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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



U. S. DEPARTMENT OF ENERGY

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Robert E. Bergstrom and Neil F. Shimp
Principal Investigators



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Illinois State Geological Survey

# 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. Koening, 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. (02IL).

| Sample | Depth* (feet) | Formation | Litho- + facies | % of sample | Bed thick- ness | Average size (in Ø units) | Munsell color | Laminations type† | Laminations thickness†† | Laminations spacing†† | bioturbation# | Synaeresis abundance early | Synaeresis abundance late | Pyrite nodules size (mm) | Pyrite nodules abundance | Pyrite nodules distribution |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 01L2 | 3009.8 | Chouteau-Hannibal contact | limestone | 80 | MB | 5 to 7 | 5Y 6/1 | DWN | ML | VTKL | 5 | - | - | - | - | ---- |
| | | | IA | 20 | VTNB | 8 | 5GY4/1 | MS | - | - | 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, 3-10 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.

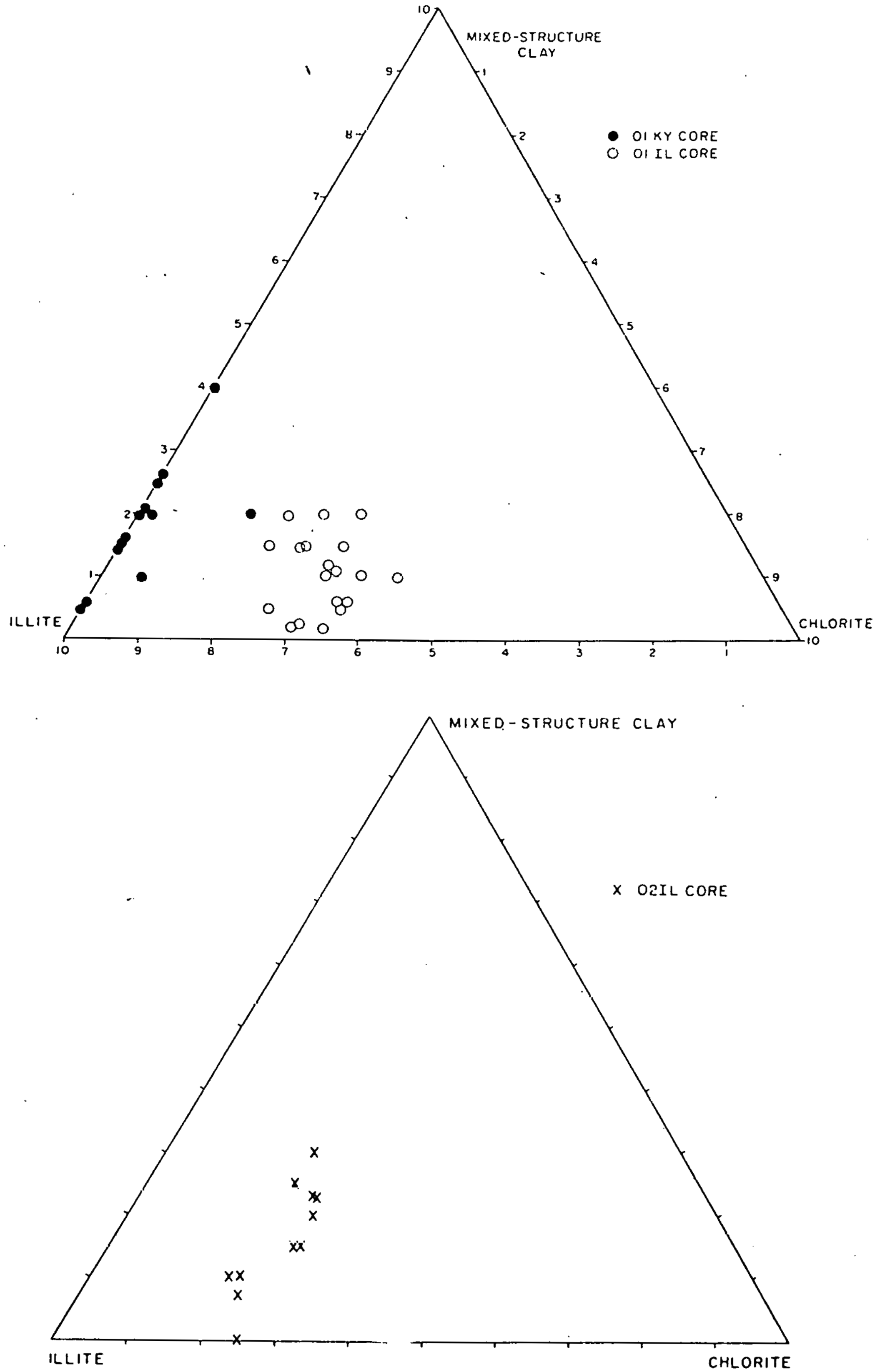


Figure IIG-1. Clay mineral composition of samples from the 01KY, 01IL, and 02IL cores. No kaolinite was detected in these samples.

