CLIFFS MINERALS, INC.
EASTERN GAS SHALES PROJECT
NEW YORK #1 WELL, ALLEGANY COUNTY
PHASE III REPORT
SUMMARY OF LABORATORY ANALYSES AND MECHANICAL CHARACTERIZATION RESULTS
JANUARY 1981

EGSP-New York #1 Well, Allegany County

Executive Summary

This report summarizes the results of characterization work performed on approximately 1,650 feet of 3 1/2-inch diameter oriented core retrieved from the EGSP-New York #1 well in Allegany County. Information provided in previous reports by Cliffs Minerals, Inc. includes a definitive lithologic description and tabulated fracture data resulting from detailed core examinations, and stratigraphic interpretations as indicated in the core and on geophysical logs. Plane of weakness orientations stemming from a program of physical properties testing are also summarized.

Core retrieval began on August 7 and was completed August 26, 1978. Six formations were identified and described; these include: Perrysburg Formation, Java Formation, West Falls Formation, Sonyea Formation, Genesee Formation, and Tully Limestone. Natural fractures in the core indicate a major near-vertical fracture set striking between N30°E and S55°E with a concentration of fractures striking N72°E; a minor, near-vertical fracture set striking between N22°W and N50°W. Physical properties tests (point load and directional ultrasonic velocity) and pretest fracture orientations suggest preferred directions of fracturing at N60°E and N90°E.

EGSP-New York #1 Well, Allegany County

Technical Summary

General

This summary presents a detailed characterization of the Devonian Shale occurrence in the EGSP-New York #1 well. Information provided includes a stratigraphic summary and lithology and fracture analyses resulting from detailed core examinations and geophysical log interpretations at the EGSP Core Laboratory. Plane of weakness orientations stemming from a program of physical properties testing at Michigan Technological University are also summarized; the results of physical properties testing are dealt with in detail in the accompanying report. The data presented was obtained from the study of approximately 1,650 feet of core retrieved from a well drilled in Allegany County of southwestern New York.

Location

The EGSP-New York #1 well in Allegany County is located approximately ten miles northwest of Hornell, New York. Specific site location is as follows: Latitude - N42°20'56", Longitude - W77°49'08".

Stratigraphy

A total of 1,649 feet of core was retrieved from the EGSP-New York #1 well. Designated core point was at 370 feet (depth from surface) in the Perrysburg Formation. Coring was terminated at 2,929 feet, approximately five feet into the Tully Limestone. Four isolated zones within the cored

interval were plug drilled. Formation depths and thicknesses encountered in the well and a summary description of each formation is provided below.

FORMATION THICKNESSES

Formation	Depths	Formation Thicknesses	Depths Cored
Perrysburg Formation			
Dunkirk Shale	C.P.- 515'	-	370'- 515'
Java Formation:			
Hanover Shale	515'- 984'	469'	515'- 546' 963'- 984'
Pipe Creek Member	984'-1,018'	34'	984'-1,018'
West Falls Formation:			
Angola Shale	1,018'-1,335'	317'	1,018'-1,021' 1,328'-1,335'
Rhinestreet Shale	1,335'-2,345'	1,010'	1,335'-2,345'
Sonyea Formation:			
Cashaqua Shale	2,345'-2,495'	150'	2,345'-2,359' 2,486'-2,495'
Middlesex Shale	2,495'-2,629'	134'	2,495'-2,629'
Genesee Formation:			
West River Shale	2,629'-2,730'	101'	2,629'-2,664' 2,723'-2,730'
Genundewa Limestone	2,730'-2,737'	7'	2,730'-2,737'
Pen Yan Shale	2,737'-2,866'	129'	2,737'-2,866'
Lodi Limestone	2,866'-2,876'	10'	2,866'-2,876'
Geneseo Shale	2,876'-2,924'	48'	2,876'-2,924'
Tully Limestone	2,924'-T.D.	-	2,924'-2,929'

Perrysburg Formation

The Dunkirk (core point to 515 ft.) is primarily fine clastic sediments, thinly laminated to thin bedded. The dominant rock types are silty mudstone, siltstone, and mudstone. Commonly these occur in an ordered vertical sequence of thin, upward-fining graded beds.

The upper part of the Dunkirk (370 to 430 ft.) consists mostly of laminated silty mudstone and mudstone. Isolated, very thin beds of siltstone occur beneath some of the silty mudstones. The siltstones often are cross-laminated or ripple-laminated. Silty sandstones and very fine sandstones occur rarely as the basal constituents of these beds. The silty mudstones and mudstones generally are olive gray and dark greenish gray in color; dark shale laminae are notably absent. Fossil content is sparse, consisting of occasional carbonaceous fragments and poorly-preserved casts of small brachiopod shells. Bioturbation is minimal. Thin, dark yellowish brown concretionary bands (siderite ?) are common in the upper 60 feet of the Dunkirk, but do not occur in the lower part.

The lower part of the Dunkirk interval (430 to 515 ft.) contains less mudstone and more siltstone than the upper part. Olive gray and dark greenish gray are the dominant colors. However, the uppermost silty mudstone laminae often are olive black or brownish black. Bioturbation is rare. Carbonaceous fragments and casts of articulate brachiopod shells are more plentiful than above. No sandstone is present. Ripple lamination, cross-stratification, and disrupted stratification are common sedimentary structures in the siltstones.

Java Formation

Hanover Shale Member:

The thickness of the Hanover in this well is 469 feet (515 to 984 ft.). Only the upper 32 feet and the lower 20 feet of the interval were cored.

Consequently, a detailed core description was obtained for only a small part of this shale member.

The upper and lower parts of the section are conspicuously sandy. Within the individual beds, the basal sandstones or siltstones rest upon sharp scour surfaces which frequently exhibit sole marks. Disrupted stratification and mud clasts are common features in the coarser clastic zones. Silty mudstones and siltstones in the middle of the beds generally contain cross-lamination or ripple-lamination. The silty mudstones at the top of the beds frequently are weakly bioturbated.

A few dark-shale laminae are present in the Hanover; these occur about 15 feet above the base of the unit. The dominant colors in the cored sections are olive gray and light olive gray.

Pipe Creek Member:

The Pipe Creek Member occurs between the depths of 984 and 1,018 feet in the core. Coarse clastic units are less abundant than in the Hanover, and dark laminae of silty mudstone and mudstone are more common. The dominant colors are olive black, brownish black, and dark greenish gray. Fossil content, consisting of carbonaceous fragments and casts of small pelecypod shells, is somewhat greater than in the Hanover. A single, thin concretionary band (siderite ?), similar to those in the Dunkirk, occurs near the top of the Pipe Creek Member.

West Falls Formation

Angola Shale Member:

The Angola Shale occurs between the depths of 1,018 and 1,335 feet; almost the entire interval was plug drilled. Approximately four feet at

the top and seven feet at the bottom of the Angola were cored. The top of the interval resembles the overlying Pipe Creek and the contact is lithologically indistinct. The contact with the underlying Rhinestreet Shale is transitional.

Rhinestreet Shale Member:

The Rhinestreet Member is present between the depths of 1,335 and 2,345 feet. The entire Rhinestreet interval was cored.

The Rhinestreet Shale is composed of large numbers of upward-fining beds which are similar in appearance to units higher in the section. Individual beds vary from about two inches to two feet in thickness. Silty mudstone and siltstone are the dominant lithology; mudstone and very fine sandstone are also present in many of the thicker beds. The darkest rock colors (grayish black or darker) occur within mudstones and silty mudstones at the top of the graded beds. The lower and middle parts of the beds are lighter-colored siltstones and silty mudstones.

Concretionary structures are abundant in the Rhinestreet Shale below a depth of 1,650 feet. Two types are present: moderate yellowish brown calcareous (siderite ?) concretionary bands with diffuse boundaries and light olive gray calcareous bands and lenses.

Carbonaceous plant fragments are scattered throughout the Rhinestreet Shale, but concentrations of these fragments are rare. Pyritized spores are also common. Pelecypod shell fragments occur occasionally through the upper part of the interval and are plentiful in the lowest 100 feet. Bioturbation is confined to the fine clastic sediments at the top of the graded beds and usually is weakly developed. In some cases, burrow structures are pyritized.

Sonyea Formation

Cashaqua Shale Member:

The New York #1 well was plug drilled through most of the Cashaqua Shale interval (2,345 to 2,495 ft.). The uppermost 11 feet and bottom 7 feet were cored. The thickness of the Cashaqua in this well is 150 feet.

The top 11 feet consists of dark greenish gray and olive gray silty mudstone, containing numerous thin olive black zones. Small diameter burrow structures are common, although the overall intensity of bioturbation is slight. Pelecypod and brachiopod shell fragments and casts are rarely present.

The basal seven feet of the Cashaqua is made up of silty mudstone and mudstone. Predominant rock colors are olive black, brownish black, and dark gray. Bioturbation and fossils are present in the lower Cashaqua, as above. A relatively thick gradational contact exists between the Cashaqua and the underlying Middlesex Member.

Middlesex Shale Member:

Dark silty mudstone and mudstone are the dominant lithologies throughout the Middlesex. The major colors are olive black and brownish black, with isolated zones of dark greenish gray and olive gray in the lower 1/2. Very thin siltstones deposited on weak scour surfaces occur at isolated locations within the Middlesex. Fossil content is sparse. Isolated carbonaceous fragments (generally large coaly pieces) are present at several locations. Carbonized and pyritized spore occur in the interval, but are not common. The cephalopod casts are present near the middle of the unit.

Pyrite is common and occurs as isolated irregular laminae, small nodules, and disseminated grains in the middle and lower parts of the unit.

Genesee Formation

West River Shale Member:

Approximately 101 feet of the West River Shale is present in the New York #1 well. Of this, the upper 36.5 feet and the lower 7 feet were cored. The cored portion consists of thinly to thickly laminated olive gray, dark greenish gray, and olive black silty mudstone, most of which is weakly to strongly calcareous. Casts of cephalopod, pelecypod, and articulate brachiopod shells are common in the upper 1/3. Pyrite occurs in burrow structures, as nodules and irregular laminae, and in disseminated form.

Genundewa Limestone Member:

The Genundewa Limestone is present between the depths of 2,730 and 2,737 feet. The dominant lithologies are impure lime mudstone, wackestone, and packstone. These beds are commonly separated by thin zones of olive black calcareous silty mudstone. Soft-sediment deformation features are common throughout. The wackestones and packstones are restricted to the upper half. The dark calcareous mudstones contain numerous casts of small articulate brachiopod and pelecypod shells.

Pen Yan Shale Member:

The Pen Yan is present between the depths of 2,737 and 2,866 feet. It consists of silty mudstones, silty shales, and shaly mudstones. Olive black is the dominant rock color with greenish black, grayish black, and brownish black zones also common.

The upper 75 feet of the Pen Yan Member is calcareous and contains isolated graded beds with thin basal siltstones. Articulate brachiopod, pelecypod and cephalopod casts are present throughout. Some of the sediments are weakly burrowed. Lime concretions are common above 2,830 feet.

Siltstones, concretions, invertebrate fossils, and biogenic structures are absent below 2,815 feet. Fissility is greater in the lower part where the shaly zones tend to be calcareous. Small pyrite nodules are common.

Lodi Limestone Member:

Interbedded lime mudstones and calcareous silty mudstone occur between the depths of 2,866 and 2,876 feet. The lime mudstone beds are olive gray and light olive gray in color, while the silty mudstones are black and grayish black. Several of the lime beds contain soft sediment deformation features. The silty mudstones are strongly calcareous and contain numerous casts of small articulate brachipod shells.

Geneseo Shale Member:

Between 2,876 and 2,924 feet the core consists entirely of black and grayish black silty shale and shaly mudstone. These lithologies exhibit the intensely fissile structure described as "poker chips." Most of the Geneseo Shale is weakly to moderately calcareous. Carbonaceous fragments and films occasionally are present. Small nodules and thin laminae of pyrite are common.

Tully Limestone

Coring was terminated 5 feet into the top of the Tully Limestone at a depth of 2,929 feet. The portion of the Tully present at the base of the EGSP-New York #1 core is composed of mottled, thick bedded and massive bedded lime mudstones, medium dark gray and medium gray in color. Partings of the dark silty mudstone occur in the vicinity of the contact with the Geneseo Shale. The limestone is slightly fossiliferous and weakly bioturbated.

Fracture Analysis

Forty-eight natural fractures were observed in the core. About 90% of this total is composed of simple and compound joints. The distribution of natural fractures throughout the cored interval is shown on the following page.

All planar natural fractures were analyzed to identify common structural trends in the core. Two strike trends are evident.

TREND 1: ranging from N30^{o}E to S55^{o}E, near-vertical with a major concentration of fracture strikes trending N72^{o}E.

TREND 2: ranging from N22^{o}W to N50^{o}W, near-vertical.

TREND 1 includes most (84%) of the planar natural fractures. Members of this fracture set are commonly nonmineralized; when present, mineralization is either calcite or dolomite. Trend 1 contains 87% of all planar natural fractures with a vertical length in excess of 1.0 foot.

TREND 2, represented by five fractures, contains calcite and rarely dolomite-mineralized joints of variable length. Fractures in this system are restricted in the core to a zone above 2,170 feet.

DISTRIBUTION OF NATURAL FRACTURES

Formation	Depths	Cored Interval	Number Fractures	Frequency Per Foot
Perrysburg Formation:				
Dunkirk Shale	370'- 515'	145'	3	0.02
Java Formation:				
Hanover Shale	515'- 984'	58'	0	0.00
Pipe Creek Member	984'-1,018'	35'	2	0.06
West Falls Formation:				
Angola Shale	1,018'-1,335'	14'	2	0.14
Rhinestreet Shale	1,335'-2,345'	1,010'	25	0.02
Sonyea Formation:				
Cashaqua Shale	2,345'-2,495'	22'	0	0.00
Middlesex Shale	2,495'-2,629'	134'	5	0.04
Genesee Formation:				
West River Shale	2,629'-2,730'	43'	4	0.09
Genundewa Limestone	2,730'-2,737'	7'	1	0.14
Pen Yan Shale	2,737'-2,866'	129'	4	0.03
Lodi Limestone	2,866'-2,876'	10'	0	0.00
Geneseo Shale	2,876'-2,924'	48'	2	0.04
Tully Limestone	2,924'-2,929'	+5'	0	0.00

Physical Properties Testing

The results of pretest fractures, point load induced fractures, and ultrasonic velocity measurements performed on the EGSP-New York #1 core indicate that there is a preferred direction of fracturing in the core with the orientation of N60^{o}E $\pm$ 15° for each stratigraphic interval and a secondary preferred orientation of N90^{o}E $\pm$ 15°.

Available Reports

For a more detailed account of field operations, lithology and fracture analyses and physical test results, the reader is referred to the following reports:

(1) EGSP-New York #1, Allegany County, Report of Field Operations.

(2) EGSP-New York #1, Allegany County, Phase II Report, Preliminary Laboratory Results, February 1980.

PREFERRED PLANES OF WEAKNESS IN DEVONIAN GAS SHALES DETERMINED BY MECHANICAL CHARACTERIZATION

Report for

EGSP-New York #1 Well, Allegany County

Department of Mining Engineering

Michigan Technological University

Houghton, Michigan 49931

November 1980

Prepared for

Cliffs Minerals, Inc.

Under Contract No. EW-78-C-21-8199

TABLE OF CONTENTS

	Page No.
List of Figures	iii
List of Tables	iv
Summary of Mechanical Characterization Results	1
I. Introduction	2
A. Directional Ultrasonic Velocity Measurements	3
B. Point Load Testing	5
C. Directional Tensile Strength Testing	6
II. Experimental Procedures	7
A. Pretest Fracture Measurements	7
B. Directional Ultrasonic Velocity Measurements	8
C. Point Load Testing	9
D. Directional Tensile Strength Testing	9
III. Results	
A. Perrysburg Formation	12
B. Java Formation	13
C. West Falls Formation	14
D. Sonyea Formation	15
E. Genesee Formation	16
F. Well Composite	17
IV. Conclusions	18
V. Bibliography	20

APPENDICES

A	Results of Pretest Fracture Measurements	22
B	Results of Directional Ultrasonic Velocity Measurements	29
C	Results of Point Load Tests	49
D	Results of Directional Tensile Strength Tests	60

LIST OF FIGURES

Figure No.		Page No.
1	Ultrasonic Pulse Apparatus	3
2	Point Load Apparatus	5
3	Directional Tensile Strength Apparatus	6
4	Perrysburg Formation: Frequency Distribution Rose Diagram of Results	12
5	Java Formation: Frequency Distribution Rose Diagram of Results	13
6	West Falls Formation: Frequency Distribution Rose Diagram of Results	14
7	Sonyea Formation: Frequency Distribution Rose Diagram of Results	15
8	Genesee Formation: Frequency Distribution Rose Diagram of Results	16
9	Well Composite: Frequency Distribution Rose Diagram of Results	17

Appendix

B-1	Histogram of Average Velocity: Perrysburg Formation	43
B-2	Histogram of Average Velocity: Java Formation	44
B-3	Histogram of Average Velocity: West Falls Formation	45
B-4	Histogram of Average Velocity: Sonyea Formation	46
B-5	Histogram of Average Velocity: Genesee Formation	47
B-6	Histogram of Average Velocity: Well Composite	48
D-1	Histogram of DTS: Perrysburg Formation	65
D-2	Histogram of DTS: Java Formation	66
D-3	Histogram of DTS: West Falls Formation	67
D-4	Histogram of DTS: Sonyea Formation	68
D-5	Histogram of DTS: Genesee Formation	69
D-6	Histogram of DTS: Well Composite	70

LIST OF TABLES

Table No.		Page No.
1	Formations Tested	2
2	Frequency Distribution of Preferred Direction of Fracturing	11
Appendix		
A: Results of Pretest Fracture Measurements		
A-1	Scribed Orientation Grooves in Velocity Samples	23
A-2	Orientation and Length of Ultrasonic Velocity Specimens	24
A-3	Orientation and Length of Pretest Fractures in Point Load Specimens	25
A-4	Orientation and Length of Pretest Fractures in Directional Tensile Strength Specimens	26
A-5	Frequency Distribution of Pretest Fractures	28
B: Results of Directional Ultrasonic Velocity Measurements		
B-1	Directional Ultrasonic Wave Velocities	30
B-2	Orientation of Ultrasonic Velocity Minimums	35
C: Results of Point Load Tests		
C-1	Frequency Distribution of Fractures Induced by Point Load	50
C-2	Point Load Index	55
D: Results of Directional Tensile Strength Tests		
D-1	Directional Tensile Strengths	61

Summary of Mechanical Characterization Results

The purpose of mechanical characterization of samples from the EGSP-New York #1 core is to determine the orientation of preferred planes of weakness in the Devonian gas shales at the Allegany County well site.

Prior to testing, the length and orientation of pretest fractures identified in each sample were recorded. The greater number of pretest fractures identified indicated N60°E as the preferred direction of fracturing and N90°E as a secondary preferred direction (39% and 24% respectively out of 326 total pretest fractures).

Minimum ultrasonic velocity values are normal to the preferred direction of fracturing because fracture interfaces impede propagation of the sonic wave. Ultrasonic velocity measurements indicate a preferred direction of fracturing of N60°E (62% of 149 samples) with a secondary preferred direction of N90°E (32% of 149 samples).

Fractures induced by applying a point load to the central axis of a disc occur parallel to the preferred direction of fracturing. Point load induced fractures occur most frequently in the N60°E orientation (54% of 922 samples) with a secondary preferred direction of N90°E (32% of 922 samples).

Compressive loads are applied across the diameter of the specimen to induce diametrical fractures for determining tensile strengths normal to the loading axis. The plane of weakness will be in an azimuth normal to the plane of minimum tensile strength. Directional tensile strength measurements of the New York #1 core do not indicate a preferred direction of fracturing; each orientation is preferred with equal frequency.

INTRODUCTION

The purpose of mechanical characterization of samples from the EGSP-New York #1 core is to determine the orientation of preferred planes of weakness in the Devonian gas shales at the Allegany County well site.

A series of samples, representing 1,649 feet of core taken from the New York #1 well, were tested. The tested intervals occur below surface between 443 and 2,929 feet and are summarized in Table 1.

Table 1. Formations Tested.

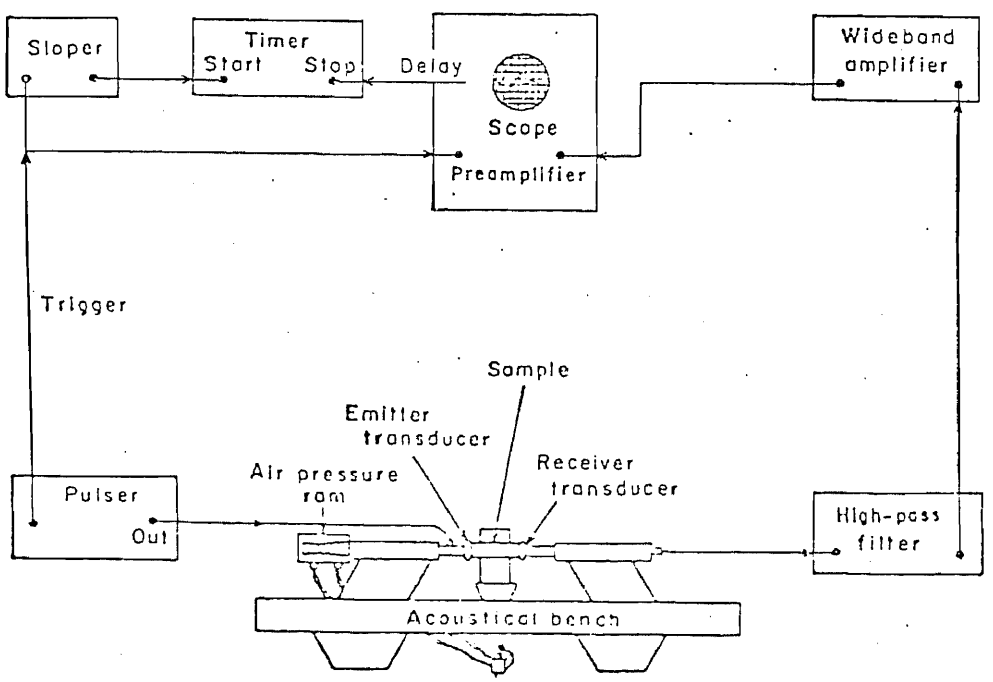
Formation	Depths Cored	Depths Tested
Perrysburg Formation		
Dunkirk Shale	370'- 515'	370'- 515'
Java Formation:		
Hanover Shale	515'- 546'	515'- 546'
	963'- 984'	963'- 984'
Pipe Creek Member	984'-1,018'	984'-1,018'
West Falls Formation:		
Angola Shale	1,018'-1,021'	1,018'-1,021'
	1,328'-1,335'	1,328'-1,335'
Rhinestreet Shale	1,335'-2,345'	1,335'-2,345'
Sonyea Formation:		
Cashaqua Shale	2,345'-2,359'	2,345'-2,359'
	2,486'-2,495'	2,486'-2,495'
Middlesex Shale	2,495'-2,629'	2,495'-2,629'
Genessee Formation:		
West River Shale	2,629'-2,664'	2,629'-2,664'
	2,723'-2,730'	2,723'-2,730'
Genundewa Limestone	2,730'-2,737'	2,730'-2,737'
Pen Yan Shale	2,737'-2,866'	2,737'-2,866'
Lodi Limestone	2,866'-2,876'	2,866'-2,876'
Geneseo Shale	2,876'-2,924'	2,876'-2,924'
Tully Limestone	2,924'-2,929'	2,924'-2,929'

The physical property tests employed are: 1) directional ultrasonic velocity measurements; 2) point load tests; and 3) directional tensile strength tests. In addition, all fractures (hereafter referred to as 'pretest fractures') are systematically recorded before the physical property tests are performed. The theories on which these tests are based are summarized as follows:

A. Directional Ultrasonic Velocity Measurements

The orientation of linear features such as microfractures in a rock specimen may be found by measuring the longitudinal wave velocity through the specimen. Fractures which are oriented perpendicular to the direction of wave propagation impede the wave; fractures which are oriented parallel to the direction of wave propagation do not (Birch, 1960). Measurements are performed diametrically at 30 degree intervals from true north. Minimum values of sonic velocity are expected to occur in azimuths normal to the preferred direction of mircofractures (Komar, Kovach, 1969).

