GROUND VIBRATIONS

Blasting versus Earthquakes

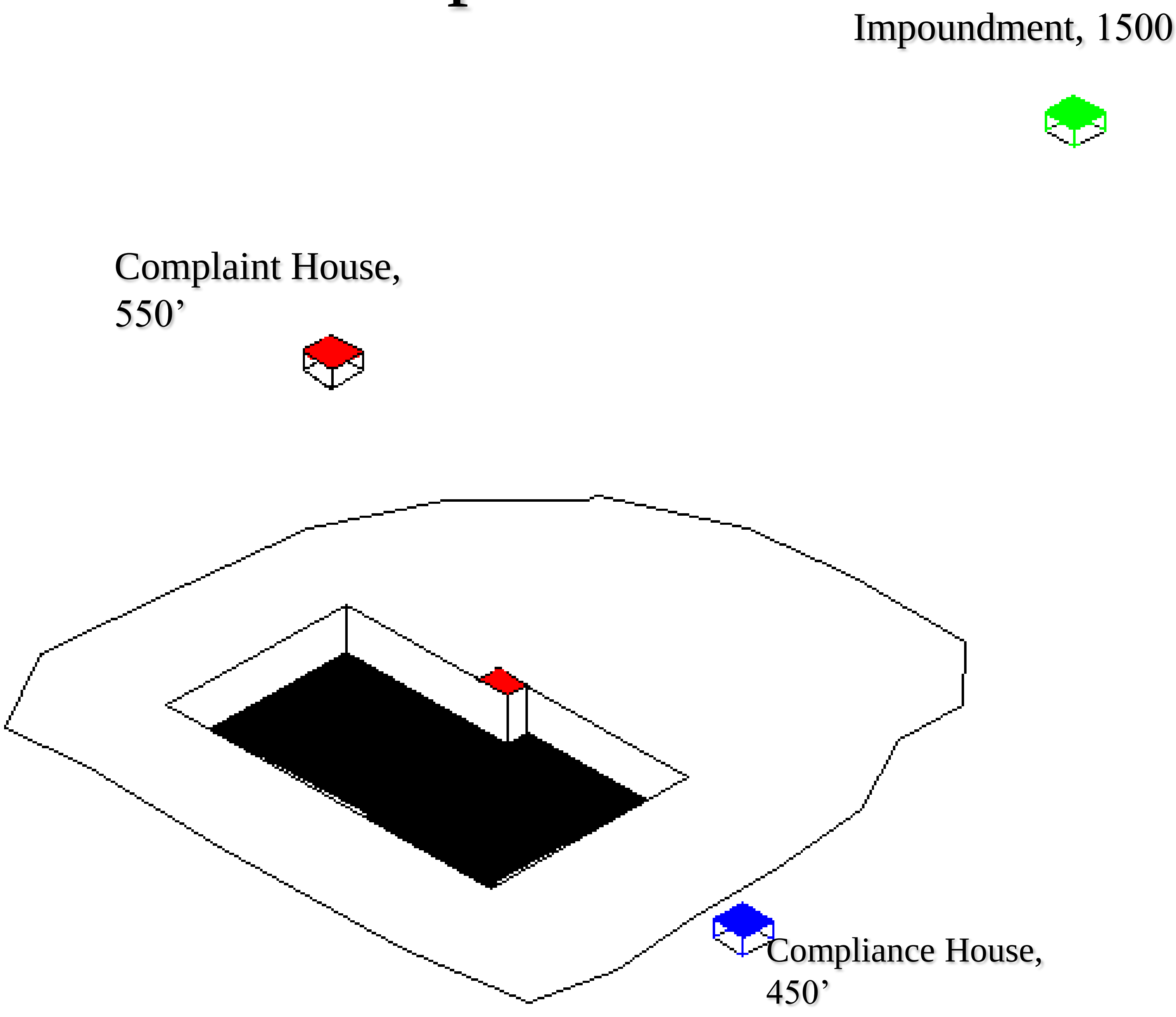
Effects and Responses on

Coal Waste Impoundments

And

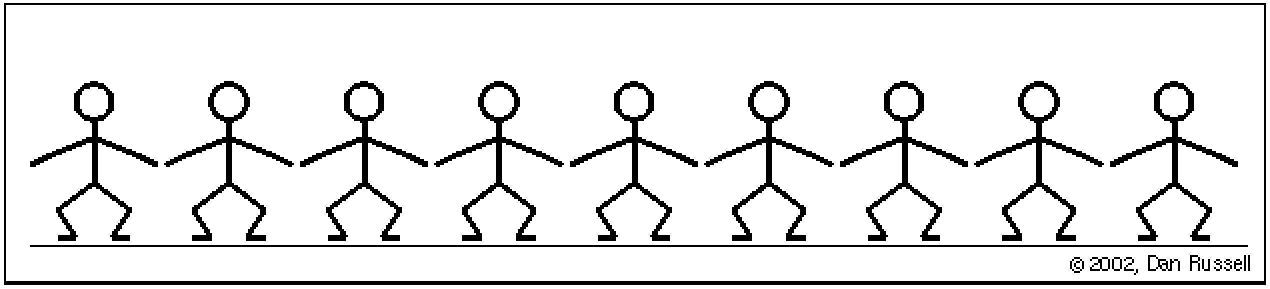
Tailings Dams

Spatial Relationships



