CLIFFS MINERALS, INC.
EASTERN GAS SHALES PROJECT
OHIO #4 WELL - ASHTABULA COUNTY

PHASE II REPORT
PRELIMINARY LABORATORY RESULTS
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1.0 INTRODUCTION

The U. S. Department of Energy is funding a research and development program entitled the Eastern Gas Shales Project designed to increase commercial production of natural gas in the eastern United States from Middle and Upper Devonian Shales. The program's objectives are as follows:

1. To evaluate recoverable reserves of gas contained in the shales.
2. To enhance recovery technology for production from shale gas reservoirs.
3. To stimulate interest among commercial gas suppliers in the concept of producing large quantities of gas from low-yield, shallow Devonian Shale wells.

The EGSP-Ohio #4 well was cored under a cooperative cost-sharing agreement between the Department of Energy (METC) and Monsanto Research Corporation during July and August 1979. The objectives of this project were to determine Devonian Shale gas potential in Ashtabula County and to test the validity of off-gassing data measured from canned core samples. To test the validity of conventional off-gassing techniques, data obtained from canned samples taken at the surface (conventional coring method) were compared with samples canned while under actual downhole pressure (pressurized core method). The results of this comparison were discussed in a presentation by Monsanto in Morgantown during January 1979. Results determined from pressurized core samples vary from those determined through conventional coring techniques. It should be noted that these determinations are based on limited data. For a more detailed account of these results, the reader is referred to Monsanto Research Corporation, Miamisburg, Ohio, and/or the Department of Energy, Morgantown Energy Technology Center, Morgantown, West Virginia.

This report summarizes the procedures and results of core characterization work performed at the Eastern Gas Shales Project Core Laboratory on core retrieved from the Ashtabula County well, designated EGSP-Ohio #4 well.

2.0 SCOPE OF WORK

The objective of work performed at the Eastern Gas Shales Project's Core Laboratory is to provide a detailed characterization of the core recovered from the EGSP-Ohio #4 well. Data are acquired from several sources for analysis. At the well site, suites of wet and dry hole geophysical logs were run, which included the following:

Dry Hole Logs: Noise
Temperature
Induction

Wet Hole Logs: Compensated Formation Density
Gamma Ray - Caliper
Compensated Neutron
Dual Induction - SFL
Compensated Sonic
Fracture Identification

At the EGSP Core Laboratory the core was laid out, washed, measured, oriented, and photographed prior to description and sampling. Characterization work performed includes photographic logs, detailed lithologic logs, fracture logs (both natural and induced types), core color variation, and stratigraphic interpretation of the cored intervals. In addition, physical property samples

were prepared. These samples were tested by Michigan Technological University under subcontract. Physical properties data obtained from specimen tests include:

- Directional Ultrasonic Velocity
- Directional Tensile Strength
- Strength in Point Load
- Trends of Microfractures

3.0 LABORATORY PROCEDURES

3.1 Review of Geophysical Logs:

During the initial stages of processing the EGSP Ohio #4 core through the laboratory, wet and dry hole geophysical logs from the well were examined and compared with published reference sections. Using the gamma ray and density logs a preliminary stratigraphic section was prepared for the cored interval. These two logs have proven to be the most useful correlation tools within the Devonian Shale sequence. Much of the development of existing formation nomenclature for the Devonian Shales is based on the recognition of characteristic features of these logs. Consequently, formation boundaries and thicknesses are, in some cases, more readily determined from gamma ray and density logs than from visual examination of the core itself.

Several other logs often provide information useful for core characterization. The fracture identification log and sonic log frequently indicate the occurrence of zones of structural discontinuity (joints, faults, concretions, zones of increased friability, etc.) within the core. The sibilation and temperature logs are useful for locating significant flows of gas into the well from isolated fractures or fracture systems.

The interpretation of prominent features on the geophysical logs in advance of core description is a means of assuring that these features will receive adequate recognition.

3.2 Photographic Log:

After the EGSP-Ohio #4 core had been laid out, washed, and oriented on a laboratory table, a series of photographs was taken to record the "as received" condition. A photographic log was then compiled for subsequent documentation. One copy of the log is to be forwarded to the Morgantown Energy Technology Center, under separate cover, together with this report.

3.3 Detailed Lithologic Logs:

After detailed visual examination the EGSP-Ohio #4 core was described in intervals which vary from about 5 feet to 10 feet in length. The first sentence of the description contains a brief summary of lithology, color and sedimentary structure. Additional remarks were recorded to describe unique features observed within the interval. These remarks may concern any (or all) of the following:

1. Coarse clastic interbeds with scour surfaces, sole marks, cross-stratification, ripple lamination, etc.

2. Macroscopic fossils such as carbonaceous and pyritized vegetal constituents, conodonts, invertebrate shell fragments and casts, fish scales and teeth, etc.

3. Bioturbation, as discrete burrows or as mottled stratification, with emphasis on distribution and association with other rock fabric features.

4. Concretions, slump features, clasts and rip-up structures, gas pits, and other inorganic structures.

5. Modes of pyritization: as disseminated occurrences, nodules, coatings on shell fragments or plant tissue fragments; as accessory mineralization with concretions or clastic interbeds; and as primary irregular lenses or laminae in euxinic black shales.

6. Occurrence of fissility and friability.

7. Carbonate content.

Lithologic terminology applied to the shales is summarized in Figure 1. The classification scheme in use at the Core Laboratory for describing limestones is that of Dunham (1962), shown in Figure 2. Core colors were described using the Rock Color Chart published by the Geological Society of America (1948).

3.4 Stratigraphic Section:

A stratigraphic section for the cored interval was prepared after the gamma ray and density logs were examined and the detailed lithologic log had been completed. Formation thicknesses were measured, contacts located as precisely as possible, and age relationships determined from published sources.

The locations of certain formation boundaries in the Devonian Shales are difficult to establish with precision. In some cases a contact between two units is gradational, or the nature of a contact may be problematical.

3.5 Color Histogram:

A color histogram for the Ohio #4 core was compiled to provide a relative measure of the distribution of light and dark shales through the cored interval. Using the G.S.A. Rock Color Chart, the net length of each color present within each 5-foot segment of the core was recorded. Colors with values darker than N3 were grouped together for each segment to determine the percentage of dark shale, and colors with values lighter than or equal to N3 were combined to determine the percentage of light shale. Use of the term "value" refers to the Munsell system of color identification wherein a specific color is defined by a unique hue, value, and chroma designation.

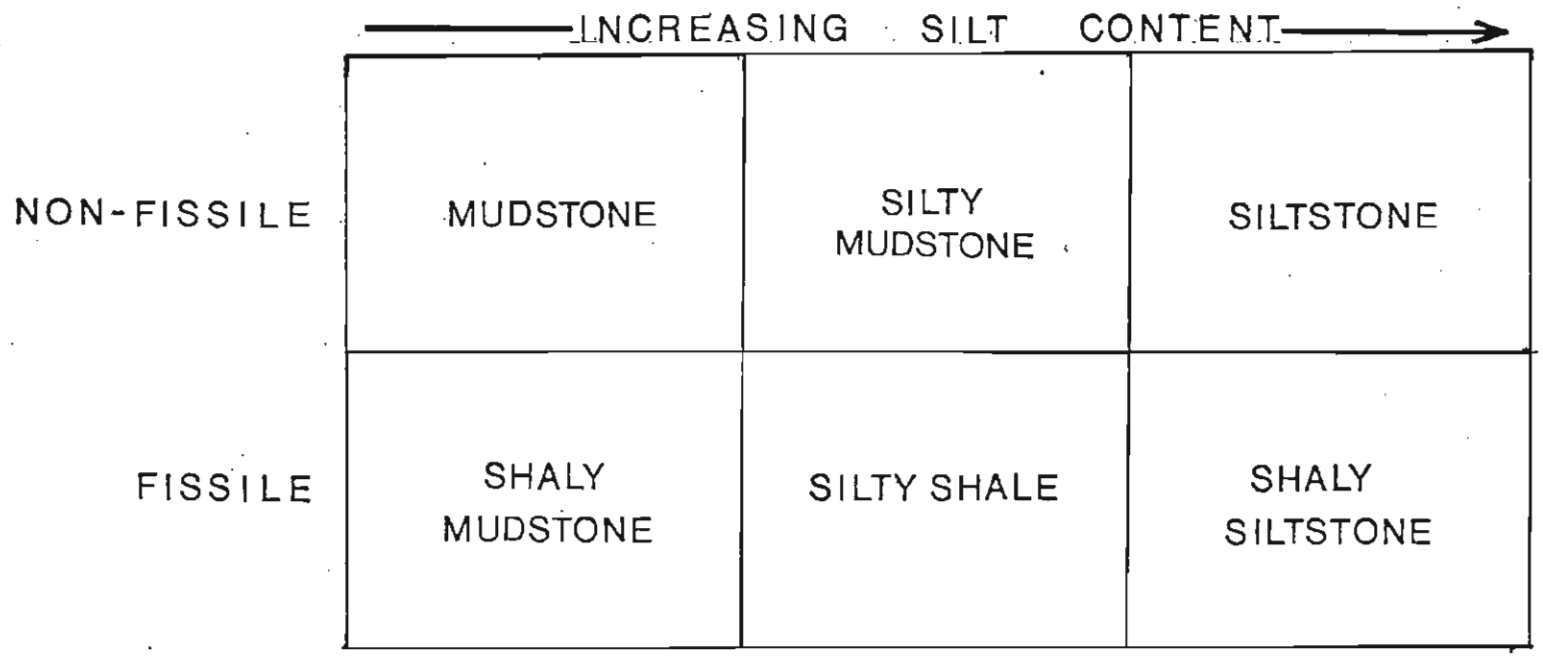

FIGURE 1

TEXTURAL CLASSIFICATION OF FINE CLASTIC SEDIMENTARY ROCKS

MUD SUPPORTED (Sand-size carbonate grains suspended in carbonate mud)		GRAIN SUPPORTED (Sand-size carbonate grains with interstitial carbonate mud)	
< 10% SAND-SIZE GRAINS	> 10% SAND-SIZE GRAINS	MUD PRESENT	NO MUD
Lime Mudstone	Wackestone	Packstone	Grainstone

BIOGENICALLY CEMENTED GRAINS: Boundstone

NO RECOGNIZABLE TEXTURE: Crystalline Limestone

FIGURE 2

TEXTURAL CLASSIFICATION OF LIMESTONES
(after Dunham, 1962)

3.6 Fracture Logs:

Methods of fracture analysis employed at the EGSP Core Laboratory are similar to those described by Kulander et al (1977). A standardized logging procedure has been developed by the Morgantown Energy Technology Center. Abbreviations and symbols used in conjunction with the EGSP Standard Core Fracture Logging Format are listed and defined in Appendix B.

