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FOSSIL ENERGY

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

Third Quarterly Progress Report, April 1—June 30, 1978

By
Robert E. Bergstrom
Neil F. Shimp

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

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

Quarterly Progress Report - April 1-June 30, 1978
Report ORO-EY-76-C-05-5203-9

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 is being 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.

Advise DOE on Drill Sites and Coring

Progress

Negotiations are underway between a drilling contractor (Rector and Stone) and DOE for a contract to take a DOE core at a "grass roots" location near Hick's Dome in Hardin County. Permission to drill has been given by the corporation owning the proposed site. This is one of the few locations in Illinois that a meaningful core can be taken without first penetrating several hundred or thousand feet of younger formations. Plans are being made to process the core material recovered in this drilling.

Problems

The lack of good core material from the central part of the basin continues to pose a problem for our work and will only be partially rectified by the Hardin County core. It is likely that accurate readings on potential gas content of the shale will not be obtained on the Hardin County core due to shallowness and disturbance, but it is hoped that mineralogic, petrographic, and chemical studies will be meaningful. We continue to remain in contact with operators who may be drilling the deeper parts of the Illinois Basin.

New Albany Well Map and Tabulation

Progress

The last quadrant of the computer-produced maps showing locations of holes penetrating the New Albany Shale in Illinois has been produced (milestone9). A map of the entire Illinois portion of the Illinois Basin is being plotted to a scale of 1:500,000. The original scales specified by MERC were 1:1,000,000 (which is too small as individual well sites cannot be discriminated) and 1:250,000 (which is needlessly large). Therefore we propose to submit final copies of the basin map at 1:500,000 for the well tabulation.

Well data on these tabulated Devonian tests were corrected and updated during the tabulation process and now form a permanent part of the Survey computer files.

Stratigraphic Cross Sections

Progress

A long cross section extending from the deep basin in Crittenden County, Kentucky, to west-central Illinois has been completed. This cross section includes the best avilable geophysical logs complemented by sample studies for all wells for which samples are avilable. For purposes of illustration, this section will probably be reduced to a more interpretive, more compact, "vertical slice" type cross section.

Discussion

The cross section is the best to date for illustrating details of facies changes and age relationships between the western Illinois section and the deep basin section of southeastern Illinois.

The cross section clearly demonstrates that the base of the New Albany Shale is older in the deep basin than in marginal areas. In fact, the base of the New Albany in western Illinois appears approximately equivalent in age to the base of the Grassy Creek Shale in the deep basin.

The cross section also shows that black shale deposition began earlier and persisted later in the deep basin than in marginal areas. Only the most prominent black shale horizons of the deep basin can be traced with much assurance into the distant marginal areas, and in the marginal areas, they are much thinner and less prominent in their geophysical characteristics. The base of the Hannibal-Saverton Shale sequence is older in western Illinois than in the deep basin, where its equivalents are largely black shale of the upper Grassy Creek.

Isopach Maps

Progress and Problems

The total thickness map for the New Albany Group is nearly finished although some problems remain, particularly where data are sparse or unreliable. A more generalized scaled-down version of the New Albany thickness map is included with this report (fig. 1). Facies transitions still pose the greatest problems in finalizing thickness values of subunits, but progress is being made toward reasonable solutions. Some of the problems of basin-wide correlation (with Indiana and Kentucky) were discussed briefly in our monthly report for May.

Discussion

Recognition of stratigraphic cutoffs, pinchouts, and erosional boundaries is important to the interpretation of the New Albany total thickness map (fig. 1). The thickest New Albany deposits are in the Devonian depocenter in southeastern Illinois. The group thins abruptly (as shown by offsets in thickness contours) along a line of vertical cutoff. This cutoff represents the westward transition of the Blocher Shale (basal formation of the New Albany Group) into the upper portion of the Lingle Limestone. The line is, of course, only a convenient method of representing a transition which actually happens more gradually.

The Chouteau Limestone, which generally overlies the New Albany conformably, is absent in a few small areas of southeastern and east-central Illinois. These areas are indicated on the map. In the southern-most of these areas, the top of the black Grassy Creek Shale is taken as the top of the New Albany Group because it is not practical to distinguish a very thin Hannibal Shale from the overlying Springville Shale in the absence of the intervening Chouteau Limestone.

Thickness contouring of the New Albany is relatively straightforward in areas where it is conformably overlain by the Chouteau Limestone, but becomes more dubious where the Chouteau and upper New Albany have been eroded. Over a large area of west-central Illinois, the New Albany is unconformably overlain by Valmeyeran (middle Mississippian) strata, mainly the Burlington Limestone or Fern Glen Formation. Although New Albany thicknesses are somewhat erratic in this area, a very general thickness contouring is both practical and meaningful. On the northern edge of its occurrence in Illinois, the New Albany is deeply eroded and overlain by Pennsylvanian strata and in some areas by Pleistocene drift. In these areas data are generally sparse, of questionable reliability, and thicknesses are erratic. For these reasons it does not appear very practical to contour thickness in these areas.

Workman and Gillette (1956) interpreted the general thickness pattern of the Kinderhookian strata (in which they included the entire New Albany) as representing two basins, the Illinois Basin in the southeast and the Petersburg Basin in west-central Illinois, separated by a northeast-southwest trending positive structure called the Vandalia Arch. Noting the facies distributions relative to thickness, Cluff and Reinbold (1978) suggested that the New Albany deposits may instead represent a thick shallow-water shelf section (in place of the Petersburg Basin) in west-central Illinois; a thin basin slope section in place of the Vandalia Arch; and a thick deep basin section in southeastern Illinois.

References

Cluff, Robert M., and Mark L. Reinbold, 1978, Anoxic conditions during New Albany Shale Group (Devonian-Mississippian) deposition in the Illinois Basin (abs.): Geological Soc. America Abstracts with Programs, v. 10, no. 6, p. 294.

Workman, L. E., and Tracy Gillette, 1956, Subsurface Stratigraphy of the Kinderhookian Series in Illinois: Illinois Geol. Survey Rept. of Inv. 189, 46 p.

Sample Studies

Progress

One hundred and fifteen sample sets have been examined since March 1978. Detailed sample logs of about 100 critical wells have been completed. Geophysical logs were used to adjust the lithology to the geophysical characterics of the New Albany Shale. Samples for vitrinite reflectance, clay mineralogy, and chemical analysis were collected from each well at each 100 foot vertical interval. Samples were picked carefully to avoid contamination. In addition, the lithology of the New Albany interval was characterized along with its geophysical characteristics for each well.

Problems

Sampling of some wells is impossible because of contamination of the samples with material caved from younger formations. Missing samples sometimes make sample studies impossible or incomplete. Generally this means moving on to a well not on the cross section or a well with less adequate geophysical logs in the same area.

Biostratigraphy

Progress

Samples from near the top of the New Albany Shale at Hick's Dome in Hardin County have been given to paleontologists of the Illinois Survey to process for Conodont specimens. If these samples are found productive, good outcrop sections and cores may be sampled systematically. Biostratigraphic control could be very helpful in determining age and facies relationships in the shale sequence.

Data Formats and Computer Maps

Progress

The following revisions in the formats for entering Devonian well data on thickness of units have been made.

Card 1

col. 3-5 County Code (col. 5 is never blank)

Card 2

col. 1-2 State code

col. 3-5 County code

col. 6-10 County well number

Move card number to col. 11-12

col. 13-15 Blank

Move Blocher Shale to col. 16-24

Move Hunton Mega-group to col. 25-33

Considerable testing of the reliability of the mapping program in the 5-county test area in southeastern Illinois was conducted during this quarter. Most problems with the programs have been worked out.

Linears

Progress

A number of prominent linear features in Illinois in areas where the New Albany Group is in the subsurface were re-examined in preparation for the DOE Eastern Gas Shale Project Linears Workshop held in Morgantown on 6 June. J. A. Lineback of the Survey staff made a presentation of the results of the linear study at the workshop.

The upper midwest has been repeatedly glaciated over the past two to three million years. These glacial events have left a complex cover of glacial drift over the preglacial bedrock surface. The glacial deposits tend to smooth out and obliterate bedrock topography and, in addition, the glaciers have left their own imprint on the landscape. Constructional and destructional glacial landforms are visible on space and air photographs of many areas of Illinois underlain by the New Albany Group. The glacial landforms include drumlins, eskers, crevasse fillings, glacial fluting, and former ice-walled stream channels. Some of these features exhibit remarkable linearity that can and has been misinterpreted as the effect of bedrock faults, joints, or other linear structures.

Medium scale (10-100 km) linear features are very pronounced in western Illinois. The glacial drift cover in this area varies from less than 10 m to more than 80 m. The longest linear is over 70 km in length, 1 to 3 km wide, and up to 30 m deep. This linear cuts into bedrock highs in places and also cuts across drift filled preglacial bedrock valleys. It and similar, but less pronounced, linear depressions are glacial in origin, but the exact mechanism of their formation is not known. Two main theories have been proposed. One is that they represent glacial fluting or gouging at the base of the ice sheet and therefore parallel the direction of ice movement. The other theory contends that the linears were cut by streams flowing in ice-walled crevasses in a stagnant and melting glacier. The linearity is inherited from the linear crevasse system in the ice.

Small scale linear features (1 to 10 km) have been identified in air photos taken over western Illinois. These linear features have been identified as drumlins and related landforms. Drumlins are deposits of glacial drift that have been moulded into streamlined shapes as they were over-ridden by glacial ice. Their long axes parallel ice movement.

Small scale (1 km) drainage patterns in the area of glacial fluting and drumlins also show linearity. However, these features are oriented at right angles to the major features. Since the drumlinized and fluted drift represents a primary depositional surface, drainage incipient on this surface will develop a trellis pattern. The major drainageways will parallel the drumlins and linear fluting, and the small drainage will flow at right angles, directly perpendicular to the linear slopes of the flutes and drumlins.

Those who study linears in glaciated terrane must be aware that constructional and destructional glacial landforms can have pronounced linearity and can be mis-interpreted as possible bedrock influenced linear patterns.

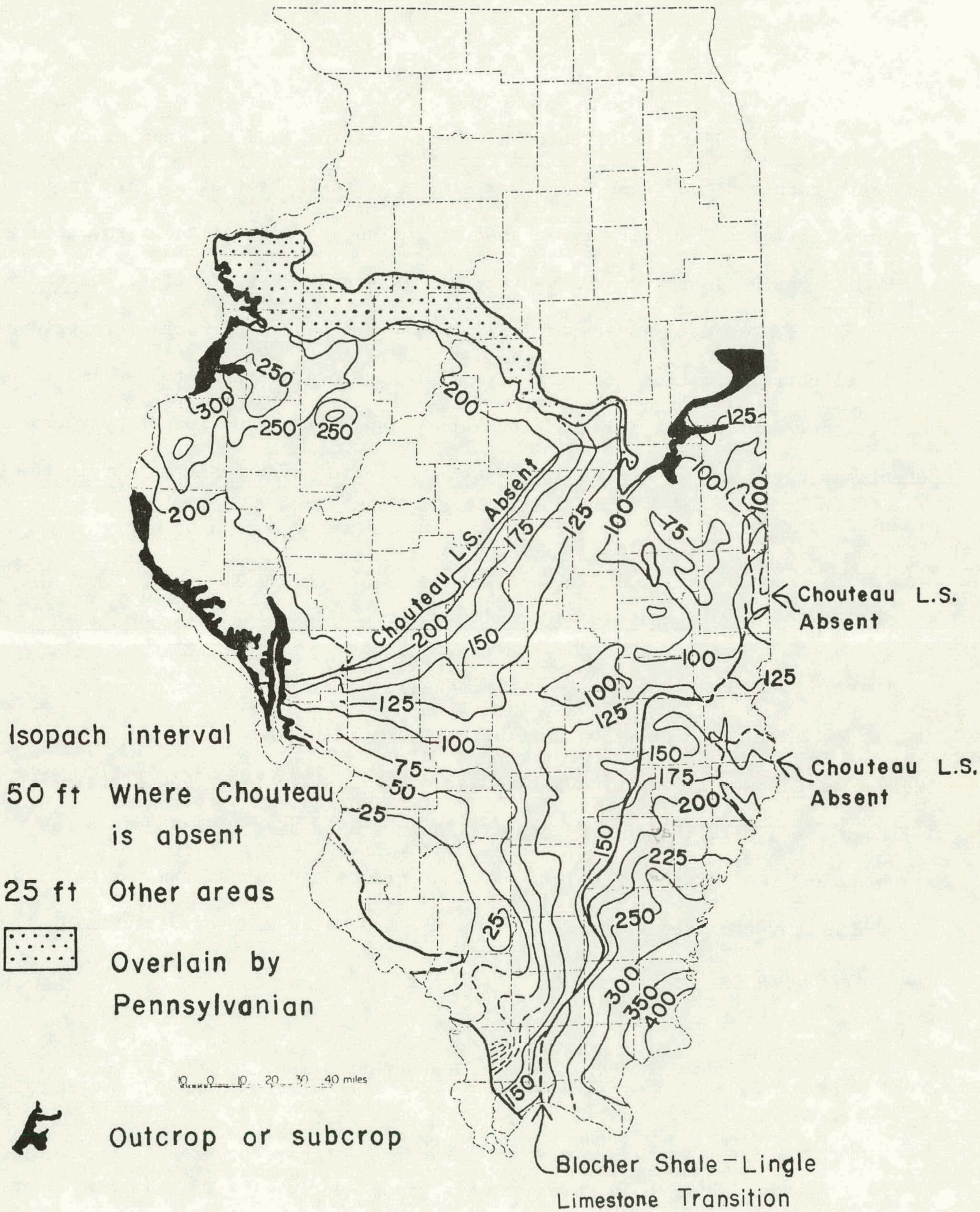

Fig. 1. Total thickness of New Albany Shale Group.

