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CHARACTERIZATION AND ANALYSIS OF DEVONIAN SHALES
AS RELATED TO RELEASE OF GASEOUS HYDROCARBONS

Quarterly Technical Progress Report, June 1977—August 1977

By
M. Jack Snyder
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October 1977
(TIC Issuance Date)

Work Performed Under Contract No. EY-76-C-05-5205

Battelle Columbus Laboratories
Columbus, Ohio

ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

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Date Published - August 31, 1977

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INTRODUCTION

This program which is a part of The Resource Inventory and Shale Characterization subprojects of ERDA's Eastern Shale Project, was initiated in September 1976 with an effective contract period of July 1, 1976 through September 30, 1977. During July and August, in anticipation of the execution of the contract, work was started in connection with the sampling of cores from Devonian shale wells which had been or were being drilled and cored. Active laboratory work was started in September. This fourth quarterly technical progress report covers progress made in the quarter from June 1977 through August 1977.

OBJECTIVE AND SCOPE

The objective of this program is to determine the relationships between shale characteristics, hydrocarbon gas content, and well location to provide a sound basis for defining the productive capacity of the Eastern Devonian shale deposits and for guiding research, development, and demonstration projects to enhance the recovery of natural gas from the shale deposits. The program includes a number of elemental tasks as a part of the Resource Inventory and Shale Characterization subprojects of ERDA's Eastern Shale Project and is designed to provide large quantities of support data for that project.

Approximately 1000 core samples of gas bearing Eastern Devonian shale will be examined in the program. After the characterization data for individual wells have been compiled, a regression-type analysis for pattern recognition will be performed to establish the interrelationship between the shale characteristics, the hydrocarbon gas content, and well locations from which the samples were obtained.

The work during the first 18-month period of this program comprises six tasks:

<u>Task</u>	<u>Descriptive Title</u>
1	Core Sampling
2	Gas Content and Gas Release Kinetics
3	Chemical Characterization of Shale
4	Physical Characterization of Shale
5	Lithology of Shale
6	Data Interpretation and Correlation

Task 1. Core Sampling

In cooperation with representatives of ERDA and of the cognizant State Geological Survey of The U.S. Geological Survey, (1) participate in the selection of core samples for characterization in the Battelle program, and (2) encapsulate the selected samples in special sealed containers to preserve their approximate "down-hole" condition and gather relevant information from on-site observations and well-log data for subsequent interpretation and correlation with characterization results on the selected samples.

Task 2. Gas Content and Gas Release Kinetics

Determine the composition of and quantity of hydrocarbon gas evolved from and surrounding the shale samples in the sealed containers. Determine the gas release kinetics by observations of the rate of pressure build-up in the sealed containers after initial release of pressure for selected samples having high initial pressures and by thermal gravimetric measurement of weight loss as a function of time at three different temperatures for specimens cut from the samples after removal from the sealed containers.

Task 3. Chemical Characterization of Shale

Determine total carbon, hydrogen, and nitrogen contents and, where appropriate, total carbonate content for all samples. Determine trace elements by optical emission spectroscopy on selected samples from each well.

Task 4. Physical Characterization of Shale

Characterize the microstructure of the samples in terms of porosity (total, open, and closed), pore size distribution, total surface area, and gas permeability.

Task 5. Lithology of Shale

Determine the mineralogical composition of the samples by x-ray diffraction techniques and define the morphology of the minerals and their relationship to the organic debris by thin-section petrography. Ascertain structural changes resulting from heating by observations on duplicate samples from the same core sample. Examine selected samples from each well by scanning electron microscopy to supplement the petrographic observations.

Task 6. Data Interpretation and Correlation

Compile the data from the field observations, well logs, and laboratory characterizations and observations into a data package for each well for input to the regression-type analysis, for input to the USGS data bank, and for transmission to the ERDA technical project officer. Determine, using a pattern recognition, statistical analysis techniques and conventional data interpretation methods, the interrelationships and trends between the hydrocarbon gas content at various levels, the well head observation, and the lithological, chemical, and physical characteristics of the shale for individual wells and as a function of location.

SUMMARY OF PROGRESS

A milestone chart depicting the planned progress on the various tasks is given in Figure 1, and the status of the sampling and characterization tasks are summarized in Table 1. The program is approximately on schedule and the requirements set by the milestone chart will likely be met by the next quarterly report. Some unforeseen difficulties in certain characterization efforts and anomalies encountered in the data have caused unexpected delays. Most of these experimental difficulties, however, have been overcome and no serious problems are expected in future investigations.

ITEM	1976						1977								
	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Quarterly Progress Report	△					▽			▽			▽			▽
Core Sampling	△														
Samples Taken	25	124	148	143	265	265	265	280	280	320	320	340	340	360	380
Wells Sampled	1	1	3	3	4	4	4	5	5	6	6	7	7	8	9
Gas Content and Release			△												
Initial Off-Gas Analyses				7	29	54	74	81	88	110	130	150	175	200	225
Kinetics of Gas Release						4	6	6	6	10	25	45	65	90	115
Chemical Characterization					△										
C, H, N Analysis						6	26	40	62	65	85	130	160	190	220
Optical Emission Spectroscopy									12	13	13	14	15	16	17
Physical Characterization			△												
Density/Porosity							9	41	72	100	120	140	165	190	220
Pore Size										2	15	30	55	80	105
Surface Area						10	10	10	21	40	50	60	75	100	125
Permeability											5	10	20	35	55
Lithology						△									
XRD								3	3	5	10	15	20	30	40
Petrographic Examination											10	10	10	15	40
Heat Treatment Followed by Petrographic											5	5	5	10	20
All Characterizations Completed													△		
Individual Samples													10	15	40
Individual Wells														1	2
Data Interpretation and Correlation				△											
Correlation Procedures Established				△								▽			
Correlation Within an Individual Well									△					▽	
Correlation Between Two or More Wells										△					▽

Note: Numbers are cumulative numbers of samples or wells completed at end of month indicated. Actual numbers are shown through March. Goals are shown for succeeding months.

△ Start of Activity

▽ Completion of Activity

FIGURE 1. MILESTONE CHART - REVISED MAY 1977

TABLE 1. QUARTERLY PROGRESS ON SAMPLING AND CHARACTERIZATION TASKS

Item	Cumulative Number Completed at End of Quarter			
	1st Quarter July-Nov. 1976	2nd Quarter Dec. 1976-Feb. 1977	3rd Quarter Mar. 1977-May 1977	4th Quarter June 1977-Aug. 1977
Core Sampling				
Samples Taken	265	280	320	356
Wells Sampled	4	5	6	9
Gas Content and Release				
Initial Off-Gas Analysis	29	81	110	356
Kinetics of Gas Release	0	6	6	21
Chemical Characterization				
C, H, N Analysis	0	40	62	86
Optical Emission Spectroscopy	0	0	12	18
Physical Characterization				
Density/Porosity	0	41	91	147
Pore Size	0	0	1	12
Surface Area	0	10	77	154
Permeability	0	0	2	10
Lithology				
XRD	0	0	3	31
Petrographic Examination	0	0	5	15
Heat Treatment/Petrography	0	0	4	10
All Characterization Complete				
Individual Samples	0	0	0	0
Individual Wells	0	0	0	0

DETAILED DESCRIPTION OF TECHNICAL PROGRESS

Task 1. Core Sampling

Two wells were sampled during the quarter. The first well is located near Monmouth, Henderson County, Illinois. Core point was reached on July 13 and coring was completed on July 17, 1977. The total depth sampled was from 319 through 620 feet. A total of 57 samples were canned for examination by BCL and other ERDA contractors.

The second well is located near Bloomington, Tazewell County, Illinois. Core point was reached on August 16 and coring was completed on August 20, 1977. The total depth sampled was from 898 through 1158 feet. A total of 56 samples were canned for examination by BCL and other ERDA contractors.

A summary of the pertinent information about all of the wells sampled to date is given in Table 2.

Task 2. Gas Content and Gas Release Kinetics

Additional data were collected on the initial pressure, volume, and composition of the gas released into the free air space around the solid shale specimen in the sealed can, following the procedures described in the first quarterly report⁽¹⁾. A total of 210 canned samples from wells C-1, C-336, C-338, T-1, and N-1 were tapped and the released gas has been measured and analyzed during this quarter; this brings the total number of samples analyzed to 356. This effort has essentially eliminated the backlog of untapped, sealed samples. However, compilation of the data for these samples is only partially complete at this time. The compiled pressure, volume and gas composition data are summarized in Tables 3 through 9.

Task 3. Chemical Characterization of Shale

Chemical analyses for carbon (total and organic), hydrogen and nitrogen have been completed, according to the milestone requirements, on the high priority wells and continued on the other wells. Specifically C-H-N data have been obtained on R-109 and C-338 wells in addition to some priority wells during this quarter.

Summary of all C-H-N is given in Tables 10 through 15. Initially both organic and total carbon contents were measured. This was accomplished in the following manner: the total

(1) ORO-5205-1, "Characterization and Analysis of Devonian Shales as Related to Release of Gaseous Hydrocarbons", M. Jack Snyder and J. R. Schorr (December 1, 1976).

