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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 for July 1—September 30, 1979

By
Robert E. Bergstrom
Neil F. Shimp

October 9, 1979

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

MASTER

Illinois Institute of Natural Resources
State Geological Survey Division
Urbana, Illinois

U. S. DEPARTMENT OF ENERGY

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Illinois State Geological Survey

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Robert E. Bergstrom and Neil F. Shimp
Principal Investigators

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Report ORO-DE-AC21-76-MC05203-12 (1979)

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GEOLOGICAL EVALUATION

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 Drilling

A core of approximately 220 feet is presently being collected in Wayne County (Section 17, T. 3 S., R. 8 E.). Details of this test were given in the last monthly report.

Gas Shows in the New Albany Shale

In the past year, the Survey has learned of several gas shows in the New Albany Shale. Only one of these shows was reported in the normal manner through scouting services. All of the other shows were learned of by word of mouth. Details of these shows are given below.:

E. L. Doheny #1 Arnold
12-5N-14W, Crawford County
Gas show on gas chromatogram. DST did not yield any gas (W. F. Meents, pers. comm.).

Joe Kesl et al., #1 A. Jones
7-4N-10W, Lawrence County
Drillers log notes a gas show from 2754 - 2765 ft. in the New Albany; well drilled in 1939. (W. Zumwalt, pers. comm.).

Texas Pacific #1 M. Streich
2-11S-6E, Pope County
Excellent gas show on gas chormatogram chart from 3476 - 3972 ft. Small amount of butane logged in the Grassy Creek where show was greatest (copy in ISGS files).

Texas Pacific #1 J. Wells
34-10S-6E, Saline County
Gas show on gas chromatogram from 3892 - 4246 ft. (entire Springville through New Albany interval). Greatest in Grassy Creek Shale (copy in ISGS files).

Fletcher Farrar #A-1 Rhine
2-8S-6E, Saline County
Scattered slight show of oil reported from 4926-4930 ft., in the Blocher Sahle (Scout check).

H. H. Weinert #10 McPhearson
3-2S-7E, Wayne County
Gas show on gas chromatogram near middle of New Albany Shale (Pers. comm. to J. A. Lineback).

Hobson Oil #2 Taylor
34-1S-7E, Wayne County
Gas show on gas chromatogram, 55' gas recovered in DST, high gas content in core of Grassy Creek Shale (copy in ISGS files).

Nation Oil #2 McIntosh
31-3S-8E, White County
Good show of gas at surface and on gas chromatogram (D. Melrose, pers. comm.).

Texas Pacific #1 Ackerman
27-5S-8E, White County
Gas show on mud logger chart, 5065 - 5210 ft., Grassy Creek Shale (copy of chart in survey files).

Wm. & P. Becker #1 Harper
1-6S-8E, White County
Gas chromatograph went off scale in upper portion of New Albany Shale on a deep test which did not penetrate the entire formation. (F. Cody, pers. comm.).

Jim Haley Prod. #1 Tuley
21-6S-10E, White County
Drilling mud was cut by strong show of gas in the New Albany Shale and the well almost blew out. Attempted to perforate the shale and complete as a gas producer but were unsuccessful (J. Avila, pers. comm.).

Rhea Fetcher #1 Karch
24-6S-10E, White County
Gas show in cable tool hole, DST did not yield any gas (M. Williams, pers. comm.).

The location of these shows is shown on Figure 1. There are several possible reasons for the rarity of shale gas shows in Illinois:

1. Most Devonian tests in Illinois are drilled with rotary tools, as opposed to numerous cable tool holes in adjacent states. Gas shows in the Devonian shales are generally more noticeable in cable tool holes.

2. The organic-rich black shale facies associated with gas production and shows in the Appalachian Basin is generally deeply buried in Illinois, and only about 300 out of the 13,000 Devonian and deeper tests in Illinois penetrate a significant thickness of this facies. In Indiana and western Kentucky the black shales are much less deeply buried and a correspondingly greater number of tests penetrate the black shale facies.

3. Mud logging units are not widely employed in Illinois.

4. Operators in Illinois show little interest in Devonian shales, partly because of their marginal economics and partly because of the lack of gas production in Illinois. It is very likely that many gas shows are not noticed, are not reported, and are ignored.

Several area geologists have been queried in this regard and all indicated that gas shows are almost invariably noted in the shale when mud logging units are on site; however, they are never reported on scout tickets. The record of shows in Illinois is therefore regarded as an unreliable and meaningless measure of the gas potential of the shale.

Coordination of Stratigraphic Maps

Nearly all problems in coordination of stratigraphic units between Illinois and Indiana have been resolved although there remain some minor philosophical differences in the best recognition of some stratigraphic boundaries. Illinois and Indiana stratigraphers had some disagreement over the use of vertical cut-offs in adjusting the Grassy-Creek Sweetland Creek contact. This problem in part, prompted the Indiana stratigraphers to resume the usage of the Indiana nomenclature, which is largely that of Lineback (1968, 1970). Further work led Reinbold and Cluff of the Illinois Survey to conclude that the Indiana nomenclature, with some revision, would be the most appropriate for the entire deep portion of the Illinois Basin including southeastern Illinois. The Indiana outcrops are lithologically more similar and are more readily correlated to the subsurface of the deep basin than are the Mississippi Valley outcrops which are the principal basis for the present Illinois nomenclature. The adoption of a dual system of nomenclature in Illinois was tentatively suggested. In this plan the Mississippi Valley nomenclature would be used in western and central Illinois (the presumed shallow shelf deposits) and the Indiana nomenclature would be extended into Southern and Eastern Illinois (the deep basin sections). In the interest of expediency, the dual nomenclature will probably not be adopted for use in this project. However, it has been alternatively suggested that we adopt the term Selmier (expanded from the original definition by Lineback, 1968) to replace the term Sweetland Creek in southeastern Illinois. The deep basin rocks which have been referred to the Sweetland Creek in Illinois are not readily correlated to the type Sweetland Creek in southeastern Iowa, but can be correlated through the subsurface to the type Selmier of the southeastern Indiana outcrop area.

Lithofacies Maps

Problems and discussion

We have concluded, as did workers in the Appalachian Basin, that the most useful lithofacies maps, in terms of gas potential are isolith (cummulative thickness) maps of "black" shale or "radioactive" shale as determined from gamma ray logs. The highly radioactive shales are generally organic-rich and are regarded as probable hydrocarbon source rocks, although they may not necessarily be good reservoir rocks.

Several problems have been encountered in defining "Radioactive" shale. Initially it seemed desirable to use a uniform quantitative definition. Consequently, following some observation and discussion, stratigraphic workers from Illinois and Indiana tentatively agreed to use a cutoff value of 200 API units on the gamma ray scale. Shales with API values higher than the cutoff were considered "radioactive". In many southeastern Illinois wells, the 200 API cutoff also seemed reasonably consistent with the distinction between "black" and "gray" shales as seen in sample studies. Unfortunately, further work revealed that this definition was less appropriate in other parts of Illinois. Great problems arose from the fact that not all gamma ray logs are scaled or calibrated uniformly.

Because of these problems, it was decided to use a method of defining "radioactive" shale which is similar to that used in the Appalachian Basin (Harper and Piotrowski, 1978). By this method, any shale with a gamma ray value >20 API units above a "normal" shale base line (determined for each well individually) is defined as "radioactive" shale. Workers in Illinois and Indiana generally agreed that 20 API units is not a large enough cutoff value. It does not seem to be a really significant departure from the "normal" shale base line and does not serve to distinguish between "black" and "gray" shales in most of the Illinois Basin. Workers from the two states have agreed that 60 API units is a more appropriate cutoff value in the Illinois Basin.

Selecting a "normal" shale base line has posed problems in some areas. Some sections contain no shales within the New Albany which could be considered "normal." The overlying Mississippian Shales provide the only reasonable reference, but they may be thin or somewhat variable in gamma ray value. In most areas the Hannibal-Saverton interval may be near "normal", but even in these shales, the gamma ray curve may be somewhat affected by silt or organic content.

In the Illinois Basin, gamma ray logs are much less abundant than are electric logs. Therefore, the lithofacies maps which rely entirely on gamma ray logs, have a much smaller data base than do the isopach maps which have utilized all available forms of data.

Progress and Discussion

Included with this report are a thickness map of "radioactive" shale in the New Albany of Illinois (fig. 2) and a percentage map of black shale within the New Albany (fig. 3). The maps are based on a 60 API unit cutoff value above the "normal" shale base line. Because of general sparsity of data and occurrence of anomalous values (probably resulting from inherent defects in the method of defining "radioactive" shale), these maps must be considered as very generalized.

Great caution should be exercised in making quantitative calculations of potential gas resources from these maps. Nevertheless, the maps do offer a reasonable approximation of the occurrence and distribution of "radioactive" shales within the New Albany.

The thickest "radioactive" shales (fig. 2) occur in southeastern Illinois and closely resemble the pattern of the total New Albany Shale thickness (fig. 4). The total thickness of "radioactive" shale decreases dramatically toward the north and west. The very thick New Albany of western Illinois (fig. 4) contains very little "radioactive" shale (fig. 2). In most of Southeastern Illinois more than 60 percent of the New Albany is "radioactive," and in some areas it is more than 80 percent (fig. 3). In parts of southwestern Illinois, the entire New Albany is "radioactive" by the definition used. However, in these areas, the total New Albany is very thin.

The patterns of "radioactive" shale distribution in Illinois serve to strengthen the earlier conclusions that a nineteen-county area in southeastern Illinois offers the best possibilities in the state for shale gas resources (see DOE monthly report February 5, 1979, p. 1-4). These conclusions are even farther reinforced by the fact that all known locations of gas shows in the New Albany to date have come from these counties (fig. 1).

Publications

On May 23, M. L. Reinbold presented a paper entitled "Facies Relationships in the Uppermost Devonian and Lowermost Mississippian Strate (Upper Part of the New Albany Shale Group) in Illinois, USA," at the Ninth International Congress of Carboniferous Stratigraphy and Geology (IX-ICC) in Urbana, Illinois. An abstract for this paper was printed in the quarterly report to DOE of January 8, 1979.

A written manuscript for the above presentation has been prepared for publication in the Compte Render (Proceedings of IX-ICC). Some of the correlations and interpretations presented in this paper, especially those most closely related to the Devonian-Mississippian boundary problem, have aroused considerable controversy within certain sectors of the Survey. The manuscript offers interpretations concerning the facies relationships and time stratigraphic classifications which are at odds, in part, with the currently accepted classification of the Illinois Survey. During this lengthy controversy, new evidence has been presented and certain compromises or concessions have been made by both sides. Revision of the manuscript is now considered to be very nearly complete, and it will soon be submitted for publication.

A manuscript by R. M. Cluff and M. L. Reinbold entitled "The New Albany Shale Group in Illinois," has been essentially completed for sometime, but has been subject to some revision based on the outcome of the controversy mentioned above. Many of the same controversial interpretation as in the IX-ICC manuscript are presented in this manuscript. The manuscript, which will be printed as an Illinois Survey Circular, will include isopach maps of the New Albany Group and formational units, as well as several cross sections.

References Cited

Harper, J. A., and Piotrowski, R. E., 1978, Stratigraphy, extent, gas production, and future gas potential of the Devonian organic-rich shales in Pennsylvania: U. S. Department of Energy, Morgantown Energy Technology Center, Second Eastern Gas Shales Symposium Preprints, V. 1, p. 310-329.

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Lineback, J. A., 1970, Stratigraphy of the New Albany Shale in Indiana: Indiana Geological Survey Bull. 44, 73 p.

Reinbold, M. L., Stratigraphic relationships of the New Albany Shale Group (Devonian-Mississippian) in Illinois: U. S. Department of Energy, Morgantown Energy Technology Center, Second Eastern Gas Shales Symposium Preprints, V. 1, p. 443-454.

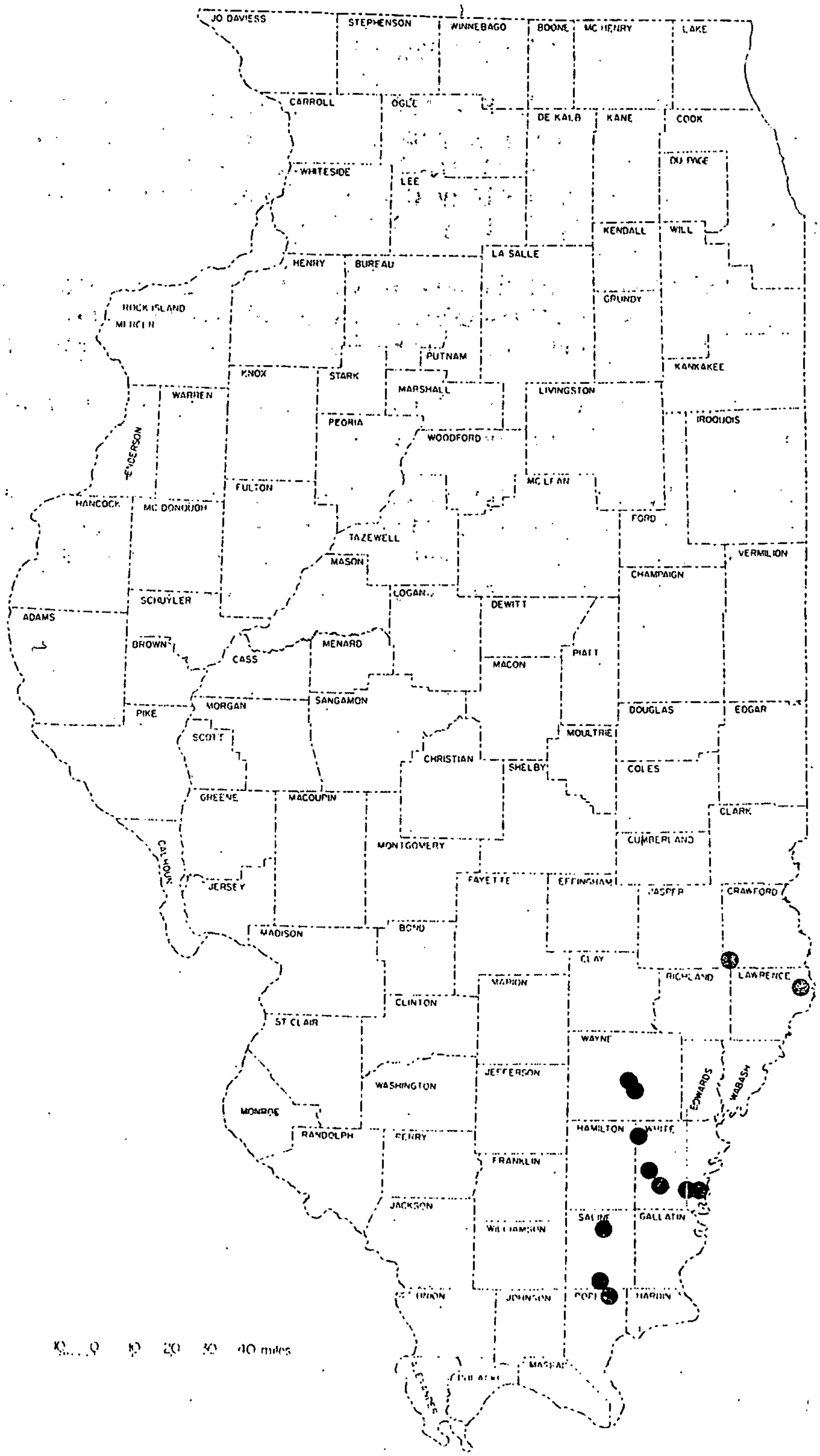

Figure 1 -- Locations of known gas shows in the New Albany Shale as of September, 1979.

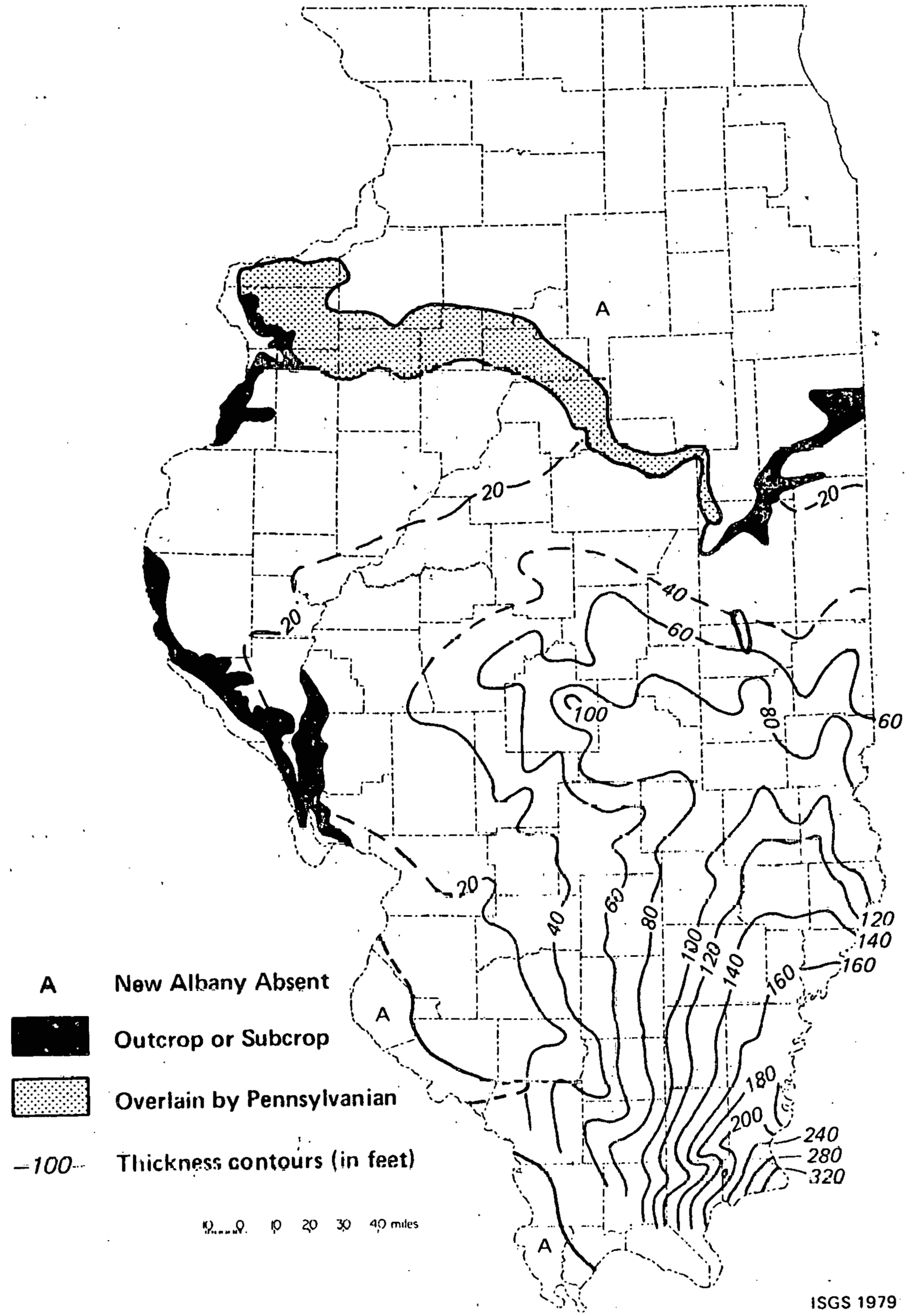

Figure 2. Cumulative thickness of radioactive shale within the New Albany Shale Group in Illinois. Radioactive shale is here defined as that having a gamma ray log value ≥60 API units above a normal shale base line.

