

ANALYSIS OF DEVONIAN-MISSISSIPPIAN CHATTANOOGA SHALE SAMPLES  
FOR GAS CONTENT AND GAS CHEMISTRY

-- METRO ENERGY GROUP, INC.

#1-34 SPRIGGS (sec. 34-T.33S.-R.13W.)

and

#1-16 McGRATH (sec. 16-T.33S.-R.14W.);

BARBER COUNTY, KANSAS

By

K. David Newell



Kansas Geological Survey

The University of Kansas

1930 Constant Avenue

Lawrence, KS 66047-3726

May 2, 2006

(to be held proprietary to May 2, 2007)

*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.*

Kansas Geological Survey Open-File Report 2023-50

## SUMMARY

Cuttings samples and sidewall cores from the Devonian-Mississippian Chattanooga Shale were collected from two Metro Energy Group, Inc. wells in Barber County, Kansas in late 2005. Cuttings samples from the #1-34 Spriggs well (SE NE NE sec. 34-T.33S.-R.13W.) calculate as having the following gas contents:

- 4875'-4885' depth<sup>1</sup> (no gas desorbed)
- 4885'-4895' depth<sup>1</sup> (11 scf/ton)
- 4895'-4905' depth<sup>1</sup> (19 scf/ton)
- 4916'-4926' depth<sup>1</sup> (15 scf/ton)
- 4926'-4901' depth<sup>1</sup> (10 scf/ton)

Sidewall cores from the same well were separated into two groups -- those from beds within the Chattanooga Shale that have relatively high gamma-ray readings, and those from beds with relatively low gamma-ray readings:

- high-gamma samples (4892', 4898', 4933', 4938' depth<sup>2</sup>) (43 scf/ton)
- low-gamma-ray samples (4902', 4908', 4913', 4918', 4924', 4928' depth<sup>2</sup>) (23 scf/ton)

Sidewall samples from the #1-16 McGrath well (NW SE NE sec. 16-T.34S.-R.14W.) calculate as having the following gas contents:

- high-gamma samples (4903', 4906', 4939', 4943' depth<sup>2</sup>) (22 scf/ton)
- low-gamma-ray samples (4899', 4915', 4926', 4932' depth<sup>2</sup>) (18 scf/ton)

<sup>1</sup>driller's depths

<sup>2</sup>wireline logging depth

The cuttings analyses recorded lower gas content than the sidewall core analyses. This may be due to the cuttings including some cavings from gas-poor dark shales.

Compositional and isotopic analysis of desorption gas from the #1-34 Spriggs indicates the desorption gas is isotopically and chemically different from conventional gases produced nearby in southern Kansas, thereby indicating that the Chattanooga Shale is not a local source of the nearby conventional gas accumulations. The Chattanooga Shale in Barber County, as indicated by data from the desorption-gas analysis, may be less mature than the source(s) for the locally produced conventional gases.

## BACKGROUND

The Metro Energy Group #1-34 Spriggs well (sec. 34-T.33S.-R.13W.), and the Metro Energy Group #1-16 McGrath well (sec. 16-T.34S.-R.14W.) in Barber County, KS, were selected for desorption tests in association with an on-going unconventional gas research project at the Kansas Geological Survey. The cuttings samples from the #1-34 Spriggs well were gathered November 29, 2005 by K. David Newell and the mudlogger

employed by Metro Energy Group. Wireline sidewall samples were later obtained by K. David Newell on December 2, 2005. Wireline sidewall samples were obtained on the #1-16 McGrath well on December 23, 2005.

The cuttings samples from the #1-34 Spriggs well were obtained during normal drilling of the well, with no cessation of drilling before zones of interest (i.e., dark shale in the Devonian-Mississippian Chattanooga Shale) were penetrated. The well was drilled using mud-system rig owned by Landward Drilling.

The samples were canistered, with surface time and canistering times noted. These samples were collected in canisters that were supplied by the Kansas Geological Survey. Lag times for cuttings samples to reach the surface (important for assessing lost gas) were determined by carbide tests prior to penetrating the Chattanooga Shale.

Five cuttings samples from the Devonian-Mississippian Chattanooga Shale were collected from the #1-34 Spriggs well:

- 4875'-4885' depth (no weight determined)<sup>1</sup>
- 4885'-4895' depth (1401 grams)
- 4895'-4905' depth (1378 grams)
- 4916'-4926' depth (555 grams)
- 4926'-4901' depth (1859 grams)

<sup>1</sup>no gas given off by sample

The cuttings were caught in kitchen strainers as they exited the well and before they were washed into 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.

Ten wireline sidewall core samples from the Devonian-Mississippian Chattanooga Shale were collected from the #1-34 Spriggs well. These were divided into two groups, respectively high- and low-gamma ray groups, based on the gamma-ray signature of the well log ran prior to the sidewall tool. The samples were:

- 4892', 4898', 4933', 4938' sidewall cores (high  $\gamma$  group) (194.6 grams)
- 4902', 4908', 4913', 4918', 4924', 4928' sidewall cores (low  $\gamma$  group) (294.6 grams)

Eight wireline sidewall core samples from the Devonian-Mississippian Chattanooga Shale were collected from the #1-16 McGrath well well. These were also divided into two groups, respectively high- and low-gamma ray groups, based on the gamma-ray signature of the well log ran prior to the sidewall tool. The samples were:

- 4903', 4906', 4939', 4943' sidewall cores (high  $\gamma$  group) (191.8 grams)
- 4899', 4915', 4926', 4932' sidewall cores (low  $\gamma$  group) (197.8 grams)

All samples were transported to the laboratory at the Kansas Geological Survey in Lawrence, KS the day they were collected. Desorption measurements were continued for

the cuttings samples at approximately 68 °F. Desorption measurements were continued for the sidewall samples at the inferred formation temperature of approximately 120 °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 obtained from SSD, Inc. in Grand Junction, CO. These canisters are 12.5 inches high (32 cm), 3 1/2 inches (9 cm) in diameter, and enclose a volume of approximately 150 cubic inches (2450 cm<sup>3</sup>). 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 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:

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

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  $P_{\text{stp}}$ ,  $V_{\text{stp}}$ , and  $T_{\text{stp}}$ , respectively, are pressure, volume and temperature at standard temperature and pressure, where standard temperature is degrees Rankine ( $^{\circ}\text{R} = 460 + ^{\circ}\text{F}$ ).  $P_{\text{rig}}$ ,  $V_{\text{rig}}$ , 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:

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

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 (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 sample is lifted from the bottom of the hole. 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 one hour for cuttings samples, and two hours for core samples. The temperature at which the lost-gas analysis was carried out was that of the mud temperature. This was respectively 84 °F for the cuttings samples and 94 °F for the sidewall samples. Subsequent desorption temperatures used for the sidewall samples in the laboratory were that inferred for the formation at depth (120 °F).

## LITHOLOGIC ANALYSIS

Upon removal from the canisters, the cuttings were washed of drilling mud, and air dried at room temperature 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 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. Two major lithologic categories were differentiated: dark shale (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 lithologic categories was weighed and the proportion of dark shale and light-colored lithologies were determined for the entire cuttings sample based on the weight percentages.

Sidewall samples were air dried at room temperature for several weeks until their weight stabilized.

## 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) desorption graph for individual samples, and 4) gas chemistry diagrams.

### *Data Tables of the Desorption Analyses (Table 1, 2, 3)*

These are the basic data used for lost-gas analysis and determination of total gas desorbed from the 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 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. Gas content of sidewall samples was calculated taking into account the contraction and expansion of headspace in the canister with changes in temperature and atmospheric pressure.

### *Lost-Gas Graphs (Figures 2-9)*

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 two hours after the start of desorption (i.e., the time off bottom), thus data are presented in the lost-gas graphs for only up to 2 hours after the off-bottom time. Lost-gas volumes derived from this analysis are incorporated in the data tables described above.

### *Desorption Graph (Figures 10)*

This graph (Figure 10) has all the desorption curves on it at a common scale.

### *Gas Chemistry (Figures 11-14)*

Gas isotopic chemistry is crossplotted and compared to other nearby gases (Figures 11, 12, 13, and 14).

