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EASTERN GAS SHALES PROJECT OUTGASSING ANALYSIS - SPECIAL REPORT

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EASTERN GAS SHALES PROJECT OUTGASSING ANALYSIS SPECIAL REPORT

by

Donald L. Streib[1]

ABSTRACT

Two methods are used on the Eastern Gas Shales Project to measure the gas volume of encapsulated shale samples. The direct method measures pressure and volume and is initiated almost immediately upon encapsulation of the sample. A second method measures pressure, volume, and composition, and is initiated after pressure is allowed to build up over several weeks. A combination of the two methods has been used on selected samples, and yields more data as it allows extrapolation to account for gas lost prior to encapsulation.

The stratigraphic horizons, characterized by dark shales with high organic and high carbon content and a relatively high gamma ray intensity of 200+ API units also have high gas contents (relative to other units within the same well). The Lower Huron, Rhinestreet, and Marcellus Shales are high in gas content relative to other stratigraphic units at the same sites. The difference in gas content of the same stratigraphic horizon between well sites appears to be controlled by the thermal maturity. Kinetic studies have shown that, in some samples, significant amounts of gas are released after the time when the gas volume would be initially measured. Additional work needs to be performed to determine why the rates and volume of gas released vary between samples.

INTRODUCTION

PURPOSE AND OBJECTIVES

The purpose of this report is to summarize what has been learned from the measurement of gas volumes produced from encapsulated shale core samples and to recommend changes in analytical technique and/or data usage that will quantify the resource and aid in exploration for gas in the Devonian Shale. The objectives of the study are as follows:

- To compile all usable data on gas volumes derived from outgassing measurement and to present the data for each well in the same measurement units.

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- To identify zones of relatively high gas content within each well and to compare these zones to gamma ray intensity, lithologic description, carbon content, and vitrinite reflectance values.
- To compile and present data showing the relationship between gas volume and carbon content and to further analyze and interpret the data to refine the relationship.
- To compare gas volume to thermal maturity.
- To describe the general geologic setting of each well and to determine the general effect of geologic setting upon observed gas content.
- To present and interpret the available data from gas kinetic studies.

CONTRACTORS AND METHODS

Most of the measurements of gas volume of encapsulated core samples for the Eastern Gas Shales Project are provided by Battelle Columbus Laboratories and Mound Facility. Columbia Gas System Service Corporation performs gas volume analyses on a regular basis for their own wells, and these data are available from shale wells that were drilled and sampled as part of the EGSP. For the purposes of characterizing gas volumes in the Eastern Devonian Shale, these contractors provide the most useful data.

Battelle Columbus Laboratories collected samples every ten feet throughout the cored interval for themselves and for Mound Facility. Mound's samples were offset by five feet from the Battelle samples. Columbia Gas System Service Corporation collected their own samples, generally at ten-foot core intervals, except for Lincoln County where a five-foot interval was used. Samples were collected for special studies being conducted by the United States Geological Survey and Juniata College. These samples were collected at fifty-foot core intervals and provide little information on the volume of the gas resource. The Illinois State Geological Survey and the Indiana Geological Survey collected and encapsulated a few samples from wells in their respective states. This report is therefore based on the closely spaced samples collected for and analyzed by Battelle Columbus Laboratories, Mound Facility, and Columbia Gas System Service Corporation.

Two basic methods were used to calculate the volume of gas release by an encapsulated sample. Columbia Gas System Service Corporation used a direct measure based on pressure and volume. Battelle Columbus Laboratories and Mound Facility used a measuring system based on pressure, volume, and composition.

The direct method used by Columbia Gas System Service Corporation was developed in 1973 by Kissell, McCulloch and Elder of the United States Bureau of Mines (1)[2]. This method was designed to measure the methane released from encapsulated coal core samples. The volume of the

gas was measured by releasing it from the container into an inverted water-filled graduated cylinder (Figure 1). The advantage of this method over that used by Battelle Columbus Laboratories and Mound Facility is that measurement can begin almost immediately after encapsulation of the sample. This allows a calculation to be performed to determine gas lost during the extraction of core from the reservoir and the encapsulation process by plotting the volume of gas released versus the square root of the time and extrapolating backwards to the start of the core extraction. Columbia Gas System Service Corporation prefers to use the cumulative gas released versus the log of the time.

The direct method has several limitations as it has been applied to determining gas volume from shale. The method cannot accurately measure small volumes of gas because of the problems involved with measuring water displacement (as the method is described) and because no determination of the gas composition is made. A further limitation is the interference effects that can be created by the presence of a foreign gas such as air in the container.

Columbia Gas System Service Corporation does not believe that these limitations exist. They reserve some low pressure samples for gas analysis and have determined the hydrocarbon properties to be constant throughout the shale section. They also apply the direct method until all gas is released. Columbia also states that their method can account for the presence of foreign gas because: their analyses show the gas to be hydrocarbon with the exception of approximately two percent N_2; therefore gas released under pressure will be due to hydrocarbons (2).[2]

The method of measurement currently in use by both Battelle Columbus Laboratories and Mound Facility consists of the determination of pressure, volume, and composition. This procedure measures the volume of released gas in two steps. The volume of the gas released when the container is opened is measured at standard temperature and pressure (one atmosphere and $0^{o}C$). The fraction of hydrocarbon in the gas is measured by gas chromatograph or mass spectrometer. The containers are usually opened by Battelle Columbus Laboratories after a standard time period of three weeks. Mound Facility allows the sample at least three weeks to build up pressure, but the normal time span exceeds six weeks.

There are advantages and disadvantages to both methods. The direct method allows for the determination of volumes and rates of release soon after encapsulation; therefore allowing the gas lost prior to encapsulation to be calculated. The Battelle and Mound method has the advantage of greater accuracy of measurement because of the sophisticated equipment used to measure both volume and composition. Neither method allows for the measurement of gas release over a long period of time.

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2 Underlined numbers in parentheses refer to items in the list of references at the end of this report.

Outgassing volume data do not measure the absolute volume of gas-in-place in the shale. The data provide information on relatively high and low gas content for specific locations and stratigraphic horizons. The current measurements of gas volume indicate a total volume of gas-in-place which is low for the following reasons:

- Gas that would be released over a period of several months after the initial measurement is not determined. Mound Facility has stated that most of the gas is released during the initial storage period, and Mound provides a value for the remaining gas (3). However, other studies have shown significant amounts of gas released after the initial storage period.

- Gas lost prior to encapsulation of the core samples is not determined, although it is potentially accounted for by the direct method.

- Gas lost due to container leakage is not measured, although samples that have been detected as leaking are not used for volume determination.

In order to quantitatively determine the gas volume of the shale using outgassing measurements, the limitations listed above must be corrected. To determine the gas released over a relatively long period of time, the samples can be placed in special containers and analyses for volume performed at set time intervals. The logistics, expense, and time required to use this method limits this option. An alternative method is to determine physical and chemical characteristics of the samples used for the determination of long term gas release. From a comparison of physical and chemical properties to gas volume and release rates, it should be possible to establish some type of correlation. An estimate of total gas content should be possible at this point by comparing the rock characteristics and measured gas volume of previous samples to the same variables which are correlated to release rates and total gas volume.

To determine gas lost prior to sample encapsulation, the rate of release and change in rate must be determined and then extrapolated back to the time when coring of the sample was initiated. A series of measurements beginning at the well site shortly after encapsulation will be necessary in order to construct the curve. In order to obtain an accurate measurement, a method of determining gas composition in the field is necessary. A portable gas chromatograph could provide the most accurate answer. Battelle Columbus Laboratories and Mound Facility have proposed using a procedure incorporating a portable gas chromatograph (3). The direct method does not provide the degree of accuracy needed, especially on samples with a low gas content. Gas loss by leakage from the container could be corrected by the use of a better quality container. Mound Facility has reported few leaking containers (3), but other contractors have not been so fortunate. Mound facility also double cans samples showing positive pressure. This is a procedure that would solve the problem if the double canning was done in the field, but appears to be of limited use if performed after the container is

delivered to the laboratory. The container used by the United States Bureau of Mines is leakproof under normal use but is expensive. The best alternative appears to be the modified naval surplus powder cans used by the Indiana Geological Survey and the Illinois State Geological Survey. These have proven satisfactory to both of the above contractors and Battelle Columbus Laboratories. However, Battelle has used these containers only on a limited basis.

IDENTIFICATION OF GAS ZONES

APPALACHIAN BASIN

The EGSP wells cored in the Appalachian Basin (Figure 2) have shown a higher gas content and a higher thermal maturity than the Illinois Basin wells (Figure 3). Data for seven wells in the Appalachian Basin are available (Table 1).

Table 1

Appalachian Basin Wells

Location	Map Number (Figure 2)
Wise County, Virginia	1
Washington County, Ohio	2
Lincoln County, West Virginia	3
Lincoln County, West Virginia	4
Martin County, Kentucky	5
Mason County, West Virginia	6
Monongalia County, West Virginia	7

Wise County, Virginia (Well #1)

The interval from the top of the Devonian Shale to the top of the Middle Devonian Onondaga Limestone is 810 feet at the well site (4). Core samples for outgas analysis were taken from a depth of 4871 feet to 4981 feet and from 5211 feet to 5488 feet.

The area is structurally complex and related to the thin-skinned nature of previous tectonic activity. The Pine Mountain overthrust is located to the west of the site. All of the shallow and surface features in the area are thought to be related to shallow decollement faulting in the Devonian Shale (5). The well was located so as to be in a synclinal low, bounded on the east by the north-south trending, thrust-faulted Buck Knob Anticline and on the west by the Rogers Ridge Fault (4).

The area of the well site is bounded by lineation zones identified by Landsat and Skylab imagery. The well is sited on the northwest-southeast trending Powell River Lineament and is adjacent to the northwest-southeast trending Guest River-Critical Fork Lineament (5). These features originate at the Buck Knob Anticline.

Core samples were analyzed from two zones in this well by Battelle Columbus Laboratories, Mound Facility, and Columbia Gas System Service Corporation. The upper zone began at a depth of 4872 feet and extended to 4980 feet. The lower zone began at 5212 feet and extended to 5469 feet (Plate 1)[3].

The upper cored zone is divided into two zones of relatively different gas content. From a depth of 4872 feet to 4940 feet, the gas volume ranges from 1.48 to 3.27 cubic feet of gas per cubic foot of shale with an average content of 2.32 cubic feet per cubic foot. Total carbon content of this zone ranges from 2.3 to 6.2 percent and averages 4.3 percent. Gas content and percent carbon are averages of all available data. The interval is composed of over 90 percent black shale, relatively radioactive, averaging 180 to 220 API, as compared with the adjacent zone.

From a depth of 4940 feet to 4980 feet, the gas volume, carbon, lithology, and gamma ray intensity change from that of the upper adjacent zone. The gas volume of this zone ranges from 0.05 to 1.26 cubic feet of gas per cubic foot of shale and averages 0.65 cubic feet per cubic foot. Total carbon content ranges from 0.4 to 3.4 percent and averages 1.9 percent. The black shale drops to approximately 40 percent of the total, and the gamma ray intensity is approximately 50 API units lower, on the average, than the adjacent upper zone.

The break between the zones of high and low gas volume matches almost exactly the break between the Cleveland Member and the Chagrin Member (Table 2, Figure 4).

The lower cored interval extends from a depth of 5212 feet to 5469 feet. This interval averages 1.64 cubic feet of gas per cubic foot of shale for the entire interval. There are several zones of unusually high gas content within the interval. From 5303 feet to 5322 feet, the average gas content is 2.12 cubic feet of gas per cubic foot of shale and the average carbon content is 2.3 percent. This intervals is over 80 percent black shale with a corresponding high gamma ray intensity, generally over 200 API.

From 5348 feet to 5382 feet, the average gas content is 2.04 cubic feet of gas per cubic foot of shale with an average carbon content of 4.2 percent. The percentage of black shale in this sequence ranges from 80 to 100 percent with corresponding high gamma ray intensities, ranging from 220 to 380 API.

From 5414 feet to 5482 feet the average gas content is 2.68 cubic feet of gas per cubic foot of shale with an average carbon content of 4.53 percent. Black shale content ranges from 70 to 85 percent of the rock with a corresponding high gamma ray intensity ranging from 200 to 300 API.

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3 Due to their size, the Plates were not printed. If you wish copies of the Plates, please contact the Morgantown Energy Technology Center Library.

Stratigraphic units with average gas volumes and carbon contents are shown in Table 2.

Table 2

Gas Volume and Carbon by Stratigraphic Unit
Wise County, Virginia (Well #1)

Stratigraphic Zone	Depth	Gas Vol ft^3/ft^3	Carbon Content %
Chagrin Member	4868'-4870'	-	-
Cleveland Member	4870'-4938'	1.41	4.55
Chagrin Member	4938'-5036'	0.43	2.03
Upper Huron	5036'-5086'	-	-
Chagrin-Chemung	5086'-5330'	0.87	1.74
Lower Huron	5330'-5480'	1.20	3.24
Upper Olentangy	5480'-5506'	-	-
Pipe Creek Member	5506'-5520	-	-
Upper Olentangy	5520'-5630'	-	-
Rhinestreet Member	5630'-5678'	-	-

The shale at this site is thermally mature with an Ro (optical reflectance) value obtained from vitrinite reflectance measurement ranging from 0.91 to 1.28 using average figures, and from 1.15 to 1.47 if the maximum values are used.

Washington County, Ohio (Well #2)

The interval from the base of the Lower Mississippian Bedford Shale to the top of the Middle Devonian Onondaga Limestone is approximately 2200 feet at this site. The Devonian Shale is divided into the Ohio Shale and the Olentangy Shale. The upper unit or the Ohio Shale is subdivided into the Cleveland Shale, Chagrin Shale, and the Huron Shale (6). The Cleveland Shale is a highly carbonaceous, bluish-black to brownish-black shale with gas potential (7). The middle unit or the Chagrin Shale underlies the Cleveland Shale and is a carbonaceous, clayey shale. The basal unit or the Huron Shale is petrographically similar to the Cleveland Shale except the Huron contains argillaceous nodules and calcareous concretions (6). The bluish-gray Olentangy Shale underlies the Ohio Shale and overlies the Onondaga Limestone.

The Devonian Shales have an east to southeast regional dip and subsurface relief is minimal. The site is located southwest of the anticlinal Cambridge Arch which trends $N10^{o}W$.

Core samples were taken at this site from a depth of 3491 feet to 3711 feet. Data are displaced in Plate 2. Gas content averages 0.50 cubic feet of gas per cubic foot of shale over the entire cored

interval. From 3491 feet to 3580 feet, the shale averages 0.28 feet of gas per cubic foot of shale and carbon averages 1.62 percent. The samples analyzed ranged from 25 to 95 percent black shale in this zone.

From 3580 feet to 3610 feet, the shale contains an average of 0.76 cubic feet of gas per cubic foot of shale and the carbon content averages 3.61 percent. The percentage of black shale in this interval ranges from 70 to 90 percent with a corresponding high gamma ray intensity (224 to 344 API).

From 3610 feet to 3670 feet, the gas content averages 0.83 cubic feet of gas per cubic foot of shale and carbon averages 3.26 percent. Black shale averages range from 10 to 100 percent with corresponding gamma ray intensity.

From 3670 to 3711 feet, gas volume averages 0.54 cubic feet of gas per cubic foot of shale and carbon averages 1.58 percent. Black shale ranges from 15 to 70 percent of the rock with corresponding gamma ray intensity. Only three samples were analyzed using vitrinite reflectance at this site. The range of Ro values is too great to make any conclusions as to the relative thermal maturity of the site. (Refer to Well #2, Appendix, for data)

Lincoln County, West Virginia (Wells #3 and 4)

The Devonian Shale interval from the Berea Sandstone to the Onondaga Limestone is approximately 1400 feet thick in Lincoln County, West Virginia (8). In order to avoid incorrect correlations of accepted stratigraphic units, six shale horizons are identified in the Lincoln County wells. These units are: (1) Upper Gray, which is silty and medium gray to greenish-gray in color; (2) Upper Brown, mostly dark gray with higher organic content than the Upper Gray; (3) Middle gray, medium to dark gray with higher carbon content than the Upper Gray; (4) Middle Brown, black with medium gray zones and high carbon content; (5) Lower Gray, blue-gray with black layers; and (6) Lower Brown, black and similar in content to the Middle Brown (Figure 5) (9).

Lincoln County, West Virginia is located in the central portion of the Appalachian Plateau Province and is characterized by numerous small synclines that together form a broad, elongated synclinorium. In the area of Lincoln County, these synclines are less apparent, and the most prominent surface structural feature is the Guthrie Syncline at the southern end of the county (10). Detailed information on the subsurface structure is not available due to the lack of sufficient deep wells in the area.

A zone of deep-seated faulting (11) has been postulated as a major mechanism in producing fracture systems and fracture porosities in the Devonian Shales in areas of southwestern West Virginia that historically have produced gas from the Devonian Shales (12,13,14). The major basement structural feature that may underlie Lincoln County is the Rome Trough (Figure 6) (15). Recent studies of the Cottageville Gas Field in Jackson and Mason Counties, West Virginia, located approximately 80 miles northeast of the study area, suggest that movement of the basement

fault blocks in the Rome Trough has resulted in the fracturing observed in the Devonian Shales (14,16). Insufficient deep structural data on Lincoln County preclude hypothesizing, at this time, that similar basement movements caused the fracturing observed in cores from Columbia Wells #20402 and #20403, although a preliminary inspection of the data suggests similar directional trends of fractures and postulated strike of the basement faults in both areas. The dominant fracture trend, based on these two wells, strikes northeast (8). Studies of the Cottageville Field show a similar northeast fracture trend, but the orientations are more dispersed. DeWys and Shumaker (14) show that the trends appear to approximate the postulated strike of the basement faulting.

Well #3 in this study corresponds to Columbia Gas System #20403. Core samples were taken from a depth of 2735 feet to 4051 feet. Data are illustrated in Plate 3. The average gas content for the entire interval was 0.25 cubic feet of gas per cubic foot of shale. Gas content is an average of all data from all sources.

The Chagrin Member of the zone which corresponds to the Upper Gray Shale, from 2735 feet to approximately 2945 feet, has an average gas content of 0.05 cubic feet of gas per cubic foot of shale and an average carbon content of 0.95 percent. Most of this zone contains 30 percent or less black shale.

The Upper Brown Shale or Cleveland Member, extending from 2945 feet to 3008 feet, has an average gas content of 0.09 cubic feet of gas per cubic foot of shale and an average carbon content of 1.98 percent. Black shale content ranges from 10 to 90 percent with corresponding high gamma ray intensity (200+ API).

The Middle Gray Shale including the Chagrin Member, Upper Huron Member, and Chagrin-Chemung, extending from 3000 feet to 3404 feet, has an average gas content of 0.14 cubic feet of gas per cubic foot of shale and an average carbon content of 1.23 percent. Black shale ranges from 10 to 100 percent of the rock in this zone. Gamma ray intensities do not appear to correlate with zones of higher black shale in the Middle Gray zone.

The Middle Brown Shale or Lower Huron Member extends from 3404 feet to 3662 feet and has an average gas content of 0.36 cubic feet of gas per cubic foot of shale and an average carbon content of 3.73 percent. Black shale ranges from 0 to 95 percent and the entire zone is characterized by a high gamma ray intensity (200 to 350 API). At the top of the zone from 3421 feet to 3467 feet, there is a zone averaging 0.46 cubic feet of gas per cubic foot of shale.

The Lower Gray Shale or Upper Olentangy and Pipe Creek Member extends from 3662 feet to 3942 feet. The average gas content of this zone is 0.29 cubic feet of gas per cubic foot of shale, and the average carbon content is 0.46 percent. The percentage of black shale in the sequence is generally low, ranging from 0 to a maximum of 60 percent but more commonly averaging about 20 percent. Gamma ray intensity is variable throughout the sequence (200 to 350 API).

The Lower Brown Shale or Rhinestreet, Lower Olentangy, and Marcellus Members extends from a depth of 3942 to 4051 feet. Gas content in this sequence of shale averages 1.02 cubic feet of gas per cubic foot of shale, and the carbon content averages 4.3 percent (only two carbon data points). Black shale ranges from 30 to 100 percent and is generally high with a gamma ray intensity ranging from 200-400 API.

There are no vitrinite reflectance data available for this well.

The stratigraphic units as defined by Columbia Gas System Service Corporation are illustrated in Figure 7. The gas volumes and carbon contents by stratigraphic unit are illustrated in Table 3.

Table 3

Gas Volume and Carbon by Stratigraphic Units
Lincoln County, West Virginia (Well #3)

Stratigraphic Zones	Depth	Gas Vol ft^3/ft^3	Carbon Content %
Chagrin Member	2735'-2945'	0.05	0.95
Cleveland Member	2945'-3008'	0.09	1.98
Chagrin Member	3008'-3074'	0.09	0.95
Upper Huron	3074'-3196'	0.15	1.03
Chagrin-Chemung	3196'-3404'	0.13	1.29
Lower Huron	3404'-3662'	0.36	3.73
Upper Olentangy	3662'-3742'	0.11	-
Pipe Creek Member	3742'-3760'	0.46	1.50
Upper Olentangy	3760'-3942'	0.31	-
Rhinestreet Member	3942'-4012'	0.87	2.80
Lower Olentangy	4012'-4022	0.76	-
Marcellus Shales	4022'-4051	1.13	5.80

Lincoln County well #4 designated #20402 by Columbia Gas, was only cored at four intervals. Data are presented in Plate 4. The first interval was taken from 2655 feet to 2766 feet and would be stratigraphically located within the Upper Gray Shale. The gas content averages less than 0.02 cubic feet of gas per cubic foot of shale, and the carbon content averages 0.4 percent, although based on only three samples. Black shale content ranges from 0 to 70 percent and is generally low with relatively low gamma ray intensity of approximately 175 API.

The second cored interval was from 3000 feet to 3116 feet and would fall within the Middle Gray Shale. Gas content averages 0.18 cubic feet of gas per cubic foot of shale and carbon content averages 1.1 percent. Black shale ranges from 0 to 95 percent of the rock with slightly higher gamma ray intensities (190 to 200 API) than were recorded in the Upper Gray Shale Zone.

The third cored zone extends from 3298 to 3586 feet and includes the lower section of the Middle Gray Shale and the upper section of the Middle Brown Shale. The break between the units would occur at approximately 3343 feet.

The lower zone of the Middle Gray Shale, 3298 feet to 3343 feet, averages 0.42 cubic feet of gas per cubic foot of shale and 1.05 percent carbon based on two data points (for carbon). If data from both zones of the Middle Gray Shale are combined, the results are an average 0.21 cubic feet of gas per cubic foot of shale and an average 2.17 percent carbon.

Gamma ray intensity is used to determine the base of the Middle Shale at 3343 feet. This zone averages 0.43 cubic feet of gas per cubic foot of shale and 3.43 percent carbon. Black shale ranges from 10 to 100 percent and is generally high with high gamma ray intensity.

The lower cored interval, 3896 to 3971 feet, would be within the Lower Brown Shale as based on the high gamma ray intensity of up to 300 API. Gas content averages 0.85 cubic feet of gas per cubic foot of shale and carbon content averages 4.43 percent. Black shale ranges from 30 to 100 percent, and the lower half of the sequence is about 100 percent black shale.

No vitrinite reflectance data are available for this site.

Martin County, Kentucky (Well #5)

The Devonian Shale interval at this site is approximately 1000 feet thick. It begins in the Chagrin member of the Conewango Series and finishes in the Marcellus Member of the Erie Series (Figure 8) (8).

The well is sited on the downthrown block of the Warfield Fault (south side).

No core samples were encapsulated from the Upper Chagrin Member. The Cleveland Member of the Conewango Series extends from 2432 feet to 2512 feet. The average gas content of the Cleveland Member is 0.56 cubic feet of gas per cubic foot of shale and the average carbon content is 5.66 percent. Gas and carbon content are based on averages of all samples. On the two samples that were tested for organic carbon, organic carbon composed 89 percent and 93 percent of the tested carbon. This interval is composed almost entirely of black shale, and the gamma ray intensity is relatively low (200 API) when compared with lower units (Plate 5).

The Chagrin appears again in the sequence between 2512 feet and 2654 feet (Figure 8). The average gas content is 0.07 cubic feet of gas per cubic foot of shale and the average carbon content is 1.36. These samples were tested for organic carbon and represented 93, 94, and 45 percent respectively of total carbon. Black shale composes only a small percentage of the rock, and the gamma ray intensity is relatively low, averaging less than 200 API.

The Upper Huron Member of the Conewango Series extends from 2654 feet to 2795 feet (Figure 8). The average gas content is 0.09 cubic feet of gas per cubic foot of shale and the carbon content averages 3.16 percent. Organic carbon (4 samples) represented 95, 96, 93, and 84 percent of the total. The interval is composed almost entirely of black shale with some variation in gamma ray intensity ranging from 200 to 300 API (Plate 9).

A sequence defined as Chagrin inter-tonguing Chemung is found between 2795 feet and 2910 feet. The average gas content of this zone is 0.15 cubic feet of gas per cubic foot of shale and the carbon content averages 1.57 percent. Organic carbon from four samples ranged from 17 percent to 99 percent of total carbon. The lower half of the sequence is composed primarily of black shale, and the upper half is composed of light shale with a slightly higher gamma ray intensity in the dark zone (Plate 9).

The Huron Member of the Conewango Series extends from 2910 feet to 3128 feet. The average gas content is 0.55 cubic feet of gas per cubic foot of shale and the carbon content averages 3.90 percent. Organic carbon averages 2.88 percent. Black shale content ranges from 40 to 100 percent of the rock, and gamma ray intensity is high, generally greater than 300 API.

Within the Lower Huron Member are two high gas zones. Between 2960 feet and 2970 feet the average gas content is 1.56 cubic feet of gas per cubic foot of shale and carbon content averages 6.37 percent. This zone is characterized by a black shale percentage composing 100 percent of the rock and an intense gamma ray, approximately 400 API.

The second high gas zone in the Lower Huron is between 3085 feet and 3099 feet. Gas content averages 1.54 cubic feet of gas per cubic foot of shale and carbon content averages 5.86 percent. Black shale ranges from 80 to 100 percent and gamma ray intensity is high (300+ API).

The Upper Olentangy Member of the Seneca Series extends from 3128 feet to 3189 feet. The gas content averages 0.12 cubic feet of gas per cubic foot of shale and the carbon content averages 1.32 percent. Black shale is almost completely absent and gamma ray intensity is low (less than 200 API).

The Pipe Creek Member of the Seneca Series extends from 3189 feet to 3212 feet. Gas content averages 0.11 cubic feet of gas per cubic foot of shale and carbon averages 1.59 percent. Shale is light in color and has a relatively low gamma ray intensity of less than 200 API.

The Upper Olentangy Member appears again between 3212 feet and 3360 feet. Gas content averages 0.20 cubic feet of gas per cubic foot of shale and carbon averages 1.37 percent. Shale is light in color with a low gamma ray intensity, generally less than 200 API.

The Rhinestreet Member of the West Falls Group of New York extends from 3360 feet to 3409 feet. Gas content averages 0.43 cubic feet of gas per cubic foot of shale and carbon content averages 3.79 percent.

Black shale composes from 0 to 95 percent of the rock with corresponding gamma ray intensities, ranging from less than 200 to almost 400 API.

Ro values from the vitrinite reflectance determination are relatively constant throughout the cored interval. Minimum Ro ranges from 0.17 to 0.38 with an exception of 0.60. Maximum values range from 0.38 to 1.00; average values range from 0.38 to 0.71. The mean minimum value is 0.25, the mean maximum value is 0.83, and the mean average is 0.52.

Stratigraphic units with average gas volumes and carbon contents are shown in Table 4.

Table 4

Gas Volume and Carbon by Stratigraphic Unit
Martin County, Kentucky (Well #5)

Stratigraphic Zone	Depth	Gas Vol ft^3/ft^3	Carbon Content %
Cleveland Member	2432'-2512'	0.56	5.66
Chagrin Member	2512'-2654'	0.07	1.36
Upper Huron Member	2654'-2795'	0.09	3.16
Chagrin Chemung	2795'-2910'	0.15	1.57
Huron Member	2910'-3128'	0.55	3.90
	2960'-2970'	1.56	6.37
	3085'-3099'	1.54	5.86
Upper Olentangy	3128'-3189'	0.12	1.32
Pipe Creek Member	3189'-3212'	0.11	1.59
Upper Olentangy	3212'-3360'	0.20	1.37
Rhinestreet Member	3360-3409'	0.43	3.79

Mason County, West Virginia (Well #6)

The Devonian Shale at the Mason County site is approximately 1600 feet thick. The base of the Berea is at a depth of approximately 1750 feet and the top of the Onondaga is at a depth of 3400 feet. The cored interval is from 2673 feet to 3420 feet. The cored section extends from the top of the Huron Member to the base of the Rhinestreet Member (Figure 9). The Huron Member extends from 2678 to 3050 feet. The Java Formation is divided into the Hanover Shale (3050 to 3096 feet) and the Pipe Creek Shale (3096 to 3159 feet). The West Falls Formation is divided into the Angola Shale (3159 to 3329 feet) and the Rhinestreet Member (3329 to 3407 feet) (12).

The well is located on the east flank of the Parkersburg Syncline which dips gently to the northeast. Two sets of natural fractures were identified striking to the northwest and northeast respectively. The northeast trend is believed to represent present *in situ* stress orientation (17).

Core samples were collected from 2700 feet to 3385 feet. The average gas content of all samples of the Huron Member is 0.20 cubic feet of gas per cubic foot of shale and the average carbon content is 3.08 percent. The organic carbon average is 2.74 percent. Black shale content ranges from 10 to 95 percent, and the gamma ray intensity approximately corresponds to the black shale percentage.

The Hanover Shale of the Java Formation has an average gas content of 0.22 cubic feet of gas per cubic foot of shale and a carbon content average of 0.43 percent. Two samples tested for organic carbon showed respectively 46 and 85 percent of the carbon to be organic. This is a light colored shale with low gamma ray intensity, less than 200 API.

The Pipe Creek Shale of the Java Formation has an average gas content of 0.25 cubic feet of gas per cubic foot of shale and an average carbon content of 0.82 percent. No tests were performed for organic carbon within this interval. Black shale content increases from that of the Hanover Shale, but gamma ray intensity remains the same, less than 200 API.

The Angola Shale of the West Falls Formation has an average gas content of 0.27 cubic feet of gas per cubic foot of shale and an average carbon content of 0.44 percent. No organic carbon data are available from this interval. This is a predominantly light colored shale with low gamma ray intensity, less than 200 API.

The Rhinestreet Member of the West Falls Formation has an average gas content of 0.64 cubic feet of gas per cubic foot of shale. No carbon data are available for this interval. This zone is almost 100 percent black shale with a corresponding high gamma ray intensity (200 to 300 API).

