

CLIFFS MINERALS, INC.  
EASTERN GAS SHALES PROJECT  
PENNSYLVANIA #1 WELL, MCKEAN COUNTY

PHASE II REPORT  
PRELIMINARY LABORATORY RESULTS  
MAY 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 technology for production from shale gas reservoirs.
3. To stimulate interest among commercial gas suppliers in the concept of producing large quantities of gas from low-yield shallow Devonian Shale wells.

During February of 1979, the Department of Energy and Minard Run Oil Company funded the drilling/coring of the Minard Run Exploration #1 well in McKean County, Pennsylvania, hereafter referred to as EGSP-Pennsylvania #1. 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 McKean County well, designated EGSP-Pennsylvania #1.

## 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 #1 well. Data are acquired from several sources for analysis. At the well site, a suite of geophysical well logs was run, which include the following:

## GEOPHYSICAL LOGS

Borehole Compensated Sonic	Gamma Ray
Caliper	Fracture Identification Log
Temperature Log	Sibilation
Dual Induction	Compensated Neutron
Compensated Density	Spherically Focused Log
Coriband	Mechanical Properties Log

At the EGSP Core Laboratory, the EGSP-Pennsylvania #1 core was laid out, washed, measured, oriented, and photographed prior to description and sampling. Characterization work performed includes photographic logs, detailed lithologic logs, fracture logs (both natural and induced types), core color variation, and stratigraphic interpretation of the cored intervals. In addition, physical property samples were selected and prepared for testing. These samples were tested by Michigan Technological University under subcontract. Physical properties data obtained from specimen tests include:

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

### 3.0 LABORATORY PROCEDURES

#### 3.1 Review of Geophysical Logs:

One of the first laboratory procedures performed on the EGSP-Pennsylvania #1 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 intervals. 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 on these logs. Consequently, formation boundaries and thicknesses are, in some cases, more readily determined from gamma ray and density logs than from visual examination of the core itself.

Several other logs often provide information useful for core characterization. The fracture identification log and sonic log frequently indicate the occurrence of zones of structural discontinuity (joints, faults, concretions, zones of increased friability, etc.) within the core. The Shallow/Deep Laterolog measures resistivity values of the rock, and is useful in locating zones of hydrocarbon saturation.

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

### 3.2 Photographic Log:

After the EGSP-Pennsylvania #1 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.

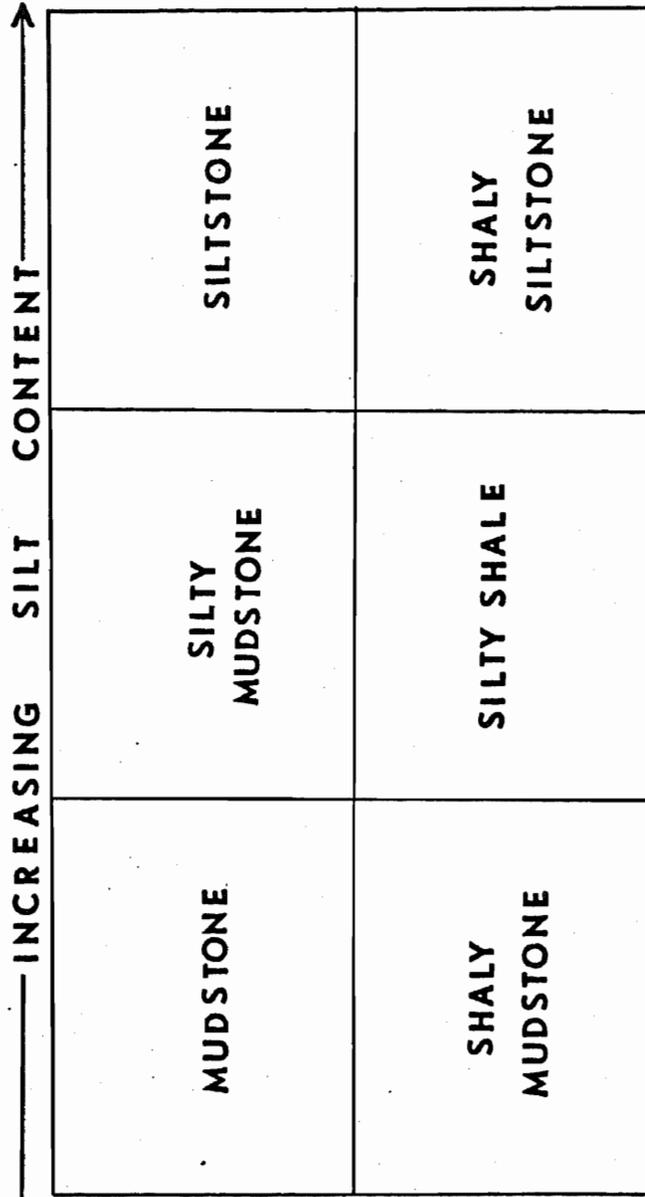
### 3.3 Detailed Lithologic Log:

After detailed visual examination, the EGSP-Pennsylvania #1 core was described in intervals which vary from about 5 to 15 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 content.

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



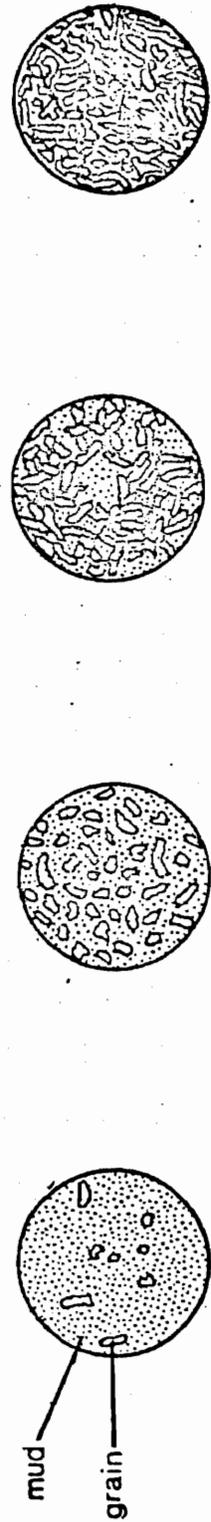
**NON-FISSILE**

**FISSILE**

FIGURE 1

TEXTURAL CLASSIFICATION OF FINE CLASTIC SEDIMENTARY ROCKS

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



BIOLOGICALLY CEMENTED GRAINS: Boundstone  
 NO RECOGNIZABLE TEXTURE: Crystalline Limestone

FIGURE 2  
 TEXTURAL CLASSIFICATION OF LIMESTONES

### 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 #1 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 the 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 pre-existing fracture surface orthogonally.
3. Hackle marks becoming progressively coarser in the vicinity of the core margin or pre-existing fracture surface.
4. Twist hackle originating near the core margin or pre-existing 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 pre-existing fracture surface.

## NATURAL FRACTURES EXHIBIT THE FOLLOWING CHARACTERISTICS

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

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

### 3.7 Measurement of Shore Hardness:

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

## 4.0 REPORTING OF RESULTS

A correlation chart has been compiled at a scale of 1 inch to 50 feet which provides a visual display of the following data recorded for the EGSP-Pennsylvania #1 core:

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

The correlation chart accompanies this report as an enclosure.

Discussions of core stratigraphy, lithology, and the occurrence of fractures are provided in Section 5.0. 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 #1 core has been concluded, a final (Phase III) report will be issued 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-proof barrier and packaged in 3-foot boxes for temporary

archiving at the EGSP Core Laboratory. Following a 90-day period the Pennsylvania core will be transferred to the Pennsylvania Geological Survey.

## 5.0 DISCUSSION OF RESULTS

### 5.1 General:

The EGSP-Pennsylvania #1 well is located 10 miles south of Bradford in Lafayette Township, McKean County, Pennsylvania (Figure 3). Specific site location is as follows: Cyclone Quadrangle, 2900 feet east of Longitude 78°37'30". 1100 feet south of Latitude 41°52'30".

Coring of the Pennsylvania #1 well began on February 8 and was completed on February 22, 1979. A conventional Ideco rotary rig equipped with a sixty-foot core barrel was used. The hole was cored without a plastic core barrel liner due to the small hole requirements of the owner. The coring medium was soap and water without stiff foam additives. Numerous zones of rubble (coring-induced) and poker chips, which hampered coring, are present throughout. Coring was also hampered by extreme weather conditions; snow and temperatures to -20°F.

### 5.2 Geologic Setting:

The EGSP-Pennsylvania #1 well site is situated in north-central McKean County on a north facing exposure of Permian-, Mississippian- and Devonian-age strata. Ridges in this area are capped by the sandstones, conglomerates and a few thin shales and coals of the Permian Pottsville Group. Gray, hard, massive cross-bedded sandstones and conglomerates of the Mississippian Pocono Group, and greenish gray to gray shales, siltstones and sandstones of the Devonian Oswayo Formation

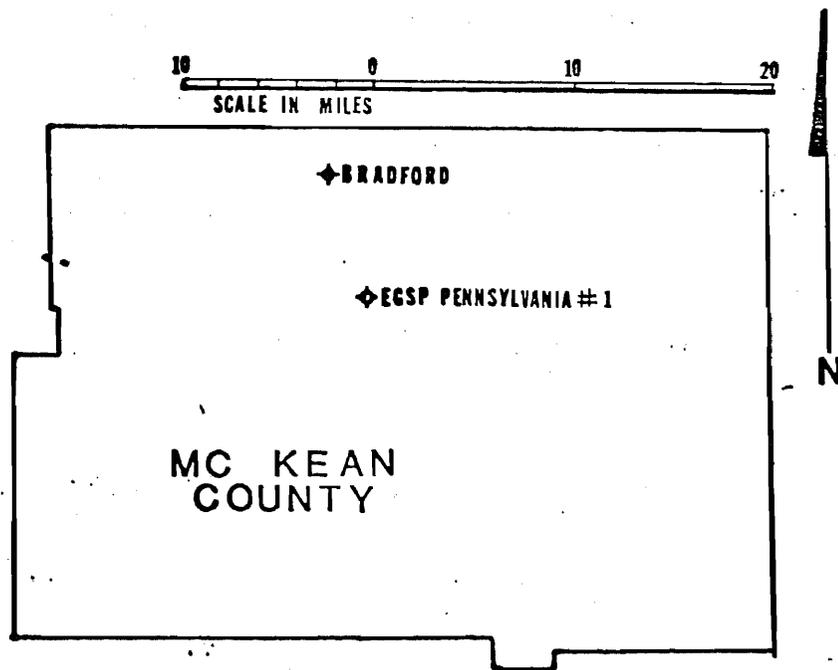
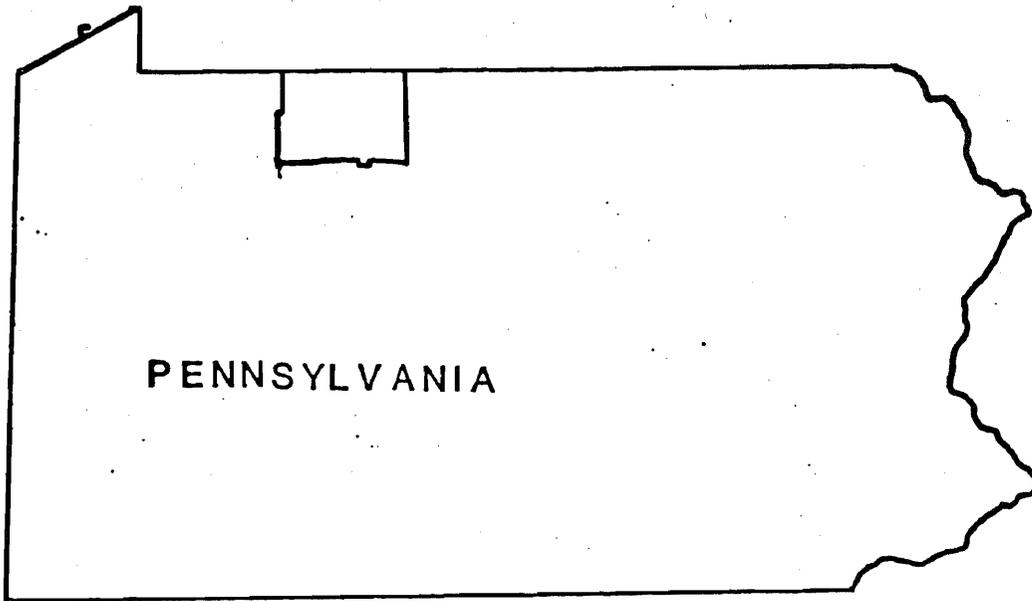


FIGURE 3

LOCATION OF THE EGSP-PENNSYLVANIA #1 WELL, MCKEAN COUNTY,  
PENNSYLVANIA

compose the valley walls. Minard Run, the local drainage feature, exposes outcrops containing the red, gray and brown shales and sandstones of the Cattaraugus Formation, and the gray to olive brown shales, graywackes and sandstones of the Devonian Marine Beds.

Although some minor anticlinal/synclinal folding probably does occur in the Bradford area, much of the major folding and faulting occurs to the east. Topographically, the area is rugged; differences in elevation of 500 feet between valley floors and ridge tops are common.

### 5.3 Stratigraphy

A total of 741 feet of core was cut from two intervals within the EGSP-Pennsylvania #1 well. A 58-foot core was cut from 3,470 to 3,528 feet for the purpose of identifying the contact between the Angola Shale and the Rhinestreet Shale. The interval from 3,528 to 4,530 feet was plug drilled. Coring resumed at 4,530 feet in the Middlesex Shale and was terminated at 5,213 feet in the Marcellus Shale. T.D. was to have been in the Onondaga Limestone, but high drill pressures (600-650 PSI) and caving problems caused early termination of drilling. Formations encountered in the well are summarized in Table 1, which is followed by a summary description of each formation or member. The stratigraphic nomenclature used in the report is patterned after that used by Piotrowski and Krajewski (1977), and Roen, Wallace and De Witt (1978).

TABLE 1  
FORMATION THICKNESSES

<u>Formation</u>	<u>Depths</u>	<u>Thickness</u>	<u>Depths Cored</u>
West Falls Formation:			
Angola Shale	C.P.-3,485.3'	---	3,470.0'-3,485.3'
Rhinstreet Shale	3,485.3'-4,371.0'	885.7'	3,485.3'-3,528.0'
Sonyea Formation:			
Cashaqua Shale	4,371.0'-4,486.0'	115.0'	-----
Middlesex Shale	4,486.0'-4,553.0'	67.0'	4,530.0'-4,553.0'
Genesee Formation:			
Undifferentiated	4,553.0'-4,734.0'	181.0'	4,553.0'-4,734.0'
Geneseo Shale	4,734.0'-4,768.0'	34.0'	4,734.0'-4,768.0'
Hamilton Group:			
Moscow Shale	4,768.0'-4,808.7'	40.7'	4,768.0'-4,808.7'
Ludlowville Shale	4,808.7'-5,101.0'	292.3'	4,808.7'-5,101.0'
Skaneateles Shale	5,101.0'-5,176.0'	75.0'	5,101.0'-5,176.0'
Marcellus Shale	5,176.0'-T.D.	---	5,176.0'-5,213.0'

West Falls Formation

Angola Shale:

The uppermost portion of the retrieved core contains the lower 15.3 feet of the Angola Shale (3,470.0 - 3,485.3 ft.). The Angola is composed of alternating laminae and bands (<1.0 ft. thick) of light olive gray (5Y 6/1) siltstone and olive gray (5Y 3/2) silty mudstone. These lithologies are thinly laminated to thin bedded. Many of the siltstones in the upper ten feet of the interval exhibit cross-bedding, and contain mud filled burrow structures and load casts as basal features. Pyrite mineralized burrow structures occur throughout the interval, as do resinous and pyrite coated spore bodies (Tasmanites sp.). A few partially pyritized Styliolina (?) casts (6 mm diam. by 40 mm) are located between 3,471.0 and 3,476.4 feet. Carbonaceous plant fragments,

a single brachiopod mold, and several mats of disseminated pyrite grains are also present. Current lineations occurring on partings at 3,470.6 and 3,481.7 feet exhibit a NE-SW orientation.

The contact (3,485.3 ft.) between the Angola Shale and the underlying Rhinestreet Shale, also of the West Falls Formation, is gradational both in the core and on the geophysical logs. Preceding downcore across the contact, the core changes from an olive gray silty mudstone to a pale olive siltstone. The gamma log increases from 140 API units in the Angola to 160 API units in the Rhinestreet; the bulk density log shows a decrease across the contact from 2.65 to 2.60 g/cc.

#### Rhinestreet Shale Member:

The cored portion of the Rhinestreet (3,485.3 - 3,528.5 ft.) is composed primarily of a pale olive (10Y 6/2) siltstone; laminae and thin beds of olive gray (5Y 3/2) and light olive brown (5Y 5/6) mudstone and silty mudstone are also contained within this interval. Many of the siltstone bands are calcareous, and are both cross-bedded and cross-laminated, occasionally possessing basal load casts and scour features. Resinous spore bodies are prevalent throughout the interval, as are burrow structures, most of which are mud filled. Pyrite is frequently present as disseminated grains, and rarely, as nodules and mineralization on plant fragments.

The contact zone between the Rhinestreet and the underlying Cashaqua Shale of the Sonyea Formation appears sharply on the geophysical logs: there is an overall decrease in the gamma ray count from 165 to 145 API counts; the variance in bulk density is not as pronounced,

merely increasing .05 g/cc - from 2.60 g/cc in the Rhinestreet to 2.65 g/cc in the Cashaqua.

### Sonyea Formation

#### Cashaqua Shale Member:

The Cashaqua (4,371.0 - 4,486.0 ft.) was not cored in this well. Its contact with the underlying Middlesex member of the Sonyea is fairly sharp: the gamma ray log registers an increase of radiation from 145 API units in the Cashaqua to 180 API units in the Middlesex.

#### Middlesex Shale Member:

The majority of the Middlesex Shale (4,486.0 - 4,553.0 ft.) was not cored. The retrieved core extends from 4,530.0 to 4,553.0 feet, and consists of thin laminae to thin beds of olive black (5Y 2/1) silty mudstone and a brownish black (5YR 2/1) silty shale. Pyrite mineralized burrow structures and carbonaceous spore bodies (Tasmanites sp.) are the only visible features within this core, the entirety of which is noncalcareous.

The contact (4,553.0 ft.) between the Middlesex Shale and the Genesee Formation is visually indistinguishable; the core throughout the contact area appears as an olive black silty shale. The contact is more distinct on the geophysical logs: gamma radiation decreased from 180 API units in the Middlesex to a range of 120 to 160 API units in the Genesee; bulk density differences are more gradational, and unlike the expected increase in opposition to the gamma log, a slight decrease registers downcore across the contact from 2.60 to 2.55 g/cc.