## RESULTS and DISCUSSION

The following gas contents are calculated based on dry weight of the sample. The #1-34 Spriggs well (SE NE NE sec. 34-T.33S.-R.13W.) cuttings calculate as having the following gas contents:

- 4875'-4885' depth<sup>1</sup> (no gas desorbed)
- 4885'-4895' depth<sup>1</sup> (11 scf/ton)
- 4895'-4905' depth<sup>1</sup> (19 scf/ton)
- 4916'-4926' depth<sup>1</sup> (15 scf/ton)
- 4926'-4901' depth<sup>1</sup> (10 scf/ton)

Sidewall cores from the #1-34 Spriggs well were separated into two groups -- those from beds within the Chattanooga Shale that have relatively high gamma-ray readings, and those from beds with relatively low gamma-ray readings:

- high-gamma samples (4892', 4898', 4933', 4938' depth<sup>2</sup>) (43 scf/ton)
- low-gamma-ray samples (4902', 4908', 4913', 4918', 4924', 4928' depth<sup>2</sup>) (23 scf/ton)

Sidewall samples from the #1-16 McGrath well (NW SE NE sec. 16-T.34S.-R.14W.) calculate as having the following gas contents:

- high-gamma samples (4903', 4906', 4939', 4943' depth<sup>2</sup>) (22 scf/ton)
- low-gamma-ray samples (4899', 4915', 4926', 4932' depth<sup>2</sup>) (18 scf/ton)

<sup>1</sup>driller's depths

<sup>2</sup>wireline logging depth

The higher gas content in the high gamma-ray samples (as compared to the low gamma ray samples) is consistent with the higher organic content inferred for these samples.

The desorption of cuttings was an experiment to determine if cuttings can be used to determine gas content of a shale. The lack of desorption gas from cuttings of the Chattanooga Shale above 4885' (driller's depth) could indicate that this part of the Chattanooga Shale is not prospective for shale gas. Lithologically, this sample contained little shale darker than the colors N3 (dark gray), N2 (grayish black), and N1 (black) on dry surface.

The gas content of the Chattanooga Shale cuttings are lower than that determined from sidewall cores. The uniformly lower gas content of the cuttings samples, as compared to the sidewall samples at the Spriggs well may be due to some extraneous lithologies such as cavings of dark, non-gas-bearing shale from younger formations being counted as Chattanooga Shale. Nevertheless, the relative gas content of these depth intervals

investigated by cuttings analyses may be useful in for estimating the relative gas content of various depth intervals in the Chattanooga.

Sidewall samples were tested for their density. Dried samples were weighed and immersed in water in a graduated cylinder, the increase in volume in the cylinder was then noted. The following density measurements were calculated:

#1-34 Spriggs well

<i>unit</i>	<i>depth</i>	<i>density (g/cc ± 0.03)</i>	
high $\gamma$ group	4892'	2.31	
high $\gamma$ group	4898'	2.69	
high $\gamma$ group	4933'	2.46	
high $\gamma$ group	4938'	2.39	average = 2.46
low $\gamma$ group	4902'	2.54	
low $\gamma$ group	4908'	2.57	
low $\gamma$ group	4913'	2.61	
low $\gamma$ group	4918'	2.57	
low $\gamma$ group	4924'	2.53	
low $\gamma$ group	4928'	2.49	average = 2.55

#1-16 McGrath well

<i>unit</i>	<i>depth</i>	<i>density</i>	
high $\gamma$ group	4903'	2.46	
high $\gamma$ group	4906'	2.41	
high $\gamma$ group	4939'	2.54	
high $\gamma$ group	4943'	2.40	average = 2.45
low $\gamma$ group	4899'	2.57	
low $\gamma$ group	4915'	2.50	
low $\gamma$ group	4926'	2.58	
low $\gamma$ group	4932'	2.54	average = 2.55

Compositional and isotopic chemistry were performed on gas obtained from the desorption canisters for the Spriggs #1-34 cuttings samples at the finish of the desorption process. These analyses were performed by Isotech Laboratories in Champaign, IL.

*Isotopic Analyses*

$\delta^{13}\text{C}_{\text{methane}}$	-42.00
$\delta\text{DC}_{\text{methane}}$	-238.8
$\delta^{13}\text{C}_{\text{ethane}}$	-40.96
$\delta^{13}\text{C}_{\text{propane}}$	-35.22

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

<b>Component (%)</b>	
Methane	14.32
Ethane	4.37
C <sub>2</sub> H <sub>2</sub>	0.0021
Propane	4.55
n-Butane	1.29
iso-Butane	0.327
n-Pentane	0.22
iso-Pentane	0.327
Hexane+	0.142
Nitrogen	63.12
Oxygen	6.93
Argon	0.78
Hydrogen	3.52
Carbon Dioxide	0.24
Helium	0

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

<b>Component (%)<sup>1</sup></b>	
Methane	21.30
Ethane	6.51
C <sub>2</sub> H <sub>2</sub>	0.0031
Propane	6.78
n-Butane	1.92
iso-Butane	0.487
n-Pentane	0.33
iso-Pentane	0.487
Hexane+	0.212
Nitrogen	55.63
Argon	0.70
Hydrogen	5.25
Carbon Dioxide	0.34
Helium	0

<sup>1</sup>atmospheric component (based on oxygen content) subtracted from the analysis, with components recalculated to 100%

*Summary*

Calculated BTU <sup>3</sup>	652
Total % non-HCs	61.92
HC Wetness (%)	43.95

<sup>3</sup>based on composition of the sample after atmospheric contribution was subtracted.

The Chattanooga desorption gas is compared to a suite of nearby conventional gases (data from Jenden and others, 1988), the locations of which are shown in Figure 11. Plotting of the methane isotopes and gas wetness (Figure 12) indicates that the Chattanooga desorption gas is thermogenic in origin, but its maturation is lower than that of nearby Mississippian and Pennsylvanian gases. This discrepancy in maturation indicates that many of the conventional gas accumulations in southern Kansas are not sourced locally from the Chattanooga Shale, but are likely derived from more mature source rocks farther south and deeper in Oklahoma. Long-distance migration updip from the Anadarko basin may be the most likely mechanism for emplacement of these gases and associated oils, rather than local migration.

The low-BTU value of the Chattanooga desorption gas, as compared to the nearby conventional gases, also militates for a separate origin from that of the nearby conventional gases. The hydrocarbon wetness of the Spriggs desorption gas (i.e.,  $(\Sigma C_{2..C6+})/(\Sigma C_{1..C6+})$ ) is greater than that of the nearby conventional gases (Figure 13). This possibly indicates that cracking processes that usually affect heavier hydrocarbons in the higher-maturity part of the oil window and early part of the gas window have not yet significantly affected the adsorbed hydrocarbons in the Chattanooga Shale at the Spriggs locality.

Ethane  $\delta^{13}C$  and propane  $\delta^{13}C$  can be used to estimate maturation (Figure 14), but the type of organic matter can also exert an influence on these isotopic values (Jenden and other, 1988). A maturation relationship proposed by Faber (1987) (solid line in Figure 13) indicates that the maturation of the Chattanooga desorption gas is less than 0.6 Ro -- barely in the oil window. Conversely, the isotopic signatures of the nearby conventional gases indicate thermal maturities from 0.63 to 0.83 Ro. Rock-Eval maturation measurements (personal communication, Robert Pfannenstiel, 2/2006) indicate the maturity of the Chattanooga Shale at the Spriggs locality to be approximately 0.8 Ro. The reason for the discrepancy between the Rock-Eval data and the gas isotopes is not known, but it may be due to lack of an adequate calibration between the gas isotopes and a direct maturation indicator. If so, then the isotopic signatures of shale gases derived from desorption tests at other localities can possibly be used to calibrate the maturation, and thus determine the producibility of gas from the Chattanooga and other unconventional reservoirs.

## REFERENCES

- Dake, L.P., 1978, *Fundamentals of Reservoir Engineering*, Elsevier Scientific Publishing, New York, NY, 443 p.
- Faber, E., 1987, Zur isotopengeochemie gasformiger Kohlenwasserstoffe: Erdöl, Erdgas, Kohle, v. 103, p. 210-218.
- Jenden, P.D., Newell, K.D., Kaplan, I.R., and Watney, W.L., 1988, Composition and stable-isotope geochemistry of natural gases from Kansas, Midcontinent, U.S.A.: *Chemical Geology*, v. 71, p. 117-147.