TABLE 2. IDENTIFICATION OF CORED WELLS AND SAMPLES SELECTED

Well Code Number	Location of Well	Well Operator	Date Sampled	Core Depth Interval, feet	Number of Samples
C-1	Lincoln County, WV	Columbia Gas	Jan. 1976	2746 - 4045	82
C-2	Lincoln County, WV	Columbia Gas	Jan. 1976	2655 - 3971	17
R-109	Washington County, OH	River Gas	July 30, 1976	3494 - 3705	25
P-1	Sullivan County, IN	Energy Resources of Indiana, Inc.	Sept. 1, 1976	2495 - 2595	11(a)
O-1	Christian County, KY	Orbit Gas	Sept. 18, 1976	2183 - 2319	13(b)
C-336	Martin County, KY	Columbia Gas	Nov. 6, 1976	2434 - 3405	117(c)
T-1	Effingham County, IL	Tri-Star	Feb. 13-18, 1977	3006 - 3106	15(d)
C-338	Wise County, VA	Columbia Gas	Apr. 22-30, 1977	4871 - 5469	40(e)
N-1	Henderson County, IL	No. Illinois Gas	July 13-17, 1977	319 - 620	31(f)
N-2	Tazewell County, IL	No. Illinois Gas	Aug. 16-20, 1977	898 - 1158	23(g)

(a) An additional 6 samples were selected and encapsulated for other ERDA contractors.

(b) An additional 4 samples were selected and encapsulated for other ERDA contractors.

(c) An additional 90 samples were selected and encapsulated for other ERDA contractors.

(d) An additional 16 samples were selected and encapsulated for other ERDA contractors.

(e) An additional 41 samples were selected and encapsulated for other ERDA contractors.

(f) An additional 26 samples were selected and encapsulated for other ERDA contractors.

(g) An additional 29 samples were selected and encapsulated for other ERDA contractors.

TABLE 3.

INITIAL GAS RELEASE DATA: WELL C- 2

SAMPLE ID	FREE PRESSURE TORR	CORE VOLUME CC	OPEN VOLUME CC	POROSITY PCT.	GAS COMPOSITION, VOLUME PERCENT							GAS RELEASED/			
					TOTAL							CARBON	UNIT VOLUME	SEQ	
					METHANE	ETHANE	PROPANE	BUTANE	PENTANE	HYDROC.	NITROGEN	OXYGEN	DIOXIDE	OF SHALE	NO.
C 2-2655.	740.	516.	934.	1.41	8.47	.81	.28	0.00	0.00	9.56	85.33	1.95	3.16	.05	1
C 2-2710.	750.	440.	1010.	2.22	1.87	1.36	.63	.04	0.00	13.90	82.60	1.36	2.15	.06	2
C 2-2761.	740.	363.	1087.	2.57	12.69	1.81	.99	.10	0.00	15.59	81.15	1.37	1.88	.05	3
C 2-3000.	925.	523.	927.	.71	25.88	3.36	1.84	.53	.20	31.81	64.57	.83	2.78	.22	4
C 2-3025.	920.	346.	1104.	.68	23.08	4.31	3.81	.77	.17	32.14	63.72	.72	3.42	.12	5
C 2-3050.	890.	703.	747.	.64	22.93	3.15	1.56	.38	0.00	27.72	67.86	.05	3.38	.31	6
C 2-3101.	1100.	561.	889.	.63	32.38	5.93	2.54	.66	.34	42.40	54.70	.73	2.16	.39	7
C 2-3303.	750.	535.	915.	.54	19.58	4.09	2.92	.54	.21	27.34	68.50	.99	3.17	.16	8
C 2-3328.	720.	446.	1004.	.50	23.98	5.63	3.42	.74	.16	34.18	58.95	2.60	4.31	.14	9
C 2-3378.	830.	478.	972.	.30	54.10	5.10	13.05	3.11	.76	86.12	12.57	.35	.88	.46	10
C 2-3428.	780.	484.	966.	.29	47.29	10.47	6.31	2.07	.47	66.61	32.17	.67	.61	.34	11
C 2-3478.	845.	711.	739.	.95	16.34	2.87	1.56	.51	.12	21.40	69.95	7.12	1.46	.23	12
C 2-3528.	760.	296.	1154.	.36	57.76	15.82	10.01	2.75	.78	87.12	11.05	.98	.85	.22	13
C 2-3896.	990.	637.	813.	1.51	47.48	13.59	7.72	1.77	.48	71.04	26.98	.46	1.53	.72	14
C 2-3922.	750.	622.	828.	.66	46.33	20.46	13.27	3.96	.99	85.01	13.64	.69	.65	.63	15
C 2-3961.	955.	424.	1026.	.32	65.19	18.39	9.79	2.05	.44	95.86	3.69	.10	.36	.50	16
C 2-3971.	775.	516.	934.	.34	59.08	17.99	11.27	2.10	.33	90.77	7.38	1.54	.32	.51	17

8

TABLE 4.

INITIAL GAS RELEASE DATA: WELL C-336															
SAMPLE ID	PRESSURE TORR	FREE CORE OPEN			GAS COMPOSITION, VOLUME PERCENT								GAS RELEASED/		
		VOLUME CC	VOLUME CC	POROSITY PCT.	METHANE	ETHANE	PROPANE	BUTANE	PENTANE	HYDROC.	NITROGEN	OXYGEN	DIOXIDE	UNIT VOLUME OF SHALE	SEQ NO.
C336-2434.	740.			.60	33.78	8.08	3.99	1.79	0.00	47.64	47.26	3.68	1.38		1
C336-2444.	1110.	DATA ARE INCOMPLETE			28.61	6.88	3.30	1.71	0.00	40.50	53.42	4.70	1.39	INCOMPLETE	2
C336-2454.	940.	DATA ARE INCOMPLETE			17.03	10.60	1.78	.40	0.00	29.81	60.21	7.24	2.74	INCOMPLETE	3
C336-2463.	725.			.28	.23	1.56	.22	.05	0.00	2.06	77.06	20.66	.21		4
C336-2464.	1125.			.29	27.67	7.99	2.51	.62	0.00	38.79	55.29	3.47	2.46		5
C336-2473.	770.	DATA ARE INCOMPLETE			23.67	9.66	4.16	.46	.16	43.11	52.49	.74	3.64	INCOMPLETE	6
C336-2494.	750.	DATA ARE INCOMPLETE			19.12	5.70	2.50	.96	0.00	28.28	61.23	7.33	3.13	INCOMPLETE	7
C336-2504.	725.			.26	13.22	9.73	2.90	1.39	0.00	32.24	57.84	6.41	3.51		8
C336-2514.	760.	DATA ARE INCOMPLETE			5.91	2.46	.71	0.00	0.00	12.08	71.72	12.51	3.68	INCOMPLETE	9
C336-2514.Z	740.			.230	3.00	0.00	0.00	0.00	0.00	0.00	77.97	21.94	.05		10
C336-2524.	775.	DATA ARE INCOMPLETE			6.70	1.60	.05	.01	0.00	8.36	79.60	9.50	1.90	INCOMPLETE	11
C336-2534.	700.	DATA ARE INCOMPLETE			2.10	.53	.42	.01	0.00	3.06	79.30	16.57	.94	INCOMPLETE	12
C336-2545.	725.	DATA ARE INCOMPLETE			1.09	1.24	.33	0.00	0.00	2.66	80.02	15.53	1.85	INCOMPLETE	13
C336-2555.	725.	DATA ARE INCOMPLETE			.38	0.00	.42	0.00	0.00	.80	77.66	21.13	.41	INCOMPLETE	14
C336-2565.	810.			.99	13.69	5.02	1.96	.70	0.00	21.37	70.07	2.64	5.30		15
C336-2565.Z	725.			.22	.48	1.96	.59	.21	0.00	4.24	78.18	17.23	.42		16
C336-2575.	710.	DATA ARE INCOMPLETE			2.06	1.97	1.81	.28	0.00	6.12	77.06	16.32	.50	INCOMPLETE	17
C336-2586.	800.	DATA ARE INCOMPLETE			1.38	.28	.30	.02	0.00	1.98	79.21	18.67	14.26	INCOMPLETE	0
C336-2588.	740.	DATA ARE INCOMPLETE			0.00	0.00	.48	0.00	0.00	.48	77.87	21.49	.17	INCOMPLETE	18
C336-2595.	760.			1.74	.18	0.00	.14	.02	0.00	.34	79.00	19.29	1.38		19
C336-2607.	740.	DATA ARE INCOMPLETE			4.77	1.61	.72	.98	0.00	8.08	77.20	13.20	2.40	INCOMPLETE	20
C336-2617.	750.	DATA ARE INCOMPLETE			0.00	0.00	.30	0.00	0.00	.30	77.24	22.36	.12	INCOMPLETE	22
C336-2617.Z	750.			1.97	.21	.19	0.00	0.00	0.00	.40	78.39	21.21	.97		24
C336-2637.	750.	DATA ARE INCOMPLETE			.13	0.00	.26	0.00	0.00	.39	77.41	21.76	.34	INCOMPLETE	25
C336-2646.	750.	DATA ARE INCOMPLETE			10.41	7.27	1.28	.97	0.00	19.93	67.56	7.29	5.22	INCOMPLETE	26
C336-2656.	760.	DATA ARE INCOMPLETE			11.28	9.34	2.67	1.40	.03	24.72	63.07	7.66	4.56	INCOMPLETE	27
C336-2666.	710.	DATA ARE INCOMPLETE			9.70	4.06	3.62	.58	.18	18.14	79.78	1.32	.76	INCOMPLETE	28
C336-2666.Z	750.	DATA ARE INCOMPLETE			5.62	5.06	1.58	.37	0.00	12.63	70.19	13.32	3.57	INCOMPLETE	29
C336-2676.	725.	DATA ARE INCOMPLETE			8.79	3.69	2.45	.63	.15	15.71	68.93	11.40	3.91	INCOMPLETE	30
C336-2686.A	740.	DATA ARE INCOMPLETE			3.84	3.05	.94	.24	0.00	8.07	71.47	16.90	3.56	INCOMPLETE	31
C336-2686.B	740.	DATA ARE INCOMPLETE			3.47	3.95	1.57	.51	0.00	9.50	71.50	16.93	2.07	INCOMPLETE	32
C336-2696.	725.	DATA ARE INCOMPLETE			4.67	2.47	2.12	.52	.17	9.95	71.67	15.42	3.00	INCOMPLETE	33
C336-2705.	725.	DATA ARE INCOMPLETE			.71	.50	.57	.12	0.00	1.90	77.52	18.96	2.06	INCOMPLETE	34
C336-2715.	725.	DATA ARE INCOMPLETE			1.26	.95	1.05	.28	.13	3.67	75.09	18.65	2.59	INCOMPLETE	35
C336-2725.	725.	DATA ARE INCOMPLETE			.45	.50	.98	.08	0.00	2.01	78.45	18.76	1.52	INCOMPLETE	36
C336-2725.Z	725.	DATA ARE INCOMPLETE			1.36	.84	1.73	.19	.08	4.20	74.39	18.68	2.73	INCOMPLETE	37
C336-2735.	740.			.66	10.12	2.89	2.73	.50	.18	16.42	72.33	4.49	6.85		38
C336-2745.	725.	DATA ARE INCOMPLETE			.86	.32	.36	.05	0.00	1.59	77.18	20.33	.99	INCOMPLETE	39
C336-2755.	725.	DATA ARE INCOMPLETE			.95	.52	.49	.16	0.00	2.12	79.12	16.33	2.43	INCOMPLETE	40
C336-2763.	750.			.84	1.76	.91	1.08	.66	.25	4.66	76.08	17.36	1.88		41
C336-2773.	725.	1123.	327.	.73	3.21	1.25	.87	.29	.17	5.79	75.09	16.12	2.99	.19	42
C336-2784.	725.	DATA ARE INCOMPLETE			3.04	1.41	1.38	.28	1.25	7.36	73.32	15.51	3.80	INCOMPLETE	43
C336-2784.Z	720.	DATA ARE INCOMPLETE			.60	.32	.39	.04	0.00	1.35	78.39	19.55	.85	INCOMPLETE	44
C336-2793.	760.	DATA ARE INCOMPLETE			1.30	.59	.64	.08	0.00	2.61	77.63	17.54	2.19	INCOMPLETE	45
C336-2802.	750.	DATA ARE INCOMPLETE			.74	.53	.52	.09	0.00	1.88	78.22	18.21	1.70	INCOMPLETE	46