The mean minimum vitrinite reflectance (Ro) is 0.40, the mean maximum is 0.89, and the mean average is 0.63.

Data are illustrated in Plate 6 and Table 5.

Table 5

Gas Volume and Carbon by Stratigraphic Unit
Mason County, West Virginia (Well #6)

Stratigraphic Zone	Depth	Gas Vol ft^3/ft^3	Carbon Content %
Huron Member	2678'-3050'	0.20	3.08
Java Formation	3050'-3159'	0.22	0.66
Hanover Shale	3050'-3096'	0.22	0.43
Pipe Creek Shale	3096'-3159'	0.25	0.82
West Falls Formation	3159'-3407'	0.49	1.77
Angola Shale	3159'-3329'	0.27	0.44
Rhinestreet Member	3329'-3407'	0.64	

Monongalia County, West Virginia (Well #7)

The thickness of the Devonian Shale at this site is approximately 1700 feet. The shale was cored and samples encapsulated for gas volume analysis from 7192 feet to 7501 feet. Mound collected a series of cuttings beginning at 2010 feet and continued at 500-foot and then 100-foot intervals until coring depth was reached in order to do a complete vitrinite reflectance study of the shale sequence.

The well site is located ten miles west of the Chestnut Ridge Anticline. This structure is thought to be a result of ramping from a decollement at the Ordovician level. The Fayette Anticline is located one mile east of the well site and may be genetically related to the Chestnut Ridge Anticline. The Fayette Anticline may have been formed from ramping up from a decollement in the Devonian Shales with associated high angle thrust splaying resulting from the ramping (18).

In the cored interval, the Tully (?) limestone and shale extended from 7163 feet to 7230 feet (19). The average gas content is 0.26 cubic feet of gas per cubic foot of shale and the average carbon content is 3.95 percent. The interval is composed of black shale and gamma ray intensity is low, less than 200 API (Plate 7).

The Mahatango Shale extends from 7230 feet to 7394 feet (19). The average gas content is 0.27 cubic feet of gas per cubic foot of shale and the average carbon content is 2.29 percent. The shale is black with a low gamma ray intensity, less than 200 API (Plate 7).

The Marcellus Shale extends from 7394 feet to 7509 feet (19). The average gas content is 0.38 cubic feet of gas per cubic foot of shale and the average carbon content is 6.79 percent. This is a black organic shale with a high gamma ray intensity, 200+ API (Plate 7).

The mean minimum Ro is 1.60, the mean maximum is 2.96, and the mean average is 2.29.

Stratigraphic units with gas volume and carbon content are shown in Table 6.

Table 6

Gas Volume and Cargon by Stratigraphic Unit
Monongalia County, West Virginia (Well #7)

Stratigraphic Zone	Depth	Gas Vol ft^3/ft^3	Carbon Content %
Tully Limestone and Shale	7163'-7230'	0.26	3.95
Mahatango Shale	7230'-7394'	0.27	2.29
Marcellus Shale	7394'-7509'	0.38	6.79

ILLINOIS BASIN

The EGSP wells cored in the Illinois Basin have not yielded significant amounts of gas, with the exception of the Sullivan County, Indiana well. The shale of the Illinois Basin is less thermally mature than the shale of the Appalachian Basin. Data for five wells in the Illinois Basin are available (Table 7).

Table 7

Illinois Basin Wells

Location	Map Number (Figure 3)
Tazewell County, Illinois	1
Henderson County, Illinois	2
Effingham County, Illinois	3
Sullivan County, Indiana	4
Christian County, Kentucky	5

Tazewell County, Illinois (Well #1)

The total thickness of the New Albany Shale group at this site is 221 feet. The upper unit or the Hannibal-Saverton Shales extends from a depth of 925 feet to 1055 feet. The Grassy Creek Shale extends from 1055 feet to 1126 feet. The Sweetland Creek Shales extend from 1126 feet to 1146 feet (20).

The site is located approximately 50 miles west of the LaSalle Anticlinal Belt. The average gas content of the canned samples is less than 0.010 cubic feet of gas per cubic foot of shale.

The Hannibal-Saverton Shales have an average gas content of .006 cubic feet of gas per cubic foot of shale, an average carbon content of 1.78 percent, and an average organic carbon content of 0.73 percent (from an average of all samples). There are no sample descriptions for the first 93 feet (927 feet to 1020 feet depth). The Illinois State Geological Survey (20) describes this interval as a greenish-gray shale with some black laminae. The lower section is composed of approximately 50 percent black shale. The sequence has a low gamma ray intensity (less than 100 API) (Plate 8).

The Grassy Creek Shales have an average gas content of .020 cubic feet of gas per cubic foot of shale, an average carbon content of 5.03 percent, and an average organic carbon content of 3.44 percent. Black shale ranges from 50 to 100 percent of the total and is generally high. No change in gamma ray is noted from the Hannibal-Saverton Shales above (Plate 8).

The Sweetland Creek Shales have an average gas content of 0.003 cubic feet of gas per cubic foot of shale (based on averaging all analyses), a carbon content of 2.00 percent (1 sample), and an organic

carbon content of 1.58 percent (1 sample). Lithologic descriptions are not available for most of the interval, but the Illinois Geological Survey reports the unit as an olive-gray shale (20). Gamma ray intensity is slightly higher than the units above, but still less than 100 API.

Ro values as determined by vitrinite reflectance are relatively constant at this site. The mean minimum Ro is 0.36, the mean maximum is 0.60, and the mean average is 0.46.

Stratigraphic units with gas volume and carbon content are summarized in Table 8.

Table 8

Gas Volume and Carbon by Stratigraphic Unit
Tazewell County, Illinois (Well #1)

Stratigraphic Zones	Depth	Gas Volume ft^3/ft^3	Carbon Content %	Organic Carbon Content %
Hannibal-Saverton Shales	925'-1055'	0.006	1.78	0.73
Grassy Creek Shales	1055'-1126'	0.020	5.03	3.44
Sweetland Creek Shales	1126'-1146'	0.003	2.00	1.58

Henderson County, Illinois (Well #2)

The Henderson County site has 288 feet of New Albany Shale. The Hannibal-Saverton Shales occupy the interval between a depth of 316 feet and 442 feet. The average carbon content is 2.34 percent, and the average organic carbon content is 0.39 percent. No sample descriptions are available for this sequence, but the Illinois State Geological Survey describes the interval as dark greenish-gray at the top and oliver-gray to olive-black with greenish-gray interbedding at the bottom (20). Gamma ray intensity is low, around 100 API (Plate 9).

The Grassy Creek Shales extend from a depth of 442 to 583 feet. The average gas content of these shales is 0.007 cubic feet of gas per cubic foot of shale, the average carbon content is 2.58 percent, and the average organic carbon is 1.85 percent. The interval is composed of black shale, and the gamma ray intensities are higher than those of the unit above, ranging from 100 to 200 API.

The Sweetland Creek Shales extend from a depth of 583 to 604 feet. One gas anaysis showed a gas content of 0.001 cubic feet of gas per cubic foot of shale. The average carbon content was 6.20 percent. One sample was analyzed for organic carbon and showed 0.14 percent which was only 2.33 percent of the total carbon. No lithologic description was

available, and the Illinois State Geological Survey describes the shale as olive to greenish-gray in color. The shale is dolomitic, which accounts for the high inorganic carbon (20). Gamma ray intensity is low, around 100 API (Plate 9).

The mean vitrinite reflectance (Ro) at this site is 0.27 and the mean maximum Ro is 0.56. The mean average Ro is 0.43.

Stratigraphic units with gas volume and carbon content are shown in Table 9.

Table 9

Gas Volume and Carbon by Stratigraphic Unit
Henderson County, Illinois (Well #2)

Stratigraphic Zone	Depth	Gas Volume ft^3/ft^3	Carbon Content %	Organic Carbon Content %
Hannibal-Saverton Shales	316'-442'		2.34	0.39
Grassy Creek Shales	442'-583'	0.007	2.58	1.85
Sweetland Creek Shales	583'-604'	0.001	6.20	0.14

Effingham County, Illinois (Well #3)

The New Albany Shale is 90 feet thick at this site (20). The well site is located approximately 50 miles west-southwest of the La Salle Anticlinal Belt.

The upper 70 feet, between a depth of 3010 and 3080 feet, is composed of the Grassy Creek Shales. The average gas content is 0.474 cubic feet of gas per cubic foot of shale and the average carbon content is 6.21 percent based on an average of all analyses. The organic carbon was determined on only four samples and ranged from 83 to 89 percent of the total carbon. The interval is composed of black shale, and the gamma ray intensity is high (300 to 375 API) (Plate 10).

The lower 20 feet of the section is composed of the Sweetland Creek Shales. The average gas content is 0.538 cubic feet of gas per cubic foot of shale. The average carbon content is 6.86 percent. Only one sample was analyzed for organic carbon which showed it to be 98 percent of the total carbon. This sequence is composed of black shale with a high gamma ray intensity, greater than 200 API (Plate 10).

The average minimum Ro value is 0.19, the mean maximum Ro is 0.76, and the mean average Ro value is 0.49.

Sullivan County, Indiana (Well #4)

The New Albany Shale is 125 feet thick at this site. The Grassy Creek Shales extend from a depth of 2504 to 2589 feet, and the Sweetland Creek Shales extend from 2589 to 2629 feet (21).

The average gas content of the Grassy Creek Shales is 1.552 cubic feet of gas per cubic foot of shale and the average carbon content is 6.40 percent. Organic carbon determined on two samples was 67 percent and 97 percent respectively of the total carbon (Plate 11).

The sample descriptions are incomplete, but the upper half of the sequence is approximately 50 percent black shale. The shale is described by the Indiana Geological Survey as black to dark brown (21). Gamma ray intensity is relatively low and even, around 150 API (Plate 11).

The Sweetland Creek Shales are described as gray and grayish-green near the top and grayish-brown toward the bottom (21). They extend from a depth of 2589 to 2629 feet. One sample was analyzed and showed 1.18 cubic feet of gas per cubic foot of shale and 6.1 percent carbon. Gamma ray intensity is around 150 API (Plate 11).

The mean minimum Ro value is 0.41, mean maximum Ro value is 0.71, and the mean average Ro value is 0.53.

Christian County, Kentucky (Well #5)

The New Albany Shale is 147 feet thick at this site. The Grassy Creek Shales extend from 2177 to 2253 feet and are described by the Illinois State Geological Survey as brownish-black (20). The average gas content is 0.512 cubic feet of gas per cubic foot of shale and the average carbon content is 7.43 percent. Gamma ray intensity is high, ranging from 200 to 375 API (Plate 12).

The Sweetland Creek Shales extend from 2253 to 2304 feet and are described as primarily brownish-black in color and calcareous (20). The average gas content is 0.373 cubic feet of gas per cubic foot of shale and the average carbon content is 9.92 percent. Gamma ray intensity is high, from 175 to 375 API (Plate 12).

The Blocher Shale occupies the base of the New Albany at this site, extending from 2304 to 2423 feet. It is described as brownish-black in color and calcareous (20). The average gas content is 0.230 cubic feet of gas per cubic foot of shale and the average carbon content is 16.75 percent. Gamma ray intensity is lower than the upper units, 175 to 200 API (Plate 12).

The mean minimum Ro value is 0.27, the mean maximum is 0.70, and the mean average is 0.45.

The stratigraphic units with gas volume and carbon content are shown in Table 10.

Table 10

Gas Volume and Carbon by Stratigraphic Unit
Christian County, Kentucky (Well #5)

Stratigraphic Zone	Depth	Gas Volume ft^3/ft^3	Carbon Content %	Organic Carbon Content %
Grassy Creek Shales	2177'-2253'	0.512	7.43	-
Sweetland Creek Shales	2253'-2304'	0.373	9.92	-
Blocher Shale	2304'-2423'	0.230	16.75	

SUMMARY OF GAS ZONES

The Chagrin Member of the Conewango Series was sampled in four wells. It was the only stratigraphic unit sampled in the Washington County, Ohio well. The unit was low in gas content relative to the surrounding units at all sites sampled. Table 11 shows a summary of gas content at the four well sites.

Table 11

Comparison of Chagrin Shale

Location	Av. ft^3 gas/ft^3 shale	Av.C%
Wise County, Virginia	0.43	2.03
Washington, County, Ohio	0.50	2.40
Lincoln County, West Virginia (Well #3)	0.07	0.95
Martin County, Kentucky	0.07	1.36

The Cleveland Shale was identified and sampled at three locations and was high in gas content relative to the Chagrin which bounded it both above and below. Gas content varies from 0.09 to 1.41 cubic feet of gas per cubic foot of shale. Table 12 summarizes the gas content and carbon of the Cleveland Member of the Conewango Series.

Table 12

Comparison of Cleveland Shale

Location	Av. ft^3 gas/Av.ft^3 shale	Av.C%
Wise County, Virginia	1.41	4.55
Lincoln County, West Virginia (Well #3)	0.09	1.98
Martin County, Kentucky	0.56	5.66

The Upper Huron Member of the Conewango Series was identified and sampled at two sites, and gas content was low at both. The Chagrin intertonguing Chemung was identified and sampled at three sites and was low in gas content relative to other units at all three sites.

The Lower Huron Member of the Conewango Series was identified and sampled at four sites. Three of these sites have vitrinite reflectance data which are shown in Table 13 for comparison to gas content and carbon.

Table 13

Comparison of Lower Huron Shale

Location	Av. ft^3 gas/ ft^3 shale	Av.C.%	Mean Min Ro	Mean Max Ro	Mean Av Ro
Wise County, Virginia	1.20	3.24	.66	1.34	1.02
Martin County, Kentucky	0.55	3.90	.24	.83	.52
Mason County, West Virginia	0.20	3.08	.40	.89	.63
Lincoln County, West Virginia (Well #3)	0.36	3.73	NA	NA	NA

The Upper Olentangy Member of the Seneca Series was sampled at two sites and was relatively low in gas content at both. The Pipe Creek Member of the Seneca Series was sampled at three sites, and the gas content and carbon are summarized in Table 14.

Table 14

Comparison of Pipe Creek Shale

Location	Av.ft^3gas/ft^3shale	Av.C.%
Lincoln County, West Virginia (Well #3)	0.46	1.50
Martin County, Kentucky	0.11	1.59
Mason County, West Virginia	0.25	0.82

The Rhinestreet Member of the West Falls Group was sampled at three locations and was high in gas content at all sites. Data are summarized in Table 15.

Table 15

Comparison of Rhinestreet Shale

Location	Av.ft^3gas/ft^3shale	Av.C.%
Lincoln County, West Virginia (Well #3)	0.87	2.80
Martin County, Kentucky	0.43	3.79
Mason County, West Virginia	0.64	NA

The Lower Olentangy Member of the Seneca Series was identified and sampled only in Lincoln County, West Virginia. The Marcellus Member of the Erie Series, sampled at two locations, had a gas content that was high relative to other units at both sites. The Hanover Shale, the West Falls Formation, the Angola Shale, the Mahatango Shale, and the Tully Limestone and Shale were each sampled at one location.

In the Illinois Basin, the Hannibal-Saverton Shales, Grassy Creek Shales, and Sweetland Creek Shales compose the New Albany Shale at each location. Tables 16, 17, and 18 summarize gas and carbon data.

Table 16

Comparison of Hannibal-Saverton Shales

Location	Av.ft^3gas/ft^3shale	Av.C.%
Tazewell County, Illinois	0.006	1.78
Henderson County, Illinois	NA	2.34
Effingham County, Illinois	NA	NA
Sullivan County, Indiana	NA	NA
Christian County, Kentucky	NA	NA

Table 17

Comparison of Grassy Creek Shales

Location	Av.ft^3gas/ft^3shale	Av.C.%
Tazewell County, Illinois	0.020	5.03
Henderson County, Illinois	0.007	2.58
Effingham, County, Illinois	0.474	6.21
Sullivan County, Indiana	1.552	6.40
Christian County, Kentucky	0.512	7.43

Table 18

Comparison of Sweetland Creek Shales

Location	Av.ft^3gas/ft^3shale	Av.C%
Tazewell County, Illinois	0.003	2.00
Henderson County, Illinois	0.001	6.20
Effingham County, Illinois	0.538	6.86
Sullivan County, Indiana	1.18	6.10
Christian County, Kentucky	0.373	9.92

Thermal maturity as determined by vitrinite reflectance is illustrated in Table 19.

Table 19

Thermal Maturity of Illinois Basin Wells

Location	Mean Min Ro	Mean Max Ro	Mean Average Ro
Tazewell County, Illinois	0.27	0.56	0.43
Henderson County, Illinois	0.19	0.76	0.49
Effingham County, Illinois	0.36	0.60	0.46
Sullivan County, Indiana	0.41	0.71	0.53
Christian County, Kentucky	0.27	0.70	0.45

STATISTICAL CORRELATIONS, GAS VOLUME VERSUS CARBON

Although there is undoubtedly a statistical relationship between gas volume and carbon, the purpose of this study is to determine if a direct relationship exists that can be used to predict zones of high gas content. No complex statistics are used, only regression analysis.

APPALACHIAN BASIN

Wise County, Virginia

When the carbon values were plotted on the Y axis and the gas volume values were plotted on the X axis, the resulting correlation coefficient (r^2) was only .295 and the regression coefficient (r) was only .543, indicating a lack of a linear relationship between the variables (Figure 10). When the organic carbon was plotted against gas volume, the values increased to r^2 = .787 and r = .887 indicating a much greater degree of correlation (Figure 11).

When the stratigraphic units present in the column at this site were each treated as one sample and the average gas volume and carbon percentage used for the interval as one set of X and Y points, the plot shown in Figure 12 resulted. The value of r^2 increased to .724 from the previous .295 (Figure 12). This indicates that within a specific stratigraphic unit the carbon and gas volume are related more significantly than when considered as individual samples. Table 2 lists the gas volume and carbon content for the ten stratigraphic units sampled at this site.

There were not enough organic carbon determinations within individual units to make comparisons.

When the number of points is decreased, the value of "r" can be expected to increase if any correlation was exhibited by the prior plots. In this case, an r^2 value of .295 would indicate no correlation. Mound Facility has suggested that each unit be statistically analyzed separately rather than by the technique used.

Washington County, Ohio

The regression analysis of the gas volume and carbon from Washington County, Ohio gives a value of $r = 0.83$ and $r^2 = 0.67$ (Figure 13). No organic carbon analyses were performed on these samples, and the entire cored interval is within the Chagrin Shale (19). The division of carbon into organic and inorganic forms would have increased the degree of correlation as the detailed lithologic description showed the presence of calcareous material throughout the interval.

Lincoln County, West Virginia

Well #3 (#20403) shows an $r = .546$ when carbon is plotted against gas volume and an $r^2 = .298$ (Figure 14). When the carbon and gas volume measurements are averaged within the lithologic unit identified in the well and plotted for regression analysis, the value of r increases to .825 and r^2 to .681 (Figure 15). A similar increase is noted when the stratigraphic units (which do not correspond to the lithologic units) are used in the same way (Table 3). The value of r increases to .822 and r^2 to .676 (Figure 16).

Well #4 (#20402) has an r value of .630 and $r^2 = .400$ for carbon versus gas volume (Figure 17). The well was not continuously cored, and the additional statistical analyses performed on well #3 were not possible.

No organic carbon analyses are available for these wells.

Martin County, Kentucky

The correlation of gas volume to carbon in this well showed an r value of only .404 and an $r^2 = .163$ (Figure 18). The substitution of organic carbon for total carbon only raises the values to $r = .409$ and $r^2 = .167$ (Figure 19). When the different stratigraphic units are used with average carbon and gas volume values (Table 4), $r = .814$ and $r^2 = .663$ (Figure 20).

Mason County, West Virginia

In the Mason County well, regression analysis indicates no significant relationship between gas volume and carbon. The value of r was only -.297 and $r^2 = .088$ (Figure 21). The correlation between organic carbon and gas volume was better but was not strong. The r value was .511 and $r^2 = .261$ (Figure 22). No division of stratigraphic units was possible for statistical purposes.

Monongalia County, West Virginia

There is very little apparent correlation within this well between gas volume and carbon. The r value of the regression analysis was .253 and r^2 = .064 (Figure 23). Only three stratigraphic units were sampled and this would not be great enough for a significant test by stratigraphic unit. There are two possible problems at this site that may explain the low correlation and low gas content. The vitrinite reflectance data indicate a thermally mature shale that may alreay have lost the gas formed at lower temperatures. A greater percentage of the gas content may have been lost prior to encapsulation at this site than at other wells.

ILLINOIS BASIN

Tazewell County, Illinois

No correlation is indicated between total carbon and gas volume at this site. The value of r on the regression analysis is .059 and r^2 = .003 (Figure 24). When organic carbon is plotted against gas volume, the value of r increases to .538 and r^2 = .289 (Figure 25).

Henderson County, Illinois

The regression coefficient is relatively low between total carbon and gas volume with r = .403 and r^2 = .162 (Figure 26). However, a strong relationship is indicated between the organic carbon and the gas volume with r = .918 and r^2 = .843 (Figure 27).

Effingham County, Illinois

No relationship is indicated by the regression analysis of total carbon versus gas volume. The regression coefficient for the analysis was r = -.193 and r^2 = .067 (Figure 28). When the organic carbon was plotted against gas volume, the values increased to r = .481 and r^2 = .258 (Figure 29).

Sullivan County, Indiana

No relationship is indicated between carbon and gas volume at this site. The values of r = .313 and r^2 = .098 are indicative of little or no relationship between the variables (Figure 30). Organic carbon data were not available at this site.

Christian County, Kentucky

An r value of .183 and r^2 = .033 indicate no relationship between carbon and gas volume (Figure 31). No organic carbon data were available for this site.

The gas released after the initial measurements are taken is not currently accounted for in the determination of gas volume. Battelle Columbus Laboratories measures the gas volume after an equilibration period of three weeks. Mound Facility measures the gas volume after a three-week minimum, but most samples are allowed over six weeks to equilibrate. Columbia Gas System Service Corporation begins measurements of gas volume at the well site as soon as pressure begins to build up in the containers and continues to take measurements until no further gas is released. Work performed by Battelle Columbus Laboratories and West Virginia University indicate that significant amounts of gas are released after these initial equilibration periods (22, 23).

The following table (Table 20) is from the Battelle Columbus Laboratories Quarterly Technical Progress Report, July-September 1978, and shows the increase in gas released by the shale from the initial tap and measurement at eleven weeks (22). The samples tested were from the Mason County, West Virginia well.

Tables 21 and 22 were taken from a West Virginia University report by Chase (23). These tables illustrate the significant amounts of gas released after the initial equilibration period. These gas desorption rates of the samples were affected by extreme temperature changes of up to $30^{o}F$ during the 11-week period. The temperature changes prevent these samples from serving as more than illustrations of the gas desorbed after the initial measurement (23). These samples were collected at the Monongalia County, West Virginia well site.

Battelle Columbus Laboratories monitored gas release rates for 65 days on five samples from the Allegany County, New York well. Foreign gas was evacuated from the containers prior to sealing. Table 23 shows the pressure buildup over the 65-day period (24).

Table 20

Increase in Gas Release After Two Months Wait for Equilibrium
(Battelle Columbus Laboratories)

1	2	3	4	5	6	7	8
Sample I.D.	P_o, torrs	ΔP_o, torrs	$\left(\frac{\text{H.C. Gas}^*}{\text{Shale Vol.}}\right)_o$	P_t, torrs	ΔP_t, torrs	$\left(\frac{\text{H.C. Gas}^*}{\text{Shale Vol.}}\right)_t$	%H.C. Gas in Free Space
R-146-2763	780	44.5	0.040	840	104.5	0.094	5.70
R-146-2869	825	41.5	0.050	860	76.2	0.093	5.00
R-146-2967	810	40.9	0.060	855	85.9	0.126	5.05
R-146-3074	875	106.0	0.110	1040	271.0	0.280	12.13
R-146-3389	1125	391.5	0.560	1250	516.0	0.740	34.80

Column 1 Battelle's shale I.D. number.
Column 2 Can pressure at the time of initial gas analyses (usually three weeks after canning).
Column 3 Hydrocarbon gas partial pressure at the time of gas analyses.
Column 4 Volume of hydrocarbon gas per unit volume of shale at the time of gas analyses.
Column 5 Can pressure at two months after the gas analyses.
Column 6 Hydrocarbon partial pressure at two months after the initial gas analyses.
Column 7 Hydrocarbon gas volume per unit volume of shale at two months after the initial gas analyses.
Column 8 Percent hydrocarbon gas in free space (inside the sealed can) at the time of initial gas analyses.

* Hydrocarbon Gas

Table 21

Gas Release Data, Monongalia County, Sample #5
Shale: 7357.2' to 7357.75' (After Ref. 23)

Time (wk)	Rate (cc/g - wk)	Cumulative Gas (cc)
1	0.178	472.3
2	0.008	492.7
3	0.013	527.0
4	0.000	527.0
5	0.000	527.0
6	0.000	527.0
7	0.002	531.9
8	0.010	558.5
9	0.001	562.4
10	0.013	595.6
11	0.002	601.4

Table 22

Gas Release Data, Monongalia County, Sample #3
Shale: 7349.2' to 7349.7' (After Ref. 23)

Time (wk)	Rate (cc/g - wk)	Cumulative Gas (cc)
1	0.082	215.9
2	0.0004	216.9
3	0.009	240.9
4	0.005	253.3
5	0.000	253.3
6	0.000	253.3
7	0.006	269.1
8	0.005	282.0
9	0.008	302.7
10	0.014	339.7
11	0.003	347.6

Table 23

Pressure Increase over a 65-Day Period (After Ref. 24)

(Pressure Buildup in Torr)

Time, days	Sample Identification (EGSP-NY1 Series) 530	1939	2119	2538	2832
0	22	22	22	22	20
1	33	36	46	91	58
5	32	49	52	240	63
15	34	83	61	345	72
40	34	137	69	318	*
65	37	193	76	318	*

*Air accidentally admitted to container

Battelle uses the following Equations to analyze the data:

$$\frac{P}{P_\infty} = 1 - \Sigma \frac{4a\ (1+a)}{4 + 4a + a^2 q_n^2} e^{-Dq_n^2\ t/r^2} \qquad (1)$$

r = sample radius (4.4 cm)
a = ratio of the capacity of the shale to the capacity of the free space in the container
qn's = positive non-zero root of the equation

$$aq_n J_o\ (q_n) + 2J_1\ (q_n) - 0 \qquad (2)$$

J's = 0 and first order Bessel function

Solutions for qn's are available in tabular form for various values of "a" (capacity parameter), which is determined by fitting the data to Equation 1. If the sorption of gas by the shale is low, the value of "a" is also low and is determined by the back volume of the shale and the shale porosity. When high sorption occurs, the value of "a" can be very high. Equation 1 becomes insensitive to "a" at a value of "a" = 10. Between the values of "a" = 0 to 10, the pressure response curve is sensitive to "a".

The data cited in Table 24 yield the following results when applied to Equation 1.

Table 24

Rate of Pressure Change Based on Pressure Increase over a 65-Day Period (After Ref. 24)

Sample No.	P∞, torr	D, cm^2/sec	a
530	34	2×10^{-6}	0.3
1939	1650	8.5×10^{-9}	large
2119	77	1×10^{-6}	0.43
2538	319	4×10^{-6}	large
2832	(120)	(1×10^{-6})*	(2)*

*Insufficient data; values cited are rough estimates.

Battelle calculated curves for three samples designated 1939, 2119, and 2538. These curves and the experimental data are shown in Figures 32, 33, and 34 (24).

It is not possible to determine the quantitative value of the total gas per unit volume of shale from these samples. When the value of "a" is greater than ten, as in two of the samples, only qualitative determinations can be performed. Another obvious problem is the gas lost during the evacuation pump-out procedure (24).

Samples 1939 and 2538 have large "a" values indicating relatively large gas capacities. Sample 1939 has a small diffusion constant, and 2538 has a relatively large diffusion constant. These data indicate that much of the gas in sample 1939 was retained, and much of the original gas in 2538 could have been lost during canning and evacuation procedures (24).

This sample comparison indicates possible errors in gas capacity measurements after the 20 to 30 day time period usually allowed for equilibration. Sample 1938 would not have had enough time to outgas prior to encapsulation. The variation of capacities lessens the value of the initial pressure measurement (24).

CONCLUSIONS

The best procedure to accurately measure gas volume is a combination of the methods used by Columbia Gas System Service Corporation, Battelle Columbus Laboratories, and Mound Facility. The gas volume should be measured using pressure, volume, and composition, and the measurements should ideally be initiated at the well site or immediately after return to the laboratory if well site initiation is

logistically impossible. This procedure would allow the determination of an estimate of the gas prior to encapsulation of the sample. Columbia Gas System Service Corporation has used this combination technique by analyzing the gas each time it is withdrawn and also by analyzing low pressure samples after three months and then moving to the direct method. They have determined the gas composition to be rather uniform throughout a given shale section.

To determine the gas desorbed after the initial equilibration period, release rates and gas volume must be determined over a period of months on a set of samples with different physical and chemical variables. Comparisons of total volume of gas released and the rate of release can be made to different sets of chemical and physical variables to determine what control these variables exercise on the release of gas from the shale. If a correlation between these chemical and physical variables and gas release can be established, then an estimate of the total gas in place can be made using available gas release data and the chemical and physical variables. This would enable a more accurate estimate of the gas resource to be determined based on off-gassing data.

In Wise County, Virginia, the Cleveland Member and the Lower Huron Shale represents zones of high gas content. The Washington County, Ohio core was taken from within the Chagrin Shale which has had low gas volume at every location tested. In Lincoln and Mason Counties, West Virginia, and Martin County, Kentucky the Rhinestreet Shale has a relatively high gas content. The Marcellus Shale is high in gas content at Lincoln County, West Virginia, and relatively high at Monongalia County, West Virginia.

The relationship between stratigraphic horizons with high and low contents appears to be constant within every location. If the difference between locations is compared, thermal maturity appears to be the dominant factor.

The upper and lower limits of thermal maturity that would allow gas to form and be retained are not clearly known. The level of maturity in Wise County, Virginia appears to be the optimum for gas in the Appalachian Basin. With the exception of Monongalia County, West Virginia, other Appalachian wells demonstrate a lower thermal maturity. The thermal maturity of the Monongalia County well is very high, and it could be that gas was formed and then distilled out of the shale by heat.

In the Appalachian Basin, the thermal maturity is little affected by depth of burial. Proximity to structural features appears to be the primary factor controlling the degree of maturity.

In general, the shale of the Illinois Basin is less mature than the shale of the Appalachian Basin. In most Illinois Basin wells, thermal maturity increases with depth, and although the shale generally has little gas, occasionally these zones show a high gas content at the base. The Sullivan County, Indiana well showed a substantial gas content. This well is slightly more thermally mature than the other Illinois Basin wells.

