to canister)
= 0.522
= SQRT(0.272 hrs.)
= 16.3 min.
1324' to 1326' (Lexington/Anna Shale) cuttings in canister Stoeckinger #1
Petrol Oil & Gas #7-1 Trulove; NW NW SE 7-T.21S.-R.14E., Coffey County, KS

Figure 5.
1482.7' to 1483.6' (V Shale) core in canister MER 2
Petrol Oil & Gas #7-1 Trulove; NW NW SE 7-T.21S.-R.14E., Coffey County, KS

elapsed time (cutting to canister)
= 1.538
= SQRT(2.367 hrs.)
= 142.0 min.

192cc estimated lost gas

Figure 6.
1483.6' to 1484.5' (Croweburg coal) core in canister MER 1
Petrol Oil & Gas #7-1 Trulove; NW NW SE 7-T.21S.-R.14E., Coffey County, KS

elapsed time (cutting to canister)
= 1.516
= SQRT(2.300 hrs.)
= 138.0 min.

480cc estimated lost gas

Figure 7.
1552.7' to 1553.5' ("Tebo shale") core in canister 8
Petrol Oil & Gas #7-1 Trulove; NW NW SE 7-T.21S.-R.14E., Coffey County, KS

elapsed time (cutting to canister)
= 1.708
= SQRT(2.917 hrs.)
= 175.0 min.

253cc estimated lost gas

Figure 2.

Figure 8.
1556.1' to 1556.8' (Tebo(?) coal) core in canister 6
Petrol Oil & Gas #7-1 Trulove; NW NW SE 7-T.21S.-R.14E., Coffey County, KS

elapsed time (cutting to canister)
= 1.580
= SQRT(2.496 hrs.)
= 149.7 min.

715cc estimated lost gas

Figure 9.
1728' to 1731' (Riverton coal) cuttings in canister 10
Petrol Oil & Gas #7-1 Trulove; NW NW SE 7-T.21S.-R.14E., Coffey County, KS

Elapsed time (off-bottom to canister)
= 0.632
= SQRT(0.400 hrs.)
= 24.0 min.

362cc estimated lost gas

Figure 10.
1728' to 1731' (Riverton coal) cuttings in canister MER Fe
Petrol Oil & Gas #7-1 Trulove; NW NW SE 7-T.21S.-R.14E., Coffey County, KS

![Graph](image)

**Figure 11.**

- Elapsed time (off-bottom to canister) = 0.645
- = SQRT(0.417 hrs.)
- = 25.0 min.

188cc estimated lost gas
Desorption Characteristics of Cuttings Samples
Petrol Oil & Gas #7-1 Trulove, NW NW SE 7-21S-14E, Coffey Co., KS

LITHOLOGIC COMPONENT SENSITIVITY ANALYSIS for calculation of gas content of Lake Neosho Shale from 1264-1268'

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

total gas desorbed = 38.4 ccs

TOTAL DRY WEIGHT OF SAMPLE = 458.69 grams

- weight of light-colored lithologies = 307.67 grams (67.1%)
- weight of dark shale = 151.02 grams (32.9%)
- weight of coal = 0.00 grams (0.0%)

\[
\begin{array}{c|c|c|c|c}
\text{sieve size} & \text{grams} & \% \text{coal} & \% \text{dark shale} & \% \text{light-colored liths} \\
\hline
>0.0930^* & 84.74 & 0.00\% & 62.05\% & 37.95\% \\
>0.0661^* & 94.81 & 0.00\% & 40.72\% & 59.28\% \\
>0.0460^* & 117.81 & 0.00\% & 31.28\% & 68.72\% \\
>0.0331^* & 75.05 & 0.00\% & 19.13\% & 80.87\% \\
<0.0331^* & 86.29 & 0.00\% & 10.00\% & 90.00\% \\
\hline
\text{458.69 TOTAL}
\end{array}
\]

\[
8.2 \text{ scf/ton}
\]

Figure 12.
Desorption Characteristics of Cuttings Samples
Petrol Oil & Gas #7-1 Trulove, NW NW SE 7-21S-14E, Coffey Co., KS

LITHOLOGIC COMPONENT SENSITIVITY ANALYSIS for calculation of gas content of Anna Shale from 1324-1326'

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

total gas desorbed = 65.1 ccs

TOTAL DRY WEIGHT OF SAMPLE = 422.45 grams

\begin{align*}
\text{weight}_{\text{light-colored lithologies}} & = 75.06 \text{ grams (17.8\%)} \\
\text{weight}_{\text{dark shale}} & = 347.39 \text{ grams (82.2\%)} \\
\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>
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</thead>
<tbody>
<tr>
<td>&gt;0.0930*</td>
<td>90.98</td>
<td>0.00% / 76.27% / 23.73%</td>
</tr>
<tr>
<td>&gt;0.0661*</td>
<td>103.89</td>
<td>0.00% / 82.34% / 17.66%</td>
</tr>
<tr>
<td>&gt;0.0460*</td>
<td>112.43</td>
<td>0.00% / 84.75% / 15.25%</td>
</tr>
<tr>
<td>&gt;0.0331*</td>
<td>63.20</td>
<td>0.00% / 83.89% / 16.11%</td>
</tr>
<tr>
<td>&lt;0.0331*</td>
<td>51.95</td>
<td>0.00% / 85.00% / 15.00%</td>
</tr>
</tbody>
</table>

422.45 TOTAL

Figure 13.
Desorption Characteristics of Cuttings Samples
Petrol Oil & Gas #7-1 Trulove, NW NW SE 7-21S-14E, Coffey Co., KS

