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CLIFFS MINERALS, INC.
EASTERN GAS SHALES PROJECT
OHIO #10 WELL, MEIGS CUUNTY

PHASE II REPORT
PRELIMINARY LABORATORY RESULTS
NOVEMBER 1982

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1.0 INTRODUCTION

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

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

In early July 1982, the Department of Energy entered into a cooperative agreement with Columbia Gas and Gruy Federal to continue to explore Devonian shale gas potential in Meigs County, Ohio. Objectives of the agreement were:

1. To explore the gas potential of the fracture pattern which was uncovered by the drilling of the rat hole in Ohio #9 well.
2. To drill an offset well and explore that fracture pattern.
3. To compare the actual fracture pattern with the computer model and make indicated improvements.

This report summarizes the procedures and results of core characterization work performed at the Eastern Gas Shales Project Core Laboratory on core retrieved from the Meigs County well, designated EGSP-Ohio #10.

2.0 SCOPE OF WORK

The objective of work performed at the Eastern Gas Shales Project's Core Laboratory is to provide characterization of core recovered from the EGSP-Ohio #10 well. Data are acquired from several sources for analysis. At the well site the following suites of wet and dry hole geophysical logs are run:

Dry Hole Logs:	Gamma Ray
	Compensated Formation Density
	Caliper
	Temperature
	Sibiliation
Wet Hole Logs:	Compensated Formation Density
	Gamma Ray - Caliper
	Compensated Neutron
	Dual Induction
	Laterolog
	Compensated Sonic
	Fracture Identification
	Spontaneous Potential

At the EGSP Core Laboratory, the core was laid out, washed, measured, oriented, and photographed prior to description. 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 this instance, no physical property samples were prepared for testing at Michigan Technological University.

3.0 LABORATORY PROCEDURES

3.1 Review of Geophysical Logs:

During the Ln.Lt.LaL stages of processing the EGSP-Ohio #10 core through the laboratory, wet and dry hole geophysical logs from EGSP-Ohio #9 were examined and compared with published reference sections. Using the gamma ray and density logs, a preliminary stratigraphic section was prepared for the cored interval. These two logs have proven to be the most useful correlation tools within the Devonian Shale sequence. Much of the development of existing formation nomenclature for the Devonian Shales is based on the recognition of characteristic features of these logs. Consequently, formation boundaries and thicknesses are, in some cases, more readily determined from gamma ray and density logs than from visual examination of the core itself.

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

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

3.2 Photographic Log:

After the EGSP-Ohio #10 core had been laid out, washed, and oriented on a laboratory table or a group of 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 included in this report.

3.3 Detailed Lithologic Log:

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

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

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

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

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

5. Modes of pyritization: as disseminations, 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 fissi1ity 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 Survey of America (1948).

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3.4 Stratigraphic Section:

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

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

3.5 Color Histogram:

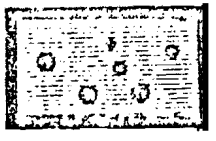
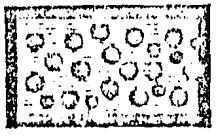
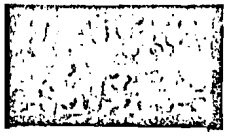
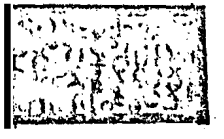
A color histogram for the Ohio #10 core was compiled to provide a relative measure of the distribution of light and dark shales through the cored interval. Using the *C.S.A.* Rock Color Chart. the net length of each color present within each 5-foot segment of the core was recorded. Colors with values darker than N3 were grouped together for each segment to determine the percentage of dark shale. and colors with values lighter than or equal to N3 were combined to determine the percentage of light shale. Use of the term "vaLue" refers to the Munsell system of color identification wherein a specific color is defined by a unique hue. value. and chroma designation.

	INCREASING SILT CONTENT →		
NON-FISSILE	MUDSTONE	SILTY MUDSTONE	SILTSTONE
FISSILE	SHALY MUDSTONE	SILTY SHALE	SHALY SILTSTONE

FIGURE 1

CLASSIFICATION OF FINE CLASTIC SEDIMENTARY ROCKS

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

810GENICALLY CEMENTED GRAINS: Boundstone

NO RECOGNIZABLE TEXTURE: Crystalline Limestone

FIGUHE 2

TEXTURAL CLASSIFICATION OF LIMESTONES
(after DUNHAM, 1962)

3.6 Fracture Logs:

Methods of fracture analysis employed at the EGSP Core Laboratory are similar to those described by Ku1ander, et at. (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 approximately bilateral symmetry.)
7. Hackle marks on a vertical or near-vertical planar fracture diverging down-core from from the center of the plane toward the margin.

8. An abrupt change in the direction of fracture propagating (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 also were logged in detail. This information provides additional documentation regarding the condition of the core as received from the field; it is useful for assessing the fractures (generally the most prevalent and least diagnostic type of induced fracture) and is recorded in the form of a histogram.

3.7 Measurement of Shore Hardness:

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

4.0 REPORTING OF RESULTS

For this particular well, a schematic diagram has been prepared in lieu of the normal correlation chart. The reasons for doing so are:

1. The correlation chart for EGSP-Ohio #9 well has already been done. This well is only a few hundred feet away and the lithology and stratigraphy of #9 and #10 are essentially the same. The reader, therefore, is referred to the Phase II Report for Ohio #9 for details of lithology and stratigraphy.

2. The primary purpose of this well is fracture examination. Of specific interest are the fractures containing gas at the bottom of the Ohio #9 well. As many details about them as possible are included herein.

After characterization was completed the core was sealed in a moisture barrier and packaged in three-foot core boxes for temporary archiving at the EGSP Core Laboratory. Following a 30-day period, the Ohio #10 core will be transferred to the Ohio Geological Survey.

5.0 DISCUSSION OF RESULTS

5.1 General:

The area of interest is located approximately 12 miles northeast of the town of Pomeroy, in Chester Township of Northwestern Meigs County, Ohio (Figure 3).

The well was drilled to core point with a conventional oil field rotary drilling rig. Core point was at 3,360 feet. The well was intentionally deviated from a vertical orientation, and many problems were encountered between the surface and corepoint. Drilling was initiated on July 15, 1982 and coring began September 24, 1982. Coring was done with a Stratapak core bit using an air-mist drilling medium. Torsional fractures and consequent barrel jamming were a common occurrence. The cored interval 3,360' to 3,684' was drilled at an angle of 20° - 22° from the vertical. Coring was completed September 28, 1982 and the field team returned to Morgantown the same day.