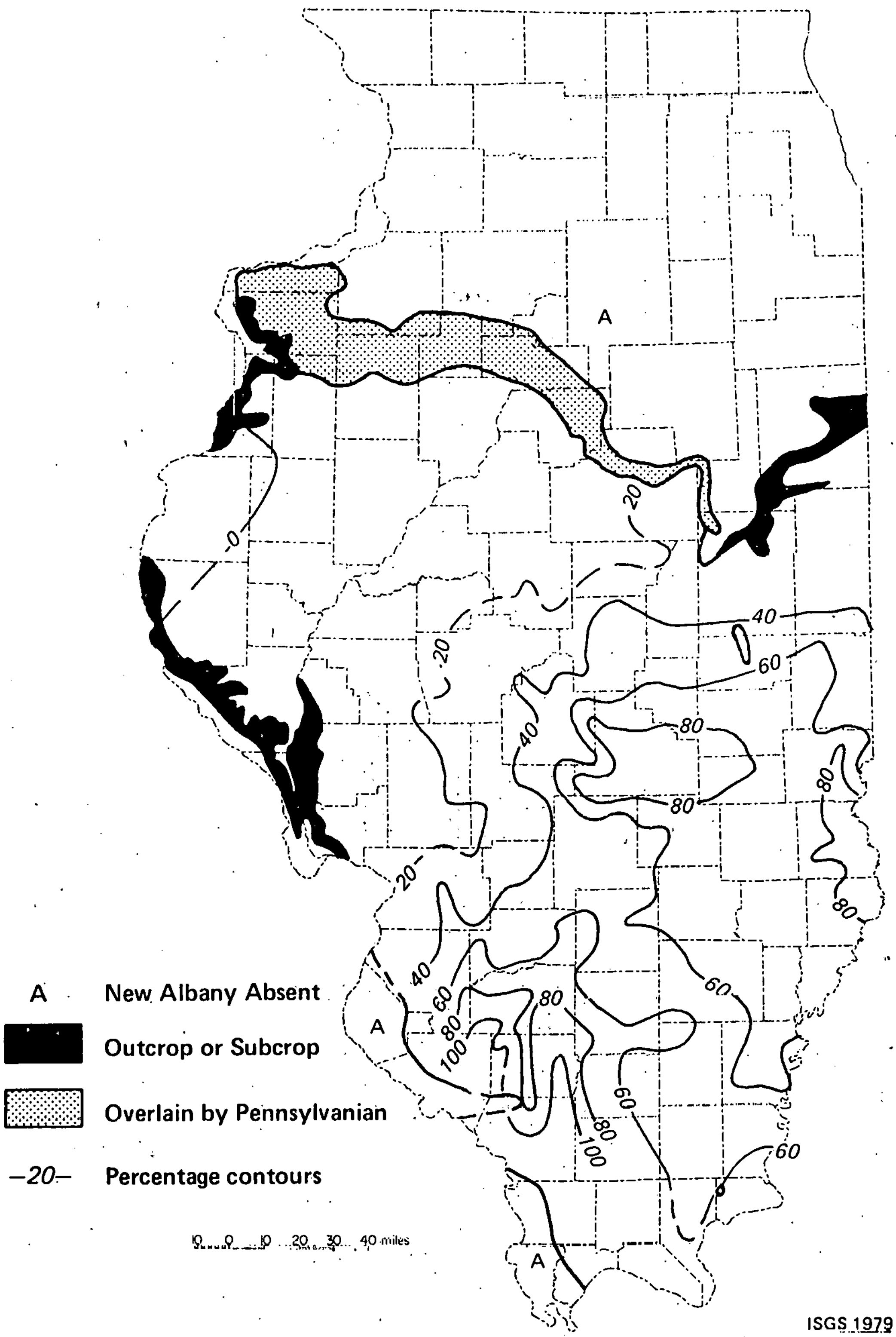

Figure 3. Percentage of radioactive shale within the New Albany Shale Group in Illinois. (See figure 2 for definition of radioactive shale.)

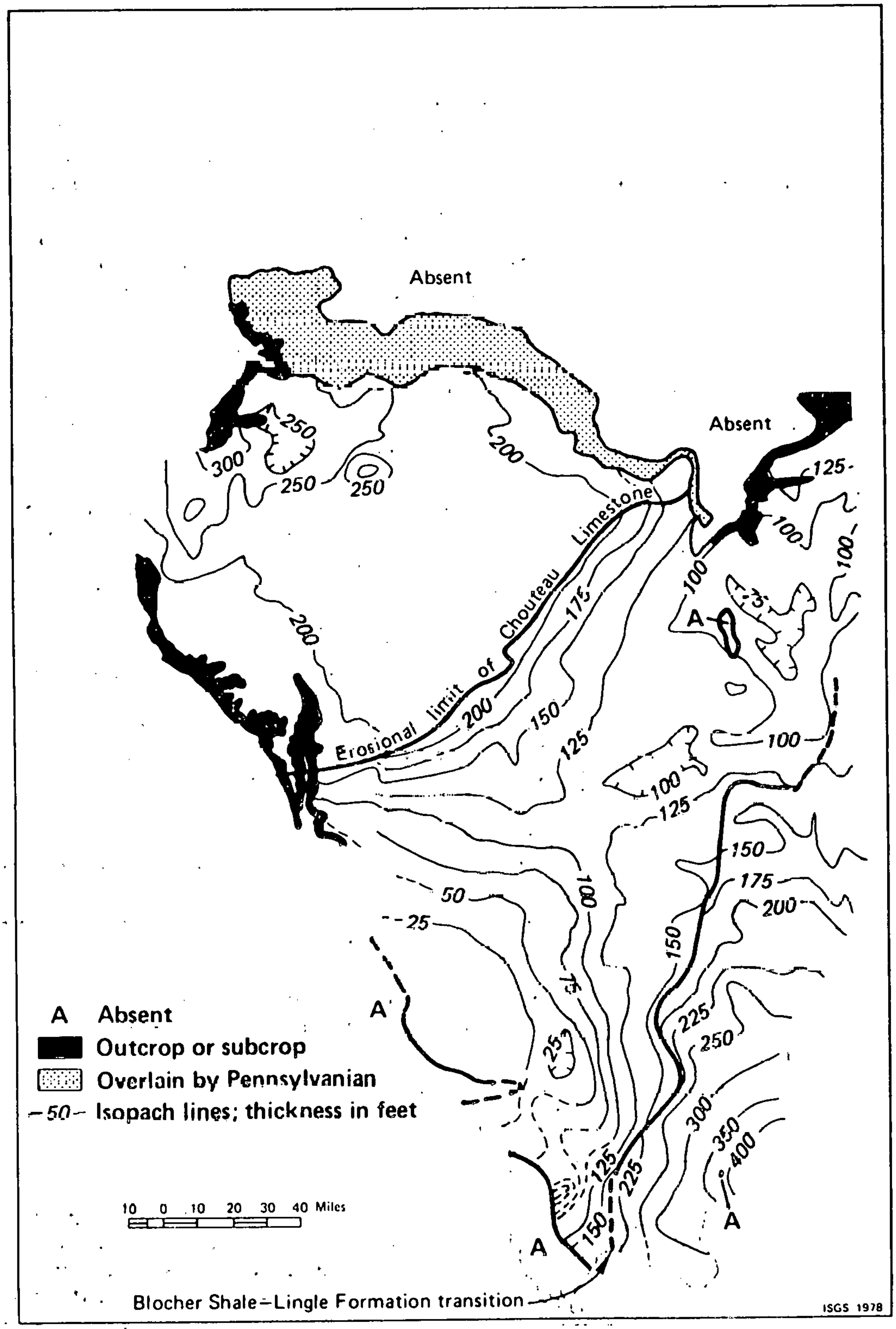

Figure 4. Total thickness of the New Albany Shale Group in Illinois (from Reinbold, 1978).

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.

Highlights of Work Performed in FY 1979

1) Thirty-six samples for lithologic and radiographic analysis were collected from New Albany Shale cores in Fayette County, Hardin County, and Wayne County, Illinois. Radiography of all samples except the Wayne County samples has been completed.

2) Collection of supplementary drill cutting samples from various Devonian tests throughout Illinois was completed. Table 1 lists the sample numbers and wells sampled by location in Illinois. Several additional samples from wells in Indiana were provided by the Indiana Geological Survey and these are listed in Table 2.

3) X-ray diffraction mineralogy was completed for 130 clay samples and 121 whole rock samples. Clay orientation indices were determined for 42 core samples.

4) Vitrinite reflectance analysis was completed for 102 acid-macerated samples, including samples from 1 deep well. Reflectance analysis was also completed for the Fayette County, Illinois (10IL)core. Acid maceration of all drill cutting samples was completed.

5) Visual fluorescence analysis was completed for 117 drill cutting samples.

6) Scanning electron microscope examination of selected samples representing the full range of lithologies found in the New Albany Shale was completed.

7) A paper summarizing our findings on the occurrence and maturation of organic matter in the New Albany, and its relationship to oil and gas, was completed for the Joint DOE/EGSP-ES/AAPG Symposium.

Microscope Characterization

Progress

The scanning electron microscope (SEM) study of the samples representing the shale lithotypes was completed during FY 79. This work has provided some useful information in characterizing the shales: information on clay orientation and its relationship to shale fabric data on the forms of pyrite and their relationship to the shale matrix and organic matter, and data on organic matter and its relationship to the shale matrix. The writing of a report on this work is now in progress.

Lithologic and Radiographic Characterization

Progress

Preparation of samples for radiographic characterization was completed for all samples from the Fayette County, Illinois (10IL), the Hardin County, Illinois (11IL), and Wayne County, Illinois (12IL) cores. Preparation of thin sections was delayed due to scheduling conflicts and several are still in progress. Detailed summaries of the lithologic and radiographic analysis will be prepared when the thin section analyses have been completed for all core samples.

X-ray Diffraction and Clay Orientation

Progress

Clay mineralogy, clay orientation indices and whole-rock mineralogy data for all samples completed during FY 1979 are presented in Tables 3 through 10. Maps showing the variation in clay mineralogy and whole rock mineralogy of the New Albany Shale across Illinois will be prepared in the coming months.

Vitrinite Reflectance

Progress

Vitrinite reflectance data for all samples to date, including FY 77 and FY 78 are presented in Tables 11 and 12. Visual fluorescence data for all samples completed to date are presented in Table 13. A technical report summarizing our work on the types of organic matter in the New Albany Shale, vitrinite reflectance, fluorescence, and their relationship to oil and gas in Illinois was prepared for the Joint DOE/EGSP-ES/AAPG Symposium in Morgantown, West Virginia. The paper is appended to this report.

TABLE 1 - LOCATION OF NEW ALBANY SHALE (NAS) SAMPLES TAKEN FROM WELL CUTTINGS IN ILLINOIS (Note that several samples were taken from a single well)

Sample Numbers (NAS-)	County	Sec-T-R	Well Name
001-027	(various	locations)	outcrop samples
028-029	Clay	16-3N-6E	So. Ill. Oil #1 Mearns
030-032	Effingham	32-6N-5E	Juniper Petrl. 12x-32 Gerth
033-034	Jefferson	18-3S-1E	Dunnill #1 Kujawa
035-039	Madison	35-5N-7W	B. Hall #1 Wehling
040-043	Mason	3-19N-10W	Pinkston #1 Blessman
044-045	Washington	30-2S-3W	Amoco Prod. #1 Kolweier
046-047	Washington	27-3S-1W	Juniper Petrl. #24x-27 Kubiak
048-051	Washington	1-3S-4W	Anschutz #1 Elgenrauch
052-055	Wayne	27-1N-7E	Pure Oil #3 Billington
056-059	Wayne	14-1N-8E	Nation Oil #1 Van Fossan-Brown
060-063	Wayne	28-1S-6E	Texaco NCT-1 Fuhrer
064-068	Wayne	29-2S-9E	Collins Bros. #1 Hill
069-074	Wayne	4-3S-7E	Savage/Zephyr #1 Sprague
075-082	Wise, VA		
083-088	Christian	28-13N-1W	Union Oil #1 Cleveland
089-092	Gallatin	11-8S-10E	Humble Oil #33 Busiek-Crawford
093-097	Gallatin	29-9S-9E	Texaco #1 Walters
098-102	Greene	32-11N-11W	Kewanee Oil #1 Eula
103-105	Lawrence	29-4N-12W	Atlantic Richfield #77 Lewis
106-107	Logan	7-19N-3W	Allspach #1 Park
108-112	Macon	33-18N-2E	Hill #1 Haynes
113-117	Pope	10-13S-6E	Williams #1 Austin
118-121	Saline	34-10S-6E	Texas Pacific #1 Wells
122-126	Saline	32-10S-7E	Texota Oil #1 King
127-133	Wabash	9-1S-12W	So. Triangle Oil #D2 Zimmerman
134-135	Woodford	28-27N-3W	Centrl. Ill. Light #C18 Cilco
136-138	Champaign	12-22N-11E	Peoples Gas #1 Condit
139-141	Christian	25-11N-1E	Franks Petrl. #1 Wagner
142-146	Clay	11-2N-5E	Keystone Oil #1 Woomer-Campbell
147-149	Clark	4-10N-11W	Corley #1 Miller
150-151	Coles	27-12N-7E	Energy Prod. #G-1 Arterburn
152-155	Coles	20-14N-7E	Brehm #1 Lambert
156-157	Crawford	2-5N-11W	Bell #1 Miller
158-161	Crawford	12-5N-14W	Doheny #1 Arnold
162	Crawford	36-6N-11W	Slape Drilling #1 Kincaid
163	Crawford	6-7N-11W	K Oil #1 Mehler
164-165	Crawford	12-7N-11W	W Drilling #1 Brown
166-167	Crawford	31-7N-13W	Ill. Oil Invest #1 Mallory et a
168-170	Cumberland	4-10N-9E	Texaco #1 McCandlish
171-174	De Witt	1-20N-4E	Peoples Gas #1 Lamb
175-176	Edgar	4-14N-11W	Jones-Simpson Drill. #1 Steele-Mos
177-178	Edgar	1-14N-14W	Wansan Petrl. #1 Sims
179-181	Effingham	3-7N-7E	Energy Res. #1 Niemerg
182-186	Hamilton	1-4S-5E	Kewanee Oil #1 Wellen
187-190	Hamilton	13-6S-5E	Shell Oil #4 Mohave
191-193	Hamilton	6-6S-7E	Texaco #1 Cuppy

TABLE 1 - CONTINUED

Sample Numbers (NAS-)	County	Sec-T-R	Well Name
194-196	Iroquois	21-24N-13W	Peoples Gas #1 Mumm
197-199	Iroquois	13-25N-11W	Peoples Gas #1 Keen
200-203	Jasper	1-8N -8E	Total Leonard #1 Thoele
204-206	Jefferson	32-4S-3E	Juniper Petrl. #33x-32 Hayse
207-208	Lawrence	9-3N-11W	Shellensker Drill. #1 Seward
209	Madison	23-4N-5W	Stocker & Sitler #1 Suess
210-212	Marion	35-3N-2E	Brehm Drill. #1 Behnke
213-215	Lawrence	25-3N-13W	Highland Oil #1 Hobbs
216-217	McDonough	23-4N-2W	Bur-Kan Petrl. #1 Chipman
218-220	McLean	33-23N-2E	Zimmerman #1 McLean Co.
221-225	McLean	31-23N-3E	Union Hill Gas #1 Bozarth
226-227	McLean	26-23N-6E	Garland & Hoover #1 Green
228-230	Piatt	13-21N-6E	Union Hill Gas #1 Buchan
231-233	Sangamon	11-15N-3W	Corley #1 Anderson
234-235	Sangamon	1-16N-6W	Caney Oil #1 Eugene
236-238	Vermillion	12-19N-11W	Allied Chem. #1 Allied Chem.
239-240	Vermillion	10-23N-11W	Peoples Gas Layden
241-243	Vermillion	15-23N-14W	Peoples Gas #1 Swanson
244-250	White	23-6S-9E	Haley Prod. #1 Trainor
251-253	Williamson	25-8S-3E	Brehm Drill. #1 Harris Unit
254-257	Macoupin	23-12N-6W	Crown II Mine (Penn. samples)
258-260	Williams	17-9S-4E	Amax-Delta Mine (Penn.samples)
261-264	Gallatin	14-10S-8E	Eagle Strip Mine (Penn.sample
291-294	Bond	12-5N-4W	Texas Co. #1 Sybert
295	Champaign	33-17N-9E	Beatty #Bozdeck
296-299	Champaign	23-19N-10E	Peoples Gas #1 Tracy
300-303	Champaign	19-19N-8E	Vickery Drilling Co. B-0-1
304-307	Clark	33 11N-14W	Fanchot #A-1 Elliott
308-309	Clay	16-3N-5E	Southern Ill. Oil Prod. #1Fat
310	Clay	15-2N-7E	Steele #1 Leak
311-314	Coles	16-13N-9E	Union Oil of Calif.#1 Moler
315-318	DeWitt	16-21N-3W	Harris #1 Lewis
319-321	Douglas	31-16N-8E	Cabot Corp. #2 Cabot-Tuscola
322	Douglas	2-14N-10E	Joe Beckner Drill. #1 Jividen
323-327	Fayette	21-6N-2E	Brehm #1 Ireland
328-331	Fayette	31-5N-3E	Shell Oil #1 Ford
332-335	Franklin	36-6S-2E	Shell Oil #19 C.W.& F. Coal
336-339	Franklin	19-7S-2E	Callaghor #1 Zeigler Coal & C
340-343	Franklin	20-6S-4E	Texaco #1 U.S. Steel
344-346	Jackson	36-9S-2W	Grammer #1 Dickerson
347-348	Jackson	11-7S-2W	Texaco #1 Harsha
349-352	Jackson	21-10S-3W	National Assoc.Pet.Co. #1 Hay
353-356	Jefferson	28-3S-2E	Crystal Oil Co. #1 Storey
357	Montgomery	8-7N-2W	Calvert Drill, #1 Blackburn
358-360	Johnson	34-13S-3E	Texas Pacific Oil #1 Farley
361-363	Knox	2-11N-2E	Illinois Power G-2
364-366	Macon	36-16N-1E	Corley #1 Hill
367-369	Macoupin	19-12N-6W	Wright #1 Thoron
370-372	Marion	25-4N-3E	Total Leonad #1-25 Lane
373-377	Montgomery	11-9N-3W	Mobil Oil Co. #1 Dewerff
378-380	Montgomery	33-12N-5W	Phillips Pet. Co. #5 Farmersvl