## Genesee Formation

### Undifferentiated:

An undifferentiated interval of the Genesee Formation extends from 4,553.0 to 4,734.0 feet. The interval consists primarily of alternating laminae and bands (<1.0 ft. thick) of brownish black (5YR 2/1) and olive gray (5Y 4/1) silty mudstone in the upper 130 feet, and olive black (5Y 2/1) silty shale in the lower 50 feet. Carbonaceous spore bodies are prevalent in, and limited to, the upper 90 feet; brachiopods and carbonaceous fragments are limited to the lower portion of the interval. Other fossils and sedimentary structures which are present include: occasional straight and coiled cephalopods, numerous pyrite nodules and mats of disseminated pyrite grains, many siltstone concretions and calcite laminae, a few *Styliolina* (?) casts, burrow structures, mud filled and pyrite mineralized burrow structures, and several areas of wavy laminae. The top half of the interval is noncalcareous, while the core of the bottom half ranges from slightly to highly calcareous.

The contact (4,734.0 ft.) between the undifferentiated portion of the formation and the basal member of the Genesee, the Geneseo Shale, is gradational over several feet in the core. Olive black silty mudstone of the undifferentiated portion of the Genesee changes to olive black silty shale of the Geneseo at this contact; an increase in fissility downcore is the only visible identifying characteristic across the contact. On the geophysical logs, the gamma ray log reflected a sharp increase from the range of 120 to 160 API units in the Genesee to 200+ API units in the Geneseo; a smaller pronounced change occurs on the

bulk density log - 2.55 g/cc in the upper part of the Genesee Formation decreases to 2.42 g/cc in the Genesee Shale Member.

#### Genesee Shale Member:

The Genesee Shale (4,734.0 - 4,768.0 ft.) consists of a uniformly colored olive black (5Y 2/1) shaly mudstone. A calcite mineralized vertical joint is present in association with an olive gray (5Y 4/1) calcareous concretion (≈10 cm diam.) at 4,739.7 feet. Occasional pyrite nodules are found throughout the member. A few isolated wood fragments, less than 1.0 cm in length, are restricted to a zone extending from 4,745.4 to 4,749.0 feet. Other than these fragments, the interval is void of fossils; sedimentary and biogenic structures are also absent.

The Genesee's contact (4,768.0 ft.) with the underlying Moscow Formation is gradational over several inches in the core. The lithology changes from the olive black shaly mudstone of the Genesee to the olive gray mudstone of the Moscow. The geophysical logs record an abrupt change downcore across the contact: gamma radiation decreases sharply from 200+ to 150 API units; bulk density also decreases sharply from 2.42 g/cc to the range of 2.00 - 2.30 g/cc.

#### Hamilton Group

##### Moscow Formation:

The Moscow Formation extends from 4,768.0 to 4,808.7 feet, and consists primarily of thin to thick beds of olive black (5Y 2/1) calcareous mudstone; half a dozen thin beds of olive gray (5Y 4/1) argillaceous limestone are contained within the mudstone. Fossils present within the formation include: many articulate and inarticulate brachiopod molds,

carbonaceous and pyrite coated plant fragments, and sparsely occurring crinoid stems. Pyrite is found in various forms: occasionally as mats and laminae of disseminated grains, rarely as lenses, and most frequently, as nodules and as mineralization on burrow structures. Several areas of core also exhibit some calcite mineralization, either in association with pyrite nodules or septarian concretions.

The contact (4,808.7 ft.) between the Moscow Formation and the upper undifferentiated portion of the Ludlowville Shale is gradational over several feet in the core. The contact area is marked by a change from an olive gray mudstone to an olive black mudstone. The geophysical logs register a sharp and more distinguishable change across the contact: the gamma ray log decreases from 150 API units in the Moscow to 130 API units in the undifferentiated Ludlowville; a similar change occurs on the bulk density log, which registers an increase across the contact from 2.32 to 2.55 g/cc.

#### Ludlowville Shale:

The uppermost portion of the Hamilton Group's Ludlowville Shale is composed of an undifferentiated interval extending from 4,808.0 to 4,832.5 feet. Thin and thick beds of olive black (5Y 2/1) calcareous mudstone and olive gray (5Y 3/2) shaly mudstone are the primary constituents of this upper undifferentiated portion; olive gray argillaceous limestone is present within the bottom foot of the interval. Brachiopod molds, some of which are calcite mineralized, are the most prevalent fossils that occur within the Ludlowville. Other fossil forms to occur throughout the interval include: both carbonaceous spore bodies

(Tasmanites sp.) and plant fragments, and pyrite coated plant fragments. Pyrite also is commonly present as mineralization on burrow structures.

The contact (4,832.5 ft.) between the upper undifferentiated portion of the Ludlowville Shale and the underlying Tichenor Limestone, also of the Ludlowville, is sharp, both in the core and on the geophysical logs. Preceding downcore across the contact, the core changes from an olive black mudstone to an olive gray argillaceous limestone. Gamma radiation in the upper undifferentiated Ludlowville, 130 API units, is high as compared to the Tichenor, 40 API units. The bulk density log registers an increase across this contact from 2.55 to 2.75 g/cc.

#### Tichenor Limestone:

The Tichenor Limestone (4,832.5 - 4,843.3 ft.), also of the Ludlowville Shale, is primarily composed of thin to thick beds of olive gray (5Y 3/2) argillaceous limestone in the upper five feet of the interval, and of thin beds of olive gray (5Y 4/1) calcareous mudstone throughout the remainder. Occasional beds of lime mudstone and wackestone also occur within the Tichenor. The interval is highly fossiliferous, containing numerous brachiopods, coiled cephalopods, and crinoid stems. Curved, sinuous fractures filled with clay, which appear to be vertical stylolites, are found in a zone extending from 4,832.5 to 4,836.9 feet. Many calcite concretions are also found within the interval.

The contact (4,843.3 ft.) between the Tichenor Limestone and the underlying lower undifferentiated portion of the Ludlowville Shale is fairly sharp on the geophysical logs, but is difficult to distinguish

in the core, appearing gradational over approximately six feet. The contact zone is represented by an intermixing of olive gray (5Y 4/1 and 5Y 3/2) mudstones. On the logs, there is a noticeable increase in gamma ray count from 40 API units in the Tichenor to 110 API units in the undifferentiated Ludlowville; bulk density decreases across the contact from 2.75 to 2.60 g/cc.

The lower portion of the undifferentiated interval of the Ludlowville Shale extends from 4,843.3 to 5,101.0 feet. The upper 60 feet of the interval consists of alternating laminae and bands of olive gray (5Y 4/1 and 5Y 3/2) calcareous mudstone, some of which is shaly. The interval increases in fissility downcore, with silty shale becoming the predominant lithology between 5,044.1 and 5,088.4 feet, and finally being the only rock type present from 5,088.4 feet to the bottom of the interval. The entire Ludlowville is moderately fossiliferous. These fossils include: occasional carbonaceous and resinous spore bodies, numerous articulate and inarticulate brachiopods, several straight and coiled cephalopods, some pelecypods, and many carbonaceous plant fragments. Pyrite occurs in several forms: as sparse laminae and disseminated grains, and frequently, as nodules. Pyrite mineralized and mud filled burrow structures commonly occur within the interval, as do feeding trails (?) on core partings; these trails are most prevalent downcore from 5,020.8 feet. Calcareous concretions are found in the zone extending from 4,990.0 to 5,057.1 feet.

The contact (5,101.0 ft.) between the Ludlowville Shale and the underlying Skaneateles Shale is gradational over several feet in the core. The core changes from an olive black silty shale to an olive gray

shaly mudstone. This contact zone is more distinct on the geophysical logs: the gamma ray log registers a sharp increase in radiation from 110 API units in the Ludlowville to a range of 180 to 200+ API units in the Skaneateles; bulk density readings of 2.60 g/cc drop to 2.47 g/cc across the contact.

Skaneateles Shale:

The Skaneateles Shale (5,101.0 - 5,176.0 ft.), also of the Hamilton Group, is composed of thinly laminated to thin bedded olive black (5Y 2/1) shaly mudstones, with alternating laminae and bands (<1.0 ft. thick) of olive gray (5Y 4/1) and (5Y 3/2) shaly mudstone scattered throughout. Light olive gray (5Y 6/1) lime mudstone occurs as two single, thin beds located at 5,134.3 and 5,173.5 feet. Fossils are not very common in this interval, and consist of occasional brachiopods, cephalopods, and pelecypods. Pyrite is present as isolated nodules. Only a few small zones of mud filled burrow structures are present; feeding trails (?) at core partings are rare.

The contact (5,176.0 ft.) between the Skaneateles Shale and Marcellus Shale is gradational over several feet in the core. The lithology changes from an olive gray lime mudstone to a black shaly mudstone across the contact. The contact between the Skaneateles and the Marcellus is more distinct on the geophysical logs: gamma radiation increases markedly from slightly above 200 API units to over 400 API units; bulk density decreases sharply from 2.47 g/cc to a range of 2.30 to 2.40 g/cc in the Marcellus.

## Marcellus Shale:

The cored portion of the Marcellus Shale (5,176.0 - 5,213.5 ft.) is primarily composed of a black (N1) or grayish black (N2) shaly mudstones containing olive gray (5Y 4/1) laminae and bands (<0.5 ft. thick). Occasional thin beds of dark gray (N3) and olive black (5Y 2/1) calcareous mudstone and medium dark gray (N4) and light olive gray (5Y 6/1) argillaceous limestone are also contained within the interval. Fossils are rare, and consist of a few vitrinite fragments and a few woody fragments. Pyrite occurs as several isolated nodules, as a single bleb, and as a small cluster of crystals. Calcite-filled microfractures occur throughout the Marcellus.

### 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. Forty-two natural fractures consisting of 14 simple joints, 5 compound joints, 6 faults, and 17 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>
West Falls Formation:				
Angola Shale	3,470'-3,485'	15'	1	0.07
Rhinestreet Shale	3,485'-3,528'	43'	3	0.07
Sonyea Formation:				
Cashaqua Shale	----	--	-	----
Middlesex Shale	4,530'-4,553'	23'	0	0.00
Genesee Formation:				
Undifferentiated	4,553'-4,734'	181'	6	0.03
Geneseo Shale	4,734'-4,768'	34'	6	0.18
Hamilton Group:				
Moscow Shale	4,768'-4,808'	40'	0	0.00
Ludlowville Shale	4,808'-5,101'	293'	4	0.01
Skaneateles Shale	5,101'-5,176'	75'	6	0.08
Marcellus Shale	5,176'-5,213'	37'	16	0.43

All natural fractures in the EGSP-Pennsylvania #1 core were analyzed to identify common structural trends. Figure 4 is a graphic representation of the data plotted in polar form on a Schmidt (Equal Area) stereonet. The data have been contoured to determine locations of maximum pole density using the method described by Ragan (1968). Figure 5 is a graphic representation of the bearing and plunge of linear slickensides plotted on a Schmidt (Equal Area) stereonet and contoured to determine locations of maximum point density.

Two major trends are present throughout the core. The first trend consists of joints and strikes from N16°W to N66°W with a concentration at N32°W. The dips are generally vertical. The second trend consists of fault planes and strikes N77°W to N90°W and N52°E to N90°E with a concentration at N78°E. The dips average 20° - 30° in either a

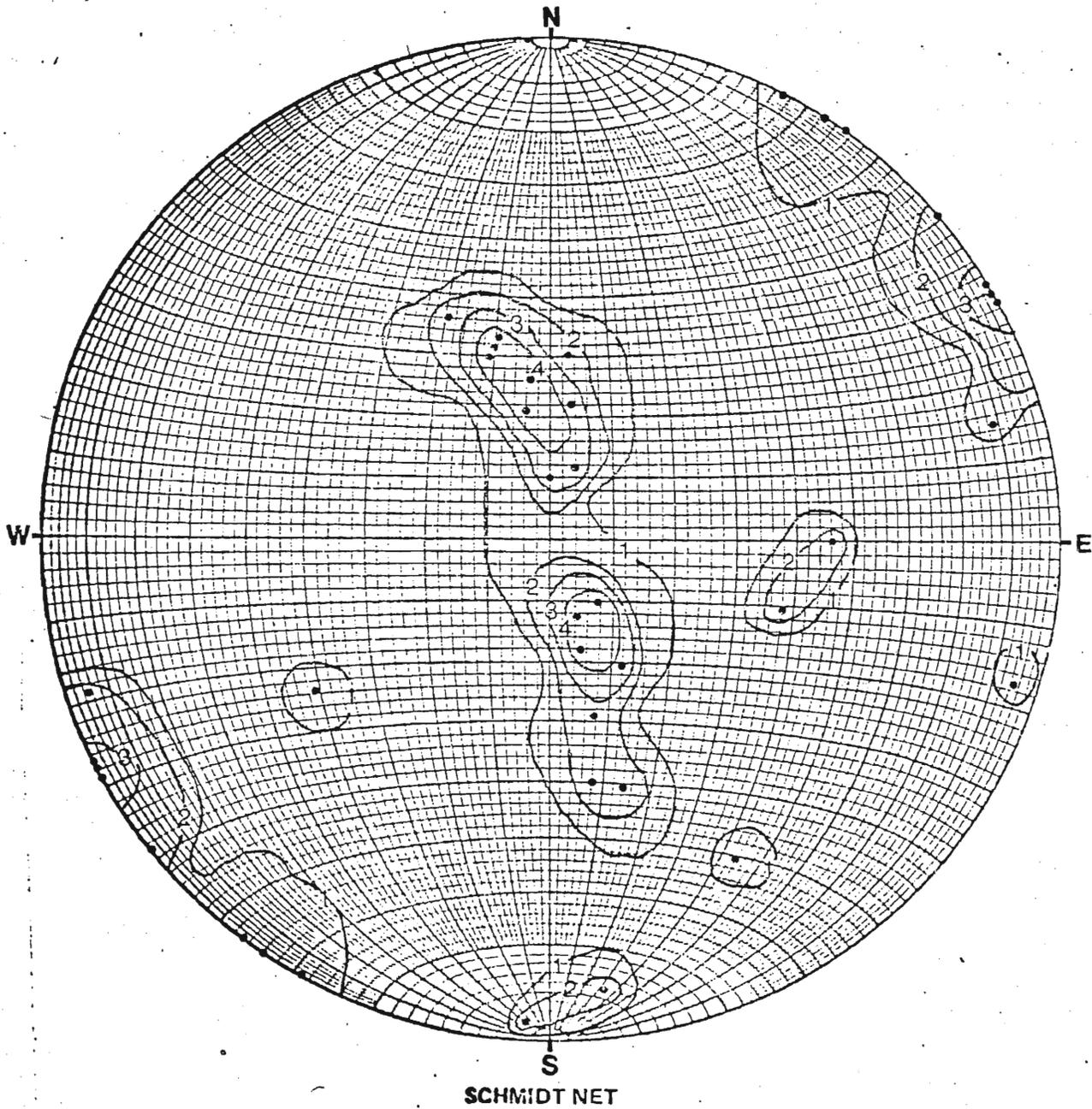


FIGURE 4

CONTOURED DIAGRAM OF POLES TO NATURAL FRACTURES

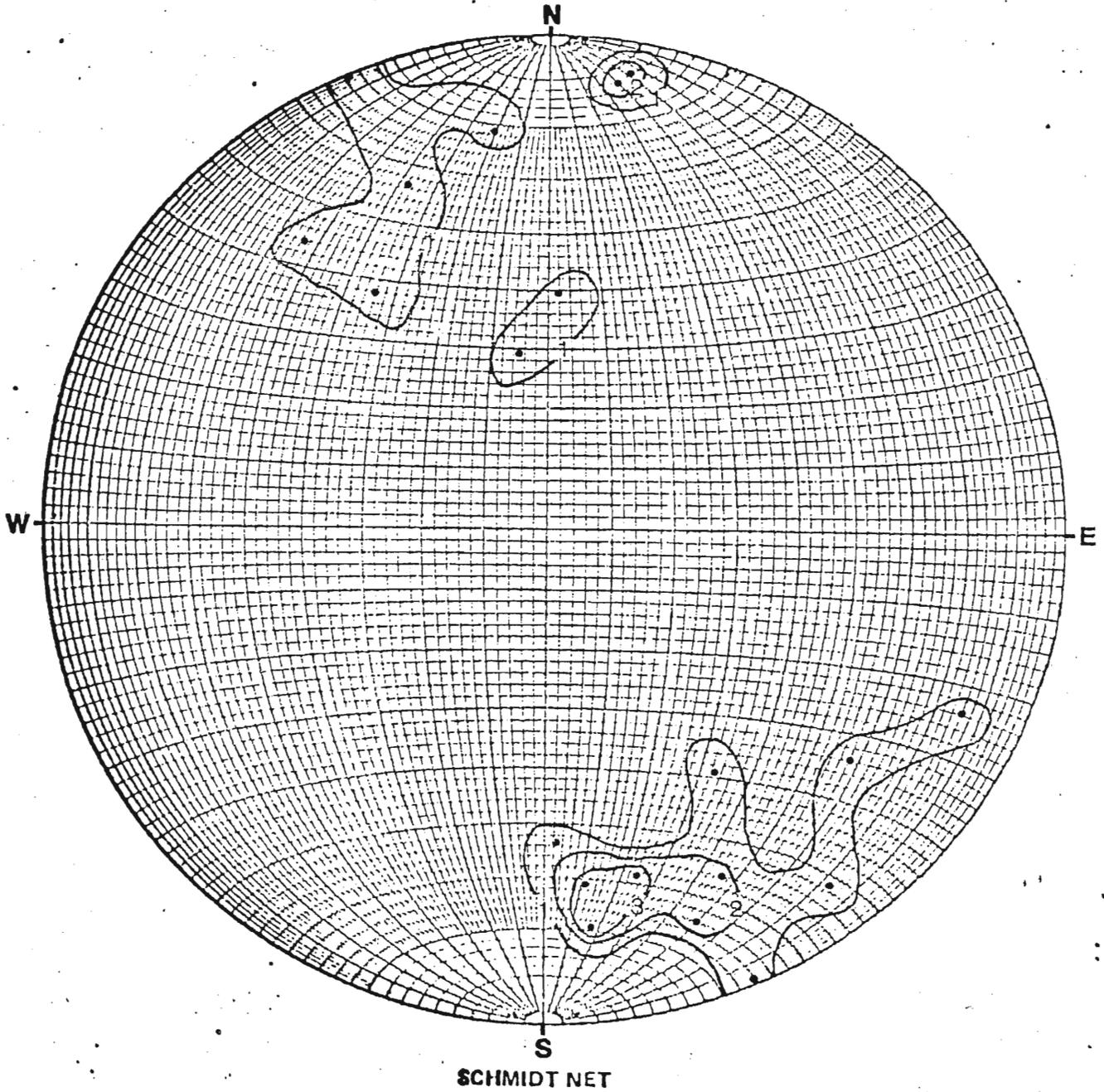


FIGURE 5

CONTOURED DIAGRAM OF THE BEARING AND PLUNGE OF SLICKENLINES

northwesterly or southeasterly direction. The bearing of the slickenlines, taken from the fault planes, range from N9°E to N40°W and from S2°E to S66°E with concentrations at N20°W and S20°E, respectively. The plunge ranges from 0° to 60°, with an average of 12°.

