

CLIFFS MINERALS, INC.
EASTERN GAS SHALES PROJECT
PENNSYLVANIA #4, INDIANA COUNTY

PHASE II REPORT
PRELIMINARY LABORATORY RESULTS
JANUARY 1981

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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 techniques 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.

During November of 1979 the Department of Energy and Gruy Federal, Inc. funded the drilling/coring of the Glenn McCall #5 well, hereafter referred to as EGSP-Pennsylvania #4. This report summarizes the procedures and results of core characterization work performed at the Eastern Gas Shales Project's Core Laboratory on core retrieved from the Indiana County well, designated EGSP-Pennsylvania #4.

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-Pennsylvania #4 well. Data were acquired from several sources for analysis. At the well site, a suite of wet and dry hole geophysical logs was run, which included the following:

Geophysical Log Suite

Dual Induction	Gamma Ray
Borehole Compensated Sonic	Caliper
Borehole Compensated Density	Temperature
Compensated Neutron	Sibilation
Spherically Focused Log	Formation Density

At the EGSP Core Laboratory, the EGSP-Pennsylvania #4 core was laid out, washed, measured, oriented, and photographed prior to description and sampling. Characterization work performed included 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
- ° Microfracture Trends

3.0 LABORATORY PROCEDURES

3.1 Review of Geophysical Logs:

One of the first laboratory procedures performed on the EGSP-Pennsylvania #4 core was the examination of the geophysical logs and comparison of them 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 were, 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 to assure that these features will receive adequate recognition.

3.2 Photographic Log:

After the EGSP-Pennsylvania #4 core had been laid out, washed, and oriented on a group of laboratory tables, 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 Log:

After detailed visual examination, the EGSP-Pennsylvania #4 core was described in intervals which vary from about 5 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 laminations, 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 cement.

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

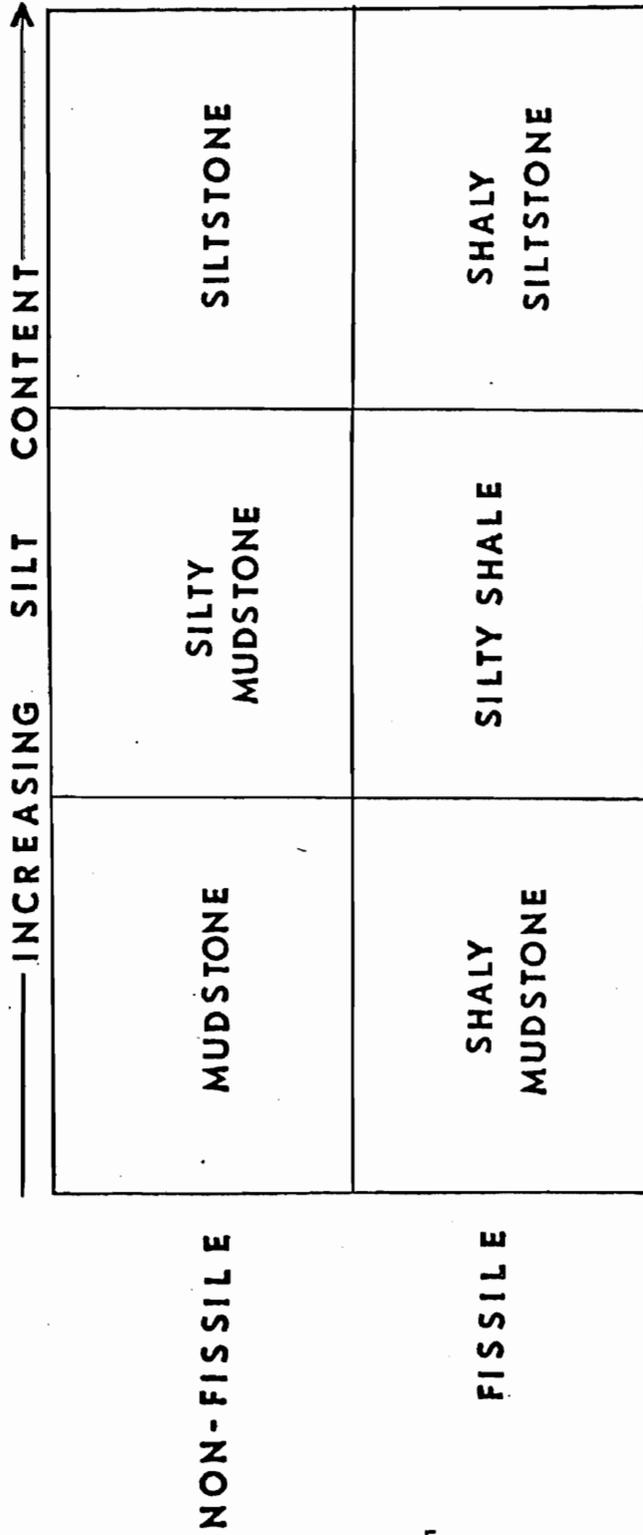
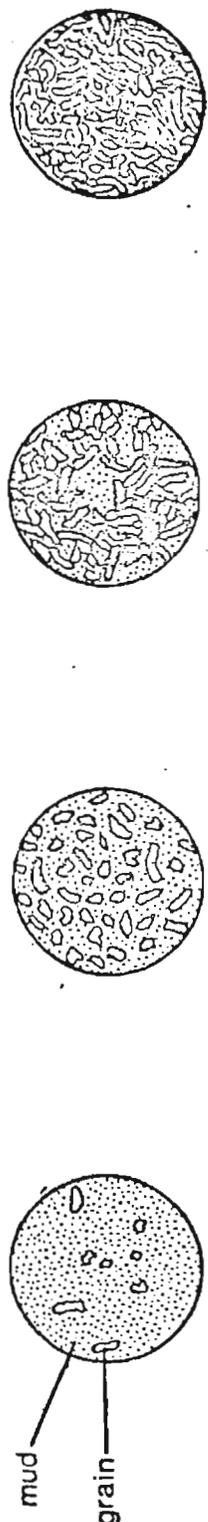


FIGURE 1

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



BIOLOGICALLY CEMENTED GRAINS: Boundstone
 NO RECOGNIZABLE TEXTURE: Crystalline Limestone

FIGURE 2

TEXTURAL CLASSIFICATION OF LIMESTONES (AFTER DUNHAM, 1962)

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 Pennsylvania #4 core was compiled to provide a relative measure of the distribution of light and dark shales throughout 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 dark gray (N3) were grouped together for each segment to determine the percentage of dark shale, and colors with values lighter than or equal to dark gray (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.

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 of vital interest for 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 fractures orthogonally.

Coring- and handling-induced fractures 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 effect of problems encountered during drilling. The frequency of disc fractures (generally the most prevalent and least diagnostic type of induced fracture) was 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, questionable accuracy, and nonreproducible results. Subsequent methods of hardness testing are being considered.

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-Pennsylvania #4 core:

1. Stratigraphic Column
2. Lithology
3. Color Histogram
4. Gamma Ray Log
5. Compensated Bulk Density Log
6. Temperature Log
7. Sibilation 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 5.0. 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-Pennsylvania #4 core has been concluded, a final (Phase III) report will be issued

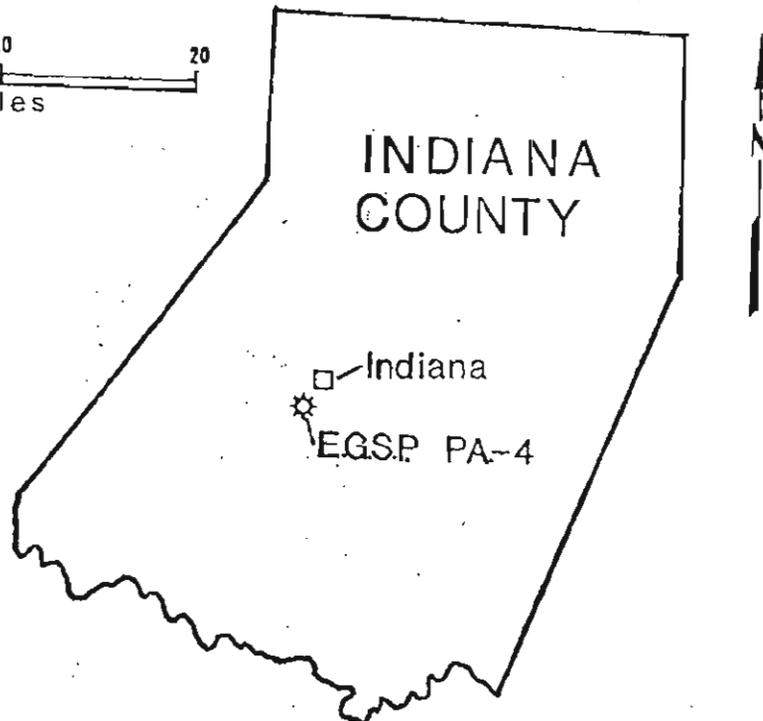
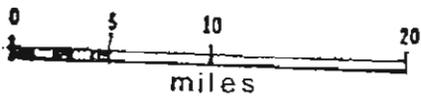
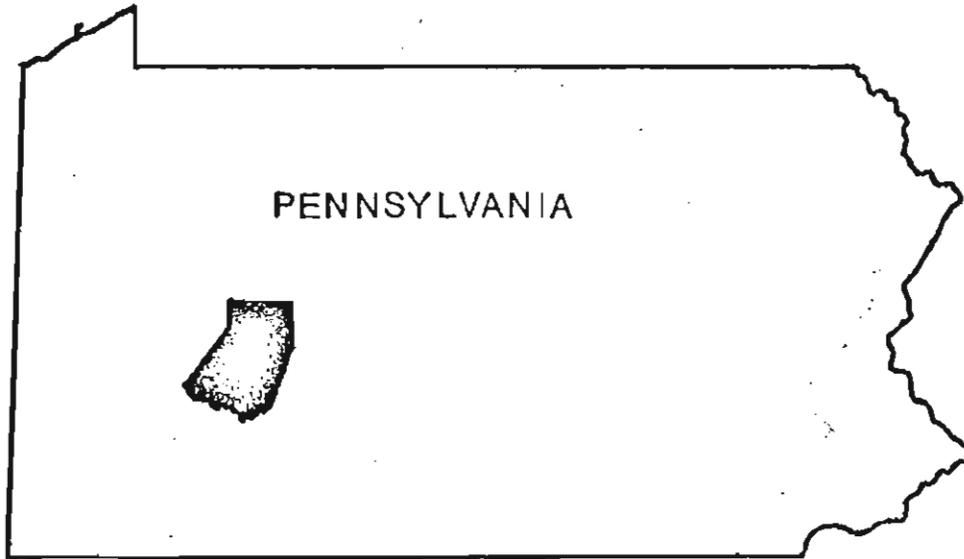


FIGURE 3

LOCATION OF THE PENNSYLVANIA #4 WELL, INDIANA COUNTY

containing an analysis of those data together with a summary of the information already compiled at the 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 EGSP-Pennsylvania #4 core will be transferred to the Pennsylvania Geological Survey.

5.0 DISCUSSION OF RESULTS

5.1 General:

The area of interest (Figure 3) is located in central Indiana County, three miles southwest of Indiana, Pennsylvania. The Crete, Cherry Hill, Jacksonville, Nolo, and Strongstown fields, with discoveries dating back to 1956, lie within Indiana County, Pennsylvania. The Crete gas field is the closest gas reservoir, and is southwest of the town of Indiana (Gruy Federal, 1979 and Douglas G. Patchen, et al., 1978). The proposed production in the Pennsylvania #4 well was from the Bradford Sands, which are stratigraphically higher than the Devonian Shales. The DOE bore the cost of deepening the well to obtain stratigraphic and geophysical information from the Devonian Shales (Gruy Federal, 1979).

The EGSP-Pennsylvania #4 well was drilled/cored with a standard-size oil-field rotary rig. A sixty-foot core barrel was used; the drilling medium was KCl mud. Numerous problems were encountered during the EGSP-Pennsylvania #4 coring operation. Stratigraphic contacts were approximately 230 feet lower than expected, leading to a deeper bottom hole depth. Subsequent pressures, temperatures, and a lack of

adequate fluid circulation caused the plastic liner to jam on several occasions and to even collapse. At ~8,000 feet from surface, the core barrel jammed and momentarily could not be moved up or down. After numerous attempts to free the barrel, it was unjammed and coring resumed. Further coring and another jam resulted in the loss of the core barrel and the camera at the bottom of the hole. After the monel collar broke free and was retrieved, the lower ~150 feet of the well collapsed. Consequently, geophysical logs are not available for this interval.

5.2 Geologic Setting:

The surface topography at the Indiana County well site consists of rolling hills and isolated knobs dissected by stream valleys. The well site lies on the western edge of the Valley and Ridge Province of the Appalachian Basin. Outcrops consist of the Conemaugh, Allegheny, and Pottsville shales and sandstones, all of which are Pennsylvanian in age. The Allegheny Structural Front lies approximately 35 miles to the east and trends N40°E to N50°E. The Chestnut Ridge Anticline runs through central Indiana County (Gruy Federal, 1979).

5.3 Stratigraphy:

A total of 891 feet of core was recovered from the interval 7,098 to ~8,009 feet. Twenty of the lower 65 feet could not be recovered due to repeated jamming of the core barrel and rubblization of the contained core. The core within this interval is extremely fissile and further hindered recovery. Core point was picked at 7,098 feet in the Cashaqua Shale Member of the Sonyea Formation and coring was terminated in the Marcellus Shale (?) at ~8,009 feet. Formation thicknesses

encountered in the cored interval are summarized in Table 1, which is followed by a summary description of each formation.

TABLE 1
FORMATION THICKNESSES

<u>Formation</u>	<u>Depths</u>	<u>Formation Thickness</u>	<u>Depths Cored</u>
Sonyea Formation:			
Cashaqua Shale Member	6,906'-7,240'	334'	7,098'-7,240'
Middlesex Shale Member	7,240'-7,350'	110'	7,240'-7,350'
Genesee Formation:			
Undifferentiated	7,350'-7,548'	198'	7,350'-7,548'
Geneseo Shale Member	7,548'-7,574'	26'	7,548'-7,574'
Hamilton Group:			
Tully Limestone	7,574'-7,616'	42'	7,574'-7,616'
Mahantango Shale	7,616'-7,675'	59'	7,616'-7,675'
Marcellus Shale	7,675'-T.D.	---	7,675'-8,009'

Sonyea Formation

Cashaqua Shale Member

Approximately 142 feet (7,098 to 7,240 ft.) of the Cashaqua Shale Member is present in the upper portion of the EGSP-Pennsylvania #4 core. The cored portion consists of thinly laminated to thin bedded silty mudstones, mudstones, and sparse siltstones. These lithologies range in color from medium dark gray (N4) and dark gray (N3), to olive gray (5Y 4/1). The interval is predominantly composed of alternating laminae and bands, up to 2.0 feet in thickness. Pyrite is common in the Cashaqua Shale, especially in the lower 1/2, and occurs primarily as mineralization on burrow structures, and pelecypod and nautiloid casts

(<30 mm diam.). Thin laminae of disseminated pyrite grains and mineralized spore bodies are also present. Mud filled burrow structures, both horizontal and vertical, occur throughout the interval. Load casts and primary current lineations are present in the lower 65 feet, and exhibit a bearing of $\sim N62^{\circ}E$. Mud filled brachiopod (both articulate and inarticulate), cephalopod, and pelecypod casts (up to 35 mm diam.) are found within the core. A few thin zones (<1.0 ft. thick) between 7,168.0 and 7,193.0 feet are weakly calcareous.

The contact between the Cashaqua Shale and the underlying Middlesex Shale is gradational in the core. It is distinguished on the gamma ray geophysical log as the first in a series of slightly higher peaks which range from 170 API units to 230 API units.

Middlesex Shale Member

Approximately 110 feet (7,240 to 7,350 ft.) of the Middlesex Shale Member is present in the EGSP-Pennsylvania #4 core. The cored interval consists predominantly of thinly to thickly laminated silty shales and silty mudstones, with sparse siltstones and mudstones also present. Colors range from black (N1) and grayish black (N2) to olive gray (5Y 4/1). Pyrite is abundant throughout the interval, occurring as lenses (<40 mm in length), small nodules (<30 mm diam.) and laminae of disseminated grains. Pyrite is also present as coatings on spore bodies in the upper 15 feet. Two large vitrified bark fragments (20 mm thick by 90 mm diam.) with preserved cellular structure (telenite?), occur between 7,266 and 7,322 feet. The upper 15 feet contains a few mud filled pelecypod casts. Well preserved rill marks occur at 7,333.2

feet. Thin zones, 1.0 foot thick, which occur throughout the interval are weakly calcareous.

The contact between the Marcellus Shale Member and the underlying Geneseo Shale Member is gradational in the core. On the geophysical logs it is designated by a decrease in gamma radiation from 230 API units to a range of 130 to 200 API units.

Genesee Formation

Approximately 224 feet (7,350 to 7,574 ft.) of the Genesee Formation is present in the EGSP-Pennsylvania #4 core. It can be divided into two units with the use of the geophysical logs: an undifferentiated portion and the Geneseo Shale Member. The undifferentiated portion (7,350 to 7,548 ft.) can be identified by its relatively flat gamma radiation curve (120 to 200 API units). The Geneseo Shale Member (7,548 to 7,574 ft.) has fluctuating gamma radiation and bulk density curves (90 to over 400 API units and 2.10 to 2.75 g/cc, respectively), and probably correlates with the Burkett Shale Member of the Harrel Formation (Piotrowski and Krajewski, 1977).

The upper interval, 7,350 to 7,548 feet, contains silty mudstones, mudstones, and numerous siltstone concretions throughout. All rock types are thinly laminated to thin bedded, and vary in fissility. Colors range from grayish black (N2) and black (N1) to dark gray (N3). Also, the aforementioned concretions are light gray (N7) to olive gray (5Y 4/1) in color. Numerous mud filled fossil casts, including inarticulate and articulate brachiopods (<5 mm diam.), cephalopods (<15 mm diam.), and pelecypods (<40 mm diam.) occur within the interval. Both

mud filled and pyrite mineralized horizontal and vertical burrow structures (<40 mm by 8 mm diam.) are present. Pyrite also occurs as nodules (<25 mm by 15 mm), lenses (<50 mm by 10 mm), and laminae of disseminated grains. Primary current lineation marks such as load casts and sole marks are common. Two open (10 mm), near vertical, calcite and dolomite mineralized fractures, striking N60°W and N12°E, occur between 7,516 and 7,525 feet. Thin zones throughout the interval are weakly to moderately calcareous.

Geneseo Shale Member

The Geneseo Shale Member (7,548 to 7,574 ft.) consists of silty mudstones and silty shales. The core is grayish black (N2), dark gray (N3), and medium dark gray (N4) in color and is thinly laminated to thin bedded. Mud filled cephalopod and pelecypod shell casts, as well as burrow structures, are present within this unit. Thin zones within the silty shales are weakly calcareous.