TABLE 1 - CONTINUED

Sample Numbers (NAS-)	County	Sec-T-R	Well Name
381-383	Morgan	15-13W-8W	Panhandle E. Pipe Line Co. #7-15 Whitelock
384	Moultrie	7-15N-6E	Felmont Okl Corp. #1 Ware
385-386	Perry	19-5S-2W	Total Leonard Inc. #1 Pick
387-390	Piatt	5-19N-5E	Texaco #1 Irenchard
391-397	Saline	8-10S-5E	Parker #1 Parker
398-404	Saline	9-9S-5E	Brehm Drill. & Prod. #1 Ozmen
405-407	Shelby	17-9N-3E	Energy Resources of IL #1 Gre
408-411	Shelby	3-10N-5E	Total Leonard Inc. #1 Engel
412-414	Tazewell	36-24N-7W	Centrall IL Light #1 Rutherfo
415	Shelby	17-9N-3E	Total Leonard Inc. #1 Engel
416-418	Union	12-12S-1W	Fry #1 Hill
419-425	Wayne	21-1S-9E	Luttrell #1 Fetherling
426-432	White	21-3S-9E	National Oil Co. #1 Granger
433-438	Crittenden, KY		Shell Oil #1 Davis
439	Johnson	8-12S-3E	Outcrop sample (Penn.)
440	Union	25-11S-1E	Outcrop sample (Penn.)
441-444	Clinton	6-2N-4W	Anschutz #1 Schroder
445-451	Jasper	17-5N-10E	Pure Oil Co. #A-5 Honey
452-454	Mason	9-22N-7W	Engelke #1 Woodrow
455-459	Montgomery	11-8N-5W	Calif. Co. #1 Schmidt
460-462	Peoria	25-11N-8E	Prentiss #1 Coon
463-465	Pike	32-3S-4W	A. W. Neal Co. #1 Crump
466-468	Pike	23-6S-3W	Texaco #1 Scott
469-471	Schuyler	11-1N-3W	Kerwin #1 Wrench
472-477	White	15-5S-9E	Brehm #1 Reinwald
478-486	Effingham	15-6N-6E	Kingwood Oil #1 McWhorter
487-504	Hamilton	6-6S-7E	Texaco #1 Cuppy
505-521	Pope	2-11S-6E	Texas Pacific #1 Streich Comm.
522-536	Gallatin	29-9S-9E	Texaco #1 Walters
537-547	Shelby	19-14N-2E	NRA YES Inc #1 Stoggsd. 11
548-552	Fulton	10-6N-1E	New Jersey Zinc #H-16 Thompso
553-556	Fulton	13-8N-2E	New Jersey Zinc #H-23 William
557-562	Knox	31-11N-2W	New Jersey Zinc #J-16 Gumm

TABLE 2 - LOCATION OF NEW ALBANY SHALE (NAS) SAMPLES OBTAINED FROM WELL CUTTINGS IN INDIANA (Courtesy of the Indiana Geological Survey)

Sample Numbers (NAS-)	County	Sec-T-R	Box Numbers
265	Daviess	16-3N-7W	9806
266	Spencer	3-6S-4W	9684
267	Foutain	33-22N-7W	4754
268	Lawrence	20-5N-2E	6088
269	Martin	5-3N-4W	3577
270	Sullivan	14-8N-8W	7029
271	Posey	18-5S-13W	9339
272	Sullivan	36-7N-10W	8080
273	Harrison	2-6S-4E	7358
274	Crawford	18-3S-1W	10437
275	Putnam	12-12N-3W	5411
276-281	Elkhart		500-595
282	Warrick	36-4S-9W	3951
283	Montgomery	14-17N 3W	4969
284	Vermillion	27-14N-9W	10060
285	DeKalb	8-35N-14E	7177
286	Sullivan	32-8N-8W	3274
287	Owen	14-9N-5W	6561
288	Morgan	3-12N-1W	6752
289	Hendricks	12-14N-1E	6069
290	Washington	17-2N-5E	10021

TABLE 3 - SILT MINERALOGY, DRILL CUTTING SAMPLES

OBSERVED PEAK HEIGHTS (COUNTS/SEC)

SAMPLE NUMBER	DEPTH	MCA 19.8	QTZ 20.8	FLD 23.5	KSP 27.6	PLG 27.9	KSP/PLG	CAL 29.4	DOL 30.8	CAL+DOL	SID+APA 32.1	PYR 33.2	MAR 52.0	PYR+MAR	MINERAL TWO THETA
NAS-028		42	125	25	40	45	47/ 52	30	42	72	15	27	5	32	
NAS-031		51	162	15	0	50	0/100	53	35	88	15	25	0	25	
NAS-032		82	160	30	0	72	0/100	83	52	135	20	27	5	32	
NAS-034		50	115	25	35	45	43/ 56	55	25	80	10	30	7	37	
NAS-036		37	138	17	47	45	51/ 48	188	156	344	13	13	0	13	
NAS-037		50	117	21	50	50	50/ 50	100	117	217	15	16	5	21	
NAS-041		72	155	35	60	0	100/ 0	30	145	175	18	15	0	15	
NAS-043		47	100	20	42	35	54/ 45	0	45	45	10	15	5	20	
NAS-045		62	154	25	40	65	38/ 61	0	70	70	18	18	0	18	
NAS-046		57	130	23	0	55	0/100	0	50	50	16	27	5	32	
NAS-049		69	140	31	45	58	43/ 56	0	20	20	20	25	5	30	
NAS-055		58	182	33	50	63	44/ 55	0	45	45	18	56	10	66	
NAS-057		61	165	42	51	51	50/ 50	0	42	42	17	20	0	20	
NAS-059		62	142	27	0	65	0/100	0	40	40	25	36	14	50	
NAS-061		60	131	31	45	45	50/ 50	0	33	33	13	21	6	27	
NAS-062		60	149	21	40	57	41/ 58	15	102	117	17	20	6	26	
NAS-065		52	125	30	40	45	47/ 52	40	40	80	19	19	0	19	
NAS-067		47	122	25	30	42	41/ 58	16	25	41	17	25	0	25	
NAS-068		29	64	15	20	23	46/ 53	295	118	413	5	8	0	8	
NAS-071		55	125	30	38	40	48/ 51	35	30	65	30	25	0	25	
NAS-073		43	92	20	30	40	42/ 57	88	97	185	15	15	0	15	
NAS-085		57	163	35	48	50	48/ 51	38	25	63	10	10	0	10	
NAS-088		50	114	32	50	55	47/ 52	0	25	25	12	25	15	40	
NAS-090		42	124	22	35	25	58/ 41	20	28	48	10	31	7	38	
NAS-091		55	120	27	30	45	39/ 59	20	40	60	19	25	10	35	
NAS-092		50	110	25	0	50	0/100	50	105	155	23	20	0	20	
NAS-093		43	150	22	0	50	0/100	18	27	45	20	23	0	23	
NAS-094		44	99	27	35	50	41/ 58	0	30	30	21	28	8	36	
NAS-095		37	105	22	37	45	45/ 54	0	46	46	22	22	0	22	
NAS-096		32	76	20	30	30	50/ 50	117	112	229	5	10	5	15	
NAS-101		45	92	23	40	29	57/ 42	0	13	13	13	13	5	18	
NAS-103		26	80	17	30	41	42/ 57	10	41	51	10	32	9	41	
NAS-104		42	90	14	25	30	45/ 54	14	112	126	22	15	0	15	
NAS-106		51	110	22	38	33	53/ 46	15	19	34	10	5	0	5	
NAS-107		40	86	21	32	0	100/ 0	20	23	43	8	35	8	43	
NAS-110		46	93	22	27	30	47/ 52	0	0	0	12	14	0	14	
NAS-111		56	93	20	0	32	0/100	60	15	75	15	12	0	12	
NAS-114		50	145	20	36	36	50/ 50	0	46	46	18	31	0	31	
NAS-115		58	105	25	30	56	34/ 65	0	30	30	27	28	7	35	
NAS-116		51	105	18	26	47	35/ 64	13	77	90	19	17	5	22	
NAS-117		46	122	26	34	35	49/ 50	212	145	357	10	23	5	28	
NAS-119		52	157	31	50	45	52/ 47	48	44	92	17	38	6	44	
NAS-120		46	144	24	39	48	44/ 55	25	42	67	25	25	5	30	
NAS-121		50	135	22	0	50	0/100	25	64	89	15	25	0	25	
NAS-123		45	108	28	0	45	0/100	24	85	109	16	30	0	30	
NAS-124		50	97	21	30	45	39/ 59	0	44	44	40	65	9	74	
NAS-125		60	125	25	50	58	46/ 53	0	135	135	38	15	0	15	
NAS-126		41	125	20	33	40	45/ 54	98	169	267	13	53	5	58	
NAS-129		57	154	22	41	38	51/ 48	22	28	50	15	25	10	35	
NAS-130		54	113	22	33	43	43/ 56	13	23	36	13	28	10	38	
NAS-131		32	68	20	29	25	53/ 46	207	150	357	9	19	0	19	
NAS-134		41	96	27	45	0	100/ 0	30	245	275	10	10	0	10	
NAS-135		40	130	16	0	27	0/100	176	58	234	16	15	0	15	
NAS-138		101	185	35	65	60	51/ 47	0	95	95	25	30	5	35	
NAS-13[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	

TABLE 3 - CONTINUED

NAS-144	65	195	35	53	48	52/ 47	28	55	83	12	30	10	40
NAS-145	69	160	33	45	65	40/ 59	70	105	175	15	46	0	46
NAS-148	50	115	25	27	39	40/ 59	25	35	60	15	46	9	55
NAS-151	45	95	21	40	39	50/ 49	0	20	20	12	20	0	20
NAS-154	55	90	33	47	39	54/ 45	0	25	25	15	25	7	32
NAS-157	40	110	20	35	40	46/ 53	32	32	64	10	39	12	51
NAS-160	55	129	30	45	45	50/ 50	30	25	55	16	17	0	17
NAS-161	51	116	27	40	50	44/ 55	25	45	70	17	25	0	25
NAS-162	63	122	26	40	44	47/ 52	25	140	165	19	15	5	20
NAS-164	65	115	27	35	35	50/ 50	38	27	65	19	15	0	15
NAS-169	58	150	26	47	37	55/ 44	0	54	54	15	30	8	38
NAS-172	55	92	36	52	0	100/ 0	143	26	169	16	17	5	22
NAS-176	50	110	26	35	0	100/ 0	43	43	86	15	35	0	35
NAS-178	60	121	25	40	45	47/ 52	0	34	34	20	22	5	27
NAS-181	47	117	25	41	50	45/ 54	18	38	56	14	25	8	33
NAS-183	76	221	45	65	70	48/ 51	0	61	61	23	65	12	77
NAS-186	57	120	33	50	59	47/ 52	33	78	111	15	22	7	29
NAS-188	55	129	40	50	45	52/ 47	33	47	80	24	35	6	41
NAS-192	40	100	25	40	45	47/ 52	37	29	66	20	23	5	28
NAS-193	29	94	17	30	25	54/ 45	180	110	290	7	7	0	7
NAS-195	45	80	28	45	0	100/ 0	17	61	78	10	18	5	23
NAS-196	48	81	32	45	0	100/ 0	15	35	50	10	18	7	25
NAS-199	40	96	18	36	0	100/ 0	0	35	35	15	22	8	30
NAS-202	43	87	21	42	40	51/ 48	28	24	52	15	21	7	28
NAS-206	43	117	22	30	46	39/ 60	30	27	57	12	22	8	30
NAS-207	50	133	23	40	40	50/ 50	22	51	73	22	25	5	30
NAS-208	57	148	30	45	55	44/ 54	13	45	58	43	26	0	26
NAS-212	51	111	20	0	58	0/100	32	32	64	15	25	7	32
NAS-213	54	170	30	55	0	100/ 0	0	34	34	18	18	0	18
NAS-214	55	115	32	45	63	41/ 58	0	34	34	20	23	10	33
NAS-215	40	111	21	36	30	54/ 45	191	165	356	10	28	5	33
NAS-216	45	94	28	41	35	57/ 42	0	36	36	12	13	0	13
NAS-220	46	102	25	32	25	56/ 43	20	30	50	15	21	0	21
NAS-223	39	125	17	42	30	58/ 41	75	42	117	16	12	0	12
NAS-224	41	115	20	35	0	100/ 0	48	70	118	15	11	0	11
NAS-227	40	89	22	35	33	51/ 48	61	62	123	14	32	0	32
NAS-230	47	90	23	40	0	100/ 0	20	22	42	14	14	4	18
NAS-233	42	90	22	43	35	55/ 44	21	27	48	10	25	0	25
NAS-234	41	100	30	50	0	100/ 0	27	47	74	10	13	5	18
NAS-237	50	88	22	38	28	57/ 42	18	67	85	15	10	0	10
NAS-240	35	86	30	46	0	100/ 0	20	40	60	10	32	6	38
NAS-242	38	135	23	37	0	100/ 0	0	50	50	10	17	0	17
NAS-246	45	145	21	35	40	46/ 53	38	36	74	9	31	8	39
NAS-248	44	124	18	33	44	42/ 57	0	59	59	15	33	7	40
NAS-249	30	85	20	25	31	45/ 54	205	146	351	8	15	0	15
NAS-252	41	105	27	31	50	38/ 61	15	32	47	13	26	5	31
NAS-253	45	127	25	23	36	43/ 56	11	60	71	15	20	0	20
NAS-294	85	237	36	0	87	0/100	50	90	140	30	52	12	64
NAS-295	97	252	40	0	70	0/100	35	77	112	30	35	10	45
NAS-299	103	200	40	72	76	48/ 51	31	42	73	32	42	10	52
NAS-303	70	203	32	71	62	53/ 46	112	203	315	30	56	7	63
NAS-306	102	276	45	0	95	0/100	0	100	100	62	50	15	65
NAS-308	76	198	48	0	95	0/100	65	72	137	30	47	10	57
NAS-313	80	213	35	70	60	46/ 53	35	60	95	20	65	15	80
NAS-318	83	245	35	75	142	34/ 65	91	100	191	30	50	6	56
NAS-320	84	198	40	61	75	44/ 55	0	100	100	24	53	16	69
NAS-322	74	332	40	151	150	50/ 49	95	150	245	32	45	10	55
NAS-327	88	209	42	75	105	41/ 58	25	65	90	30	45	14	59
NAS-330	95	207	31	0	90	0/100	101	55	156	25	38	11	49
NAS-333	90	285	56	90	105	46/ 53	66	40	106	32	30	2	32
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