MINERALOGIC AND PETROGRAPHIC CHARACTERIZATION

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, diagenetic history, and for evaluation of hydrocarbon potentials based on the degree of thermal maturation of organic matter in the New Albany Shale.

Lithologic and Radiographic Characterization

Progress

During the previous quarter, all available samples from the 04IL (Henderson County, Illinois), 05IL (Edgar County, Illinois), 06IL (Tazewell County, Illinois), and 07IL (Fayette County, Illinois) cores were embedded in epoxy, slabbed, and radiographed. Thirty-one radiographs and slabs from the 04IL core have been characterized to date. Prints are now being made of all remaining radiographs and no further delays are anticipated.

Microscopic Characterization

Progress

Forty-seven thin sections were prepared from the 03IL (White County, Illinois), 04IL, and 06IL cores during the last quarter. An additional 15 thin sections of rotary drill cuttings from various wells in Illinois were also prepared and described. Twenty-five thin sections, all from the 04IL core, have been described in detail. Characterization of the remaining samples is being postponed until radiographs are available.

Preparation and examination of twelve scanning electron microscopy samples was begun in May. Information on the fabric, mineralogy, and microfossils is expected to result from this work. More details of the work will be reported next month.

Problems

Thin section preparation was delayed during the previous quarter due to the lack of materials and parts. Our thin section machine required a new grinding plate, which was not received until mid-June. The machine is now in full operation, and we expect to complete all thin sectioning during July. Characterization of the samples should be completed by late July or early August.

X-ray Diffraction Mineralogy and Clay Orientation

Clay mineralogy, clay orientation, and silt mineralogy have been completed for the 03IL, 04IL, 05IL, 06IL, 07IL, and 09IL cores. Updated computer printouts of all the data on these cores are given in Tables 1 through 10.

In addition, forty whole-rock samples in Illinois have been run. Some of these samples are notable because kaolinite was detected. Kaolinite is usually absent in the samples of New Albany shales we have studied.

Vitrinite Reflectance

Progress

Vitrinite reflectance analysis of the 04IL and 06IL cores was completed in April. The results are summarized in Tables 11 and 12 and Figures 1 and 2. These average random reflectance values are consistent with their position in the basin as they are approximately the same as the value obtained for the 05IL core, and they are lower than values measured in samples obtained from the southern portion of the state.

Vitrinite reflectance analysis of the 07IL and 09IL (St. Clair County, Illinois) cores and twenty supplementary drill cutting samples was completed in May. The results are summarized in Table 13 and in Figures 3 and 4. The average random reflectance value of the 07IL core is approximately the same as the value for the 02IL (Effingham County, Illinois) core and is consistent with its position in the basin.

The vitrinite reflectance data for the 20 supplementary drill cutting samples indicate an increase in vitrinite reflectance toward the structurally deeper portion of the basin in southeastern Illinois (fig. 4). The highest reflectance values obtained to date were from drill cutting samples in Wayne County. The values ranged from 0.62 to 0.70 and indicate the highest degree of thermal maturity found thus far. Some inconsistency in the reflectance values from the drill cutting samples may be expected despite carefully picking of the samples as in some cases contamination from shales above may be very difficult to detect.

Acid and heavy mineral separation has been completed for 22 more supplementary drill cutting samples and polishing of the samples is now in progress.

Problems

Problems with the sample mounting method used by the INIEX coal research laboratory in Liege, Belgium, delayed the preparation of twenty-seven drill cutting samples and four 06IL samples. For reasons still undetermined, the ethyl acetate used does not completely dissolve the filter paper on which the samples have been sedimented. Because of this problem, the samples have been mixed with epoxy, mounted on blocks, and polished. This method, similar to one followed by Chevron Oil Field Research Company, is slightly faster than our original method.

Papers

R. M. Cluff and M. L. Reinbold presented a paper on the lithofacies of the New Albany Shale at the annual meeting of the North-Central Section of the Geological Society of America, May 1-2, 1978, Ann Arbor. The abstract, entitled "Anoxic Conditions During New Albany Shale Group (Devonian-Mississippian) Deposition in the Illinois Basin", appeared in G.S.A. Abstracts with Programs, v. 10, no. 6, p. 249.

Three abstracts concerning different aspects of the project were prepared for consideration for presentation at the October 1978 annual meeting of the Geological Society of America, Toronto. One abstract, entitled "Organism-sediment Relationships in the New Albany Shale Group (Devonian-Mississippian) of Illinois", has been accepted for presentation at the "Fossils and Shales" symposium sponsored by the Paleontological Society and Society of Economic Paleontologists and Mineralogists.

The other abstracts, concerning our research on vitrinite reflectance of the shales and on some unusual microfossils in the 01KY (Christian County, Kentucky) core are still under consideration.

Copies of all four abstracts are appended to this report.

TABLE 1 - CLAY MINERALOGY AND ORGANIC CONTENT, WHITE COUNTY, ILLINOIS, CORE SAMPLES.

SAMPLE NUMBER	DEPTH*	clays (parts/10)			LTA
		ILL	CHL	EXP	%
03IL04L1	4510	7.0	1.0	2.0	9.6
03IL09L1	4560	8.0	1.0	1.0	4.5
03IL19L1	4661	6.5	1.5	2.0	9.1
03IL20L2	4675	8.5	0.0	1.5	3.1
03IL22L1	4695	8.5	1.0	1.0	3.3
03IL24L1	4715	7.5	0.0	2.5	2.4
03IL26L2	4744	7.0	0.0	3.0	2.5

*Depth (to top of sample) below drilling reference at 385 feet above mean sea level.

Column Headings: ILL = illite; CHL = chlorite; KAO = kaolinite; EXP = expandable mixed-structure clays; COI = clay orientation index; LTA = organic content determined by weight loss during low-temperature ashing.

TABLE 2 - CLAY MINERALOGY AND ORIENTATION, HENDERSON COUNTY, ILLINOIS, CORE SAMPLES.

SAMPLE NUMBER		DEPTH*	clays (parts/10)				COI
			ILL	CHL	KAO	EXP	
04IL01C1		323.3	7.5	2.5	0.0	0.0	1.4
04IL02C1		333.0	6.0	2.0	0.0	1.5	1.5
04IL03C1		343.4	5.5	2.5	0.0	2.0	1.0
04IL04C1		353.0	6.0	2.5	0.0	1.5	1.9
04IL05C1		363.3	5.5	2.0	0.0	2.5	1.3
04IL06C1		373.2	5.5	2.5	0.0	2.0	1.5
04IL07C1		383.4	5.0	2.0	0.0	3.0	1.2
04IL08C1		393.1	5.0	2.5	0.0	2.5	1.5
04IL09C1		403.5	5.0	2.0	0.0	3.0	1.3
04IL10C1		413.4	6.0	3.0	0.0	1.5	1.4
04IL11C1		424.4	5.5	3.0	0.0	1.5	1.2
04IL12C1		433.3	6.0	2.5	0.0	1.5	1.5
04IL13C1		443.2	6.0	2.5	0.0	1.5	1.5
04IL14C1		453.0	6.5	2.5	0.0	1.0	2.5
04IL15C1		463.2	5.5	2.5	0.0	1.5	1.7
04IL16C1		473.0	5.0	2.0	0.0	3.0	1.3
04IL17L1		480.2	6.5	2.5	0.0	1.0	1.2
04IL17C1		482.4	5.0	2.5	0.0	3.0	1.3
04IL18C1		493.2	5.0	2.5	0.0	2.5	1.1
04IL19C1		503.2	6.5	2.0	0.0	1.0	1.1
04IL19L1	1	505.7	5.5	2.5	0.0	2.0	1.6
04IL19L1	2	505.7	0.0	0.0	0.0	0.0	3.3
04IL20C1		513.4	6.5	2.0	0.0	1.5	1.4
04IL21C1		523.2	6.5	2.0	0.0	2.0	2.0
04IL22C1		533.0	5.5	2.5	0.0	1.5	1.7
04IL23C1		542.2	5.0	2.5	0.0	2.5	1.9
04IL24C1		553.4	6.5	2.5	0.0	1.5	1.3
04IL25C1		563.2	6.5	2.5	0.0	1.5	1.4
04IL26C1		573.0	6.0	2.5	0.0	1.5	1.2
04IL27L1	1	582.6	6.5	3.0	0.0	.5	1.3
04IL27L1	2	582.6	0.0	0.0	0.0	0.0	1.0
04IL27C1		583.4	6.0	2.5	0.0	1.5	1.3
04IL28C1		593.2	5.5	2.5	0.0	2.0	1.1
04IL29L1		603.2	5.5	2.0	.5	1.5	1.3
04IL29L1	2	603.2	5.0	1.5	0.0	3.0	****
04IL29L1	3	603.2	7.5	2.0	0.0	.5	****
04IL29C1		604.5	6.5	1.5	0.0	2.0	****
04IL30C1		613.3	6.0	2.0	0.0	2.0	****

*Depth (to top of sample) below drilling reference at 772 feet above mean sea level.

See Table 1 for column headings.

TABLE 3 - CLAY MINERALOGY AND ORIENTATION, EDGAR COUNTY, ILLINOIS, CORE SAMPLES.

SAMPLE NUMBER	DEPTH*	clays (parts/10) ILL	CHL	KAO	EXP	COI
Ø5ILØ1L1	655.9	4.5	2.5	.5	2.5	1.7
Ø5ILØ1L2	660.2	5.Ø	2.5	.5	2.Ø	1.7
Ø5ILØ1L3	662.2	4.Ø	2.Ø	.5	3.5	1.5

*Depth (to top of sample) below drilling reference at 654 feet above mean sea level.

See Table 1 for column headings.

TABLE 4 - CLAY MINERALOGY AND ORIENTATION, TAZEWELL COUNTY, ILLINOIS, CORE SAMPLES.