The contact between the Geneseo Shale Member and the underlying Tully Limestone is distinct in both the core and on the gamma radiation and bulk density geophysical logs. In the core, a thin marker bed called the Leicester Pyrite (John Roen, personal communication) occurs at the base of the Geneseo Shale. The Leicester Pyrite is <1.0 foot thick and occurs at 7,574 feet. It consists of grayish black (N2) silty mudstones in the upper 1/3, a highly burrowed medium dark gray (N4) silty mudstone in the middle 1/3, and a medium dark gray packstone in the lower 1/3. These burrows are heavily mineralized with pyrite, are both vertical and horizontal, and are up to 3 mm in diameter. This feature rests unconformably on the Tully Limestone (John Roen, personal

communication). Across this contact, geophysical logs display a characteristic decrease in gamma radiation from over 400 to 72 API units and an increase in the bulk density from 2.50 to 2.65 g/cc.

Hamilton Group

Tully Limestone

Approximately 42 feet (7,574 to 7,616 ft.) of the Tully Limestone is present in the EGSP-Pennsylvania #4 core. It consists of thinly laminated to thin bedded, medium dark gray (N4) and medium gray (N5) calcareous mudstones and packstones. Fossils, including unidentified calcified shell fragments and crinoid columnals, up to 5 mm in diameter, are abundant. Pyrite occurs as mineralization on horizontal and vertical burrows (<4 mm diam.) and as nodules (5 mm diam.). Calcite mineralized burrows and laminae (flanking concretions) are also present within the interval. Numerous calcareous concretions and concretionary bands, up to 1.5-foot thick, are found throughout.

The contact between the Tully Limestone and the underlying Mahantango Shale Member is easily distinguished in the core and on the geophysical logs. The contact in the core is marked by an abrupt change in lithology and color, from a medium gray (N5) calcareous lime mudstone (Tully) to a grayish black (N2) fissile silty shale (Mahantango). On the gamma ray geophysical log, an increase is noted from 120 to approximately 230 API units. A decrease from 2.75 to 1.85 g/cc is present on the bulk density log.

Mahantango Shale

Approximately 59 feet (7,616 to 7,675 ft.) of the Mahantango Shale is present in the EGSP-Pennsylvania #4 core. It consists of dark gray (N3) and grayish black (N2) silty shales and silty mudstones. It is thinly to thickly laminated and varies slightly in fissility. Several mud filled articulate and inarticulate shell casts are present throughout the interval. These include both Lingula sp. (? , <4 mm diam.) and Orbiculoidea sp. (? , <10 mm diam.). Pyrite occurs as small nodules (<3 mm diam.), mineralization on burrow structures (<3 mm diam.) and as laminae of disseminated grains. The interval is weakly calcareous between 7,645 and 7,659 feet.

The contact between the Mahantango Shale and the underlying Marcellus Shale is gradational within the core; however, it is distinguishable on the geophysical logs. It is characterized by an increase in gamma radiation from 200 to 350 API units. On the bulk density log, the density decreases from 2.70 to 1.50 g/cc over a 16.0 foot interval.

Marcellus Shale

The upper contact of the Marcellus Shale, as picked from the geophysical logs, is present at 7,675 feet; the lower contact is undetermined due to problems encountered during coring. Consequently, the geophysical logs were run down only to 7,850 feet as requested by Gruy Federal. This was done to prevent getting stuck on the fishing tools still in the hole. Also, due to problems in coring, only 314 feet of the 334 feet of core cut were recovered. Core depths within the Marcellus are uncertain due to numerous rubblized zones. The core retrieved consists of dark gray (N3), grayish black (N2), and medium dark gray

(N4) silty mudstones and silty shales. The interval is thinly laminated to thin bedded and fissility varies throughout. The core is devoid of fossils except for a few mud filled pelecypod casts (<5 mm diam.) and unidentified shell fragments. Pyrite is abundant, occurring as mineralization on both horizontal and vertical burrow structures (4 mm diam.), small nodules (<5 mm diam.) and laminae of disseminated grains and crystals (<1 mm square). Several calcite and mud filled burrow structures also occur throughout. The core contains numerous medium light gray (N6) and light gray (N7) calcareous siltstone and silty mudstone concretions (<0.3 ft. diam.). The interval is weakly calcareous in zones.

Although the contact between the Marcellus Shale and the underlying Onondaga Limestone was not observed in the core, the lower 12 feet of the core does contain characteristic calcareous siltstone concretions, pyrite mineralized burrows, and sparse calcite replaced shell fragments. These features are indicative of a transitional zone between the Marcellus and Onondaga. Any estimate on the depth of this contact, however, is purely speculation.

5.4 Fracture Analysis:

Both natural- and coring-induced fractures are present within the core and 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. One-hundred sixty-eight natural fractures (76 simple joints, 33 compound joints, 54 faults, and 5 microfaults) are present in the core. The distribution of these fractures throughout the cored intervals is shown in Table 2.

TABLE 2
DISTRIBUTION OF NATURAL FRACTURES

<u>Formation</u>	<u>Depths Cored</u>	<u>Core Length</u>	<u>Number of Fractures</u>	<u>Fractures Per Foot</u>
Sonyea Formation:				
Cashaqua Shale Member	7,098'-7,240'	142'	9	0.06
Middlesex Shale Member	7,240'-7,350'	110'	27	0.24
Genesee Formation:				
Undifferentiated	7,350'-7,548'	198'	64	0.32
Genesee Shale Member	7,548'-7,574'	26'	18	0.69
Hamilton Group:				
Tully Limestone	7,574'-7,616'	42'	0	0.00
Mahantango Shale	7,616'-7,675'	59'	5	0.08
Marcellus Shale	7,675'-8,009'	334'	45	0.13

All natural fractures in the EGSP-Pennsylvania #4 core were analyzed to identify common structural trends. Figures 4 and 5 are graphic representations of the data plotted in polar form on a Schmidt (Equal Area) stereonet. The data have been contoured to determine locations of the maximum pole density using the method described by Ragan (1968). Figure 6 is a graphic representation of the bearing and plunge of linear slickenlines plotted on a Schmidt (Equal Area) stereonet and contoured to determine locations of maximum point density.

Two natural joint trends are present throughout the core. The major trend strikes from N42°W to N62°W, with a concentration at N55°W. The dips range from 75° to 90° to the northeast. The minor trend exhibits varying strike directions, but the fractures commonly have near-horizontal dips.

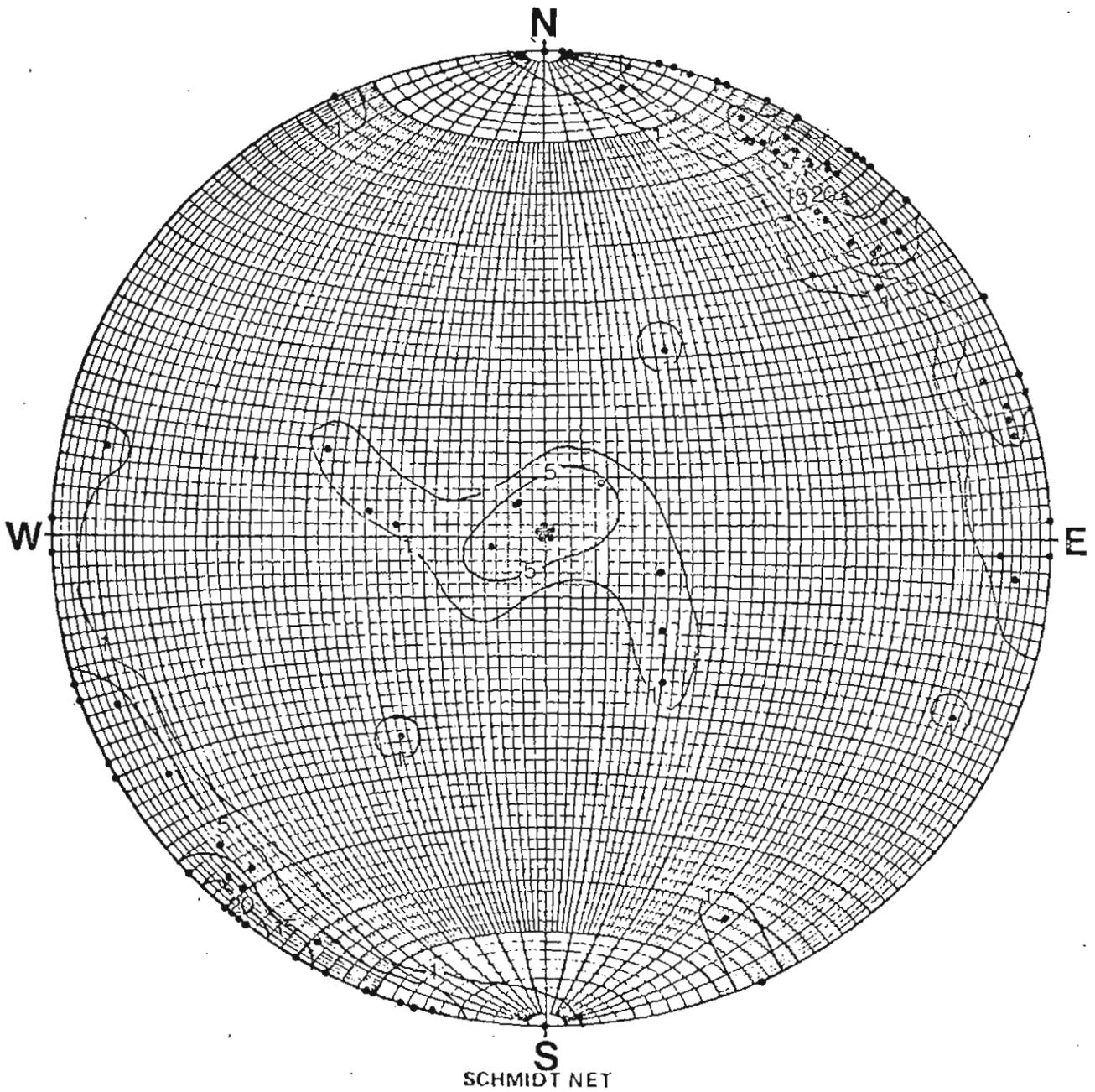


FIGURE 4

CONTOURED DIAGRAM OF POLES TO JOINTS

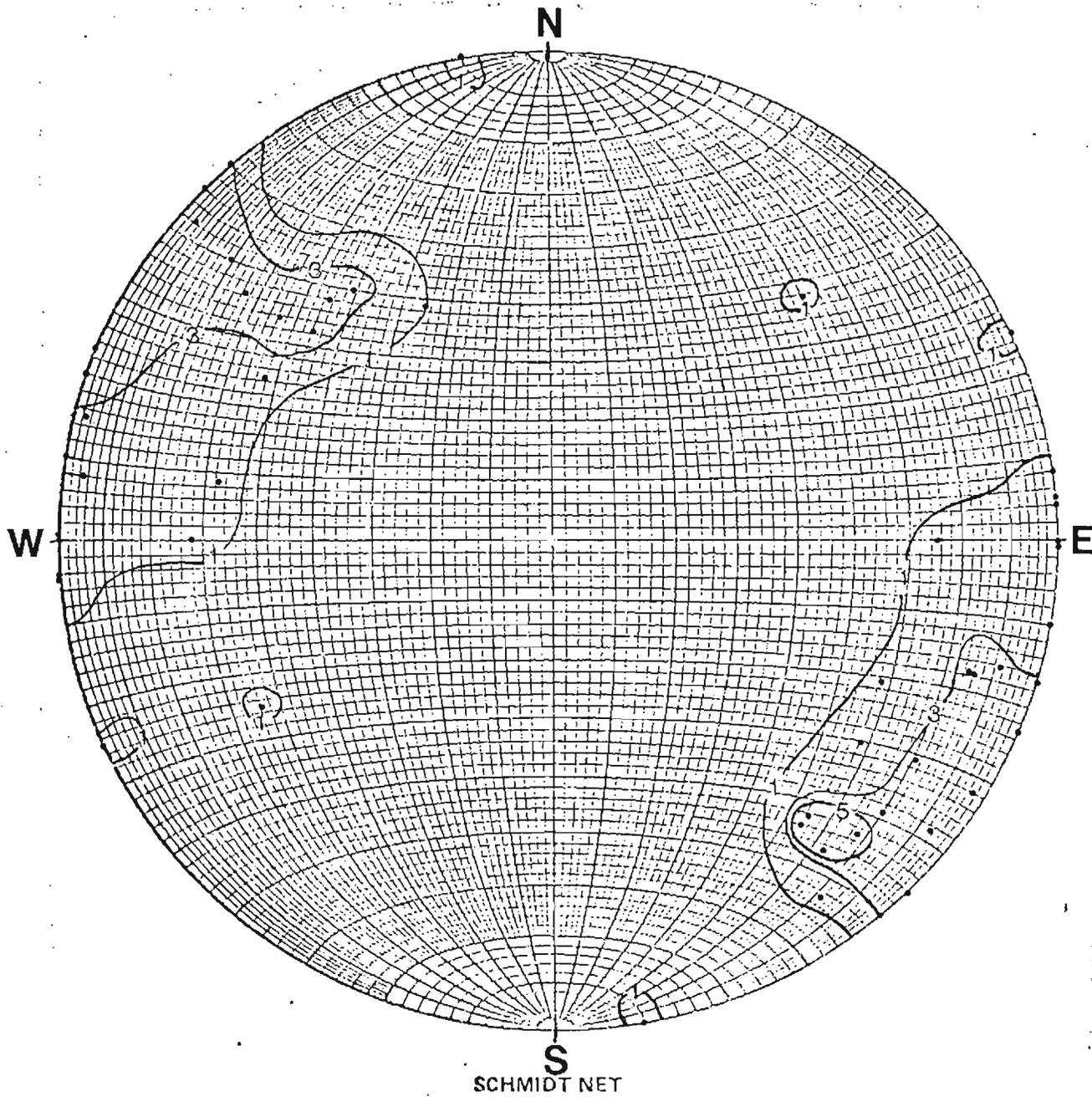


FIGURE 6

CONTOURED DIAGRAM DISPLAYING THE BEARING AND PLUNGE OF SLICKENLINES

The fault planes present in the Pennsylvania #4 core are predominantly horizontal, with a small concentration at N40°E, 20°-35°SE. Slickenlines, which are measureable on 65% of the faults and microfaults, are concentrated at 24°, S42°E, and range from 0° to 40° at S36°E to N80°E.

These trends reflect the general orientation of fracture sets within the core. Because of the intensely rubblized zones, which hampered core and fracture orientation, some of the data are questionable. The fractures range in length from 0.1 to 5.6 feet, and most contain pyrite or calcite and pyrite mineralization. Two of the most notable fractures, occurring between 7,516.0 and 7,524.0 feet, are heavily calcite and dolomite mineralized (~10 mm thick) and are offset by ~3 mm.

The occurrence and type of natural fractures contained within each formation were also analyzed. Criteria examined include: location of fracture concentrations or conversely, the lack of fractures within the stratigraphic unit and any predominance of fracture strike or slickenline trends.

Cashaqua Shale Member

The Cashaqua Shale contains nine natural fractures. Of these, six are simple joints, two are compound joints and one is a fault. All joints are calcite or calcite and pyrite mineralized and strike between N50°W and N60°W, dipping from 80° to 85° to the southwest. The fault plane orientation is N36°E, 18°SE, with slickenlines plunging 16° in the direction S58°E. All the natural fractures are planar and ~2.0 feet in length. The strike and frequency of natural fractures and the bearing

and frequency of their associated slickenlines are presented in Figures 7 and 8, respectively.

Middlesex Shale Member

The Middlesex Shale contains twenty-seven natural fractures. Of these, sixteen are compound joints, and four are faults. All of the joints are calcite or calcite and pyrite mineralized. The majority of the fractures (16) strike between $N0^{\circ}W$ and $N60^{\circ}W$, with a concentration between $N50^{\circ}W$ and $N60^{\circ}W$. All faults are within 5° of horizontal and are slickensided. Three of the four faults are present between 7,313.0 and 7,325.2 feet, and have slickenlines which plunge from 0° to 5° , and bear between $N80^{\circ}W$ and $N85^{\circ}W$. A single horizontal fault at 7,259.1 feet exhibits movement in the direction $N65^{\circ}E$. The strike and frequency of all natural fractures and the bearing and plunge of the associated slickenlines are presented in rosette form in Figures 9 and 10, respectively.

Geneseo Shale Member

The Geneseo Shale contains eighty-two natural fractures, which include: thirty-two simple joints, fifteen compound joints, thirty-three faults, and two microfaults. The majority of the joints are calcite mineralized and strike between $N50^{\circ}W$ and $N60^{\circ}W$. Minor trends strike from $N40^{\circ}W$ to $N50^{\circ}W$, $N0^{\circ}E$ to $N10^{\circ}E$, and $N30^{\circ}E$ to $N40^{\circ}E$. Another trend, shared by both the joints and faults, is horizontal, with no measureable strike.