These trends reflect the general orientation of fracture sets within the core. Several of the largest, most well developed fractures are not included in the figures because an equipment failure during coring prevented the orientation of the core where they occur.

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

#### West Falls Formation

The cored portion of the West Falls Formation consists of approximately 15 feet of the Angola Shale Member and 43 feet of the Rhinestreet Shale Member. This section contained four natural fractures; one microfault in the Angola and one microfault and two simple joints in the Rhinestreet section. The microfaults are associated with small lenses of siltstone and may be due to slumping. The strike of the microfault planes is to the northeast and the bearing of the slickenlines is N2°E and N8°E. The two simple joints both strike N28°W and have vertical dips. The strike and frequency of all natural fractures and the bearing and frequency of slickenlines for the cored portion of the West Falls Formation are presented in Figures 6 and 7, respectively.

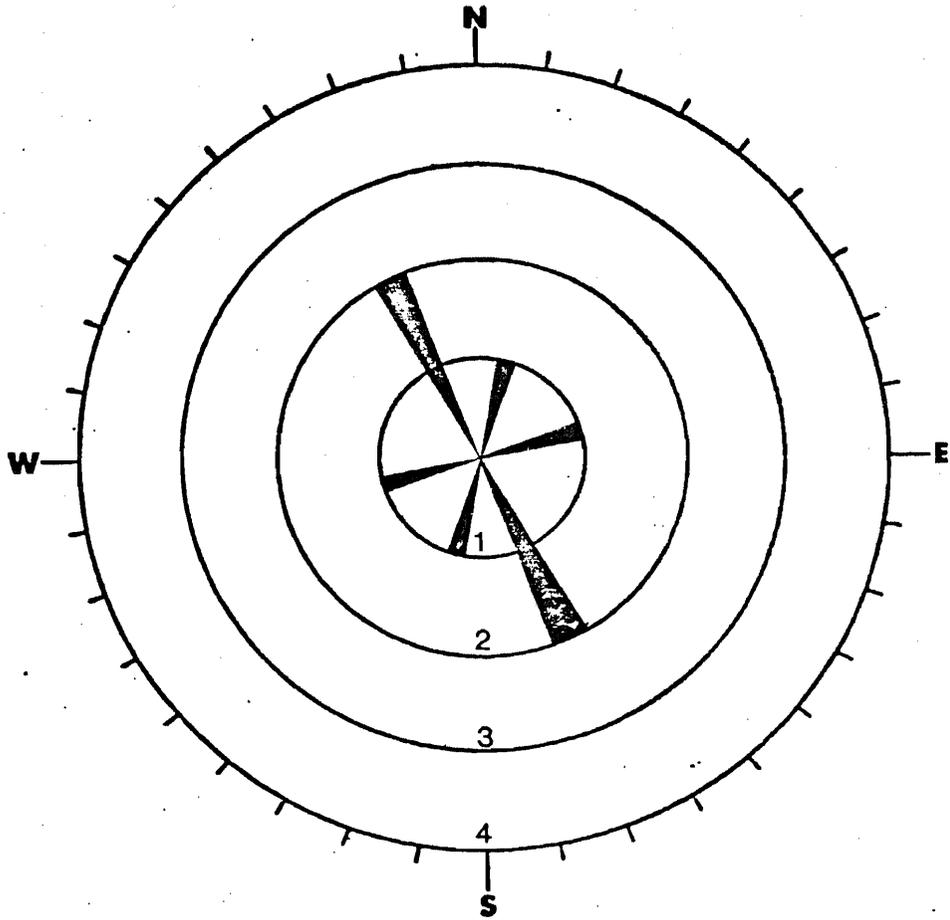


FIGURE 6

STRIKE AND FREQUENCY OF NATURAL FRACTURES IN THE  
WEST FALLS FORMATION

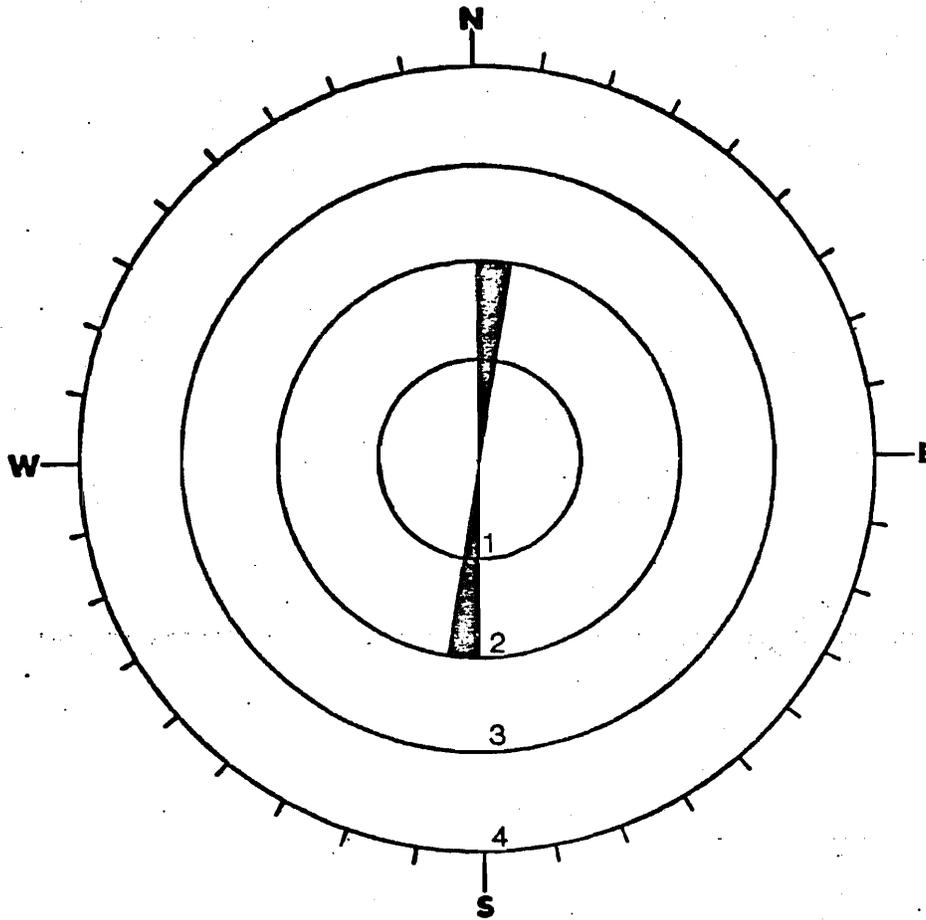


FIGURE 7

ORIENTATION AND FREQUENCY OF SLICKENLINES IN THE  
WEST FALLS FORMATION

## Sonyea Formation

### Middlesex Shale Member:

There are no natural fractures present in the 23 feet of core cut from the Middlesex Shale.

## Genesee Formation

The Genesee Formation is subdivided into an undifferentiated portion and the Genesee Shale Member. Twelve natural fractures are recorded, but six of these are without orientation due to an equipment failure during coring.

### Undifferentiated Portion of the Genesee:

The undifferentiated portion of the Genesee Formation contains six natural fractures. three microfaults, one simple joint, one compound joint, and one fault. One of the microfaults is in the unoriented section. The simple joint and the compound joint occurring in lime concretions are curvilinear and mineralized with calcite. No trend is discernible for these fractures. The microfaults are also associated with lime concretions. The microfault plane strikes are  $N76^{\circ}E$  and  $N80^{\circ}E$ , and the slickenline bearings are  $N22^{\circ}W$  and  $S26^{\circ}E$ , respectively; the plunge is  $\sim 25^{\circ}$ . The fault occurs at the base of a thin limestone bed. The fault plane orientation is  $N50^{\circ}E$ ,  $13^{\circ}NW$ , with slickenlines plunging  $5^{\circ}$  in the direction  $N9^{\circ}E$ . The strike and frequency of all natural fractures and the bearing and frequency of slickenlines for the undifferentiated portion of the Genesee Shale are shown in Figures 8 and 9.

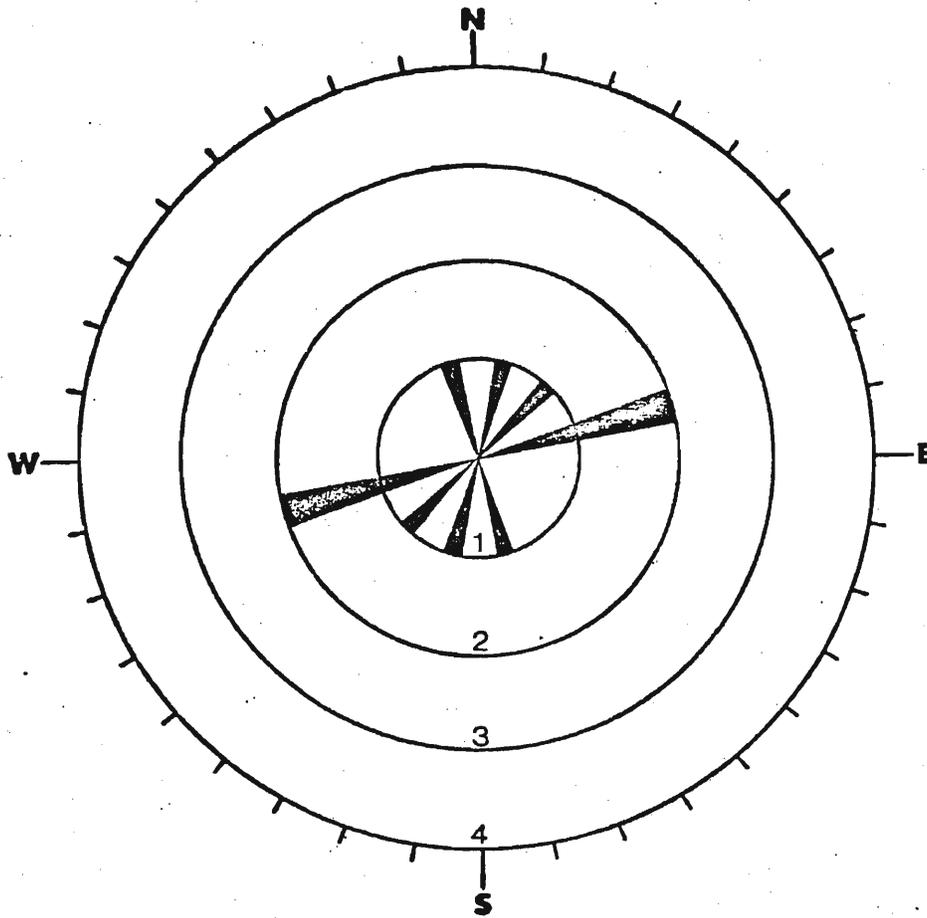


FIGURE 8

STRIKE AND FREQUENCY OF NATURAL FRACTURES IN THE  
UNDIFFERENTIATED PORTION OF THE GENESEE FORMATION

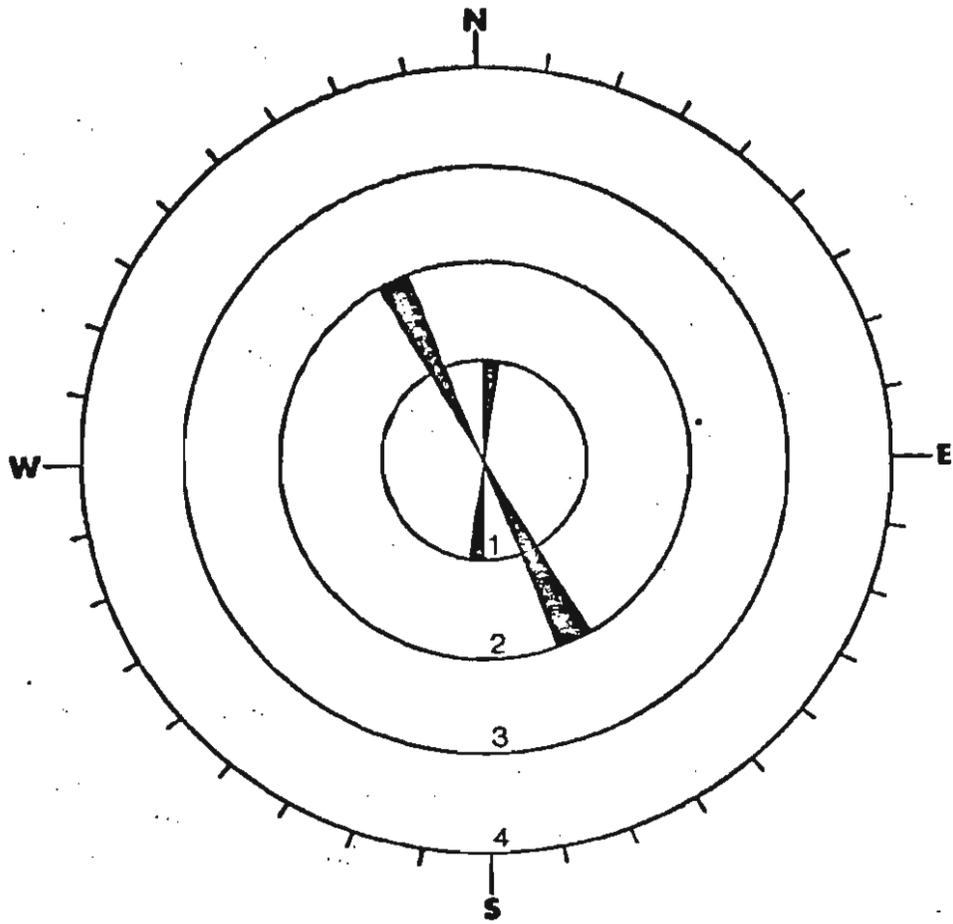


FIGURE 9

ORIENTATION AND FREQUENCY OF SLICKENLINES IN THE  
UNDIFFERENTIATED PORTION OF THE GENESEE FORMATION

#### Geneseo Shale Member:

The Geneseo Shale contains six natural fractures. These include two compound joints, two simple joints, one fault, and one microfault. All of these fractures except for the microfault occur in an unoriented section of the core. The two compound joints may be related. They are separated by a lime concretion which is faulted on both its upper and lower surface. This fracture system is 4.4 feet long, mineralized with calcite, breaks into multiple planes near the ends and contains planes of different orientation near the fault. The two simple joints are both approximately one foot in length and mineralized with calcite. The microfault, which occurs at the top of a limestone bed, has an orientation of  $N65^{\circ}E$ ,  $40^{\circ}SE$ , with slickenlines plunging approximately  $35^{\circ}$  in the direction  $S34^{\circ}E$ . This orientation is shown in Figures 10 and 11.

There are no natural fractures present in the 40 feet of core cut from the Moscow Shale.

#### Ludlowville Formation:

The Ludlowville Shale contains four natural fractures. Of these, three are simple joints and one is a compound joint. These fractures range in length from 1.7 to 7.6 feet, and all are mineralized with calcite. The orientation of the strikes ranges from  $N40^{\circ}W$  to  $N62^{\circ}W$ , and dips are vertical. The strike and frequency of these fractures is presented in Figure 12.

#### Skaneateles Formation:

The Skaneateles Shale contains six natural fractures. These consist of two simple joints, two faults, and two microfaults. The