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.

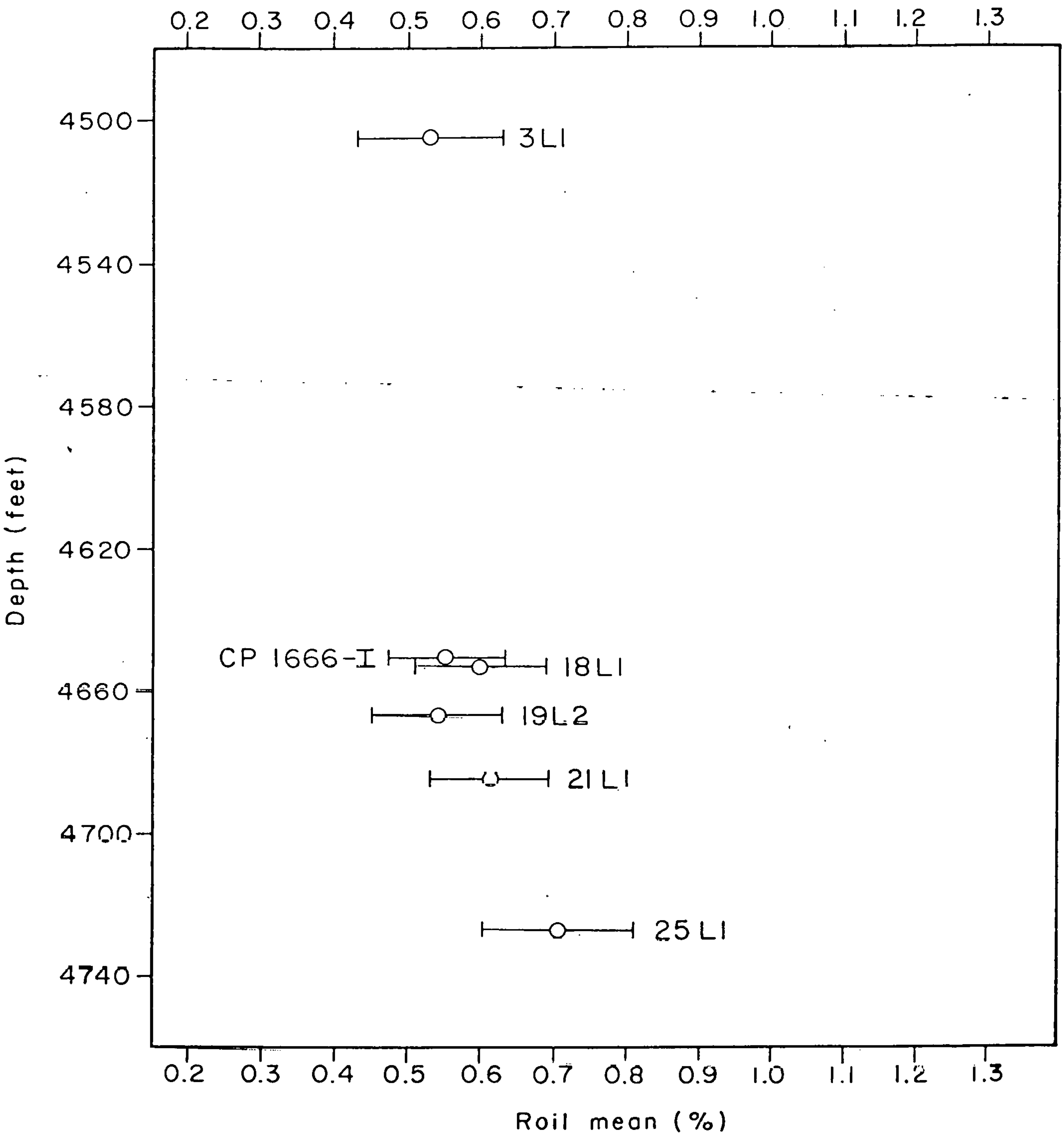


Figure IIG-2. Mean-random vitrinite reflectance, in oil, White County, Illinois samples (03IL). Error bars correspond to ± one standard deviation. Depths are below reference level of 385 ft. above mean sea level.

