

ANALYSIS OF CHEROKEE GROUP CUTTINGS SAMPLES FOR GAS CONTENT --
GENE M. BAILEY #12-K KIMBALL
(NE NE SW sec. 19-T.30S.-R.16E.), WILSON COUNTY, KANSAS

By
K. David Newell
and
Jonathan Lange



Kansas Geological Survey
The University of Kansas
1930 Constant Avenue
Lawrence, KS 66047-3726

November, 2004

KANSAS GEOLOGICAL SURVEY OPEN-FILE REPORT 2004-50

Disclaimer

The Kansas Geological Survey does not guarantee this document to be free from errors or inaccuracies and disclaims any responsibility or liability for interpretations based on data used in the production of this document or decisions based thereon. This report is intended to make results of research available at the earliest possible date, but it is not intended to constitute final or formal publication.

BACKGROUND

The Gene M. Bailey #12-K Kimball well in NE NE SW sec. 19-T.30S.-R16E. (Wilson County, KS) was selected for cuttings desorption tests in association with an on-going coalbed gas research project at the Kansas Geological Survey. The samples were gathered October 28, 2002 by K. David Newell and Jonathan Lange of the Kansas Geological Survey, with well site collection aided by Jim Stegeman of Colt Energy (in partnership with Bailey on this well). Samples were obtained during normal drilling of the well, with no cessation of drilling before zones of interest (i.e., coals in the Cherokee and Marmaton Groups) were penetrated. The well was drilled using an air rotary rig by Jim Lorenz. Lag times for samples to reach the surface (important for assessing lost gas) were determined by noting the time delay for cuttings to reach the surface following resumption of drilling after new pipe was added to the drill string. This delay time was added to the time noted for the samples reaching the surface in order to determine the time the samples were off bottom.

Three cuttings samples from the Pennsylvanian Marmaton and Cherokee Groups were collected: Lexington coal at 565-566', Summit coal at 664' to 670', Mulky coal at 683.5' to 685', and Riverton coal at 1065' to 1067'. The canister containing the Lexington sample was subsequently revealed to leak, thus data are not returned for this sample. The Summit, Mulky, and Riverton samples respectively weighed 1290, 1306, and 1227 grams.

The cuttings samples were caught in a kitchen strainer at the air stream exit by the mud pit. The samples were briefly rinsed in water, then placed in desorption canisters, with formation water, for testing. A temperature bath for the desorption canisters was on site, with temperature at approximately 80 degrees F. The canistered samples were later that day transported to the laboratory at the Kansas Geological Survey and desorption measurements were continued at 80 degrees F ambient temperature. Desorption measurements were periodically made until the canisters produced no more gas upon testing for at least two successive days. All cuttings were depleted of gas within about two weeks following collection.

DESORPTION MEASUREMENTS

Desorption volumes for the Mulky and Riverton samples were measured by displacement of water in dual connected graduated glass cylinders, which enabled compensation for pressure necessary for displacement of water columns by the desorbed gas. Barometric pressures were recorded using a field barometer whose readings were correlated to a master barometer back at the Kansas Geological Survey. Gas volumes were converted in a spreadsheet to gas volumes at standard temperature and pressure.

The Summit sample was put into a canister having no nozzle and valve for volumetric measuring. The only means to measure evolved gas was a pressure gauge. The increase in pressure was noted for this canister and the gas periodically released to equilibrate the

sample with atmosphere. Before removing the sample from the canister, the cylindrical volume in the free space above the formation water was noted, and the amount of gas needed to equal the recorded pressures was calculated. Lost gas was assumed to be approximately 13% of the total gas evolved (i.e., 10 cc). This value is in line with lost gas for other cuttings samples.

LITHOLOGIC ANALYSIS

Upon removal of the cuttings from the canisters, the cuttings were washed of drilling mud, and then dried overnight in an oven at 150 degrees C. 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 inches. In case of large sample sizes, the cuttings were ran through a sample splitter and a lesser portion of them were sieved and weighed. The majority of cuttings – about 75% by weight – were caught in the largest sieve size, with usually successively less percentages caught in the smaller sieve sizes.

