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**GEOLOGIC AND GEOCHEMICAL STUDIES OF THE NEW ALBANY GROUP
(DEVONIAN BLACK SHALE) IN ILLINOIS TO EVALUATE ITS
CHARACTERISTICS AS A SOURCE OF HYDROCARBONS**

Quarterly Progress Report, October 1—December 31, 1977

By
Robert E. Bergstrom
Neil F. Shimp

Work Performed Under Contract No. EY-76-C-05-5203

University of Illinois
Illinois State Geological Survey
Urbana, Illinois

MASTER

U. S. DEPARTMENT OF ENERGY

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Robert E. Bergstrom and Neil F. Shimp
Principal Investigators

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INTRODUCTION

This is a quarterly progress report for the three-month period ending December 31, 1977. It summarizes accomplishments on the eight projects that are included in our contract for study of the New Albany Group in Illinois, in format consistent with that followed since the initiation of the contract in 1976.

We have received notice of new guidelines and a new format for reports on the Eastern Gas Shales Program (EGSP), based on work packages and tasks. The work packages do not conform to our eight projects, but we will revise our reporting format starting next month.

GEOLOGIC STUDIES

Stratigraphy and Structure of New Albany in Illinois (I G)

Introduction

This project is a detailed analysis of the lithology, stratigraphy, and structure of the New Albany Group in Illinois to determine those characteristics of lithology, thickness, regional distribution, vertical and lateral variability, and deformation that are most relevant to the occurrence of hydrocarbons.

This study will result in the preparation of cross sections, facies maps, and geologic structure maps based on subsurface data available in the Illinois Survey files. Previous work in Illinois will be re-evaluated and updated. New data on the physical, chemical, and mineralogic characteristics of the New Albany will be derived from the studies of new cores in Illinois and will be incorporated into the stratigraphic and structural investigations of existing data.

Results

Formation thickness data and depths of key geophysical horizons have been gathered for approximately 60 percent of the area of Illinois underlain by the New Albany Shale (milestone 1). This area includes most of southern and eastern Illinois, where the greatest density of data points is available. In areas with special stratigraphic problems or rapid lithologic change, several wells per township have been examined where available.

In conjunction with gathering thickness data, existing cross sections are being revised, and short supplementary cross sections are being prepared to aid correlation in problem areas. Preliminary isopach maps are being prepared as data are gathered. A computer data format sheet has been prepared, and work has begun on encoding the isopach data for the computer files.

The computer data file on holes penetrating the Devonian shales in the northeastern quadrant of Illinois has been completed (milestone 2).

Problem Areas.

Most recent stratigraphic work has been done in the southwestern and northeastern areas of the New Albany in Illinois. The northeastern area (extending from Clark and Cumberland Counties northward through Vermilion and Champaign Counties) presents some problems of special interest. A supplementary north-south cross section near the Indiana state line has been helpful in correlating units in this area.

Geophysical characteristics suggest that the Blocher Shale lithology is more extensive in the northeastern area than was shown by North (1969)** but perhaps less extensive than shown by Collinson and others (1967).^{*} Correlation of geophysical logs and sample studies indicates that the Blocher Shale lithology intertongues and grades laterally into the Lingle Limestone.

The proportion of black shale to greenish-gray and gray shale decreases markedly northward. In much of the northern part of the area, the Grassy Creek and Sweetland Creek Shales cannot be reliably distinguished from each other, either geophysically or with sample studies. The thickness of the Hannibal-Saverton Shales increases substantially northward.

The New Albany Group as a whole thins considerably over an area closely corresponding to the LaSalle Anticlinal Belt. In most of the area in question, the stratigraphic section appears complete with no evidence of erosional thinning. Also, the thin intervals are predominantly gray or greenish-gray shale. These lines of evidence suggest that parts of the LaSalle Anticlinal Belt were positive areas as early as late Devonian time.

The Chouteau Limestone is absent in parts of this area. The Chouteau generally thins toward the areas of its absence, and in the areas where it is absent, logs indicate calcareous shales that are at least in part equivalent to the Chouteau. These lines of evidence suggest that the Chouteau is stratigraphically pinched out and that the Borden Siltstone succeeds the New Albany Group in these areas with little or no interruption in sedimentation.

Additional supplementary cross sections will be constructed as necessary to solve these stratigraphic problems so that the data we obtain on thickness of the New Albany and its subunits will be as accurate and consistent as possible.

Quarterly Work Plan.

During the next quarter (January 1-March 31, 1978), we intend to complete the gathering of isopach data for the New Albany in Illinois. When that task is completed, we will be able to finalize cross-section correlations and have that isopach information placed in computer storage. At that point, we will be ready for the next phase: the construction of the various isopach maps.

Also during the upcoming quarter, we will produce a computer map showing locations of Devonian holes in the northeastern quadrant of the Illinois Basin and tabulate the drill holes through the Devonian black shales in the northwestern quadrant of Illinois.

^{*}Collinson, C. W., L. E. Becker, G. W. James, J. W. Koenig, and D. H. Swann, 1967, Illinois Basin, in International Symposium on the Devonian System: Alberta Society of Petroleum Geologists, v. 1, p. 940-962.

^{**}North, W. G., 1969, Middle Devonian strata of southern Illinois: Illinois State Geological Survey Circular 441, 45 p.

Mineralogic and Petrographic Characterization
of New Albany in Illinois (II G)

Introduction

This project is directed at characterizing in detail the mineralogic and petrographic properties of the New Albany Shale in Illinois. This includes the quantitative and qualitative characterization, by optical and X-ray techniques, of the inorganic mineral constituents, the dispersed organic matter, and the fabric of the shale. The data generated will provide a fundamental basis for regional and local correlations of geologic data, for interpretation of the sedimentology, depositional environment, and diagenetic history, and for evaluation of hydrocarbon potentials based on the degree of thermal maturation of organic matter in the New Albany Shale.

Results

Core Logging and Sampling.

Detailed logging and lithologic sampling of the 05IL (Edgar County, Illinois) and 06IL (Tazewell County, Illinois) cores were completed in November.

The 05IL core is an unoriented partial core (8.3 feet long) consisting of interbedded greenish-gray and black shales. Three samples were selected for lithologic and chemical analysis.

Nine lithologic samples were selected from the 06IL core, in addition to the 23 "canned" samples removed at the drill site.

Sample Preparation.

The canned samples taken for gas release and chemical analysis from the 04IL (Henderson County, Illinois) and 06IL cores were removed from their cans late in November. Orientation of the core segments and the initial stages of sample preparation for chemical and lithologic studies have been completed. A total of 68 chemical (or canned) and lithologic samples were removed from the two cores. X-ray diffraction samples have been prepared for the 06IL core and are now being run. Thirteen thin sections were prepared from the 02IL (Effingham County, Illinois) core during October, and their study is about half completed. Vitrinite reflectance pellets for the 02IL core were prepared and polished during December and are now being run.

Nineteen thin sections were prepared from outcrop samples collected during November. Most of these samples are from thin sandstones and carbonates found within the New Albany Group. These samples and thin sections are now being studied.

Radiography and Slab Description.

Examination of X-ray radiographs and accompanying slabs from the 02IL (Effingham County, Illinois) core was completed during December. The descriptions of the samples are summarized in table IIG-1. The style used to report sample descriptions is slightly different from that used in previous reports

because several of the samples were taken from intervals in which greenish-gray and black shales are thinly interbedded. These samples are described as two distinct lithologies, with the proportion of each and the bed thicknesses indicated in columns 5 and 6.

