(Champaign County, Ohio)

by

Christena Marie Harvey

The Ohio State University

May 31, 1978

Submitted as partial requirement for the
Degree of Bachelor of Science in Geology and Mineralogy

Approved by

Helen C. Voltmier

Advisor
Department of Geology & Mineralogy

Acknowledgements

Without the help of these people, this thesis would not have been possible. My thanks go to them:

Mr. John W. Harvey who expertly wielded the hammer and provided a helping hand when needed.

Dr. Hal Noltimier for his invaluable assistance and guidance.

Mr. Bob Alberts of the American Aggregates Corporation for the permission to use the quarry, and all the help and information he provided.

Dr. Richard Goldthwait for his assistance in choosing a location for the survey.

Table of Contents

A SHALLOW SEISMIC SURVEY OF THE CABLE GRAVEL PIT
(Champaign County, Ohio)

Location

The survey was conducted in the Cable Gravel Pit in Champaign County, Ohio. The quarry is owned by the American Aggregates Corporation and is located along State Route 290 in Range 12, Township 6.

Introduction

The climate of Champaign County is a humid-temperate, continental type. The average annual precipitation is about 38 inches (Soil Survey, 1971). The field work was delayed several times due to heavy rains and had to be postponed several weeks because of snow and severe winter weather. The instrument cannot be operated effectively when the ground is frozen or snow covered.

Champaign County lies completely within the glaciated section of Ohio. Two wide bands of morainal deposits cross the county in a north-south direction (Soil Survey, 1971). The Cable Gravel Pit is situated on the eastern belt, more precisely on the Cable Moraine. Most of the county is covered by a thick layer of glacial drift and topographic relief is not significantly influenced by bedrock. The surface deposits are considered to be of "late" Wisconsin age, associated with the 18,000 year old terminal Wisconsin advance (Goldthwait, 1959, p. 199).

Silurian rocks consisting of limestones, dolomites, and thin shales, make up the bedrock surface of most of the country. These

shales and limestones represent the southern-most limit of the Bellefontaine Outlier (Quinn, 1972, p. 11). The Bellefontaine Outlier is a bedrock high, in Logan County to the north, which caused the ice to split into two lobes.

Purpose

The purpose of this thesis was to obtain a subsurface profile of the Cable Gravel Pit from a seismic survey. The results were checked against exposures and auger drill data furnished by the American Aggregates Corporation.

Equipment

The instrument used for the survey was a Soiltest MD-9 Refraction Seismograph. The equipment consists of a seismograph, two geophones, amplifier, sledge hammer, strike plate, and the connecting cables. Two people are required to operate the seismograph; one to hit the strike plate with the sledge hammer, and another to operate the instrument and record the results.

Instrument Set-Up and Operation

When the area for the survey or "line" is decided upon the instrument is set up (Figure 1). The recording geophone is pressed into the ground near the seismograph and connected by a cable to the instrument. A length of measuring tape is laid out in a straight line. Along this the second geophone, which triggers the timing circuit, the amplifier and the strike plate are moved by five foot intervals. This geophone is connected to the instrument by a long length of cable. A geophone is a type of microphone devised to "listen" to small ground vibrations in the earth (Sharma, 1976).

The seismic waves are produced by the impact of the sledge hammer on the strike plate. The wave or signal travels a short distance along the surface to the trigger geophone and through the ground as well as along the surface to the recording geophone.

The MD-9 Seismograph shows a waveform on a small cathode ray tube and is equipped with a memory. Successive hammer blows can therefore be recorded and the waves added to produce a better waveform display. A sufficient summed wave is usually produced with an average of five or six hammer blows. After a good waveform has been summed, an electronic marker is moved along the display waveform to the positive rises of the signal waveform. A digital display shows the time intervals in milliseconds for the shock waves to travel to the recording geophone. The arrival times of the successive positive peaks are recorded and the strike plate and trigger geophone are moved an additional five feet and the procedure is repeated.

The waveform on the CRT represents the transit time intervals of the seismic waves between two reference points (strike point or trigger geophone and receiver geophone) from the surface and subsurface.

Theoretical Background

The object of a seismic survey is to correlate the arrival times of a seismic wave with the earth's underlying structure. Using the two basic principles of seismology; reflection and refraction, and the effects of layers of different velocities it is possible to infer the underlying structure.

When the sound wave generated by the sledge hammer strikes a layer interface at an angle less than its critical angle, the wave will be

reflected back up to the surface (Figure 2). After the critical angle has been reached, the wave will be refracted into the lower layer and along the layer interface (Figure 3). At greater distances the instrument is receiving three types of waves: the surface wave, the reflected wave, and the refracted wave. As the length of the survey is increased, the seismic waves can travel to greater depths. With a hammer there is a limit to the depth obtainable. For greater depths, small explosive charges are used. When the critical angle is exceeded, the wave will travel along the layer interface and providing that the lower layer has a higher velocity than the overlying layer, the wave will be accelerated and reach the receiver geophone before the reflected wave traveling through the slower upper layer. Figure 4 is a plot of a seismic problem involving three layers of increasing velocity. Notice the ray representing the faster third layer arrives before the rays for layers one and two, after a certain lateral distance between source and receiver has been exceeded.

A great disadvantage of the seismic refraction method is that it is "blind" to low velocity layers located in between two layers of relatively higher velocity. Low velocity layers will usually appear as an exaggerated thickness of the overlying layer (Figure 5). The exaggeration is a function of the thickness of the low velocity layer and the velocity contrast. Also, the "invisible" low velocity layer makes the depth value computed too shallow (Sharma, 1976).

The depth to a layer interface can be determined from the "break point" distance and the velocities of the two layers (Figure 4). The "break point" distance is the lateral distance from the source, where the ray for the lower layer intersects the ray representing the overlying layer.

$$d = \frac{X_b}{2}\sqrt{\frac{V_2-V_1}{V_2+V_1}} \qquad \text{Equation 1}$$

In this equation d equals the depth to the interface, X_b equals the "break point" distance, V_2 is the velocity of the lower layer, and V_1 is the velocity for the overlying layer.

The velocity is obtained by dividing the distance in feet from the instrument to the strike point by the transit time in seconds. Velocity can also be thought of as the inverse of the line slope, which results from plotting on the vertical axis the arrival times at the five foot intervals, with distance on the horizontal axis.

Quarry Description

The particular location for this survey was chosen with the assistance of Dr, Richard P. Goldthwait, because it was believed no low velocity layers were present. This simplifies the interpretations greatly.

The quarry is long and narrow and most of the western floor was underwater. Due to heavy snow and rainfall before and during the survey, the water level was very high, causing some problems during the latter stages of the field work because major portions of the quarry floor were submerged. The quarry walls were badly slumped and overgrown, but there were a few good exposures that could be used as a check of the seismic data. Figure 6 is a map of the quarry with the locations of the survey lines indicated.

Interpretations

Lines were run on the top, floor and at various other levels in the quarry. Elevation differences were recorded for all positions with reference to the quarry rim and when possible the exposed top of the limestone. Elevation differences were obtained with a Brunton compass

and clinometer.

The first "line" was run on the northwest top surface of the quarry. I will use it as an example of how the information was interpreted. After the arrival time-distance data was plotted, three trends were observed on the graph. The most representative straight line is drawn through a trend and the inverse slop of this line is the velocity of the layer. The depths to the layer can be calculated using Equation 1.

The velocities are used to interpret the underlying structure by comparison with a table of typical velocities for different rock types (Table 1).

The first layer of this survey had a velocity of 600 feet/sec. and was interpreted as soil with a thickness of 3.2 feet. The second layer, with a velocity of 1136 feet/sec., and a thickness of 2.8 feet was interpreted as a mixture of gravel, sand and soil. The third layer had a typical limestone velocity of 15,000 fee/sec. The limestone layer here seems to occur at an unusually shallow depth. There were no available exposures to check the results against and no auger drill results in the immediate area of the survey line. Several factors may assist in explaining this anomalous depth. First of all, the bedrock contours on the auger test results map (Figure 13) show a bedrock valley extending through the quarry area. The first survey appears to be on a slight bedrock ridge. Also the bedrock has a regional dip to the south-east of between 2 - 5°. The dip was difficult to measure due to irregularities of the exposed limestone surface.

The first survey was a simple problem of three layers with increasing velocity with depth. All the other survey interpretations have been represented in a cross sectional form (Figure 7).

The second survey (Figure 8-2) illustrates the important idea of multiple reflections. The lines with velocities of 3200 f.p.s. and 2272 f.p.s. are multiples of the 4714.3 f.p.s. line which represents limestone. This is caused by the seismic wave undergoing one or more additional reflections either from the surface or from a lower interface (Sharma, 1976). Figure 9 illustrates this.

The fourth and ninth survey lines were difficult to interpret; low velocity layers of till or sand may be present under the gravel. On the graphs of these surveys (Figures 8-4, 8-9) the three higher velocity lines are not multiples of the gravel layers; therefore, a low velocity layer is a possible explanation for this pattern.

Conclusions

The geology of the Cable Gravel Pit is basically three layers of increasing velocity with depth. The layers are comprised of soil and till, gravel, and limestone. Any low velocity layers are very localized. The seismic data was checked wherever possible with exposures. A map with the American Aggregates Corporation's auger test drill results has been included. Figure 14 shows the generalized auger drill results in the areas of the survey lines. Auger drill data was available only for the southern portion of the quarry; therefore comparison was difficult for survey lines 1, 2, 3, 10, and 11. From Figure 13 the bedrock contours clearly show the bedrock valley which is the major cause for the difference in the limestone elevations observed.

Figure 1 - Layout of Field Equipment

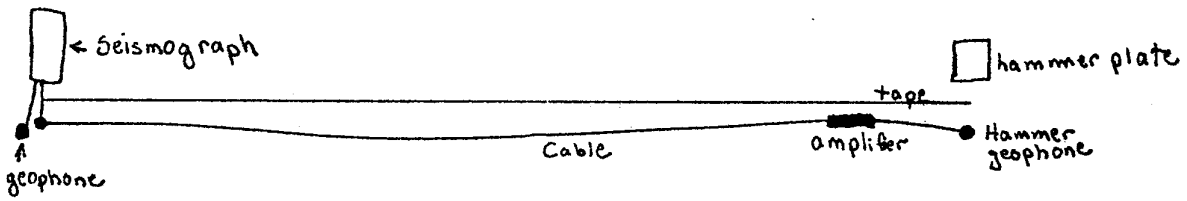
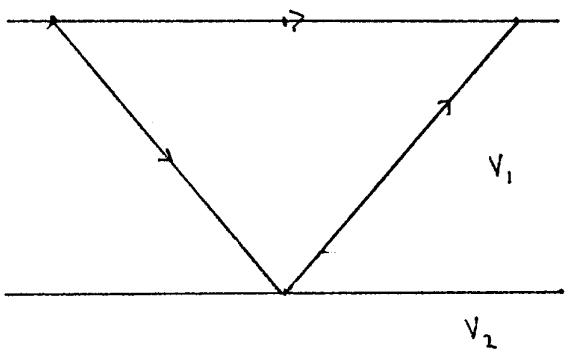
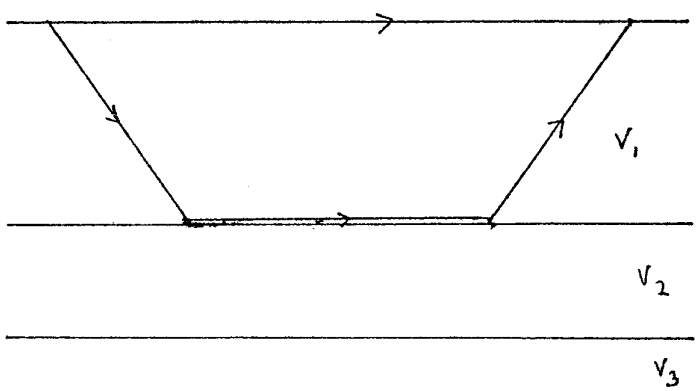