Figure 1. Schematic Diagram of Ultrasonic Pulse Apparatus (Thill, Peng, 1974)



An ultrasonic pulse measurement system operates as shown in Figure 1. A pulse generator supplies a rectangular electrical pulse which is converted to a mechanical pulse by a piezoelectric transducer and transmitted into one end of the specimen. The mechanical pulse is received at the other end of the specimen by another piezoelectric transducer and is converted back to an electrical signal. An oscilloscope and timer are synchronized with the output of each pulse to the specimen by the trigger pulse from the pulse generator. Low frequency noise is filtered from the arrival signal and the signal is tapped to the vertical amplifier of the oscilloscope. The first arrival is highly amplified and the sensitivity of the stop trigger of the timer is adjusted to a level just exceeding the noise level of the received signal. Therefore, the time elapsed between initiation of the pulse at the pulse generator and the first arrival of the elastic wave at the receiver is recorded automatically (Thill, Bur, 1969; Thill, Peng, 1974). The counter averages 100 pulses before displaying the digitized result to 0.001 microseconds (Komar, et al, 1976).

Travel times are corrected for instrumentation and system delays using various lengths of aluminum standards. A plot of length versus transit time is made; the intersection of the least squares line indicates the instrument delay time (Thill, Bur, 1969).

The velocity, V, of the longitudinal wave is calculated using the distance, D, traversed by the wave (the diameter of the specimen) and the travel time, t, by the formula (Anderson, Liebermann, 1966):

$$V = Dt^{-1}$$

The ultrasonic pulse method is the laboratory counterpart of field seismic methods that operate at much lower frequencies.

The statistical analysis of these measurements identifies the 95% confidence interval. This is a statistical parameter which indicates the interval in which the measurement will occur 95% of the time, and is calculated by the formula:

$$\bar{X} \pm tsN^{-1/2}$$

where: $\bar{X}$ = mean

t = t factor for 5 degrees of freedom and 95% confidence

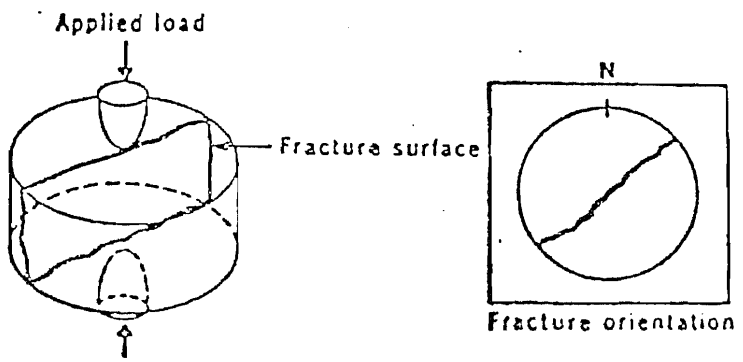
s = standard deviation

N = number of measurements

B. Point Load Testing

The orientation of a weakness plane in rock specimens may be found by inducing tensile fractures in discs when a load is applied through the disc's central axis (Anderson, Liebermann, 1966; McWilliams, 1966) (Figure 2).

Figure 2. Schematic Diagram of Point Load Test (Anderson, Liebermann, 1966)



Fracture direction at random unless a "preferred direction" of failure exists.

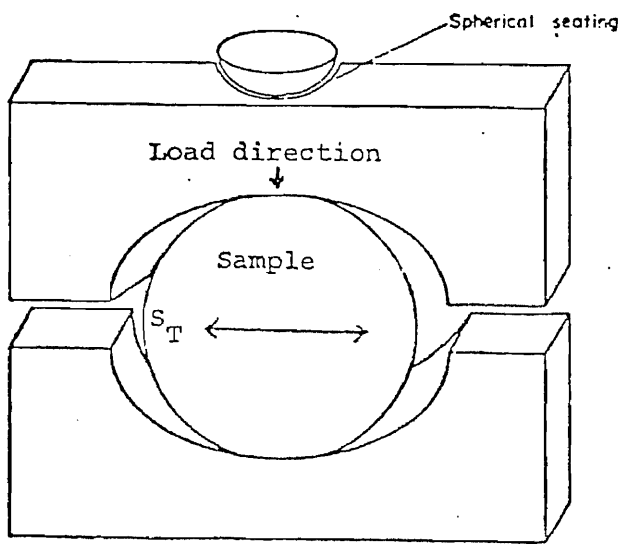
The point load testing apparatus consists of a load frame with two identical platens. These loading contact points are spherically truncated cones between which the specimen is axially centered.

Fractures induced by point load will indicate a random orientation only if the rock specimens are of homogeneous isotropic material; if the specimen is anisotropic, the induced fracture would be expected to occur in directions parallel to the preferred directions of microfracture (Peng, Ortiz, 1972).

C. Directional Tensile Strength Testing

The orientation of minimum tensile strength may be found by applying a compressive load across the diameter of a cylindrical specimen (Mellor, Hawkes, 1971) (Figure 3).

Figure 3. Directional Tensile Strength Test Apparatus



Curved-jaw loading rig for the "Brazilian" indirect tensile test on rock discs (Hawkes and Mellor).

In this diametric or line load test, tensile strength normal to the axes of loading is determined from the magnitude of the applied load at failure by the formula (Peng, Ortiz, 1972):

$$S_T = 2P(\pi dt)^{-1}$$

where: S_T = tensile strength, psi

P = applied load at failure, lb.

d = diameter of disc, in.

t = thickness of disc, in.

Line load specimens are tested diametrically at 30 degree intervals from true north. Tensile strength minimums are expected to occur in azimuths normal to the preferred direction of fracture (Anderson, Liebermann, 1966).

EXPERIMENTAL PROCEDURES

Tests follow the "Field and Laboratory Procedures for Oriented Core Analysis of Devonian Shales" published by Morgantown Energy Technology Center, U. S. Department of Energy, and incorporates American Society of Testing Methods and International Society of Rock Mechanics suggested methods as guidelines.

A. Pretest Fracture Measurements

Pretest fractures are recorded on all speciments prior to testing as summarized:

1. The surface of the specimen is dampened with a moist sponge.
2. When water evaporates from the surface, the cracks are accentuated because the water is momentarily retained by the fractures; the cracks are traced by pencil while they are still visible.
3. The orientation of the crack is determined by running a line parallel to the crack through the center of the oriented specimen. The orientation of the crack is recorded in degrees from true north.

4. The length of the crack is recorded in inches.

5. A sketch is made of each specimen illustrating the pretest fractures.

6. A composite sheet is kept with the orientation and length of each identified fracture for all tested specimens.

B. Directional Ultrasonic Velocity Measurements

Directional ultrasonic velocity measurements are performed as summarized:

1. Pretest fractures are recorded as outlined above including a description of bedding or other significant features.

2. The mid-portion of the sample is taped with black vinyl tape. Three strips of tape are used which touch but do not overlap each other. The ends of the tape are positioned at an orientation groove so the transducer heads are not positioned over the splice.

3. The sample is placed on the (foam rubber) cushioned, indexed, rotating stage with the north orientation mark against the transmitting head.

4. A generous amount of high vacuum silicone grease is applied to each of the 12 contact positions at 30 degree intervals from true north.

5. The opposite traveling head is moved to nearly touch the core surface to avoid jarring the specimen.

6. The solenoid switch is actuated, gripping the specimen with an indicated air hydraulic pressure of 35 psi.

7. With the pulse rate set at 30 sec^{-1}, the powerstat is turned on and increased to an indicated 62%.

8. A wait of three minutes is necessary for the decay and stabilization of indicated travel time.

9. While waiting, the diameter of the core at this position is recorded (to .001 inch) using the on line dial indicator.

10. After three minutes, ten consecutive travel time values registered on the digital counter are recorded (to .001 microseconds). Each travel time recorded is the average of 100 pulses.

11. The pressure is released on the sample.

12. The specimen is rotated on the stage to the next marked 30 degree interval and numbers 5 through 12 are repeated until the travel times in each of the six orientations, 0, 30, 60, 90, 120, 150 degrees, have been recorded.

C. Point Load Testing

The point load test is performed as summarized:

1. At intervals of 10 feet, 2-inch diameter by approximately 5/8-inch thick samples are selected.

2. Pretest fractures are recorded as outlined above.

3. The dimensions of the samples are recorded; diameter and thickness in inches.

4. The circumference of the samples are taped with masking tape to preserve the fractures after the point load test is performed.

5. The sample is centered and placed vertically between two conical platens in the load frame (see Figure 2).

6. A compressive load is applied directly in the center on both the top and bottom sides of the sample.

7. The magnitude of the applied load at failure is recorded and the point load strength index can be obtained by the formula (Roberts, 1977):

$$I_S = P \times a(D^2)^{-1}$$

where: I_S = point load strength index

P = applied load at failure, lbs.

D = distance between load applicators at failure, in.

a = piston area (5)

8. The induced fractures are sketched and their orientation recorded on a composite sheet.

D. Directional Tensile Strength Testing

Directional tensile strength measurements are determined as summarized:

1. At intervals of 10 feet, six to ten closely grouped samples (2-inch diameter by approximately 5/8-inch thick) are selected.

2. Pretest fractures are recorded as outlined above.

3. Each sample is oriented and marked in one of six directions (0°, 30°, 60°, 90°, 120°, 150°), and its edges corresponding to this mark are sanded if necessary to insure even loading.

4. The dimensions of the samples are recorded; diameter and thickness in inches; if necessary, the samples are taped with masking tape.

5. The sample is placed diametrically between two platens in the load frame (see Figure 3).

6. A compressive load is applied across the previously oriented diameter of the sample.

7. The magnitude of the applied load at failure is recorded.

8. Tensile strength normal to the axis of loading is determined using the formula: $S_T = 2P(\pi dt)^{-1}$ as defined in the introduction.

9. The induced fractures are sketched.

RESULTS

The results of the physical property measurements of pretest fractures, directional ultrasonic velocity, point load induced fractures, and directional tensile strength tests are compiled in Appendices A, B, C, and D, respectively.

Table 2 is a summary of the mechanical property testing results for each formation.

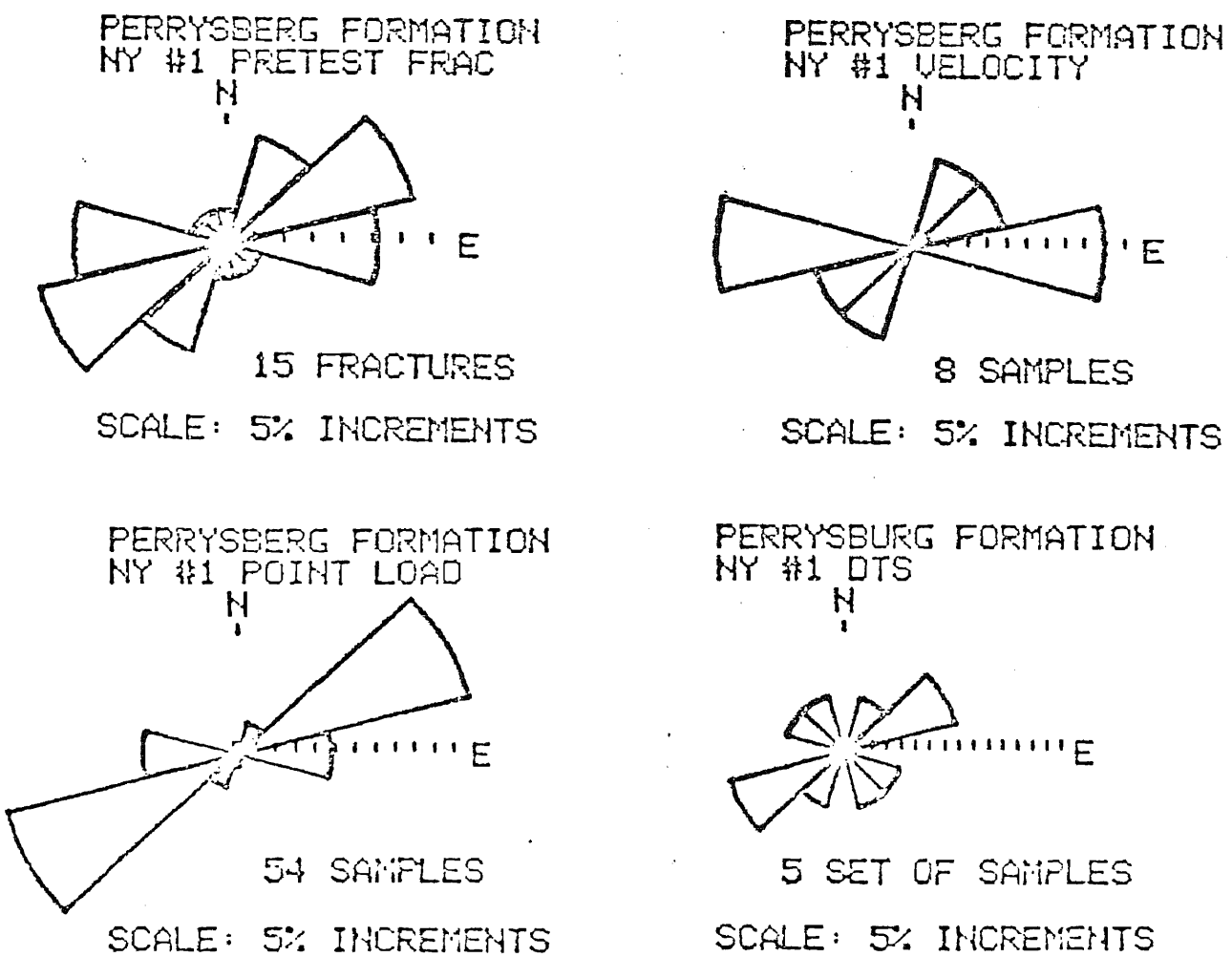
Table 2
EGSP-New York #1
Frequency Distribution of Preferred
Direction of Fracturing
Orientation in Degrees from North

Formation	Test	0°	30°	60°	90°	120°	150°	Total Samples
Perrysburg 370'-515'	Pretest Fracture	1	3	5	4	1	1	15
	Velocity	0	2	2	4	0	0	8
	Point Load	2	5	33	13	1	0	54
	DTS	0	1	2	0	1	1	30
Java 515'-1,018'	Pretest Fracture	0	0	1	1	0	0	2
	Velocity	0	0	7	0	1	0	8
	Point Load	3	8	24	8	0	0	43
	DTS	0	2	1	2	2	0	42
West Falls 1,018'-2,345'	Pretest Fracture	10	17	98	55	23	7	210
	Velocity	2	0	58	36	2	0	98
	Point Load	10	31	338	221	28	5	633
	DTS	15	6	16	18	16	15	516
Sonyea 2,345'-2,629'	Pretest Fracture	4	5	14	14	5	2	44
	Velocity	0	1	11	4	0	0	16
	Point Load	3	12	44	27	5	1	92
	DTS	1	4	1	3	2	4	90
Genesee 2,629'-2,924'	Pretest Fracture	3	12	9	3	4	23	54
	Velocity	0	1	15	3	0	0	19
	Point Load	4	7	59	23	4	3	100
	DTS	2	5	2	0	5	2	96
Composite	Pretest Fracture	18	38	127	77	33	33	326
	Velocity	2	4	93	47	3	0	149
	Point Load	22	63	498	292	38	9	922
	DTS	18	18	22	23	26	22	774

Perrysburg Formation: 370 to 515 feet

Pretest fractures occur most frequently in the N60°E orientation (5 out of 15 pretest fractures). Of the eight ultrasonic velocity samples received, the preferred orientation is distributed between N30°E to N90°E with N90°E preferred by 4 out of the 8 samples. Point load induced fractures occur most frequently in the N60°E orientation (33 out of 54 induced fractures). Two directional tensile strength sets out of five tested show a preferred orientation of N60°E. Figure 4 displays the frequency distribution of the preferred directions of fracturing in the Perrysburg Formation. Tabulated results are presented in Appendices A, B, C, and D.

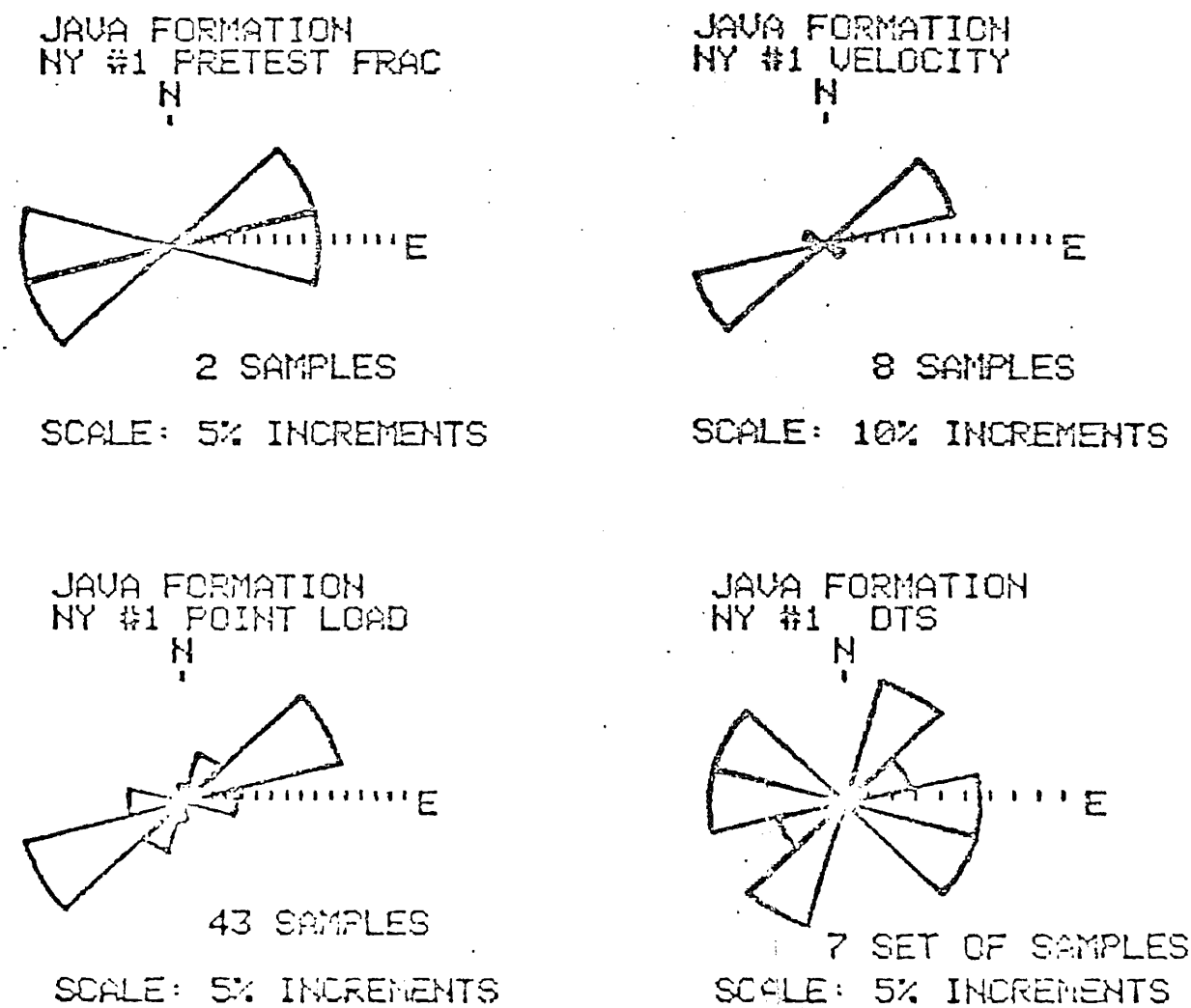
Figure 4



Java Formation: 515 to 1,018 feet

Two pretest fractures were identified; these trend N60°E and N90°E. The preferred direction found by ultrasonic velocity measurements is well defined in the N60°E orientation (7 out of 8 velocity samples). Point load induced fractures occur most frequently in the N60°E orientation (24 out of 43 induced fractures). Directional tensile strength measurements preferred orientations ranging from N30°E to N120°E. Figure 5 displays the frequency distribution of preferred directions of fracturing in the Java Formation. Tabulated results are presented in Appendices A, B, C, and D.