Bedding and laminations are used with two distinctly different meanings in these descriptions. Bedding is used to refer to layers of distinct color, structure, and composition, whereas laminations refer to thin, planar sedimentary structures that are usually segregations of organic matter or silty material. We interpret the interbedding of greenish-gray and black shale to be the result of changes in the oxygen content of the bottom waters in the New Albany, whereas laminations are the result of minor fluctuations in currents or sediment supply, without any significant change in the bottom environment.

The lithofacies classification of Harvey et al., 1977,* based on study of the 01IL and 01KY cores, was found adequate to characterize all of the shale lithologies found in this core. The lithofacies definitions used here have been modified slightly to permit a wider range of color within each lithofacies. The majority of the samples studied fall in either lithofacies IIA (indistinctly bedded, dark greenish-gray to olive-gray shales, lacking synaeresis) or IVB (finely laminated, brownish-black to black shales, with numerous pyrite nodules). Only two samples exhibit extensive synaeresis (samples 01C1 and 05L2, lithofacies IIB), although a few synaeresis fractures are present in several of the samples (table IIG-1, column 13). Two samples (02C1 and 06L2) were intermediate in character between lithofacies IIA and IIIA.

Samples of the Chouteau Limestone and Lingle Formation, at the top and bottom of the New Albany Shale Group, respectively, are not easily characterized by the same criteria used to describe shale samples. A different descriptive format is now being developed, and the lithofacies classification will be expanded to include the carbonates within and adjacent to the New Albany Shale in future reports.

*Harvey, R. D., W. A. White, R. M. Cluff, J. K. Frost, and P. B. DuMontelle, 1977, Petrology of New Albany Shale Group (Upper Devonian and Kinderhookian) in the Illinois Basin, a preliminary report: Preprints, First Eastern Gas Shales Symposium, Oct. 17-19, 1977, Morgantown, W. Va., p. 239-265.

Table IIG-1 - Petrography: Macrocharacterization, Effingham County, Illinois, core samples. (021L)

Sample	Depth* (feet)	Formation	Litho- facies	# of sample	Bed thick- ness	Average size (in Ø units)	Munsell color	Laminations			bioturbation [†]	Synaeresis abundance		Pyrite nodules size (mm)	abundance	Distribution
								type [‡]	thickness [‡]	spacing [‡]		early	late			
01L2	3009.8	Chouteau-Hannibal contact	limestone IA	80 20	MB VTNB	5 to 7 8	5Y 6/1 5GY4/1	DWN MS	ML -	VTKL -	5 5	-	-	-	-	----
01C1	3011.4	Grassy Creek	IIB	100	TNB	8	N2-N4	MS	-	-	4-5	>25	-	5-15	15	burrows
02C1	3021.4	Grassy Creek	IIA or IIIA	100	>MB	8	5YR2/1	MS	-	-	5	<10	-	2-10	5	burrows
03C1	3041.3	Grassy Creek	IVB	100	>MB	8	5YR2/1	E	VTNL	TNL	0	-	-	1-5	>25	bedding
04C1	3053.0	Grassy Creek	IVB	100	>MB	8	5Y 2/1	E	VTNL	TNL	0	-	-	5-15	<10	random
04C2	3059.2	Grassy Creek	IVB	100	>MB	8	5Y 2/1	E	VTNL	TNL	0	-	-	2-8	>25	bedding
05C1	3065.3	Grassy Creek	IVB	100	>MB	8	5Y 3/1	E	VTNL	TNL	0	-	-	2-7	>25	bedding
05L2	3071.5	Grassy Creek	IIIA	50	MB	8	5Y 2/1	DE	ML	ML	2	<10	-	5-15	<10	bedding
			IIB	50	MB	8	5Y 4/1	MS	-	-	6	>25	-	-	-	----
05C1	3073.3	Grassy Creek	IVB	80	TNB	8	5YR2/1	E	TNL	ML	0	-	-	1-3	<20	bedding
			IIA	20	VTNB	8	5Y 4/1	MS	-	-	4	<5	-	10-15	2	burrows?
06L2	3081.1	Sweetland Creek	IIA	80	TNB	8	5Y 4/1	MS	-	-	5	<15	-	5-10	5	burrows
			IIA or IIIA	20	VTNB	8	5Y 2/1	MS	-	-	2	-	-	-	-	----
07C1	3085.6	Sweetland Creek	IIA	50	TNB	8	5GY6/1	MS	-	-	5	<5	-	2-5	<10	random
			IIIA	50	TNB	8	5Y 2/1	DE	VTNL	ML	0	-	-	2-10	<5	bedding
08C1	3096.7	Sweetland Creek	IVB	100	>MB	8	5YR2/1	E	TNL	ML	1	-	-	1-10	>25	bedding
09L1	3106.0	Lingle	limestone	100	TNB	2	10YR5/2	MS	-	-	3?	-	-	-	-	----

* Depth below logging reference @ 612.1 feet above mean sea level.

+ Lithofacies classification used in previous reports and defined in Harvey et al. (1977).

@ MB= medium beds, 10-30 cm; TNB= thin beds, 1-10 cm; VTNB= very thin beds, <1cm. Because no samples are longer than 30 cm, samples which are all one lithology are recorded as >MB.

† E= even, parallel; DE= discontinuous, even, parallel; DWN= discontinuous, wavy, parallel; MS= massive and unlaminated.

‡ VTKL= very thick, >30 mm; TKL= thick, 10-30 mm; ML= medium, 2-10 mm; TNL= thin, 1-3 mm; VTNL= very thin, <1 mm.

6= completely bioturbate; 5= very strong bioturbate, but rest of bedding still visible; 4= strongly bioturbate; 3= medium bioturbate; 2= weakly bioturbate; 1= sporadic traces; 0= no bioturbation.

Clay Mineralogy.

Clay mineral analysis of the 02IL (Effingham County, Illinois) core was completed during October, and the results are presented in table IIG-2. The clay compositions in this core are similar to those observed in the 01IL (Sangamon County, Illinois) core, as shown in figure IIG-1. Clay orientation indices are also recorded in table IIG-2. The observed orientation varies from 1.2 to 2.5 and does not show any systematic variation with depth or lithology. An orientation index of 1.0 represents a totally random alignment of clay flakes; increasing indices represent more perfect parallel alignment of the clays.

TABLE IIG-2—CLAY MINERALOGY
EFFINGHAM COUNTY, ILLINOIS (02IL) CORE

Sample number	Depth (ft)*	Clay minerals (parts/10)			Clay orientation index
		Illite	Chlorite	Mixed-layer	
01C1	3011.4	5.5	2.5	2.5	2.5
02C1	3021.4	6.0	2.5	1.5	1.2
03C1	3043.3	5.5	2.5	2.0	2.4
04C1	3053.0	7.0	2.0	1.0	2.1
04C2	3059.5	7.0	2.0	0.5	1.5
05C1	3065.3	6.0	2.5	1.5	1.7
05L2	3071.5	7.0	2.0	1.0	1.3
06C1	3073.3	5.5	2.0	2.5	2.3
06L2	3081.1	7.5	2.5	nil	2.1
07C1	3085.6	5.0	2.0	3.0	1.8
08C1	3096.7	5.5	2.5	2.5	2.5

*Depth below logging reference @ 612.1 ft. above mean sea level.

Figure IIG-1. Clay mineral composition of samples from the OlKY, OlIL, and O2IL cores. No kaolinite was detected in these samples.

Clay mineral analysis of the 03IL (White County, Illinois) core was completed during December, and the results are presented in table IIG-3. The samples from this core have low chlorite contents and are intermediate in composition compared to the 01KY and 01IL core samples.

The organic content of the samples was determined from the weight loss during low-temperature ashing and is recorded in the last column of table IIG-3. These are only approximate values because the efficiency of the ashing process is dependent upon the size of the crushed particles placed in the asher (<20 mesh, in this case).