TABLE 3 - CONTINUED

NAS-341	75	237	52	87	128	40/ 59	67	36	103	25	29	0	29
NAS-345	89	220	45	85	78	52/ 47	106	74	180	21	25	0	25
NAS-348	76	197	45	0	90	0/100	31	100	131	40	60	11	71
NAS-349	80	205	45	85	93	47/ 52	95	90	185	22	40	6	46
NAS-355	86	265	45	85	100	45/ 54	109	45	154	41	20	0	20
NAS-359	77	215	49	80	106	43/ 56	0	64	64	25	75	15	90
NAS-360	83	197	50	94	110	46/ 53	0	115	115	30	44	6	50
NAS-363	103	167	25	70	68	50/ 49	0	118	118	30	18	0	18
NAS-365	60	145	43	78	80	49/ 50	0	44	44	25	20	5	25
NAS-369	75	270	50	75	65	53/ 46	46	66	112	32	25	16	41
NAS-370	75	197	35	65	81	44/ 55	76	67	143	23	48	7	55
NAS-376	75	246	41	0	101	0/100	88	50	138	21	38	10	48
NAS-378	74	227	54	0	90	0/100	66	55	121	24	36	8	44
NAS-381	85	210	58	93	91	50/ 49	0	45	45	25	51	5	56
NAS-390	85	195	40	85	0	100/ 0	55	65	120	40	32	0	32
NAS-394	75	257	51	85	95	47/ 52	0	77	77	20	57	18	75
NAS-397	93	257	55	0	105	0/100	30	137	167	25	31	5	36
NAS-399	91	276	55	0	103	0/100	0	100	100	25	45	14	59
NAS-404	92	223	43	75	107	41/ 58	0	234	234	42	29	7	36
NAS-407	90	227	40	81	95	46/ 53	0	80	80	30	51	13	64
NAS-411	80	245	35	70	61	46/ 53	26	94	120	20	55	15	70
NAS-412	70	182	57	105	0	100/ 0	30	253	283	26	37	0	37
NAS-418	86	220	48	92	105	46/ 53	68	60	128	25	40	10	50
NAS-422	82	250	45	67	90	42/ 57	43	63	106	22	103	15	118
NAS-425	90	240	42	0	110	0/100	40	96	136	35	42	11	53
NAS-428	70	251	41	0	98	0/100	0	102	102	25	72	12	64
NAS-390	85	195	40	85	0	100/ 0	55	65	120	40	32	0	32
NAS-394	75	257	51	85	95	47/ 52	0	77	77	20	57	18	75
NAS-397	93	257	55	0	105	0/100	30	137	167	25	31	5	36
NAS-399	91	276	55	0	103	0/100	0	100	100	25	45	14	59
NAS-404	92	223	43	75	107	41/ 58	0	234	234	42	29	7	36
NAS-407	90	227	40	81	95	46/ 53	0	80	80	30	51	13	64
NAS-411	80	245	35	70	61	46/ 53	26	94	120	20	55	15	70
NAS-412	70	182	57	105	0	100/ 0	30	253	283	26	37	0	37
NAS-418	86	220	48	92	105	46/ 53	68	60	128	25	40	10	50
NAS-422	82	250	45	67	90	42/ 57	43	63	106	22	103	15	118
NAS-425	90	240	42	0	110	0/100	46	96	136	35	42	11	53
NAS-428	70	251	41	0	98	0/100	0	102	102	25	72	12	64
NAS-430	87	233	47	0	109	0/100	0	85	85	30	40	10	50
NAS-435	58	268	38	0	85	0/100	290	123	413	20	75	14	89
NAS-437	55	160	50	0	59	0/100	>500	110	> 610	23	27	5	32
NAS-443	80	170	47	0	130	0/100	163	92	255	20	29	0	29
NAS-448	79	215	40	0	76	0/100	38	86	124	15	40	6	46
NAS-450	81	175	35	0	85	0/100	75	127	202	25	40	5	45
NAS-452	90	192	40	90	65	58/ 41	0	49	49	38	20	0	20
NAS-459	80	180	35	71	83	46/ 53	28	30	58	20	40	15	55
NAS-461	78	153	45	85	0	100/ 0	0	125	125	22	25	5	30
NAS-465	105	193	32	85	60	58/ 41	0	92	92	25	21	0	21
NAS-467	92	205	36	75	67	52/ 47	0	37	37	30	20	0	20
NAS-471	90	234	35	75	65	53/ 46	0	47	47	25	15	0	15
NAS-473	75	205	35	0	167	0/100	112	45	157	55	19	0	19
NAS-474	92	193	45	65	90	41/ 58	0	98	98	45	35	5	40
NAS-477	57	170	32	46	50	47/ 52	284	257	541	15	30	0	30
NAS-479	50	135	25	0	60	0/100	217	100	317	90	22	8	30
NAS-480	101	173	30	60	0	100/ 0	94	32	126	20	17	0	17
NAS-481	86	168	23	60	60	50/ 50	262	85	347	23	24	0	24
NAS-482	50	193	25	0	67	0/100	342	94	436	15	18	0	18
NAS-483	73	166	27	0	87	0/100	108	57	165	21	49	15	64
NAS-484	61	136	32	63	75	45/ 54	207	213	420	14	23	0	23
NAS-485	26	75	29	50	0	100/ 0	245	>500	> 745	13	0	0	0
NAS-486	75	99	25	35	35	[illegible]	[illegible]	73	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

TABLE 3 - CONTINUED

NAS-487	65	215	30	0	91	0/100	67	0	67	50	5	0	5
NAS-488	69	206	30	0	90	0/100	29	75	104	71	8	0	8
NAS-489	90	335	30	55	58	48/ 51	21	0	21	52	7	5	12
NAS-490	65	170	17	117	0	100/ 0	275	35	310	20	24	0	24
NAS-491	67	182	26	55	50	62/ 37	305	172	477	25	12	0	12
NAS-492	0	25	0	0	0	0/ 0	>500	216	> 716	0	0	0	0
NAS-493	45	198	25	40	42	48/ 51	350	122	472	16	18	0	18
NAS-494	70	183	30	0	75	0/100	171	200	371	32	21	6	27
NAS-495	80	170	34	0	85	0/100	61	115	176	33	24	0	24
NAS-496	55	182	32	0	67	0/100	247	85	332	22	18	0	18
NAS-497	20	177	35	50	0	100/ 0	330	>500	> 830	5	0	0	0
NAS-498	26	77	20	45	30	56/ 43	>500	356	> 856	10	13	0	13
NAS-499	0	30	12	25	0	100/ 0	45	>500	> 545	5	0	0	0
NAS-500	31	120	20	30	35	46/ 53	93	>500	> 593	16	8	0	8
NAS-501	20	110	10	25	23	52/ 47	50	>500	> 550	15	12	0	12
NAS-502	7	105	0	41	0	100/ 0	44	>500	> 544	0	18	0	18
NAS-503	0	40	0	0	0	0/ 0	30	>500	> 530	0	0	0	0
NAS-504	20	179	35	105	52	66/ 33	347	>500	> 847	2	0	0	0
NAS-505	97	137	30	0	50	0/100	48	52	100	115	0	0	0
NAS-506	91	142	0	0	0	0/ 0	0	58	58	76	18	0	18
NAS-507	20	55	0	0	28	0/100	<500	160	660	0	0	0	0
NAS-508	62	232	47	0	88	0/100	50	58	108	27	53	12	65
NAS-509	65	172	26	0	85	0/100	90	95	185	35	30	5	35
NAS-511	72	188	30	0	77	0/100	0	92	92	31	30	5	35
NAS-512	55	118	30	0	60	0/100	350	40	390	20	15	0	15
NAS-513	5	12	0	0	0	0/ 0	<500	445	945	0	0	0	0
NAS-514	0	38	0	0	0	0/ 0	>500	>500	>1000	7	10	0	10
NAS-515	0	60	22	30	49	37/ 62	20	>500	> 520	0	0	0	0
NAS-516	0	45	0	85	0	100/ 0	40	>500	> 540	12	0	0	0
NAS-517	0	30	0	0	15	0/100	>500	>500	>1000	0	0	0	0
NAS-518	0	155	5	0	20	0/100	20	>500	> 520	0	0	0	0
NAS-519	0	52	5	39	22	63/ 36	20	>500	> 520	0	0	0	0
NAS-520	0	12	0	15	0	100/ 0	12	>500	> 512	0	0	0	0
NAS-521	25	123	47	282	235	54/ 45	265	>500	> 765	50	15	0	15
NAS-521	25	123	47	282	235	54/ 45	265	>500	> 765	50	15	0	15
NAS-522	70	156	30	0	95	0/100	95	35	130	90	22	0	22
NAS-523	85	205	31	0	68	0/100	70	37	107	100	10	0	10
NAS-524	79	149	25	0	57	0/100	226	170	396	50	15	0	15
NAS-525	110	183	31	0	70	0/100	0	46	46	63	25	0	25
NAS-526	75	140	40	60	40	59/ 39	325	160	485	47	8	0	8
NAS-527	0	35	0	0	0	0/ 0	>500	208	> 708	0	7	0	7
NAS-528	80	275	45	0	95	0/100	45	55	100	25	43	0	43
NAS-529	81	210	40	0	90	0/100	0	90	90	31	47	5	52
NAS-530	82	203	35	0	83	0/100	0	77	77	59	35	8	43
NAS-531	27	86	0	35	45	43/ 56	>500	160	> 660	[illegible]	18	0	18
NAS-532	32	127	65	0	43	0/100	>500	231	> 731	0	7	0	7
NAS-533	76	175	42	75	103	42/ 57	143	100	243	20	23	0	23
NAS-534	52	170	47	55	75	42/ 57	>500	203	> 703	15	25	0	25
NAS-535	0	20	0	15	0	100/ 0	>500	172	> 672	0	0	0	0
NAS-536	20	170	40	65	0	100/ 0	>500	280	> 780	8	20	0	20
NAS-537	65	235	40	0	132	0/100	37	35	72	55	5	0	5
NAS-538	74	221	26	0	103	0/100	0	102	102	70	22	0	22
NAS-539	81	230	28	0	57	0/100	0	18	18	65	7	0	7
NAS-540	82	160	40	0	45	0/100	285	71	356	10	9	0	9
NAS-541	101	155	27	0	45	0/100	144	131	275	17	10	0	10
NAS-542	106	185	32	52	62	45/ 54	120	45	165	20	15	0	15
NAS-543	77	168	58	87	87	50/ 50	35	85	120	28	35	8	43
NAS-544	62	235	53	0	50	0/100	450	63	513	18	17	5	22
NAS-545	32	150	36	56	0	100/ 0	303	160	463	20	36	0	36
NAS-546	62	115	28	45	40	52/ 47	>500	130	> 630	56	20	0	20
NAS-547	33	102	0	45	0	100/ 0	52	>500	> 552	20	0	0	0

TABLE 4 - CLAY MINERALOGY, DRILL CUTTING SAMPLES

SAMPLE NUMBER	DEPTH	ILL	CHL	KAO	EXP	K+C
NAS-028		6.0	2.0	0.0	2.0	0.0
NAS-031		3.5	2.0	.5	3.5	0.0
NAS-032		5.0	2.5	0.0	2.5	0.0
NAS-034		5.0	2.0	0.0	3.0	0.0
NAS-036		4.0	2.0	1.5	2.5	0.0
NAS-037		5.5	2.0	0.0	2.5	0.0
NAS-041		5.5	2.5	0.0	1.5	0.0
NAS-043		5.0	2.5	0.0	2.0	0.0
NAS-045		6.0	2.0	0.0	2.0	0.0
NAS-046		4.5	1.5	0.0	3.5	0.0
NAS-049		5.5	2.5	0.0	2.5	0.0
NAS-055		6.5	1.5	0.0	2.0	0.0
NAS-057		6.5	2.0	0.0	1.5	0.0
NAS-059		6.5	1.5	0.0	2.0	0.0
NAS-061		4.5	2.0	1.0	2.5	0.0
NAS-062		5.5	2.0	0.0	2.5	0.0
NAS-065		5.5	1.5	0.0	2.5	0.0
NAS-067		6.0	1.5	0.0	2.5	0.0
NAS-068		7.5	0.0	0.0	2.5	0.0
NAS-071		6.0	2.0	0.0	2.5	0.0
NAS-073		5.5	1.5	.5	2.0	0.0
NAS-085		5.0	3.0	0.0	2.0	0.0
NAS-088		5.5	2.5	0.0	2.0	0.0
NAS-090		6.5	1.5	0.0	2.5	0.0
NAS-091		6.5	1.5	0.0	2.0	0.0
NAS-092		6.0	1.5	.5	2.0	0.0
NAS-093		7.5	0.0	0.0	2.5	0.0
NAS-094		7.5	1.0	0.0	1.5	0.0
NAS-095		6.5	1.0	0.0	2.5	0.0
NAS-096		7.0	0.0	0.0	3.0	0.0
NAS-101		5.5	3.5	0.0	1.0	0.0
NAS-103		6.5	.5	0.0	2.5	0.0
NAS-104		8.5	0.0	0.0	1.5	0.0
NAS-106		5.5	3.0	0.0	1.5	0.0
NAS-107		6.0	2.5	0.0	1.5	0.0
NAS-110		4.5	2.0	.5	2.5	0.0
NAS-111		4.0	1.5	1.0	3.5	0.0
NAS-114		6.5	0.0	0.0	2.5	.5
NAS-115		6.0	1.5	.5	2.5	0.0
NAS-116		6.0	1.5	0.0	2.5	0.0
NAS-117		8.0	0.0	0.0	2.0	0.0
NAS-119		7.5	0.0	0.0	2.5	0.0
NAS-120		7.0	1.0	0.0	2.5	0.0
NAS-121		6.5	1.0	0.0	2.0	0.0
NAS-123		6.5	.5	0.0	2.5	0.0
NAS-124		9.0	0.0	0.0	1.0	0.0
NAS-125		7.0	0.0	0.0	3.0	0.0
NAS-126		8.0	0.0	0.0	2.0	0.0
NAS-129		7.0	1.5	0.0	2.0	0.0
NAS-130		5.0	1.0	0.0	4.0	0.0
NAS-131		5.5	0.0	0.0	4.5	0.0
NAS-134		5.5	2.5	0.0	2.0	0.0
NAS-135		5.5	2.5	1.0	1.0	0.0
NAS-138		5.5	2.5	.5	2.0	0.0
NAS-141		5.0	2.5	0.0	2.5	0.0
NAS-144		5.5	1.5	0.0	3.0	0.0
NAS-145		6.5	2.0	0.0	2.0	0.0
NAS-148		5.5	2.0	0.0	2.5	0.0

TABLE 4 - CONTINUED

NAS-151	5.5	2.5	0.0	2.0	0.0
NAS-154	5.5	2.5	0.0	2.0	0.0
NAS-157	5.5	1.5	0.0	2.5	0.0
NAS-160	6.0	2.0	0.0	2.0	0.0
NAS-161	6.0	2.0	0.0	2.0	0.0
NAS-162	6.0	1.5	.5	2.0	0.0
NAS-164	4.0	2.0	1.0	3.0	0.0
NAS-169	4.0	2.0	.5	3.5	0.0
NAS-172	5.5	2.5	0.0	2.0	0.0
NAS-176	5.0	2.0	0.0	2.5	0.0
NAS-178	5.5	2.5	0.0	1.5	0.0
NAS-181	5.5	2.0	0.0	2.0	0.0
NAS-183	6.0	1.5	0.0	2.5	0.0
NAS-186	5.5	1.5	0.0	2.5	0.0
NAS-188	5.5	1.5	.5	2.5	0.0
NAS-192	6.5	1.0	0.0	2.0	0.0
NAS-193	7.5	0.0	0.0	2.5	0.0
NAS-195	4.0	2.0	.5	4.0	0.0
NAS-196	5.5	2.5	0.0	2.0	0.0
NAS-199	6.0	2.5	0.0	1.5	0.0
NAS-202	5.5	2.5	0.0	2.5	0.0
NAS-206	5.5	2.0	0.0	1.5	0.0
NAS-207	5.0	2.0	0.0	3.5	0.0
NAS-208	7.0	.5	0.0	2.5	0.0
NAS-212	5.0	2.5	0.0	3.0	0.0
NAS-213	5.0	1.5	.5	3.0	0.0
NAS-214	5.5	1.5	.5	2.0	0.0
NAS-215	7.0	2.0	0.0	1.0	0.0
NAS-216	5.5	2.5	0.0	2.0	0.0
NAS-220	5.5	3.0	0.0	1.5	0.0
NAS-223	5.0	3.0	0.0	1.5	0.0
NAS-224	5.5	2.5	0.0	2.0	0.0
NAS-227	5.0	2.0	.5	2.0	0.0
NAS-230	6.0	2.0	0.0	2.0	0.0
NAS-233	4.5	2.5	1.5	2.0	0.0
NAS-234	5.5	2.5	0.0	2.0	0.0
NAS-237	5.0	2.5	.5	2.0	0.0
NAS-240	5.5	2.5	0.0	2.0	0.0
NAS-242	5.5	2.5	0.0	2.5	0.0
NAS-246	6.0	1.5	0.0	2.5	0.0
NAS-248	6.5	1.5	0.0	2.5	0.0
NAS-249	7.0	1.5	0.0	2.0	0.0
NAS-252	6.5	1.5	0.0	2.0	0.0
NAS-253	6.5	1.0	0.0	2.5	0.0
NAS-294	6.5	1.0	.5	2.0	0.0
NAS-295	5.5	2.5	0.0	2.0	0.0
NAS-299	5.5	2.5	0.0	2.0	0.0
NAS-303	5.0	2.0	.5	3.0	0.0
NAS-306	7.0	2.5	0.0	.5	0.0
NAS-308	6.5	1.5	0.0	2.5	0.0
NAS-313	7.0	2.0	0.0	.5	0.0
NAS-318	5.5	2.0	.5	2.0	0.0
NAS-320	6.5	2.5	0.0	1.5	0.0
NAS-322	5.5	1.5	.5	2.5	0.0
NAS-327	6.0	2.0	0.0	2.0	0.0
NAS-330	4.0	2.0	.5	3.5	0.0
NAS-333	7.0	2.5	0.0	.5	0.0
NAS-339	5.5	1.5	0.0	3.0	0.0
NAS-341	5.5	1.5	0.0	3.0	0.0
NAS-345	5.0	2.0	0.0	3.0	0.0
NAS-348	8.0	1.0	0.0	1.0	0.0