TABLE 4. (Continued) INITIAL GAS RELEASE DATA: WELL C-336

SAMPLE ID	FREE PRESSURE TORR	CORE VOLUME CC	OPEN VOLUME CC	POROSITY PCT.	GAS COMPOSITION, VOLUME PERCENT								GAS RELEASED/ UNIT VOLUME OF SHALE			SEQ NO.
					METHANE	ETHANE	PROPANE	BUTANE	PENTANE	HYDROC.	NITROGEN	OXYGEN	DIOXIDE			
C336-2814.	760.	DATA ARE INCOMPLETE			.73	.78	.42	.02	0.00	2.00	79.61	15.76	2.62	INCOMPLETE	47	
C336-2822.	760.	1050.	400.	1.51	.54	.24	.37	.02	0.00	1.17	75.99	21.86	.98	.03	48	
C336-2830.	760.	DATA ARE INCOMPLETE			.44	.31	.47	.03	0.00	1.25	77.16	21.07	.49	INCOMPLETE	49	
C336-2842.	760.	DATA ARE INCOMPLETE			.52	.35	.49	.05	0.00	1.41	77.48	19.60	1.49	INCOMPLETE	50	
C336-2842.Z	750.			.95	3.30	1.50	1.10	.03	.09	6.02	78.10	13.80	1.80		51	
C336-2852.	725.	DATA ARE INCOMPLETE			13.56	4.79	3.11	.72	.62	22.80	65.59	5.09	6.55	INCOMPLETE	52	
C336-2862.	735.	DATA ARE INCOMPLETE			5.93	1.63	1.12	.28	0.00	8.96	74.76	11.55	4.62	INCOMPLETE	53	
C336-2872.	875.	DATA ARE INCOMPLETE			14.80	2.87	2.48	.91	0.00	21.06	68.50	3.84	6.53	INCOMPLETE	54	
C336-2881.	775.			1.69	2.94	.88	.66	.18	0.00	4.66	77.71	15.92	1.71		55	
C336-2891.	750.	DATA ARE INCOMPLETE			9.89	2.52	1.97	.44	.19	15.01	72.34	8.42	4.24	INCOMPLETE	56	
C336-2901.	775.	DATA ARE INCOMPLETE			3.69	.87	.73	.24	0.00	5.53	78.50	15.09	.87	INCOMPLETE	57	
C336-2901.A	820.	1168.	282.	.51	8.77	4.05	1.51	1.00	.02	15.35	69.57	10.83	4.17	.69	58	
C336-2911.	730.	DATA ARE INCOMPLETE			4.62	1.51	1.80	.50	0.00	8.43	73.53	16.93	1.04	INCOMPLETE	59	
C336-2921.	810.	DATA ARE INCOMPLETE			8.44	1.40	1.50	.34	.36	12.44	73.59	10.90	3.06	INCOMPLETE	60	
C336-2931.	760.	DATA ARE INCOMPLETE			25.24	9.20	6.06	1.86	.97	43.33	49.79	.78	6.13	INCOMPLETE	61	
C336-2940.	725.	DATA ARE INCOMPLETE			4.79	1.55	1.49	.33	.33	8.79	75.75	11.62	3.81	INCOMPLETE	62	
C336-2950.	950.			.67	28.27	8.53	6.29	1.64	.44	45.17	48.41	3.21	3.21		63	
C336-2960.	840.	1122.	328.	.82	25.23	7.85	5.47	1.39	.31	40.25	52.92	5.26	1.52	1.52	64	
C336-2960.Z	825.	1009.	441.	.36	21.39	7.85	5.54	1.79	1.09	37.66	54.45	4.43	3.46	.93	65	
C336-2970.	725.	DATA ARE INCOMPLETE			9.49	2.19	1.34	.27	.20	13.49	74.37	9.49	2.36	INCOMPLETE	66	
C336-2980.	760.	DATA ARE INCOMPLETE			15.65	7.57	5.49	2.08	1.28	32.07	57.38	6.19	4.39	INCOMPLETE	67	
C336-2990.	750.	1161.	283.	2.12	4.00	.90	1.10	.70	.23	6.93	76.58	15.91	.67	.27	68	
C336-2999.	725.	DATA ARE INCOMPLETE			20.58	8.11	5.01	1.42	1.03	36.15	57.97	3.37	3.42	INCOMPLETE	69	
C336-3009.	725.			.37	3.67	1.62	1.11	.31	.47	7.38	72.97	17.96	1.17		70	
C336-3019.	725.	DATA ARE INCOMPLETE			3.62	1.53	1.17	.30	.45	7.07	77.31	14.84	.72	INCOMPLETE	71	
C336-3019.7	725.	DATA ARE INCOMPLETE			1.82	.55	.42	.06	0.00	2.85	76.78	18.48	1.57	INCOMPLETE	72	
C336-3029.	750.			.99	12.31	4.91	3.20	4.19	3.13	27.74	59.12	10.65	2.48		73	
C336-3038.	740.	DATA ARE INCOMPLETE			42.22	14.55	9.43	2.59	.81	69.70	29.00	.47	1.78	INCOMPLETE	74	
C336-3049.	745.	DATA ARE INCOMPLETE			37.58	11.20	3.30	0.00	0.00	58.00	39.60	.53	1.84	INCOMPLETE	75	
C336-3054.	1470.			.53	36.62	3.10	5.02	1.73	.49	53.96	41.97	2.20	1.87		76	
C336-3069.	900.	767.	483.	.99	27.93	6.52	3.31	1.04	.26	39.06	54.61	4.98	1.34	.52	77	
C336-3069.Z	750.	DATA ARE INCOMPLETE			46.81	12.65	5.51	2.11	.63	70.71	27.20	.40	1.64	INCOMPLETE	78	
C336-3079.	1225.	DATA ARE INCOMPLETE			27.14	7.99	4.97	1.40	1.46	42.96	51.85	.85	4.35	INCOMPLETE	79	
C336-3089.	850.			.57	33.73	13.90	11.10	3.53	0.00	64.26	33.24	.43	3.09		80	
C336-3099.	975.	972.	475.	.95	19.13	5.03	3.20	1.02	0.00	28.44	60.48	7.79	3.28	.74	81	
C336-3107.	740.	DATA ARE INCOMPLETE			1.10	.31	0.00	0.00	0.00	1.51	77.81	20.30	.33	INCOMPLETE	82	
C336-3117.	700.	DATA ARE INCOMPLETE			5.54	1.73	.66	.19	0.00	8.08	78.48	7.36	6.08	INCOMPLETE	83	
C336-3127.	730.	DATA ARE INCOMPLETE			6.43	.72	2.75	.13	0.00	10.04	74.90	11.78	3.29	INCOMPLETE	84	
C336-3137.	715.	DATA ARE INCOMPLETE			1.05	.53	.25	.04	0.00	2.50	78.82	15.61	3.07	INCOMPLETE	85	
C336-3137.7	775.	DATA ARE INCOMPLETE			4.55	.91	1.11	.24	.07	6.92	79.43	1.17	12.51	INCOMPLETE	86	
C336-3146.	725.	DATA ARE INCOMPLETE			7.24	2.95	2.06	.49	.14	12.88	73.29	7.80	6.07	INCOMPLETE	87	
C336-3157.	760.	DATA ARE INCOMPLETE			1.25	.24	.24	.02	0.00	1.78	78.44	19.15	.63	INCOMPLETE	88	
C336-3166.	725.	DATA ARE INCOMPLETE			2.37	.56	.63	.07	0.00	3.70	81.24	11.37	3.67	INCOMPLETE	89	
C336-3176.	750.	760.	590.	4.10	11.95	2.31	1.79	.29	.06	15.76	71.98	9.89	2.36	.17	90	
C336-3186.	800.	DATA ARE INCOMPLETE			7.12	1.57	.73	.18	.06	9.66	78.30	9.16	2.88	INCOMPLETE	91	