TABLE IIG-3—CLAY MINERALOGY AND
ORGANIC MATTER CONTENT, WHITE COUNTY, ILLINOIS (03IL) CORE

Sample number	Depth (ft)*	Clay minerals [†] (parts/10)			Organic [†] matter (wt.%)
		Illite	Chlorite	Mixed structure	
04L1	4515	7	1	2	9.6
09L1	4565	8	1	1	4.5
19L1	4661	6.5	1.5	2	9.1
20L2	4673	8.5	nil	1.5	3.1
22L1	4695	8.5	1	1	3.3
24L1	4715	7.5	nil	2.5	2.4
26L2	4744	7	nil	3	2.5

*Depth below reference level of 385 ft. above mean sea level.

†Kaolinite was not detected in these samples.

†Calculated from weight loss after low-temperature ashing.

Vitrinite Reflectance.

Reflectance analysis of the 03IL core was completed in December, and the results are presented in table IIG-4. Sample CP1666-I was a pellet made several years ago by N. Bostick and stored in Illinois Survey files; the other five samples were processed during October and November, 1977. The average reflectances of the samples vary from 0.53 to 0.70 percent Ro, with a slight increase in reflectance towards the base of the New Albany (fig. IIG-2). These reflectance values are slightly higher than the reflectances observed in either the 01KY or 01IL cores and correspond to a level of organic metamorphism of 8 to 9 (scale of Hood et al., 1975).^{*} The higher maturity of these samples compared to the cores previously studied probably is due to the greater depth of burial, and supports the proposal that the best prospects for hydrocarbon recovery are in the deeper areas of the Illinois Basin (ISGS Annual Report, Sept. 30, 1977, p. 149).

^{*}Hood, A., C. C. M. Gutjahr, and R. L. Heacock, 1975, Organic metamorphism and the generation of petroleum: American Association of Petroleum Geologists Bulletin, v. 59, no. 6, p. 986-996.

TABLE IIG-4—VITRINITE REFLECTANCE,
WHITE COUNTY, ILLINOIS (03IL) CORE

Sample number	Depth (ft)*	# Readings	Ro (%)	
			Average	Std. deviation
03L1	4505	35	0.53	0.10
CP1666-I	4651	27	0.55	0.08
18L1	4653	50	0.60	0.09
19L2	4667	50	0.54	0.09
21L1	4685	62	0.61	0.08
25L1	4728	33	0.70	0.10

*Depth below reference level of 385 ft. above mean sea level.

Figure IIG-2. Mean-random vitrinite reflectance, in oil, White County, Illinois samples (03IL). Error bars correspond to $\pm$ one standard deviation. Depths are below reference level of 385 ft. above mean sea level.

Field Studies.

On October 6, J. A. Lineback, M. L. Reinbold, R. M. Cluff, and J. T. Wickham of the Illinois Survey staff visited the Indiana Geological Survey. Cluff met with Nelson Shaffer (Indiana Survey) to discuss the petrography of the New Albany and to study one of the New Albany cores drilled in Indiana. On October 7, Lineback led a field trip to several exposures of the New Albany in southeastern Indiana. Similarities between the New Albany of Illinois and Indiana and a number of interpretive problems were discussed on this field trip.

On November 3 and 4, Cluff, Reinbold, and J. W. Baxter of the Illinois Survey were joined by J. Bassett and N. Hasenmueller of the Indiana Survey on a field trip to several exposures of the New Albany in western Illinois and eastern Missouri. The New Albany Group is predominantly greenish-gray shales in this region. The principal focus of the trip was to study the environments and relationships of the shale and the carbonates above, within, and below the New Albany. This is an important area for detailed field work because subsurface records are generally poor and widely scattered. The thin carbonate bodies within the New Albany Group in this region are found over only a relatively small area and represent unique depositional environments. Their relationship to the greenish-gray and black shales is important in constructing an overall depositional model for the New Albany in the Illinois Basin.

On November 14 and 15, Cluff, Reinbold, and Baxter were joined in southern Illinois by Bassett, Hasenmueller, Shaffer, and P. Chen of the Indiana Survey. The zone between the upper New Albany Shale and the Fort Payne chert, which contains several thin but stratigraphically important units, was studied at exposures in Hardin County, Illinois. Structural uplift of over 5000 feet has brought Devonian rocks to the surface in the vicinity of Hicks Dome, and these exposures present a unique opportunity to study shale deposited near the center of the Devonian Illinois Basin. Exposures of the New Albany Shale and laterally equivalent Middle Devonian limestones were also visited in Union County, Illinois. The facies transition from black shale to limestone in southern Illinois is not sufficiently delineated and requires additional study.

Personnel.

To support the fluorescence and scanning electron microscope work required on this study, we have employed Mary R. Hansman, B.S. (geology), June 1977, University of Illinois. Ms. Hansman will begin work on the project on January 16, 1978.

Equipment.

Bids were let for the purchase of a motorized interference filter and control unit for our Leitz MPV II research microscope. This equipment will enable us to begin characterizing the fluorescence spectra of spores and other organic particles in the shale.

First Eastern Gas Shales Symposium.

R. Harvey and R. Cluff attended the EGS Symposium at Morgantown, West Virginia, on October 17-19. A paper was given that summarized our progress on this project to that date.

Lectures.

R. Cluff gave two one-hour presentations on the stratigraphy and petrology of the New Albany Shale: one at the Northern Illinois University Department of Geology in De Kalb on October 31, and one at Chevron Oil Field Research Company in La Habra, California, on December 19. A wide variety of questions concerning the Eastern Gas Shales Project and the geology of the New Albany Shale was brought up by members of the audience at these talks. The people at Chevron Research, in particular, have extensive experience with source rock studies and made a number of useful suggestions and comments. One problem they have encountered is that of bitumen coating vitrinite particles in shales, which lowers the reflectance below the value expected for their burial history. They stressed the importance of using several measures of maturity to judge adequately the source rock potential of a black shale.

Analysis of Physical Properties of the Devonian Black Shale (III G)

Introduction

This project is a study of the index properties, directional properties, and strength of oriented core of Devonian black shale from the Illinois Basin. Index properties include moisture content, specific gravity, bulk density, and Shore hardness. Directional seismic velocities will be determined with an acoustical bench. Strength tests include point load fracture strength, and indirect tensile strength (Brazilian split). Fracture frequency, drilling rate, and core recovery are also compiled as an additional mechanical index.

Results

Indirect Tensile Strength (Brazilian Split).

Preliminary testing of samples from core 01KY has been completed and routine testing is in progress. However, as of the end of December, not enough samples have been tested to indicate any preferred direction of tensile strength. A few samples of limestone below the New Albany Shale have also been tested. The values of tensile strength for the limestone (4.32 to 9.92 MPa) are similar to the tensile strengths of the black shales (4.76 to 10.36 MPa). Structural flaws (burrows, pyrite nodules, fractures) have in some cases altered the location of the failure surface, or induced splitting along the bedding.

Point Load Testing.

Preliminary sample testing is also completed for core 01KY. Values of the point load index have shown a sizeable range: black shales, 1.32 to 4.89 MPa; limestones, 3.20 to 10.80 MPa. In addition, there seemed to be considerable deviation from the original axial loading of the sample during failure. However, the orientations of the fractures have shown the following apparent preferred orientations:

<u>Lithology</u>	<u>Location</u>	<u>Orientation</u>
Black Shale	Upper New Albany	$140^{\circ}/320^{\circ} \pm 25^{\circ}$
Black Shale	Lower New Albany	$95^{\circ}/275^{\circ} \pm 15^{\circ}$
Limestone	Below New Albany	$170^{\circ}/350^{\circ} \pm 40^{\circ}$

Mineral Resources Evaluation System {MINERS} (IV G)

Introduction

This project involves the development of a Mineral Resources Evaluation System that will store all the data related to Illinois State Geological Survey studies of the Devonian black shale of the Illinois Basin, and retrieve, process in many ways, and display in various ways these data.