Kissel, F.N., McCulloch, C.M., and Elder, C.H., 1975, The direct method of determining methane content of coals for ventilation design: U.S. Bureau of Mines, Report of Investigations, RI7767.

McLennan, J.D., Schafer, P.S., and Pratt, T.J., 1995, A guide to determining coalbed gas content: Gas Research Institute, Chicago, IL, Reference No. GRI-94/0396, 180 p.

## FIGURES, TABLES, and APPENDICES

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

TABLE 1. Desorption measurements for Spriggs #1-34 cuttings samples.

TABLE 2. Desorption measurements for Spriggs #1-34 sidewall samples.

TABLE 3. Desorption measurements for McGrath #1-16 sidewall samples.

FIGURE 2. Lost-gas graph for Spriggs #1-34 cuttings (4885'-4895').

FIGURE 3. Lost-gas graph for Spriggs #1-34 cuttings (4895'-4905').

FIGURE 4. Lost-gas graph for Spriggs #1-34 cuttings (4916'-4926').

FIGURE 5. Lost-gas graph for Spriggs #1-34 cuttings (4926'-4941').

FIGURE 6. Lost-gas graph for Spriggs #1-34 sidewalls (high  $\gamma$  group).

FIGURE 7. Lost-gas graph for Spriggs #1-34 sidewalls (low  $\gamma$  group).

FIGURE 8. Lost-gas graph for McGrath #1-16 sidewalls (high  $\gamma$  group).

FIGURE 9. Lost-gas graph for McGrath #1-16 sidewalls (low  $\gamma$  group).

FIGURE 10. Desorption graph for all samples.

FIGURE 11. Location map for samples with gas chemistry.

FIGURE 12. Methane isotopes of desorption gas compared to nearby conventional gases.

FIGURE 13. Methane carbon and hydrogen isotopes vs. hydrocarbon wetness of desorption gas compared to nearby conventional gases.

FIGURE 14. Ethane and propane carbon isotopes of desorption gas compared to nearby conventional gases.

# Correlation of Field Barometer to KGS Petrophysics Lab Barometer

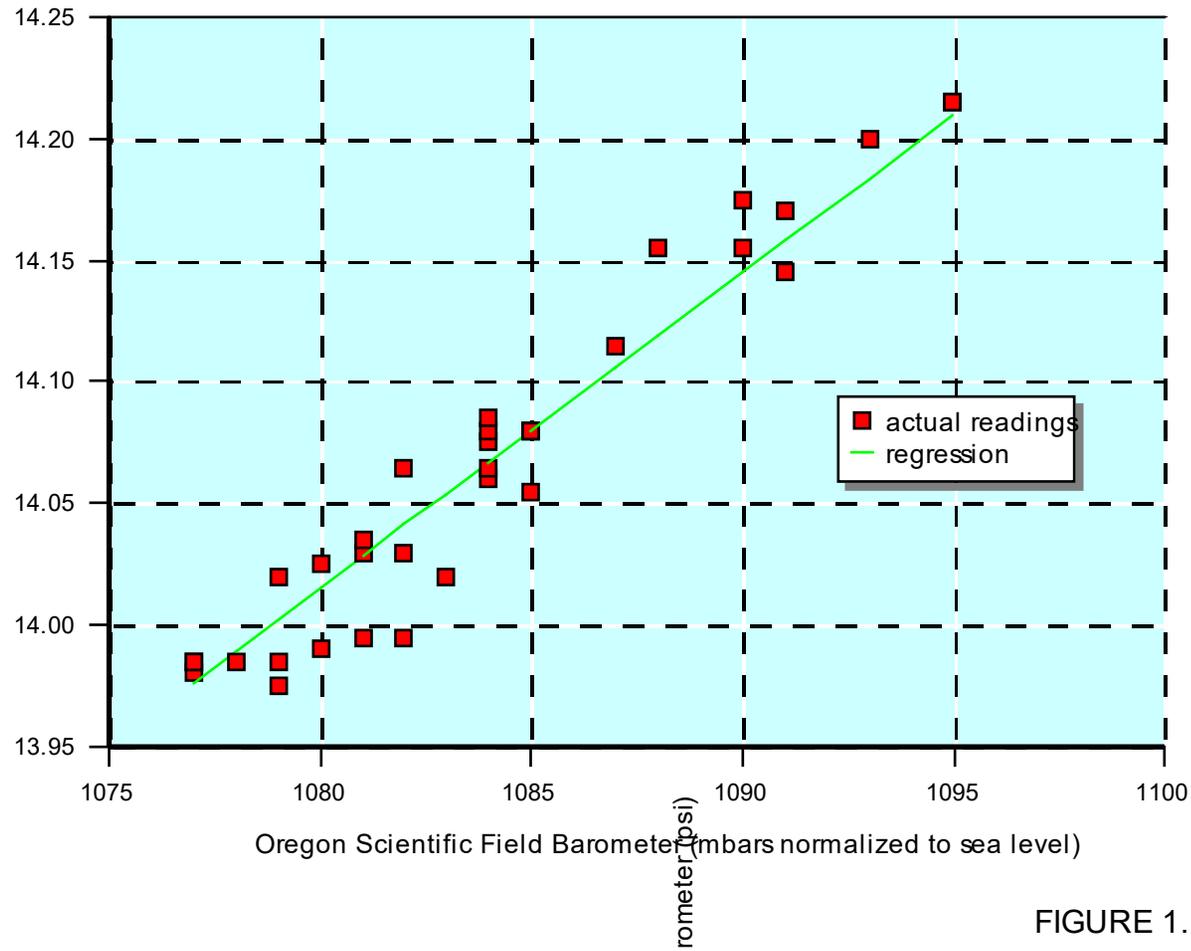


FIGURE 1.

4885' to 4895' (Chattanooga Shale) cuttings in canister M  
 Metro Energy Group #1-34 Spriggs; SE NE NE 34-T.33S.-R.13W., Barber County, KS