TABLE 4. (Continued) INITIAL GAS RELEASE DATA: WELL C-336

SAMPLE ID	PRESSURE TORR	FREE VOLUME CC	CORE VOLUME CC	OPEN POROSITY PCT.	GAS COMPOSITION, VOLUME PERCENT								GAS RELEASED/ CARBON UNIT VOLUME		SEQ NO.
					METHANE	ETHANE	PROPANE	BUTANE	PENTANE	HYDROC.	NITROGEN	OXYGEN	DIOXIDE	OF SHALE	
C336-3186.Z	725.	DATA ARE INCOMPLETE			.34	.20	.37	.02	0.00	.93	79.35	18.98	.47	INCOMPLETE	92
C336-3196.A	730.	DATA ARE INCOMPLETE			4.53	.43	1.98	.06	0.00	7.00	74.68	17.09	1.23	INCOMPLETE	93
C336-3196.B	725.	DATA ARE INCOMPLETE			2.47	.52	.64	.07	.01	3.71	82.54	13.52	.18	INCOMPLETE	94
C336-3206.	810.			3.89	7.31	1.45	.42	.16	.23	9.57	76.05	14.02	.36		95
C336-3216.	1200.	DATA ARE INCOMPLETE			27.07	7.92	4.57	1.18	.31	41.05	53.66	.75	4.54	INCOMPLETE	96
C336-3224.	750.	DATA ARE INCOMPLETE			1.73	.39	.46	.02	0.00	2.60	80.09	15.69	1.61	INCOMPLETE	97
C336-3234.	720.	DATA ARE INCOMPLETE			1.51	.39	.38	.02	0.00	2.30	79.20	14.54	3.93	INCOMPLETE	98
C336-3244.	740.	DATA ARE INCOMPLETE			.37	.17	.22	.01	0.00	.77	78.74	19.66	.84	INCOMPLETE	99
C336-3244.Z	840.			4.53	10.58	1.74	.82	.10	.02	13.26	74.21	10.64	1.87		100
C336-3254.	930.	DATA ARE INCOMPLETE			18.60	5.72	2.98	.70	.17	28.17	64.62	.91	6.27	INCOMPLETE	101
C336-3264.	760.	DATA ARE INCOMPLETE			4.47	1.86	1.63	.32	.08	8.36	78.27	7.33	6.04	INCOMPLETE	102
C336-3274.	730.	DATA ARE INCOMPLETE			3.01	1.72	1.19	.39	.13	6.44	80.91	5.86	6.75	INCOMPLETE	103
C336-3284.	730.	DATA ARE INCOMPLETE			0.00	0.00	0.00	0.00	0.00	0.00	80.70	18.73	.57	INCOMPLETE	104
C336-3294.	660.	DATA ARE INCOMPLETE			1.81	.53	.42	.03	0.00	2.79	86.05	6.02	5.14	INCOMPLETE	105
C336-3304.	730.	DATA ARE INCOMPLETE			1.05	.21	.17	.02	0.00	1.45	89.26	6.56	2.73	INCOMPLETE	106
C336-3304.7	725.	DATA ARE INCOMPLETE			9.18	2.73	1.55	.41	.12	13.99	74.19	6.75	5.10	INCOMPLETE	108
C336-3315.	840.			2.55	20.13	5.36	3.68	1.08	.37	30.62	60.39	7.55	1.45		109
C336-3325.	810.	DATA ARE INCOMPLETE			10.94	3.33	2.45	.61	.16	17.49	74.03	1.14	7.37	INCOMPLETE	110
C336-3355.	750.	DATA ARE INCOMPLETE			4.98	1.72	1.28	.29	.08	8.35	79.70	9.72	2.27	INCOMPLETE	111
C336-3345.	760.	DATA ARE INCOMPLETE			7.38	2.94	1.97	.42	.11	12.82	76.95	8.25	2.00	INCOMPLETE	112
C336-3345.Z	950.	DATA ARE INCOMPLETE			20.58	6.58	3.99	1.14	.35	32.64	61.87	1.15	4.33	INCOMPLETE	113
C336-3355.	800.	DATA ARE INCOMPLETE			24.61	8.75	6.28	1.65	.44	41.73	52.49	.82	4.93	INCOMPLETE	114
C336-3365.	840.			73	36.03	11.85	7.67	1.86	.46	57.87	39.03	.50	2.56		115
C336-3375.	1025.	DATA ARE INCOMPLETE			18.85	4.64	2.10	.78	.22	26.59	61.81	11.09	.51	INCOMPLETE	116
C336-3384.	850.	DATA ARE INCOMPLETE			30.81	10.02	6.53	1.41	.31	49.08	39.52	.63	2.63	INCOMPLETE	117
C336-3394.	850.	DATA ARE INCOMPLETE			21.50	6.08	2.89	.71	.21	31.39	62.51	1.63	4.45	INCOMPLETE	118
C336-3404.	740.	DATA ARE INCOMPLETE			.16	.06	.18	0.00	0.00	.40	79.32	20.04	.24	INCOMPLETE	119

TABLE 5.

INITIAL GAS RELEASE DATA: WELL C-338

SAMPLE ID	PRESSURE TORR	FREE	CORE	OPEN	GAS COMPOSITION, VOLUME PERCENT								GAS RELEASED/		
		VOLUME CC	VOLUME CC	POROSITY PCT.	METHANE	ETHANE	PROPANE	BUTANE	PENTANE	HYDROC.	NITROGEN	OXYGEN	CARBON DIOXIDE	UNIT VOLUME OF SHALE	SEQ NO.
C338-4872.	2100.	DATA ARE INCOMPLETE			64.00	6.74	.84	.24	0.00	71.82	26.55	.55	1.04	INCOMPLETE	1
C338-4882.	2015.	928.	522.	1.69	61.70	6.30	.74	.15	0.00	68.89	27.20	3.80	.11	3.25	2
C338-4892.	1907.	DATA ARE INCOMPLETE			64.50	6.70	.86	.08	0.00	72.14	25.10	2.80	.03	INCOMPLETE	3
C338-4902.	1450.	923.	527.	1.73	53.40	7.63	.95	0.00	0.00	71.98	26.10	1.93	.41	2.40	4
C338-4912.	2170.	881.	569.	1.77	55.90	6.99	.84	.10	0.00	73.83	25.10	.89	.22	3.27	5
C338-4922.	1795.	DATA ARE INCOMPLETE			66.60	6.99	.74	.33	0.00	65.66	31.30	2.35	.71	INCOMPLETE	6
C338-4930.	1460.	882.	568.	2.09	51.00	3.99	.53	0.00	0.00	55.52	37.30	6.70	.49	1.66	7
C338-4940.	1613.	900.	550.	1.51	52.20	5.57	.63	0.00	0.00	58.45	35.22	5.36	.98	2.03	8
C338-4950.	1220.	DATA ARE INCOMPLETE			64.10	4.41	.59	.11	0.00	49.21	44.60	2.23	3.91	INCOMPLETE	9
C338-4960.	1000.	860.	540.	2.29	61.81	3.87	.53	0.00	0.00	46.21	47.30	2.79	3.69	.89	10
C338-4970.	710.	911.	519.	.53	2.73	3.00	0.00	0.00	0.00	2.73	76.79	19.99	.51	.05	11
C338-4980.	760.	913.	517.	1.61	10.50	15.76	.11	0.00	0.00	27.67	63.50	.63	8.30	.47	12
C338-5212.	1050.	855.	595.	5.27	38.70	3.33	3.71	0.00	0.00	45.80	53.24	1.27	3.06	.91	13
C338-5222.	1075.	823.	627.	2.83	39.50	3.87	.35	0.00	0.00	43.91	52.28	1.06	2.75	.82	14
C338-5232.	1975.	512.	938.	2.77	65.23	4.15	.30	0.00	0.00	69.68	29.02	.41	.88	.99	15
C338-5242.	1475.	888.	562.	2.13	58.01	4.62	.36	0.00	0.00	63.01	34.20	1.21	1.58	1.93	16
C338-5253.	1558.	876.	574.	1.15	55.40	8.00	.65	0.00	0.00	64.05	34.28	.47	1.23	2.00	17
C338-5263.	1640.	695.	755.	1.31	57.21	5.27	.61	0.00	0.00	63.09	35.45	.48	.99	1.25	18
C338-5273.	750.			2.06	58.12	3.25	1.10	0.00	0.00	67.47	30.80	.42	1.25		19
C338-5283.	800.	744.	706.	2.09	57.81	9.07	.54	0.00	0.00	77.72	20.81	.34	.67	.86	20
C338-5293.	925.	759.	681.	2.16	71.31	9.30	.60	0.00	0.00	81.97	17.22	.26	.55	1.13	21
C338-5303.	2900.	423.	957.	1.16	77.50	4.78	.44	0.00	0.00	82.72	16.70	.33	.26	1.62	22
C338-5312.	1250.	1057.	383.	2.15	47.39	6.37	.54	0.00	0.00	54.30	42.62	.60	2.50	2.49	23
C338-5322.	1770.	826.	624.	2.55	51.70	5.25	.43	.09	0.00	67.47	31.10	.43	.98	2.08	24
C338-5332.	870.	512.	538.	2.37	21.50	1.50	.07	0.00	0.00	23.17	63.60	11.90	1.35	.45	25
C338-5342.	1225.	797.	653.	.40	72.10	6.80	.61	0.00	0.00	79.51	19.80	.59	.13	1.56	26
C338-5347.	1740.	645.	805.	1.16	50.30	4.56	.43	.09	0.00	65.08	32.80	.98	1.21	1.19	27
C338-5357.	1150.	712.	738.	.96	70.50	6.15	.51	0.00	0.00	77.16	21.30	.34	1.29	1.13	28
C338-5362.	1150.	DATA ARE INCOMPLETE			73.70	7.91	.63	.06	0.00	82.50	16.70	.33	.53	INCOMPLETE	29
C338-5372.	975.	DATA ARE INCOMPLETE			78.30	8.50	.71	0.00	0.00	87.50	11.30	.57	.22	INCOMPLETE	30
C338-5382.	1000.	906.	544.	.73	66.50	6.70	.61	0.00	0.00	73.91	23.10	2.80	.20	1.62	31
C338-5394.	1075.	722.	728.	2.11	35.35	2.92	.45	0.00	0.00	39.03	53.15	6.37	1.41	.55	32
C338-5404.	850.	DATA ARE INCOMPLETE			51.33	6.35	.75	.07	0.00	58.20	36.55	4.96	.29	INCOMPLETE	33
C338-5414.	1490.	972.	478.	.49	52.50	6.10	.47	0.00	0.00	69.47	26.47	4.01	.78	2.77	34
C338-5424.	2600.	807.	643.	2.36	59.35	5.71	.41	0.00	0.00	75.97	21.55	2.38	.09	3.26	35
C338-5434.	1125.	796.	654.	1.11	55.20	5.80	.65	0.00	0.00	61.68	34.50	3.60	.20	1.11	36
C338-5444.	1125.	DATA ARE INCOMPLETE			71.30	7.50	.55	0.00	0.00	79.35	18.80	1.67	.08	INCOMPLETE	37
C338-5447.	2337.	803.	647.	.74	68.90	6.34	.40	0.00	0.00	75.64	23.40	.46	.48	2.89	38
C338-5457.	975.	DATA ARE INCOMPLETE			56.30	5.10	.36	0.00	0.00	61.76	32.00	6.20	.08	INCOMPLETE	39
C338-5467.	1075.	DATA ARE INCOMPLETE			80.40	7.50	.55	0.00	0.00	88.45	11.10	.46	.41	INCOMPLETE	40