SAMPLE NUMBER		DEPTH*	clays (parts/10)				COI
			ILL	CHL	KAO	EXP	
06IL04C1		933.4	4.5	2.0	0.0	3.5	.9
06IL05C1		943.5	7.5	2.0	0.0	.5	****
06IL06C1		954.0	5.5	2.0	0.0	2.5	1.2
06IL07C1		962.2	5.0	2.0	0.0	2.5	1.2
06IL08C1		973.4	5.5	2.5	0.0	2.5	1.2
06IL09C1		984.2	5.5	2.5	0.0	2.0	1.3
06IL10C1		993.1	5.0	2.5	0.0	2.5	1.3
06IL11C1		1003.2	6.0	3.0	0.0	1.0	1.3
06IL11L1		1005.3	6.0	2.5	0.0	1.5	2.5
06IL12C1		1014.1	6.5	3.0	0.0	1.0	1.5
06IL13C1		1024.1	6.0	2.5	0.0	1.0	2.0
06IL13L1		1025.5	4.5	2.0	0.0	3.5	1.4
06IL13L1	2	1025.5	0.0	0.0	0.0	0.0	2.0
06IL13L2		1029.1	5.0	2.5	0.0	2.5	2.9
06IL14L1	1	1032.8	4.5	2.5	.5	2.5	2.2
06IL14L1	2	1032.8	0.0	0.0	0.0	0.0	1.9
06IL14C1		1034.2	6.0	2.5	0.0	1.5	1.6
06IL15C1		1044.1	6.0	2.5	0.0	1.5	1.1
06IL16C1		1053.2	6.5	2.0	0.0	1.0	1.4
06IL17C1		1063.2	6.5	2.0	0.0	1.5	1.9
06IL18C1		1073.3	6.5	2.0	0.0	1.0	1.9
06IL19C1		1083.2	7.0	2.5	0.0	.5	1.6
06IL19L1		1085.2	6.5	2.5	.5	.1	1.7
06IL19L1	2	1085.2	0.0	0.0	0.0	0.0	1.8
06IL20C1		1093.4	6.0	3.0	0.0	1.0	1.8
06IL21L1	1	1101.8	5.0	2.5	.1	2.0	1.5
06IL21L1	2	1101.8	0.0	0.0	0.0	0.0	2.0
06IL21C1		1103.1	6.5	2.5	0.0	1.0	1.7
06IL22L1		1111.4	6.0	2.5	.1	2.0	1.3
06IL22L1	2	1111.4	0.0	0.0	0.0	0.0	1.7
06IL22C1		1113.4	6.5	2.5	0.0	1.0	1.4
06IL23C1		1123.5	6.5	2.5	0.0	1.0	1.9
06IL24C1		1133.4	6.0	2.5	0.0	1.5	1.2
06IL25L1	1	1141.1	7.5	2.5	0.0	.1	1.3
06IL25L1	2	1141.1	0.0	0.0	0.0	0.0	1.8
06IL25C1		1143.5	6.0	1.5	0.0	2.5	2.4
06IL25L2	1	1145.7	0.0	0.0	0.0	0.0	2.0
06IL25L2	2	1145.7	0.0	0.0	0.0	0.0	1.9

*Depth (to top of sample) below drilling reference at 641 feet above mean sea level.

See Table 1 for column headings.

TABLE 5 - CLAY MINERALOGY AND ORIENTATION, FAYETTE COUNTY, ILLINOIS (07IL), AND ST. CLAIR COUNTY, ILLINOIS (09IL), CORE SAMPLES.

SAMPLE NUMBER	DEPTH*	clays (parts/10) ILL	CHL	EXP	COI
07IL01L1	2719	6.5	2.0	1.5	1.0
07IL01L2	2731	5.0	2.5	3.0	1.0
07IL01L3	2737	7.5	2.0	1.0	1.0
07IL02L1	2771.8	6.0	2.5	1.5	****
07IL02L2	2773.0	6.0	2.0	2.0	1.0
07IL03L1	2780.4	5.5	2.0	2.5	1.2
07IL04L1	2811.0	7.0	2.5	.5	1.7
07IL04L2	2813.1	7.0	2.5	.5	1.4
07IL05L1	2821.5	6.0	2.0	2.0	****
09IL01L3	1774	6.5	2.5	1.0	****

*Depth (to top of sample) below drilling reference at 525 feet above mean sea level for 07IL core; 474 feet above mean sea level for 09IL core.

See Table 1 for column headings.

TABLE 6 - WHOLE ROCK MINERALOGY, WHITE COUNTY, ILLINOIS, CORE SAMPLES.

OBSERVED PEAK HEIGHTS (COUNTS/SEC)

SAMPLE	DEPTH*	MCA	QTZ	FLD	KSP	PLG	KSP/PLG	CAL	DOL	CAL+DOL	SID+APA	PYR	MAR	PYR+MAR	MINERAL
NUMBER		19.8	20.8	23.5	27.6	27.9		29.4	30.8		32.1	33.2	52.0		TWO THETA
03IL01L1	4480	35	66	15	0	30	0/100	305	40	345	15	0	0	0	
03IL07L1	4540	45	144	20	0	50	0/100	12	40	52	15	45	17	62	
03IL12L1	4590	55	132	25	35	50	41/ 58	0	35	35	17	30	13	43	
03IL20L1	4673	72	120	33	50	65	43/ 56	20	97	117	15	10	0	10	
03IL20L3	4676	47	107	35	45	55	44/ 54	0	213	213	15	10	0	10	
03IL23L1	4705	48	122	25	0	53	0/100	15	93	108	10	37	5	42	
03IL26L1	4735	52	137	30	50	45	52/ 47	30	135	165	10	16	0	16	

*Depth (to top of sample) below drilling reference at 385 feet above mean sea level.

MCA = mica; QTZ = quartz; FLD = all feldspars; KSP = potassium feldspar; PLG = plagioclase; CAL = calcite; DOL = dolomite; SID & APA = siderite and/or apatite; PYR = pyrite; MAR = marcasite.

TABLE 7 - WHOLE ROCK MINERALOGY, HENDERSON COUNTY, ILLINOIS CORE SAMPLES.

OBSERVED PEAK HEIGHTS (COUNTS/SEC)

SAMPLE	DEPTH*	MCA	QTZ	FLD	KSP	PLG	KSP/PLG	CAL	DOL	CAL+DOL	SID+APA	PYR	MAR	PYR+MAR	MINERAL
NUMBER		19.8	20.8	23.5	27.6	27.9		29.4	30.8		32.1	33.2	52.0		TWO THETA
04IL01C1	323.3	65	125	50	70	0	100/ 0	0	245	245	15	12	0	12	
04IL02C1	333.0	60	145	35	65	0	100/ 0	0	280	280	20	25	0	25	
04IL03C1	343.4	60	110	40	55	0	100/ 0	0	360	360	15	15	0	15	
04IL04C1	353.0	65	105	45	70	0	100/ 0	0	230	230	12	10	0	10	
04IL05C1	363.3	55	120	45	65	0	100/ 0	0	360	360	12	20	0	20	
04IL06C1	373.2	60	120	55	75	0	100/ 0	0	265	265	10	17	0	17	
04IL07C1	383.4	70	100	65	75	0	100/ 0	0	225	225	20	20	0	20	
04IL08C1	393.1	60	90	55	35	0	100/ 0	0	200	200	15	20	0	20	
04IL09C1	403.5	60	100	50	55	0	100/ 0	0	160	160	17	15	0	15	
04IL10C1	413.4	70	110	50	55	0	100/ 0	0	135	135	12	10	0	10	
04IL11C1	424.4	60	105	45	50	0	100/ 0	0	165	165	15	20	0	20	
04IL12C1	433.3	60	115	45	70	0	100/ 0	0	165	165	12	25	0	25	
04IL13C1	443.2	60	110	50	70	0	100/ 0	0	150	150	10	0	0	0	
04IL14C1	453.0	65	105	50	70	0	100/ 0	0	125	125	15	25	0	25	
04IL15C1	463.2	85	165	26	45	45	50/ 50	20	45	65	25	17	0	17	
04IL16C1	473.0	75	175	35	50	0	100/ 0	20	70	90	25	15	0	15	
04IL17L1	480.2	55	140	20	50	0	100/ 0	0	60	60	15	15	0	15	
04IL17C1	482.4	80	195	25	50	40	55/ 44	25	75	100	0	15	0	15	
04IL18C1	493.2	80	190	25	50	45	52/ 47	25	40	65	20	15	0	15	
04IL19C1	503.2	80	190	35	50	45	52/ 47	20	45	65	0	0	0	0	
04IL19L1	505.7	55	120	20	40	38	51/ 48	0	36	36	18	12	0	12	
04IL20C1	513.4	75	160	20	70	0	100/ 0	20	50	70	12	25	5	30	
04IL21C1	523.2	80	135	25	50	50	50/ 50	0	90	90	30	17	0	17	
04IL22C1	533.0	75	140	25	50	50	50/ 50	30	95	125	30	40	0	40	
04IL23C1	542.2	75	125	30	50	50	50/ 50	0	90	90	30	30	5	35	
04IL24C1	553.4	75	145	25	60	55	52/ 47	25	160	185	35	25	5	30	
04IL25C1	563.2	75	120	30	50	50	50/ 50	0	200	200	0	15	0	15	
04IL26C1	573.0	70	135	20	40	40	50/ 50	20	65	85	25	35	10	45	
04IL27L1	582.6	55	82	25	35	23	60/ 39	29	350	379	10	15	0	15	
04IL27C1	583.4	60	75	20	25	20	55/ 44	0	500	500	15	25	0	25	
04IL28C1	593.2	70	95	20	25	15	62/ 37	15	500	515	0	15	0	15	
04IL29L1	603.2	16	125	10	18	0	100/ 0	20	500	520	0	0	0	0	
04IL29C1	604.5	20	175	5	25	0	100/ 0	60	500	560	5	55	0	55	
04IL30C1	613.3	20	40	0	0	0	0/ 0	500	500	1000	0	10	0	10	

*Depth (to top of sample) below drilling reference at 772 feet above mean sea level.
MCA = mica; QTZ = quartz; FLD = all feldspars; KSP = potassium feldspar; PLG = plagioclase; CAL = calcite; DOL = dolomite; SID & APA = siderite and/or apatite; PYR = pyrite; MAR = marcasite.

TABLE 8 - WHOLE ROCK MINERALOGY, EDGAR COUNTY, ILLINOIS, CORE SAMPLES.

OBSERVED PEAK HEIGHTS (COUNTS/SEC)

SAMPLE	DEPTH*	MCA	QTZ	FLD	KSP	PLG	KSP/PLG	CAL	DOL	CAL+DOL	SID+APA	PYR	MAR	PYR+MAR	MINERAL
NUMBER		19.8	20.8	23.5	27.6	27.9		29.4	30.8		32.1	33.2	52.0		TWO THETA
05IL01L1	655.9	60	115	25	40	0	100/ 0	0	55	55	20	47	7	54	
05IL01L2	660.2	65	140	28	48	0	100/ 0	0	62	62	15	25	0	25	
05IL01L3	662.2	48	105	28	45	0	100/ 0	0	65	65	13	34	6	40	

*Depth (to top of sample) below drilling reference at 654 feet above mean sea level.

See Table 6 for column headings.

TABLE 9 - WHOLE ROCK MINERALOGY, TAZEWELL COUNTY, ILLINOIS, CORE SAMPLES.