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:

| Lithology | Location | Orientation |
|---|---|---|
| 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 $^{13}C/^{12}C$ 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 valves 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 $\pm 1^{\circ}C$.

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. | GEOL. 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) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 300021 | 01KY0101 | 1822.2 | 53.2 | 10.1 | 6.85 | 7.46 | .74 | .14 | .74 | 3.06 | 3.52 | .56 | .10 | 110 |
| 02 | 0201 | 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 | 4.50 | .71 | < .01 | 270 |
| 05 | 05C1 | 2240.1 | 48.0 | 10.0 | 7.74 | 10.2 | 1.69 | 7.30 | .74 | 2.61 | 2.75 | .45 | 1.25 | 410 |
| 06 | 06C1 | 2250.0 | 59.0 | 16.4 | 4.40 | 5.30 | 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 | 3.93 | 4.19 | .70 | .07 | 160 |
| 08 | 08C1 | 2270.3 | 57.9 | 14.4 | 3.37 | 3.19 | 2.10 | 2.03 | .92 | 4.23 | 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 | 4.38 | .68 | .05 | 220 |
| 11 | 11C1 | 2299.7 | 45.0 | 9.77 | 4.28 | 4.79 | 4.75 | 7.50 | .87 | 2.93 | 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 | 2318.8 | 46.0 | 7.07 | 3.09 | 3.67 | 4.08 | 11.7 | .45 | 2.61 | 3.02 | .35 | .19 | 360 |
| 33 | 09L1 | 2273.5 | 55.0 | 14.5 | 5.05 | 5.46 | 1.82 | 1.69 | .80 | 4.14 | 5.02 | .71 | .12 | 200 |
| 34 | 10L1 | 2287.5 | 54.3 | 1[illegible].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 | 8.07 | 2.62 | 2.78 | 4.25 | 10.3 | .54 | 2.64 | 3.19 | .37 | .19 | 370 |
| 37 | 13L1 | 2312.[illegible] | 49.8 | 7.59 | 3.05 | 3.33 | 4.19 | 9.32 | .53 | 2.63 | 3.06 | .36 | .25 | 360 |

| SAMPLE NO. | MN (PPM) (OE-P) | V (PPM) (CE-D) | V (PPM) (OE-F) | S (%) | CL (%) | TOTAL C (%) | ORGANIC C (%) | INORG. C (%) | H (%) | TOTAL CEC MEQ/100G | SB (PPM) | AS (PPM) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 300021 | 120 | 160 | 220 | 2.42 | .02 | 14.13 | 14.03 | .10 | 1.93 | 4.7 | 4.9 | 66 |
| 02 | 290 | 140 | 160 | 1.84 | .02 | 10.86 | 10.29 | .57 | 1.43 | 3.4 | 3.3 | 38 |
| 03 | 220 | 170 | 160 | 1.93 | .01 | 7.78 | 7.03 | .75 | 1.27 | 4.7 | 5.6 | 42 |
| 04 | 260 | 150 | 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 | 1.22 | .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 | >560 | 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 | 200 | 190 | 220 | .64 | .01 | 10.56 | 9.23 | 1.33 | 1.36 | 2.6 | 1.6 | 10 |
| 11 | 360 | 150 | 150 | 1.35 | .02 | 10.16 | 7.43 | 2.73 | .95 | 2.5 | 2.1 | 16 |
| 12 | 360 | 230 | 240 | 1.06 | .01 | 8.32 | 5.67 | 2.65 | 1.06 | 1.7 | 2.6 | 17 |
| 13 | 330 | 480 | 320 | 1.16 | .01 | 10.38 | 7.32 | 3.06 | .89 | 1.2 | 5.7 | 19 |
| 33 | 170 | 260 | 230 | .89 | .01 | 6.84 | 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 | | .90 | .01 | 8.90 | 5.79 | 3.11 | .86 | 1.6 | 2.5 | 12 |
| 37 | | 245 | | 1.02 | .01 | 8.93 | 5.93 | 3.02 | .85 | 1.2 | 4.1 | 17 |