Additional study is needed to determine the lower limits of thermal maturity for gas to be generated from the organic matter and the upper limits of thermal maturity for gas to remain resident in the reservoir. The effects of structural features on maturity should be investigated to determine at what point of proximity to a feature the lower limit of gas formation is reached.

When gas volumes are plotted against the percentage of total carbon in the shale, results range from no correlation to a strong correlation. The regression and correlation coefficients can be increased by using organic carbon rather than total carbon, but in many cases the degree of correlation will remain low. This could possibly be explained by a limited amount of gas migration within the shale. This is reinforced somewhat by the variation in gas volume from adjacent samples. However, when an individual lithology or stratigraphic unit is considered as one sample and each unit plotted, the regression and correlation coefficients appear strong. This supports the presence of specific stratigraphic horizons or lithologic zones that can possibly be exploited for gas.

REFERENCES

1. Kissell, F. N., C. M. McCulloch, and C. H. Elder, 1973, The direct method of determining methane content of coalbeds for ventilation design, Bureau of Mines, RI 7767, 17 p.

2. Smith, E. C., 7/26/79, Personal Communication to R. D. Manilla, METC.

3. Zielinski, R. L., 4/30/78, Personal Communication to A. E. Hunt, METC.

4. Wilson, E. N. and J. Zafar, 1978, Kentucky Geological Survey, Personal Communication to John Curtis, SAI.

5. Columbia Gas Transmission Corporation, 1977, Columbia Gas Transmission Corporation well site selection report, Well No. 20338, Wise County, Virginia, DOE/METC.

6. Janssens, A., and W. deWitt. 1976, Potential natural gas resources in the Devonian Shale in Ohio: State of Ohio, Dept. Natural Resources, Div. Geologic Survey, Geol. Date No. 3, p. 3.

7. Byrer, C. W., M. K. Vickers, S. J. Rhoades, and B. G. Easterday, 1978, Lithologic description of the Chagrin Shale (Devonian Brown Shale) in Washington County, Ohio: DOE/METC.

8. Byrer, C. W., M. K. Vickers, S. J. Rhoades, and B. G. Easterday, 1976, Lithologic description of cored wells #20402 and #20403 in the Devonian Shale in Lincoln County, West Virginia: USERDA-Morgantown Energy Research Center, MERC/TPR-76/9.

9. Smith, E. C., K. M. Forrest, and W. F. Morse, February 1978, Devonian Shale characterization and gas content research: a draft report to Morgantown Energy Technology Center by Research Dept., Columbia Gas System Service Corp.

10. Cardwell, D. H., 1978, West Virginia Geological and Economic Survey, Personal Communication to John Curtis/SAI.

11. Woodward, H. P., 1968, Basement map, geologic map of West Virginia, West Virginia Geological and Economic Survey.

12. Shumaker, R. C., 1976, A digest of Appalachian structural geology, in Devonian Shale production and potential, edited by R. C. Shumaker and W. K. Overbey, Jr., USERDA-Morgantown Energy Research Center, MERC/SP-76/2, p. 79-93.

13. Martin, P., and E. B. Nuckols, 1976, Geology and oil and gas occurrence in the Devonian Shales - northern West Virginia, in Devonian Shale production and potential, edited by R. C. Shumaker and W. K. Overbey, Jr., USERDA-Morgantown Energy Research Center, MERC/SP-76/2, p. 20-40.

14. deWys, J. N., and R. C. Shumaker, 1978, Pilot study of gas production analysis methods applied to Cottageville Field, DOE-Morgantown Energy Research Center, MERC/CR-78/6.

15. Patchen, Douglas G., 1977, Subsurface stratigraphy and gas production of the Devonian Shales in West Virginia, USERDA-Morgantown Energy Research Center, MERC/CR-77/5.

16. Nuckols, E. B., 1978, The Cottageville gas field, Jackson County, West Virginia - a case study of Devonian Shale gas production, preliminary draft report to DOE-Morgantown Energy Technology Center.

17. Evans, Mark A., 1978, Fracture density and orientation study of the Reel Energy #3 D/K core from Mason County, West Virginia: EGSP Special Report, DOE/METC.

18. Overbey, William, Morgantown Energy Technology Center, Personal Communication.

19. Dean, C., Morgantown Energy Technology Center, Personal Communication.

20. Bergstrom, R. E., and N. F. Shimp, 1977, Geological and geochemical studies of the New Albany Group in Illinois (Devonian Black Shales) to evaluate its characteristic as a source of hydrocarbon, Annual Report, Illinois State Geological Survey.

21. Bassett, J., and N. Hasenmueller, 1979, Preliminary cross section, Indiana Geological Survey.

22. Kalyoncu, R. S., and M. J. Snyder, 7-9/1978, Characterization and analysis of Devonian Shales as related to release of gaseous hydrocarbons, Quarterly Report, Battelle Columbus Laboratories.

23. Chase, R. W., July 1978, EGSP monthly progress report to DOE-Morgantown Energy Technology Center by West Virginia University under contract EY-77-C-21-8087.

24. Kalyoncu, R. S. and M. J. Synder, 9-12/1978, Characterization and analysis of Devonian Shales as related to release fo gaseous hydrocarbons, Quarterly Report, Battelle Columbus Laboratories.

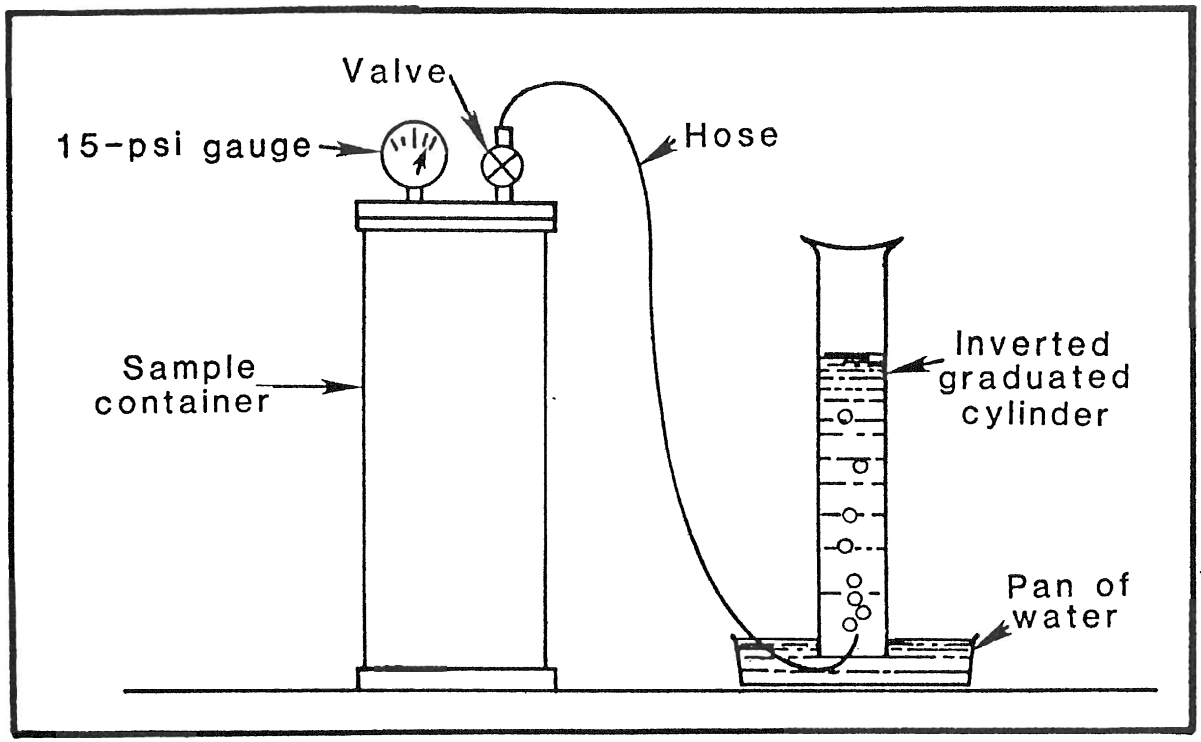

Figure 1 - Gas Measurement by Direct Method (After Ref. 1)

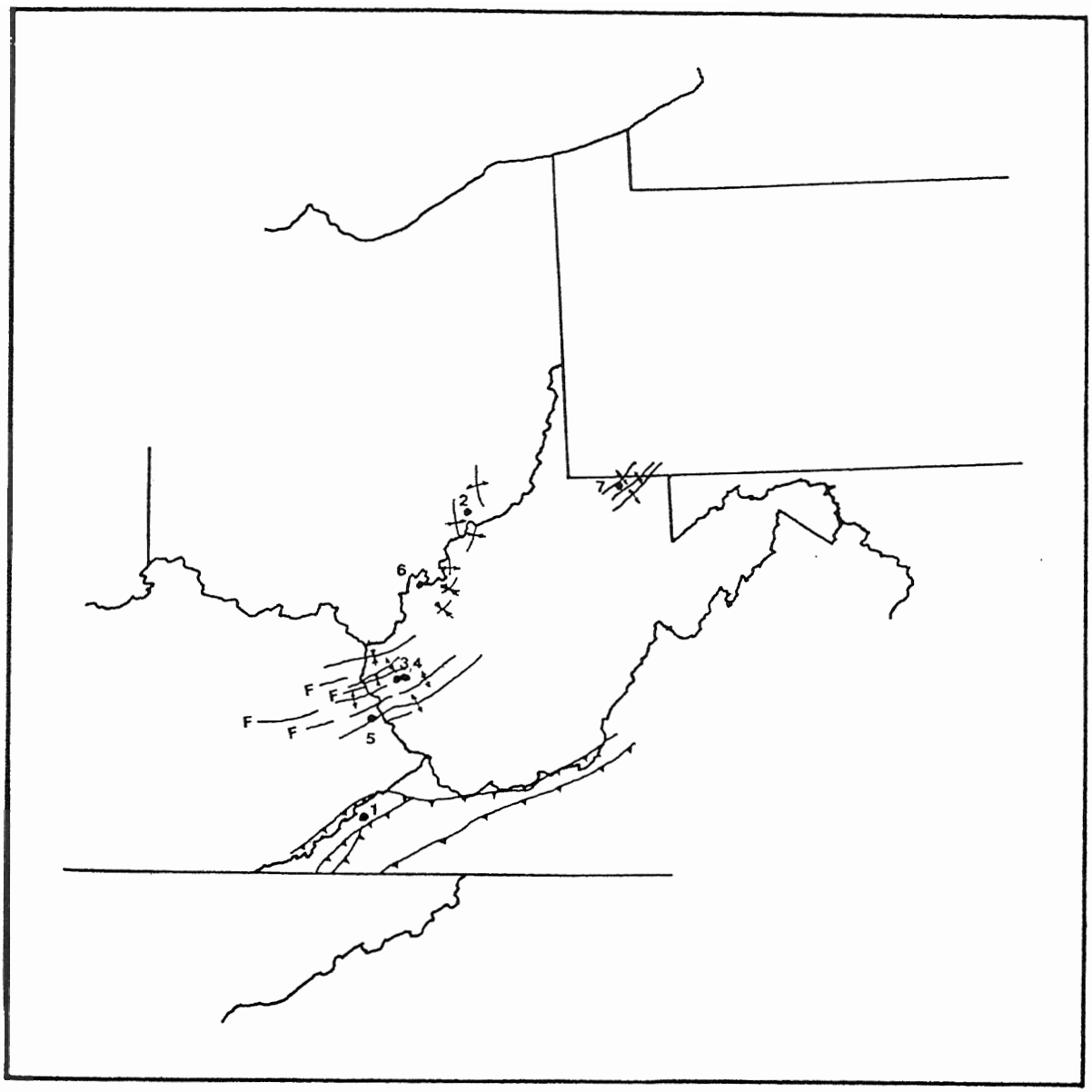

Figure 2 - Location of EGSP Wells and Adjacent Structures
in the Appalachian Basin

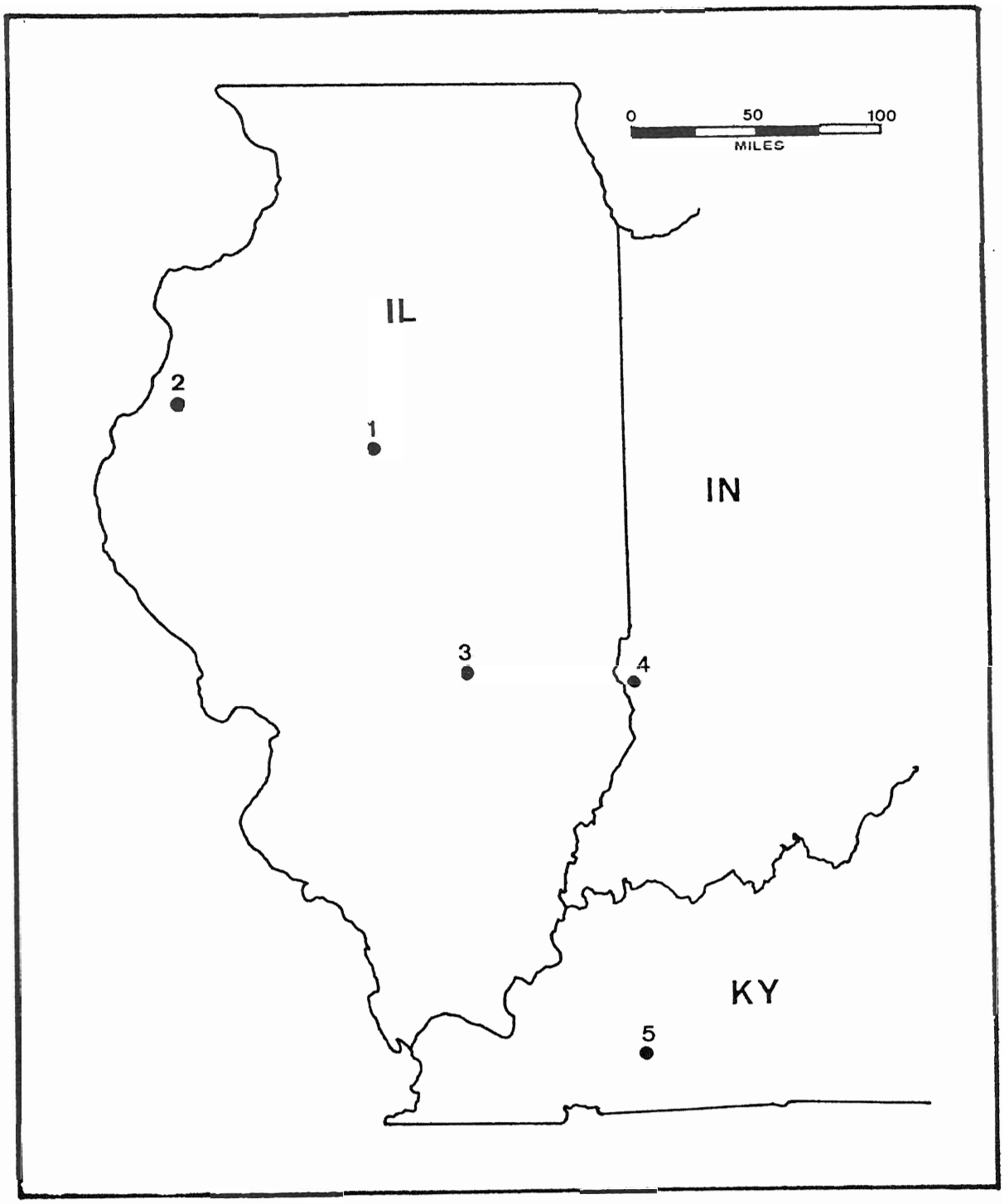

Figure 3 - Location of EGSP Wells in the Illinois Basin

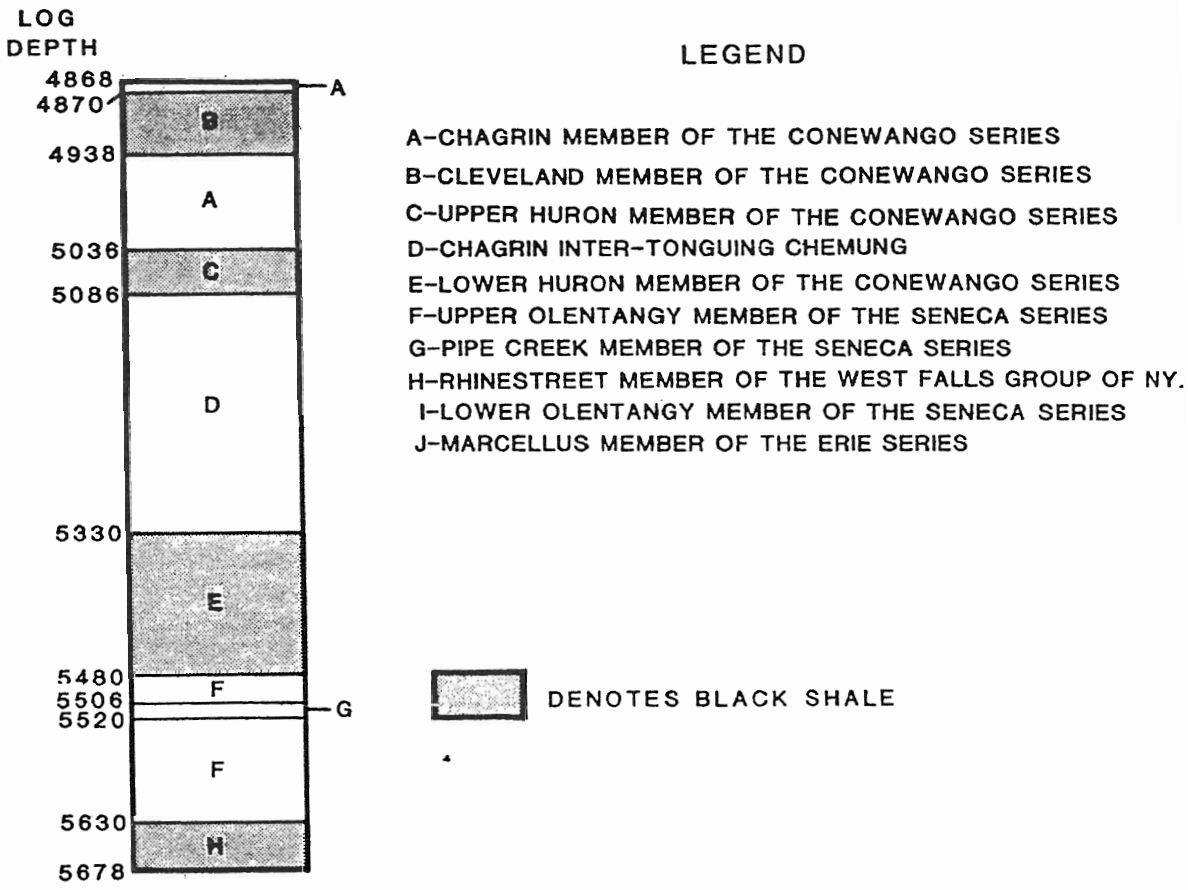

Figure 4 - Columnar Section - Wise County, Virginia (After Ref. 9)

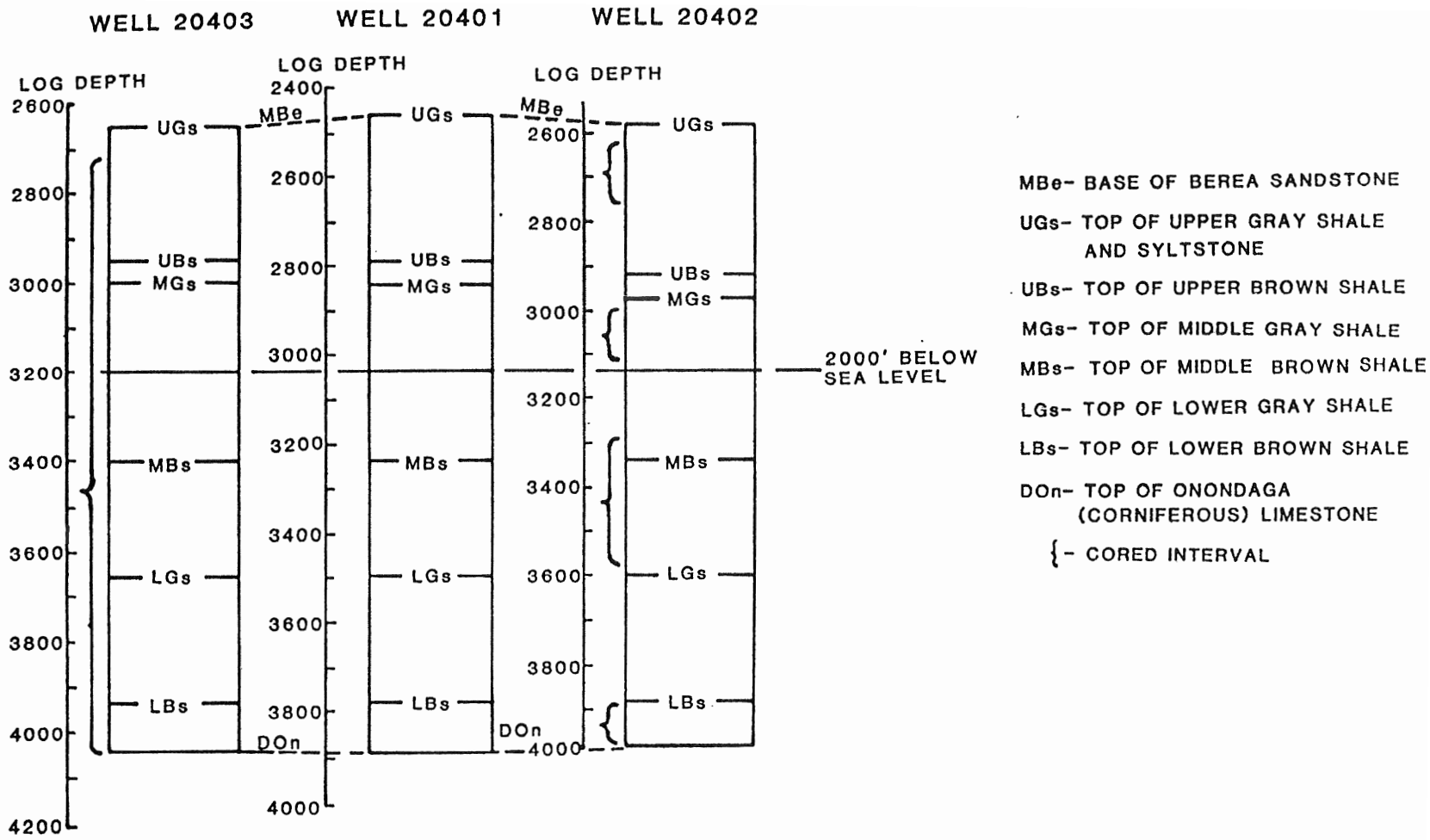

Figure 5 - Lithologies at Lincoln County, West Virginia (After Ref. 9)

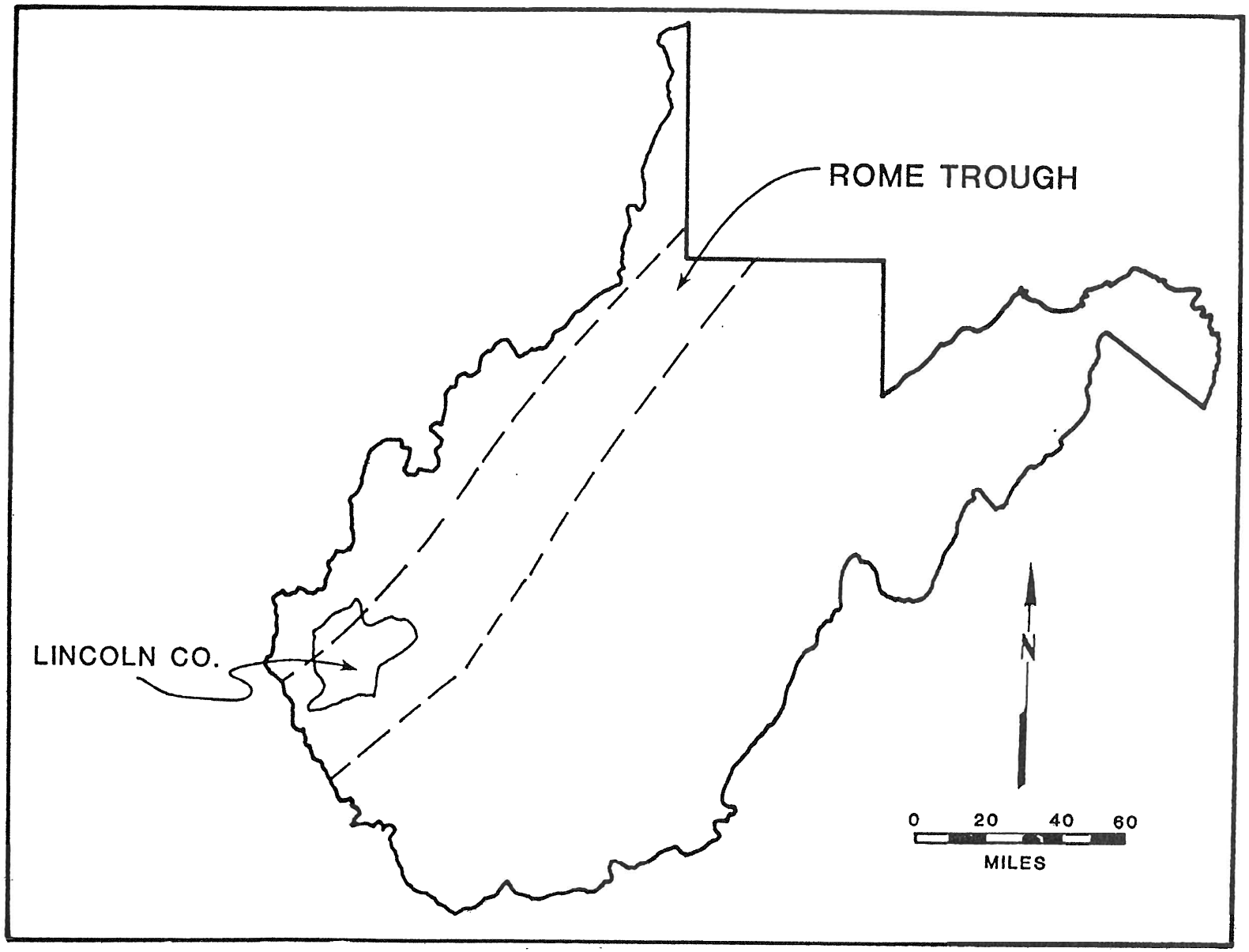

Figure 6 - Location of Lincoln County, West Virginia, with Respect to Approximate Location of Rome Trough (After Ref. 15)

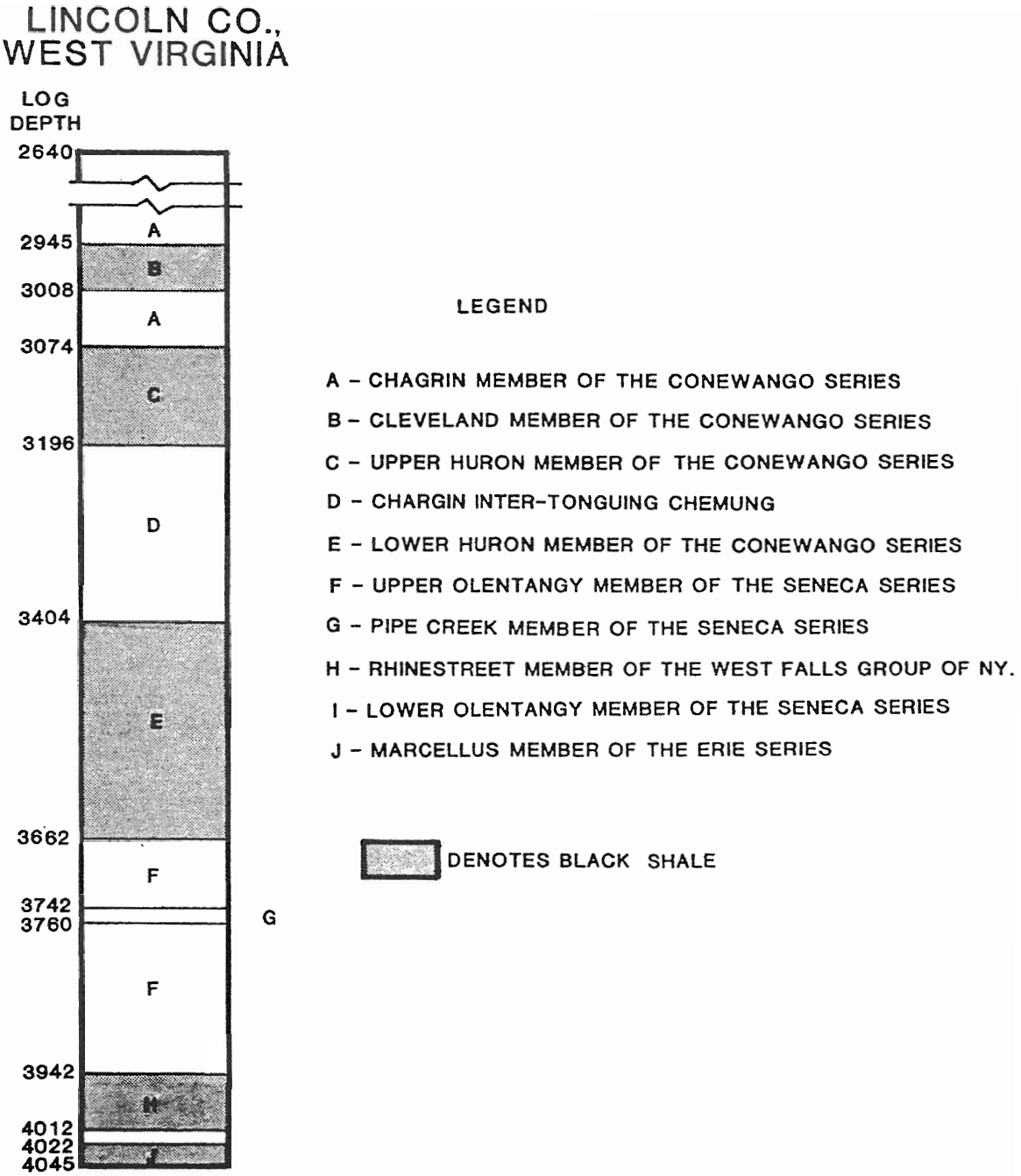

Figure 7 - Columnar Section - Lincoln County, West Virginia
(After Ref. 9)

