ANALYSIS OF CHEROKEE GROUP CUTTINGS SAMPLES FOR GAS CONTENT -- DEVON ENERGY #35-1 R. JOHN WELL (sec. 35-T.29S.-R.18E.), NEOSHO COUNTY, KANSAS

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BACKGROUND

The Devon Energy Corporation #35-1 Robert John well in SE SW sec. 35-T.29S.-R18E. (Neosho 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 15, 2002 by K. David Newell of the Kansas Geological Survey, with well site collection by John D. Taylor of Devon Energy and other Devon wellsite personnel. Samples were obtained during normal drilling of the well, with no cessation of drilling before zones of interest (i.e., coals in the Cherokee Group) were penetrated. The well was drilled using an air rotary rig operated by McPherson Drilling. This rig was equipped with dual compressors, thus cuttings reached the surface from depths of several hundred feet in a matter of seconds.

Six cuttings samples from the Cabaniss and Krebs Formations of the Cherokee Group were collected: Bevier coal at 661-662', Croweburg coal at 685-687', Weir-Pittsburg coal at 831-832', upper Rowe coal at 938-940'; lower Rowe coal at 943'-946', and Riverton coal at 996-999'. These samples ranged in weight from 247 to 1219 grams.

The cuttings samples were caught in a kitchen strainer at the air stream exit at the mud pit. They were briefly rinsed in water, then placed in desorption canisters for testing. A temperature bath for the desorption canisters was on site, with temperature at approximately at 70 degrees F. The canistered samples were later that day transported to the laboratory at the Kansas Geological Survey and desorption measurements were continued. 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 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.

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 under a dissecting microscope. Three major lithologic categories were differentiated: coal, dark shales (generally GSA 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 each 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 results for the size classes also could be compared to each other. The total weight of each of the lithologic categories in the entire cuttings sample was then 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) data tables for the desorption analyses, 2) lost-gas graphs, 3) "lithologic component sensitivity analyses" showing the interdependence of gas evolved from dark shales and coals 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

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 and 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 1 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 collection of two or more successively drilled lithologies in the kitchen sieve at the collection point, 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:

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

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.

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 3-5 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, hence it is impossible that the *gas content*$_{dark\ shale}$ could be as high as 30 to 50 scf/ton. In such cases, the *gas content*$_{dark\ shale}$ is no doubt 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 analytical results for that sample.

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 most tightly constrained results were obtained for the Bevier coal. The percentage of dark shale in this sample was very low (i.e., 2.1%). If this miniscule amount of dark shale has a relatively rich gas capacity of 50 scf/ton, the Bevier coal gas content assays to 70 scf/ton. Even if this dark shale has no gas capacity at all (i.e., 0 scf/ton), the Bevier coal will hold 73 scf/ton.

Conversely, the Croweburg and Weir-Pittsburg samples had only 6.5% and 1.9% coal content, respectively. Dark shale in these samples registered 71.3% and 13.4%, respectively. In both cases, the resultant gas content for the coals varies greatly with only minor variation in the gas capacity for the associated dark shale. The value of these samples may actually be better for estimating the gas content of the dark shale in the stratigraphic vicinity of these two coals rather than for the coals themselves. In the case the dark shale admixed with the Croweburg coal likely produces less than 20 scf/ton, whereas the dark shale near the Weir-Pittsburg coal is richer, likely on the order of 40 to 50 scf/ton.

Marginal results were obtained for the upper and lower Rowe samples, for they assayed only 15.7% and 11.5% coal respectively. However, the lower Rowe coal is evidently richer in gas than the upper Rowe coal, for the lower Rowe sample collectively generated 42 scf/ton gas compared to only 11 scf/ton for the upper Rowe sample. Interestingly, since these two sample were collected very close to each other in depth (938-940’ vs. 943-946’), the shale in both samples arguably may be identical in gas content. Assuming that this may be the case, if the “break-even” gas content of 11 scf/ton for the upper Rowe is used as a maximum gas content for the dark shale in both samples, the lower Rowe coal will have a gas content of at least 100 scf/ton, and perhaps as much as 110 to 115 scf/ton. The upper Rowe will only at best have a gas content of 50 to 60 scf/ton, and only if its associated dark shales generate less than 11 scf/ton.

Despite the results carrying some uncertainty due to it having 27.4% dark-shale content, the Riverton sample has the best gas content of all the samples. Assuming a 30 to 50 scf/ton gas content for its dark shale, the Riverton coal has a gas content ranging from 142 to 155 scf/ton. If the associated dark shales have a gas content of less than 20 scf/ton, the Riverton coal will have a gas capacity in excess of 160 scf/ton.

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 up 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.

In any case, data may 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 adjacent to 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 need to be tested from cores before it can reliably applied to cuttings, however.

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.