Determination of the number, location, orientation, and character of natural fractures intercepted in the cored interval is vital to the selection of appropriate well completion and stimulation techniques. Criteria applied to distinguish natural fractures from fractures induced during coring and handling are listed below (quoted from Evans, 1978):

CORING-INDUCED FRACTURES EXHIBIT THE FOLLOWING CHARACTERISTICS

1. Fracture origin within the core or on the core margin.
2. Hackle plumes diverging from the origin to intersect the core margin or preexisting fracture surface orthogonally.
3. Hackle marks becoming progressively coarser in the vicinity of the core margin or preexisting fracture surface.
4. Twist hackle originating near the core margin or preexisting fracture surface.
5. Hackle plumes diverging in a spiral pattern from the central part of the core on a subhorizontal fracture surface; indicative of torsional stress.
6. Closely spaced arrest lines on a vertical or near-vertical planar fracture; arrest lines are convex down core and exhibit approximate bilateral symmetry.
7. Hackle marks on a vertical or near-vertical planar fracture diverging down core from the center of the plane toward the margins.

8. An abrupt change in the direction of fracture propagation (hook) near the core margin or preexisting fracture surface.

NATURAL FRACTURES EXHIBIT THE FOLLOWING CHARACTERISTICS

1. Smooth, polished planar fracture faces, with or without slickensides.
2. Mineralization coating fracture surfaces, or filling a closed fracture.
3. A smooth fracture extending across the core against which later fractures terminate.
4. Small conchoidal chips or hook features at the intersection of an inclined fracture plane and the core margin; the chips hook to meet the inclined fracture orthogonally.

Coring- and handling-induced fractures also were logged in detail. This information provides additional documentation regarding the condition of the core as received from the field, and it is useful for assessing the effects of problems encountered during drilling. The frequency of disc fractures (generally the most prevalent and least diagnostic type of induced fracture) is recorded in the form of a histogram.

3.7 Measurement of Shore Hardness:

The Shore hardness tests were deleted from core characterization work due to high equipment maintenance requirements in addition to questionable accuracy and nonreproducibility of results. Alternative testing methods are being considered for future core characterization work.

4.0 REPORTING OF RESULTS

A correlation chart has been compiled at a scale of 1 inch to 20 feet which provides a visual display of the following data recorded for the EGSP-

Ohio #4 core:

1. Stratigraphic Column
2. Lithology
3. Color Histogram
4. Gamma Ray Log
5. Compensated Density Log
6. Sonic Log
7. Temperature Log
8. Orientation/Distribution of Natural Fractures
9. Frequency of Induced Fractures

The correlation chart accompanies this report as an enclosure.

Discussions of core stratigraphy, lithology, and the occurrence of fractures are provided in Section 5. Appendix A contains a detailed lithologic description of the core. Terminology applied in describing natural and induced fractures is provided in Appendix B and the fracture data are presented in Appendix C.

One copy of the photographic log was submitted as a separate document to the Morgantown Energy Technology Center. A second copy is available for inspection at the EGSP Core Laboratory.

When physical properties testing of samples from the EGSP-Ohio #4 core has been concluded at the Michigan Technological University testing laboratory, a final (Phase III) report will be issued containing an analysis of those data together with the information already compiled at the EGSP Core Laboratory.

After characterization was completed the core was sealed in a moisture barrier and packaged in 3-foot core boxes for temporary archiving at the EGSP

Core Laboratory. Following a 90-day period the Ohio #4 core will be transferred to the Ohio Geological Survey.

5.0 DISCUSSION OF RESULTS

5.1 General:

Drilling and coring the Ohio #4 well was hindered by the restricted capability of a rotary head type rig and the introduction and use of pressurized coring equipment. The drill rig was a blasthole-type machine designed for 25-foot drill steel changes. Consequently, handling a 40-foot core barrel was difficult and slow. Mechanically, the pressure core barrel seemed to function satisfactorily except that the first pressurized core was contaminated with the kerosene flush fluid when a valve failed to close properly.

5.2 Geologic Setting:

EGSP-Ohio #4 well, in Ashtabula County, is located on the west side of Conneaut Creek one-fourth mile southeast of Conneaut, Ohio (Figure 3). Conneaut Creek, the prominent drainage feature in the area, flows into Lake Erie one mile north of the well site.

The topography consists mostly of rolling hills dissected by shallow stream-cut valleys. Two wave-cut escarpments are recognized in the area. The lower of the two is located on the northern edge of Conneaut and parallels the present day Lake Erie shoreline. It is a modern wave-cut cliff. The upper escarpment is located 1.5 miles southeast of Conneaut and trends northeast-southwest. This escarpment was cut during a high water level stage (glacial?) of Lake Erie (Goldthwait, et al, 1965). The topography between these escarpments represents the original glacial topography modified by the rapid down cutting of area streams.

FIGURE 3

LOCATION OF THE EGSP OHIO #4 WELL

ASHTABULA COUNTY, OHIO

A thick cover of Quaternary sediment covers the study area. Pleistocene lake deposits are present southwest of the well site (Bernison, 1978). The surficial sediments at the Ohio #4 well site are fluvial sediments overlying glacial drift. Directly beneath this is flat lying, undifferentiated Devonian bedrock. Bedrock outcrops are rare. Piotrowski, et al, (1978) report production of Devonian Shale gas from several low pressure wells to the east of Conneaut during the 1800's.

5.3 Stratigraphy:

A total of 412 feet of core was recovered from the EGSP-Ohio #4 well. Designated core point was at 508 feet in the upper part of the Chagrin Shale. Coring was terminated approximately 26 feet into the Onondaga Limestone. As shown on the correlation chart which accompanies this report, five isolated zones within the cored interval were plug drilled and two zones were pressure cored. Formations encountered in the Ohio #4 well are summarized in Table 1. A summary description of each formation or member is provided below.

TABLE 1
FORMATIONS CORED

Formation	Depths	Formation Thickness	Cored
Chagrin Shale	*- 838'	330'+	508'- 566' 746'- 826'
Dunkirk Formation	838'- 862'	24'	838'- 862'
Java Formation:			
Hanover Shale	862'- 969'	107'	862'- 876' 949'- 969'
Pipe Creek Member	969'- 986'	17'	969'- 986'
West Falls Formation:			
Angola Shale	986'-1,060'	74'	986'- 989'
Rhinestreet Shale	1,060'-1,202'	142'	1,069'-1,108' 1,119'-1,159' 1,169'-1,202'
Hamilton Group:			
Tully Limestone	1,202'-1,250'	48'	1,202'-1,209'
Mahantango Shale	1,250'-1,330'	80'	1,309'-1,330'
Marcellus Shale	1,330'-1,360'	30'	1,330'-1,360'
Onondaga Limestone	1,360'- *	26'+	1,360'-1,386'

* Contact undetermined

Chagrin Shale

Total thickness of the Chagrin Shale could not be determined from the well data obtained. At least 330 feet (508'-838') is present in the EGSP-Ohio #4 well. Only the upper 58 and the lower 80 feet were cored. Consequently, a detailed lithologic description was obtained for only part of the Chagrin Shale.

The upper part (508'-566') consists of olive gray (5Y 3/2) and olive black (5Y 2/1) silty mudstone and mudstone. Occasional layers of ripple-laminated siltstone resting on basal scour surfaces, are also present. All are thinly laminated to thin bedded. Fossils contained within the upper part include spores, carbonaceous fragments, and articulate brachiopods with pyritized spores and carbonaceous fragments being the most common. Vitrinite fragments, articulate brachiopods, and spore resin bodies are rarely present. Burrows and mottled zones (bioturbations) occur throughout the lower 1/2 and at one isolated zone in the upper 1/2. Pyrite occurs in nodular and disseminated form, as coatings on spores, and is most common between 508 and 530 feet.

The lower 80 feet (746'-826') is predominantly olive gray (5Y 3/2), dusky yellow green (5GY 5/2), and olive black (5Y 2/1) silty mudstone. The olive black shale beds are less common in this interval. Occasional layers of ripple-laminated siltstone resting on basal scour surfaces and thin bedded mudstone are also present. Fossil content of the lower cored interval differs greatly from the upper one. It contains inarticulate brachiopods, spore resin bodies, carbonaceous fragments, fish scales, and conodont remains. These fossils occur throughout the interval except for the conodonts which are restricted to the lower 1/2. Carbonaceous fragments occur as large individual pieces or as finely divided particles. Many of the dusky yellow green zones exhibit varying degrees of mottling (bioturbation). Pyrite occurs rarely as nodules.

The contact between the Chagrin Shale and the underlying Dunkirk Formation is marked by a change in color from light to dark, an increase in gamma radiation, and a decrease in density.