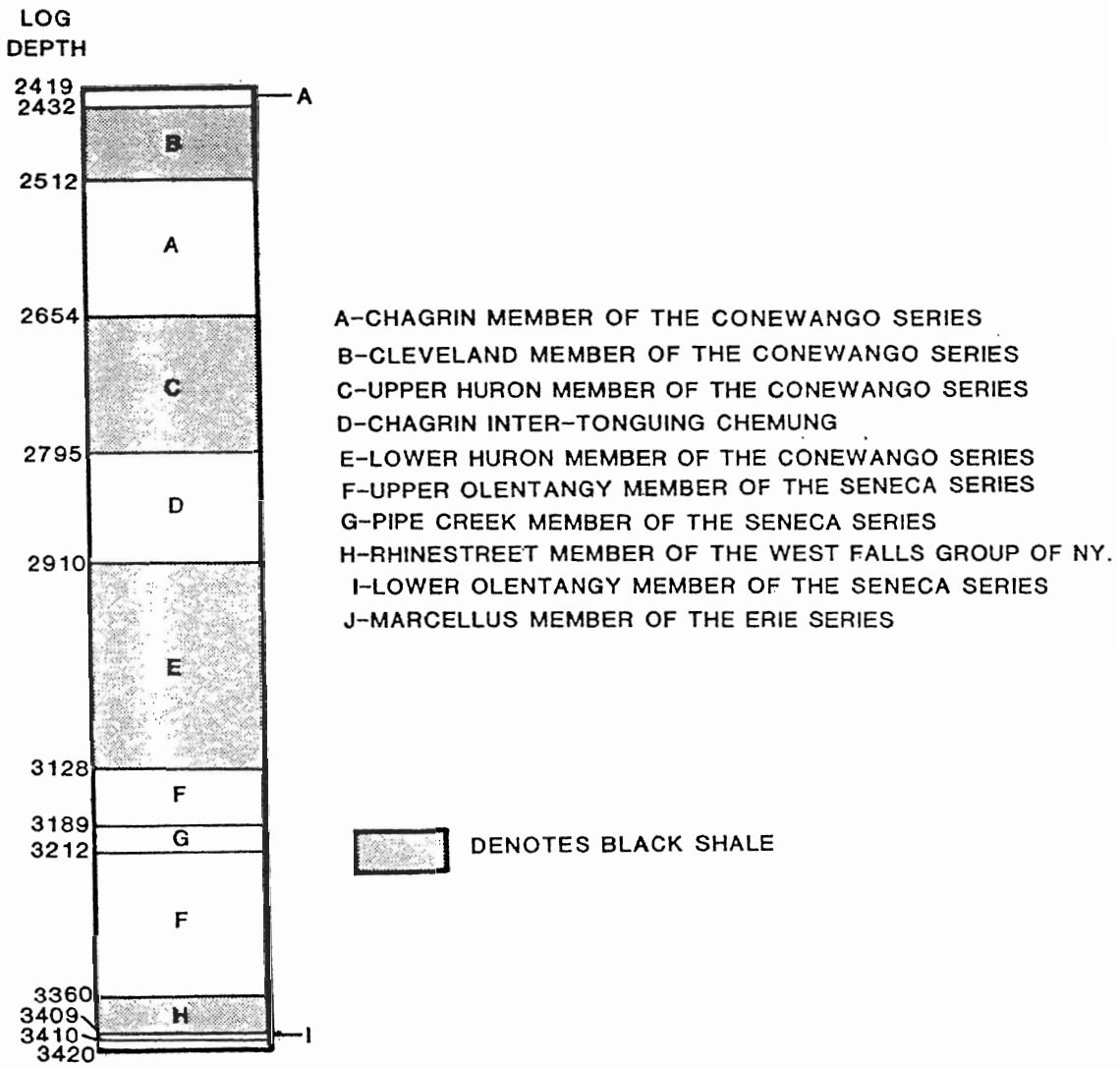

Figure 8 - Columnar Section - Martin County, Kentucky
(After Ref. 9)

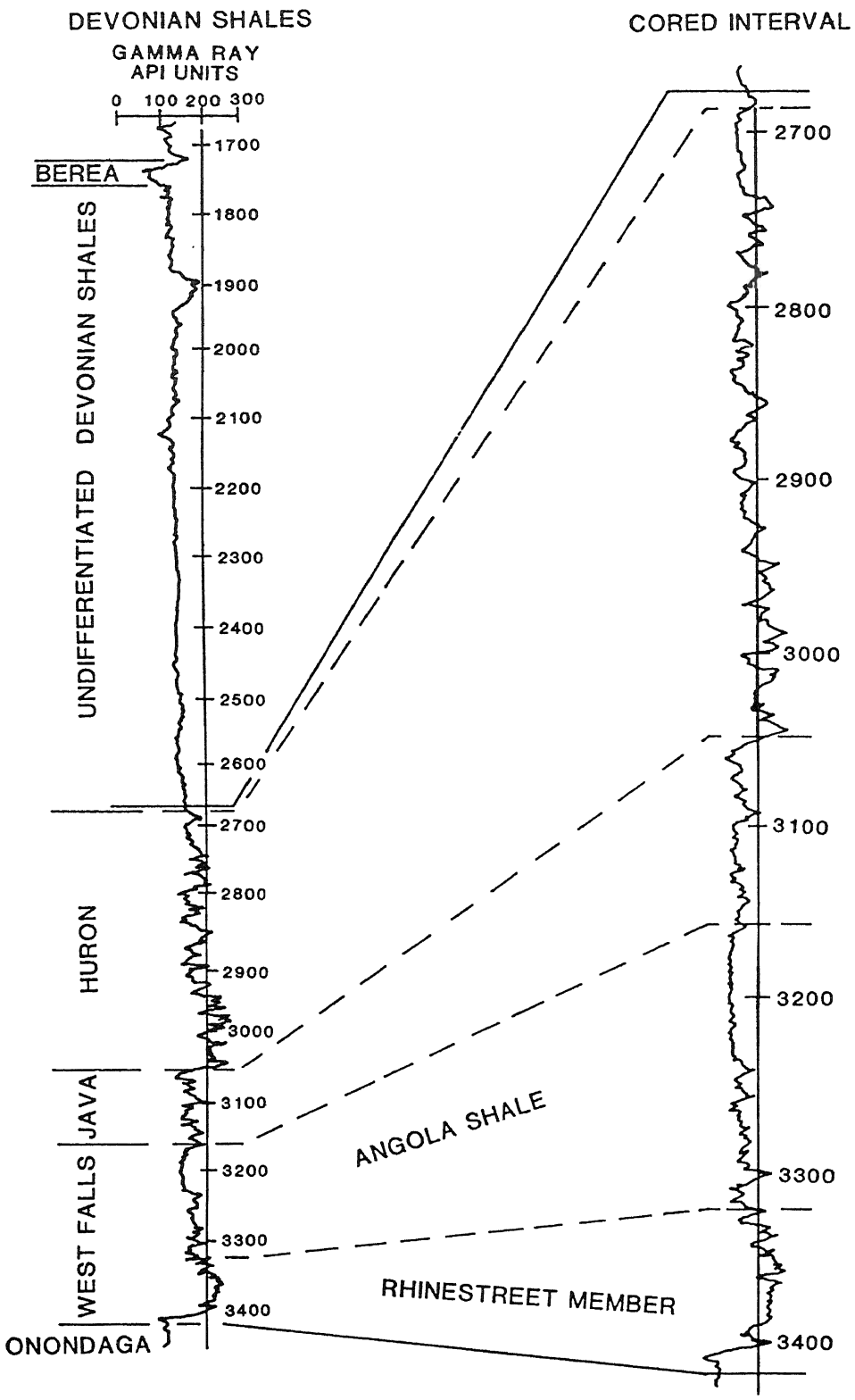

Figure 9 - Columnar Section - Mason County, West Virginia (After Ref. 17)

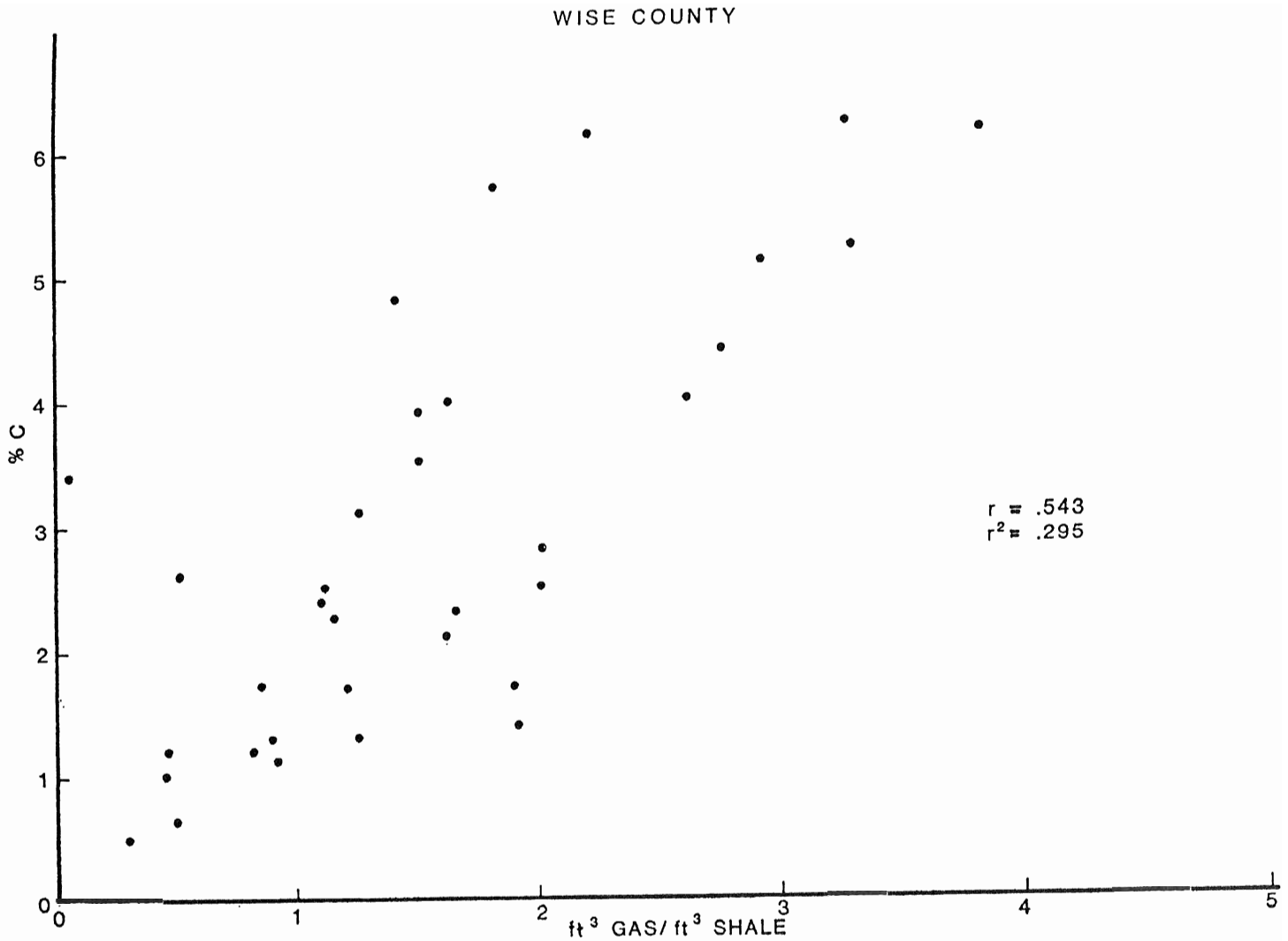

Figure 10 - Gas Volume vs. Carbon - Wise County, Virginia

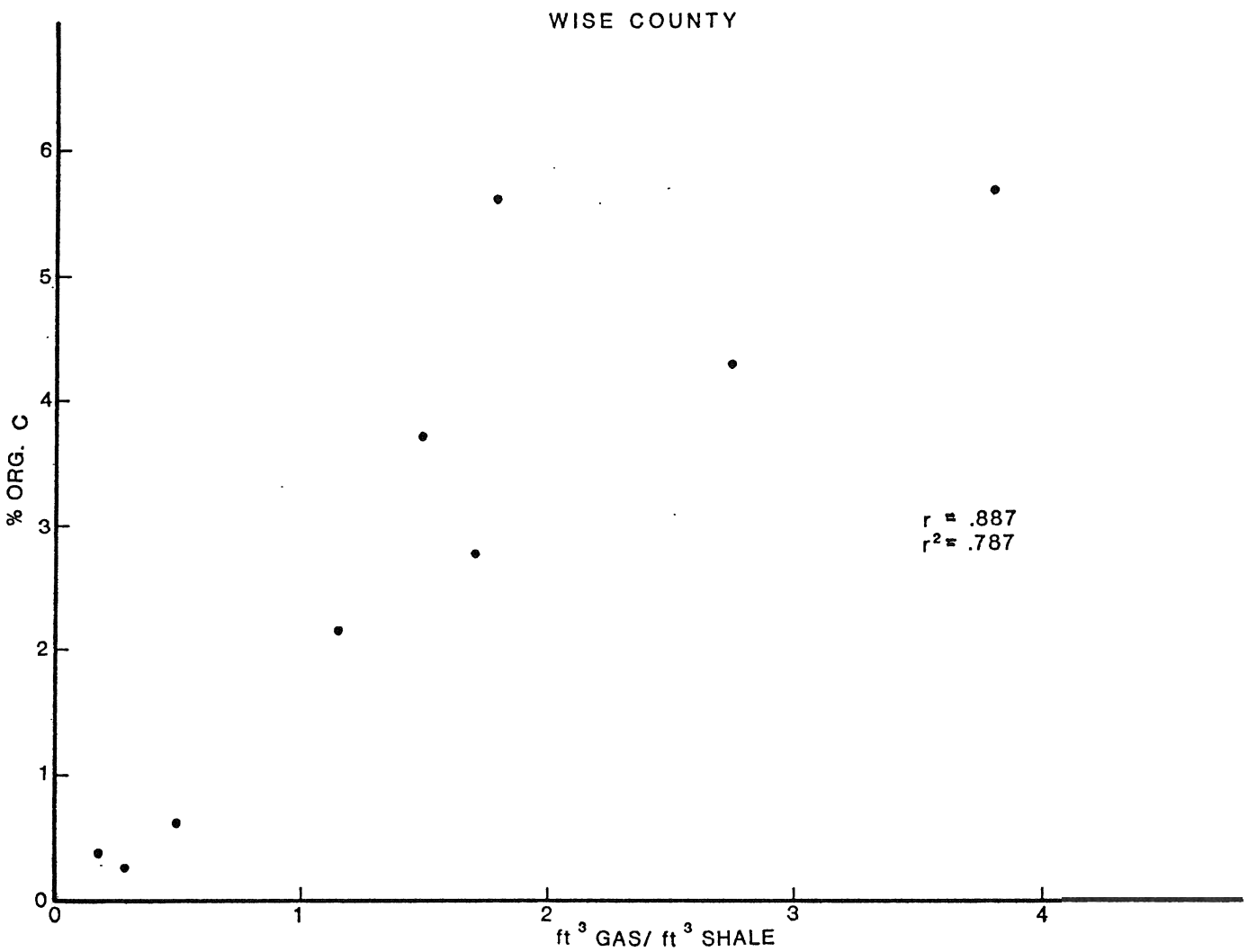

Figure 11 - Gas Volume vs. Organic Carbon - Wise County, Virginia

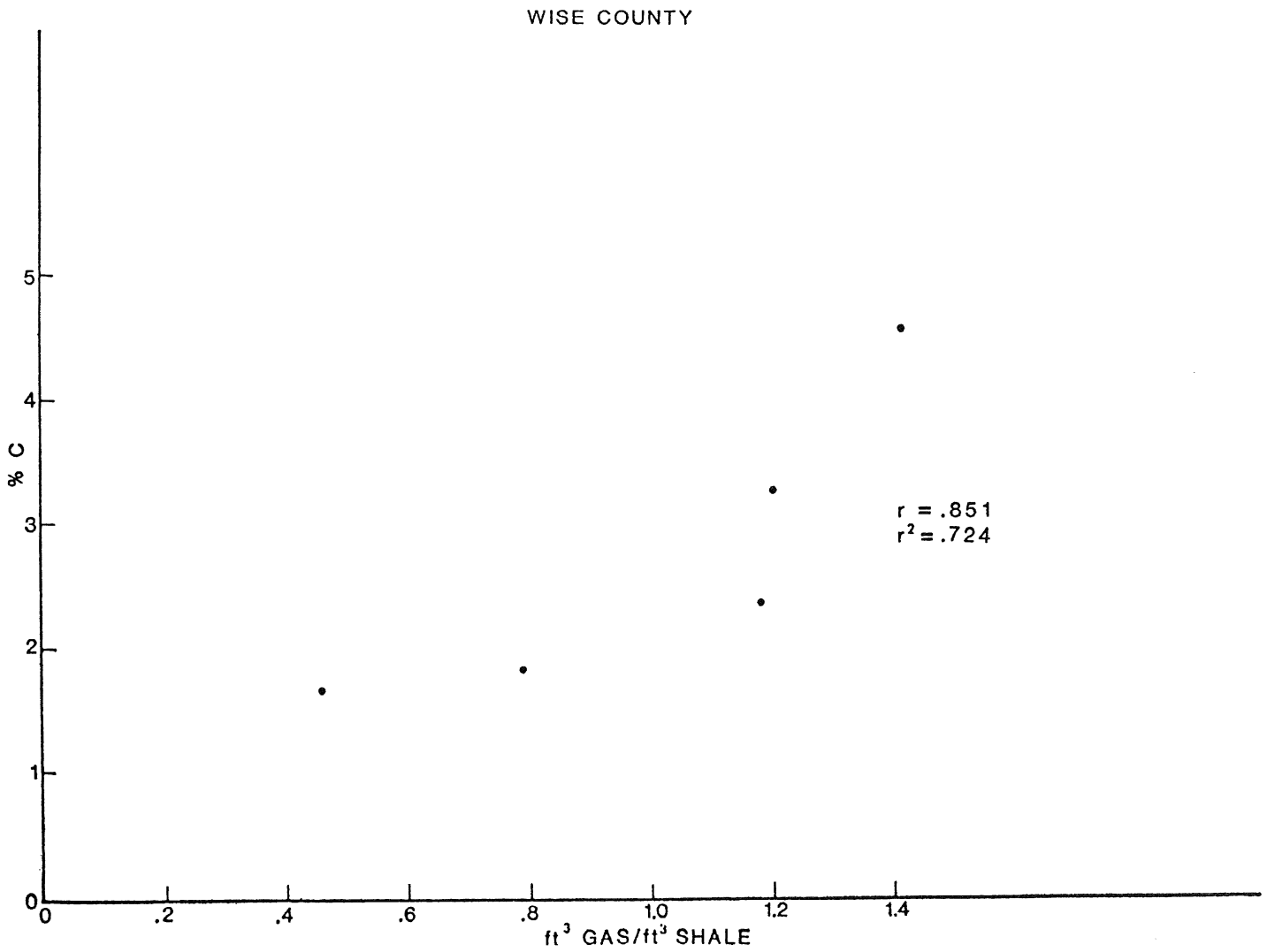

Figure 12 - Gas Volume vs. Carbon by Stratigraphic Unit - Wise County, Virginia

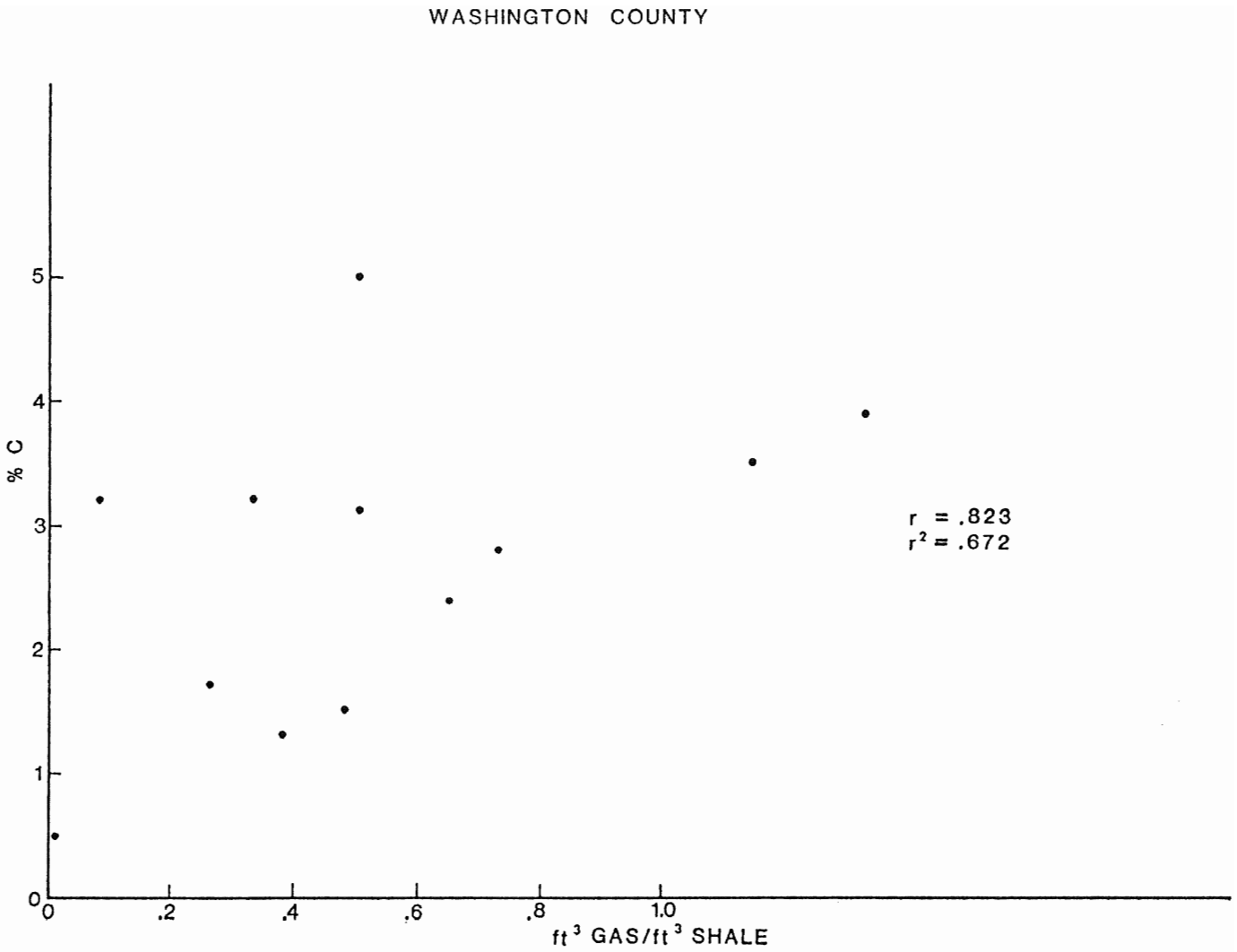

Figure 13 - Gas Volume vs. Carbon - Washington County, Ohio

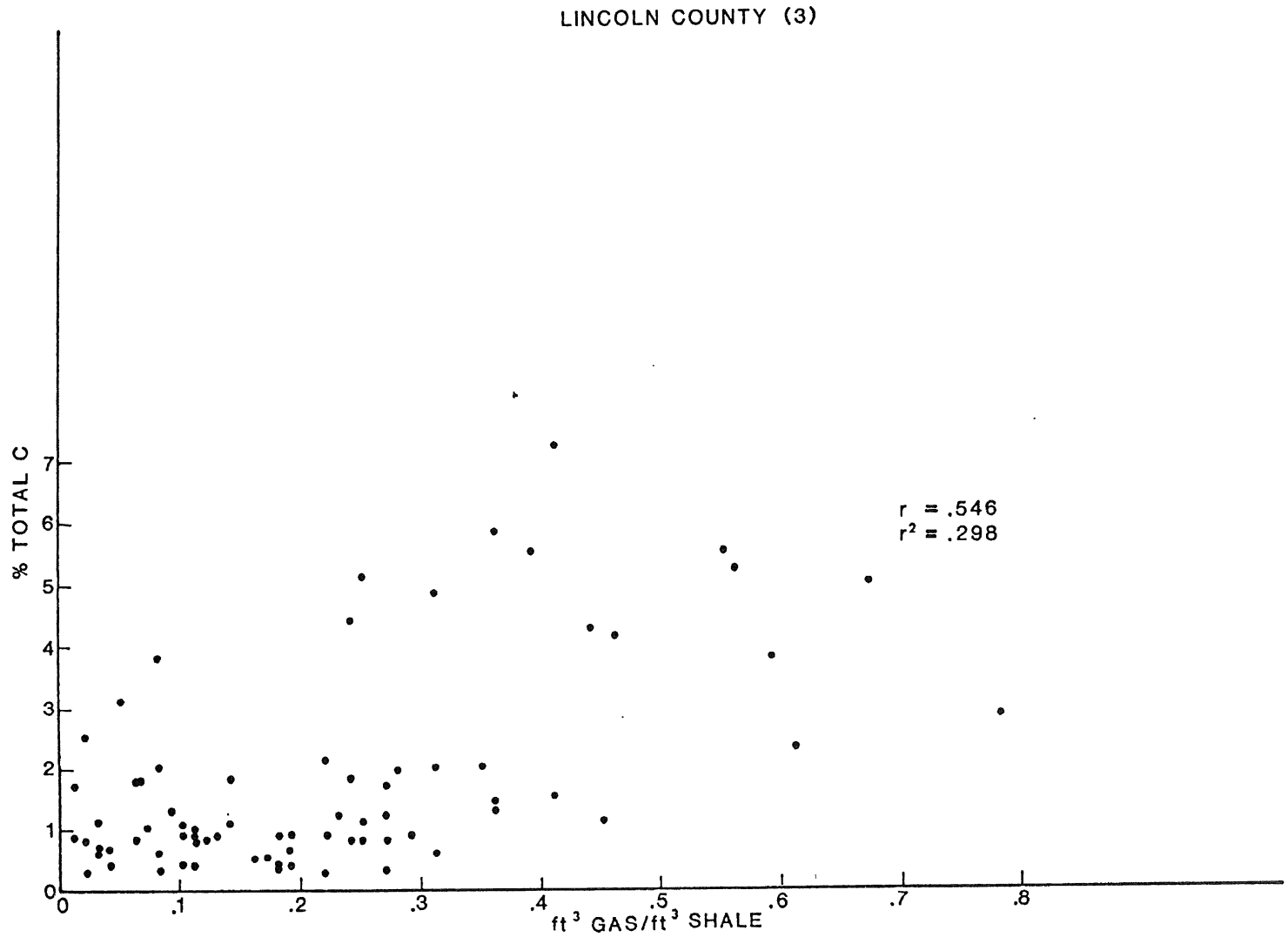

Figure 14 - Gas Volume vs. Carbon - Lincoln County, West Virginia (Well #3)

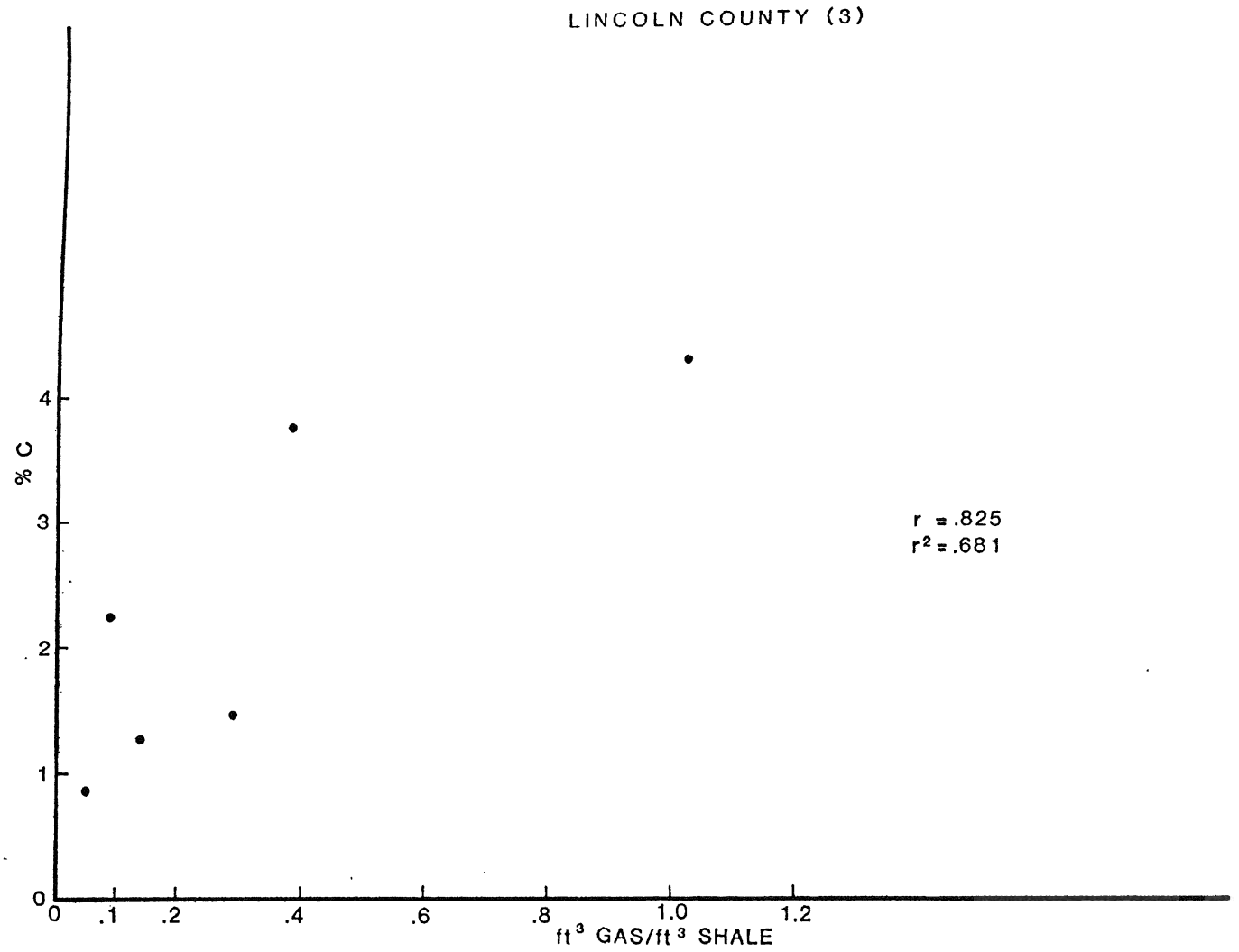

Figure 15 - Gas Volume vs. Carbon by Lithologic Unit - Lincoln County, West Virginia (Well #3)