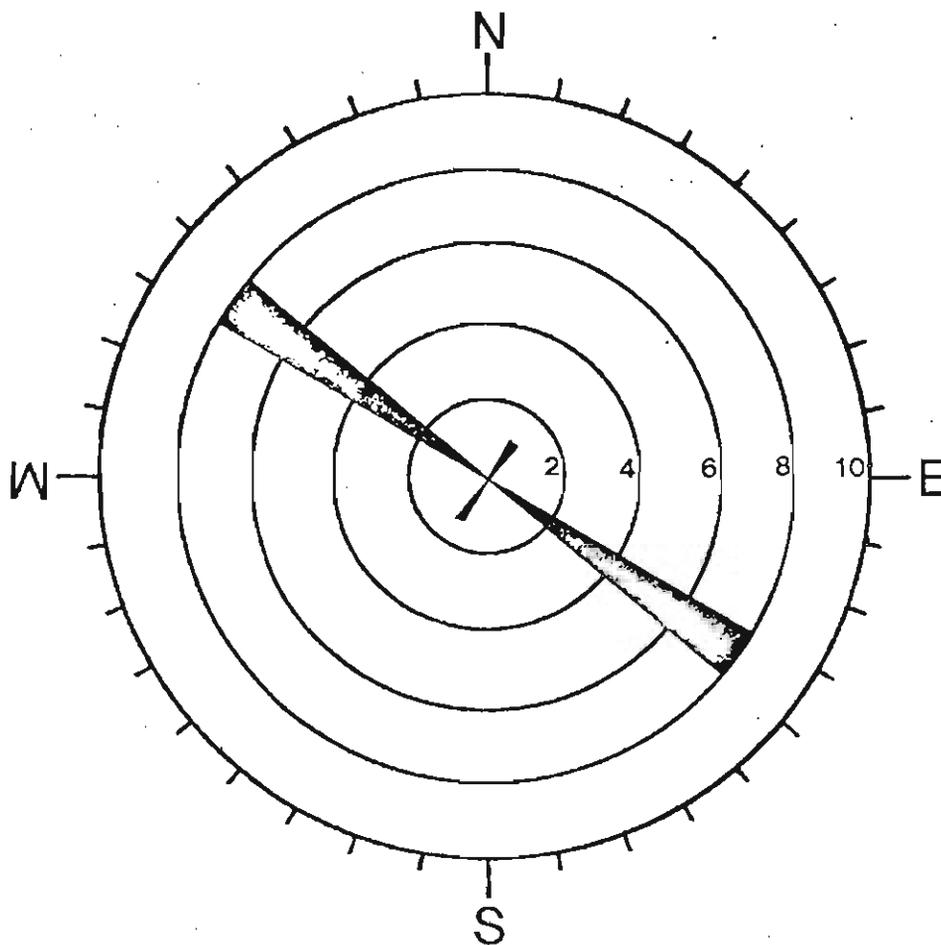


FIGURE 7

ORIENTATION AND FREQUENCY OF NATURAL FRACTURES IN THE CASHAQUA SHALE

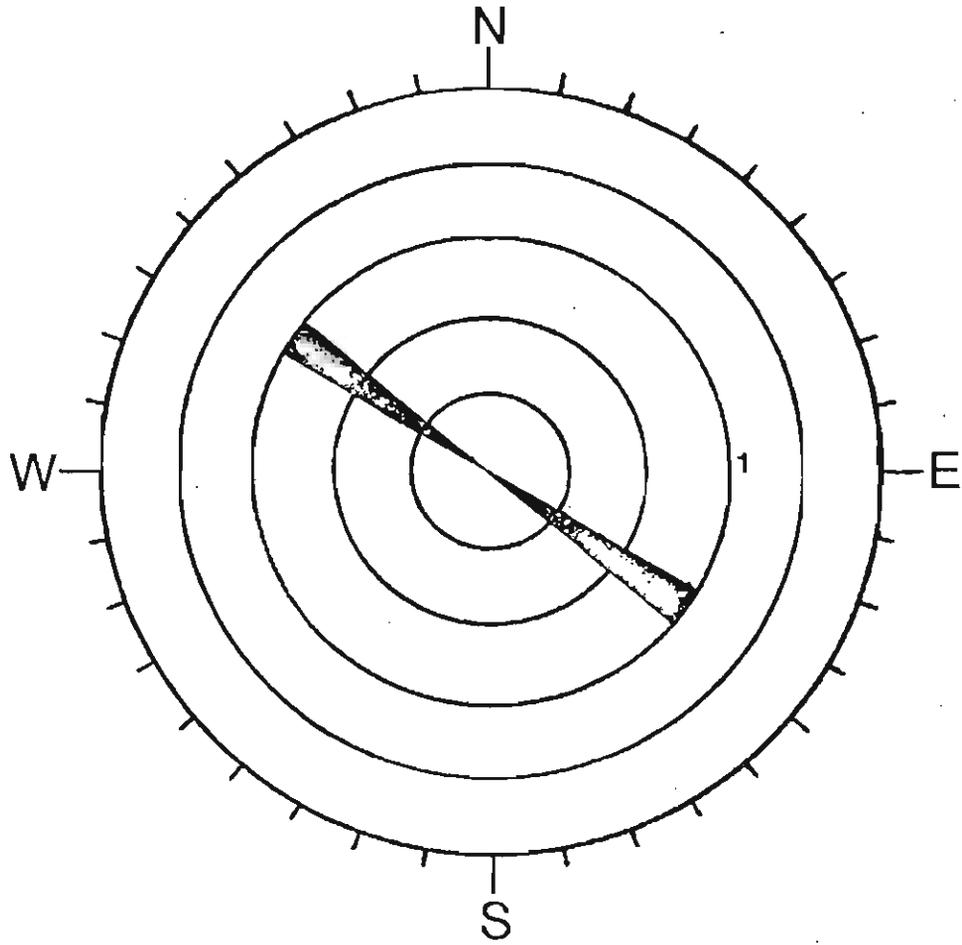


FIGURE 8

ORIENTATION AND FREQUENCY OF SLICKENLINES IN THE
CASHAQUA SHALE

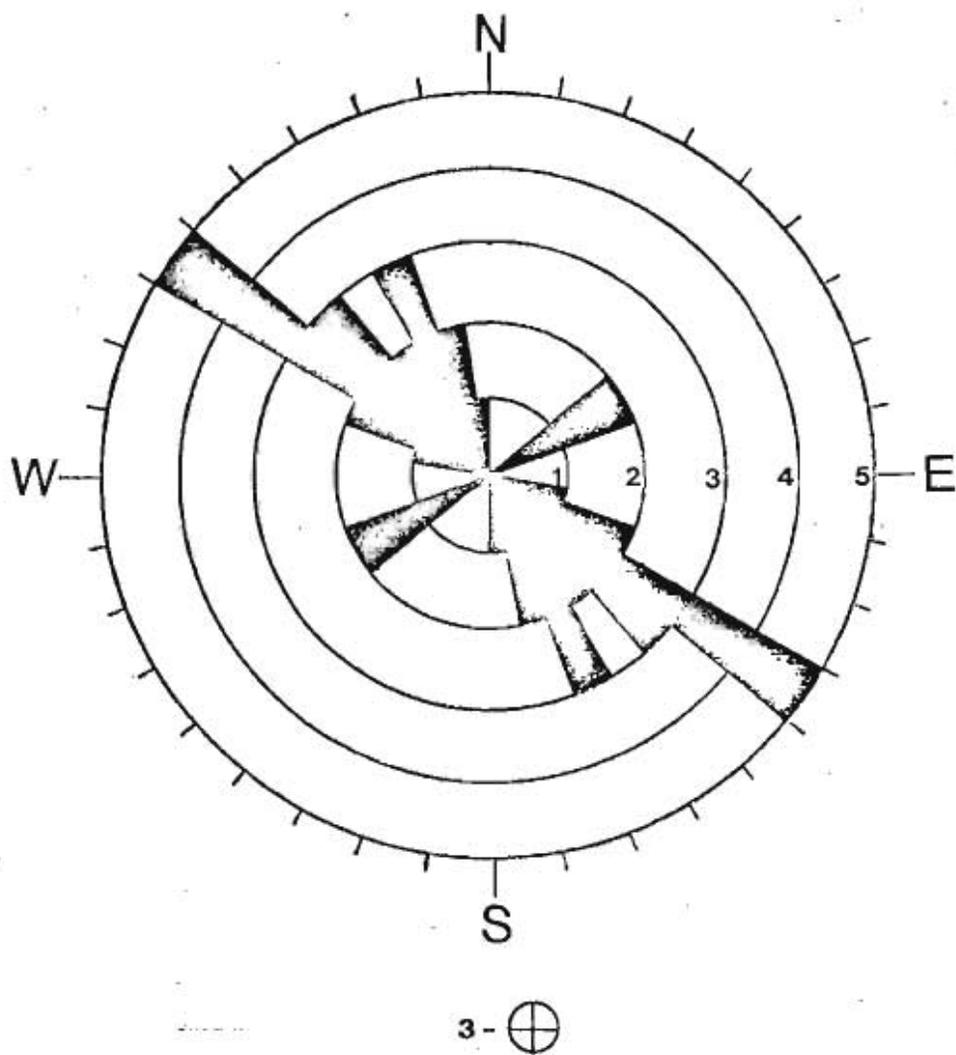


FIGURE 9

ORIENTATION AND FREQUENCY OF THE NATURAL FRACTURES IN THE
MIDDLESEX SHALE

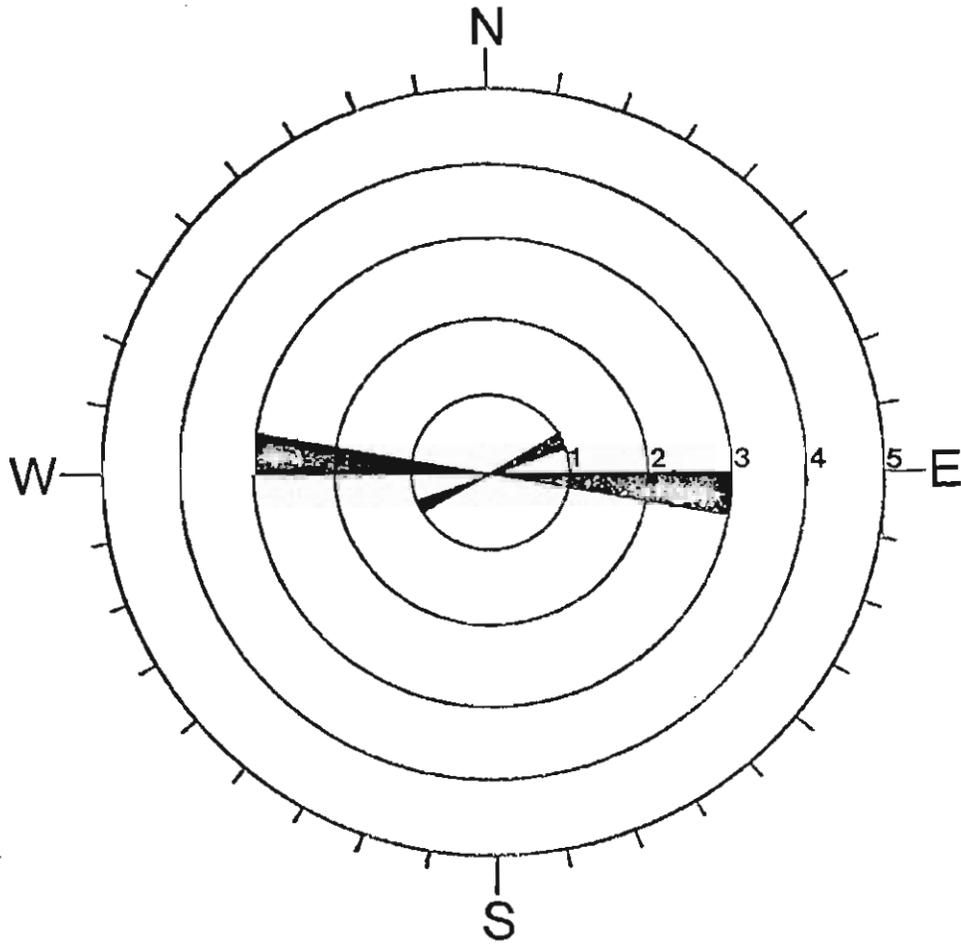


FIGURE 10

ORIENTATION AND FREQUENCY OF THE SLICKENLINES IN THE
MIDDLESEX SHALE

The slickenlines occur in a major grouping which bears between N40°W and N60°W. One horizontal rotational set was observed at 7,354.8 feet and bears from S10°W to S10°E.

The strike and frequency of all natural fractures and the bearing and frequency of the associated slickenlines within the Geneseo Shale are presented in rosette form in Figures 11 and 12, respectively.

Tully Limestone

There are no natural fractures present in the 42 feet of core cut from the Tully Limestone.

Mahantango Shale

The Mahantango Shale contains five natural fractures, three simple joints and two faults. All of the joints are calcite mineralized and are between 0.9 and 2.0 feet in length. The joints strike between N20°E and N30°E and from N40°W to N50°W.

The faults strike between N50°E and N60°E and from N70°E to N80°E, and show movement in the direction of 3°, N75°W, and 8°, S74°E, respectively. The strike and frequency of all the natural fractures and the bearing and frequency of their associated slickenlines are presented in rosette form in Figures 13 and 14, respectively.

Marcellus Shale

The Marcellus Shale contains forty-five natural fractures, eighteen simple joints, eight compound joints, sixteen faults and three microfaults. All of the joints and a majority of the faults are calcite