OBSERVED PEAK HEIGHTS (COUNTS/SEC)

SAMPLE	DEPTH*	MCA	QTZ	FLD	KSP	PLG	KSP/PLG	CAL	DOL	CAL+DOL	SID+APA	PYR	MAR	PYR+MAR	MINERAL
NUMBER		19.8	20.8	23.5	27.6	27.9		29.4	30.8		32.1	33.2	52.0		TWO THETA
06IL04C1	933.4	65	125	35	55	0	100/ 0	0	315	315	10	0	0	0	
06IL05C1	943.5	60	130	30	52	0	100/ 0	0	90	90	17	0	0	0	
06IL06C1	954.0	55	170	20	65	0	100/ 0	0	235	235	8	13	0	13	
06IL07C1	962.2	56	113	24	40	0	100/ 0	10	110	120	14	13	0	13	
06IL08C1	973.4	70	100	30	50	0	100/ 0	0	117	117	15	15	0	15	
06IL09C1	984.2	62	125	30	60	0	100/ 0	15	120	135	15	5	0	5	
06IL10C1	993.1	65	115	30	55	0	100/ 0	13	148	161	15	5	0	5	
06IL11C1	1003.2	65	126	30	50	0	100/ 0	0	81	81	10	10	0	10	
06IL11L1	1005.3	50	102	20	33	0	100/ 0	0	187	187	5	10	0	10	
06IL12C1	1014.1	65	115	35	57	40	58/ 42	20	83	103	20	15	0	15	
06IL13C1	1024.1	67	105	30	60	0	100/ 0	0	126	126	10	10	0	10	
06IL13L1	1025.5	60	95	25	50	0	100/ 0	0	82	82	10	5	0	5	
06IL13L2	1029.1	70	103	30	50	0	100/ 0	0	25	25	5	5	0	5	
06IL14L1	1032.8	57	80	30	50	0	100/ 0	0	180	180	10	13	0	13	
06IL14C1	1034.2	65	103	45	70	0	100/ 0	0	91	91	10	15	0	15	
06IL15C1	1044.1	80	140	50	65	0	100/ 0	0	125	125	20	22	0	22	
06IL16C1	1053.2	70	105	42	65	0	100/ 0	0	137	137	13	15	0	15	
06IL17C1	1063.2	48	106	40	63	0	100/ 0	0	190	190	15	20	0	20	
06IL18C1	1073.3	58	110	46	80	0	100/ 0	0	63	63	15	15	5	20	
06IL19C1	1083.2	45	100	45	70	0	100/ 0	0	45	45	13	20	7	27	
06IL19L1	1085.2	60	119	35	62	0	100/ 0	0	20	20	15	38	15	53	
06IL20C1	1093.4	51	120	30	52	30	62/ 37	15	20	35	15	60	10	70	
06IL21L1	1101.8	49	140	26	40	0	100/ 0	72	15	87	15	45	20	65	
06IL21C1	1103.1	56	125	25	48	40	54/ 45	0	25	25	20	25	5	30	
06IL22L1	1111.4	70	140	25	35	35	50/ 50	0	26	26	10	15	5	20	
06IL22C1	1113.4	60	125	25	35	35	50/ 50	0	20	20	20	15	0	15	
06IL23C1	1123.5	57	86	23	40	0	100/ 0	0	50	50	15	25	5	30	
06IL24C1	1133.4	60	150	25	50	0	100/ 0	25	165	190	10	10	1	11	
06IL25L1	1141.1	65	155	26	45	0	100/ 0	0	97	97	15	15	0	15	
06IL25C1	1143.5	55	127	30	45	0	100/ 0	15	63	78	15	30	0	30	
06IL25L2	1145.7	25	75	8	15	8	65/ 34	175	500	675	10	40	5	45	

*Depth (to top of sample) below drilling reference at 641 feet above mean sea level.

MCA = mica; QTZ = quartz; FLD = all feldspars; KSP = potassium feldspar; PLG = plagioclase; CAL = calcite; DOL = dolomite; SID & APA = siderite and/or apatite; PYR = pyrite; MAR = marcasite.

TABLE 10 - WHOLE ROCK MINERALOGY, FAYETTE COUNTY, ILLINOIS (07IL), AND

ST. CLAIR COUNTY, ILLINOIS (09IL) CORE SAMPLES.

OBSERVED PEAK HEIGHTS (COUNTS/SEC)

SAMPLE	DEPTH*	MCA	QTZ	FLD	KSP	PLG	KSP/PLG	CAL	DOL	CAL+DOL	SID+APA	PYR	MAR	PYR+MAR	MINERAL
NUMBER		19.8	20.8	23.5	27.6	27.9		29.4	30.8		32.1	33.2	52.0		TWO THETA
07IL01L1	2719	8	12	0	0	0	0/ 0	500	20	520	0	0	0	0	
07IL01L2	2731	71	108	32	50	53	48/ 51	0	20	20	15	0	0	0	
07IL01L3	2737	55	87	25	45	50	47/ 52	152	95	247	15	0	0	0	
07IL02L1	2771.8	60	172	35	52	70	42/ 57	15	15	30	12	5	0	5	
07IL02L2	2773.0	20	75	0	18	17	51/ 48	400	25	425	5	20	0	20	
07IL03L1	2780.4	65	218	37	50	70	41/ 58	0	23	23	12	3	0	3	
07IL04L1	2811.0	60	137	32	45	55	44/ 54	0	20	20	11	22	8	30	
07IL04L2	2813.1	47	117	25	47	45	51/ 48	0	35	35	15	19	5	24	
07IL05L1	2821.5	8	330	0	0	0	0/ 0	120	315	435	0	15	0	15	
09IL01L3	1774	59	137	25	35	45	43/ 56	0	20	20	15	18	7	25	

*Depth (to top of sample) below drilling reference at 525 feet above mean sea level for 07IL core; 474 feet above mean sea level for 09IL core.

See Table 6 for column headings.

TABLE 11—VITRINITE REFLECTANCE
HENDERSON COUNTY, ILLINOIS, CORE SAMPLES (04IL)

Sample Number	Depth* (ft)	# Readings	Ro (%) Average	Std. Deviation
09C1	403.5	32	0.45	0.08
13C1	443.2	50	0.47	0.08
17C1	482.4	50+	0.47	0.03
17C1	482.4	50	0.41	0.11
21C1	523.2	46	0.48	0.09
25C1	563.2	50	0.51	0.09

*Depth (to top of sample) below drilling reference at 772 ft. above mean sea level.

+Thin vitrain band.

TABLE 12—VITRINITE REFLECTANCE,
TAZEWELL COUNTY, ILLINOIS, CORE SAMPLES (06IL)

Sample Number	Depth* (ft)	# Readings	Ro (%) Average	Std. Deviation
10C1	993.1	37	0.50	0.08
13C1	1024.1	43	0.49	0.08
16C1	1053.2	52	0.45	0.07
19C1	1083.2	50	0.42	0.06
25C1	1143.5	50	0.41	0.07

*Depth (to top of sample) below drilling reference at 641 ft. above mean sea level.

TABLE 13—VITRINITE REFLECTANCE, FAYETTE COUNTY, ILLINOIS, CORE SAMPLES (07IL)

Sample Number	Depth* (ft.)	# Readings	Ro (%) Average	Std. Deviation
01L2	2731	50	0.56	0.12
02L1	2771.8	41	0.55	0.11
03L1	2780.4	47	0.44	0.13
04LI	2810.9	39	0.46	0.08
04L2	2813.1	52	0.50	0.07

* Depth below surface elevation of 525 feet above mean sea level.

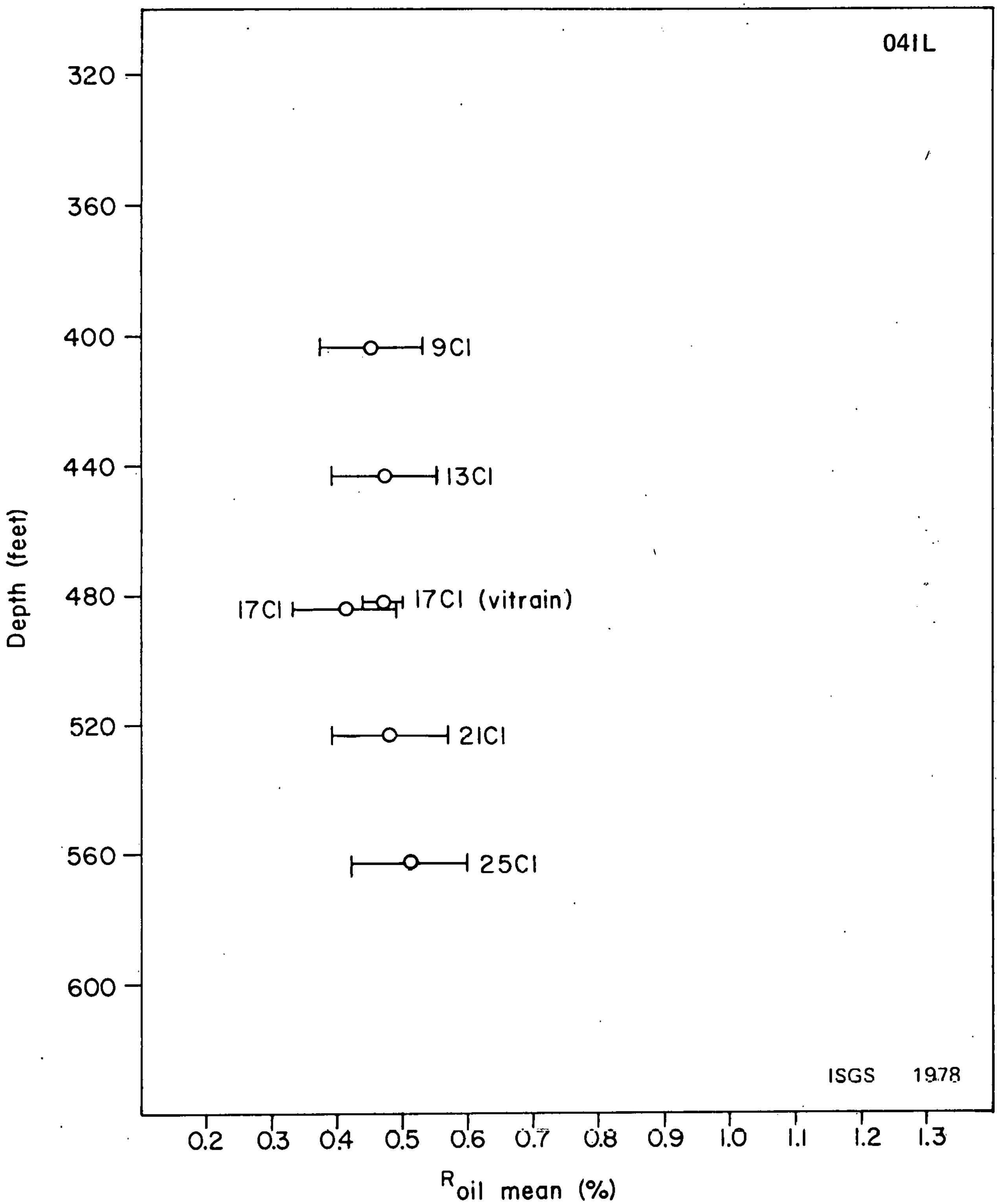

Fig. 1. Mean-random vitrinite reflectance of Henderson County, Illinois, core samples (04IL). Error bars correspond to ± one standard deviation. Depths are below a reference level of 772 feet above mean sea level.

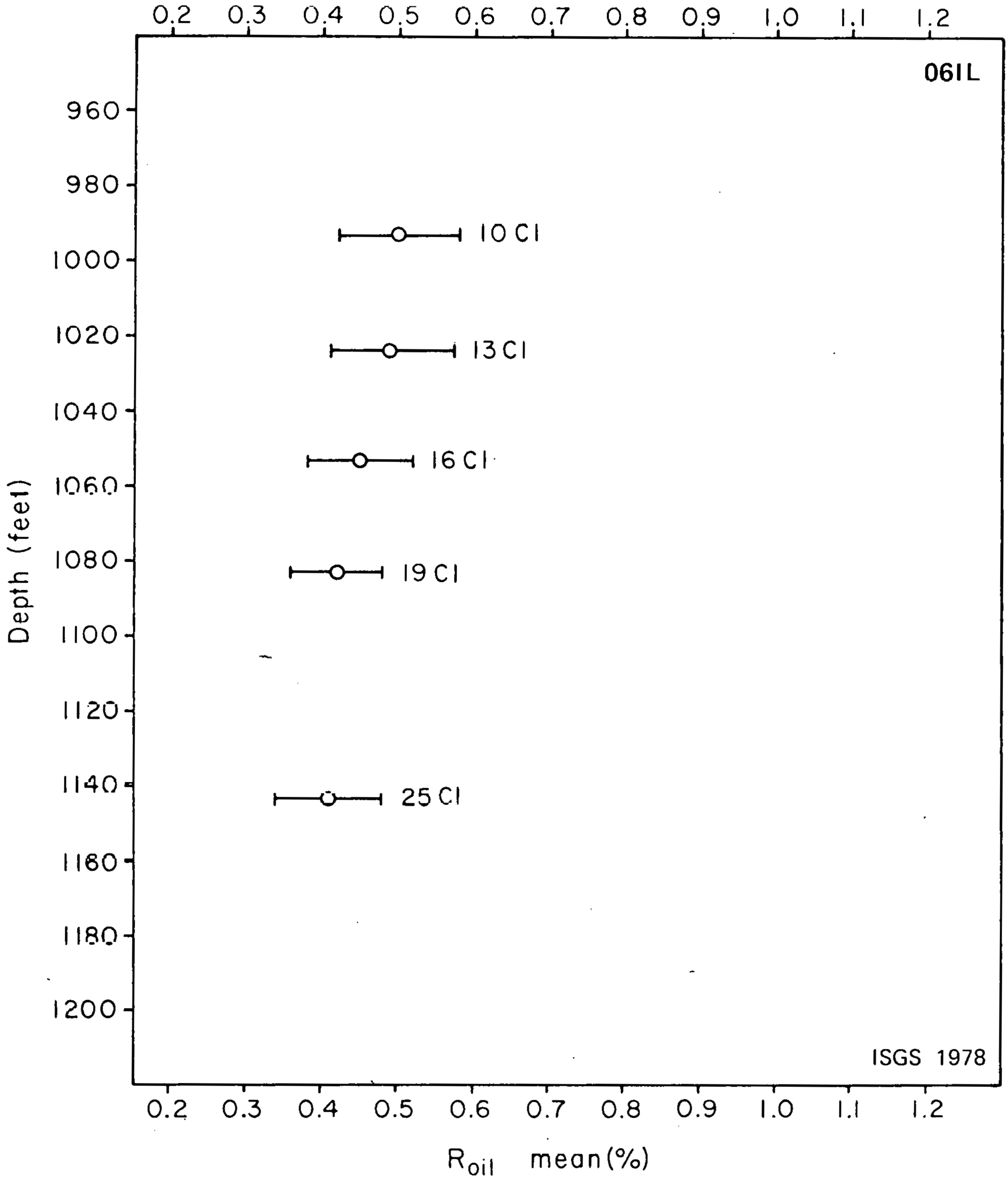

Fig. 2. Mean-random vitrinite reflectance of Tazewell County, Illinois, core samples (06IL). Error bars correspond to ± one standard deviation. Depths are below a reference level of 641 feet above mean sea level.