Figure 2: Path of Reflected Ray



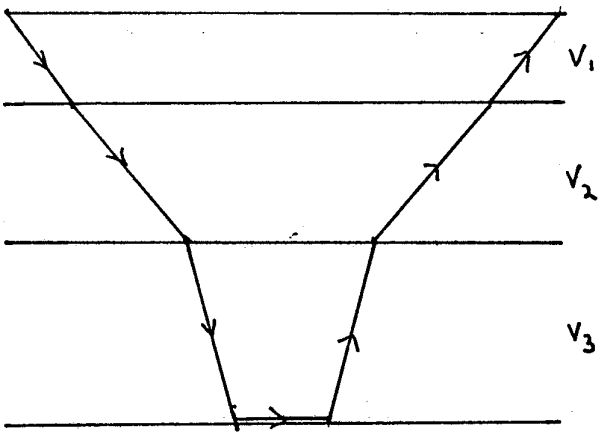
$V_1 < V_2$

Figure 3 Refracted Ray

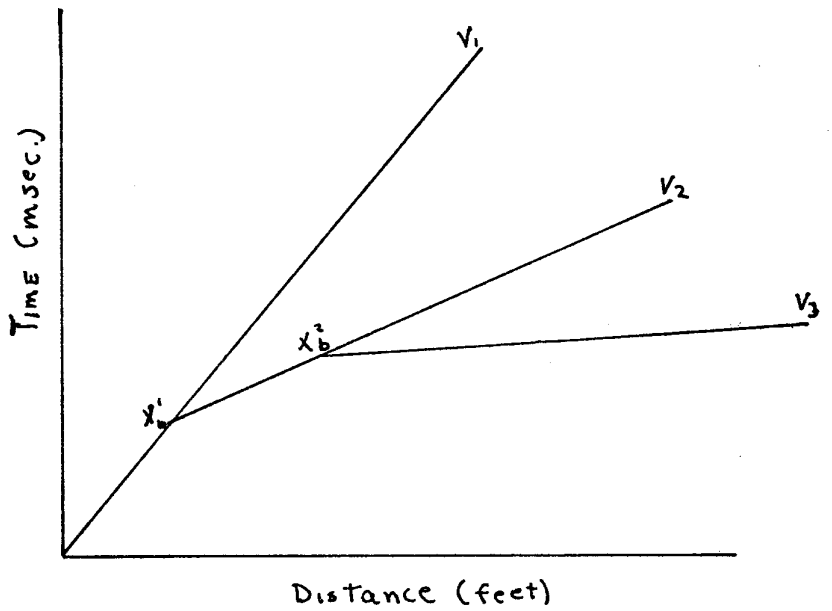


$V_1 < V_2 < V_3$

Figure 4

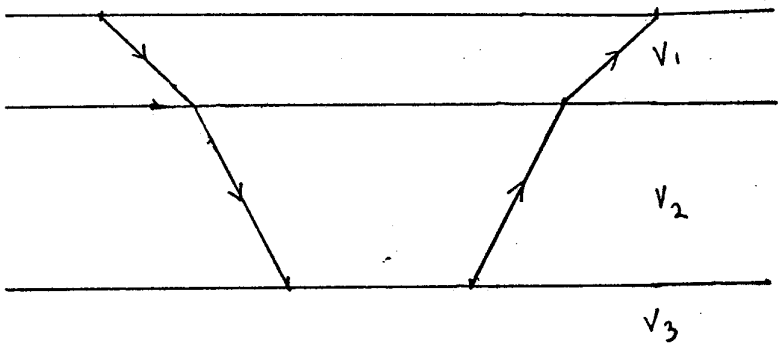


$V_1 < V_2 < V_3$



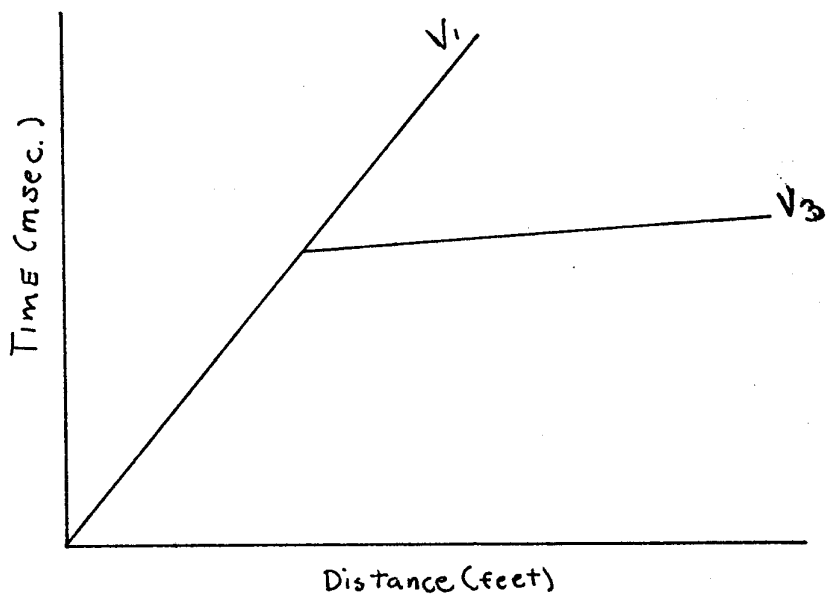
(Three Layer Seismic Problem - Layers of increasing velocity)

Figure 5



$V_1 > V_2, V_3 > V_1$

Seismic Problem, with a low velocity Layer



1" = 8'

0'

8'

Figure 7-1
No1 Top on N-W Side

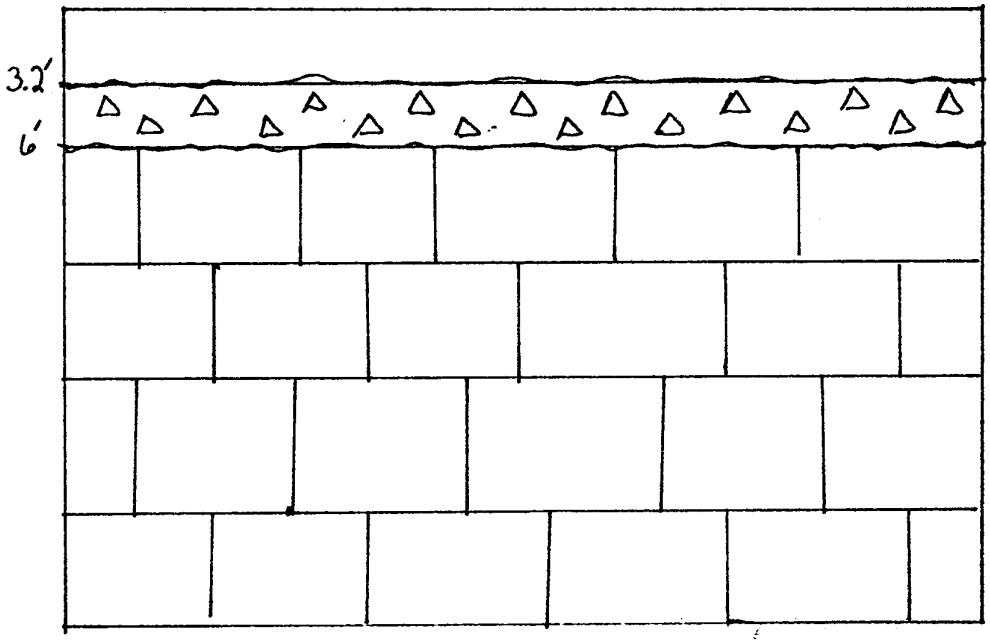
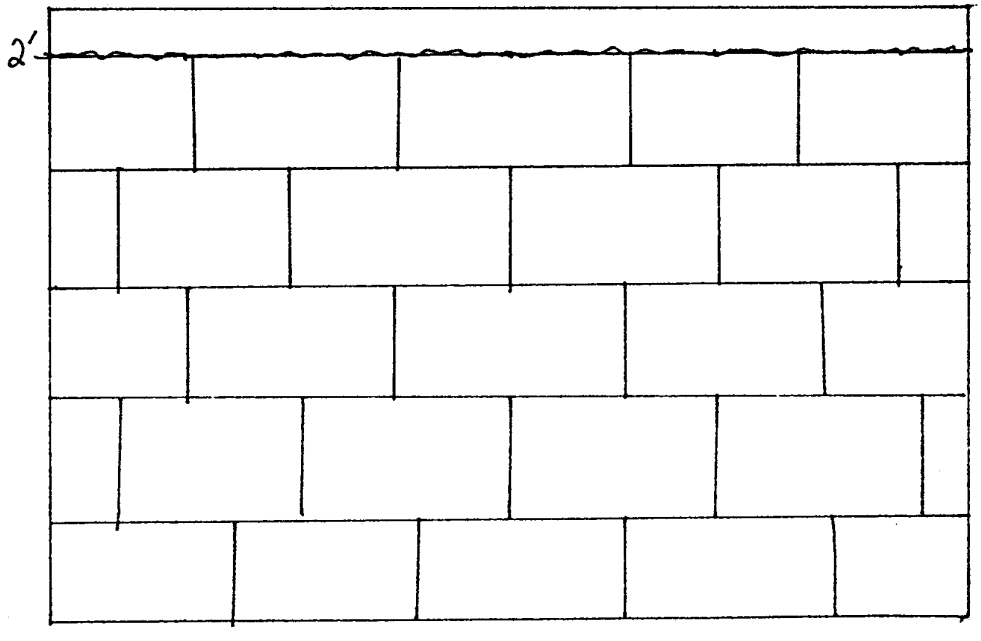


Fig. 7-2
No. 2 Floor of Quarry at N. end of Water



1" = 8'

0'

8'

Fig. 7-3

No. 3 Floor of Quarry Near Water Table

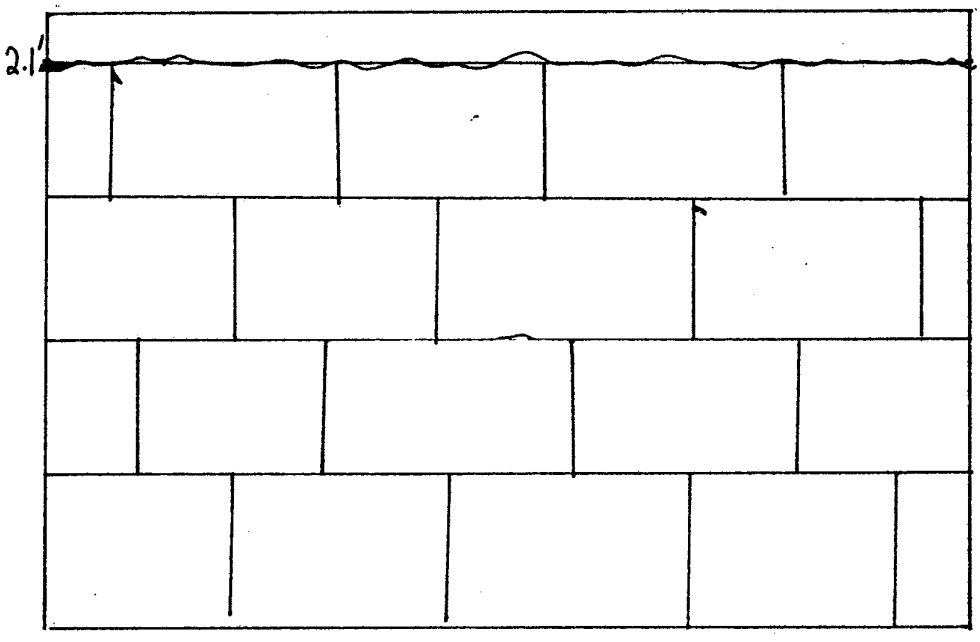
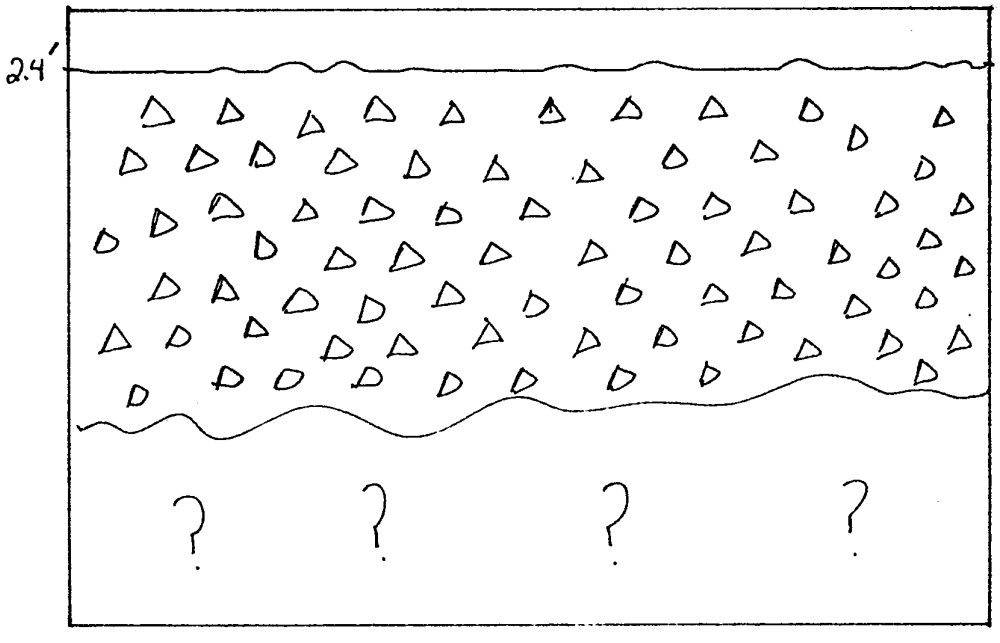


Fig. 7-4-

No. 4 Top of Quarry S-E Side



1" = 8'
0'
8'

