47

CLIFFS MINERALS, INC.
EASTERN GAS SHALES PROJECT
VIRGINIA #1 - WISE COUNTY
PHASE III REPORT
SUMMARY OF LABORATORY ANALYSES AND MECHANICAL CHARACTERIZATION RESULTS
OCTOBER 1982

TABLE OF CONTENTS

	Page No.
Summary of Mechanical Characterization Results	1
I. Introduction	3
Table 1: Formations Tested	
II. Results	4
Table 2: Frequency Distribution of Preferred Direction of Fracturing	
A. Cleveland Shale	4
B. Chagrin Shale	6
C. Middle Huron Shale	7
D. Lower Huron Shale	8
E. Well Composite	9
III. Conclusions	10

APPENDICES

A. Results of Directional Ultrasonic Velocity Measurements	12
Figures: Histograms of Average Velocity	
B Results of Point Load Tests	18
C Results of Directional Tensile Strength Tests	19
Figures: Histograms of Average Tensile Strength	

Summary of Mechanical Characterization Results

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

The physical property tests employed were: 1) directional ultrasonic velocity measurements; 2) point load induced fracturing; and 3) directional tensile strength tests. There was no record of pretest fractures.

In point load testing, fractures induced by applying a point load to the central axis of a disc are assumed to propagate parallel to the preferred direction of fracturing. Point load induced fractures indicate N600E+15° as the preferred direction of fracturing in 58 out of 186 total induced fractures.

In ultrasonic velocity testing, minimum velocity values are assumed to be perpendicular to the preferred direction of fracturing because large numbers of microcracks encountered along this direction will impede propagation of the sonic wave. Ultrasonic velocity measurements indicate N600E±15° as the preferred direction of fracturing in 14 out of 32 total velocity samples.

In directional tensile strength testing, compressive loads are applied across the diameter of the specimen in order to induce diametrical fractures and thus determine tensile strength normal to the loading axis. Samples from a given interval are tested with the loading axis in six different orientations by this method. The preferred direction of fracture

will be parallel to the loading axis in the specimen for which the lowest tensile strength value was obtained. The twenty-five sets of directional tensile strength measurements do not indicate a statistically significant preferred direction of fracturing in this well.

INTRODUCTION

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

A series of samples, representing 365 feet of core taken from the Virginia #1 well, were tested by the Mound Facility in Miamisburg, Ohio. The raw lab data was interpreted and put into report form by the Rock Mechanics Research Facility at Michigan Technological University, Houghton, Michigan. The tested core intervals extend from 4,870 feet to 4,984 feet and 5,226 feet to 5,475 feet below surface and are summarized in Table 1.

TABLE 1

EGSP-Virginia #1
Wise County
Formations Tested

Lithology	Depth Interval	Depth Tested	Type of Test
Cleveland Shale	4,870'-4,938'	4,872.0'-4,937.5'	Point Load
		4,870.6'-4,937.5'	DTS
		4,870.0'-4,932.0'	Velocity
Chagrin Shale	4,838'-4,990'	4,941.6'-4,984.0'	Point Load
		4,940.2'-4,962.4'	DTS
		4,943.0'-4,984.0'	Velocity
Middle Huron Shale	5,080-'5,355'	5,233.8'-5,353.5'	Point Load
		5,240.2'-5,309.2'	DTS
		5,226.0'-5,353.0'	Velocity
Lower Huron Shale	5,355'-5,480'	5,364.3'-5,475.3'	Point Load
		5,361.9'-5,469.9'	DTS
		5,365.0'-5,473.0'	Velocity

RESULTS

The results of the physical property measurements of directional ultrasonic velocity, point load induced fracturing, and directional tensile strength tests are compiled in Appendices A, Band C respectively. There was no record of pretest fractures. The point load index was not calculated; the distance between load platens at failure had not been recorded. Table 2 is a summary of the mechanical property testing results for each stratigraphic formation.

TABLE 2

EGSP-Virginia #1, Core
Wise County
Frequency Distribution of Preferred Direction of Fracturing

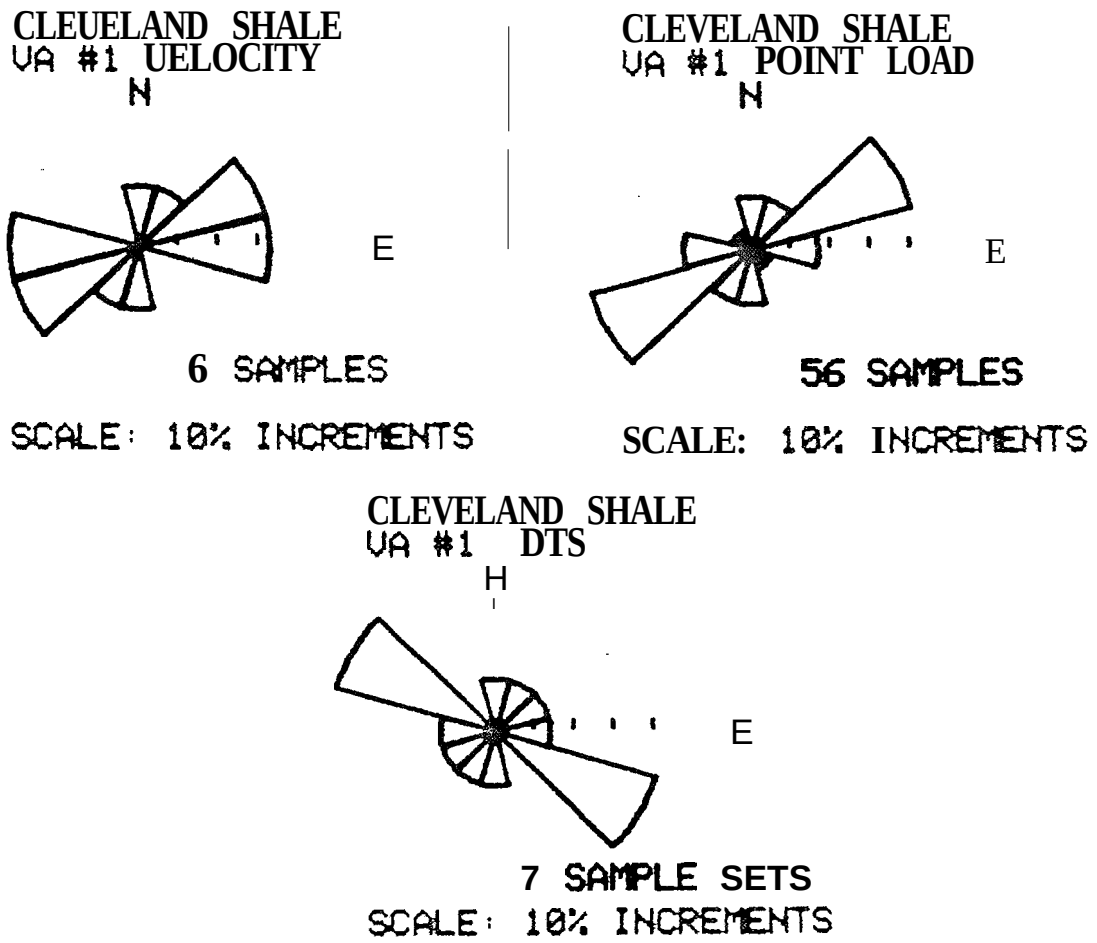
Formation	Test	Orientation in Degrees East of North						
		0°	30°	60°	90°	120°	150°	Total
Cleveland Shale	Velocity	1	1	2	2	0	0	6
4,870'-4,937' tested	Point Load	8	8	24	10	3	3	56
	DTS	1	1	1	1	3	0	7 sets
Chagrin Shale	Velocity	0	1	2	1	0	0	4
4,940'-4,984' tested	Point Load	4	3	4	2	3	1	17
	DTS	0	1	0	1	0	1	3 sets
Middle Huron Shale	Velocity	1	3	4	2	0	1	11
5,225'-5,353 tested	Point Load	7	9	15	8	5	9	53
	DTS	1	1	1	2	1	0	6 sets
Lower Huron Shale	Velocity	0	4	6	0	1	0	11
5,361'-5,475' tested	Point Load	13	13	15	10	5	4	60
	DTS	3	1	1	2	1	1	9 sets
Well Composite	Velocity	2	9	14	5	1	1	32
4,870'-4,984' and	Point Load	32	33	58	30	16	17	186
5,226'-5,475' tested	DTS	5	4	3	6	5	2	25 sets

Cleveland Shale; 4,870 to 4,937 feet tested:

Ultrasonic velocity measurements indicate N60oE+15° and N90oE+15° as the preferred directions of fracturing in a sum of four out of six velocity samples. Point load induced fractures indicate N60oE+15° as the preferred direction of fracturing in 24 out of 56 induced fractures. Directional tensile strength measurements indicate N120oE+15° as the preferred plane of weakness in three out of the seven sets of samples. Figure 1 illustrates the frequency distribution rose diagrams of preferred direction of fracturing in the Cleveland Shale. Tabulated results are presented in Appendices A, Band C.