TABLE 6.

INITIAL GAS RELEASE DATA: WELL O- 1

SAMPLE ID	PRESSURE TORR	FREE	CCRE	OPEN	GAS COMPOSITION, VOLUME PERCENT								GAS RELEASED/		
		VOLUME CC	VOLUME CC	POROSITY PCT.	METHANE	ETHANE	PROPANE	BUTANE	PENTANE	HYDROC.	NITROGEN	OXYGEN	CARBON DIOXIDE	UNIT VOLUME OF SHALE	SEQ NO.
0 1-2183.	800.	620.	830.	.53	81.55	6.11	1.10	.11	0.00	88.87	11.01	0.00	.13	.70	1
0 1-2191.	2150.	381.	1063.	.55	67.21	4.47	1.03	.09	0.00	72.80	24.77	1.91	.52	.73	2
0 1-2220.	1100.	636.	814.	.53	35.65	2.79	1.05	.21	.02	39.72	52.99	5.18	2.11	.45	3
0 1-2230.	1000.	612.	833.	.54	27.46	1.88	.07	.09	.02	29.46	61.04	7.73	1.14	.28	4
0 1-2239.	1750.	551.	899.	.62	57.44	3.90	1.18	.21	0.00	62.73	34.88	.96	1.43	.89	5
0 1-2251.	850.	424.	1026.	1.71	25.30	2.00	.40	.02	0.00	27.72	64.00	6.90	1.20	.13	6
0 1-2259.	2100.	487.	963.	.50	69.12	2.98	1.83	.05	0.00	73.98	24.16	1.43	.43	1.03	7
0 1-2271.	1370.	330.	1120.	.36	50.46	2.78	2.30	.06	0.00	55.60	40.88	2.26	1.26	.30	8
0 1-2281.	1690.	686.	764.	.52	59.93	2.17	0.00	0.00	0.00	62.10	34.19	2.68	1.02	1.24	9
0 1-2290.	1200.	607.	843.	.44	43.46	1.78	0.00	0.00	0.00	45.24	48.30	5.45	1.00	.51	10
0 1-2300.	1225.	562.	888.	.43	43.40	1.97	0.00	0.00	0.00	45.37	48.41	4.93	1.27	.46	11
0 1-2310.	1250.	467.	983.	.44	46.64	1.88	0.00	0.00	0.00	48.52	45.21	5.15	1.12	.38	12
0 1-2319.	860.	255.	1195.	.43	71.57	2.45	0.00	0.00	0.00	74.02	24.12	.84	1.01	.18	13

TABLE 7.

INITIAL GAS RELEASE DATA: WELL P- 1

SAMPLE ID	PRESSURE TORR	FREE	CORE	OPEN	GAS COMPOSITION, VOLUME PERCENT							GAS RELEASED/			SEQ NO.
		VOLUME CC	VOLUME CC	PEROSITY PCT.	METHANE	ETHANE	PROPANE	BUTANE	PENTANE	HYDROC.	NITROGEN	OXYGEN	CARBON DIOXIDE	UNIT VOLUME OF SHALE	
P 1-2495.	900.	887.	563.	5.08	21.47	4.61	3.53	1.72	.63	31.96	65.87	.91	1.27	.60	1
P 1-2505.	1345.	801.	649.	.64	56.41	3.60	.22	0.00	0.00	70.23	21.86	2.18	6.53	1.53	2
P 1-2515.	1900.	950.	500.	1.06	58.46	4.19	.26	.05	0.00	62.96	29.95	2.68	4.41	2.99	3
P 1-2528.	2104.	737.	653.	.55	50.60	2.59	0.00	0.00	0.00	63.19	28.34	.88	6.79	2.14	4
P 1-2536.	1770.	720.	730.	1.67	54.60	2.27	1.65	0.00	0.00	58.52	31.29	2.31	7.92	1.35	5
P 1-2547.	1700.	735.	715.	2.26	61.32	6.01	.20	0.00	0.00	67.53	27.72	.54	4.22	1.55	6
P 1-2554.	1900.	647.	803.	1.61	62.95	5.42	.34	.07	.03	68.81	27.23	.65	3.31	1.38	7
P 1-2565.	1390.	708.	742.	1.93	52.58	5.04	1.63	.59	.29	60.13	35.52	.74	3.52	1.05	8
P 1-2575.	1970.	780.	670.	.62	62.81	4.60	0.00	0.00	0.00	67.41	27.33	.12	5.14	2.04	9
P 1-2585.	1340.	741.	709.	.62	45.00	3.30	0.00	0.00	0.00	48.30	40.30	4.10	7.20	.89	10
P 1-2595.	2030.	573.	877.	.77	59.01	4.95	2.36	.98	.30	67.60	26.58	.56	5.51	1.18	11

TABLE 8.

INITIAL GAS RELEASE DATA: WELL R-109

SAMPLE ID	PRESSURE TORR	FREE	CORE	OPEN	GAS COMPOSITION, VOLUME PERCENT								GAS RELEASED/		
		VOLUME CC	VOLUME CC	POROSITY PCT.	METHANE	ETHANE	PROPANE	BUTANE	PENTANE	HYDROC.	NITROGEN	OXYGEN	CARBON DIOXIDE	UNIT VOLUME OF SHALE	SEQ NO.
R109-3494.	860.	508.	942.	1.67	30.81	10.10	7.04	2.26	.52	50.73	47.92	.86	.51	.31	1
R109-3506.	925.	339.	1111.	.74	61.86	11.38	5.63	1.29	.45	80.61	5.81	.38	.48	.30	2
R109-3516.	775.	444.	1006.	.89	51.81	12.82	7.48	2.05	.46	84.62	14.49	.71	.53	.38	3
R109-3526.	740.	392.	1058.	2.52	68.73	12.52	6.59	2.12	.45	90.41	8.56	.54	.48	.33	4
R109-3536.	750.	238.	1212.	.78	32.81	6.56	2.79	.68	.29	43.13	50.30	5.72	.84	.08	5
R109-3545.	750.	307.	1143.	.66	37.65	7.03	3.05	.91	.32	48.96	42.63	3.64	.72	.13	6
R109-3555.	780.	481.	969.	1.04	50.15	13.72	8.71	2.16	.53	75.27	22.49	1.94	.30	.38	7
R109-3564.	740.	260.	1190.	.62	65.28	14.55	7.65	2.16	.46	90.10	8.38	1.53	0.00	.19	8
R109-3575.	875.	321.	1129.	.57	68.46	10.30	3.45	1.11	.33	83.65	15.80	.11	.43	.27	9
R109-3585.	745.	702.	748.	.65	35.54	8.40	3.60	1.70	.47	49.71	45.93	4.11	.71	.46	10
R109-3593.	950.	796.	654.	.57	37.65	6.60	2.51	.82	.39	47.97	46.53	4.47	1.02	.73	11
R109-3605.	750.	543.	907.	.52	62.31	13.54	7.57	2.13	.55	86.10	12.75	.77	.38	.51	12
R109-3606.A	740.	594.	856.	.61	49.47	12.97	7.05	2.52	.50	72.51	24.04	2.85	.62	.49	13
R109-3606.B	930.	1123.	327.	.55	26.16	6.66	4.25	1.19	.30	38.56	55.13	3.78	2.54	1.62	14
R109-3616.	1050.	707.	743.	.65	40.65	6.57	2.95	.85	.23	51.25	45.90	.85	2.01	.67	15
R109-3626.	775.	609.	841.	.94	48.04	8.18	3.08	.86	.20	60.36	38.00	.57	1.07	.45	16
R109-3634.	750.	412.	1038.	.53	53.84	7.37	2.43	.70	.19	64.53	32.97	1.44	1.07	.25	17
R109-3644.A	1120.	870.	580.	1.26	34.19	6.20	2.36	.68	.27	43.70	51.37	3.42	1.51	.97	18
R109-3644.B	825.	1303.	147.	.42	14.27	3.57	1.98	.50	.16	20.48	69.69	7.57	2.25	1.97	19
R109-3665.	2165.	312.	1138.	.79	60.51	13.65	6.98	1.88	.36	83.38	15.85	.17	.57	.65	20
R109-3675.	760.	470.	980.	.88	66.65	14.98	6.55	1.90	.74	90.82	8.83	.11	.25	.44	21
R109-3685.	1300.	236.	1214.	1.00	60.93	10.76	4.86	1.52	.43	78.52	20.25	.71	.53	.26	22
R109-3695.	1745.	630.	820.	.40	47.53	8.49	7.41	1.04	.26	64.73	32.56	1.70	1.02	1.14	23
R109-3705.	730.	490.	960.	1.28	18.11	3.60	1.99	.49	.18	24.37	50.83	7.61	.56	.12	24
R109-3711.	860.	1026.	424.	1.46	19.02	4.60	2.02	.65	.17	26.46	68.06	4.29	1.19	.73	25