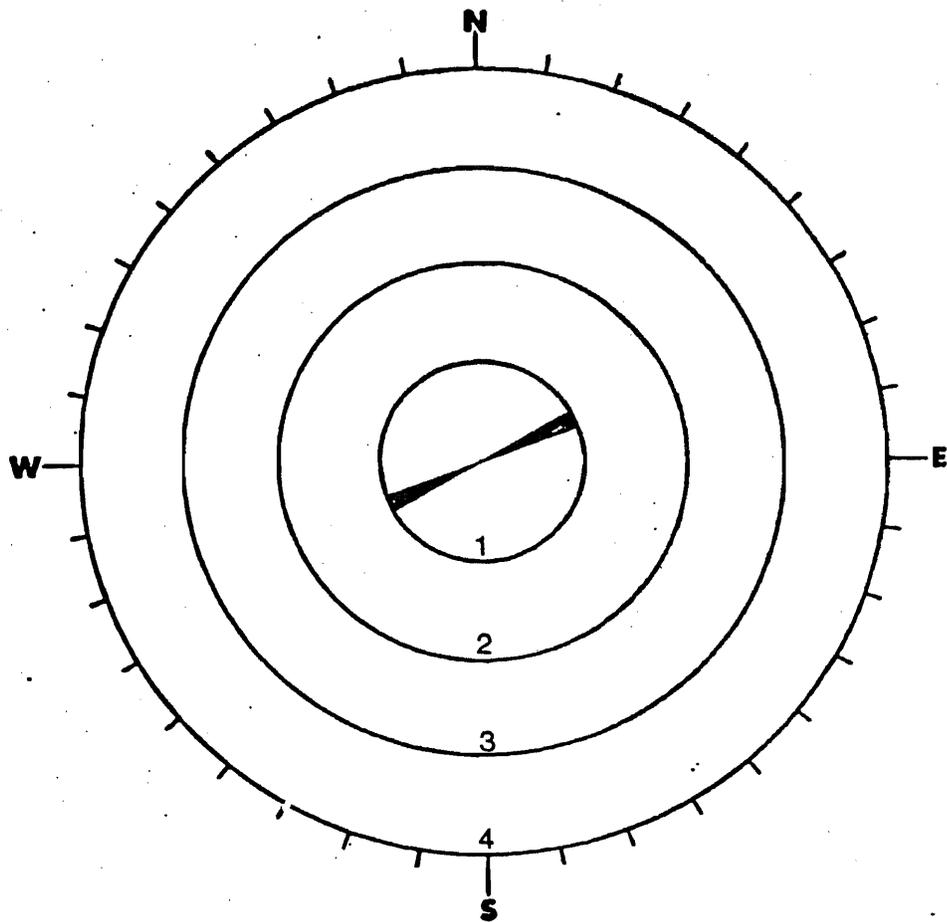


FIGURE 10

STRIKE AND FREQUENCY OF NATURAL FRACTURES IN THE  
GENESEEO SHALE

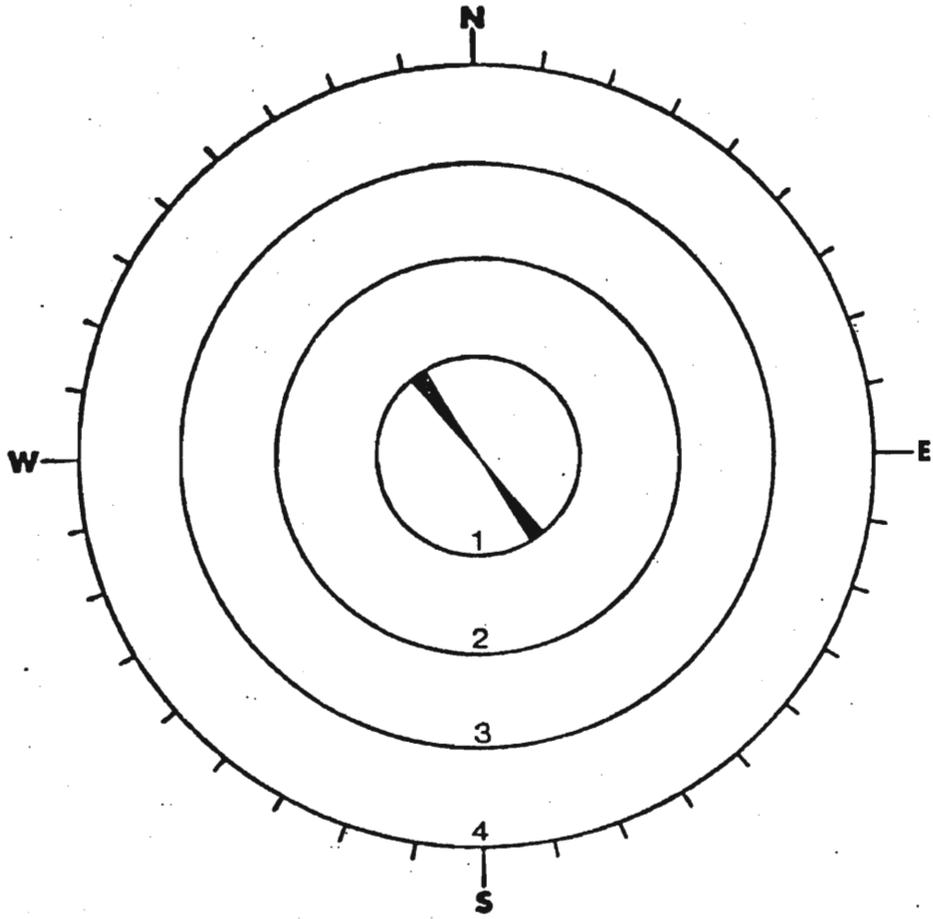


FIGURE 11

ORIENTATION AND FREQUENCY OF SLICKENLINES IN THE  
GENESEO SHALE

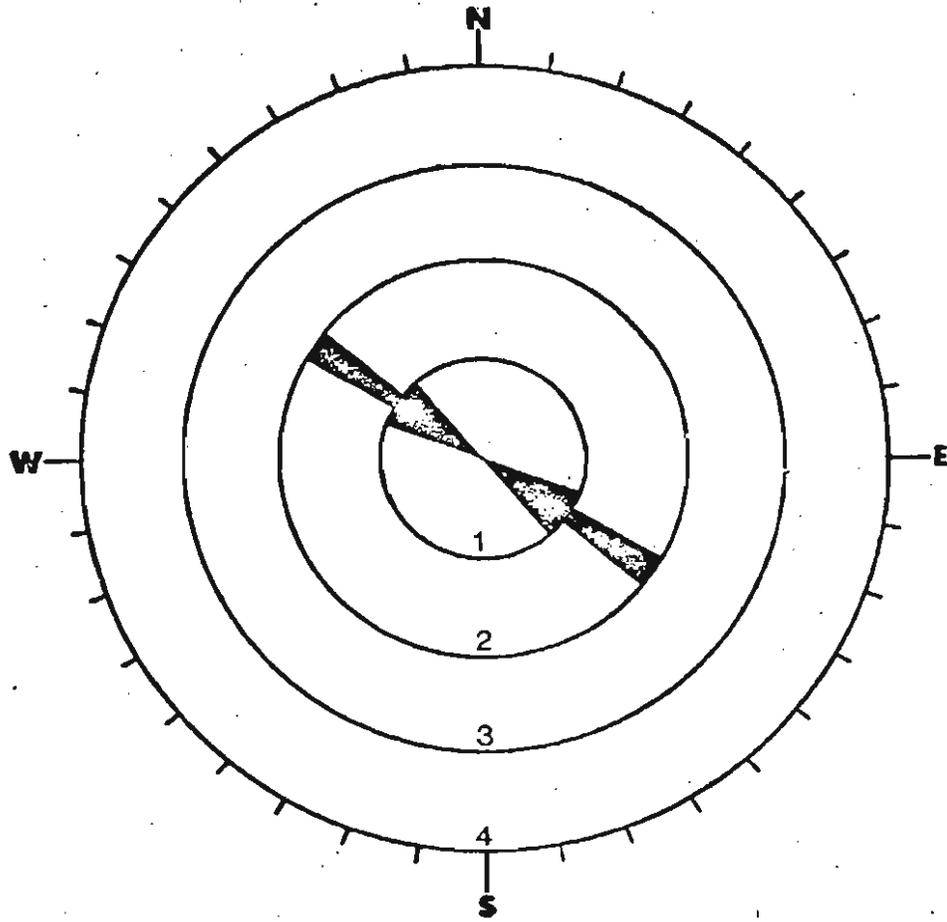


FIGURE 12

STRIKE AND FREQUENCY OF NATURAL FRACTURES IN THE  
LUDLOWVILLE SHALE

microfaults are associated with limestone concretions and do not show any discernible trends. Regarding the joints, one is within a limestone concretion and the other has its origin in a concretion. Both strike in the same general direction, N30°W and N34°W, respectively, and both are mineralized with calcite. A fault, at 5,165.3 feet, cuts through a large carbonaceous fragment, and has an orientation of N74°E, 33°SE, with slickenlines plunging 30° in the direction N36°W. The other fault plane is horizontal with slickenlines bearing N24°W. The strike and frequency of associated slickenlines are presented in Figures 13 and 14.

#### Marcellus Formation:

The Marcellus Shale contains sixteen natural fractures. These include nine microfaults, four simple joints, two faults, and one compound joint. All of these fractures are associated with limestone beds or concretions. Microfault plane orientations range from N60°E to N90°E and from N72°W to N88°W and dip approximately 30° with slickenlines plunging an average of 23° in the direction of S10°W to S20°E and from N0°W to N10°W, respectively. The faults also strike within this range.

The joints tend to be short in length, mineralized with calcite, and are probably extensional features associated with faulting. A group of three joints at 5,199 feet have orientations which range from N74°E to N84°E and dip from 41° to 80° in a northwesterly direction. The remaining joint occurs in a limestone and strikes N14°W with a dip of 80°SW.

The compound joint occurs in the last foot of the core. It has multiple curvilinear, calcite mineralized fracture planes with

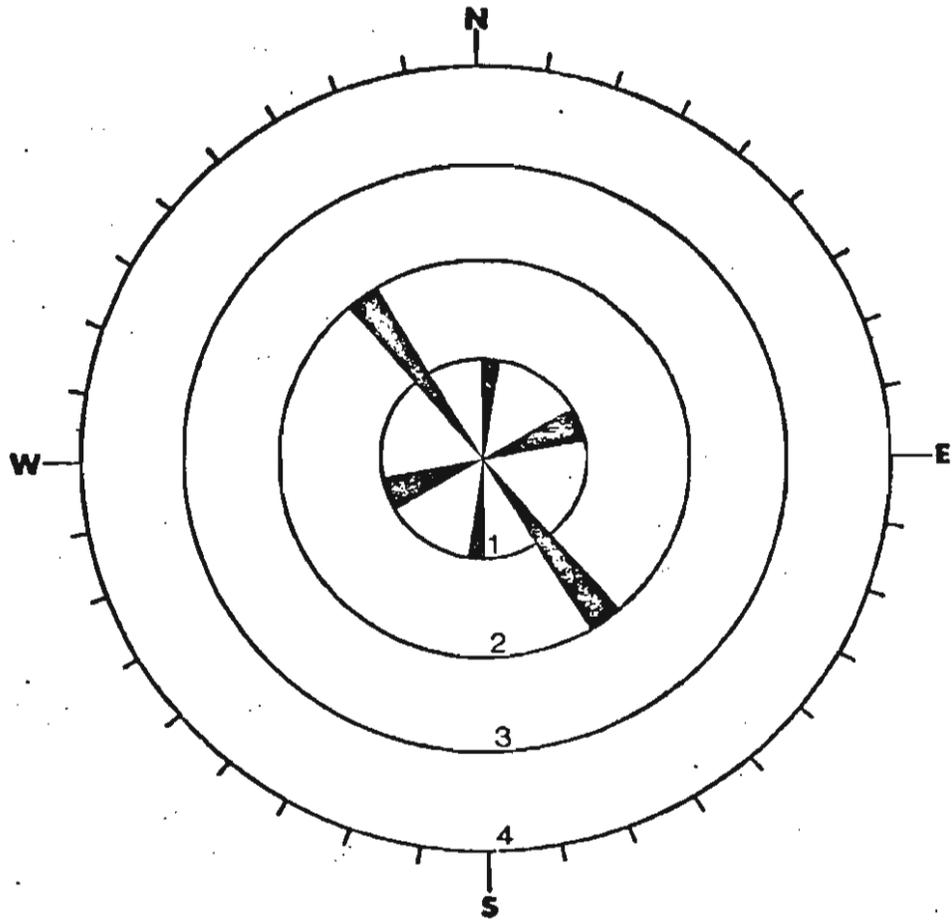


FIGURE 13

STRIKE AND FREQUENCY OF NATURAL FRACTURES IN THE  
SKANEATELES SHALE

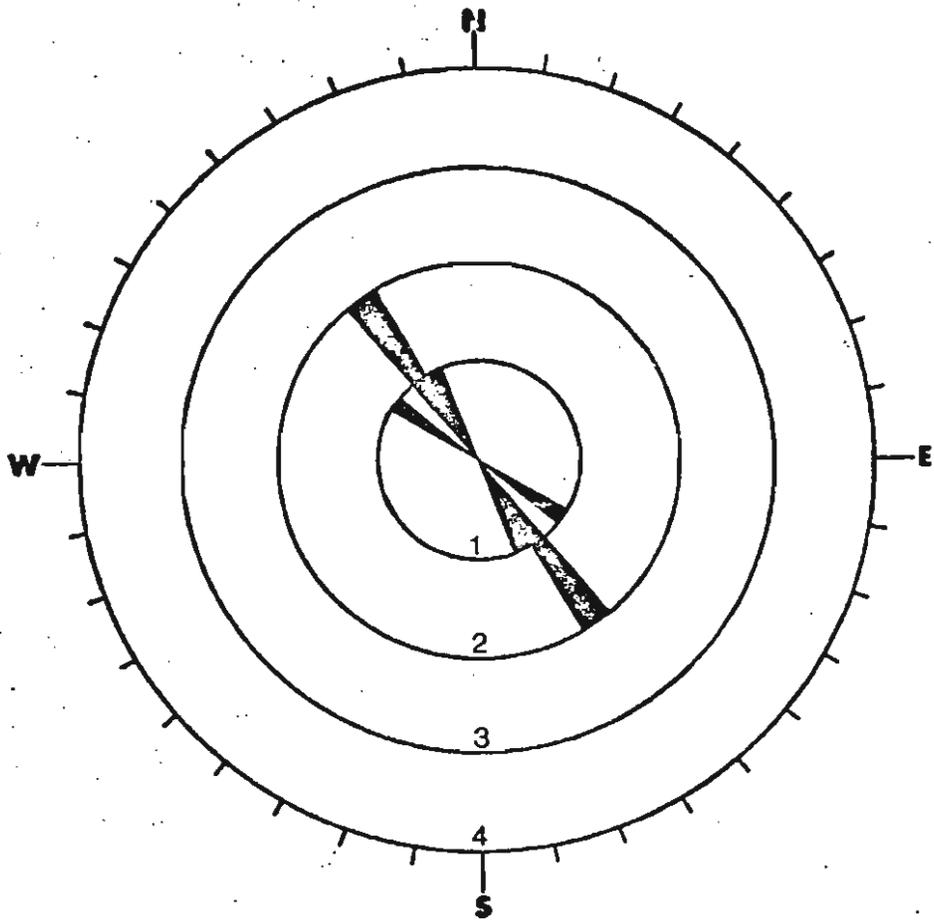


FIGURE 14

ORIENTATION AND FREQUENCY OF SLICKENLINES IN THE  
SKANEATELES SHALE

differing orientation, in what appears to be a brecciated zone. The orientation and frequency of fracture planes and the bearing and frequency of slickenlines are shown in Figures 15 and 16.

#### Coring-Induced Fractures:

Ninty-nine percent of the fractures examined in the Pennsylvania #1 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 flexural rigidity of rock parallel to bedding. These data are provided in Appendix C.

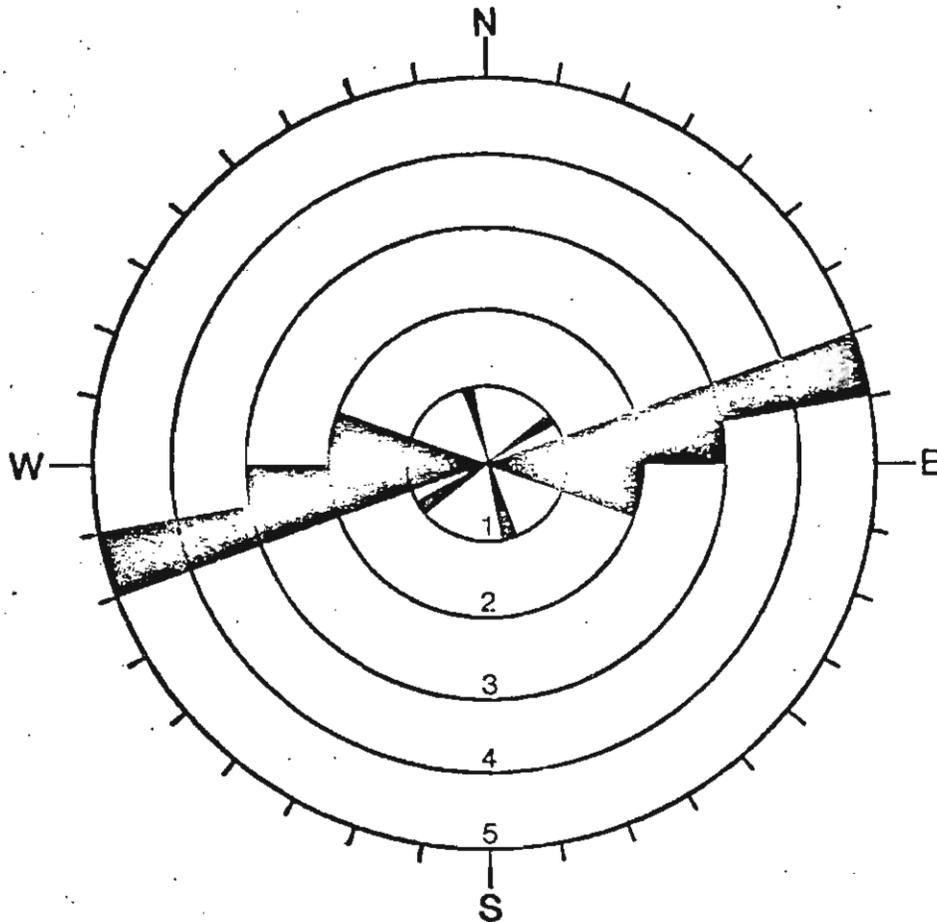


FIGURE 15

STRIKE AND FREQUENCY OF NATURAL FRACTURES IN THE  
MARCELLUS SHALE

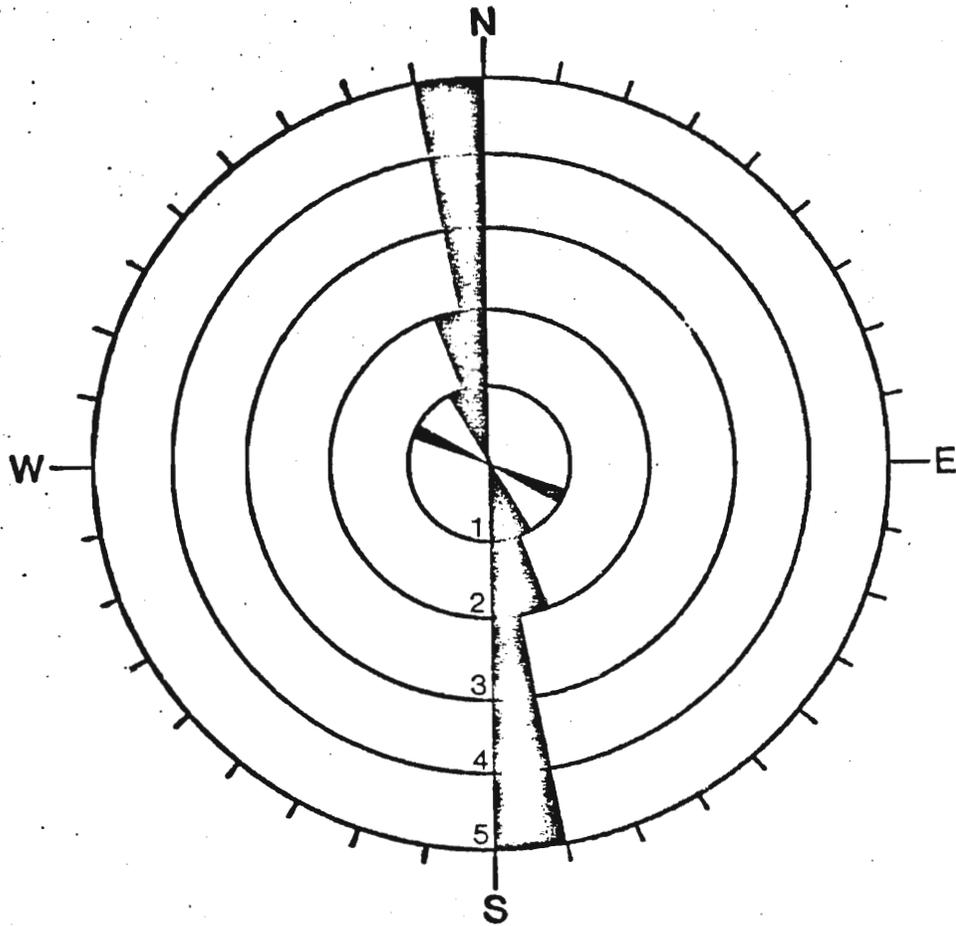


FIGURE 16

ORIENTATION AND FREQUENCY OF SLICKENLINES IN THE  
MARCELLUS SHALE

A P P E N D I X A

DETAILED LITHOLOGIC DESCRIPTION

EGSP-PENNSYLVANIA #1 WELL, MCKEAN COUNTY

INTERVALDESCRIPTION

3,470.0' - 3,479.9'  
(9.9')

Siltstones, silty mudstones, and mudstones, light olive gray (5Y 6/1), olive gray (5Y 4/1), and olive black (5Y 2/1), thinly laminated to thin bedded. The interval is composed of alternating laminae and bands (<1.0 ft. thick) of light olive gray siltstone, olive gray silty mudstone, and olive black mudstone. Several of the siltstone zones exhibit cross-bedding; current lineations within one such zone (3,470.6 ft.) are oriented NE-SW. A single load cast occurs at the base of a siltstone bed (3,477.2 ft.), as do mud filled burrow structures (up to 5 mm diam. by 40 mm) which are present at 3,470.4'. Pyrite mineralized burrow structures are contained within the lighter zones. A few partially pyritized *Styliolina* (?) casts (6 mm diam. by 40 mm) occur between 3,471.0 and 3,476.4 feet. A brachiopod mold (5 mm diam.) is found at 3,472.8 feet. Carbonaceous plant fragments (5 mm diam. by 15 mm) are located at 3,472.9 and 3,478.0 feet. Resinous spore bodies (*Tasmanites* sp.) are present at 3,474.5 feet. Numerous grains of disseminated pyrite occur at 3,474.3 feet. A 0.1-foot thick zone of siltstone (3,475.0 ft.) is slightly calcareous.