Ground Vibrations

- Ground Vibrations from either a Blast or Earthquake is a ***Forced Vibration***
- In a Forced Vibration the frequency of the vibration is the frequency of the force or motion applied
- In a Vibration there is a rapid oscillation of a particle, back & forth across a central position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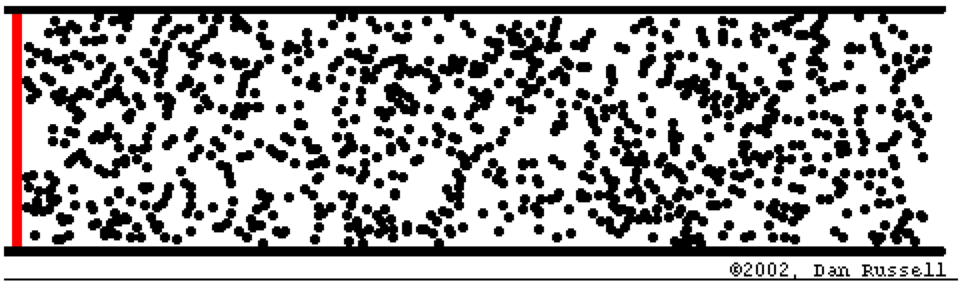
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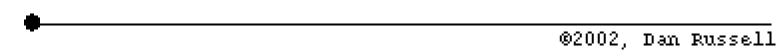