Dunkirk Formation

The Dunkirk Formation consists of thinly laminated to thin bedded olive black (5Y 2/1) silty mudstone. Inarticulate brachiopods, spore resin bodies, carbonaceous fragments, and fish fossils occur in the upper 1/2. The carbonaceous fragments occur as large individual pieces or as finely divided particles. Fish fossils are primarily scales, with one probable fish bone noted at 846.6'. Mud-filled and pyritized burrow structures are present near the base of the interval. Pyrite nodules, some up to 1 cm in diam, are common throughout. Some disseminated grains and an occasional lamina are also present.

The contact between the Dunkirk Formation and the underlying Java Formation is marked by a decrease in gamma count and an increase in rock density on the geophysical logs. The contact is gradational in the core but can be distinguished by a gradual shift to lighter colors.

Java Formation

The Java Formation, composed of the Hanover Shale and the Pipe Creek Member, was intercepted in the Ohio #4 well. The top 14 feet and the bottom 20 feet of the Hanover Shale and the total thickness of the Pipe Creek Member were cored.

The members of the Java Formation are more readily distinguishable on geophysical logs than from the core itself. The top of the Hanover Shale Member is marked by a decrease in gamma count and an increase in rock density.

The limits of the underlying Pipe Creek Member are defined by two spikes (sudden decreases in sonic velocity and rock density on the geophysical log), the lowermost spike being more pronounced than the uppermost.

Hanover Shale:

The top 14 feet (862'-876') of the Hanover Shale is composed of dusky yellow green (5GY 5/2) and olive black (5Y 2/1) thin bedded silty mudstones. Dusky yellow green is the dominant color. This interval appears to be void of fossils. Pyritized burrows and pyrite nodules of various sizes are present in the upper 1/2. Calcareous concretionary bands, grayish yellow green (5GY 2/1), occur near the center of the interval.

The bottom 20 feet (949'-969') of the Hanover Shale consists of dusky yellow green (5GY 5/2) and olive black (5Y 2/1) thin bedded silty mudstone and mudstone. Inarticulate brachiopods, occasional fish scales, shell fragments, cephalopods, and a single horn coral are present within the interval. Pyrite occurs in nodular and disseminated form in the lower 1/2. A single grayish yellow green (5GY 7/2) calcareous concretionary band and a layer of barite (?) are present near the base of the interval.

Pipe Creek Member:

The Pipe Creek Member is present from 969 to 986 feet in the Ohio #4 well. It consists of thin bedded, grayish olive green (5GY 3/2) and olive black (5Y 2/1) silty mudstone and mudstone. The interval appears to be void of fossils except for several large coaly fragments near the base. Horizontal, mud-filled burrows and occasional small pyrite nodules occur throughout; disseminated pyrite is present near the base. The interval also contains several grayish yellow green (5GY 7/2) calcareous concretionary bands.

West Falls Formation

The West Falls Formation, which is composed of two members (the Angola Shale and the Rhinestreet Shale), is present in the Ohio #4 well between 986 feet and 1,202 feet.

Angola Shale:

The Angola Shale, the uppermost member of the West Falls Formation, is 74 feet thick (986'-1,060') in the Ohio #4 well. Only three feet at the base of the member were cored, an interval consisting of thin bedded, grayish olive green (5GY 3/2) silty mudstone. No fossils or biogenic structures were observed. Pyrite occurs in nodular and disseminated form.

The contact zone between the Angola Shale and the underlying Rhinestreet Member was not cored. The contact is identifiable on geophysical logs by a slight increase in gamma radiation and by slight decreases in rock density and sonic velocity.

Rhinestreet Shale:

The Rhinestreet is present in the Ohio #4 well from 1,060 feet to 1,202 feet. Between these depths three oriented cores were taken.

The uppermost core (1,069'-1,108') consists of thinly laminated to thin bedded, grayish olive green (5GY 3/2) and olive black (5Y 2/1) silty mudstone and mudstone. Mudstone is dominant in the upper 1/3 and silty mudstone dominates the remainder of the cored interval. Horizontal, mud-filled burrows occur throughout, heavily pyritized in the tops of the dark zones and weakly pyritized throughout the light zones. Pyrite nodules and lenses are present in the dark zones. Spore resin bodies and carbonaceous fragments occur near the center and a single grayish yellow green (5GY 7/2)

calcareous concretionary band is present at the base of the interval.

The middle core (1,119'-1,159') is composed of thinly laminated to thin bedded, grayish olive green (5GY 3/2), olive black (5Y 2/1), and grayish olive (10Y 4/2) mudstone and silty mudstone. This interval contains a variety of fossils and biogenic structures. Articulate brachiopods (some partially pyritized), spore resin bodies, and carbonaceous fragments are the most common fossils, but coiled cephalopods and conodonts are also present. Burrows and mottled zones, many weakly to moderately pyritized, occur throughout. Pyrite also occurs as small nodules near the base of the interval. Grayish olive green (5GY 3/2) calcareous concretions are present throughout.

The lower core (1,169'-1,202') consists of thinly laminated to thin bedded silty mudstone. Olive black (5Y 2/1) is the dominant color at the top and bottom of the core and grayish olive green (5GY 3/2) is dominant throughout the remainder. Several siltstones and one sandstone are present near the base of the interval. Fossils contained in the upper 1/2 include inarticulate brachiopods, spore resin bodies, large carbonaceous fragments, fish scales, and fecal pellets. The lower 1/2 contains finely divided carbonaceous fragments and cephalopod fossils. Vitrinite fragments occur throughout. Pyrite nodules and laminae occur in the olive black zones. A tuffaceous laminae, possibly the Belpre or Center Hill Ash, is present at 1,192 feet. A lime concretion containing oil-stained septarian cracks occurs near the center of the interval.

The contact between the Rhinestreet and the underlying Tully Limestone is marked by an unconformity in the core and by a distinct change in

lithology from olive black (5Y 2/1) silty mudstone to grayish olive (10Y 4/2) highly calcareous mudstone. On the geophysical logs this contact is marked by a decrease in gamma radiation and by increases in rock density and sonic velocity.

Hamilton Group

The Hamilton Group and its subdivisions, the Tully Limestone, Mahantango Shale, and Marcellus Shale, is present from 1,202 feet to 1,360 feet.

Tully Limestone:

The Tully Limestone is 48 feet thick (1,202'-1,250') in the Ohio #4 well, but only the upper 6 feet was cored. The core consists of thick bedded, grayish olive (10Y 4/2) calcareous mudstone. Articulate brachiopod casts, crinoid stems, lime concretions, and large pyrite nodules occur within it.

The contact between the Tully Limestone and underlying Mahantango Shale was not intercepted in a cored interval and is difficult to determine from gamma ray and density logs. Sonic log readings vary greatly within the Tully Limestone but are less variable in the Mahantango Shale. This differing degree of variance was used to determine the position of the Tully-Mahantango contact.

Mahantango Shale:

The Mahantango Shale is 80 feet thick (1,250'-1,330') in the Ohio #4 well. Only 21 feet at the base of the member was cored, an interval consisting of thin bedded, olive gray (5Y 3/2) mudstone containing a variety of fossils and biogenic structures. Articulate brachiopods, spore resin bodies, and cephalopod remains occur throughout. Fossils restricted to the lower

1/3 include fecal pellets, bone fragments (fish?), crinoid stems, and pelecypod casts. Pyritized burrow structures occur within the highly calcareous upper 1/2 of the interval.

The contact between the Mahantango Shale and the underlying Marcellus Shale is identified by a very gradual change in color from olive gray (5Y 4/1) to olive black (5Y 2/1). On geophysical logs the contact appears as an increase in gamma radiation and a decrease in rock density.

Marcellus Shale:

The Marcellus Shale is present in the Ohio #4 well between 1,330 and 1,360 feet. Cored throughout, the member consists of thin bedded olive black (5Y 2/1) and olive gray (5Y 3/2) mudstone. Articulate and inarticulate (Orbiculoides Media) pyritized brachiopods, pelecypods, and cephalopods are widespread. Spore resin bodies and concentrations of shell fragments are present at the top of the interval. Finely divided carbonaceous fragments are present at the center of the interval. Pyrite occurs in nodular and disseminated form throughout the lower 2/3.

The contact between the Marcellus Shale and the underlying Onondaga Limestone is marked by a color change from dark to light and by a gradual lithologic change from mudstone to lime mudstone to limestone. On the geophysical logs the contact is identified by a decrease in gamma radiation and by increases in rock density and sonic velocity.

Onondaga Limestone

The Ohio #4 core contains 26 feet (1,360'-1,386') of Onondaga Limestone. The upper 1/2 consists of thin to thick bedded lime mudstone. The lower 1/2

is composed of lime mudstone and lime wackestone, the latter containing occasional chert nodules. Colors vary from olive gray (5Y 3/2 and 5Y 4/1), and olive black (5Y 2/1) at the top of the interval to olive gray (5Y 3/2) and light olive gray (5Y 5/2) at the bottom. The upper 1/2 contains concentrations of shell fragments and zones of bioturbation. The lower 1/2 contains solitary horn corals, articulate brachiopods, pelecypods, and crinoid stems. Burrows occur throughout the interval; stylolites and several unidentifiable fossil fragments occur at the base.

5.4 Fracture Analysis:

Both natural and induced fractures present in the core were examined in detail. The resulting fracture logs are reproduced in Appendix C of this report. Terminology and abbreviations used in log compilation are summarized in Appendix B.

Four natural fractures (1 compound joint, 3 microfaults) were observed in the core. The distribution of these fractures throughout the cored interval is shown in Table 2.

All natural fractures in the Ohio #4 core occur in the Rhinestreet Member of the West Falls Formation. These fractures include one closed hairline compound joint (?) and three microfaults, one of which is associated with a concretion. The microfaults are curviplanar and strikes and dips could not be measured. Strike and dip data were obtained for the compound joint, but there is some doubt as to whether this is a true natural fracture. Polar plots and rose diagrams for the natural fractures were not constructed due to the absence of natural fracture data.