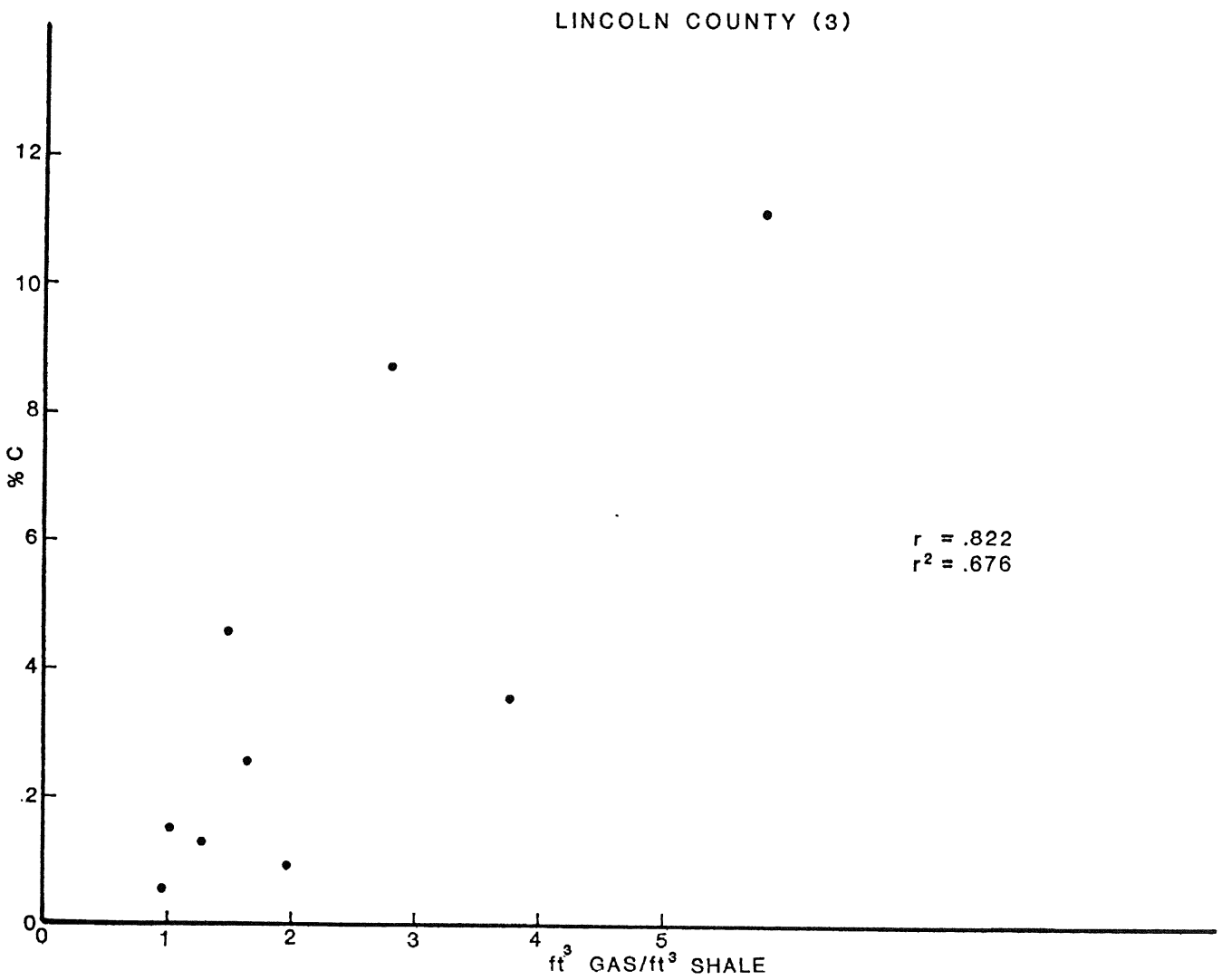

Figure 16 - Gas Volume vs. Carbon by Stratigraphic Unit - Lincoln County, West Virginia (Well #3)

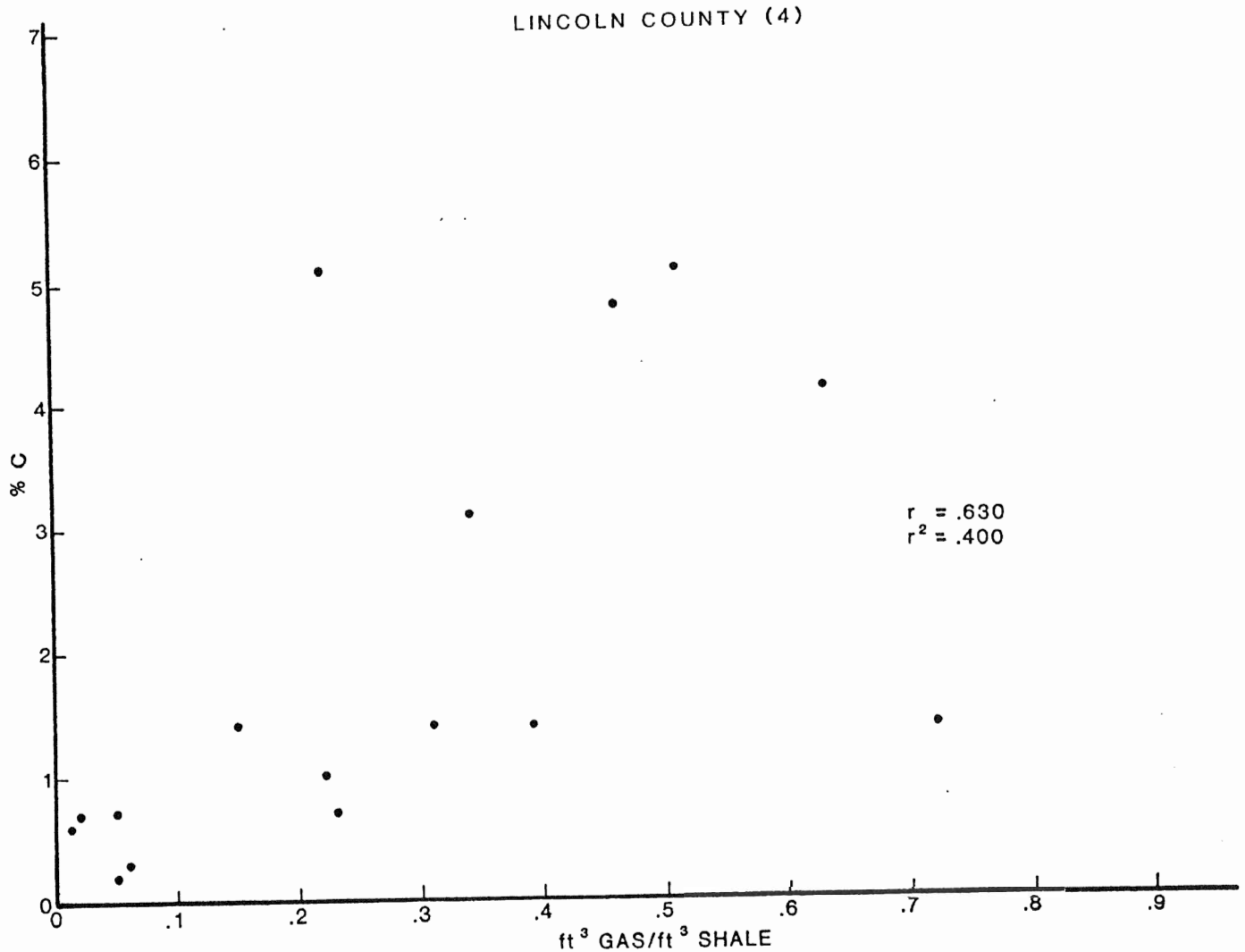

Figure 17 - Gas Volume vs. Carbon - Lincoln County, West Virginia (Well #4)

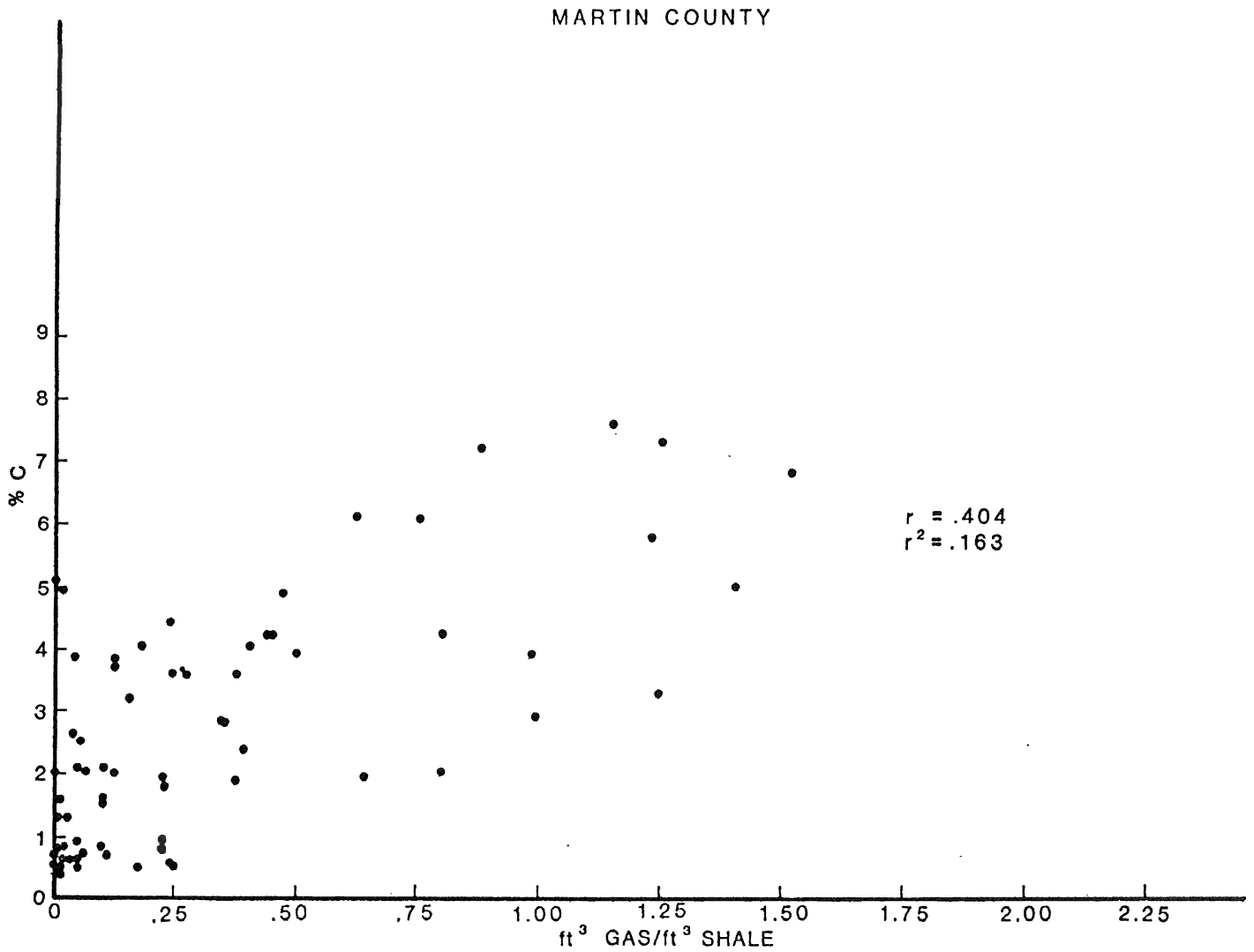

Figure 18 - Gas Volume vs. Carbon - Martin County, Kentucky

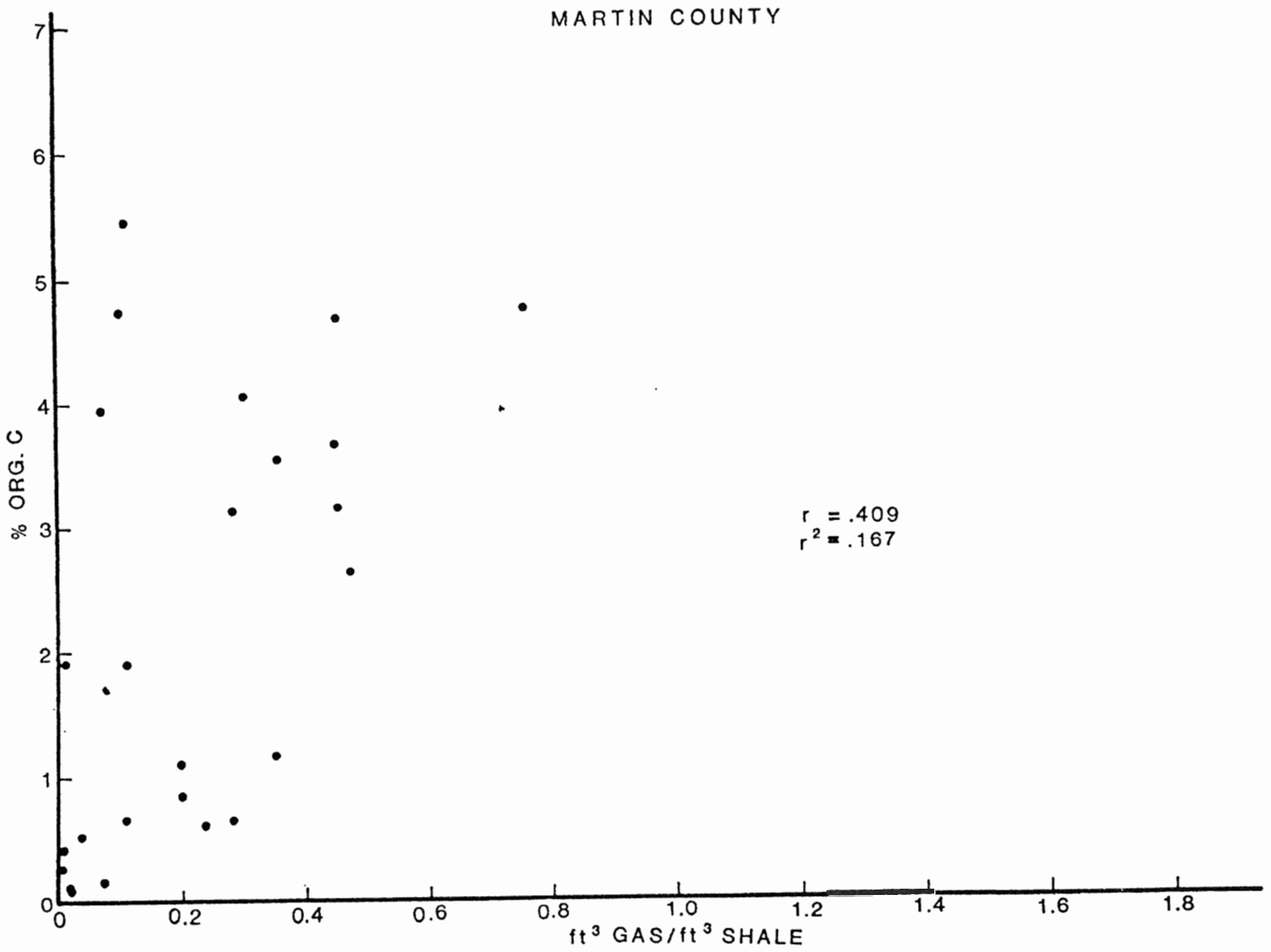

Figure 19 - Gas Volume vs. Organic Carbon - Martin County, Kentucky

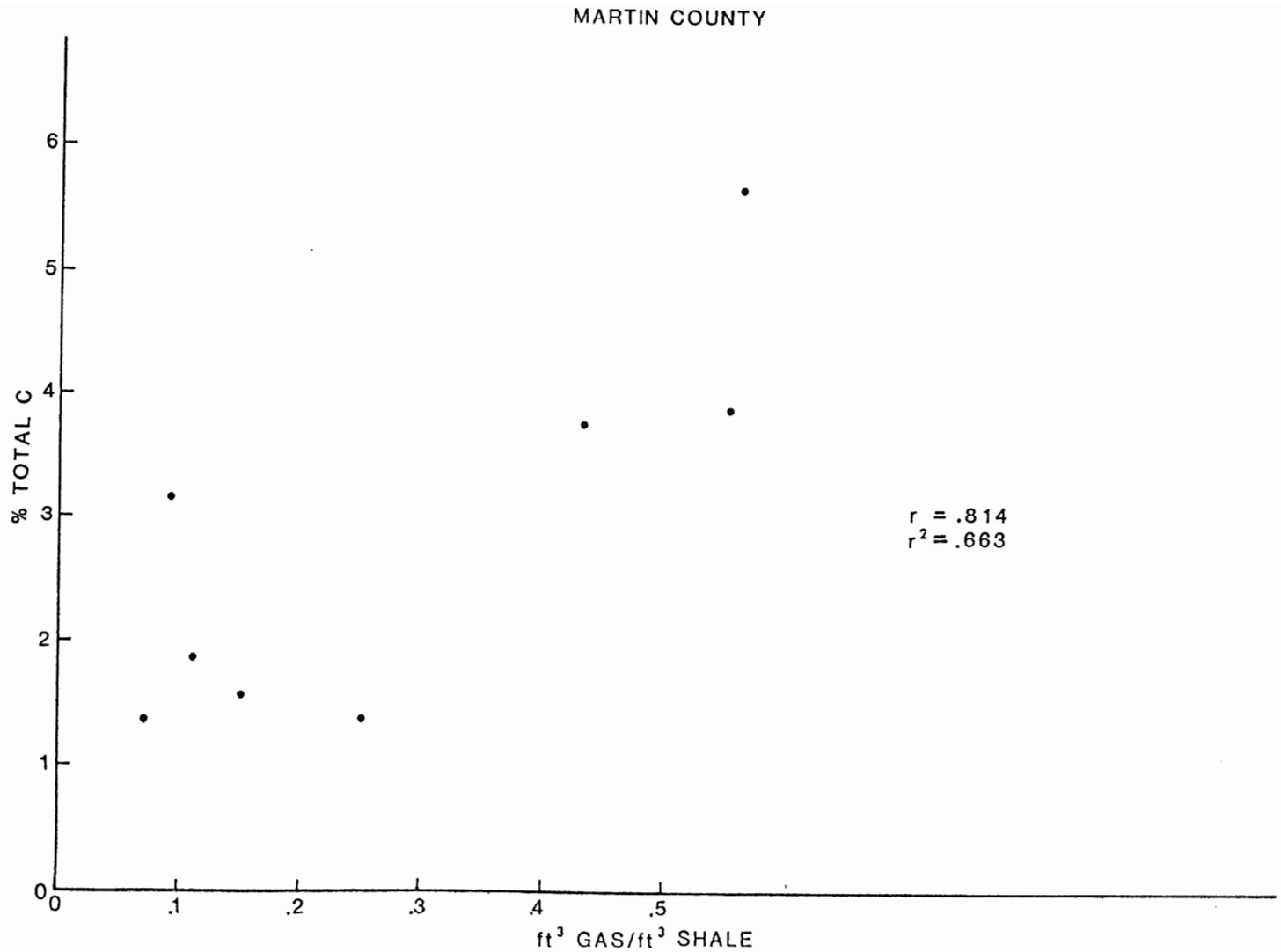

Figure 20 - Gas Volume vs. Carbon by Stratigraphic Unit - Martin County, Kentucky