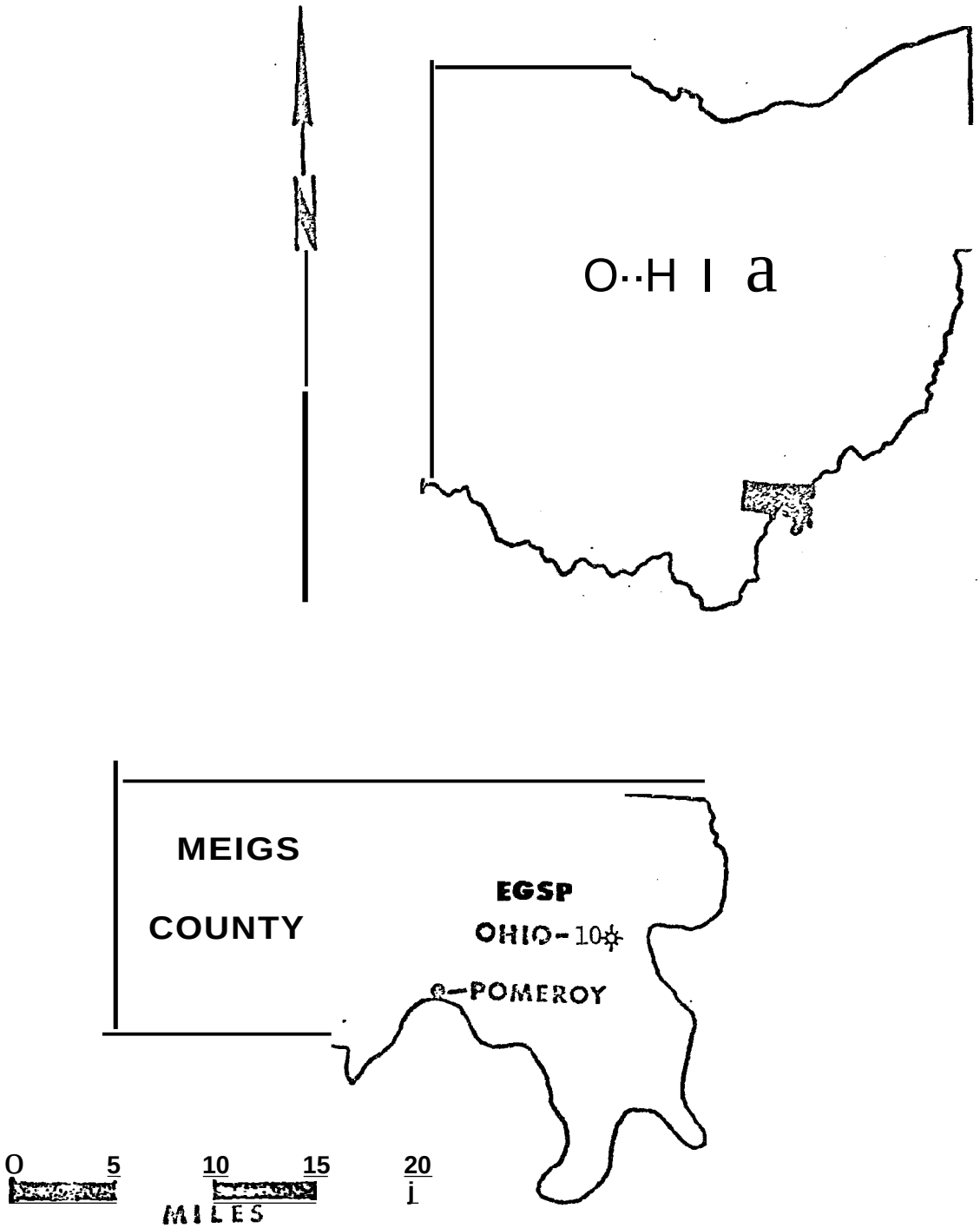


FIGURE 3

LOCATION OF THE EGSP-OHIO 10 WELL, HEIGS COUNTY, OHIO

5.2 Stratigraphy:

The geologic setting, stratigraphy, and lithology are all similar to that of EGSP-Ohio #9 well, and the reader is again referred to the Phase II Report for details for the same.

TABLE 1

FORMATION THICKNESS

FORMATION	DEPTHS	THICKNESS	DEPTHS CORED
Ohio Shale:			
Middle Huron Shale Member	?		
Lower Huron Shale Member	?		
Olentangy Shale	?		

In this area the Lower Huron is nearly 400 feet thick (378 feet in EGSP-Ohio #9). It appears that most of the core came from this strata with the bottom 70± feet of core being part of the Olentangy Formation. The contact between Lower Huron and Olentangy is gradational so that a finer distinction could not be made. A set of geophysical logs was not furnished to Cliffs Minerals, Inc. in time for this report. Thus additional detailed stratigraphic data was not available.

5.4 Fracture Analysis:

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

Twenty-three natural fractures were observed. The distribution of these fractures throughout the cored interval is shown in Table 2. The fractures in the first 80' - 100' of core cannot be oriented due to a mix-up in drill collars while coring. It appears, however, that these fractures follow the same trends as those below.

TABLE 2

DISTRIBUTION OF NATURAL FRACTURES

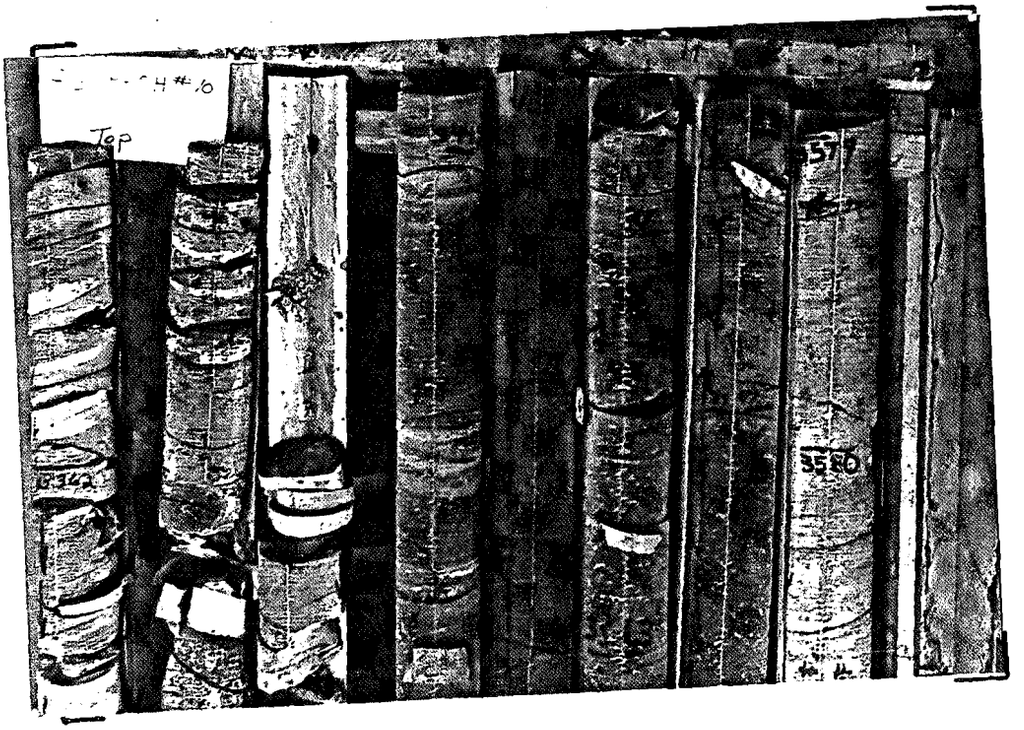
FORMATION	DEPTHS CORED	CORE LENGTH	NUMBER OF FRACTURES	FRACTURES/ FOOT
Ohio Shale:				
Lower Huron Shale Member	?		23	
Olentangy Formation	?		0	

All the natural fractures in this core occur in the Lower Huron. Some that are subhorizontal occur in association with calcareous concretions. One subhorizontal fault occurs at 3,454.7', but it is not associated with a concretion. It may be a decollement-type fault.

Included with this report is a schematic diagram of the cored section of the well and the intersected fractures. The core is being shipped to the Ohio Geological Survey at Columbus, Ohio for storage.