TABLE 4 - CONTINUED

NAS-349	6.0	2.5	0.0	1.5	0.0
NAS-355	5.5	2.0	0.0	2.5	0.0
NAS-359	6.5	1.5	0.0	2.0	0.0
NAS-360	6.0	1.5	0.0	2.5	0.0
NAS-363	5.0	1.5	0.0	3.0	0.0
NAS-365	5.5	2.5	0.0	2.0	0.0
NAS-369	5.0	2.5	.5	2.0	0.0
NAS-370	5.5	2.0	0.0	2.0	0.0
NAS-376	6.0	3.0	0.0	1.5	0.0
NAS-378	5.5	2.5	0.0	2.0	0.0
NAS-381	5.5	2.5	0.0	2.0	0.0
NAS-390	5.5	2.5	0.0	2.0	0.0
NAS-394	6.5	2.0	0.0	1.5	0.0
NAS-397	6.5	2.0	0.0	2.0	0.0
NAS-399	6.0	1.0	0.0	3.0	0.0
NAS-404	6.0	2.0	0.0	2.0	0.0
NAS-407	6.0	2.0	0.0	2.0	0.0
NAS-411	5.5	2.0	.5	1.5	0.0
NAS-412	5.5	3.0	0.0	1.5	0.0
NAS-418	6.5	2.5	0.0	1.0	0.0
NAS-422	6.0	1.5	0.0	2.5	0.0
NAS-425	7.0	1.5	0.0	1.5	0.0
NAS-428	6.0	1.5	0.0	2.5	0.0
NAS-390	5.5	2.5	0.0	2.0	0.0
NAS-394	6.5	2.0	0.0	1.5	0.0
NAS-397	6.5	2.0	0.0	2.0	0.0
NAS-399	6.0	1.0	0.0	3.0	0.0
NAS-404	6.0	2.0	0.0	2.0	0.0
NAS-407	6.0	2.0	0.0	2.0	0.0
NAS-411	5.5	2.0	.5	1.5	0.0
NAS-412	5.5	3.0	0.0	1.5	0.0
NAS-418	6.5	2.5	0.0	1.0	0.0
NAS-422	6.0	1.5	0.0	2.5	0.0
NAS-425	7.0	1.5	0.0	1.5	0.0
NAS-428	6.0	1.5	0.0	2.5	0.0
NAS-430	6.5	1.0	0.0	2.5	0.0
NAS-435	6.5	0.0	0.0	1.5	0.0
NAS-437	7.0	1.0	0.0	2.0	0.0
NAS-443	6.0	2.5	0.0	1.5	0.0
NAS-448	6.5	2.0	0.0	1.5	0.0
NAS-450	6.5	2.0	0.0	1.5	0.0
NAS-452	6.0	2.5	0.0	1.5	0.0
NAS-459	6.5	2.5	0.0	1.0	0.0
NAS-461	6.0	3.0	0.0	1.0	0.0
NAS-465	7.0	2.5	0.0	.5	0.0
NAS-467	6.5	2.5	0.0	1.0	0.0
NAS-471	6.5	3.0	0.0	.5	0.0
NAS-474	7.5	1.5	0.0	1.0	0.0
NAS-477	6.5	2.0	0.0	1.5	0.0

ILL = ILLITE (PARTS/10)
CHL = CHLORITE (PARTS/10)
KAO = KAOLINITE (PARTS/10)
EXP = EXPANDABLE MIXED-STRUCTURE CLAYS (PARTS/10)
K+C = KAOLINITE + CHLORITE UNDIFFERENTIATED (PARTS/10)

TABLE 5 - SILT MINERALOGY, FAYETTE COUNTY, ILLINOIS (10IL) 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
10IL01L1		73	167	26	57	66	46/ 55	21	42	63	25	50	9	59	
10IL01L2		77	174	35	110	75	59/ 40	0	118	118	18	36	5	41	
10IL01L3		47	346	25	52	76	40/ 59	0	246	246	17	42	5	47	
10IL01L4		26	66	20	0	32	0/100	>500	235	> 735	9	16	0	16	
10IL01L5		17	193	0	0	0	0/ 0	338	422	760	2	25	0	25	
10IL01L6		45	146	22	35	0	100/ 0	222	>500	> 722	2	35	0	35	
10IL01L7		10	352	0	0	0	0/ 0	333	346	679	2	13	0	13	

COLUMN HEADINGS:

MCA = MICA, QTZ = QUARTZ, FLD = ALL FELDSPARS, KSP = K-FELDSPAR, PLG = PLAGIOCLASE.
CAL = CALCITE, DOL = DOLOMITE, SID = SIDERITE, APA = APATITE, PYR = PYRITE, MAR = MARCASITE

TABLE 6 - CLAY MINERALOGY, FAYETTE COUNTY, ILLINOIS (10IL) CORE SAMPLES

SAMPLE NUMBER	DEPTH	ILL	CHL	KAO	EXP	COI
10IL01L1		6.5	2.0	0.0	1.5	5.0
10IL01L2		7.5	1.0	.1	1.5	****
10IL01L3		7.0	0.0	0.0	3.0	1.0
10IL01L4		7.0	.5	0.0	2.0	1.7
10IL01L5		7.5	0.0	0.0	2.5	2.0
10IL01L6		7.0	0.0	0.0	3.0	****
10IL01L7		7.5	.1	0.0	2.5	****

ILL = ILLITE (PARTS/10)
CHL = CHLORITE (PARTS/10)
KAO = KAOLINITE (PARTS/10)
EXP = EXPANDABLE MIXED-STRUCTURE CLAYS (PARTS/10)
COI = CLAY ORIENTATION INDEX (1=PERFECTLY RANDOM; INCREASING INDEX REFLECTS INCREASINGLY PERFECT ORIENTATION.)
**** = TEST NOT RUN

TABLE 7 - SILT MINERALOGY, HARDIN COUNTY, ILLINOIS (11IL) CORE SAMPLES

OBSERVED PEAK HEIGHTS (COUNTS/SEC)

SAMPLE NUMBER	DEPTH	MCA	QTZ	FLD	KSP	PLG	KSP/PLG	CAL	DOL	CAL+DOL	SID+APA	PYR	MAR	PYR+MAR	MINERAL
		19.8	20.8	23.5	27.6	27.9		29.4	30.8		32.1	33.2	52.0		TWO THETA
11IL02C1		78	176	72	0	178	0/100	0	30	30	25	65	15	80	
11IL03C1		30	135	120	0	250	0/100	0	100	100	63	48	20	68	
11IL04C1		20	102	135	0	390	0/100	0	125	125	95	36	15	51	
11IL04L1		25	168	93	185	141	56/ 43	0	58	58	0	100	30	130	
11IL04L1		13	94	52	117	85	57/ 42	0	>500	> 500	20	75	21	96	
11IL05C1		62	160	85	123	150	45/ 54	0	187	187	100	43	8	51	
11IL06C1		15	106	117	0	320	0/100	0	300	300	81	48	15	63	
11IL07C1		92	173	71	126	120	51/ 48	0	67	67	135	12	3	15	
11IL08C1		78	182	87	0	142	0/100	0	140	140	145	9	0	9	
11IL09C1		2	90	115	228	265	46/ 53	0	>500	> 500	25	30	15	45	
11IL10C1		0	88	143	0	425	0/100	0	235	235	0	33	0	33	
11IL10L1		15	81	96	0	203	0/100	0	>500	> 500	0	20	15	35	
11IL11C1		26	140	135	205	230	47/ 52	0	227	227	0	15	0	15	
11IL11L1		0	185	157	292	180	61/ 38	0	480	480	0	20	0	20	
11IL12C1		8	75	151	0	470	0/100	0	265	265	0	35	0	35	
11IL12L1		0	102	152	0	394	0/100	0	>500	> 500	0	15	23	38	
11IL13C1		6	115	125	210	280	42/ 57	0	195	195	0	50	0	50	
11IL14C1		25	136	120	215	265	44/ 55	0	150	150	0	50	10	60	
11IL15C1		35	200	106	0	195	0/100	0	95	95	0	46	10	56	
11IL16C1		0	220	105	205	252	44/ 55	0	185	185	0	47	5	52	
11IL17C1		36	158	125	195	190	50/ 49	0	202	202	0	24	5	29	
11IL17C2		0	133	92	183	225	44/ 55	0	110	110	0	165	10	175	
11IL18C1		41	163	140	215	175	55/ 44	0	141	141	0	20	10	30	
11IL19C1		0	192	134	0	310	0/100	0	210	210	0	17	0	17	
11IL20C1		0	159	105	0	293	0/100	0	280	280	0	40	10	50	
11IL21C1		0	107	140	0	327	0/100	0	461	461	0	20	15	35	

COLUMN HEADINGS:

MCA = MICA, QTZ = QUARTZ, FLD = ALL FELDSPARS, KSP = K-FELDSPAR, PLG = PLAGIOCLASE,
CAL = CALCITE, DOL = DOLOMITE, SID = SIDERITE, APA = APATITE, PYR = PYRITE, MAR = MARCASITE

TABLE 8 - CLAY MINERALOGY, HARDIN COUNTY, ILLINOIS (11IL) CORE SAMPLES

SAMPLE NUMBER	DEPTH	ILL	CHL	KAO	EXP	COI
11IL02C1		9.5	0.0	0.0	.5	****
11IL03C1		8.5	0.0	0.0	1.5	2.5
11IL04C1		8.0	0.0	2.0	0.0	5.5
11IL05C1		9.0	0.0	2.0	1.0	7.2
11IL06C1		5.5	0.0	2.0	1.5	3.0
11IL07C1		9.0	0.0	2.0	1.0	4.8
11IL08C1		9.0	0.0	2.0	1.0	1.0
11IL09C1		6.5	0.0	0.0	3.5	****
11IL13C1		9.5	.1	0.0	.5	4.5
11IL14C1		[illegible]	0.0	2.0	0.0	6.5
11IL15C1		9.5	0.0	0.0	.5	2.9
11IL17C1		8.5	0.0	0.0	1.5	5.3
11IL18C1		9.5	0.0	0.0	.5	6.5
11IL20C1		5.5	0.0	[illegible]	4.5	****

ILL = ILLITE (PARTS/10)
CHL = CHLORITE (PARTS/10)
KAO = KAOLINITE (PARTS/10)
EXP = EXPANDABLE MIXED-STRUCTURE CLAYS (PARTS/10)
COI = CLAY ORIENTATION INDEX (1=PERFECTLY RANDOM; INCREASING INDEX REFLECTS INCREASINGLY PERFECT ORIENTATION.)
**** = TEST NOT RUN

TABLE 9 - SILT MINERALOGY, WAYNE COUNTY, ILLINOIS (12IL) CORE SAMPLES
OBSERVED PEAK HEIGHTS (COUNTS/SEC)

SAMPLE NUMBER	DEPTH	MCA	QTZ	FLD	KSP	PLG	KSP/PLG	CAL	DOL	CAL+DOL	SID+APA	PYR	MAR	PYR+MAR	MINERAL
		19.8	20.8	23.5	27.8	27.9		29.4	30.8		32.1	33.2	52.2		TWO THETA
12IL01C1		72	175	45	87	82	51/ 48	0	32	32	27	65	8	73	
12IL02C1		90	235	50	77	72	51/ 48	0	75	75	25	35	0	35	
12IL03C1		172	215	60	0	101	0/100	0	52	52	25	27	0	27	
12IL04C1		86	222	51	0	100	0/100	0	47	47	26	26	0	26	

COLUMN HEADINGS:

MCA = MICA, QTZ = QUARTZ, FLD = ALL FELDSPARS, KSP = K-FELDSPAR, PLG = PLAGIOCLASE,
CAL = CALCITE, DOL = DOLOMITE, SID = SIDERITE, APA = APATITE, PYR = PYRITE, MAR = MARCASITE

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TABLE 10 - CLAY MINERALOGY, WAYNE COUNTY, ILLINOIS (12IL) CORE SAMPLES

SAMPLE NUMBER	DEPTH	ILL	CHL	EXP
12IL01C1		7.0	2.5	1.0
12IL02C1		7.0	2.5	.5
12IL03C1		6.5	2.5	1.5
12IL04C1		6.5	2.5	1.5

ILL = ILLITE (PARTS/10)
CHL = CHLORITE (PARTS/10)
EXP = EXPANDABLE MIXED-STRUCTURE CLAYS (PARTS/10)

TABLE 11 - MEAN RANDOM VITRINITE REFLECTANCE, ILLINOIS AND KENTUCKY CORE SAMPLES

API NUMBER	SAMPLE NUMBER	N	R_0	STD DEV	<.25	.30	.35	.40	.45	.50	.55	.60	.65	.70	.75	.80	.85	.90	.95	1.0	>1	VITRAIN BAND
					PERCENT VITRINITE IN EACH REFLECTANCE CLASS																	
1604731175	01KY01L1	35	.46	.05	0	0	3	9	17	49	23	0	0	0	0	0	0	0	0	0	0	
1604731175	01KY01C1	33	.52	.07	0	0	0	0	9	39	21	21	0	6	3	0	0	0	0	0	0	
1604731175	01KY02L1	50	.48	.09	0	0	0	18	24	16	20	12	6	4	2	0	0	0	0	0	0	
1604731175	01KY02C1	31	.56	.09	0	0	0	0	13	13	23	13	19	10	10	0	0	0	0	0	0	
1604731175	01KY03L1	36	.46	.09	0	0	11	14	17	14	22	19	0	3	0	0	0	0	0	0	0	
1604731175	01KY03C1	46	.53	.08	0	0	0	2	30	35	13	2	9	4	0	0	0	0	0	0	0	
1604731175	01KY04C1	49	.82	.30	0	0	0	4	2	10	12	6	4	4	2	2	2	2	12	4	32	
1604731175	01KY04L1	50	.53	.11	0	0	0	8	20	18	14	6	16	14	0	2	2	0	0	0	0	
1604731175	01KY05C1	33	.41	.08	0	0	22	22	22	22	9	3	0	0	0	0	0	0	0	0	0	
1604731175	01KY05L1	48	.58	.11	0	0	2	6	2	10	15	19	19	15	6	4	2	0	0	0	0	
1604731175	01KY07C1	62	.39	.06	0	0	16	31	31	14	3	0	2	0	0	0	0	0	0	0	0	
1604731175	01KY07L1	12	.37	.05	0	0	33	25	42	0	0	0	0	0	0	0	0	0	0	0	0	
1604731175	01KY08C1	44	.52	.07	0	0	0	2	14	20	27	27	4	2	2	0	0	0	0	0	0	
1604731175	01KY08L1	23	.44	.04	0	0	4	13	30	48	4	0	0	0	0	0	0	0	0	0	0	
1604731175	01KY09C1	43	.55	.10	0	0	2	2	16	5	16	26	21	5	2	5	0	0	0	0	0	
1604731175	01KY10L1	16	.46	.07	0	0	0	12	25	19	25	12	6	0	0	0	0	0	0	0	0	
1604731175	01KY10C1	32	.52	.11	0	0	9	3	12	19	9	16	12	19	0	0	0	0	0	0	0	
1604731175	01KY11L1	24	.51	.08	0	0	4	0	12	29	12	29	8	4	0	0	0	0	0	0	0	
1604731175	01KY11C1	16	.44	.10	0	0	12	31	25	6	6	12	6	0	0	0	0	0	0	0	0	
1604731175	01KY12C1	23	.79	.30	0	0	9	9	9	0	9	0	9	0	4	4	4	0	4	4	36	
1604731175	01KY12L1	27	.60	.14	0	0	0	0	15	7	11	15	18	15	7	0	4	4	4	0	0	
1604731175	01KY13L1	21	.53	.12	0	0	0	14	19	19	9	5	9	9	9	5	0	0	0	0	0	
1604731175	01KY13C1	17	.51	.20	12	12	12	18	0	6	12	6	0	0	0	0	6	0	12	0	6	
1216700115	01IL01L2	15	.43	.06	0	0	7	20	33	33	7	0	0	0	0	0	0	0	0	0	0	
1216700115	01IL04L1	14	.46	.13	0	0	28	7	21	7	14	7	0	7	7	0	0	0	0	0	0	
1216700115	01IL10L1	6	.49	.11	0	0	0	17	33	17	0	0	33	0	0	0	0	0	0	0	0	
1216700115	01IL14L1	33	.45	.07	0	0	15	9	18	36	6	15	0	0	0	0	0	0	0	0	0	
1216700115	01IL11L1	29	.43	.07	0	0	17	10	24	34	7	3	3	0	0	0	0	0	0	0	0	
1216700115	01IL16L1	44	.45	.07	0	0	16	18	20	25	14	7	0	0	0	0	0	0	0	0	0	
1216700115	01IL17L1	31	.44	.10	0	0	19	16	23	16	6	6	10	3	0	0	0	0	0	0	0	
1216700115	01IL19L1	39	.45	.07	0	0	3	10	41	31	3	8	3	0	3	0	0	0	0	0	0	
1216700115	01IL21L1	22	.38	.05	0	0	18	41	36	5	0	0	0	0	0	0	0	0	0	0	0	
1204922705	02IL01C1	45	.66	.14	0	0	0	0	2	9	11	16	11	13	9	13	4	2	7	2	0	
1204922705	02IL02C1	50	.52	.07	0	0	2	4	4	24	28	28	8	2	0	0	0	0	0	0	0	
1204922705	02IL03C1	50	.44	.07	0	0	6	22	32	22	10	4	4	0	0	0	0	0	0	0	0	
1204922705	02IL03C1	51	.49	.03	0	0	0	0	12	39	45	4	0	0	0	0	0	0	0	0	0	VIT
1204922705	02IL04C1	26	.49	.06	0	0	0	4	19	23	46	0	4	4	0	0	0	0	0	0	0	
1204922705	02IL04C2	29	.47	.07	0	0	0	10	28	34	14	10	0	3	0	0	0	0	0	0	0	
1204922705	02IL05C1	31	.48	.06	0	0	3	6	16	23	32	19	0	0	0	0	0	0	0	0	0	
1204922705	02IL05L2	26	.47	.08	0	0	4	12	31	15	23	12	4	0	0	0	0	0	0	0	0	
1204922705	02IL06C1	50	.47	.07	0	0	4	6	18	34	32	2	0	4	0	0	0	0	0	0	0	
1204922705	02IL06L2	27	.52	.09	0	0	4	0	11	30	15	18	7	15	0	0	0	0	0	0	0	
1204922705	02IL07C1	36	.51	.10	0	0	6	14	11	14	11	14	25	6	0	0	0	0	0	0	0	
1204922705	02IL08C1	50	.56	.03	0	0	0	0	0	2	32	52	14	0	0	0	0	0	0	0	0	VIT
1219304694	03IL03L1	35	.53	.10	0	0	3	6	11	9	31	17	3	17	3	0	0	0	0	0	0	
1219304694	CP1666-I	27	.55	.08	0	0	0	0	15	7	26	18	26	0	7	0	0	0	0	0	0	
1219304694	03IL18L1	50	.60	.09	0	0	0	2	4	6	12	20	24	16	8	6	2	0	0	0	0	
1219304694	03IL19L2	50	.54	.09	0	0	0	8	6	20	16	20	20	2	6	2	0	0	0	0	0	
1219304694	03IL21L1	62	.61	.08	0	0	0	0	0	6	18	24	24	11	8	6	2	0	0	0	0	
1219304694	03IL25L1	33	.70	.10	0	0	0	0	0	3	0	9	9	27	27	6	9	3	3	3	0	
1207120411	04IL09C1	32	.45	.08	0	0	6	25	19	22	12	9	6	0	0	0	0	0	0	0	0	
1207120411	04IL13C1	50	.47	.08	0	0	4	12	30	20	14	8	10	2	0	0	0	0	0	0	0	
1207120411	04IL17C1	50	.47	.03	0	0	0	0	28	52	18	2	0	0	0	0	0	0	0	0	0	VIT
1207120411	04IL17C1	50	.41	.11	10	26	20	6	18	4	8	6	2	0	0	0	0	0	0	0	0	
1207120411	04IL21C1	46	.48	.08	0	2	13	17	35	11	13	6	2	0	0	0	0	0	0	0	0	
1207120411	04IL25C1	50	.51	.09	0	0	6	4	16	16	22	18	14	4	0	0	0	0	0	0	0	
1204501209	05IL01L1	45	.46	.07	0	0	7	7	24	31	20	7	4	0	0	0	0	0	0	0	0	