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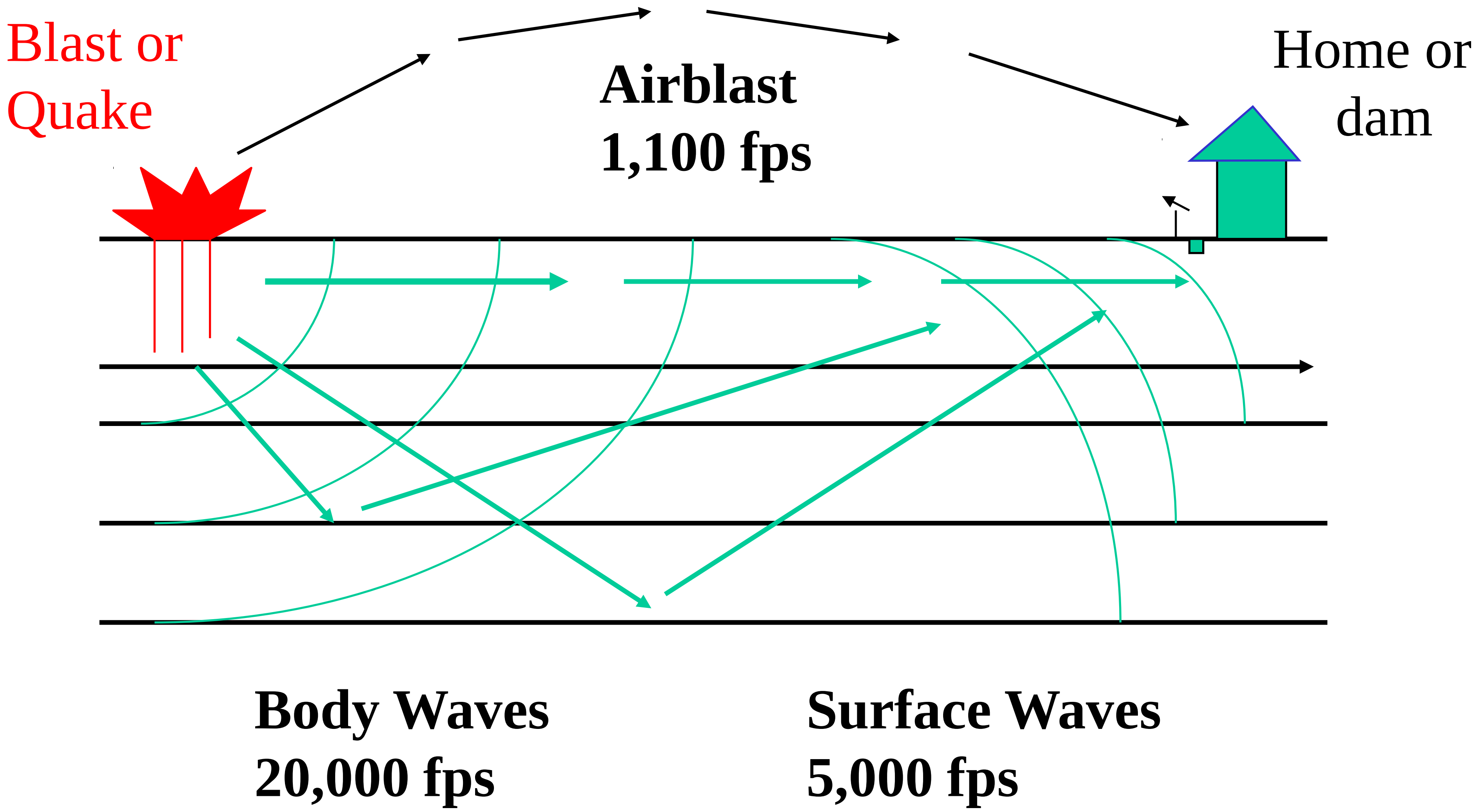
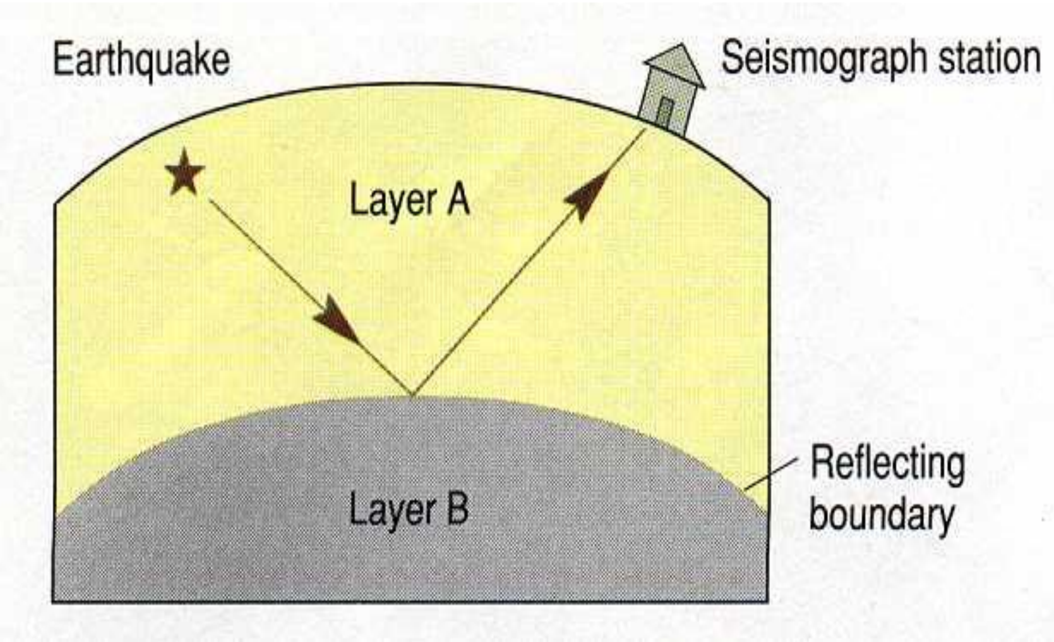
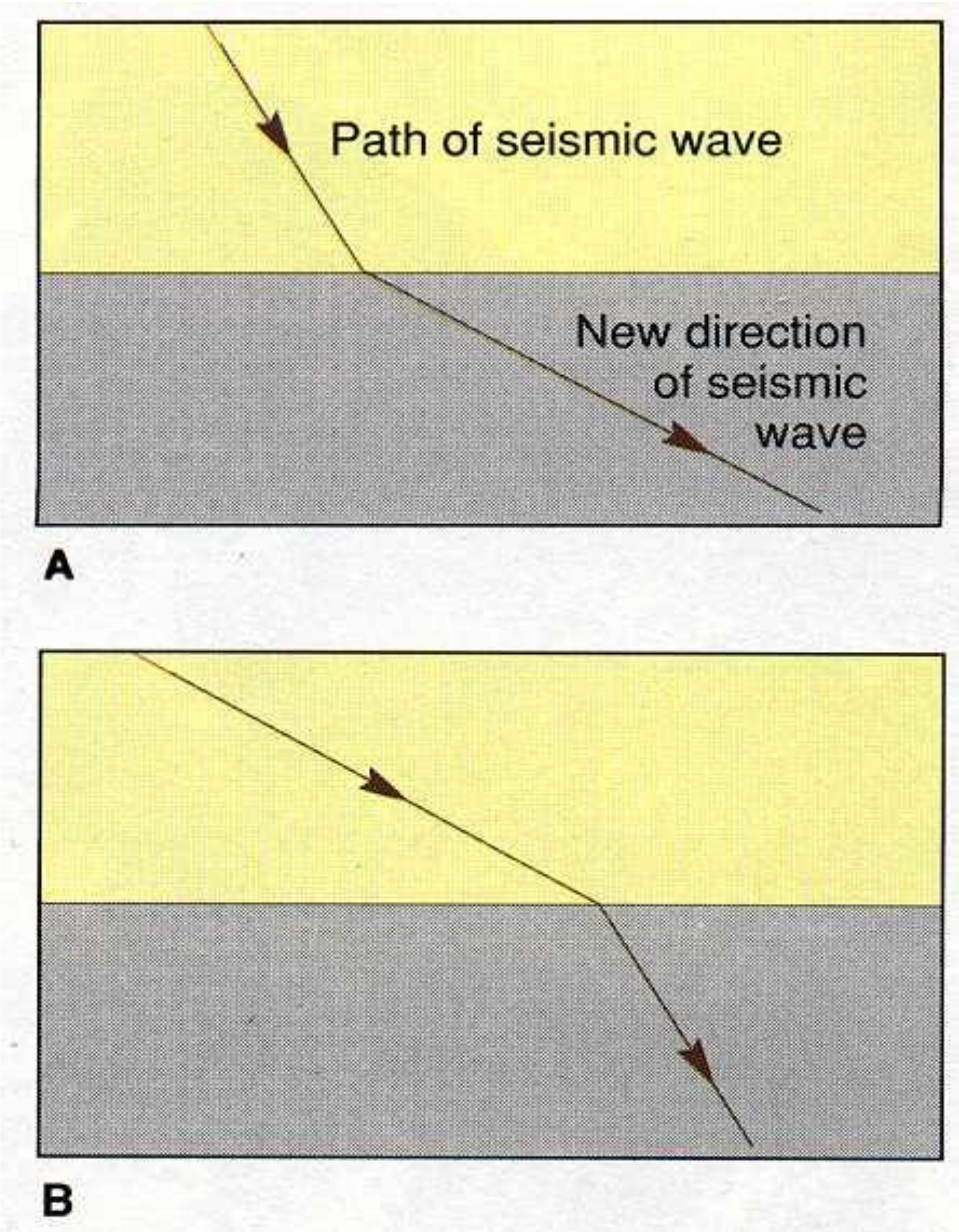
Vibration Energy



