Cross-Hole Velocity and the Myth about Refracted Waves

by

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Hmmmmm?

ASTM D4428 / D4428M

Significance and Use

The seismic crosshole method provides a designer with information pertinent to the seismic wave velocities of the materials in question **(1).**[2] This data may be used as input into static/dynamic analyses, as a means for computing shear modulus, Young'modulus, and Poisson'ratio, or simply for the determination of anomalies that might exist between boreholes.

Fundamental assumptions inherent in the test methods are as follows:

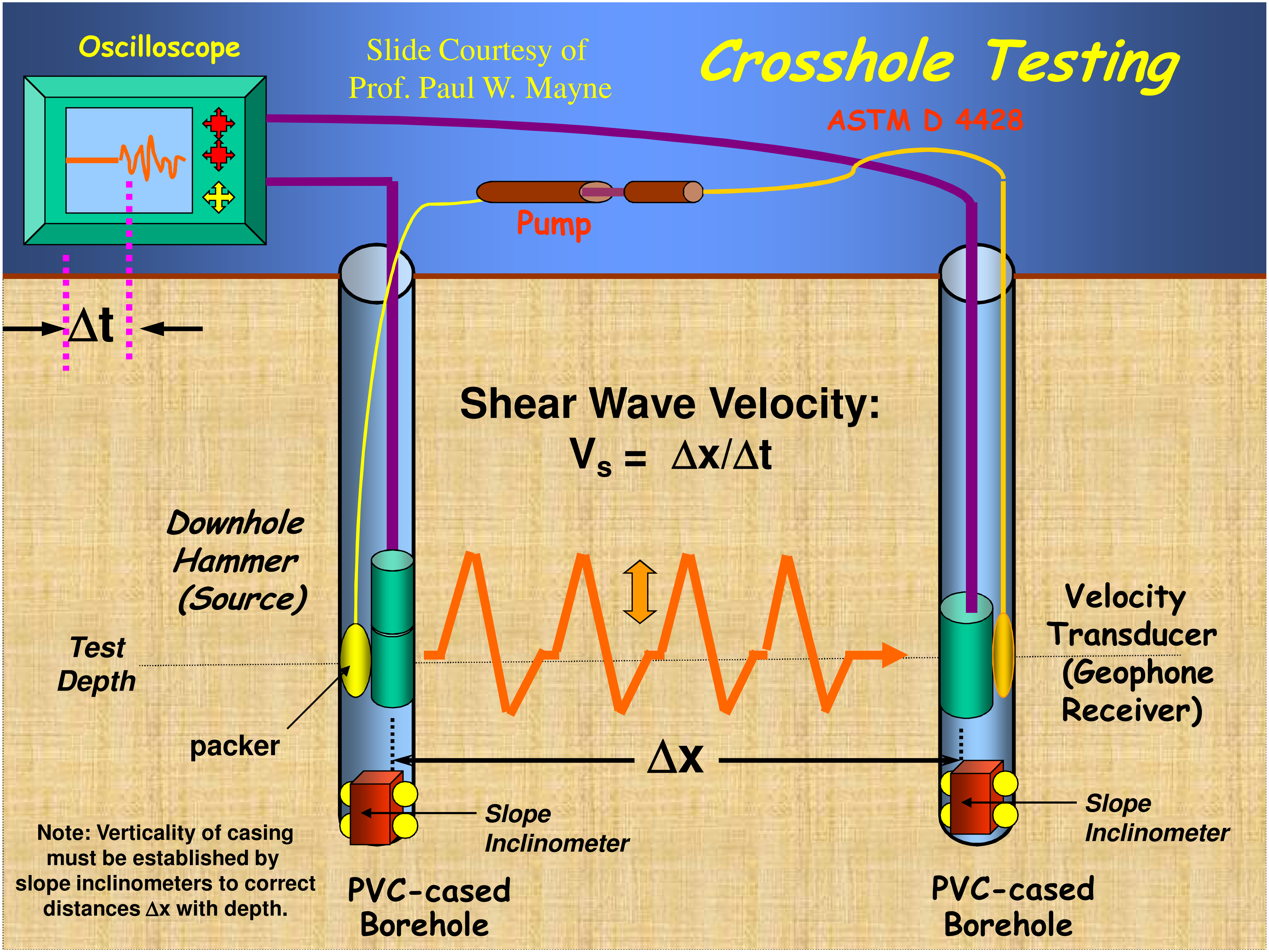
5.2.1 Horizontal layering is assumed.

5.2.2 Snell'laws of refraction will apply. If Snell'laws of refraction are not applied, velocities obtained will be unreliable.