TABLE 2

DISTRIBUTION OF NATURAL FRACTURES

Formation	Depths	Core Length	Number of Fractures	Fractures Per Foot
Chagrin Shale	*- 838'	140'	0	0.00
Dunkirk	838'- 862'	24'	0	0.00
Java:				
Hanover Shale	862'- 969'	34'	0	0.00
Pipe Creek Member	969'- 986'	17'	0	0.00
West Falls:				
Angola Shale	986'-1,060'	2'	0	0.00
Rhinestreet Shale	1,060'-1,202'	112'	4	0.04
Hamilton Group:				
Tully Limestone	1,202'-1,250'	7'	0	0.00
Mahantango Shale	1,250'-1,330'	21'	0	0.00
Marcellus Shale*	1,330'-1,360'	30'	0	0.00
Onondaga Limestone*	1,360'- *	26'	0	0.00

* Contact undetermined

Of the total number of fractures in the EGSP-Ohio #4 core, more than 99% are believed to be coring or handling induced. Disc fractures were the most common type observed. Because these fractures are less diagnostic than other types they were not recorded individually. However, disc fracture frequency provides a rough measure of the flexural rigidity of the rock parallel to bedding, and these data are reported in Appendix C.

Of the 85 fractures individually logged in the Ohio #4 core, more than 95% are believed to be coring induced. Torsional fractures and disc fractures with circular slickenlines are most common. Petal fractures are also present. They occur in the Rhinestreet Member of the West Falls Formation (14), in the Chagrin Shale (5), and in the Mahantango Shale of the Hamilton Group (2). Distribution of these features is indicated in Table 3.

TABLE 3

DISTRIBUTION OF PETAL FRACTURES

Formation	Depths	Core Length	Number of Fractures	Fractures Per Foot
Chagrin Shale	508'- 838'	140'	5	0.04
Dunkirk	838'- 862'	24'	0	0.00
Java:				
Hanover Shale	862'- 969'	34'	0	0.00
Pipe Creek Member	969'- 986'	17'	0	0.00
West Falls:				
Angola Shale	986'-1,060'	2'	0	0.00
Rhinestreet Shale	1,060'-1,202'	112'	14	0.13
Hamilton Group:				
Tully Limestone	1,202'-1,250'	7'	0	0.00
Mahantango Shale	1,250'-1,330'	21'	2	0.10
Marcellus Shale	1,330'-1,360'	30'	0	0.00
Onondaga Limestone	1,360'-1,386'	26'	0	0.00

All planar petal fractures were analyzed to identify common structural trends in the core. Figure 4 is a graphic representation of the data plotted in polar form on a Schmidt stereonet. The data have been contoured to determine locations of maximum pole density using the method described by Ragan (1973).

In the core, petal fractures exhibit little, if any, similarity in strike or dip (Figure 4). It should be noted that this interpretation is based on limited data and that more data may be necessary to identify possible structural trends.

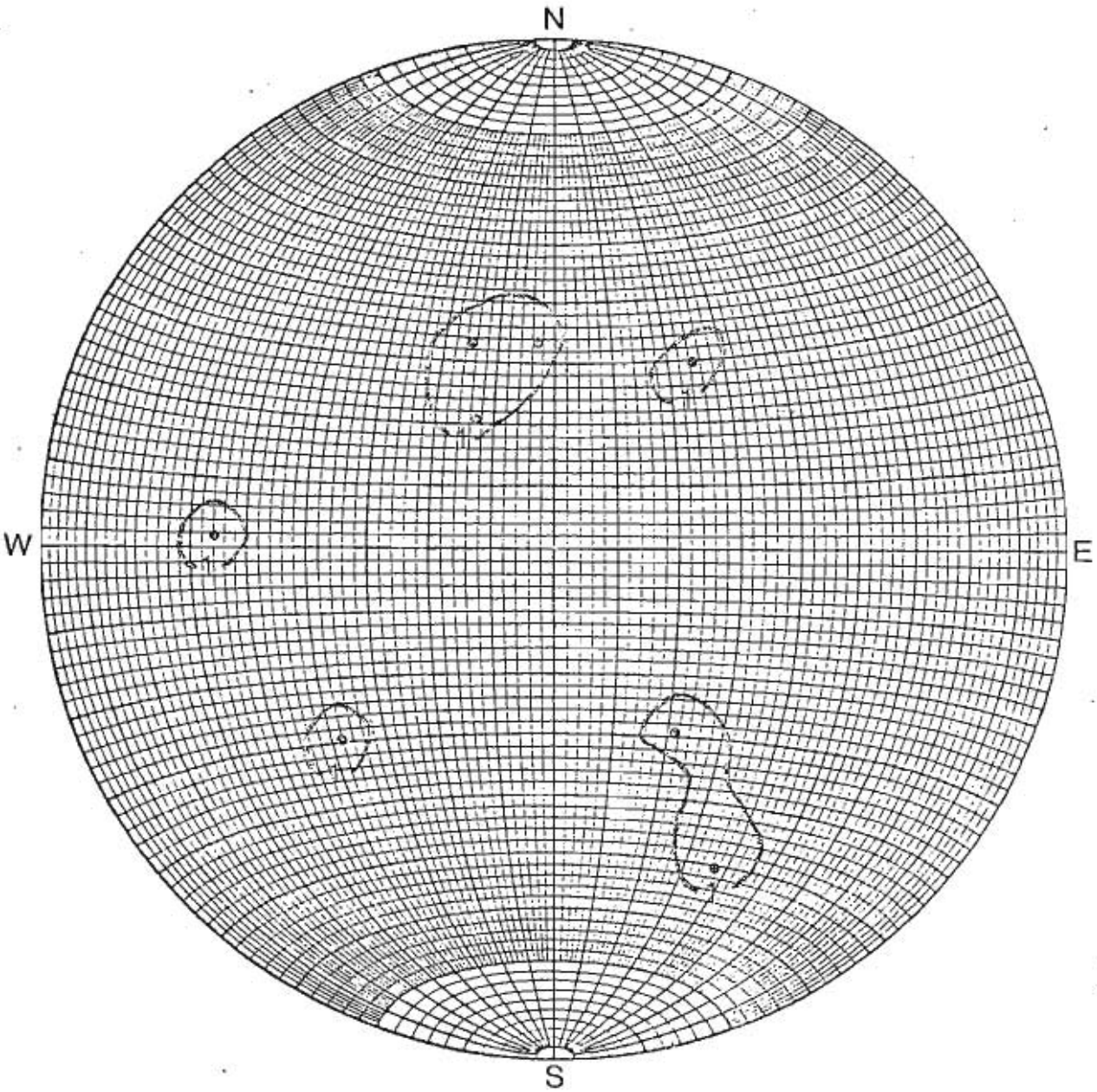

FIGURE 4

CONTOURED DIAGRAM OF POLES TO PETAL FRACTURES IN THE EGSP OHIO #4 CORE

APPENDIX A

DETAILED LITHOLOGIC DESCRIPTION

EGSP OHIO #4 WELL - ASHTABULA COUNTY

INTERVAL	DESCRIPTION
508.0' - 514.7' (6.7')	Mudstone, shaly mudstone, and silty mudstone, grayish olive green (5GY 3/2) and olive black (5Y 2/1), thin bedded. Isolated pyrite nodules (2-4 mm), some partially oxidized, pyritized spores, and spore casts are present. A single large carbonaceous fragment was observed at 511.6'.
514.7' - 520.3' (5.6')	Silty mudstone and silty shale, olive gray (5Y 3/2), olive black (5Y 2/1), and dark greenish gray (5GY 4/1), thin bedded. The olive black zones in the lower 1/2 are mottled by bioturbation. Small burrows and carbonaceous fragments (a few pyritized) are present throughout. Disseminated pyrite was observed at 515.1'. Spore casts and articulate brachiopod shells are present in the lower 1/2.
520.3' - 525.0' (4.7')	Silty mudstone and mudstone, olive gray (5Y 3/2), olive black (5Y 2/1) and dark greenish gray (5GY 4/1), thinly laminated to thin bedded. Weak scour surfaces were observed at 522.0'. An irregular zone of disseminated pyrite is present at 523.1'. The lower 1/2 of the interval is slightly to moderately fissile. Pyritized spores and carbonaceous fragments are present. A calcareous silty mudstone occurs at 524.5'.
525.0' - 529.5' (4.5')	Silty mudstone, mudstone, and siltstone, olive gray (5Y 3/2) and grayish olive green (5GY 3/2), thickly laminated. Two ripple-laminated and slightly calcareous siltstones, approximately 3 to 4 cm thick, occur at 528.6' and 529.0'. Thin, upward fining sediment sequences with scour marks at the bases are present at 528.9' and 529.1'. Pyritized spores and nodules occur from 526.6' to 528.0'. Carbonaceous fragments are present throughout. The interval is calcareous between 527.3' and 527.4'.
529.5' - 536.0' (6.5')	Mudstone and silty mudstone, olive gray (5Y 3/2), grayish olive green (5GY 3/2) and olive black (5Y 2/1), thinly laminated to thin bedded. The olive-gray zones and the tops of the olive-black zones have been moderately to intensely churned by burrowing organisms. The upper 1/2 contains numerous large (1 cm diam) burrow structures. Pyritized spores were observed at 530.4'.