APPENDIX A

PHOTOGRAPHIC LOG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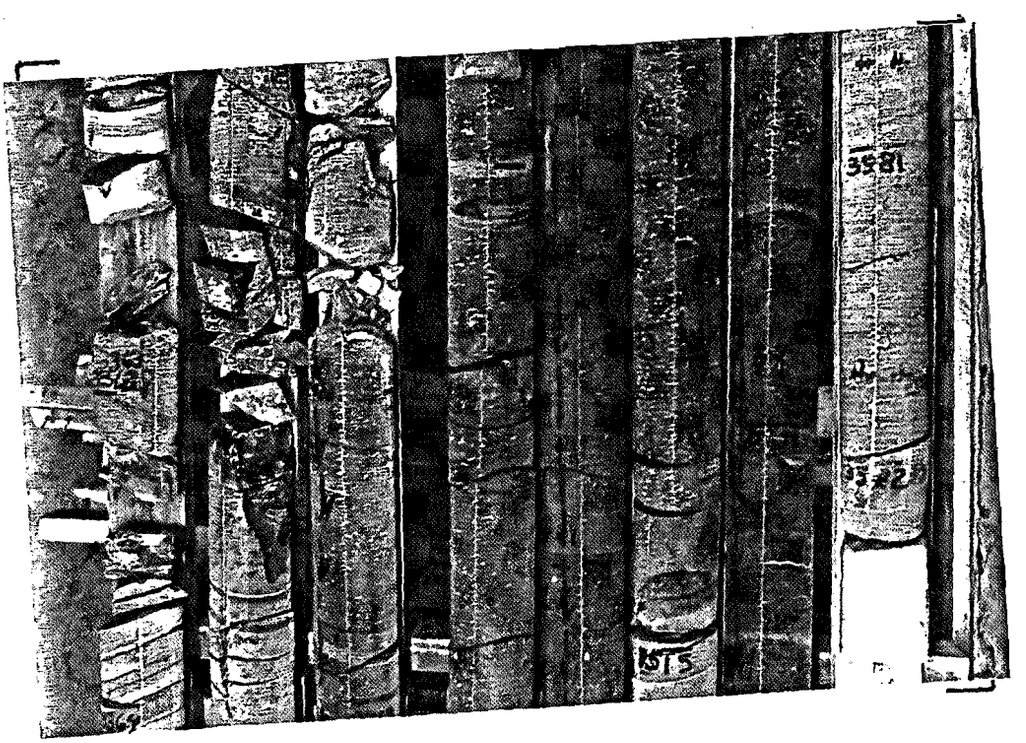
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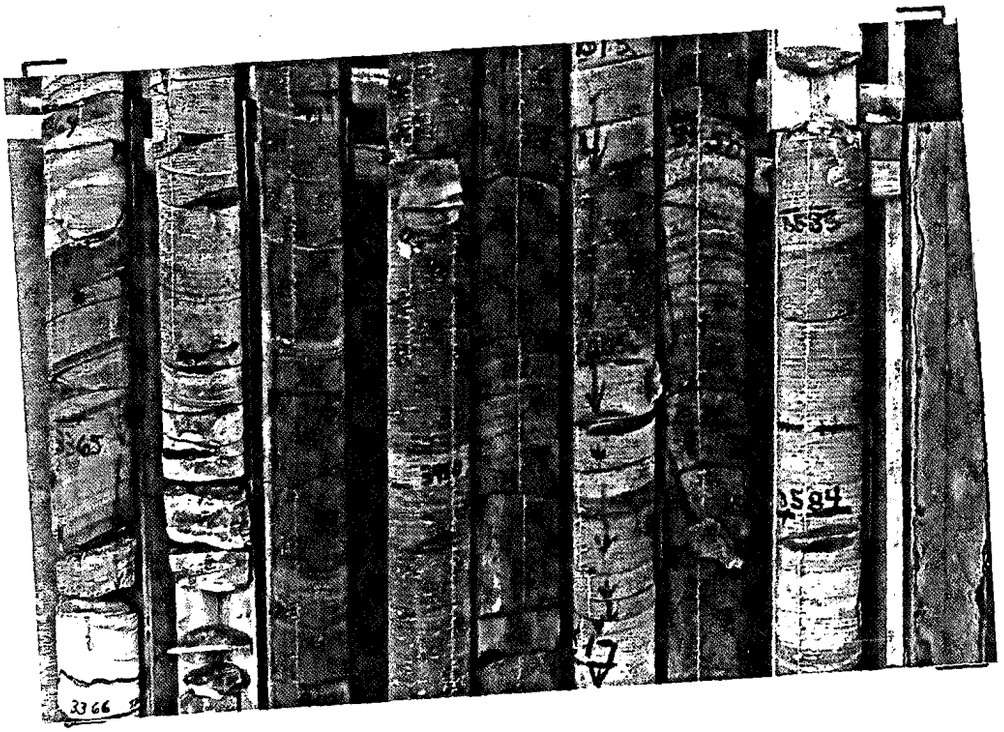
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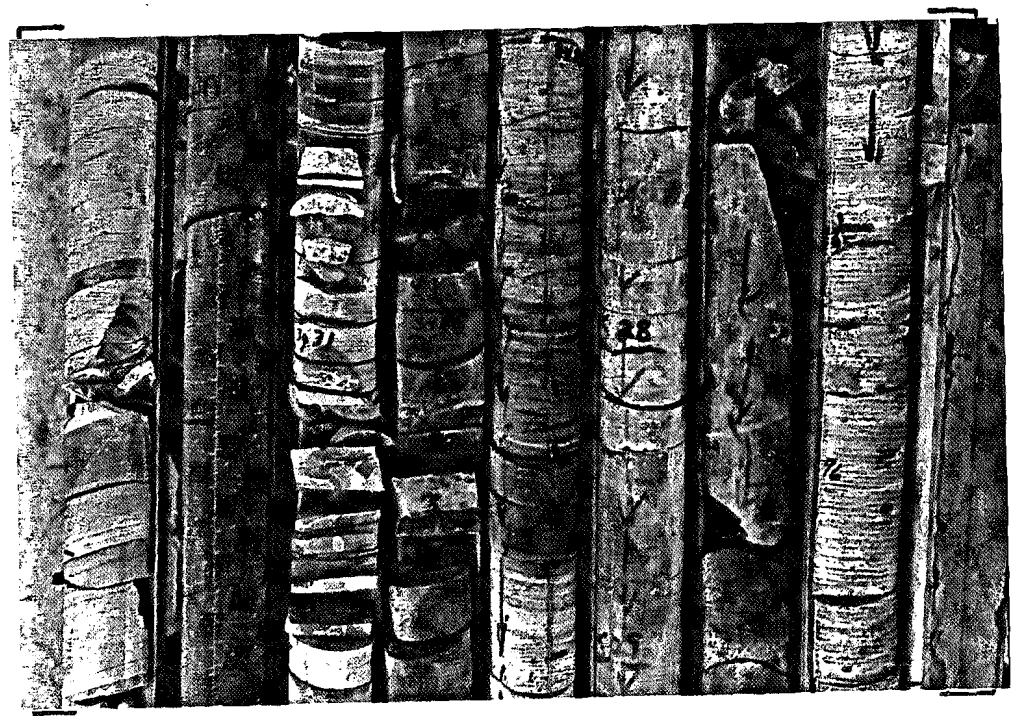