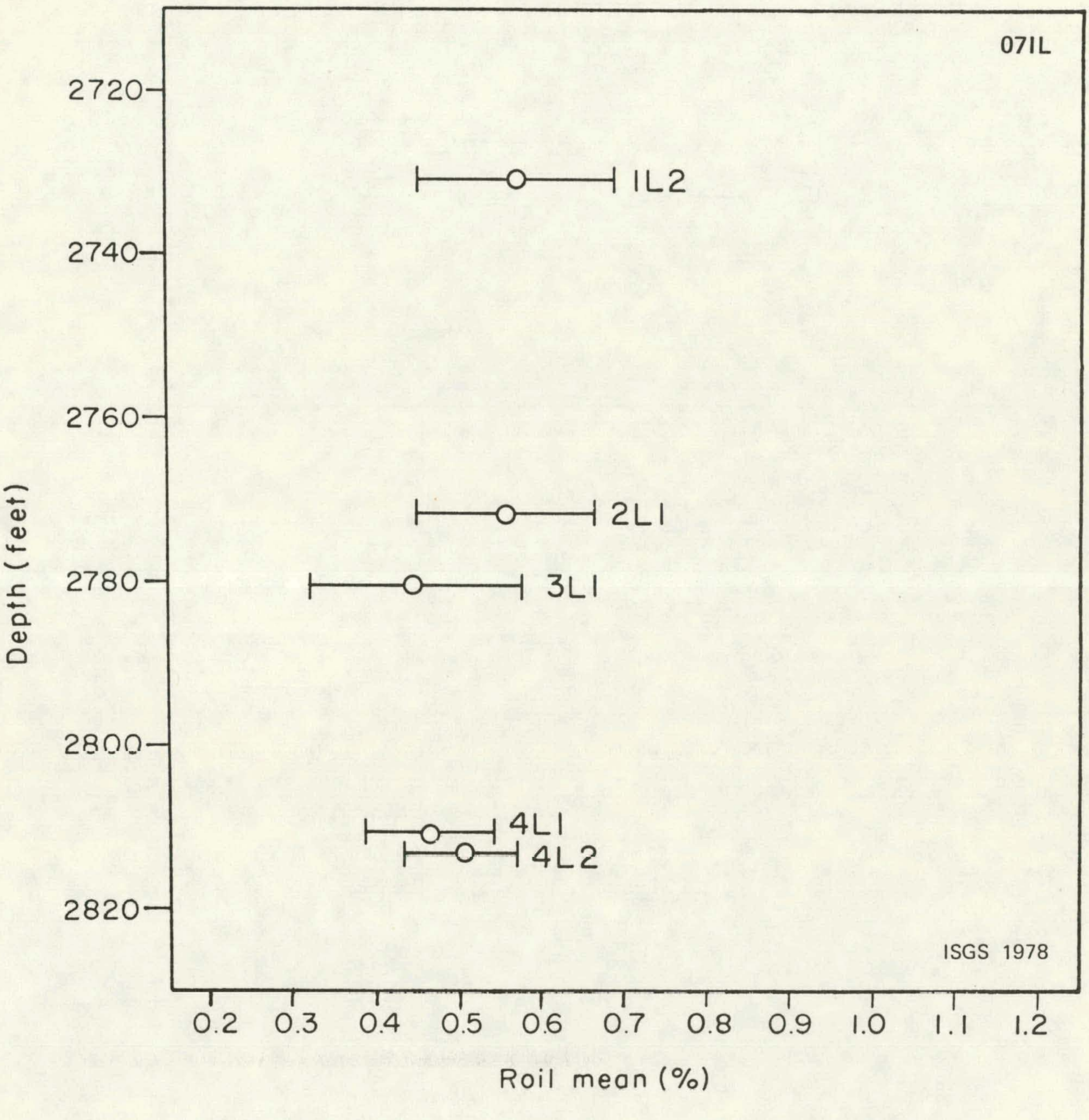

Fig. 3. Mean-random vitrinite reflectance of Fayette County, Illinois, core samples (07IL). Error bars correspond to ± one standard deviation. Depths are below a surface elevation of 525 feet above mean sea level.

Fig. 4. Mean-random vitrinite reflectance of supplementary well cutting samples. The number to the right of the slash indicates the number of samples measured, the number to the left of the slash the average reflectance of those samples.

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ABSTRACT FORM

Exact format shown on instruction sheet must be followed.

ORGANISM - SEDIMENT RELATIONSHIPS IN THE NEW ALBANY SHALE GROUP (DEVONIAN-MISSISSIPPIAN) OF ILLINOIS.

CLUFF, Robert M., Illinois State Geological Survey, Urbana, Illinois 61801

The distribution of lithofacies in the New Albany Shale Group of Illinois was controlled by the effects of wave energy, bottom topography, and bottom oxygenation on benthic organisms. A transect from the margin to the center of the Illinois Basin reveals a complete transition from high energy, aerobic, shallow-water environments to quiet, anaerobic, deep-water environments.

Shallow areas at the margin of the basin are characterized by rapid and complex facies transitions over short distances. Brachiopods, crinoids, trilobites, and other calcified marine invertebrates are abundant. High energy, very shallow conditions are recorded by thin oolitic-skeletal grainstones and packstones. Bioturbation has not destroyed primary sedimentary structures in these facies. Offshore, less agitated areas are represented by highly bioturbate carbonate wackestones, argillaceous quartz siltstones, and greenish-gray mudstones. Calcified invertebrates are generally rare in these facies, indicating dysaerobic conditions. Basinward, slope areas are characterized by olive-gray to black, weakly bioturbate shales commonly interbedded with thickly laminated black shales. Trace fossils, including Zoophycos, Chondrites, and Planolites, are abundant along the bases of the olive-gray beds. In areas where the anaerobic/dysaerobic boundary intersected the bottom slope, slight fluctuations of the position of the boundary resulted in thin interbedding of olive-gray and black shales and laterally persistent interfingering of the two lithologies. Finally, in the deepest areas of the basin, anaerobic conditions prevailed during most of New Albany time, and finely laminated, undisturbed, pelagic black shales were deposited.

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ABSTRACT FORM

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ANOXIC CONDITIONS DURING NEW ALBANY SHALE GROUP (DEVONIAN-MISSISSIPPIAN) DEPOSITION IN THE ILLINOIS BASIN

CLUFF, Robert M., and REINBOLD, Mark L., Illinois State Geological Survey, Urbana, Illinois 61801

Detailed study of well logs and of several cores from the New Albany Shale Group in the Illinois Basin suggests a consistent pattern of shale deposition in a stratified anoxic basin. The finely laminated black shales of the Grassy Creek and Blocher Shales were deposited in an anaerobic bottom environment in which benthic invertebrates were unable to survive. The interbedded laminated black shales and moderately bioturbated greenish-gray shales of the Sweetland Creek Shale suggest deposition in a transitional anaerobic-to-dysaerobic zone. The extensively bioturbated gray and greenish-gray shale of the Hannibal and Saverton Shales lack calcified benthic invertebrates and were deposited in a dysaerobic environment. Limestones above, below, and within the New Albany Group contain rich invertebrate faunas and were deposited in aerobic environments.

Stratigraphic correlations suggest that limestone, greenish-gray shale, and black shale were deposited contemporaneously during certain intervals and that several formations in the New Albany Group are, in part, laterally equivalent facies. A deepwater stratified basin, in which limestone was deposited in shallow, well-oxygenated areas; greenish-gray mud was deposited in deeper, poorly oxygenated area; and black shale was deposited in the deepest portions, is proposed as a model for New Albany deposition. Fluctuations in the level of the anaerobic/dysaerobic boundary resulted in the expansion or contraction of black shale deposition across the basin. This model is compared to a shallow water model for the origin of black shale deposition in the Illinois Basin.

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Phone numbers and dates where senior author can be contacted 217-344-1481, ext. 262; weekdays 8-5

ABSTRACT FORM

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PROBLEMATICAL MICROFOSSILS FROM THE NEW ALBANY SHALE GROUP (DEVONIAN—MISSISSIPPIAN) IN WESTERN KENTUCKY

CLUFF, R. M., and BAXTER, J. W., Illinois State Geological Survey, Urbana, Illinois 61801

Well preserved calcareous microfossils were found in a core sample of upper Grassy Creek Shale in the Orbit Gas #1 Ray Clark well, Christian County, Kentucky. The microfossils occur with *Tasmanites* and consist of two concentric perforate spheres connected by numerous thin bars. The outer sphere ranges from 80 to 160 μm in diameter and the inner sphere, from 50 to 80 μm. Long (40-160 μm), slender spines project from the outer sphere of a few specimens. The microfossils are filled with (and preserved by) a poorly developed, radial fibrous chalcedony cement. Similar but poorly preserved features have also been found in well cuttings from White County, Illinois, and in outcrop samples from west-central Kentucky. The location of all of these occurrences—within the upper 40 feet of the Grassy Creek Shale—suggests that these microfossils may have biostratigraphic significance.

Very similar microfossils have been described from Upper Devonian carbonates in Central Russia and placed in the calcisphere genus *Radiina*. It was speculated that these microfossils may be related to dasycladacean algae. We consider these fossils, however, to be quite unrelated to any other known type of calcisphere or calcareous algae. Morphologically, they are most similar to radiolarians, although they are calcareous, smaller, and more coarsely structured than typical Devonian radiolaria such as those from the Caballos Novaculite of west Texas.

The overall structure of these microfossils suggests that they are protozoans. They may represent an unusual early variant of radiolarians or a previously unrecognized group of planktonic protozoans.

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CLASSIFICATION
You must specify one. If more than one category is appropriate, indicate your order of preference by numbers. Be specific.

ABSTRACT FORM

Exact format shown on instruction sheet must be followed.

ORGANIC MATURITY OF THE NEW ALBANY SHALE GROUP (DEVONIAN-MISSISSIPPIAN) IN ILLINOIS

HANSMAN, Mary, CLUFF, Robert M., HARVEY, Richard D., and BURKE, David A., Illinois State Geological Survey, Urbana, IL 61801

Shales of the New Albany are being studied to evaluate their thermal history for gas resource purposes. The organic matter in samples from many parts of Illinois was separated by acid maceration. The mean random reflectance of the vitrinite ranged from 0.3 to 0.6 percent for all samples. The reflectance of vitrinite in the vitrain bands found in some cores were identical to those in associated macerated samples. A regional trend of increasing reflectance was observed towards the deep portion of the Illinois Basin, but, through the 100 m or less of shale in a single core, no increase with depth was detected. Sapropelic matter, which is nonfluorescent under blue light, is the predominant component of solid organic matter in the laminated black shale facies. Alginite (mainly *Tasmanites*), vitrinite, and fusinite are minor components. *Tasmanites* fluoresce bright yellow. Fusinite and vitrinite are the predominant organic components in the bioturbate, greenish-gray mudstone facies. The crystallinity of the illite and the organic carbon content were also determined for each sample.