Fig. 7-5

No. 5 On Ledge Below No. 4

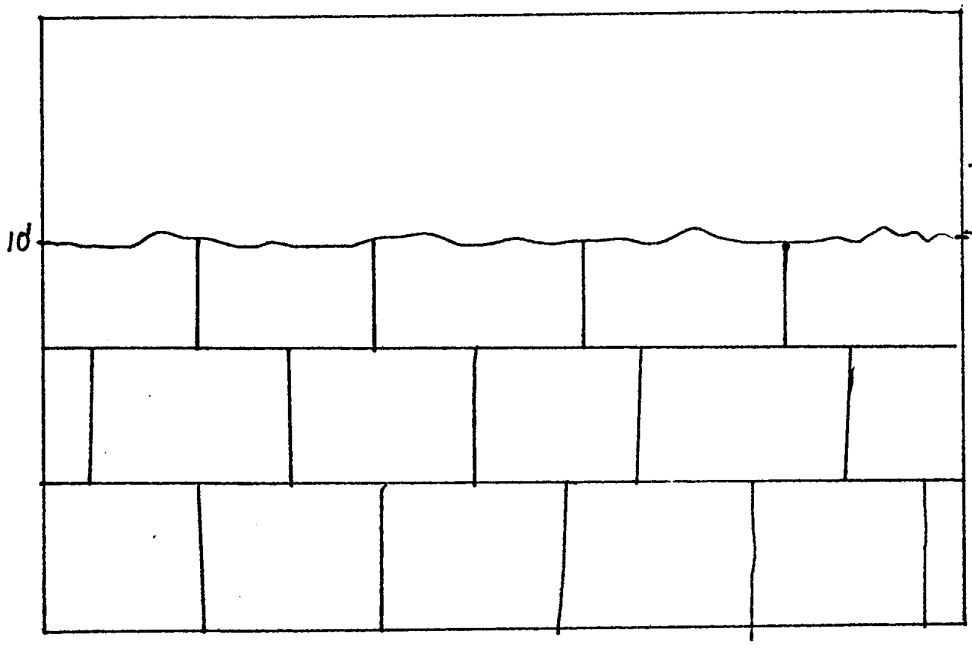
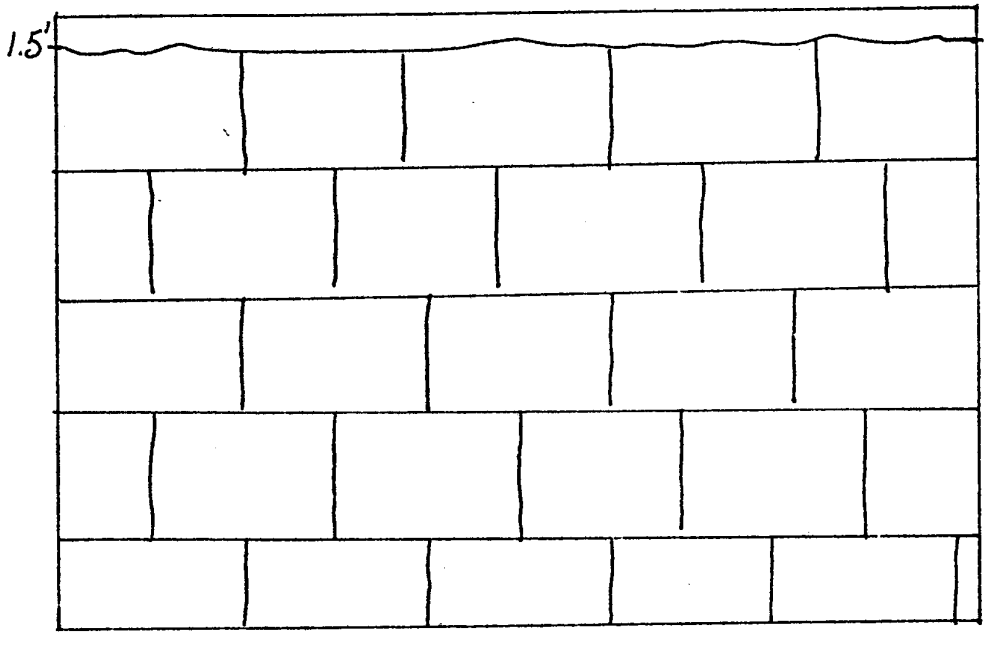


Fig. 7-6

No. 6 Near Quarry Floor Level of Limestone



1" = 8'

0'

8'

Fig. 7-7

No. 7 South Floor of Quarry Near Water

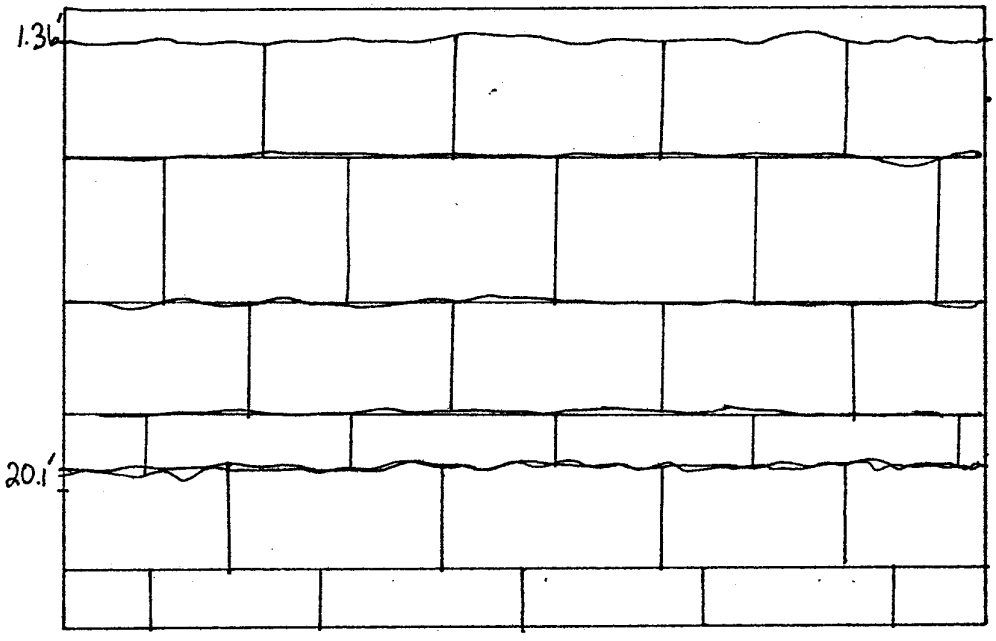
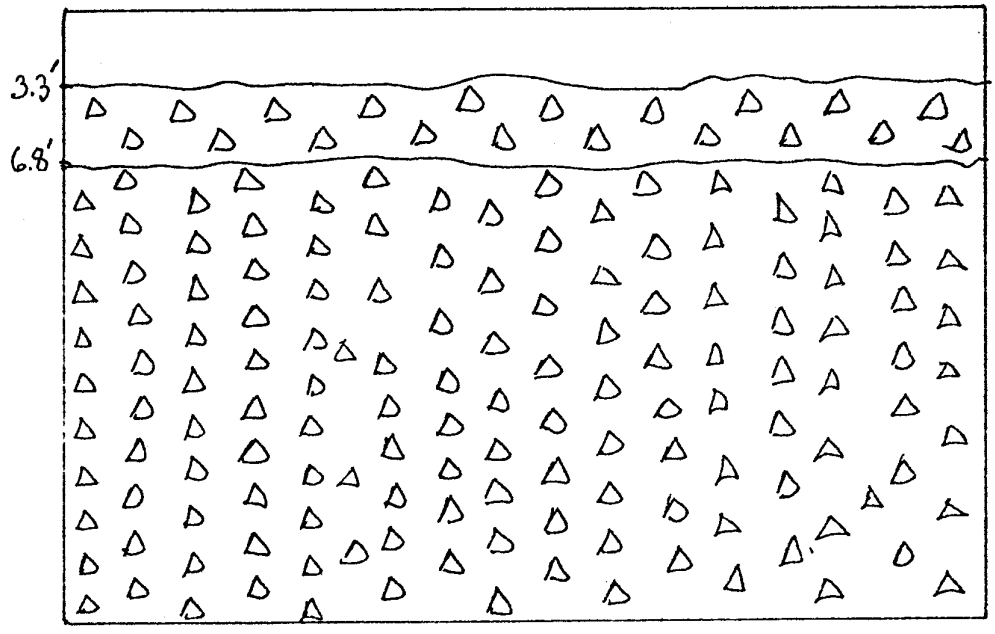


Fig. 7-8

No. 8 Top of South End of Quarry



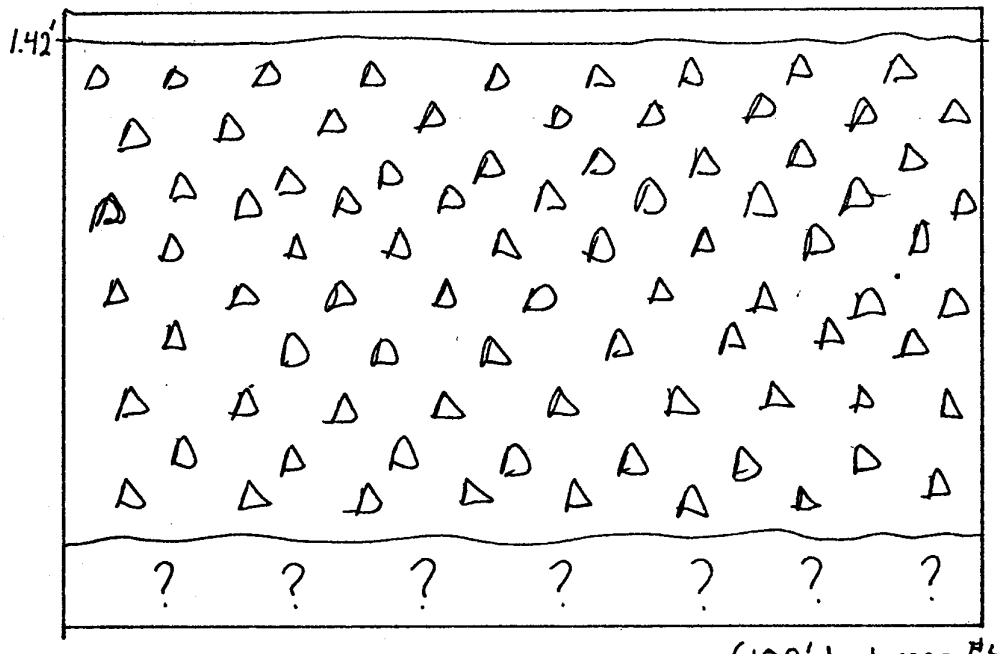
1" = 8'

0'

8'

Fig. 7-9

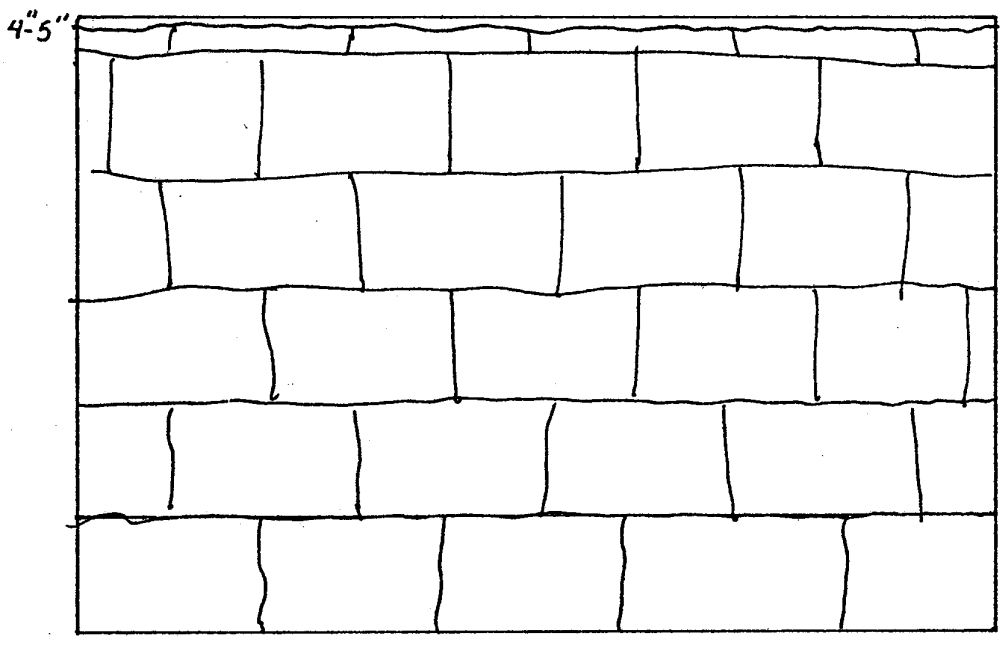
No. 9 East Side of Quarry



(100' between #4-#9)