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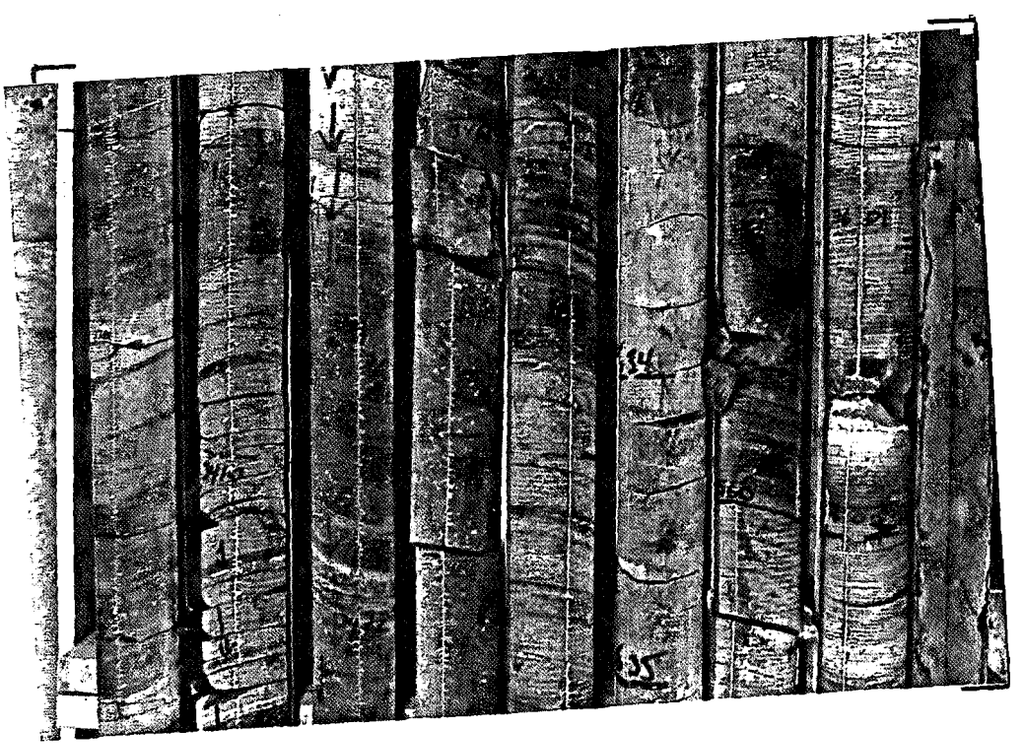

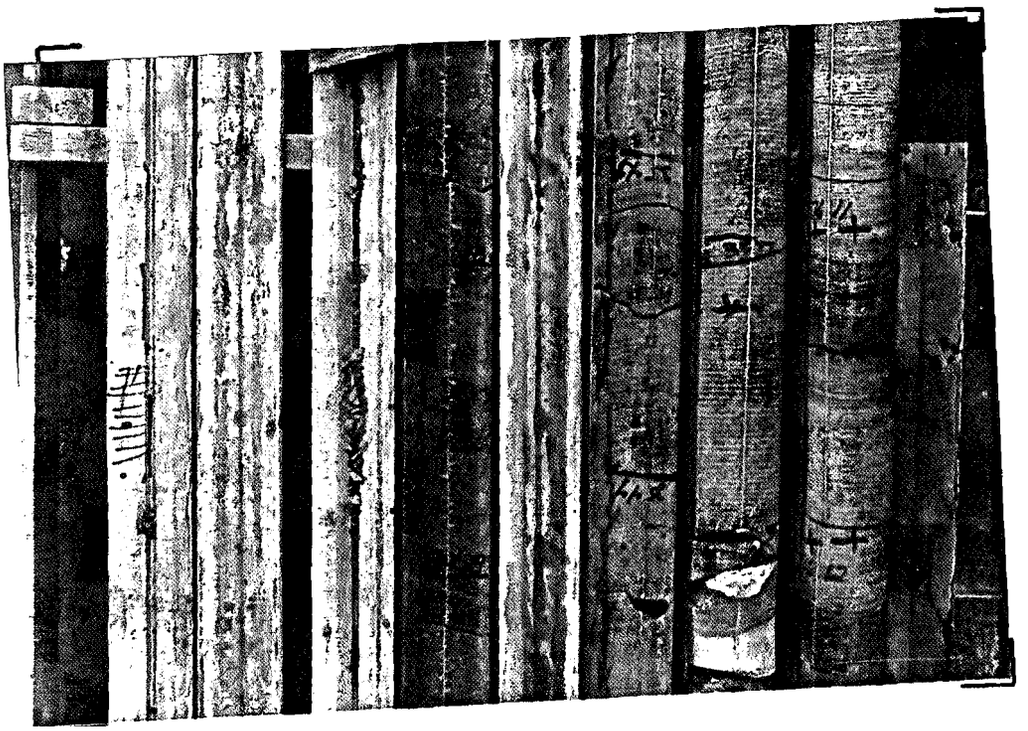

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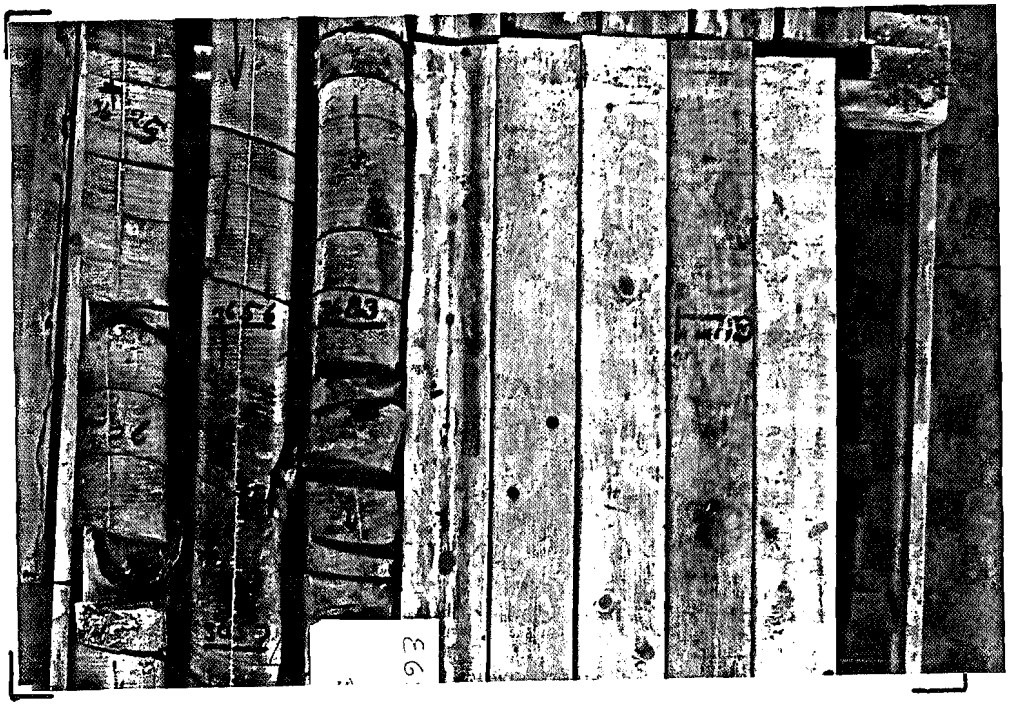