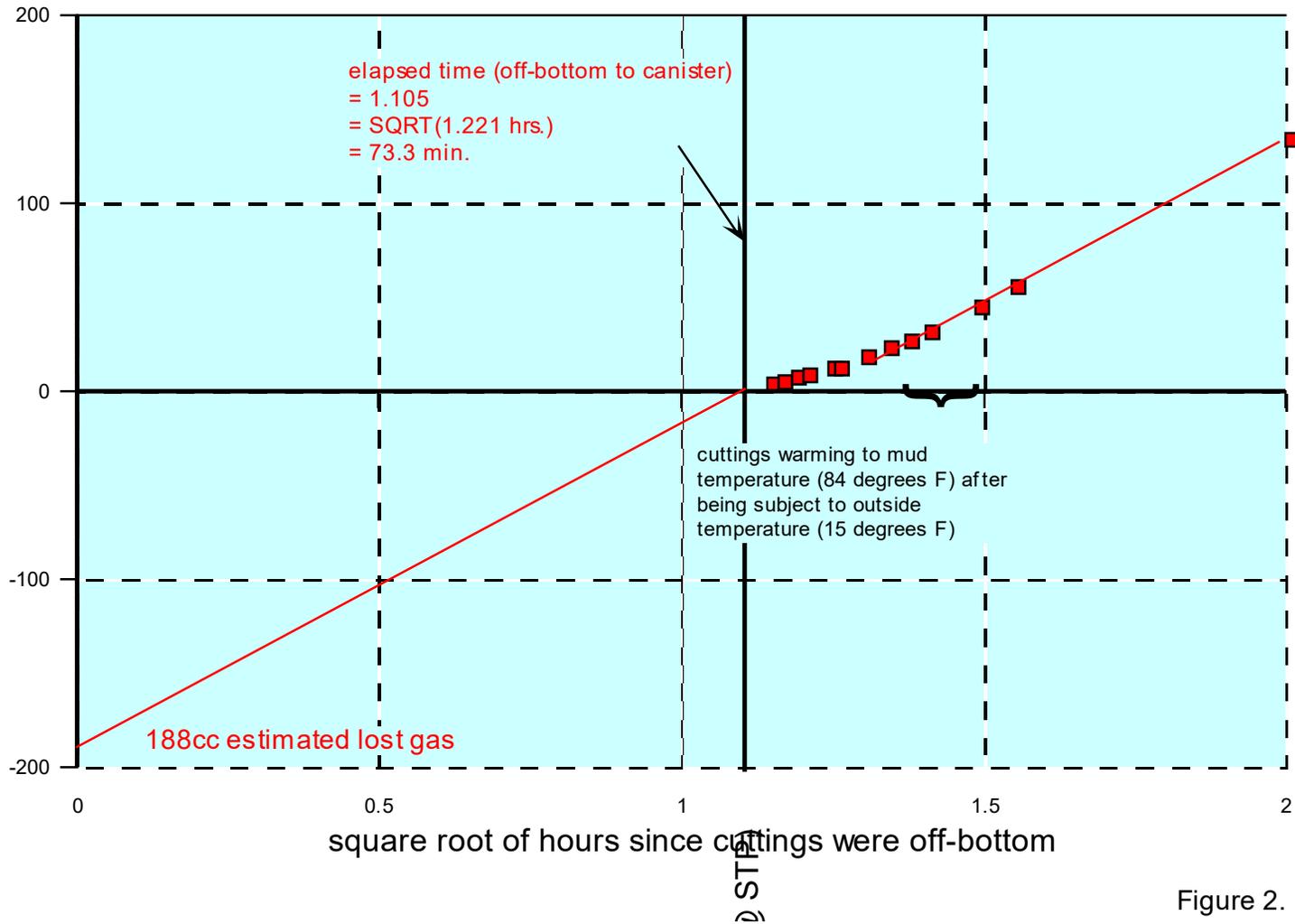


Figure 2.

4895' to 4905' (Chattanooga Shale) cuttings in canister S1  
 Metro Energy Group #1-34 Spriggs; SE NE NE 34-T.33S.-R.13W., Barber County, KS

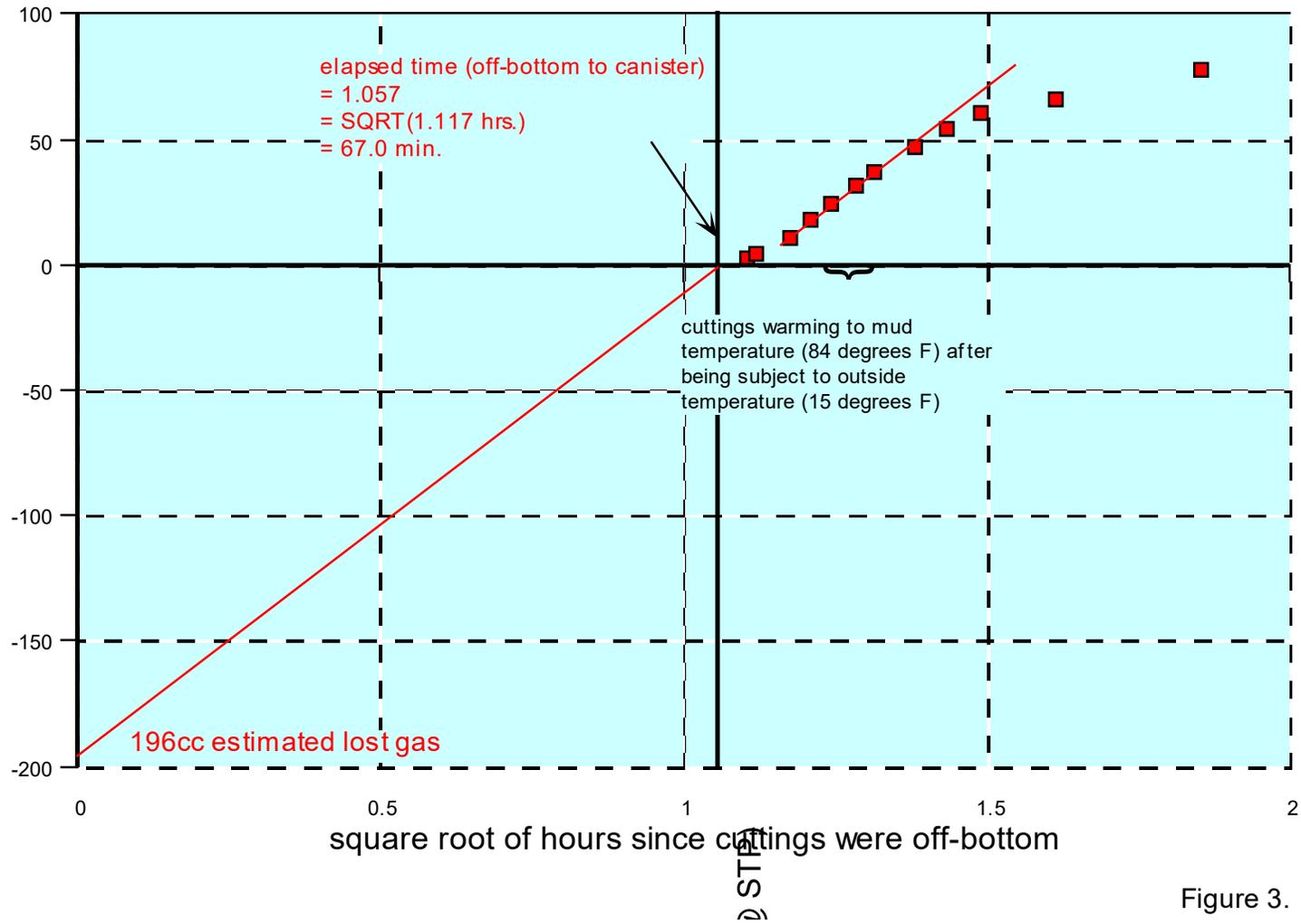


Figure 3.

4916' to 4926' (Chattanooga Shale) cuttings in canister DN1  
 Metro Energy Group #1-34 Spriggs; SE NE NE 34-T.33S.-R.13W., Barber County, KS