CHEMICAL DATA ON CHRISTIAN COUNTY, KENTUCKY 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) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 800001 | 01KY01C1 | 1822.2 | 900 | 3.6 | 3.6 | 120 | 5 | 82 | 5.4 | 65 | 74 | 84 | 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 | 170 | 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 | 10 |
| 12 | 12C1 | 2310.5 | 270 | 2.0 | 3.3 | 150 | 3 | 48 | 4.2 | 55 | 56 | 75 | 11 | 14 |
| 13 | 13C1 | 2318.8 | 510 | 2.2 | 3.6 | 130 | 4 | 58 | 4.0 | 87 | 68 | 98 | 13 | 14 |
| 33 | 08L1 | 2273.5 | 380 | 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 | 61 | 6.0 | 9.1 |
| 35 | 11L1 | 2292.9 | 280 | 4.4 | 4.0 | 315 | <5 | 51 | 5.8 | 79 | 71 | 68 | 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 |

| SAMPLE NO. | 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) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| S00001 | 56 | 89 | 99 | 5.6 | 1.6 | 640 | 1.4 | 17 | 1.4 | <12 | 3.0 | 30 |
| 02 | 38 | 60 | 82 | 4.4 | 1.3 | 630 | 1.3 | 15 | 2.0 | <10 | 3.0 | 14 |
| 03 | 20 | 82 | 90 | 4.8 | 1.3 | 500 | 1.0 | 13 | 1.7 | <12 | 3.1 | 36 |
| 04 | 12 | 61 | 78 | 4.7 | 1.3 | 900 | 1.6 | 22 | 1.5 | <11 | 3.0 | 19 |
| 05 | 23 | 78 | 72 | 17 | 5.0 | 2925 | 6.2 | 11 | < .4 | <11 | 4.5 | 26 |
| 06 | 9.6 | 36 | 35 | 5.4 | 1.4 | 895 | 1.9 | 23 | < .4 | <11 | 5.2 | 11 |
| 07 | 26 | 160 | 170 | 6.4 | 1.9 | 745 | 1.3 | 22 | 1.0 | <10 | 3.5 | 23 |
| 08 | 16 | 140 | 240 | 5.6 | 1.8 | 885 | 1.4 | 19 | < .4 | <11 | 4.6 | 29 |
| 09 | 11 | 130 | 180 | 6.8 | 1.4 | 770 | 1.7 | 16 | < .4 | <11 | 5.1 | 14 |
| 10 | 11 | 190 | 340 | 6.4 | 1.6 | 820 | 1.7 | 16 | 1.1 | <11 | 4.6 | 30 |
| 11 | 11 | 130 | 190 | 6.6 | 1.6 | 865 | 1.8 | 14 | < .4 | <11 | 3.3 | 33 |
| 12 | 12 | 125 | 250 | 6.1 | 1.5 | 920 | 1.3 | 13 | < .4 | <11 | 2.3 | 24 |
| 13 | 10 | 210 | 270 | 7.0 | 1.9 | 920 | 2.3 | 12 | .6 | <11 | 2.6 | 14 |
| 33 | 12 | 150 | 210 | 6.5 | 1.7 | 950 | 2.6 | 22 | .7 | <11 | 4.2 | 26 |
| 34 | 8.0 | 64 | 120 | 6.0 | 1.2 | 875 | 1.2 | 21 | < .4 | <11 | 3.7 | 7.2 |
| 35 | 12 | 155 | 180 | 6.6 | 1.4 | 770 | 2.0 | 16 | 2.4 | <11 | 3.6 | 11 |
| 36 | | 120 | | 6.5 | 1.5 | 970 | .9 | 13 | < .4 | <11 | 2.3 | |
| 37 | | 110 | | 7.8 | 1.5 | 860 | 2.3 | 6.7 | < .4 | <11 | 2.5 | |