FIGURE 1

Cleveland Shale
Frequency Distribution Rose Diagrams of Results

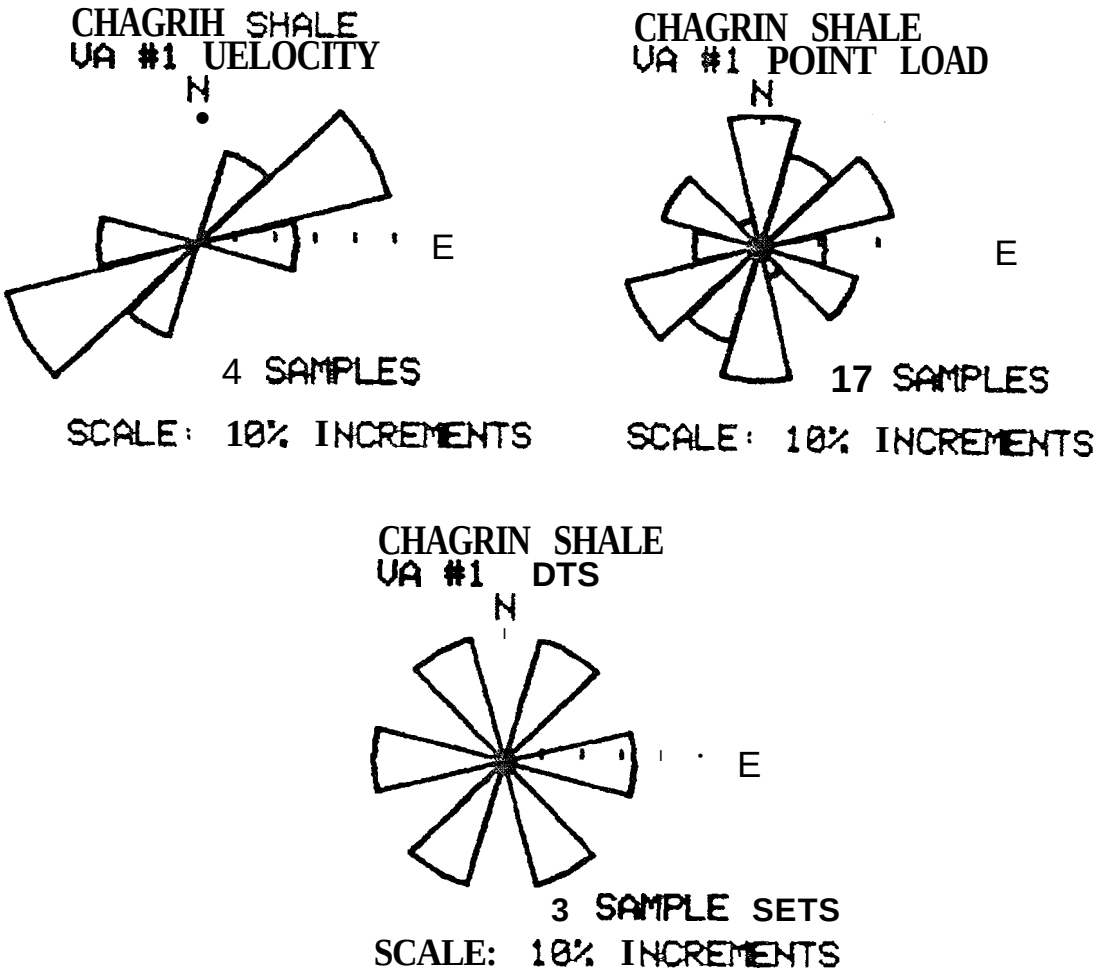


Chagrin Shale; 4,940 to 4,984 feet tested:

Two out of the four ultrasonic velocity measurements in this depth interval indicate N60oE+lSo as the preferred direction of fracturing. Point load induced fracturing of 17 samples and directional tensile strength measurements of 3 sets of samples do not indicate a statistically significant preferred plan of weakness. Figure 2 illustrates the frequency distribution rose diagrams of preferred direction of fracturing in the Chagrin Shale. Tabulated results are presented in Appendices A, Band C.

FIGURE ·2

Chagrin Shale
Frequency Distribution Rose Diagrams of Results

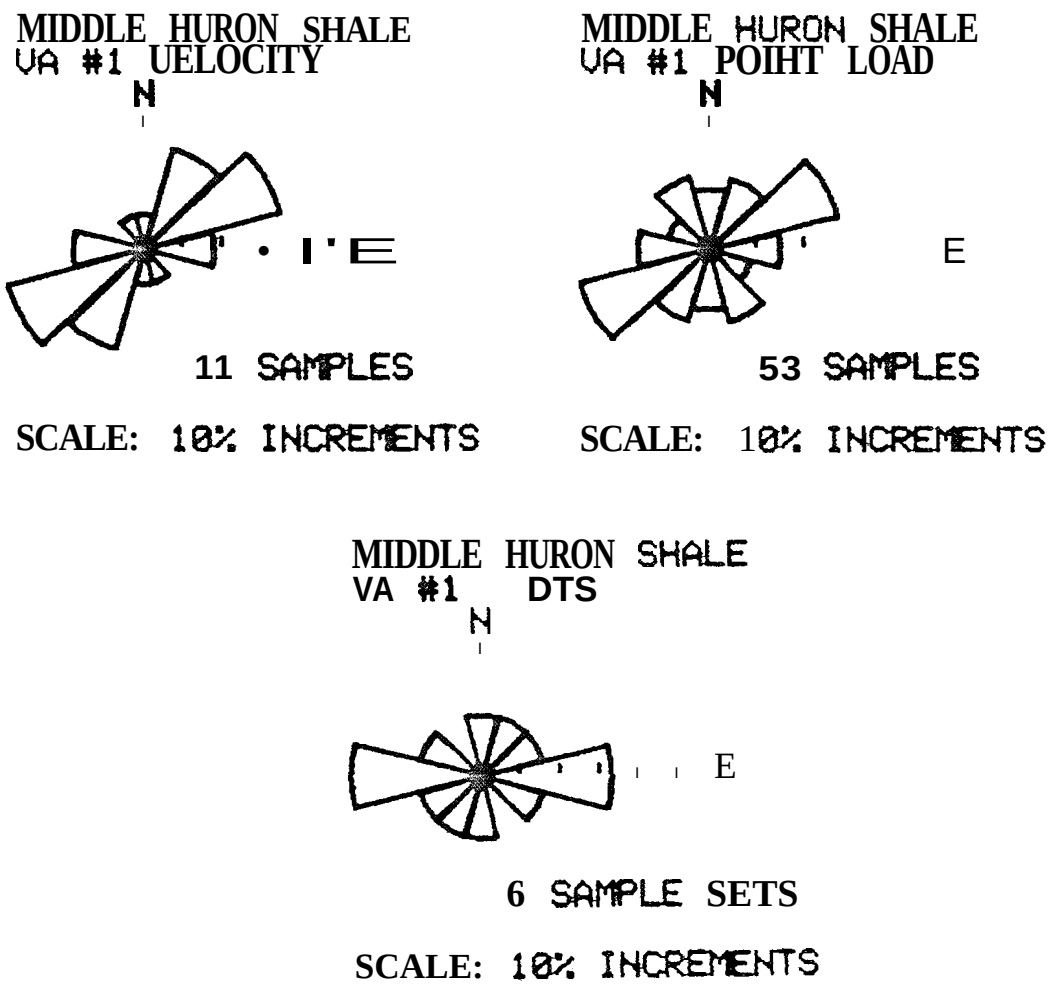


Middle Huron Shale; 5,226 to 5,353 feet tested:

Four out of the eleven ultrasonic velocity measurements and 15 out of the 53 point load induced fractures indicate N60°E±15° as the preferred direction of fracturing. Two out of the six sets of directional tensile strength measurements indicate N90°E±15° as the preferred plane of weakness. Figure 3 illustrates the frequency distribution rose diagrams of 'preferred direction of fracturing in the Middle Huron Shale. Tabulated results are presented in Appendices A, Band C.