Figure 5



West Falls Formation: 1,018 to 2,345 feet

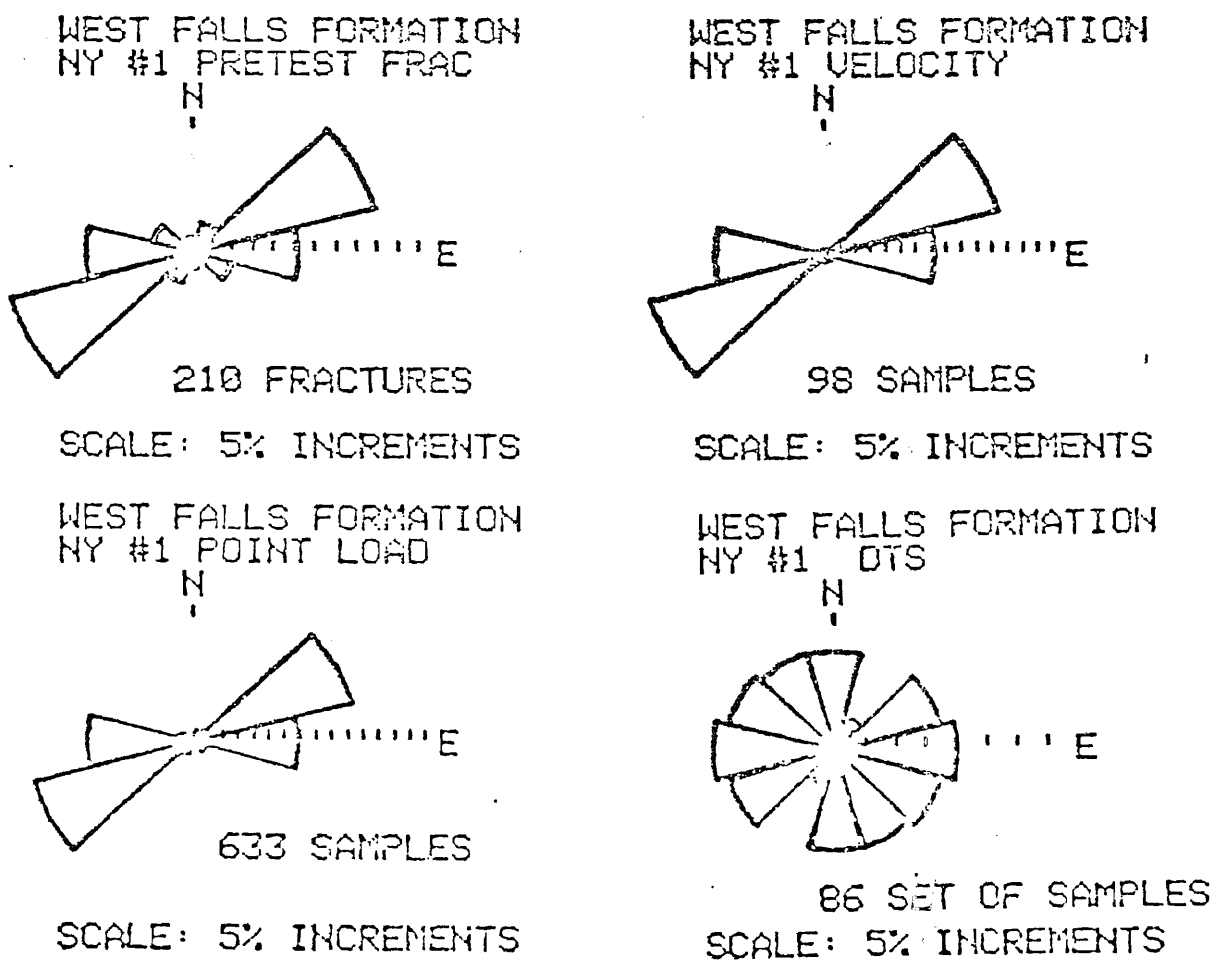
Angola Shale Member: 1,018 to 1,335 feet

No samples received

Rhinestreet Shale Member: 1,335 to 2,345 feet

The preferred direction of fracturing in the Rhinestreet Shale Member is N60°E as indicated by: pretest fractures (98 out of 210 pretest fractures); point load induced fractures (338 out of 633 induced fractures); ultrasonic velocity measurements (58 out of 98 velocity samples). The directional tensile strength measurements show no statistically significant preferred orientation. Figure 6 displays the frequency distribution of preferred directions of fracturing in the Rhinestreet Shale Member of the West Falls Formation. Tabulated results are presented in Appendices A, B, C, and D.

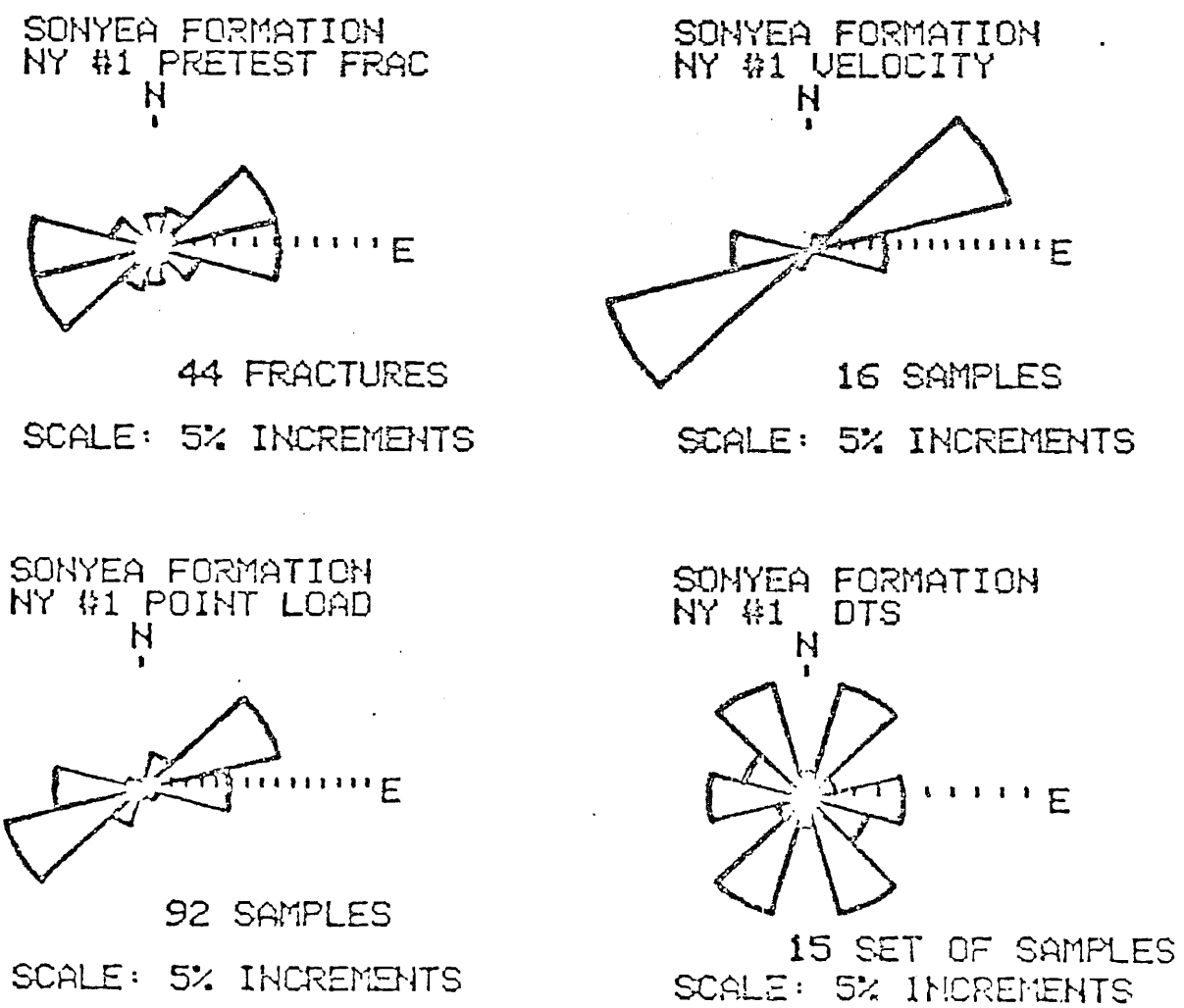
Figure 6



Sonyea Formation: 2,345 to 2,629 feet

The preferred direction of fracturing in the Sonyea Formation is N60°E as indicated by: pretest fractures (14 out of 44 pretest fractures); ultrasonic velocity measurements (11 out of 16 velocity samples); and point load induced fractures (44 out of 92 induced fractures). The directional tensile strength measurements show no statistically significant preferred orientation. Figure 7 displays the frequency distribution of preferred directions of fracturing in the Sonyea Formation. Tabulated results are presented in Appendices A, B, C, and D.

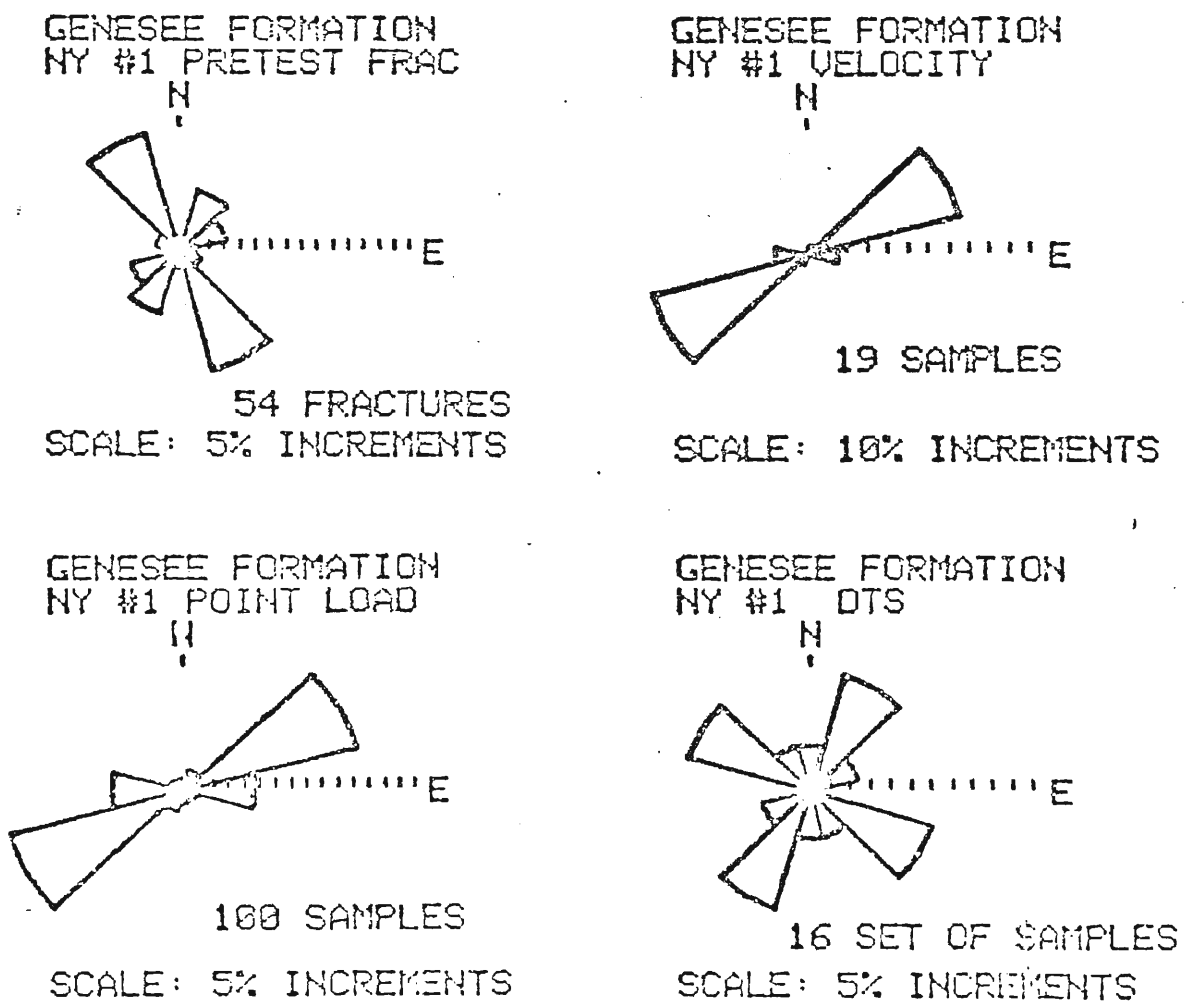
Figure 7



Genesee Formation: 2,29 to 2,924 feet

Pretest fractures occur most frequently in the N150°E orientation (23 out of 54 pretest fractures). The ultrasonic velocity measurements and the point load induced fractures both indicate N60°E as the preferred direction of fracturing (15 out of 19 velocity samples and 59 out of 100 induced fractures). The directional tensile strength measurements show no statistically significant preferred orientation. Figure 8 displays the frequency distribution of preferred directions of fracturing in the Genesee Formation. Tabulated results are presented in Appendices A, B, C, and D.

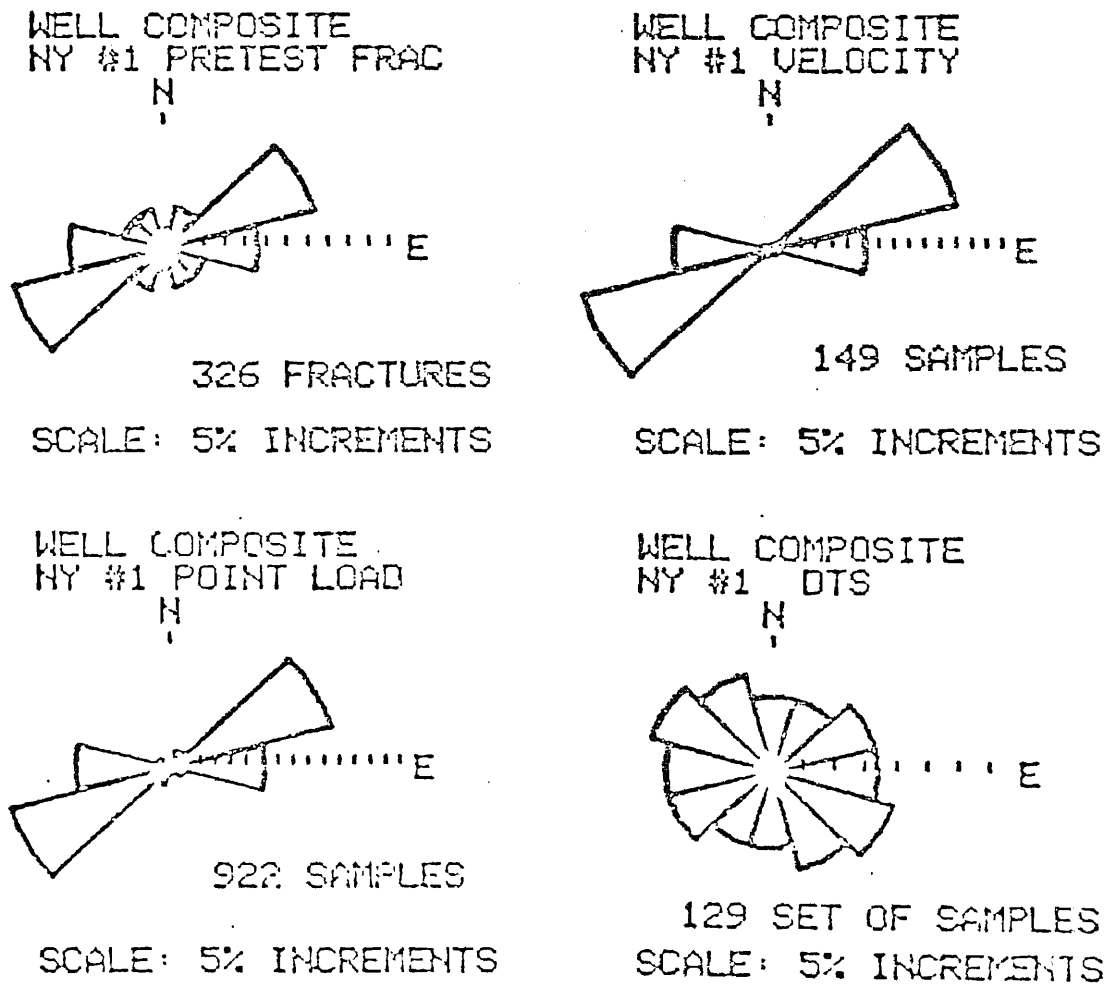
Figure 8



Well Composite:

The preferred direction of fracturing in each stratigraphic interval and in the well composite is N60°E±15°. The N60°E orientation is the most preferred direction in the well composite for each test. N60°E was indicated by 39% of the pretest fractures, 62% of the ultrasonic velocity measurements, and 54% of the point load induced fractures. The directional tensile strength measurements show no statistically significant preferred orientation. Figure 9 displays the frequency distribution of preferred directions of fracturing in the well composite. Tabulated results are presented in Appendices A, B, C, and D.

Figure 9



CONCLUSIONS

The data presented in this report indicate that core samples from the EGSP-New York #1 well exhibit a directional variation in physical properties. Prediction of the preferred direction of induced fracturing at the Allegany County well site was based on inherent weaknesses in the core samples found by: 1) point load induced fractures; 2) directional tensile strength measurements; 3) normality to measured ultrasonic velocity minimum; and 4) the trend of frequently occurring pretest fractures. Test results from directional tensile strength measurements show no statistically significant preferred orientation in the Allegany County core samples. The overall agreement between the remaining tests for each stratigraphic interval suggests that these physical property measurements do indicate a common preferred direction of fracturing in Allegany County core samples.

The following conclusions can be drawn from this investigation:

1) The preferred direction of fracturing for the Dunkirk Shale Member of the Perrysburg Formation (top of core 370 to 515 feet) is N60^{o}E$\pm$15° as indicated by pretest fractures, point load induced fractures, and directional tensile strength measurements.

2) The preferred direction of fracturing for the Java Formation (515 to 1,018 feet) is N60^{o}E$\pm$15° as indicated by pretest fractures, point load induced fractures, and ultrasonic velocity measurements.

3) The preferred direction of fracturing for the West Falls Formation (1,018 to 2,345 feet) is N60^{o}E$\pm$15° as indicated by pretest fractures, point load induced fractures and ultrasonic velocity measurements.

4) The preferred direction of fracturing for the Sonyea Formation (2,345 to 2,629 feet) is N60°E±15° as indicated by pretest fractures, point load induced fractures and ultrasonic velocity measurements.

5) The preferred direction of fracturing in the Genesee Formation (2,629 to 2,924 feet) is N60°E±15° as indicated by point load induced fractures and ultrasonic velocity measurements. Pretest fractures trend most frequently N150°E ± 15°.

6) The preferred direction of fracturing in the Tully Limestone Member of the Hamilton Group (2,924 to 2,929) cannot be interpreted because of the statitically small number of samples received.

7) Each stratigraphic interval appears to have a secondary preferred orientation of N90°E ± 15°.

BIBLIOGRAPHY

Anderson, O. L., and Liebermann, R. C., 1966, Sound Velocities in Rocks and Minerals: VESIAC State-of-the-Art Report 7885-4-X, Willow Run Laboratories, University of Michigan, 182 pp.

Birch, F., 1960, The Velocity of Compressional Waves in Rocks to 10 Kilobars, Part I: J. Geophys. Res., v. 65, pp. 1083-1102.

GangaRao, H. V. S., Advani, S. H., Chang, P., Lee, S. C., and Dean, C. S., 1979, In Situ Stress Determination Based on Fracture Responses Associated with Coring Operations: 20th U.S. Symposium on Rock Mechanics, Austin, Texas, June 1979.

Komar, C. A. and Kovach, S. J., 1969, Directional Ultrasonic Pulses Orient Failure Planes in Sedimentary Rocks: W. Va. Acad. Sci., West Liberty, W. Va., (Abstract).

Komar, C. A. Overbey, W. K., Jr., and Watts, R. J., 1976, Prediction of Fracture Orientation from Oriented Cores and Aerial Photos, West Poison Spider Field, Casper, Wyoming: U.S. Energy Res. & Dev. Admin., March 1976.

McWilliams, J. R., 1966, The Role of Microstructure in the Physical Properties of Rock: ASTM STP 402, pp. 175-189.

Mellor, M. and Hawkes, I., 1971, Measurement of Tensile Strength by Diametral Compression of Discs and Annuli: Engineering Geol., v. 5, pp. 173-225.

Peng, S. S. and Ortiz, C., 1972, Crack Propagation and Fracture of Rocks Loaded in Compression: Proc. Int'l. Conf. Dynamic Crack Propagation, Lehigh Univ., July 1972, pp. 113-129.

Roberts, A. F., 1977, "Geotechnology": 1st ed., Pergamon Press, Oxford, NY.

Smith, M. B., Holman, G. B., Fast, C. R., and Covlin, R. J., 1978, The Azimuth of Deep, Penetrating Fractures in the Wattenberg Field: Jour. Pet. Tech., February 1978, pp. 185-193.

Thill, R. E. and Bur, T. R., 1969, An Automated Ultrasonic Pulse Measurement System: Geophysics, v. 34, no. 1, pp. 101-105.

Thill, R. E. and Peng, S. S., 1974, Statistical Comparison of the Pulse and Resonance Methods for Determining Elastic Moduli: U.S. Bureau of Mines RI 7831, p. 9.