CHEMICAL DATA ON CHRISTIAN COUNTY, KENTUCKY CORE

| SAMPLE NO. | GEOL. NO. | DEPTH (FT) | LA (PPM) | LU (PPM) | MO (PPM) (OE-D) | MO (PPM) (NAA) | NI (PPM) (OE-D) | NI (PPM) (OE-P) | NI (PPM) (NAA) | RB (PPM) | SM (PPM) | SC (PPM) | AG (PPM) (OE-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 | ND | 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 | 97 | 6.8 | 10 | < .8 | 110 |
| 13 | 13C1 | 2318.8 | 31 | .5 | 110 | 86 | 200 | 252 | 280 | 93 | 9.5 | 13 | < .8 | 160 |
| 33 | 08L1 | 2273.5 | 39 | .4 | 17 | 40 | 130 | 150 | 120 | 100 | 7.9 | 20 | < .7 | 170 |
| 34 | 10L1 | 2287.8 | 35 | .4 | 4 | 85 | 69 | 76 | 62 | 140 | 4.9 | 14 | < .8 | 220 |
| 35 | 11L1 | 2292.9 | 32 | .4 | 11 | 20 | 100 | 120 | 96 | 120 | 6.3 | 16 | < .6 | 150 |
| 36 | 12L1 | 2311.1 | 29 | .5 | 36 | ND | 140 | | 120 | 82 | 8.5 | 11 | | 150 |
| 37 | 13L1 | 2312.6 | 31 | .5 | 39 | 59 | 150 | | 160 | 84 | 7.5 | 12 | | 190 |

| SAMPLE NO. | SR (PPM) (OE-D) | TA (PPM) | TB (PPM) | TH (PPM) | SN (PPM) (OE-D) | SN (PPM) (OE-P) | U (PPM) | YB (PPM) | ZN (PPM) (OE-P) | ZN (PPM) (NAA) | ZN (PPM) (OE-D) | ZR (PPM) (OE-D) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 800001 | 110 | .9 | 1.1 | 7.1 | 2.4 | <1.4 | 61 | 2.3 | 72 | 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 | 2.0 | 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 | 1.0 | .8 | 14 | 4.4 | <1.7 | 5 | 2.9 | 43 | 150 | 66 | 180 |
| 07 | 250 | .8 | 1.2 | 9.1 | 3.8 | <1.4 | 45 | 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 | 9.7 | 6 | 3.3 | 83 | 150 | 61 | 200 |
| 10 | 150 | 1.0 | 1.0 | 11 | 3.6 | 15 | 6 | 3.3 | 120 | 140 | 98 | 130 |
| 11 | 170 | .7 | 1.1 | 7.6 | 3.6 | 4.2 | 3 | 3.1 | 160 | 210 | 80 | 190 |
| 12 | 130 | .6 | .7 | 6.0 | 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 | 260 | 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 | 72 | 150 |