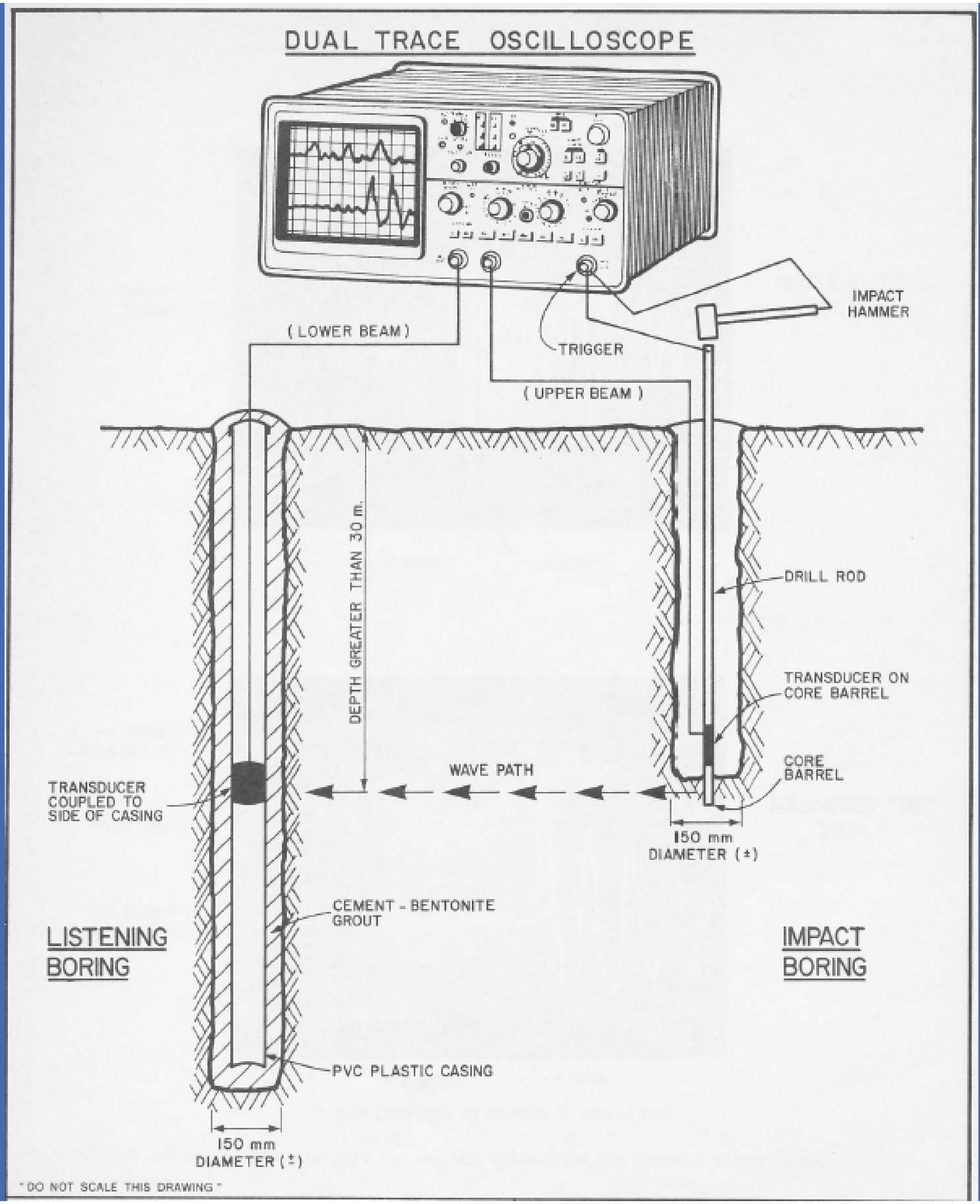
Stokoe and Woods

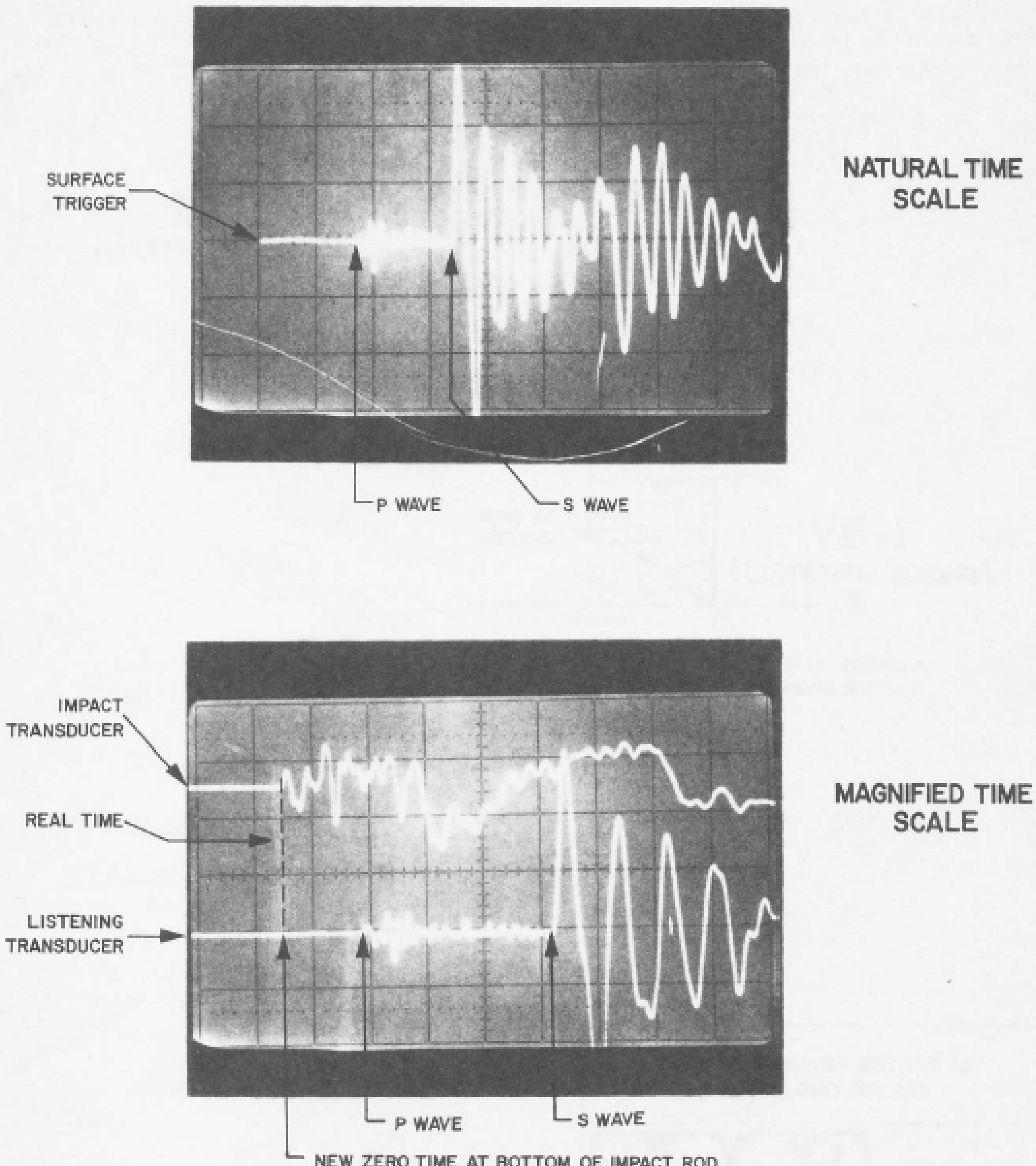
SHARE

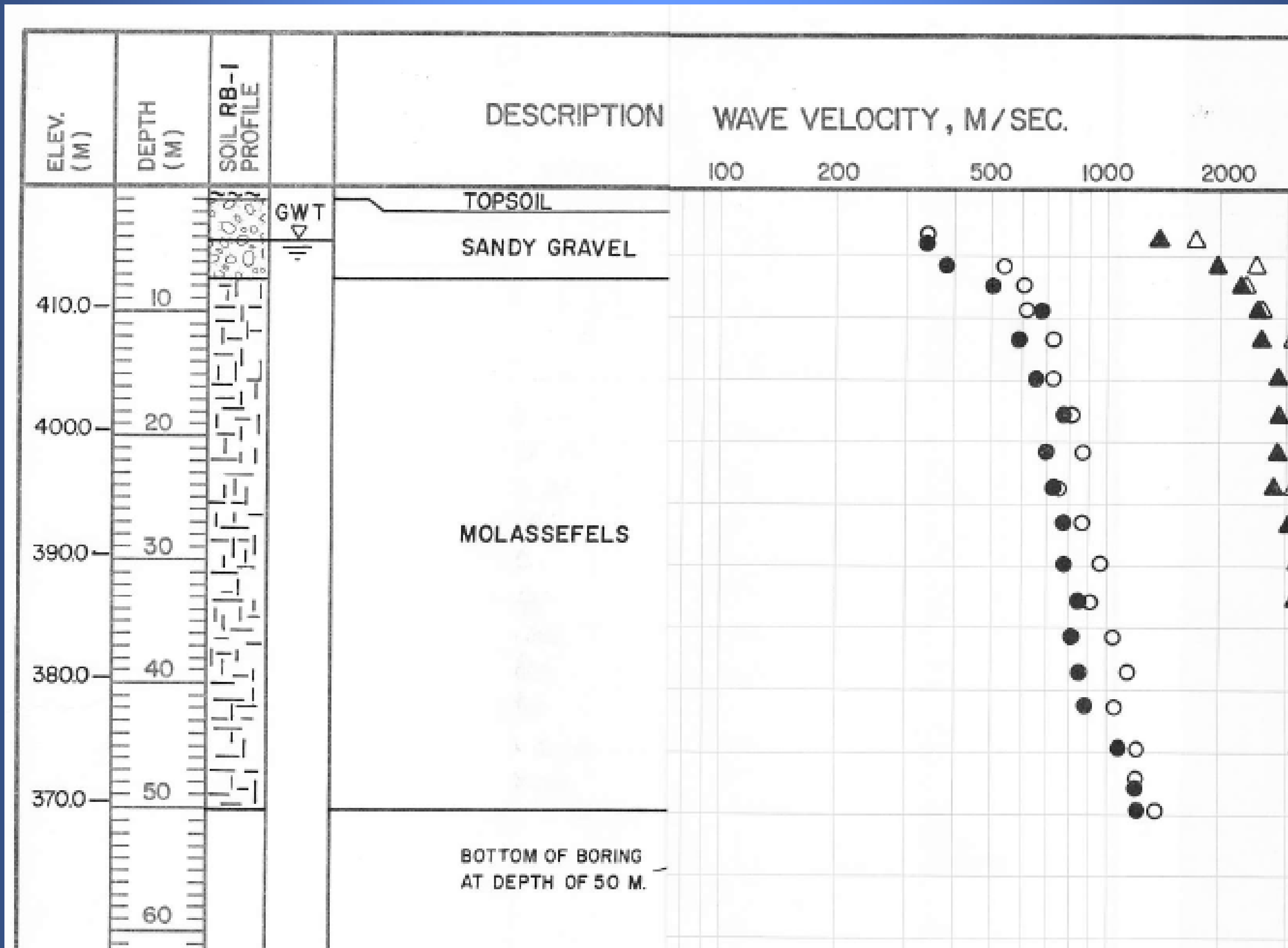
Title:	**IN SITU SHEAR WAVE VELOCITY BY CROSS-HOLE METHOD**
Accession Number:	00236365
Abstract:	THE CROSS-HOLE SEISMIC SURVEY TECHNIQUE IS PRESENTED AS A MEANS OF DETERMINING IN SITU SHEAR WAVE VELOCITY. BY THIS METHOD, THE TRAVEL TIME OF BODY WAVES TRAVELING BETWEEN TWO POINTS IN A SOIL MASS IS MEASURED. BODY WAVES MAY BE EITHER COMPRESSION OR SHEAR WAVES. EMPHASIS IS PLACED ON IDENTIFICATION OF THE SHEAR WAVE BECAUSE IT IS DIRECTLY USED TO CALCULATE THE DYNAMIC SHEAR MODULUS OF THE SOIL AND CAN BE MEASURED ABOVE OR BELOW THE WATER TABLE. A GENERAL TEST PROCEDURE IS DESCRIBED. TYPICAL TRAVEL TIME RECORDS OF ARRIVING ENERGY ARE SHOWN AND THE COMPRESSION AND SHEAR WAVE ARRIVALS ARE IDENTIFIED. PRELIMINARY TESTS DEMONSTRATING THE VALIDITY AND USE OF THE METHOD ARE PRESENTED. THREE CASE STUDIES USING THE METHOD UNDER VARIOUS FIELD CONDITIONS ARE ALSO PRESENTED. /AUTHOR/