TABLE 11 - CONTINUED

1204501209	05IL01L4	50	.47	.02	0	0	0	0	10	82	8	0	0	0	0	0	0	0	0	0	0VIT
1217921198	06IL10C1	37	.50	.06	0	0	5	5	11	27	19	16	14	3	0	0	0	0	0	0	0
1217921198	06IL13C1	43	.49	.06	0	0	5	7	12	26	30	9	12	0	0	0	0	0	0	0	0
1217921198	06IL16C1	52	.45	.07	0	0	2	17	35	23	14	8	0	2	0	0	0	0	0	0	0
1217921198	06IL19C1	50	.42	.06	0	0	18	22	24	28	2	6	0	0	0	0	0	0	0	0	0
1217921198	06IL25C1	50	.41	.07	0	0	12	40	28	8	8	0	2	2	0	0	0	0	0	0	0
1205101324	07IL01L2	50	.56	.12	0	0	4	10	6	10	12	10	20	16	10	2	0	0	0	0	0
1205101324	07IL02L1	41	.55	.11	0	0	0	10	10	17	10	17	10	15	5	7	0	0	0	0	0
1205101324	07IL03L1	39	.40	.11	0	0	10	15	21	15	10	8	13	5	3	0	0	0	0	0	0
1205101324	07IL04L1	39	.46	.08	0	0	10	15	18	28	15	8	3	3	0	0	0	0	0	0	0
1205101324	07IL04L2	52	.50	.07	0	0	2	4	21	25	23	15	8	2	0	0	0	0	0	0	0
1216301757	09IL01L3	51	.50	.04	0	4	8	6	12	10	29	16	14	2	0	0	0	0	0	0	0
1205125257	10IL01L1	55	.53	.06	0	0	0	0	5	24	36	18	13	4	0	0	0	0	0	0	0
1205125257	10IL01L4	53	.51	.07	0	0	0	4	21	19	23	17	17	0	0	0	0	0	0	0	0

TABLE 12 - MEAN FANDOM VITRINITE REFLECTANCE, DRILL CUTTING SAMPLES

API NUMBER	SAMPLE NUMBER	N	R 0	STD DEV	PERCENT VITRINITE IN EACH REFLECTANCE CLASS <.25	.30	.35	.40	.45	.50	.55	.60	.65	.70	.75	.80	.85	.90	.95	1.0	>1
1202505036	NAS- 028	50	.49	.14	0	0	18	10	18	14	8	4	12	8	2	0	6	0	0	0	0
1204922498	NAS- 031	50	.56	.14	0	0	6	6	4	12	16	14	10	12	10	2	4	4	0	0	0
1204922498	NAS- 032	50	.62	.11	0	0	0	2	2	6	18	22	14	10	6	12	4	4	0	0	0
1200101167	NAS- 033	50	.60	.10	0	0	2	2	2	6	20	16	16	18	12	2	4	0	0	0	0
1211901187	NAS- 036	50	.51	.11	0	0	8	6	10	20	28	12	4	4	4	0	4	0	0	0	0
1211901187	NAS- 037	50	.52	.09	0	0	2	6	10	28	14	22	12	2	2	0	0	2	0	0	0
1212500062	NAS- 043	50	.49	.06	0	0	2	10	22	22	22	10	8	4	0	0	0	0	0	0	0
1216902066	NAS- 045	50	.54	.09	0	0	4	0	8	20	26	18	16	2	2	0	4	0	0	0	0
1216923041	NAS- 046	50	.59	.06	0	0	0	0	6	4	20	22	14	24	8	2	0	0	0	0	0
1216922957	NAS- 050	51	.53	.06	0	0	0	0	10	23	23	28	10	2	0	2	0	2	0	0	0
1219100027	NAS- 053	50	.70	.09	0	0	0	0	0	0	0	8	20	22	20	14	6	10	0	0	0
1219106524	NAS- 058	50	.69	.12	0	0	0	0	0	4	6	16	14	16	20	8	4	2	4	6	0
1219106524	NAS- 059	51	.64	.13	0	0	0	6	2	8	4	8	22	24	10	6	6	8	0	2	0
1219100503	NAS- 061	50	.66	.10	0	0	0	0	0	4	6	14	8	22	26	6	8	8	0	0	0
1219100503	NAS- 062	51	.57	.11	0	0	0	2	10	10	26	14	14	18	0	4	0	4	0	0	0
1219104404	NAS- 066	41	.59	.14	0	0	0	2	12	15	7	20	17	2	2	7	5	7	0	0	0
1219104404	NAS- 067	50	.59	.11	0	0	0	4	4	12	20	14	16	14	10	2	2	2	0	0	0
1219104404	NAS- 068	42	.66	.11	0	0	0	0	0	2	10	14	10	17	17	14	5	12	0	0	0
1219104240	NAS- 071	51	.70	.16	0	0	0	0	0	4	10	16	14	10	2	12	2	8	10	10	0
1219104240	NAS- 072	53	.72	.13	0	0	0	0	2	4	4	9	8	17	11	13	11	13	4	4	0
1202102375	NAS 085	50	.54	.09	0	0	4	2	8	20	18	22	18	4	2	2	0	0	0	0	0
1202102375	NAS 087	36	.44	.08	0	0	8	29	21	18	11	5	8	0	0	0	0	0	0	0	0
1205902832	NAS 090	50	.49	.10	0	0	4	10	24	16	18	10	6	6	4	2	0	0	0	0	0
1205902832	NAS 091	50	.55	.09	0	0	0	0	5	19	41	14	2	10	5	3	0	0	0	0	0
1205902832	NAS 092	51	.50	.08	0	0	0	10	14	27	24	8	10	6	2	0	0	0	0	0	0
1205903316	NAS 093	50	.70	.16	0	0	0	6	6	6	12	6	2	8	6	2	14	14	14	4	0
1205903316	NAS 094	53	.69	.11	0	0	0	0	0	0	11	11	8	23	15	17	9	0	6	0	0
1205903316	NAS 095	51	.85	.08	0	0	0	0	0	0	0	0	2	2	6	18	12	35	18	4	4
1205903316	NAS 096	50	.74	.10	0	0	0	0	0	0	0	2	18	20	20	16	6	4	10	4	0
1206100189	NAS 102	22	.47	.08	0	0	5	23	18	18	9	18	9	0	0	0	0	0	0	0	0
1210107425	NAS 103	51	.52	.07	0	0	0	0	22	14	25	27	4	4	4	0	0	0	0	0	0
1210107425	NAS 104	52	.60	.06	0	0	0	0	2	2	12	29	37	12	8	0	0	0	0	0	0
1210700113	NAS 107	51	.44	.06	0	0	6	8	45	37	0	0	2	2	0	0	0	0	0	0	0
1215100244	NAS 116	31	.72	.16	0	0	0	0	3	10	6	10	10	3	10	3	19	10	13	3	0
1215100244	NAS 117	40	1.09	.12	0	0	0	0	0	0	0	0	0	0	0	5	0	5	0	5	85
1216523981	NAS 120	55	1.00	.12	0	0	0	0	0	0	0	0	0	0	0	5	7	7	9	22	48
1216523981	NAS 121	52	1.02	.13	0	0	0	0	0	0	0	0	2	6	0	10	12	17	19	8	26
1216526176	NAS 128	69	.62	.12	0	0	0	0	3	9	16	25	16	9	4	7	6	4	0	1	0
1216526176	NAS 130	41	.48	.06	0	0	2	5	24	34	12	10	10	2	0	0	0	0	0	0	0
1216526176	NAS 131	35	.62	.07	0	0	0	0	0	9	9	14	14	37	17	0	0	0	0	0	0
1220300235	NAS 135	25	.58	.10	0	0	0	0	4	8	24	32	12	0	8	8	4	0	0	0	0
1201901424	NAS 137	21	.45	.06	0	0	5	14	19	43	14	5	0	0	0	0	0	0	0	0	0
1201922776	NAS 140	50	.52	.08	0	0	0	6	10	22	32	8	14	6	2	0	0	0	0	0	0
1202501447	NAS 143	36	.53	.09	0	0	0	3	11	31	17	14	14	8	3	0	0	0	0	0	0
1202501447	NAS 146	44	.63	.06	0	0	0	0	0	2	7	20	32	25	9	5	0	0	0	0	0
1202323824	NAS 148	44	.54	.06	0	0	0	2	2	16	34	25	18	2	0	0	0	0	0	0	0
1202922459	NAS 151	46	.62	.10	0	0	0	0	0	8	13	25	25	6	6	8	8	0	0	0	0
1202922450	NAS 155	24	.54	.07	0	0	0	0	4	21	33	17	21	4	0	0	0	0	0	0	0
1203300524	NAS 156	27	.49	.07	0	0	4	11	11	26	30	11	4	4	0	0	0	0	0	0	0
1202922450	NAS 159	47	.72	.11	0	0	0	0	2	0	4	11	4	4	28	28	11	2	4	2	0
1203300710	NAS 161	40	.64	.08	0	0	0	0	3	5	3	18	23	25	15	10	0	0	0	0	0
1203302496	NAS 162	46	.55	.08	0	0	0	2	7	15	33	20	7	11	7	0	0	0	0	0	0
1203300294	NAS 164	50	.61	.14	0	0	0	6	10	10	6	16	12	12	10	8	4	2	4	0	0
1203330012	NAS 166	30	.59	.07	0	0	0	0	3	7	20	30	23	10	3	3	0	0	0	0	0
1203330012	NAS 167	61	.61	.10	0	0	0	2	2	8	20	15	23	11	11	3	3	2	0	0	0
1203531385	NAS 169	63	.56	.11	0	0	2	6	5	13	27	16	13	10	3	3	0	3	0	0	0
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

TABLE 12 - CONTINUED

1204500960	NAS	177	51	.50	.30	0	0	0	3	13	35	26	19	3	2	0	0	0	0	0	0	0
1204922470	NAS	160	46	.50	.30	0	0	0	0	0	15	30	33	11	7	4	0	0	0	0	0	0
1206501270	NAS	104	40	.79	.13	0	0	0	0	0	0	3	5	8	13	13	20	8	10	13	5	5
1206501270	NAS	106	21	.70	.49	0	0	0	0	0	0	0	15	11	37	7	11	4	15	0	0	0
1206500760	NAS	190	43	.60	.00	0	0	0	0	0	0	2	12	21	26	19	7	9	5	0	0	0
1206503450	NAS	192	50	.74	.00	0	0	0	0	0	0	2	0	6	24	30	6	12	10	4	2	0
1206503450	NAS	193	29	.64	.10	0	0	0	0	3	3	17	3	21	24	14	7	3	3	0	0	0
1207500990	NAS	195	50	.52	.10	0	0	0	8	10	32	4	16	8	6	6	2		0	0	0	0
1207500990	NAS	196	40	.52	.00	0	0	0	3	15	25	20	18	15	5	0	0	0	0	0	0	0
1207501010	NAS	198	51	.40	.07	0	0	0	10	25	20	25	20	0	0	0	0	0	0	0	0	0
1207922570	NAS	201	42	.73	.09	0	0	0	0	0	0	0	5	10	14	21	26	12	7	2	2	0
1208122940	NAS	205	51	.60	.00	0	0	0	0	0	0	6	12	29	29	8	4	6	6	0	2	0
1210127790	NAS	207	50	.57	.09	0	0	0	2	6	18	16	16	18	14	6	4	0	0	0	0	0
1210127790	NAS	208	50	.50	.30	0	0	0	4	20	24	15	34	2	0	0	0	0	0	0	0	0
1212125030	NAS	211	47	.50	.07	0	0	0	0	2	6	28	28	23	6	4	2	0	0	0	0	0
1210102020	NAS	213	46	.63	.10	0	0	0	0	0	4	15	24	15	15	9	11	2	4	0	0	0
1211300357	NAS	227	50	.51	.06	0	0	0	4	24	14	18	24	16	0	0	0	0	0	0	0	0
1214700040	NAS	229	51	.54	.08	0	0	0	4	10	8	25	24	18	12	0	0	0	0	0	0	0
1216722304	NAS	233	42	.50	.10	0	0	5	10	17	14	17	19	10	10	0	0	0	0	0	0	0
1216701441	NAS	235	49	.50	.07	0	0	0	2	14	35	24	10	10	4	0	0	0	0	0	0	0
1218301040	NAS	237	27	.50	.09	0	0	0	4	7	11	22	19	11	22	4	0	0	0	0	0	0
1218301025	NAS	242	62	.50	.10	0	0	2	11	18	27	11	15	8	3	3	2	0	0	0	0	0
1218301025	NAS	243	53	.53	.07	0	0	0	2	11	19	28	19	13	8	0	0	0	0	0	0	0
1219307015	NAS	245	50	.56	.00	0	0	0	0	6	18	12	26	20	18	0	0	0	0	0	0	0
1219307015	NAS	247	51	.56	.00	0	0	0	0	10	14	20	18	20	14	6	0	0	0	0	0	0
1219307015	NAS	249	27	.59	.07	0	0	0	0	0	7	11	33	37	4	4	4	0	0	0	0	0
1219902531	NAS	252	50	.80	.00	0	0	0	0	0	0	0	0	0	0	0	12	24	26	14	10	14
1219902531	NAS	253	27	.80	.12	0	0	0	0	0	0	0	4	0	4	4	4	22	11	26	11	15
1211700000	NAS	255	52	.44	.07	0	0	0	31	37	13	6	6	8	0	0	0	0	0	0	0	0
1211700000	NAS	256	52	.50	.04	0	0	0	0	8	33	44	15	0	0	0	0	0	0	0	0	0
1219900000	NAS	259	51	.65	.05	0	0	0	0	0	0	4	6	35	47	6	0	2	0	0	0	0
1219900000	NAS	260	50	.64	.05	0	0	0	0	0	2	4	10	32	40	12	0	0	0	0	0	0
1205900000	NAS	261	56	.67	.05	0	0	0	0	0	0	0	11	20	43	23	2	0	2	0	0	0
1205900000	NAS	262	50	.74	.00	0	0	0	0	0	0	2	8	2	8	20	32	22	6	0	0	0
1205900000	NAS	263	55	.80	.06	0	0	0	0	0	0	0	0	4	5	5	16	44	22	4	0	0
1205900000	NAS	264	50	.72	.00	0	0	0	0	0	0	0	6	8	22	30	14	14	4	2	0	0
1302700000	NAS	265	45	.58	.10	0	0	0	2	2	16	22	20	16	9	7	4	2	0	0	0	0
1314700000	NAS	266	50	.59	.00	0	0	0	0	2	6	18	32	16	14	8	4	0	0	0	0	0
1304500000	NAS	267	50	.57	.00	0	0	0	0	6	10	24	26	12	18	4	0	0	0	0	0	0
1309300000	NAS	268	50	.56	.08	0	0	0	0	8	12	28	22	16	10	0	4	0	0	0	0	0
1310100000	NAS	269	50	.57	.00	0	0	0	0	2	8	28	32	16	12	2	0	0	0	0	0	0
1315300000	NAS	270	50	.64	.10	0	0	0	0	0	4	14	16	18	18	16	8	4	0	2	0	0
1312900000	NAS	271	50	.56	.08	0	0	0	2	6	6	16	26	16	16	12	0	0	0	0	0	0
1315300000	NAS	272	50	.60	.10	0	0	0	2	6	6	22	8	18	14	14	10	0	0	0	0	0
1306100000	NAS	273	50	.00	.08	0	0	0	0	0	6	24	28	14	8	14	6	0	0	0	0	0
1302500000	NAS	274	50	.54	.05	0	0	0	0	2	12	42	26	12	6	0	0	0	0	0	0	0
1313300000	NAS	275	50	.53	.08	0	0	0	2	12	26	20	20	12	8	0	0	0	0	0	0	0
1303900000	NAS	276	50	.54	.09	0	0	0	0	18	25	18	12	10	14	4	0	0	0	0	0	0
1303900000	NAS	277	50	.50	.04	0	0	0	0	24	22	24	26	4	0	0	0	0	0	0	0	0
1303900000	NAS	278	50	.51	.07	0	0	0	0	22	24	16	18	20	0	0	0	0	0	0	0	0
1303900000	NAS	279	50	.54	.06	0	0	0	0	10	24	22	12	20	10	2	0	0	0	0	0	0
1303900000	NAS	280	50	.54	.07	0	0	0	0	8	24	16	28	14	10	0	0	0	0	0	0	0
1303900000	NAS	281	50	.51	.07	0	0	0	0	25	13	23	26	11	2	0	0	0	0	0	0	0
1317300000	NAS	282	52	.50	.07	0	0	0	0	2	8	21	33	19	13	4	0	0	0	0	0	0
1310700000	NAS	283	50	.50	.07	0	0	0	4	20	22	26	16	12	0	0	0	0	0	0	0	0
1310500000	NAS	284	50	.51	.07	0	0	0	6	10	30	22	18	10	4	0	0	0	0	0	0	0
1303300000	NAS	285	50	.54	.07	0	0	0	2	6	16	26	30	18	0	2	0	0	0	0	0	0
1315300000	NAS	286	50	.56	.07	0	0	0	2	0	12	28	26	18	10	4	0	0	0	0	0	0
1311900000	NAS	287	51	.52	.07	0	0	0	2	14	18	31	24	4	8	0	0	0	0	0	0	0
[illegible]	NAS	288	50	.53	[illegible]	0	0	0	0	5	10	25	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