CHEMICAL DATA ON CHRISTIAN COUNTY, KENTUCKY CORE

| SAMPLE NO. | GEOL. NO. | DEPTH (FT) | ZR (PPM) (OE-P) | 500 DEG. ASH (%) | ND (PPM) |
|---|---|---|---|---|---|
| S00001 | 01KY01C1 | 1822.2 | 210 | 79.68 | 32 |
| 02 | 02C1 | 2191.1 | 210 | 86.17 | 20 |
| 03 | 03C1 | 2220.3 | 220 | 87.62 | 31 |
| 04 | 04C1 | 2230.2 | 220 | 95.46 | 21 |
| 05 | 05C1 | 2240.1 | 270 | 90.12 | 80 |
| 06 | 06C1 | 2250.0 | 210 | 95.80 | 26 |
| 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 | 92.08 | 29 |
| 12 | 12C1 | 2310.5 | 130 | 92.06 | 28 |
| 13 | 13C1 | 2318.6 | 180 | 90.43 | 32 |
| 33 | 08L1 | 2273.5 | 180 | 89.13 | 39 |
| 34 | 10L1 | 2287.0 | 180 | 95.51 | |
| 35 | 11L1 | 2292.9 | 210 | 91.72 | 30 |
| 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) | 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) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| S00014 | 01IL01_2 | 1576.0 | 64.5 | 10.5 | 4.31 | 4.56 | 2.25 | 1.04 | 1.00 | 3.91 | 4.32 | .87 | .08 | 220 |
| 15 | 03_1 | 1589.4 | 71.8 | 8.54 | 2.61 | 3.07 | 1.84 | 2.03 | 1.25 | 2.98 | 3.43 | .93 | .33 | 290 |
| 16 | 04L1 | 1602.0 | 74.0 | 6.19 | 2.20 | 2.51 | 1.13 | .32 | 1.37 | 3.81 | 3.55 | .95 | .03 | 120 |
| 17 | 05L1 | 1615.1 | 70.4 | 6.77 | 2.88 | 3.55 | 1.48 | .39 | 1.22 | 3.47 | 4.11 | .99 | <.01 | 150 |
| 18 | 07L1 | 1631.6 | 51.7 | 6.81 | 2.07 | 3.00 | 2.59 | 15.5 | .88 | 2.35 | 2.60 | .56 | .31 | 960 |
| 19 | 09L1 | 1647.4 | 58.8 | 12.7 | 4.01 | 4.88 | 2.70 | 1.35 | 1.02 | 4.08 | 4.86 | .93 | .02 | 340 |
| 20 | 09L2 | 1656.2 | 65.4 | 12.1 | 4.72 | 5.72 | 1.62 | .30 | 1.11 | 4.26 | 4.95 | 1.00 | .05 | 240 |
| 21 | 10L1 | 1657.0 | 65.3 | 11.7 | 5.84 | 7.83 | 1.64 | .06 | .98 | 3.85 | 4.38 | .87 | .01 | 210 |
| 22 | 11L1 | 1667.5 | 57.9 | 13.9 | 5.00 | 6.52 | 1.90 | .01 | .71 | 5.40 | 6.10 | .84 | .06 | 260 |
| 23 | 12L1 | 1678.6 | 60.2 | 15.0 | 5.01 | 5.86 | 2.63 | .43 | .79 | 5.32 | 6.55 | .89 | <.01 | 280 |
| 24 | 13L1 | 1688.0 | 58.8 | 16.1 | 5.09 | 6.29 | 2.74 | .36 | .75 | 5.63 | 6.01 | .81 | .02 | 280 |
| 25 | 14L1 | 1698.2 | 56.5 | 14.1 | 5.20 | 6.29 | 2.22 | .52 | .75 | 4.69 | 5.31 | .77 | <.01 | 230 |
| 26 | 15L1 | 1710.9 | 51.5 | 13.2 | 5.19 | 6.88 | 2.17 | .18 | .59 | 4.96 | 5.90 | .66 | .05 | 240 |
| 27 | 16L1 | 1723.3 | 53.8 | 11.7 | 5.35 | 8.54 | 2.24 | .71 | .73 | 3.78 | 4.22 | .68 | .03 | 260 |
| 28 | 17L1 | 1730.5 | 57.1 | 12.2 | 4.62 | 6.49 | 1.54 | .61 | .82 | 3.74 | 4.29 | .66 | .04 | 230 |
| 29 | 18L1 | 1740.2 | 62.5 | 11.7 | 4.15 | 4.46 | 1.27 | .47 | .84 | 3.48 | 4.16 | .64 | .08 | 190 |
| 30 | 19L1 | 1753.5 | 55.0 | 12.2 | 5.62 | 5.65 | 1.67 | .56 | .75 | 3.66 | 4.82 | .62 | .10 | 270 |
| 31 | 20L1 | 1763.3 | 56.0 | 12.3 | 4.37 | 4.41 | 2.22 | 2.26 | .92 | 3.87 | 4.72 | .69 | .08 | 340 |
| 32 | 21L1 | 1776.2 | 56.4 | 14.8 | 4.83 | 3.84 | 2.15 | .77 | .75 | 4.86 | 5.94 | .67 | .03 | 340 |