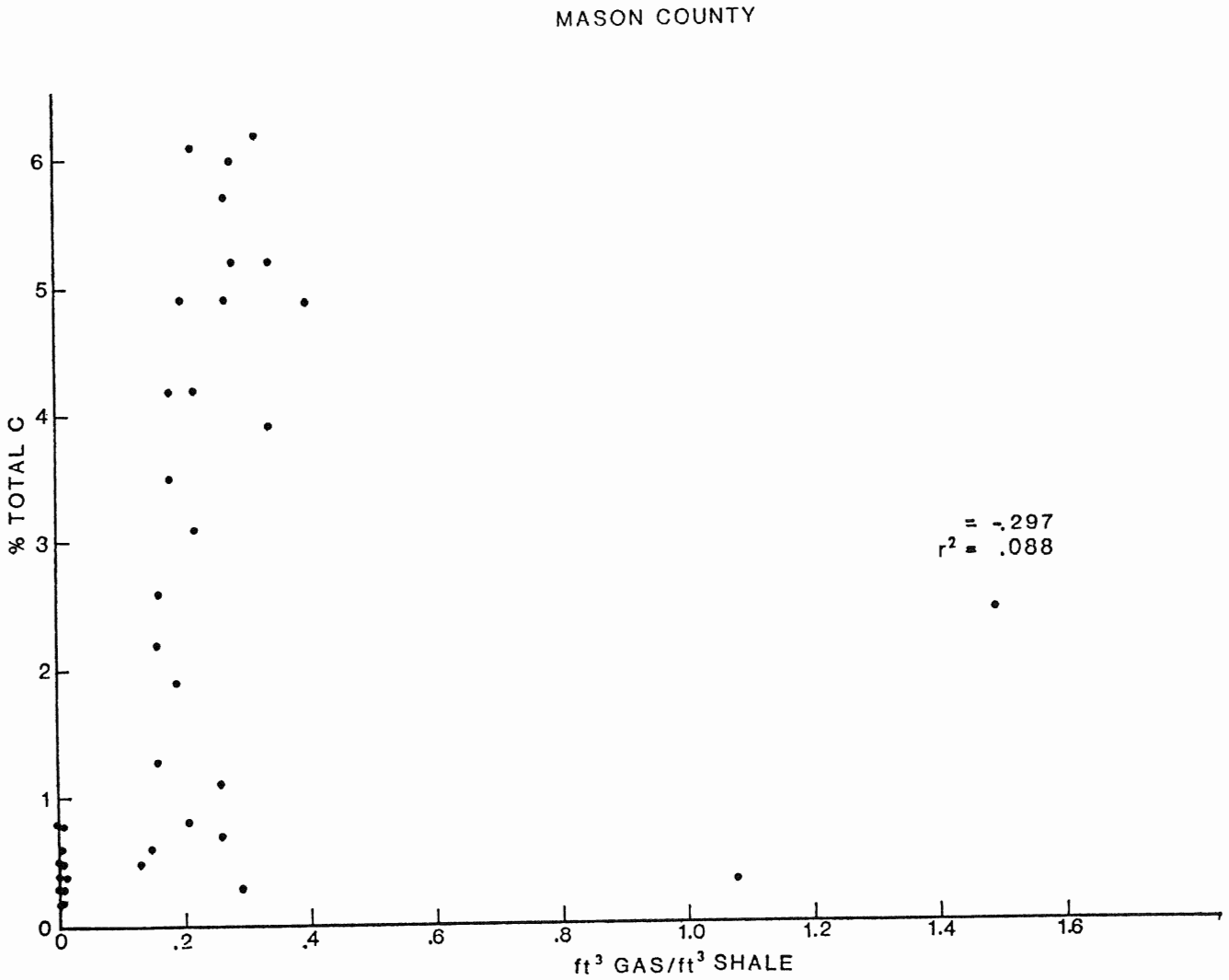

Figure 21 - Gas Volume vs. Carbon - Mason County, West Virginia

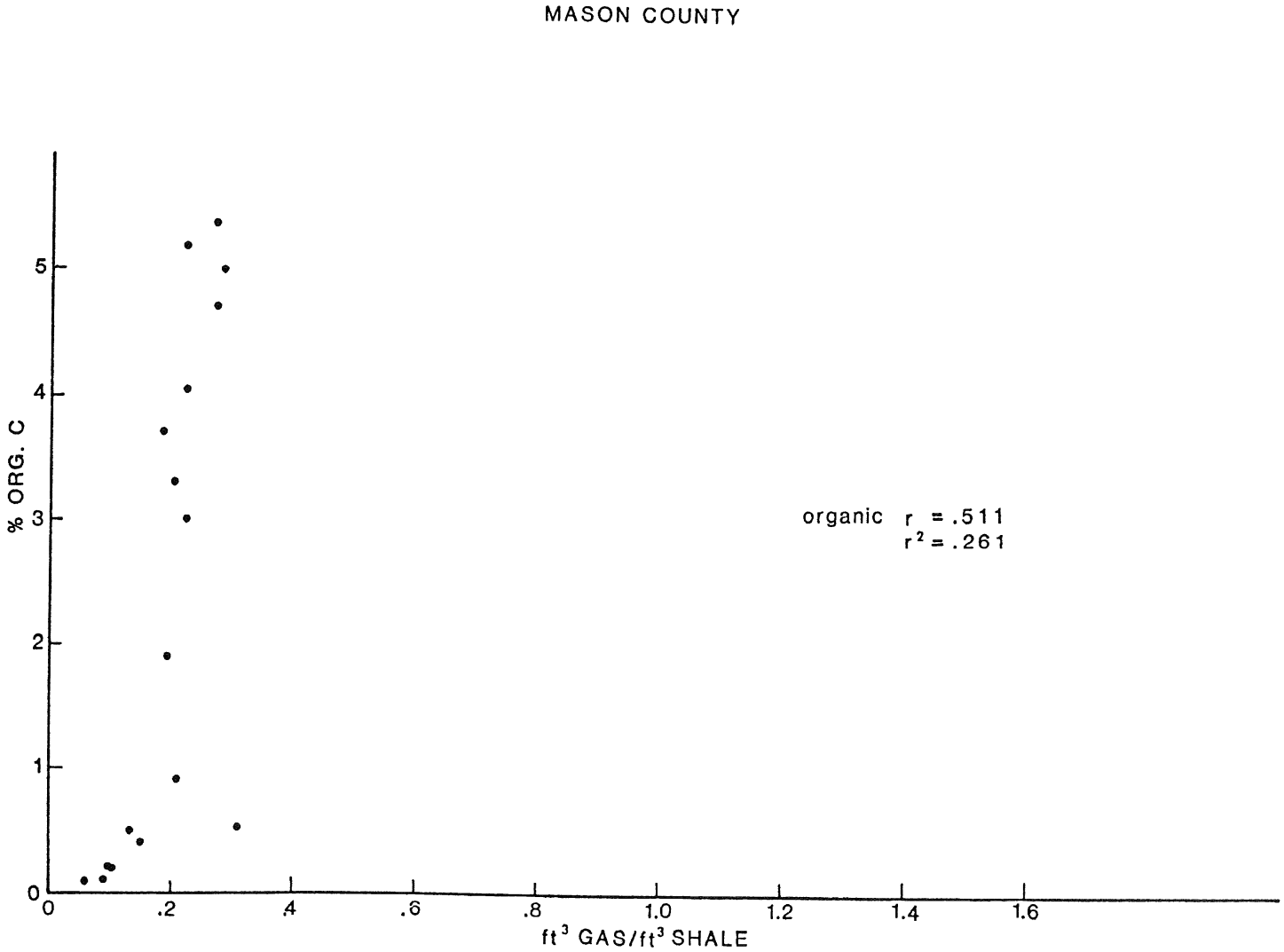

Figure 22 - Gas Volume vs. Organic Carbon - Mason County, West Virginia

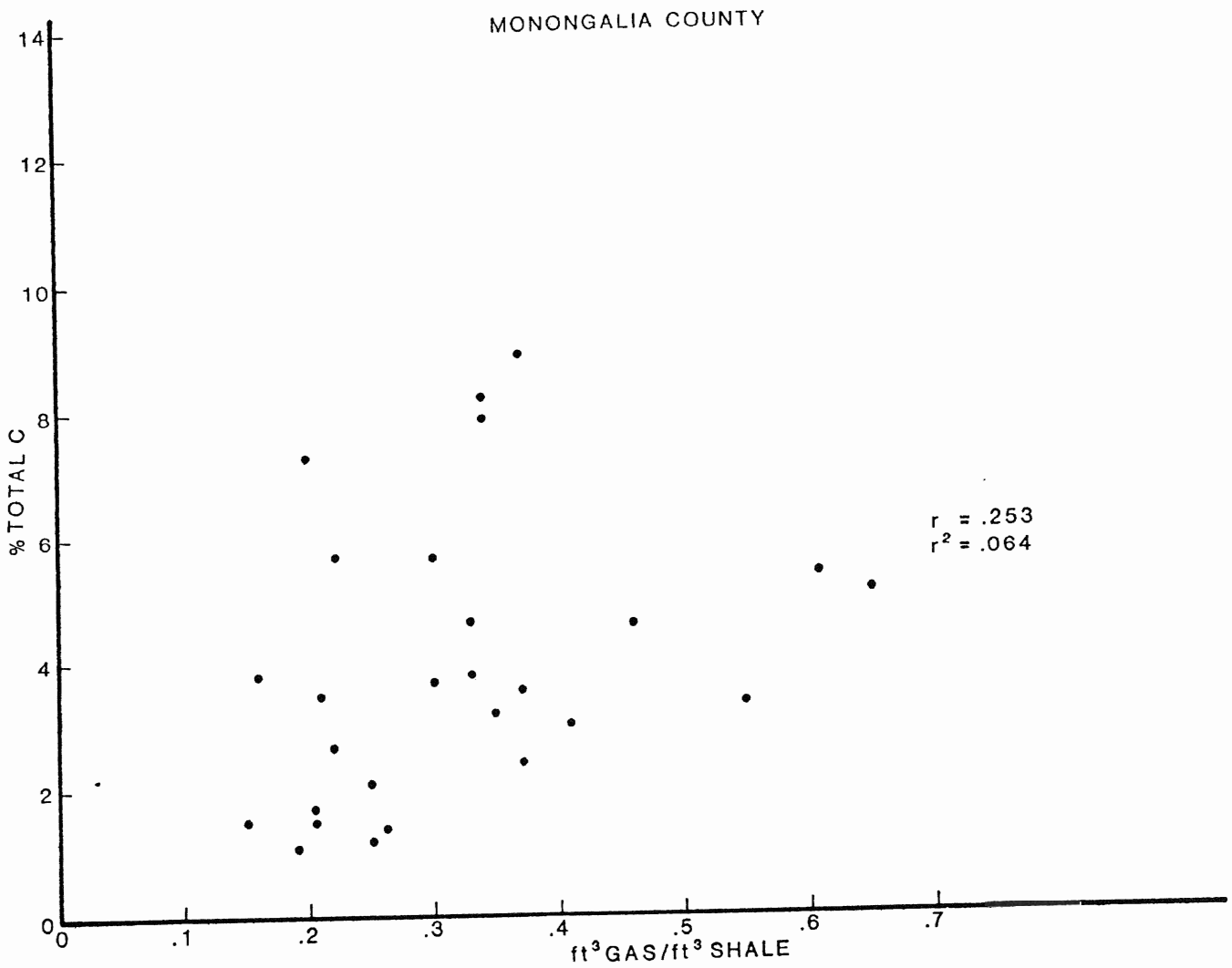

Figure 23 - Gas Volume vs. Carbon - Monongalia County, West Virginia

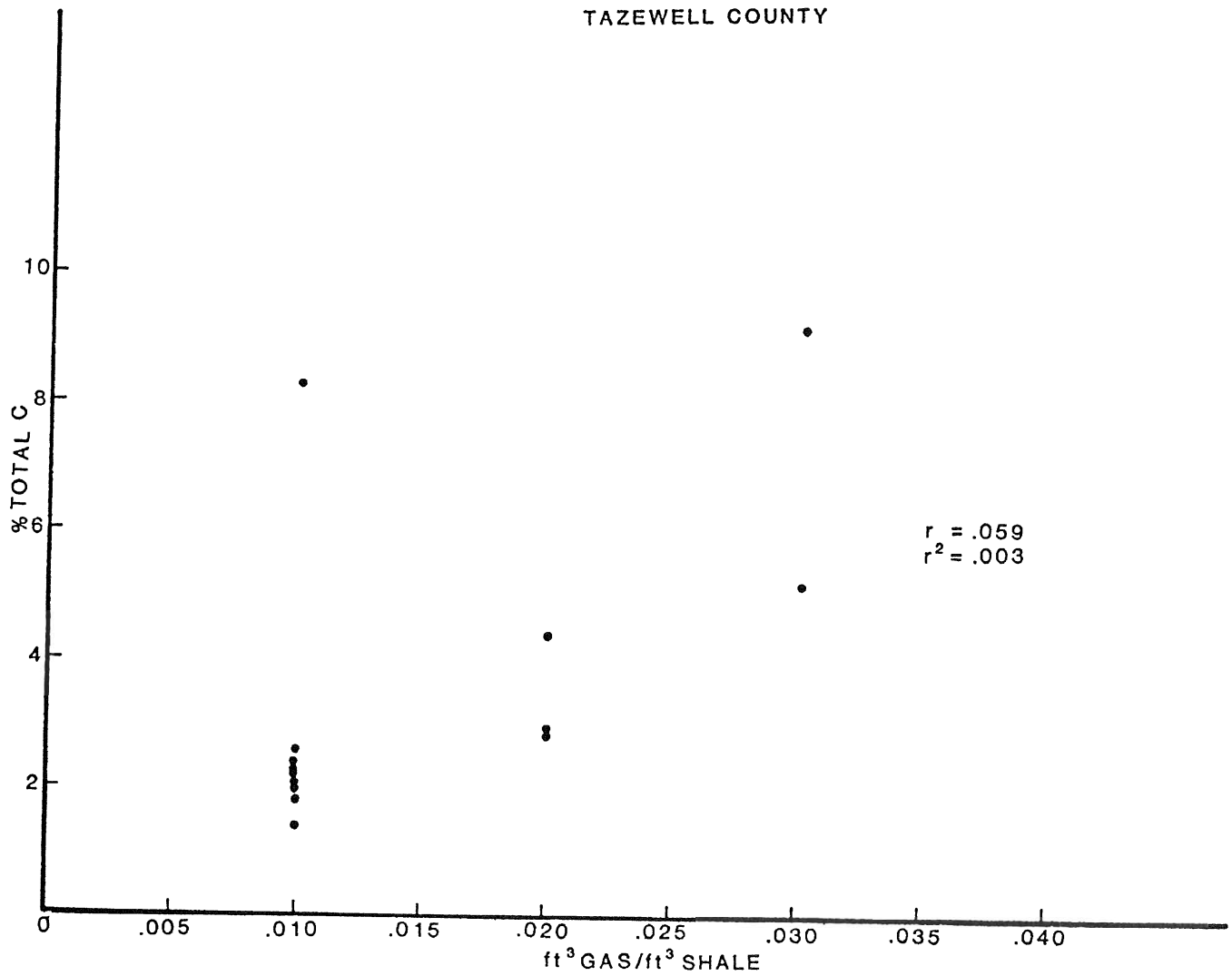

Figure 24 - Gas Volume vs. Carbon - Tazewell County, Illinois

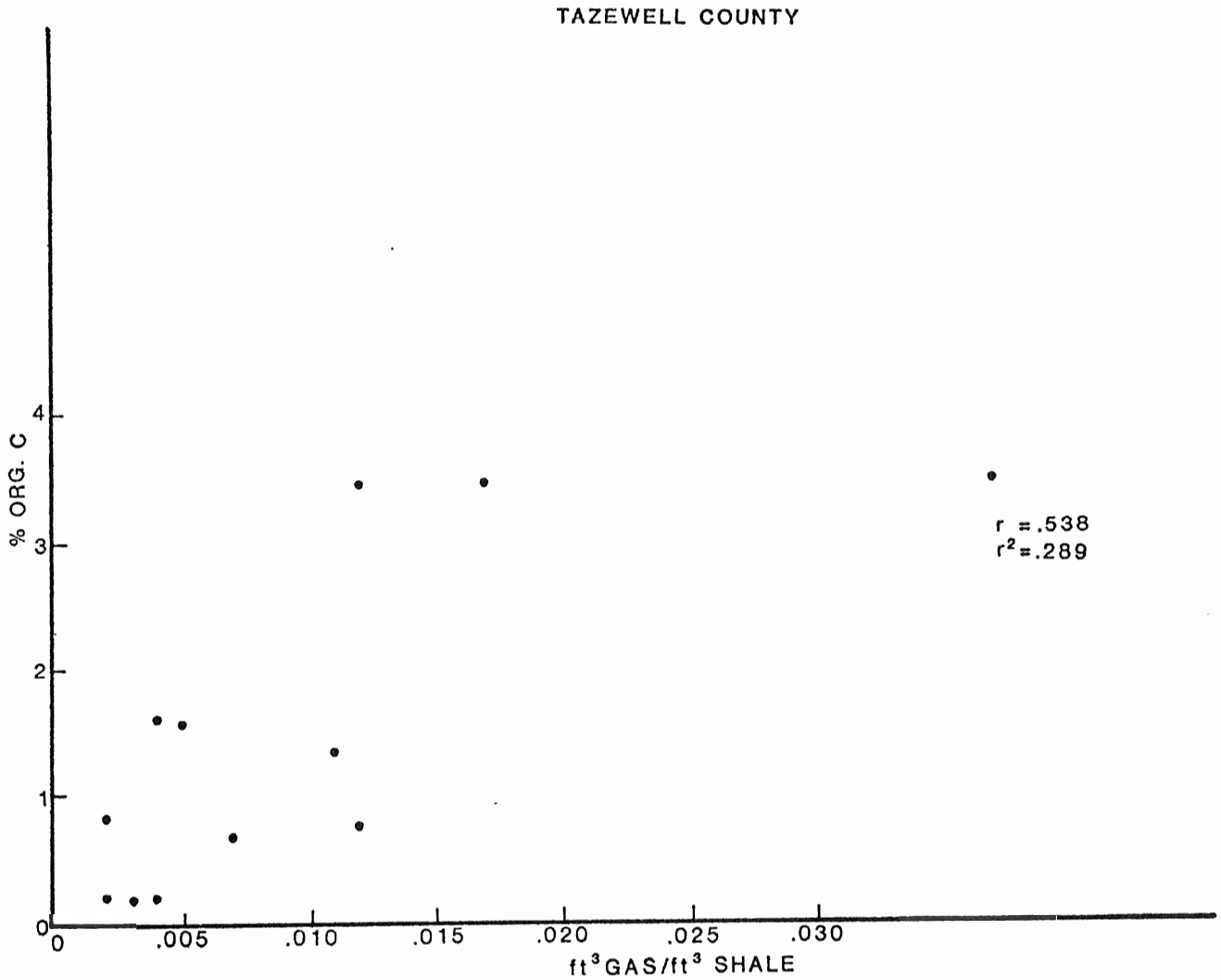

Figure 25 - Gas Volume vs. Organic Carbon - Tazewell County, Illinois

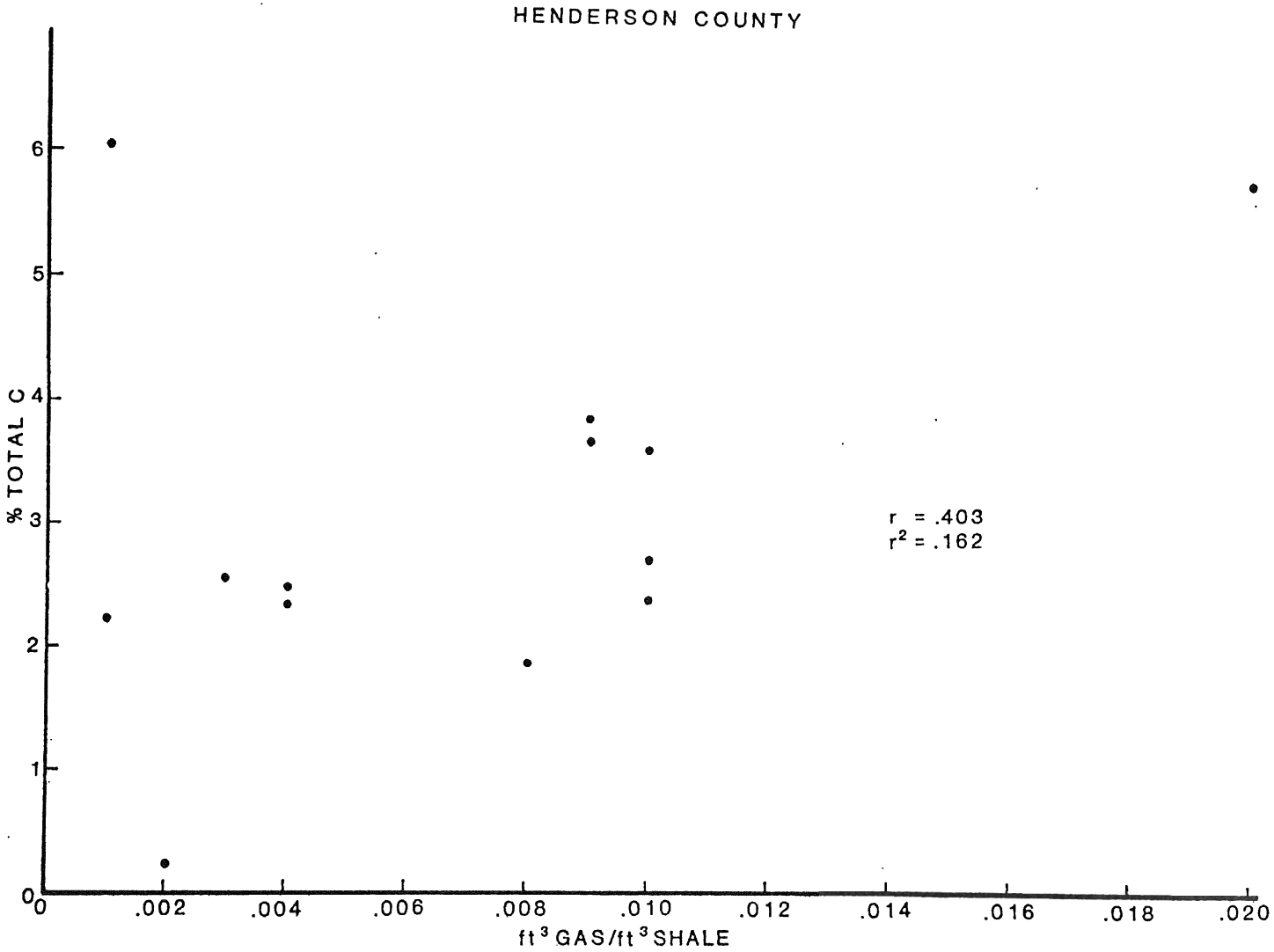

Figure 26 - Gas Volume vs. Carbon - Henderson County, Illinois

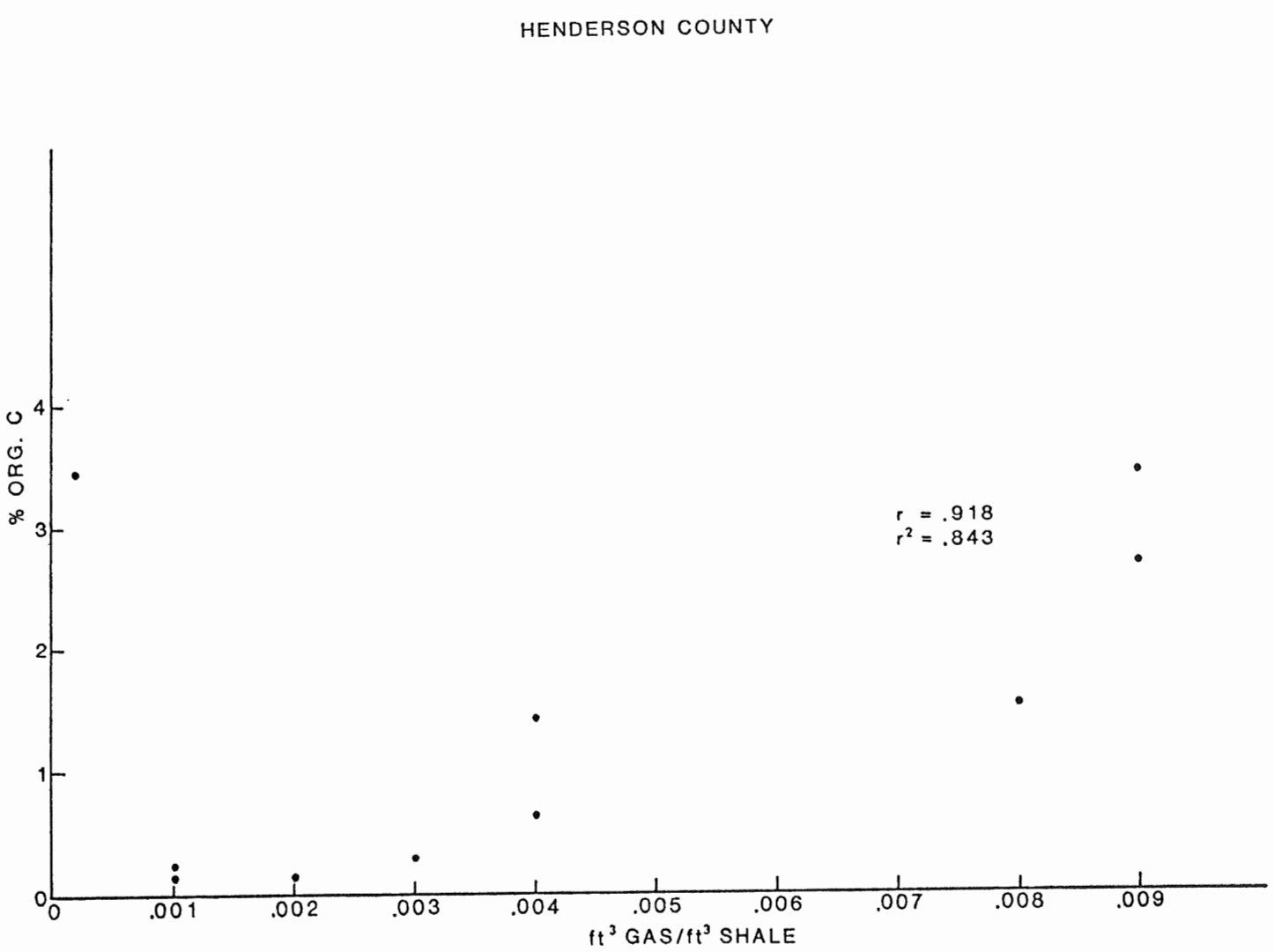

Figure 27 - Gas Volume vs. Organic Carbon - Henderson County, Illinois

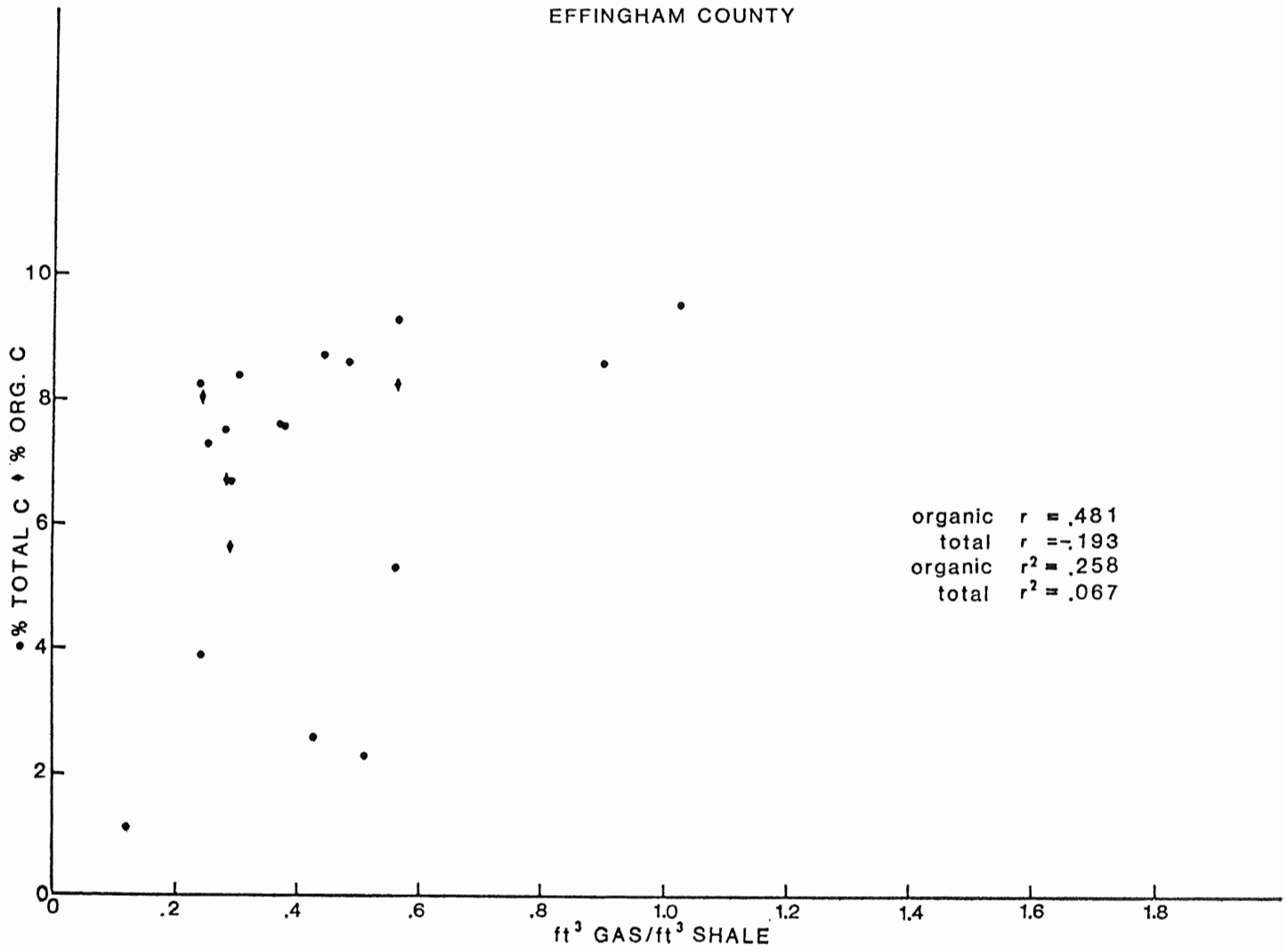

Figure 28 - Gas Volume vs. Carbon - Effingham County, Illinois
Figure 29 - Gas Volume vs. Organic Carbon - Effingham County, Illinois

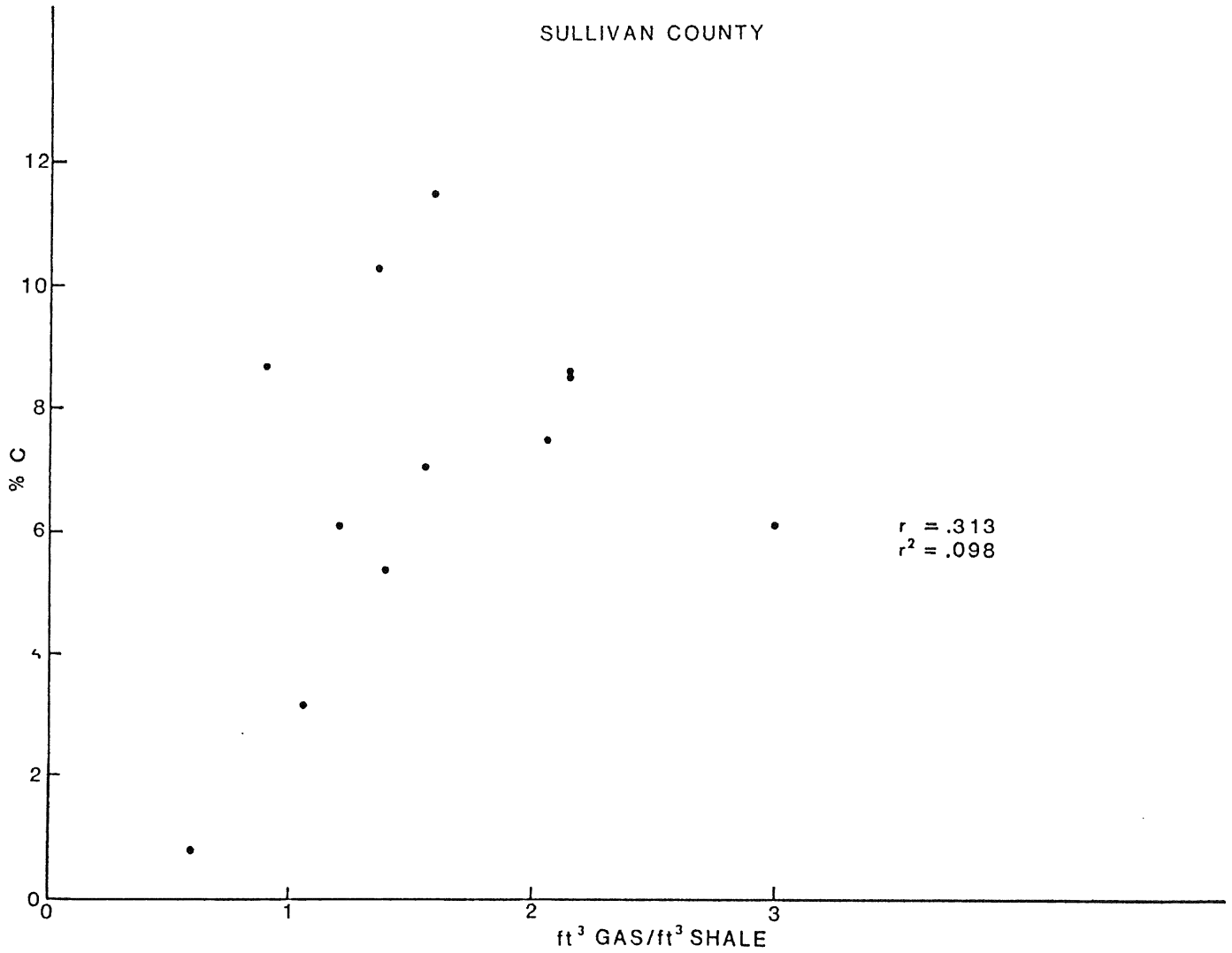

Figure 30 - Gas Volume vs. Carbon - Sullivan County, Indiana

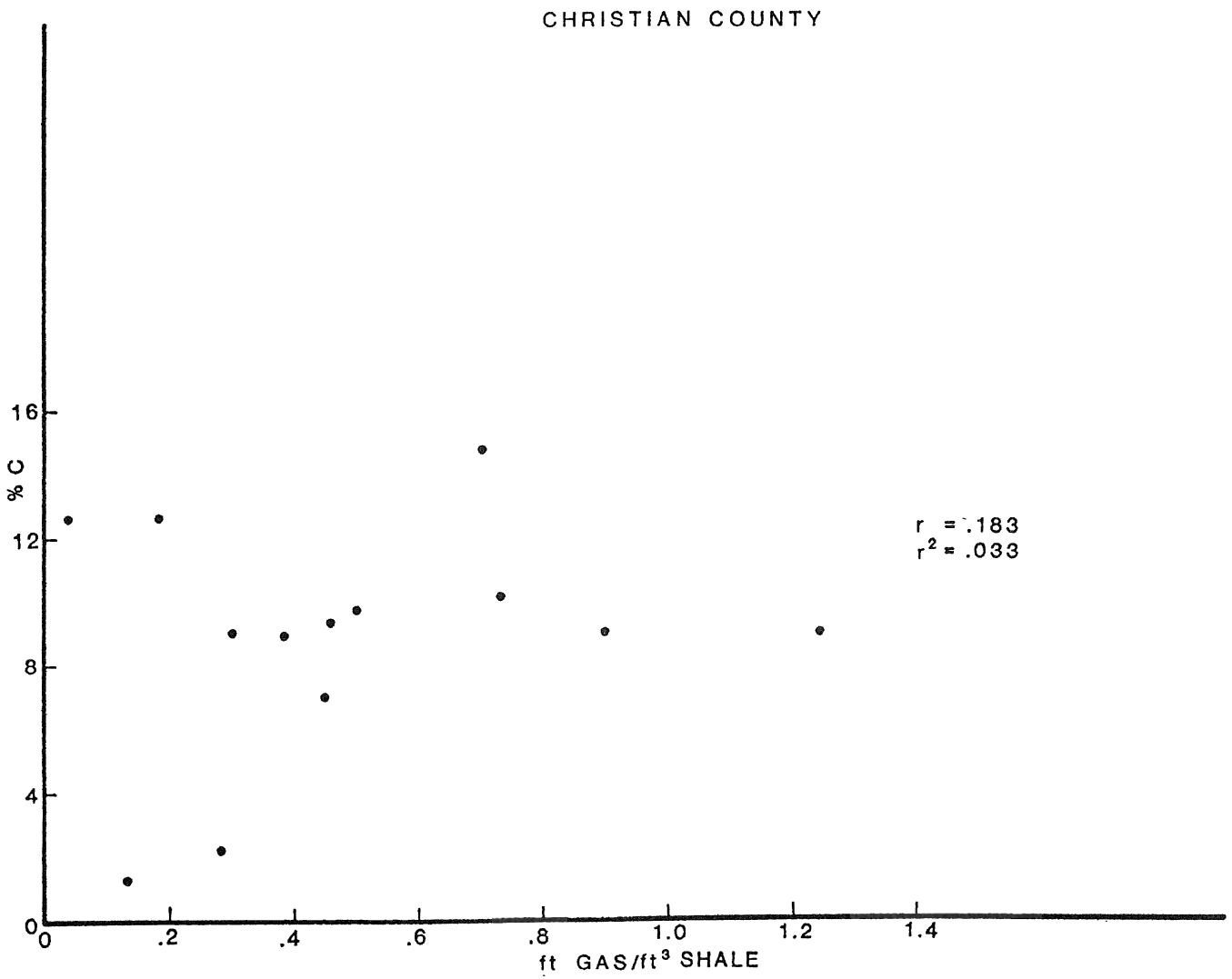

Figure 31 - Gas Volume vs. Carbon - Christian County, Kentucky

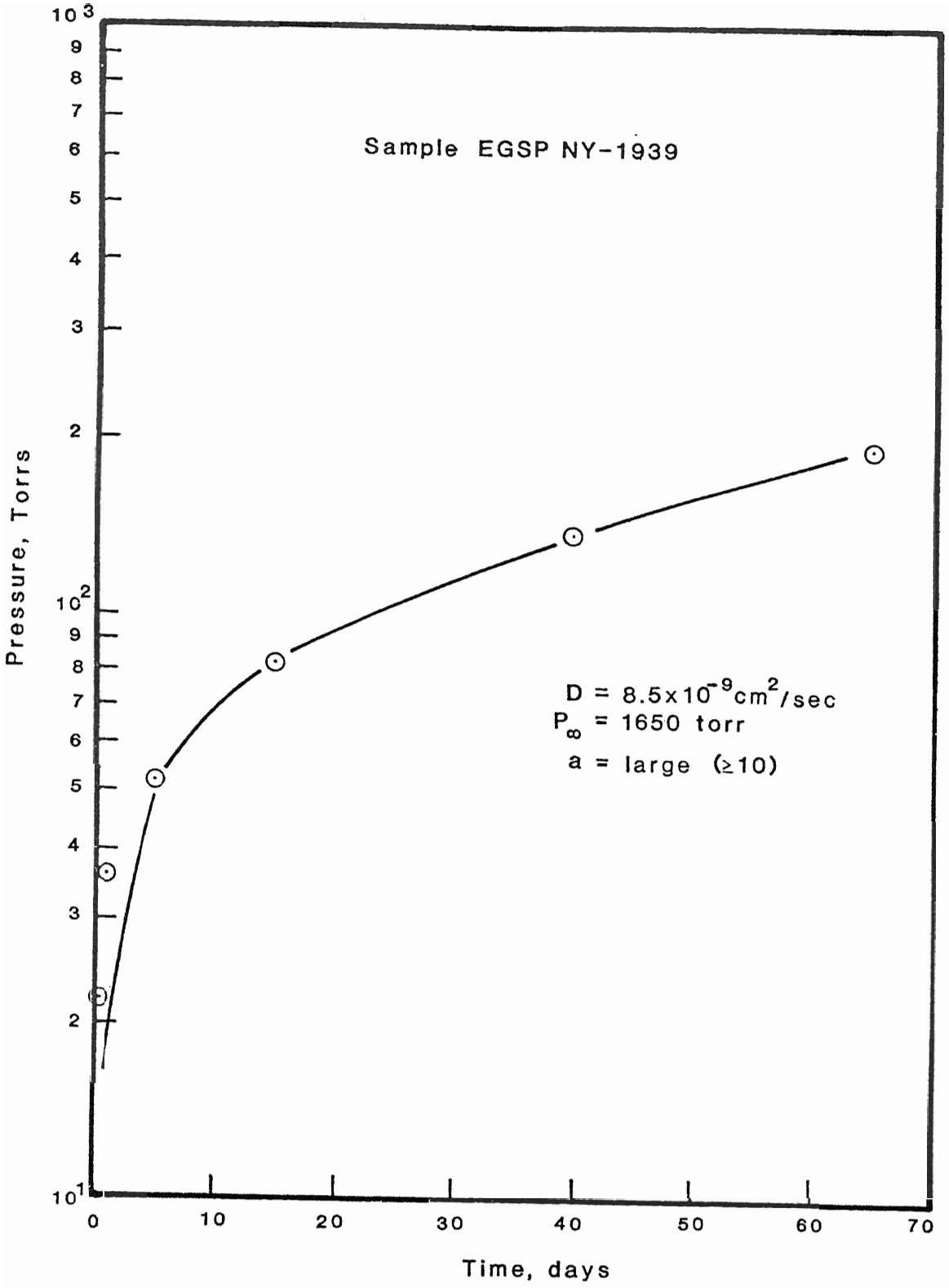

Figure 32 - Experimental and Calculated Gas Release Rates, Sample 1939 (After Ref. 24)