3,479.9' - 3,485.3'  
(5.4')

Silty mudstones and siltstones, olive gray (5Y 3/2), light olive gray (5Y 5/2), pale olive (10Y 6/2), and light olive brown (5Y 5/6), thinly laminated to thin bedded. Alternating laminae and bands (<1.0 ft. thick) of olive gray and light olive gray silty mudstone, and pale olive siltstone comprise the interval; occasional light olive brown bands (<0.1 ft. thick) are present in the upper 2.0 feet. Some calcite mineralization occurs within the core. Numerous vertical and subhorizontal, pyrite mineralized and mud filled burrow structures are found throughout the interval. Current lineations at 3,481.7 feet are oriented NE-SW. Pyrite coating is found on occasionally occurring spore bodies. A siltstone bed from 3,484.5 to 3,485.3 feet is very slightly calcareous; the remainder of the interval is noncalcareous.

INTERVALDESCRIPTION

3,485.3' - 3,494.8'  
(9.5')

Siltstones, silty mudstones and mudstones, pale olive (10Y 6/2), olive gray (5Y 3/2), and light olive brown (5Y 5/6), thinly laminated to thin bedded. The core contains alternating laminae and bands (<1.0 ft. thick) of pale olive siltstone and olive gray and light olive brown silty mudstone and mudstone. Cross-bedding occurs in siltstone beds at 3,488.2 feet, and in the bottom 0.2 feet of the interval. A highly calcareous siltstone concretion, flanked by disturbed laminae, is present from 3,491.1 to 3,491.3 feet. The upper foot of the interval contains carbonaceous, horizontal burrow structures (5 mm in length) and carbonaceous plant fragments; a carbonaceous plant fragment (10 mm diam. by 35 mm) with an iron-stained rim (oxidized pyrite ?) occurs at 3,489.6 feet. Sparse pyrite nodules are also found within the core. The entire interval is noncalcareous.

3,494.8' - 3,505.7'  
(10.9')

Siltstones, mudstones and silty mudstones, pale olive (10Y 6/2), olive gray (5Y 3/2), and light olive brown (5Y 5/6), thinly laminated to thin bedded. Pale olive siltstone, much of which is cross-bedded, and olive gray mudstone and silty mudstone occur throughout the interval as alternating laminae and bands (<1.0 ft. thick); several light olive brown bands occur within the upper 1.0 foot. Load casts and scour surfaces are present as basal siltstone features at 3,497.6 and 3,501.9 feet, respectively. Siltstone also occurs within the interval as occasional lenses, and a highly calcareous concretion (5 by 15 cm) flanked by disturbed laminae (3,502.2 ft.). Mud filled burrow structures (up to 5 mm diam. by 30 mm) found throughout the interval, are prevalent in the mid-section. Partially pyrite mineralized plant fragment molds are present at 3,497.9 and 3,499.8 feet. Resinous spore bodies (Tasmanites sp.) occur from 3,503.6 to 3,504.0 feet.

INTERVALDESCRIPTION

3,505.7' - 3,510.1'  
(4.4')

Siltstones, silty mudstones and mudstones, pale olive (10Y 6/2) and olive gray (5Y 3/2), thinly laminated to thin bedded. Numerous olive gray silty mudstone and mudstone laminae and beds are contained within the pale olive siltstones. Cross-bedding is common throughout the siltstones; these cross beds are often truncated against overlying mudstone beds. A highly calcareous siltstone concretion, 0.1-foot thick, is present at 3,505.8 feet. Horizontal, mud filled burrow structures (5 mm in length) occur at 3,506.9 feet. Resinous spore bodies, some of which are carbonized, are found at 3,505.9 feet. Disseminated pyrite grains are present throughout the interval. The siltstones in the upper 2.0 feet of the interval are moderately calcareous; the remainder of the interval is noncalcareous.

3,510.1' - 3,518.4'  
(8.3')

Siltstones, mudstones, and silty mudstones, pale olive (10Y 6/2), olive gray (5Y 3/2), and light olive brown (5Y 5/6), thinly laminated to thin bedded. The interval is comprised of alternating laminae and bands (<1.0 ft. thick) of pale olive siltstone and olive gray mudstone and silty mudstone; occasional light olive brown bands occur throughout. The horizontal burrow structures which are present are both silt filled (10 mm in length) and mud filled (up to 5 mm diam. by 40 mm), and occur in the upper 4.0 feet of the interval. Disseminated pyrite grains are present throughout. A single brachiopod (?) mold (15 mm by 20 mm) is found at 3,514.2 feet. Resinous spore bodies are located at 3,515.0 and 3,518.2 feet. The entire interval is noncalcareous.

3,518.4' - 3,528.5'  
(10.1')

Siltstones, silty mudstones and mudstones, pale olive (10Y 6/2), olive gray (5Y 3/2), and light olive brown (5Y 5/6), thinly laminated to thick bedded. The interval is comprised of thin and thick beds of pale olive siltstone which contain thin laminae and beds of olive gray and light olive brown silty mudstone and mudstone. Cross-bedding is present throughout the lower 2.0 feet of the interval. Load casts and scour features are found at 3,526.0 and 3,526.9 feet, respectively. Horizontal, mud filled burrow structures (3 mm diam. by 25 mm) occur at 3,518.6 and 3,521.5 feet; carbonized burrow structures (2 mm diam. by 3 mm) are present at 3,523.7 feet. Resinous spore bodies are located at 3,518.6 feet. The entire interval is noncalcareous.

<u>INTERVAL</u>	<u>DESCRIPTION</u>
3,528.5' - 4,530.0' (1,001.5')	This interval was not cored.
4,530.0' - 4,544.9' (14.9')	Silty mudstones, silty shales, and mudstones, olive black (5Y 2/1) and olive gray (5Y 4/1), thinly laminated to thin bedded. The interval is uniform in appearance; numerous shaly zones occur throughout. Pyrite mineralized burrow structures are present at 4,539.4 feet. Carbonaceous spore bodies are found at 4,531.2 feet. The entire interval is noncalcareous.
4,544.9' - 4,553.0' (8.1')	Silty shales and silty mudstones, brownish black (5YR 2/1) and olive gray (5Y 4/1), thinly laminated to thin bedded. The interval is uniform in appearance, predominantly consisting of brownish black silty shales. A single, thin calcite lamina is present at 4,549.5 feet. The entire interval is noncalcareous.
4,553.0' - 4,563.9' (10.9')	Silty shales and silty mudstones, olive black (5Y 2/1) and olive gray (5Y 4/1), thinly laminated to thin bedded. The interval is uniform in appearance; olive black silty shales are dominant, and vary in degrees of fissility. Occasional thin calcite laminae are scattered throughout the interval. The mold of a coiled cephalopod (1.0 cm diam.) is present at 4,562.7 feet. Carbonaceous spore bodies are located at 4,554.8 feet. The interval is noncalcareous.
4,563.9' - 4,576.7' (12.8')	Silty mudstones and silty shales, olive black (5Y 2/1) and brownish black (5YR 2/1), thinly laminated to thin bedded. The interval is almost uniform in appearance. A single siltstone lens (4,566.3) and occasional thin siltstone lamina occur within the core. Two pyrite lenses (5 mm diam. by 20 mm) are present at 4,575.5 feet; disseminated grains of pyrite are found at 4,574.0 feet. A single brachiopod mold (5 mm diam.) is found at 4,564.2 feet. Carbonaceous spore bodies ( <i>Tasmanites</i> sp.) occur at 4,571.5 feet and in the bottom 2.0 feet of the interval. The entire interval is noncalcareous.

INTERVALDESCRIPTION

4,576.7' - 4,588.2'  
(11.5')

Silty mudstones and silty shales, olive black (5Y 2/1), brownish black (5YR 2/1), and olive gray (5Y 4/1), thinly laminated to thin bedded. The interval consists of alternating laminae and bands (<1.0 ft. thick) of olive black, brownish black, and olive gray silty mudstone, and olive black and brownish black silty shale; the silty shales occur in the upper 1.0 foot, and extend from 4,580.8 to 4,582.8 feet. Carbonaceous spore bodies are common throughout the interval. Pyrite occurs as occasional disseminated grains and as nodules (4,587.8 feet). Horizontal, mud filled feeding trails are located at 4,586.4 and 4,587.1 feet. The interval is noncalcareous.

4,588.2' - 4,599.4'  
(11.2')

Silty mudstones and silty shales, brownish black (5YR 2/1) and olive gray (5Y 3/2), thinly laminated to thin bedded. The interval is composed predominantly of a brownish black color; olive gray occurs as occasional thin and thick laminae. Thin calcite laminae and crystals are found within the interval. Carbonaceous spore bodies commonly occur throughout. Several pyrite nodules and lenses are present between 4,592.0 and 4,594.4 feet, as well as a single nodule located at 4,599.3 feet. The interval is noncalcareous.

4,599.4' - 4,609.5'  
(10.1')

Silty mudstones and silty shales, brownish black (5YR 2/1) and olive gray (5Y 4/1), thinly laminated to thin bedded. Brownish black silty mudstone dominates the interval. Several olive gray silty mudstone zones occur between 4,603.6 and 4,606.5 feet; silty shales occur throughout. An olive gray concretion (6.0 cm in thickness) flanked by disturbed laminae, some of which are partially oxidized, is present at 4,603.8 feet. Very thin iron stained (partially oxidized ?) siltstone laminae are also present, and extends from 4,604.0 to 4,605.6 feet. A 0.1-foot thick zone of wavy bedding occurs at 4,605.3 feet. Occasional grains of disseminated pyrite are present throughout the interval; numerous carbonaceous spore bodies are also present throughout. A few carbonaceous fragments are found at 4,604.9 feet. The interval is noncalcareous.

INTERVALDESCRIPTION

4,609.5' - 4,620.7'  
(11.2')

Silty mudstones, silty shales, and siltstones, brownish black (5YR 2/1), olive gray (5Y 4/1), and light olive gray (5Y 5/2), thinly laminated to thin bedded. The upper 3.0 feet of the interval consists of a brownish black silty shale, while the remaining 8.2 feet is composed of alternating laminae and bands (<0.5 ft. thick) of brownish black and olive gray silty mudstone and light olive gray siltstone. Calcite crystals and numerous spore bodies, some of which are pyritized, occur throughout the interval; pyrite is also present in the form of sparse nodules (4,160.0 ft.). A single carbonaceous Craniops sp. (?) mold (2 mm diam.) along with a carbonaceous Lingula sp. (4 mm diam.) are also present.

4,620.7' - 4,633.5'  
(12.8')

Silty mudstones, silty shales, and siltstones, olive gray (5Y 4/1), olive black (5Y 2/1), and light olive gray (5Y 5/2), thinly laminated to thin bedded. The core is comprised of alternating laminae and bands (<0.5 ft. thick) of olive gray and olive black silty mudstone and silty shale, and light olive gray siltstone. A highly calcareous siltstone concretion (35 mm diam. by 85 mm), flanked by disturbed laminae, is located at 4,632.1 feet. Disseminated grains of pyrite, as well as carbonaceous spore bodies, are common throughout the interval. A single carbonaceous fragment (5 mm diam. by 15 mm) is present at 4,632.8 feet.

4,633.5' - 4,645.7'  
(12.2')

Silty mudstones, siltstones, and silty shales, olive gray (5Y 4/1), olive black (5Y 2/1), and light olive gray (5Y 5/2), thinly laminated to thin bedded. Alternating laminae and bands (<1.0 ft. thick) of olive gray and olive black silty mudstone, light olive gray calcareous siltstone, and several zones of dark silty shale comprise the interval. A highly calcareous siltstone concretion (2.0 cm diam. by 3.0 cm) flanked by disturbed laminae, is located at 4,639.7 feet; a second, smaller concretion is present at 4,641.2 feet. A 0.1-foot thick bioturbated zone is present at 4,635.0 feet. Horizontal, pyrite mineralized burrow structures (averaging 5.0 mm in length) are prevalent in the olive gray zones extending from 4,634.0 to 4,635.0 feet, and from 4,641.6 feet to the bottom of the interval. Many carbonaceous bodies are scattered throughout the interval. A few carbonaceous fragments and brachiopods are situated at 4,642.7 feet.

INTERVALDESCRIPTION

4,645.7' - 4,655.7'  
(10.0')

Silty mudstones, siltstones, and silty shales, olive gray (5Y 4/1), olive black (5Y 2/1), and light olive gray (5Y 6/1), thinly laminated to thin bedded. Alternating laminae and bands (<1.0 ft. thick) of olive gray and olive black silty mudstone, and numerous light olive gray siltstone laminae comprise the interval. A single zone of olive black silty shale extends from 4,649.3 to 4,649.8 feet. Two calcareous siltstone concretions (35 mm diam. by 80 mm, and 1 cm diam.) are found at 4,650.5 and 4,650.8 feet, respectively. Horizontal and subvertical, mud filled and pyrite mineralized burrow structures (averaging 4.0 mm in length) occur throughout the interval, predominating in the olive gray zones. Pyrite also occurs commonly as disseminated grains and occasionally as nodules. Many brachiopod molds (averaging 3.0 mm in diam.) are scattered throughout the core; carbonaceous fragments are scarce. A single, iron stained (pyrite oxidized ?) plant fragment (5.0 mm diam. by 30.0 mm) is present at 4,652.6 feet. The interval is slightly calcareous.

4,655.7' - 4,667.4'  
(11.7')

Silty mudstones, silty shales, and siltstones, olive gray (5Y 4/1), olive black (5Y 2/1), and light olive gray (5Y 6/1), thinly laminated to thin bedded. The interval is comprised of alternating laminae and bands (<1.0 ft. thick) of olive gray and olive black silty mudstone and silty shale, and light olive gray siltstone; the silty shales occur in four zones: 4,655.9 to 4,656.2 feet, 4,658.3 to 4,658.8 feet, 4,662.0 to 4,662.5 feet, and 4,664.8 to 4,666.8 feet. Siltstone is present in several forms: as several calcareous concretions (up to 12 mm diam. by 25 mm) located at 4,657.5 and 4,663.2 feet, as wavy bedding, as a filling in horizontal burrow structures (up to 8 mm in length) in a 0.1-foot thick zone at 4,662.8 feet, and as thin and thick laminae throughout the core. Horizontal, mud filled and pyrite mineralized burrow structures (averaging 5.0 mm in length) commonly occur in the upper 2.0 feet of the interval, and sparsely in the remainder of the core. Numerous brachiopod molds, including some *Styliolina* (?) molds are found in zones extending from 4,657.3 to 4,659.1 feet, and from 4,663.3 to the bottom of the interval. The interval is slightly calcareous.

INTERVALDESCRIPTION

4,667.4' - 4,680.3'  
(12.9')

Silty mudstones, silty shales, and siltstones, olive gray (5Y 4/1), olive black (5Y 2/1), and light olive gray (5Y 6/1), thinly laminated to thin bedded. The interval is composed predominantly of olive gray silty mudstones, olive black silty shales, and thin laminae of light olive gray siltstone. The silty shales occupy the following four zones: 4,668.8 to 4,669.9 feet, 4,672.0 to 4,674.0 feet, 4,675.5 to 4,675.6 feet, and 4,678.0 to 4,679.5 feet. Siltstone occurs in a variety of forms, all found within an olive gray zone extending from 4,670.1 to 4,670.7 feet: as wavy bedding; as burrow fillings; as load casts; and as a single concretion. Thin siltstone laminae commonly occur throughout the interval, as do many brachiopod molds (averaging 3.0 mm diam.). A vitrified plant fragment extends across the diameter of the core at 4,668.8 feet. Horizontal, mud filled burrow structures are situated at 4,672.8 feet. The interval is slightly calcareous.

4,680.3' - 4,693.0'  
(12.7')

Silty shales, silty mudstones, and siltstones, olive black (5Y 2/1), olive gray (5Y 4/1), and light olive gray (5Y 5/2), thinly laminated to thin bedded. Alternating laminae and bands (<1.0 ft. thick) of olive black and olive gray silty shale and silty mudstone comprise the interval. Thin and thick laminae of light olive gray siltstone, some of which are wavy, occur throughout. Concentrations of these siltstones occur from 4,685.0 to 4,686.2 feet, and from 4,688.3 to 4,688.7 feet. There is a scattering of pyrite nodules throughout the interval; disseminated grains of pyrite are sparse. Rare carbonaceous fragments are found at 4,686.4 feet. A single, *Styliolina* (?) mold (5 mm diam. by 75 mm) is present at 4,687.0 feet. A calcite nodule (5 mm diam.) occurs at 4,687.5 feet. The interval is moderately calcareous.