INTERVAL	DESCRIPTION
536.0' - 544.0' (8.0')	Silty mudstone and siltstone, grayish olive green (5GY 3/2), olive gray (5Y 4/1), and olive black (5Y 2/1), thinly laminated and thin bedded. Silty mudstone is more numerous in the lower 1/2. Ripple-laminated silty mudstone and siltstone occurs from 540.9' to 542.0' and from 543.4' to 544.1'. The olive gray and olive black zones from 537.2' to 542.5' are moderately to intensely bioturbated. Unusual large diameter, near vertical burrows are present between 542.4' and 542.5'. Calcareous zones are present from 537.5' to 538.4' and from 539.2' to 539.9'. Casts of plant fragments (one partially pyritized) are also present.
544.0' - 551.0' (7.0')	Mudstone, silty mudstone, and siltstone, olive gray (5Y 3/2), light olive gray (5Y 5/2), and greenish gray (5GY 6/1), thinly laminated and thin bedded. Greenish gray siltstone with prominent sole marks is present from 544.0' to 544.4' and from 550.4' to 550.6'. Several of the light olive gray zones exhibit varying degrees of bioturbation. Minor amounts of carbonaceous material and disseminated pyrite occur throughout the interval. A large vitrain fragment is present at 547.3'.
551.0' - 558.7' (7.7')	Silty mudstone, mudstone, and siltstone, olive black (5Y 2/1), and grayish olive green (5GY 3/2), thinly laminated. Slightly calcareous siltstone laminae overlying weak scour surfaces are present near the top of the interval. Bioturbated zones are present from 551.8' to 552.2' and from 553.2' to 553.9'. Some of the burrows in these zones are partially pyritized. Pyritized spores occur from 555.9' to 556.8'. Carbonaceous fragments are present at 557.4' and 558.6'.
558.7' - 565.9' (7.2')	Silty mudstone, grayish green (10GY 5/2), olive gray (5Y 3/2), and olive black (5Y 2/1), thinly laminated to thin bedded. Grayish green zones are intensely mottled by bioturbation at 560.8' and from 562.6' to 562.8'. Burrow structures (1 cm in diam by 5 cm in length) are present beneath these bioturbated zones. Pyritized spores were observed at 560.9'. Spore resin bodies occur in the 5Y 2/1 zones throughout the lower 1/2.
565.9' - 746.0' (180.1')	This interval was plug drilled.
746.0' - 758.0' (12.0')	Silty mudstone, mudstone, and siltstone, olive gray (5Y 3/2), olive black (5Y 2/1), dusky yellow green (5GY 5/2), grayish olive (10Y 4/2), and grayish yellow green (5GY 7/2). Grayish yellow green, ripple-laminated siltstone occurs from 749.4' to 749.5' and from 757.8' to 757.9'. Most of the olive gray and dusky yellow green zones and the upper 5 cm of the grayish olive zones are strongly bioturbated. A large carbonaceous fragment is present at 749.1'. Pyrite nodules are present between 752.9' and 753.1'.

INTERVAL	DESCRIPTION
758.0' - 771.9' (13.9')	Silty mudstone, olive gray (5Y 3/2), olive black (5Y 2/1), and dusky yellow green (5GY 5/2), thin bedded. A few of the dusky yellow green zones are bioturbated. Large carbonaceous fragments are present at 766.9' and 771.9'. A few pyrite nodules were observed at 769.4'. A single inarticulate brachiopod shell (Lingula sp.) occurs at 771.9'. Spore resin bodies, in the olive black zones, occur throughout the interval.
771.9' - 783.2' (11.3')	Silty mudstone, olive gray (5Y 3/2) and dusky yellow green (5GY 5/2), thinly laminated to thin-bedded. The dusky yellow green zones and the tops of the olive gray zones are weakly mottled by bioturbation. Vitrinite fragments and fish scales were observed in the upper 2/3. Spore resin bodies are present in the lower 2/3. A single inarticulate brachiopod shell (Lingula sp.) occurs at 782.0'.
783.2' - 787.4' (4.2')	Silty mudstone and siltstone, olive gray (5Y 3/2), dusky yellow green (5GY 5/2), and grayish yellow green (5GY 7/2), thin bedded. The dusky yellow green zones are weakly mottled by bioturbation. A few small (4 mm diam) pyrite nodules occur at 785.5'.
787.4' - 795.8' (8.4')	Silty mudstone, olive gray (5Y 3/2) and dusky yellow green (5GY 5/2), thin bedded. Dusky yellow green zones are weakly mottled by bioturbation. Isolated conodonts and spore resin bodies were noted in the upper 1/2. A single inarticulate brachiopod shell (Lingula sp.) is present at 794.5'.
795.8' - 803.7' (7.9')	Silty mudstone, olive gray (5Y 3/2), thin bedded. Isolated conodonts were observed throughout the interval. Fish scales and a single inarticulate brachiopod shell (Lingula sp.) are present in the upper 1/3.
803.7' - 810.8' (7.1')	Silty mudstone, olive gray (5Y 3/2), and dusky yellow green (5GY 5/2), thin bedded. Burrow structures (1 cm diam) occur in the dusky yellow green zones. A single conodont is present in the upper 1/3. A small (1 mm by 5 mm) carbonaceous fragment occurs at 807.0'. A single pyrite nodule and fish scale occur in the lower 1/3.
810.8' - 821.6' (10.8')	Silty mudstone, mudstone, and siltstone, olive gray (5Y 3/2), grayish green (10GY 5/2), and grayish yellow green (5GY 7/2), thin bedded. Ripple-laminated siltstone, present from 821.5' to 821.6', overlies a weak scour surface. A few carbonaceous fragments occur throughout the interval. Isolated conodonts and fish scales were observed in the upper 1/2. A large (2 cm by 2 cm) vitrain fragment and a few spore resin bodies are present near the center of the interval.

INTERVAL	DESCRIPTION
821.6' - 826.2' (4.6')	Mudstone and silty mudstone, dusky yellow green (5GY 5/2), and olive gray (5Y 3/2), thin bedded. Very thin beds of grayish yellow green (5GY 7/2), ripple-laminated siltstone are present at 823.4' and 825.2'.
826.2' - 836.0' (9.8')	This interval was pressure cored.
836.0' - 847.0' (11.0')	Silty mudstone, olive black (5Y 2/1), and grayish green (10GY 5/2), thinly laminated to thin bedded. Spore resin bodies occur throughout the olive black zones. A vitrain fragment and a carbonaceous fragment were observed in the upper 1/3. Inarticulate brachiopod shells (Lingula sp.) are present in the upper 2/3. Isolated pyrite nodules were noted in the lower 2/3.
847.0' - 858.0' (11.0')	Silty mudstone, olive black (5Y 2/1), thin bedded. Isolated fish scales were observed in the upper and lower 1/3. A single, small (5 mm by 5 mm) fish bone is present at 846.6'. Pyrite nodules and layers occur at 851.2' and 848.3'. A large (2 cm by 5 cm) carbonaceous fragment is present at 849.1'.
858.0' - 868.4' (10.4')	Silty mudstone, dusky yellow green (5GY 5/2), and olive black (5Y 2/1), thin bedded. Very large (5 cm by 4 cm) pyrite nodules occur in several of the olive black zones. Smaller pyrite nodules and layers of disseminated crystals are present throughout. Unusual burrow structures (3 mm to 20 mm in diam) occur in a slightly calcareous dusky yellow green zone from 860.4' to 860.9'. These burrows are filled with medium gray (N5), highly calcareous silty mudstone. Small (2 mm by 10 mm), partially pyritized, horizontal burrows are common throughout.
868.4' - 875.8' (7.4')	Silty mudstone, dusky yellow green (5GY 5/2), thin bedded. Two grayish yellow green (5GY 7/2) calcareous concretionary bands occur from 869.5' to 869.6' and from 871.6' to 871.8'. Small (2 mm by 5 mm), horizontal, partially pyritized burrow structures are present throughout.
875.8' - 949.0' (73.2')	This interval was plug drilled.
949.0' - 957.6' (8.6')	Silty mudstone, grayish olive green (5GY 3/2), and olive black (5Y 2/1), thin bedded. Olive black zones occur as thin laminae within the lower 1/2. Burrow structures of various sizes were noted throughout. A few shell fragment casts are present near the bottom of the interval. The upper 1/3 is slightly calcareous.

INTERVAL	DESCRIPTION
957.6' - 966.6' (9.0')	Silty mudstone, grayish olive green (5GY 3/2), and olive black (5Y 2/1), thin bedded. A grayish yellow green (5GY 7/2) calcareous concretionary band is present from 964.3' to 964.4'. Disseminated pyrite layers and occasional nodules occur in the lower 1/2. Fish scales and an inarticulate brachiopod shell (possibly Lingula sp. or Schizobolus concentricus) are noted near the center of the interval. A single coiled cephalopod and a recrystallized solitary horn coral (?) occur between 964.0' and 965.0'. Burrow structures are present throughout. Unusual noncalcareous clasts or concretions are present at 961.6' and 965.0'.
966.6' - 978.5' (11.9')	Silty mudstone, grayish olive green (5GY 3/2), and olive black (5Y 2/1), thin bedded. Grayish yellow green (5GY 7/2) calcareous concretionary bands occur at 972.1' and from 978.0' to 978.1'. The interval is slightly calcareous from 970.9' to 972.4' and from 976.9' to 978.5'. Horizontal burrow structures and a few small pyrite nodules are present throughout.
978.5' - 988.6' (10.1')	Mudstone and silty mudstone, grayish olive green (5GY 3/2), and olive black (5Y 2/1), thin bedded. Grayish yellow green (5GY 7/2) calcareous concretionary bands are noted at 984.2' and 987.1'. Disseminated pyrite and occasional small nodules occur throughout. Several microfaults are present between 978.5' and 988.6'. The middle of the interval contains a large coaly fragment at 980.0' and several mud-filled burrows at 983.7'.
988.6' - 1,069.0' (80.4')	This interval was plug drilled.
1,069.0' - 1,084.2' (15.2')	Mudstone and silty mudstone, grayish olive green (5GY 3/2), and olive black (5Y 2/1), thin bedded. Grayish yellow green (5GY 7/2) calcareous concretionary bands occur from 1,071.8' to 1,072.0'. Irregular nodules and lenses of pyrite are present in the 5Y 2/1 zones. Nonmineralized (mud-filled) and weakly pyritized, horizontal burrow structures occur in the 5GY 3/2 zones.
1,084.2' - 1,096.2' (12.0')	Silty mudstone, grayish olive green (5GY 3/2), and olive black (5Y 2/1), thin bedded. The tops of the 5Y 2/1 zones contain burrow structures, usually heavily pyritized. Weakly pyritized burrow structures occur in the light zones. The interval contains occasional pyrite nodules and a few carbonaceous fragments. Spore resin bodies are present in the lower 1/3.