Supplemental Notes:	PROC PAPER 8904
TRIS Files:	HRIS
Pagination:	p. 443-60
Authors:	Stokoe, K H Woods, R D
Publication Date:	1972-5
Serial:	**ASCE Journal of Soil Mechanics & Foundations Div** Volume: 98 Issue Number: sm5
Index Terms:	**Cross hole**; **Crossheadings**; **Field tests**; **Insitu methods**; **S waves**; **Seismic investigations**; **Seismicity**; **Shear modulus**; **Soil mechanics**; **Travel time**; **Wave motion**; **Wave velocity**
Subject Areas:	Geotechnology; Highways
Last Modified:	Jul 9 1972 12:00AM

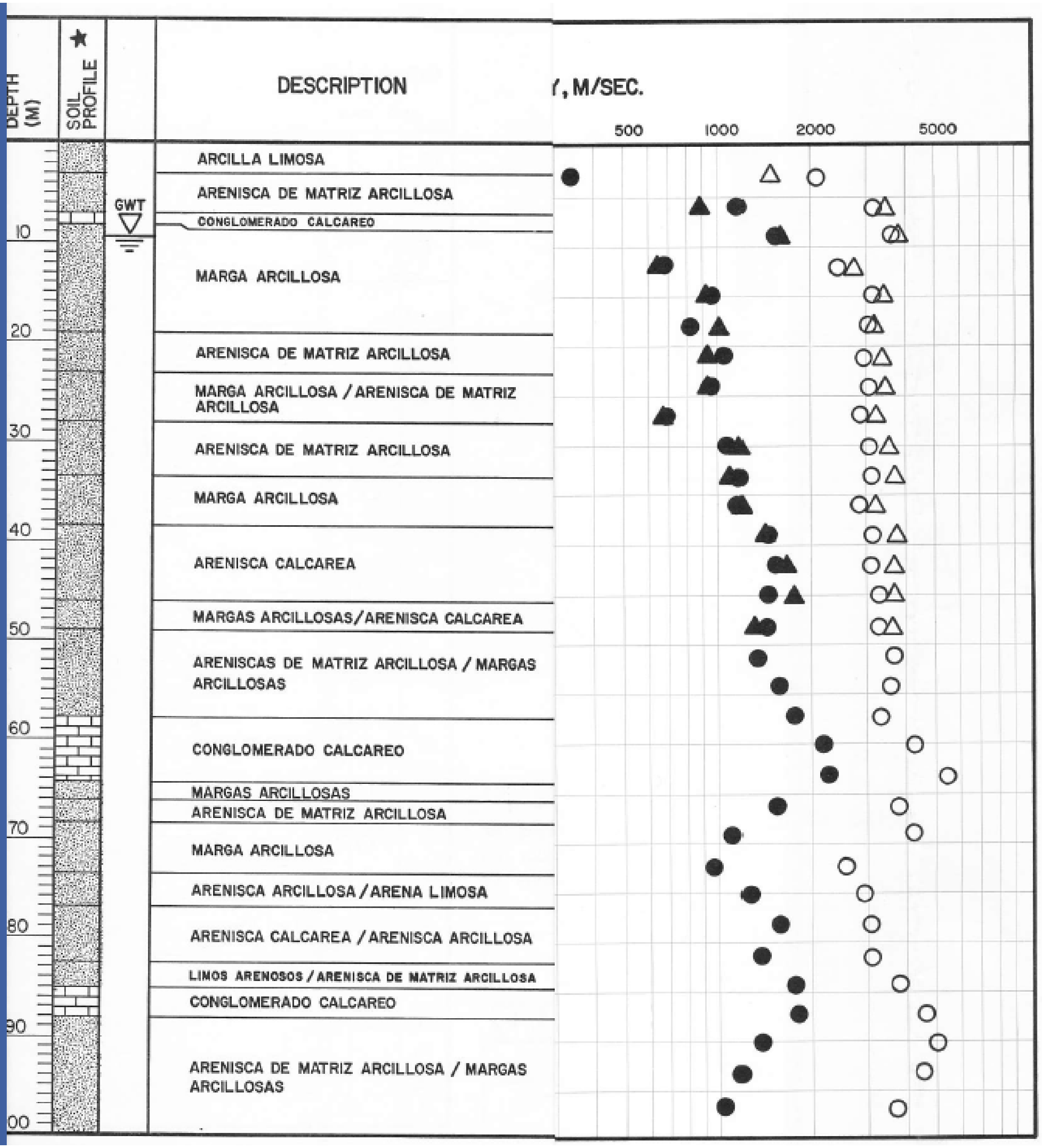


Oscilloscope
Slide Courtesy of
Prof. Paul W. Mayne
Crosshole Testing
ASTM D 4428
Pump
Δt
Shear Wave Velocity:
Vs = Δx/Δt
Downhole
Hammer
(Source)
Test
Depth
packer
Velocity
Transducer
(Geophone
Receiver)
Δx
Slope
Inclinometer
Slope
Inclinometer
Note: Verticality of casing
must be established by
slope inclinometers to correct
distances Δx with depth.
PVC-cased
Borehole
PVC-cased
Borehole