<u>INTERVAL</u>	<u>DESCRIPTION</u>
4,693.0' - 4,701.1' (8.1')	Silty shales, silty mudstones, and siltstones, olive black (5Y 2/1), olive gray (5Y 4/1), and light olive gray (5Y 5/2), thinly laminated to thin bedded. The interval is predominantly composed of olive black silty shales; the less frequent and less fissile olive gray silty mudstones are irregularly spaced throughout the interval, as are laminae of occasionally wave-form light olive gray siltstone. Siltstone also occurs as small nodules (2-3 mm diam.) in a 5.0-foot zone extending from 4,695.5 to 4,700.0 feet, and as large concretions (4 cm diam. by 12 cm) and (0.2 ft. thick) located at 4,699.9 and 4,699.4 feet, respectively. The former concretion is flanked by disturbed laminae, and the latter contains disseminated pyrite grains within the mass. Occasional feeding trails occur throughout the interval, along with rare carbonaceous fragments. A single <u>Styliolina</u> (?) mold (4.0 mm diam. by 50 mm) is present at 4,698.0 feet. The interval is moderately calcareous.
4,701.1' - 4,711.5' (10.4')	Silty shales, silty mudstones, and siltstones, olive black (5Y 2/1) and olive gray (5Y 4/1), thinly laminated to thin bedded. The interval predominantly consists of an olive black silty shale, with laminae and thin beds of olive black and olive gray silty mudstone interspersed throughout. Brachiopod molds and coiled cephalopods (all less than 4.0 mm diam.) are common, as are horizontal feeding trails. A single, straight cephalopod (1.0 cm diam. by 6.0 cm) is present at 4,711.4 feet. Pyrite occurs within the core in several forms: as stringers (up to 1.0 cm diam. by 6.0 cm), as nodules (2.0 cm diam. by 4.0 cm) found at 4,704.1 feet, and as disseminated grains contained within a siltstone concretion (15 mm diam. by 40 mm). A second siltstone concretion (4,707.3 ft.) is flanked by disturbed calcite veins. Occasional carbonaceous fragments and calcite crystals are also contained within the core. The interval is moderately to highly calcareous.

INTERVALDESCRIPTION

4,711.5' - 4,724.0'  
(12.5')

Silty shales, silty mudstones, and siltstones, olive black (5Y 2/1) and olive gray (5Y 4/1), thinly laminated to thin bedded. The core consists of olive black silty shales and silty mudstones; aside from a 0.4-foot thick olive gray bed at 4,718.7 feet, the occurrence of this color is rare. Siltstone is present as occasional thin and thick laminae, and as concretions (0.1 ft. thick) at 4,715.8 and 4,722.1 feet, both of which are flanked by disturbed laminae. Frequent horizontal feeding trails occur throughout the interval, often accompanied by coiled cephalopod and brachiopod molds (less than 4.0 mm). Carbonaceous plant fragments are present at 4,720.0 and 4,720.3 feet. The interval is moderately to highly calcareous.

4,724.0' - 4,734.0'  
(10.0')

Silty mudstones, silty shales, and siltstones, olive black (5Y 2/1) and olive gray (5Y 4/1), thinly laminated to thin bedded. Olive black silty mudstones and silty shales comprise the interval. Olive gray is present as a 1.0-foot thick zone extending from 4,730.5 to 4,731.5 feet, which contains many large veins (up to 3.0 cm diam.) of calcite, rimmed by siltstones and carbonaceous fragments. Several coiled cephalopod molds (up to 3.0 cm diam.) along with a straight cephalopod mold are present at 4,724.2 feet; brachiopod molds (<3.0 mm diam.) are common throughout, as are horizontal feeding trails. Pyrite occurs as a nodule (1.0 cm diam. by 3.0 cm) at 4,726.5 feet, and as mineralization on a burrow structure (7.0 mm diam. by 50 mm) at 4,732.0 feet. The interval changes from moderately calcareous in the upper half to slightly calcareous in the lower half.

4,734.0' - 4,745.4'  
(11.4')

Shaly mudstones and silty mudstones, olive black (5Y 2/1) and olive gray (5Y 4/1), thinly to thickly laminated. Olive gray is restricted to a single thick silty mudstone lamina at 4,743.1 feet and to a calcareous concretion (10 cm estimated diam.) at 4,739.7 feet. Fault planes and a calcite mineralized vertical joint are associated with this concretion. Partially oxidized pyrite nodules ranging in diameter from 1 mm to 1 cm are rare. Fossils and biogenic structures appear to be absent from the interval. The interval is moderately calcareous in the lighter zones, noncalcareous throughout the remainder.

INTERVALDESCRIPTION

4,745.4' - 4,757.2'  
(11.8')

Shaly mudstones, olive black (5Y 2/1), and olive gray (5Y 4/1), thinly to thickly laminated. Olive gray is present only from 4,725.0 to 4,752.2 feet and at 4,752.8 feet. Partially oxidized pyrite nodules, most less than 5 mm in diameter, are rare. A few isolated wood fragments, less than 1 cm in length, are restricted to the upper 1/3. Other than these fragments, the interval is void of fossils. The interval is noncalcareous.

4,757.2' - 4,768.0'  
(10.8')

Shaly mudstone, olive black (5Y 2/1), thinly laminated. The interval is slightly to moderately calcareous and contains partially oxidized pyrite nodules. These nodules range from 5 mm to 2 cm in diameter and are commonly encased in a tight mud envelope. Fossils and biogenic structures are present. A one-foot thick zone, which was rubblized during coring, occurs from 4,763.5 to 4,764.5 feet.

4,768.0' - 4,772.0'  
(4.0')

Calcareous mudstones and argillaceous limestone, olive gray (5Y 3/2 and 5Y 4/1) and light olive gray (5Y 5/2), thin to thick bedded. The argillaceous limestone occurs in a single, thin bed at the center of the interval; it contains numerous septarian cracks and vugs filled with calcite and fibrous gypsum (?). This interval is sparsely to moderately fossiliferous throughout. These fossils consist of pyrite-coated plant fragments, articulate and inarticulate brachiopod shells, calcareous crinoid stems, and bryozoa (?) fragments. A few subhorizontal, pyrite filled burrow structures occur throughout.

4,772.0' - 4,775.6'  
(3.6')

Mudstone, olive black (5Y 2/1), thick bedded. The interval is very slightly calcareous; composition and texture are uniform throughout. A few carbonaceous plant fragments, and tiny (~2 mm) inarticulate brachiopods (Lingula sp.) occur near the base of this interval.

<u>INTERVAL</u>	<u>DESCRIPTION</u>
4,775.6' - 4,780.0' (4.4')	Calcareous mudstones and argillaceous limestones, olive black (5Y 2/1) and olive gray (5Y 4/1), thin bedded. The limestone occurs in two distinct beds at 4,776.5 and 4,779.0 feet; it is composed of dense, fine-grained calcite, and appears to be concretionary in origin. This interval is sparsely fossiliferous, containing carbonaceous plant fragments and occasional inarticulate brachiopods ( <u>Lingula</u> sp.). A few subhorizontal, pyrite mineralized burrow structures occur in the basal one foot.
4,780.0' - 4,787.0' (7.0')	Mudstones and calcareous mudstones, olive black (5Y 2/1) and olive gray (5Y 3/2), thick bedded. Pyrite occurs throughout as nodules (3 mm to 5 mm diam.), irregular laminae, and thin lenses. A few subhorizontal, pyrite mineralized burrow structures are present. Fossils are sparse in this interval, consisting of carbonaceous plant fragments and inarticulate brachiopods ( <u>Lingula</u> sp.).
4,787.0' - 4,792.7' (5.7')	Calcareous mudstone, olive black (5Y 2/1), thick bedded. Pyrite nodules and laminae occur throughout; the laminae are very irregular. A few subhorizontal, pyrite mineralized burrow structures are present. Fossils are moderately abundant in this interval, consisting of carbonaceous plant fragments and inarticulate brachiopod shells ( <u>Lingula</u> sp.).
4,792.7' - 4,798.5' (5.8')	Calcareous mudstones, olive black (5Y 2/1) and dark yellowish brown (10YR 4/2), thin to thick bedded. The yellowish brown zones, which are highly pyritic, are present between 4,795.8 and 4,796.0 feet and from 4,797.8 to 4,797.9 feet. Pyrite occurs in these zones as nodules, laminae, disseminated crystals, and mineralization in subhorizontal burrow structures. Many of the larger pyrite nodules contain septarian-like cracks filled with calcite. Although pyrite is most abundant in the yellowish brown zones, it is not restricted to these zones; pyrite nodules and burrow fillings occur throughout the interval. Fossils are common and consist of inarticulate brachiopods ( <u>Lingula</u> sp.) and carbonaceous fragments.

INTERVALDESCRIPTION

4,798.5' - 4,803.1'  
(4.6')

Calcareous mudstone, olive black (5Y 2/1), thick bedded. This interval is uniform in composition and texture throughout. A few pyrite nodules with associated calcite mineralization are present. Fossils are scattered throughout, consisting predominantly of inarticulate brachiopod shells and shell fragments (Lingula sp.), and occasional carbonaceous plant fragments.

4,803.1' - 4,808.7'  
(5.6')

Calcareous mudstones and argillaceous limestones, olive gray (5Y 3/2 and 5Y 4/1) and light olive gray (5Y 5/2 and 5Y 6/1), thin bedded. Indistinct beds of argillaceous limestone are present at 4,803.5, 4,804.3 and 4,806.7 feet. Pyrite occurs throughout as nodules and coatings on shell fragments; a few subhorizontal, pyrite mineralized burrow structures are also present. Calcite mineralization is associated with many of the pyrite nodules and occurs as vug fillings and mineralization on shell casts in the limy zones. Fossils in this interval include articulate and inarticulate brachiopods, carbonaceous plant fragments, and crinoid stems.

4,808.7' - 4,815.4'  
(6.7')

Calcareous mudstone, olive black (5Y 2/1), thick bedded. Pyrite occurs sparsely throughout as nodules, lenses and coatings on plant and shell fragments. Occasional, pyrite mineralized subhorizontal burrow structures are also present. Fossils occurring in this interval include inarticulate brachiopods (Lingula sp.) and carbonaceous plant fragments.

4,815.4' - 4,822.8'  
(7.4')

Calcareous mudstones, olive black (5Y 2/1) at the top of the interval, lightening to olive gray (5Y 3/2) at the base, thick bedded. Subhorizontal, pyrite mineralized burrow structures and pyrite coated plant fragments are present on partings in the lower 1/2. Small, carbonaceous spore bodies (Tasmanites sp. ?) and carbonaceous plant fragments occur throughout, but are most common in the upper 1/2. A few inarticulate brachiopod shells and shell fragments (Lingula sp.) are present throughout.

<u>INTERVAL</u>	<u>DESCRIPTION</u>
4,822.8' - 4,830.0' (7.2')	Calcareous shaly mudstones, olive gray (5Y 3/2) at the top, darkening to olive black (5Y 2/1) at the base, thin bedded. This interval is very fissile, rubblized, and lithologically similar to the aforementioned interval. Pyrite nodules and lenses are common in this interval; pyrite coated plant fragments and subhorizontal, pyrite mineralized burrow structures occur throughout. Fossils are relatively scarce, consisting of inarticulate brachiopod shells and shell fragments ( <u>Lingula</u> sp.), and carbonaceous plant fragments. A few carbonaceous spore bodies ( <u>Tasmanites</u> sp.) occur on partings in the upper 1/2.
4,830.0' - 4,832.5' (2.5')	Calcareous mudstones and argillaceous limestones, olive black (5Y 2/1) and olive gray (5Y 3/2), thin bedded. Calcareous mudstone occurs in the upper 1/2 of this interval; carbonate content increases downcore and this lithology eventually becomes argillaceous limestone. A few inarticulate brachiopod shells ( <u>Lingula</u> sp.) occur in the calcareous mudstones. The argillaceous limestones contain numerous, calcite mineralized articulate brachiopod shells.
4,832.5' - 4,836.9' (4.4')	Argillaceous limestones, lime mudstones, and wackestones, olive gray (5Y 3/2), light olive gray (5Y 5/2), and yellowish gray (5Y 7/2), thickly laminated to thin bedded. The different carbonate units in this interval are distributed in irregular, uneven zones with indistinct bedding planes and poorly defined boundaries. Many curved, sinuous fractures occur throughout; these are filled with clay and appear to be vertical stylolites (?). The grain component of the wackestone units consists of crinoid stems, articulate brachiopod shell fragments, and bryozoa (?) fragments. This interval is fossiliferous throughout; articulate brachiopods and crinoid stems are common. A concentration of large crinoids occurs at the base of the interval (4,836.8 ft.).

<u>INTERVAL</u>	<u>DESCRIPTION</u>
4,836.9' - 4,843.3' (6.4')	Calcareous mudstones and argillaceous limestones, olive gray (5Y 4/1) and light olive gray (5Y 6/1), thin bedded. Argillaceous limestone occurs throughout as numerous, calcareous concretions. Several of the concretions contain septarian cracks and vugs filled with coarse brown calcite crystals. This interval is highly fossiliferous, containing abundant articulate brachiopod shells and shell fragments, occasional crinoid stems, a few bryozoa, and a single cephalopod shell (?) at 4,842.95 feet.
4,843.3' - 4,850.1' (6.8')	Calcareous mudstones and mudstones, olive gray (5Y 3/2), thick bedded. Although most of this interval is calcareous, a few noncalcareous zones occur near the base. Subhorizontal, pyrite mineralized burrow structures are scattered sparsely throughout. This interval is highly fossiliferous, containing abundant casts of articulate brachiopods and pelecypods.
4,850.1' - 4,856.0' (5.9')	Calcareous mudstone, olive gray (5Y 3/2), thick bedded. Pyrite occurs throughout as nodules, laminae, and coatings on shells. This interval contains abundant fossils on several partings; these include articulate brachiopod and pelecypod shells, crinoid stems and segments, and fragments of bryozoa. A few inarticulate brachiopods and carbonaceous fragments occur throughout.
4,856.0' - 4,860.1' (4.1')	Calcareous mudstone, olive gray (5Y 3/2 and 5Y 4/1), thin bedded. Carbonaceous plant fragments are abundant throughout, occurring on nearly every parting. A few small pyrite nodules and inarticulate brachiopod shells ( <u>Lingula</u> sp.) are present.
4,860.1' - 4,868.9' (8.8')	Calcareous mudstone, olive gray (5Y 4/1), thinly laminated to thin bedded. Numerous, thin carbonate laminae occur in the upper two feet; a near-vertical fracture mineralized with calcite is also present in the upper 1/2. Subhorizontal, pyrite mineralized burrow structures are abundant throughout; a few pyrite nodules are present. Carbonaceous plant fragments are very common in this interval, occurring on nearly every parting. A few inarticulate brachiopods occur throughout; articulate brachiopod shells and shell fragments are present in the lower 1/2. A pelecypod shell occurs on a parting at 4,867.1 feet.

<u>INTERVAL</u>	<u>DESCRIPTION</u>
4,868.9' - 4,875.1' (6.2')	Calcareous mudstones, olive gray (5Y 4/1 at top, 5Y 3/2 at base), thick bedded. This interval contains abundant fossils, including inarticulate and articulate brachiopods, pelecypods, and carbonaceous plant fragments. The cast of an unusual triangular shell, possibly a conularida (?), occurs on a parting at 4,871.0 feet.
4,875.1' - 4,880.5' (5.4')	Calcareous mudstones, olive gray (5Y 4/1 and 5Y 3/2), thinly to thickly laminated. The alternating dark and light colored zones give the core a banded appearance. Fossils are sparse in this interval, consisting of carbonaceous plant fragments and a few inarticulate brachiopod shells ( <u>Lingula</u> sp.).
4,880.5' - 4,885.0' (4.5')	Calcareous mudstones, olive gray (5Y 4/1) and light olive gray (5Y 5/2), thin bedded. The lighter zones are highly calcareous and occur in the upper 1/2. A few near-vertical burrow structures are present in the lighter zones; a distinct burrow occurs from 4,880.7 to 4,880.8 feet. A few carbonaceous plant fragments and inarticulate brachiopod shell fragments occur throughout.
4,885.0' - 4,893.5' (8.5')	Calcareous mudstones, olive gray (5Y 4/1 at top, 5Y 3/2 at base), thin to thick bedded. Alternating light and dark zones in the upper 1/2 give the core a banded appearance. The lower 1/2 of the interval is slightly shaly; fissility is more apparent when the rock is wet. This interval is barren of fossils except for a single parting at 4,889.9 feet which contains several gastropod casts.
4,893.5' - 4,900.0' (6.5')	Calcareous mudstones, olive gray (5Y 4/1 and 5Y 3/2), thinly to thickly laminated. Alternating light and dark zones give the core a banded appearance. A few subhorizontal, pyrite mineralized burrow structures are present in the darker laminae in the lower 1/2. Fossils are nearly absent from this interval; a few carbonaceous plant fragments are scattered throughout.

<u>INTERVAL</u>	<u>DESCRIPTION</u>
4,900.0' - 4,907.8' (7.8')	Calcareous mudstones, olive gray (5Y 4/1 and 5Y 3/2), thinly to thickly laminated. Alternating dark and light zones give the core a faint banded appearance. A few pyrite nodules and subhorizontal, pyrite mineralized burrow structures occur throughout. The only other fossils present in this interval are a few carbonaceous plant fragments.
4,907.8' - 4,914.6' (6.8')	Calcareous mudstones, olive gray (5Y 4/1 and 5Y 3/2), thinly to thickly laminated. Alternating dark and light zones give the core a faint banded appearance. A few small pyrite nodules and subhorizontal, pyrite mineralized burrow structures occur throughout. Several tiny (1 to 2 mm), rhombohedral calcite crystals are scattered between 4,910 and 4,912 feet. A few, poorly-preserved pelecypod and articulate brachiopod shells occur throughout the lower 1/2.
4,914.6' - 4,920.5' (5.9')	Calcareous mudstone, olive gray (5Y 4/1), thin bedded. The core has a very faint banded appearance; slightly darker zones are present throughout. Several small nodules of crystalline calcite are present between 4,916 and 4,918 feet. Subhorizontal, pyrite mineralized burrow structures occur sparsely throughout the lower 1/2. Fossils are rare in this interval, consisting of a few scattered articulate brachiopod shell fragments. Partings in the lower 1/2 occasionally contain carbonaceous spore bodies ( <u>Tasmanites</u> sp.).
4,920.5' - 4,928.1' (7.6')	Calcareous mudstones, shaly in parts, olive gray (5Y 3/2 and 5Y 4/1), thinly to thickly laminated. Alternating light and dark zones give the core a faint banded appearance. Mud filled casts of feeding trails are present on a parting at 4,925.25 feet. This interval is barren of fossils, except for a few carbonaceous plant fragments and occasional spore bodies ( <u>Tasmanites</u> sp.).