INTERVAL	DESCRIPTION
1,096.2' - 1,108.4' (12.2')	Silty mudstone and mudstone, grayish olive green (5GY 3/2), and olive black (5Y 2/1), thinly laminated to thin bedded. A single grayish yellow green (5GY 7/2) calcareous concretionary band is present from 1,106.8' to 1,107.1'. The interval contains pyritized burrow structures and nodules in the upper 2/3. The grayish olive green mudstones are weakly calcareous.
1,108.4' - 1,119.4' (11.0')	This interval was plug drilled.
1,119.4' - 1,132.0' (12.6')	Mudstone and silty mudstone, grayish olive green (5GY 3/2), and olive black (5Y 2/1), thinly laminated to thin bedded. Grayish olive green (5GY 3/2) calcareous concretions, 1-3 cm thick, are present throughout. Horizontal, weakly pyritized burrow structures were noted in the light zones. Pyrite nodules occur within the dark zones. Articulate brachiopod and coiled cephalopod casts, conodonts, and carbonaceous fragments are present but rare. Spore resin bodies are numerous in the lower 10 cm. The grayish olive green zones are weakly mottled and calcareous.
1,132.0' - 1,142.5' (10.5')	Silty mudstone and mudstone, grayish olive green (5GY 3/2), and olive black (5Y 2/1), thinly laminated to thin bedded. Small (2 and 8 cm) calcareous concretions are present at 1,134.2' and 1,137.4'. Pyritized burrow structures are common in the light zones. Isolated coiled cephalopod casts were observed throughout.
1,142.5' to 1,151.1' (8.6')	Mudstone, silty mudstone, and siltstone, grayish olive green (5GY 3/2), and olive black (5Y 2/1), thin bedded. Grayish yellow green (5GY 7/2) siltstone laminae, 0.5 to 2 cm thick, were noted throughout. A single grayish yellow green (5GY 7/2) calcareous concretion is present between 1,148.2' and 1,148.7'. Pyritized burrow structures are common. Two coiled cephalopod casts were noted at 1,145.3'. Small pyritized articulate brachiopod casts are present at 1,150.7' and 1,151.1'.
1,151.1' - 1,159.3' (8.2')	Mudstone, grayish olive (10Y 4/2), and olive black (5Y 2/1), thinly laminated to thin bedded. The zone from 1,154.0' to 1,155.0' contains numerous torsional fractures and is highly fragmented. Burrow structures, some pyritized, and small pyrite nodules occur throughout. Spore resin bodies, numerous poorly preserved small articulate brachiopod casts, and pyritized fossil fragments occur within a zone from 1,152.5' to 1,155.9'. The grayish olive zones are slightly calcareous.

INTERVAL	DESCRIPTION
1,159.3' - 1,169.1' (9.8')	This interval was pressure cored.
1,169.1' - 1,185.9' (16.8')	Silty mudstone, olive black (5Y 2/1), and olive gray (5Y 3/2), thinly laminated. Pyrite nodules and thin lenses of disseminated pyrite occur throughout. Several small inarticulate brachiopod shells are noted at 1,182.3'. The interval contains abundant spore resin bodies. Fish scales and coprolites (?) are present between 1,176.0' and 1,179.1'. A large vitrinite fragment is present at 1,184.0'.
1,185.9' - 1,192.1' (6.2')	Silty mudstone, olive gray (5Y 3/2), and olive black (5Y 2/1), thinly laminated and thin bedded. Several thin, tuffaceous laminae are present between 1,190.5' and 1,191.3'. Large carbonaceous fragments occur between 1,188.8' and 1,189.2'. The olive black zones contain numerous spore resin bodies. Several inarticulate brachiopod casts (Lingula sp.) are present in the lower 10 cm. Occasional pyrite nodules were noted throughout.
1,192.1' - 1,198.9' (6.8')	Silty mudstone and siltstone, light olive gray (5Y 5/2) and olive black (5Y 2/1), thinly laminated. Light olive gray ripple-laminated siltstones with scour features are present in the lower 1/2. Two large (10 cm diam) lime concretions, surrounded by distorted laminae, occur between 1,196.0' and 1,198.2'. The lower concretion contains septarian cracks with slight oil staining. A tuffaceous lamination is present at 1,192.4'. Several carbonaceous and vitrinite fragments occur in the lower 10 cm. A single cephalopod fragment occurs at 1,192.8'.
1,198.9' - 1,202.3' (3.4')	Silty mudstone, siltstone, and sandstone, olive black (5Y 2/1) and dark gray (N3), thinly laminated. Dark gray thinly laminated siltstone and very fine sandstones occur throughout. The interval is noncalcareous and contains nodules and layers of pyrite throughout. A single large (1 cm by 4 cm) carbonaceous fragment occurs at 1,199.8'.
1,202.3' - 1,209.2' (6.9')	Calcareous mudstone, grayish olive (10Y 4/2), thick bedded. Several small (10 cm diam) lime concretions occur between 1,204.9' and 1,207.9'. Occasional poorly preserved burrow structures are noted throughout. Crinoid stems and articulate brachiopod shells occur within the lower 1/2. Large (3 cm diam) pyrite nodules are present in the upper 1/3. The interval is moderately to strongly calcareous throughout.

INTERVAL	DESCRIPTION
1,209.2' - 1,309.1' (99.9')	This interval was plug drilled.
1,309.1' - 1,321.1' (12.0')	Mudstone, olive gray (5Y 3/2), thin bedded. Burrow structures, some partially pyritized, are present throughout. The lower 1/2 of the interval contains large spore resin bodies, small articulate brachiopod casts and pyritized cephalopod fragments. The interval is strongly calcareous throughout.
1,321.1' - 1,330.1' (9.0')	Mudstone, olive gray (5Y 3/2), thin bedded. The interval contains large spore resin bodies, coprolites, bone fragments, articulate brachiopod shells, coiled cephalopod and pelecypod casts, crinoid stems, and a few pyrite nodules.
1,330.1' - 1,339.0' (8.9')	Mudstone, olive gray (5Y 3/2), thin bedded. Occasional large spore resin bodies are present throughout. Pyritized pelecypod and articulate brachiopod shells occur between 1,332.3' and 1,334.8'.
1,339.0' - 1,344.6' (5.6')	Mudstone, olive black (5Y 2/1), and olive gray (5Y 4/1), thin bedded. Articulate brachiopod shells, pyritized pelecypod casts and cephalopod shell fragments are present in the upper 1/3. Large carbonaceous plant fragments were noted at 1,341.2' and 1,342.5'. Concentrations of shell fragments and disseminated pyrite occur between 1,344.0' and 1,345.2'. The upper 1/3 and lower 1/3 are calcareous.
1,344.6' - 1,351.2' (6.6')	Mudstone, olive black (5Y 2/1), thin bedded. A concentration composed of pyritized articulate and inarticulate brachiopod shells (Orbiculoides media) was observed at 1,348.6'. The lower 1/3 contains several cephalopod casts and Orbiculoides media shells.
1,351.2' - 1,360.3' (9.1')	Mudstone, olive gray (5Y 3/2), thin bedded. Abundant inarticulate brachiopod shells (Orbiculoides media), pyritized articulate brachiopod shells and a few cephalopod casts occur in the lower 1/2. A few pyrite nodules are present throughout. The upper 2/3 is slightly calcareous.
1,360.3' - 1,363.8' (3.5')	Lime mudstone and mudstone, olive black (5Y 2/1) and olive gray (5Y 4/1), thin bedded. Thin to thick laminae of olive gray silty mudstone with shell fragments occur throughout.
1,363.8' - 1,374.8' (11.0')	Lime mudstone, olive gray (5Y 3/2), thick-bedded. Occasional articulate brachiopod fragments and burrow structures occur throughout. The core is strongly bioturbated near 1,366.7'.

INTERVAL	DESCRIPTION
1,374.8' - 1,380.6' (5.8')	Lime wackestone and lime mudstone, light olive gray (5Y 5/2), thick bedded. Thin convoluted olive gray (5Y 3/2) laminae occur at 1,377.3'. Fossil constituents including brachiopod and pelecypod shells, solitary horn corals, crinoid stems, and burrow structures are abundant throughout.
1,380.6' - 1,386.2' (5.6')	Lime wackestone, light olive gray (5Y 5/2) and olive gray (5Y 3/2), thin bedded. Convoluted, olive gray zones are present throughout. The lower 1/2 contains small (5 cm diam) chert nodules. Articulate brachiopod and pelecypod shells, crinoid stems, and other unidentifiable fragments are abundant in the upper 1/2 and common in the lower 1/2. Stylolites occur between 1,383.6' and 1,386.1'.

APPENDIX B

SYMBOLS, TERMS, AND ABBREVIATIONS USED IN FRACTURE LOGGING

EGSP OHIO #1 WELL - ASHTABULA COUNTY

Appendix B

1. CHARACTER: Specifically, the character of the fracture plane.

   (P): Planar
   (CP): Curviplanar

2. FRACTURE TYPE: These terms are used to classify the different types of fractures into genetic groups.

   (N): Natural

   Spl. Jt. (Simple Joint): One discrete fracture plane, no displacement.

   Cpd. Jt. (Compound Joint): Two or more parallel, closely spaced (approximately 1 cm or less) fracture planes, no displacement.