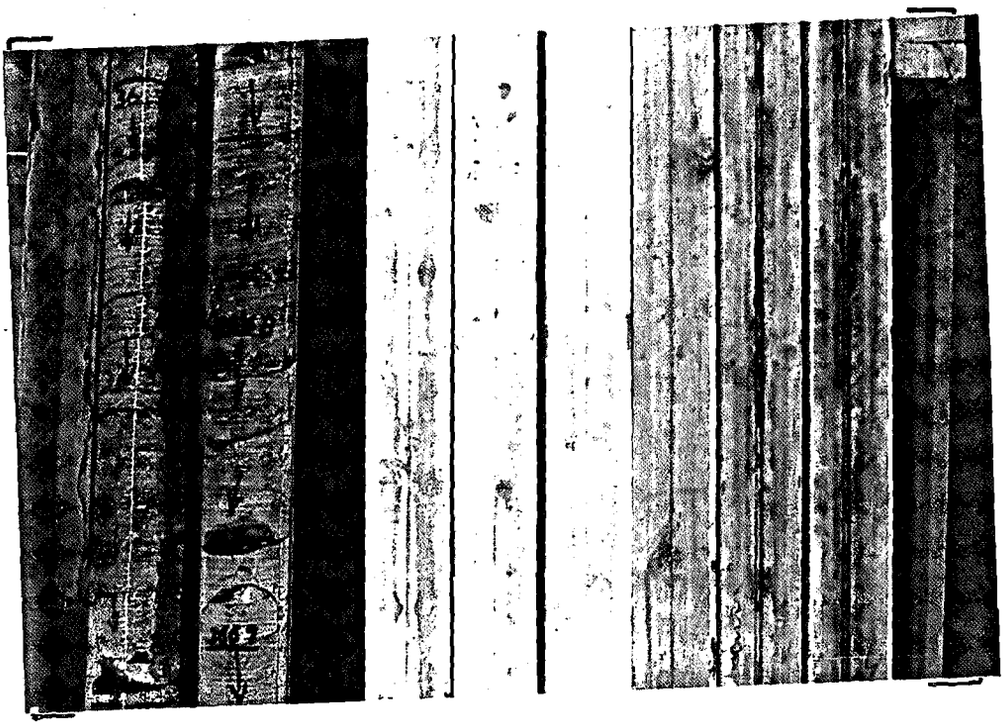

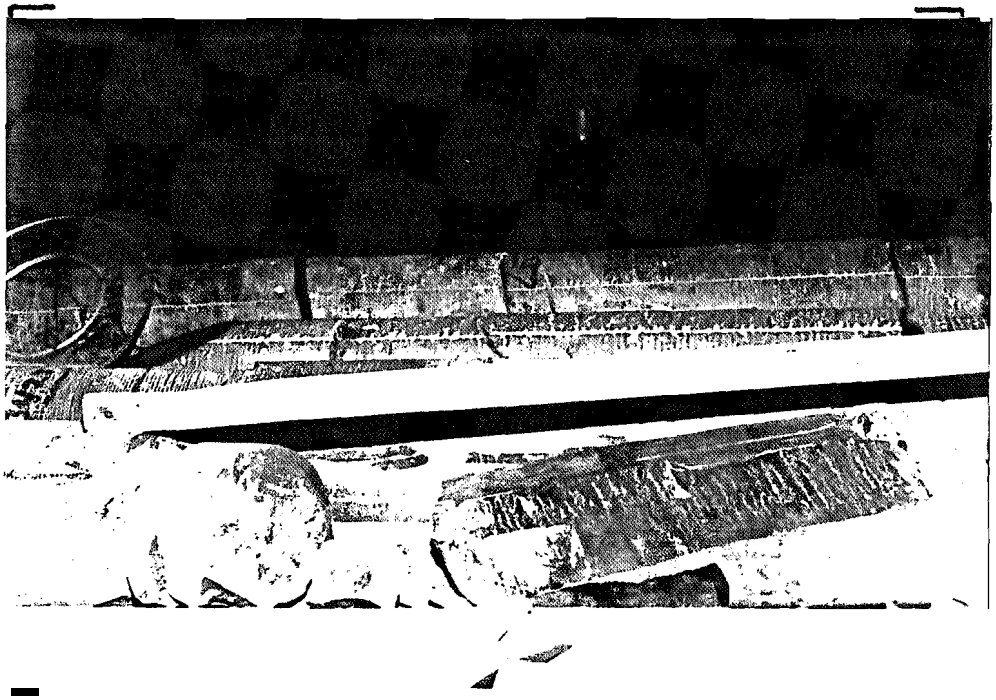

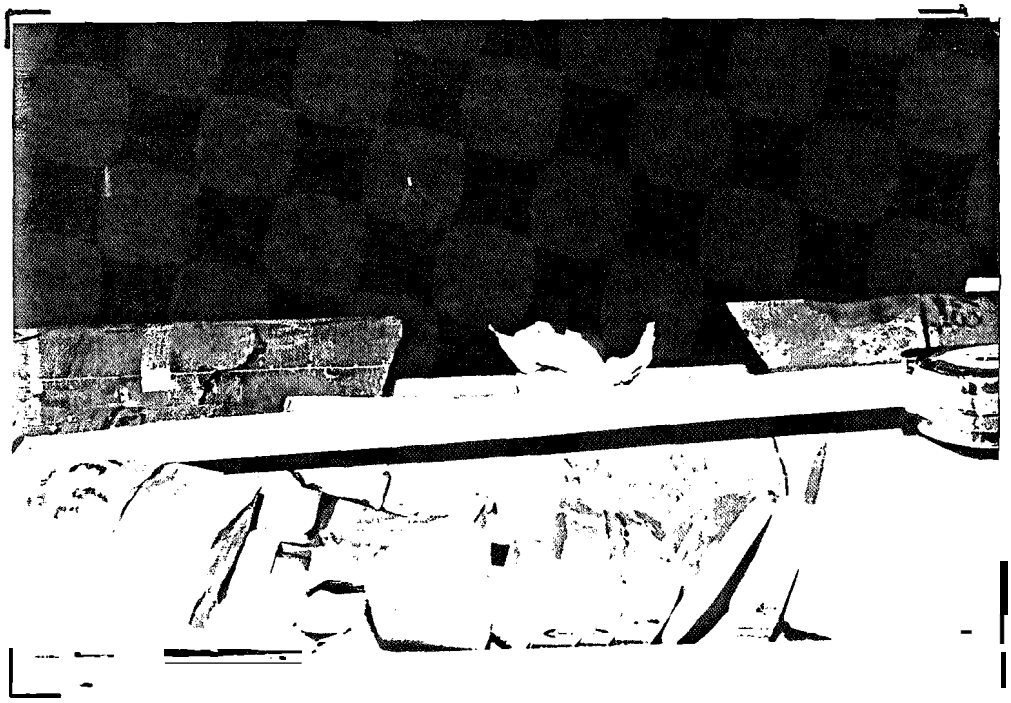

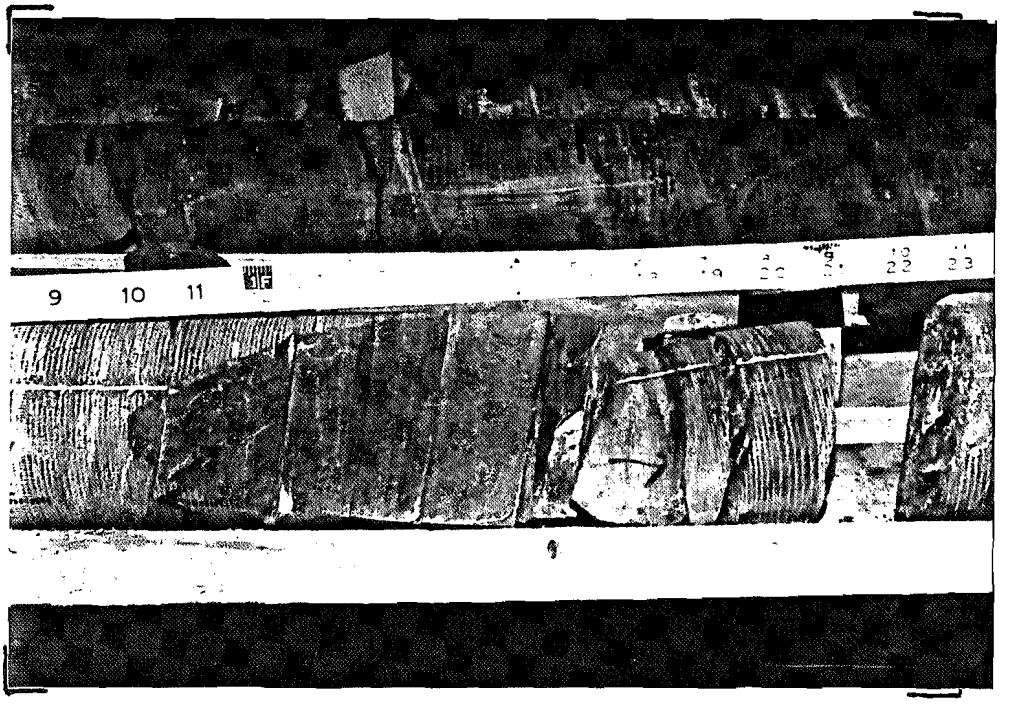
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