Fig. 7-10

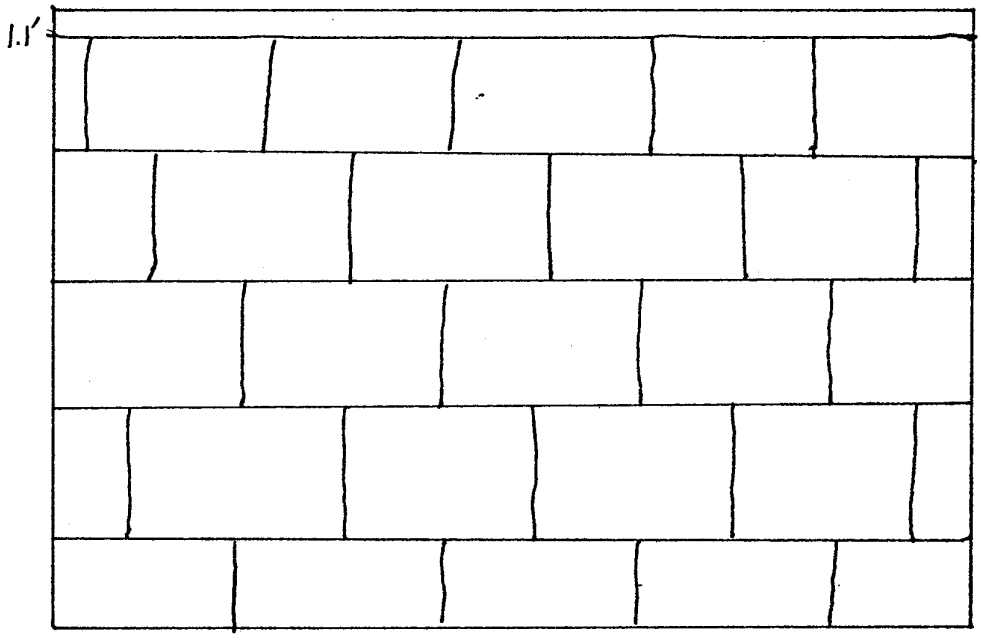
No. 10 N-E Side of Quarry



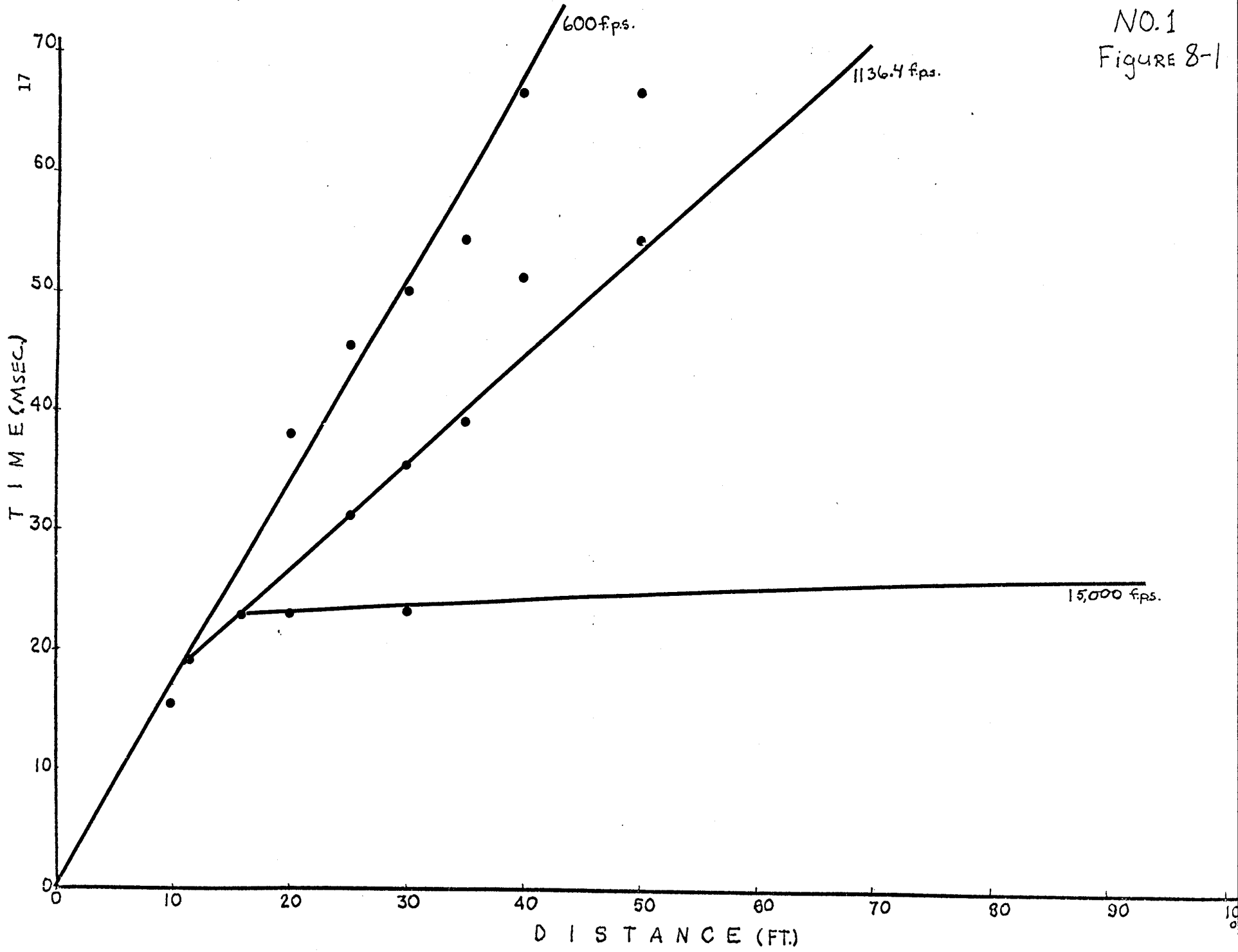
1" = 8'