   Flt. (Fault): A shear fracture with demonstrable displacement indicated by displaced primary features or slickensides.

   Mcr. Flt. (Micro-Fault): A small-scale shear fracture, generally curviplanar; of the same order of size as the core diameter.

   (CI): Coring Induced

   PF (Petal Fracture): An oblique fracture, usually planar or slightly curviplanar, which originates at the core margin and terminates against bedding within the core.

   PFC (Petal-Centerline Fracture): A fracture originating as a petal fracture which curves down-core and bisects the core as a vertical planar fracture. The strike of the vertical fracture and the petal fracture is identical. The face of the vertical fracture is characterized by regularly spaced arrest lines, convex down-core and symmetrical about the core axis.

   DF (Disc Fracture): A subhorizontal fracture originating within the core and displaying hackle plumes radiating from the fracture origin to meet the core margin orthogonally.

TF (Torsional Fracture): A spiraling or irregular fracture developed when a couple is applied to the core.

DCS (Disc Fracture with Circular Slickensides): A feature induced by coupling with the inner and outer core barrels, causing core in the barrel to rotate against a stationary core stump.

KES (Knife Edge Spall): A fracture, typically conchoidal, formed by scribe knives cutting orientation grooves into the core. This fracture type can be used to determine the down-core direction and the relative age of induced fractures.

CBS (Core Bit Spall): A tiny conchoidal fracture caused by a diamond from the core bit plucking a chip off the edge of a preexisting fracture. When the face of the preexisting fracture is viewed with the core in normal position the spalls should appear along the right-hand margin. This fracture type is useful in inferring relative fracture chronology.

3. FRACTOGRAPHIC FEATURES:

Orig. (Fracture Origin): A discrete fracture surface irregularity from which hackles originate. Fractures may originate at the boundaries of fossils, concretions, preexisting fractures, etc.

Hkl. (Hackle): A linear marking on a fracture face, similar to a striation, which trends in the direction of fracture propagation. Hackles radiate away from the origin, are perpendicular to arrest lines, and will curve to meet preexisting surfaces orthogonally.

Fn. Hkl. Plm. (Fine Hackle Plume): A very fine, wispy plumose structure on an otherwise featureless fracture face.

Incl. Hkl. (Inclusion Hackle): A hackle trailing an inclusion or obstacle on the fracture plane.

Cs. Tw. Hkl. (Coarse Twist Hackle); A hackle composed of discrete steps generally appearing as a fringe near the edge of a fracture face.

Ar. Ln. (Arrest Line): A crescentic feature with a cusp-like profile which marks the still stand of the fracture front. Two types are noted:

Term. Ar. Ln.: Terminal Arrest Lines.
Int. Ar. Ln.: Intermediate Arrest Lines.

Hk. (Hook): The curving of a fracture plane to adjust to a change in the stress field orientation. Fractures hook to meet preexisting free surfaces orthogonally and in the vicinity of the neutral axis developed in bending.

4. TERMINATIONS: These terms are used to describe how a fracture terminates. The upper entry depicts the upper termination, the lower entry depicts the lower.

M: The fracture exits the margin of the core.

Ⓜ: A subhorizontal fracture that exits the margin of the core. This symbol is entered only once straddling the dividing line.

⟶: A fracture that terminates within the core as a dying hairline fracture.

 : The upper and lower extents of the fracture die out within the core. This symbol is drawn straddling the dividing line.

?: Missing or disrupted core prohibits observation of the mode of termination.

?/M: Same as above, but the fracture probably exits the core margin.

?/Ⓒ Same as above, but the fracture probably terminates within the core margin.

BDG: The fracture terminates along a conspicuous bedding plane indicating an abrupt change in lithology.

TAL: The fracture terminates as a terminal arrest line which is visible only on the fracture face.

(TAL): The fracture terminates in a terminal arrest line so that the fracture enters one side of the core but does not exit the other. This symbol is entered only once straddling the dividing line.

F22: This symbol is used when one fracture terminates against another (i.e., fracture 23 terminates against fracture 22).

APPENDIX C

FRACTURE LOGS

EGSP OHIO #4 WELL - ASHTABULA COUNTY

CORING RUN NO.(S) _____
(INDICATE BEGINNING & END)
CORING DATE: 8/79
LOG DATE: 10/79

EGSP STANDARD CORE FRACTURE LOGGING FORMAT

WELL: OHIO No. 4, ASHTABULA CO.

LOG CLASSIFICATION
☒ INDIVIDUALS ☐ INTERVALS
FRACTURE TYPE(S): coring induced & natural

NUMBER	DEPTH EXTENT	LENGTH	LITHOLOGY	TERMINATIONS	CHARACTER	STRIKE / DIP	INTERPRETATION	FRACTURE TYPE	MINERALIZATION	SLICKENSIDES	FRACTOGRAPHIC FEATURES	COMMENTS
1	509.2		Mdst, 5GY3/2		CP+P		cI	TF+DCS				Non-oriented core (core shaved by scribe knives).
2	509.8		A/A		CP+P		cI	TF+DCS				
3	510.1		A/A		CP		cI	TF				
4	510.3		Mdst, 5Y2/1		P		cI	DCS				
5	510.8		Mdst, 5GY3/2		P		cI	DCS				
6	512.5		A/A		CP+P		cI	TF+DCS				
7	514.3		A/A		P		cI	DCS				
8	514.7		Sl. mdst, 5Y3/2		CP+P		cI	TF+DCS				
9	515.3		Sl. mdst, 5GY3/2		CP+P		cI	TF+DCS				
10	516.2		Sl. mdst, 5Y3/2		CP+P		cI	TF+DCS				
11	516.5		A/A		P		cI	DCS				
12	518.0		Sl. mdst, 5Y2/1		P		cI	DCS				
13	518.7		Sl. mdst, 5GY3/2		CP+P		cI	TF+DCS				
14	524.7		A/A		CP+P		cI	TF+DCS				NON-ORIENTED CORE This interval
15	526.7		A/A		CP+P		cI	TF+DCS				
16	528.6		A/A		CP		cI	TF				
17	532.6		Sl. mdst, 5Y2/1		P		cI	DCS				
18	536.6		Sl. mdst, 5GY3/2		P		cI	DCS				
19	538.1		Sl. mdst, 5Y3/2		P		cI	DCS				
20	539.9		Sltst, 5Y4/1		P		cI	DCS				
21	540.4		Sl. mdst, 5Y2/1		P		cI	DCS				
22	541.7		Sl. mdst, 5GY3/2		P		cI	DCS				
23	542.0		Sl. mdst, 5Y3/2		P		cI	DCS				
24	544.6		A/A		P		cI	DCS				
25	547.4		Mdst, 5Y2/1		P		cI	DCS				
26	548.0		Sl. mdst, 5Y3/2		P		cI	DCS				
27	550.4		A/A		P		cI	DCS				

CORING RUN NO.(S) _____
(INDICATE BEGINNING & END)
CORING DATE: 8/79
LOG DATE: 10/79

EGSP STANDARD CORE FRACTURE LOGGING FORMAT

WELL: OHIO No.4, ASHTABULA CO.

LOG CLASSIFICATION
☒ INDIVIDUALS ☐ INTERVALS
FRACTURE TYPE(S): all

NUMBER	DEPTH EXTENT	LENGTH	LITHOLOGY	TERMINATIONS	CHARACTER	STRIKE / DIP	INTERPRETATION	FRACTURE TYPE	MINERALIZATION	SLICKENSIDES	FRACTOGRAPHIC FEATURES	COMMENTS
28	551.3		St. mdst. 5GY3/2		CP+P		cI	TF+DCS				
29	551.5		St. mdst, 5Y3/2		P		cI	DCS				
30	552.5		A/A		CP+P		cI	TF+DCS				
31	553.4		St. mdst. 5Y2/1		P		cI	DCS				
32	554.9		A/A		P		cI	DCS				
33	555.2		St. mdst, 5GY3/2		P		cI	DCS				
34	555.6		A/A		P		cI	DCS				
35	556.1		St. mdst, 5Y2/1		CP+P		cI	TF+DCS				
36	556.8		A/A		CP		cI	TF				
37	558.1		St. mdst, 5GY4/1		CP+P		cI	TF+DCS				NON-ORIENTED CORE This interval
38	558.9		St. mdst, 5Y3/2		CP+P		cI	TF+DCS				
39	559.0		St. mdst 5GY4/1		CP		cI	TF				
40	560.6		St. mdst. 5Y3/2		P		cI	DCS				
41	563.7		St. mdst. 5Y2/1		CP		cI	TF				
42	563.8		A/A		P	20	cI	PF				
43	563.9		St mdst. 5GY4/1		CP		cI	TF				
44	565.9		St. mdst. 5Y3/2		P		cI	DCS				
45	752.8		St. mdst, 5GY5/2		CP		cI	TF				
46	762.3		St. mdst. 5Y2/1		P		cI	DCS				
47	763.7		St. mdst. 5Y4/1		P	26	cI	PF				
48	764.7		St. mdst. 5Y2/1		P		cI	DCS				
49	785.5 / 785.9	0.4'	St. mdst. 5Y3/2		CP		cI	TF+PF			Cs. Tw. Hkl.	2 Petals, Spiraling ⇐ down-core
50	785.5 / 785.8	0.3'	A/A		CP		cI	TF+PF			A/A	A/A
51	820.4		A/A		P	N57E / 36NW	cI	PF				
52	820.9		A/A		CP		cI	TF				
53	855.0 / 855.1	0.1'	St. mdst, 5Y2/1		CP		cI	DF			Prominent hook to lower margin; Hkl. Plm.	
54	950.8		St. mdst, 5GY3/2		CP		cI	TF				

CORING RUN NO.(S) _____
(INDICATE BEGINNING & END)
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EGSP STANDARD CORE FRACTURE LOGGING FORMAT

WELL: OHIO No.4, ASHTABULA CO.