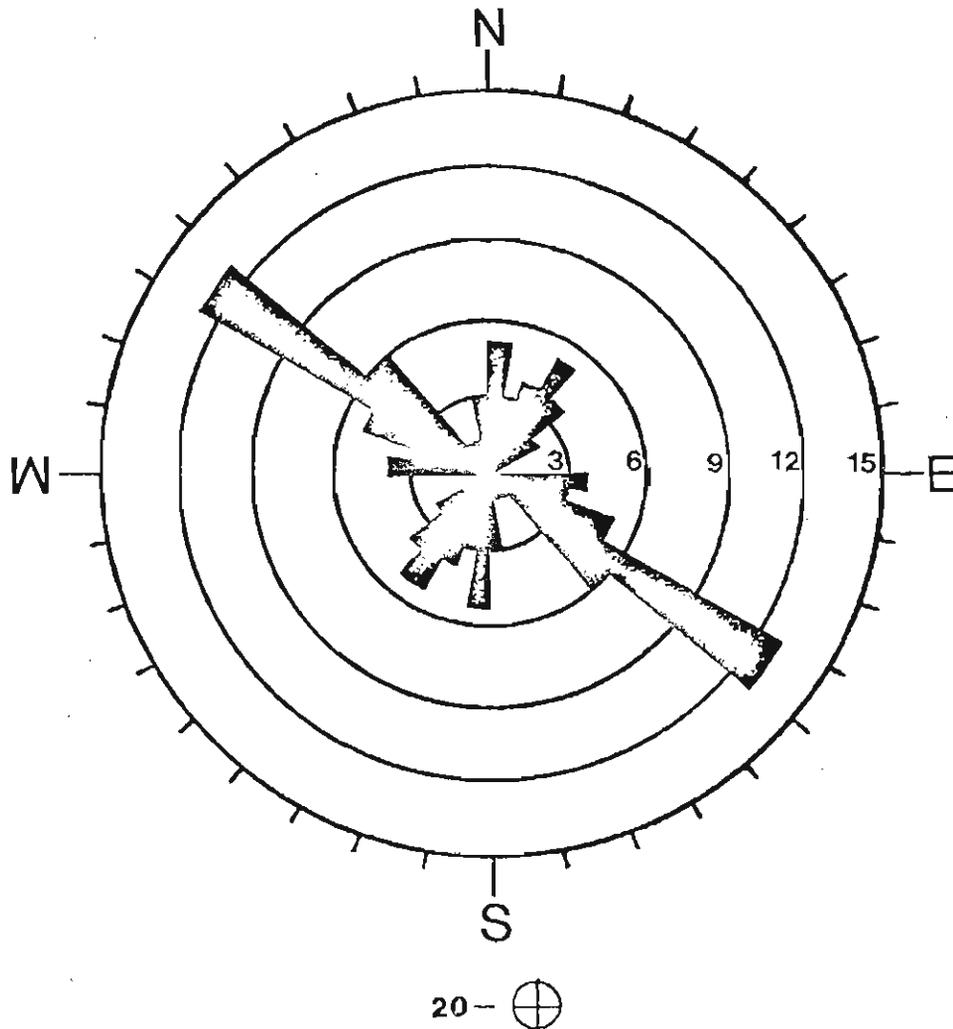


FIGURE 11

ORIENTATION AND FREQUENCY OF THE NATURAL FRACTURES IN THE
GENESEEO SHALE

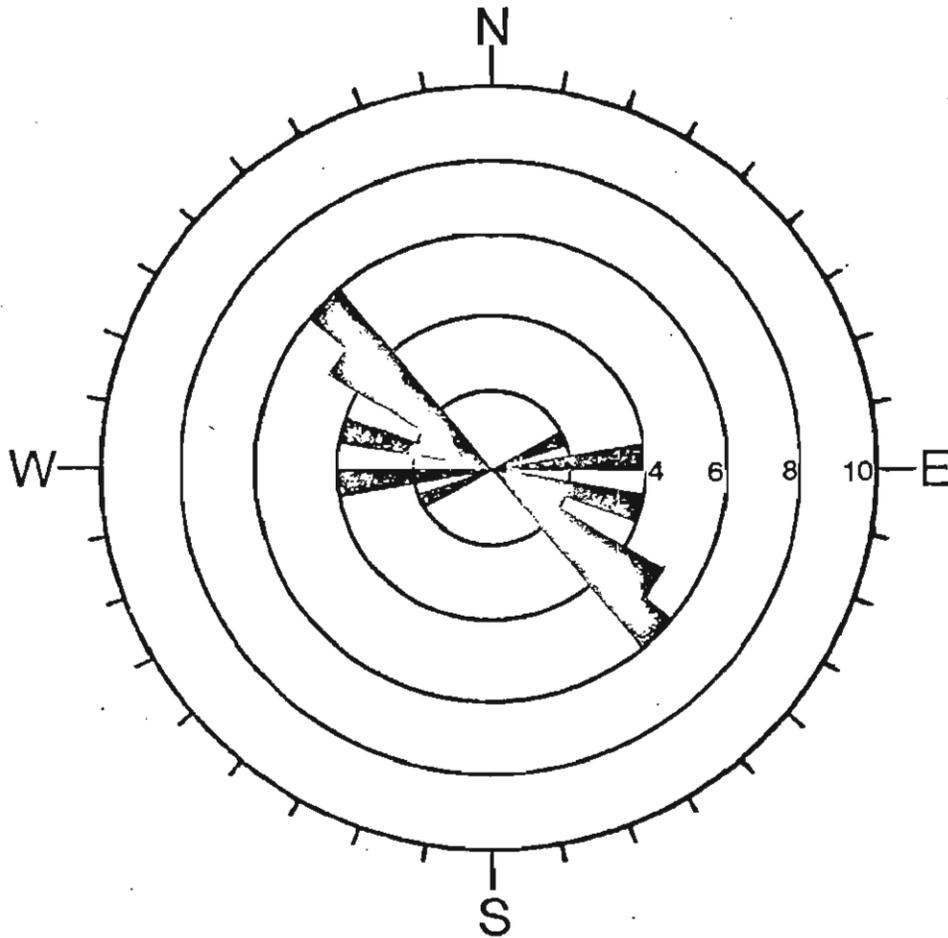


FIGURE 12

ORIENTATION AND FREQUENCY OF THE SLICKENLINES IN THE
GENESEEO SHALE

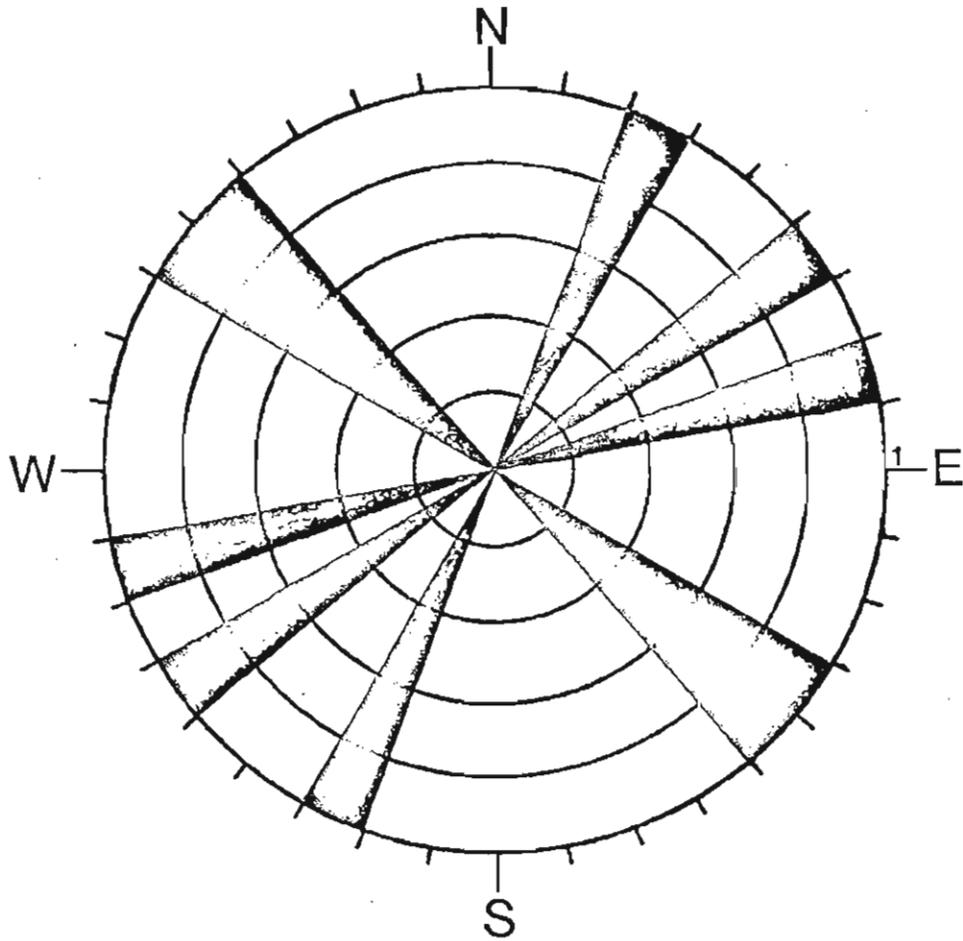


FIGURE 13

ORIENTATION AND FREQUENCY OF THE NATURAL FRACTURES IN THE
MAHANTANGO SHALE

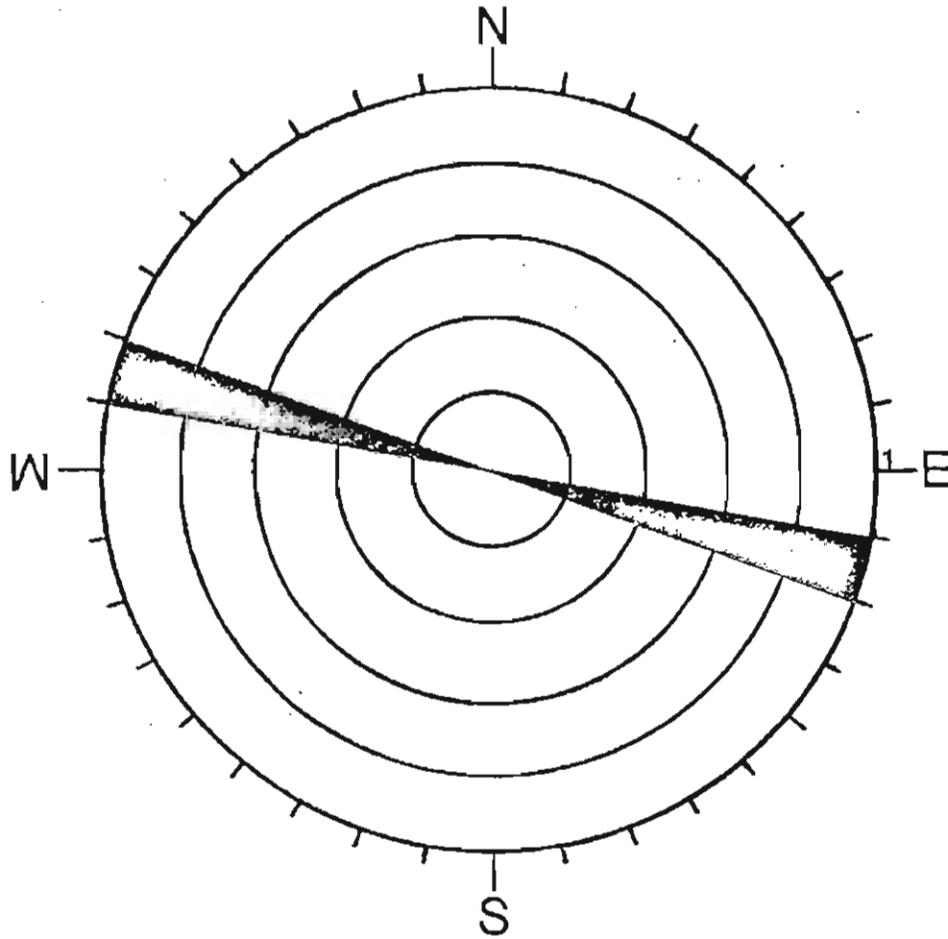


FIGURE 14

ORIENTATION AND FREQUENCY OF THE SLICKENLINES IN THE
MAHANTANGO SHALE

mineralized. Two major strike trends are present, these are between N50°W and N60°W, and from N40°E to N50°E. Twenty of the joints could not be oriented due to extensive rubblization; an additional seven are horizontal. These fractures were not plotted. Slickenlines bear between N40°W and N90°W and from N80°E to N90°E.

The strike and frequency of the natural fractures and the bearing and frequency of their contained slickenlines are presented in rosette form in Figures 15 and 16, respectively.

Coring-Induced Fractures

Ninety-nine percent of the fractures examined in the EGSP-Pennsylvania #4 core were interpreted 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 does provide a rough measure of the flexural rigidity of the rock parallel to bedding. These data are provided in Appendix C.

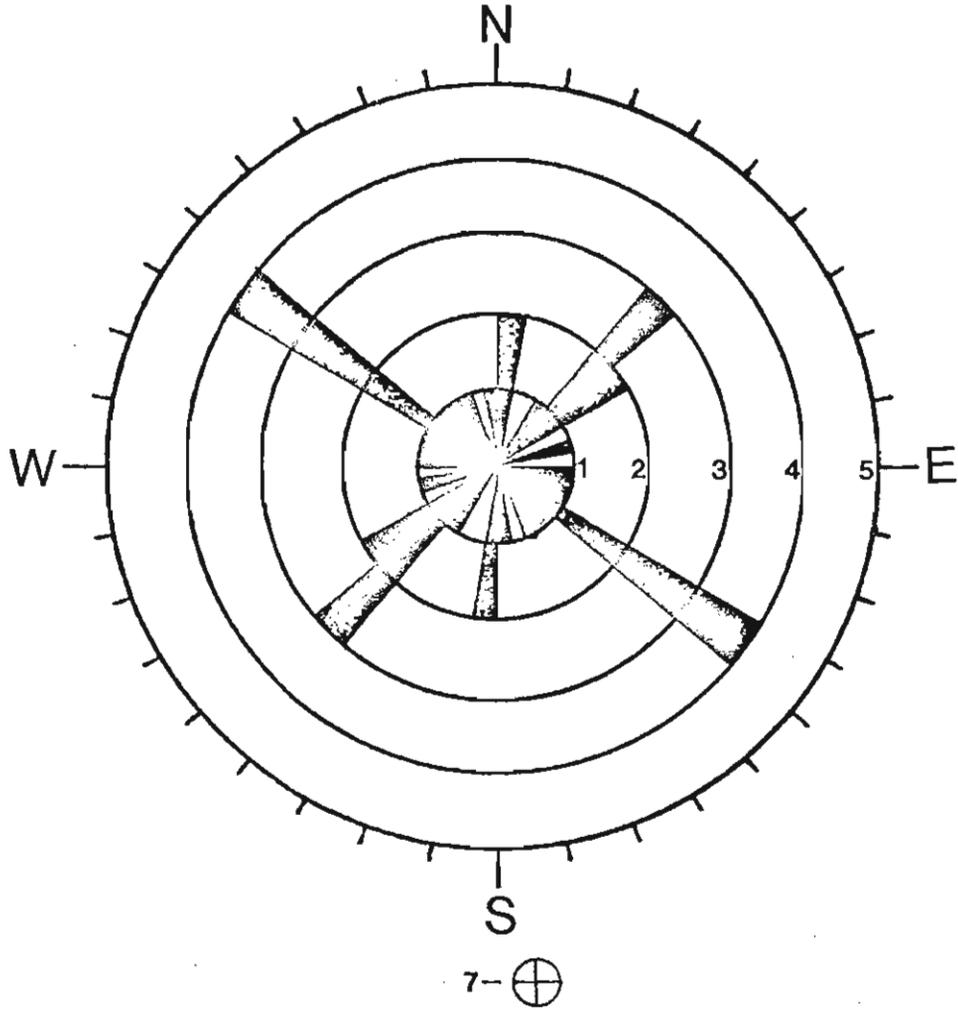


FIGURE 15

ORIENTATION AND FREQUENCY OF THE NATURAL FRACTURES IN THE
MARCELLUS SHALE

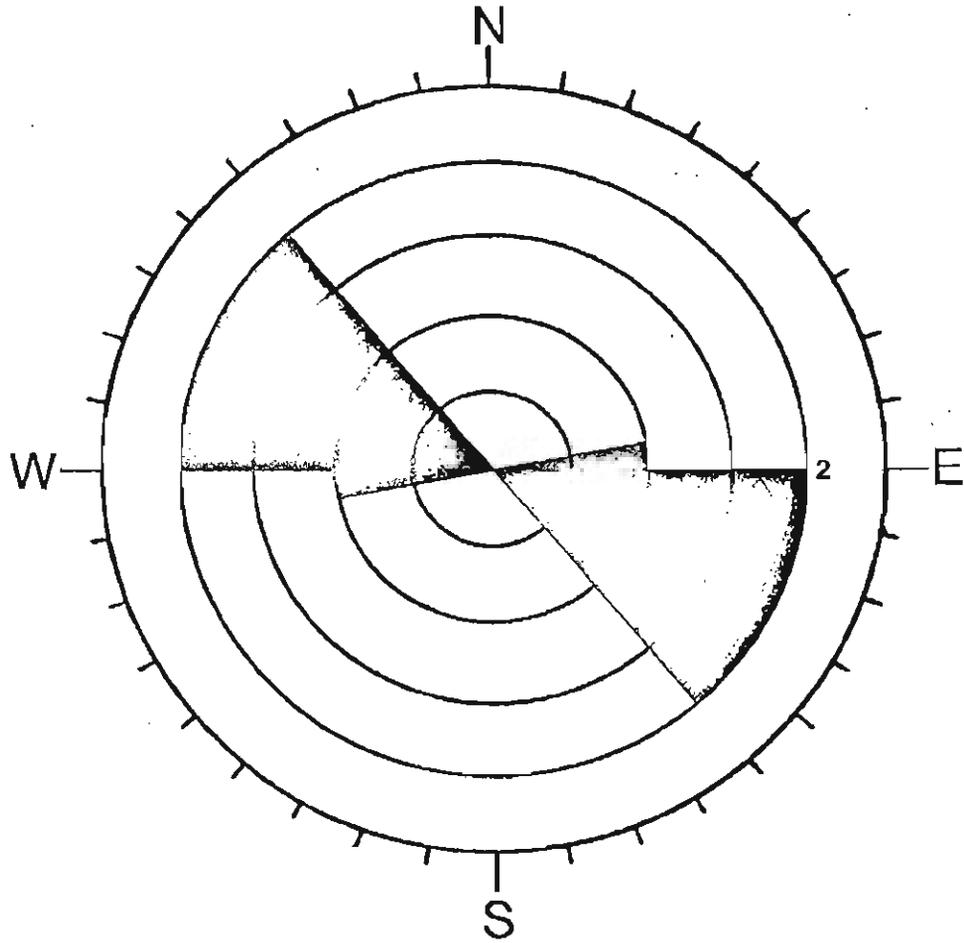


FIGURE 16

ORIENTATION AND FREQUENCY OF THE SLICKENLINES IN THE
MARCELLUS SHALE

A P P E N D I X A

DETAILED LITHOLOGIC DESCRIPTION
EGSP-PENNSYLVANIA #4-INDIANA COUNTY

<u>INTERVAL</u>	<u>DESCRIPTION</u>
7,098.0' - 7,108.3' (10.3')	Silty mudstones and mudstones, dark gray (N3), medium dark gray (N4), and olive gray (5Y 4/1), thinly laminated to thin bedded. The interval is comprised of alternating medium dark gray, dark gray, and olive gray silty mudstone laminae and thin beds. Numerous small brachiopod and nautiloid casts (<1 cm diam.) occur within the interval. Pyrite is rare and occurs as either burrow structure fillings or replaced plant fragments.
7,108.3' - 7,120.3' (12.0')	Silty mudstones and mudstones, medium dark gray (N4) and olive gray (5Y 4/1), thinly laminated. The core is made up of alternating medium dark gray and olive gray silty mudstones and mudstones. A few brachiopods (4 mm by 5 mm) are present at 7,119.4 feet. Numerous mud filled nautiloid casts (<2 cm diam.) occur throughout the interval. Pyrite mineralized nautiloid casts are present, but rare.
7,120.3 - 7,133.3' (13.0')	Silty mudstones and mudstones, olive gray (5Y 4/1), medium dark gray (N4), and brownish gray (5YR 4/1), thinly laminated to thin bedded. Alternating olive gray, medium dark gray, and brownish gray laminae are found throughout the core. A mud filled brachiopod cast (<1 cm diam.) occurs at 7,123.9 feet. A weakly pyritized plant fragment is present at 7,128.9 feet.
7,133.3' - 7,142.4' (9.1')	Silty mudstones and mudstones, medium dark gray (N4), and olive gray (5Y 4/1), thinly to thickly laminated. The interval is composed of alternating medium dark gray, and olive gray silty mudstones and mudstone laminae. A single, small brachiopod, <i>Lingula</i> sp., is present at 7,137.4 feet. Mud filled burrow structures are sparse. The interval is devoid of pyrite, and is non-calcareous.
7,142.4' - 7,153.9' (11.5')	Silty mudstones, mudstones, and siltstones, medium dark gray (N4), dark gray (N3), and medium gray (N5), thinly laminated to thin bedded. The core consists of alternating medium dark, and dark gray silty mudstones and mudstone laminae. Several thin (<2 cm) bands containing medium gray, siltstone laminae occur throughout. Small mud filled pelecypod and nautiloid casts are present at 7,143.1 and 7,143.6 feet, respectively. Mud-filled burrows and plant fragment imprints are rare. The interval is devoid of pyrite and is noncalcareous.

<u>INTERVAL</u>	<u>DESCRIPTION</u>
7,153.9' - 7,164.4' (10.5')	Silty mudstones, mudstones, and siltstones, medium dark gray (N4), dark gray (N3), and medium light gray (N6), thinly laminated to thin bedded. The interval is uniform in appearance, and contains sparse dark gray mudstones and medium light gray siltstone laminae throughout. Several mud filled nautiloid casts and a brachiopod (7,156.2 ft.) are present. Mud filled burrow structures occur throughout. A small (<1 cm diam.) pyritized burrow structure occurs at 7,162.1 feet. The interval is noncalcareous.
7,164.4' - 7,168.7' (4.3')	Mudstones and silty mudstones, dark gray (N3), and olive gray (5Y 4/1), thinly to thickly laminated. The core is comprised of alternating dark gray and olive gray mudstones and silty mudstone bands up to 0.2 feet thick. A 0.2-foot long linear structure (possibly a plant imprint) is present at 7,167.0 feet. The core is devoid of both pyrite and obvious fossils, and is noncalcareous.
7,168.7' - 7,175.9' (7.2')	Silty mudstones, silty shales, and siltstones, medium dark gray (N4), olive gray (5Y 4/1), dark gray (N3), and medium light gray (N6), thinly laminated to thin bedded. The upper 0.9 feet is dark gray silty shale, the remainder being olive gray and medium dark gray silty mudstones. A few bands (<5 cm thick) of medium light gray, weakly calcareous siltstone are present between 7,174.6 and 7,174.8 feet. Brachiopods occur within the interval, but are sparse. Pyrite is present as burrow fillings and as mineralization on a shell fragment (?) at 7,176.5 feet.
7,175.9' - 7,193.0' (17.1')	Silty mudstones and siltstones, dark gray (N3) and medium light gray (N6), thinly laminated to thin bedded. The interval contains numerous weakly calcareous, planar-laminated siltstones up to 0.5 feet in thickness. A brachiopod is present at 7,176.9 feet. Numerous mud filled burrow structures occur throughout the interval. Pyritized spore bodies and burrow structures are rare. Faint primary current lineation marks and load casts are found at 7,179.2 feet.

<u>INTERVAL</u>	<u>DESCRIPTION</u>
7,193.0' - 7,205.5' (12.5')	Silty mudstones and mudstones, medium dark gray (N4), olive gray (5Y 4/1), and brownish gray (5YR 4/1), thinly to thickly laminated. The interval is composed of alternating dark gray mudstone laminae, contained within the olive gray and brownish gray silty mudstones and mudstones. A single, slightly pyritized nautiloid cast is present at 7,202.3 feet. Pyritized mud filled burrow structures, up to 15 mm in diameter, are found throughout the interval. The core is noncalcareous.
7,205.5' - 7,216.1' (10.6')	Silty mudstones, mudstones, and shaly mudstones, dark gray (N3) and olive gray (5Y 4/1), thinly to thickly laminated. The core is composed of irregularly spaced dark gray mudstones and shaly mudstone laminae contained within the dark gray and olive gray silty mudstones. A shaly mudstone zone is present between 7,210.5 and 7,212.3 feet. Both mud filled and lightly pyritized, burrow structures occur within the interval. Lightly pyritized, straight cephalopod casts (25 mm diam. by 35 mm long) are found at 7,212.6 feet. A few mud filled pelecypod casts occur in the lower one foot. The interval is noncalcareous.
7,216.1' - 7,228.0' (11.9')	Silty mudstones, mudstones, and shaly mudstones, dark gray (N3), medium dark gray (N4), and medium light gray (N5), thinly to thickly laminated. The interval is mostly medium dark gray silty mudstones with numerous irregularly spaced dark gray mudstone laminae present throughout. Several medium light gray silty mudstone laminae are also present in the lower 2.0 feet. The upper 3.0 feet is dark gray shaly mudstone. Brachiopods, nautiloids and pelecypods (all ~ 1 cm diam.) are present within the lower 4.0 feet. Pyrite occurs as mineralized burrow structures (~5 mm diam.), and as very thin laminae of disseminated grains. Numerous parallel groove marks, which exhibit a primary paleocurrent direction (N62°E - S62°W), are present at 7,227.8 feet. Several of the thin silty mudstones in the upper 5.0 feet are weakly calcareous.

INTERVALDESCRIPTION

7,228.0' - 7,239.6'
(11.6')

Silty mudstones, silty shales, and mudstones, dark gray (N3), grayish black (N2), and medium light gray (N6), thinly to thickly laminated. The interval is generally composed of alternating dark gray and grayish black silty mudstone laminae. Medium light gray, weakly calcareous, silty mudstone laminae are also present in a grayish black, silty shale zone between 7,230.0 and 7,233.0 feet. Numerous, mud filled, nautiloid and pelecypod casts (<1 cm diam.) occur in the lower 5.0 feet. Pyrite is present as mineralization on burrow structures, in very thin laminae of disseminated grains, and as thin (<1 cm) laminae flanking a concretionary structure at 7,234.8 feet.