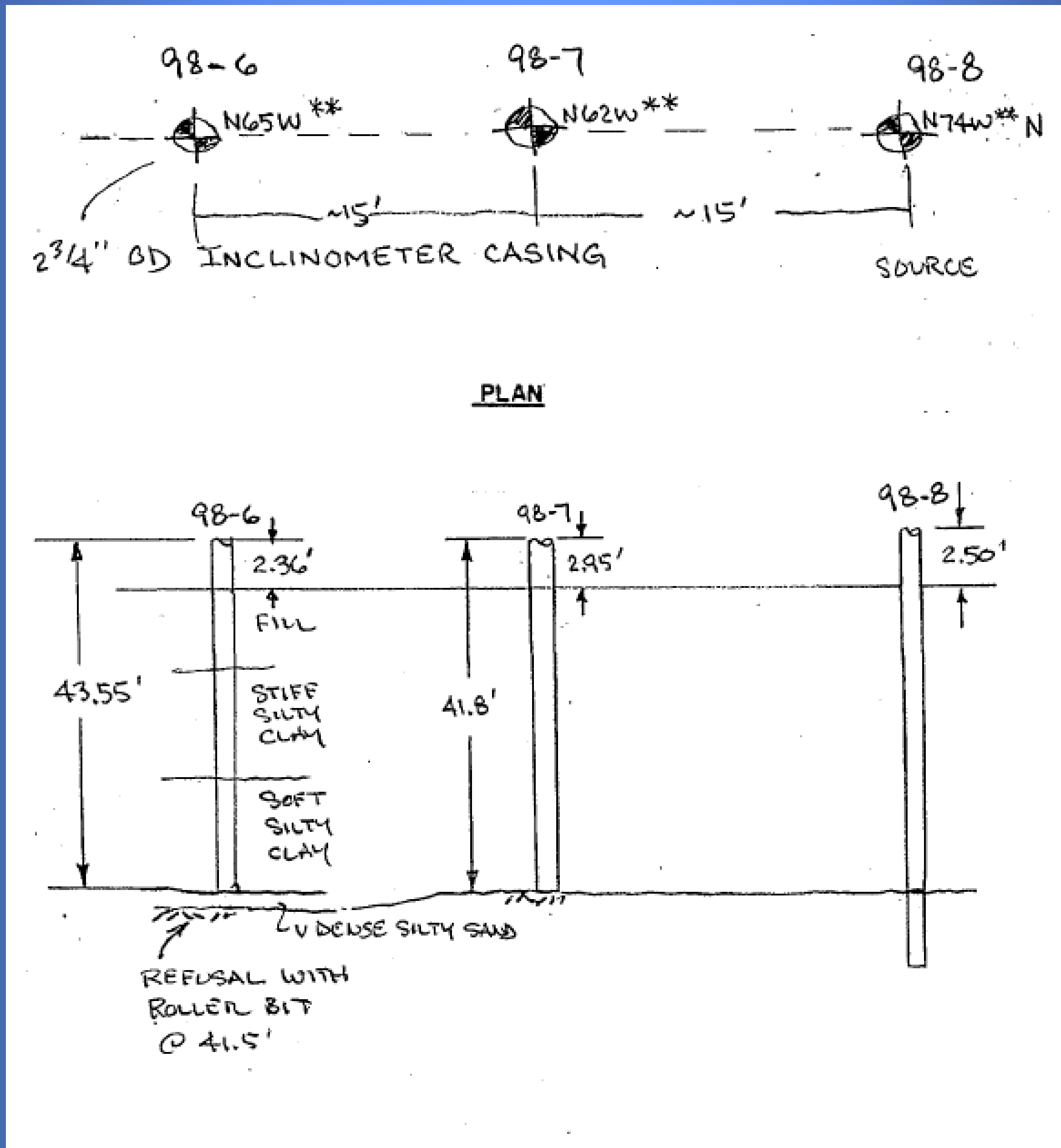

DUAL TRACE OSCILLOSCOPE
IMPACT HAMMER
(LOWER BEAM)
TRIGGER
(UPPER BEAM)
DEPTH GREATER THAN 30 m.
DRILL ROD
TRANSDUCER ON CORE BARREL
WAVE PATH
CORE BARREL
TRANSDUCER COUPLED TO SIDE OF CASING
150 mm DIAMETER (±)
CEMENT - BENTONITE GROUT
LISTENING BORING
IMPACT BORING
PVC PLASTIC CASING
150 mm DIAMETER (±)
"DO NOT SCALE THIS DRAWING"


SURFACE TRIGGER
P WAVE
S WAVE
NATURAL TIME SCALE
IMPACT TRANSDUCER
REAL TIME
LISTENING TRANSDUCER
P WAVE
S WAVE
NEW ZERO TIME AT BOTTOM OF IMPACT ROD
MAGNIFIED TIME SCALE


ELEV. (M)
DEPTH (M)
SOIL RB-I PROFILE
DESCRIPTION
WAVE VELOCITY, M/SEC.
100
200
500
1000
2000
GWT
TOPSOIL
SANDY GRAVEL
MOLASSEFELS
BOTTOM OF BORING AT DEPTH OF 50 M.
410.0
400.0
390.0
380.0
370.0
10
20
30
40
50
60