Results

In response to a proposal that the Illinois State Geological Survey coordinate the Illinois Basin portion of the Devonian black shale studies, a study was undertaken in October 1977 to determine what changes, if any, would be needed in MINERS in order to store, process, and display data from states other than Illinois. Because the well numbering system started more than fifty years ago in Illinois differs from most if not all other states, some changes in our file generation and retrieval methods were required. In Illinois each county has a well number 00001, 00002, 00003, etc., whereas in most states there is only one well numbered 00001 in the state. We took advantage of the Illinois numbering system and organized our files on a county basis. During retrieval runs, locations of records could be calculated instead of searched for. Inasmuch as some changes to MINERS were necessary, we expanded our analysis of MINERS to include the entire system in order to make certain that the file generation and retrieval changes would not be detrimental to other portions of the system. In so doing we found several procedures that could be improved. Our study indicated that all the changes that we thought to be necessary, or an improvement, should be accomplished by the completion date of October 1, 1978. A list of milestones was prepared, which appeared in the November 1977 monthly report.

Most of the changes are in the file generation and retrieval portions of MINERS; hence, file generation and maintenance is being worked on first. Work to be accomplished during each milestone is being broken down into individual tasks, and starting January 1978 it will be reported task by task.

GEOCHEMICAL STUDIES

Quantitative Determination of Major, Minor, and Trace Elements in Eastern U. S. Shales (I C)

Introduction

Determine not less than 49 major, minor, and trace elements in 900 shale samples, which are representative cross sections of the cores taken. Include organic and mineral carbon; total hydrogen; pyritic*, sulfate*, and total sulfur; total nitrogen; exchangeable cations (Ca, Na, K, Mg); and base exchange capacity. Also, report other elements observed during normal routine analysis. The data generated will be used to evaluate 1) the potential economic importance of trace element concentrations in organic-rich shales, 2) new geochemical exploration techniques for natural gas, 3) trace element enrichment in shale organic matter, 4) the occurrence of heavy metal sulfides in shale, 5) potential catalytic effects of trace elements on shale pyrolysis yields, and 6) potential disposal problems.

* Where total sulfur exceeds 0.5%

Results

The latest computer print-out of available chemical data is presented.

Trace Element Distribution Between Shale Inorganic and Organic Phases (II C)

Introduction

Develop chemical and/or physical methods for the separation of the organic and inorganic phases of shales, and determine the trace elements that are associated with each phase. Methods tested include float-sink gravity separations, mechanical separations (Humphrey Spiral), acid extractions, and zonal centrifugation. Compare results of analyses for ten shales, their gravity fractions, and their separated organic phases to determine the elements closely associated with organic matter. Separation procedures that are most promising will be used to study further the organically combined trace elements in additional shale samples. This research is designed to yield new information concerning chemical variations in shale organic matter, which is the shale component about which little is known and which may be the most characteristic feature of gas-bearing shales.

Results

Preliminary investigations have been made on methods for the separation of an organic fraction from Devonian black shale. Standard float-sink procedures, acid dissolution, and Humphrey Spiral techniques have been studied, and work is underway on the application of froth flotation to this problem. Procedures for the separation of humic acid and bitumen fractions have also been investigated.

Of these methods, the acid dissolution procedure has been the most satisfactory. Using it, an organic fraction containing approximately 1.5% ash has been separated from the shale. Data on trace element concentrations of this product have shown that enrichment of some constituents and depletion of others do occur. Other separation techniques have not been as successful; however, investigations are continuing. No humic acids have been isolated from the shales thus far, but samples of bitumen have been obtained and are presently undergoing analysis. With the exception of gradient density procedures, the next quarter will see the conclusion of these preliminary investigations concerning separation of an organic fraction.

Mode of Occurrence and Relative Distribution of Hydrocarbon Phases in Shale (III C)

Introduction

Determine the character of off-gases from approximately 10-foot intervals in cores collected in the Illinois Basin. In addition, determine the relative distribution of hydrocarbons in ten specially prepared core samples, which are the same as those in Project II C. Preserve the samples in airtight containers and subsequently analyze them for evolved gases; highly volatile, low-molecular weight liquids; medium-volatile hydrocarbons; and solvent-extracted, low-volatile hydrocarbons using GC/MS methods. Determine non-volatile, high-molecular weight hydrocarbons by GC analysis of shale pyrolytic products. In addition, conduct a feasibility study to see whether collection procedures for obtaining representative gas samples for $^{13}\text{C}/^{12}\text{C}$ isotopic analyses can be developed. From this, a decision will be made on whether additional isotopic studies are warranted.

Data accumulated can be evaluated to gain a better understanding of the origin, migration, and location of natural gas associated with the shales.

Results

Off-gas studies have been completed on all cores collected in the Illinois Basin to date. This phase of the project has been interrupted until further cores are taken.

The second phase of the project - determination of the relative distribution of hydrocarbons in ten specially prepared core samples - is awaiting funds for equipment purchases. In the interim a literature search is being conducted in a quest of methods already developed that will enhance the conduct of the second phase. Preliminary "dry-run" extractions and separations are being conducted to test and/or to modify these procedures where it is deemed necessary.

Adsorption/Desorption Studies of Gases Through Shales (IV C)

Introduction

With nitrogen and carbon dioxide, determine internal surface area on 900 shale core samples; on 100 of these, use methane as the adsorbate. Determine methane adsorption isotherms for the 100 shales at pressures within the range of <1 to 80 atmospheres. Comparison of these properties in gas-producing and non-gas-producing shales will be made to determine the relationship of shale physical properties to gas recovery.

Results

Shale samples have come in for study at a very slow rate this past quarter, and this has delayed our milestone objectives. We had hoped to complete internal surface area measurements on some 200 samples from the Illinois Basin by the end of this quarter. About 60 samples have been examined to the present time. Twenty-two samples from a core taken from Tazewell County, Illinois are now being studied and internal surface area values for these samples should be available for the next (January) monthly report. The organic carbon contents of these samples appear to be low.

Eleven samples selected from the Appalachian Basin were kindly supplied us by Dr. Barry Maynard of the University of Cincinnati for evaluation and comparison with samples from the Illinois Basin. Some variations were found which warrant additional examination of a few more selected samples from the Appalachian Basin. Dr. Maynard will be sending these samples in the near future.

We have examined 6 selected samples in the high-pressure (1 to 80 atmospheres) methane sorption apparatus thus far. This apparatus is designed for research rather than for routine measurement, and only 100 selected samples are scheduled for examination. Improved temperature control has been achieved so that small gas volumes sorbed under increasing pressures do not vary because of slight changes in temperature (1 degree centigrade can cause appreciable scatter on the plotted curve). Our temperature controlled to within about $\pm 1^{\circ}\text{C}$.

Reexamination of the blacker shale samples from the Christian County, Kentucky core is being made to see whether the problem of the long time required (several hours) for the sorbed gas to reach equilibrium at each increased pressure point can be shortened. (With the lighter-hued gray shales equilibrium is reached in a matter of minutes.) Six x 12 -mesh sieve-size fractions are used for the high-pressure studies. If slabs or sections of 1-inch core are run, for example, the time involved for the gas to reach equilibrium with the shale becomes days, or even weeks. This behavior, of course, reflects the major differences in gas release rates between the black and gray shales that are observed in practice with canned shale samples. Consequently, we believe our apparatus can obtain meaningful data on gas release rates from the different shale types. We are attempting to study these differences (in addition to obtaining the more routine sorption isotherms) by releasing the methane pressure (from 80 atmospheres back down to 1 atmosphere) rather suddenly, and then measuring the volume of methane released as a function of time at atmospheric pressure. This tends to duplicate that which actually occurs in practice when a hole is drilled and gas flows into it.