APPENDICES

		Page No.
Appendix A	Results of Pretest Fracture Measurements	
Table A-1	Scribed Orientation Grooves in Velocity Samples	23
A-2	Orientation and Length of Fractures in Ultrasonic Velocity Specimens	24
A-3	Orientation and Length of Fractures in Point Load Specimens	25
A-4	Orientation and Length of Fractures in Directional Tensile Specimens	26
A-5	Frequency Distribution Pretest Fractures	28
Appendix B	Results of Directional Ultrasonic Velocity Measurements	
Table B-1	Directional Ultrasonic Wave Velocities	30
B-2	Orientation of Ultrasonic Velocity Minimums: Perrysburg and Java Formations	35
B-3	Orientation of Ultrasonic Velocity Minimums: West Falls Formation	36
B-4	Orientation of Ultrasonic Velocity Minimums: Sonyea Formation	41
B-5	Orientation of Ultrasonic Velocity Minimums: Genesee Formation	42
Figure B-1	Histogram of Average Velocity: Perrysburg Formation	43
B-2	Histogram of Average Velocity: Java Formation	44
B-3	Histogram of Average Velocity: West Falls Formation	45
B-4	Histogram of Average Velocity: Sonyea Formation	46
B-5	Histogram of Average Velocity: Genesee Formation	47
B-6	Histogram of Average Velocity: Well Composite	48
Appendix C	Results of Point Load Tests	
Table C-1	Frequency Distribution of Fractures Induced by Point Load	50
C-2	Point Load Index	55
Appendix D	Results of Directional Tensile Strength Tests	
Table D-1	Directional Tensile Strengths	61
Figure D-1	Histogram of DTS: Perrysburg Formation	65
D-2	Histogram of DTS: Java Formation	66
D-3	Histogram of DTS: West Falls Formation	67
D-4	Histogram of DTS: Sonyea Formation	68
D-5	Histogram of DTS: Genesee Formation	69
D-6	Histogram of DTS: Well Composite	70

APPENDIX A

Results of Pretest Fracture Measurements

TABLE A-1

New York #1

Scribed Orientation Grooves in Velocity Samples

Depth	Orientation of Scribed Grooves (Degrees from North)
455.2	80,300
466.9	200
503.3	230
513.4	290
1,333.8	20
1,399.4	260
1,541.7	80
1,682.2	110
1,695.2	270
1,806.8	160
1,921.6	250
2,178.2	270
2,194.8	160
2,792.2	100,250

TABLE A-2
New York #1

Orientation and Length of Pretest Fractures in
Ultrasonic Velocity Samples*

	Depth	0°	30°	60°	90°	120°	150°
PERRYSBURG FORMATION:							
Dunkirk Shale	455				1,1		
	485	2		1,2			
	495		1				
	505		1	1,1			
	515		1	3	1,1		
JAVA FORMATION:							
Pipe Creek	995				1		
WEST FALLS FORMATION:							
Rhinestreet Shale	1,375				2,5,2.5,3		
	1,400			2			
	1,465			3,2.5			
	1,475				1		2
	1,545				1		
	1,665			2			
	1,685				1		
	1,695				1		
	1,715			1,1.5,.8,.8			
	1,785					1.5	
	1,805	1					
	1,816				3		
	1,875				3.5		
	1,925			1,2			
	2,035			3.5			
	2,085				3.2		
	2,175				.8		
	2,195					3	
SONYEA FORMATION:							
Middlesex	2,615			1.2			
GENESEE FORMATION:							
Pen Yan Shale	2,795			1	1		
WELL COMPOSITE:							
	Total Inches	3	3	30.3	28.5	5.5	3
	Total Frequency	2	3	18	17	3	2

* Length values in inches

TABLE A-3
New York #1

Orientation and Length of Pretest Fractures in
Point Load Samples*

	Depth	0°	30°	60°	90°	120°	150°
JAVA FORMATION:							
Pipe Creek	1,005			.5			
WEST FALLS FORMATION:							
Rhinestreet Shale	1,355			1.5,1.5,1			
	1,485					1	
	1,545			1	.7,.7		
	1,565			1.1		.7	
	1,575			1.4,1.1,1.1			
	1,615			.9			
	1,635			1.9			
	1,655				1.2		
	1,665			1.4,.3,1.3		1.7	
	1,685				1.8		
	1,715				.2,.4	.1,.3	
	1,725				.3		
	1,755			1.9			
	1,775	.3	1.3	.4			
	1,785				.3,.3		
	1,795			1	1.2,.5		
	1,815			.3,.3	.4		
	1,845		1.8				
	1,865			.2			
	1,895			.6			
	1,905				1.3,.4		
	1,955			.8	.7,.7		
	1,995	1.7					
	2,095			1.2	1.6		
	2,115		.8,.8				
	2,125			1.2		.7	
	2,155			1,1,1,1			
	2,175			.8			
	2,185			.3			
	2,255		1.5		1.5		
	2,265				.4		
	2,305	1.4			.5,1.5		
SONYEA FORMATION:							
Middlesex Shale	2,505			1.4,1.7,1.3			
	2,525				.4	.4	
	2,585				1.5		.8
GENESEE FORMATION:							
West River Shale	2,645	1.5,.8	1,.4,1.2,.3,.3,.3				
	2,655						.3
	2,725			1.2,1			.6,.7
Genundewa Limestone	2,735					.7	
Pen Yan Shale	2,755			.8			
	2,775			1.2			
	2,795				.7	.4	
Lodi Limestone	2,875				.3		
Geneseo Shale	2,895			1.9			
	2,925		.4				1.6,.7
WELL COMPOSITE:							
	Total Inches	5.7	10.1	39.5	19.5	6	4.7
	Total Frequency	5	12	38	25	9	6

* Length value in inches

TABLE A-4
New York #1

Orientation and Length of Pretest Fractures in
Directional Tensile Strength Samples*

	Depth	0°	30°	60°	90°	120°	150°
WEST FALLS FORMATION:							
Rhinestreet Shale	1,355		.6				
	1,395			1.2			
	1,405		.5	1.2			
	1,445			.4,1.5			
	1,455			1.6			
	1,475			1.3			
	1,525			1.1			
	1,565		.5	.1,.4,1,.2			
	1,575		.3,.2	.2			
	1,585		1.1,.8,.5	.6,1.2		.6	
	1,595		.6				
	1,605			1.5			.2
	1,615					.4	.3,.4,.4
	1,625			.4,1.3,.4, 2,1.6,1.2	2.1		
	1,635		.6	1.1,.3,.3	1	.3	
	1,655	.5				.5,.3	
	1,675			.3,1.4			
	1,685			.5	1.2		
	1,695			.3,.6,.5,.5		.6,.5,.4,.4,.8	
	1,705					.7	
	1,715			1.8	.2		
	1,725				.6		
	1,745					.3	
	1,755			.7			
	1,775			1.4	.3,.3,.3,.7		
	1,835			.4	.2		
	1,915				.4		
	1,925			1.8	.4,.3,.9,.6,.3, .6,.3,.8		
	2,025			1,1,.5,1.9,.8			
	2,085		.7	.7,1.1,.8			
	2,095			1	1.6,1.7		
	2,105			.9,1			
	2,115	.5,.8	.6	2,2			
	2,135	.2					.3
	2,155			1.3,.5			
	2,175			1			
	2,205	1.4	1.4	.8,.4	.5		
	2,215			.2,.3		1.4	
	2,245					.7	
	2,335			.5,1.2	.5		1.2
	2,345	.3				.3	
SONYEA FORMATION:							
Cashaqua Shale	2,355			.3,.5	1,1.5,1.1	2,1.8	.5
Middlesex Shale	2,495	.4,.6	.2		.6,.4,2		
	2,505		.2		1		
	2,525	1.3		1	1,.3		
	2,545		.3,.3		1.3		
	2,565		.2	.5	.8		
	2,575	.3					
	2,585			.9		.9	
	2,605				1	1	
	2,615			.3,.6,.4,.3,.5			

* Length value in inches

TABLE A-4
(continued)

	Depth	0°	30°	60°	90°	120°	150°
GENESEE FORMATION:							
West River Shale	2,645	1.8	1.8				
Pen Yan Shale	2,745						.8
	2,775		.6				
	2,805		.5			.4	
	2,825					1.0	
	2,865		.8,1.1	.3,.5,.4			1.3,.6
Geneseo Shale	2,925						1.5,1.5,1.7, .7,1,.4,.7,1.6, 1.3,.7,1.5,.4,.5, .6,1.8
WELL COMPOSITE:							
	Total Inches	8.1	14.4	59.7	27.8	15.3	21.9
	Total Frequency	11	23	71	35	21	25

* Length value in inches

TABLE A-5
New York #1

Frequency Distribution of Pretest Fractures

	0°	30°	60°	90°	120°	150°
PERRYSBURG FORMATION:						
Sonic Velocity	1	3	5	4	1	1
Pt. Load						
DTS						
Total	1	3	5	4	1	1
%	7	20	33	27	7	7
JAVA FORMATION:						
Sonic Velocity				1		
Pt. Load			1			
DTS						
Total			1	1		
%			50	50		
WEST FALLS FORMATION:						
Sonic Velocity	1	0	11	11	2	1
Pt. Load	3	5	29	21	6	0
DTS	6	13	58	23	15	6
Total	10	17	98	55	23	7
%	5	8	47	26	11	3
SONYEA FORMATION:						
Sonic Velocity			1			
Pt. Load			3	2	1	1
DTS	4	5	10	12	4	1
Total	4	5	14	14	5	2
%	9	11	32	32	11	5
GENESEE FORMATION:						
Sonic Velocity			1	1		
Pt. Load	2	7	5	2	2	5
DTS	1	5	3	0	2	18
Total	3	12	9	3	4	23
%	6	22	17	6	7	42
WELL COMPOSITE:						
Total Frequency	18	38	127	77	33	33
%	5	12	39	24	10	10

APPENDIX B

Results of Directional Ultrasonic Velocity Measurements

Table B-1

WELL # 1 IN NEW YORK

DIRECTIONAL P WAVE VELOCITIES

AVERAGE VELOCITIES IN KM/SEC & ORIENTATION IN DEGREES FROM NORTH

	DEPTH IN FEET	0 DEG	30 DEG	60 DEG	90 DEG	120 DEG	150 DEG
PERRYSBURG FM	443.8	4.807	4.846	4.871	4.813	4.852	4.818
- Lower Dunkirk	455.2	4.98	5.031	5.053	5.011	4.967	4.923
Shale	466.9	4.889	5.012	5.053	4.896	4.709	4.735
	475.9	4.828	4.874	4.917	4.908	4.874	4.843
	482.5	4.745	4.794	4.805	4.793	4.738	4.731
	497.8	4.78	4.824	4.812	4.893	4.851	4.785
	503.3	4.764	4.804	4.818	4.853	4.827	4.791
	513.4	4.746	4.809	4.838	4.801	4.693	4.744
JAVA FORMATION	526.7	4.877	4.974	5.049	5.031	4.918	4.836
- Hanover Shale	535.3	3.887	4.076	4.147	4.048	3.875	3.768
	542.1	4.925	4.958	5.028	5.028	4.972	4.924
	968.4	5.166	5.218	5.247	5.223	5.185	5.138
	973.6	4.971	5.078	5.132	5.067	4.958	4.881
	982.6	4.891	4.992	5.139	5.103	4.966	4.887
- Pipe Creek Sh	993.3	5.141	5.11	5.181	5.268	5.307	5.19
	1000.9	4.839	4.91	4.984	4.937	4.875	4.819
	1013.8	4.907	4.943	5.049	5.042	4.991	4.917
WEST FALLS FM	1333.8	5.169	5.25	5.284	5.274	5.158	5.126
- Rhinestreet Sh	1349.7	4.748	4.939	5.103	5.017	4.813	4.697
	1355	5.086	5.205	5.252	5.259	5.155	5.116
	1368.4	5.188	5.363	5.455	5.429	5.316	5.154
	1378	4.114	4.422	4.687	4.604	4.258	4.257
	1382.1	4.967	5.016	5.11	5.114	5.014	4.963
	1399.4	5.149	5.269	5.315	5.228	5.169	5.137
	1409.9	5.296	5.348	5.467	5.464	5.364	5.283
	1415.8	5.256	5.423	5.574	5.528	5.385	5.242

1422.9	5.034	5.134	5.183	5.157	5.078	4.999
1430.8	5.034	5.116	5.187	5.169	5.037	5.012
1440.7	4.049	4.459	4.743	4.623	4.21	3.953
1455.5	5.099	5.172	5.265	5.198	5.166	5.119
1461.2	5.326	5.391	5.437	5.465	5.396	5.32
1473.9	5.103	5.174	5.232	5.195	5.108	5.109
1483.4	5.457	5.422	5.22	5.149	5.187	5.348
1493.4	5.075	5.253	5.423	5.35	5.209	5.054
1506.7	5.231	5.373	5.5	5.414	5.189	5.119
1514.7	5.054	5.159	5.228	5.191	5.089	5.02
1522.2	4.262	4.676	4.965	4.909	4.337	4.158
1536.4	4.922	4.921	5.095	5.126	5.045	4.913
1541.7	4.934	5.042	5.142	5.123	5.044	4.953
1550.2	4.959	5.027	5.08	5.065	4.999	4.943
1564	4.859	5.144	5.351	5.281	5.036	4.852
1573.9	4.589	4.965	5.274	5.081	4.722	4.496
1584	5.137	5.304	5.424	5.399	5.246	5.035
1591.7	5.19	5.271	5.333	5.332	5.247	5.172
1601.2	5.202	5.373	5.484	5.365	5.184	5.1
1611.3	5.282	5.345	5.366	5.338	5.291	5.261
1622.1	5.052	5.124	5.158	5.139	5.069	5.025
1634.7	4.99	5.062	5.166	5.15	5.078	5.003
1647	5.156	5.271	5.28	5.288	5.198	5.135
1653.4	5.144	5.243	5.328	5.327	5.241	5.139
1662.7	5.32	5.387	5.451	5.448	5.372	5.319
1673.8	4.944	5.027	5.107	5.084	5.042	5.236
1682.2	4.926	4.898	4.978	5.051	5.107	5.03
1695.2	4.848	4.858	4.888	4.974	5.046	5.04
1702.3	5.094	5.29	5.405	5.362	5.27	5.069
1715.1	5.397	5.498	5.565	5.574	5.499	5.401
1726.2	5.225	5.3	5.36	5.348	5.268	5.202
1730.8	5.287	5.446	5.584	5.582	5.406	5.316
1743.1	5.212	5.329	5.458	5.458	5.303	5.194
1758.4	5.375	5.455	5.557	5.567	5.505	5.391
1762.4	5.256	5.36	5.461	5.445	5.339	5.242

1773.4	4.838	4.897	4.967	5.001	4.942	4.851
1781.4	5.119	5.209	5.324	5.321	5.262	5.17
1793	5.107	5.169	5.303	5.339	5.249	5.15
1806.8	5.113	5.296	5.4	5.412	5.276	5.15
1816.4	5.099	5.154	5.231	5.283	5.193	5.103
1823.1	5.285	5.293	5.25	5.224	5.23	5.275
1833	4.943	5.027	5.116	5.106	5.003	4.937
1845.9	5.141	5.21	5.364	5.417	5.304	5.135
1858	5.13	5.229	5.313	5.319	5.25	5.167
1864.6	5.132	5.215	5.315	5.296	5.217	5.135
1878.9	4.998	5.24	5.49	5.412	5.139	4.983
1882.7	4.978	5.093	5.451	5.446	5.229	4.993
1891.2	4.672	4.89	5.208	5.295	5.077	4.811
1905	5.21	5.345	5.417	5.36	5.282	5.215
1921.6	5.323	5.462	5.542	5.512	5.43	5.313
1931	4.789	5.196	5.446	5.382	4.957	4.742
1946	5.119	5.112	5.208	5.216	5.271	5.354
1951.5	5.629	5.673	5.664	5.731	5.715	5.671
1966.3	5.106	5.198	5.286	5.285	5.194	5.11
1975.8	5.172	5.221	5.265	5.278	5.23	5.191
1980.5	5.043	5.074	5.101	5.104	5.074	5.046
2039.6	5.205	5.274	5.327	5.32	5.211	5.149
2042.8	5.341	5.409	5.529	5.566	5.497	5.369
2052.1	5.107	5.217	5.457	5.303	4.941	4.747
2063.4	5.101	5.172	5.198	5.182	5.104	5.074
2071.9	5.083	5.217	5.322	5.27	5.159	5.067
2077.4	5.245	5.322	5.413	5.415	5.339	5.248
2080.9	5.301	5.426	5.571	5.572	5.415	5.318
2092	5.307	5.392	5.597	5.553	5.338	5.269
2102.5	5.319	5.395	5.469	5.447	5.358	5.286
2118.9	4.688	4.761	4.828	4.804	4.736	4.682
2122.9	5.215	5.352	5.307	5.239	5.155	5.08
2137.5	5.175	5.317	5.396	5.377	5.235	5.161
2147.3	4.778	4.838	4.868	4.876	4.827	4.769
2151.6	5.112	5.206	5.331	5.428	5.319	5.162

	2164.7	4.937	5.359	5.392	5.116	4.942	4.864
	2178.2	4.986	5.016	5.111	5.094	4.992	4.908
	2194.8	5.084	5.253	5.284	5.229	5.141	5.118
	2203.3	5.085	5.154	5.251	5.185	5.084	4.998
	2211.3	5.109	5.209	5.287	5.244	5.139	5.057
	2226.9	5.198	5.267	5.348	5.351	5.289	5.181
	2233	5.064	5.275	5.311	5.244	5.122	5.083
	2241.6	5.375	5.501	5.547	5.454	5.34	5.291
	2256.8	5.107	5.183	5.285	5.249	5.177	5.105
	2262.8	5.445	5.515	5.533	5.596	5.55	5.487
	2276.2	5.025	5.122	5.209	5.205	5.081	5.027
	2284.5	5.088	5.164	5.311	5.352	5.177	5.064
	2297.2	5.227	5.306	5.385	5.403	5.342	5.243
	2306.8	5.072	5.16	5.283	5.168	5.093	5.037
	2318.2	5.032	5.128	5.267	5.173	5.088	5.021
	2322	5.017	5.11	5.18	5.161	5.071	5.012
	2330.7	4.612	4.701	4.776	4.761	4.676	4.613
	2340.5	5.134	5.186	5.244	5.241	5.183	5.126
SONYEA FORMATION	2353	5.17	5.269	5.327	5.298	5.229	5.177
- Cashaqua Sh	2489.8	5.001	5.171	5.254	5.196	5.127	5.065
- Middlesex Sh	2495.5	5.107	4.904	4.973	4.93	4.883	4.807
	2501.3	4.949	5.039	5.11	5.107	5.047	4.965
	2512.4	5.048	5.144	5.211	5.191	5.104	5.018
	2521.3	5.045	5.145	5.218	5.2	5.121	5.061
	2531.6	5.055	5.096	5.197	5.192	5.138	5.066
	2540.5	4.867	4.91	4.993	4.973	4.926	4.864
	2550.6	5.132	5.236	5.275	5.207	5.102	5.08
	2561.2	4.997	5.083	5.084	5.033	4.943	4.907
	2570.7	4.895	4.978	4.981	4.936	4.874	4.857
	2581	4.983	5.05	5.088	4.964	4.936	4.909
	2592.1	5.023	5.096	5.116	5.023	4.931	4.936
	2609	4.995	5.059	5.1	5.087	5.055	4.975
	2614.1	4.758	4.824	4.857	4.856	4.794	4.739
	2622.1	4.749	4.818	4.861	4.826	4.752	4.693
GENESEE FM	2630.9	5.009	5.07	5.114	5.102	5.051	4.996

- West River Sh	2541.6	5.089	5.155	5.177	5.155	5.099	5.063
	2652.6	5.08	5.141	5.165	5.127	5.071	5.041
	2660.8	4.957	5.022	5.066	5.054	5.004	4.939
	2725.1	5.072	5.131	5.177	5.155	5.077	5.063
- Genundewa LS	2733	5.735	5.879	5.739	5.583	5.541	5.584
- Penn Yan Shale	2745.6	5.038	5.089	5.111	5.084	5.037	5.008
	2750.7	5.138	5.409	5.356	5.212	5.098	5.049
	2765.9	5.09	5.136	5.166	5.135	5.08	5.055
	2772.9	5.055	5.11	5.126	5.091	5.045	5.037
	2786.2	4.944	4.976	5.04	4.989	4.942	4.893
	2792.2	4.945	5.004	5.046	5.041	4.986	4.951
	2802.4	4.903	4.99	5.055	5.048	4.97	4.899
	2811.7	4.932	4.999	5.075	5.055	4.99	4.916
	2821.8	4.927	5.012	5.064	5.056	4.968	4.871
	2840.2	4.894	4.929	4.991	5.001	4.963	4.908
	2861.4	4.923	4.949	5.015	5.064	5.054	4.979
- Lodi Limestone	2870.5	5.191	5.148	5.16	5.186	5.14	5.1
- Geneseo Shale	2880.5	4.906	4.955	4.992	4.987	4.931	4.885
	AVERAGE VELOCITY	5.035	5.133	5.211	5.187	5.09	5.019

Table B-2

ORIENTATION OF ULTRASONIC VELOCITY MINIMUM
WELL # 1 IN NEW YORK

PERRYSBURG AND JAVA FORMATION

	DEPTH IN FEET	DEGREES FROM NORTH 0	30	60	90	120	150
PERRYSBURG FORMATION	443.8	MIN					
	455.2						MIN
	466.9					MIN	
	475.9	MIN					
	482.5						MIN
	497.8	MIN					
	503.3	MIN					
	513.4					MIN	
JAVA FORMATION	526.7						MIN
	535.3						MIN
	542.1						MIN
	968.4						MIN
	973.6						MIN
	982.6						MIN
	993.3		MIN				
	1000.9						MIN
	1013.8	MIN					

FREQUENCY VS ORIENTATION

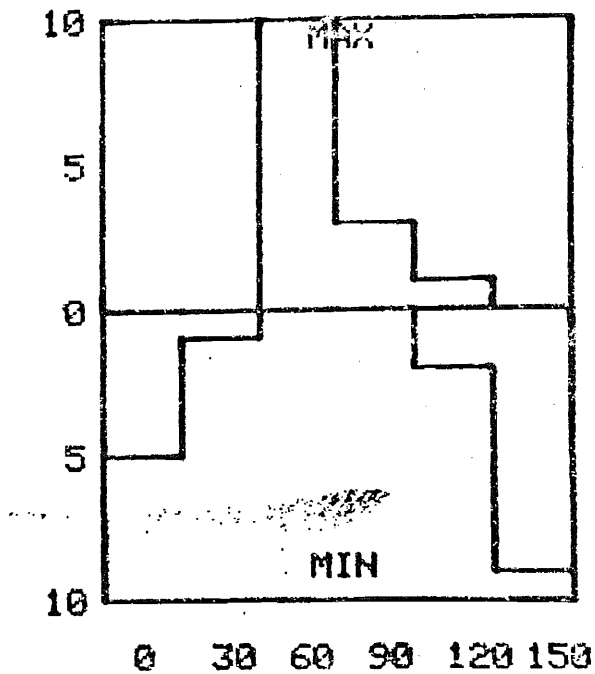


Table B-3

ORIENTATION OF ULTRASONIC VELOCITY MINIMUM
WELL # 1 IN NEW YORK WEST FALLS FORMATION

DEPTH IN FEET	DEGREES FROM NORTH 0	30	60	90	120	150
1333.8						MIN
1349.7						MIN
1355	MIN					
1368.4						MIN
1379	MIN					
1382.1						MIN
1399.4						MIN
1409.9						MIN
1415.8						MIN
1422.9						MIN
1430.8						MIN
1440.7						MIN
1455.5	MIN					
1461.2						MIN
1473.9	MIN					
1483.4				MIN		
1493.4						MIN
1506.7						MIN
1514.7						MIN
1522.2						MIN
1536.4						MIN
1541.7	MIN					
1550.2						MIN
1564						MIN
1573.9						MIN
1584						MIN
1591.7						MIN

FREQUENCY VS ORIENTATION

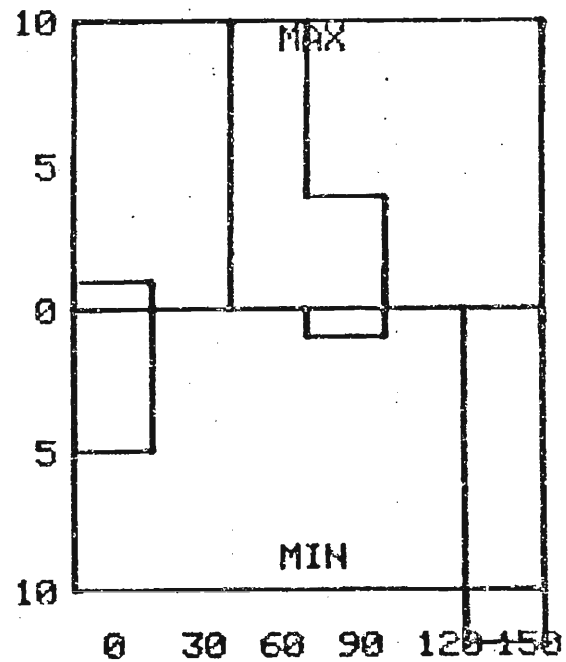


Table B-3 cont'd.