7,239.6' - 7,253.0'
(13.4')

Silty mudstones and silty shales, brownish black (5YR 2/1), olive black (5Y 2/1), and grayish black (N2), thinly to thickly laminated. The interval is predominantly brownish black and black silty mudstones. Two silty shale zones are present from 7,242.6 to 7,244.0 feet and from 7,251.0 to 7,253.0 feet. Several mud filled pelecypod casts are present within the interval. Pyrite occurs as very thin laminae of disseminated grains, and as mineralization on sparse spore bodies and burrow structures. The interval is noncalcareous.

7,253.0' - 7,266.0'
(13.0')

Silty shales, silty mudstones, and siltstones, grayish black (N2), dark gray (N3), and olive gray (5Y 4/1), thinly laminated to thin bedded. The interval is composed of irregularly spaced dark and olive gray bands of silty mudstone, up to 1.0 foot thick, contained in the grayish black silty shales. A dark gray calcareous siltstone septarian concretion occurs between 7,263.0 and 7,263.8 feet. Pyrite is present as nodules (<2 cm diam.), waveform laminae, small lenses (<1 cm in thickness) and laminae of disseminated grains. A single, small (<2 cm thick) mud replaced bark fragment occurs at 7,255.8 feet.

<u>INTERVAL</u>	<u>DESCRIPTION</u>
7,266.0' - 7,278.3' (12.3')	Silty shales and silty mudstones, grayish black (N2), dark gray (N3), olive gray (5Y 4/1), and medium light gray (N6), thinly laminated to thin bedded. The interval contains numerous dark gray silty mudstone bands (<0.8 ft. in thickness) contained within grayish black silty shales. A single, slightly calcareous, medium light gray silty mudstone band occurs between 7,273.6 and 7,273.7 feet. A vitritized (?) bark fragment (telenite?, 90 mm diam. by 3 mm thick) is present at 7,272.2 feet. Pyrite occurs throughout as waveform laminae, thin (<1 cm thick) lenses, and sparse nodules.
7,278.3' - 7,291.0' (12.7')	Silty shales and silty mudstones, grayish black (N2) and black (N1), thinly to thickly laminated. The interval's uniform appearance is disrupted only by fissile zones which occur throughout. Pyrite is sparse, and occurs as small nodules (<1 cm diam.), and as zones containing laminae of disseminated grains at 7,278.3 and 7,289.8 feet. The interval is devoid of fossils and is noncalcareous.
7,291.0' - 7,304.4' (13.4')	Silty shales, black (N1), and grayish black (N2), thinly to thickly laminated. The interval is uniform in appearance and lithology. Very sparse pyrite nodules (<1 cm diam.), and a thin pyritic lens (10 mm by 34 mm, 7,303.4 ft.) are present within the interval. The core is devoid of fossils and plant fragments, and is noncalcareous.
7,304.4' - 7,322.8' (18.4')	Silty shales and silty mudstones, black (N1) and grayish black (N2), thinly to thickly laminated. The interval is uniform in color and lithology. Pyrite occurs as a single lens (~2 mm), and a vitritized wood fragment, 3 cm by 8 cm, is present at 7,316.9 feet. The interval is devoid of fossils and is weakly calcareous between 7,309.0 and 7,310.0 feet.

<u>INTERVAL</u>	<u>DESCRIPTION</u>
7,322.8' - 7,341.7' (18.9')	Silty shales and silty mudstones, black (N1), grayish black (N2), and olive gray (5Y 4/1), thinly laminated to thin bedded. The core is composed of approximately 60% black and grayish black silty shales, and 40% olive gray silty mudstone bands, up to 4.0 feet thick. Pyrite is present as sparse nodules (some with crystal-line faces) and as laminae of disseminated grains. Numerous well preserved sole and rill marks occur at 7,333.2 feet and exhibit a N70°E-S70°W paleocurrent direction. No fossils are found within this interval. A zone between 7,327.0 and 7,329.5 feet is weakly calcareous.
7,341.7' - 7,353.2' (11.5')	Silty shales, black (N1) and grayish black (N2), thinly to thickly laminated. The interval is uniform in both color and lithology. Pyrite is present as very small nodules (<5 mm diam.), and laminae of disseminated grains at 7,345.7 and 7,352.6 feet. The interval is noncalcareous and is devoid of fossils.
7,353.2' - 7,364.0' (10.8')	Silty shales, silty mudstones, and siltstones, grayish black (N2), black (N1), olive gray (5Y 4/1), and light gray (N7), thinly laminated to thin bedded. The core is composed of 90% grayish black, olive gray, and black silty shales and mudstones; the remainder consists of laminae of light gray, weakly calcareous siltstone. Pyrite occurs as sparse nodules, and in a thin zone of disseminated grains between 7,360.1 and 7,360.2 feet. The interval is devoid of fossils and is weakly calcareous.
7,364.0' - 7,378.0' (14.0')	Silty mudstones, silty shales, mudstones, and siltstones, olive gray (5Y 4/1), grayish black (N2), dark gray (N3), and light gray (N7), thinly to thickly laminated. The upper 1/2 of the core consists of dark gray and grayish black silty shales, which contain several olive gray mudstones and silty mudstone bands, up to 1.0 foot in thickness. The lower 1/2 consists of alternating dark gray and light gray silty mudstones, and weakly calcareous siltstone laminae. Small pyrite nodules (<5 mm diam.) are present, but rare within the interval. A single calcareous light gray siltstone concretion (50 mm by 15 mm) occurs at 7,373.1 feet. Numerous mud filled burrow structures and small sole marks occur in the lower 2.0 feet. Weakly calcareous silty zones, up to 1.5 feet thick, are present in the upper 1/2.

<u>INTERVAL</u>	<u>DESCRIPTION</u>
7,378.0' - 7,393.2' (15.2')	Silty shales, silty mudstones, and mudstones, grayish black (N2), olive black (5Y 2/1), olive gray (5Y 4/1), and light gray (N7), thinly laminated to thin bedded. The interval consists of zones of alternating olive gray and light gray mudstones and silty mudstones contained within the predominant grayish black and olive black silty shales. Numerous mud filled burrow structures are present throughout the interval. The core is devoid of pyrite. Several sole marks and ripple structures occur within the interval. Numerous silty mudstone laminae occur throughout the interval and are weakly calcareous.
7,393.2' - 7,407.0' (13.8')	Silty mudstones, silty shales, and mudstones, dark gray (N3), olive gray (5Y 4/1), olive black (5Y 2/1), and light gray (N7), thinly to thickly laminated. The interval is composed of alternate dark gray, olive gray, and light gray silty mudstone laminae. The lower 3.0 feet is olive black silty shale; an olive gray mudstone band also occurs between 7,403.9 and 7,404.0 feet. Numerous mud filled burrow structures (<15 mm diam.) are present throughout. Sole marks and load casts occur within the interval. The core is devoid of fossils and pyrite. Several of the light gray silty mudstone laminae contained in the upper 1/2 are weakly calcareous.
7,407.0' - 7,419.0' (12.0')	Silty shales, silty mudstones, and siltstones, grayish black (N2), olive black (5Y 2/1), olive gray (5Y 4/1), and light gray (N7), thinly laminated to thin bedded. Weakly calcareous, light gray siltstone laminae and olive gray silty mudstone bands (<1.0 ft. thick) are contained within the predominant grayish and olive black silty shales. Numerous mud filled burrow structures (<2 cm diam.) and small sole marks are present within the interval. A small curvilinear fault, possibly a soft-sediment deformational feature, occurs at 7,416.9 feet. A single mud filled cephalopod (<u>Tornoceras</u> sp. ?) shell cast (15 mm by 30 mm in length) is present at 7,418.1 feet. The interval is devoid of any form of pyrite.

<u>INTERVAL</u>	<u>DESCRIPTION</u>
7,419.0' - 7,432.7' (13.7')	Silty mudstones, silty shales, mudstones, and siltstones, olive black (5Y 2/1), olive gray (5Y 4/1), grayish black (N2), and light gray (N7), thinly laminated to thin bedded. The interval is composed of olive black and olive gray silty mudstone bands (up to 2.0 ft. in thickness), zones (<2.0 ft. thick) of alternating grayish black and light gray silty mudstone and siltstone laminae, and thin olive gray mudstone bands. Numerous groove and sole marks are present in the upper 1/2. Several brachiopods (<i>Orbiculoidea</i> sp., <4 mm diam.) occur in the upper 2.0 feet. Pyrite is present as small nodules (<4 mm diam.), and is restricted to the lower 4.0 feet. The interval is noncalcareous.
7,432.7' - 7,441.6' (8.9')	Silty mudstones, silty shales, and siltstones, dark gray (N3), olive gray (5Y 4/1), and light gray (N7), thinly laminated to thin bedded. The dark gray silty shales and calcareous light gray laminated siltstone zones (<1.5 ft. in thickness) are contained within the dark gray silty mudstones. A calcareous septarian concretion is present between 7,332.8 and 7,333.1 feet. Mud filled and pyrite mineralized burrow structures (~4 mm diam.) are common throughout. Pyrite also occurs as small nodules (<5 mm diam.) and as waveform laminae. Small (<3 mm diam.) brachiopods are found in the lower 2.0 feet. Several of the siltstone laminae which occur throughout the interval are weakly calcareous.

<u>INTERVAL</u>	<u>DESCRIPTION</u>
7,441.6' - 7,455.3' (13.7')	<p>Silty mudstones, silty shales, and mudstones, olive black (5Y 2/1), olive gray (5Y 4/1), and medium light gray (N6), thinly to thickly laminated. The interval is comprised of a few olive black silty shale zones (<1.0 ft. in thickness) contained within the predominant olive black and olive gray silty mudstones. Numerous, weakly to moderately calcareous, thin siltstone laminae occur throughout; a thicker (0.1 ft.) zone occurs at 7,454.1 feet. Mud filled and pyrite mineralized burrow structures (up to 40 mm in length by 8 mm diam.) are common throughout. Pyrite also occurs as waveform laminae and nodules (~25 mm by 15 mm), which are somewhat concentrated within the olive black and olive gray silty mudstones. A large wood fragment imprint (30 mm by 75 mm) is present at 7,454.7 feet. Pelecypod and brachiopod casts (<5 mm diam.) occur throughout. Several siltstone laminae, and a zone between 7,441.9 and 7,442.3 feet are weakly to moderately calcareous.</p>
7,455.3' - 7,465.7' (10.4')	<p>Silty mudstones and silty shales, olive black (5Y 2/1), grayish black (N2), and medium gray (N5), thinly laminated to thin bedded. The interval is comprised of approximately equal parts of olive black and grayish black silty mudstone and silty shale, which contain numerous medium gray silty mudstone laminae throughout. Two medium gray calcareous silty mudstone concretions are present from 7,460.9 to 7,461.1 feet and between 7,465.0 and 7,465.7 feet. Pyrite is present as mineralized horizontal and vertical burrow structures (~3 mm diam.), and as small nodules. Mud filled burrow structures (<1 cm diam.) occur throughout the interval. Several small (3 mm diam.) mud filled brachiopod and pelecypod casts are present within the interval. The core is weakly calcareous.</p>

<u>INTERVAL</u>	<u>DESCRIPTION</u>
7,465.7' - 7,475.5' (9.8')	Silty shales and siltstones, grayish black (N2), black (N1), and medium gray (N5), thinly to thickly laminated. The interval is predominantly grayish black and black silty shales, several calcareous medium gray siltstone laminae are also present. Numerous mud filled brachiopod, nautiloid (7,469.6 ft.), and pelecypod casts (~15 mm diam.) are also present. Pyrite occurs as sparse mineralization on burrow structures, and as laminae of disseminated grains which are concentrated between 7,469.2 and 7,470.0 feet. Sparse horizontal and vertical mud filled burrow structures (<15 mm diam.) occur throughout. The interval is weakly calcareous.
7,475.5' - 7,489.0' (13.5')	Silty shales, black (N1) and grayish black (N2), thinly to thickly laminated. The interval is uniform in lithology and contains very subtle color differences. Numerous mud filled burrow structures (<3 mm diam.), sole marks, and load casts occur throughout. Mud filled pelecypod and brachiopod casts (<5 mm diam.) are present throughout the interval. Pyrite occurs between 7,481.0 and 7,481.3 feet as a small lens (10 mm by 55 mm in length) surrounded by laminae of disseminated pyrite grains. The interval is weakly calcareous.
7,489.0' - 7,503.8' (14.8')	Silty shales and silty mudstones, black (N1), grayish black (N2), and medium dark gray (N4), thinly to thickly laminated. The interval is composed of black and grayish black silty shales, containing calcareous medium dark gray concretionary silty mudstone laminae which occur between 7,496.0 and 7,498.4 feet. Calcite laminae flank a concretion (0.2 ft. wide) at 7,507.0 feet. Mud filled burrow structures (4 mm diam. by 30 mm) occur throughout the interval. Mud filled nautiloid casts (~15 cm diam.) are present in a zone between 7,491.5 and 7,495.0 feet. Pelecypod and brachiopod casts (5 mm diam.) are distributed throughout. The interval is moderately calcareous.

<u>INTERVAL</u>	<u>DESCRIPTION</u>
7,503.8' - 7,516.2' (12.4')	Silty shales, olive black (5Y 2/1) and black (N1), thinly laminated. The interval is uniform in lithology and color; the degree of fissility varies throughout. A calcareous, silty concretion, containing pyrite laminae, occurs from 7,509.3 to 7,509.4 feet. Pyrite also occurs in a narrow zone (0.3 ft. thick) which contains laminae of disseminated grains in and around this concretion. Mud filled pelecypod and brachiopod casts (~3 mm diam.) are common throughout; nautiloid casts (~5 mm diam.) are present below 7,506.9 feet. The interval is moderately calcareous.
7,516.2' - 7,525.0' (8.8')	Silty mudstones, and silty shales, dark gray (N3), medium dark gray (N4), grayish black (N2), and medium light gray (N6), thinly laminated to thin bedded. The upper 7.8 feet is comprised of alternating dark gray, medium dark gray and medium light gray silty mudstone laminae; the remainder of the interval is grayish black silty shales. Sparse mud filled, brachiopod and pelecypod casts (~3 mm diam.) are present throughout. Two large dolomite and calcite mineralized (crystals up to 5 mm across) open fractures, with 1 cm displacement, occur from 7,516.2 to 7,524.3 feet. The interval is moderately calcareous.
7,525.0' - 7,539.9' (14.9')	Silty shales, grayish black (N2), and black (N1), thinly laminated. The interval is uniform in color and lithology. Mud filled brachiopod and pelecypod casts (<3 mm diam.) occur frequently throughout. Pyrite (7,532.2 ft.) and calcite (7,530.7 and 7,539.8 ft.) laminae are present within the interval. Mud filled burrow structures (8 mm diam. by 50 mm) are sparse. The interval is moderately calcareous throughout.
7,539.9' - 7,553.4' (13.5')	Silty shales and silty mudstones, black (N1), grayish black (N2), and dark gray (N3), thinly laminated to thin bedded. A calcareous, dark gray, silty mudstone concretion containing both disseminated pyrite and elongate pyrite crystals is present between 7,342.5 and 7,343.0 feet. Numerous calcite laminae underlie this concretion. Several mud filled brachiopod, nautiloid, and pelecypod casts (<5 mm diam.) and burrow structures (~4 mm diam.) occur throughout. The core is moderately calcareous.

<u>INTERVAL</u>	<u>DESCRIPTION</u>
7,553.4' - 7,565.4' (12.0')	Silty mudstones and silty shales, dark gray (N3), grayish black (N2), and medium dark gray (N4), thinly laminated to thin bedded. The interval predominantly consists of dark gray and medium dark gray silty mudstones; grayish black silty shale zones (<1.0 ft. thick) occur throughout. Two thin calcite laminae occur between 7,553.1 and 7,553.5 feet, a calcite-lined silty mudstone concretion ? (40 mm by 80 mm) is present at 7,458.0 feet. Numerous mud filled pelecypod and nautiloid casts (<10 mm diam.) and burrow structures (~3 mm diam.) are present throughout. The interval is moderately calcareous.
7,565.4' - 7,574.0' (8.6')	Silty mudstones and silty shales, grayish black (N2), black (N1), and dark gray (N3), thinly laminated to thin bedded. The interval is predominantly grayish black and dark gray silty mudstones; thin (<2.0 ft.) grayish black and black silty shales are also present. Small (<3 mm diam.) mud filled nautiloid and pelecypod molds are sparse. In the lower 4.0 feet incipient calcite crystal rosettes (?) (~1 mm) are present. The interval is moderately calcareous.
7,574.0' - 7,574.7' (0.7')	Silty mudstones and limestones, grayish black (N2) and medium dark gray (N4), thinly to thickly laminated. The upper 1/3 is composed of grayish black silty mudstone, the middle 1/3 is a highly burrowed silty mudstone zone, and the lower 1/3 contains medium dark gray limestones. Pyrite is present as mineralization on vertical and horizontal burrows (2 mm diam.) and as small nodules (4 mm). Some incipient calcite rosettes are present throughout. This interval is Leicester Pyrite, a marker bed that rests unconformably on the Tully Limestone (John Roen, personal communication). The interval is moderately calcareous.

<u>INTERVAL</u>	<u>DESCRIPTION</u>
7,574.7' - 7,592.8' (18.1')	Limestones and calcareous silty mudstones, medium dark gray (N4), medium gray (N5), and dark gray (N3), thickly laminated to thin bedded. The interval is comprised of alternating medium dark gray and medium gray limestones and dark gray silty mudstones up to 2.5 feet in thickness. The interval contains numerous fossils, including: calcite and pyrite mineralized burrow structures (~3 mm diam. by 10 mm), calcified crinoid columnals (3 mm diam.) and numerous shell fragments. Pyrite also occurs as small nodules (~5 mm diam.) and as a calcite-flanked concretion (? , 20 mm by 30 mm) at 7,578.8 feet. Several stylolites are present within the limestone bands. The interval is strongly calcareous.
7,592.8' - 7,606.1' (13.3')	Limestones and calcareous silty mudstones, medium dark gray (N4), medium light gray (N6), and medium gray (N5), thickly laminated to thin bedded. The interval is composed of alternating medium dark gray and medium light gray limestones, and medium dark gray silty mudstones, up to 1.5 feet in thickness. Calcite replaced crinoid columnals (<4 mm diam.) and assorted shell fragments are abundant throughout. Pyrite occurs sparsely as mineralization on burrow structures (<3 mm diam.) and as small nodules (3 mm diam.). Some iron staining is present. Stylolites are found within the limestone bands. The interval is strongly calcareous.
7,606.1' - 7,616.1' (10.0')	Calcareous silty mudstones and limestones, medium dark gray (N4), medium gray (N5), and light gray (N7), thickly laminated to thin bedded. The interval is composed of alternating medium dark gray and medium gray limestones and silty mudstones, and light gray limestones, up to 1.0 foot thick. Calcite replaced shell fragments and crinoid columnals (<3 mm diam.) primarily occur in the lower 0.7 feet, with some distributed throughout the remainder of the core. Pyrite is rare and occurs as mineralized horizontal and vertical burrow structures (<3 mm diam.). Stylolites are found in the limestone bands. The interval is heavily calcareous.