Our data indicate the level of organic maturity of the New Albany shales in Illinois is less than the main stage of oil generation. Vitrinite reflectances are anomalously lower than those of the overlying Pennsylvanian coals. The restricted escape of volatile gases from organic matter within thick and impermeable shale strata, compared to more permeable beds, retards the maturation reaction and may account for the lower reflectance. The depositional environment may have also contributed to the lower reflectance values for vitrinite by selectively preserving potentially lower reflecting particles by chemical or physical means.

geochemistry Organic 1

geology
- archeologic
- coal 3
- economic

- education
- engineering
- environmental
- extraterrestrial
- general
- history of
- marine

- mathematical
- Precambrian
- Quaternary
- structural

geomorphology

geophysics

geoscience information
hydrogeology
mineralogy/crystallography
paleontology/paleobotany

petrology
- experimental
- igneous
- metamorphic

sedimentology
- sedimentary petrology 2

stratigraphy
tectonics
volcanology
OTHER

☒ Oral ☐ Poster ☐ Either

☐ Symposium ______ (title of symposium)

Speaker ______

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PHYSICAL CHARACTERIZATION

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 test 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.

Destructive Testing

Progress

CORE 04IL

The destructive testing and initial analysis of core 04IL have been completed. In summary, there is a preferred strength orientation (North Northwest-South Southeast). The degree of expression and the orientation appear to be controlled by the lithology. Figure 1 is a summary of the fracture orientation data resulting from the point load testing program. The general trend of the fractures is East Northeast-West Southwest. Figure 2 shows the corresponding trend as represented by the results of the indirect tensile testing program.

The point-load tests are performed fast (approx 8 cm/min) and the test value recorded as the point load index (load at failure divided by the thickness squared). The loading points are hardened 60^{o} cones with a 5-mm radius. Point load samples are approximately half the core diameter in thickness with ends 0.05 cm parallelism. Sample preparation for the point-load test is not critical, as the quality of the test is usually determined by delamination sub-parallel to the bedding.

The indirect tensile tests are performed slowly (approximately 0.002 cm/min) and the test value recorded as the tensile strength (2 load divided by the diameter x thickness x π). The strength values are shown in the testing direction. As with the point-load test, delamination, due to geologic flaws, was a problem. There are too few comparable samples (similar in lithology, direction, and quality) to quantitatively assess the influence of this splitting on the test results.

This splitting is caused by: irregular bedding, fossils or non-planar mineralized nodules and coring induced fractures. The fast test rate (maximum machine rate) is the only control that has tended to minimize the effect of splitting (usually sample reorientation) for the point load tests.

Core 04IL is predominantly lithology I (greenish-gray mudstone) and lithology II (olive-gray shale), both of which have lower strength than the dark gray or black shale. The combination of lithologic type and presence of coring induced fractures resulted in achieving fewer than half of the preferred number of test specimens.

GENERAL

Figures 3 and 4 show the general relationship between lithology and "tensile strength" for the three completed cores (01KY, 02IL, 04IL). The general conclusion is that the organic component is acting as a cement resulting in increasing strength as the rock becomes darker. However, in the lighter shales, carbonate may also be a cement and can result in an increase in strength.

Seminar

An informal seminar-workshop was hosted by the Illinois Geological Survey June 20, in Urbana, Illinois. The topic of the meeting was the measurement of anisotropic properties in shale. The meeting was attended by researchers from the Illinois Geological Survey and by representatives of the Indiana Geological Survey, the U. S. Bureau of Mines, and the Civil Engineering and Geology Departments of the University of Illinois.

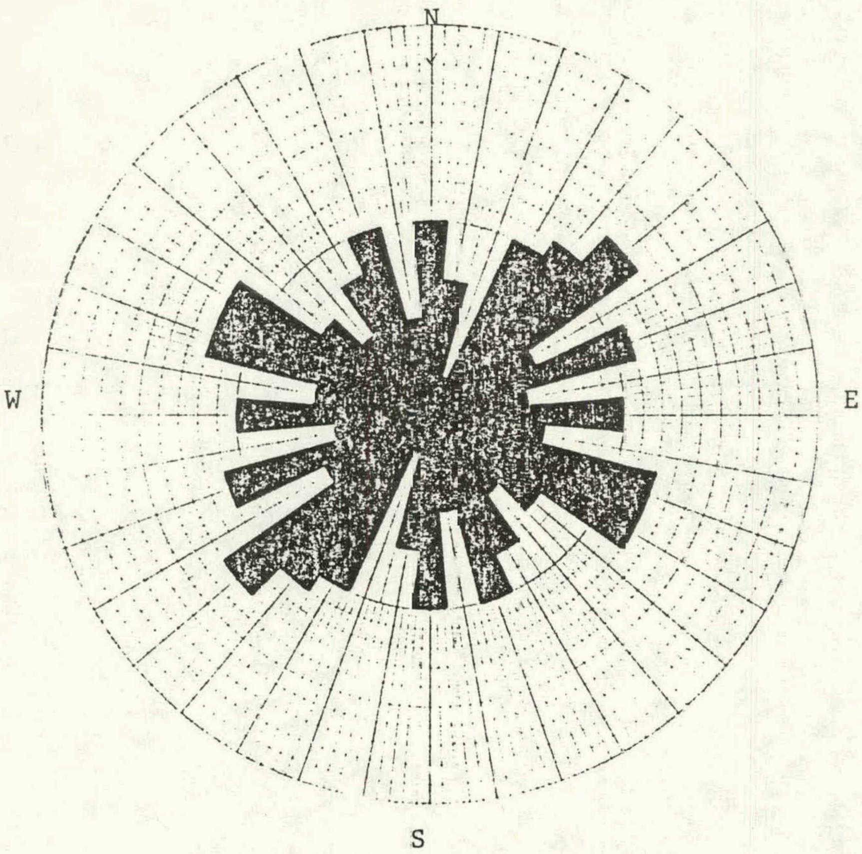


Fig. 1. Frequency plot of fracture orientations from point-load tests, core 04IL, all tests.

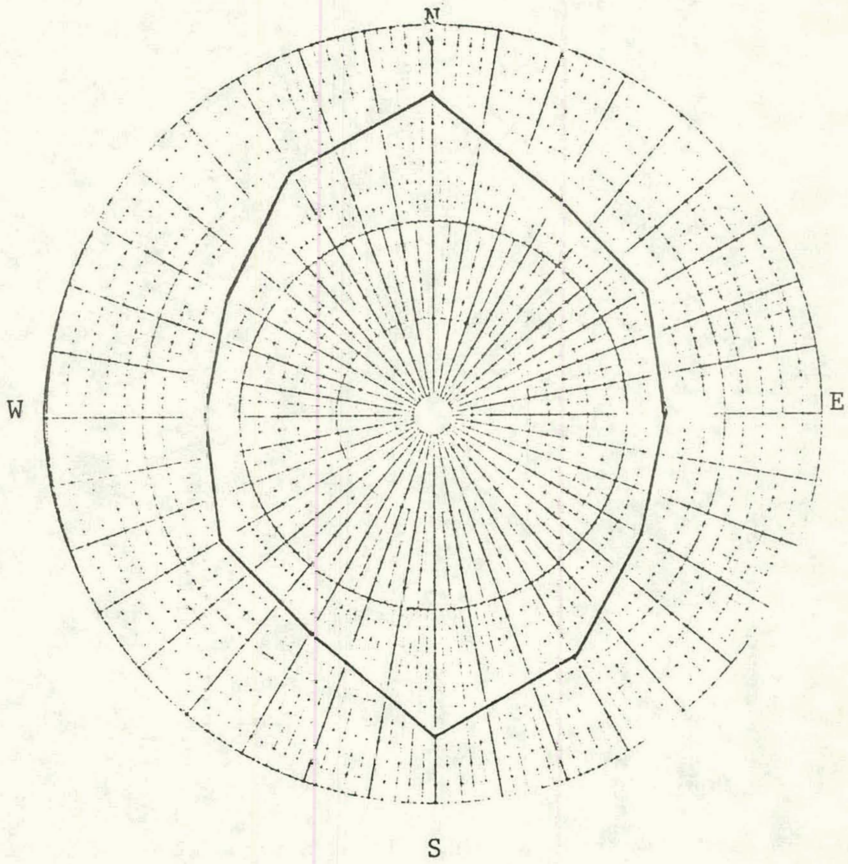
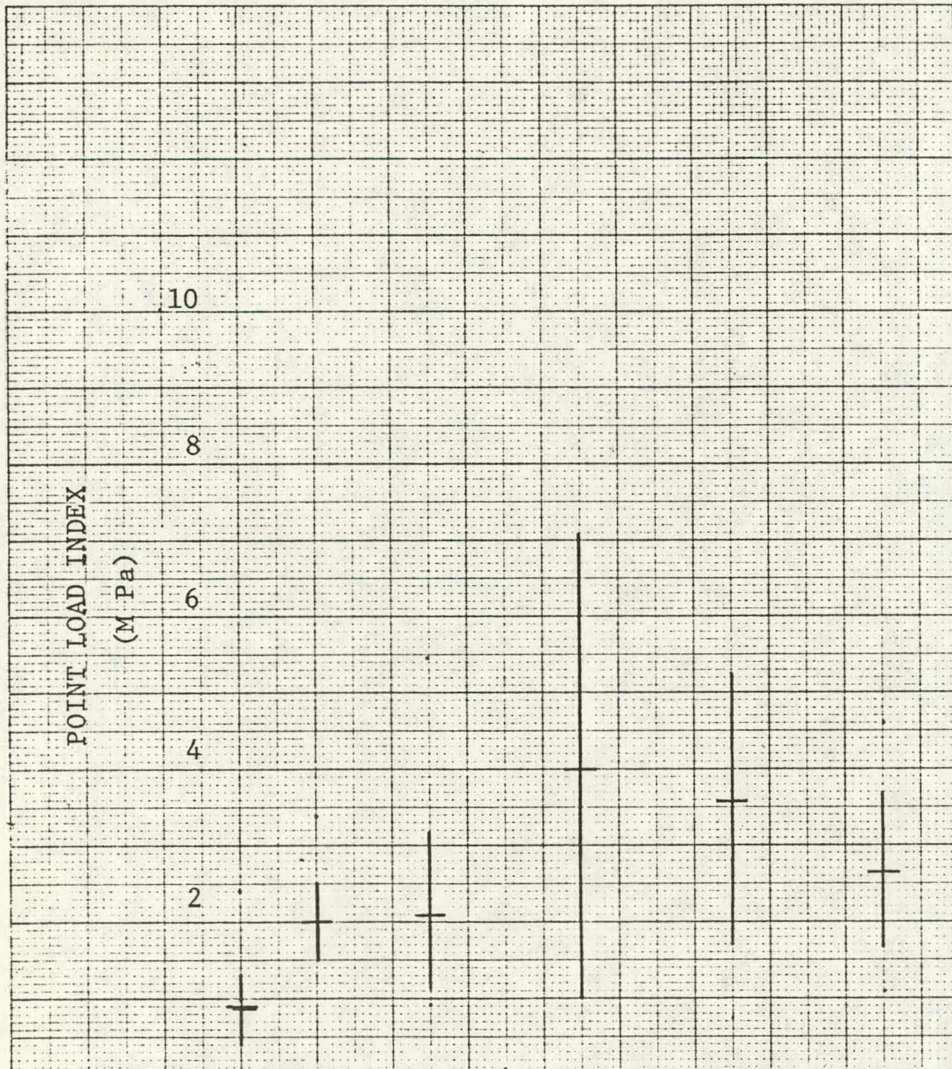
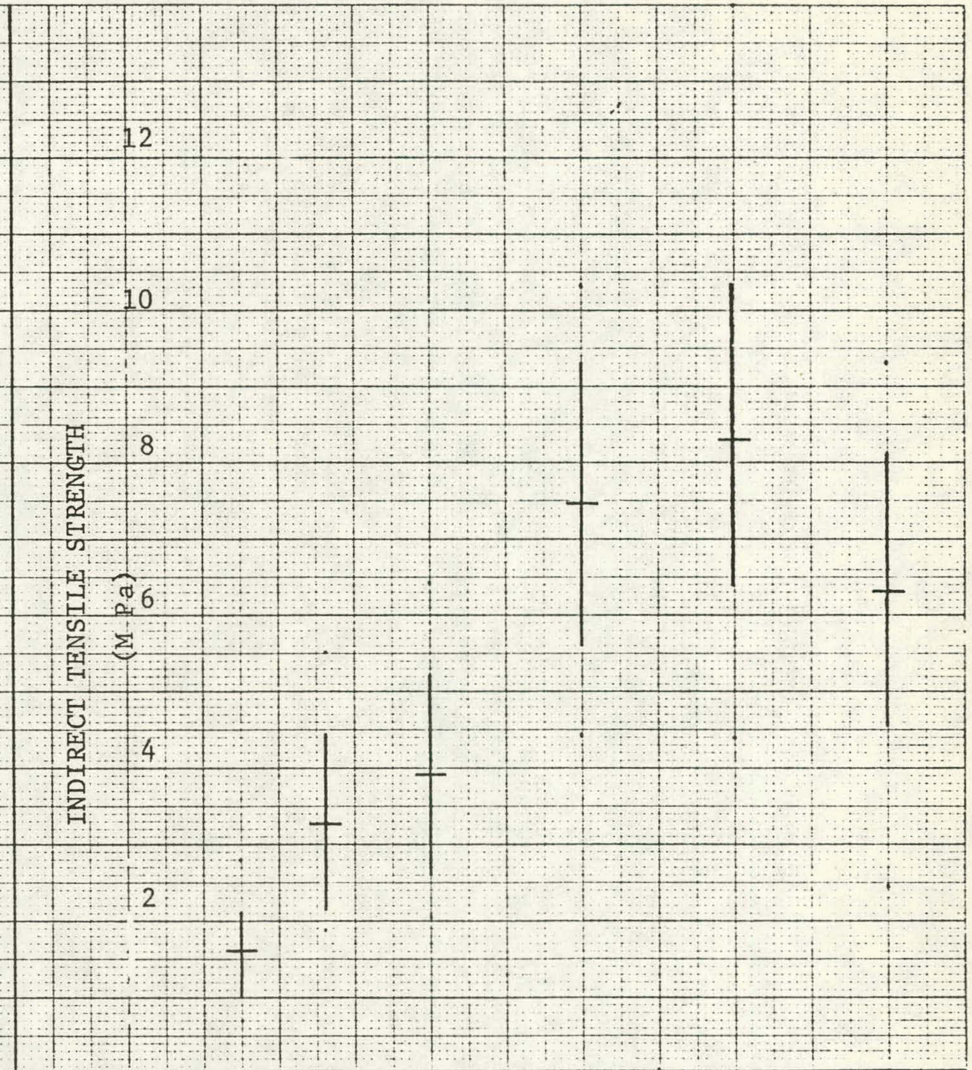