TABLE 12 - CONTINUED

1317500000	NAS	290	51	.55	.07	0	0	0	0	8	18	18	22	27	8	0	0	0	0	0	0	0
1200500484	NAS	293	51	.52	.08	0	0	0	8	16	22	12	22	18	4	0	0	0	0	0	0	0
1201900307	NAS	295	50	.54	.07	0	0	0	4	6	14	30	32	10	4	0	0	0	0	0	0	0
1201901323	NAS	297	37	.49	.06	0	0	0	16	16	22	27	8	5	3	0	3	0	0	0	0	0
1201900630	NAS	302	38	.50	.08	0	0	0	5	29	24	11	13	16	3	0	0	0	0	0	0	0
1203900091	NAS	316	31	.50	.09	0	0	0	10	26	16	16	13	10	10	0	0	0	0	0	0	0
1202902104	NAS	312	31	.54	.08	0	0	0	0	6	23	26	23	13	6	0	3	0	0	0	0	0
1204121220	NAS	319	41	.57	.08	0	0	0	2	7	10	12	32	20	15	2	0	0	0	0	0	0
1204100352	NAS	322	35	.50	.06	0	0	0	14	9	23	23	20	11	0	0	0	0	0	0	0	0
1205124969	NAS	326	50	.56	.06	0	0	0	0	4	6	38	22	18	10	2	0	0	0	0	0	0
1205101748	NAS	329	47	.54	.06	0	0	0	2	6	15	26	38	6	6	0	0	0	0	0	0	0
1205501572	NAS	334	36	.63	.07	0	0	0	0	0	3	8	17	33	22	11	3	3	0	0	0	0
1205502641	NAS	337	28	.64	.07	0	0	0	0	0	0	7	25	18	29	14	4	4	0	0	0	0
1207701511	NAS	347	56	.62	.07	0	0	0	0	0	0	16	29	26	19	3	5	2	0	0	0	0
1207701440	NAS	350	50	.60	.08	0	0	0	0	0	8	18	22	18	24	8	2	0	0	0	0	0
1208123131	NAS	354	45	.72	.07	0	0	0	0	0	0	0	2	13	16	36	22	7	0	4	0	0
1208720285	NAS	359	43	.88	.06	0	0	0	0	0	0	0	0	0	5	2	9	12	26	26	16	5
1208720285	NAS	360	44	.89	.08	0	0	0	0	0	0	0	0	0	0	0	11	18	25	20	14	12
1211521101	NAS	365	36	.52	.05	0	0	0	0	6	31	22	33	8	0	0	0	0	0	0	0	0
1211700920	NAS	368	30	.46	.07	0	0	0	21	26	29	13	5	5	0	0	0	0	0	0	0	0
1212105712	NAS	371	55	.54	.07	0	0	0	0	4	24	29	22	13	5	4	0	0	0	0	0	0
1213521027	NAS	376	53	.58	.08	0	0	0	0	2	19	19	17	23	15	6	0	0	0	0	0	0
1213500347	NAS	378	52	.48	.06	0	0	0	4	25	37	21	8	2	4	0	0	0	0	0	0	0
1213700346	NAS	382	50	.54	.03	0	0	0	0	10	26	6	32	18	8	0	0	0	0	0	0	0
1214523255	NAS	386	50	.55	.07	0	0	0	0	4	16	34	28	8	6	2	2	0	0	0	0	0
1214700207	NAS	388	52	.49	.06	0	0	0	4	27	29	19	15	6	0	0	0	0	0	0	0	0
1216502400	NAS	392	50	.94	.09	0	0	0	0	0	0	0	0	0	0	0	4	4	20	28	24	20
1216503631	NAS	401	46	1.03	.10	0	0	0	0	0	0	0	0	0	0	0	0	2	2	13	15	68
1204900445	NAS	478	50	.51	.05	0	0	0	0	12	30	38	12	8	0	0	0	0	0	0	0	0
1204900445	NAS	479	50	.60	.04	0	0	0	0	0	0	4	50	30	10	6	0	0	0	0	0	0
1204900445	NAS	480	50	.60	.09	0	0	0	0	2	10	18	24	22	10	6	2	6	0	0	0	0
1204900445	NAS	481	46	.63	.06	0	0	0	0	0	2	9	15	37	22	11	4	0	0	0	0	0
1204900445	NAS	482	53	.67	.14	0	0	0	0	0	11	17	8	11	11	13	9	6	4	6	4	0
1204900445	NAS	483	38	.60	.07	0	0	0	0	0	0	29	18	29	11	13	0	0	0	0	0	0
1204900445	NAS	484	26	.60	.13	0	0	0	0	12	12	12	27	19	4	0	4	8	0	0	4	0
1204900445	NAS	485	14	.79	.13	0	0	0	0	0	0	7	0	0	29	7	7	7	7	21	14	0
1204900445	NAS	486	80	.65	.12	0	0	0	0	1	11	21	6	5	5	18	24	8	1	0	0	0
1205722019	NAS	548	20	.51	.04	0	0	0	0	5	45	35	10	5	0	0	0	0	0	0	0	0
1205722019	NAS	549	10	.53	.05	0	0	0	0	0	30	40	20	0	10	0	0	0	0	0	0	0
1205722019	NAS	550	50	.52	.06	0	0	0	0	16	12	28	32	8	4	0	0	0	0	0	0	0
1205722019	NAS	551	19	.57	.06	0	0	0	0	0	0	42	26	11	21	0	0	0	0	0	0	0
1205722019	NAS	552	50	.58	.06	0	0	0	0	0	10	16	44	20	10	0	0	0	0	0	0	0
1205722020	NAS	553	47	.55	.06	0	0	0	0	2	15	28	38	11	4	0	2	0	0	0	0	0
1205722020	NAS	554	50	.53	.06	0	0	0	0	10	16	24	38	12	0	0	0	0	0	0	0	0
1205722020	NAS	555	50	.45	.06	0	0	0	16	32	34	8	8	0	2	0	0	0	0	0	0	0
1205722020	NAS	556	38	.46	.08	0	0	3	24	21	29	8	3	11	3	0	0	0	0	0	0	0
1209521010	NAS	558	24	.53	.06	0	0	0	0	13	13	25	38	8	4	0	0	0	0	0	0	0
1209521010	NAS	559	21	.51	.06	0	0	0	0	14	29	29	24	5	0	0	0	0	0	0	0	0
1209521010	NAS	560	18	.54	.04	0	0	0	0	0	11	61	28	0	0	0	0	0	0	0	0	0
1209521010	NAS	561	44	.54	.03	0	0	0	0	0	5	57	36	2	0	0	0	0	0	0	0	0
1209521010	NAS	562	36	.52	.03	0	0	0	0	0	31	53	11	6	0	0	0	0	0	0	0	0

TABLE 13 - VISUAL FLUORESCENCE DATA, DRILL CUTTING SAMPLES

Sample Numbers (NAS-)	Color of Fluorescence					
	Pale Yellow	Yellow	Yellow Orange	Orange	Pale Orange	No Fluorescence
050	———					
058					———	
059			———	———		
061		———	———			
062		- - -		———		
066			———			
067			———			
068			———	———		
071			———		- - -	
072			- - -	- - -	———	———
085		———				
090		———				
091			———			
092			———			
093						———
094						———
095						———
096						———
102		———				
103		———	———			
104			———			
107			———			
116						———
117						———
120						———
121					- - -	———
128			———			
130			———			
131					———	
135		———		———		

TABLE 13 - (continued)

Color of Fluorescence

Sample Numbers (NAS-)	Pale Yellow	Yellow	Yellow Orange	Orange	Pale Orange	No Fluorescence
137	———					
140	———	———				
143			———			
146			———	- - - - -		
148			———			
162					———	
164		———	———			
166			———			
167		———	———			
169				———		
176		———	———			
177		———	———			
180		- - - - -	- - - - -	———		
186						———
195	———					
196		———				
201						———
205			———			
207			———			
208					———	
211		- - - - -	———			
213				———		
227	———					
229	———					
233		- - - - -			- - - - -	
235	———					
237	- - - - -				- - - - -	
240	———					
243		———			- - - - -	
245			- - - - -		———	

TABLE 13 - (continued)

Color of Fluorescence

Sample Numbers (NAS-)	Pale Yellow	Yellow	Yellow Orange	Orange	Pale Orange	No Fluorescence
247			- - -	———		
249			- - -	———		
252						———
253						———
265		———	———			
266			———			
267		- - -	———	- - -		
268		- - -	- - -	———		
269				———		
270				———		
271				———		
272			———	———		
273		———	———	- - -		
274		———				
275			———	- - -		
276		———				
277	———					
278	———	———				
279		———				
280		———	- - -			
281		———	- - -			
282			- - -	———		
283			———			
284			———	- - -		
285			- - -	———		
286				———		
287				———		
288			- - -	———		
289			———	———		
290		———	———			

TABLE 13 - (continued)

Color of Fluorescence

Sample Numbers (NAS-)	Pale Yellow	Yellow	Yellow Orange	Orange	Pale Orange	No Fluorescence
293		——	-----			
297		——				
302		——				
316				——		
319		-----	——		-----	
322			——			
326		——	——			
329		——	——	-----		
334		——	——			
337				——	——	
347			——			
350			——	——		
359					-----	——
360						——
365		-----	——			
371		——	——	-----		
378		-----	——			
382		——	——			
401						——
548		——				
549		——				
550		——	——			
551				——		
552			——			
553			——			
554	——					
555	——					

—— fluorescence color range most frequently observed.
----- fluorescence color range occasionally observed.

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 sulfur and when that exceeds 0.5%, pyritic and sulfate sulfur. 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 shales, 5) potential catalytic effects of trace elements on shale pyrolysis yields, and 6) potential disposal problems.

Elemental Analysis

Progress

Shale samples received for complete analysis for major, minor and trace elements total 355; on another 25 samples analyses for certain elements only, usually total and inorganic carbon, have been requested. Twenty-five to 35 more samples are expected to complete the sample load for the project, 13 in October and the rest in December or January from a core currently being drilled.

Most of the analyses by the various analytical methods being used have been completed on more than 325 of the 355 samples. These include X-ray fluorescence analysis for the major and minor elements, neutron activation analysis for 34 major, minor and trace elements, and the determination of fluorine via ion-selective electrode, the determination of total carbon and hydrogen by tube-furnace combustion and measurement of absorbed CO_2 and H_2O, the determination of inorganic carbon and total sulphur by wet chemical methods, and the determination of forms of sulphur by gravimetric methods (on samples with total sulphur $\geq$0.5%).

Compilation of the extensive neutron activation analysis data and resumption of analysis for 13 trace elements, on the last 130-160 samples, by optical emission spectroscopy proceed slowly.

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

Progress

Released Gas Analysis

Released gas analyses of the four samples obtained from the Wayne County, Illinois core were completed. The canisters equilibrated for a total of 68 days, and the internal pressure was monitored aperiodically (3 to 7 days intervals). A rapid increase in pressure occured throughout the first 40 days; thereafter a much slower increase in pressure was observed indicating an equilibrium state was being approached. After 52 days, the gas was released from the canister containing core sample 12IL01C2. During the next 16 days there was a significant increase in pressure in this canister, following which time all the samples were removed from their canisters. This indicates that hydrocarbons would be released from the shale over a longer time interval if the released gas were bled off occasionally.

Even though the four shale samples were taken at relatively short 12 foot intervals of the shale core, there was a considerable variation in the amount of gas released per unit volume of shale.

The composition of the released hydrocarbons was nearly indentical for the gas released from the three deeper samples. There was slightly more methane and less ethane and propane in the uppermost sample. The ethane content is higher and the butane and higher hydrocarbon content is much lower than is usual for natural gas.

In contrast to past experience there was only a slight decrease in the oxygen to nitrogen ratio in the headspace gas over that for air. There was a significant increase in the carbon content indicating that some oxidation may have taken place.

The released gas data for these few samples indicates there may be some potential for gas production from the black shale in the Wayne County, Illinois area.

Samples for off-gas analyses will be collected from a second core presently being drilled in Wayne County, Illinois.

Volatile Hydrocarbon Analysis

A manuscript has been prepared concerning the volatile and medium volatile hydrocarbon analyses. This manuscript was published in the Proceedings of the Joint DOE/EGSP-ES/AAPG Symposium held in Morgantown, West Virginia,October 1-4, 1979.

Medium Volatile Hydrocarbon Analysis

Pyrolysis

See Volatile Hydrocarbon Analysis.

Solvent Extraction

A 300 g sample of black shale (01IN04C1) from the Sullivan County, Indiana core was extracted with benzene in a soxhlet extraction apparatus. An amount of organic matter equal to 0.66% of the shale was extracted. The extract was separated into aliphatic, aromatic, and asphaltene fractions on a silica gel column, The extracted organic matter was 40% aliphatic, 25% aromatic, and 33% asphaltene. About 3% was lost on the column.

The aromatic fraction from the benzene-methanol extraction of an Eastern Black Shale sample (01KY03C2) was further separated by ion-exchange chromatography. The neutral fraction so obtained was analyzed by gas chromatography using both a SP2100 packed column and a SP2100 capillary (SCOT) column.

The gas chromatogram of the neutral aromatic fraction from this shale shows only very small amounts, if any, of lower boiling compounds. This is in constrast to a chromatogram of a similar aromatic fraction separated from a coal pyrolysis product.

Further analysis and identification is being carried out by GC/MS. The analysis has been run and the results are being interpreted.

Isotopic Analysis of Off-Gases

The off-gas from the Wayne Co. (12IL) core was analyzed isotopically four different times during the outgassing period. The results of these analyses are shown in Table 1. Analyses of the samples taken on May 29, 1979 were carried out on very small amounts of methane (especially sample 01C4) and during a time when the mass spectrometer was very unstable. The possible error in these analyses may therefore be larger than is normal and are so noted on the table. If this fact is considered, then the data show little variation, either with time, or among core samples.

Table 1. Isotopic analysis of CH_4 (δC^{13} values) from the Wayne Co. core (12IL).

Depth Interval	Sample	5/29/79	6/14/79	6/27/79	7/18/79
4834.1 4834.5'	01C1	-51±1	-52.3	-52.1	-52.3
4838.0-4838.5'	01C2	-51±1	-51.4	-51.5	*
4843.0-4843.5'	01C3	-53±1	-52.3	-51.9	-50.9
4846.25-4846.75'	01C4	-49±2	-52.0	-52.0	*

* The isotope-ratio mass spectrometer was out of order when these samples were collected and leakage of the sample vial resulted in the samples being contaminated with air before they could be analyzed.

Previous off-gas samples have been compared to a "maturity plot" based on the model of Stahl (1974) which relates the isotopic composition of methane to the chemical composition of the gas. The relationship of the samples from this core to Stahl's model is shown on Figure 1. The samples do not fall within the zone predicted by Stahl, but are very similar to the samples from the Effingham Co. core (see 1977 annual report). For that core, a close correlation was observed between the composition of the gas from the cores and that of solution gas from oil directly beneath the black shale.

Laboratory Study of Chemical and Isotopic Fractionation

To determine the changes in chemical and isotopic composition accompanying release of gas from Devonian shales, 3/4" diameter cores have been evacuated and then pressurized with gas of known composition.

The first vessel (with the exception of a blank) from which the gas was released contained a 3/4" diameter shale core which was 2.9" long. This sample had been pressurized to 42.4 atm (609 psig) and sealed. The pressure dropped for approximately 65 days (a result of uptake of gas by the shale) and then stabilized at 35.4 atm (505 psig) on the 130th day, the pressure was decreased to 1 atm over a period of 142 minutes. Figure 2 shows the rate of pressure drop in the vessel, the cumulative amount of gas released, and the chemical and isotopic composition of the gas as a function of time. The results show that all of the gas released during this initial bleed-down is enriched in CH_4 and depleted in C^{12} relative to the gas introduced. It should be noted, however, that most of this gas was present in the dead space within the vessel. This implies that equilibrium between the gas in the dead space and the gas in the shale had not yet been achieved. This was expected, and it is the reason that the other cores are being given longer equilibration times before bleed-down.

After the initial bleed-down, the vessel was sealed and the gas diffusing out of the shale was allowed to accumulate, simulating the situation which occurs when samples are collected in the field. After 14 days, this gas was released and collected for analysis. This gas is depleted in CH_4 and enriched in C^{12} relative to the starting material.

The final sample was bled off after 154 days, and these are the final results shown on Figure 2. This sample is also depleted in CH_4 and enriched in C^{12} relative to the starting gas, but only slightly more than the sample collected during the first 14 days of outgassing at low pressure. These data imply that there may be a strong fractionation involved as the gas migrates into the shale plug, but only a slight fractionation as the gas migrates out. Mass balance calculations indicate that virtually all of the gas introduced into the vessel was recovered.