Fig. 7-11

No. 11 N-E End of Quarry Floor

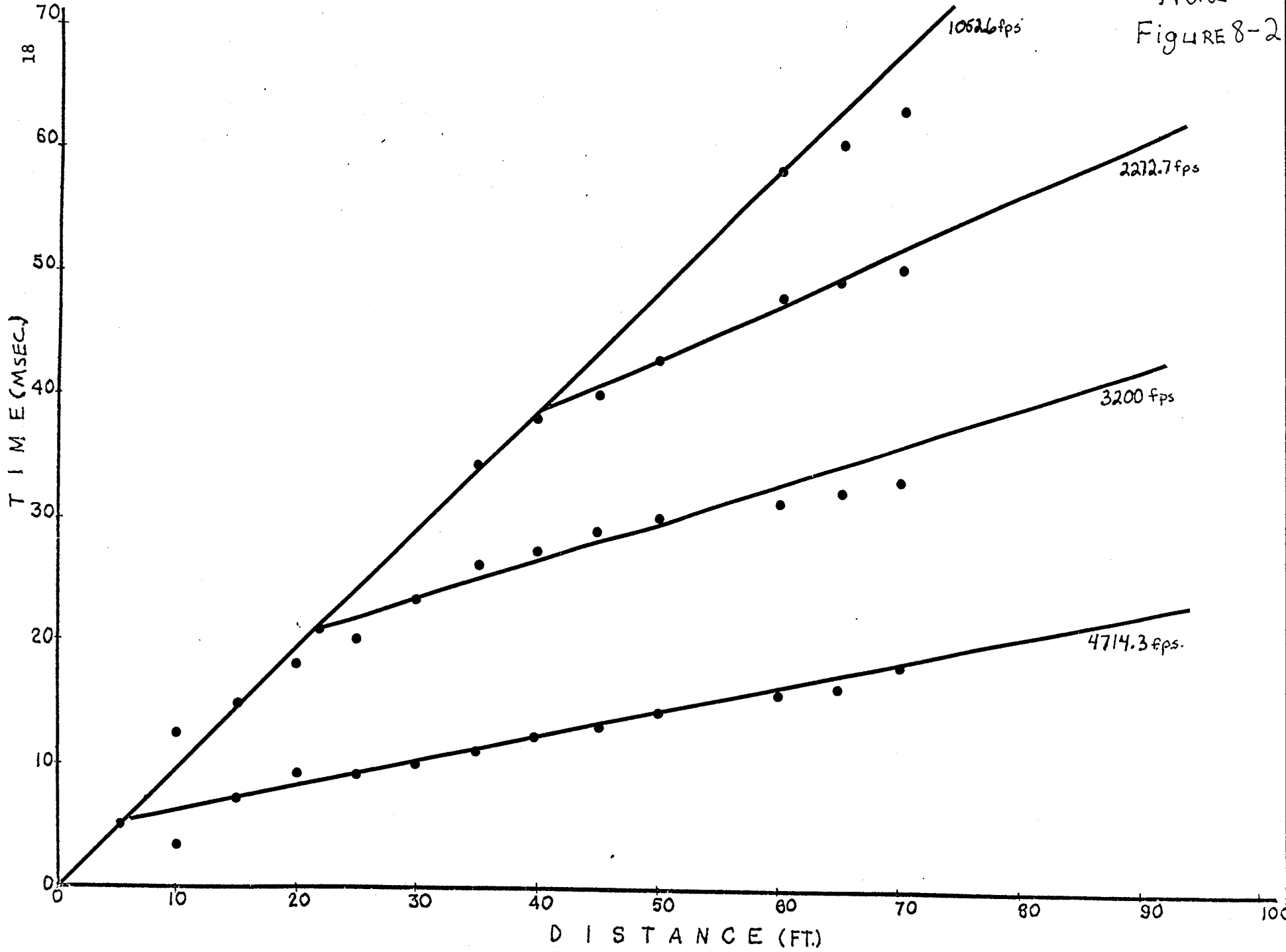


NO. 1
FIGURE 8-1

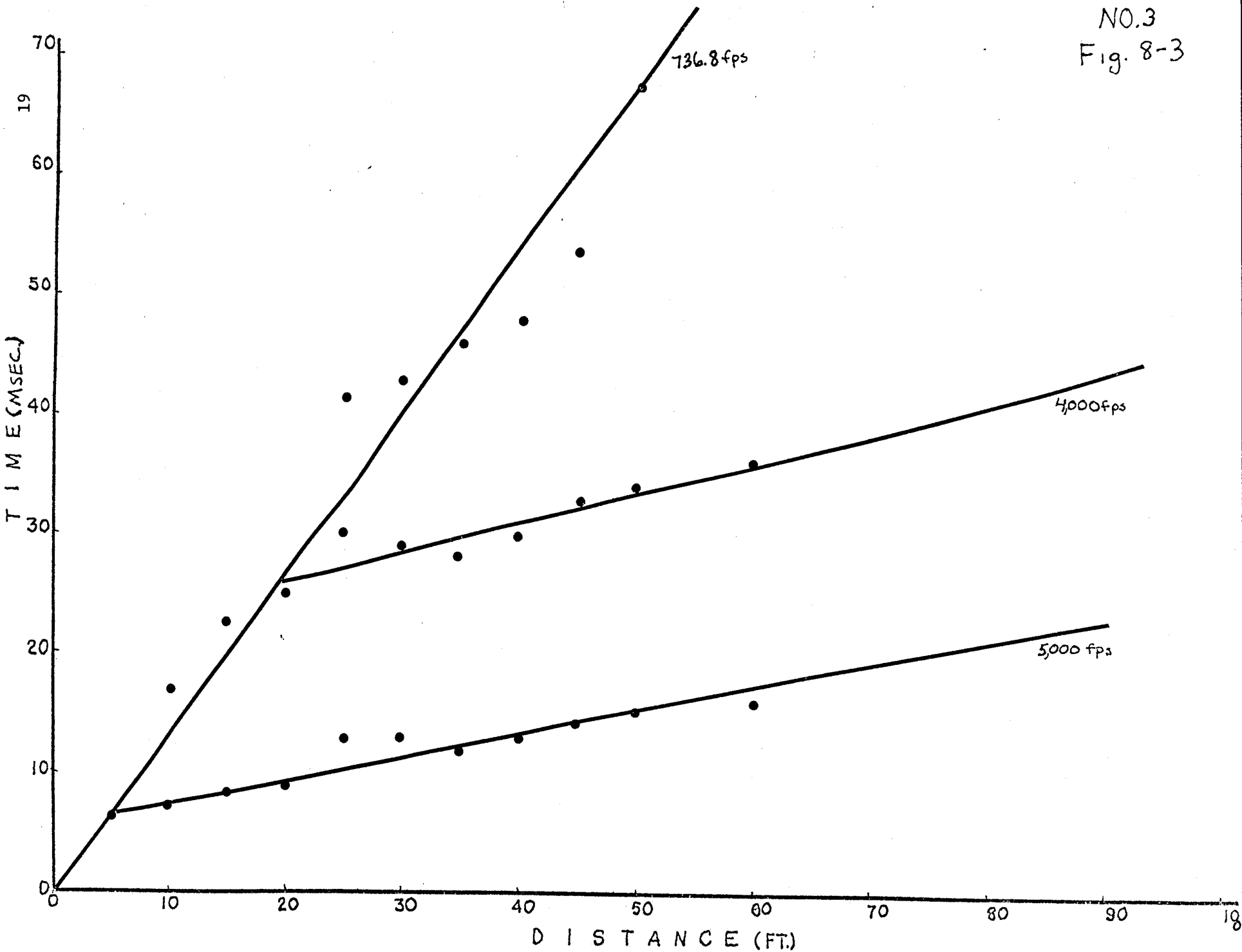


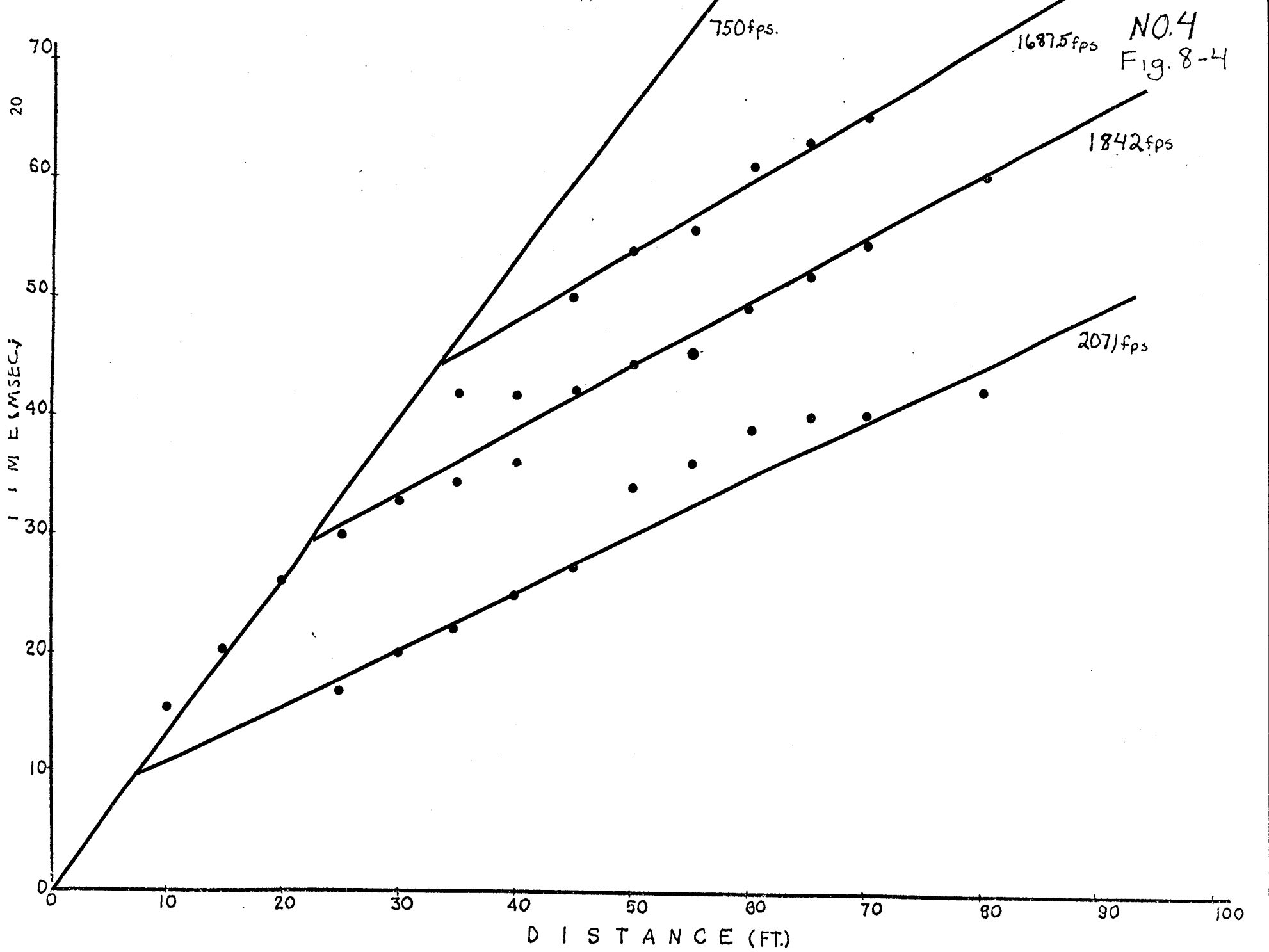
NO.2

FIGURE 8-2

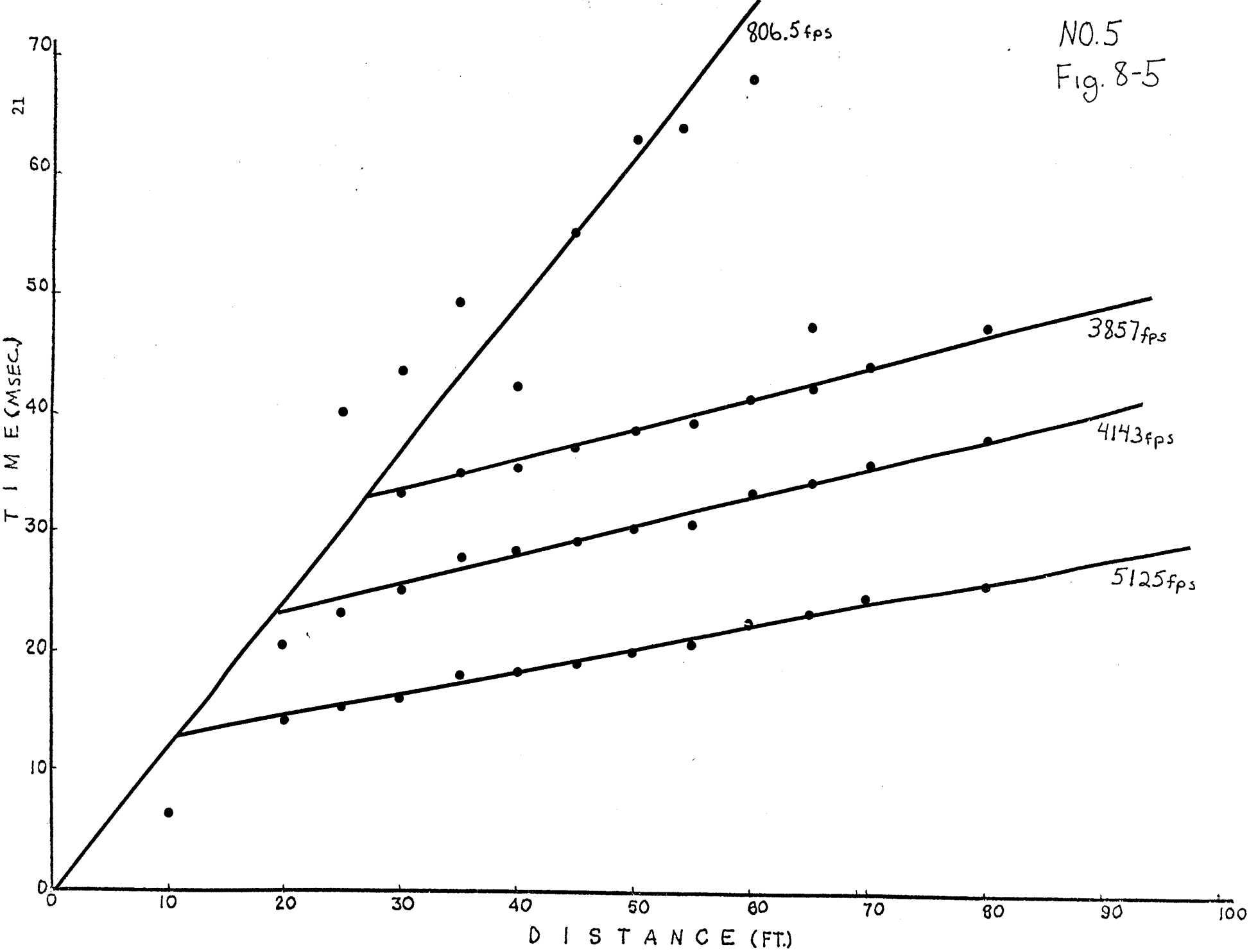


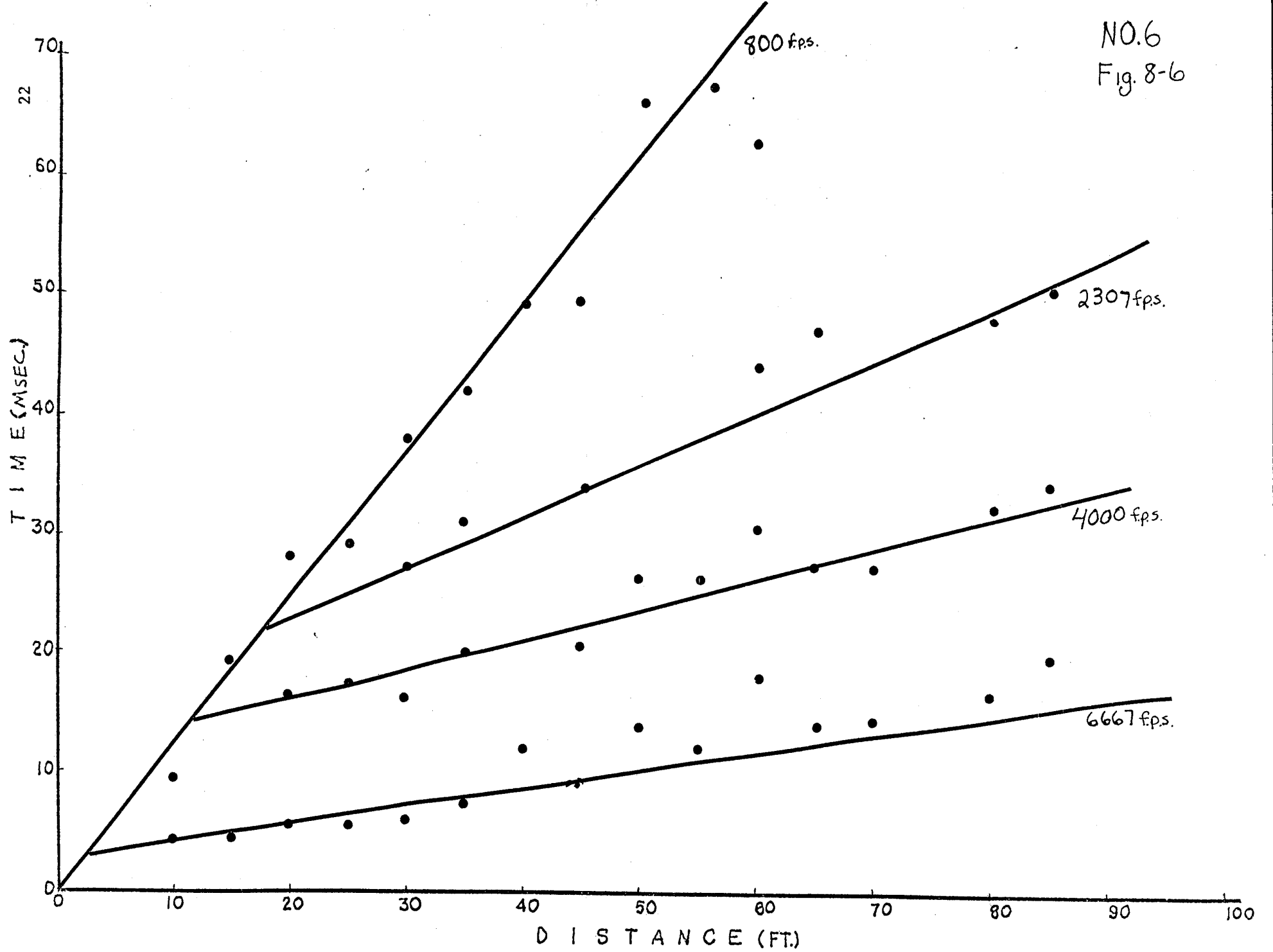
NO.3
Fig. 8-3


736.8 fps
4,000 fps
5,000 fps
TIME (MSEC.)
DISTANCE (FT.)
0
10
20
30
40
50
60
70
80
90
100

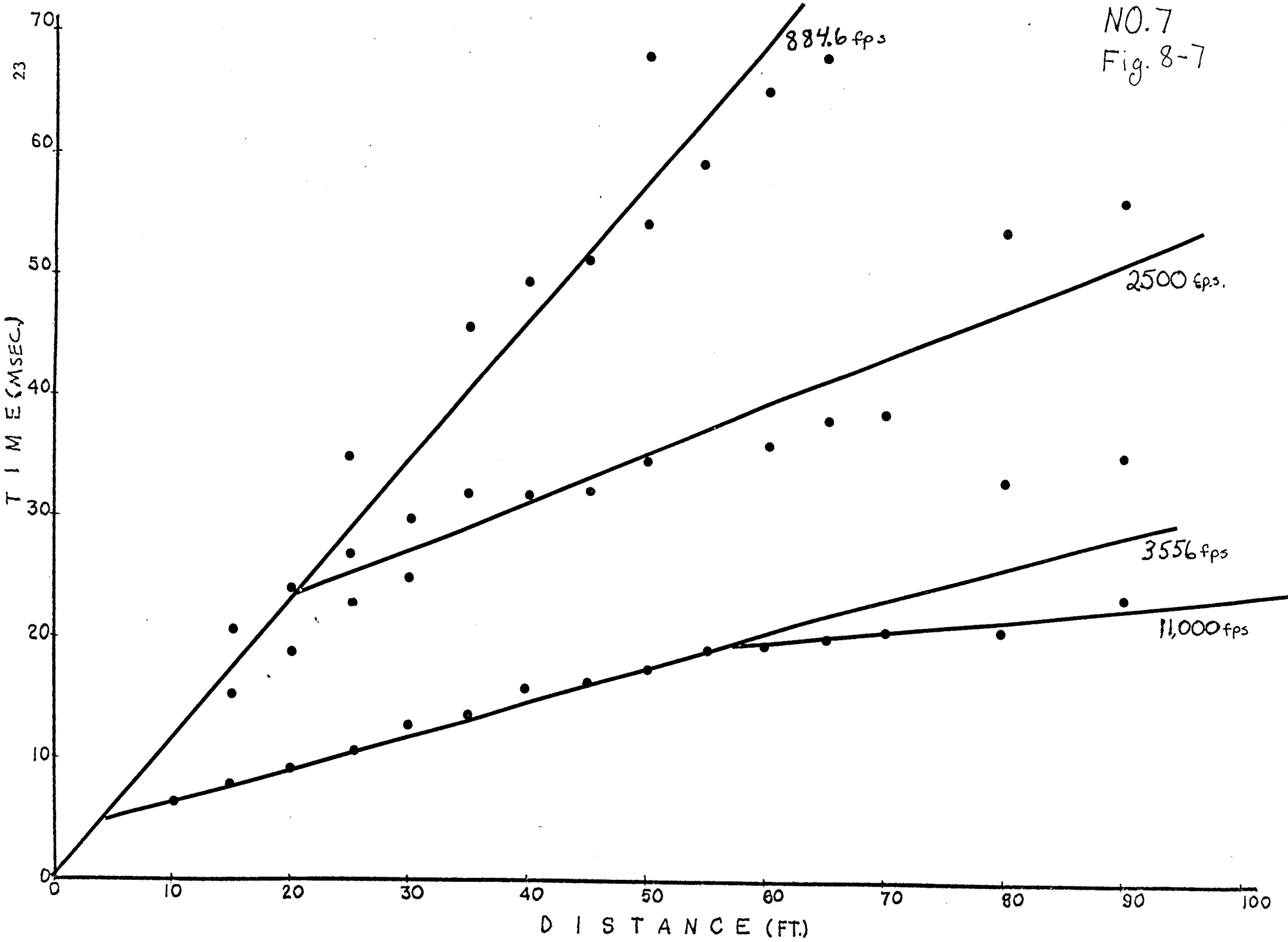

NO.4
Fig. 8-4
750fps.
1687.5fps
1842fps
2071fps
TIME (MSEC.)
DISTANCE (FT.)
0
10
20
30
40
50
60
70
80
90
100