<u>INTERVAL</u>	<u>DESCRIPTION</u>
4,928.1' - 4,936.6' (8.5')	Calcareous mudstones, olive gray (5Y 3/2 and 5Y 4/1), thinly laminated to thin bedded. Alternating light and dark zones give the core a faint banded appearance. A few partings contain casts of trails. Fossils are rare in this interval, consisting of a few articulate brachiopod shells and carbonaceous plant fragments.
4,936.6' - 4,944.8' (8.2')	Calcareous mudstones, shaly in parts, olive gray (5Y 4/1 and 5Y 3/2), and olive black (5Y 2/1), thickly laminated to thin bedded. Alternating light and dark zones give the core a faint banded appearance. Fissility is restricted to the darker units. This interval is barren of fossils, except for a few carbonaceous plant fragments.
4,944.8' - 4,951.6' (6.8')	Calcareous mudstones, olive gray (5Y 3/2 and 5Y 4/1) and light olive gray (5Y 5/2), thickly laminated to thin bedded. The lighter zones are highly calcareous and appear to be concretionary; most occur in the upper 1/2. This interval is barren of fossils, except for a few carbonaceous plant fragments.
4,951.6' - 4,955.8' (4.2')	Calcareous mudstones, olive gray (5Y 3/2 and 5Y 4/1), thickly laminated to thin bedded. Alternating light and dark zones give the core a faint banded appearance. This interval is barren of fossils.
4,955.8' - 4,961.8' (6.0')	Calcareous mudstones, olive gray (5Y 3/2 and 5Y 4/1) and light olive gray (5Y 5/2), thin bedded. Alternating light and dark zones give the core a faint banded appearance. A near-vertical, calcite filled natural fracture is present in the lower 1/2. This interval is barren of fossils.
4,961.8' - 4,969.7' (7.9')	Calcareous mudstones, olive gray (5Y 3/2) and olive black (5Y 2/1), thin bedded, shaly in parts. The interval is very faintly banded and contains a long, near vertical, calcite filled compound natural fracture. This interval is barren of fossils, except for a few carbonaceous plant fragments.

<u>INTERVAL</u>	<u>DESCRIPTION</u>
4,969.7' - 4,977.7' (8.0')	Calcareous mudstones, olive gray (5Y 3/2) and olive black (5Y 2/1), thin to thick bedded. Alternating light and dark zones give the core a faint banded appearance; a few shaly zones occur throughout. This interval is barren of fossils, except for a few carbonaceous plant fragments.
4,977.7' - 4,979.6' (1.9')	Argillaceous limestone, olive gray (5Y 4/1), thick bedded. Numerous, small vertical cracks filled with dark material occur throughout; these appear to be vertical stylolites. Several poorly-preserved fossils occur throughout, including coiled-cephalopod casts, articulate and inarticulate brachiopod shell fragments, pelecypod (?) casts, and carbonaceous plant fragments and spore bodies ( <u>Tasmanites</u> sp.).
4,979.6' - 4,985.6' (6.0')	Calcareous mudstones and argillaceous limestones, olive gray (5Y 4/1 and 5Y 3/2), thin to thick bedded. Argillaceous limestone occurs in concretions throughout, and as a single thin bed in the lower 1/2. Occasional, pyrite-coated plant fragments are present in the lower 1/2. A few articulate and inarticulate brachiopod shells and shell fragments occur throughout.
4,985.6' - 4,990.0' (4.4')	Calcareous mudstone, olive gray (5Y 4/1), thick bedded. Pyrite nodules (3 to 10 mm in diam.) are common near the middle of the interval; a pyritic lamina occurs at 4,987.3 feet. Carbonate is commonly associated with the pyrite. A few nodules of calcite are present in the lower 1/2. Small articulate brachiopod shells and shell fragments are common throughout.
4,990.0' - 5,001.5' (11.5')	Calcareous mudstones, olive gray (5Y 3/2 and 5Y 4/1), thinly laminated to thin bedded. The interval is composed of alternating laminae and bands (<1.0 ft. thick) of the various olive gray shades. Individual calcite crystals and a few calcite concretions (up to 5 mm diam.) are scattered within the upper half of the interval. Several pyrite nodules occur in the upper two feet. No fossils or sedimentary structures are present.

INTERVALDESCRIPTION

5,001.5' - 5,012.9'  
(11.4')

Calcareous mudstones, olive gray (5Y 4/1 and 5Y 3/2), thinly laminated to thin bedded. Alternating laminae and bands (<1.0 ft. thick) of the olive gray shades comprise this interval. A single, horizontal mud filled burrow structure (4 mm diam. by 15 mm) is present at 5,010.3 feet. A few calcite concretions occur within the upper half of the interval. No sedimentary structures are present.

5,012.9' - 5,020.8'  
(7.9')

Silty mudstones, mudstones, and siltstones, olive gray (5Y 3/2 and 5Y 4/1) and yellowish gray (5Y 7/2), thinly laminated to thin bedded. The interval is composed of alternating laminae and bands (<1.0 ft. thick) of olive gray (5Y 3/2 and 5Y 4/1) silty mudstone and mudstone. Thin and thick laminae of yellowish gray silty mudstone occur within the bottom four feet of the core; bioturbation is associated with these yellowish gray zones. Many brachiopod molds and shells, along with a few straight cephalopods (all less than 1 cm in length), occur throughout the interval, becoming more prevalent in the bottom half. Small calcite concretions (3 mm in diam.), some of which contain grains of disseminated pyrite, are scattered within the core. The entire interval is calcareous.

5,020.8' - 5,033.3'  
(12.5')

Mudstones and silty mudstones, olive gray (5Y 3/2) and light olive gray (5Y 6/1), thinly laminated to thin bedded. The interval is comprised of thin and thick laminae of light olive gray silty mudstone contained throughout an olive gray mudstone and silty mudstone core; the frequency of these light olive gray bands increases downcore. Bioturbation is evident throughout, with many horizontal feeding trails noted at partings within the core. Brachiopod molds (up to 6 mm diam.) are especially prevalent within the bottom half of the interval. A single trilobite mold (? the bottom 1/3 of which is visible), is located at 5,027.6 feet, and is approximately 5 mm diam. by 8 mm in length. Small concretions containing calcite crystals (up to 4 mm diam. by 8 mm) are common throughout the interval. The entire interval is highly calcareous.

INTERVALDESCRIPTION

5,033.3' - 5,044.1'  
(10.8')

Silty mudstones, mudstones, and silty shales, olive gray (5Y 3/2 and 5Y 4/1), thinly laminated to thin bedded. Alternating laminae and bands (<1.0 ft. thick) of varying shades of olive gray silty mudstone and mudstone constitute the interval; several small zones (up to 0.2 ft. thick) of olive gray (5Y 3/2) silty shale are also contained within this interval, becoming more prevalent towards the bottom. Only a few brachiopod molds (5 mm diam.) are present, and occasional horizontal feeding trails only occur at bedding partings within the bottom third of the core. Concretions containing calcite crystals (up to 7 mm in length), some of which are rimmed with pyrite, are found throughout this moderately calcareous interval.

5,044.1' - 5,057.1'  
(13.0')

Silty shales and silty mudstones, olive black (5Y 2/1) and olive gray (5Y 3/2 and 5Y 4/1), thinly laminated to thin bedded. This interval is predominantly composed of silty shales with alternating laminae and bands (<0.5 ft. thick) of olive black and olive gray (5Y 3/2); olive gray (5Y 4/1) silty mudstones are interspersed within the bottom three feet of the interval. Several brachiopod molds (up to 5 mm diam.), as well as a few small plant fragments are found throughout the core; individual calcite crystals and their associated concretions are limited to the upper half. Horizontal burrow trails occur on many bedding partings within the interval. The core is slightly to moderately calcareous.

5,057.1' - 5,067.2'  
(10.1')

Silty shale, olive black (5Y 2/1) and olive gray (5Y 4/1), thinly laminated to thin bedded. The interval is uniform in appearance, being composed of alternating olive black and olive gray laminae and bands (<1.0 ft. thick), and varying only in fissility. Single, brachiopod (4 mm diam.) and coiled cephalopod (15 mm diam.) molds occur within the upper two feet of the interval. Occasional horizontal feeding trails are also present at various partings along the core. The entire interval is moderately calcareous.

<u>INTERVAL</u>	<u>DESCRIPTION</u>
5,067.5' - 5,077.8' (10.3')	Silty shales, silty mudstones, and mudstones, olive black (5Y 2/1) and olive gray (5Y 4/1), thinly laminated to thin bedded. The core is comprised of alternating olive black and olive gray laminae and bands (<1.0 ft. thick); varying degrees of fissility occur throughout. A few small brachiopod molds and a scattering of feeding trails are the only fossils present in this interval. The interval is moderately calcareous.
5,077.8' - 5,088.4' (10.6')	Silty shales and silty mudstones, olive black (5Y 2/1) and olive gray (5Y 4/1), thinly laminated to thin bedded. Alternating laminae and bands (<1.0 ft. thick) of olive black and olive gray silty shale are predominant within the interval. Several small brachiopod molds (3 mm diam.), carbonaceous fragments, and horizontal feeding trails are contained within the core; no pyrite is present. The interval is moderately calcareous.
5,088.4' - 5,101.0' (12.6')	Silty shale, olive black (5Y 2/1), thinly laminated to thin bedded. The interval is uniform in appearance, and varies only in the degree of fissility. Calcite crystals are prevalent throughout the interval. Fossils are rare; only occasional feeding trails are present. No pyrite is present. The interval is moderately calcareous.
5,101.0' - 5,111.1' (10.1')	Shaly mudstones, olive gray (5Y 3/2), thinly laminated. Two fossils are present within the interval which include: a pelecypod at 5,101.6 feet and a poorly preserved brachiopod imprint at 5,104.3 feet. Several straight organism trails, 3 mm across by core diameter, are present throughout. The interval is moderately calcareous.
5,111.1' - 5,124.7' (13.6')	Shaly mudstones, olive gray (5Y 4/1) and grayish black (N2), thinly laminated to thin bedded. The upper 3 feet is grayish black; the remainder of the interval is olive gray. Several large pelecypod fragments, numerous small brachiopod fragments and a single cephalopod are present at 5,111.3 feet. Individual brachiopod and cephalopod fragments also occur rarely throughout. A light olive gray (5Y 6/1) calcareous concretion having an estimated diameter of 15 cm occurs at 5,113.5 feet. The grayish black zone is noncalcareous; the olive gray zones are moderately calcareous.

INTERVALDESCRIPTION

5,124.7' - 5,134.3'  
(9.6')

Shaly mudstones, olive black (5Y 2/1) to grayish black (N2), thinly to thickly laminated. The core gradually grades from olive black to grayish black in a downcore direction within the length of the interval. Fossil and pyrite occurrences are restricted to a single cephalopod at 5,215.3 feet and a nodule at 5,131.0 feet. The interval is slightly calcareous.

5,134.3' - 5,135.4'  
(1.1')

Lime mudstones, light olive gray (5Y 6/1) and olive gray (5Y 4/1), thin bedded. The interval is composed of a single thin bed of lime mudstone containing small (less than 5 mm diam. by 1 cm length) burrows and recrystallized pelecypod shell fragments.

5,135.4' - 5,148.0'  
(12.6')

Shaly mudstones, olive black (5Y 2/1), dark gray (N3) and olive gray (5Y 4/1), thinly to thickly laminated. The olive gray shaly mudstone is restricted to a zone between 5,143.0 and 5,143.2 feet. The olive black shaly mudstones occur in the upper three feet and are noncalcareous. The dark gray and olive gray zones occur throughout the remainder of the interval and are weakly to moderately calcareous. Pelecypods, straight cephalopods and inarticulate brachiopods occur throughout but are concentrated in and adjacent to a highly calcareous zone at 5,143.0 feet. Wood fragments, some of which are pyritized, and pyrite nodules occur in isolated instances scattered throughout the interval.

5,148.0' - 5,160.6'  
(12.6')

Shaly mudstones, olive black (5Y 2/1) and black (N1), thinly to thickly laminated. The interval is predominantly olive black; the black shaly mudstones are restricted to a two-foot thick zone near the center of the interval. Occasional pelecypod fragments and pyrite nodules of various sizes occur throughout. A concentration of fossil shell fragments is present at 5,160.1 feet. The majority of the interval is slightly to moderately calcareous, the black zones are noncalcareous.

INTERVAL	DESCRIPTION
5,160.6' - 5,166.8' (6.2')	Shaly mudstones, olive black (5Y 2/1) and olive gray (5Y 4/1), thinly to thickly laminated. Olive gray is restricted to a single thick lamina at 5,162.0 feet and to a calcareous concretion containing calcite filled septarian cracks at 5,166.3 feet. Pyrite is contained within the interval and occurs as large partially oxidized nodules, up to 4 cm across, and as small euhedral crystals, up to 1 to 4 mm across. A concentration of fossil shell fragments, including pelecypods, cephalopods, wood fragments and possibly a gastropod occur at 5,162.6 feet. The interval is slightly to moderately calcareous.
5,166.8' - 5,173.5' (6.7')	Shaly mudstone, olive black (5Y 2/1), thinly to thickly laminated. Several of the partings in the upper one foot contain abundant inarticulate brachiopods ( <i>Orbiculoides</i> sp.) and pelecypods. Two poorly preserved straight cephalopod imprints are noted in the lower one foot. Two sulfate (?) nodules, approximately 4 cm in diameter, are present in the upper 1/3. The interval is slightly calcareous.
5,173.5' - 5,176.0' (2.5')	Lime mudstones and calcareous mudstones, olive gray (5Y 4/1), light olive gray (5Y 6/1) and olive black (5Y 2/1), thinly laminated to thin bedded. The upper 1/2 consists of an olive gray and light olive gray lime mudstone containing calcified shell fragments, dewatering (?) cracks and large (1 cm diam. by 3 cm length) mud filled burrow structures. The lower 1/2 is composed of olive black and olive gray calcareous mudstone containing abundant pelecypod (?) shell fragments and finely divided carbonaceous materials.
5,176.0' - 5,183.0' (7.0')	Shaly mudstones, black (N1) and olive gray (5Y 4/1), thinly to thickly laminated. The interval is predominantly black with only a few thick olive gray laminae present. A single fossil imprint is present at 5,176.2 feet. Euhedral pyrite crystals and pyritized mud lumps, usually less than 3 mm across, are common in the lower 1/2. The interval is noncalcareous. Two zones, each less than one half of a foot thick, which were rubblized during coring occur in the upper three feet.

<u>INTERVAL</u>	<u>DESCRIPTION</u>
5,183.0' - 5,190.0' (7.0')	Shaly mudstones, black (N1) and olive gray (5Y 4/1), thinly to thickly laminated. The black to olive gray ratio is similar to that in the preceding interval. Pyrite blebs, some up to 5 mm across, occur near the center of the interval. Occasionally, this mineral appears to be partially oxidized. A single, well preserved fish tooth is present at 5,185.6 feet. The interval is noncalcareous.
5,190.0' - 5,197.5' (7.5')	Shaly mudstones, black (N1), grayish black (N2), and olive gray (5Y 4/1), thinly to thickly laminated. Color occurrences within this interval are similar to those in the preceding intervals, with the only exception being a lightening from black to grayish black at the base of the interval. Well preserved woody fragments (?) exhibiting delicate surface structures are present at 5,194.9 feet. Pyrite is occasionally present. Tiny vitrinite fragments, usually less than 0.5 mm across, occur throughout.
5,197.5' - 5,199.4' (1.9')	Calcareous mudstones and argillaceous limestones, dark gray (N3) and medium dark gray (N4), thin bedded. This carbonate unit appears to be concretionary in origin; slickensided surfaces are present both above and below. Calcite-mineralized shell fragments and calcite-filled microfractures occur throughout.
5,199.4' - 5,203.2' (3.8')	Shaly mudstone, grayish black (N2), thinly to thickly laminated. Wood fragments (?) similar to those described in the interval 5,190.0 to 5,197.5 feet, are present in the upper foot. A zone containing calcified shell fragments occurs from 5,202.1 to 5,202.3 feet. Occasional pyrite nodules and tiny vitrinite fragments are distributed throughout. The interval is moderately calcareous.
5,203.2' - 5,205.3' (2.1')	Calcareous mudstones and argillaceous limestones, olive black (5Y 2/1) and olive gray (5Y 4/1), thin bedded. The limestone occurs as a single bed between 5,203.5 and 5,205.2 feet; it is sharply bounded above and below. The argillaceous limestone consists of a very fine, dense, tightly cemented matrix of small calcite crystals (micrite) and clay. Numerous irregular near-vertical fractures occur throughout, are filled with clay, and appear to be stylolites. No fossils are present in this interval.

INTERVAL

DESCRIPTION

5,205.3' - 5,210.1'  
(4.8')

Shaly mudstone, grayish black (N2), thinly to thickly laminated. Wood and vitrinite fragments as described in several of the preceding intervals are also present in the upper one foot of this interval. Large, partially oxidized pyrite nodules, up to 1 cm across, occur near the center. The interval is moderately calcareous.

5,210.1' - 5,213.5'  
(3.4')

Calcareous shaly mudstones, argillaceous limestones, and wackestones, grayish black (N2), dark gray (N3), and light olive gray (5Y 6/1), thickly laminated to thin bedded. This interval is highly fractured; numerous slickensided surfaces, calcite-filled septarian cracks, and calcite mineralized ? microfractures occur throughout. The wackestone occurs in a single bed at 5,210.5 feet. Most of the argillaceous limestone units appear to be concretionary in origin. This interval is barren of fossils.