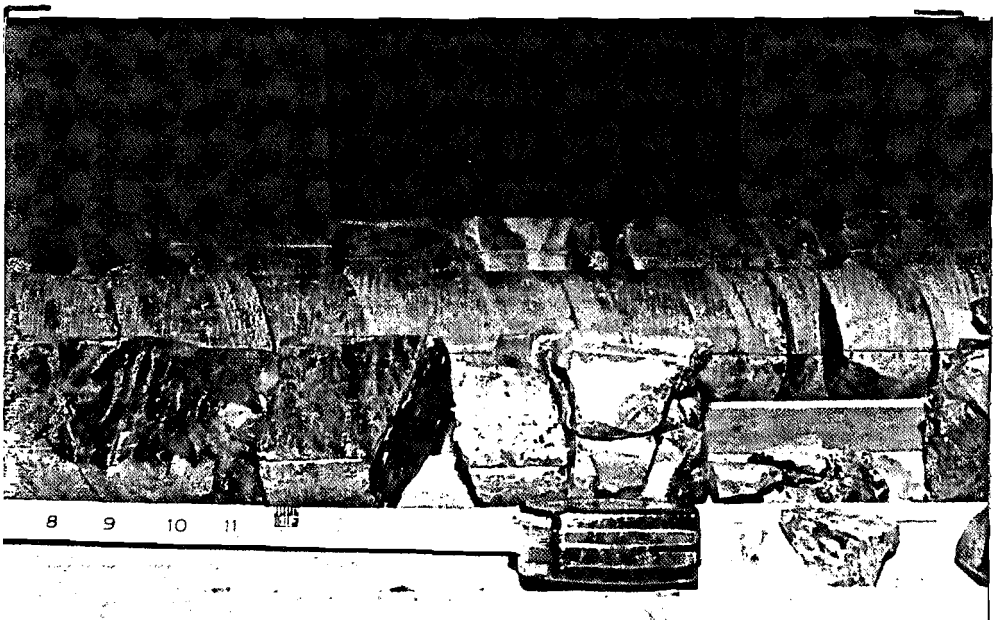
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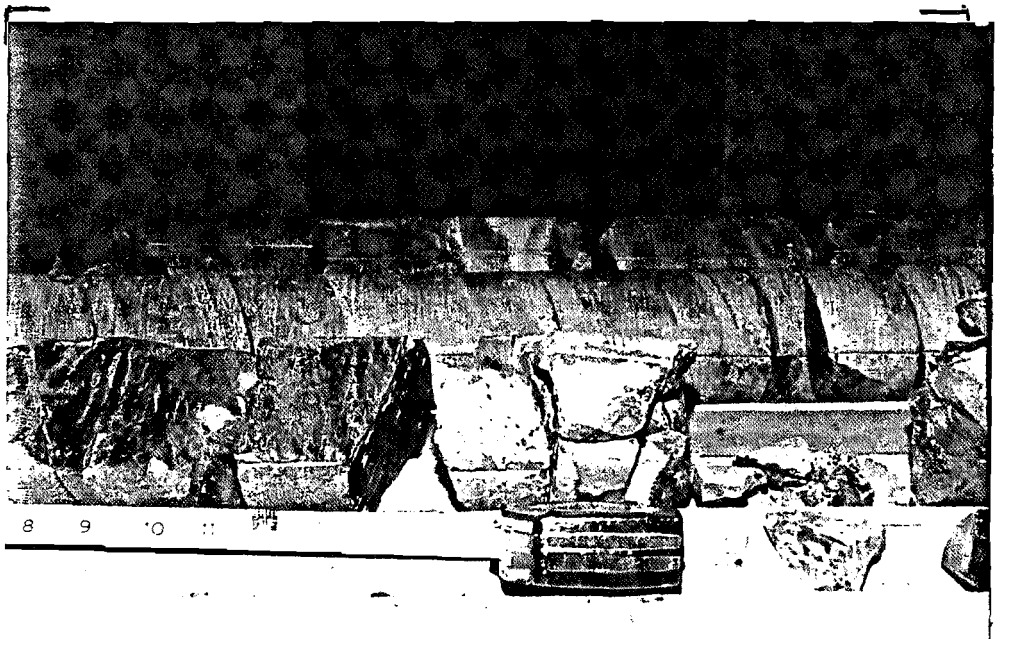
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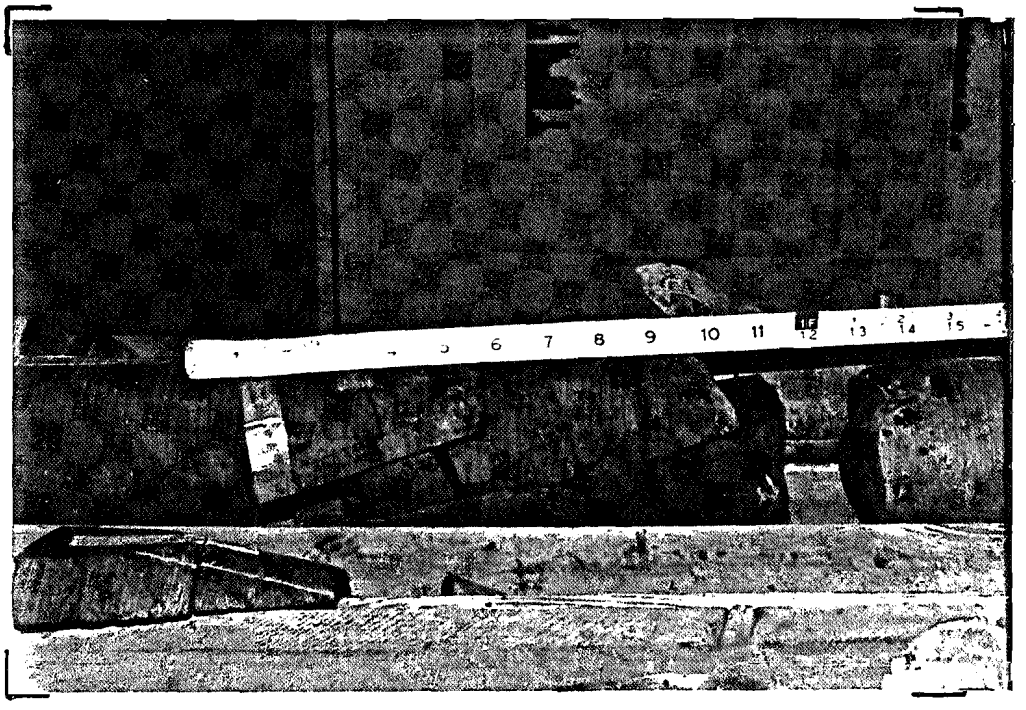

