ANALYSIS OF CHEROKEE GROUP CUTTINGS SAMPLES FOR GAS CONTENT
-- KLM EXPLORATION #7 DUNN;
NW SE SE sec. 33-T.8S.-R.20E.; JEFFERSON COUNTY, KANSAS

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SUMMARY

Three cuttings samples from the Pennsylvanian Cherokee Group were collected from the KLM Exploration #7 Dunn well, NW SE SE sec. 33-T.8S.-R.20E., Jefferson County, KS. The samples calculate as having the following gas contents:

- Bevier coal at 1098' to 1099' depth[1,2]   (38 scf/ton)
- Rowe coal at 1425'-1426' depth[1]   (152 scf/ton)
- ? coal at 1449'-1450' depth[1,2]   (74 scf/ton)

[1]assuming accompanying dark shales in sample desorb 3 scf/ton
[2]reliability of result is unclear due to small amount of coal in the sample

BACKGROUND

The KLM Exploration #7 Dunn well, NW SE SE sec. 33-T.8S.-R.20E. in Jefferson County 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 September 22, 2004 by K. David Newell of the Kansas Geological Survey, with assistance of Stephen J. Miller (consultant to KLM Exploration). Samples were obtained during normal drilling of the well, with no cessation of drilling before zones of interest (i.e., coals and dark shales in the Cherokee Group) were penetrated. The well was drilled using a mud rotary rig owned by KAN-DRILL, Inc.

The samples were canistered, with surface time and canistering times noted. Lag times for samples to reach the surface (important for assessing lost gas) were determined by using a rule-of-thumb up-hole velocity of 100' per minute.

Three cuttings samples from the Pennsylvanian Cherokee Group were collected:
- Bevier coal at 1098' to 1099' depth   (276 grams dry wt.)
- Rowe coal at 1425'-1426' depth   (266 grams dry wt.)
- ? coal at 1449'-1450' depth   (188 grams dry wt.)

The cuttings were caught in kitchen strainers and a settling bucket as they exited the ditch emptying to the mud pit. The samples were then washed in water while in the kitchen strainers to rid them of as much drilling mud as possible before the cuttings were placed in desorption canisters. Water with zephyrn chloride biocide was then added to the canisters, with a headspace of 1 to 2 inches being preserved at the top of the canister.

All samples were transported September 22nd 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 made in-house at the Kansas Geological Survey. These canisters are approximately 1 foot in length (30 cm), 2 inches in diameter (5 cm), and enclosed a volume of 44 cubic inches (720 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 (Figure 1). The regression equation shown graphically in Figure 1 was entered into a spreadsheet and was used to automatically convert the millibar measurement to barometric pressure in pounds per square inch (psi).

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

$n = PV/RT$

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

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

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

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

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

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

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

Lost gas for samples (i.e., the gas lost from the sample from the time it was drilled, brought to the surface, to the time it was canistered) were 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.

LITHOLOGIC ANALYSIS

Upon removal from the canisters, the cuttings were washed of drilling mud, and air dried for 7 to 21 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) was sieved and weighed, and the derived size-fraction ratios were applied to the entire sample.

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

DATA PRESENTATION

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

Lost-Gas Graphs (Figure 2-4)
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 5-7)
The rapidity of penetration of a well makes collection of pure lithologies from relatively thin-bedded strata rather difficult. Mixed lithologies are more the norm rather than the exception. Some of this mixing is due to cavings from strata farther up hole. The mixing may also be due to collection of two or more successively drilled lithologies in the kitchen sieve at the exit line, or differential lifting of relatively less-dense coal compared to other lithologies, all of which are more dense than coal.

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

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

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

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 visa 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, though, to assume that all the gas evolved from a cuttings sample is derived solely from the coal would result in an erroneously high gas content for the coal.

Summary Component Analysis for all Samples (Figure 8)
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 9)
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

The best constrained data are that associated with the Rowe sample (1425'-1426'), which contained 21% coal. The Bevier (1098'-1099') and unknown coal (1449'-1450') samples (1096'-1097') respectively contained 8% and 6% coal, thus their results are not as well constrained as is the Rowe sample.

Shale associated with the Rowe sample (1425'-1426') was very dark and thus may be generating more than the 3 scf/ton assumed for this lithology. Dark brown siltstone accompanied the other two samples and this lithology is assumed to not generate more gas than 3 scf/ton.

REFERENCES
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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 Bevier coal at 1098' to 1099' depth.
FIGURE 3. Lost-gas graph for Rowe coal at 1425'-1426' depth.
FIGURE 4. Lost-gas graph for ? coal at 1449'-1450' depth.

FIGURE 5. Sensitivity analysis for Bevier coal at 1098' to 1099' depth.
FIGURE 6. Sensitivity analysis for Rowe coal at 1425'-1426' depth.
FIGURE 7. Sensitivity analysis for ? coal at 1449'-1450' depth.

FIGURE 8. Lithologic component sensitivity analyses for all samples.

FIGURE 9. Desorption graph for all samples.