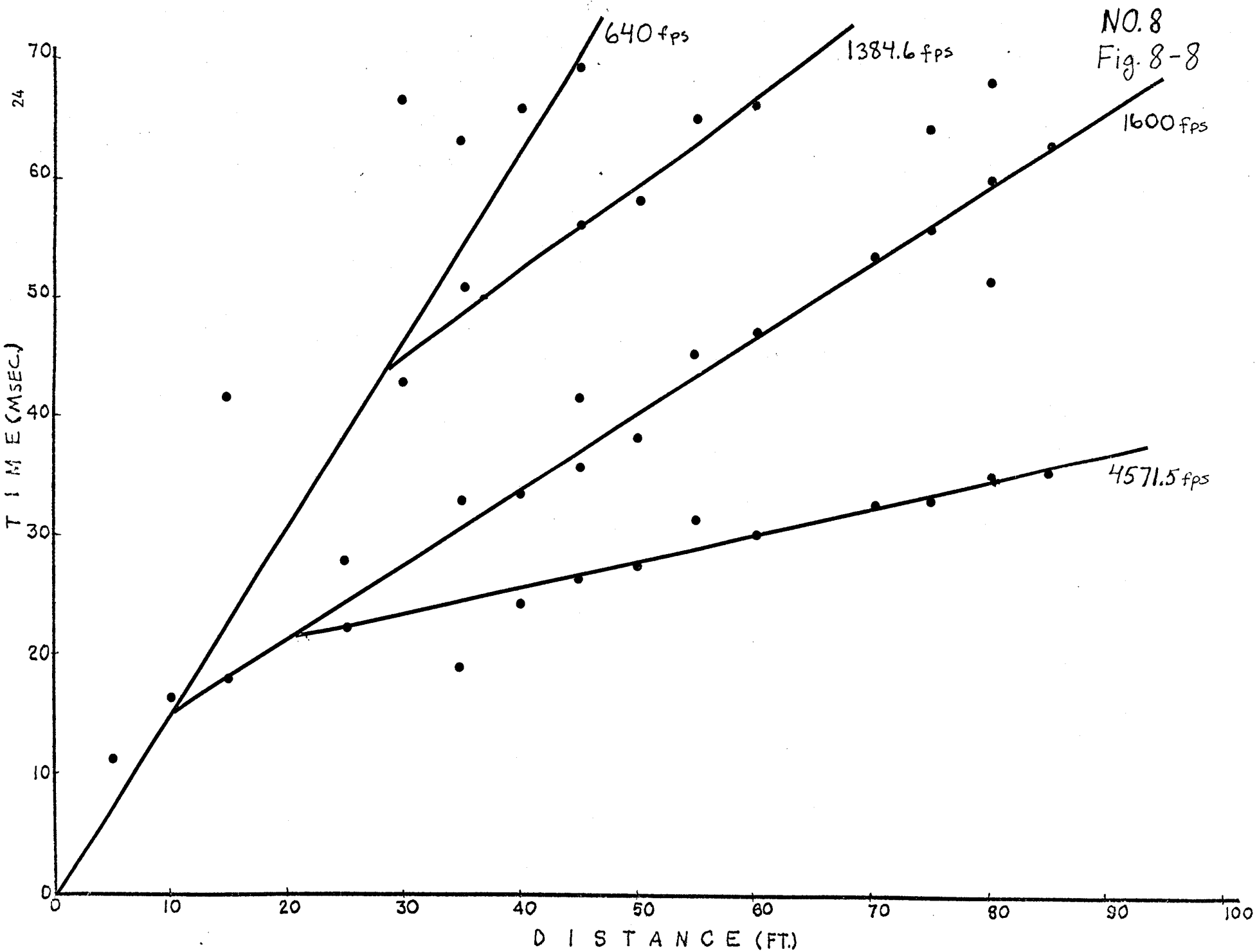
NO.5
Fig. 8-5

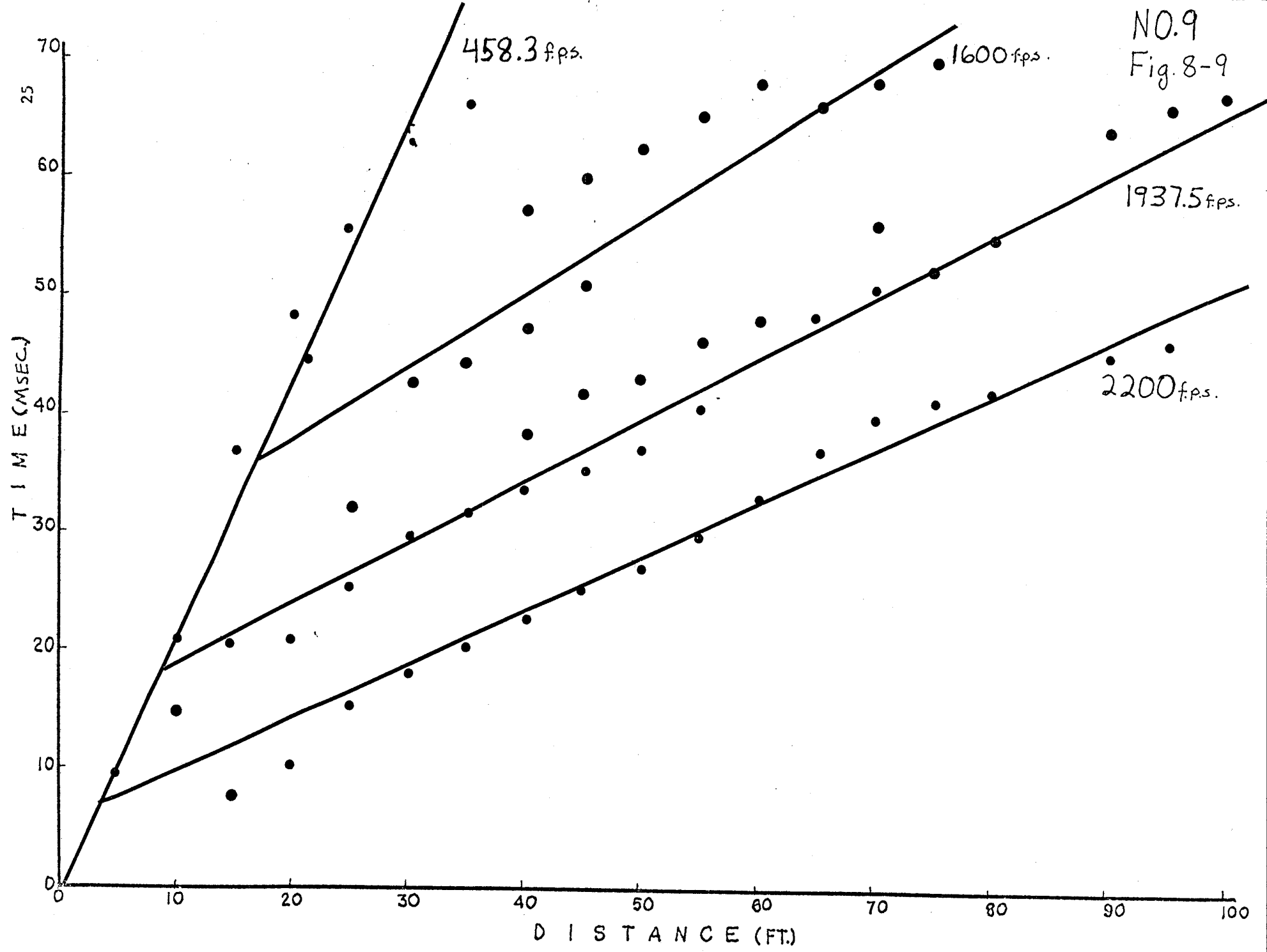

806.5 fps
3857 fps
4143 fps
5125 fps
TIME (MSEC.)
DISTANCE (FT.)
0
10
20
30
40
50
60
70
80
90
100


NO.6
Fig. 8-6
800 f.p.s.
2307 f.p.s.
4000 f.p.s.
6667 f.p.s.
TIME (MSEC.)
DISTANCE (FT.)
0
10
20
30
40
50
60
70
80
90
100
22

NO. 7
Fig. 8-7

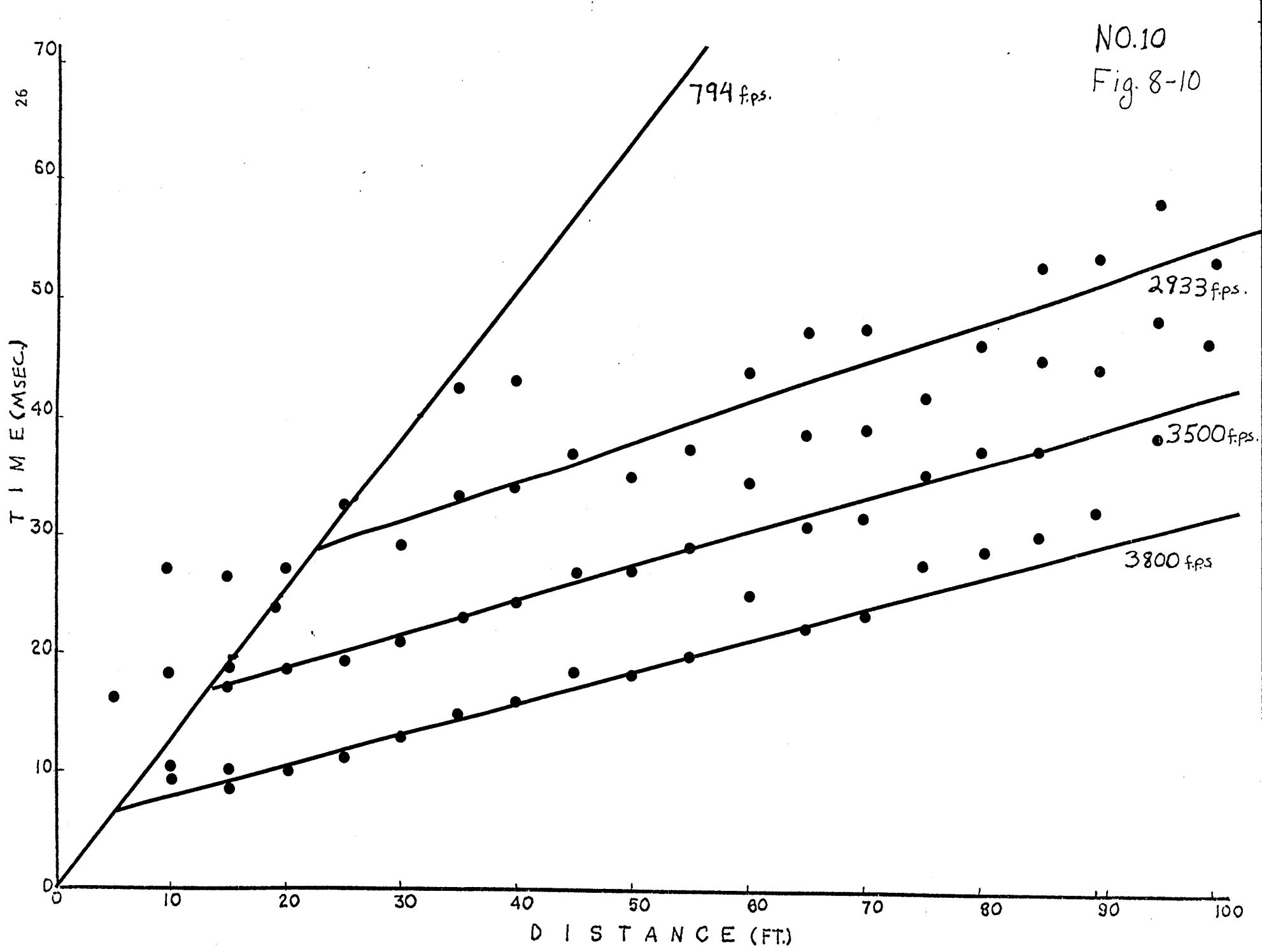

884.6 fps
2500 fps.
3556 fps
11,000 fps
TIME (MSEC.)
DISTANCE (FT.)
0
10
20
30
40
50
60
70
80
90
100