FIGURE 3

Middle Huron Shale
Frequency Distribution Rose Diagrams of Results

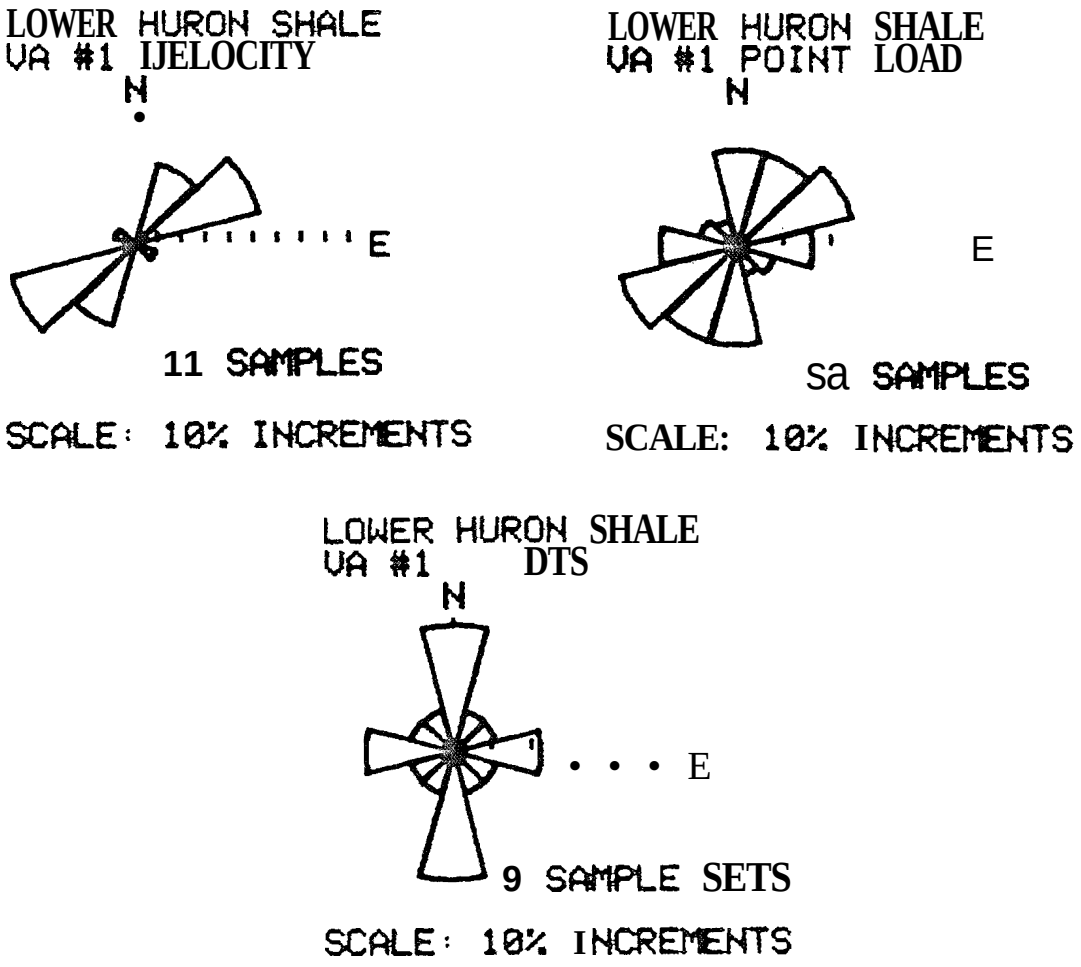


Lower Huron Shale; 5,361 to 5,475 feet tested:

Six out of the eleven ultrasonic velocity measurements and 15 out of the 60 point load induced fractures indicate N60oE+15° as the preferred direction of fracturing. The nine sets of directional tensile strength measurements do not indicate a statistically significant preferred plane of weakness. Figure 4 illustrates the frequency distribution rose diagrams of preferred direction of fracturing in the Lower Huron Shale. Tabulated results are presented in Appendices A, Band C.

FIGURE 4

Lower Huron Shale
Frequency Distribution Rose Diagram of Results

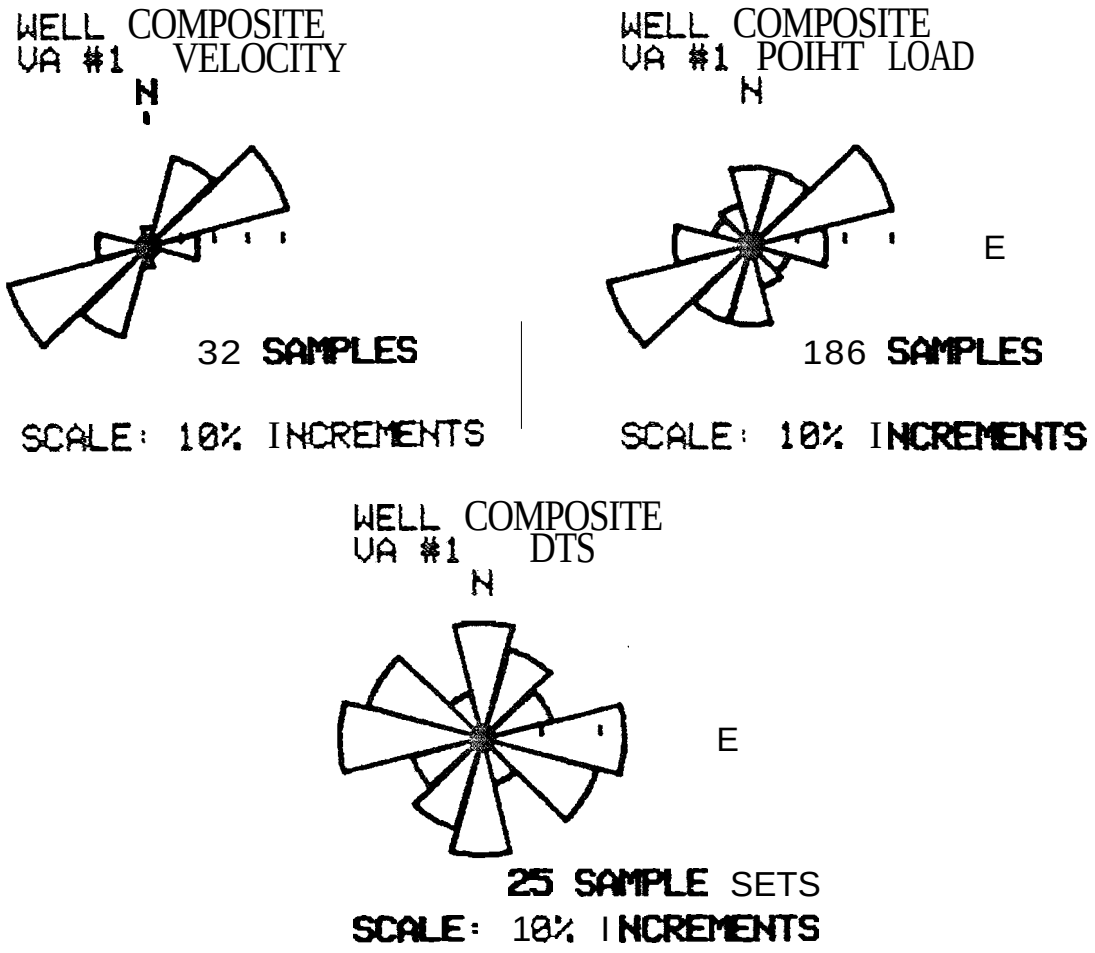


Well Composite; 4,87Q to 4,984 feet and 5,226 to 5,475 feet. tested:

Ultrasonic velocity measurements and point load fractures indicate N60EO+15° as the preferred direction of fracturing (14 out of 32 total velocity samples and 58 out of 186 total induced fractures). The twenty-five sets of directional tensile strength measurements do not indicate a statistically significant preferred direction of fracturing. Figure 5 illustrates the frequency distribution rose diagrams of preferred direction of fracturing in the EGSP-Virginia #1 Wise County well composite. Tabulated results are presented in Appendices A, Band C.

FIGURE 5

Virginia #1 Well Composite; 4,870'-4,984 and 5,226'-5,475' Tested
Frequency Distribution Rose Diagram of Results



CONCLUSIONS

The data presented in this report indicate that core samples from the EGSP-Virginia #1 well exhibit a directional variation in physical properties. Prediction of the preferred direction of induced fracturing at the Wise County well site was based on inherent weaknesses in the core samples found by: (1) point load induced fractures; (2) directional tensile strength measurements; and (3) normality to measured ultrasonic velocity minimums. These tests were performed by the Mound Facility in Miamisburg, Ohio. The raw lab data from Mound Facility was interpreted and put into report form by the Rock Mechanics Research Facility at Michigan Technological University, Houghton, Michigan. The overall agreement between these tests in each stratigraphic interval suggests that these physical property measurements do indicate a preferred direction of fracturing in core samples.

The following conclusions may be drawn from this data:

(1) The preferred direction of fracturing in the Cleveland Shale (4,870 to 4,937 feet tested) is N60°E±15° as indicated by point load induced fracturing and ultrasonic velocity measurements.

(2) The preferred direction of fracturing in the Chagrin Shale (4,940 to 4,984 feet tested) is N60°E+15° as indicated by ultrasonic velocity measurements.

(3) The preferred direction of fracturing in the Middle Huron Shale (5,226 to 5,353 feet tested) is N60°E+15° as indicated by ultrasonic velocity measurements and point load induced fracturing.

CONCLUSIONS Continued

(4) The preferred direction of fracturing in the Lower Huron Shale (5,361 to 5,475 feet tested) is N60oE+15° as indicated by the ultrasonic velocity measurements and point load induced fracturing.