ORIENTATION OF ULTRASONIC VELOCITY MINIMUM
WELL # 1 IN NEW YORK

WEST FALLS FORMATION CONT'D

DEPTH IN FEET	DEGREES FROM NORTH 0	30	60	90	120	150
1601.2						MIN
1611.3						MIN
1622.1						MIN
1634.7	MIN					
1647						MIN
1653.4						MIN
1662.7						MIN
1673.8	MIN					
1682.2		MIN				
1695.2	MIN					
1702.3						MIN
1715.1	MIN					
1726.2						MIN
1730.8	MIN					
1743.1						MIN
1758.4	MIN					
1762.4						MIN
1773.4	MIN					
1781.4	MIN					
1793	MIN					

FREQUENCY VS ORIENTATION

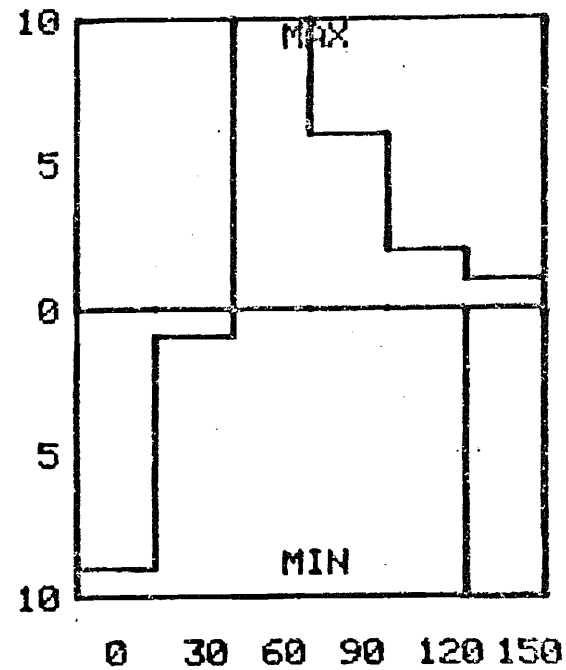


Table B-3 cont'd.

ORIENTATION OF ULTRASONIC VELOCITY MINIMUM
WELL # 1 IN NEW YORK

WEST FALLS FORMATION CONT'D

DEPTH IN FEET	DEGREES FROM NORTH 0	30	60	90	120	150
1806.8	MIN					
1816.4	MIN					
1823.1				MIN		
1833						MIN
1845.9						MIN
1858	MIN					
1864.6	MIN					
1878.9						MIN
1882.7	MIN					
1891.2	MIN					
1905	MIN					
1921.6						MIN
1931						MIN
1946		MIN				
1951.5	MIN					
1966.3	MIN					
1975.8	MIN					
1980.5	MIN					

FREQUENCY VS ORIENTATION

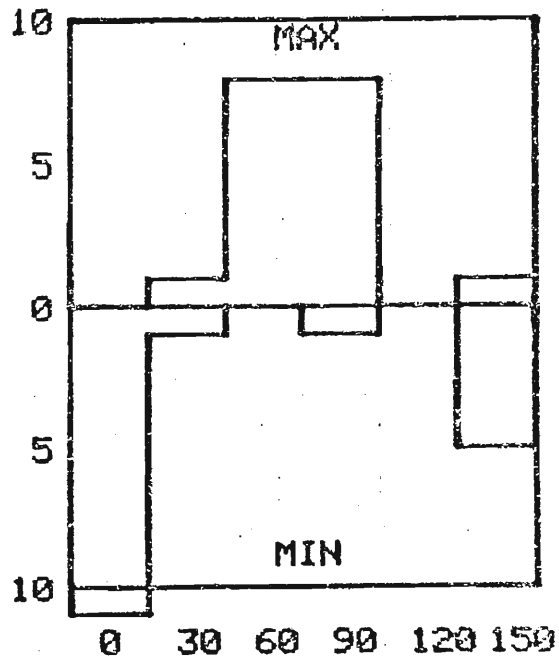


Table B-3 cont'd.

ORIENTATION OF ULTRASONIC VELOCITY MINIMUM
WELL # 1 IN NEW YORK

WEST FALLS FORMATION CONT'D

DEPTH IN FEET	0	30	60	90	120	150
2039.6						MIN
2042.8	MIN					
2052.1						MIN
2063.4						MIN
2071.9						MIN
2073.4	MIN					
2080.9	MIN					
2092						MIN
2102.5						MIN
2118.9						MIN
2122.9						MIN
2137.5						MIN
2147.3						MIN
2151.6	MIN					
2164.7						MIN
2178.2	MIN					
2194.8	MIN					

FREQUENCY VS ORIENTATION

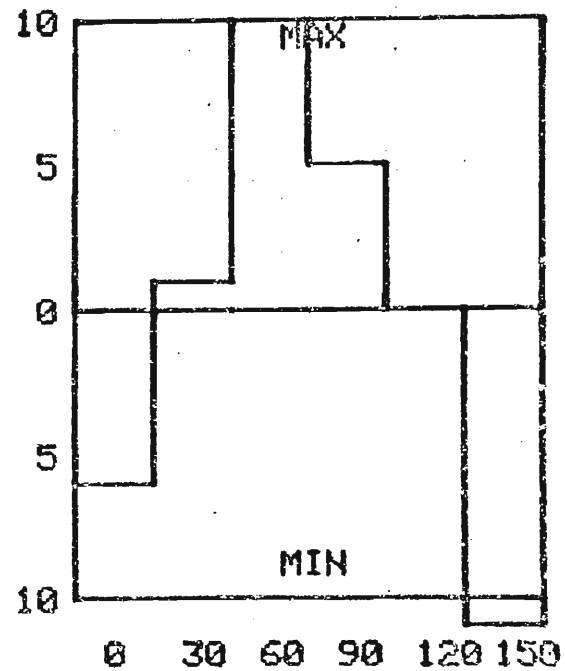


Table B-3 cont'd.

ORIENTATION OF ULTRASONIC VELOCITY MINIMUM
WELL # 1 IN NEW YORK

WEST FALLS FORMATION CONT'D

DEPTH IN FEET	DEGREES FROM NORTH 0	30	60	90	120	150
2203.3						MIN
2211.3						MIN
2226.9						MIN
2233						MIN
2241.6						MIN
2256.8						MIN
2262.8	MIN					
2276.2	MIN					
2284.5						MIN
2297.2	MIN					
2306.8						MIN
2318.2						MIN
2322						MIN
2330.7	MIN					
2340.5						MIN

FREQUENCY VS ORIENTATION

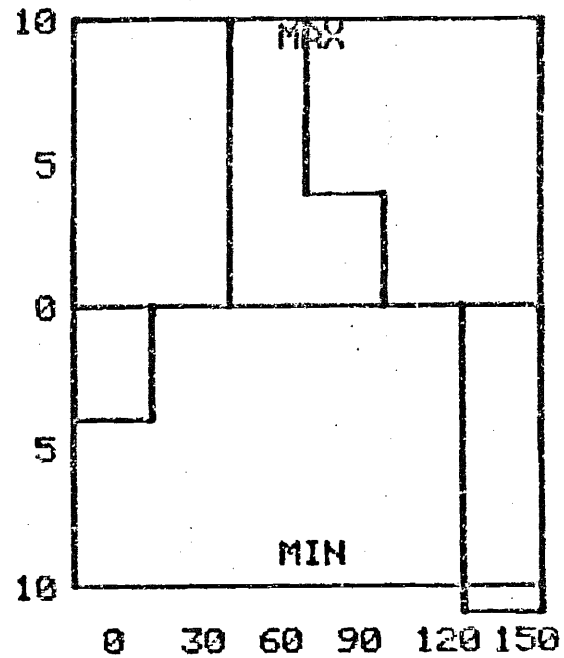


Table B-4

ORIENTATION OF ULTRASONIC VELOCITY MINIMUM
WELL # 1 IN NEW YORK SONYEA FORMATION

DEPTH IN FEET	DEGREES FROM NORTH 0	30	60	90	120	150
2353	MIN					
2489.8						MIN
2495.5						MIN
2501.3	MIN					
2512.4						MIN
2521.3	MIN					
2531.6	MIN					
2540.5						MIN
2550.6						MIN
2561.2						MIN
2570.7						MIN
2581						MIN
2592.1					MIN	
2609						MIN
2614.1						MIN
2622.1						MIN

FREQUENCY VS ORIENTATION

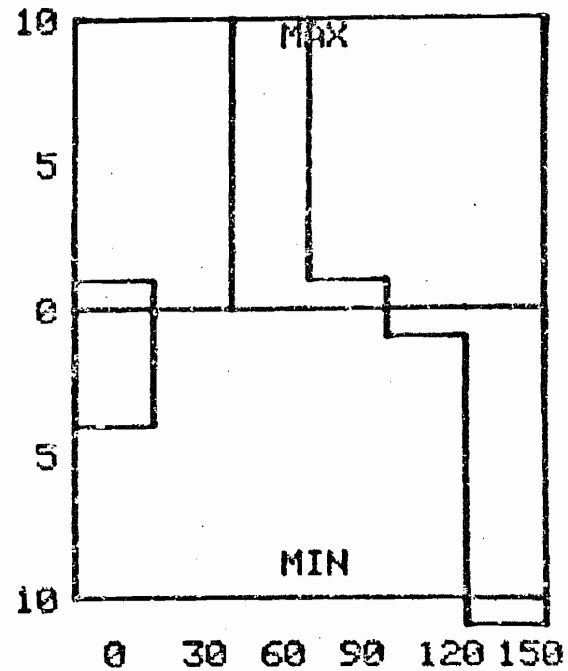


Table B-5

ORIENTATION OF ULTRASONIC VELOCITY MINIMUM
WELL # 1 IN NEW YORK GENESEE FORMATION

DEPTH IN FEET	DEGREES FROM NORTH 0	30	60	90	120	150
2630.9						MIN
2641.6						MIN
2652.6						MIN
2660.8						MIN
2725.1						MIN
2733					MIN	
2745.6						MIN
2750.7						MIN
2765.9						MIN
2772.9						MIN
2786.2						MIN
2792.2	MIN					
2802.4						MIN
2811.7						MIN
2821.8						MIN
2840.2	MIN					
2861.4	MIN					
2870.5						MIN
2880.5						MIN

FREQUENCY VS ORIENTATION

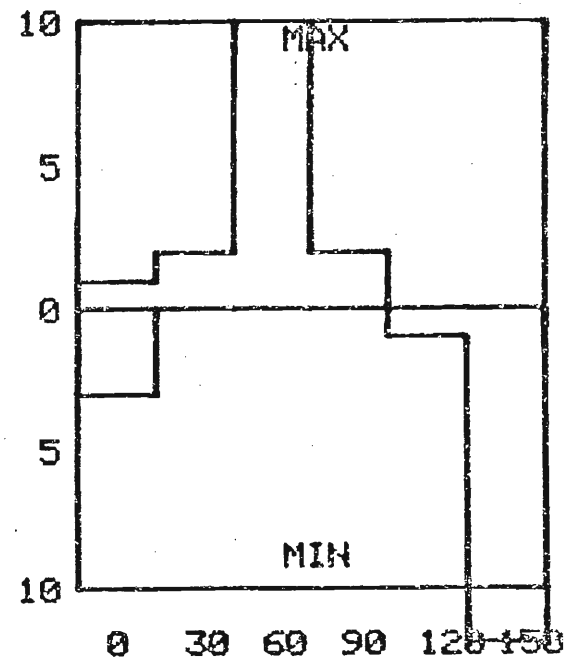


Figure B-1

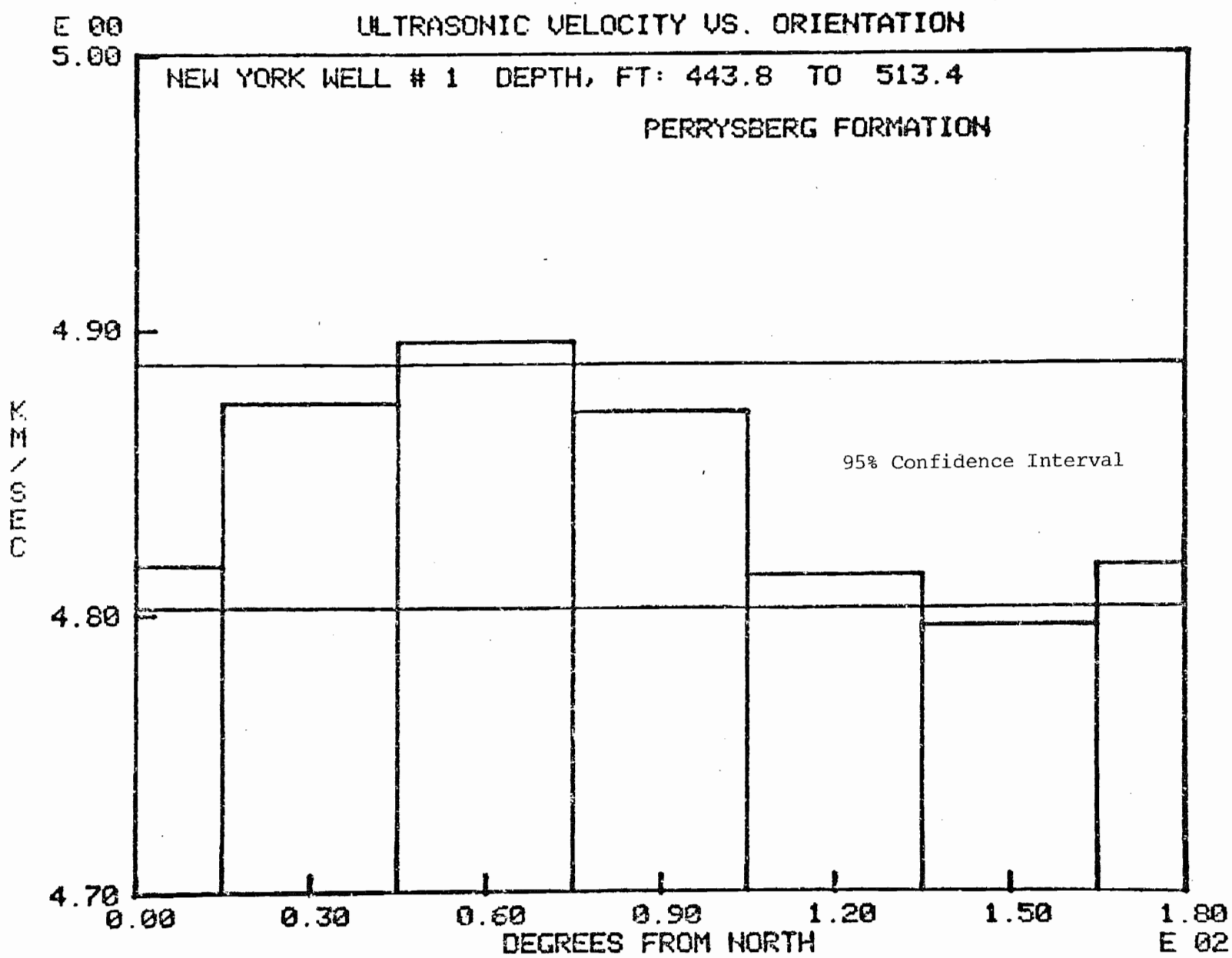

ULTRASONIC VELOCITY VS. ORIENTATION
NEW YORK WELL # 1 DEPTH, FT: 443.8 TO 513.4
PERRYSBERG FORMATION
95% Confidence Interval
E 00
5.00
4.90
4.80
4.70
KM/SEC
0.00
0.30
0.60
0.90
1.20
1.50
1.80
E 02
DEGREES FROM NORTH

Figure B-2

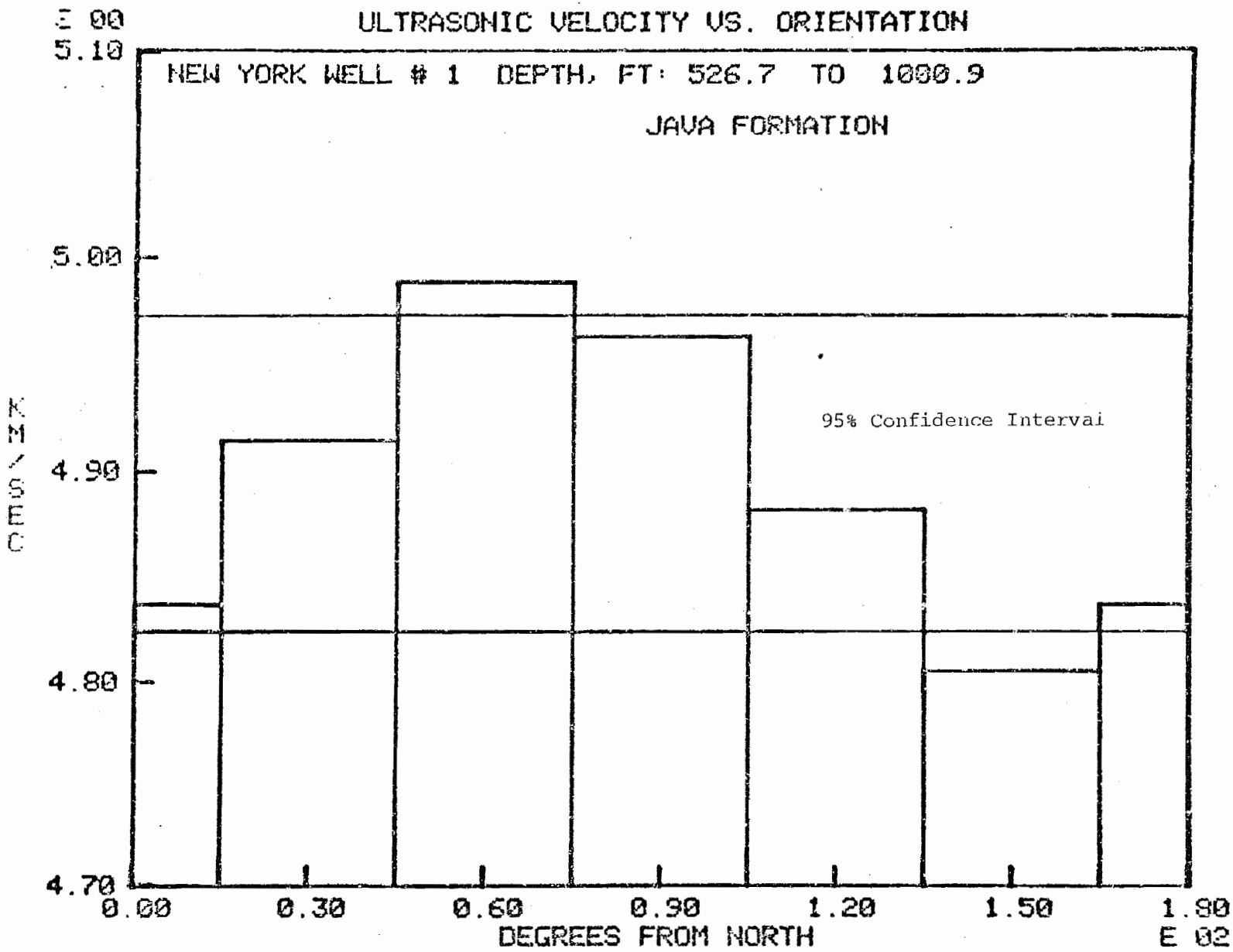

ULTRASONIC VELOCITY VS. ORIENTATION
NEW YORK WELL # 1 DEPTH, FT: 526.7 TO 1000.9
JAVA FORMATION
95% Confidence Interval
E 00
5.10
5.00
4.90
4.80
4.70
KM/SEC
0.00
0.30
0.60
0.90
1.20
1.50
1.80
E 02
DEGREES FROM NORTH