INTERVAL	DESCRIPTION
7,616.1' - 7,631.0' (14.9')	Silty shales and silty mudstones, dark gray (N3) and grayish black (N2), thinly to thickly laminated. The interval is uniform in color and lithology and varies only in the degree of fissility. Pyritized burrow structures and small nodules (~2 mm diam.) are rare. Mud filled <u>Lingula</u> sp. (?) shell molds (4 mm diam.) occur in the upper 4.0 feet of the interval. The core is noncalcareous.
7,631.0' - 7,645.0' (14.0')	Silty shales and silty mudstones, dark gray (N3) and grayish black (N2), thinly to thickly laminated. The interval is predominantly dark gray and grayish black silty shale, with thin zones (<0.5 ft. thick) of dark gray silty mudstone occurring throughout. A single <u>Orbiculoidea</u> sp. (? , 10 mm diam.) is present at 7,637.2 feet. Pyrite is rare, and occurs as mineralization on burrow structures and as small nodules (<3 mm). The interval is noncalcareous.
7,645.0' - 7,659.1' (14.1')	Silty shales and silty mudstones, dark gray (N3), and grayish black (N2), thinly to thickly laminated. The interval is uniform in color, and contains zones of moderate fissility. A few mud filled <u>Lingula</u> sp. (?) molds (2 mm diam.) occur at 7,654.7 feet. Pyrite is present as mineralization on burrow structures (1 mm diam.), as laminae of disseminated grains (7,655.1 ft.) and as waveform laminae (7,657.8 ft.). The core is weakly calcareous between 7,653.8 and 7,654.2 feet.
7,659.1' - 7,673.0' (13.9')	Silty shales, grayish black (N2) and dark gray (N3), thinly to thickly laminated. The interval is uniform in color and lithology varying only in the degree of fissility. Several mud filled articulate brachiopod (<u>Craniops</u> sp.?) molds (2 mm diam.) are present within the lower 12.0 feet. Pyrite occurs sparsely as staining on burrow structures, and as small nodules (3 mm diam.). A small calcite (?) nodule (2 mm by 4 mm) is present at 7,659.6 feet. The interval is noncalcareous.

<u>INTERVAL</u>	<u>DESCRIPTION</u>
7,673.0' - 7,687.6' (14.6')	Silty mudstones and silty shales, dark gray (N3), brownish black (5YR 2/1), and olive black (5Y 2/1), thinly to thickly laminated. The interval contains numerous brownish black and olive black silty shale zones within the predominant dark gray and brownish black mudstones. A plant (?) fragment (25 mm by 15 mm) is present at 7,678.1 feet. Only trace amounts of pyrite (stained burrows) occur within the interval. The core is noncalcareous.
7,687.6' - 7,700.7' (13.1')	Silty shales and silty mudstones, dark gray (N3), olive black (5Y 2/1), and olive gray (5Y 4/1), thinly to thickly laminated. The interval is predominantly olive black, olive gray and dark gray silty shales, with a dark gray calcareous silty mudstone concretion present between 7,692.3 and 7,692.5 feet. Thin calcite laminae flank this concretion. The interval is devoid of fossils, and pyrite is present as very slightly mineralized burrow structures (<3 mm by 65 mm). Except for the concretion, the core is noncalcareous.
7,700.7' - 7,713.2' (12.5')	Silty mudstones and silty shales, dark gray (N3) and medium dark gray (N4), thinly laminated to thin bedded. The interval is uniform in color and lithology and contains several fissile zones, up to 0.2 feet thick. The interval is devoid of fossils. Sparse pyrite stained burrow structures (<2 mm diam.) and waveform laminae occur throughout. The core is noncalcareous.
7,713.2' - 7,726.4' (13.2')	Silty mudstones and silty shales, dark gray (N3), medium dark gray (N4), and olive gray (5Y 4/1), thinly laminated to thin bedded. The interval is constant in color and lithology. The core is devoid of fossils, and no traces of pyrite are found. A thin (<0.3 ft.) weakly calcareous silty mudstone zone is present near the center of the interval.

<u>INTERVAL</u>	<u>DESCRIPTION</u>
7,726.4' - 7,741.0' (14.6')	Silty mudstones and silty shales, dark gray (N3), thinly to thickly laminated. The interval is predominantly dark gray silty mudstones; numerous dark gray silty shale zones, up to 1.0 foot thick are present throughout. There are no fossils present within the interval. Pyrite occurs as a small nodule (<2 mm diam.) at 7,727.8 feet and as the center of a calcareous concretion (18 mm by 4 mm) at 7,728.8 feet. The interval, except for the aforementioned concretion, is noncalcareous.
7,741.0' - 7,753.9' (12.9')	Silty mudstones and silty shales, dark gray (N3), medium dark gray (N4), and grayish black (N2), thinly to thickly laminated. The core is uniform in color and varies only in the degree of fissility. Several mud filled burrow structures (~4 mm by 20 mm) and faint groove marks are present throughout the interval. The core is devoid of fossils and pyrite. The interval is noncalcareous.
7,753.9' - 7,766.0' (12.1')	Silty mudstones and silty shales, dark gray (N3), and medium dark gray (N4), thinly to thickly laminated. The interval is uniform in color and contains silty shale zones up to 0.5 foot thick. The interval is devoid of fossils and pyrite. Small, faint (~2 mm by 8 mm) mud filled groove casts occur throughout.
7,766.0' - 7,779.1' (13.1')	Silty shales and silty mudstones, dark gray (N3), medium dark gray (N4), and olive gray (5Y 4/1), thinly to thickly laminated. The interval is a uniform color and contains thin (<3.0 ft.) zones of silty shale within the predominant silty mudstones. The interval is devoid of fossils and pyrite. Very faint groove marks (3 mm wide by 1 mm deep) are rare. The interval is noncalcareous.
7,779.1' - 7,793.9' (14.8')	Silty mudstones and siltstones, dark gray (N3), medium dark gray (N4), and light gray (N7), thickly laminated to thin bedded. The interval is predominantly dark gray and medium dark gray silty mudstones; several light gray weakly calcareous siltstone bands and concretions (<0.2 ft. diam.) occur throughout. Small (<5 mm diam.) sparse calcite-replaced shell fragments are present within the lower 11.0 feet. Pyrite occurs as small crystals (<1 mm) and as sparse shell mineralization. Only the aforementioned siltstones are weakly calcareous.

<u>INTERVAL</u>	<u>DESCRIPTION</u>
7,793.9' - 7,808.2' (14.3')	Silty mudstones and siltstones, dark gray (N3), olive gray (5Y 4/1), and light gray (N7), thickly laminated to thin bedded. The interval is predominantly dark gray and olive gray silty mudstones, which contains thin (<0.2 ft. thick) light gray weakly calcareous fine siltstone bands and concretions. Calcite-mineralized burrow structures (25 mm by 3 mm) and crinoid columnals (4 mm diam.) are present in the upper 5.0 feet. The interval is noncalcareous.
7,808.2' - 7,817.7' (9.5')	Silty mudstones, dark gray (N3), medium dark gray (N4), olive gray (5Y 4/1), and light gray (N7), thinly to thickly laminated. The interval is predominantly dark gray, medium dark gray and olive gray silty mudstones; a few small (<0.2 ft. thick) light gray calcareous silty mudstone concretions are also present. Mud-filled pelecypod casts (<5 mm diam.) are rare. The core is devoid of pyrite.
7,817.7' - 7,831.1' (13.4')	Silty mudstones, dark gray (N3), medium dark gray (N4), and medium gray (N5), thinly laminated to thin bedded. The interval is predominantly dark and medium dark gray silty mudstones, with a few medium gray calcareous silty mudstone concretions (<0.2 ft. diam.) present between 7,821.9 and 7,824.2 feet. Several mud filled burrow structures (3 mm by 15 mm) are present within the interval. The core is devoid of fossils and pyrite.
7,831.1' - 7,844.3' (13.2')	Silty mudstones and siltstones, dark gray (N3), grayish black (N2), and medium light gray (N6), thickly laminated to thin bedded. The interval is predominantly composed of dark gray and grayish black silty mudstones. Several weakly to moderately calcareous medium light gray fine siltstone concretionary bands are also present. A calcite and pyrite mineralized shell fragment (trilobite cephalus ?, 6 mm by 9 mm) is present at 7,841.3 feet. The interval is weakly calcareous between 7,834.0 and 7,837.0 feet.

<u>INTERVAL</u>	<u>DESCRIPTION</u>
7,844.3' - 7,855.9' (11.6')	Silty mudstones and siltstones, dark gray (N3), olive gray (5Y 4/1), and medium light gray (N6), thickly laminated to thin bedded. The interval is predominantly dark gray and olive gray silty mudstones. Numerous medium light gray calcareous fine siltstone concretionary bands, <0.2 ft. thick, are also present. Numerous partially calcite-mineralized pelecypod shell fragments (<9 mm by 6 mm) are present between 7,846.5 and 7,848.5 feet. Pyritized burrow structures (<2 mm diam.) occur in the lower 1/2 of the interval. The core is weakly calcareous in the lower 1/2.
7,855.9' - 7,873.0' (17.1')	Silty mudstones and silty shales, dark gray (N3), olive black (5Y 2/1), and medium light gray (N6), thinly laminated to thin bedded. The interval is predominantly dark gray and olive black silty mudstones. Also, medium light gray laminae and concretionary bands, <0.1 ft. thick, occur throughout the interval. Calcite mineralized shell fragments (<10 mm diam.) and sparse, horizontal and vertical burrow structures (<5 mm diam.) occur throughout. Pyrite is present as mineralization on burrow structures (linings) and as small nodules (<5 mm diam.). The upper 10.0 feet are moderately calcareous.
7,873.0' - 7,886.9' (13.9')	Silty shales and silty mudstones, black (N1), and grayish black (N2), thinly to thickly laminated. The core is a uniform black and grayish black color, and varies only in the degree of fissility. Pyrite is present predominantly in the upper 1/2 as mineralized burrow structures, and as lenses (both <10 mm diam. by 80 mm in length). Calcite nodules or possibly mineralized burrow structures, up to 4 mm in diameter, also occur in the upper 1/2. The core is weakly calcareous in the upper 2.0 feet.
7,886.9' - 7,900.0' (13.1')	Silty shales, black (N1) and grayish black (N2), thinly to thickly laminated. The interval is uniform in lithology and color. The interval is devoid of fossils and pyrite. The core is noncalcareous.

<u>INTERVAL</u>	<u>DESCRIPTION</u>
7,900.0' - 7,912.1' (12.1')	Silty shales, black (N1) and grayish black (N2), thinly to thickly laminated. The interval is a uniform black and grayish black color, and varies slightly in the degree of fissility. The core is devoid of fossils. A single, pyrite-mineralized, calcite-filled burrow structure (30 mm by 5 mm) is present at 7,911.7 feet. The interval is noncalcareous.
7,912.1' - 7,923.2' (11.1')	Silty shales, black (N1) and grayish black (N2), thinly to thickly laminated. The interval is a uniform color, varying only in the degree of fissility. The interval is devoid of any form of pyrite. A single, mud filled burrow structure (or fossil imprint ?) 30 mm in length by 6 mm in diameter, is present at 7,919.0 feet. The interval is noncalcareous.
7,923.2' - 7,932.2' (9.0')	Silty shales and silty mudstones, black (N1), grayish black (N2), olive black (5Y 2/1), and medium dark gray (N4), thinly to thickly laminated. The upper 8.4 feet contain grayish black, black, and olive black silty shales, varying in fissility. The lower 0.6 feet is composed of medium dark gray and olive black silty mudstones. The core is devoid of fossils. A single, calcite-flanked pyrite laminae (<3 mm diam.), and a calcite-replaced crinoid columnal (<4 mm diam.) is present in the lower 2.0 feet. The interval is weakly calcareous in thin (<1.0 ft.) zones throughout.
7,932.2' - 7,945.0' (12.8')	Silty shales and silty mudstones, black (N1), grayish black (N2), olive black (5Y 2/1), and medium gray (N5), thinly to thickly laminated. The upper 3.0 feet consist of olive black and grayish black silty mudstones and silty shales; the remainder is black and grayish black silty shales. A few medium gray calcareous silty mudstone concretions and bands (<0.8 ft. thick) are present in the upper 2.0 feet. Calcite replaced crinoid columnals and nodules (<5 mm diam.) also occur in the upper 2.0 feet. Some pyrite mineralization is present within these nodules. Calcite laminae flanking a concretion are found at 7,934.3 feet. The interval is weakly calcareous.

<u>INTERVAL</u>	<u>DESCRIPTION</u>
7,945.0' - 7,952.3' (7.3')	The core within this interval was rubblized during coring and could not be retrieved.
7,952.3' - 7,954.6' (2.3')	Silty shales, black (N1), and grayish black (N2), thinly to thickly laminated. The interval is a uniform black and grayish black color, and varies slightly in the degree of fissility. The core is devoid of fossils and pyrite. Thin zones, <0.2 feet in thickness, which occur throughout the interval, are calcareous.
7,954.6' - 7,964.1' (9.5')	The core within this interval was rubblized during coring and could not be retrieved.
7,964.1' - 7,976.6' (12.5')	Silty shales, black (N1) and grayish black (N2), thinly to thickly laminated. The interval is a uniform black and grayish black color, and varies only slightly in the degree of fissility. Small (<1 mm diam.) gypsum (?) crystals occur within the upper 1/2. The interval is devoid of fossils and pyrite and is weakly calcareous.
7,976.6' - 7,984.9' (8.3')	Silty shales and silty mudstones, black (N1), grayish black (N2), and medium dark gray (N4), thinly to thickly laminated. The interval is predominantly black and grayish black silty shales, with a medium dark gray calcareous silty mudstone band (<0.3 ft. thick) present at ~7,983.5 feet. Pyrite crystals (<2 mm diam.) and laminae of disseminated grains occur within this band. The interval is devoid of fossils. The core is weakly calcareous in the upper 2.0 feet.
~7,984.9' - ~7,987.4' (~2.5')	The core within this interval was rubblized during coring and could not be retrieved. This footage is approximated due to the uncertainty of the exact thickness of the zone.
~7,987.4' - ~7,994.0' (~6.6')	Silty shales and silty mudstones, black (N1) and grayish black (N2), thinly to thickly laminated. The core is predominantly black and grayish black silty shales, varying only slightly in the degree of fissility. A small (30 mm wide by 60 mm long) calcareous grayish black calcite-flanked concretion is present at ~7,987.7 feet. The interval is devoid of fossils. Several calcite and pyrite mineralized natural joints (possibly a related set) are present within the interval. Only the aforementioned concretion and joints are calcareous.

INTERVALDESCRIPTION

~7,994.0' - ~8,008.9'
(~14.9')

Silty mudstones, silty shales, and limestones, grayish black (N2), dark gray (N3), and black (N1), thinly laminated to thin bedded. The core is predominantly grayish black and dark gray silty mudstones, with a few grayish black and dark gray silty shales and limestone zones (<3.0 ft. thick). A dark gray calcareous silty mudstone concretion (~35 mm wide by ~85 mm long) is present at 7,995.9 feet. A 1.0 foot thick zone containing horizontal, pyrite-mineralized burrow structures (5 mm diam. by 55 mm) is found between 7,995.0 and 7,996.0 feet. Mud-, calcite-, and pyrite-filled burrows also occur between 8,003.8 and 8,005.0 feet. Several mud-filled straight cephalopod casts (<8 mm diam. by 20 mm) occur between 8,000.0 and 8,001.0 feet. Numerous calcite-replaced shell fragments and crinoid columnals (9 mm diam.) are present between 8,003.0 and 8,005.0 feet. A zone containing disseminated pyrite grains and slightly pyrite-mineralized fractures occurs in the lower 2.0 feet of the core. The lower 1/2 of the interval is weakly to moderately calcareous.

A P P E N D I X B

SYMBOLS, TERMS, AND ABBREVIATIONS USED
IN FRACTURE LOGGING

EGSP-PENNSYLVANIA #4 - INDIANA COUNTY

Appendix B

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

(P): Planar
(CP): Curvilinear

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 curvilinear; of the same order of size as the core diameter.

(CI): Coring Induced

PF (Petal Fracture): An oblique fracture, usually planar or slightly curvilinear, 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 of 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 fracture chronology.

3. FRACTOGRAPHIC FEATURES:

Org.	(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 pre-existing surfaces orthogonally.
Fn. Hkl. Plm.	(Fine Hackle Plume): A very fine, wispy plumose structure on an otherwise featureless fracture face.
Inc. 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.

(M): 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).