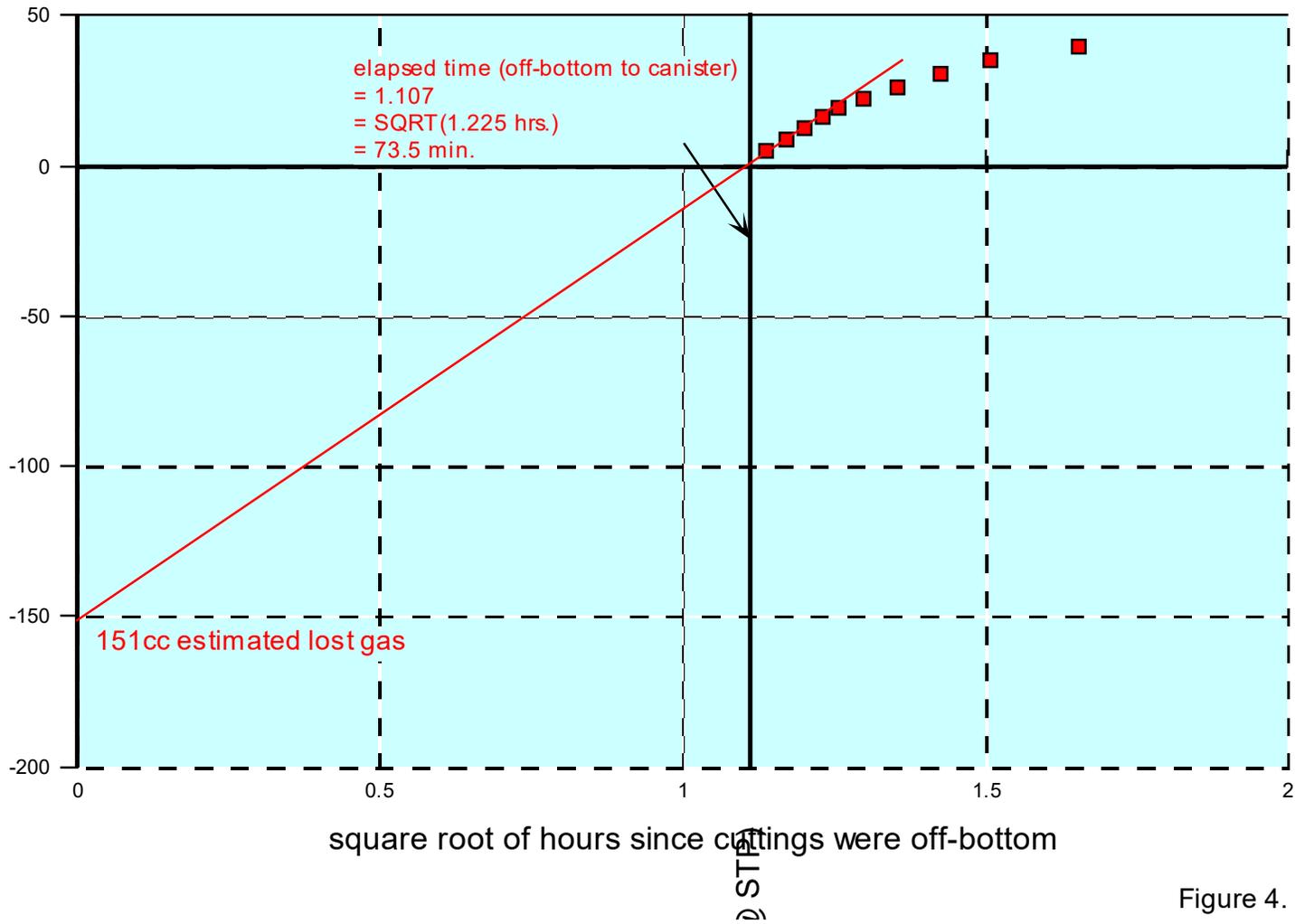


Figure 4.

4926' to 4941' (Chattanooga Shale) cuttings in canister MER 2  
 Metro Energy Group #1-34 Spriggs; SE NE NE 34-T.33S.-R.13W., Barber County, KS

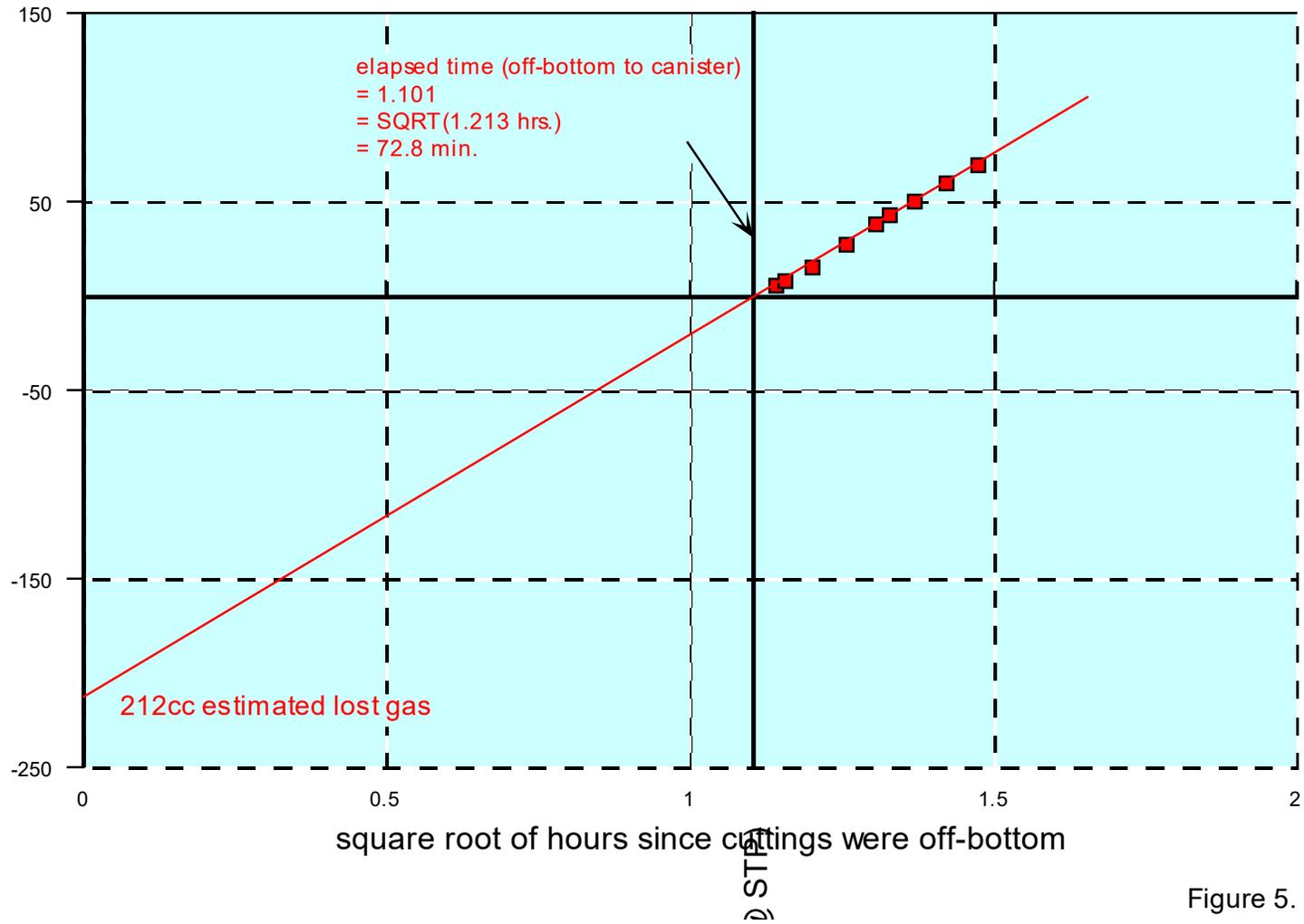


Figure 5.

4892', 4898', 4933', 4938' sidewall cores  
 (from high gamma-ray part of Chattanooga Shale) in canister S2  
 Metro Energy Group #1-34 Spriggs; SE NE NE 34-T.33S.-R.13W., Barber County, KS