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 were weighed. Dividing the sample into size fractions aided in confidence and consistency of the lithologic sorting. Similarly sized cuttings were more easily compared to each other, and the weight-percentage results for the size classes also could be compared. The total weight of each of the lithologic categories in the entire cuttings sample was determined. In all cases the percentages of coal, dark shale and lighter-colored lithologies varied little (generally <10%) for each size category.

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

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

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

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”

The rapidity of penetration of an air-drilled well makes collection of pure lithologies rather difficult and problematic. 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 content than the dark-colored shale. Although 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:

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

A unique solution for *gas content_{coal}* in this equation is not possible because *gas content_{dark shale}* is similarly not known. 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 analyses” therefore expresses the bivariant nature inherent in the analysis 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 general understanding of the “lithologic component sensitivity analyses” diagrams, the calculated $gas\ content_{coal}$ is given for assumed $gas\ content_{dark\ shale}$ at 30 scf/ton and 50 scf/ton. In some cases, the resultant $gas\ content_{coal}$ is a negative number for 30 scf/ton and 50 scf/ton $gas\ content_{dark\ shale}$, hence it is impossible that $gas\ content_{dark\ shale}$ could be as high as 30 to 50 scf/ton. In such cases, the $gas\ content_{dark\ shale}$ 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 analyses” diagrams, a “break-even” point also is noted where the gas content of the coal is equal to that of the dark shale. This “break-even” point is likely the minimum gas content assignable to the coal and likely the 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

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

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

According to the summary component analysis, the Riverton coal had the most tightly constrained results. The percentage of dark shale in the Riverton sample was 66%, whereas coal was 13%. If this amount of dark shale has a relatively rich gas capacity of 50 scf/ton, the Riverton coal gas content assays in to the negative range for scf/ton. If the dark shale carries 30 scf/ton, the coal will assay at 30 scf/ton, and commensurately more gas content if the dark shale has less gas content. If the dark shale has no gas capacity at all (i.e., 0 scf/ton), the Riverton coal will hold 181 scf/ton. The "break-even point" at which the gas capacity of the shale is equal to that of the coal is 30 scf/ton. This point can also be thought of as the absolute minimum gas capacity for the coal and the absolute maximum gas capacity for the dark shale. Recent work in southeast Kansas at the nearby Colt Energy #1 Honeycutt well (6-T.31S.-R.17E.) (superimposed on the sensitivity diagram for the Riverton coal for this well) has an intersection of their two respective lines near 0 scf/ton for the dark shale. This indicates that shale cuttings admixed with the Riverton cuttings likely are not very rich in gas content content , hence the *gas*

content_{coal}. for the Riverton in both samples is likely near the maximum for both samples. If a nominal value of 3 scf/ton for *gas content_{dark shale}* is used, the Riverton in the Bailey #12-K Kimball well would contain 166 scf/ton.

Conversely, the Mulky sample had only 3.5% coal content. Dark shale in this sample registered 84%. The resultant gas content for the Mulky can thus vary greatly with only minor variation in the gas capacity for the associated dark shale. Since the scf/ton value for the Mulky would be unrealistically high if the dark shale in this sample registered gas content as low as what is inferred for the shale in the vicinity of the Riverton coal (i.e. approximately 3 scf/ton), we conclude that the dark shale in proximity to the Mulky probably has a gas capacity between 33.8 scf/ton scf/ton and 39.2 scf/ton. The former value of 33.8 scf/ton is the *gas content_{dark shale}* that results in a 166 scf/ton for the Mulky coal. (We do not expect the *gas content_{coal}* of the Mulky to exceed that of the Riverton.). The latter value (39.2 scf/ton) is the "break-even point" for the sample where *gas content_{coal}* equals *gas content_{dark shale}*.

In case of the Summit coal sample, its value may be better for estimating the gas content of the dark shale near the Summit coal, for no coal was detected in the sample. With consideration of the inherent inaccuracy working with a pressure measurement instead of a volumetric measurement, 2.3 scf/ton measure for the Summit sample indicates it is relatively gas poor. A 13scf/ton for the Colt Energy #1 Honeycutt well (6-T.31S.-R.17E.) Summit sample supports this analysis. The Summit coal may be either a very poorly developed coal or carbonaceous shale, or perhaps the actual Summit coal was simply missed entirely during sample collection in both wells.