TABLE 9.

INITIAL GAS RELEASE DATA: WELL T- 1

SAMPLE ID	PRESSURE TORR	FREE	CORE	OPEN	GAS COMPOSITION, VOLUME PERCENT								GAS RELEASED/		
		VOLUME CC	VOLUME CC	FOROSITY PCT.	METHANE	ETHANE	PROPANE	BUTANE	PENTANE	TOTAL HYDROC.	NITROGEN	OXYGEN	CARBON DIOXIDE	UNIT VOLUME OF SHALE	SEQ NO.
T 1-3012.	750.	2333.	726.	6.55	2.36	.81	.40	.20	0.00	3.77	79.01	16.62	.61	.12	1
T 1-3022.	750.	2388.	671.	3.11	9.73	2.90	1.24	.66	.08	14.61	71.61	13.70	.11	.51	2
T 1-3043.	825.	2584.	475.	.73	4.39	1.35	.50	.21	.02	6.47	76.88	14.65	1.99	.38	3
T 1-3051.B	750.	DATA	ARE	INCOMPLETE	2.09	.56	.23	.06	0.00	2.94	77.48	19.25	.32	INCOMPLETE	4
T 1-3056.	750.	2244.	815.	.59	7.01	1.26	.84	.13	.04	9.28	73.77	16.17	.78	.25	5
T 1-3063.	925.	1962.	1097.	.52	11.15	1.62	.67	.18	.16	13.78	70.96	14.59	.82	.30	6
T 1-3067.B	833.	2524.	435.	.59	5.60	.89	.60	.15	0.00	7.24	74.90	17.30	.52	.48	7
T 1-3074.	900.	2002.	1057.	.67	13.47	1.69	.84	.47	0.00	16.47	68.34	14.42	.76	.37	8
T 1-3080.	775.	2312.	747.	1.05	4.64	1.31	.92	.45	.15	7.47	74.94	16.61	.98	.24	9
T 1-3080.B	950.	2730.	329.	2.14	12.83	3.32	1.52	.66	0.00	18.43	69.04	11.01	1.55	1.91	10
T 1-3086.	750.	1677.	1382.	2.90	23.01	6.38	4.27	2.40	.30	36.16	56.91	5.92	1.05	.43	11
T 1-3094.B	800.	2759.	300.	.96	4.43	.93	.31	.12	0.00	5.79	77.25	16.64	.29	.56	12
T 1-3099.	750.	2328.	731.	.61	11.10	1.69	.36	.31	0.00	13.96	69.60	15.90	.58	.44	13
T 1-3106.B	750.	2911.	148.	1.04	4.05	.70	.19	.34	0.00	5.28	78.55	15.65	.09	1.02	14

TABLE 10.

CHEMICAL CHARACTERIZATION DATA, 6/77

SAMPLE ID	CARBON	TOTAL, PERCENT		NITROGEN	LOW TEMPERATURE ASH, %		CARD CODE	SEQ NO.
		HYDROGEN			200 C	100 C		
C 1-2927.A	1.1	.6		.2			5	13
C 1-2999.	2.1	.5		.1			5	20
C 1-3085.	1.9	.6		.1			5	23
C 1-3175.	.9	.5		.1			5	33
C 1-3198.	1.9	.7		.1			5	35
C 1-3396.	1.3	.6		.1			5	51
C 1-3426.	4.8	.7		.2			5	52
C 1-3573.	5.5	.8		.2	4.60		5	59
C 1-3593.	1.5	.6		.1			5	62
C 1-3651.	5.2	.8		.1	4.60		5	66
C 1-3701.	7.2	1.0		.2	2.62		5	67
C 1-3869.	2.9	.6		.1			5	79
C 1-3998.	2.8	.6		.1			5	85
C 1-4045.	5.8	.8		.2	4.06		5	86

TABLE 11.

CHEMICAL CHARACTERIZATION DATA, 6/77

TABLE 12. CHEMICAL CHARACTERIZATION DATA

Sample ID	Carbon	Hydrogen	Nitrogen
C-338-4892	4.7	0.5	0.1
C-338-4922	3.2	0.4	0.1
C-338-5232	0.8	0.5	0.1
C-338-5322	1.8	0.5	0.2
C-338-5357	1.9	0.4	0.1
C-338-5362	6.2	0.6	0.2
C-338-5372	4.7	0.5	0.2
C-338-5404	3.8	0.5	0.2
C-338-5414	5.3	0.6	0.2
C-338-5424	5.0	0.5	0.2
C-338-5444	6.2	0.6	0.2

TABLE 13.

CHEMICAL CHARACTERIZATION DATA, 6/77

SAMPLE ID	CARBON	TOTAL PERCENT		NITROGEN	LOW TEMPERATURE ASH, %		CARD CODE	SEQ NO.
		HYDROGEN			200 C	100 C		
0 1-2183.	14.7	1.5		.5			5	1
0 1-2191.	10.5	1.1		.4			5	2
0 1-2220.	7.1	.9		.2			5	3
0 1-2230.	2.2	.5		.2			5	4
0 1-2239.	8.8	1.0		.3			5	5
0 1-2251.	1.3	.4		.1			5	6
0 1-2259.	12.6	1.3		.5	12.40	12.60	5	7
0 1-2271.	9.0	.8		.2	6.06		5	8
0 1-2281.	8.9	.9		.4			5	9
0 1-2290.	9.8	.8		.3			5	10
0 1-2300.	9.3	.8		.3			5	11
0 1-2310.	8.9	.8		.2			5	12
0 1-2319.	12.6	1.0		.3			5	13

TABLE 14.

CHEMICAL CHARACTERIZATION DATA, 6/77

SAMPLE ID	CARBON	TOTAL, PERCENT		NITROGEN	LOW TEMPERATURE ASH, %		CARD CODE	SEQ NO.
		HYDROGEN			200 C	100 C		
P 1-2495.	.8	.5		.1			5	1
P 1-2505.	11.5	1.3		.3	10.80	11.50	5	2
P 1-2515.	6.1	.8		.2	5.90		5	3
P 1-2528.	8.6	1.0		.2			5	4
P 1-2536.	10.3	1.1		.2	8.95	9.24	5	5
P 1-2547.	7.1	.9		.2			5	6
P 1-2554.	5.4	.8		.3	4.46		5	7
P 1-2565.	3.2	.6		.1			5	8
P 1-2575.	7.5	1.0		.2			5	9
P 1-2585.	8.7	1.0		.2			5	10
P 1-2595.	6.1	.8		.1			5	11

TABLE 15. CHEMICAL CHARACTERIZATION DATA

Sample ID	Carbon	Hydrogen	Nitrogen
R-109-3506	1.5	0.5	0.1
R-109-3516	1.6	0.6	0.1
R-109-3526	3.2	0.7	0.1
R-109-3536	2.2	0.6	0.1
R-109-3555	1.3	0.6	0.1
R-109-3593	2.8	0.6	0.1
R-109-3605	3.1	0.7	0.1
R-109-3606A	5.0	0.8	0.1
R-109-3606B	3.9	0.7	0.1
R-109-3665	2.4	0.5	0.1
R-109-3685	1.7	0.5	0.1
R-109-3695	3.5	0.7	0.2
R-109-3705	0.5	0.5	0.1
R-109-3711	0.5	0.5	0.1
R-109-3494	0.4	0.5	0.1
R-109-3536	2.0	0.6	0.1
R-109-3545	1.3	0.6	0.1
R-109-3585	2.2	0.6	0.1
R-109-3606B	4.0	0.7	0.1
R-109-3626	0.9	0.6	0.1
R-109-3634	2.3	0.6	0.1
R-109-3644B	2.5	0.6	0.1
R-109-3675	1.8	0.6	0.1
R-109-3695	3.3	0.6	0.1

carbon was determined by combusting as received samples and determining the carbon content from thermal conductivities of the combustion gases. The samples were also treated with hydrochloric acid, dried, and the total carbon determined in the same manner. The carbon found in acid treated samples was taken as the organic carbon (carbonate-free). The difference between the carbon content of as received, untreated and acid treated sample was defined as the inorganic (carbonate) carbon. The acid treatment was abandoned in the experiments as no significant differences were observed in the measured carbon contents between the untreated and acid treated shale samples, which, of course, means that the inorganic carbonate content in the shales is very low indeed compared to western oil shales where carbonates comprise as much as 10-12 percent of the mineral matrix. A number of striking features are noted in the C-H-N data.