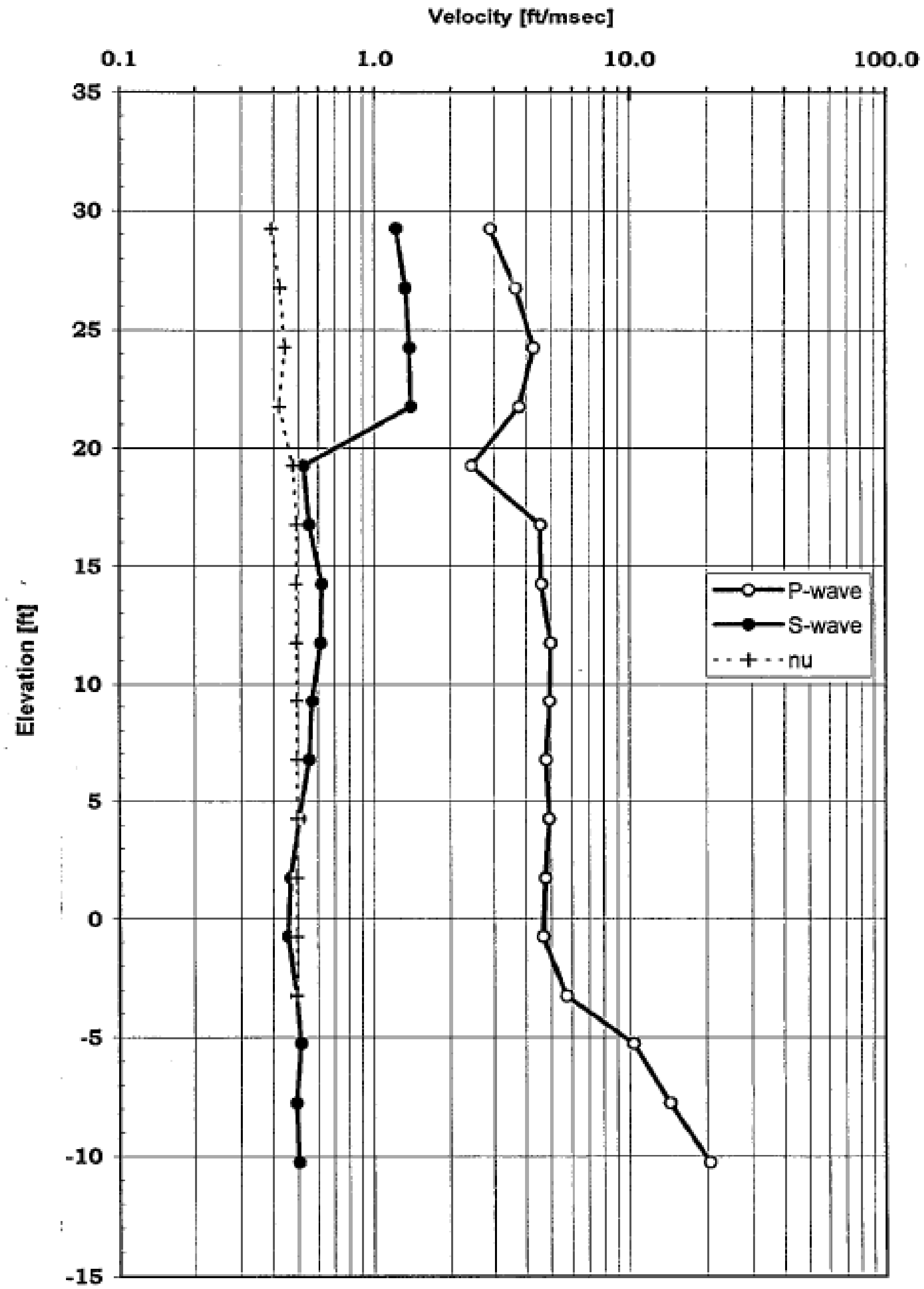


DEPTH (M)
SOIL PROFILE
★
DESCRIPTION
, M/SEC.
500
1000
2000
5000
GWT
ARCILLA LIMOSA
ARENISCA DE MATRIZ ARCILLOSA
CONGLOMERADO CALCAREO
MARGA ARCILLOSA
ARENISCA DE MATRIZ ARCILLOSA
MARGA ARCILLOSA / ARENISCA DE MATRIZ ARCILLOSA
ARENISCA DE MATRIZ ARCILLOSA
MARGA ARCILLOSA
ARENISCA CALCAREA
MARGAS ARCILLOSAS/ARENISCA CALCAREA
ARENISCAS DE MATRIZ ARCILLOSA / MARGAS ARCILLOSAS
CONGLOMERADO CALCAREO
MARGAS ARCILLOSAS
ARENISCA DE MATRIZ ARCILLOSA
MARGA ARCILLOSA
ARENISCA ARCILLOSA / ARENA LIMOSA
ARENISCA CALCAREA / ARENISCA ARCILLOSA
LIMOS ARENOSOS / ARENISCA DE MATRIZ ARCILLOSA
CONGLOMERADO CALCAREO
ARENISCA DE MATRIZ ARCILLOSA / MARGAS ARCILLOSAS
10
20
30
40
50
60
70
80
90
00



98-6
98-7
98-8
N65W **
N62W **
N74W ** N
~15'
~15'
2 3/4" OD INCLINOMETER CASING
SOURCE
PLAN
98-6
98-7
98-8
2.36'
2.95'
2.50'
FILL
43.55'
STIFF SILTY CLAY
41.8'
SOFT SILTY CLAY
V DENSE SILTY SAND
REFUSAL WITH ROLLER BIT @ 41.5'

In Situ Seismic Wave Velocity Test Data
"Shot" Hole to Boring 98-7 at Distance ~15 Feet



A Problem?

ASTM D4428 / D4428M

Significance and Use

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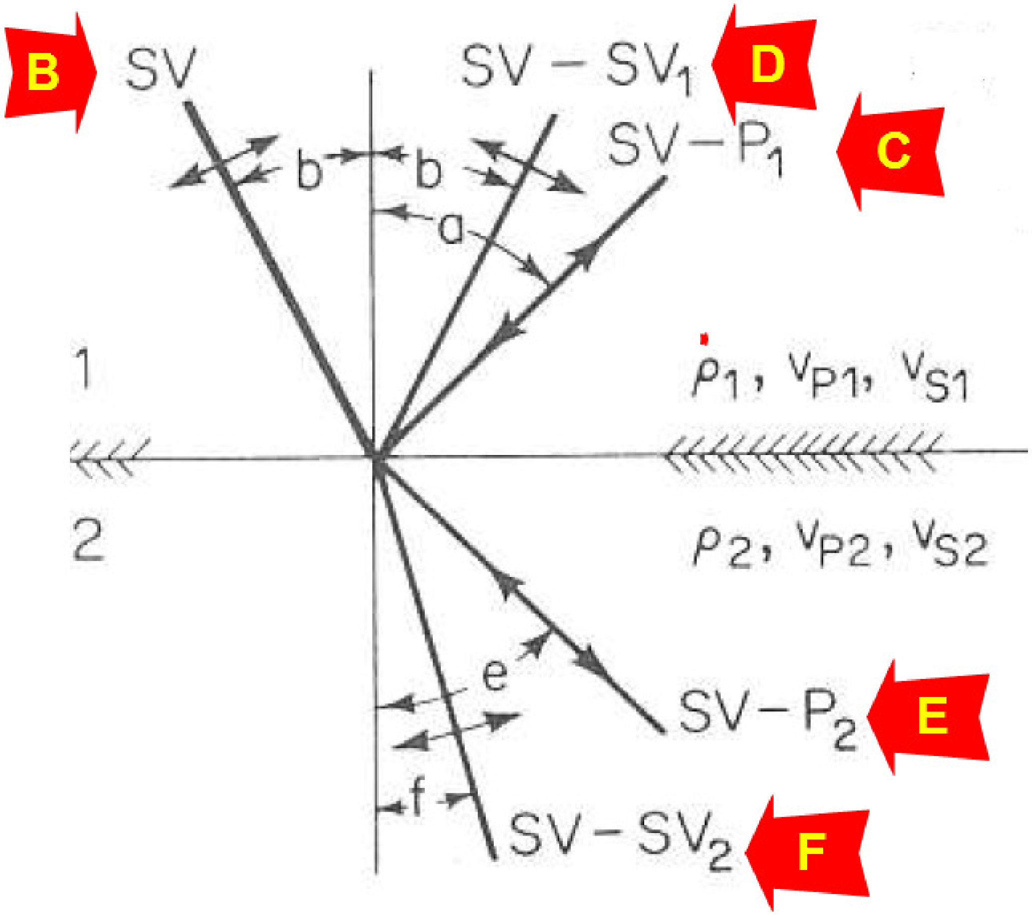
Snell's Law



Incident SV−Wave.

Snell's Law

$$\frac{\sin a}{v_{P1}} = \frac{\sin b}{v_{S1}} = \frac{\sin e}{v_{P2}} = \frac{\sin f}{v_{S2}}$$

Zoeppritz Equations (1907)