A P P E N D I X B

SYMBOLS, TERMS, AND ABBREVIATIONS USED  
IN FRACTURE LOGGING

EGSP-PENNSYLVANIA #1 - MCKEAN 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 #1 WELL, MCKEAN COUNTY

CORING DATE: FEBRUARY 1979		EG.S.P. REVISED FRACTURE LOGGING FORMAT										PAGE 1 OF 3	
LOG DATE: MARCH 1981		WELL: EGSP-PENNSYLVANIA #1, MCKEAN COUNTY										NATURAL	
NUMBER	DEPTH EXTENT	LENGTH	LITHOLOGY	TERMINATIONS	CHARACTER	STRIKE DIP	FRACTURE TYPE	MINERALIZATION	SLICK-ENDES	FRACTOGRAPHIC FEATURES	COMMENTS		
1	3481.1 3481.2	0.1	Mudstone 5Y 3/2	↘	CP	N17°E 40°NW	Mer. Flt.	None	8° N8°E		Occurs above a small lens of siltstone.		
2	3517.1 3517.3	0.2	A/A	↘	CP	N72°E 62°NW	Mer. Flt.	None	~50° N2°E		Occurs around a concretion and through a siltstone bed.		
3	3517.3 ?	?	A/A	BDG. ?	P	N28°W 90°	Spl. Jt.	Calcite	----- -----	None	Closed fracture. Sampling termination unknown.		
4	3519.2 3520.1	0.9	Siltstone 5Y 5/2	BDG. →	P	N28°W 90°	Spl. Jt.	None	----- -----	None	Closed fracture.		
5	4614.8 4614.9	0.10	Shaly Mudstone N1	(M)	P	N50°E 13°NW	Flt.	None	5° N9°E		Base of a lime concretion. Direction of movement N9°E.		
6	4699.3 4699.4	0.10	Limestone 5Y 4/1	→	CP	N76°E 42°NW	Mer. Flt.	None	N22°W		Top of a lime concretion.		
7	4699.8 4699.9	0.10	Limestone 5Y 3/2	M →	CP	N80°E 24°SE	Mer. Flt.	None	22° S26°E		Top of a lime concretion. Movement direction NW.		
8	4699.9 4700.1	0.20	A/A	→	CP	N20°W 85°NE	Spl. Jt.	Calcite	----- -----	None	Closed fracture. Lime concretion.		
9	4707.8 4708.2	0.40	A/A	M ↘	CP	N18°E 85°NW	Cpd. Jt.	Calcite		None	Closed fracture. Lime concretion.		
10	4731.5 4731.7	0.20	Shaly Mudstone N3	↘	CP	No orient.	Mer. Flt.	None	Present No orient	None	No Orientation. Base of concretion.		
11	4738.1 4739.6	1.50	Shaly Mudstone N2	→ F12	P	No orient.	Cpd. Jt.	Calcite	----- -----	None	Closed fracture, multiple planes Changing orientation.		
12	4739.4 4740.0	0.60	Limestone 5Y 3/2	M M	CP	No orient.	Flt.	None	Present no orient	None	Slicks curve around concretion		
13	4739.8 4742.7	2.90	Shaly Mudstone N2	F12 →	P	No orient.	Cpd. Jt.	Calcite	----- -----	None	Closed fracture, two planes near the end.		
14	4743.5 4744.5	1.00	A/A	↘	P	No orient.	Spl. Jt.	Calcite	----- -----	None	Closed fracture.		
15	4755.5 4756.8	1.30	A/A	↘	P	No orient.	Spl. Jt.	Calcite	----- -----	None	Closed fracture.		
16	4768.0 ---	<0.1	A/A	(M)	CP	N65°E 40°SE	Mer. Flt.	None	40° S34°E		Top of limestone bed.		
17	4860.0 4861.7	1.7	Shaly Mudstone 5Y 4/1	?/c →	P	N54°W 90°	Spl. Jt.	Calcite	----- -----	None	Closed fracture, Starts in ground up zone of connection.		

CORING DATE: FEBRUARY 1979

## EG.S.P. REVISED FRACTURE LOGGING FORMAT

PAGE 2 OF 3

LOG DATE: MARCH 1981

WELL: EGSP-PENNSYLVANIA #1, MCKEAN COUNTY

NATURAL

WELL NUMBER	DEPTH EXTENT	LENGTH	LITHOLOGY	TERMINATIONS	CHARACTER	STRIKE DIP	FRACTURE TYPE	MINERALIZATION	SLICKENSIDES	FRACTOGRAPHIC FEATURES	COMMENTS
18	4861.6 4864.8	3.2	Shaly Mudstone 5Y 4/1	M	P	N62°W 90°	Spl. Jt.	Calcite		Closed fracture	Possible 2nd plane, but core rotation caused rock to break.
19	4956.6 4962.?	5.4+	Shaly Mudstone 5Y 3/2	?/c	P	N57°W 90°	Spl. Jt.	Calcite		Fn. Hkl. Pln.	Closed fracture, broken core prevents determination of length
20	4962.6 4970.2	7.6	A/A	M	P	N40°W 90°	Spl. Jt.	Calcite		Fn. Hkl. Pln.	2 plane near center
21	5113.6 5113.7	0.1	Shaly Mudstone N1	M	CP	N 0°E 47°W	Mer. Flt.	None	25° S52°E		Occurs at bottom of concretion
22	5165.3 5165.5	0.2	A/A	M	CP	N74°E 33°SE	Flt.	Calcite	27° N36°W		Occurs above a lime concretion or bed.
23	5165.8 5165.9	0.1	A/A	M	CP	N60°E 24°NW	Mer. Flt.	None	22° N40°W		Occurs above a lime concretion or bed.
24	5165.9 5166.8	0.9	Limestone 5Y 4/1	M	CP	N30°W 90°	Spl. Jt.	Calcite			Closed fracture - septarian vein or extensional.
25	5172.1 ---	<0.1	Shaly Mudstone N1	M	CP		Flt.	None	0° N24°W		May be associated with F-26? Eminates from a small 1 x 1 cm concretion.
26	5172.1 5172.2	0.1	A/A	M	P	N34°W 46°NE	Spl. Jt.	Calcite			
27	5195.0 ---	<0.1	A/A	M	CP	N72°W 12°SW	Mer. Flt.	None	8° S20°E		
28	5197.7 5197.9	0.2	A/A	M	CP	N72°E 31°SE	Flt.	None	28° S 6°E		Occurs above limestone bed.
29	5197.9 5198.1	0.2	A/A	M	CP	N76°E 34°SE	Flt.	None	30° S 2°E		Occurs above limestone bed.
30	5199.1 5199.3	0.2	A/A	M	CP	N74°E 43°NW	Spl. Jt.	Calcite			Base of limestone - possible extension joint.
31	5199.3 ---	<0.1	A/A	M	CP	No orient	Mer. Flt.	None	No orient		A/A
32	5199.2 5199.4	0.2	A/A	M	CP	N80°E 41°NW	Spl. Jt.	Calcite			A/A
33	5199.3 5199.4	0.1	A/A	M	CP	N84°E 80°NW	Spl. Jt.	Calcite			A/A
34	5210.8 5211.0	0.2	A/A	M	CP	N80°W 23°SW	Mer. Flt.	None	19° S 6°E		Occurs in lime concretion.



NUMBER	DEPTH EXTENT	LENGTH	LITHOLOGY	TERMINATIONS	CHARACTER	STRIKE DIP	FRACTURE TYPE	MINERALIZATION	SLICK- ENSIDES	FRACTOGRAPHIC FEATURES	COMMENTS
1	3481.4 3481.5	0.1	Siltstone 5Y 6/1	↗	CP	N20°W 90°	See Comment				Scribe line fracture
2	3507.9 3508.0	<0.1	Silty Mudstone 5GY 4/1	→	CP	N60°E 30°SE	Hk				Start on siltstone. Silty mudstone contact
3	3507.9 3508.0	<0.1	A/A	→	CP	N70°E 30°NW	Hk				Start on siltstone. Silty mudstone contact.
4	3911.4 3911.5	<0.1	A/A	→	CP	N56°E 30°NW	Hk				Start on siltstone. Silty mudstone contact.
5	3911.4 3911.5	<0.1	A/A	→	CP	N70°E 18°SE	Hk				Start on siltstone. Silty mudstone contact.
6	4603.4 4603.6	0.2	Shaly Mudstone N2	(M)	CP		TF				Top of a concretion
7	4604.2 4605.0	0.8	Silty Mudstone 5Y 4/1	M	CP		TF				Series of torsional fractures in a concretion.
8	4614.0 4614.7	0.7	Limestone 5Y 3/2	M	CP		TF				Series of torsional fractures in a lime concretion; connection?
9	4647.9 4648.4	0.5	Shaly Mudstone N2	↘	CP		TF				
10	4656.2 4656.5	0.3	Shaly Mudstone 5Y 2/1	→	CP	N56°E 84°SE	TF				
11	4736.4 4736.7	0.3	Shaly Mudstone N2	→	CP		TF				Connection.
12	4758.2 ---	<0.1	A/A	(M)	CP		DCS		Present		
13	4864.3 4864.5	0.2	Shaly Mudstone 5Y 4/1	(M)	CP		TF				Connection
14	4864.6 4864.7	0.1	A/A	(M)	CP		TF				
15	4864.9 4865.0	0.1	A/A	(M)	CP		TF				
16	4865.7 4865.8	0.1	A/A	(M)	CP		TF				
17	4866.0 4866.1	0.1	A/A	(M)	CP		TF				

CORING DATE: FEBRUARY 1979		E.G.S.P. REVISED FRACTURE LOGGING FORMAT					PAGE 2 OF 4				
LOG DATE: MARCH 1981		WELL: EGSP-PENNSYLVANIA #1, MCKEAN COUNTY							CORING INDUCED FRACTURES		
NUMBER	DEPTH EXTENT	LENGTH	LITHOLOGY	TERMIN ATIONS	CHAR- ACTER	STRIKE DIP	FRACTURE TYPE	MINERALIZATION	SLICK- ENSIDES	FRACTOGRAPHIC FEATURES	COMMENTS
18	4866.3 4866.4 4866.5	0.1	Shaly Mudstone SY 4/1 A/A	(M)	CP		TF				
19	4866.6 4867.1 4867.2	0.1	A/A A/A	(M)	CP		TF				
20	4867.3 4867.4 4867.6 4867.7	0.1	A/A A/A	(M)	CP		TF				
21	4867.9 4868.0 4868.2 4868.3	0.1	A/A A/A	(M)	CP		TF				
22	4868.5 4868.6 4868.7	0.1	A/A A/A	(M)	CP		TF				
23	4868.9 4869.0 4869.2 4869.5	0.1	A/A A/A	(M)	CP		TF				
24	4869.6 4869.8 4870.0	0.1	A/A A/A	(M)	CP		TF				
25	4871.9 4872.0 4873.9	0.1	A/A A/A	(M)	CP		TF				
26	4874.0 4888.5 ---	<0.1	A/A A/A	(M)	CP		TF		Present		Connection
27	4898.4 ---	<0.1	A/A	(M)	CP		DCS		Present		

NUMBER	DEPTH EXTENT	LENGTH	LITHOLOGY	TERMINATIONS	CHARACTER	STRIKE DIP	FRACTURE TYPE	MINERALIZATION	SLICK-ENSIDES	FRACTOGRAPHIC FEATURES	COMMENTS
35	4898.9 ---	<0.1	Shaly Mudstone 5Y 4/1	(M)	CP		DCS		Present		Air pressure problem during coring A/A
36	4899.3 ---	<0.1	A/A	(M)	CP		DCS		Present		
37	4899.7 ---	<0.1	A/A	(M)	CP		DCS		Present		A/A
38	4900.0 ---	<0.1	A/A	(M)	CP		DCS		Present		A/A
39	4900.2 ---	<0.1	A/A	(M)	CP		DCS		Present		A/A
40	4900.7 ---	<0.1	A/A	(M)	CP		DCS		Present		A/A
41	4907.7 ---	<0.1	A/A	(M)	CP		DCS		Present		A/A
42	4919.4 ---	<0.1	A/A	(M)	CP		DCS		Present		A/A
43	4919.9 ---	<0.1	A/A	(M)	CP		DCS		Present		Connection A/A
44	4920.5 4920.6	0.1	A/A	(M)	CP		TF				A/A
45	4922.1 4922.2	0.1	A/A	(M)	CP		TF				A/A
46	4939.1 ---	<0.1	A/A	(M)	CP		DCS		Present		Connection; top of run
47	4943.3 ---	<0.1	A/A	(M)	CP		DCS		Present		
48	4974.9 ---	<0.1	A/A	(M)	CP		DCS		Present		
49	5001.1 5002.0	0.9	Shaly Mudstone 5Y 3/2	→ M	CP		TF				
50	5003.1 5003.8	0.7	A/A	M	CP		TF				
51	5012.9 5013.0	0.1	A/A	(M)	CP		TF				Connection



EASTERN GAS SHALES PROJECT  
DISC FRACTURE FREQUENCY LOG  
EGSP-PENNSYLVANIA #1 WELL, MCKEAN COUNTY

<u>Top of Interval</u>	<u>Frequency Per Foot</u>	<u>Top of Interval</u>	<u>Frequency Per Foot</u>
3470	3.2	4680	11.4
3475	2.8	4685	18.0
3480	3.6	4690	20.6
3485	3.0	4695	28.4
3490	4.6	4700	23.2
3495	4.4	4705	35.0*
3500	3.0	4710	19.8
3505	3.4	4715	28.2
3510	5.0	4720	16.4
3515	3.8	4725	19.2
3520	4.8	4730	9.0
3525 - 3528.5	4.0	4735	14.8
3528.5 - 4530	Plug Drilled	4740	34.0
4530	15.8	4745	20.4
4535	19.4	4750	22.8
4540	29.0	4755	32.6
4545	23.6	4760	27.0
4550	28.6	4765	7.8
4555	20.6	4770	3.6
4560	19.4	4775	6.4
4565	18.0	4780	3.2
4570	27.4	4785	4.0
4575	29.2	4790	2.8
4580	18.6	4795	2.2
4585	15.0	4800	2.6
4590	22.0	4805	2.2
4595	23.6	4810	2.4
4600	11.6	4815	1.8
4605	25.0	4820	5.0
4610	21.8	4825	7.6
4615	6.6	4830	1.0
4620	8.6	4835	1.2
4625	6.8	4840	1.6
4630	4.6	4845	1.6
4635	13.0	4850	4.8
4640	7.0	4855	5.0
4645	5.4	4860	2.4
4650	2.6	4865	3.6
4655	7.6	4870	2.2
4660	4.2	4875	2.4
4665	12.4	4880	4.0
4670	10.0	4885	4.4
4675	12.0	4890	5.6

EASTERN GAS SHALES PROJECT

DISC FRACTURE FREQUENCY LOG  
EGSP-PENNSYLVANIA #1 WELL, MCKEAN COUNTY  
PAGE 2

<u>Top of Interval</u>	<u>Frequency Per Foot</u>	<u>Top of Interval</u>	<u>Frequency Per Foot</u>
4895	4.0	5105	22.4
4900	2.8	5110	20.0
4905	3.2	5115	18.0
4910	2.8	5120	19.8
4915	3.4	5125	13.2
4920	4.4	5130	2.8
4925	5.6	5135	4.8
4930	4.4	5140	27.0
4935	6.2	5145	24.6
4940	6.2	5150	14.2
4945	2.2	5155	7.4
4950	4.2	5160	8.8
4955	5.2	5165	5.2
4960	9.0	5170	13.0
4965	14.6	5175	9.8
4970	9.8	5180	8.8
4975	3.2	5185	6.4
4980	2.6	5190	10.0
4985	2.0	5195	10.0
4990	2.0	5200	12.0
4995	2.0	5205	15.8
5000	2.8	5210 - 5213.4	7.9
5005	1.2	* Greatest frequency in this well.	
5010	2.2		
5015	2.0		
5020	2.2		
5025	2.0		
5030	4.0		
5035	4.8		
5040	9.4		
5045	19.4		
5050	18.2		
5055	14.0		
5060	14.2		
5065	14.4		
5070	14.8		
5075	10.6		
5080	19.8		
5085	17.2		
5090	17.0		
5095	17.0		
5100	11.0		

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



PREPARED UNDER  
CONTRACT NO. DE-AC21-78MC08199

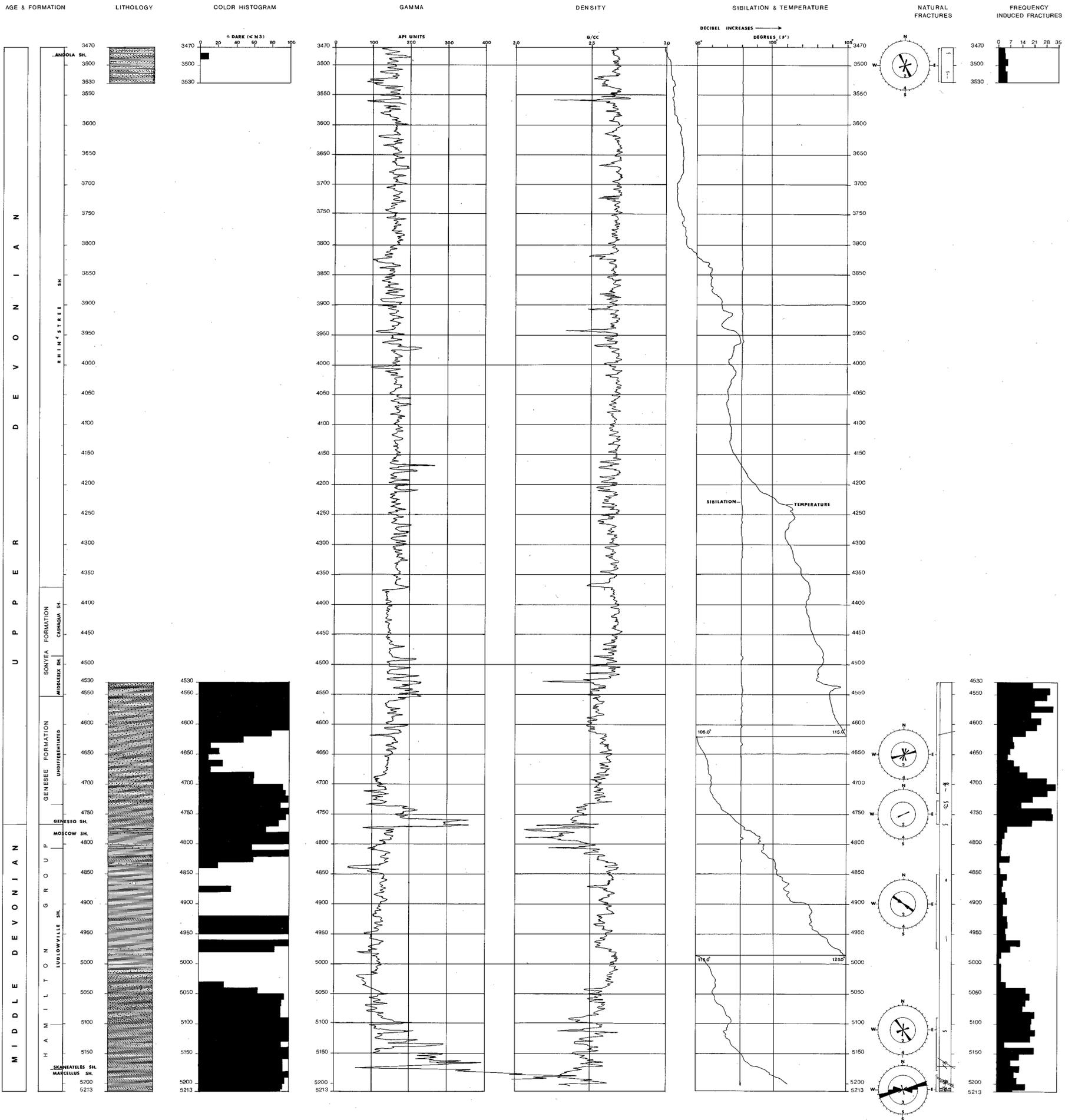
**EGSP PA-1, MCKEAN CO.**

WELL: M.R. EX. #1

A.P.I. NO. 37-083-37291

DRILLING COMPLETED: FEBRUARY 22, 1979

DRAWN MAY, 1981



**LEGEND**

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