TABLE A-I

EGSP-Virginia #1, Wise County

Directional P Wave Velocities
Average Velocities in km/sec

Depth in Ft	Orientation in Degrees East of North 0°	30°	60°	90°	120°	150°
Cleveland						
4,870'	4.818	4.782	4.782	4.732*	4.766	4.805
4,895'	4.223	4.350	4.463	4.437	4.369	4.196*
4,905'	4.521	4.586	4.393	4.286	4.284*	4.289
4,913'	4.235*	4.610	4.661	4.654	4.539	4.348
4,920'	4.336*	4.490	4.780	4.721	4.576	4.453
4,932'	4.732	4.817	4.741	4.772	4.721	4.714*
Average	4.478	4.606	4.637	4.600	4.543	4.468*
Chagrin						
4,943'	4.639*	4.685	4.728	4.813	4.851	4.833
4,985'	5.027	5.110	5.127-	5.090	4.975*	4.979
4,972'	5.254	5.563	5.701	5.318	5.040	5.024*
4,984'	4.999	5.073	4.918	5.032	5.045	4.817*
Average	4.980	5.108	5.119	5.063	4.978	4.913*
Middle Huron Shale						
5,226'	4.714	4.776	4.860	4.859	4.590	4.506*
5,231'	4.973	5.026	5.011	4.927	4.816*	4.873
5,254'	4.878	4.937	4.915	4.878	4.797*	4.802
5,260'	4.858	4.881	4.904	4.165	3.975*	4.394
5,285'	5.305	5.225	4.790*	4.943	4.913	5.159
5,290'	4.716	4.814	5.032	4.862	4.753	4.575*
5,301'	4.794*	4.858	4.821	4.898	4.886	4.884
5,322'	4.621*	4.667	4.953	5.067	5.000	4.716
5,339'	4.895	4.963	5.008	4.934	4.810	4.760*
5,340'	4.906	5.038	5.090	4.979	4.932	4.844*
5,353'	4.762	4.692	4.610	4.575*	4.698	4.803
Average	4.857	4.898	4.909	4.826	4.743*	4.756
Lower Huron Shale						
5,365'	4.593	4.464	4.725	4.706	4.628	4.297*
5,373'	4.547	4.677	4.684	4.630	4.486*	4.490
5,380'	4.713	4.791	4.800	4.627	4.576*	4.593
5,399'	4.556	4.772	4.847	4.673	4.459*	4.459*
5,403'	4.565	4.626	4.646	4.552	4.520	4.501*
5,412'	5.206	5.104*	5.272	5.260	5.170	5.189
5,422'	4.651	4.792	4.838	4.732	4.732	4.617*
5,432'	4.542	4.671	4.682	4.772	4.438*	4.492
5,441'	4.556	4.900	4.596	4.427	4.305*	4.350
5,451'	4.442	4.800	4.857	4.811	4.423	4.261*
5,460'	4.586	4.830	4.839	4.863	4.753	4.552*
5,743'	4.361	4.648	4.674	4.602	4.337	4.244*
Average	4.610	4.756	4.788	4.721	4.569	4.504*
Well Composite						
	4.713	4.819	4.841	4.775	4.672	4.631*

*Minimum velocity of ten foot interval

Figure A-I

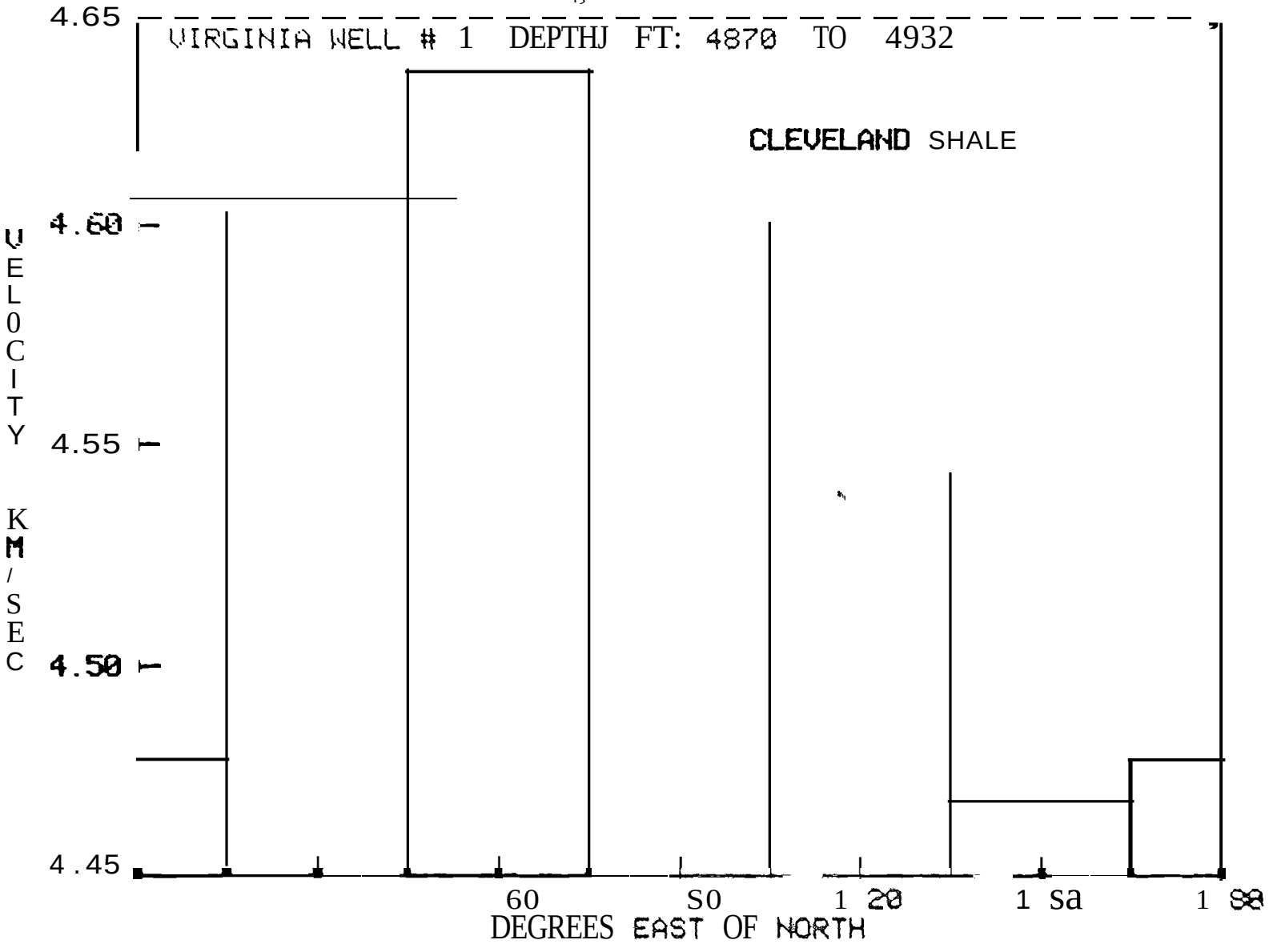

VIRGINIA WELL # 1 DEPTHJ FT: 4870 TO 4932
CLEVELAND SHALE
VELOCITY KM/SEC
4.65
4.60
4.55
4.50
4.45
60
S0
1 20
1 sa
1 S8
DEGREES EAST OF NORTH

Figure A-2

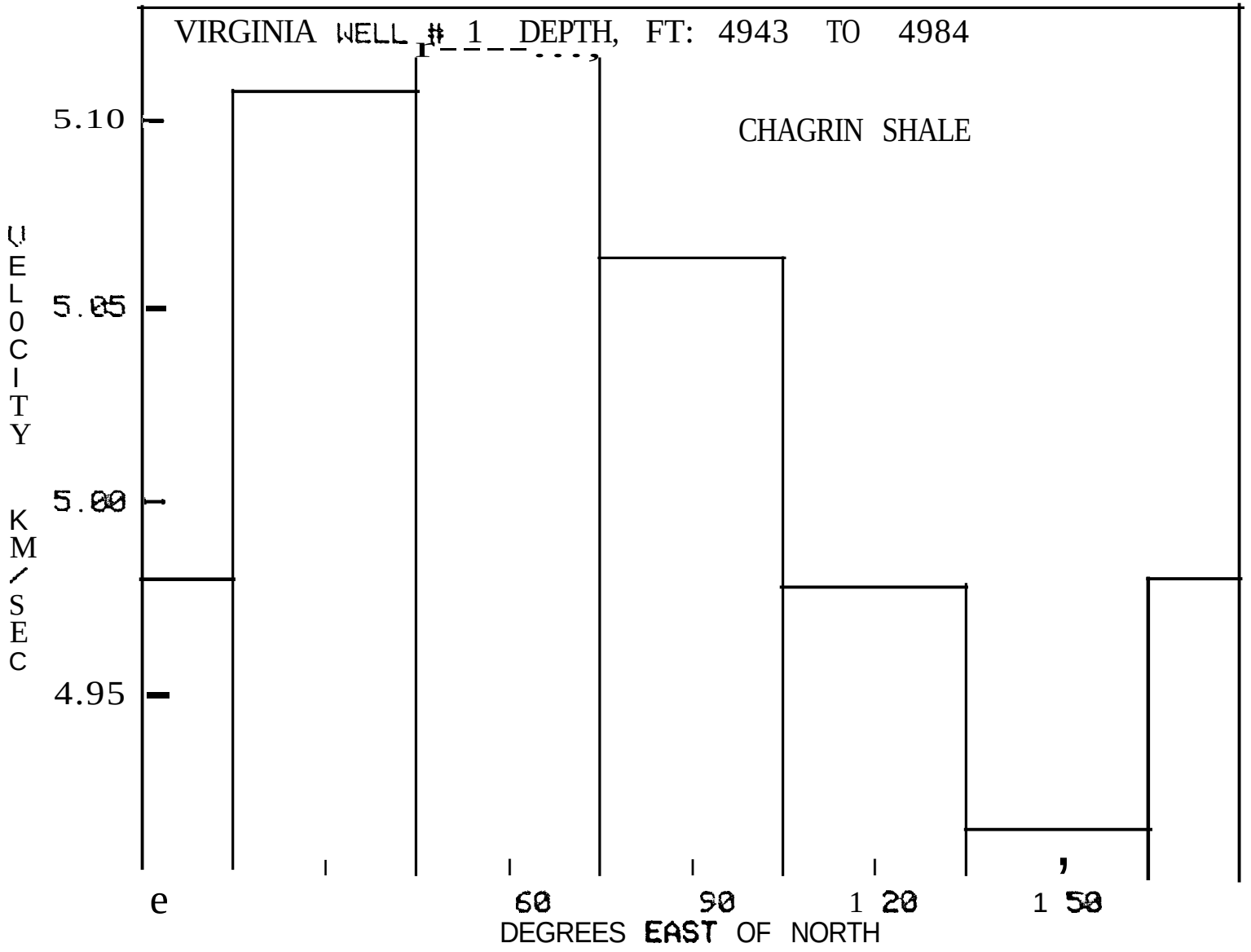

VIRGINIA WELL # 1 DEPTH, FT: 4943 TO 4984
CHAGRIN SHALE
VELOCITY KM/SEC
5.10
5.05
5.00
4.95
e
60
90
1 20
1 50
DEGREES EAST OF NORTH