LITHOLOGIC COMPONENT SENSITIVITY ANALYSIS for calculation of gas content of Riverton coal from 1728-1731'

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}}}

\underline{sample in canister 10}

\text{total gas desorbed} = 2952.7 \text{ ccs}

\text{TOTAL DRY WEIGHT OF SAMPLE} = 919.74 \text{ grams}
\text{weight}_{\text{light-colored lithologies}} = 41.96 \text{ grams (4.6%)}
\text{weight}_{\text{dark shale}} = 125.52 \text{ grams (13.7%)}
\text{weight}_{\text{coal}} = 752.26 \text{ grams (81.8%)}

\begin{tabular}{c|c|c|c}
\text{sieve size} & \text{grams} & \% coal & \% dark shale & \% light-colored liths \\
\hline
>0.0930" & 506.71 & 92.03\% & 5.75\% & 2.22\% \\
>0.0661" & 211.64 & 81.61\% & 14.83\% & 3.56\% \\
>0.0460" & 138.46 & 62.12\% & 28.98\% & 8.90\% \\
>0.0331" & 39.27 & 46.25\% & 38.74\% & 15.02\% \\
<0.0331" & 26.67 & 40.00\% & 40.00\% & 20.00\% \\
\end{tabular}

919.74 TOTAL

\underline{sample in canister Mer Fe}

\text{total gas desorbed} = 1319.9 \text{ ccs}

\text{TOTAL DRY WEIGHT OF SAMPLE} = 311.40 \text{ grams}
\text{weight}_{\text{light-colored lithologies}} = 10.79 \text{ grams (3.5%)}
\text{weight}_{\text{dark shale}} = 31.74 \text{ grams (10.2%)}
\text{weight}_{\text{coal}} = 268.88 \text{ grams (86.3%)}

\begin{tabular}{c|c|c|c|c}
\text{sieve size} & \text{grams} & \% coal & \% dark shale & \% light-colored liths \\
\hline
>0.0930" & 159.79 & 96.46\% & 2.96\% & 0.58\% \\
>0.0661" & 70.22 & 87.29\% & 9.94\% & 2.76\% \\
>0.0460" & 52.57 & 73.45\% & 20.65\% & 5.90\% \\
>0.0331" & 17.19 & 52.49\% & 33.03\% & 14.48\% \\
<0.0331" & 11.64 & 50.00\% & 30.00\% & 20.00\% \\
\end{tabular}

311.40 TOTAL

\begin{figure}
\centering
\includegraphics[width=\textwidth]{figure14.png}
\caption{Figure 14.}
\end{figure}
PETROL OIL & GAS #7-1 TRULOVE
NW NW SE 7-21S-14E, Coffey Co., KS
cuttings desorption curves

![Graph showing desorption curves with data points for various depths and sample types including actual data and likely desorption curve without late biogenic gas.]

Figure 15.
Desorption Characteristics of Core Samples
Petrol Oil & Gas #7-1 Trulove; NW NW SE 7-T.21S.-R.14E., Coffey County, KS

Figure 16.
Figure 17.

eastern Kansas conventional gas (from Jenden et al., 1988)

analysis of coalbed desorption gas
March 19, 2004

William T. Stoeckinger
5742 Hazel Rd.
Bartlesville, OK 74006

Attn: William T. Stoeckinger

Please find listed below analysis on the following sample.

Lab ID: SM10-1  Sample ID: Riverton Large 859.11.

<table>
<thead>
<tr>
<th></th>
<th>As Received</th>
<th>Moisture Free</th>
<th>MAF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture</td>
<td>2.23%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ash</td>
<td>7.59%</td>
<td>7.76%</td>
<td></td>
</tr>
<tr>
<td>Volatile Matter</td>
<td>36.65%</td>
<td>37.49%</td>
<td></td>
</tr>
<tr>
<td>Fixed Carbon</td>
<td>53.53%</td>
<td>54.75%</td>
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<tr>
<td>BTU/lb</td>
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<td>15,207</td>
</tr>
<tr>
<td>Sulfur</td>
<td>2.21%</td>
<td>2.26%</td>
<td></td>
</tr>
</tbody>
</table>

84.81% Coal Floated at 1.65  Specific Gravity 1.31
Air Dried weight of sample 857.1 gm

Respectfully,

Carrol Lumun

CGL:pdl
March 19, 2004

William T. Stoeckinger
5742 Hazel Rd.
Bartlesville, OK 74006

Attn: William T. Stoeckinger

Please find listed below analysis on the following sample.

Lab ID: SM10-2  Sample ID: Riverton Large 270-88.

<table>
<thead>
<tr>
<th></th>
<th>As Received</th>
<th>Moisture Free</th>
<th>MAF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture</td>
<td>1.91%</td>
<td>6.47%</td>
<td></td>
</tr>
<tr>
<td>Ash</td>
<td>6.35%</td>
<td></td>
<td>6.47%</td>
</tr>
<tr>
<td>Volatile Matter</td>
<td>38.71%</td>
<td>39.46%</td>
<td></td>
</tr>
<tr>
<td>Fixed Carbon</td>
<td>53.03%</td>
<td>54.07%</td>
<td></td>
</tr>
<tr>
<td>BTU/lb</td>
<td>13,981</td>
<td>14,253</td>
<td>15,239</td>
</tr>
<tr>
<td>Sulfur</td>
<td>2.12%</td>
<td>2.16%</td>
<td></td>
</tr>
</tbody>
</table>

86.98% Coal Floated at 1.65 Specific Gravity 1.31
Air Dried weight of sample 271.1 gm

Respectfully,

Carrol Luman

CGL:pdl