Travel through the ground



Reflected



Refracted

Frequency

- Number of cycles per second
- Measured in Hertz (Hz)

$$\mathbf{f = 1/T}$$

T(Period) is the time of one cycle

$$\mathbf{T = 1/f}$$

- Zero-crossing used by seismographs

$$f = 1 / (2t)$$

t is the time of ½ a cycle or where the wave crosses zero

Displacement or Amplitude

- The distance a particle moves (A)
- A measured in inches (in)
- Important for damage assessment

Velocity (v)

Peak Particle Velocity

- The rate or speed at which a particle moves
- V is in inches per second (in/s)
- For sine waves: $v = 2 \pi f A$
- f is frequency, Hz
- π is 3.14
- Important for compliance

Acceleration

- The rate at which a particle changes speed
- a is in inches per second squared (in/s^2) or gravities (g)
- For sine waves, a **= 2 π f v**
- Important for coupling

Acceleration

- Acceleration in "g's" $a_g = \mathbf{2\,\pi\, f\;\; v/386}$

Where a_g = Acceleration

f = frequency

v = velocity

(To express acceleration in "g's" divide by 386 inches per second squared)

Seismic Wave Lengths

- Wave Length = propagation velocity/ frequency

  L = V/f

- V: the propagation velocity is that of any measurable wave along the surface of the ground
- A practical rule for structures for estimating wave-length-structure size ratio is to use L = 300 ft.
- The effects of any structure would be it extent divided by L, and the greatest differential displacement would be the extent/(L/2)

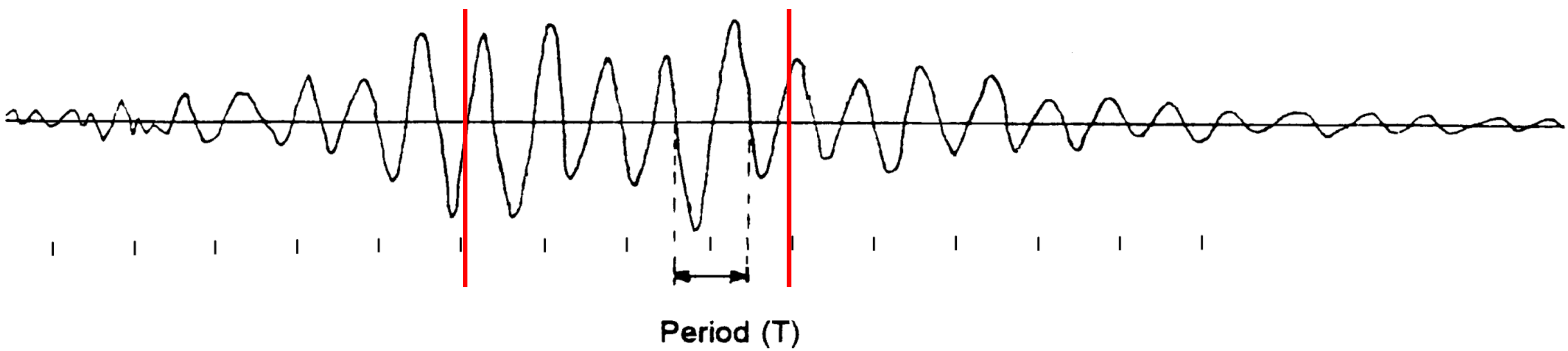
GV-BLAST TIME HISTORY RECORD EXAMPLE

BLASTING TIME HISTORY

Amplitude versus time.
For this record, it is particle velocity amplitude. Vibration records could also be acceleration or displacement time histories depending on the devices used to measure the motion.

Period (T) is the time in seconds for one complete vibration cycle or "seconds per cycle."