Figure A-3

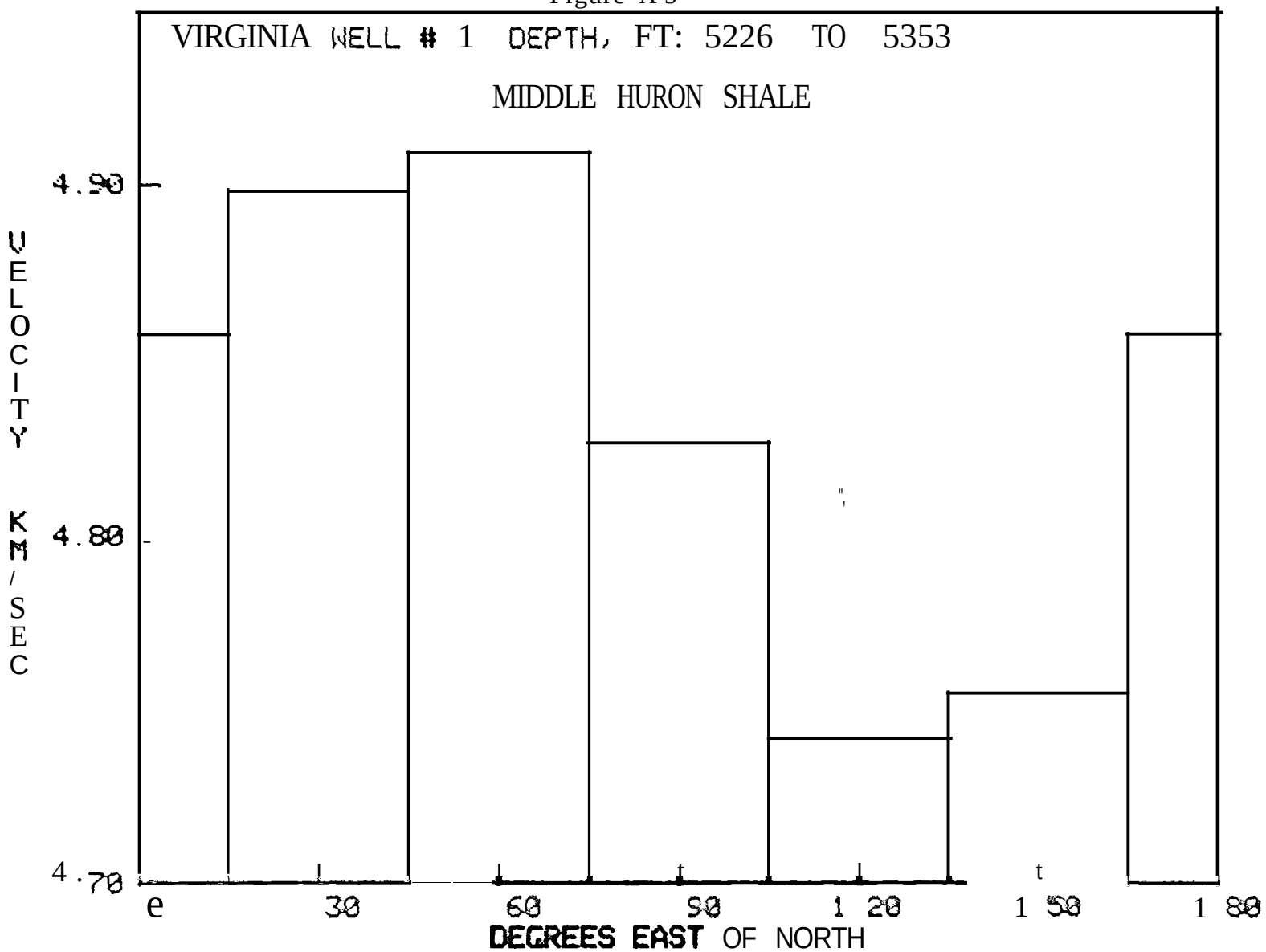

VIRGINIA WELL # 1 DEPTH, FT: 5226 TO 5353
MIDDLE HURON SHALE
VELOCITY KM/SEC
4.90
4.80
4.70
e
30
60
90
1 20
1 50
1 80
DEGREES EAST OF NORTH

Figure A-4

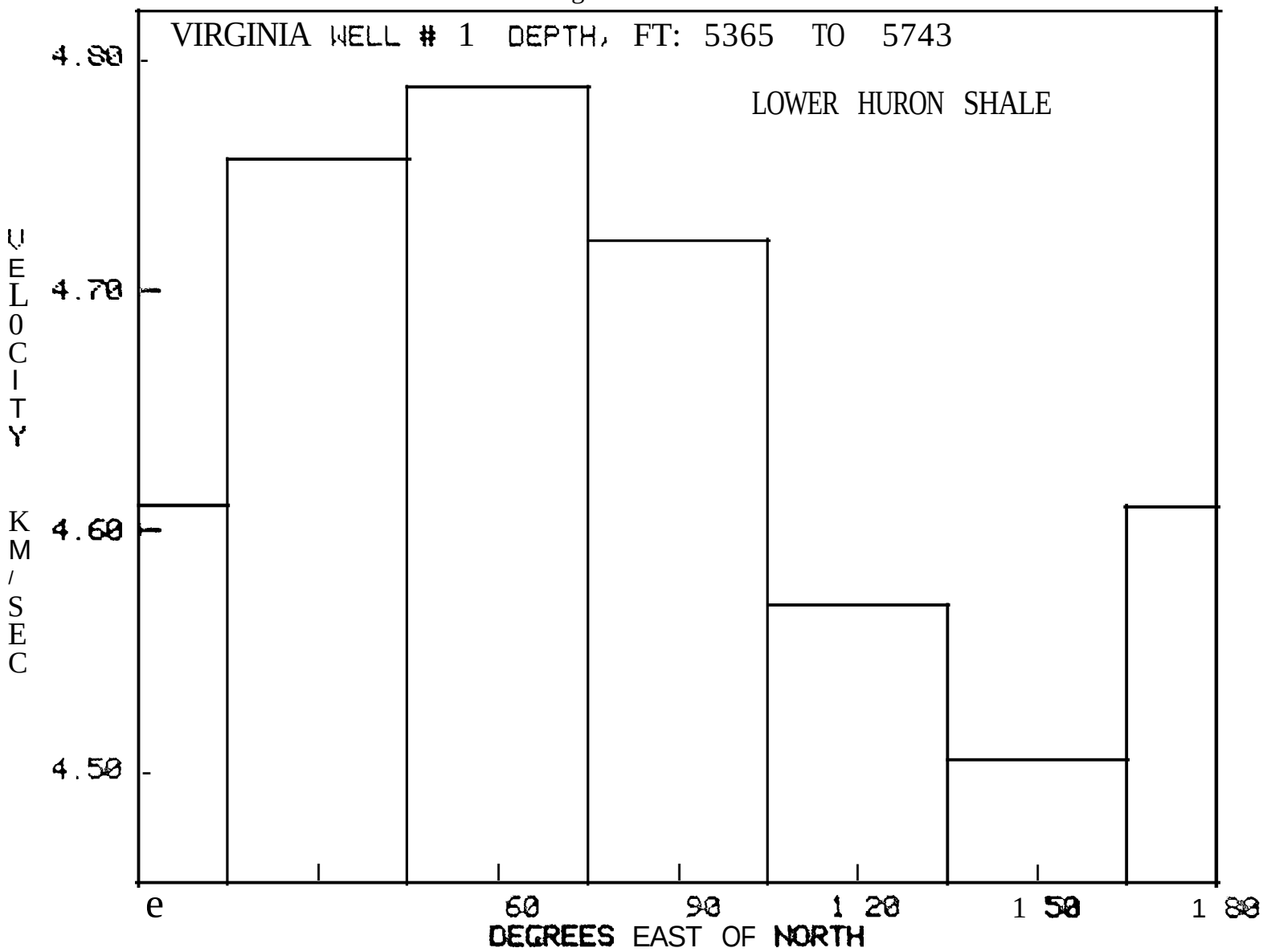

VIRGINIA WELL # 1 DEPTH, FT: 5365 TO 5743
LOWER HURON SHALE
VELOCITY KM/SEC
4.80
4.70
4.60
4.50
e
60
90
1 20
1 50
1 80
DEGREES EAST OF NORTH