Vessel #3 was pressurized at the same time and under the same conditions as vessel #2. The initial pressure was 42.4 atm (609 psig) which decreased for approximately 65 days and then stabalized at 36.1 atm (515 psig.) On the 287th day after inital pressurization, the gas was released following the same procedure as in the previous case. The preliminary results of the analyses of the samples collected are shown in Figure 3. The ratio of CH_4/C_2H_6 for the gas collected during the initial pressure release is fairly constant and significantly higher than that of the gas originally introduced. This indicates

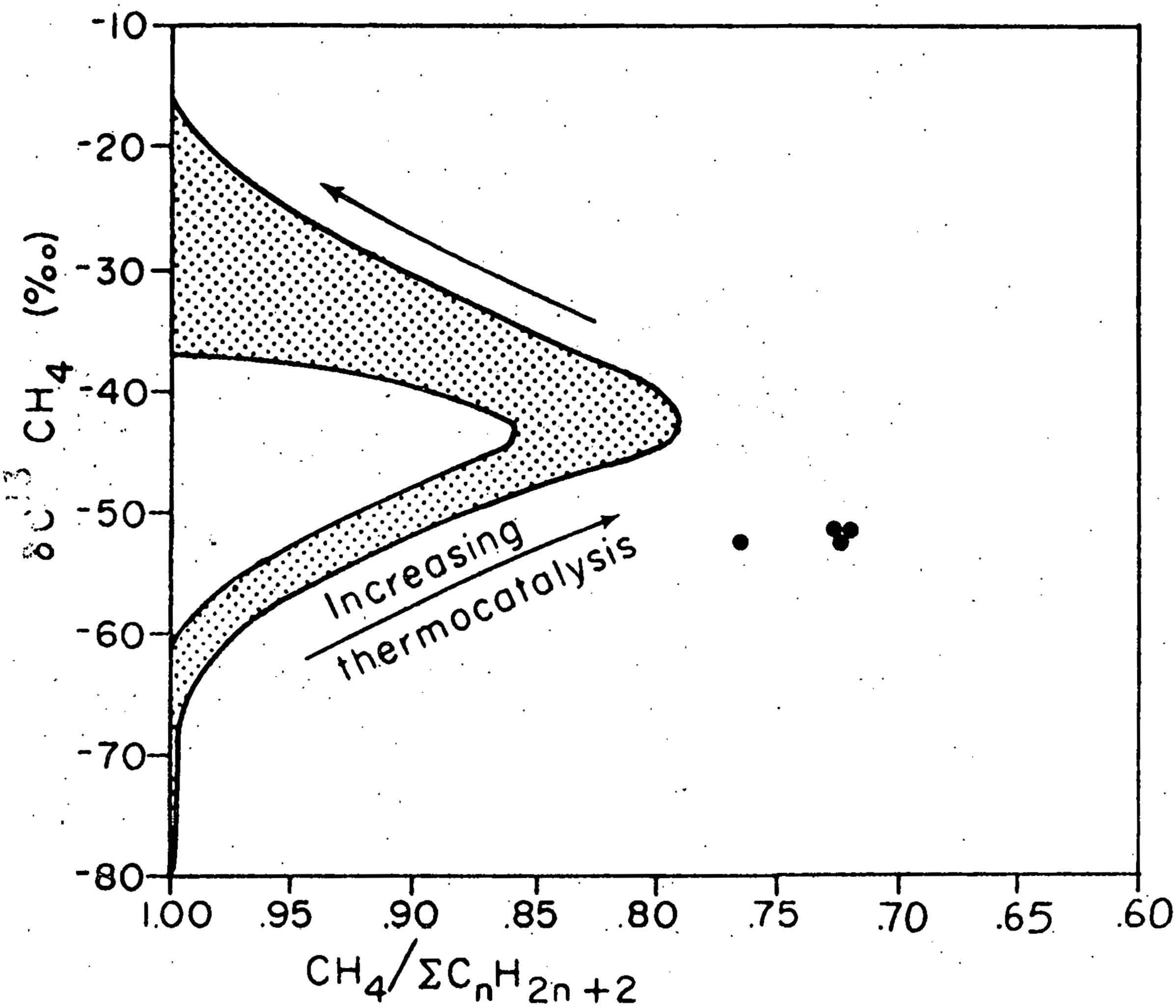

Figure 1. Hydrocarbon and isotopic compositions of off-gas samples from the Wayne Co. core (012IL) compared to the compositions predicted by the model of Stahl (1974).

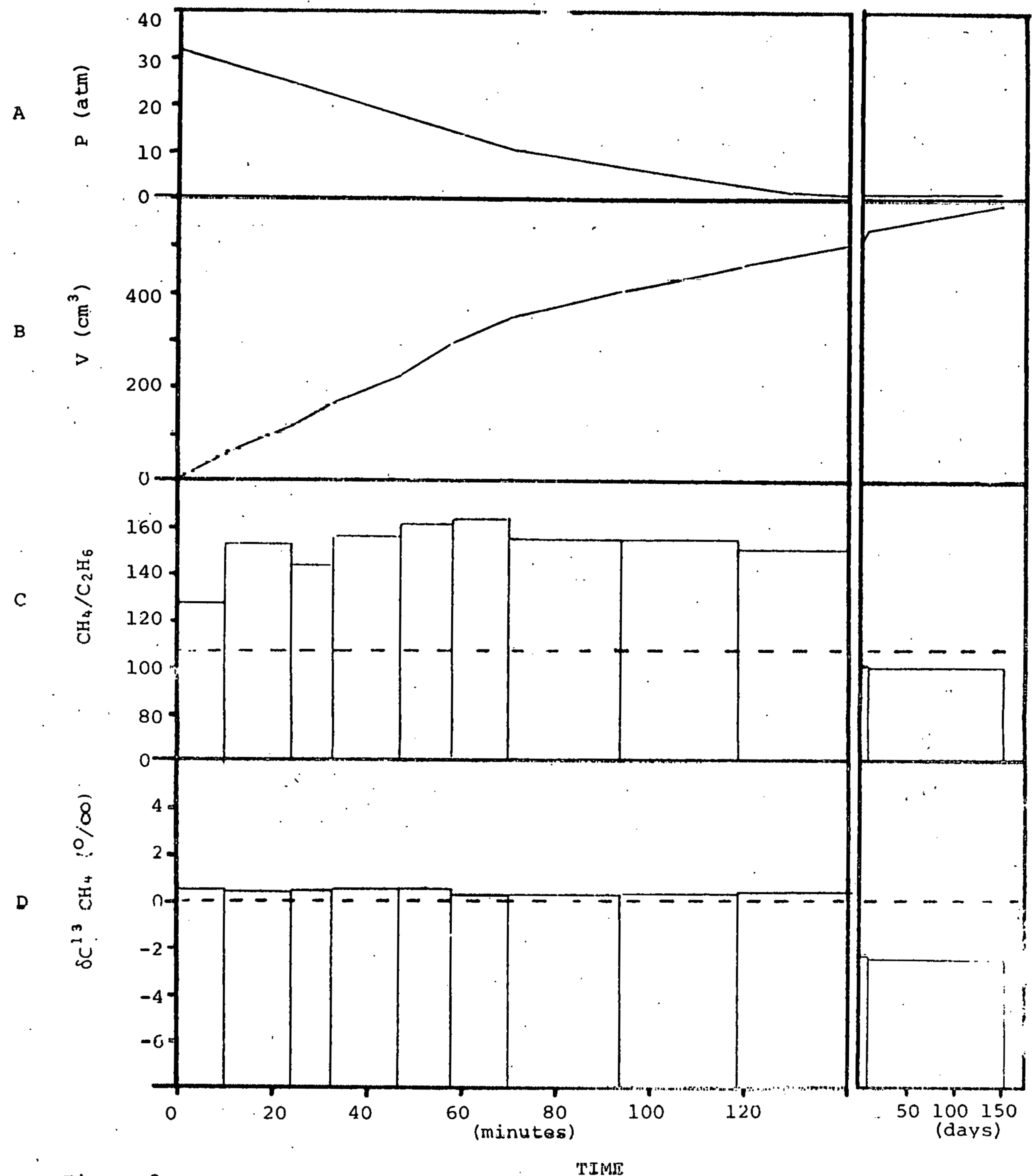

Figure 2.

Composition of gas released from high pressure vessel #1. The left portion of graph shows data for the inital release of gas from the vessel. The time scale is in minutes. The right portion of the figure shows data for the gas which later accumulated in the vessel as a result of degassing of the shale plug. The time scale here is in days. Dashed lines show the composition of the gas originally injected.

a) Pressure in the vessel during the release of gas.
b) Cumulative volume of gas released from the vessel
c) Methane to ethane ratio of the gas released. Analyses were done on the gas released during the times represented by the widths of the bars.
d) Bargraph showing the δC^{13} values of the released gas. All values are relative to the original gas.

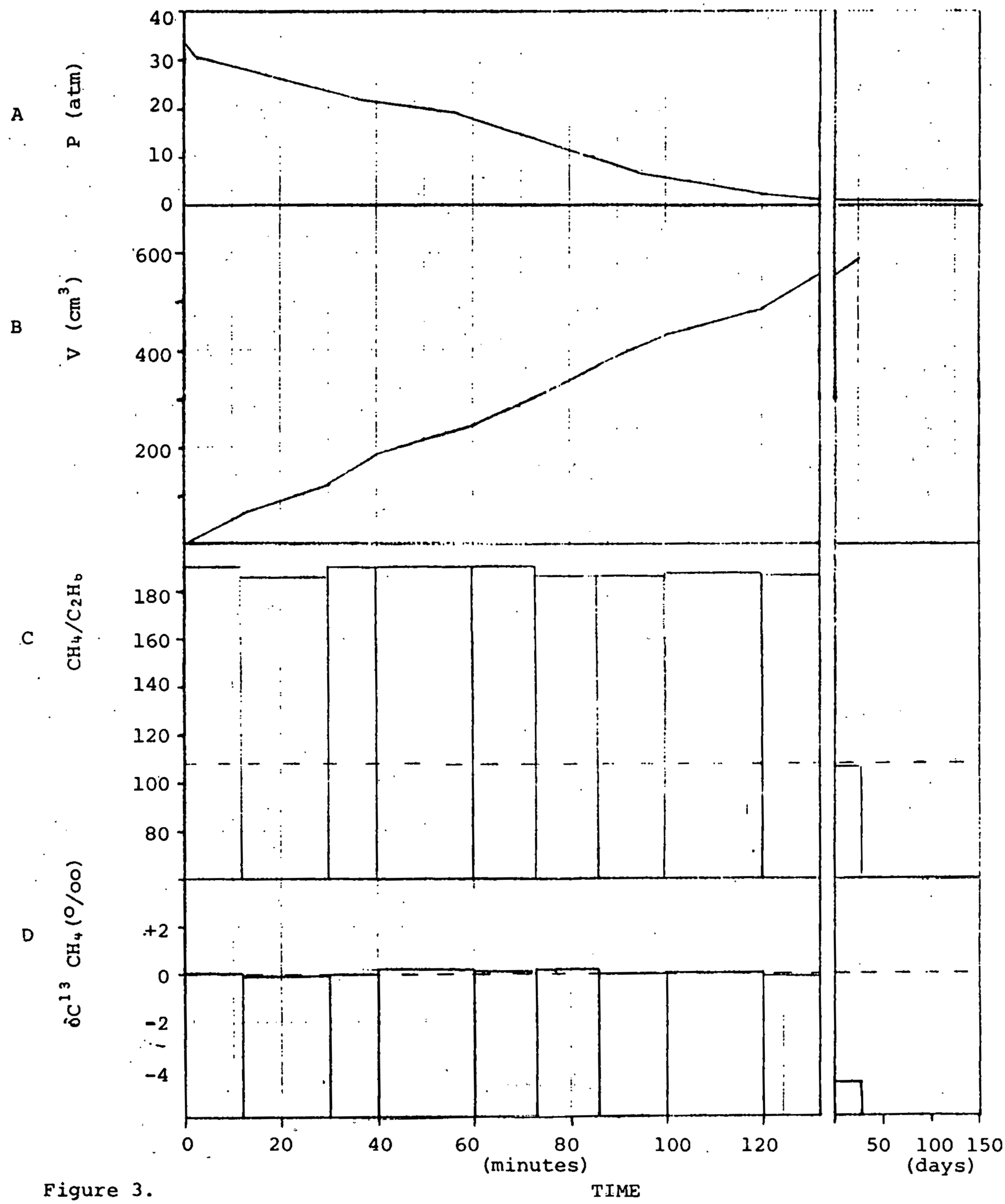

Figure 3.

Composition of gas released from high pressure vessel #2. The left portion of graph shows data for the inital release of gas from the vessel. The time scale is in minutes. The right portion of the figure shows data for the gas which later accumulated in the vessel as a result of degassing of the shale plug. The time scale here is in days. Dashed lines show the composition of the gas originally injected.

a) Pressure in the vessel during the release of gas.
b) Cumulative volume of gas released from the vessel
c) Methane to ethane ratio of the gas released. Analyses were done on the gas released during the times represented by the widths of the bars.
d) Bargraph showing the δC^{13} values of the released gas. All values are relative to the original gas.

that the gas in the head space of the pressure vessel is enriched in CH_4 relative to C_2H_6 and implies that the gas adsorbed by the shale must be depleted in CH_4. The first sample collected during the desorption of the shale, however, is only slightly depleted in CH_4 relative to C_2H_6. If these data are valid, and there is no reason to suspect otherwise, then future samples of desorbed gas will have to be highly depleted in CH_4.

The isotopic compositions of the samples collected during the inital pressure release are fairly constant and similar to that of the original gas. This implies that isotopic equilibrium has been achieved between the methane in the dead volume and that in the shale. The first sample collected during the degassing of the shale is significantly enriched in C^{12} relative to the original gas. Perhaps, for the first time, the isotopic fractionation which occurs as methane is released from shale is being observed without any overshadowing by the effects of incomplete equilibration.

REFERENCE

Stahl, W. J., 1974, Carbon isotope fractionations in natural gases: Nature, v. 251, p. 134-135.

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.

Progress

Internal surface area values for four shale core samples from Wayne County, Illinois (core 12IL) are shown in the following table.

Internal Surface Area Values for Shale Samples from Wayne County, IL (core 12IL)

Sample No.	Depth to top of sample, Ft.	ISA, m^2/g CO_2	ISA, m^2/g N_2	ISA, CO_2/N_2
12IL01C1	4834.1	19.0	1.5	12.8
12IL02C1	4838.0	10.1	1.4	7.25
12IL03C1	4843.0	13.8	1.5	9.5
12IL04C1	4846.3	9.4	1.5	6.4

These four samples were taken over a relatively short interval (12 feet) and all contained gas (see August 3, 1979 monthly report). We are awaiting samples from a core now being collected in Wayne County, Illinois which will provide a larger number of samples over a greater interval.

These data show that at the relatively greater depth of burial in the Illinois Basin, both the N_2 and CO_2 internal surface area values are appreciably lower than values obtained for shale samples from lesser depths. This reflects the greater compaction and closing of available pore structure to the adsorbing gases. Nitrogen values are much lower (yielding increased CO_2/N_2 ISA ratios) which reflects the presence of an increasing proportion of pores having diameters less than 5 angstrom units. The rate of gas release from such structures is quite low. At present, the rate of gas release in our high pressure apparatus is being studied.

During this past quarter, we reported ISA data for the core samples from Bullitt Co., KY (core 02KY) and high pressure methane adsorption data for selected samples from the Sullivan Co., IND core (core 01IN).

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

Of those procedures thoroughly studied, the chemical is the best method for isolating organic matter from shales. Two products have been prepared by this procedure with ash contents of less than 0.5 percent and submitted for analysis. Thirty trace and minor elements have been determined thus far. The remaining samples yet to be analyzed have been selected from cores showing the greatest gas bearing potential (01KY, 02IL, 11IL). These samples are currently being demineralized via the chemical procedure.

Although a number of elements are contained in the kerogen, only six - Br, Cr, Fe, Ni, Sb, and Se - in the group of 30 elements have concentrations comparable to or greater than that given for the original shale. Other elements of interest, e.g., Cu and V, are yet to be reported.

Developmental work using a density gradient separation continued to yield less than satisfactory concentrations of organic matter for analysis. The failure of the separation is partially due to the initial low organic carbon concentration of the shales available for this study. In addition, in an effort to reduce the ash content of the coal product prepared by the chemical procedure, it was used in a separation run. However, no significant reduction of ash content occurred. Further developmental work continues in an effort to better separations by the density gradient method.

CONTRACTOR FINANCIAL MANAGEMENT REPORT

REPORT FOR MONTH ENDING: August 1979

TO: U.S. Department of Energy
Contract Division
Research Contracts, Procedures and Reports Branch
P.O. Box E, Oak Ridge, Tennessee 37830

FROM: Robert E. Bergstrom
Neil F. Shimp
Illinois State Geological Survey
Urbana, Illinois 61801

2. CONTRACT VALUE $
3. FUND LIMITATION $
4. INVOICE AMOUNTS BILLED $
5. TOTAL PAYMENTS RECEIVED $

1. DESCRIPTION OF CONTRACT
a. TYPE: Contract
b. NO. (US ERDA) DE-AC-21-76-MC05203
c. SCOPE OF WORK: Geology, Geochemistry Devonian Black Shale
d. AUTH. CONTRACT REPRESENTATIVE (Signature) Robert E. Bergstrom, Neil F. Shimp
PREPARATION DATE: 10/9/79

6. REPORTING CATEGORY	7. COSTS INCURRED: DURING MONTH a.	7. COSTS INCURRED: CUMULATIVE TO DATE b.	8. ESTIMATED COSTS/$ TO COMPLETE: SUBSEQUENT MONTH a.	8. ESTIMATED COSTS/$ TO COMPLETE: BALANCE OF FISCAL YEAR b.	8. ESTIMATED COSTS/$ TO COMPLETE: BALANCE OF CONTRACT c.	9. ESTIMATED FINAL COSTS
Salaries, wages	$ 7,571.55	$319,896.78	$ 7,600.00	$ 65,564.55		
Indirect cost	4,997.22	209,149.85	5,000.00	43,959.65		
Fringe benefits	605.44	26,924.42	600.00	46,300.10		
Commodities, materials, supplies	2,497.60	18,633.71	1,000.00	10,872.57		
Travel	----	10,040.14	500.00	5,903.78		
Equipment	555.05	55,685.86	200.00	1,219.64		
Laboratory preparation	----	1,011.30	----	1,988.60		
Computer	1,401.19	25,178.06	----	287.16		
Contractual	----	5.10	----	2,045.90		
Nuclear reactor	----	4,132.50	----	5,132.50		
Mass spectrograph	----	4,600.00	----	9,900.00		
Telecommunications	21.64	999.46	20.00	600.54		
Totals	$17,649.69	$676,257.18	$14,920.00	$193,774.99		

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