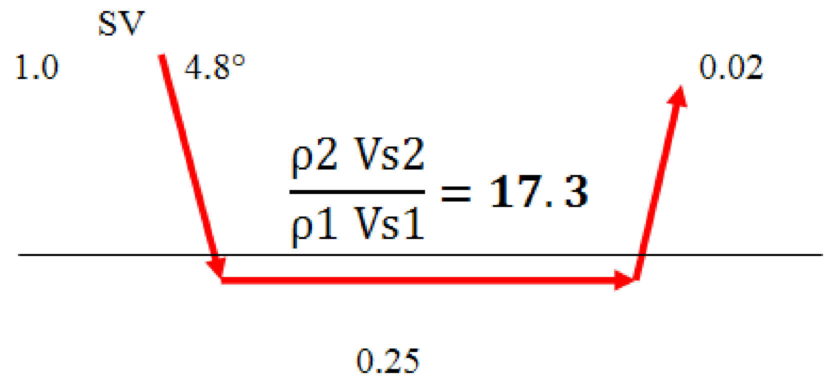
For incident *SV*-wave—

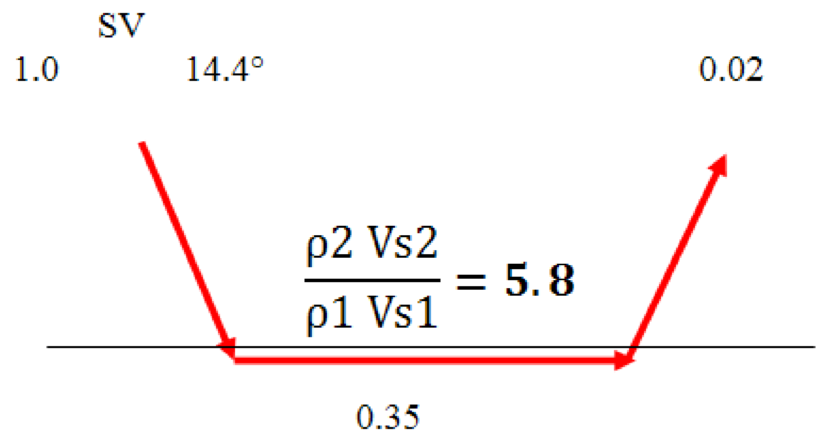
$$(B + D)\sin b + C\cos a - E\cos e - F\sin f = 0$$

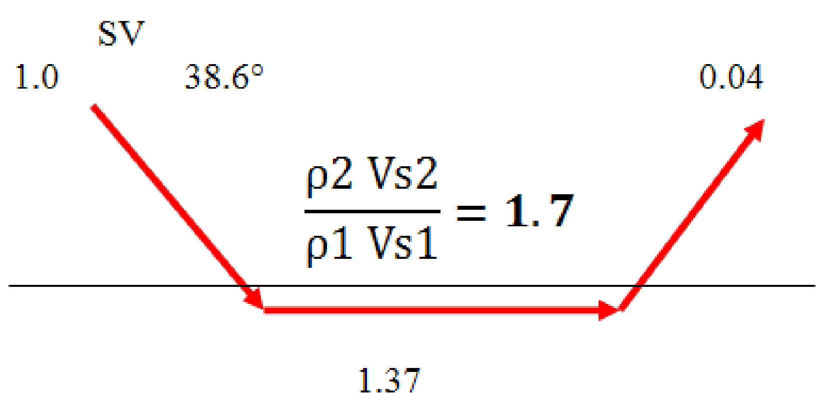
$$(B - D)\cos b + C\sin a + E\sin e - F\cos f = 0$$

$$(B + D)\cos 2b - C\frac{v_{S1}}{v_{P1}}\sin 2a + E\frac{\rho_2}{\rho_1}\frac{v_{S2}^2}{v_{S1}v_{P2}}\sin 2e - F\frac{\rho_2}{\rho_1}\frac{v_{S2}}{v_{S1}}\cos 2f = 0$$

$$-(B - D)\sin 2b + C\frac{v_{P1}}{v_{S1}}\cos 2b + E\frac{\rho_2}{\rho_1}\frac{v_{P2}}{v_{S1}}\cos 2f + F\frac{\rho_2}{\rho_1}\frac{v_{S2}}{v_{S1}}\sin 2f = 0$$


SV
1.0
4.8°
0.02
$\frac{\rho 2\ Vs2}{\rho 1\ Vs1} = 17.3$
0.25


SV
1.0
14.4°
0.02
$\frac{\rho 2\ Vs2}{\rho 1\ Vs1} = 5.8$
0.35


SV
1.0
38.6°
0.04
$\frac{\rho 2\ Vs2}{\rho 1\ Vs1} = 1.7$
1.37

Conclusions

1. Cross-Hole Shear wave energy created by a split spoon soil sampler is transmitted primarily in a direction perpendicular to the sampler as an SV wave.

2. The velocity transducer is optimally oriented to be most sensitive to the directly transmitted SV wave.

3. The velocity transducer orientation reduces its sensitivity to the refracted SV wave.

4. Conclusions 2 and 3 combined with the refracted SV wave amplitude being less than 5% means that refracted SV waves have negligible effect on the recorded wave.

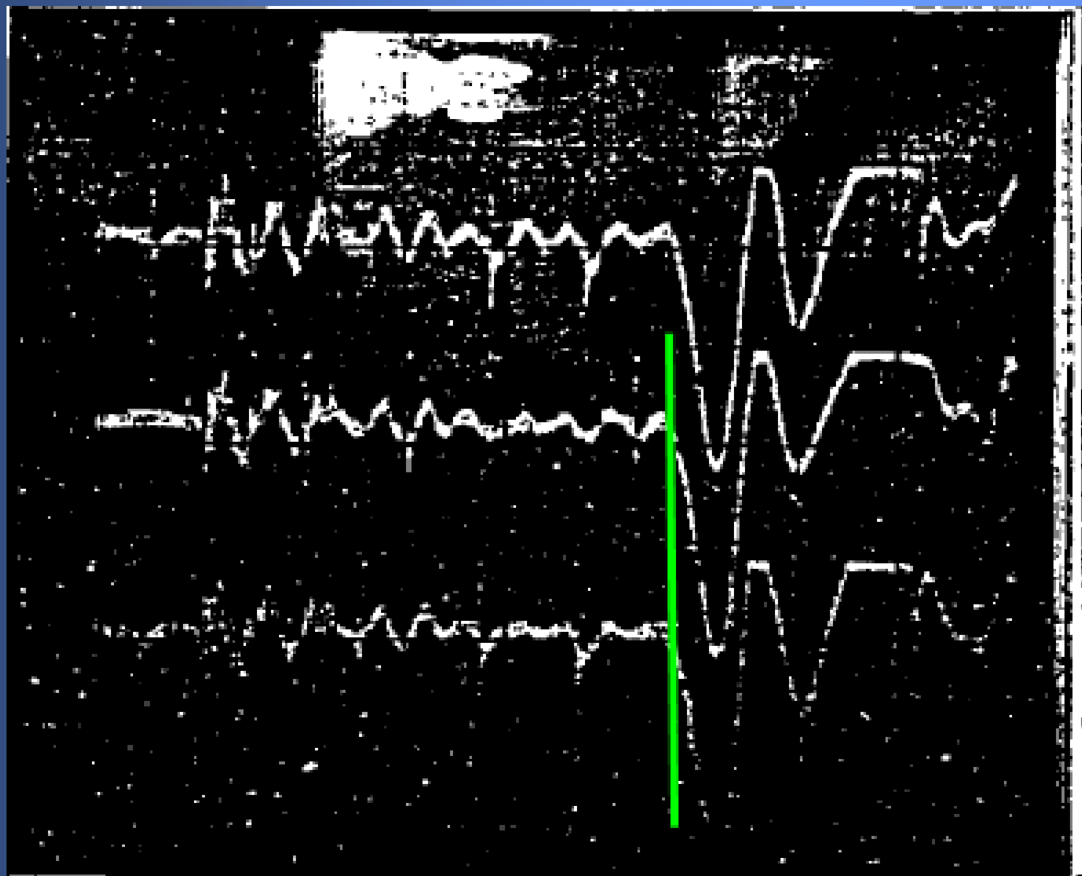
Myth Busted!!

Thank you!