CHEMICAL DATA ON CHRISTIAN COUNTY, KENTUCKY CORE

SAMPLE NO.	GEOLOG. NO.	DEPTH (FT)	SiO2 (%)	AL2O3 (%)	FE2O3 (%) (XRF)	FE AS FE2O3 (%) (NAA)	MGO (%)	CaO (%)	NA AS NA2O (%) (NAA)	K2O (%) (XRF)	K AS K2O (%) (NAA)	TiO2 (%)	P2O5 (%)	MN (PPM) (NAA)
500021	01KY01-1	1022.2	53.2	10.1	6.85	7.46	.74	.14	.74	3.06	3.52	.56	.10	110
02	02C1	2191.1	59.3	9.65	5.40	6.08	1.21	1.63	.66	2.71	3.05	.50	.06	310
03	03C1	2220.3	57.8	9.93	7.21	7.66	1.08	1.60	.68	2.76	3.24	.54	.10	260
04	04C1	2230.2	62.8	15.0	3.91	3.69	1.49	.56	.86	4.22	4.54	.71	.01	270
05	05C1	2240.1	48.0	10.0	7.74	10.2	1.69	7.32	.74	2.61	2.75	.45	2.25	410
06	06C1	2250.0	59.0	16.4	4.40	5.32	1.98	1.25	.98	4.31	4.84	.83	.07	360
07	07C1	2260.3	49.9	13.5	6.20	6.38	1.05	.26	.77	3.95	4.19	.70	.07	160
08	08C1	2270.3	57.9	14.4	3.37	3.19	2.10	2.03	.92	4.25	4.86	.73	.13	190
09	09C1	2280.0	51.9	11.5	3.60	4.27	3.59	4.81	.80	3.49	3.66	.71	.01	360
10	10C1	2290.7	53.0	11.5	2.64	3.11	2.83	3.69	.75	3.81	4.10	.60	.05	200
11	11C1	2299.7	45.0	9.77	4.20	4.79	4.75	7.50	.87	2.99	3.53	.52	.19	400
12	12C1	2310.5	51.6	8.44	3.16	3.29	4.31	7.51	.56	2.87	3.34	.43	.15	320
13	13C1	2310.8	46.0	7.07	3.09	3.67	4.08	11.7	.45	2.61	3.02	.35	.19	360
33	04L1	2273.5	55.0	14.5	5.05	5.46	1.82	1.69	.84	4.14	5.82	.71	.12	200
34	12L1	2281.8	54.3	11.9	2.90	2.72	3.62	5.67	.75	3.62	4.16	.71	.03	360
35	11L1	2292.9	51.8	13.9	3.42	3.62	3.47	5.50	.76	3.53	3.96	.63	.04	330
36	12L1	2311.1	49.8	3.97	2.62	2.78	4.25	10.3	.54	2.84	3.19	.37	.14	370
37	12L1	2312.5	49.8	7.59	3.05	3.33	4.19	9.32	.53	2.83	3.86	.36	.25	360

	MN (PPM) (DE-F)	V (PPM) (CE-D)	V (PPM) (DE-F)	S (%)	CL (%)	TOTAL C (%)	ORGANIC C (%)	INORG. C (%)	H (%)	TOTAL CEC MEC/1000	SH (PPM)	AS (PPM)
500021	120	160	220	2.42	.02	14.13	14.03	.10	1.93	4.7	4.9	68
02	290	40	160	1.84	.02	10.36	10.29	.07	1.43	3.4	3.3	38
03	220	70	160	1.93	.01	7.78	7.03	.75	1.27	4.7	5.6	42
04	260	50	150	.35	.02	2.24	1.64	.60	.74	5.1	1.8	17
05	340	120	120	2.27	.02	7.01	5.81	1.20	.91	3.2	4.2	37
06	310	150	150	.22	.02	1.69	.66	1.03	.59	7.3	1.4	9.8
07	150	56.7	450	1.74	.01	12.61	12.30	.31	1.72	5.0	11	45
08	170	190	200	.53	.02	6.00	5.04	.96	1.29	4.9	2.0	15
09	320	170	190	.62	.01	7.51	5.39	2.12	1.10	3.3	2.6	12
10	240	190	200	.64	.01	10.56	9.23	1.33	1.36	2.6	1.6	10
11	360	150	150	1.36	.02	10.16	7.43	2.73	.96	2.5	2.1	16
12	360	230	240	1.00	.01	8.32	5.67	2.65	1.06	1.7	2.6	17
13	330	480	320	1.16	.01	10.36	7.32	3.04	.89	1.2	5.7	19
33	170	260	230	.89	.01	8.84	8.02	.82	1.27	4.6	3.0	23
34	310	120	130	.42	.01	5.65	3.40	2.25	.75	4.0	.6	6.2
35	300	120	130	.78	.02	8.64	6.74	1.90	1.03	3.2	1.0	11
36		220		.00	.01	8.90	5.79	3.11	.86	1.6	2.5	12
37		245		1.32	.01	8.93	5.93	3.00	.65	1.2	4.1	17

CHEMICAL DATA ON CHRISTIAN COUNTY, KENTUCKY CORE

SAMPLE NO.	GEOLOGICAL NO.	DEPTH (FT)	BA (PPM)	BE (PPM) (OE-D)	BE (PPM) (OE-P)	B (PPM)	BR (PPM)	CE (PPM)	CS (PPM)	CR (PPM) (NAA)	CR (PPM) (OE-D)	CR (PPM) (OE-P)	CU (PPM) (NAA)	CO (PPM) (OE-D)
800001	01KYR1C1	1022.2	900	3.6	3.6	120	5	82	5.4	65	74	80	39	44
02	02C1	2191.1	1100	4.3	5.0	140	4.5	65	4.5	56	62	65	29	32
03	03C1	2220.3	880	4.2	4.4	180	4	67	5.1	59	65	73	23	26
04	04C1	2230.2	570	3.2	5.2	240	3	60	6.5	69	98	110	11	12
05	05C1	2240.1	1800	3.0	3.4	180	3	172	4.5	64	60	70	32	34
06	06C1	2250.0	790	2.6	4.4	290	4	91	9.1	99	100	110	12	11
07	07C1	2260.3	820	2.9	5.0	210	5	81	7.4	89	100	120	23	29
08	08C1	2270.3	460	2.3	5.2	240	4	77	7.8	100	120	150	14	14
09	09C1	2280.0	350	2.5	5.1	225	3.6	70	6.9	85	99	110	11	13
10	10C1	2290.7	410	2.6	5.0	190	5.0	75	7.7	97	88	110	12	12
11	11C1	2299.7	390	2.4	3.8	165	3	63	5.3	65	60	66	13	14
12	12C1	2310.5	270	2.0	3.3	150	3	48	4.2	55	56	75	11	14
13	13C1	2310.8	510	2.2	3.6	130	4	58	4.0	87	68	98	13	14
33	08L1	2273.5	180	4.5	4.9	190	3	71	8.3	120	110	140	13	14
34	10L1	2287.8	150	2.9	3.6	230	4	52	5.6	71	75	81	6.0	9.1
35	11L1	2292.9	280	4.4	4.8	315	4.5	51	5.8	79	71	80	8.4	7.3
36	12L1	2311.1	280	2.8		150	4	47	3.9	63	58		9.7	14
37	13L1	2312.6	400	2.6		120	2	47	4.0	67	61		11	12