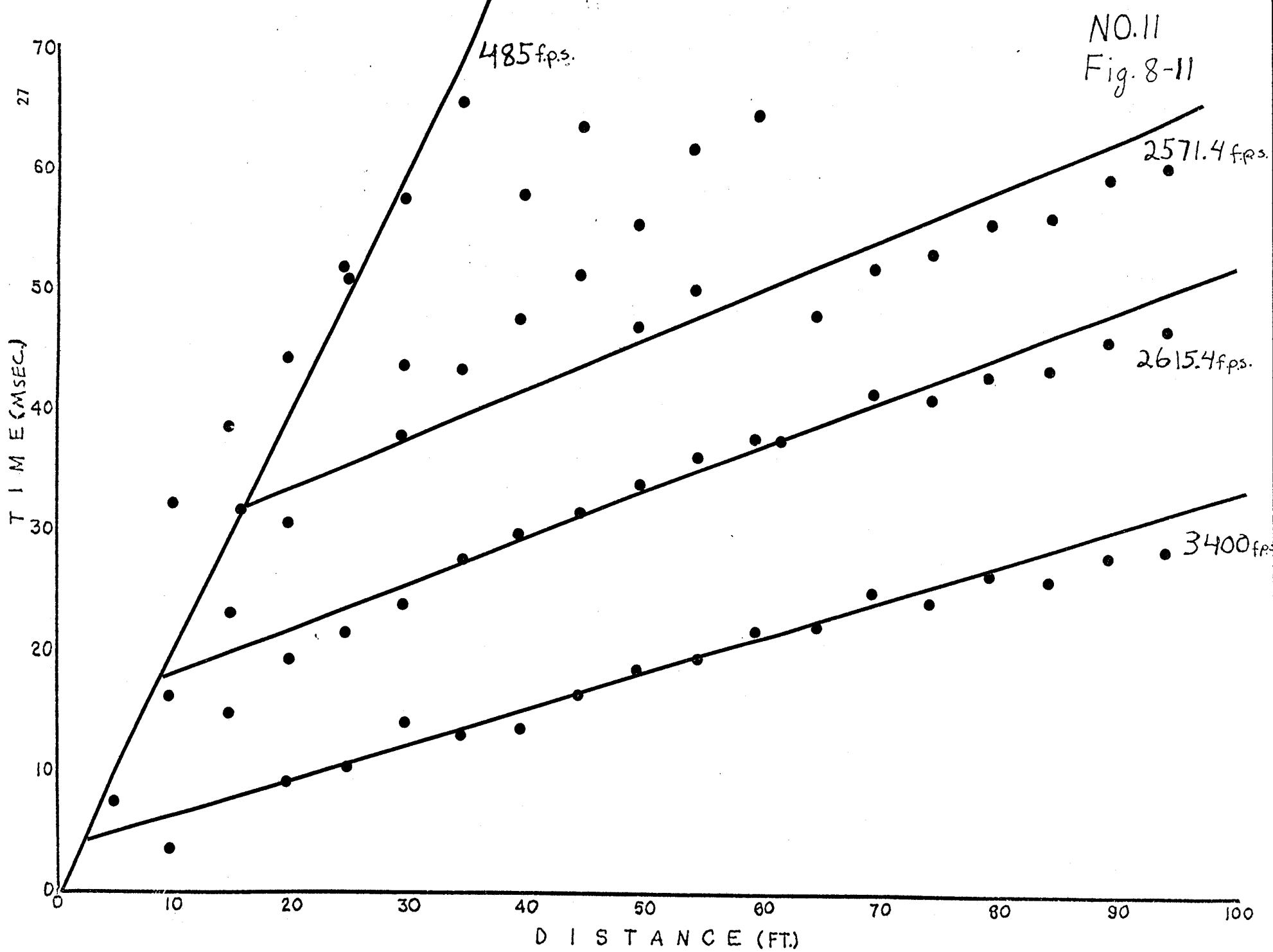

NO. 8
Fig. 8-8
640 fps
1384.6 fps
1600 fps
4571.5 fps
TIME (MSEC.)
DISTANCE (FT.)
0
10
20
30
40
50
60
70
80
90
100


NO.9
Fig. 8-9
458.3 f.p.s.
1600 f.p.s.
1937.5 f.p.s.
2200 f.p.s.
TIME (MSEC.)
DISTANCE (FT.)
0
10
20
30
40
50
60
70
80
90
100
25

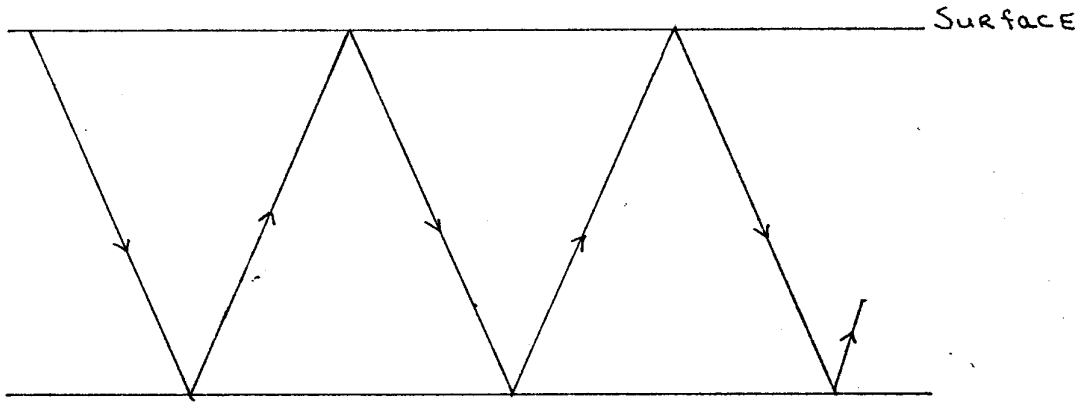
NO.10

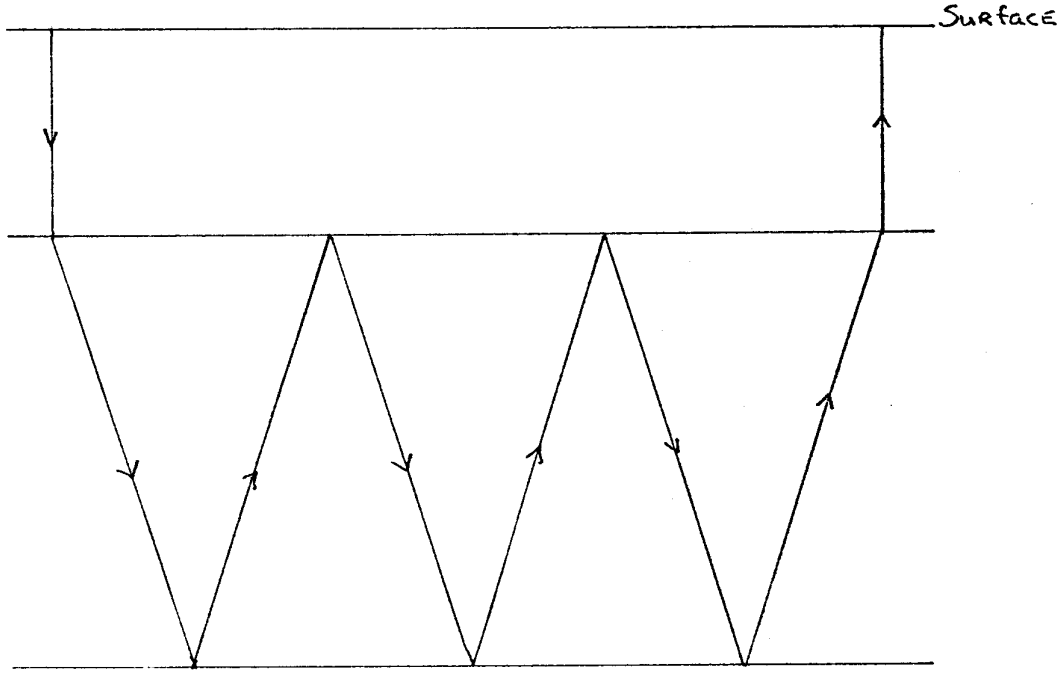
Fig. 8-10


794 f.p.s.
2933 f.p.s.
3500 f.p.s.
3800 f.p.s
TIME (MSEC.)
DISTANCE (FT.)
0
10
20
30
40
50
60
70
80
90
100


NO.11
Fig. 8-11
485 f.p.s.
2571.4 f.p.s.
2615.4 f.p.s.
3400 f.p.s.
TIME (MSEC.)
DISTANCE (FT.)
0
10
20
30
40
50
60
70
80
90
100

Example of Some Possible Multiple Reflections Figure 9





(From Sharma, 1976)