A P P E N D I X C

FRACTURE LOGS

EGSP-PENNSYLVANIA #4 - INDIANA COUNTY

E.G.S.P. REVISED FRACTURE LOGGING FORMAT

CORING DATE: OCTOBER 1979 WELL: EGSP-PENNSYLVANIA #4, INDIANA COUNTY

LOG DATE: OCTOBER 1980 NATURAL FRACTURES

DEPTH NUMBER	EXTENT	LENGTH	LITHOLOGY	TERMIN ATIONS	CHAR- ACTER	STRIKE DIP	FRACTURE TYPE	MINERALIZATION	SLICK- ENDSIDES	FRACTOGRAPHIC FEATURES	COMMENTS
1	7121.4	1.3'	SLTY. MDST. 5Y4/1, N4	→	P	N 53° W	SPL.JT.	SLIGHT CALCITE			
	7122.7			M		80° SW					
	7129.4		SLTY. MDST.	M		N 57° W		SLIGHT			
2	7131.2	1.8'	5Y4/1, N3	M		80° SW	CMR.JT.	CALCITE			BIFURCATES AT 7130.2
	7135.7		A/A	M		N 56° W		SLIGHT			
	7137.9	2.2'	A/A	M		81° SW	SPL.JT.	CALCITE			
	7169.5		SLTY. MDST. N2	(M)		N 36° E			16°		
	7179.3		SLTY. MDST. N3, 5Y4/1	M		18° SE	FLT.	SLIGHT CALCITE	5.58° E		
	?			?		N 58° W	SPL.JT.				
	7180.5		SLTY. MDST. SLTSM.	? M		84° SW		SLIGHT CALCITE AND PYRITE			BIFURCATES AT 7181.8
6	7182.2	1.7'	N4, N3	M		79° SW	CMR.JT.	HEAVY CALCITE			
	7205.1		SLTY. MDST.	M		N 56° W					
	7207.0	1.9'	N3, 5Y4/1	M		85° SW	SPL.JT.				
	7216.1		SLTY. SH. SLTY. MDST.	M		N 52° W		V. SLIGHT			
	7218.5	2.4'	N3, N4	? →		85° SW		CALCITE			
	7223.4		SLTY. MDST.	M		N 54° W		SLIGHT			
	7225.3	1.9'	N4, N3	M		85° SW		CALCITE			
	7240.5		SLTY. MDST. SATL. SH.	M?		N 38° W		SLIGHT			
	7243.5	3.0'	5Y4/1, N2	M?		85° NE		CALCITE			
	7256.9		SLTY. SH. SLTY. MDST.	↗		N 52° W		V. SLIGHT CALCITE AND PYRITE			
	7257.6	0.7'	N2, N3	↘		85° NE		V. SLIGHT			
	7257.6		A/A	→		N 44° W		CALCITE			
	7258.5	0.9'	A/A	M		81° NE		CALCITE			
	7258.0		A/A	↘		N 49° W		V. SLIGHT			
	7258.8	0.8'	A/A	↘		80° NE		CALCITE			POSSIBLE COMPOUND
	7258.4		A/A	→		N 49° W		MODERATE			
	7258.9	0.5'	A/A	M		80° SW		CALCITE			JOINT SET
	7259.1		A/A	(M)		⊕	FLT.		0°		
	7258.8		A/A	→		N 50° SW		SLIGHT	N 65° E		
	7260.7	1.9'	A/A	M		85° NE	SPL.JT.	CALCITE			
	7261.7		A/A	↘		N 65° W		V. SLIGHT			
	7262.3	0.6'	A/A	↘		85° SW	SPL.JT.	CALCITE			

CORING DATE: <u>OCTOBER 1979</u>		E.G.S.P. REVISED FRACTURE LOGGING FORMAT		PAGE <u>2</u> OF <u>10</u>							
LOG DATE: <u>OCTOBER 1980</u>		WELL: <u>EGSP-PENNSYLVANIA #4, INDIANA COUNTY</u>		NATURAL FRACTURES							
NUMBER	DEPTH EXTENT	LENGTH	LITHOLOGY	TERMINATIONS	CHARACTER	STRIKE DIP	FRACTURE TYPE	MINERALIZATION	SLICK-ENDES	FRACTOGRAPHIC FEATURES	COMMENTS
18	7262.1 7262.7	0.6	SLTY. SH., SLTY. MDST. N2, N3	→ M	P	N 63° W 80° SW	SPL. JT.	SLIGHT CALCITE			
19	7263.7 7263.7	0.3	SLTY. MDST. N4, N5	↘ ↘	CP	N 65° E 75° NW		HEAVY CALCITE			↑
20	7263.4 7263.7	0.3	A/ A	↘ ↘	CP	N 73° W ~90°		HEAVY CALCITE			SEPTARIAN CRACKS IN A CONCRETION
21	7263.5 7263.7	0.2	A/ A	↘	CP	N 65° E ~90°		HEAVY CALCITE			BIFURCATION OF F19? ↓
22	7278.7 7279.3?	0.6?	SLTY. SH., SLTY. MDST. N2, N1	M ? →	P	N 20° W 80° SW		SLIGHT CALCITE			
23	7279.3? 7280.2?	0.9?		? ↘ ? →		N 15° W 85° SW		SLIGHT CALCITE			BIFURCATION OF F22?
24	7280.6 7280.7?	0.4		? → ? →		N 20° W 82° SW	↓	SLIGHT CALCITE			
25	7281.6 7313.0	1.4		M (M)		N 20° W ~90°	SPL. JT.	SLIGHT CALCITE	0° N 80° W		
26	7320.3			(M)	↓		FLT.		0°		
27	7325.2			(M)			FLT.		N 85° E 5°		
28	7327.9 7328.2	0.3		↘ ↘	CP	N 55° E 6° SE	FLT.	SLIGHT CALCITE	N 82° W		~ 5 RELAY JOINTS IN THE SET
29	7326.7 7328.2	0.1		M (M)	CP	N 38° W 73° SW	CMR JT.				POSSIBLE LOW ANGLE THRUST RELATED TO F's 29
30	7336.6 7337.0	0.4		↘ ↘	P	N 56° W 37° SW					
31	7337.9 7337.9	1.3		M ↘		N 52° E 6° SE					
32	7337.2 7338.6	1.4		↘ ↘		N 50° W 90°					
33	7337.2 7338.6	1.4		M ↘		N 13° W 85° SW					ORIENTATION QUESTIONABLE DUE TO RUBBLE ZONE ↓
34	7337.2 7338.6	1.4		↘ F35		N 17° W 85° SW	↓				

CORING DATE: OCTOBER 1979 **E.G.S.P. REVISED FRACTURE LOGGING FORMAT** PAGE 3 OF 10

LOG DATE: OCTOBER 1980 WELL: EGSP-PENNSYLVANIA #4, INDIANA COUNTY CORING INDUCED FRACTURES

NUMBER	DEPTH EXTENT	LENGTH	LITHOLOGY	TERMINATIONS	CHARACTER	STRIKE DIP	FRACTURE TYPE	MINERALIZATION	SLICK-ENDES	FRACTOGRAPHIC FEATURES	COMMENTS
35	7338.6 7339.5	0.9	SLTY. SH., SLTY. MDST. NI, NZ	F34 ?	P		CMP JT.	SLIGHT CALCITE			
36	7349.2 7351.9	2.7	SLTY. SH. NI	M M	P	N 57° W 80° SW	SPL. JT.	SLIGHT CALCITE			
37	7353.2		SLTY. SH., SLTY. MDST. NZ, NI	(M)	P	⊕	FLT.		PRESENT		HIGHLY POLISHED SURFACE LOW ANGLE THRU-FAST FAULT WITH DRAG PRESENT
38	7354.2 7354.6	0.2		M M	CP	N 20° E 35° NW	FLT.	HEAVY CALCITE	25° S 40° E		COMPOUND JOINT SET WITH CURVILINEAR SLICKS
39	7354.6 7356.4	1.8		F3B →	CP	N 75° W ~90°	CMP JT.	MODERATE CALCITE	0° TO S 10° W		PREDATE F 39 TWO PARALLEL JOINTS OFFSET AT 7356.0
40	7354.6			(M)	P	⊕	FLT.				
41	7355.3 7356.4	1.1		M →		N 70° W ~90°	CMP JT.	MODERATE CALCITE			
42	7356.7 7358.4	1.7		M ?		N 80° W 83° SW	SPL. JT.	SLIGHT CALCITE			
43	7360.7 7362.4	1.7		M M		N 62° W 81° SW	CMP JT.	SLIGHT CALCITE			THE ORIENTATION OF THESE FRACTURES IS QUESTIONABLE
44	7361.0 7363.0	2.0		M M		N 64° W 80° SW	CMP JT.				DUE TO RUBBLE ZONES, CAUSED BY THE CORE BARREL JAMMING.
45	7364.0 7364.1	0.1	SLTY. MDST., SLTY. SH. SY 4/1, NZ	(M)	→	N 20° E 78° SE	FLT.		14° S 72° E		
46	7364.6			(M)	P	⊕	FLT.		0°		
47	7365.3 7365.4	0.1		→ M	CP	N 34° E 60° NW	FLT.		S 40° E 45°		
48	7383.4 7383.9	0.5	SLTY. SH., SLTY. MDST. NZ, SY 2/1	M F49	P	N 30° W ~90°	CMP. JT.	SLIGHT CALCITE	N 38° W		PARALLEL JOINTS ABOUT F49 WITH A SMALL OFFSET
49	7383.6 7387.6	4.0		M M	P	N 38° W ~90°	CMP. JT.				
50	7390.3 7390.8	0.5		M M	~P	N 55° W 65° SW	SPL. JT.				
51	7416.8 7416.9	0.1		M →	CP	Variable	MGR. FLT.		PRESENT		~ 10 mm DISPLACEMENT

EG.S.P. REVISED FRACTURE LOGGING FORMAT

CORING DATE: OCTOBER 1979
OCTOBER 1980

WELL: EGSP-PENNSYLVANIA #4, INDIANA COUNTY

LOG DATE: _____

DEPTH EXTENT	LENGTH	LITHOLOGY	TERMINATIONS	CHARACTER	STRIKE DIP	FRACTURE TYPE	MINERALIZATION	SLICK- ENSIDES	FRACTOGRAPHIC FEATURES	COMMENTS
7432.7		SLTY MDST, SLTY SH. 5Y 2/1	(M)	CP	⊕	SPL.JT.	MODERATE CALCITE		↑	TOP FLANK OF A CONCRETION
7432.7		A	M	P	N 90° E ~ 90°					
7432.8	0.1	A	F 55		N 2° E ~ 90°					SEPTARIAN CRACKS IN A CONCRETION
7432.8	0.3	SLTY MDST, SLTY SH.	↙	CP						
7432.9			(M)	P	⊕					
7433.1			(M)	CP	⊕					BOTTOM FLANK OF A CONCRETION
7443.0			(M)	CP	⊕					
7443.3			(M)	CP	⊕					
7457.8		SLTY MDST 5Y 2/1, N2	(M)	CP	⊕	SPL.JT.		0°	↓	TOP FLANK OF A CONCRETION
7462.8			(M)	P	⊕	MCR,FLT.		S 62° W		
7462.8			(M)		⊕	FLT.	MODERATE CALCITE	0°		
7464.8			(M)		⊕	FLT.	SLIGHT CALCITE AND PYRITE	0°		
7464.8			(M)		⊕	FLT.	MODERATE	~ N 70° W		
7464.8			F 61		N 61° W					
7464.9	0.1		F 63		85° NE	SPL.JT.	CALCITE			
7464.9			(M)		N 41° E	FLT.	HEAVY CALCITE	11°		
7465.0			(M)		17° NW	FLT.	MODERATE CALCITE	S 36° E		LOW ANGLE THRUST FAULT
7465.0			(M)		⊕	FLT.	MODERATE CALCITE	PRESENT		
7465.0			F 64		N 4° W		V. SLIGHT			
7465.4	0.4		→		~ 90°	SPL.JT.	CALCITE			CLASTIC FILLED FRACTURE
7465.7			(M)		N 9° W	SPL.JT.	MODERATE CALCITE			
7469.0			(M)		9° NE	SPL.JT.	CALCITE			
7469.2	0.2	SLTY SH. SLTSP. N2	M	↘	N 36° E		SLIGHT			
7469.1			F 68		20° NW	FLT.	CALCITE			
7469.1		A	M		N 49° E	FLT.	SLIGHT	30°		
7469.2	0.1	A	M	P	33° NW	FLT.	CALCITE	N 50° W		~ 10MM DISPLACEMENT

EG.S.P. REVISED FRACTURE LOGGING FORMAT

CORING DATE: OCTOBER 1979
LOG DATE: OCTOBER 1980

WELL: EGSP-PENNSYLVANIA #4, INDIANA COUNTY

NUMBER	DEPTH EXTENT	LENGTH	LITHOLOGY	TERMINATIONS	CHARACTER	STRIKE DIP	FRACTURE TYPE	MINERALIZATION	SLICK-ENDES	FRACTOGRAPHIC FEATURES	COMMENTS
69	7471.5 7471.6	0.1	SILTY. SH., SILTSH. N2, N1	M M	~P	N 33° E 18° NW	FLT.	SLIGHT CALCITE	16° S 45° E		
70	7475.5 7475.7	0.2		F69 →	P	N 75° W ~82° SW	CMP. JT.	SLIGHT CALCITE			
71	7475.6 7475.7	0.1		F69 →	P	N 69° W ~90°	CMP. JT.	SLIGHT CALCITE			
72	7476.6		SLTY. SH. N2, N1	→	CP	N 50° E 40° NW	FLT.	V. SLIGHT CALCITE	PRESENT		
73	7476.6			(M)	P	⊕	SPL. JT.	MODERATE CALCITE			
74	7477.5 7477.8	0.3		↗	P	N 54° W 70° SW	SPL. JT.	SLIGHT CALCITE			
75	7480.1 7480.6	0.5		→	P	N 46° W 14° NE	SPL. JT.	MODERATE CALCITE			
76	7480.8 7481.0	0.2	SLTY. SH. N2	M	CP	N 14° W 35° SW	FLT.	MODERATE CALCITE	18° S 40° E		
77	7496.2 7496.4	0.2	SLTY. SH., SILTY. MDSZ N1, N2	M	CP	VARIABLE N 40° E			PRESENT 15°		SOFT SEDIMENT DEFORMATION SURROUNDING A CONCRETION A / A
78	7496.4			M	CP	N 20° SE			S 50° E		
79	7496.9 7497.1	0.2		M	P	N 81° W 35° NE		V. SLIGHT CALCITE			
80	7497.2 7497.5	0.3		M	P	N 34° E 60° NW	↓	MODERATE CALCITE AND PYRITE			
81	7497.8 7498.0	0.2		M	P	N 4° E 48° NW	FLT.	MODERATE CALCITE	WEAK		
82	7498.4 7498.6	0.2		M	P	N 52° W ~90°	SPL. JT.	HEAVY CALCITE			
83	7498.7 7498.8	0.1		↖	CP	N 54° W 43° NE	FLT.	SLIGHT CALCITE	32° S 60° W		LOW ANGLE THREAT FAULT POSSIBLE FLANK OF A CONCRETION
84	7503.9 7503.1	0.2		M	CP	N 52° E 31° NW	SPL. JT.	SLIGHT CALCITE			
85	7514.1 7514.9	0.8	SLTY. SH. S3, N1	↖	P	N 2° E 80° NW	↓	V. SLIGHT CALCITE			

NUMBER	DEPTH EXTENT	LENGTH	LITHOLOGY	TERMINATIONS	CHARACTER	STRIKE DIP	FRACTURE TYPE	MINERALIZATION	SLICK-ENDES	FRACTOGRAPHIC FEATURES	COMMENTS
86	7516.2 7518.5	2.3'	SLTY. MDST. N4, N3	M M	P	N 68° W 85° SW	SPL. JT.	V. HEAVY CALCITE AND DOLOMITE			EXTRE OPEN FRACTURE FILLING ~ 10 MM WIDE, 3 MM DEPTH
87	7519.4 7521.0	1.6'		M M?	P	N 12° E 80° SE		A / A			HIGH ANGLE REVERSE FAULT NORTHWEST SIDE DOWN
88	7520.8 7524.2	3.4'		M M	P	N 5° E 84° NW		A / A			(2 PHASES OF MINERALIZATION)
89	7523.7 7523.8	0.1'		FBR M	CP	N 5° W 25° SW		HEAVY CALCITE			
90	7529.0 7529.6	0.6'	SLTY. MDST, SHLY. MDST N2	M →	P	N 45° W 75° SW	CMP. JT.	MODERATE CALCITE			
91	7529.4 7530.4	1.0'	SLTY SH. SLTY. MDST N1, N2	→ M?		N 42° W 78° SW					3 RELAY JOINTS IN THE SPT
92	7530.1 7530.5	0.4'		→ M?		N 42° W 78° SW					
93	7530.8			(M)		⊙	FLT.		0°		
94	7539.8			(M)		⊙			N 90° E		
95	7539.9			(M)		⊙			0°		
96	7542.3 7542.4	0.1'	SLTY GH, SLTY MDST N1, N2	→ M	CP	N 39° E 36° NW		SLIGHT CALCITE AND PYRITE			
97	7542.4 7542.5	0.1'		M F98	P	N 44° W ~90°	SMP. JT.	SLIGHT CALCITE			
98	7542.5 7543.0	0.5		↘ M	CP	N 48° E 40° NW	FLT.	SLIGHT PYRITE			POSSIBLE 40 MM OPENING PYRITE AND MUDSTONE MATRIX FILLING
99	7543.5			(M)	CP	⊙	FLT.	SLIGHT CALCITE AND PYRITE	0°		UPPER FLANGE OF A CONCRETION
100	7543.0 7543.1	0.1		M M	CP	N 40° E 25° NW	SPL. JT.	SLIGHT CALCITE			
101	7553.2 7553.3	0.1		M F102	~P	N 22° E 40° SE		SLIGHT CALCITE AND PYRITE	35°		LOW ANGLE THRUST FAULT
102	7553.3			(M)	CP	N 18° E 20° NW	CMP. JT.	SLIGHT CALCITE AND PYRITE	15°		

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NUMBER	DEPTH EXTENT	LENGTH	LITHOLOGY	TERMINATIONS	CHARACTER	STRIKE DIP	FRACTURE TYPE	MINERALIZATION	SLICK-ENDESIDES	FRACTOGRAPHIC FEATURES	COMMENTS		
103	7555.5 7557.7 7556.0	2.2'	SILTY MDST N3, N2	→ M M	P P	N 88° W ~90° ⊕	SPL. JT. FLT.	SLIGHT CALCITE	0° S 73° E				
104	7558.0 7556.1	0.3'		M M	CP	N 86° W ~90°	SPL. JT.	SLIGHT CALCITE					
106	7556.1 7556.3	0.2'		F 105 →	CP	N 54° W ~90°	SPL. JT.	SLIGHT CALCITE					
107	7557.9 7558.0	0.1'		M	CP	N 24° E 15° NW	FLT.		14° S 72° E		LOW ANGLE THRUST FAULT SLICKS OFF SET BY F108		
108	7557.9 7558.0	0.1'		↘	P	N 64° W ~90°	SPL. JT.	SLIGHT CALCITE					
109	7558.0 7558.1 7558.2			M M M		N 8° E 30° SE ⊕	FLT.	MODERATE CALCITE	27° S 56° E 10°				
110	7559.8 7560.3	0.5'		M F 113		N 60° W 80° SW ⊕	FLT. SPL. JT.	SLIGHT CALCITE AND PYRITE	0°				
112	7560.2 7560.3	0.1'		M		N 13° E 24° NW ⊕	FLT.	V. SLIGHT CALCITE	N 54° W 21° N 50° W				
113	7560.3 7560.7	1.4'	SILTY MDST, SILTY SH. N3, N2	M ?		N 50° W 80° SW	CMP. JT.	SLIGHT CALCITE AND PYRITE					
115	7560.6 7562.0	1.4'		M M		N 56° W 80° SW	CMP. JT.	SLIGHT CALCITE AND PYRITE			PARALLEL TO F114		
116	7566.2 7566.4	0.2'		↘		N 50° W 81° SW	SPL. JT.	MODERATE CALCITE					
117	7572.1 7573.6	1.5'		↘		N 52° W ~90°		SLIGHT CALCITE			QUESTIONABLE CORRELATION TIME TO RUBBLE ZONE		
118	7573.7 7574.9	0.7'		↘		N 50° W 75° SW		SLIGHT CALCITE					
119	7616.1 7617.4	1.3'	SILTY SH., SILTY MDST N3, N2	? → M		N 24° E 78° NW	↓ ↓	SLIGHT CALCITE					