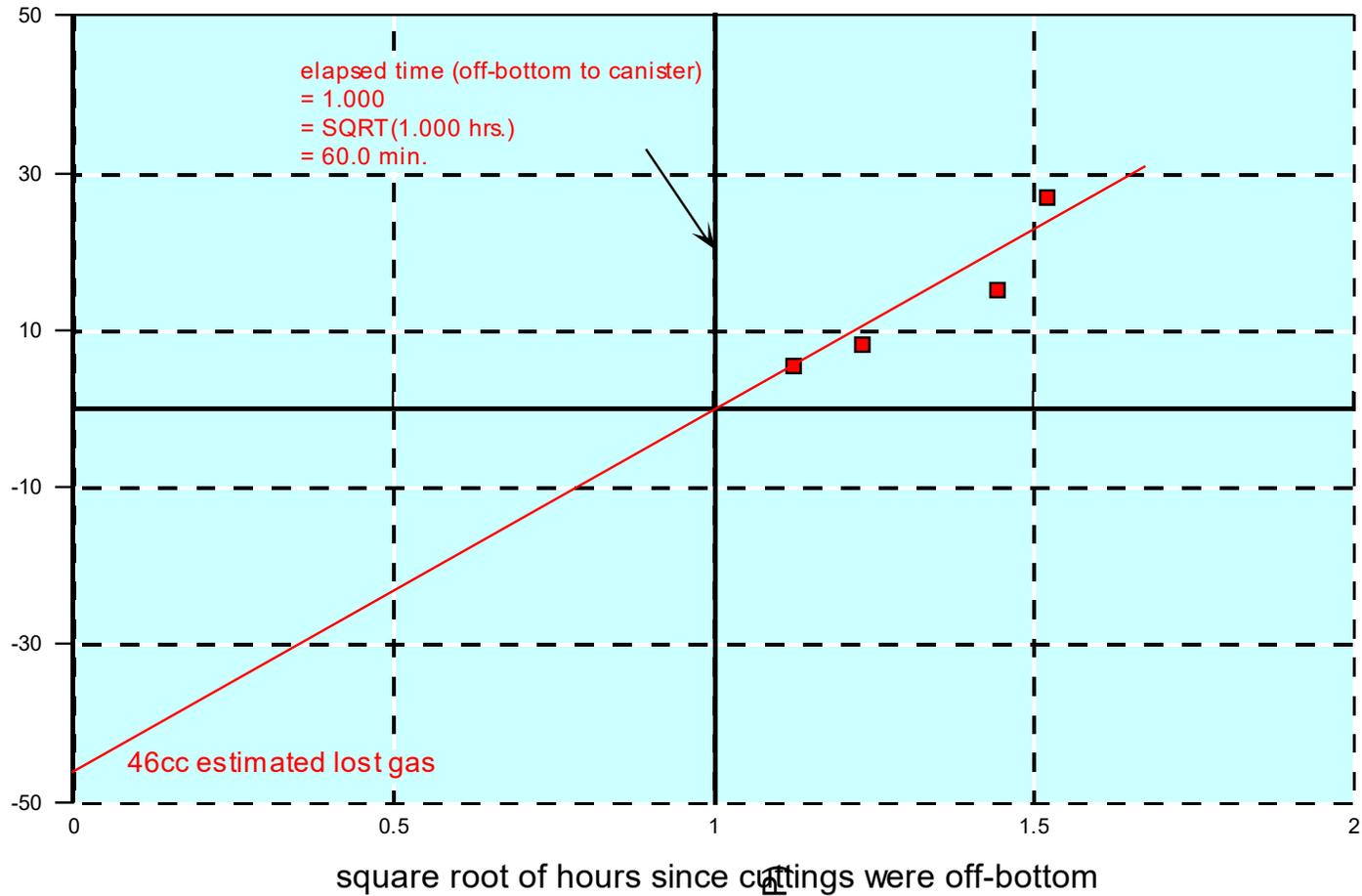


Figure 6.

4902', 4908', 4913', 4918', 4924', 4928' sidewall cores  
 (from low gamma-ray part of Chattanooga Shale) in canister DN (blank)  
 Metro Energy Group #1-34 Spriggs; SE NE NE 34-T.33S.-R.13W., Barber County, KS

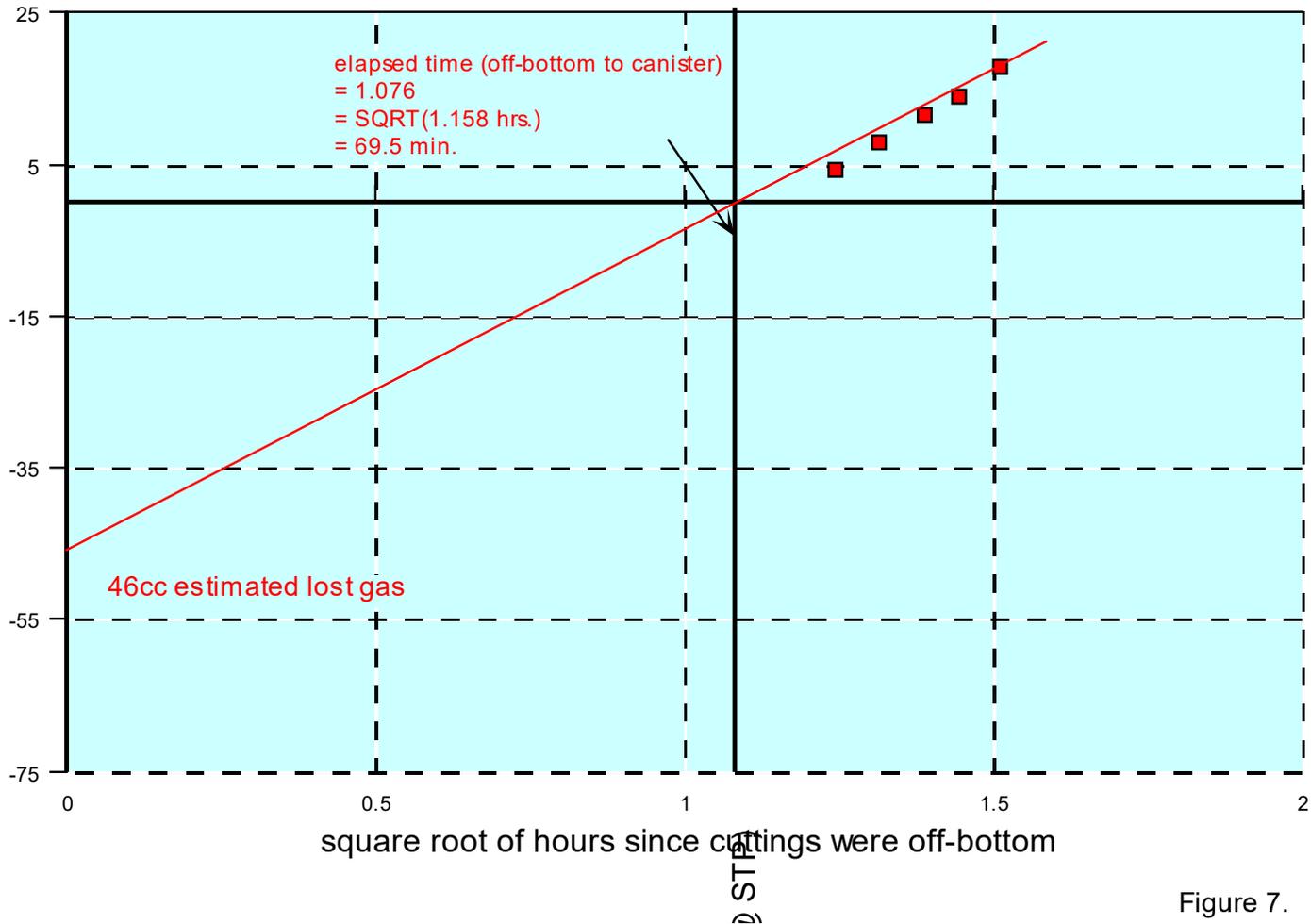


Figure 7.

4903', 4906', 4939', 4943' sidewall cores  
 (from high gamma-ray part of Chattanooga Shale) in canister 1  
 Metro Energy Group #1-16 McGrath; NW SE NE 16-T.33S.-R.14W., Barber County, KS