OPPORTUNITY FOR FURTHER STUDY

The samples obtained for this study were gathered during normal drilling, and no special provisions during drilling were made to high-grade the sample quality. Nevertheless, reasonable results were obtained for some of the samples. Better results likely can be obtained by ceasing drilling just above the coal and circulating up cuttings in the annulus so as to clean the hole before collecting the coal sample. Slow drilling ahead, about one foot at a time until a good coal sample is obtained, will also do much to high-grade the cuttings sample. However, these sampling tactics may be a difficult proposition if the driller is paid by the foot.

Sieving and separating cuttings by density at the drill site may also be a tactic by which more coal could be concentrated in a cuttings sample. A calcium chloride solution at 1.2 grams/cc density (in which some shales would sink more readily than the coal) may be adequate to concentrate coal in the cuttings sample. Sieving the sample at the wellsite and separately canistering the size fractions may be worthwhile to ascertain if there is a minimum size of cutting that evolves gas. This is potentially important for volumetric measurements

In any case, data may also be obtained that can provide a solution to the problem posed by the respective gas contents of the dark shale vs. coal. If a reasonable proxy for the relative gas content of a dark shale stratigraphically above a coal could be found, this relationship could provide a unique solution to the equations expressed in “lithologic component sensitivity analyses”. An inverse ratio of the density, total organic carbon, or ash content of the coals vs. shales may mimic that of their gas contents. Such data needs to be tested from cores before it can reliably applied to cuttings, however.

A possible solution to this black shale-coal problem in figuring gas content in cuttings is as follows: two cuttings samples could be taken for desorption work, with the first being as close as possible to the coal but above it (in order to get as much of the overlying black shale as possible), then one from the coal itself. Realistically, mixtures of coal and shale are likely to be obtained in with both samples, but hopefully there will be greater percentage of dark shale in the overlying sample, and a greater percentage of coal in the underlying sample. The underclay of the coal need not be specifically sampled, for it is usually a lighter-colored shale that is depleted in organic material. Sorting of the cuttings also eliminated this material.

With the data from these two paired samples, the linear equations expressing the gas content of the shale and the coal (the line expressed in the sensitivity diagrams that were in the report) could be solved simultaneously. The underlying assumption is that the black shale cuttings in both samples have the same gas content. This is likely the case, since cuttings data inherently are averaged due to their grinding and mixing during drilling. Similarly, if coal is present in both samples, the coal in one sample is implicitly assumed to have identical gas content to the coal in the other sample.

Interestingly, there are tests for data quality built into this system. If the samples are taken correctly, the dark shale content in the upper sample should be greater than in the lower sample. This is not necessary for a calculating a unique solution, but it certainly fortifies the confidence in the result. The resultant gas content for the dark shales and coals in both samples should calculate as positive numbers though. This would be expressed graphically as the two lines produced by the sample sensitivity analyses intersecting only in the area greater than zero for coal gas content. Furthermore and ideally, the calculated coal gas content would be greater than that of the dark shale.

Geologically, we reckon most shale in the underclay of the coal is organic-poor and thus gas poor. It is the dark shale above the coal that likely complicates the results when only one sample of cuttings is taken for a particular zone. Judging from what we have seen of underclays, they are usually gummy and light gray. The light-colored lithologies are not counted as gas generating lithologies in the sample sorting process anyway.

The utility of cuttings for a relatively rapid gas analysis of coals in a well could be realized with employment of a sample splitter on site at the well. A portion of the cuttings collected could be saved separately from the portion that is canistered. While the canistered cuttings are desorbing, lithologic analysis of the uncanistered cuttings split could be proceeding. Upon completion of their outgassing, the canistered cuttings need

only be washed and weighed. The lithologic weight ratios derived from the concurrent study of the uncanistered cuttings could then be applied to the canistered cuttings for a rapid gas analysis which could be available as soon as the desorption process is finished, likely within a couple of weeks of drilling.