Figure B-3

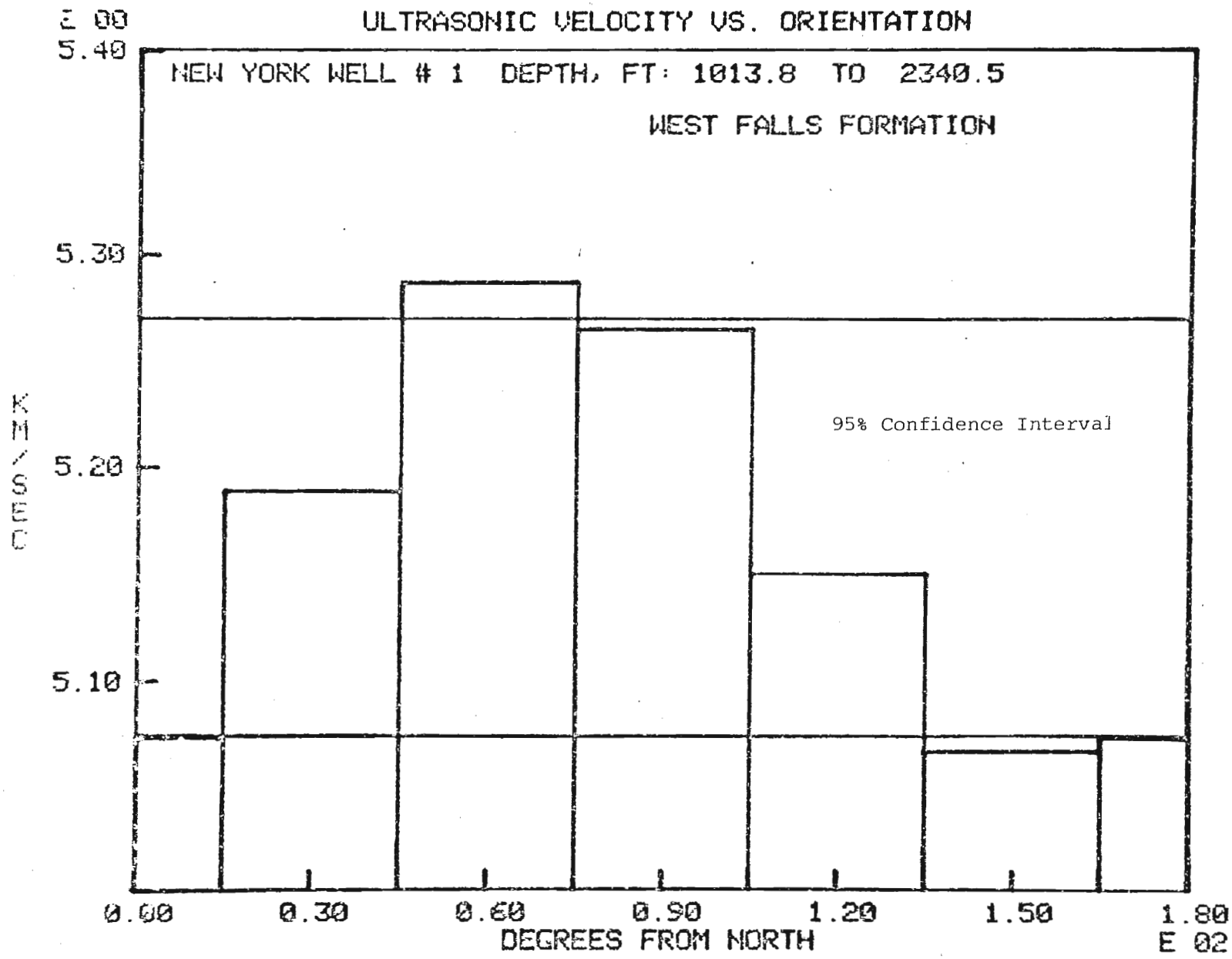

ULTRASONIC VELOCITY VS. ORIENTATION
NEW YORK WELL # 1 DEPTH, FT: 1013.8 TO 2340.5
WEST FALLS FORMATION
95% Confidence Interval
E 00
5.40
5.30
5.20
5.10
KM/SEC
0.00
0.30
0.60
0.90
1.20
1.50
1.80
E 02
DEGREES FROM NORTH

Figure B-4

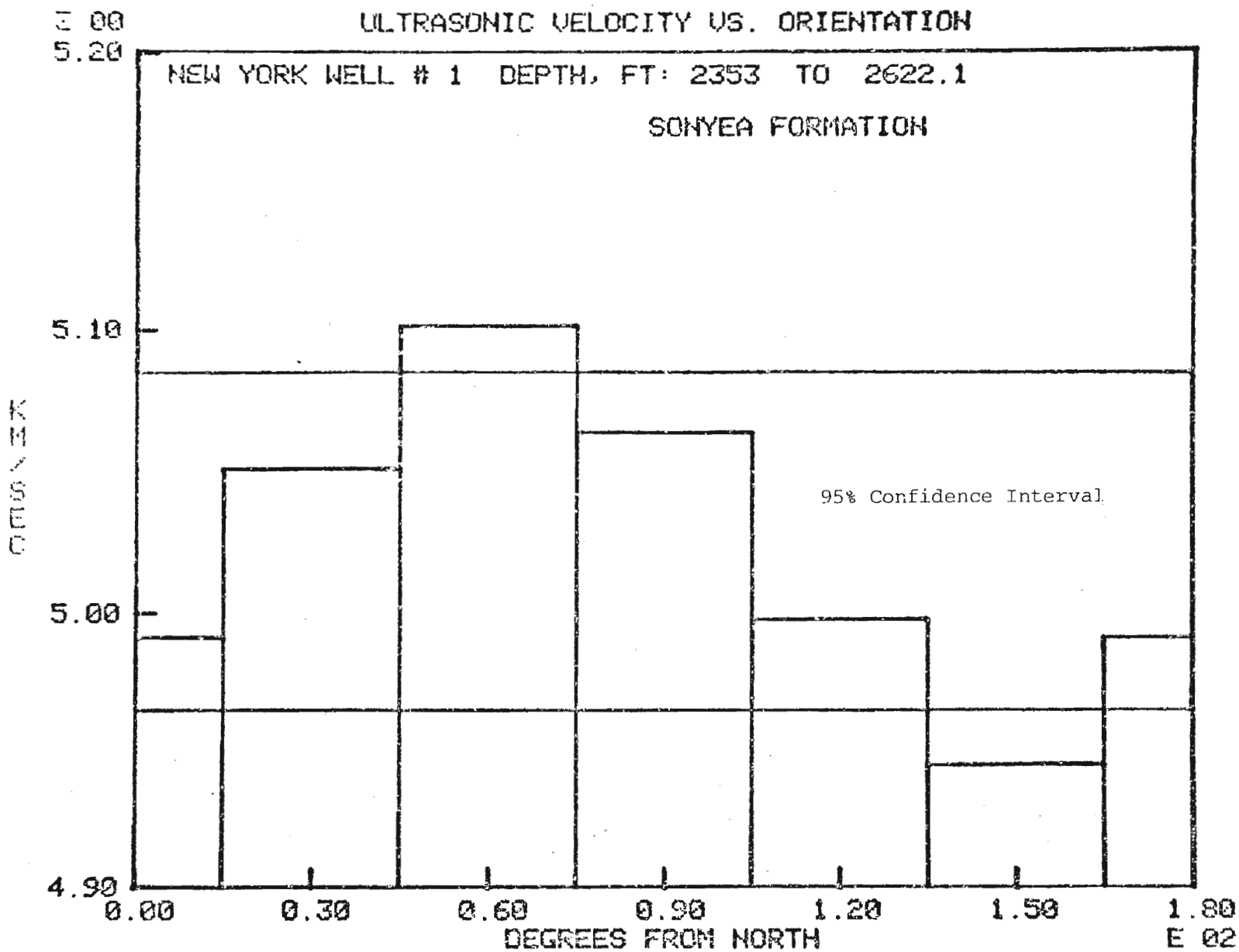

ULTRASONIC VELOCITY VS. ORIENTATION
NEW YORK WELL # 1 DEPTH, FT: 2353 TO 2622.1
SONYEA FORMATION
95% Confidence Interval
E 00
5.20
5.10
5.00
4.90
KM/SEC
0.00
0.30
0.60
0.90
1.20
1.50
1.80
E 02
DEGREES FROM NORTH

Figure B-5

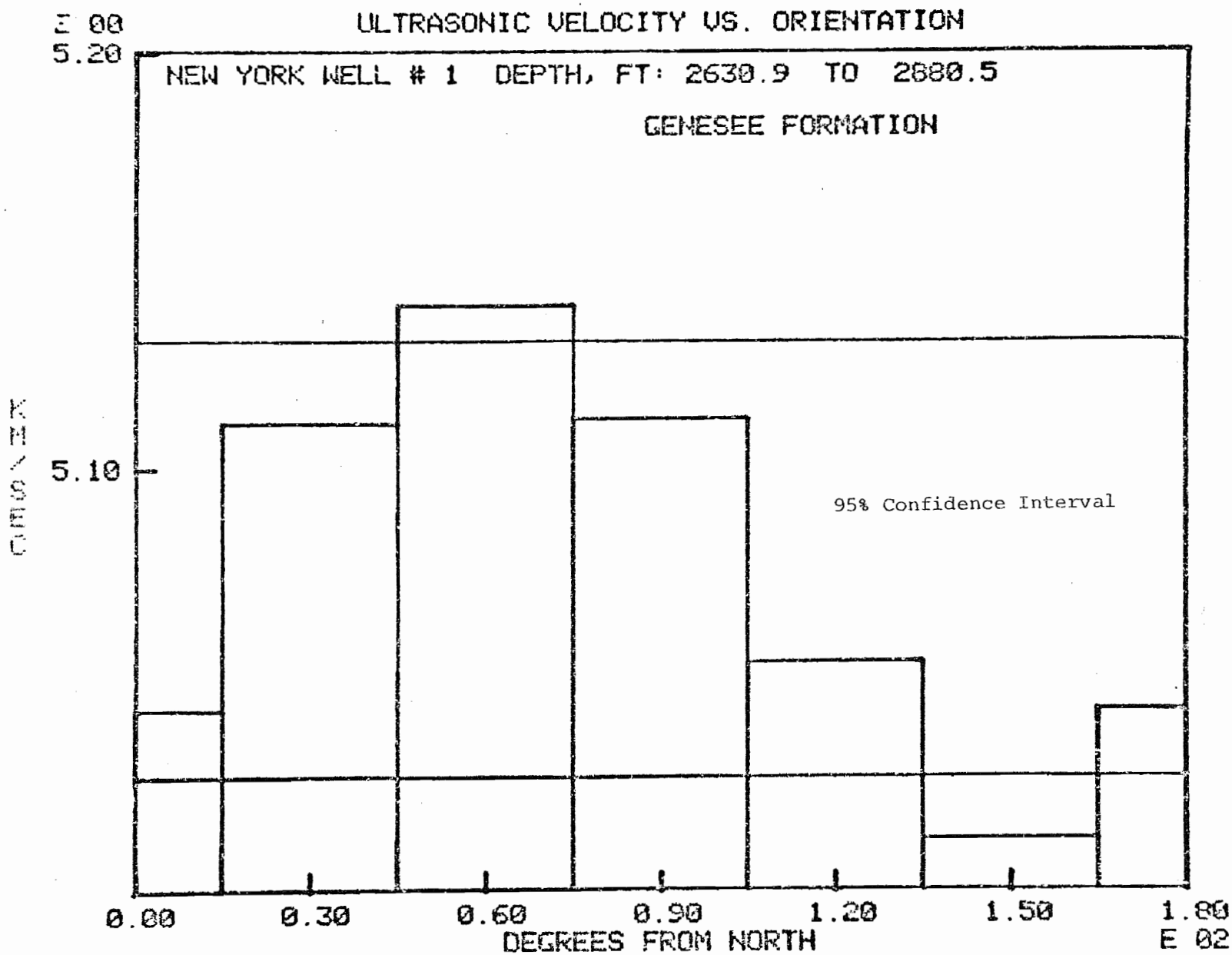
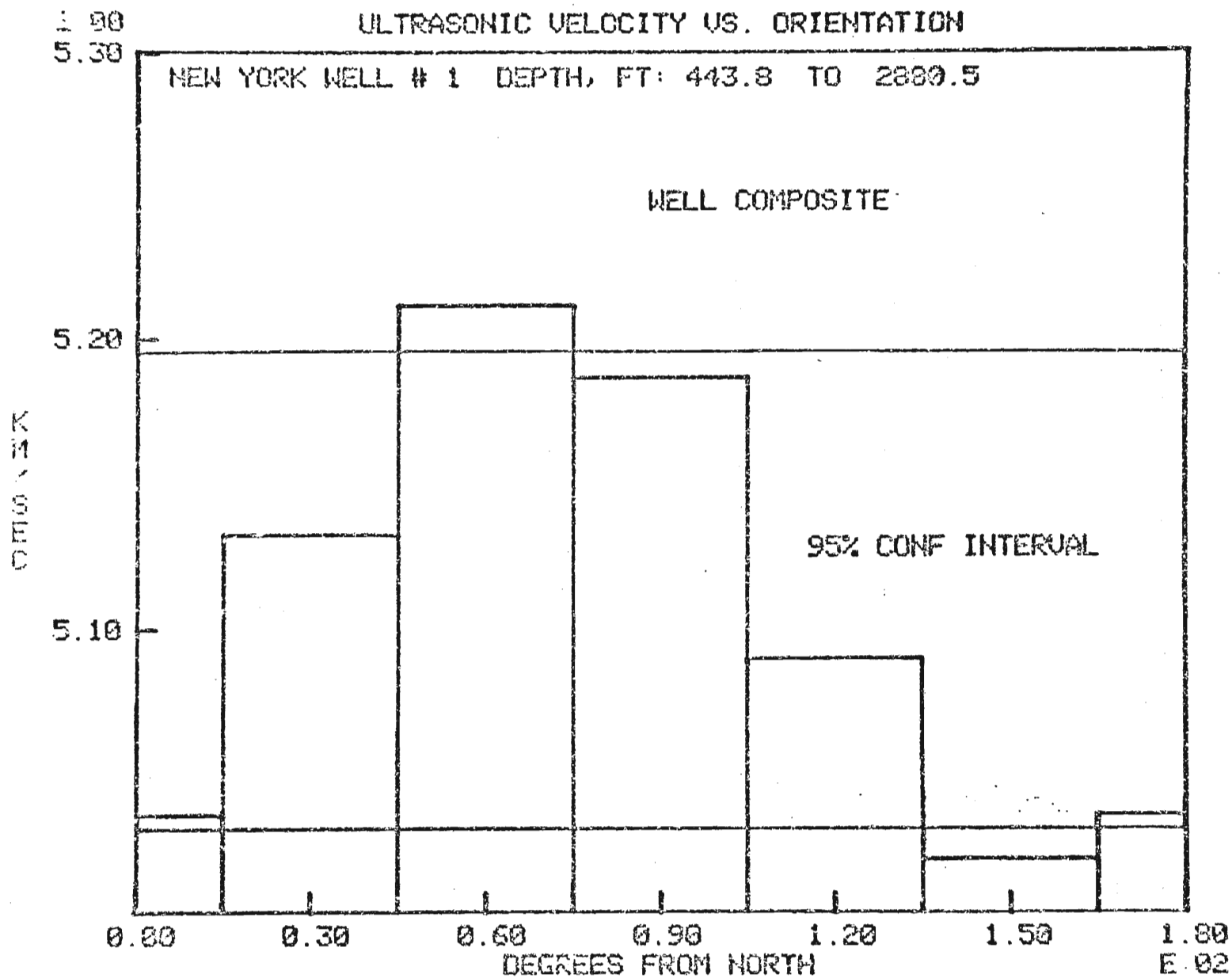

ULTRASONIC VELOCITY VS. ORIENTATION
NEW YORK WELL # 1 DEPTH, FT: 2630.9 TO 2680.5
GENESEE FORMATION
95% Confidence Interval
E 00
5.20
5.10
0.00
0.30
0.60
0.90
1.20
1.50
1.80
E 02
DEGREES FROM NORTH

Figure B-6


ULTRASONIC VELOCITY VS. ORIENTATION
NEW YORK WELL # 1 DEPTH, FT: 443.8 TO 2880.5
WELL COMPOSITE
95% CONF INTERVAL
1.00
5.30
5.20
5.10
KM/SEC
0.00
0.30
0.60
0.90
1.20
1.50
1.80
E 02
DEGREES FROM NORTH

APPENDIX C

Results of Point Load Tests

Table C-1

WELL # 1 IN NEW YORK

FREQUENCY OF FRACTURES INDUCED BY POINT LOAD
ORIENTATION IS IN DEGREES FROM NORTH; DEPTH IS MIDPT OF 10 FOOT INTERVAL

	DEPTH FEET	FREQUENCY 0 DEG	30 DEG	60 DEG	90 DEG	120 DEG	150 DEG	# OF SAMPLES
PERRYSBURG FM	445	0	0	3	1	0	0	4
-Lower Dunkirk	455	0	0	5	0	0	0	5
Shale	465	1	0	2	3	0	0	6
	475	0	3	4	1	0	0	8
	485	0	0	6	1	0	0	7
	495	0	0	3	1	0	0	4
	505	0	1	3	1	1	0	6
JAVA FORMATION	515	0	1	5	2	0	0	8
-Hanover Shale	525	1	0	2	3	0	0	6
	535	1	3	2	1	0	0	7
	545	0	2	8	0	0	0	10
	955	0	0	5	0	0	0	5
	975	2	2	1	1	0	0	6
	985	0	1	2	1	0	0	4
-Pipe Creek	995	0	0	2	3	0	0	5
Shale	1005	0	0	4	2	0	0	6
	1015	0	0	6	1	0	0	7
WEST FALLS FM	1325	0	0	0	2	0	0	2
-Angola Shale	1335	0	0	1	3	0	0	4
-Rhinestreet	1345	0	1	3	3	0	0	7
Shale	1355	0	0	3	2	0	0	5
	1365	0	0	3	4	0	0	7
	1385	0	2	1	3	2	0	8
	1395	0	1	1	1	0	0	3
	1405	0	1	2	1	0	0	4
	1415	0	0	6	1	0	0	7
	1425	1	0	2	4	0	0	7

Table C-1 continued

-Rhinestreet Shale	1435	0	0	6	0	0	1	7
	1445	0	0	2	2	0	0	4
	1455	0	0	1	5	0	0	6
	1465	0	0	1	3	0	0	5
	1475	0	1	2	1	0	0	4
	1485	0	0	3	1	1	0	5
	1495	0	1	1	3	0	0	5
	1505	0	2	1	2	1	0	6
	1515	0	0	7	0	0	0	7
	1525	1	0	2	2	0	0	5
	1535	1	0	2	1	0	1	5
	1545	0	0	2	4	1	0	7
	1555	0	0	4	0	1	0	5
	1565	0	2	2	2	0	0	6
	1575	0	0	3	1	0	0	4
	1585	0	0	5	3	0	0	8
	1595	0	1	1	1	0	0	3
	1605	0	0	5	3	0	0	8
	1615	0	0	4	2	0	0	6
	1625	0	0	8	2	0	0	10
	1635	0	0	5	2	0	0	7
	1645	0	0	3	2	0	0	5
	1655	0	0	3	2	1	0	6
	1665	0	1	2	1	0	0	4
	1675	0	0	1	3	1	0	5
	1685	0	0	4	1	1	0	6
	1695	0	0	1	0	0	0	1
	1705	0	0	5	2	0	0	7
	1715	0	0	5	1	0	0	6
	1725	0	1	1	4	0	0	6
	1735	0	0	5	1	1	0	7
	1745	0	0	2	3	0	0	5
	1755	0	0	3	1	1	0	5
	1765	0	0	5	2	0	0	7
	1775	0	0	1	1	2	0	4

Table C-1 continued

-Rhinestreet Shale	1735	0	0	2	3	0	0	5
	1795	0	1	3	5	0	0	9
	1805	0	0	4	6	0	0	10
	1815	0	0	3	3	0	0	6
	1825	2	0	1	4	0	0	7
	1835	1	0	4	1	0	0	6
	1845	0	0	2	4	0	0	6
	1855	0	0	0	4	0	0	4
	1865	0	0	6	3	0	0	9
	1875	0	0	2	3	0	0	5
	1885	1	0	6	2	0	0	9
	1895	0	1	3	6	0	0	10
	1905	0	0	4	3	0	0	7
	1915	0	0	4	3	2	0	9
	1925	0	0	3	1	0	0	4
	1935	0	0	3	2	0	0	5
	1945	0	0	5	4	0	0	9
	1955	0	0	2	5	0	0	7
	1965	0	1	4	2	0	0	7
	1975	0	0	4	1	0	0	5
	1985	0	0	3	1	0	0	4
	1995	0	1	4	3	0	0	8
	2005	0	0	6	1	0	0	7
	2015	0	0	6	1	0	0	7
	2025	0	0	5	0	0	0	5
	2035	0	1	1	1	0	0	3
	2045	0	0	7	1	0	0	8
	2055	0	0	0	0	1	0	1
	2065	0	0	2	3	0	0	5
	2075	0	0	3	2	0	0	5
	2085	1	2	5	2	0	0	10
	2095	0	0	4	3	0	0	7
	2105	0	0	4	5	1	0	10
	2115	0	0	4	2	0	0	6
	2125	1	0	7	1	1	0	10

Table C-1 continued

-Rhinestreet Shale	2135	0	0	5	2	0	0	7
	2145	0	0	2	1	0	0	3
	2155	0	0	2	0	2	0	4
	2165	0	0	5	1	0	1	7
	2175	0	0	1	4	0	0	5
	2185	0	0	3	0	0	0	3
	2195	0	1	2	2	0	0	5
	2205	0	1	3	1	1	0	6
	2215	0	0	4	1	0	1	6
	2225	0	0	6	3	0	0	9
	2235	0	0	4	1	1	0	6
	2245	0	1	1	3	0	0	5
	2255	0	0	7	2	0	0	9
	2265	0	0	6	1	1	0	8
	2275	0	0	3	2	0	0	5
	2285	0	0	0	5	2	1	9
	2295	0	0	2	7	0	0	9
	2305	0	1	3	2	0	0	6
	2315	0	2	0	0	1	0	8
	2325	0	1	0	1	2	0	9
	2335	1	0	2	1	0	0	4
	2345	0	3	4	0	0	0	7
SONYEA FORMATION	2355	0	0	4	1	0	0	5
-Middlesex Shale	2495	0	0	3	1	1	0	5
	2505	0	0	3	2	0	0	5
	2515	0	1	3	2	0	0	6
	2525	0	0	3	2	1	0	6
	2535	1	0	0	4	1	0	6
	2545	0	1	3	4	0	0	8
	2555	0	3	3	0	0	0	6