Figure A-S

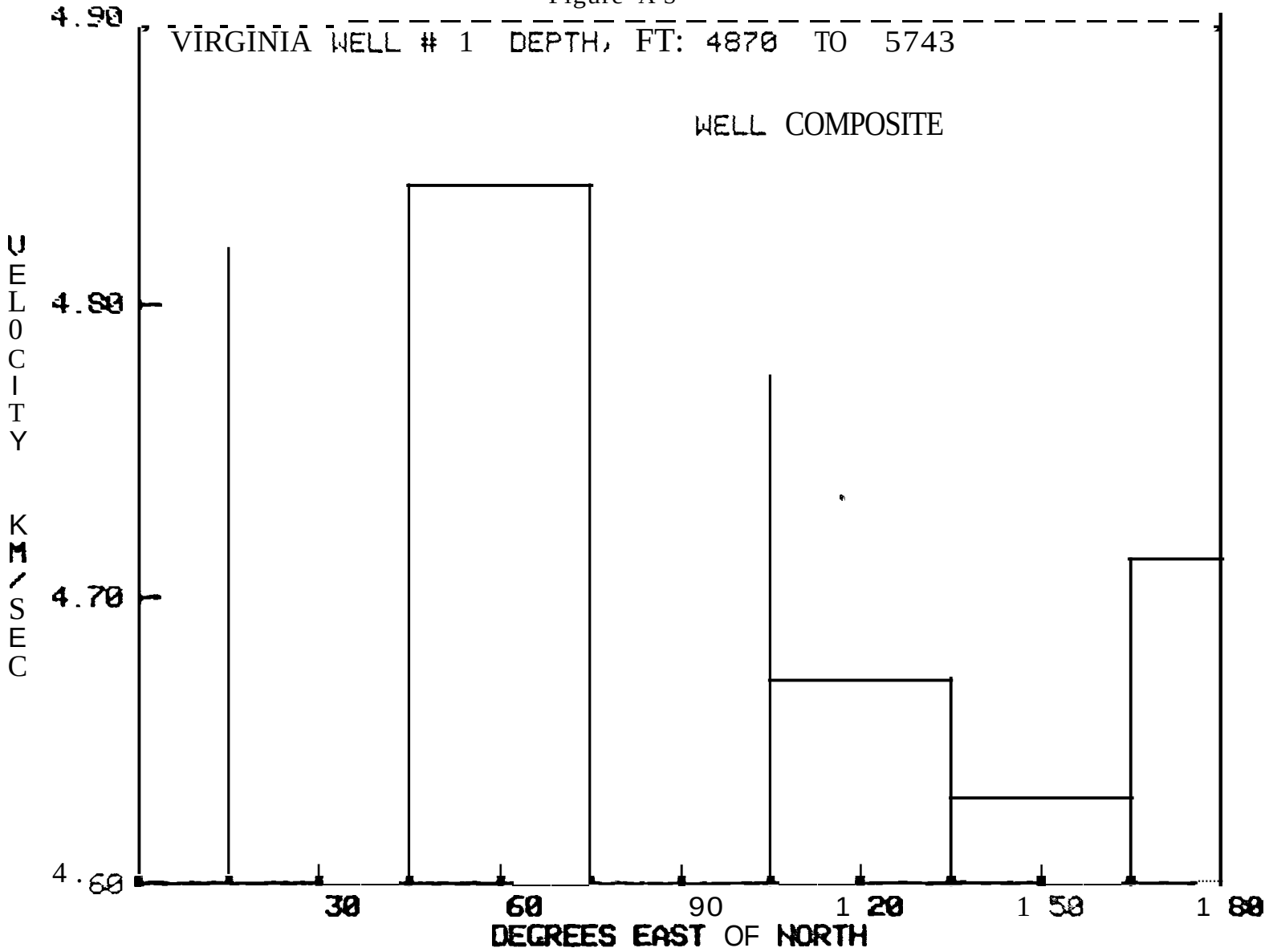

VIRGINIA WELL # 1 DEPTH, FT: 4870 TO 5743
WELL COMPOSITE
VELOCITY KM/SEC
4.90
4.80
4.70
4.60
30
60
90
120
150
180
DEGREES EAST OF NORTH

TABLE B-1

EGSP-Virginia #1, Wise County

Frequency of Fractures Induced by Point Load
Depth is Midpoint of 10 ft. Interval

Depth in Ft.	Orientation in Degrees East of North 0°	30°	60°	90°	120°	150°	Total
Cleveland							
4,875'		3	2	2			7
4,885'	1		4	1		1	7
4,895'	1		8	1		1	11
4,905'		2	2	3	2		9
4,915'	2	1	4	1			8
4,925'	1		3	2			6
4,935'	3	2	1		1	1	8
Total	8	8	24	10	3	3	56
Chagrin							
4,945'	2		2		3		7
4,955'	1	1	1	2			5
4,961.9'		1					1
4,970.7-1.9	1	1				1	3
4,984.0			1				1
Total	4	3	4	2	3	1	17
Middle Huron Shale							
5,235'		2			1		3
5,245'			1	1			2
5,255'	1	1	1			1	4
5,265'		2	1	1			4
5,275'		1	2	1	1	4	9
5,285'		2					2
5,295'	2	1	4	2	1		10
5,305'			1	1	1	2	5
5,315'	1			1		1	3
5,325'	1		1	1		1	4
5,335'			2				2
5,340'	1		2		1		4
5,353'	1						1
Total	7	9	15	8	5	9	53
Lower Huron Shale							
5,365'	2		1		1		4
5,375'		2	2				4
5,385'	2			1			3
5,398'			1				1
5,405'	1		1	2			4
5,415'		2	3		2		7
5,425'	4	3	1	3		1	12
5,435'		1	3	3			7
5,445'		3			1	1	5
5,465'	2	2			1	2	7
5,475'	2		3	1			6
Total	13	13	15	10	5	4	60
Well Composite Total	32	33	58	30	16	17	186

TABLE C-1

EGSP-Virginia #1, Wise County

Directional Tensile Strengths
Tensile Strength in psi

Depth in Feet	Load Axis in Degrees East of North 0°	30°	60°	90°	120°	150°
Cleveland						
4,875'	425*	471	578	558	568	1,651
4,885'	660	500	705	267*	300	660
4,895'	765	919	976	1,489	558*	1,237
4,905'	722	693	544*	733	847	657
4,915'	951	429	888	781	377*	842
4,925'	706	282*	546	857	1,000	1,208
4,935'	844	831	654	1,260	325*	1,704
Average	725	589	699	849	568*	1,137
Chagrin						
4,945'	1,112	1,190	1,290	514*	895	1,220
4,955'	1,380	891*	1,117	1,126	1,352	1,322
4,965'	636	960	715	791	1,225	529*
Average	1,043	1,014	1,041	810*	1,157	1,024
Middle Huron Shale						
5,245'	511*	711	927	838	790	399
5,265'	795	596*	712	953	730	753
5,275'	724	746	842	691*	739	977
5,285'	907	753	582*	767	859	946
5,295'	1,266	801	722	620*	823	761
5,305'	771	737	629	687	601*	810
Average	829	724*	736	760	757	774
Lower Huron Shale						
5,365'	637	395*	1,142	1,174	896	836
5,375'	940	916	243*	972	668	
5,405'	589*	722	865	947	795	714
5,415'	927	869	935	857	364*	614
5,425'	267*	682	966	1,319	761	786,684
5,435'	931	912	1,054	656*	964	922
5,445'	910	946	943	939	782	253*
5,455'	772	1,014	786	247*	841	806
5,465'	323*	620	1,002		533	800
Average	700*	786	882	790	734	713
Well Composite	779	743*	815	802	744	884

*Minimum strength for ten foot interval in Load Axis Orientation; the tensile strenth calculated is for the orientation perpendicular the load axis.