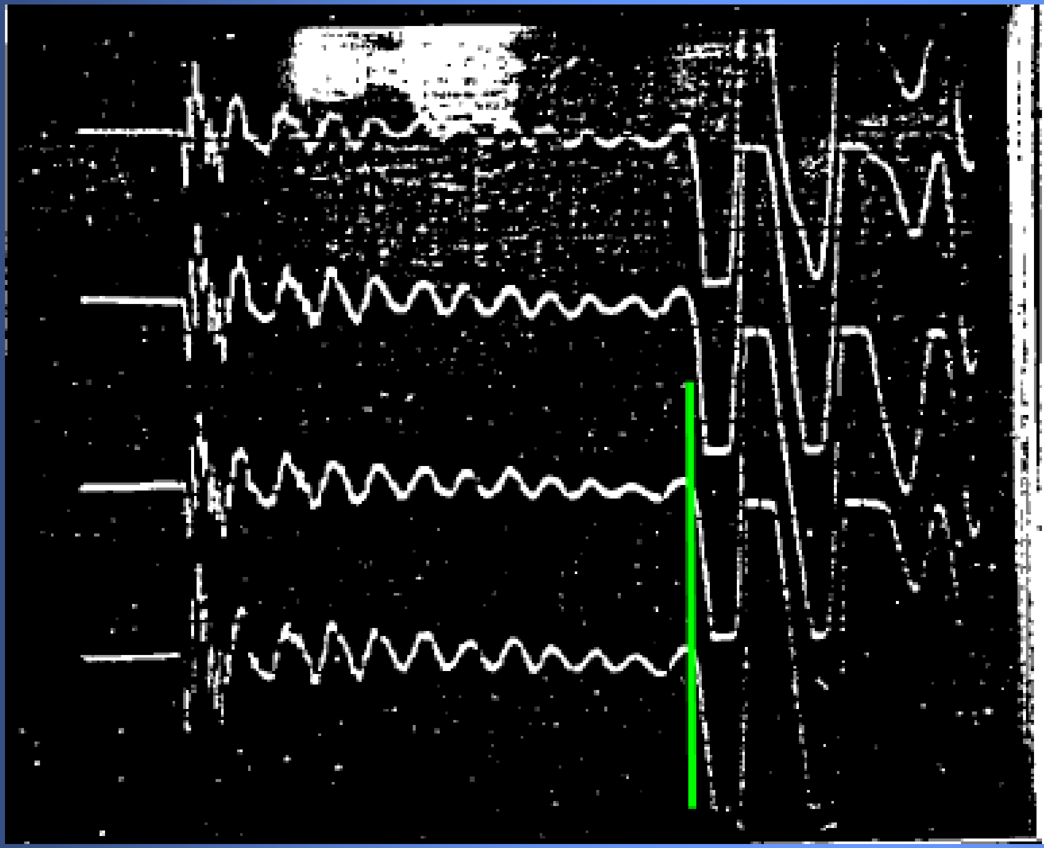
Questions, Comments?

End

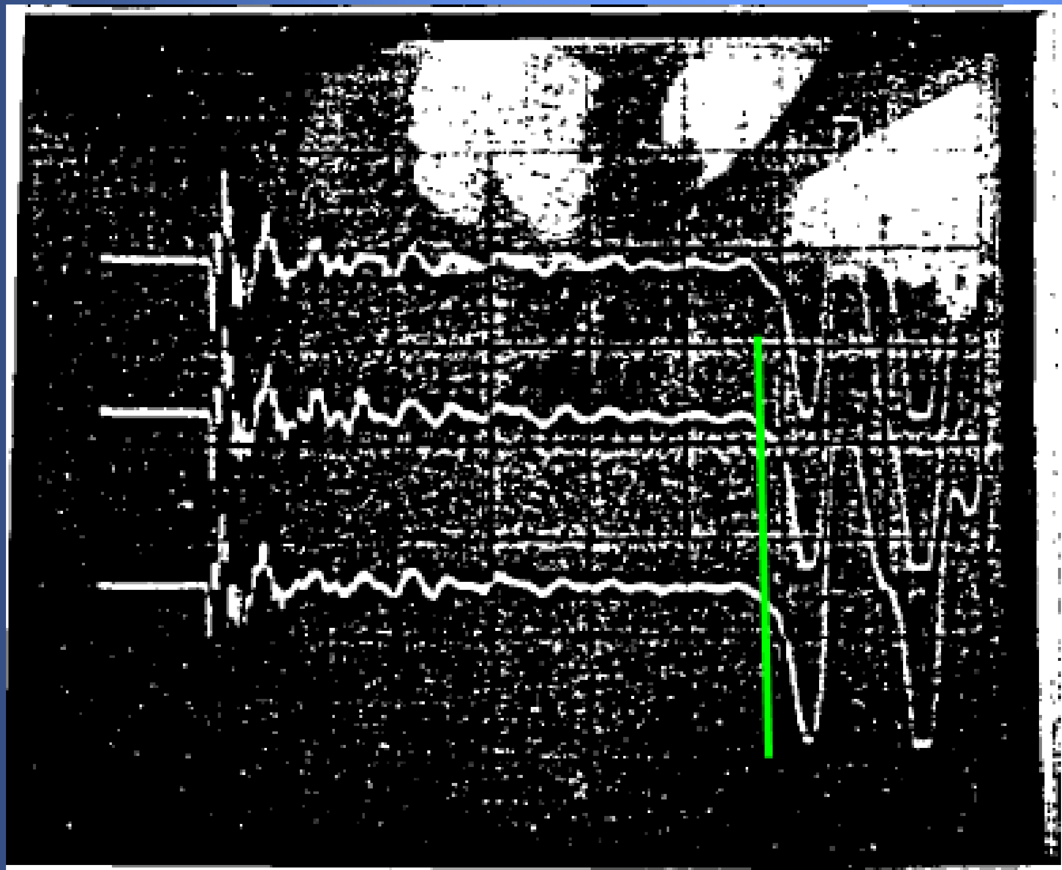
Set of traces:



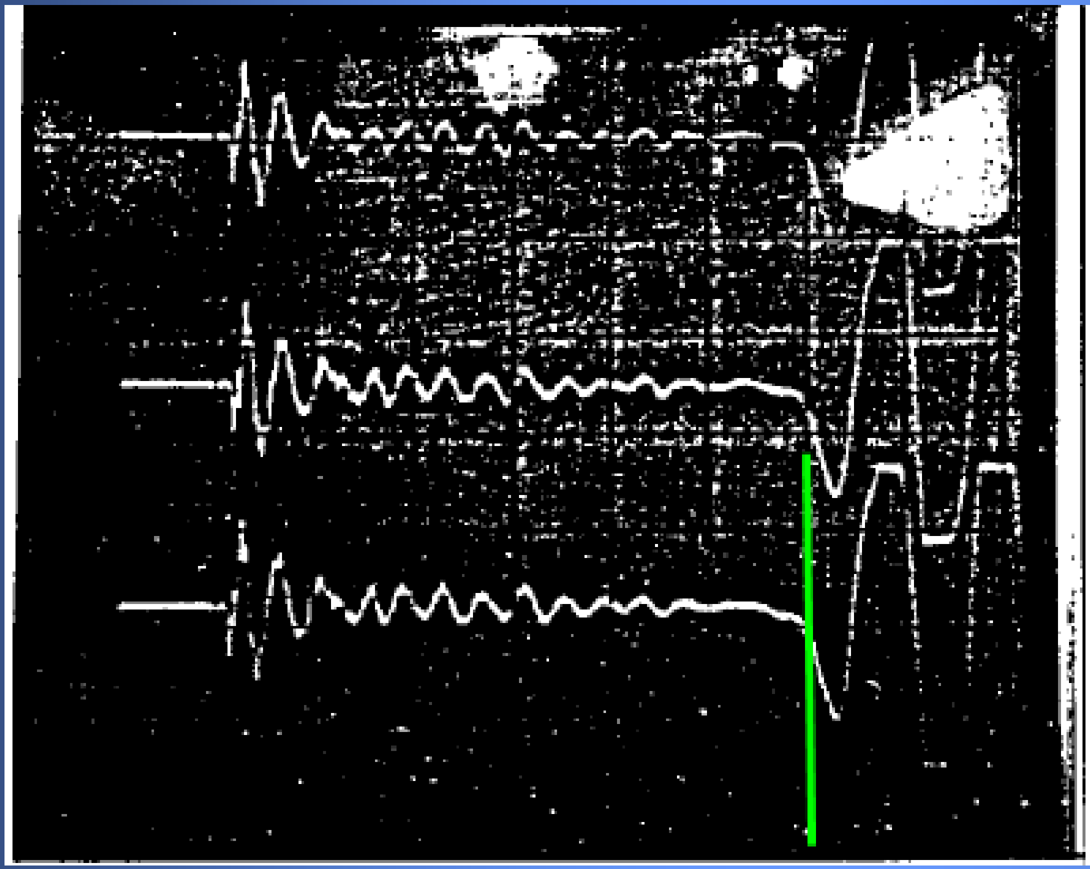
98-7: 10B
Elev. 6.7 ft



98-7: 11B
Elev. 4.4 ft.

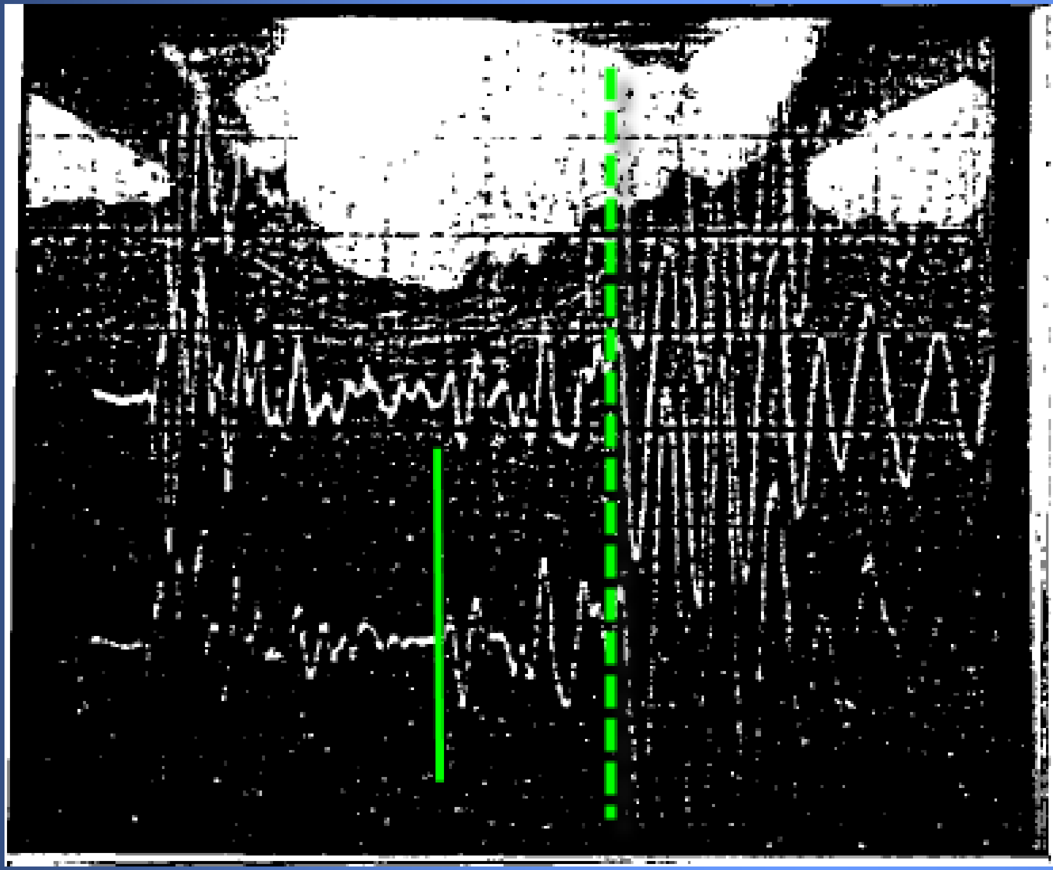


98-7: 12B
Elev. 1.7 ft

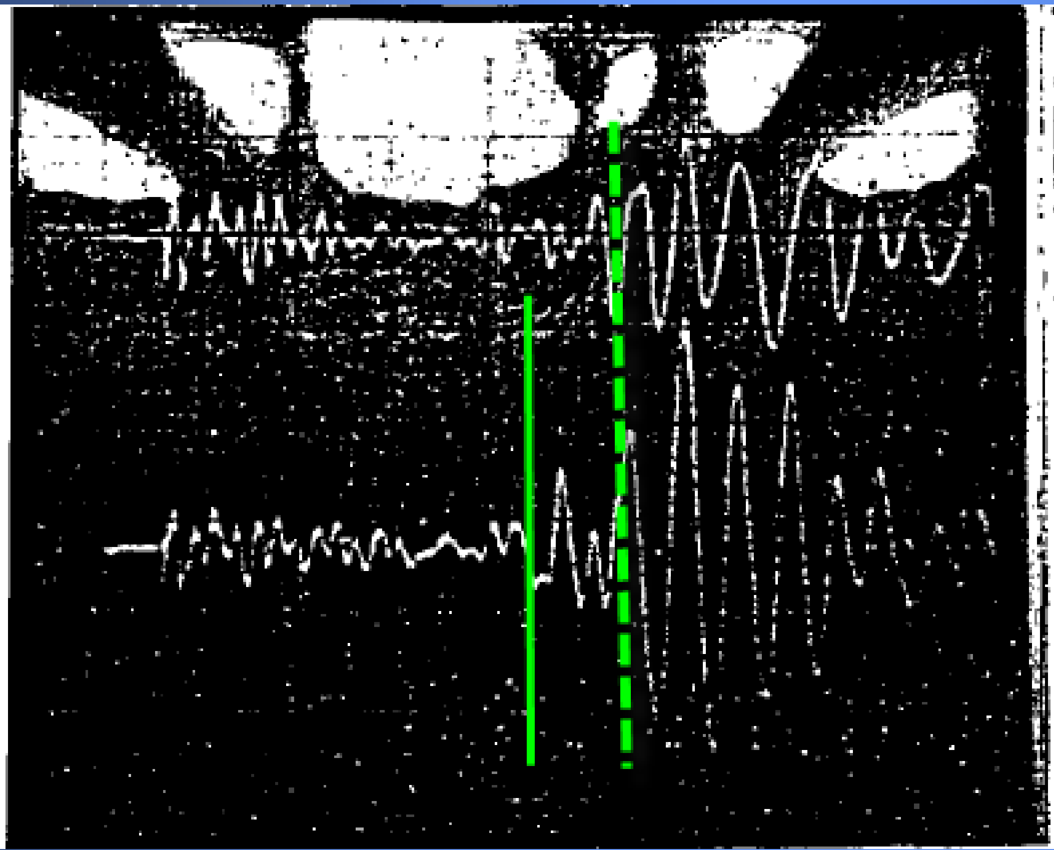


98-7: 13B
Elev. -0.7 ft

98-7: 14B
Elev. -3.3 ft



98-7: 16B
Elev. -6.0 ft
Source in Rock



98-7: 17A
Elev. -10.0 ft
Source in
Rock