| SAMPLE NO. | MN (PPM) (OE-P) | V (PPM) (OE-D) | V (PPM) (OE-P) | S (%) | CL (%) | TOTAL C (%) | ORGANIC C (%) | INORG. C (%) | H (%) | TOTAL CEC MEQ/100G | SR (PPM) | AS (PPM) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| S00214 | 240 | 220 | 270 | .02 | .13 | .88 | .43 | .45 | .75 | 7.3 | .6 | 2.6 |
| 15 | 290 | 76 | 140 | .05 | .06 | .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 | 6.0 |
| 21 | 180 | 75 | 110 | .49 | .09 | 1.30 | 1.28 | .02 | .78 | 6.7 | .9 | 9.8 |
| 22 | 270 | 170 | 192 | .27 | .10 | 2.93 | 2.90 | .03 | .91 | 9.4 | .9 | 7.7 |
| 23 | 310 | 140 | 180 | .10 | .12 | 1.88 | 1.72 | .16 | .66 | 7.7 | 1.2 | 6.2 |
| 24 | 270 | 160 | 190 | .31 | .14 | 2.96 | 2.90 | .06 | 1.07 | 6.2 | 1.2 | 10 |
| 25 | 220 | 160 | 240 | .54 | .12 | 4.34 | 4.26 | .08 | 1.09 | 9.3 | 1.7 | 19 |
| 26 | 200 | 220 | 200 | .52 | .09 | 7.61 | 7.54 | .07 | 1.49 | 11.4 | 4.6 | 25 |
| 27 | 240 | 240 | 240 | 1.20 | .09 | 9.74 | 9.59 | .15 | 1.54 | 6.0 | 6.6 | 22 |
| 28 | 200 | 120 | 160 | 1.10 | .09 | 6.55 | 6.50 | .05 | 1.01 | 8.6 | 2.8 | 14 |
| 29 | 200 | 140 | 170 | .92 | .09 | 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 | .80 | .09 | 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 | 01IL01L2 | 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 | 410 | 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 | <4 | 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 | 90 | 110 | 25 | 26 |
| 27 | 16L1 | 1723.4 | 1230 | 3.2 | 5.1 | 120 | <5 | 100 | 9.5 | 96 | 73 | 96 | 44 | 47 |
| 28 | 17L1 | 1730.6 | 860 | 3.9 | 4.4 | 132 | <4 | 92 | 5.9 | 110 | 74 | 64 | 29 | 21 |
| 29 | 18L1 | 1740.2 | 550 | 3.5 | 3.7 | 130 | <7 | 58 | 6.5 | 62 | 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 | 102 | 120 | 11 | 16 |

| SAMPLE NO. | 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 | 5.6 | 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 | <12 | 8.0 | <2.4 |
| 19 | 13 | 8.4 | 22 | 4.5 | 1.2 | 560 | 2.0 | 22 | 1.6 | <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 | 602 | 2.3 | 16 | 2.4 | <11 | 7.1 | <2.3 |
| 22 | 26 | 34 | 63 | 3.9 | 1.2 | 972 | 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 | 28 | 39 | 4.5 | 1.1 | 942 | 2.0 | 25 | .6 | <11 | 4.8 | 24 |
| 25 | 17 | 32 | 54 | 5.1 | 1.2 | 815 | 1.9 | 22 | 1.5 | <11 | 4.8 | 17 |
| 26 | 32 | 59 | 74 | 5.1 | 1.3 | 945 | 2.2 | 21 | 1.2 | <12 | 4.0 | 37 |
| 27 | 45 | 150 | 260 | 6.7 | 1.4 | 675 | 3.3 | 14 | 1.2 | <12 | 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 | 642 | 1.7 | 11 | 1.5 | <11 | 4.4 | 19 |
| 30 | 38 | 56 | 66 | 6.2 | 1.4 | 865 | 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. | GEOL. NO. | DEPTH (FT) | LA (PPM) | LU (PPM) | MO (PPM) (OE-D) | MO (PPM) (NAA) | NI (PPM) (OE-D) | NI (PPM) (OE-P) | NI (PPM) (NAA) | RB (PPM) | SM (PPM) | SC (PPM) | AG (PPM) (OE-P) | SR (PPM) (NAA) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| S00014 | 01IL01L2 | 1576.0 | 36 | .4 | < .4 | ND | 38 | 55 | 49 | 160 | 5.3 | 15 | < .8 | |
| 15 | 02L1 | 1589.4 | 45 | .7 | < .4 | ND | 23 | 25 | 29 | 110 | 14 | 10 | < .8 | 110 |
| 16 | 04L1 | 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 | 7.8 | 10 | < .8 | 56 |
| 19 | 08L1 | 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 | 10L1 | 1657.6 | 34 | .4 | 16 | 31 | 38 | 50 | 43 | 190 | 5.9 | 18 | < .8 | |
| 22 | 11L1 | 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 | 38 |
| 25 | 14L1 | 1698.2 | 39 | .3 | 21 | 28 | 61 | 98 | 70 | 220 | 6.3 | 21 | < .8 | |
| 26 | 15L1 | 1710.0 | 33 | .4 | 82 | 110 | 78 | 99 | 91 | 230 | 6.0 | 22 | < .7 | |
| 27 | 16L1 | 1723.4 | 33 | .4 | 96 | ND | 79 | 130 | 100 | 210 | 13 | 21 | < .7 | 31 |
| 28 | 17L1 | 1732.5 | 30 | .3 | 39 | ND | 60 | 48 | 33 | 190 | 11 | 19 | < .7 | |
| 29 | 18L1 | 1740.2 | 32 | .3 | 47 | 100 | 53 | 76 | 42 | 140 | 9.2 | 15 | < .7 | 80 |
| 30 | 19L1 | 1753.5 | 34 | .4 | 67 | 140 | 77 | 96 | 69 | 120 | 7.5 | 16 | < .7 | |
| 31 | 20L1 | 1763.3 | 34 | .4 | 22 | ND | 61 | 66 | 69 | 130 | 5.4 | 15 | < .6 | 100 |
| 32 | 21L1 | 1776.2 | 38 | .3 | 29 | ND | 125 | 150 | 110 | 140 | 5.6 | 17 | < .8 | |