Figure C-l

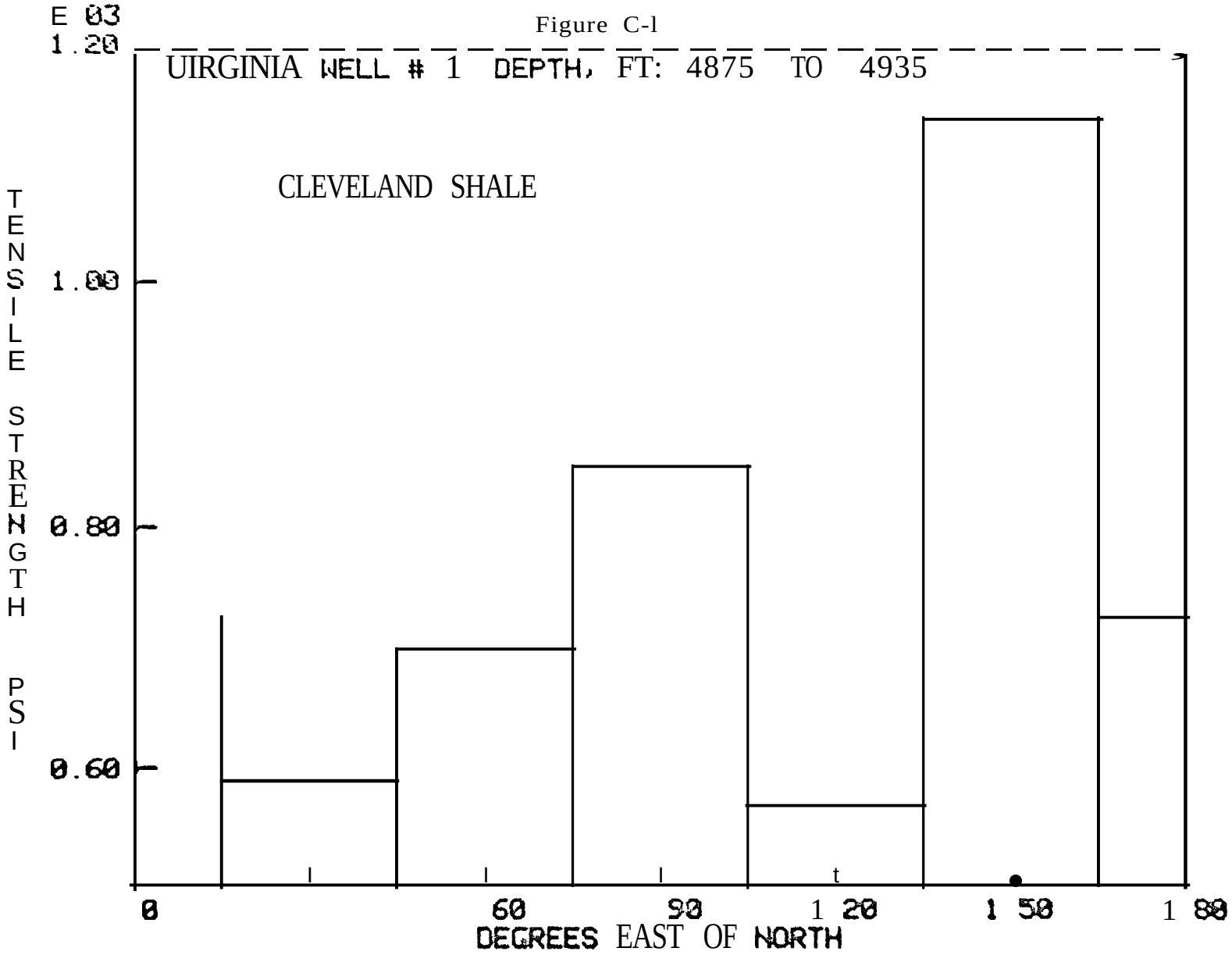

E 03
1.20
UIRGINIA WELL # 1 DEPTH, FT: 4875 TO 4935
CLEVELAND SHALE
TENSILE STRENGTH PSI
1.00
0.80
0.60
0
60
90
1 20
1 50
1 80
DEGREES EAST OF NORTH

Figure C-2

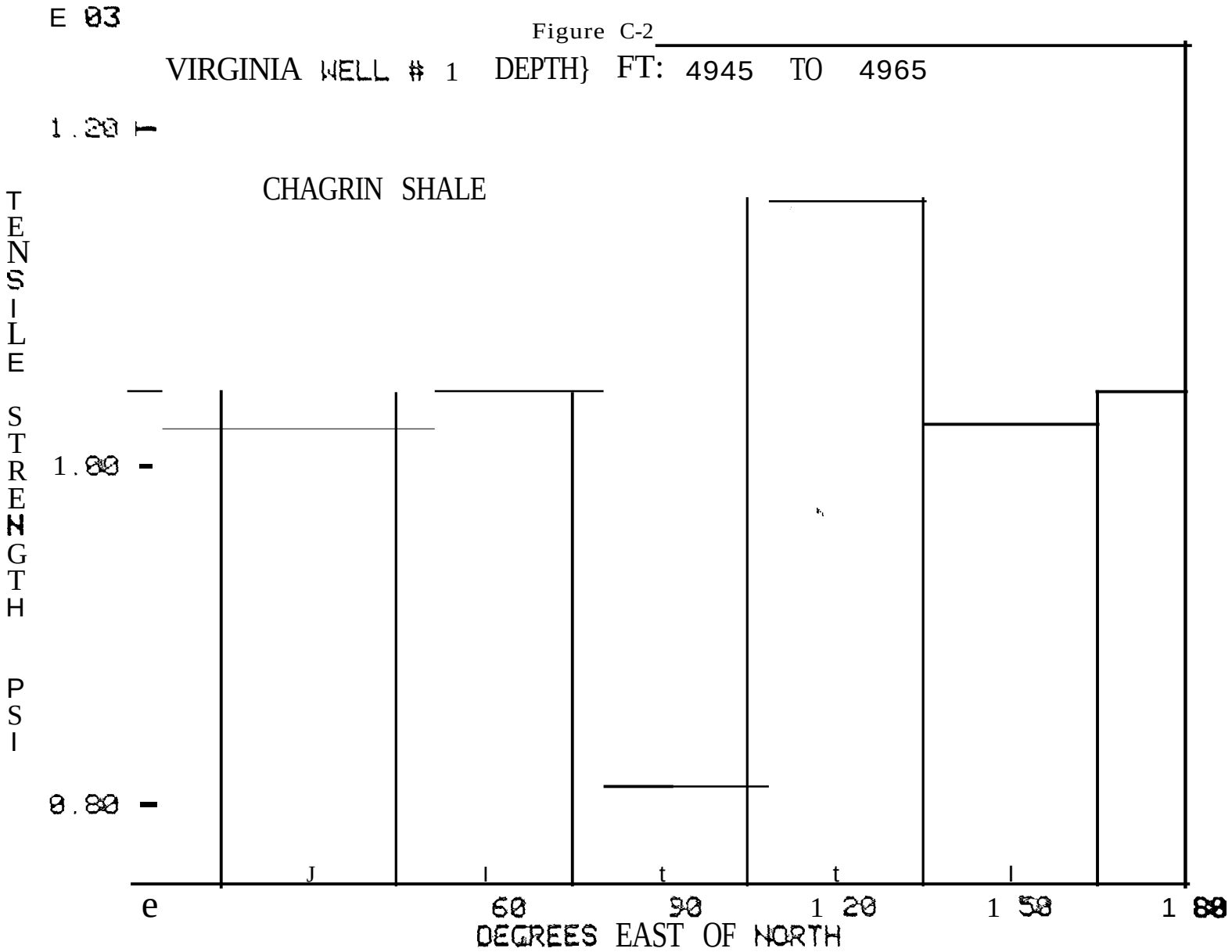

E 03
VIRGINIA WELL # 1 DEPTH} FT: 4945 TO 4965
1.20
CHAGRIN SHALE
TENSILE STRENGTH PSI
1.00
0.80
J
I
t
t
I
e
60
90
1 20
1 50
1 80
DEGREES EAST OF NORTH

Figure C-3

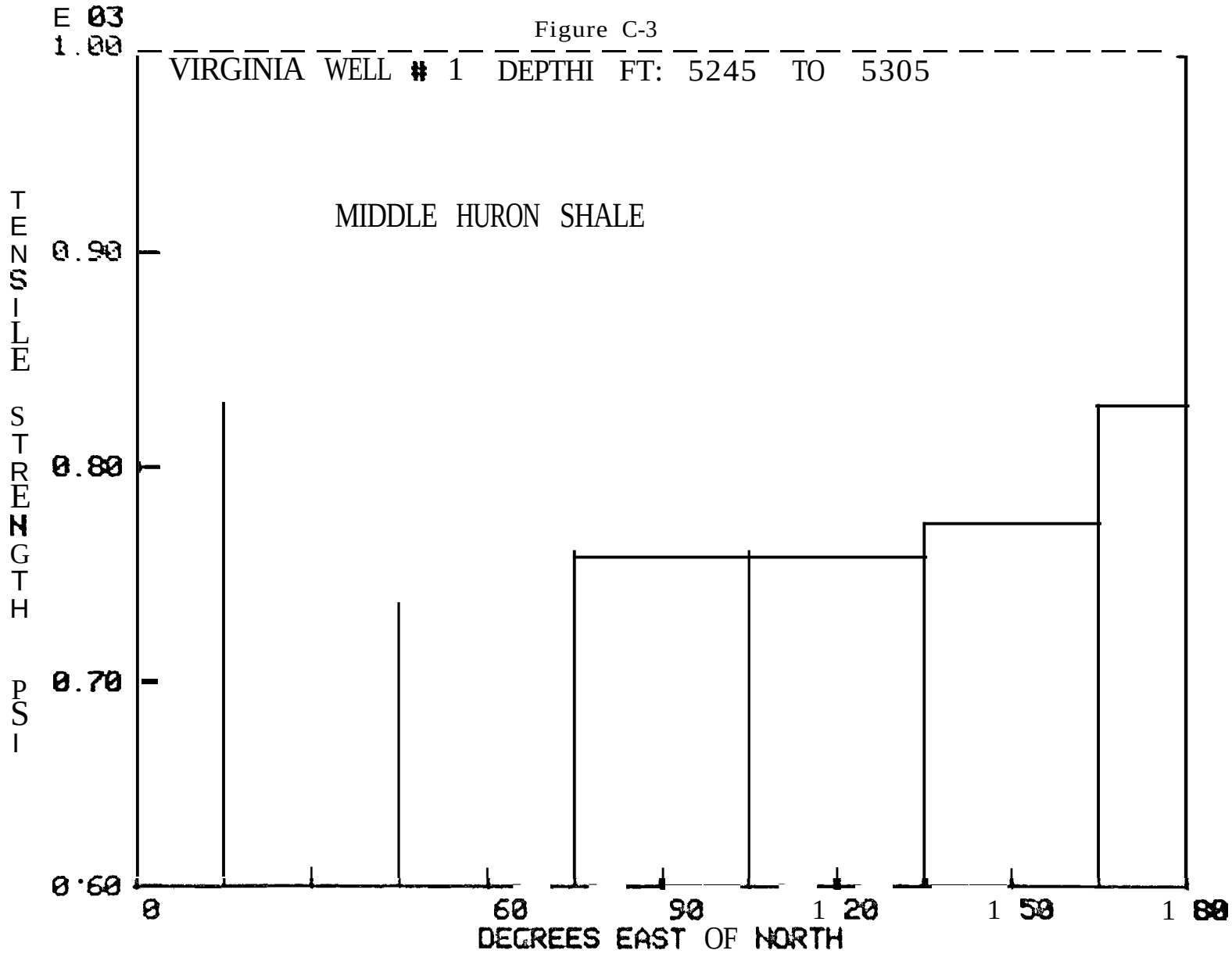

E 03
1.00
VIRGINIA WELL # 1 DEPTHI FT: 5245 TO 5305
MIDDLE HURON SHALE
TENSILE STRENGTH PSI
0.90
0.80
0.70
0.60
0
60
90
120
150
180
DEGREES EAST OF NORTH