Table C-1 continued

	2565	0	0	0	5	1	0	6
	2575	0	1	3	2	0	0	6
	2585	0	2	4	1	0	0	7
	2595	0	1	4	1	0	0	6
	2605	1	0	2	0	1	1	5
	2615	0	1	6	0	0	0	7
	2625	0	1	1	1	0	0	3
GENESEE FM	2635	1	1	2	1	0	0	5
-West River	2645	1	1	3	2	1	0	8
Shale	2655	0	1	4	0	0	0	5
	2665	0	2	3	1	0	0	6
	2725	0	0	5	0	0	0	5
-Genundewa LS	2735	0	1	2	1	0	1	5
-Pen Yan Shale	2745	0	0	6	0	0	0	6
	2755	1	0	6	2	0	0	9
	2765	0	1	7	0	1	0	9
	2775	1	0	2	1	0	0	4
	2785	0	0	3	2	0	0	5
	2795	0	0	2	3	0	0	5
	2805	0	1	3	1	0	0	5
	2815	0	0	1	2	1	0	4
	2825	0	0	4	1	0	0	5
	2865	1	0	2	3	0	0	6
-Lodi Limestone	2875	0	0	3	2	0	2	7
-Geneseo Shale	2885	0	0	3	0	0	0	3
	2895	0	0	0	1	0	0	1
	2905	0	0	0	0	1	0	1
	2925	0	0	0	1	0	0	1
	TOTAL FREQ	22	63	498	292	38	9	922

Table C-2

WELL # 1 IN NEW YORK

POINT LOAD INDEX FOR RESPECTIVE TESTS VS DEPTH
(DEPTH IS MIDPT OF 10 FOOT INTERVAL)

	DEPTH FEET	POINT LOAD INDEX 1	2	3	4	5	6	7	8	9	10
PERRYSBURG FORMATION	445	2664	2435	4623	5763	0	0	0	0	0	0
	455	3379	2954	4044	2539	3013	0	0	0	0	0
	465	2759	2762	2984	2637	2455	3928	0	0	0	0
	475	3470	3832	3974	3154	3301	2755	3922	4091	0	0
	485	3880	4005	2344	2302	2333	2688	2832	0	0	0
	495	3832	4607	2866	2915	0	0	0	0	0	0
	505	2409	2524	4370	3104	3303	2819	0	0	0	0
JAVA FORMATION	515	2931	1434	7030	3863	2940	3723	3284	4328	0	0
	525	3938	6192	6486	3798	3737	4774	0	0	0	0
	535	4202	4389	4402	4751	1827	5632	4865	0	0	0
	545	4256	5295	4208	5756	3220	4204	4180	3998	4401	4327
	965	2384	2568	2562	2993	2687	0	0	0	0	0
	975	3173	2843	2620	4214	3294	3502	0	0	0	0
	985	4111	3689	3971	3162	0	0	0	0	0	0
	995	2625	2595	2469	2648	2953	0	0	0	0	0
	1005	2408	2332	1522	1621	3591	3764	0	0	0	0
	1015	3312	3217	4319	3121	2940	6134	5573	0	0	0
WEST FALLS FORMATION	1325	3348	4221	0	0	0	0	0	0	0	0
	1335	5168	3985	4356	3712	0	0	0	0	0	0
	1345	1685	1709	2167	2681	2861	3759	2975	0	0	0
	1355	3735	2348	2982	3185	2731	0	0	0	0	0
	1365	2816	3863	3862	2857	2904	2637	5377	0	0	0
	1385	2472	3163	4629	2672	3134	5336	4057	3056	0	0
	1395	3371	5314	1932	0	0	0	0	0	0	0
	1405	3965	3972	4279	4369	0	0	0	0	0	0
	1415	2840	3959	3875	3412	3770	3901	4528	0	0	0
	1425	6703	2551	3658	2746	4561	3254	3654	0	0	0
	1435	6307	7113	3156	3047	6922	5036	8640	0	0	0

Table C-2 continued

1445	2965	2679	3109	3815	0	0	0	0	0	0
1455	5784	5341	5809	3334	5764	6037	0	0	0	0
1465	2533	3262	2994	4581	769	0	0	0	0	0
1475	6565	7774	7491	3774	0	0	0	0	0	0
1485	10801	6066	3529	4270	6235	0	0	0	0	0
1495	7146	5648	5516	5872	7232	0	0	0	0	0
1505	4176	4179	2839	3111	4100	2284	0	0	0	0
1515	3108	2840	4313	3881	2747	4111	4696	0	0	0
1525	2866	4101	3496	2224	2834	0	0	0	0	0
1535	2767	3200	5517	3833	4612	0	0	0	0	0
1545	4302	2731	3205	2692	1934	3815	5252	0	0	0
1555	3689	2247	5163	3078	3070	0	0	0	0	0
1565	2312	2334	1989	1455	2734	1068	0	0	0	0
1575	2176	844	3423	3193	0	0	0	0	0	0
1585	2962	2818	1365	1074	2556	2200	3437	2905	0	0
1595	2156	2312	1795	0	0	0	0	0	0	0
1605	4489	2416	2496	2804	1947	1880	2899	1440	0	0
1615	2252	4593	3300	1775	2395	2149	0	0	0	0
1625	2589	2715	2217	1995	1920	2488	2128	3716	2341	2992
1635	2093	2542	1677	2911	2610	2923	9838	0	0	0
1645	3193	1903	1903	2928	2400	0	0	0	0	0
1655	3242	2703	3875	5204	4090	2706	0	0	0	0
1665	1125	3021	2502	3845	0	0	0	0	0	0
1675	2583	4107	1108	2205	2995	0	0	0	0	0
1685	2182	7057	2154	2149	1917	2166	0	0	0	0
1695	2162	2182	0	0	0	0	0	0	0	0
1705	4954	1831	4288	3599	4740	2447	3273	0	0	0
1715	4102	2470	1640	960	1640	3510	0	0	0	0
1725	4384	2476	2610	2791	3830	2976	0	0	0	0
1735	4637	3180	2677	4828	5754	1875	2446	0	0	0
1745	2528	1982	2040	1602	2463	0	0	0	0	0
1755	3379	2662	2070	4475	2200	0	0	0	0	0
1765	2643	2986	2243	2149	1997	2801	2554	0	0	0
1775	3525	2826	2349	2583	0	0	0	0	0	0
1785	2293	3343	2435	2603	2707	0	0	0	0	0

Table C-2 continued

1795	3210	2454	1385	2786	2882	3765	3232	9895	5917	0
1805	6249	5952	5219	4676	4970	3950	4236	3465	2042	3055
1815	4576	2518	1625	4253	4734	3625	0	0	0	0
1825	3138	2850	1837	2441	1330	1620	7226	0	0	0
1835	2760	1527	3381	2315	2976	10755	0	0	0	0
1845	3662	2188	2258	3107	3415	2405	0	0	0	0
1855	2150	2975	2464	3950	0	0	0	0	0	0
1865	3344	2896	1432	1948	2845	4649	5056	3327	1837	0
1875	2534	2956	3409	2756	3394	0	0	0	0	0
1885	2510	2801	1630	9011	4656	3423	2502	2800	2861	0
1895	4385	4833	5743	3687	4676	4051	3957	3254	2743	5819
1905	2984	2660	1944	4250	2962	2022	1531	0	0	0
1915	1024	1939	2137	1936	3562	2679	5235	2310	2463	0
1925	2160	3269	1540	2380	0	0	0	0	0	0
1935	8450	9105	6792	2958	3887	0	0	0	0	0
1945	3637	4595	5425	3020	3784	4001	5432	2852	7669	0
1955	6168	1620	2956	1966	3537	1492	1304	0	0	0
1965	7601	7014	2502	8458	4252	4432	8809	0	0	0
1975	2535	5318	2985	3220	3582	0	0	0	0	0
1985	2205	1923	1938	11972	0	0	0	0	0	0
1995	2765	3298	2282	5127	4173	3069	5743	1876	0	0
2005	3291	4979	4609	3548	1929	3029	3643	0	0	0
2015	2855	1954	1753	2001	2355	3422	1771	0	0	0
2025	4334	3042	2571	2788	1564	0	0	0	0	0
2035	5765	7222	3555	0	0	0	0	0	0	0
2045	6791	5750	2003	2550	3785	3424	3366	4180	0	0
2055	2361	0	0	0	0	0	0	0	0	0
2065	6468	3154	5018	4464	5980	0	0	0	0	0
2075	3943	6578	5333	4859	4636	0	0	0	0	0
2085	7862	10840	8746	9847	6574	5210	1601	6262	4562	
2731										
2095	2880	4347	3462	3011	5447	4003	3554	0	0	0
2105	2308	4282	4590	4172	4676	3589	5516	6755	3308	5101
2115	4734	6332	8575	3071	7859	4391	0	0	0	0
2125	3366	3501	3533	5232	4126	4309	4068	3638	2849	4144

Table C-2 continued

	2135	11016	13634	4883	3860	3759	7231	5397	0	0	0
	2145	4866	8479	5875	0	0	0	0	0	0	0
	2155	4581	4181	6608	8464	0	0	0	0	0	0
	2165	14183	5637	4213	5205	4207	4160	3966	0	0	0
	2175	7384	3780	5628	2777	4396	0	0	0	0	0
	2185	1222	2096	2766	0	0	0	0	0	0	0
	2195	1621	2081	2469	4598	2446	0	0	0	0	0
	2205	2629	2100	1461	1242	6975	3559	0	0	0	0
	2215	2467	2051	3971	3079	3250	4471	0	0	0	0
	2225	2983	4337	4249	3621	2050	2932	3264	2414	2200	0
	2235	8776	5622	4167	5232	4338	6331	0	0	0	0
	2245	4945	5308	5854	5612	5028	0	0	0	0	0
	2255	1813	2036	1950	2884	2563	3720	2441	1145	2024	0
	2265	1284	3611	3446	4335	5521	3725	3281	3826	0	0
	2275	1427	5313	2078	3232	3437	0	0	0	0	0
	2285	4058	8650	5562	6530	1654	6697	7179	3200	7035	0
	2295	6155	2498	4806	3685	2532	3990	3214	3294	7047	0
	2305	2662	3953	1587	2592	3520	1975	0	0	0	0
	2315	2684	2776	2936	3005	4010	2473	2260	2777	0	0
	2325	1767	3385	2741	5184	2633	3245	2738	4285	2450	0
	2335	3317	3410	2252	2249	0	0	0	0	0	0
	2345	3957	2678	1911	1522	2089	2226	2037	0	0	0
SONYEA FORMATION	2355	1769	2559	2659	2107	1976	0	0	0	0	0
	2365	2587	4166	5258	5871	4509	0	0	0	0	0
	2375	3833	2988	3364	4117	6855	0	0	0	0	0
	2385	5114	4382	2227	2928	3726	2238	0	0	0	0
	2395	2459	3009	2847	2231	2428	3167	0	0	0	0
	2405	5771	4877	6925	4793	4844	4533	0	0	0	0
	2415	1868	3282	4072	3840	4690	4468	4941	3579	0	0
	2425	4422	2554	1601	1495	2515	3381	0	0	0	0
	2435	3619	3214	3192	4570	4803	2349	0	0	0	0

Table C-2 continued

	2575	3445	2400	1978	2670	3565	4463	0	0	0	0
	2585	2511	4048	3988	4234	3198	3599	4196	0	0	0
	2595	4000	3873	5131	2834	2503	3447	0	0	0	0
	2605	4965	4824	5096	4873	5553	0	0	0	0	0
	2615	3915	3233	4713	3537	2946	4823	6575	0	0	0
	2625	4795	5131	6051	0	0	0	0	0	0	0
GENESEE	2635	2764	3387	3352	3096	3539	0	0	0	0	0
FORMATION	2645	3247	4324	2663	4021	3528	3132	1596	1904	0	0
	2655	3583	4175	2237	4691	3159	0	0	0	0	0
	2665	3011	3295	3518	2557	3357	2378	0	0	0	0
	2725	3162	2550	3535	5615	4558	0	0	0	0	0
	2735	2917	4029	3065	3228	5955	0	0	0	0	0
	2745	3348	2749	2384	3539	5313	4006	0	0	0	0
	2755	2135	1981	3227	3480	1734	1785	2195	3772	3710	0
	2765	3136	2203	1331	1781	2380	1760	4650	2348	1837	0
	2775	2320	2893	2878	6477	0	0	0	0	0	0
	2785	2561	4022	3275	2834	2857	0	0	0	0	0
	2795	2500	3503	3720	2618	3652	0	0	0	0	0
	2805	3109	3124	2536	4189	2634	0	0	0	0	0
	2815	2678	2835	3068	3285	0	0	0	0	0	0
	2825	4013	2816	1781	4528	3956	0	0	0	0	0
	2835	1692	1827	2243	2341	1536	2746	0	0	0	0
	2875	2679	2822	2478	2478	2412	2387	3278	0	0	0
	2885	2428	4288	2552	0	0	0	0	0	0	0
	2895	1831	0	0	0	0	0	0	0	0	0
	2905	1416	0	0	0	0	0	0	0	0	0
	2925	3306	0	0	0	0	0	0	0	0	0

APPENDIX D

Results of Directional Tensile Strength Tests

Table D-1

WELL NUMBER 1 IN NEW YORK

DIRECTIONAL TENSILE STRENGTHS

TENSILE STRENGTH IN PSI & ORIENT OF LOAD AXIS IN DEGREES FROM NORTH

	DEPTH IN FEET	0 DEG	30 DEG	60 DEG	90 DEG	120 DEG	150 DEG
PERRYSBURG FM	465	1333	1302	1307	1661	2038	1319
- Dunkirk Shale	475	1414	1621	1791	1969	1674	1130
	495	1560	1518	1230	1375	1396	1587
	505	1425	1369	1550	1352	1301	1873
JAVA FORMATION	515	1644	1495	1493	1580	1803	1515
- Hanover Shale	525	1504	1732	2097	1616	1356	1549
	535	1912	1953	1784	1688	1844	1833
	965	2488	2623	2333	2591	2595	2711
	975	1117	914	795	1152	750	937
- Pipe Creek Sh	985	892	766	1136	682	1075	843
	995	1090	585	972	1078	803	1121
	1005	696	647	1259	957	943	918
WEST FALLS FM	1015	2434	2308	2081	2769	2496	2413
- Angola Shale	1335	688	851	1221	1094	1251	886
- Rhinestreet Sh	1345	1086	739	1360	908	964	701
	1355	1223	1603	1586	1649	2676	844
	1365	1022	910	1273	1033	767	927
	1375	2745	1280	1742	2334	1244	1587
	1385	1070	1036	1014	956	2032	794
	1395	2381	2468	2457	1775	2252	2333
	1405	1243	1383	965	688	1635	1532
	1415	785	1188	523	910	1359	1030
	1425	1220	1314	1657	1253	1868	1244
	1435	2433	2880	2781	2683	2568	2299
	1445	1477	2358	3077	1175	1108	1256
	1455	3059	2598	2562	0	2543	2443

Table D-1 continued

Rhinestreet Sh	1455	1264	1600	1958	2236	2541	871
	1475	2915	3104	1420	1873	2080	3416
	1485	513	847	870	1165	882	838
	1495	2834	2673	2717	713	2499	2831
	1505	829	1115	998	706	867	1045
	1515	2600	2187	2444	2416	1740	1103
	1525	499	822	1004	1027	1123	1267
	1535	1589	787	708	1499	768	897
	1555	690	1275	977	1048	1415	722
	1565	1025	703	845	1629	1601	1201
	1575	842	1154	1173	692	1084	1141
	1585	1079	2323	816	811	838	1294
	1595	2357	1468	838	916	1268	2776
	1605	896	984	1149	814	708	984
	1615	877	893	1566	1457	1189	2448
	1625	1478	1048	1238	1040	1153	1323
	1635	968	802	484	986	1265	951
	1645	957	1365	933	935	1123	870
	1655	853	981	1024	1093	823	838
	1665	836	880	835	1177	1227	1239
	1675	807	993	464	737	822	1132
	1685	997	994	848	1017	1328	1583
	1695	1156	777	670	1330	902	1128
	1705	1081	536	1082	1017	855	832
	1715	0	841	548	1488	652	946
	1725	1151	837	892	2081	1531	969
	1735	811	426	809	874	2639	592
	1745	1110	1059	1047	726	1029	1209
	1755	573	875	1200	1071	1036	626
	1765	1141	949	1261	944	638	1132
	1775	766	1074	945	694	1002	721
	1785	847	602	921	626	723	1032
	1815	1283	2685	560	774	2075	792
	1825	2110	2188	1765	1899	1713	1521
	1835	277	1253	989	1980	1421	511

Table D-1 continued

Rhinestreet Sh	1845	717	942	629	54	1592	773
	1865	1478	1221	1225	1650	706	947
	1875	445	2885	936	1078	1241	2139
	1885	1171	794	853	1011	407	912
	1915	614	942	996	580	2322	2276
	1925	1103	917	1385	1204	1043	759
	1935	1016	1013	851	730	895	1184
	1945	1034	898	977	788	851	912
	1965	879	962	798	993	781	819
	1975	1483	1142	1101	1168	1515	2877
	1985	1337	1243	1113	803	1181	975
	1995	975	1080	1247	919	769	899
	2005	1981	2834	2569	2334	2471	3033
	2015	1207	889	827	1502	996	809
	2025	1138	1031	896	1355	1240	1388
	2045	2605	2887	3201	3271	2841	825
	2055	478	815	581	1252	638	1027
	2065	584	1016	1032	1014	892	1235
	2075	1232	1219	780	714	1240	935
	2085	2042	1781	2176	2314	1803	1700
	2095	820	3557	1811	1036	2053	1051
	2105	3359	3836	2003	1930	1893	2371
	2115	1631	1129	1304	1079	1051	1189
	2135	1083	1145	1224	1336	1229	1342
	2145	1155	1302	629	803	566	1211
	2155	693	2102	2749	3251	1419	3593
	2165	1242	1221	1416	1381	1313	1163
	2175	1199	2366	4023	1771	1553	847
	2195	1238	889	1292	483	978	1080
	2205	772	822	1023	976	946	1114
	2215	1012	970	856	1026	962	988
	2235	2880	2857	1913	1812	2924	2997
	2245	1119	846	925	851	470	828
	2255	2252	973	1583	1717	2121	1733
	2275	1320	1193	876	948	901	1104

Table D-1 continued

- Rhinestreet Sh	2335	1084	1015	924	863	906	963
	2345	1149	1332	1385	1472	1077	1712
SONYA FORMATION	2355	1323	1006	1420	1502	1150	1607
- Middlesex Sh	2495	866	857	1079	784	972	907
	2505	1106	1259	1015	1203	1357	1111
	2515	733	890	936	856	1058	713
	2525	1411	528	1169	0	0	0
	2535	1332	1057	1726	950	1193	1190
	2545	1238	1049	1343	1183	1202	825
	2555	796	741	1027	899	1041	855
	2565	1148	1043	997	972	780	865
	2575	1188	1070	1179	1290	1261	1025
	2585	1112	920	1151	1035	1260	1126
	2595	1182	1121	1122	598	581	916
	2605	637	898	935	793	1175	1711
	2615	1387	0	1353	1530	1387	1273
	2625	997	965	1057	755	1069	984
GENESEE FM	2635	1097	1312	1203	1117	1017	1227
- West River Sh	2645	979	0	0	1628	1359	1473
	2655	1335	1142	1389	581	920	1258
	2665	1189	1055	1249	1285	1291	1432
	2725	1278	970	1379	1642	2003	1655
- Penn Yan Shale	2745	1292	1176	835	1139	1199	878
	2775	1206	1339	1382	1371	1157	1763
	2785	1668	1181	1206	1530	1465	1107
	2795	1154	1231	1762	1250	1096	1609
	2805	1395	989	959	1387	951	1299
	2815	0	1272	1082	0	0	1070
	2825	0	1053	1182	0	0	1143
	2845	0	1046	1181	0	850	0
	2855	927	850	930	998	1348	1329
- Geneseo Shale	2895	0	0	1047	1068	0	0
	2925	1135	1506	1286	1473	1181	1567
	AVERAGE STRENGTH	1274	1305	1296	1273	1315	1310

FIGURE D-1

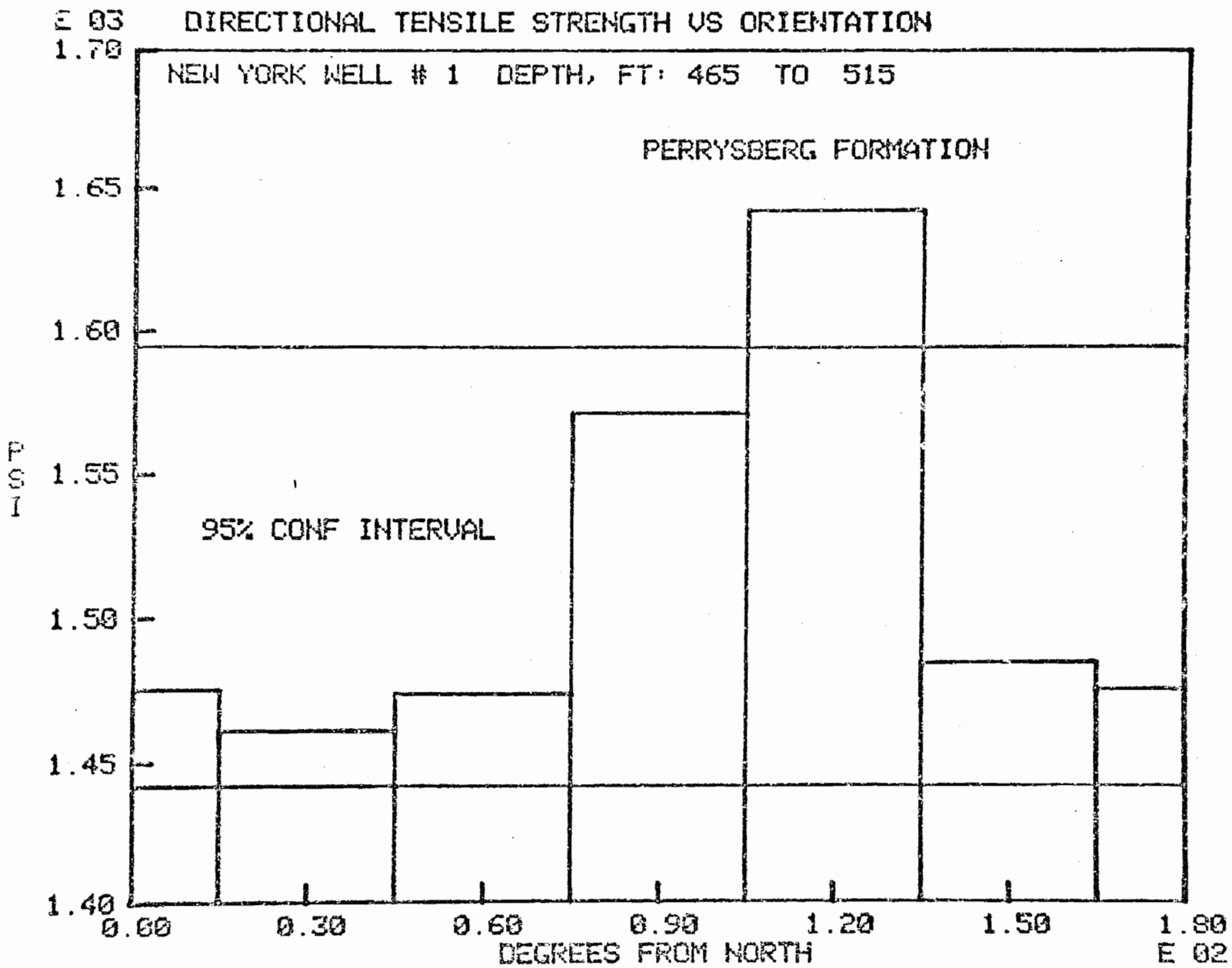

E 03
DIRECTIONAL TENSILE STRENGTH VS ORIENTATION
NEW YORK WELL # 1 DEPTH, FT: 465 TO 515
PERRYSBERG FORMATION
95% CONF INTERVAL
PSI
1.70
1.65
1.60
1.55
1.50
1.45
1.40
0.00
0.30
0.60
0.90
1.20
1.50
1.80
E 02
DEGREES FROM NORTH