| SAMPLE NO. | SR (PPM) (OE-D) | TA (PPM) | TB (PPM) | TH (PPM) | SN (PPM) (OE-D) | SN (PPM) (OE-P) | U (PPM) | YB (PPM) | ZN (PPM) (OE-P) | ZN (PPM) (NAA) | ZN (PPM) (OE-D) | ZR (PPM) (OE-D) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| S00014 | 73 | 1.3 | .6 | 12 | 3.9 | 11 | <5 | 2.4 | 48 | 92 | 59 | 240 |
| 15 | 91 | 1.4 | 1.6 | 11 | 1.7 | <1.7 | <6 | 3.6 | 57 | 51 | 30 | 325 |
| 16 | 91 | 1.5 | 1.0 | 12 | 2.6 | 8.7 | <5 | 3.1 | 180 | 110 | 130 | 425 |
| 17 | 62 | 2.0 | 1.1 | 16 | 2.3 | 8.7 | <5 | 3.3 | 40 | 71 | 49 | 420 |
| 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 | <6 | 2.6 | 32 | 180 | 29 | 280 |
| 20 | 89 | 1.5 | .9 | 15 | 4.7 | 6.7 | <4 | 2.5 | 110 | 150 | 83 | 310 |
| 21 | 64 | 1.7 | 1.1 | 14 | 3.8 | 5.2 | <6 | 2.4 | 840 | 1290 | 920 | 250 |
| 22 | 72 | 1.7 | .9 | 15 | 9.1 | 15 | <6 | 2.3 | 100 | [illegible] | 75 | 210 |
| 23 | 75 | 1.6 | .8 | 15 | 7.2 | 18 | <6 | 2.4 | 100 | 120 | 97 | 220 |
| 24 | 67 | 1.5 | .9 | 15 | 6.5 | 16 | 5 | 2.2 | 130 | 110 | 58 | 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 | 3.6 | 22 | 2.3 | 270 | 280 | 170 | 130 |
| 27 | 64 | 1.6 | 1.2 | 14 | 3.7 | 7.5 | 31 | 3.0 | 100 | 140 | 66 | 170 |
| 28 | 64 | 1.2 | 1.1 | 12 | 4.9 | 6.5 | 17 | 2.4 | 55 | 220 | 53 | 180 |
| 29 | 60 | 1.0 | .7 | 6.6 | 4.9 | 9.0 | 14 | 1.9 | 93 | 80 | 92 | 170 |
| 30 | 63 | 1.0 | .7 | 8.2 | 5.0 | 6.1 | 33 | 1.7 | 33 | 76 | 35 | 130 |
| 31 | 80 | 1.2 | .7 | 10 | 5.0 | 10 | 6 | 2.3 | 22 | 44 | 34 | 300 |
| 32 | 69 | .8 | .6 | 6.4 | 6.2 | 11 | 10 | 1.4 | 100 | 210 | 65 | 160 |

CHEMICAL DATA ON SANGAMON COUNTY, ILLINOIS CORE

| SAMPLE NO. | GEOL. NO. | DEPTH (FT) | ZR (PPM) (DE-P) | 500 DEG. ASH (%) | ND (PPM) |
|---|---|---|---|---|---|
| S00014 | 01IL01L2 | 1576.0 | 470 | 96.50 | 18 |
| 15 | 03L1 | 1589.4 | 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 | 96.44 | 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 | 1678.6 | 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 | 1732.6 | 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

*U.S. GOVERNMENT PRINTING OFFICE: 1978-740-306/9545. Region 4.