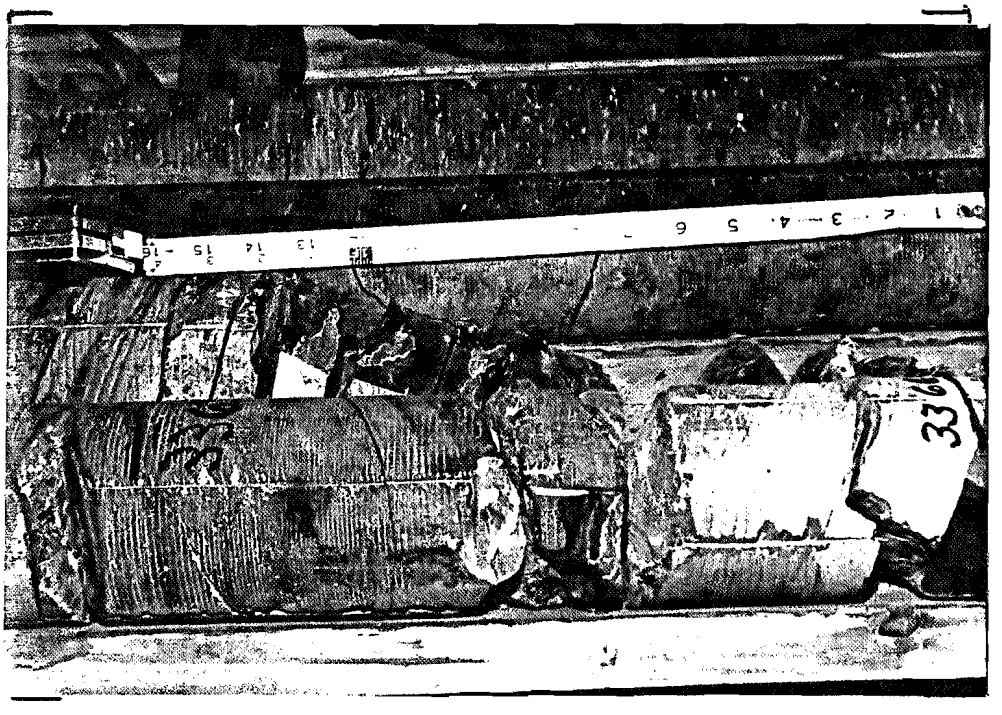
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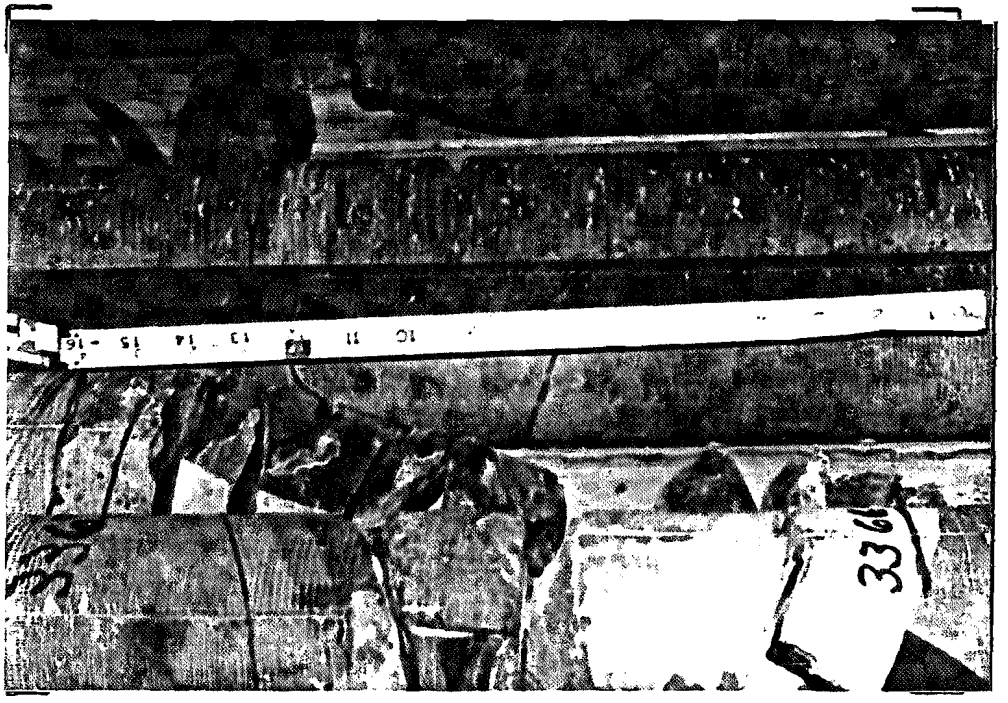