- 1) There is a significant scatter in the carbon contents of the shales within the same well. For example, the carbon contents in well C-2 (Lincoln County, West Virginia) range from 0.2 to 7.1 weight percent. Also no correlation is obvious between the well depth and carbon contents. One explanation for the wide scatter in the carbon contents may rest in the difficulties of obtaining representative samples for the C-H-N analyses. These analyses are performed on a Perkin-Elmer 240 elemental microanalyzer. Three to 5 mg samples are employed for the analyses. Even complete grinding of all the shale samples at the laboratory's disposal from a well and thorough mixing and quartering operations cannot solve the problem of obtaining a uniform representative samples for these analyses. It is most conceivable that the carbon contents might vary from one point on the core sample to the other as much as the scatter in the C-H-N data indicate.
- 2) The scatter in the hydrogen contents is not as wide as observed in the carbon contents. The hydrogen values reported are for total hydrogen (organic and inorganic). The main sources of inorganic hydrogen are free moisture and crystal water from the inorganic minerals (especially clay mineral compounds). Attempts were made to measure the free moisture content of the powdered shale specimens, kept in a constant temperature (72 F) and humidity (50% R.H.) chamber, by vacuum drying at water vapor pressure values ($\sim 0.5 \mu\text{m}$) over ice at -70°C (dry ice-alcohol cold trap). The average pressure of the system during the drying process was maintained at $15\text{-}20 \mu$. Free moisture contents of the shale sample determined by the above method ranged from 0.85 to 1.0% by weight. This accounts for about 0.1 weight percent excess hydrogen determined with Perkin-Elmer 240 microanalyzer. The contribution to total hydrogen content from the water of crystallization of the inorganic minerals (especially

clay minerals) could also account for an additional 0.05 weight percent of the measured values, which could bring the contribution of inorganic hydrogen to 15 to 20 weight percent of total hydrogen measured.

- 3) Hydrogen-to-carbon atomic ratios are unusually high for some wells, e.g., C-1 and R-109, even after the corrections are made for the contribution of inorganic sources to total hydrogen contents. We have no logical explanation for this observation at the present. The hydrogen-to-carbon ratios for the other wells, however, are much lower than the values for R-109 well and vary between 1.5 and 2.0. These ratios are very reasonable for kerogen-based organic materials as have been determined for the western oil shales.

Task 4. Physical Characterization of Shale

Effort was increased during this quarter on density (bulk, apparent, and true) and surface area measurements. About seventy density and eighty surface area measurements have been completed. Additional efforts were also devoted to refining the techniques and procedures for porosity and permeability determinations. Porosity measurements are made with a mercury-intrusion porosimeter. The experimental difficulties initially encountered in porosity measurements have now been resolved and determinations at a rate of 25 samples per month can now be accomplished. About forty porosity determinations have been made and presently a computer program is being developed for the computations. A number of permeability determinations have also been carried out.

The measured bulk density values range from 2.3 to 2.8 g/cc with typical values around 2.6 g/cc. Typical true density values are around 2.7 g/cc.

Open, closed, and total porosities have been calculated from the measured density values. The open porosity values calculated from bulk and apparent densities range from 0.6 to 5.0% and closed porosities vary between 0.3 and 7.0%. In a few instances some samples were found to have higher bulk and apparent densities than true densities. A possible explanation for this rests in the difficulty of obtaining representative samples for the characterization experiments. Different specimens from the same core are employed for the measurement of bulk and apparent and true density measurements. The possibility of utilizing unrepresentative or unlike samples is very real and is unavoidable because solid chunks are used in the bulk and apparent density measurements and powdered specimens are utilized in true density determinations. It is quite possible for a bulk density sample to contain a large amount of a high density mineral such as pyrite or siderite, in which case, the bulk density measured could be higher than the true density determined using another sample.

In general the majority of the density data are sufficiently accurate to permit the calculation of open, closed, and total porosities in the shale samples. The surface measurements are carried out with a Micromeritics Model-2205 high-speed surface area analyzer. This instrument measures total area of finely divided powders or porous materials and automatically presents the surface area values as a direct, digital readout. It utilizes a unique concept modified from the classical B.E.T. low-temperature nitrogen adsorption technique. Analysis is accomplished without the use of mixed gases or a vacuum system. Some of the surface areas obtained during this quarter are depicted in Tables 16 through 18 for wells C-1, C-338, and T-1. Shale samples high in clay minerals and low in organics exhibit much higher surface areas than the ones with relatively high organic contents which are usually darker in color.

The calculated porosities are usually higher than for the porosity values determined using the mercury intrusion porosimeter. This is not unexpected as the total porosity determined with the mercury intrusion porosimeter is a function of pore size and the pressure at which the mercury is forced into the pores. Since the instrument has a limited pressure capacity (15,000 psi in this case), pores smaller than a certain size together with most of the closed pores will not be included in the measured porosity values. A sample calculation was made of the porosity and pore size distribution for specimen C-1-3652 and the results are summarized in Figure 2. The calculated net pore volume is 0.01995 cc/g (which is about 5.0% by volume) and the average pore diameter is 0.046 μm .

About 25 permeability runs have been completed on as-received shale samples of 1-inch diameter and ¼-inch thick discs. These measurements have shown that the as-received shales are virtually impermeable to gases. Even the samples where the gas flow was parallel to the bedding planes exhibited extremely small or zero permeabilities to helium gas. These findings of the permeability measurements are supported by the density and porosity data as indicated by the small porosities and significantly high bulk densities.

The surface areas are measured in the as-received condition without any special treatment of the powdered shale samples, except 15 minute degassing and equilibration in the surface area instrument at room temperature. These surface area values should be called "apparent surface areas" for a given set of experimental parameters employed, because the measured surface areas are greatly affected by the thermal and other physical conditions under which the experiments are carried out. Figure 3 illustrates the importance of outgassing temperature on the measured surface area values.

Task 5. Lithology of Shale

X-ray diffraction analyses have now been expanded to include samples from three additional wells during the last quarter. X-ray diffraction patterns have been obtained on selected

TABLE 16. SURFACE AREA DATA

Sample Identification Number	Surface Area (m ² /g)
C-1-2755	2.47
C-1-2782	1.08
C-1-2787	1.18
C-1-2802	1.27
C-1-2837	3.22
C-1-2842	2.75
C-1-2897	1.00
C-1-2947	1.21
C-1-2959	2.89
C-1-2964	2.08
C-1-2999	3.64
C-1-3039	2.02
C-1-3085	4.31
C-1-3175	2.97
C-1-3198	3.86
C-1-3218	1.04
C-1-3326	1.82
C-1-3346	1.37
C-1-3593	4.35
C-1-3651	2.89
C-1-4045	4.59

TABLE 17. SURFACE AREA DATA

Sample Identification Number	Surface Area (m ² /g)
C-338-4882	11.94
C-338-4892	8.35
C-338-4912	8.90
C-338-4940	9.42
C-338-4950	5.93
C-338-4960	3.13
C-338-4980	2.23
C-338-5232	3.52
C-338-5283	5.54
C-338-5293	5.56
C-338-5332	2.76
C-338-5347	7.18
C-338-5357	11.20
C-338-5372	16.69
C-338-5382	11.90
C-338-5434	3.16
C-338-5394	3.89
C-338-5447	15.76
C-338-5459	18.31
C-338-5467	12.97

TABLE 18. SURFACE AREA DATA

Sample Identification Number	Surface Area (m ² /g)
T-1-3012	8.414
T-1-3022	2.364
T-1-3043	3.60
T-1-3051	7.85
T-1-3056	7.21
T-1-3063	8.67
T-1-3067B	1.35
T-1-3074	5.37
T-1-3080	3.48
T-1-3080B	7.29
T-1-3086	10.11
T-1-3094B	7.97
T-1-3099	3.32
T-1-3106B	2.12

Penetration Volume, cc/g

FIGURE 2. POROSITY AND PORE SIZE DISTRIBUTION OF CORE C-1-3652 FROM THE MERCURY-INTRUSION POROSIMETER

FIGURE 3. EFFECT OF OUTGASSING TEMPERATURES ON THE MEASURED SURFACE AREA VALUES OF TWO SHALE SAMPLES

samples from C-1, C-338, O-1, P-1, R-109, and T-1 wells. A total of about 50 XRD patterns have been analyzed and mineral constituents have been identified. Minerals identified by XRD include quartz, illite and kaolinite (as clay-minerals), nahcolite, shortite, siderite, dolomite (as carbonate minerals), and pyrite. Quartz is the most abundant single mineral. Illite appears to be the major clay mineral present, though significant amounts of kaolin minerals and traces of mica (muscovite and phlogopite) have been observed. A brief description of XRD findings on individual wells follows.

Washington County, Ohio (R-109) samples are rich in illite with the detectable amounts of kaolin minerals and chlorite making up the clay mineral constituents. Quartz is in abundance but not in as high concentration as in O-1 well samples. Some pyrite and shortite, nahcolite and dolomite were observed.

Christian County, Kentucky (O-1) samples contain illite as the major clay mineral without significant quantities of kaolin or chlorite compared with R-109 samples. These samples are richer in quartz than R-109 shale samples. All four carbonate minerals, nahcolite, shortite, dolomite and siderite are detectable by x-rays. Some albite is observed as feldspathic phase and pyrite is either absent or present in minor amounts.

Wise County, Virginia (C-338) samples contain illite as the only clay mineral detectable by x-rays. These samples contain moderate quantities of quartz (compared to O-1), together with various carbonate minerals in small amounts.