	CO (PPM) (OE-P)	CU (PPM) (OE-D)	CU (PPM) (OE-P)	DY (PPM)	EU (PPM)	F (PPM)	GO (PPM)	GA (PPM)	GE (PPM) (OE-D)	GE (PPM) (OE-P)	HF (PPM)	PP (PPM) (OE-P)
800001	56	89	99	5.6	1.6	640	1.4	17	1.4	<1.7	3.0	30
02	38	60	82	4.4	1.3	630	1.3	15	2.0	<1.6	3.0	14
03	24	82	90	4.8	1.3	500	1.0	13	1.7	<1.7	3.1	36
04	12	61	78	4.7	1.3	900	1.6	22	1.5	<1.1	3.0	19
05	23	78	72	17	5.0	2925	6.2	11	<1.4	<1.1	4.5	26
06	7.6	36	35	5.4	1.4	895	1.9	23	<1.0	<1.1	5.2	11
07	20	160	170	6.4	1.9	745	1.3	22	1.0	<1.0	3.5	23
08	16	140	240	5.6	1.8	885	1.4	19	<1.4	<1.1	4.6	29
09	11	130	180	6.8	1.4	770	1.7	16	<1.0	<1.1	5.1	14
10	11	190	340	6.4	1.6	820	1.7	16	1.1	<1.1	4.6	30
11	11	130	190	6.6	1.6	865	1.8	14	<1.4	<1.1	3.3	33
12	12	125	250	6.1	1.5	920	1.3	13	<1.4	<1.1	2.3	24
13	14	210	270	7.0	1.9	920	2.3	12	.6	<1.1	2.6	14
33	12	150	210	6.5	1.7	950	2.6	22	.7	<1.1	4.2	24
34	8.0	64	120	6.0	1.2	875	1.2	21	<1.4	<1.1	3.7	7.2
35	12	155	180	6.6	1.4	770	2.0	16	2.4	<1.1	3.6	11
36		120		6.5	1.5	970	.9	13	<1.4	<1.1	2.3	
37		110		7.8	1.5	860	2.3	16.7	<1.4	<1.1	2.5	

CHEMICAL DATA ON CHRISTIAN COUNTY, KENTUCKY COAL

SAMPLE NO.	GEOLOG. NO.	DEPTH (FT)	LA (PPM)	LU (PPM)	MO (PPM) (DE-D)	MO (PPM) (NAA)	NI (PPM) (DE-D)	NI (PPM) (DE-P)	NI (PPM) (NAA)	RB (PPM)	SM (PPM)	SC (PPM)	AG (PPM) (DE-P)	SR (PPM) (NAA)
800001	01KY01C1	1822.2	35	.5	180	240	100	180	130	110	9.1	13	< .7	76
02	02C1	2191.1	28	.3	200	200	76	100	90	95	8.2	12	< .7	77
03	03C1	2220.3	29	.4	160	170	85	110	90	100	7.7	13	< .7	230
04	04C1	2230.2	37	.4	4	37	33	42	30	150	9.2	17	< .8	120
05	05C1	2240.1	43	.9	100	74	84	87	150	25	25	14	< .7	840
06	06C1	2250.0	42	.5	< 1	NO	23	30	49	190	7.6	23	< .8	150
07	07C1	2260.3	38	.6	220	250	280	300	300	130	12	16	< .7	210
08	08C1	2270.3	44	.3	1.5	28	80	180	150	160	11	20	< .87	180
09	09C1	2280.0	36	.5	8.5	18	80	120	150	130	6.6	17	< .8	180
10	10C1	2290.7	37	.6	28	21	120	200	160	140	7.5	18	< .7	110
11	11C1	2299.7	33	.5	23	45	90	120	140	100	7.9	15	< .7	130
12	12C1	2310.5	30	.4	39	38	120	190	130	77	6.8	10	< .8	110
13	13C1	2318.8	31	.5	110	86	200	250	280	93	9.5	13	< .8	160
33	REL	2273.5	39	.4	17	40	130	150	120	100	7.9	20	< .7	170
34	REL	2287.8	35	.4	4	85	69	76	60	100	4.9	14	< .8	220
35	REL	2292.9	32	.4	11	20	100	120	96	120	6.3	14	< .6	150
36	REL	2311.1	29	.5	36	NO	140	120	120	82	8.5	11		150
37	REL	2312.6	31	.5	39	59	150	160	160	84	7.5	12		190

	SR (PPM) (DE-D)	TA (PPM)	TE (PPM)	TH (PPM)	SN (PPM) (DE-D)	SN (PPM) (DE-P)	U (PPM)	YR (PPM)	ZN (PPM) (DE-P)	ZN (PPM) (NAA)	ZN (PPM) (DE-D)	ZR (PPM) (DE-D)
800001	110	.9	1.1	7.1	2.4	< 1.4	61	2.3	70	120	80	71
02	140	.8	.8	6.9	.8	< 1.5	43	1.9	51	56	60	120
03	190	.8	.9	7.3	.9	< 1.5	22	2.4	170	230	260	140
04	190	1.0	.8	8.5	4.7	< 1.7	14	2.2	48	120	89	120
05	> 600	.7	3.6	12	1.4	< 1.6	37	5.3	110	230	160	270
06	210	1.4	.8	14	4.4	< 1.7	5	2.9	43	150	66	180
07	250	.8	1.2	4.1	3.8	< 1.4	40	2.8	410	470	230	130
08	190	1.2	.8	11	5.6	15	5	2.9	200	200	160	170
09	210	1.0	1.2	12	2.6	4.7	6	3.3	83	150	61	200
10	150	1.0	1.0	11	3.6	15	8	3.3	120	140	96	130
11	170	.7	1.1	7.6	3.6	4.2	3	3.1	160	210	80	190
12	130	.6	.7	6.4	3.6	5.3	10	2.6	100	66	48	130
13	160	.6	1.3	6.2	3.7	4.3	22	3.1	530	360	180	170
33	160	1.4	1.2	10	5.6	11	14	2.8	140	200	180	190
34	170	.9	.7	6.6	4.4	6.1	7	1.7	51	240	29	160
35	120	1.0	.8	6.2	5.0	6.9	6	2.4	270	220	220	190
36	160	.6	.7	5.6	4.2		12	2.1	250	89		170
37	145	.7	1.2	5.5	4.4		13	2.4	170	70		150

CHEMICAL DATA ON CHRISTIAN COUNTY, KENTUCKY CORE

SAMPLE NO.	GEOL. NO.	DEPTH (FT)	ZR (PPH) (DE-P)	500 DEG. ASH (%)	NO (PPH)
01	01KY01C1	1822.2	210	79.60	32
02	02C1	2191.1	210	86.17	24
03	03C1	2220.3	220	87.62	31
04	04C1	2230.2	220	95.46	21
05	05C1	2240.1	270	90.12	00
06	06C1	2250.0	210	95.84	24
07	07C1	2260.3	230	82.49	28
08	08C1	2270.3	280	91.23	16
09	09C1	2280.0	270	90.82	46
10	10C1	2290.7	180	87.83	21
11	11C1	2299.7	200	92.06	29
12	12C1	2310.5	130	92.06	28
13	13C1	2310.6	180	90.43	32
33	08L1	2273.5	180	89.13	34
34	10L1	2287.8	180	95.51	
35	11L1	2292.9	210	91.72	37
36	12L1	2311.1		93.13	
37	13L1	2312.6		92.56	26