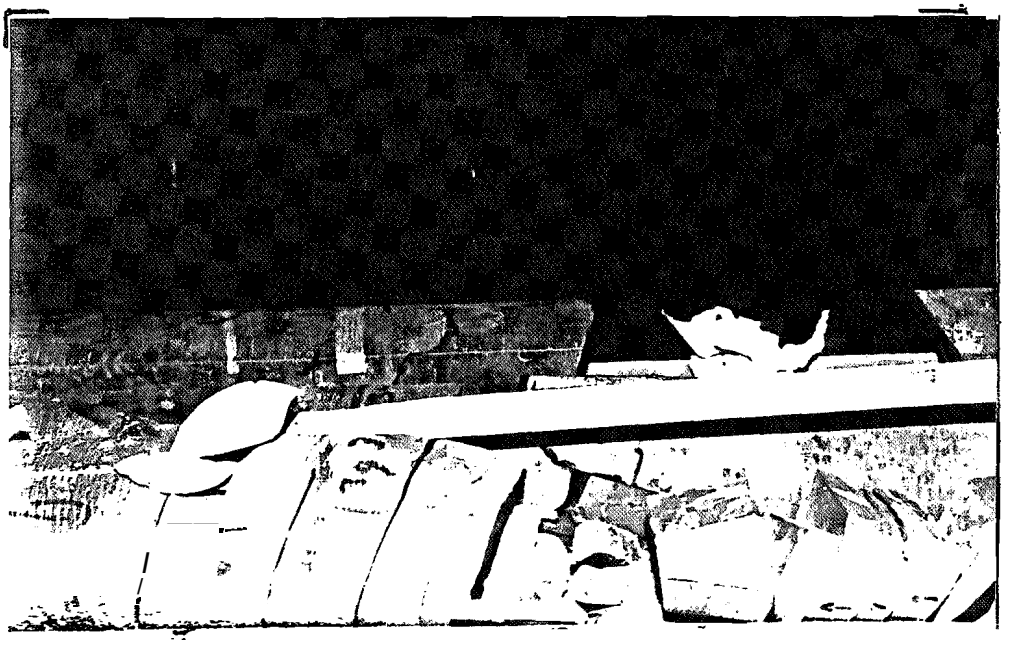

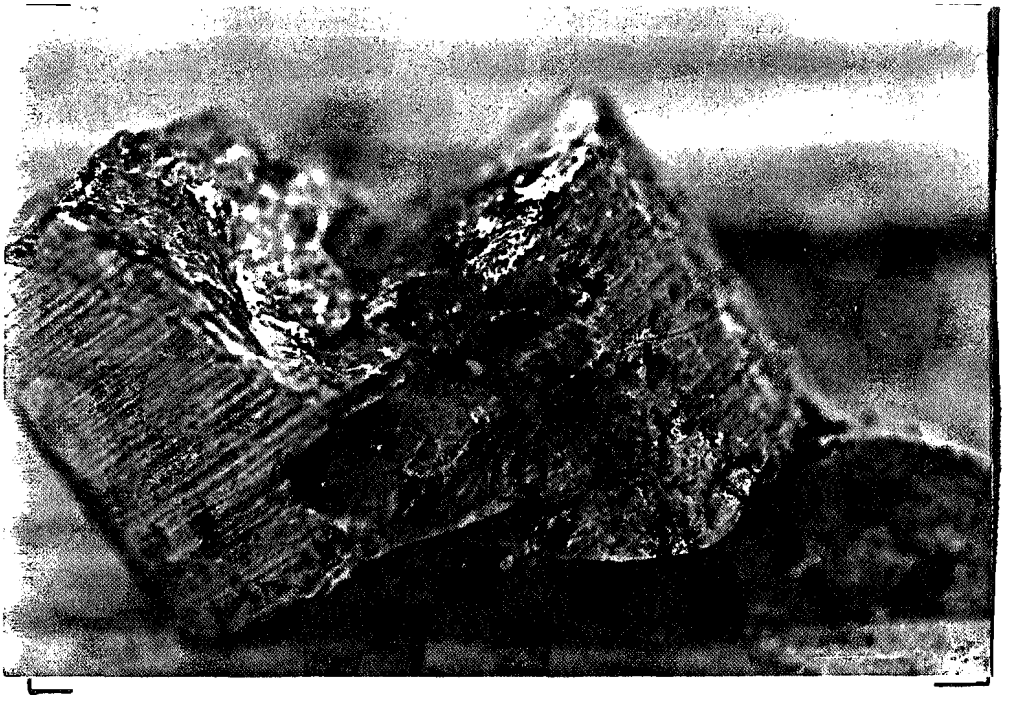

APPENDIX B

SYMBOLS, TERMS AND ABBREVIATIONS USED IN FRACTURE LOGGING

EGSP-OHIO #10 - MEIGS COUNTY

Appendix B

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

(P) : Planar
(CP): Curviplanar

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

(N): Natural

Spl. Jr.	(Simple Joint): One discrete fracture plane, no displacement.
Cpd. Jt.	(Compound Joint): Two or more parallel, closely spaced (approximately 1 em or less) fracture planes, no displacement.
Flt.	(Fault): A shear fracture with demonstrable displacement indicated by displaced primary features or slickensides.
Mer. FIt.	(Micro-Fault): A small-scale shear fracture, generally curivplanar; of the same order of size as the core diameter.

(CI): Coring Induced

PF	(Petal Fracture): An oblique fracture, usually planar or slightly curviplanar, which originates at the core margin and terminates against bedding within the core.
PFC	(Petal-Centerline Fracture): A fracture orlgl-nating as a petal fracLure which curves down-core and bisects the core as a vertical planar fracture. The strike of the vertical fracture and the petal fracture is characterized by regularly spaced arrest lines, convex downcore and symmetrical about the core axis.
DF	(Disc Fracture): A subhorizontal fracture originating withinthe 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 chronolgy.

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 preexisting surfaces orthogonally.
Fn. Hkl. Plm.	(Fine Hackle Plume): A very fine, wispy plumose structure on an otherwise featureless fracture face.
Incl. Hkl.	(Inclustion 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. <u>TERMINATIONS:</u> These terms are used to describe how a fracture terminates. The upper entry depicts the upper termination, the lower 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.
?I c	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 one straddling the dividing line.
F22:	This symbol is used when one fracture terminates against another(i.e., fracture 23 terminates against fracture 22).

APPENDIX C

FRACTURE LOGS
EGSP-OHIO #10, MEIGS COUNTY

CORING DATE: September 1982

LOG DATE: September 30, 1982

E.G.S.P. REVISED FRACTURE L'

WELL: EGSP-Ohio #10 Well, Meigs County,

NUMBER	DEPTH EXTENT	LENGTH	LITHOLOGY	TERMINATIONS	CHARACTER	STRIKE DIP	FRACTURE TYPE	MINERALIZATION
1	3365.9 3366.2	0.3"	01v B1k (5Y2/1) Mudstones	BDG 1'1	P		S:p1. Jt.	None
2	3366.2 ?	?	01v Blk (5Y 2/1) Mudstones	1'1 ?M	P		Sp1. Jt.	Slight Calcite
3	3387.5 ?	?	U1v B1k (5Y 2/1) Mudstones	BDG ?M	P		Sp1. Jt.	None
4	? 3391.0	?	01v B1k (5Y 2/1) Mudstones	?M 1'1	p		Sp1. Jt.	Slight Calcite
5	13394.0 3395.0	1.0'	01v Gry (5Y 3/2) IMudstone'	1'1 1'1	P		Sp1. Jt.	Slight Calclte
6	? 3399.1	?	01v Blk (5Y 2/1) Mudstones	? hook	P		Sp1. Jt.	None
7	3399.3 3399.8	?	01v B1k (5Y 2/1) Mudstone	? ?	p		Sp1. Jt.	None
8	3422.4 ?	?	01v B1k (5Y 2/1) Mudstone	BDG ?	P		Sp1. Jt.	None
9	3423.1 3423.7	0.6"	01v B1k (5Y 2/1) Mudstone	M	P		Spl. Jt.	None
10	3431.1 3431.7	0.6"	Drk'Greenish Gry 5GY 4/1 Mudstone	M	P		Sp1. Jt.	Slight Calcite
11	3438.5 3439.3	1.8'	01v Gry (5Y 3/2) Hudstone	M	P		FIt.	None
12	3439.6 3440.5	0.9'	01v Blk (5Y 2/1) IMudstone	M	P		Sp1. Jt.	None
13	3460.6 3461.8	1.2'	01v B1k (5Y 2/1) Mudstone	M	P	N800E Nr Vert.	Comp. Jt.	None
14	3464.8 3466.0	1.2'	Olv Blk (5Y 2/1) Muastone	M	P	N800E Nr Vert.	Spl. Jt.	None
15	3506.5 3506.6	0.1'	01v Gry (5Y 3/2) Mudstone	M	p	S600E Nr Vert.	Flt.	None
16	3507.0 3507.6	0.5'	Greenish Gry (5Y 5/2) Siltstn	See Comnts	CP		See Comments	Heavy Calcite
17	3507.-5 3508.5	1.0'	Greenish Gry (5Y 5/2) Silty Mudst	BDG ?M	CP	NOoE " Nr Vert.	FIt.	None

EASTERN GAS SHALES PROJECT

DISC FRACTURE FREQUENCY LOG
EGSP-OHIO #10 WELL - MEIGS COUNTY

Interval (Feet)	Frequency Per Foot	Interval (Feet)	Frequency Per Foot
3361 - 3365	9.25	3520	5.40
3365 - 3370	Rubble	3525	3.00
3370 - 3375	9.00	3530	3.60
3375 - 3380	5.40	3535	5.00
3380	4.60	3540	3.00
3385	Rubble	3545	1.80
3390	6.40	3550	2.60
3395	Rubble	3555	2.20
3400	2.60	3560	2.00
3405	3.20	3565	3.20
3410	6.80	3570	2.00
3415	4.60	3575	1.80
3420	3.00	3580	2.40
3425	8.00	3585	2.80
3430	5.60	3590	1.60
3435	3.80	3595	1.20
3440	5.20	3600	2.60
3445	2.60	3605	3.00
3450	2.40	3610	3.00
3455	1.60	3615	Rubble
3460	4.20	3620	3.80
3465	1.40	3625	4.20
3470	2.00	3630	5.80
3475	2.40	3635	4.00
3480	1.80	3640	4.40
3485	1.80	3645	4.20
3490	2.80	3650	4.80
3495	5.00	3655	3.60
3500	4.40	3660	3.40
3505	5.00	3665	3.80
3510	3.80	3670	2.80
3515	5.00	3675	4.80
		3680 - 3685	5.60