Figure C-4

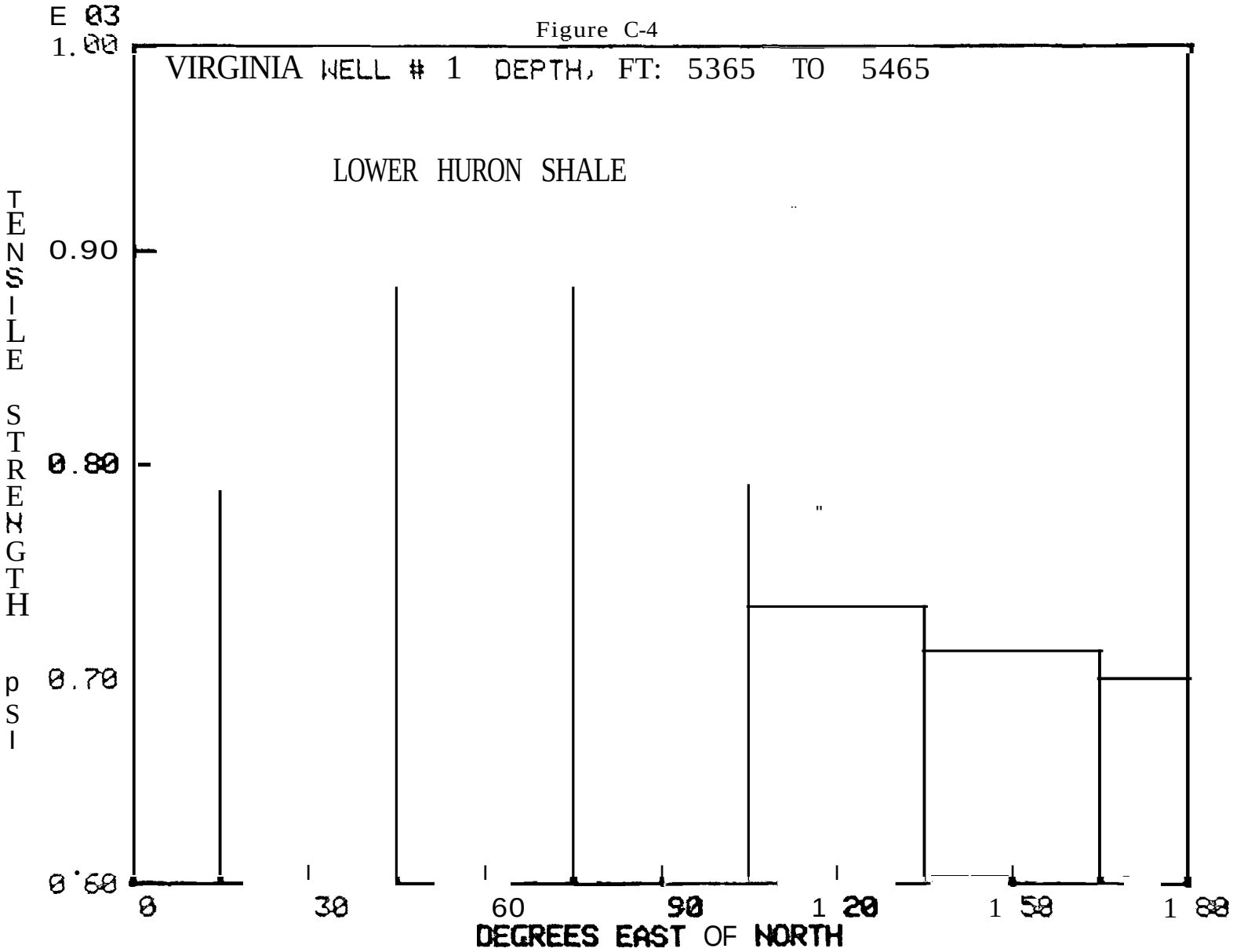
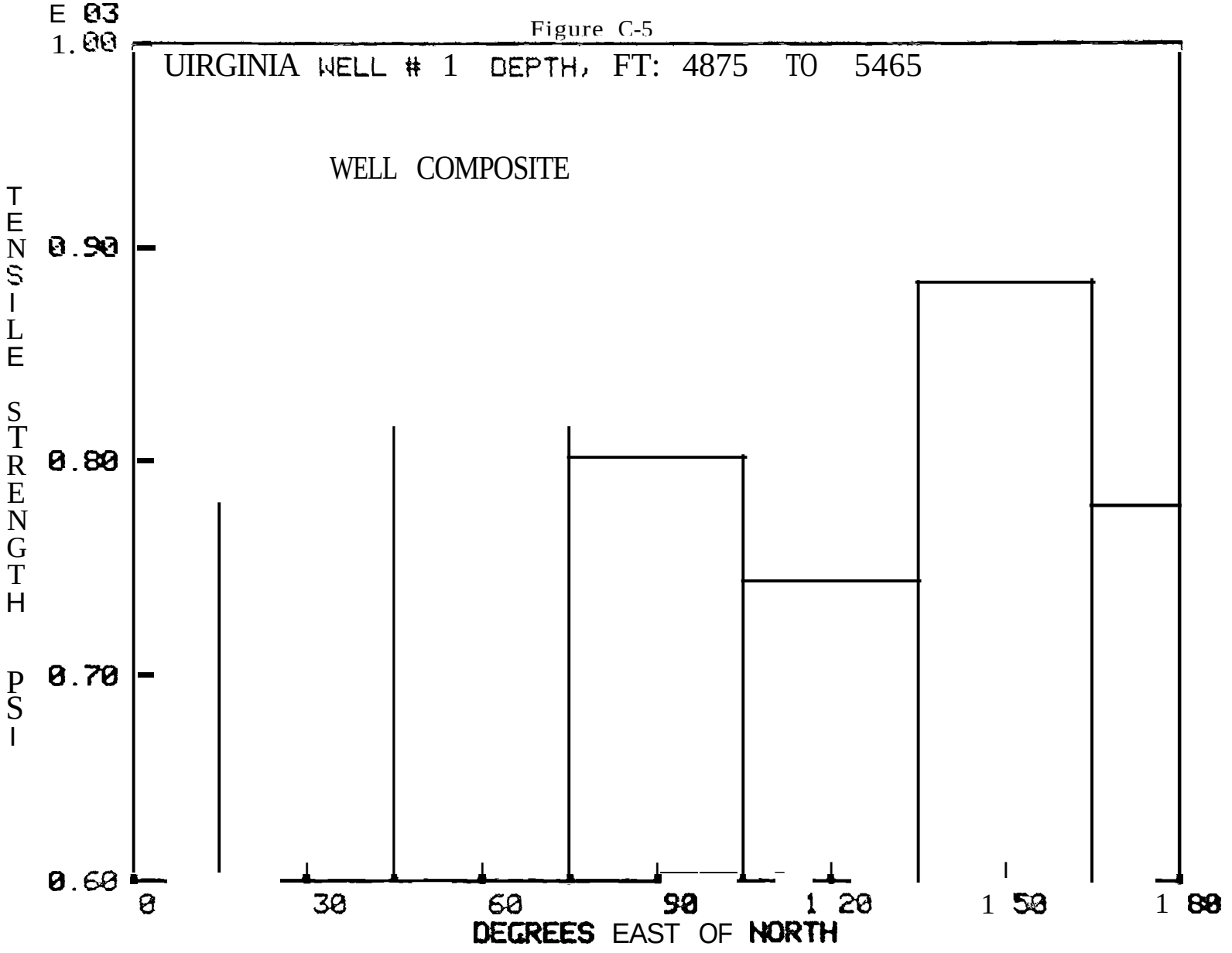

E 03
1.00
VIRGINIA WELL # 1 DEPTH, FT: 5365 TO 5465
LOWER HURON SHALE
TENSILE STRENGTH psi
0.90
0.80
0.70
0.60
0
30
60
90
120
150
180
DEGREES EAST OF NORTH

Figure C-5


E 03
1.00
UIRGINIA WELL # 1 DEPTH, FT: 4875 TO 5465
WELL COMPOSITE
TENSILE STRENGTH PSI
0.90
0.80
0.70
0.60
0
30
60
90
1 20
1 50
1 80
DEGREES EAST OF NORTH