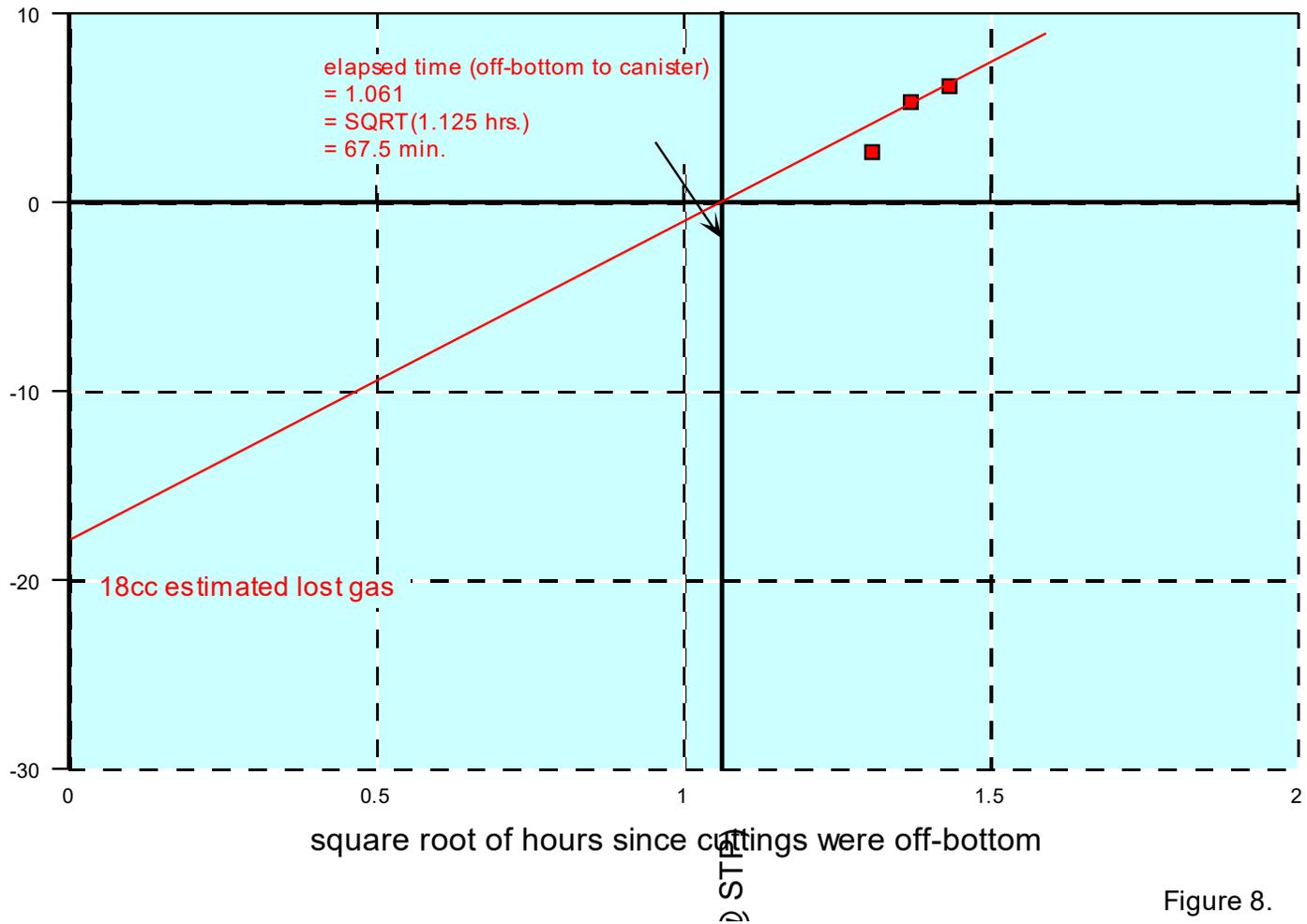


Figure 8.

4899', 4915', 4926', 4932' sidewall cores  
 (from low gamma-ray part of Chattanooga Shale) in canister DCBE  
 Metro Energy Group #1-16 McGrath; NW SE NE 16-T.33S.-R.14W., Barber County, KS

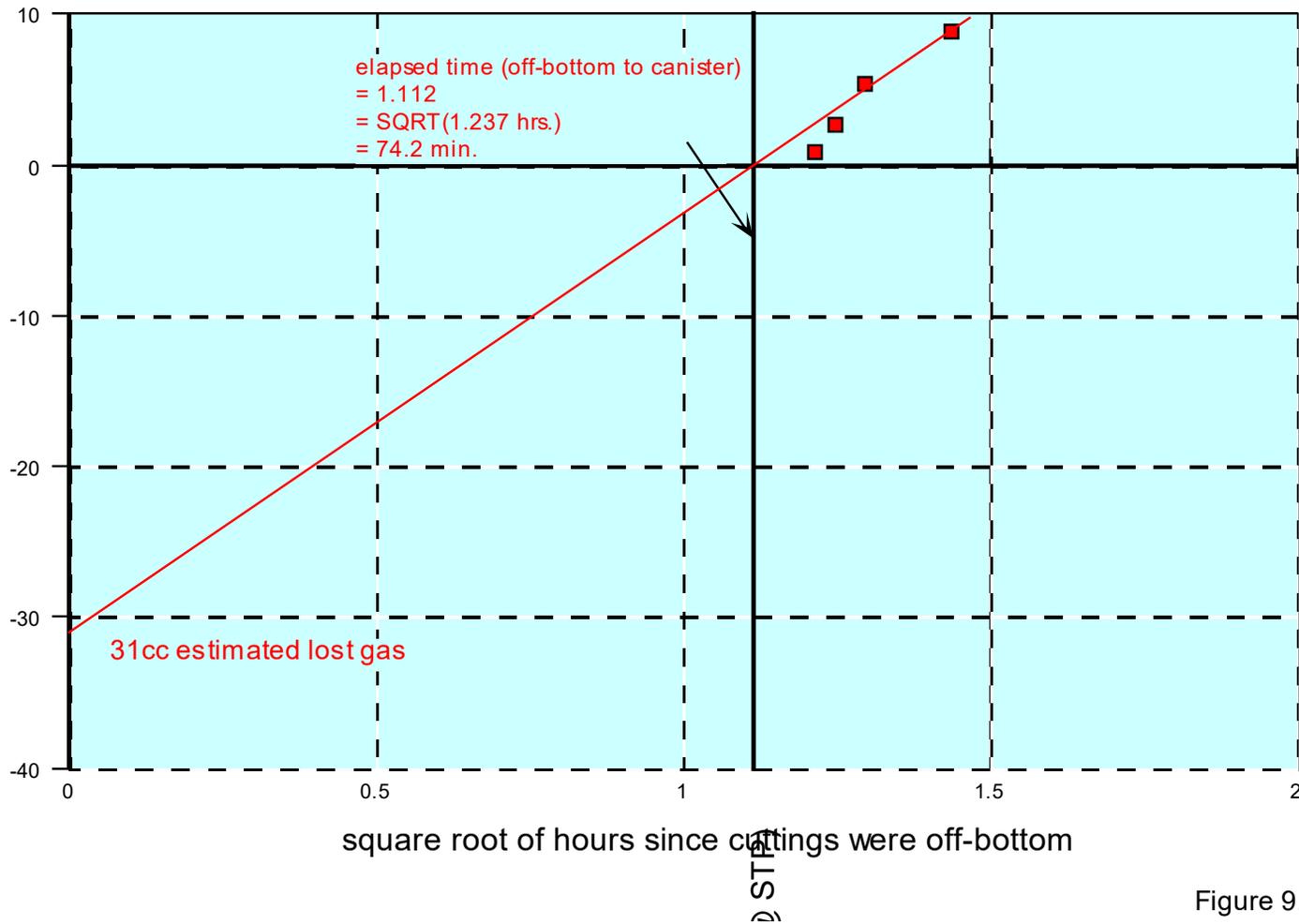


Figure 9.

# Desorption Characteristics of Cuttings and Sidewall Core Samples

based on total weight of gas-generating lithologies (i.e., dark shale) in sample  
 Metro Energy Group #1-34 Spriggs, 34-T.33S.-R.13W., Barber County, KS  
 Metro Energy Group #1-16 McGrath, 16-T.33S.-R.14W., Barber County, KS