Effingham County, Illinois (T-1) specimens contain higher quantities of kaolin minerals than the other wells and moderate amounts of illite (but still in greater quantities than kaolin minerals). The samples are very rich in free quartz and contain noticeable amounts of calcite, dolomite and nahcolite as the carbonate minerals, with no signs of pyrite present. Table 19 summarizes the minerals observed by XRD analysis of a number of selected shale specimens.

Microscopic examination of a number of thin sections of paired samples, one unheated and one heated to 900 F for 1½ hours were made as a part of the lithologic studies. The results of the microscopic findings are summarized in Table 20. The major mineral phases identified by petrographic studies are quartz, illite, muscovite and pyrite, with some dolomite. It is assumed that some of the phases observed as quartz could possibly be feldspar as the two mineral phases are not readily distinguished using microscopic techniques. Most of the thin section samples studied exhibit some stratification with illite matrices of fine particle size in which larger quartz, pyrite, and other mineral particles are interspersed with organic phases appearing as dark, cloudy structureless blobs.

A limited number of samples were also examined with the scanning electron microscope and energy-dispersive x-ray analyses were performed. Table 21 summarizes the EDAX observations on the studies C-1 samples. The analyses of the various specimens are similar, with several exceptions:

TABLE 19. MINERALS OBSERVED BY XRD ANALYSIS ON RANDOM SHALE SAMPLES

Sample No.	Quartz	Illite	Kaolin Minerals	Pyrite	Nahcolite	Shortite	Siderite	Calcite	Mica	Others
R-109-3644-A	M	—	m	m	m	M	m	m	—	
R-109-3644-B	M	M	M	M	M	M	M	?	D	
R-109-3675	M	—	m	m	m	m	m	—	D	Phlogopite
C-1-3396	M	m	m	m	m	m	m	m		Magnesite
C-1-3085	M	—	—	m	m	M	m	—	—	
C-1-2999	M	m	m	m	D	M	m	—	—	Dolomite
O-1-2230	M	m	—	m	D	M	m	—	—	Dolomite
O-1-2281	M	D	—	D	D	D	D	D	—	

M-major
m-minor
D-detectable

TABLE 20. RESULTS OF PETROGRAPHIC ANALYSES OF SHALE SAMPLES FROM WELL C-1

Sample No.		Minerals and Characteristics	
C-1-2999	Major	Illite	15 μm average platelet size
	Major	Dolomite	Polycrystalline fragments up to 50 μm average
	Major	Pyrite	4-10 μm grain size
	Major	Opaque	Spherical, bladed, and irregular shapes up to 45 μm
	Minor	Quartz or Feldspar	20-35 μm grain size
C-1-3085	Major	Illite	10 μm average platelet size
	Major	Pyrite	5-20 μm average grain size
	Minor	Quartz or Feldspar	10-40 μm grain size
	Minor	Dolomite	Single-crystal fragments and polycrystalline fragments < 10 μm
C-1-3396	Major	Illite	20 μm average platelet size
	Major	Dolomite	Polycrystalline fragments 5-45 μm across
	Minor	Pyrite	2-10 μm grain size
	Minor	Quartz or Feldspar	5-20 μm grain size
C-1-3573	Major	Illite	10 μm average platelet size
	Major	Pyrite	5-15 μm subhedral grains
	Major	Dolomite	Polycrystalline fragments 10-20 μm
	Minor	Quartz or Feldspar	15-55 μm grain size
C-1-3175	Major	Illite	20 μm average platelet size
	Major	Pyrite	3-20 μm grain size
	Minor	Quartz	5-20 μm grain size
	Minor	Dolomite	Very little
C-1-3198	Major	Illite	20 μm average platelet size
	Major	Pyrite	5-20 μm euhedral to spherical grains (plentiful)
	Minor	Quartz	10-20 μm grain size

TABLE 20. (Continued)

Sample No.	Minerals and Characteristics		
C-1-3426	Major	Illite	10 μm average platelet size
	Major	Pyrite	5-20 μm grain size
	Minor	Quartz	$\approx$ 10 μm all grains (sparse)
	Minor	Dolomite	Polycrystalline 10-20 μm
C-1-3593	Major	Illite	<5 μm average platelet size (fine grains)
	Major	Pyrite	5 μm average grain size with cluster up to 100 μm across
	Minor	Quartz	5-15 μm grain size
C-1-3651	Major	Illite	20 μm average platelet size
	Major	Pyrite	5-10 μm grain size
	Minor	Dolomite	Polycrystalline 20-40 μm
	Minor	Quartz	10-30 μm grain size
	Minor	Clear brown isotropic phase, index > 1.56	
C-1-3701	Major	Illite	10 μm average platelet size
	Major	Pyrite	3-10 μm grain size
	Minor	Quartz	10-35 μm grain size
	Minor	Dolomite	Very little

TABLE 21. ENERGY-DISPERSIVE ANALYSIS OF SHALE SAMPLES FROM WELL C-1

	Na	K	Ca	Mg	Al	Si	Fe	S	Ti	P	Fe/S	K/Al	K/Si	Al/Si
C-1-2927A	—	9.1	—	0.8	21.4	49.9	12.4	5.3	1.0	—	2.3	0.43	0.18	0.43
C-1-2999	—	7.0	—	Tr	21.7	63.3	4.5	2.5	0.9	—	1.8	0.32	0.11	0.34
C-1-3085	—	8.1	—	0.3	20.6	60.4	7.2	2.5	1.0	—	2.9	0.39	0.13	0.34
C-1-3396	—	7.2	—	0.5	21.3	59.7	6.1	4.3	0.9	—	1.4	0.34	0.12	0.36
C-1-3573	—	6.8	—	Tr	18.7	66.6	4.4	2.7	0.7	—	1.6	0.36	0.10	0.28
C-1-3998	Tr	8.7	—	1.2	18.7	13.3	5.0	2.6	0.6	—	1.9	0.47	0.14	0.30
C-1-3175	—	6.3	—	2.6	21.4	55.0	7.0	6.7	1.0	—	1.0	0.29	0.11	0.39
C-1-3198	—	9.0	—	2.6	23.4	57.9	5.6	0.7	0.8	—	8.0	0.38	0.16	0.40
C-1-3426 (Area 1)	—	4.8	4.3	—	24.6	56.1	4.4	5.3	0.5	—	0.8	0.20	0.09	0.44
C-1-3426 (Area 2)	—	5.0	8.5	2.4	19.6	52.7	4.1	4.8	0.5	2.4	0.9	0.26	0.09	0.37
C-1-3593	—	7.9	—	2.3	21.7	61.0	4.4	1.8	0.9	—	2.4	0.36	0.13	0.36
C-1-3651	—	5.2	—	—	18.3	69.9	3.3	2.9	0.4	—	1.1	0.28	0.07	0.26
C-1-3701	—	8.2	—	—	23.5	58.6	6.8	1.9	1.0	—	3.6	0.35	0.14	0.40

Sample No. C-1-3426 contained Ca and P, which were not observed in the other samples. A reexamination of a powder sample using the petrographic microscope failed to uncover a mineral (apatite) containing these elements.

Sample C-1-3426 also had a relatively low K/Al and K/Si count ratio and high Al/Si ratio, suggesting that in addition to illite a clay mineral of the kaolin group and/or a chlorite was also present.

Samples Nos. C-1-3198 and C-1-3701 showed an Fe/S count ratio of 8.0 and 3.6, respectively, whereas all other samples had ratios of nominally 1 to 2. This suggests that the pyrite in these samples had oxidized to give a higher ratio of Fe_2O_3 to FeS_2 than in the other samples.

Sample C-1-3651 had a high Si count and lower K/Si and Al/Si count ratios than most of the samples, indicating a higher content of free SiO_2 or quartz.

Sample C-1-3651 had the lowest Fe count of the samples analyzed. Its count was 3.3 compared to the nominally 4 to 7 for most of the other samples. The thin section also showed pyrite to be sparse in the less opaque areas where it could be identified.

Sample C-1-2927A had the highest Fe count, 12.4, which was substantially higher than the more common 4 to 7 Fe count.

Task 6. Data Interpretation/Correlation

The data compiled from the laboratory characterizations and observations on each well are still scattered and too incomplete for a meaningful regression-type analysis at this stage of the investigation. In a multiple regression analysis, leading to a pattern recognition, a statistically valid number of data are required. A number of one-to-one regression-type analyses involving well depth, density, surface area, and gas contents have been performed. No significant correlations between the well depth and physical properties, e.g., density and surface area and well depth and hydrocarbon gas content, have been found from these limited analyses.

So far there appears to be a general inverse relationship between initial gas content and the bulk and true densities of the shale. Also there has been observed an apparent direct relationship between the initial gas content and total carbon content.

Surprisingly, there seems to be no simple relationship between bulk density and porosity. Although one would expect that low bulk density would be accompanied by high porosity (thus, accounting for higher initial gas content), this is not always the case. Likewise, one would expect high open porosity to be accompanied by high surface area, whereas the reverse seems to be more common. Thus, in spite of the good correlation between bulk density and initial gas content, there appears to be no correlation between initial gas content and porosity or surface area.

It should be pointed out that the observed relationships (or lack of them) between gas content and shale characteristics are based on a relatively small number of samples from the first few wells sampled and may be peculiar to these wells. As additional data are gathered some of the present puzzling aspects may be clarified.

Pursuant to discussions with the Project Office in Morgantown, limited effort will be made to determine the effects of various treatments (chemical, thermal, autoclave) on the various physical properties of the shale, such as density, surface area, porosity, and permeability. As mentioned in Section 4 of this report, the permeability measurements so far have shown that these shales are either slightly permeable or not permeable to gases.