Fig. 2. Relative preference of orientation of indirect tensile strength, core 04IL, all tests.



SAMPLE SIZE	26 19	22	34	34	19
CORE	04IL	04IL	01KY	01KY	02IL
LITHOLOGY	I	II	III	IV	

Fig. 3. POINT LOAD INDEX VALUES FROM COMPLETED CORE TESTING.



SAMPLE SIZE	26 13	17	36	34	25
CORE	04IL	04IL	01KY	01KY	02IL
LITHOLOGY	I	II	III	IV	

Fig. 4. INDIRECT TENSILE STRENGTH VALUES FROM COMPLETED CORE TESTING.

GEOCHEMICAL CHARACTERIZATION

QUANTITATIVE DETERMINATION OF MAJOR, MINOR, AND TRACE ELEMENTS IN SHALES

Introduction

Determine not less than 49 major, minor, and trace elements in 300-500 shale samples, which are representative cross sections of the cores taken. Include organic and mineral carbon; total hydrogen; total sulphur and when that exceeds 0.5%, pyritic and sulphate sulphur. 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.

Elemental Analysis

Progress

To June 30, a total of 192 samples have been received for complete major, minor and trace element determinations; another 14 samples were received for analysis in which selected major and minor elements are being determined.

Data on the first 57 samples received for complete major, minor and trace element analysis were reported in previous quarterly reports. It was planned to report revised data for those samples and the results of analysis for 52 new samples in this quarterly report. All the results are in hand but their compilation will require at least another week's work. The results will be included in a future monthly report.

A table of the most recent results obtained by the Illinois Geological Survey on the two shale standards SDO-1 and Indiana Reference 1 is included.

Analysis of other shale samples on hand continues at a steady rate.

TRACE ELEMENT DISTRIBUTION IN ORGANIC AND INORGANIC FRACTIONS OF SHALE

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.

Progress

The methods tested for physical separation of the organic from the inorganic fraction of shale are float-sink gravity separation, Humphrey Spiral, and froth-floation. Thus far they have failed to yield separations of sufficient quality to be of significant value. An acid extraction procedure has, however, enabled us to arrive at a product which has an ash content of only a few (1-2) percent. Some doubt remains as to the effect of the acids on the organic fraction of the shale, and a physical separation procedure is needed to check the validity of the chemical extraction results.

Two samples of shale have been processed through the extraction procedure, which has yielded fractions that will aid in the determination of the elements associated with the various phases of these shales. Fractions of the bitumens, ion exchangeable and chelated elements, and an organic matter fraction have been prepared and are presently undergoing extensive analysis.

Problems

The development of procedures using zonal centrifugation, considered most necessary to this task as a method for the physical separation of organic matter, is awaiting receipt of equipment excessively delayed by funding problems. Shipping date for this equipment is now set for August 2, 1978. Once this device is received the project should proceed rapidly with a preliminary evaluation of the technique accomplished by the end of the next quarter. The six to seven month delay caused by this problem should be eliminated by the end of the year.

MODE OF OCCURRENCE AND RELATIVE DISTRIBUTION OF HYDROCARBON PHASES IN SHALE

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 previous unit. 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.

Determine the carbon isotopic composition of methane in off-gases from core samples whenever sufficient methane can be collected. Compare these data to other pertinent data such as gas composition and vitrinite reflectance for the purpose of making interpretations as to the origin and maturity of the gas. Perform laboratory experiments to study the relative effects and significance of chemical and isotopic fractionation that occur as gas is released from core samples.

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

Medium Volatile Hydrocarbon Analyses

Progress

Work was conducted on extraction and analysis of medium volatile hydrocarbons contained in the organic matter of two standard shales samples. These shales were extracted with benzene-methanol (70:30;V:V) and the extract separated into aliphatic, aromatic and asphaltene fractions. Elemental analysis of the fractions has been completed and infra-red spectra have been run. The fractions are being further analysed by gas chromatography.

Work has also begun on the extraction and analysis of additional black shale samples. For one of these, 02IL04CL (Effingham Co., IL), the extracted organic matter was separated into the three fractions - aliphatic, aromatic, asphaltene - on an alumina column. Elemental analyses were made on the original shale, the total extract and the fractions. Hydrogen to carbon ratios were calculated. These data are shown in Table 1.

Approximately 30% of the benzene-methanol extracted material is not eluted from the alumina column for all three samples. The hydrogen to carbon ratio for the whole shale is most likely influenced (high) by water and inorganic elements of water contained in the shale matrix initially.

Experiments on the thermal volatilization of medium and low volatile hydrocarbons directly onto the gas chromatographic column are being conducted. Preliminary results are very encouraging.

Table 1. Soxhlet Extraction, Column Chromatography and Elemental Analysis of Eastern Black Shale

Sample Number	Element	Shale	Benz-MEOH Extract	Chromatography Fraction		
				Aliphatic	Aromatic	Asphaltene
Indiana		%	0.48%	8.19%	19.94%	45.68%
Standard	C	8.80	81.40	85.14	85.83	80.44
Sample	H	1.32	9.58	12.90	10.21	8.89
	N	NA	2.05	None	None	3.17
	S	1.56	2.41	NA	NA	2.87
	H/C	(1.79)	1.40	1.82	1.42	1.32
Ohio Standard			0.41%	10.97%	17.98%	37.66%
Sample	C	13.45	81.40	86.42	87.91	82.46
SDO-1	H	1.83	10.34	13.24	10.14	9.17
	N	0.31	1.75	None	None	3.26
	S	5.25	1.19	NA	NA	1.55
	H/C	(1.62)	1.45	1.83	1.39	1.32
021L04C1		%	0.60%	18.73	19.40	27.42
Effingham	C	8.51	86.15	86.33	88.58	84.05
County, Ill.	H	1.51	11.45	13.65	11.05	9.04
	N	NA	0.78	None	0.66	1.88
	S	NA	0.71	NA	NA	1.21
	H/C	(2.11)	1.58	1.88	1.49	1.28

Problems

The project is more than 6 months behind schedule due to delays in funding and equipment purchases.

Low-Volatile Hydrocarbon Analysis

(See Medium Volatile above.)

Released Gas Analyses

Studies of released gases from all the cores collected in the Illinois Basin were completed and reported during the previous quarter. No new core samples have become available.

Isotopic Analysis of Off-Gases

Progress

No shale cores containing sufficient methane for isotopic analysis were obtained during this quarter; however, determination of C_{13}/C_{12} ratios will continue to be made as cores become available, and their relationships to maturity and source of gas will be studied.

Laboratory Study of Chemical and Isotopic Fractionation

Progress

Studies were initiated to determine the changes in chemical and isotopic compositon that occur as gas is desorbed from shale samples. Such experiments are helpful in interpreting what the actual gas composition was prior to any fractionation that occurred during sampling. New 3/4-inch diameter pressure vessels that are to be used for future degassing experiments have been assembled, pressure tested, and all pressure guages calibrated against a deadweight tester. Continuation of this work has proceeded with the arrival of a vacuum oven necessary for preparing the cores. The cutting of small cores from the large cores has begun in preparation for their use in the isotopic fractionation experiments.

ADSORPTION/DESORPTION STUDIES OF GASES THROUGH SHALES

Introduction

With nitrogen and carbon dioxide, determine internal surface area on shale core samples; on selected samples, use methane as the adsorbate (sorbate) 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.

Internal Surface Area Measurement

Progress

Internal surface area values from nitrogen and carbon dioxide adsorption were obtained for 30 samples from a Henderson County, Illinois core. As the samples from this core are gray in appearance, it is presumed that the organic carbon content is relatively low. The CO_2/N_2 ISA ratios also reflect the low organic carbon content in that the ratios are about 1.0. The samples thus are similar to those taken from the Tazewell County, Illinois core - both cores coming from the northern part of the Illinois Basin.

We believe that we have now studied the internal surface areas (ISA) of a fairly good cross-section of samples from within the Illinois Basin - a cross section of samples having a range of organic carbon content from less than 1% to 14%. The cores from Henderson County and Tazewell County in the northern part of the Illinois Basin are very low in organic carbon content. The core from Christian County, Kentucky in the southern part of the Illinois Basin is relatively high, and the core from Effingham County, Illinois near the middle of the Illinois Basin is intermediate in organic matter content. The internal surface area measurements reflect these changes because the organic matter partially occupies the inherent porosity in the shale matrix, effectively reducing pore diameters. With this occurrence, the CO_2ISA values remain large relative to N_2 ISA values.

Methane Adsorption Isotherms

Progress

Because the gamut of samples taken from the Illinois Basin is well-represented by samples from three cores - Tazewell County (Ill) Effingham County (Ill) and Christian County (Ky) - we have devoted considerable time studying gas release rates from these particular cores, once equilibrium has been attained at the highest pressure (100 atmospheres). Most of June was spent in assembling data and writing a paper for submission to the Proceedings of the Second Eastern Gas Shales Symposium to be held in Morgantown, W. Va., October 16-18, 1978. Our work has been selected for one of the oral presentations at the Symposium and the abstract is given below.