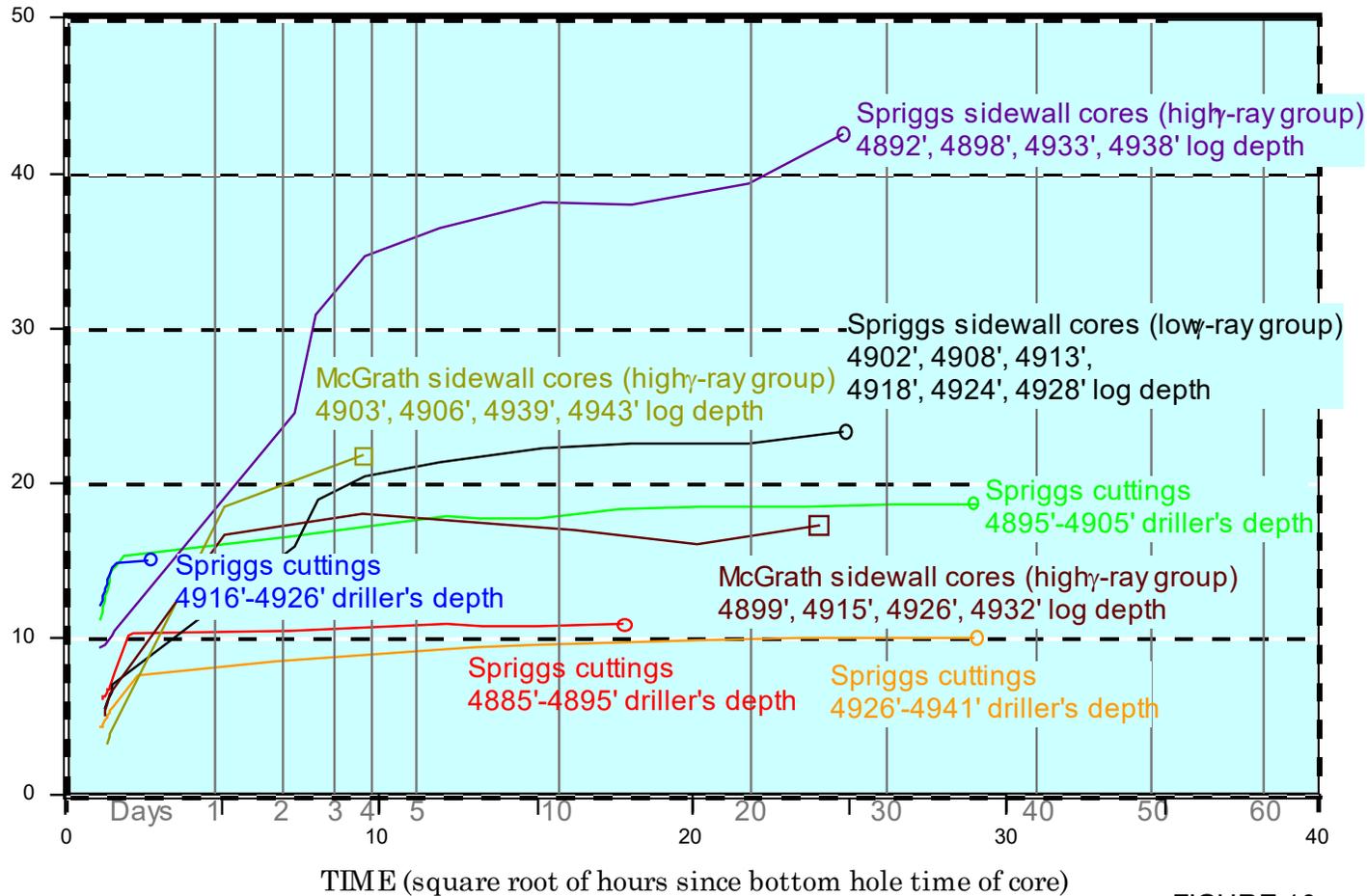


FIGURE 10.

# LOCATION OF GAS SAMPLES



(stratigraphically above basal Pennsylvanian angular unconformity)



(stratigraphically at basal Pennsylvanian angular unconformity)

- |  |   |
|--|---|
| 1. TXO Production #1A Mill Feed (sec. 19-T.31S.-R.13W.), Pennsylvanian Douglas Gp., 3776', 1039 BTU, 6.80% wetness           | 7. TXO Production #D-1 Z-Bar Cattle Co. (sec. 33-T.34S.-R.15W.), Mississippian chat, 4890', 1065 BTU, 5.05% wetness |
| 2. TXO Production #1 Colton (sec. 23-T.32S.-R.11W.), Pennsylvanian Indian Cave Ss., 2564', 961 BTU, 5.05% wetness            | 8. Pickrell Drlg. #2 Wooldridge (sec. 6-T.30S.-R.7W.), Mississippian ls., 4140', 1141 BTU, 18.25% wetness           |
| 3. F.G. Holl #1-34 Miller "C" (sec. 34-T.29S.-R.11W.), Pennsylvanian Indian Cave Ss., 2740', 1027 BTU, 5.06% wetness         | 9. TXO Production #4 McAninch-Gregg (sec. 31-T.32S.-R.16W.), Mississippian chat, 5115', 1062 BTU, 5.10% wetness     |
| 4. TXO Production #2 McMoran (sec. 8-T.35S.-R.16W.), Pennsylvanian Hertha Ls., 5132', 1054 BTU, 5.67% wetness                |   |
| 5. Attica Gas Ventures #1 City of Attica (sec. 19-T.32S.-R.8W.), Pennsylvanian Stalnaker ss., 3690', 1029 BTU, 9.21% wetness |   |
| 6. Attica Gas Ventures #3 Hospital (sec. 24-T.32S.-R.9W.), Pennsylvanian Douglas Gp. ss., 3425', 1038 BTU, 8.39% wetness     |   |

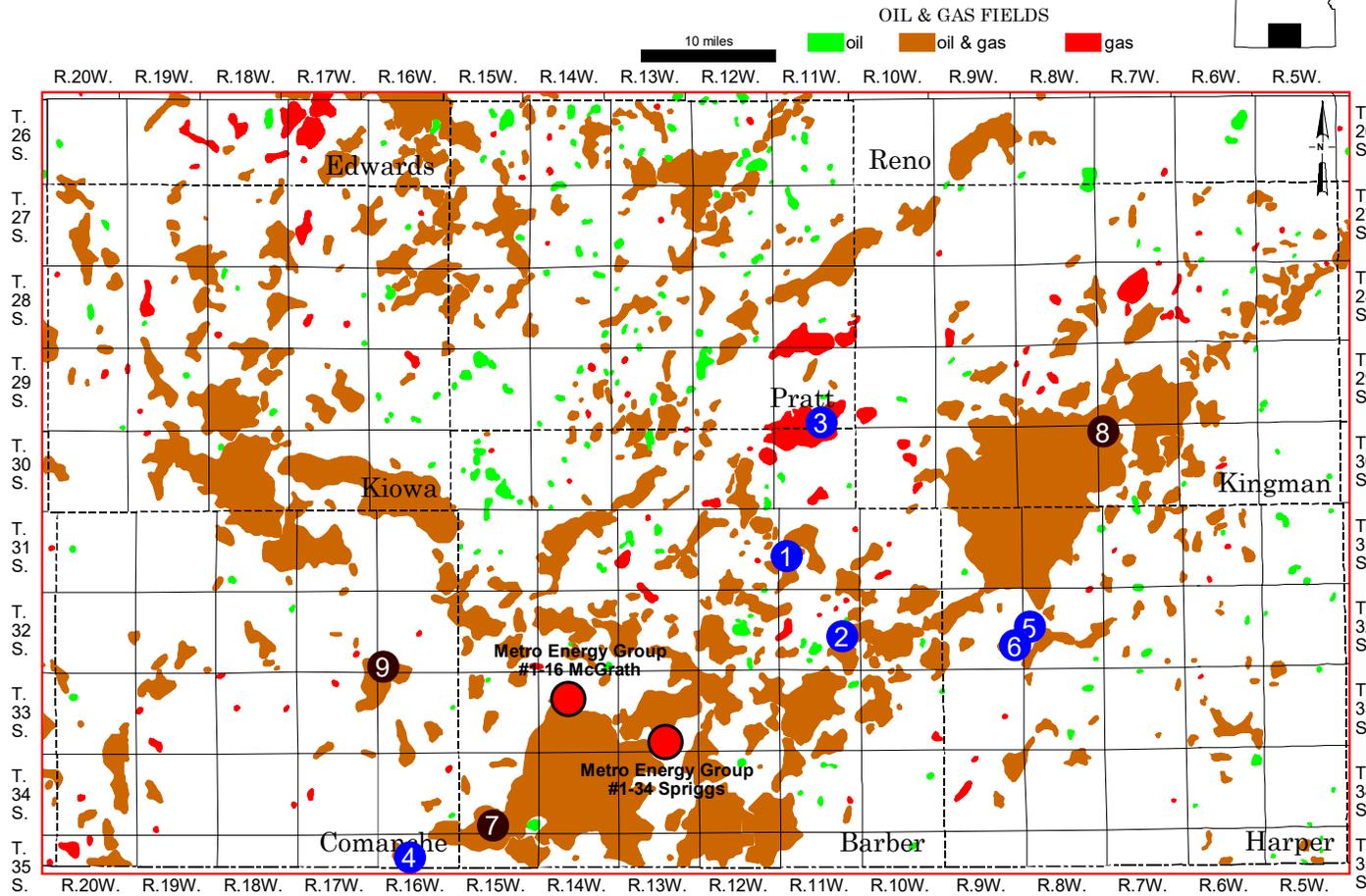


Figure 11.