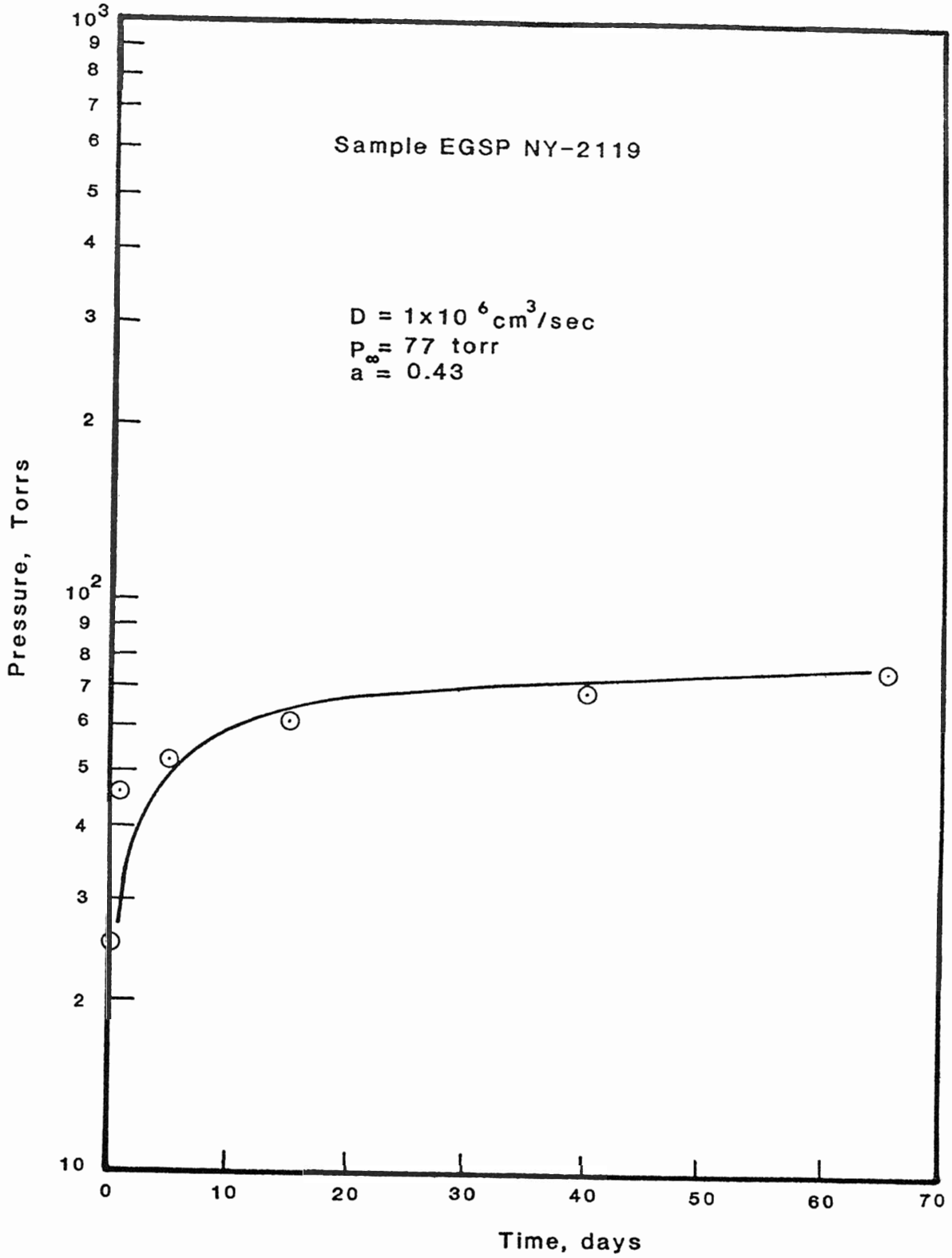

Figure 33 - Experimental and Calculated Gas Release Rates, Sample 2119 (After Ref. 24)

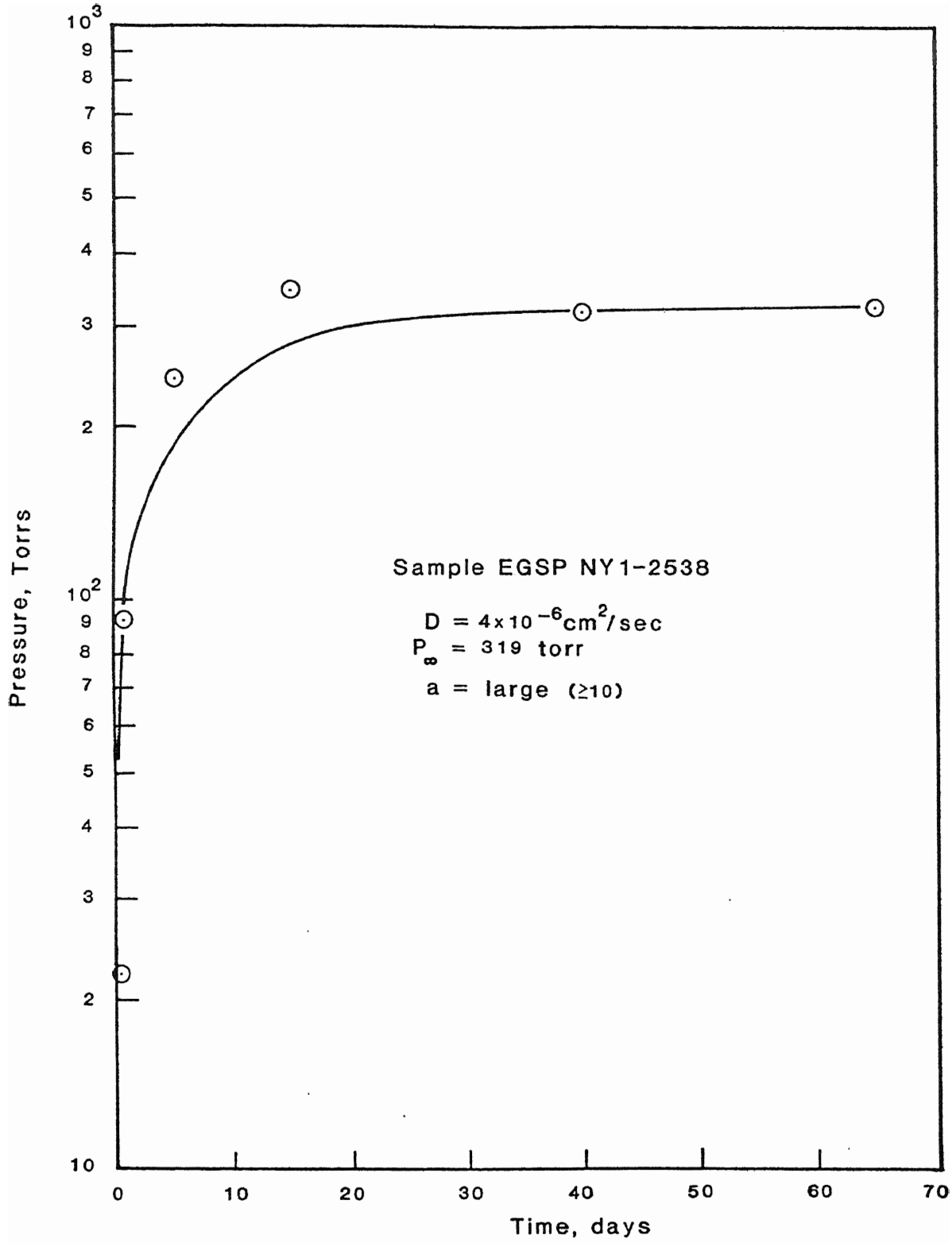

Figure 34 - Experimental and Calculated Gas Release Rates, Sample 2538 (After Ref. 24)

Well: Appalachian Basin, Well #1

Location: Wise County, Virginia

DEPTH	GAS RELEASED	% TOTAL CARBON	% ORGANIC CARBON	VITRINITE REFLECTANCE (Ro) MIN	MAX	AVG	SAMPLER
4871	0.51						Columbia
4872	2.59	4.0					Battelle
4881	0.26						Columbia
4882	3.25	6.2					Battelle
4885	1.77	5.7	5.60	0.47	1.39	0.96	Mound
4890	0.39						Columbia
4891	0.28						Columbia
4892	2.56						Battelle
4901	0.44						Columbia
4902	2.40						Battelle
4991	0.45						Columbia
4912	3.27	5.2					Battelle
4915	1.48	3.9	3.69	0.48	1.45	0.97	Mound
4921	0.31						Columbia
4922	2.17						Battelle
4930	1.66	2.3					Battelle
4931	0.24						Columbia
4940	2.03	2.8					Battelle
4941	0.02						Columbia
4945	0.19	0.4	0.36	0.67	1.41	1.19	Mound
4950	1.26	3.1					Battelle
4951	0.13						Columbia
4960	0.89	1.3					Battelle
4961	0.00						Columbia
4970	0.05	3.4					Battelle
4971	0.00						Columbia
4975	0.10			1.01	1.34	1.21	Mound
4980	0.47	1.2					Battelle
4981	0.03						Columbia
5211	0.12						Columbia
5212	0.91	1.1					Battelle
5221	0.10						Columbia
5222	0.82	1.2					Battelle
5229	0.50	0.6	0.61	1.28	1.28	1.28	Mound
5231	0.07						Columbia
5232	0.99						Battelle
5241	0.10						Columbia
5242	1.93	1.4					Battelle
5251	0.13						Columbia
5253	2.00	2.5					Battelle
5259	1.15	2.3	2.12	0.48	1.26	0.92	Mound
5261	0.03						Columbia
5263	1.25	1.3					Battelle

Well: Appalachian Basin, Well #1

Location: Wise County, Virginia

DEPTH	GAS RELEASED	% TOTAL CARBON	% ORGANIC CARBON	VITRINITE REFLECTANCE (Ro) MIN	MAX	AVG	SAMPLER
5271	0.30						Columbia
5273		1.7					Battelle
5281	0.20						Columbia
5283	0.86	1.7					Battelle
5289	1.50			0.63	1.24	0.93	Mound
5291	0.00						Columbia
5293	1.13	2.5					Battelle
5302	0.39						Columbia
5303	1.62	2.1					Battelle
5311	0.05						Columbia
5312	2.49	2.5					Battelle
5219	2.27			0.66	1.28	0.92	Mound
5321	0.26						Columbia
5322	2.08						Battelle
5331	0.10						Columbia
5332	0.45	1.0					Battelle
5341	0.36						Columbia
5342	1.56	3.5					Battelle
5347	1.19	1.7					Battelle
5348	3.31			0.67	1.36	1.01	Mound
5357	1.13						Battelle
5361	0.00						Columbia
5362	2.03						Battelle
5363	0.62						Columbia
5366	0.38						Columbia
5371	0.44						Columbia
5372	1.43						Battelle
5379	2.74	4.4	4.30	0.46	1.39	0.96	Mound
5380	0.18						Columbia
5382	1.62	4.0					Battelle
5393	0.03			0.49	1.35	1.02	Mound
5393	2.60			0.68	1.44	1.02	Mound
5394	0.55	2.6					Battelle
5401	0.63						Columbia
5404	1.49						Battelle
5409	0.29	0.50	0.24	0.53	1.47	1.10	Mound
5411	0.09						Columbia
5414	2.77						Battelle
5421	0.44						Columbia
5424	3.26						Battelle
5431	0.28						Columbia
5434	1.11	2.4					Battelle
5439	3.81	6.1	5.65	0.69	1.15	0.94	Mound

Well: Appalachian Basin, Well #1

Location: Wise County, Virginia

DEPTH	GAS RELEASED	% TOTAL CARBON	% ORGANIC CARBON	VITRINITE REFLECTANCE (Ro) MIN	MAX	AVG	SAMPLER
5441	0.53						Columbia
5444	2.23						Battelle
5445	0.38						Columbia
5447	2.89	5.1					Battelle
5451	0.56						Columbia
5457	1.36						Battelle
5461	0.24						Columbia
5467	1.41	4.8					Battelle
5469	1.68	2.8	2.77	0.64	1.25	0.91	Mound
5471	0.41						Columbia
5688	0.01						Columbia
96	99.45						

Average Gas Released = 1.04

Well: Appalachian Basin, Well #2

Location: Washington County, Ohio

DEPTH	GAS RELEASED	% TOTAL CARBON	% ORGANIC CARBON	VITRINITE REFLECTANCE (Ro) MIN	MAX	AVG	SAMPLER
3491		0.5	0.29	0.39	1.33	0.92	Mound
3494	0.31						Battelle
3506	0.48	1.5					Battelle
3516	0.38	1.6					Battelle
3519		1.0	0.21				Mound
3526	0.33	3.2					Battelle
3536	0.08	2.2					Battelle
3545	0.13						Battelle
3549		1.6	1.61				Mound
3555	0.38	1.3					Battelle
3564	0.19						Battelle
3575	0.27						Battelle
3580		3.3	2.85				Mound
3585	0.46						Battelle
3593	0.73	2.8					Battelle
3605	0.51	3.1					Battelle
3606A	0.49	5.0					Battelle
3606B	1.62	3.9					Battelle
3610		4.4	4.29	0.25	0.27	0.26	Mound
3616	0.67						Battelle
3626	0.45						Battelle
3634	0.25						Battelle
3640		2.9	2.60	0.35	0.78	0.57	Mound
3644A	0.97						Battelle
3644B	1.97						Battelle
3665	0.65	2.4					Battelle
3670		3.3	3.18				Mound
3675	0.44						Battelle
3685	0.26	1.7					Battelle
3695	1.14	3.5					Battelle
3705	0.12	0.5					Battelle
3706		0.6	0.31				Mound
3711	0.73						Battelle
25	14.01						

Average Gas Released = 0.56

Well: Appalachian Basin, Well #3

Location: Lincoln County, West Virginia

DEPTH	GAS RELEASED	% TOTAL CARBON	% ORGANIC CARBON	VITRINITE REFLECTANCE (Ro) MIN	MAX	AVG	SAMPLER
2735	0.00			No Vitrinite Reflectance			Columbia
2740	0.01			available for this well			Columbia
2745	0.00						Columbia
2745	0.23						Battelle
2750	0.03						Columbia
2755	0.10	0.4					Battelle
2755	0.01						Columbia
2760	0.00						Columbia
2765	0.00						Columbia
2770	0.00						Columbia
2775	0.03						Columbia
2782	0.03						Columbia
2782	0.08	0.6					Battelle
2782	0.03						Columbia
2787	0.04						Columbia
2792	0.00						Columbia
2797	0.00						Columbia
2797	0.04	0.7					Battelle
2802	0.00						Columbia
2802	0.02	0.3					Battelle
2807	0.04						Columbia
2812	0.03						Columbia
2817	0.00						Columbia
2827	0.05						Columbia
2827	0.08	0.3					Battelle
2832	0.08	2.0					Battelle
2832	0.05						Columbia
2837	0.00						Columbia
2837	0.06	0.8					Battelle
2842	0.07	1.8					Battelle
2842	0.05						Columbia
2847	0.08						Columbia
2852	0.02						Columbia
2852	0.16	0.5					Battelle
2857	0.14						Columbia
2862	0.00						Columbia
2872	0.00						Columbia
2877	0.00						Columbia
2882	0.03						Columbia
2887	0.11						Columbia
2892	0.00						Columbia
2897	0.01	1.7					Battelle
2897	0.07						Columbia

Well: Appalachian Basin, Well #3

Location: Lincoln County, West Virginia

DEPTH	GAS RELEASED	% TOTAL CARBON	% ORGANIC CARBON	VITRINITE REFLECTANCE (Ro) MIN	MAX	AVG	SAMPLER
2912	0.14			No Vitrinite Reflectance			Columbia
2917	0.29			available for this well			Columbia
2918	0.00						Columbia
2992	0.00						Columbia
2927	0.00						Columbia
2927A	0.03	1.1					Battelle
2933	0.03						Columbia
2938	0.03						Columbia
2941	0.19	0.4					Battelle
2943	0.00						Columbia
2947	0.22	0.9					Battelle
2947	0.00						Columbia
2952	0.01						Columbia
2959	0.02	2.5					Battelle
2959	0.05						Columbia
2964	0.19	0.6					Battelle
2964	0.05						Columbia
2969	0.14						Columbia
2974	0.11						Columbia
2979	0.05						Columbia
2984	0.17						Columbia
2989	0.05						Columbia
2994	0.08	3.8					Battelle
2994	0.06						Columbia
2999	0.22	2.1					Battelle
2999	0.01						Columbia
3004	0.08						Columbia
3009	0.00						Columbia
3014	0.17						Columbia
3019	0.13						Columbia
3024	0.11						Columbia
3025	0.00						Columbia
3029	0.15						Columbia
3034	0.14						Columbia
3035	0.09						Columbia
3039	0.01	0.9					Battelle
3039	0.12						Columbia
3044	0.08						Columbia
3049	0.10						Columbia
3054	0.08						Columbia
3059	0.09						Columbia
3064	0.11	1.0					Battelle
3064	0.09						Columbia

Well: Appalachian Basin, Well #3

Location: Lincoln County, West Virginia

DEPTH	GAS RELEASED	% TOTAL CARBON	% ORGANIC CARBON	VITRINITE REFLECTANCE (Ro) MIN	MAX	AVG	SAMPLER
3081	0.00			No Vitrinite Reflectance			Columbia
3085	0.28	1.9		available for this well			Battelle
3085	0.22						Columbia
3090	0.07	1.0					Battelle
3090	0.00						Columbia
3095	0.16						Columbia
3100	0.27	1.2					Battelle
3100	0.20						Columbia
3106	0.48						Columbia
3111	0.22						Columbia
3116	0.15						Columbia
3121	0.31	2.0					Battelle
3121	0.11						Columbia
3126	0.22						Columbia
3131	0.19						Columbia
3135							Battelle
3135	0.21						Columbia
3140	0.18	0.4					Battelle
3140	0.09						Columbia
3145	0.25	1.1					Battelle
3145	0.06						Columbia
3150	0.14	1.8					Battelle
3150	0.00						Columbia
3155	0.04	0.4					Battelle
3155	0.14						Columbia
3160	0.03						Columbia
3165	0.01	0.9					Battelle
3165	0.06						Columbia
3170	0.16						Columbia
3175	0.13	0.9					Battelle
3175	0.11						Columbia
3180	0.18	0.7					Battelle
3180	0.09						Columbia
3185	0.24						Columbia
3190	0.27						Columbia
3198	0.22	1.9					Battelle
3198	0.14						Columbia
3203	0.22						Columbia
3208	0.04						Columbia
3213	0.00						Columbia
3218	0.35	0.9					Battelle
3218	0.15						Columbia
3223	0.09						Columbia

Well: Appalachian Basin, Well #3

Location: Lincoln County, West Virginia

DEPTH	GAS RELEASED	% TOTAL CARBON	% ORGANIC CARBON	VITRINITE REFLECTANCE (Ro) MIN	MAX	AVG	SAMPLER
3228	0.12	5.9		No Vitrinite Reflectance			Battelle
3228	0.10			available for this well			Columbia
3229	0.24	0.3					Battelle
3233	0.00						Columbia
3238	0.05						Columbia
3243	0.17	0.4					Battelle
3243	0.04						Columbia
3248		0.9					Battelle
3248	0.16						Columbia
3254	0.00						Columbia
3263	0.12						Columbia
3268	0.00						Columbia
3268	0.27	0.6					Battelle
3273	0.00						Columbia
3276	0.06						Columbia
3276	0.10	0.5					Battelle
3280	0.29						Columbia
3285	0.08						Columbia
3290	0.00						Columbia
3290	0.11	0.8					Battelle
3295	0.00						Columbia
3300	0.10						Columbia
3305	0.04						Columbia
3310	0.07						Columbia
3316	0.15						Columbia
3316	0.06	1.8					Battelle
3321	0.00						Columbia
3326	0.27	0.3					Battelle
3341	0.19						Columbia
3341	0.45	1.1					Battelle
3346	0.36	1.6					Battelle
3346	0.29						Columbia
3351	0.12						Columbia
3356	0.11						Columbia
3361	0.00						Columbia
3366	0.05	3.1					Battelle
3366	0.41						Columbia
3371	0.20						Columbia
3376	0.32						Columbia
3381	0.18						Columbia
3386	0.10						Columbia
3391	0.13						Columbia
3396	0.09	1.3					Battelle

Well: Appalachian Basin, Well #3

Location: Lincoln County, West Virginia

DEPTH	GAS RELEASED	% TOTAL CARBON	% ORGANIC CARBON	VITRINITE REFLECTANCE (Ro) MIN	MAX	AVG	SAMPLER
3396	0.11			No Vitrinite Reflectance			Columbia
3401	0.00			available for this well			Columbia
3406	0.12						Columbia
3411	0.14						Columbia
3416	0.11						Columbia
3421	0.14						Columbia
3426	0.31	4.8					Battelle
3432	0.34						Columbia
3437	0.66						Columbia
3442	0.53						Columbia
3447	0.78						Columbia
3452	0.37						Columbia
3457	0.49						Columbia
3462	0.33						Columbia
3467	0.31	0.6					Battelle
3467	0.21						Columbia
3472	0.14						Columbia
3477	0.45						Columbia
3482	0.23	1.2					Battelle
3482	0.31						Columbia
3487	1.03						Columbia
3492	0.22						Columbia
3498	0.08						Columbia
3503	0.20						Columbia
3508	0.38						Columbia
3513	0.25						Columbia
3518	0.20						Columbia
3523	0.39	5.5					Battelle
3523	0.89						Columbia
3528	0.67	5.0					Battelle
3528	0.18						Columbia
3533	0.31						Columbia
3538	0.65						Columbia
3543	0.27	0.8					Battelle
3543	0.04						Columbia
3548	0.17						Columbia
3553	0.46	4.1					Battelle
3553	0.26						Columbia
3558	1.16						Columbia
3563	0.37						Columbia
3568	0.62						Columbia
3573	0.55	5.5					Battelle
3573	0.25						Columbia

Well: Appalachian Basin, Well #3

Location: Lincoln County, West Virginia

DEPTH	GAS RELEASED	% TOTAL CARBON	% ORGANIC CARBON	VITRINITE REFLECTANCE (Ro) MIN	MAX	AVG	SAMPLER
3578	0.25	5.1		No Vitrinite Reflectance			Battelle
3578	0.35			available for this well			Columbia
3583	0.32						Columbia
3588	0.10	4.1					Battelle
3588	0.25						Columbia
3593	0.29	1.5					Battelle
3598	0.81						Columbia
3606	0.59	3.9					Battelle
3609	0.21						Columbia
3611	0.19						Columbia
3616	0.36						Columbia
3621	0.23						Columbia
3626	0.12						Columbia
3631	0.24	4.4					Battelle
3631	0.19						Columbia
3636	0.44	4.2					Battelle
3636	0.27						Columbia
3641	0.50						Columbia
3646	0.24						Columbia
3651	0.56	5.2					Battelle
3651	0.12						Columbia
3656	0.10						Columbia
3661	0.62						Columbia
3666	0.00						Columbia
3671	0.00						Columbia
3676	0.06						Columbia
3681	0.07						Columbia
3686	0.14						Columbia
3691	0.02						Columbia
3696	0.26						Columbia
3701	0.41	7.2					Battelle
3701	0.21						Columbia
3706	0.34						Columbia
3711	0.00						Columbia
3716	0.01						Columbia
3721	0.03						Columbia
3726	0.04						Columbia
3732	0.00						Columbia
3737	0.18						Columbia
3740		1.2					Battelle
3743	0.04						Columbia
3748	0.41	1.5					Battelle
3748	0.40						Columbia

Well: Appalachian Basin, Well #3

Location: Lincoln County, West Virginia

DEPTH	GAS RELEASED	% TOTAL CARBON	% ORGANIC CARBON	VITRINITE REFLECTANCE (Ro) MIN	MAX	AVG	SAMPLER
3753	0.03			No Vitrinite Reflectance			Columbia
3759	1.42			available for this well			Columbia
3764	0.06						Columbia
3768	1.32						Columbia
3773	0.24	0.8					Battelle
3773	1.02						Columbia
3777	0.19						Columbia
3782	0.25	1.1					Battelle
3782	1.23						Columbia
3787	0.05						Columbia
3792	0.06	0.9					Battelle
3792	0.09						Columbia
3797	0.02	0.8					Battelle
3797	0.01						Columbia
3802	0.00						Columbia
3807	0.36	1.3					Battelle
3807	0.60						Columbia
3812	0.02						Columbia
3818	0.03	0.6					Battelle
3818	0.02						Columbia
3823	0.11						Columbia
3829	0.00						Columbia
3834	0.01						Columbia
3939	0.00						Columbia
3844	0.48						Columbia
3849	0.03	0.7					Battelle
3849	0.08						Columbia
3854	0.08						Columbia
3859	0.61	2.3					Battelle
3859	1.69						Columbia
3860	0.14	1.1					Battelle
3864	0.07						Columbia
3869		2.9					Battelle
3869	0.08						Columbia
3874	0.11	0.4					Battelle
3874	0.06						Columbia
3879	0.53						Columbia
3884	0.07						Columbia
3888	0.11	0.9					Battelle
3888	0.06						Columbia
3893	0.40						Columbia
3898	0.15						Columbia
3903	1.46						Columbia

Well: Appalachian Basin, Well #3

Location: Lincoln County, West Virginia

DEPTH	GAS RELEASED	% TOTAL CARBON	% ORGANIC CARBON	VITRINITE REFLECTANCE (Ro) MIN	MAX	AVG	SAMPLER
3908	0.25	0.8		No Vitrinite Reflectance			Battelle
3908	0.19			available for this well			Columbia
3913	0.67						Columbia
3918	0.17						Columbia
3923	0.65						Columbia
3925	0.19	0.9					Battelle
3928	0.46						Columbia
3934	0.33						Columbia
3939	0.18	0.9					Battelle
3944	0.24						Columbia
3950	0.28						Columbia
3955	0.80						Columbia
3959	0.78						Columbia
3964	1.02						Columbia
3969	0.81						Columbia
3974	2.21						Columbia
3979	1.35						Columbia
3984	1.13						Columbia
3998	0.78	2.8					Battelle
3998	0.57						Columbia
4003	0.00						Columbia
4010	1.35						Columbia
4015	0.55						Columbia
4020	0.96						Columbia
4025	0.03						Columbia
4025	0.25						Columbia
4030	2.16						Columbia
4030	2.09						Columbia
4035	1.23						Columbia
4035	1.22						Columbia
4040	1.05						Columbia
4045	0.36	5.8					Battelle
4049	2.28						Columbia
4051	0.59						Columbia
331	83.72						

Average Gas Released = 0.25

Well: Appalachian Basin, Well #4

Location: Lincoln County, West Virginia

DEPTH	GAS RELEASED	% TOTAL CARBON	% ORGANIC CARBON	VITRINITE REFLECTANCE (Ro) MIN	MAX	AVG	SAMPLER
2655	0.05	0.2		No Vitrinite Reflectance			Battelle
2660	0.01			available for this well			Columbia
2665	0.00						Columbia
2670	0.00						Columbia
2675	0.00						Columbia
2680	0.03						Columbia
2685	0.03						Columbia
2690	0.01						Columbia
2695	0.03						Columbia
2700	0.00						Columbia
2710	0.06	0.3					Battelle
2716	0.00						Columbia
2721	0.01						Columbia
2726	0.00						Columbia
2731	0.00						Columbia
2736	0.00						Columbia
2741	0.00						Columbia
2746	0.02						Columbia
2751	0.00						Columbia
2756	0.09						Columbia
2761	0.05	0.7					Battelle
2766	0.00						Columbia
3000	0.22	1.0					Columbia
3005	0.11						Columbia
3010	0.11						Columbia
3015	0.08						Columbia
3020	0.06						Columbia
3025	0.12	0.6					Battelle
3030	0.15						Columbia
3035	0.11						Columbia
3040	0.13						Columbia
3045	0.20						Columbia
3050	0.31	1.4					Battelle
3055	0.10						Columbia
3061	0.21						Columbia
3066	0.45						Columbia
3071	0.33						Columbia
3076	0.23						Columbia
3081	0.12						Columbia
3086	0.11						Columbia
3091	0.27						Columbia
3096	0.09						Columbia
3101	0.39	1.4					Battelle

Well: Appalachian Basin, Well #4

Location: Lincoln County, West Virginia

DEPTH	GAS RELEASED	% TOTAL CARBON	% ORGANIC CARBON	VITRINITE REFLECTANCE (Ro) MIN	MAX	AVG	SAMPLER
3106	0.17			No Vitrinite Reflectance			Columbia
3111	0.05			available for this well			Columbia
3116	0.50						Columbia
3298	0.07						Columbia
3303	0.19	0.7					Battelle
3308	0.63						Columbia
3313	0.80						Columbia
3318	0.74						Columbia
3323	0.22						Columbia
3328	0.14	1.4					Battelle
3333	0.10						Columbia
3338	0.23						Columbia
3343	0.13						Columbia
3343	0.46						Columbia
3353	0.00						Columbia
3358	0.26						Columbia
3363	0.12						Columbia
3368	0.21						Columbia
3373	1.16						Columbia
3378	0.46	4.8					Battelle
3383	0.83						Columbia
3388	0.22						Columbia
3393	0.09						Columbia
3398	1.22						Columbia
3403	0.12						Columbia
3408	0.26						Columbia
3413	0.00						Columbia
3418	0.26						Columbia
3423	0.58						Columbia
3428	0.34	3.1					Battelle
3433	0.08						Columbia
3438	0.00						Columbia
3443	0.27						Columbia
3449	0.80						Columbia
3454	0.15						Columbia
3459	0.67						Columbia
3464	0.74						Columbia
3469	0.82						Columbia
3473	1.27						Columbia
3478	0.23	0.7					Battelle
3483	0.29						Columbia
3488	0.36						Columbia

Well: Appalachian Basin, Well #4

Location: Lincoln County, West Virginia

DEPTH	GAS RELEASED	% TOTAL CARBON	% ORGANIC CARBON	VITRINITE REFLECTANCE (Ro) MIN	MAX	AVG	SAMPLER
3493	0.35			No Vitrinite Reflectance available for this well			Columbia
3498	0.95						Columbia
3503	0.16						Columbia
3508	0.38						Columbia
3513	0.08						Columbia
3518	0.58						Columbia
3523	0.74						Columbia
3528	0.22	5.1					Battelle
3532	0.44						Columbia
3537	0.00						Columbia
3542	0.00						Columbia
3547	2.03						Columbia
3552	0.45						Columbia
3557	0.30						Columbia
3561	0.21						Columbia
3566	1.18						Columbia
3571	0.08						Columbia
3576	0.00						Columbia
3581	0.46						Columbia
3586	0.73						Columbia
3896	0.72	1.4					Battelle
3901	0.64						Columbia
3906	2.12						Columbia
3911	2.59						Columbia
3917	0.00						Columbia
3922	0.63	4.1					Battelle
3927	0.39						Columbia
3937	0.91						Columbia
3943	1.32						Columbia
3948	0.57						Columbia
3952	0.04						Columbia
3957	0.00						Columbia
3961	0.50	7.1					Battelle
3966	1.86						Columbia
3971	0.51	5.1					Battelle
120	42.67						