ND = NOT DETECTED

CHEMICAL DATA ON SANGAMON COUNTY, ILLINOIS CORE

SAMPLE NO.	GEOL. NO.	DEPTH (FT)	SI02 (X)	AL2O3 (X)	FE2O3 (X) (XRF)	FE AS FE2O3 (X) (NAA)	MGO (X)	CaO (X)	NA AS X NA2O (X) (NAA)	K2O (X) (XRF)	K AS X K2O (X) (NAA)	TIO2 (X)	P2O5 (X)	MN (PPM) (NAA)
800014	011L01.2	1576.0	64.5	18.5	4.31	4.56	2.25	1.04	1.00	3.91	4.32	.87	.08	220
15	03L1	1589.0	71.8	2.54	2.61	3.07	1.84	2.03	1.25	2.98	3.43	.93	.33	290
16	04L1	1602.0	74.0	4.19	2.20	2.51	1.13	.32	1.37	3.81	3.55	.95	.03	120
17	05L1	1615.1	72.4	4.77	2.88	3.55	1.48	.39	1.22	3.47	4.11	.99	4.01	150
18	07L1	1631.6	51.7	4.81	2.07	3.00	2.59	15.5	.88	2.35	2.80	.56	.31	960
19	09L1	1647.4	58.8	12.7	4.01	4.88	2.72	1.35	1.02	4.08	4.86	.93	.02	340
20	09L2	1656.7	65.4	12.1	2.72	5.72	1.62	.30	1.11	4.26	4.95	1.00	.05	240
21	12L1	1657.1	65.3	11.7	5.84	7.83	1.64	.06	.98	3.85	4.38	.87	.01	210
22	13L1	1667.5	57.9	11.9	5.00	6.52	1.92	.01	.71	5.40	6.10	.84	.06	260
23	12L1	1678.4	60.2	15.0	5.01	5.86	2.63	.43	.79	5.32	6.55	.89	4.01	280
24	13L1	1688.0	58.8	16.1	5.09	6.29	2.74	.36	.75	5.63	6.41	.81	.02	280
25	14L1	1698.2	56.5	14.1	5.20	6.29	2.22	.52	.75	4.69	5.31	.77	4.01	230
26	15L1	1710.0	51.5	13.2	5.19	6.88	2.17	.18	.59	4.96	5.90	.66	.05	240
27	16L1	1723.2	53.8	11.7	5.35	8.54	2.24	.71	.73	3.78	4.22	.60	.03	260
28	17L1	1730.5	57.1	12.2	4.62	6.49	1.54	.41	.82	3.74	4.29	.66	.04	230
29	18L1	1740.2	62.5	11.7	4.15	4.46	1.27	.47	.84	3.66	4.16	.64	.08	190
30	19L1	1753.5	55.8	12.2	5.62	5.65	1.67	.50	.75	3.66	4.82	.62	.10	270
31	27L1	1763.3	56.6	12.3	4.37	4.41	2.22	2.26	.92	3.47	4.72	.69	.08	340
32	21L1	1776.2	50.4	14.8	4.83	3.84	2.15	.77	.75	4.86	5.94	.67	.03	340

	MA (PPM) (DE-P)	V (PPM) (DE-D)	V (PPM) (DE-P)	S (X)	CL (X)	TOTAL C (X)	ORGANIC C (X)	INORG. C (X)	H (X)	TOTAL CEC MED/100G	SA (PPM)	AS (PPM)
800014	240	220	270	.02	.13	.88	.43	.45	.75	7.3	.6	2.6
15	290	70	140	.05	.04	.96	.29	.67	.44	2.9	.5	2.9
16	150	70	120	.07	.14	.97	.80	.17	.48	3.1	.6	4.3
17	170	120	170	.06	.11	.44	.28	.16	.44	4.3	.7	3.9
18	820	83	90	.07	.04	3.88	.15	3.73	.36	2.2	.3	2.3
19	340	110	160	.09	.12	.75	.32	.43	.66	6.4	.5	5.9
20	230	86	120	.25	.12	.66	.57	.09	.66	5.6	.6	6.2
21	180	70	110	.09	.09	1.30	1.28	.02	.78	6.7	.9	9.8
22	270	170	180	.27	.12	2.93	2.90	.03	.91	9.4	.4	7.7
23	310	140	180	.18	.12	1.88	1.72	.16	.66	7.7	1.2	6.2
24	270	140	140	.31	.14	2.96	2.90	.06	1.07	8.2	1.2	10
25	220	160	240	.54	.12	4.34	4.26	.08	1.09	9.3	1.7	14
26	200	220	200	.92	.04	7.61	7.54	.07	1.49	11.4	4.6	25
27	240	240	240	1.26	.09	9.74	9.59	.15	1.54	8.0	6.6	22
28	200	120	160	1.10	.24	6.55	6.50	.05	1.01	8.6	2.6	14
29	200	140	170	.92	.04	5.63	5.57	.06	1.15	6.2	2.0	11
30	240	140	170	1.36	.10	6.41	6.28	.13	1.32	7.7	3.9	35
31	340	120	130	.84	.29	3.86	3.49	.37	.94	5.7	1.9	16
32	280	290	290	.71	.11	4.06	3.79	.27	1.14	7.9	2.0	16

CHEMICAL DATA ON SANGAMON COUNTY, ILLINOIS CORE

SAMPLE NO.	GEOL. NO.	DEPTH (FT)	BA (PPM)	BE (PPM) (OE-D)	BE (PPM) (OE-P)	B (PPM)	BR (PPM)	CE (PPM)	CS (PPM)	CR (PPM) (NAA)	CR (PPM) (OE-D)	CR (PPM) (OE-P)	CO (PPM) (NAA)	CO (PPM) (OE-D)
800014	011L01L2	1576.0	280	2.8	4.4	160	8.1	78	8.1	110	100	150	10	9.6
15	03L1	1589.4	360	2.2	2.5	100	8.1	110	4.9	95	80	84	6.6	5.5
16	04L1	1602.0	420	2.1	2.6	100	11	88	5.2	94	78	96	6.2	4.4
17	05L1	1615.1	418	2.7	3.2	110	8.5	99	8.5	110	84	100	8.9	6.4
18	07L1	1631.6	430	.6	2.3	72	44	82	5.0	63	44	66	7.1	7.1
19	09L1	1647.4	460	2.6	4.4	130	6.4	91	10	120	80	110	13	11
20	09L2	1656.2	580	2.8	3.5	120	7	99	10	110	79	96	16	13
21	10L1	1657.6	530	3.0	3.4	160	5.8	88	11	110	78	97	15	14
22	11L1	1667.5	570	3.7	5.6	170	8.4	89	13	140	92	130	18	15
23	12L1	1678.6	550	3.6	5.1	140	8.5	86	14	110	93	130	14	12
24	13L1	1688.0	600	3.4	5.5	140	9.4	86	13	150	100	140	18	14
25	14L1	1698.2	580	2.9	4.6	150	6.7	79	12	120	95	110	16	15
26	15L1	1710.0	810	2.9	5.4	140	7	86	11	110	98	110	25	26
27	16L1	1723.4	1230	3.2	5.1	120	45	120	9.5	96	73	96	44	47
28	17L1	1730.6	860	3.9	4.4	130	44	90	5.9	110	74	84	29	21
29	18L1	1740.2	550	3.5	3.7	130	47	58	6.5	60	67	70	20	20
30	19L1	1753.5	500	3.7	4.6	125	9.0	68	6.1	73	67	83	25	26
31	20L1	1763.3	400	3.2	3.7	140	9.4	54	6.1	80	66	94	18	20
32	21L1	1776.2	360	4.0	4.5	200	7	52	7.4	83	100	120	11	16
			CO (PPM) (OE-P)	CU (PPM) (OE-D)	CU (PPM) (OE-P)	DY (PPM)	EU (PPM)	F (PPM)	GD (PPM)	GA (PPM)	GE (PPM) (OE-D)	GE (PPM) (OE-P)	HF (PPM)	PB (PPM) (OE-P)
800014			9.1	5.1	13	5.4	1.1	920	2.7	16	2.5	<12	6.7	5.8
15			5.8	16	32	9.6	3.0	810	2.7	12	4.6	<12	11	8.1
16			5.4	6.6	14	6.1	1.1	375	2.0	14	4.0	<12	11	<2.3
17			5.7	6.9	13	6.9	1.5	505	3.0	16	4.3	<12	11	<2.4
18			5.1	6.8	11	6.5	1.8	570	2.2	8.2	4.4	<12	8.0	<2.4
19			13	8.4	20	4.5	1.2	560	2.0	27	1.8	<11	7.6	<2.3
20			15	13	24	6.3	1.3	605	2.2	25	2.7	<12	8.6	<2.4
21			12	19	32	4.1	1.3	600	2.3	16	2.4	<11	7.1	<2.3
22			24	34	63	3.9	1.2	970	2.2	24	2.8	<11	5.1	35
23			22	20	45	5.5	1.4	825	2.2	26	2.3	<11	5.4	30
24			23	20	30	4.5	1.1	940	2.0	25	.6	<11	4.8	24
25			17	32	54	5.1	1.2	815	1.9	20	1.5	<11	4.8	17
26			32	59	74	5.1	1.3	945	2.2	21	1.2	<10	4.0	37
27			45	150	260	6.7	1.4	675	3.3	14	1.2	<10	6.1	54
28			23	55	70	5.4	1.3	1000	1.3	13	1.2	<11	5.6	18
29			29	48	74	4.7	1.2	640	1.7	11	1.5	<11	4.4	19
30			38	56	64	6.2	1.4	665	1.2	19	.8	<11	3.4	18
31			29	39	66	5.3	1.1	810	2.2	23	.9	<11	5.6	16
32			15	64	79	4.3	1.0	1075	1.3	23	1.2	<11	3.0	31