CORING DATE: OCTOBER 1979		EG.S.P REVISED FRACTURE LOGGING FORMAT				PAGE 8 OF 10					
LOG DATE: OCTOBER 1980		WELL: EGSP-PENNSYLVANIA #4, INDIANA COUNTY				NATURAL FRACTURES					
NUMBER	DEPTH EXTENT	LENGTH	LITHOLOGY	TERMINATIONS	CHARACTER	STRIKE DIP	FRACTURE TYPE	MINERALIZATION	SLICK-ENDES	FRACTOGRAPHIC FEATURES	COMMENTS
120	7623.0 7623.9	0.9	SLTY. SH. SLTY. MDST. N3, N2	→ ? M	P	N 51° W 75° SW	SPL. JT.	SLIGHT CALCITE			FOOTAGE MEASURE DUE TO RUBBLE ZONE
121	7652.0 7654.0	2.0	A/ A	M		N 44° W 85° SW	SPL. JT.	SLIGHT CALCITE			
122	7668.1 7672.8		SLTY. SH. N2	(M)		N 74° E 5° SE	FLT.	SLIGHT CALCITE	3° N 75° W 8°		
123	7679.2 7679.5	0.2	A/ A	(M)		N 54° E 12° SE	↓		5.74° E		
124	7680.9 7681.0	0.1	SLTY. MDST. SLTY. SH. N3, 5YR 3/1	(M)		N 40° E 38° SE	↓		25° N 90° E	AND 35° N 38° W	TWO SETS OF SLICKENSIDES
125	7705.9 7708.4	2.5	A	M		N 51° E 39° SE	↓		30° S 65° E		LOW ANGLE THRUST FAULTS
126	7721.5 7723.5	2.0	SLTY. MDST. SLTY. SH. N3, N4	M		N 40° W 85° SW	SPL. JT.	SLIGHT CALCITE			
127	7722.1 7724.3	2.2		M		N 57° W 82° SW	OMP. JT.				↑ PARALLEL JOINT SET ↓
128	7740.5 7753.5	3.0		M		N 54° W 83° SW	OMP. JT.				
129	7813.0 7813.5	0.3	SLTY. MDST. N3	M		N 56° W 85° SW	SPL. JT.				
130	7813.4 7819.0	5.6	A/ A	M		N 77° W ~90°	SPL. JT.				
131	7876.2 7876.4	0.2	SLTY. MDST. SLTY. SH. N3	→ M	CP	N 80° W 88° SW	SPL. JT.				TWO PARALLEL PLANES IN INTERVAL
132	7885.9 7886.8	0.2	A/ A	(M)			MCR. FLT.	SLIGHT CALCITE	PRESENT		↑ THESE FRACTURES COULD NOT BE ORIENTATED DUE TO THE EXTENSIVE POORER CHIPPING AND RUBBLE ZONES WITHIN THE INTERVAL.
133	7887.0 7894.5	0.2	A/ A	→ (M)	CP		FLT.		PRESENT		
134	7911.1 7911.8	0.7	SLTY. SH. N1, N2	→ M	P		FLT.		PRESENT		
135			A/ A	→ M	P		SPL. JT.				
136			A/ A	→ M	P		FLT.				

NUMBER	DEPTH EXTENT	LENGTH	LITHOLOGY	TERMINATIONS	CHARACTER	STRIKE DIP	FRACTURE TYPE	MINERALIZATION	SLICK-ENDES	FRACTOGRAPHIC FEATURES	COMMENTS
137	7914.4 7917.3	2.9'	SLTY. SH. N1.N2	M	P	—	SPL.JT.	SLIGHT CALCITE			↑
138	7915.7 7918.0	2.3'	—	M	—	—	SPL.JT.	SLIGHT CALCITE			
139	7920.6		—	(M)	—	⊕	FLT.	SLIGHT CALCITE	PRESENT		THESE FRACTURES COULD NOT BE ORIENTATED DUE TO THE EXTENSIVE POKER CHIPPING AND BURBLE ZONES WITHIN THE INTERVAL.
140	7920.3 7922.9	2.1'	—	?	—	—	SPL.JT.	SLIGHT CALCITE			
141	7925.5 7928.6	0.1'	SLTY. SH., SILTY MDS N1.N2	M	CP	—	MCR.FLT.	SLIGHT CALCITE	PRESENT		↓
142	7925.6 7925.6		—	(M)	P	⊕	FLT.	SLIGHT CALCITE			
143	7934.8 7935.0	0.2'	—	M	CP	N 0° E 35° W	FLT.	MODERATE CALCITE	33° N 80° W		
144	7935.1 7935.2	0.1'	—	M	CP	N 6° E 30° NW	FLT.	MODERATE CALCITE	28° N 90° W		
145	7937.5 7938.2	0.7'	—	→	CP	—	SPL.JT.	MODERATE CALCITE			↑
146	7938.2		—	(M)	P	—	FLT.		PRESENT		
147	7964.6		SLTY. SH. N1.N2	(M)	—	—	MCR.FLT.		PRESENT		THE DEPTHS OF THESE FRACTURES ARE UNCERTAIN; AND THEY COULD NOT BE ORIENTATED NAE IN THE EXTENSIVE POKER CHIPPING AND BURBLE ZONES WITHIN THE INTERVAL.
148	7976.1 7976.2	?	—	→	—	—	SPL.JT.	V. SLIGHT CALCITE			
149	?	?	—	M	—	—	—	SLIGHT CALCITE			
150	?	?	—	M	—	—	—	—			
151	?	?	—	M	—	—	—	—			
152	?	?	—	M	—	—	—	—			
153	7976.9		—	(M)	—	⊕	FLT.		0° N 60° W		↓

E.G.S.P. REVISED FRACTURE LOGGING FORMAT

WELL: EGSF-PENNSYLVANIA #4, INDIANA COUNTY

NATURAL FRACTURES

CORING DATE: OCTOBER 1979

LOG DATE: OCTOBER 1980

NUMBER	DEPTH EXTENT	LENGTH	LITHOLOGY	TERMINATIONS	CHARACTER	STRIKE DIP	FRACTURE TYPE	MINERALIZATION	SLICKENSIDES	FRACTOGRAPHIC FEATURES	COMMENTS
154	7977.1 7977.3	0.2	SLTY SH. SLTY MDST N1, N2	M	CP	N 35° E 38° NW	FLT	SLIGHT CALCITE	36° N 48° W		
155	7977.5 7977.6 7977.8	0.1		M	CP	N 45° E 30° SE		SLIGHT CALCITE	25° S 42° E 30°		
156	7978.0			(M)	P	N 72° E 8° SE			S 58° E 5°		
157	7978.0			(M)	CP	N 43° E 8° SE		SLIGHT CALCITE	S 52° E		ABUTTING JOINTS ↓
158	7978.0 7978.5	0.5		↗		N 52° W ~90°	CMP. JT.				
159	7978.0 7978.5	0.5		↘		N 18° W 45° NE	CMP. JT.				
160	7983.5 7984.5	1.0		↘			SPL. JT.				THE DEPTHS OF THESE FRACTURES ARE UNCERTAIN, AND THEY COULD NOT BE ORIENTATED DUE TO THE EXTENSIVE ASKER CHIPPING AND RUBBLE ZONES WITHIN THE INTERVAL
161	7986.0 7988.0	~2.0		→							
162	7989.4 7991.1	1.7		M →	P			SLIGHT CALCITE AND PYRITE			
163	7991.7 7995.6	3.9		M →	CP	N 60° W ~90°	CMP. JT.	HEAVY CALCITE			~4 JOINT PLANES IN INTERVAL
164	7993.0			(M)	P		FLT.		PRESENT		
165	8002.5 8005.0	2.2	SLTY MDST, SLTY N4	M	~P	N 22° W 82° NE	CMP. JT.	MODERATE CALCITE			~4 JOINT PLANES IN INTERVAL
166	~8006.0 ~8007.0	1.0	SLTY MDST N4	→	P	N 33° W 80° NE	CMP. JT.	MODERATE CALCITE			
167	?	?	A/A	?	CP	?	CMP. JT.	MODERATE CALCITE			
168	?	?	A/A	?	P		FLT		PRESENT		

DEPTH NUMBER	EXTENT	LENGTH	LITHOLOGY	TERMINATIONS	CHARACTER	STRIKE DIP	FRACTURE TYPE	MINERALIZATION	SLICK- ENSIDES	FRACTOGRAPHIC FEATURES	COMMENTS
1	7157.1	0.8'	?	?	?	?	SEE COMMENTS				RUBBLE ZONE, CORE LOSS
2	7157.9	0.2'	SLTY. MDST. N3 S57W	↙	~P	N35°W ~90°	SEE COMMENTS				PLANAR FRACTURE RELATED TO F2
3	7204.2		A/A	↙	~P	N37°W ~90°	SEE COMMENTS				RUBBLE ZONE, CORE LOSS
4	7204.5		A/A				SEE COMMENTS				RUBBLE ZONE, CORE LOSS
5	7247.8	2.2'	?				SEE COMMENTS				RUBBLE ZONE CORE LOSS
6	7270.4	0.1'	SLTY. MDST. N4 N3	⊙	CP		TF				TORSIONAL FRACTURE CORE LOSS
7	7271.3	0.4'	A/A	⊙	CP		TF				RUBBLE ZONE CORE LOSS
8	7276.1	0.1'	SLTY MDST, SIL MDST N2 N1	⊙	CP		TF				RUBBLE ZONE CORE LOSS
9	7336.2		SLTY MDST, MDST N4 N3	⊙	P		DCS		MODERATE		RUBBLE ZONE CORE LOSS
10	7358.7		SLTY MDST, SIL MDST N4	⊙	CP		DCS		PRESENT		RUBBLE ZONE CORE LOSS
11	7428.0	0.3'	A/A	M	CP		TF				RUBBLE ZONE CORE LOSS
12	7496.2	0.6'	SLTY MDST, SIL MDST N4 N5	M	CP		TF				RUBBLE ZONE CORE LOSS
13	7682.0	0.6'	SLTY MDST N4	M			SEE COMMENTS				RUBBLE ZONE CORE LOSS
14	7713.2	0.3'	A/A	M	CP		TF				RUBBLE ZONE CORE LOSS
15	7741.5	1.2'	?	?	?	?	SEE COMMENTS				RUBBLE ZONE CORE LOSS
16	7748.2	0.2'	A/A	→	P	N39°E 75°NW					PLANAR FRACTURE
17	7840.4	0.4'	A/A	M	CP		TF				PLANAR FRACTURE

EASTERN GAS SHALES PROJECT

DISC FRACTURE FREQUENCY LOG
PENNSYLVANIA #4, INDIANA COUNTY

<u>Bottom of Interval</u>	<u>Frequency Per Foot</u>	<u>Bottom of Interval</u>	<u>Frequency Per Foot</u>	<u>Bottom of Interval</u>	<u>Frequency Per Foot</u>
7,105	3.4	7,315	11.6	7,525	8.0
7,110	2.8	7,320	9.6	7,530	15.6
7,115	2.6	7,325	12.0	7,535	12.6
7,120	3.8	7,330	11.4	7,540	18.2
7,125	3.4	7,335	12.8	7,545	14.2
7,130	4.2	7,340	12.0	7,550	13.0
7,135	3.8	7,345	12.6	7,555	12.0
7,140	3.0	7,350	13.8	7,560	15.4
7,145	3.2	7,355	8.2	7,565	11.2
7,150	3.0	7,360	15.8	7,570	7.4
7,155	2.2	7,365	12.6	7,575	11.2
7,160	5.4	7,370	10.4	7,580	5.2
7,165	5.0	7,375	6.6	7,585	2.2
7,170	6.2	7,380	12.0	7,590	2.0
7,175	3.2	7,385	9.2	7,595	2.8
7,180	2.4	7,390	15.4	7,600	2.8
7,185	3.8	7,395	10.0	7,605	1.0
7,190	3.0	7,400	15.4	7,610	2.2
7,195	2.8	7,405	9.0	7,615	2.2
7,200	3.8	7,410	11.4	7,620	13.6
7,205	5.4	7,415	19.6	7,625	Lost Core
7,210	8.6	7,420	17.6	7,630	7.0
7,215	11.8	7,425	8.4	7,635	11.0
7,220	13.6	7,430	7.4	7,640	7.6
7,225	12.2	7,435	5.0	7,645	10.0
7,230	5.2	7,440	5.8	7,650	10.0
7,235	10.0	7,445	4.4	7,655	5.8
7,240	4.0	7,450	7.6	7,660	7.2
7,245	6.4	7,455	7.0	7,665	9.0
7,250	9.6	7,460	7.0	7,670	7.4
7,255	13.2	7,465	8.2	7,675	6.0
7,260	8.8	7,470	10.8	7,680	4.2
7,265	5.4	7,475	16.0	7,685	6.8
7,270	Rubblized	7,480	10.4	7,690	6.8
7,275	Rubblized	7,485	16.6	7,695	9.8
7,280	9.0	7,490	16.8	7,700	6.8
7,285	16.2	7,495	19.0	7,705	5.4
7,290	18.0	7,500	15.2	7,710	8.4
7,295	13.6	7,505	16.8	7,715	6.2
7,300	14.8	7,510	23.6	7,720	5.6
7,305	12.6	7,515	17.4	7,725	8.0
7,310	15.6	7,520	14.6	7,730	4.4

EASTERN GAS SHALES PROJECT

DISC FRACTURE FREQUENCY LOG
PENNSYLVANIA #4, INDIANA COUNTY

<u>Bottom of Interval</u>	<u>Frequency Per Foot</u>	<u>Bottom of Interval</u>	<u>Frequency Per Foot</u>
7,735	9.0	7,980	12.0
7,740	10.0	7,980 - 7,990	Rubblized
7,745	15.0	7,995	7.4
7,750	8.2	8,000	3.2
7,755	9.6	8,005	5.2
7,760	12.4	8,010	Rubblized
7,765	7.8		
7,770	8.0		
7,775	8.4		
7,780	13.0		
7,785	1.8		
7,790	2.8		
7,795	1.4		
7,800	3.4		
7,805	3.8		
7,810	3.2		
7,815	3.6		
7,820	7.6		
7,825	3.2		
7,830	1.8		
7,835	3.0		
7,840	4.6		
7,845	2.8		
7,850	2.2		
7,855	2.4		
7,860	1.8		
7,865	2.0		
7,870	4.0		
7,875	2.8		
7,880	12.4		
7,885	16.4		
7,890	10.8		
7,895	11.6		
7,900	Lost Core		
7,905	Lost Core		
7,910	13.4		
7,915	11.4		
7,920	14.0		
7,925	9.2		
7,930	7.2		
7,935	5.4		
7,935 - 7,975	Rubblized		

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U. S. DEPARTMENT OF ENERGY
MORGANTOWN ENERGY TECHNOLOGY CENTER
EASTERN GAS SHALES PROJECT

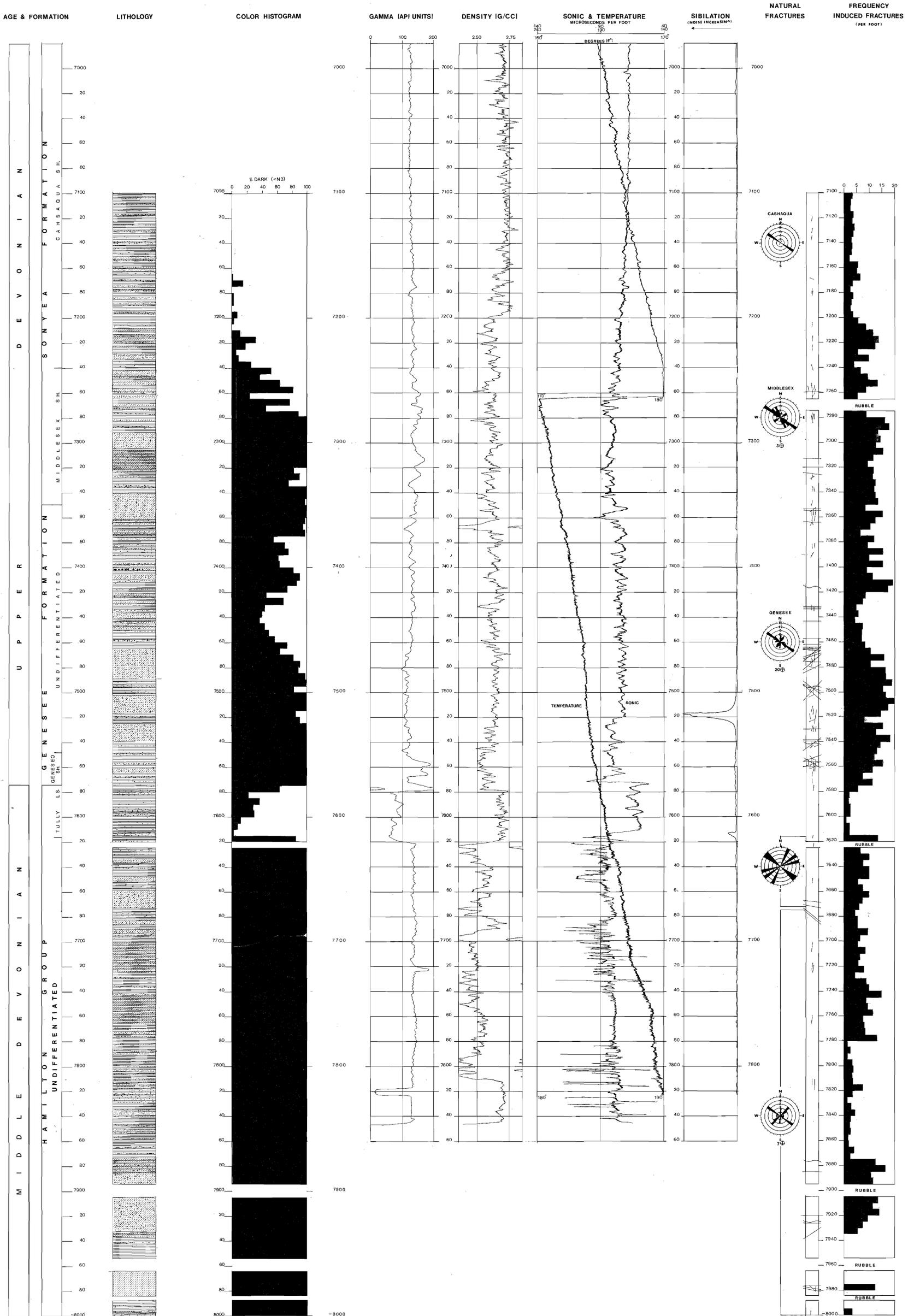
EGSP-PENNSYLVANIA NO.4, INDIANA CO.

WELL: GLENN McCALL #5

A.P.I. NO. 37-063-25073

DRILLING COMPLETED: NOVEMBER 20, 1979

DRAWN: FEBRUARY 1981



LEGEND

- | | | | |
|--|----------------|--|----------------|
| | MUDSTONE | | SILTY MUDSTONE |
| | SILTY SHALE | | SILTSTONE |
| | SHALY MUDSTONE | | LIMESTONE |