Average Gas Released = 0.36

Well: Appalachian Basin, Well #5

Location: Martin County, Kentucky

DEPTH	GAS RELEASED	% TOTAL CARBON	% ORGANIC CARBON	VITRINITE REFLECTANCE (Ro) MIN	MAX	AVG	SAMPLER
2434	1.38						Battelle
2442	0.64						Columbia
2443	0.70			0.21	0.88	0.52	Mound
2444	1.16	7.6					Battelle
2452	0.06						Columbia
2454	0.87	7.2					Battelle
2454	0.02	7.0					Battelle
2462	0.11						Columbia
2464	0.74	6.1					Battelle
2472	0.00						Columbia
2473	0.61	6.1					Battelle
2474	0.36	3.8	3.52	0.25	0.88	0.52	Mound
2482	1.78						Columbia
2490	0.00						Columbia
2493	0.71						Columbia
2494	0.40	4.1					Battelle
2503	0.43	4.1	3.64	0.20	0.87	0.56	Mound
2503	0.26						Columbia
2504	0.47	4.9					Battelle
2513	0.02						Columbia
2514	0.21	1.8					Battelle
2514	0.00	5.1					Battelle
2523	0.00						Columbia
2524	0.09	1.5					Battelle
2533	0.00						Columbia
2534	0.10	0.8					Battelle
2535	0.11	0.7	0.66	0.21	0.95	0.61	Mound
2543	0.19						Columbia
2545	0.05	0.7					Battelle
2549	0.10						Columbia
2553	0.00						Columbia
2554	0.02			0.26	0.96	0.71	Mound
2555	0.02	1.9					Battelle
2564	0.00						Columbia
2565	0.50	3.9					Battelle
2565	0.10	1.6					Battelle
2574	0.00						Columbia
2575	0.16	0.5					Battelle
2584	0.00						Columbia
2586	0.04	0.5					Battelle
2587	0.32						Columbia
2588	0.01	0.4					Battelle
2594	0.00						Columbia

Well: Appalachian Basin, Well #5

Location: Martin County, Kentucky

DEPTH	GAS RELEASED	% TOTAL CARBON	% ORGANIC CARBON	VITRINITE REFLECTANCE (Ro) MIN	MAX	AVG	SAMPLER
2595	0.00		0.7				Battelle
2597	0.01	2.0	1.91	0.28	0.98	0.67	Mound
2604	0.00						Columbia
2607	0.20	0.8					Battelle
0617		1.4					Battelle
2624	0.02						Columbia
2627	0.01	0.6	0.25	0.24	0.91	0.54	Mound
2637	0.01	0.5					Battelle
2644	0.00						Columbia
2645	0.08						Columbia
2646	0.01	0.5					Battelle
2654	0.00						Columbia
2656	0.34	2.8					Battelle
2657	0.08	4.2	3.98	0.20	1.00	0.51	Mound
2664	0.00						Columbia
2666	0.34	2.4					Battelle
2666	0.36	4.0					Battelle
2674	0.00						Columbia
2676	0.22	3.8					Battelle
2684	0.00						Columbia
2686A		4.3					Battelle
2686B		4.7					Battelle
2687	0.09	4.9	4.72	0.19	0.86	0.47	Mound
2694	0.00						Columbia
2696	0.22	4.4					Battelle
2704	0.00						Columbia
2705	0.12	3.8					Battelle
2715	0.04	2.5					Battelle
2715	0.29	4.4	4.06	0.17	0.77	0.42	Mound
2716	0.00						Columbia
2725		3.2					Battelle
2725	0.04	2.1					Battelle
2725	0.03						Columbia
2735		3.4					Battelle
2735	0.00						Columbia
2745	0.06	2.0					Battelle
2745	0.08	2.0	1.70	0.25	0.82	0.55	Mound
2745	0.00						Columbia
2755		2.0					Battelle
2755	0.05						Columbia
2762	0.00						Columbia
2763	0.08		2.1				Battelle
2765	0.00						Columbia

Well: Appalachian Basin, Well #5

Location: Martin County, Kentucky

DEPTH	GAS RELEASED	% TOTAL CARBON	% ORGANIC CARBON	VITRINITE REFLECTANCE (Ro) MIN	MAX	AVG	SAMPLER
2773	0.16	3.2					Battelle
2773	0.11	2.0	1.90	0.20	0.64	0.42	Mound
2775	0.00						Columbia
2784	0.17	4.0					Battelle
2784		3.1					Battelle
2785	0.00						Columbia
2793		0.5					Battelle
2795	0.00						Columbia
2803	0.04	0.9	0.55	0.23	0.94	0.57	Mound
2805	0.04						Columbia
2814	0.04	0.6					Battelle
2815	0.02						Columbia
2820	0.06						Columbia
2822		0.8					Battelle
2824	0.00						Columbia
2830	0.03	0.6					Battelle
2833	0.01	1.6	0.27	0.28	0.95	0.63	Mound
2835	0.00						Columbia
2842	0.07	2.0					Battelle
2842	0.09	0.8					Battelle
2845	0.00						Columbia
2852	0.12	3.7					Battelle
2855	0.68						Columbia
2861	0.28	3.6	3.30	0.18	0.89	0.46	Mound
2862		2.4					Battelle
2865	0.00						Columbia
2872		2.5					Battelle
2875	0.09						Columbia
2879	0.06						Columbia
2881	0.65	1.9					Battelle
2885	0.00						Columbia
2890	0.20	0.9	0.85	0.27	0.87	0.55	Mound
2891	0.22	0.5					Battelle
2895	0.36						Columbia
2901	0.38	1.9					Battelle
2901	0.24	0.5					Battelle
2905	0.09						Columbia
2911	1.23	3.3					Battelle
2915	0.21						Columbia
2921		8.4					Battelle
2921	0.75			0.26	0.79	0.51	Mound
2925	0.00						Columbia
2930	0.14						Columbia

Well: Appalachian Basin, Well #5

Location: Martin County, Kentucky

DEPTH	GAS RELEASED	% TOTAL CARBON	% ORGANIC CARBON	VITRINITE REFLECTANCE (Ro) MIN	MAX	AVG.	SAMPLER
2931	0.27	0.5					Battelle
2935	0.00						Columbia
2940	0.95	3.9					Battelle
2940	0.74						Columbia
2947	0.01	0.6	0.45	0.22	0.90	0.49	Mound
2947	0.27						Columbia
2950		1.1					Battelle
2957	0.28						Columbia
2960	1.24	7.3					Battelle
2960	1.52	6.8					Battelle
2967	2.02						Columbia
2970	1.46	5.0					Battelle
2977	0.20	1.3	1.11	0.25	0.60	0.42	Mound
2977	0.87						Columbia
2980	0.23	0.6					Battelle
2987	0.05						Columbia
2990	1.19	5.8					Battelle
2990	0.11	1.3					Battelle
2997	1.23						Columbia
2998	1.53						Columbia
3005	0.18			0.18	0.73	0.43	Mound
3008	0.32						Columbia
3009		4.3					Battelle
3018	0.00						Columbia
3019	0.29	3.8					Battelle
3019	0.31	2.6					Battelle
3028	0.00						Columbia
3029	0.10	0.6					Battelle
3034	0.00						Columbia
3035	0.12	5.9	5.45	0.17	0.78	0.45	Mound
3038	0.42	5.9					Battelle
3038	1.02						Columbia
3048	0.00						Columbia
3049	0.64	5.8					Battelle
3054	0.80	3.8					Battelle
3054	0.46	5.3	4.70	0.19	0.74	0.55	Mound
3058	0.00						Columbia
3068	0.00						Columbia
3069	0.10	5.3					Battelle
3069	0.74	2.8					Battelle
3078	0.00						Columbia
3079		4.6					Battelle
3085	0.75	5.2	4.77	0.23	0.86	0.51	Mound

Well: Appalachian Basin, Well #5

Location: Martin County, Kentucky

DEPTH	GAS RELEASED	% TOTAL CARBON	% ORGANIC CARBON	VITRINITE REFLECTANCE (Ro) MIN	MAX	AVG	SAMPLER
3088	2.05						Columbia
3089	1.46	5.3					Battelle
3098	1.97						Columbia
3099	1.45	7.1					Battelle
3105	0.05						Columbia
3107	0.03	5.0					Battelle
3107	0.00						Columbia
3113	0.29	1.5	0.65	0.37	0.77	0.59	Mound
3113		3.4	3.05				Columbia
3117	0.06	0.9					Battelle
3117	0.04						Columbia
3127	0.21						Battelle
3127	0.00						Columbia
3127	0.26						Battelle
3137	0.11						Battelle
3137	0.00						Columbia
3143	0.03	1.00	0.10	0.29	1.00	0.51	Mound
3146	0.13						Battelle
3147	0.13						Columbia
3157	0.17	0.8					Battelle
3157	0.11						Columbia
3163	0.00						Columbia
3168	0.06						Battelle
3168	0.07						Columbia
3171	0.45			0.25	0.84	0.53	Mound
3176	0.04	0.5					Battelle
3178	0.25						Columbia
3186		2.3					Battelle
3186	0.32	2.0					Battelle
3188	0.00						Columbia
3196	0.02	0.3					Battelle
3196	0.16	0.6					Battelle
3198	0.00						Columbia
3201	0.45	3.9	3.14	0.21	0.81	8.46	Mound
3206	0.05						Battelle
3209	0.00						Columbia
3216	0.18	0.9					Battelle
3218	0.82						Columbia
3220	0.00						Columbia
3224	0.96	2.4					Battelle
3227	0.00						Columbia
3230	0.35	1.4	1.17	0.35	0.78	0.56	Mound
3234	0.04	2.8					Battelle

Well: Appalachian Basin, Well #5

Location: Martin County, Kentucky

DEPTH	GAS RELEASED	% TOTAL CARBON	% ORGANIC CARBON	VITRINITE REFLECTANCE (Ro) MIN	MAX	AVG	SAMPLER
3237	0.04						Columbia
3244	0.04	1.5					Battelle
3244	0.02						Battelle
3247	0.00						Columbia
3254	0.32	1.1					Battelle
3257	0.08						Columbia
3260	0.02	1.6	0.12	0.38	0.38	0.38	Mound
3264	0.70						Battelle
3267	0.12						Columbia
3274	0.11						Battelle
3277	0.00						Columbia
3280	0.16						Columbia
3284	0.04						Battelle
3287	0.30						Columbia
3288	0.07	0.4	0.16	0.60	0.65	0.63	Mound
3294	0.00	0.5					Battelle
3294	0.00	0.5					Battelle
3297	0.11						Columbia
3304	0.03						Battelle
3304	0.03						Battelle
3304	0.04						Battelle
3307	0.04						Columbia
3315	0.22						Battelle
3317	0.34						Columbia
3317	0.14						Columbia
3325	0.70	2.5					Battelle
3328	0.24	0.8	0.64	0.25	0.81	0.46	Mound
3328	0.00						Columbia
3335	0.29						Battelle
3338	0.06						Columbia
3345	0.19	0.7					Battelle
3348	0.05						Columbia
3355	0.63	2.0					Battelle
3358	0.32			0.25	0.89	0.48	Mound
3358	0.80						Columbia
3365	0.67	0.9					Battelle
3368	0.20						Columbia
3375	0.83	5.8					Battelle
3378	0.64						Columbia
3379	0.51						Columbia
3384	0.47	4.3					Battelle
3386	0.47	3.1	2.63	0.24	0.81	0.53	Mound
3388	0.75						Columbia

Well: Appalachian Basin, Well #5

Location: Martin County, Kentucky

DEPTH	GAS RELEASED	% TOTAL CARBON	% ORGANIC CARBON	VITRINITE REFLECTANCE (Ro) MIN	MAX	AVG	SAMPLER
3394	0.74	2.7					Battelle
3398	0.00						Columbia
3404	0.30	8.4					Battelle
3404	0.01	1.3					Battelle
3408	0.00						Columbia
246	67.08						

Average Gas Released = 0.27

Well: Appalachian Basin, Well #6

Location: Mason County, West Virginia

DEPTH	GAS RELEASED	% TOTAL CARBON	% ORGANIC CARBON	VITRINITE REFLECTANCE (Ro) MIN	MAX	AVG	SAMPLER
2700		0.4					Battelle
2705	0.21			0.42	0.98	0.63	Mound
2710		1.5					Battelle
2715	0.19			0.54	0.99	0.73	Mound
2720		5.0					Battelle
2725	0.18	4.2	3.71	0.26	0.81	0.49	Mound
2730		1.5					Battelle
2735	0.28	5.2	4.96	0.26	0.74	0.52	Mound
2740		5.2					Battelle
2745	0.13			0.39	0.71	0.60	Mound
2750		4.6					Battelle
2758	0.25			0.35	0.85	0.60	Mound
2763		0.3					Battelle
2768	0.14			0.44	0.68	0.53	Mound
2773		1.8					Battelle
2778	0.18			0.34	0.81	0.60	Mound
2783		0.8					Battelle
2788	0.17			0.49	0.70	0.59	Mound
2793		1.7					Battelle
2798	0.21	0.8	0.80	0.38	0.90	0.64	Mound
2803		3.8					Battelle
2808	0.17			0.43	0.76	0.56	Mound
2811		4.3					Battelle
2816	0.27			0.37	0.85	0.51	Mound
2821		0.8					Battelle
2826	0.09			0.44	0.97	0.74	Mound
2841		4.8					Battelle
2846	0.10			0.39	1.04	0.72	Mound
2851		0.5					Battelle
2856	0.13			0.52	0.82	0.63	Mound
2861		2.3					Battelle
2866	0.16			0.40	1.02	0.66	Mound
2874	0.35			0.28	0.86	0.63	Mound
2879		1.1					Battelle
2884	0.31			0.33	0.81	0.57	Mound
2889		0.3					Battelle
2894	0.13	0.5	0.50	0.41	0.91	0.60	Mound
2899		0.5					Battelle
2904	0.21			0.35	0.78	0.51	Mound
2909		3.9					Battelle
2914	0.27	5.7	5.43	0.30	0.84	0.53	Mound
2919	0.21	0.8					Battelle
2927	0.20	4.9					Battelle

Well: Appalachian Basin, Well #6

Location: Mason County, West Virginia

DEPTH	GAS RELEASED	% TOTAL CARBON	% ORGANIC CARBON	VITRINITE REFLECTANCE (Ro) MIN	MAX	AVG	SAMPLER
2932	0.22	6.1	5.24	0.28	0.88	0.57	Mound
2937	0.16	2.2					Battelle
2942	0.22			0.38	0.91	0.58	Mound
2947	0.34	5.2					Battelle
2952	0.19	1.9	1.87	0.28	0.78	0.56	Mound
2957	0.32	6.2					Battelle
2962	0.22	4.2	4.12	0.28	0.68	0.49	Mound
2972	0.22	3.1	3.03	0.33	0.76	0.55	Mound
2977	0.40	5.9					Battelle
2982	0.10	0.5	0.17	0.34	0.92	0.57	Mound
2985	0.14	0.4					Battelle
2990	0.18	3.5	3.29	0.33	0.72	0.54	Mound
2995	0.34	3.9					Battelle
3000	0.27	4.9	4.70	0.27	0.89	0.62	Mound
3005	0.26	1.1					Battelle
3010	0.15	0.6	0.36	0.34	0.90	0.58	Mound
3015	0.16	2.6					Battelle
3020	0.38			0.26	0.75	0.47	Mound
3025	0.28	6.0					Battelle
3030	0.27			0.26	0.82	0.49	Mound
3035	0.16	1.3					Battelle
3040	0.06	0.2	0.12				Mound
3044	0.02	0.8					Battelle
3049	0.03						Mound
3054	0.05	0.3					Battelle
3059	1.08	0.3	0.12	0.47	0.85	0.67	Mound
3064	0.00	0.3					Battelle
3069	0.31	0.5	0.45	0.30	0.86	0.62	Mound
3079	0.15			0.33	0.96	0.63	Mound
3084	0.12	0.8					Battelle
3089	0.02						Mound
3094	0.05	0.4					Battelle
3099	0.05			0.35	0.89	0.56	Mound
3102	0.02	0.6					Battelle
3107	0.03			0.58	1.13	0.91	Mound
3112	0.03						Battelle
3117	0.03			0.67	1.06	0.94	Mound
3122	0.29	0.3					Battelle
3127	0.34			0.30	0.88	0.64	Mound
3132	0.05	0.2					Battelle
3137	0.21			0.50	1.15	0.90	Mound
3145	0.37			0.52	1.02	0.79	Mound
3152	1.49	2.4					Battelle

Well: Appalachian Basin, Well #6

Location: Mason County, West Virginia

DEPTH	GAS RELEASED	% TOTAL CARBON	% ORGANIC CARBON	VITRINITE REFLECTANCE (Ro) MIN	MAX	AVG	SAMPLER
3157	0.04			0.40	1.03	0.76	Mound
3161	0.02	0.5					Battelle
3166	0.03						Mound
3176	0.07			0.62	1.04	0.90	Mound
3181	0.05	0.2					Battelle
3186	0.03						Mound
3191	0.26	0.7					Battelle
3196	0.14			0.33	1.06	0.68	Mound
3201	0.02						Battelle
3206	0.09			0.37	1.05	0.70	Mound
3211	0.02	0.5					Battelle
3216	0.07			0.37	1.06	0.62	Mound
3220	0.06	0.3					Battelle
3225	0.26			0.42	1.22	0.79	Mound
3230	0.04	0.6					Battelle
3235	0.51			0.55	0.84	0.71	Mound
3240	0.11	0.5					Battelle
3245	0.15						Mound
3253	0.15						Battelle
3257	0.16			0.45	0.89	0.70	Mound
3262	0.14						Battelle
3267	0.35			0.42	1.14	0.70	Mound
3272	0.41						Battelle
3277	0.20			0.39	0.90	0.73	Mound
3282	0.45						Battelle
3287	0.37			0.48	0.93	0.68	Mound
3292	0.24						Battelle
3297	0.35			0.49	0.90	0.80	Mound
3308	0.24			0.44	0.91	0.64	Mound
3311	0.21						Battelle
3316	0.56			0.44	0.86	0.61	Mound
3321	0.45						Battelle
3325	0.46			0.44	0.89	0.73	Mound
3331	0.50						Battelle
3336	0.33			0.47	0.75	0.58	Mound
3346	0.20			0.48	0.91	0.63	Mound
3351	0.88						Battelle
3356	0.43			0.53	0.73	0.63	Mound
3361	0.53						Battelle
3366	0.31			0.45	0.90	0.69	Mound
3369	0.83						Battelle

Well: Appalachian Basin, Well #6

Location: Mason County, West Virginia

DEPTH	GAS RELEASED	& TOTAL CARBON	% ORGANIC CARBON	VITRINITE REFLECTANCE (Ro) MIN	MAX	AVG	SAMPLER
3374	0.69			0.42	0.92	0.65	Mound
3380	0.74						Battelle
3384	0.62			0.40	0.70	0.54	Mound
110	27.09						

Average Gas Released = 0.25

Well: Appalachian Basin, Well #7

Location: Monongalia County, West Virginia

DEPTH	GAS RELEASED	% TOTAL CARBON	% ORGANIC CARBON	VITRINITE REFLECTANCE (Ro) MIN	MAX	AVG	SAMPLER
2010				1.08	2.39	1.71	Mound
2510				0.60	2.19	1.59	Mound
3020				1.36	2.57	1.64	Mound
3500				0.65	2.33	1.75	Mound
4000				1.50	2.57	1.87	Mound
4520				1.41	2.36	1.96	Mound
5000				1.64	2.36	2.03	Mound
5520				1.64	2.96	2.15	Mound
6000				1.74	2.97	2.32	Mound
6420				2.03	2.93	2.34	Mound
6690				2.08	2.91	2.47	Mound
6810				1.74	3.37	2.68	Mound
6910				1.83	3.18	2.48	Mound
6970				1.82	3.08	2.43	Mound
7080				1.11	3.29	2.44	Mound
7130				1.96	3.27	2.41	Mound
7160				2.04	3.23	2.46	Mound
7192	0.21	3.5					Battelle
7197				2.01	3.28	2.57	Mound
7202	0.33	4.7					Battelle
7207				1.80	3.28	2.49	Mound
7210	0.33	3.8					Battelle
7218				1.67	2.99	2.50	Mound
7222	0.15	3.8					Battelle
7228				1.88	3.06	2.45	Mound
7234	0.25	1.2					Battelle
7240				1.78	3.32	2.67	Mound
7244	0.35	3.2					Battelle
7250				1.98	3.32	2.57	Mound
7254	0.25	2.1					Battelle
7260				1.25	3.28	2.62	Mound
7264	0.40	1.9					Battelle
7271				1.65	3.14	2.32	Mound
7274	0.21	1.5					Battelle
7280				1.32	2.79	2.02	Mound
7284	0.15	1.5					Battelle
7289				1.38	2.87	2.04	Mound
7299				1.14	2.93	1.60	Mound
7303	0.21	1.7					Battelle
7309				1.20	3.47	2.64	Mound
7313	0.19	1.1					Battelle
7318				1.62	3.24	2.55	Mound
7323	0.26	1.4					Battelle

Well: Appalachian Basin, Well #7

Location: Monongalia County, West Virginia

DEPTH	GAS RELEASED	% TOTAL CARBON	% ORGANIC CARBON	VITRINITE REFLECTANCE (Ro) MIN	MAX	AVG	SAMPLER
7328				1.37	3.20	2.33	Mound
7338				1.72	3.11	2.40	Mound
7339				1.50	3.16	2.53	Mound
7343	0.24	2.7					Battelle
7348				1.85	3.36	2.50	Mound
7350	0.37	2.4					Battelle
7357				1.73	3.00	2.51	Mound
7361	0.30	3.7					Battelle
7367				1.66	3.22	2.55	Mound
7371	0.41	3.0					Battelle
7376				1.57	2.93	2.33	Mound
7376				1.23	2.50	1.77	Mound
7388	0.46						Battelle
7392				1.39	3.14	2.33	Mound
7398	0.37	3.6					Battelle
7404				1.94	2.98	2.47	Mound
7409	0.61	5.4					Battelle
7414				1.26	2.97	2.03	Mound
7419	0.30	5.7					Battelle
7423				1.55	3.05	2.39	Mound
7428	0.55	3.3					Battelle
7434				1.54	2.75	2.28	Mound
7437	0.22	5.7					Battelle
7444				1.85	3.24	2.29	Mound
7446	0.20	7.3					Battelle
7452				1.89	2.63	2.24	Mound
7456	0.34	7.9					Battelle
7462				1.79	2.68	2.29	Mound
7465	0.65	5.1					Battelle
7472				1.46	2.73	2.23	Mound
7476	0.34	8.2					Battelle
7481				1.79	2.90	2.36	Mound
7481				1.78	2.71	2.36	Mound
7486	0.26	13.6					Battelle
7492				1.75	2.65	2.22	Mound
7496	0.37	8.9					Battelle
7501				1.82	2.94	2.43	Mound
29	9.28						

Average Gas Released = 0.32

Well: Illinois Basin, Well #1

Location: Tazewell County, Illinois

DEPTH	GAS RELEASED	% TOTAL CARBON	% ORGANIC CARBON	VITRINITE REFLECTANCE (Ro) MIN	MAX	AVG	SAMPLER
927	0.00	2.3					Battelle
937	0.01	1.4					Battelle
940	0.00		0.21				Mound
940	0.00		0.20				Mound
947	0.00	1.5					Battelle
951	0.00	1.8					Battelle
961	0.01	2.2					Battelle
970	0.00		0.20				Mound
971	0.01	2.1					Battelle
980	0.00	2.3					Battelle
990	0.01	1.4					Battelle
993						0.50	Illinois G.S.
995	0.00		0.84	0.43	0.68	0.55	Mound
995	0.01		0.69	0.35	0.36	0.35	Mound
1000	0.01	1.3					Battelle
1010	0.01	1.6					Battelle
1018	0.01		0.75	0.32	0.55	0.45	Mound
1020	0.01	1.4					Battelle
1024						0.49	Illinois G.S.
1030	0.01	2.0					Battelle
1040	0.01	1.8					Battelle
1048	0.00		1.60	0.36	0.63	0.50	Mound
1048	0.01		1.32	0.37	0.66	0.55	Mound
1050	0.00	1.8					Battelle
1053						0.45	Illinois, G.S.
1060	0.02	2.8					Battelle
1070	0.02	2.9					Battelle
1078	0.04		3.44	0.37	0.62	0.43	Mound
1080	0.03	5.2					Battelle
1083						0.42	Illinois G.S.
1090	0.03	9.2					Battelle
1100	0.01	8.3					Battelle
1108	0.01		3.45	0.35	0.65	0.47	Mound
1108	0.02		3.44	0.32	0.71	0.45	Mound
1110	0.02	4.4					Battelle
1120	0.00	2.4					Battelle
1130	0.00	2.0					Battelle
1138	0.01		1.58	0.34	0.50	0.41	Mound
1143						0.41	Illinois G.S.
34	0.33						

Average Gas Released = 0.01

Well: Illinois Basin, Well #2

Location: Henderson County, Illinois

DEPTH	GAS RELEASED	% TOTAL CARBON	% ORGANIC CARBON	VITRINITE REFLECTANCE (Ro) MIN	MAX	AVG	SAMPLER
321	0.00	2.0					Battelle
331	0.00	2.1					Battelle
334	0.00			0.29	0.42	0.35	Mound
341	0.00	2.4					Battelle
344	0.00	2.6					Battelle
354	0.00	2.2					Battelle
364	0.00	2.1	0.22	0.24	0.60	0.38	Mound
365	0.00	2.9					Battelle
372	0.00	2.8					Battelle
382	0.00	2.4					Battelle
392	0.00	3.6					Battelle
394	0.00	2.6	0.30	0.44	0.53	0.48	Mound
401	0.00	2.4					Battelle
403						0.45	Illinois G.S.
411	0.00	2.4					Battelle
421	0.01	2.4					Battelle
425	0.00	2.5	0.65	0.29	0.59	0.44	Mound
431	0.00	2.4					Battelle
441	0.01	2.4					Battelle
443						0.47	Illinois G.S.
451	0.01	3.6					Battelle
454	0.01	3.8	2.69	0.22	0.67	0.34	Mound
458	0.02	5.7					Battelle
468	0.01	2.7					Battelle
478	0.00	2.9					Battelle
481	0.01	3.7	3.44	0.19	0.58	0.33	Mound
482						0.47	Illinois G.S.
482						0.41	Illinois G.S.
485	0.00	0.9					Battelle
495	0.00	0.8					Battelle
505		4.0					Battelle
508	0.00	0.3	0.14				Mound
515		1.9					Battelle
523						0.48	Illinois G.S.
525		1.9					Battelle
537		1.8					Battelle
538	0.01	1.9	1.52	0.21	0.60	0.43	Mound
547		3.1					Battelle
557		2.3					Battelle
563						0.51	Illinois G.S.
564		3.0					Battelle
568	0.00	2.4	1.44	0.28	0.50	0.41	Mound

Well: Illinois Basin, Well #2

Location: Henderson County, Illinois

DEPTH	GAS RELEASED	% TOTAL CARBON	% ORGANIC CARBON	VITRINITE REFLECTANCE (Ro) MIN	MAX	AVG	SAMPLER
574		2.4					Battelle
584		6.9					Battelle
592		6.0					Battelle
598	0.00	6.0	0.14				Mound
602		5.9					Battelle
30	0.09						

Average Gas Released = 0.00

Well: Illinois Basin, Well #3

Location: Effingham County, Illinois

DEPTH	GAS RELEASED	% TOTAL CARBON	% ORGANIC CARBON	VITRINITE REFLECTANCE (Ro) MIN	MAX	AVG	SAMPLER
3011						0.66	Illinois G.S.
3012	0.12	1.1					Battelle
3021						0.52	Illinois G.S.
3022	0.51	2.3					Battelle
3023	0.56	9.3	8.23	0.18	0.77	0.45	Mound
3043						0.44	Illinois G.S.
3043						0.49	Illinois G.S.
3043	0.38	7.6					Battelle
3044	0.29	6.7	5.61	0.21	0.74	0.41	Mound
3015B		6.6					Battelle
3053						0.49	Illinois G.S.
3056	0.25	7.3					Battelle
3057	0.28	7.5	6.71	0.20	0.74	0.41	Mound
3059						0.47	Illinois G.S.
3063	0.30	8.4					Battelle
3065						0.48	Illinois G.S.
3067	0.48	8.6					Battelle
3071						0.47	Illinois G.S.
3073						0.47	Illinois G.S.
3074	0.37	7.6					Battelle
3075		7.4	6.36	0.18	0.79	0.50	Mound
3080	0.24	3.9					Battelle
3080	1.91	2.7					Battelle
3081						0.52	Illinois G.S.
3086						0.51	Illinois G.S.
3086	0.43	2.6					Battelle
3094	0.56	5.3					Battelle
3097						0.56	Illinois G.S.
3099	0.44	8.7					Battelle
3099	0.24	8.2	8.04	0.19	0.76	0.48	Mound
3106	1.02	9.5					Battelle
17	8.38						

Average Gas Released = 0.49

Well: Illinois Basin, Well #4

Location: Sullivan County, Indiana

DEPTH	GAS RELEASED	% TOTAL CARBON	% ORGANIC CARBON	VITRINITE REFLECTANCE (Ro) MIN	MAX	AVG	SAMPLER
2492	0.02	0.4	0.29	0.61	0.84	0.69	Mound
2495	0.60	0.8					Battelle
2505	1.53	11.5					Battelle
2515	2.99	6.1					Battelle
2521	0.22	7.4	7.23	0.31	0.67	0.47	Mound
2528	2.14	8.6					Battelle
2536	1.35	10.3					Battelle
2547	1.55	7.1					Battelle
2549	0.01			0.30	0.61	0.44	Mound
2554	1.38	5.4					Battelle
2565	1.05	3.2					Battelle
2575	2.04	7.5					Battelle
2585	0.89	8.7					Battelle
2595	1.18	6.1					Battelle
14	15.55						

Average Gas Released = 1.11

Well: Illinois Basin, Well #5

Location: Christian County, Kentucky

DEPTH	GAS RELEASED	% TOTAL CARBON	% ORGANIC CARBON	VITRINITE REFLECTANCE (Ro) MIN	MAX	AVG	SAMPLER
2183	0.70	14.7					Battelle
2183	0.41			0.22	0.61	0.40	Mound
2191	0.73	10.5					Battelle
2220	0.45	7.1					Battelle
2230	0.28	2.2					Battelle
2239	0.89	8.8					Battelle
2251	0.13	1.3					Battelle
2259	0.03	12.6					Battelle
2261	0.01			0.22	0.71	0.42	Mound
2271	0.30	9.0					Battelle
2281	1.24	8.9					Battelle
2290	0.51	9.8					Battelle
2292	0.06			0.29	0.70	0.48	Mound
2300	0.46	9.3					Battelle
2310	0.38	8.9					Battelle
2317	0.13			0.34	0.78	0.48	Mound
2319	0.18	12.6					Battelle
17	6.89						

Average Gas Released = 0.41