FIGURE D-2

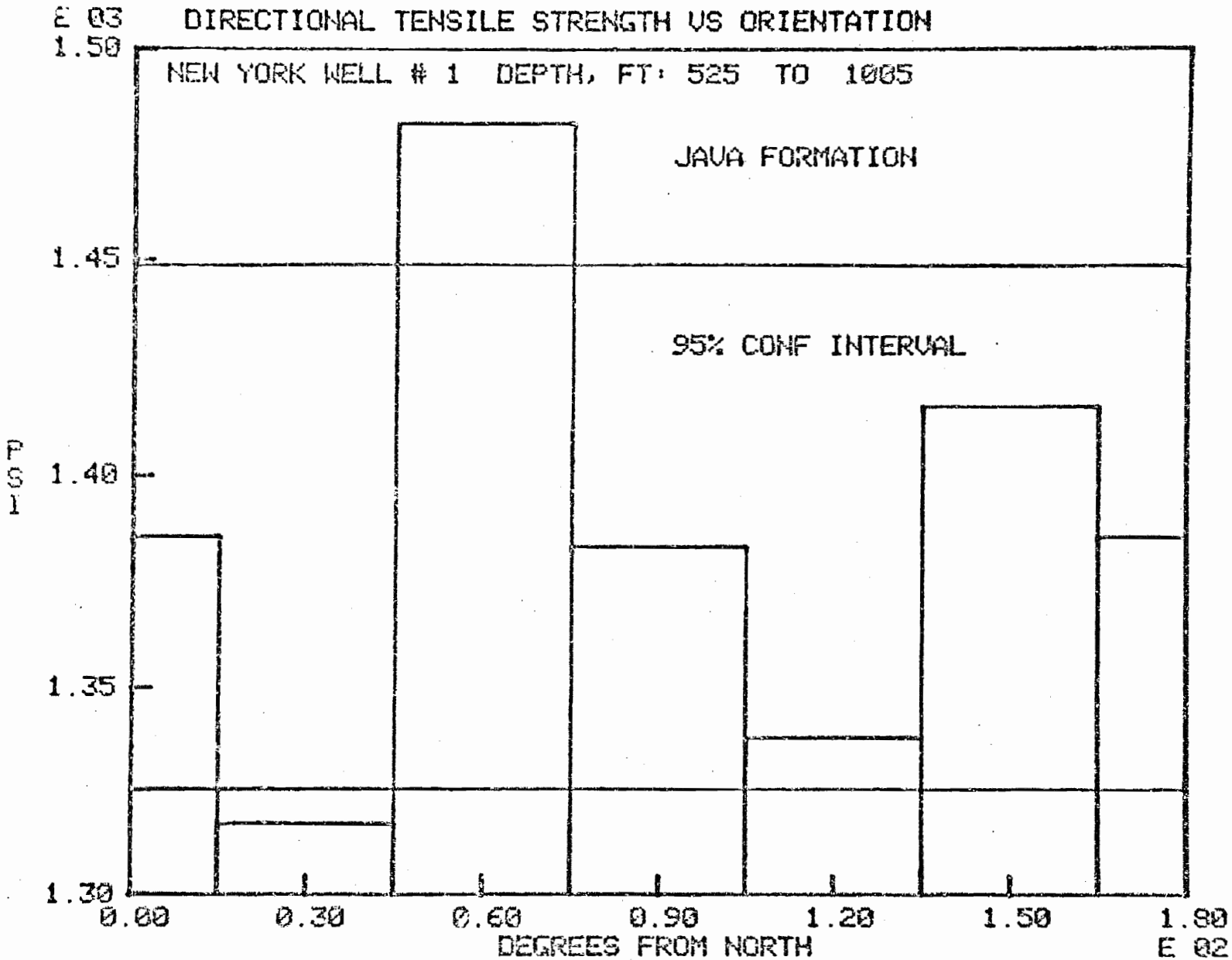

E 03
DIRECTIONAL TENSILE STRENGTH VS ORIENTATION
NEW YORK WELL # 1 DEPTH, FT: 525 TO 1005
JAVA FORMATION
95% CONF INTERVAL
PSI
1.50
1.45
1.40
1.35
1.30
0.00
0.30
0.60
0.90
1.20
1.50
1.80
E 02
DEGREES FROM NORTH

FIGURE D-3

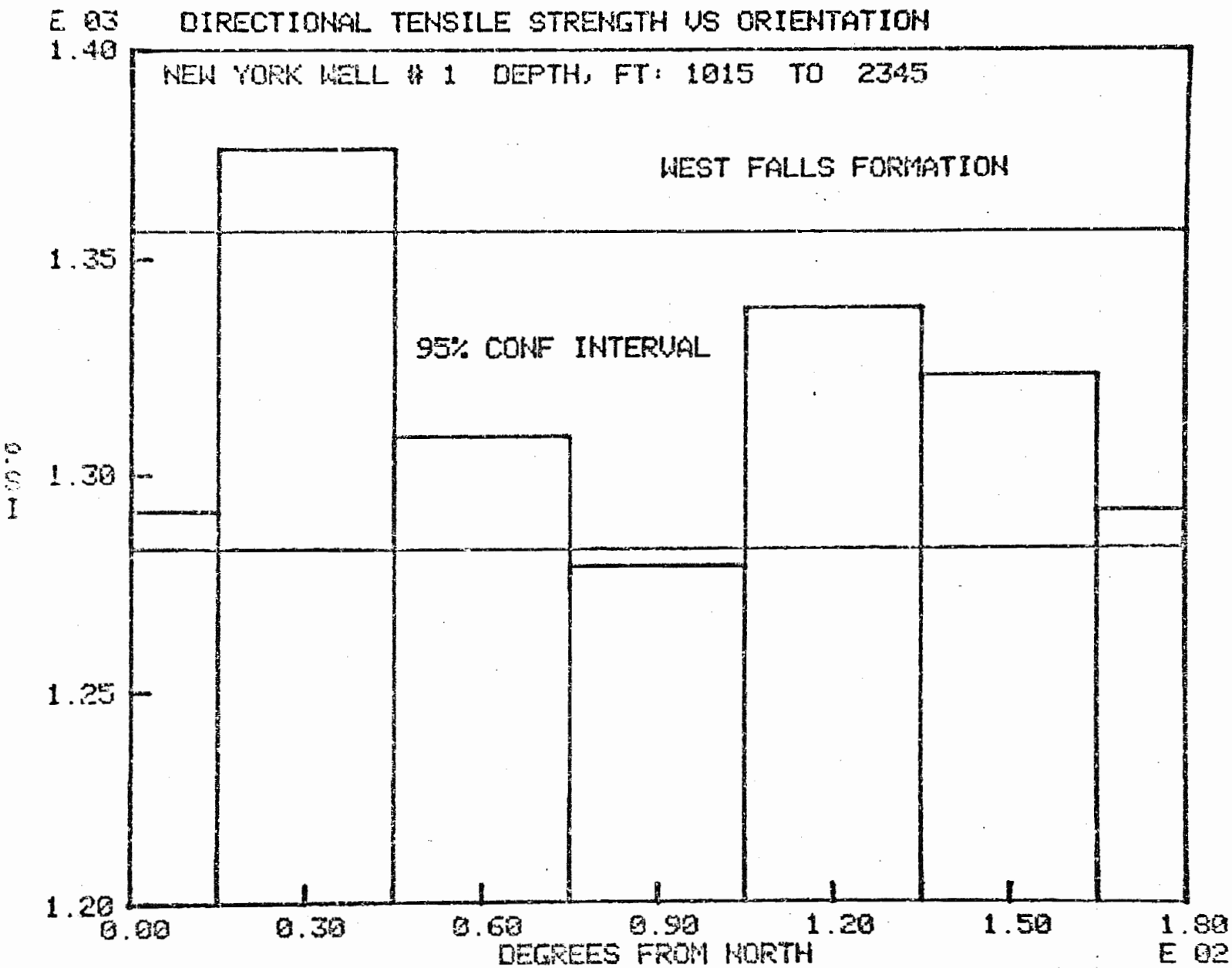

E 03
DIRECTIONAL TENSILE STRENGTH VS ORIENTATION
NEW YORK WELL # 1 DEPTH, FT: 1015 TO 2345
WEST FALLS FORMATION
95% CONF INTERVAL
1.40
1.35
1.30
1.25
1.20
0.00
0.30
0.60
0.90
1.20
1.50
1.80
E 02
DEGREES FROM NORTH

FIGURE D-4

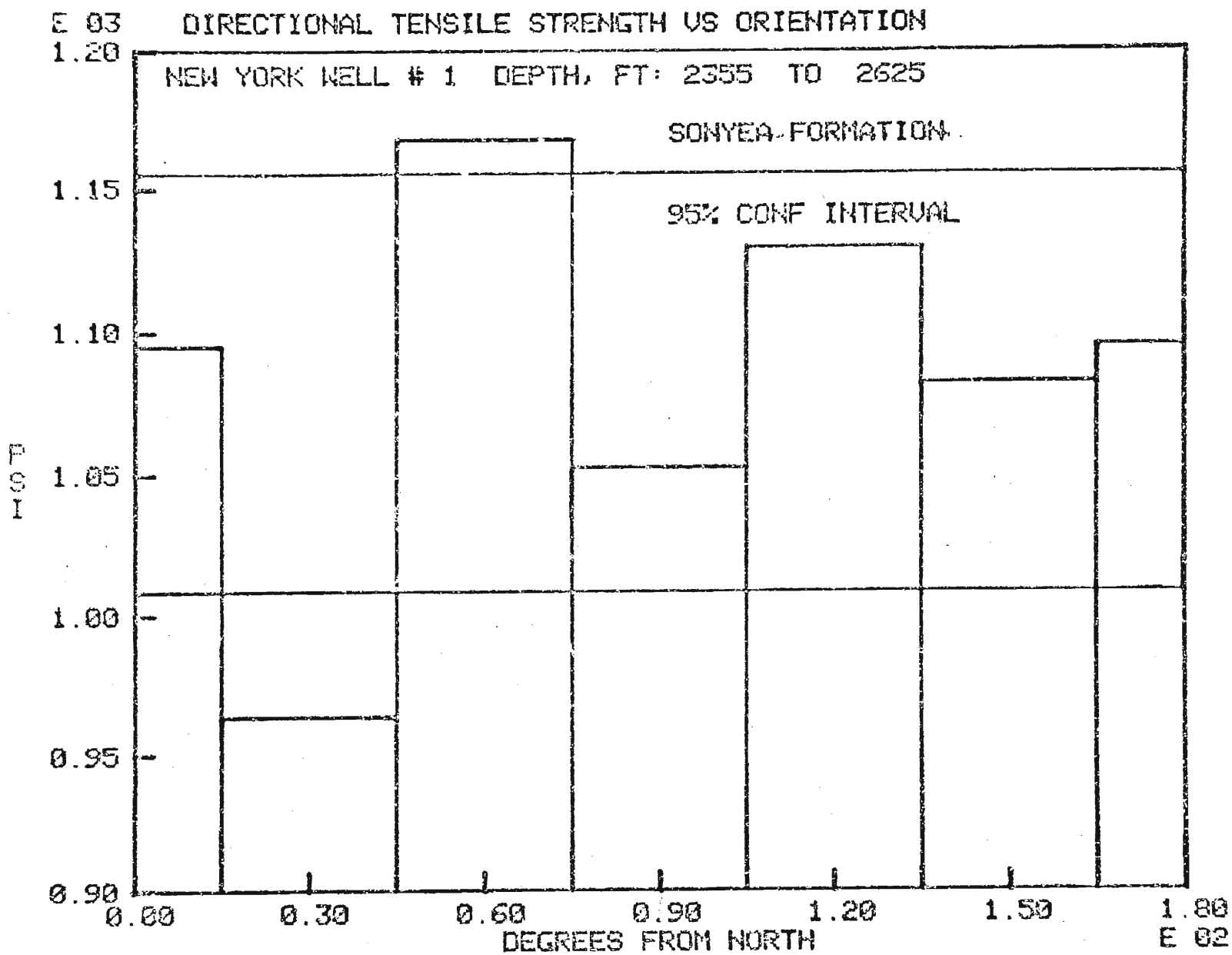

E 03
DIRECTIONAL TENSILE STRENGTH VS ORIENTATION
NEW YORK WELL # 1 DEPTH, FT: 2355 TO 2625
SONYEA FORMATION
95% CONF INTERVAL
1.20
1.15
1.10
1.05
1.00
0.95
0.90
PSI
0.00
0.30
0.60
0.90
1.20
1.50
1.80
E 02
DEGREES FROM NORTH

FIGURE D-5

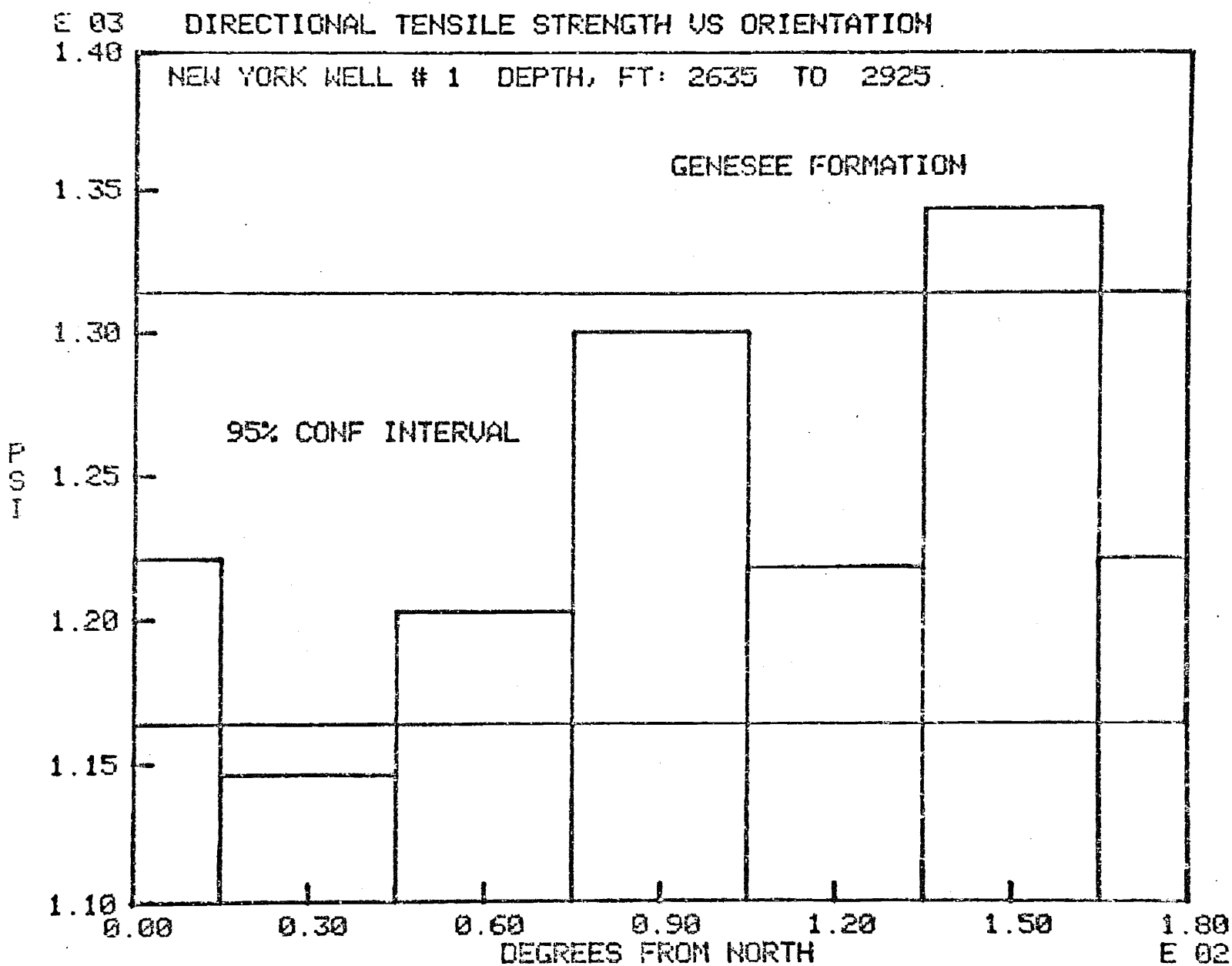
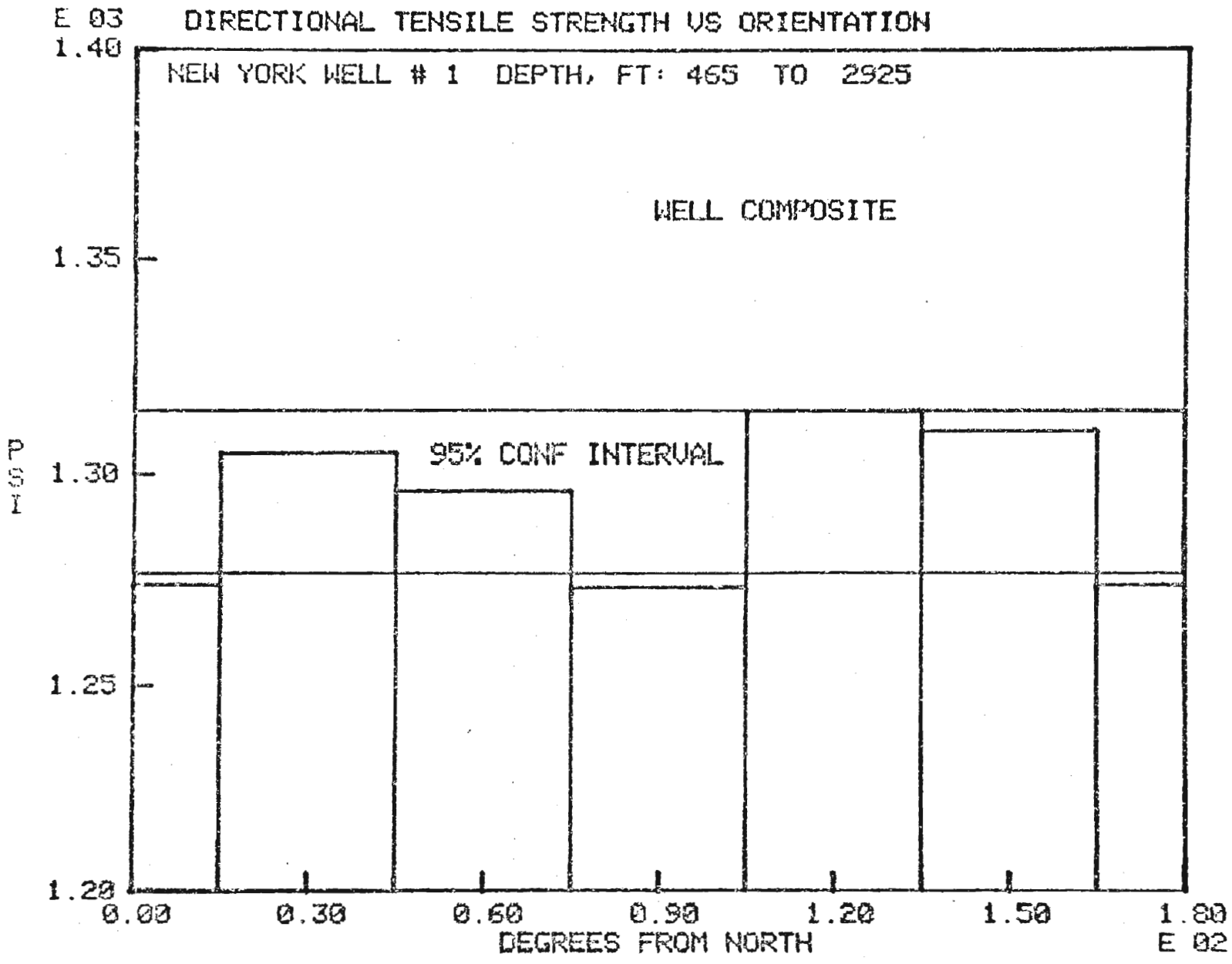

E 03
DIRECTIONAL TENSILE STRENGTH VS ORIENTATION
NEW YORK WELL # 1 DEPTH, FT: 2635 TO 2925
GENESEE FORMATION
95% CONF INTERVAL
PSI
1.40
1.35
1.30
1.25
1.20
1.15
1.10
0.00
0.30
0.60
0.90
1.20
1.50
1.80
E 02
DEGREES FROM NORTH

FIGURE D-6


E 03
DIRECTIONAL TENSILE STRENGTH VS ORIENTATION
NEW YORK WELL # 1 DEPTH, FT: 465 TO 2925
WELL COMPOSITE
95% CONF INTERVAL
PSI
1.40
1.35
1.30
1.25
1.20
0.00
0.30
0.60
0.90
1.20
1.50
1.80
E 02
DEGREES FROM NORTH