CHEMICAL DATA ON SANGAMON COUNTY, ILLINOIS CORE

SAMPLE NO.	GEOLOG. NO.	DEPTH (FT)	LA (PPM)	LJ (PPM)	MO (PPM) (DE-D)	MO (PPM) (NAA)	NI (PPM) (DE-D)	NI (PPM) (DE-P)	NI (PPM) (NAA)	RB (PPM)	SM (PPM)	SC (PPM)	AG (PPM) (DE-P)	SR (PPM) (NAA)
SP0014	011L011.2	576.0	36	.4	<.4	ND	38	55	49	160	5.3	15	<.8	
15	03.1	589.4	45	.7	<.4	ND	23	25	29	110	14	10	<.8	110
16	04.1	1602.0	37	.6	<.4	ND	24	32	40	110	6.1	11	<.8	110
17	05L1	1615.1	40	.6	<.4	ND	25	31	33	170	6.5	15	<.8	29
18	07L1	1631.6	34	.5	4.1	ND	23	21	18	100	7.0	10	<.8	56
19	09L1	1647.4	39	.4	<.4	ND	39	49	46	200	6.1	19	<.8	38
20	09L2	1656.2	43	.6	.7	ND	42	46	64	200	6.7	19	<.8	97
21	12L1	1657.6	34	.4	1.6	31	38	50	43	190	5.9	18	<.8	
22	13L1	1667.5	35	.4	4.7	ND	68	100	83	270	6.6	24	<.8	40
23	12L1	1678.8	39	.4	1.5	19	55	92	78	230	5.7	23	<.8	
24	13L1	1688.0	37	.4	4.6	15	63	100	70	270	6.0	25	<.8	30
25	14L1	1698.2	34	.3	21	28	61	98	70	220	6.3	21	<.8	
26	15L1	1710.0	33	.4	62	110	78	99	91	230	6.0	22	<.7	
27	15L1	1723.4	33	.4	44	ND	79	130	100	210	13	21	<.7	31
28	17L1	1730.5	30	.3	35	ND	60	40	33	190	11	19	<.7	
29	18L1	1740.2	32	.3	47	100	63	76	42	140	9.2	15	<.7	80
30	19L1	1753.5	34	.4	67	140	77	94	69	120	7.5	16	<.7	
31	20L1	1763.3	34	.4	22	ND	61	46	49	130	5.4	15	<.6	100
32	21L1	1776.2	38	.3	29	ND	125	150	110	140	5.6	17	<.8	

	SR (PPM) (DE-D)	TA (PPM)	TB (PPM)	TC (PPM)	SN (PPM) (DE-D)	SN (PPM) (DE-P)	U (PPM)	VR (PPM)	ZN (PPM) (DE-P)	ZN (PPM) (NAA)	ZN (PPM) (DE-D)	ZR (PPM) (DE-D)
SP0014	73	1.3	.6	12	3.9	11	<5	2.4	48	92	50	240
15	91	1.4	1.6	11	1.7	<1.7	<6	3.6	57	51	30	325
16	91	1.5	1.4	12	2.6	6.7	<5	3.1	180	110	130	425
17	62	2.0	1.1	14	2.3	8.7	<5	3.3	40	71	40	470
18	190	1.2	1.3	9.5	.7	<1.7	<4	3.0	59	35	5.5	610
19	94	1.6	1.0	14	5.2	10	<4	2.6	30	180	20	260
20	89	1.5	.9	15	4.7	6.7	<4	2.5	110	150	83	310
21	64	1.7	1.3	14	3.8	5.2	<6	2.4	400	1240	920	250
22	72	1.7	.9	15	9.1	15	<6	2.3	100	100	75	210
23	75	1.4	.8	15	7.2	18	<6	2.4	100	120	97	220
24	77	1.5	.9	15	6.5	16	4	2.2	130	110	54	200
25	72	1.4	.9	13	4.1	12	1	2.2	160	170	99	150
26	63	1.2	.9	13	3.8	4.6	20	2.3	270	200	170	130
27	64	1.4	1.2	14	3.7	7.5	31	3.0	100	140	64	170
28	64	1.2	1.1	12	4.9	6.5	17	2.4	55	220	53	180
29	60	1.0	.7	6.4	4.9	4.0	14	1.9	93	80	90	170
30	63	1.0	.7	6.2	5.0	6.1	33	1.7	33	76	35	130
31	60	1.2	.7	10	5.0	10	4	2.3	20	44	34	300
32	69	.8	.6	6.4	6.2	11	10	1.4	100	210	65	160

CHEMICAL DATA ON SARGANT COUNTY, ILLINOIS CORE

SAMPLE NO.	GEOLOGICAL NO.	DEPTH (FT)	ZR (PPM) (DE-P)	500 DEG. ASH (%)	ND (PPM)
500014	211L01L2	1576.0	470	96.50	18
15	03L1	1589.0	710	97.09	54
16	04L1	1602.0	570	97.35	25
17	05L1	1615.1	480	98.50	44
18	07L1	1631.6	460	98.85	32
19	09L1	1647.4	460	98.44	16
20	09L2	1656.2	330	97.40	42
21	10L1	1657.6	290	95.30	52
22	11L1	1667.5	300	93.30	35
23	12L1	1670.6	320	95.30	ND (<10)
24	13L1	1688.0	280	93.60	21
25	14L1	1698.2	280	93.10	ND (<20)
26	15L1	1710.0	200	87.00	35
27	16L1	1723.4	300	85.80	55
28	17L1	1730.6	240	88.90	42
29	18L1	1740.2	210	90.10	27
30	19L1	1753.5	210	88.40	
31	22L1	1763.3	290	93.40	27
32	21L1	1776.2	200	94.50	

ND = NOT DETECTED