Use of Internal Surface Area and High-Pressure Methane Sorption Data to Estimate Capacity for Gas Production From the New Albany (Devonian) Shale

Robert R. Frost and Josephus Thomas, Jr.

Abstract

Internal surface areas (ISA) measured via the BET method with N_2 and CO_2 as adsorbates at $-196^{\circ}C$ and $-77^{\circ}C$, respectively, were determined for shale samples from Christian County, Kentucky and from Effingham and Tazewell Counties in Illinois. High-pressure (up to 100 atmospheres) methane sorption isotherms at $28^{\circ}C$ were determined for selected shale samples. Subsequent to the determination of the sorption isotherms, the methane at approximately 100 atmospheres surrounding the shale samples was released to atmospheric pressure, and the rates of release of the sorbed methane then were measured at constant pressure (1 atm.)

Data are presented which show that there is a direct correlation between the CO_2 and N_2 ISA ratio, the high-pressure methane sorption capacity, and the organic carbon content of the shale samples. While the data on the initial release rates of methane from the shale samples do not show a direct correlation with either the CO_2 to N_2 ISA ratio or to the methane sorption capacity, these factors together can be used to estimate relative gas-production potentials of different shale strata.

CHEMICAL DATA ON SHALE REFERENCE STANDARDS INO, REF, 1 (S-60) AND SDO-1 (S-95)

SAMPLE NO.	GEOL. NO.	DEPTH (FT)	SIO2 (%)	AL2O3 (%)	FEO (%) (XRF)	FE AS % FEO (NAA)	MGO (%)	CAO (%)	NA AS % NA2O (NAA)	K2O (%) (XRF)	K AS % K2O (NAA)	TIO2 (%)	P2O5 (%)	MN (PPM) (NAA)
S-1-60	IN REF 1		52,67	14,87	3,39	3,03	1.92	3,11	,372	4,11	4,49	,65	,09	324
S-2-60			51,80	14,11	3,53	3,64	2,02	3,18	,361	4,17	4,44	,65	,09	326
S-3-60			52,65	14,79	3,62	3,79	2,01	3,02	,371	4,16	4,46	,63	,07	325
MEAN			52,37	14,59	3,51	3,49	1.98	3,10	,37	4,15	4,46	,64	,08	325
STDDEV			,50	,42	,12	,40	,06	,08	,01	,03	,03	,01	,01	1
S-1-95	SDO-1		49,81	12,09	7,67	8,71	1.38	1,06	,377	3,04	3,42	,73	,083	348
S-2-95			50,13	11,86	7,90	8,57	1,29	,99	,376	3,08	3,60	,75	,123	326
S-3-95			49,79	12,17	7,64	9,34	1.19	,99	,396	3,05	3,53	,73	,099	320
MEAN			49,91	12,04	7,74	8,87	1,29	1,01	,38	3,06	3,52	,74	,10	330
STDDEV			,19	,16	,14	,41	,095	,04	,01	,02	,39	,01	,02	15

	MN (PPM) (OE-P)	V (PPM) (OE-D)	V (PPM) (OE-P)	S (%)	CL (%)	TOTAL C (%)	ORGANIC C (%)	INORG. C (%)	H (%)	N (%)	CO2 (%)	SB (PPM)
S-1-60	340	283	320	1,45	,01	9,79		,99	1,32		3,63	2,16
S-2-60	320	290	320		,01			,99			3,63	2,54
S-3-60	350	280	300		,01			,96			3,52	2,79
MEAN	340	280	310	1,45	,01	9,79	8,81	,98	1,32		3,59	2,5
STDDEV	15	5	12					,02			,06	,3
S-1-95	337	164	204	5,27	,0081	13,87		,334	1,95	,31	1,22	4,3
S-2-95	342	159	196	5,24	,0279	13,71		,314	1,70	,30	1,15	4,1
S-3-95	348	166	202		,0122			,362			1,33	4,5
MEAN	340	160	200	5,25	,0094	13,79	13,45	,34	1,83	,31	1,23	4,3
STDDEV	6	4	4		,0024			,02			,09	,2

	AS (PPM)	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)
S-1-60	15,9		2,15	5,4	190,	3,16	63,8	6,84	82,8	118	150	14,5
S-2-60	14,8	452	2,34	5,2	210,	3,85	76,6	9,43	104	120	140	15,9
S-3-60	17,2	461	2,30	5,0	190,	2,51	76,4	7,98	97,6	118	140	17,4
MEAN	16	460	2,3	5,2	200	3,2	72	8,1	95	120	140	16
STDDEV	1		,1	,2	12	,7	7,3	1,3	11	1	6	1
S-1-95	80,5	875	3,27	5,76	120	3,73	78	6,4	55,2	57,1	87,9	55,2
S-2-95	79,2	974	3,38	5,30	120	3,29	87	5,8	60,3	53,7	89,4	60,3
S-3-95	80,8	1071	3,67	5,47	130	3,53	99	6,7	64,3	56,5	91,6	64,3
MEAN	80	970	3,4	5,5	120	3,5	88	6,3	60	56	90	60
STDDEV	,9	98	,2	,2	6	,2	11	,5	5	2	2	5

CHEMICAL DATA ON SHALE REFERENCE STANDARDS INC. REF. 1 (S-60) AND SDO-1 (S-95)

SAMPLE NO.	GEOL. NO.	DEPTH (FT)	CO (PPM) (OE-D)	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)
S-1-60	IN REF 1		22	20	170	160	7.64	1.49	1200	1.39	21.2	.81	<11	2.74
S-2-60			22	20	180	162	7.51	1.73		1.69	19.4	.93	<11	3.81
S-3-60			22	20	180	150	7.55	1.64		1.64	20.7	.77	<11	3.41
MEAN			22	20	180	160	7.6	1.6	1200	1.6	20	.84	<11	3.3
STDDEV					6	6	.1	.12		.3	.9	.20		.5
S-1-95	SDO-1		48	57.5	73	74.4	6.58	1.75	587	1.8	19.1	1.5	<12.9	5.2
S-2-95			48	54.2	73	73.4	6.26	1.79	615	1.9	19.0	1.2	<12.9	4.8
S-3-95			50	57.8	73	75.5	6.02	1.89	560	2.2	20.2	1.5	<12.9	4.8
MEAN			49	56	73	74	6.3	1.8	590	2.0	19	1.4	<12.9	4.9
STDDEV			1	2		1	.3	.1	28	.2	.7	.2		.2

SAMPLE NO.	PB (PPM) (OE-P)	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)
[illegible]	15	37.0	.354	17.6	40.1	110	102	160	138	9.00	16.9	< .72
S-2-60	15	35.5	.394	17.7	20.2	115	127	160	166	9.61	19.8	< .72
S-3-60	15	36.9	.337	17.2	35.2	110	93.8	150	159	8.91	19.8	< .72
MEAN	15	36	.35	18	32	110	110	160	150	9.2	19	< .72
STDDEV		.8	.04	.3	10	3	17	6	15	.4	1.7	
S-1-95	11.7	40.4	.45	190	156	96	137	106	130	11.8	15.8	< .69
S-2-95	10.9	45.0	.55	186	171	96	132	90	139	12.7	15.8	< .69
S-3-95	10.8	45.7	.65	193	138	98	137	95	140	13.4	17.1	< .69
MEAN	11	44	.55	190	155	97	135	97	136	13	16	< .7
STDDEV	.5	3	.10	4	17	1	3	8	6	.8	.8	

SAMPLE NO.	SR (PPM) (NAA)	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)
S-1-60		111	.96	.86	8.64	18	6.8	7.86	2.26	160	127	159
S-2-60	153	106	1.06	1.13	8.71	18	6.7	8.75	2.48	170	172	151
S-3-60		113	1.03	1.20	10.5	19	6.0	9.68	2.62	170	111	142
MEAN		110	1.0	1.2	9.3	18	6.5	8.8	2.5	170	140	150
STDDEV		4	.05	.14	1.1	.6	.4	.9	.2	6	32	9
S-1-95	122	71.1	1.31	1.25	9.93	<1	<1.47	43.5	3.0	76.7	70.6	110
S-2-95		69.0	1.05	1.27	8.45	<1	<1.47	48.0	3.1	70.8	50.1	111
S-3-95	24.1	70.2	1.11	1.30	9.77	<1	<1.47	47.7	3.2	82.6	49.8	118
MEAN		70	1.2	1.3	9.4	<1	<1.5	46	3.1	77	57	110
STDDEV		1	.1	.03	.8			3	.1	6	12	5

CHEMICAL DATA ON SHALE REFERENCE STANDARDS IND. REF. 1 (S-60) AND SDO-1 (S-95)

SAMPLE NO.	GEOL. NO.	DEPTH (FT)	ZR (PPM) (OE-D)	ZR (PPM) (OE-P)	500 DEG. ASH (%)	ND (PPM)	FE AS % FE2O3 (AAS)	CU (PPM) (AAS)	LI (PPM) (AAS)	PB (PPM) (AAS)	PB (PPM) (OE-D)	NI (PPM) (AAS)	ZN (PPM) (AAS)
S-1-60	IN REF 1		84	290	87.53	28.5					9.0		
S-2-60			79	270	87.40	42.6					11		
S-3-60			75	270	87.42	19.1					10		
MEAN			79	280	87.45	30					10		
STDDEV			4.5	12		12					.6		
S-1-95	SDO-1		127	374	83.90	49	9.68	63.9	30.8	33	37	80.6	56.2
S-2-95			127	376	84.07	51	9.77	62.8	29.8	25	37	83.0	54.3
S-3-95			135	383	84.02	64	9.72	61.8	31.5	40	40	81.6	54.8
MEAN			130	380	84.00	55	9.72	63	31	33	38	82	55
STDDEV			5	5		8	.04	1	.8	7	1.7	1	1

SAMPLE NO.	H2O- (%) (ASTM)	750 DEG ASH (%) (ASTM)
S-1-60		
S-2-60		
S-3-60		
MEAN		
STDDEV		
S-1-95	.57	81.48
S-2-95	.42	81.33
S-3-95		
MEAN	.50	81.41
STDDEV		

ND = NOT DETECTED

INFORMATION

DATA COMPILATION

Data Encoding

Introduction

The Illinois Survey has been designated to receive all data on the DOE Eastern Gas Shales Project that pertain to the Illinois Basin. A total of six contractors, including the Illinois Survey, plus the U. S. Geological Survey, are generating or gathering data relevant to the Illinois Basin. Encoding forms in use at the Illinois Survey have been sent to the contractors for their use, if they so desire. MINERS can accept any file format, however.

Progress

Mound and Battelle Laboratories have sent data to date on cores in the Illinois Basin. The data cover a wide range of types, consisting of determinations from geophysical logs, physical and chemical characterization, location, coring data, core surface data, and gas in shale. Other contractors have sent data to the Illinois Survey for filing.

MINERAL RESOURCES EVALUATION SYSTEM (MINERS)

Introduction

This project involves the development of a Mineral Resources Evaluation System that will store all the data related to Illinois 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.

FILE GENERATION AND MAINTENANCE

Progress

Early in the design of file generation we were advised by personnel at the University of Illinois computing center that we could save programming effort and simplify our design work by using the IBM 360 Operating System to handle much of the complicated file manipulation planned for MINERS. We were told that several of the routines necessary to accomplish the manipulations had already been written and the others would be written for us or we would be led step by step through the programs.

In fact, the routines that had already been written by the University computing center personnel would not compile. After considerable effort on our part we were able to compile the programs one by one. By the time we had the key routines working it became obvious that the IBM 360 Operating System could not handle all the file manipulations we believe necessary. Hence, in our last monthly report (May 1978) we reported that certain re-designing was required.

Very good progress has been made in writing the routines that will accomplish the file manipulation we have designed for MINERS, even though most effort during this quarterly report period has been on the retrieval portion of MINERS. The only unwritten routines are those that are given a data item name, look up the files the data items are in, fetch these files, and find the item.

RETRIEVAL

Progress

Almost all programming has been completed and testing is well along. Retrieval runs have been made successfully, and at this point in time appear to do everything we had planned. Integrating retrieval, file generation and maintenance is where most of our effort is presently being directed.

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