E-W Cross Section of Quarry

Figure 10

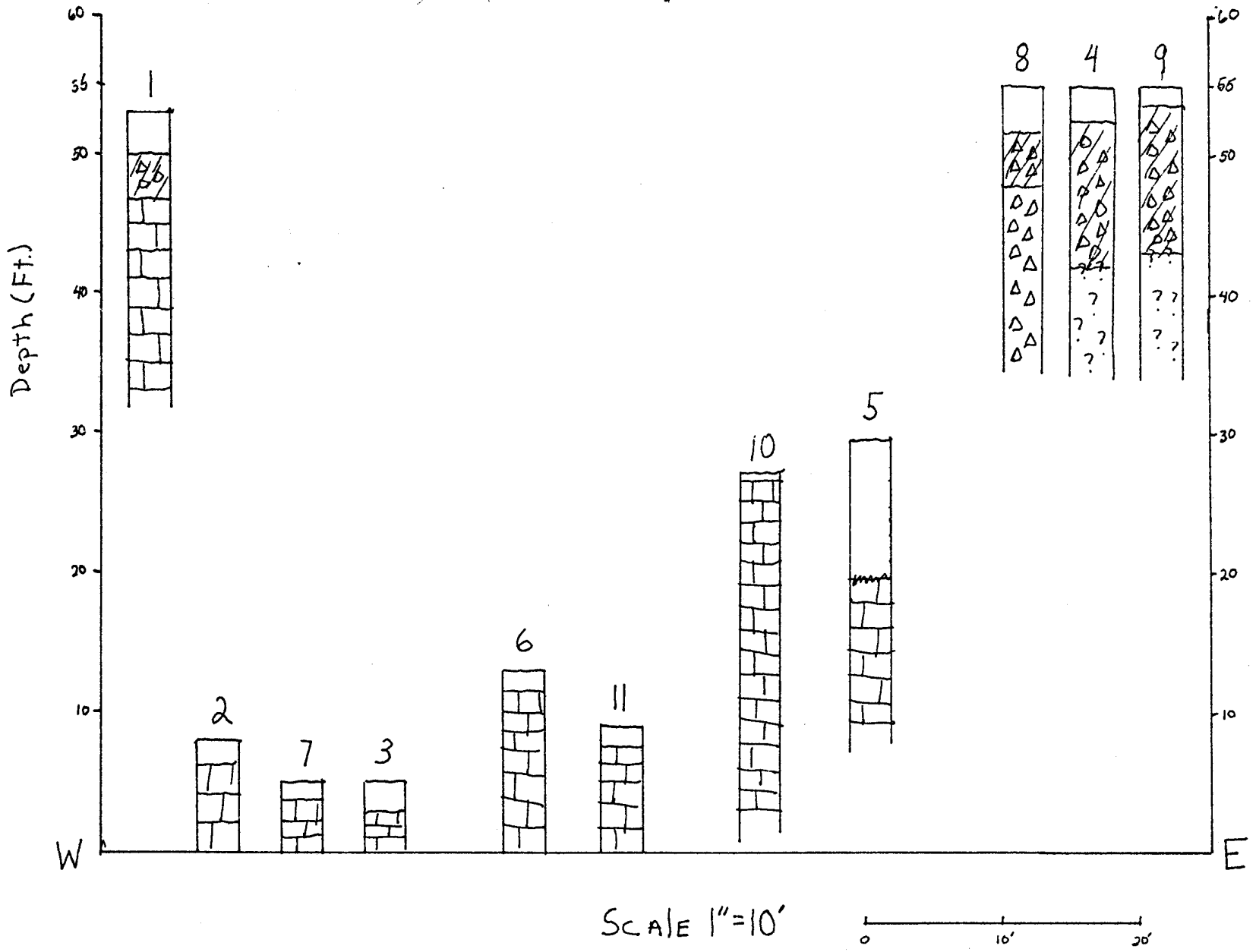


Fig. 11

N-S Cross Section of Quarry

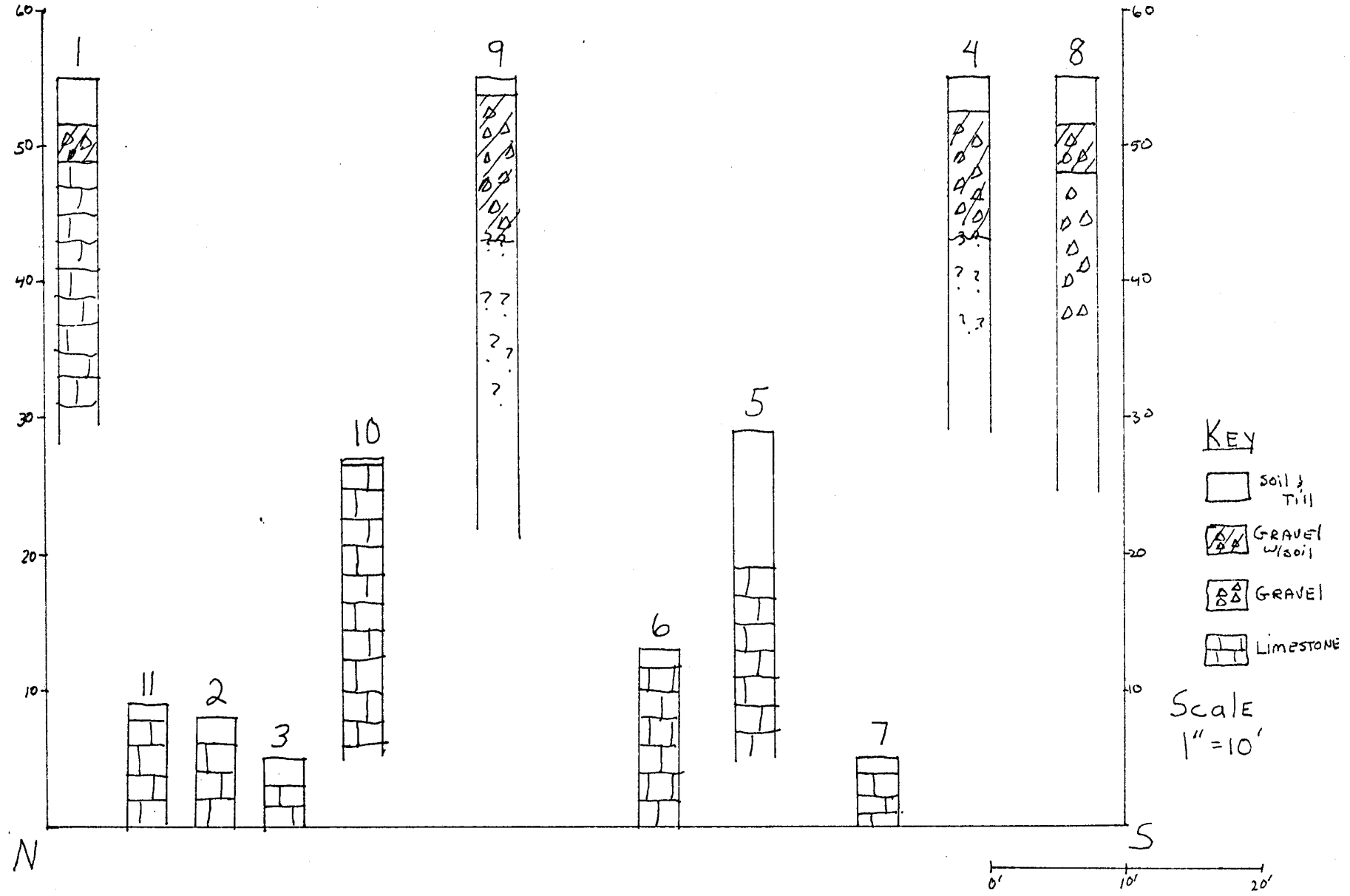
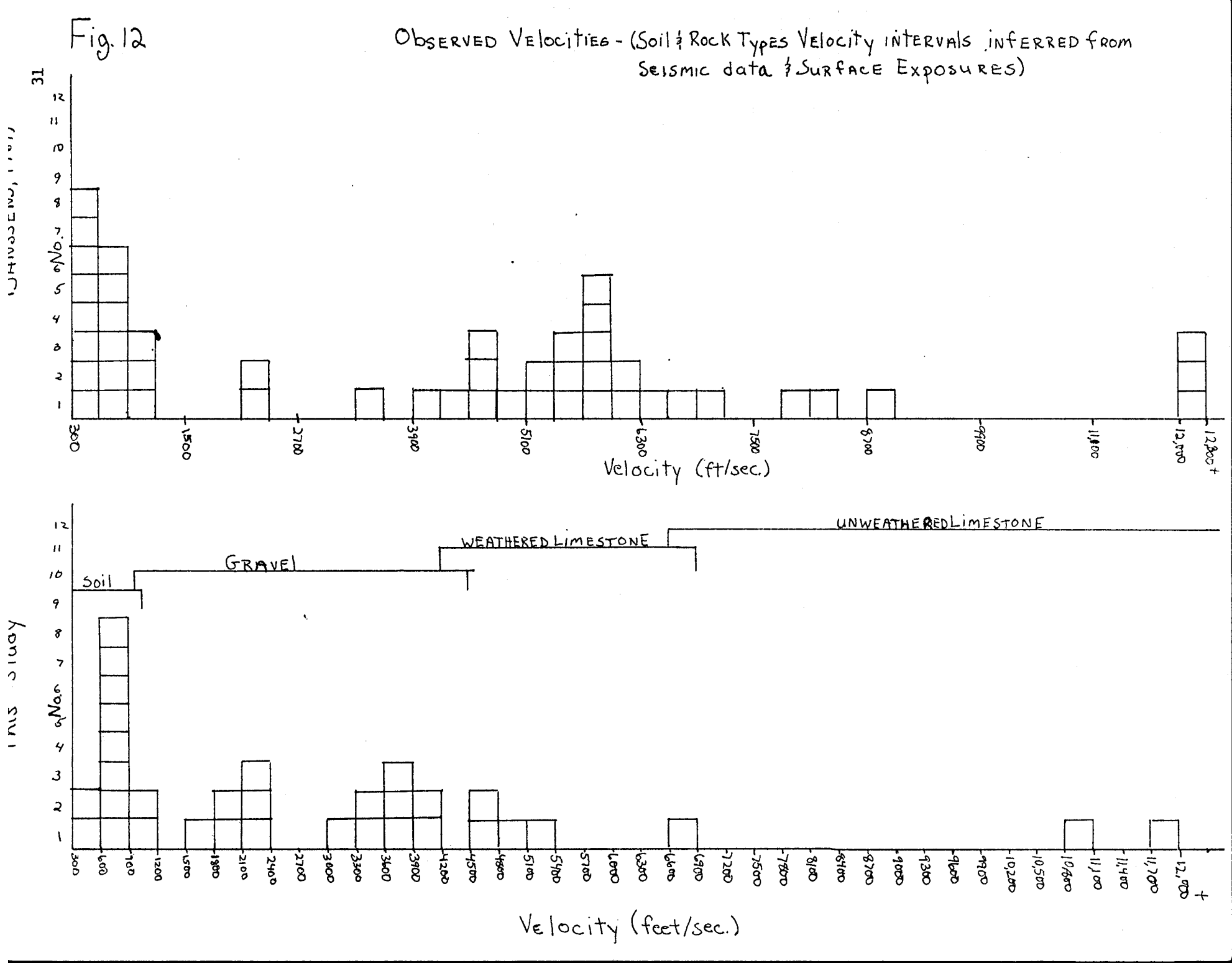


Fig. 12

Observed Velocities - (Soil & Rock Types Velocity intervals inferred from Seismic data & Surface Exposures)



E-W Section with Auger Drill Results (See Fig. 13)

Figure 14

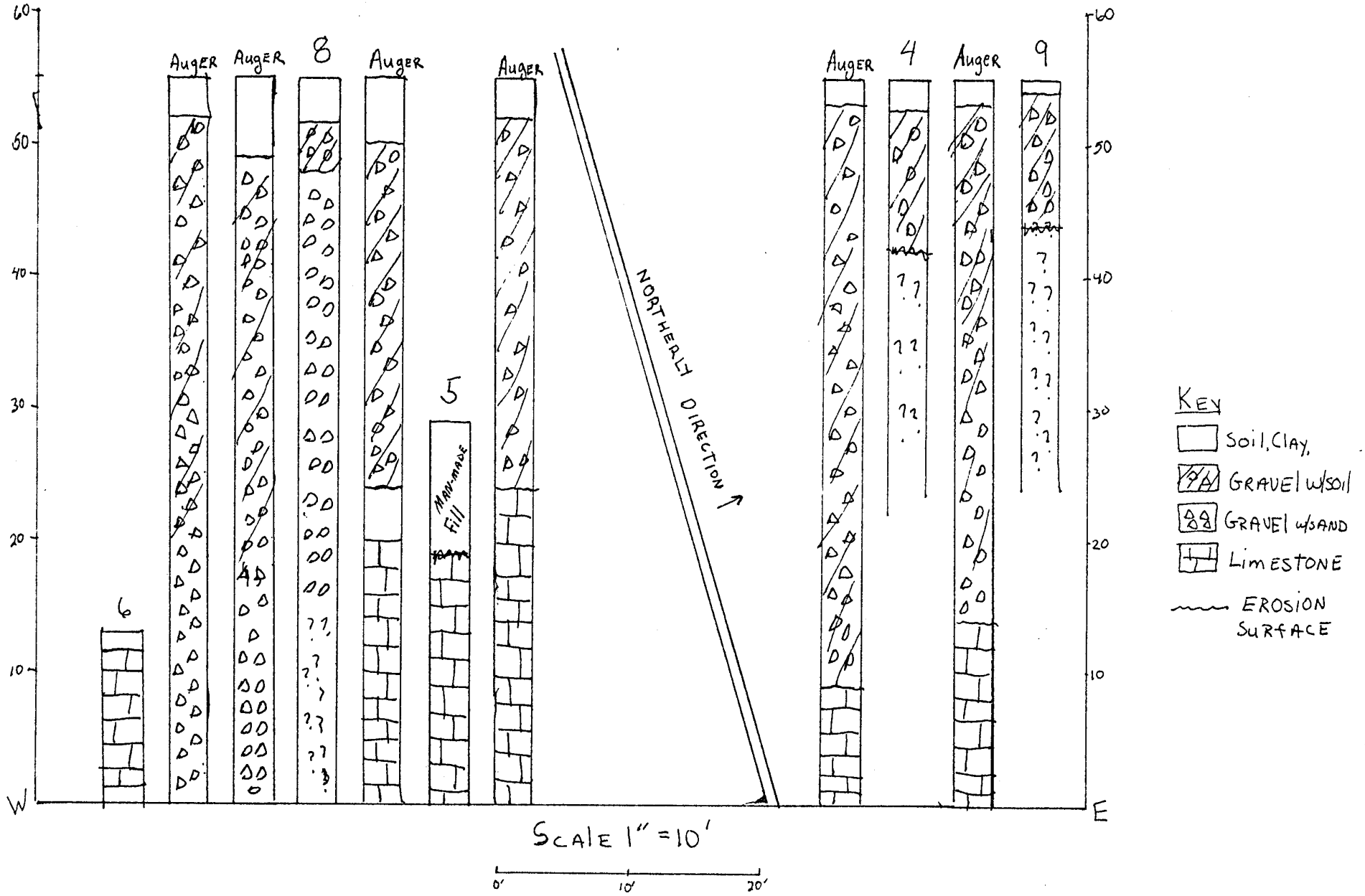


Table 1
APPROXIMATE VELOCITY RANGES OF MATERIALS

Material	Approximate Velocity Range (Ft./Sec.)
Top Soil	
Loose and Dry	500 - 800
Moist Loam or silt	900 - 1300
Clayey, Dry	1300 - 2000
Wet Loam	1500 - 2500
Frozen	5000 - 6000
Loose rock, talus	1200 - 2500
Clay	
Dense, Wet	3000 - 5000
Gravel	
Mixed with Soil	1000 - 2500
Compacted	4000 - 6000
Water Bearing Soils	5000 - 6000
Basalt	8500 - 13000
Breccia	
Weathered	3000 - 7000
Solid	6000 - 11000
Chalk	3000 - 8000
Gneiss	
Weathered	2000 - 7000
Solid	6000 - 14000
Granite	
Weathered	2000 - 8000
Solid	8000 - 20000
Greenstone	13000 - 18000
Limestone	
Weathered	3000 - 8000
Solid	8000 - 20000
Quartz (Silicious)	10000 - 20000
Schist	
Weathered	3000 - 6000
Solid	6000 - 11000
Shale	
Weathered	2500 - 5000
Solid	5000 - 13000

BIBLIOGRAPHY

Compton, Robert R. Manual of Field Geology. New York: Johy Wiley and Sons, Inc., 1962.

Goldthwait, R. P. (1959), "Scenes in Ohio During the Last Ice Age," Ohio Journal of Science, Vol. 59, pp. 193-216.

Janssens, Adriaan. (1964), "A Contribution to the Pleistocene Geology of Champaign County, Ohio;" M.Sc. thesis, The Ohio State University.

Quinn, Michael John (1972), "The Glacial Geology of Champaign County, Ohio;" M.Sc. thesis, The Ohio State University, pp. 10-20.

Sharma, P. V. Geophysical Methods in Geology. Amsterdam: Elsevier Scientific Publishing Co., 1976.

Soil Survey of Champaign County, Ohio. Washington, D.C.: Soil Conservation Service--United States Department of Agriculture, 1971.