LOG CLASSIFICATION
☒ INDIVIDUALS ☐ INTERVALS
FRACTURE TYPE(S): all

NUMBER	DEPTH EXTENT	LENGTH	LITHOLOGY	TERMINATIONS	CHARACTER	STRIKE / DIP	INTERPRETATION	FRACTURE TYPE	MINERALIZATION	SLICKENSIDES	FRACTOGRAPHIC FEATURES	COMMENTS
55	951.5		St. mdst. 5GY3/2		P		cI	DCS				
56	1069.1		A/A		P		cI	DCS				
57	1108.1 / 1108.4	0.3'	A/A		CP		cI	TF+PF			Cs. Tw. Hkl.	6 Petals, spiraling ↶ down-core.
58	1137.2 / 1137.8	0.6'	A/A		CP		cI	TF+PF			Cs. Tw. Hkl.	5 Petals, spiraling ↶ down-core. One petal is dominant. Small lime concretion isolated in fracture fragments.
59	1137.8 / 1138.2	0.4'	A/A		CP		cI	TF+PF			Cs. Tw. Hkl., Hkl. Plm.	4 Petals, spiraling ↶ down-core.
60	1138.4 / 1138.8	0.4'	A/A		CP		cI	TF+PF			Hkl. Plm.	2 Petals, spiraling ↶ down-core; petals are isolated on one side of core.
61	1153.7 / 1154.1	0.4'	Mdst. 10Y4/2		CP		cI	TF+PF			Cs. Tw. Hkl.	7 Petals, spiraling ↶ down-core; petals are long and slender
62	1154.1 / 1154.5	0.4'	A/A		CP		cI	TF+PF			Cs. Tw. Hkl.	6 Petals, spiraling ↶ down-core.
63	1154.5 / 1154.9	0.4'	A/A		CP		cI	TF				Rubble; multiple torsional fractures.
64	1155.0		A/A		CP		N	MCR.FLT.		PRESENT		
65	1155.0 / 1155.7	0.7'	A/A		CP		cI	TF+PF			Cs. Tw. Hkl.	2 Petals, one long and one short, spiraling slightly ↶ down-core.
66	1157.3		A/A with vitronite ptg.		P		N	MCR.FLT.		N40E / 18SE		
67	1157.3 / 1157.6	0.3'	A/A with vitronite ptg.		CP		cI	TF+PF			Hkl. Plm. + Ar. Lm. on 1 Petal	2 Petals, one long and one short; long petal shows slight spiral ↶ down-core. Short petal has sinistral Ar. Lm.
68	1186.8 / 1186.9	<0.1'	St. mdst. 5Y2/1		P	N42W / 47NE	cI	PF				
69	1187.8 / 1187.9	<0.1'	A/A		P	N59E / 24SE	cI	PF?				
70	1193.4 / 1193.5	<0.1'	A/A	↗	P	N17E / VERT	N?	CPD. JT.?	None		Closed hairline fractures	No. 70 includes 2 parallel, rough planar fractures.
71	1193.5 / 1193.6	<0.1'	A/A		P	N86E / 34S	cI	PF				
72	1194.3 / 1194.4	0.1'	St. mdst. 5Y5/2 + 5Y2/1		P	N81E / 45SE	cI	PF				
73	1194.3 / 1194.4	<0.1'	A/A		P	N63E / 60NW	cI	PF				
74	1195.9		A/A Bdg distorted by concretion		CP		N	MCR.FLT.		PRESENT		Compaction feature associated with concretion.
75	1197.6 / 1197.9	0.3'	Lime concretion with septarian cracks		CP		cI	DF			Prominent hook to margin.	Fracture is isolated within concretion.
76	1200.9 / 1201.0	0.1'	St. mdst. 5Y2/1		P	N2E / 55E	cI	PF				
77	1208.9 / 1209.0	<0.1'	Mdst. 10Y4/2		CP		cI	TF				2 small petals.
78	1309.0 / 1309.2	0.2'	Mdst. 5Y3/2		CP		cI	TF+PF			Cs. Tw. Hkl., Hkl. Plm.	3 Petals; Spiraling not apparent. Fracture occurs within isolated interval of shaved core.
79	1325.1 / 1325.2	<0.1'	A/A		P	N55W / 37SW	cI	PF				
80	1347.7 / 1347.8	<0.1'	Calc. mdst. 5Y2/1		CP		cI	DF			Prominent hook to margin on E side.	
81	1372.2 / 1372.3	0.1'	Lime mdst. 5Y3/2		CP		cI	DF			Prominent hook to margin on NE side.	

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EGSP STANDARD CORE FRACTURE LOGGING FORMAT

WELL: OHIO No.4, ASHTABULA CO.

LOG CLASSIFICATION
☒ INDIVIDUALS ☐ INTERVALS
FRACTURE TYPE(S): all

NUMBER	DEPTH EXTENT	LENGTH	LITHOLOGY	TERMINATIONS	CHARACTER	STRIKE / DIP	INTERPRETATION	FRACTURE TYPE	MINERALIZATION	SLICKENSIDES	FRACTOGRAPHIC FEATURES	COMMENTS
82	1373.4		Lime mdst, 5Y3/2		CP		cI	DF	Hea		Hooks to margin on both N and S sides.	
83	1374.0 1374.1	<0.1'	A/A		CP		cI	DF			Prominent hook to margin on NE side.	
84	1374.6 1374.8	0.2'	A/A		CP		cI	TF				

EASTERN GAS SHALES PROJECT

DISC FRACTURE FREQUENCY LOG

OHIO #4 - ASHTABULA COUNTY

Feet	Frequency Per Foot
510	6.5
515	7.2
520	6.8
525	6.6
530	8.2
535	4.6
540	2.6
545	3.4
550	4.4
555	3.4
560	7.6
565	4.4
565.9	6.7
565.9 to 746.0	PLUG DRILLED
750	2.3
755	2.0
760	2.2
765	1.6
770	2.2
775	4.2
780	4.6
785	4.2
790	3.4
795	3.6
800	4.0
805	3.6
810	4.4
815	5.2
820	4.0
825	3.8
826.2	4.0
826.2 to 836.0	PRESSURE CORED
840	1.8
845	2.4
850	1.2
855	1.4
860	1.2
865	1.6
870	1.8
875	1.6
875.8	3.8
875.8 to 949.0	PLUG DRILLED
950	2.0
955	1.8
960	2.6
965	3.0
970	2.8
975	2.4
980	1.8
985	2.4
988.6	3.6
988.6 to 1,069.0	PLUG DRILLED
1,070	1.0
1,075	1.8
1,080	1.6
1,085	2.4
1,090	1.8
1,095	2.0
1,100	2.2
1,105	2.0
1,108.4	3.0
1,108.4 to 1,119.4	PLUG DRILLED
1,120	2.0
1,125	1.6
1,130	1.6
1,135	1.6
1,140	1.0
1,145	1.6
1,150	1.2
1,155	1.4
1,159.3	2.1
1,159.3 to 1,169.1	PRESSURE CORED
1,170	5.0
1,175	2.0
1,180	2.4
1,185	1.6
1,190	2.4
1,195	1.6
1,200	1.4
1,205	1.6
1,209.2	3.0
1,209.2 to 1,309.1	PLUG DRILLED
1,310	1.0
1,315	2.6
1,320	6.0
1,325	5.0
1,330	5.0
1,335	5.2
1,340	4.4
1,345	2.0
1,350	2.4
1,355	3.0
1,360	2.6
1,365	1.4
1,370	0.8
1,375	0.6
1,380	1.6
1,385	1.0
1,386.2	1.3

BIBLIOGRAPHY

Bennison, A. P., 1978, Geological highway map of the Great Lakes Region: Map No. 11, AAPG, Tulsa, Okalahoma.

Dunham, R. J., 1962, Classification of Carbonate Rocks According to Depositional Texture: in W. E. Ham (Ed.), Classification of Carbonate Rocks, pp. 108-21, AAPG, Tulsa, Oklahoma.

Evans, M., 1979, Fracture Density and Orientation Study of the Reel Energy #3 D/K core from Mason County, West Virginia: (Unpublished Contract Report, U. S. Department of Energy Contract No. DE-AC21-76MC05194, Morgantown, West Virginia).

Geological Society of America, 1948, Rock Color Chart: Geological Society of America, Boulder, Colorado.

Goldthwait, R. P., et al, 1965, Pleistocene Deposits of the Erie Lobe: in H. E. Wright, Jr. and D. G. Frey (Eds.), The Quaternary of the United States, pp. 85-98, VII INQUA Congress, Boulder, Colorado.

Kulander, B. R., et al, 1977, Fractographic Logging for Determination of Precore and Core-Induced Fractures, Nicholas Combs No. 7239 Well, Hazard, Kentucky: U. S. Department of Energy, MERC/CR-7713, Morgantown, West Virginia.

Piotrowski, R. G., et al, 1978, Stratigraphy and Gas Occurrence in the Devonian Organic Rich Shales of Pennsylvania: in G. L. Schoot, et al, (Ed.), Proceedings First Eastern Gas Shales Symposium, p. 127, U. S. Department of Energy, Morgantown, West Virginia.

Ragan, D. M., 1973, Structural Geology, An Introduction to Geometrical Techniques: 2nd ed., John Wiley & Sons, New York, New York.

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U. S. DEPARTMENT OF ENERGY

MORGANTOWN ENERGY TECHNOLOGY CENTER

EASTERN GAS SHALES PROJECT

EGSP OH - 4, ASHTABULA CO.

WELL: OHIO #4

A.P.I. NO.: 34-007-21087

DRILLING COMPLETED: AUGUST 12, 1979

DRAWN: NOVEMBER, 1979