Frequency (f) is 1/T or "cycles per second" also "Hz"



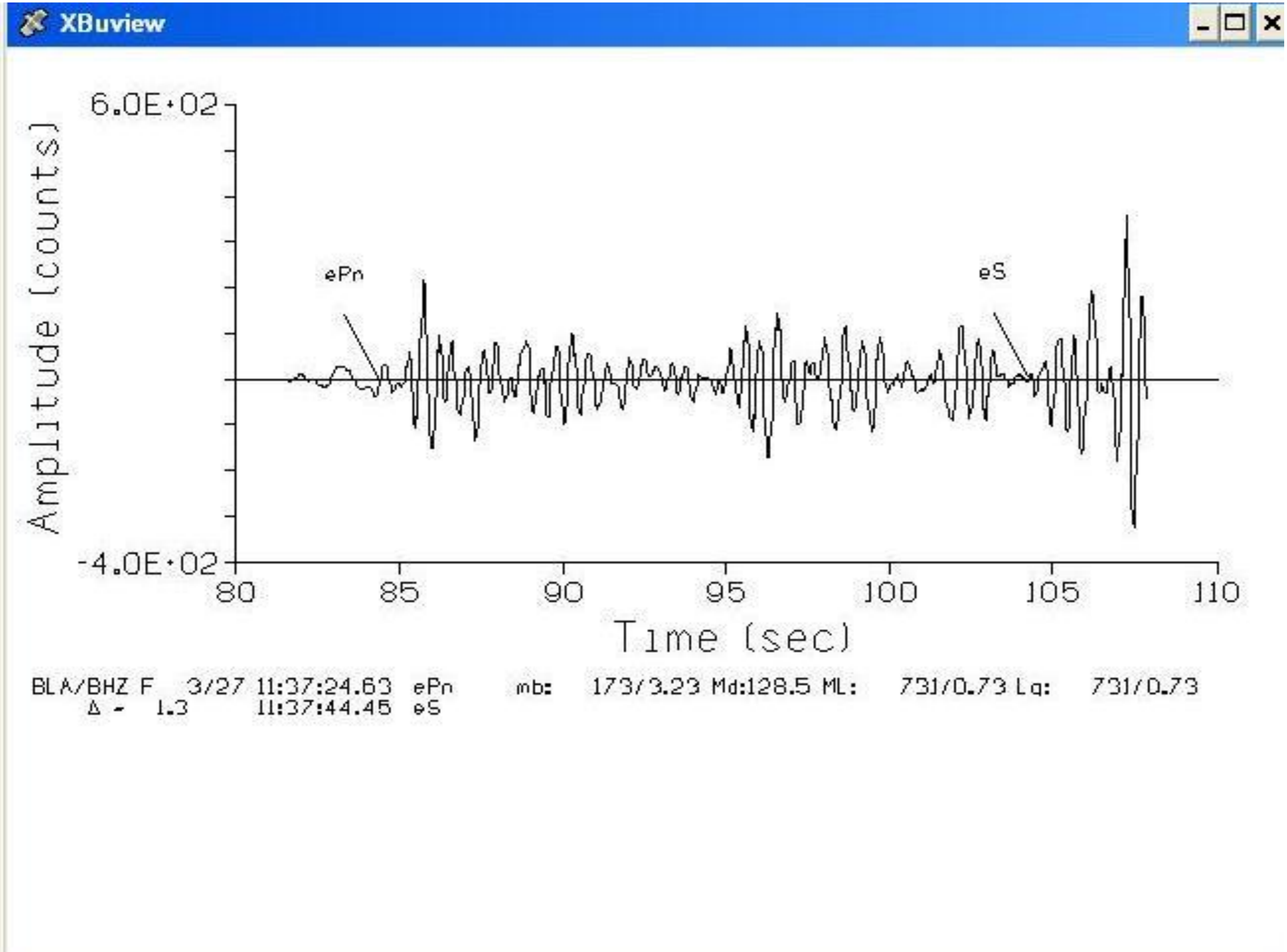
Period (and frequency) can usually be estimated by measuring the time between zero crossings, particularly for a record which has a uniform or one dominant frequency.

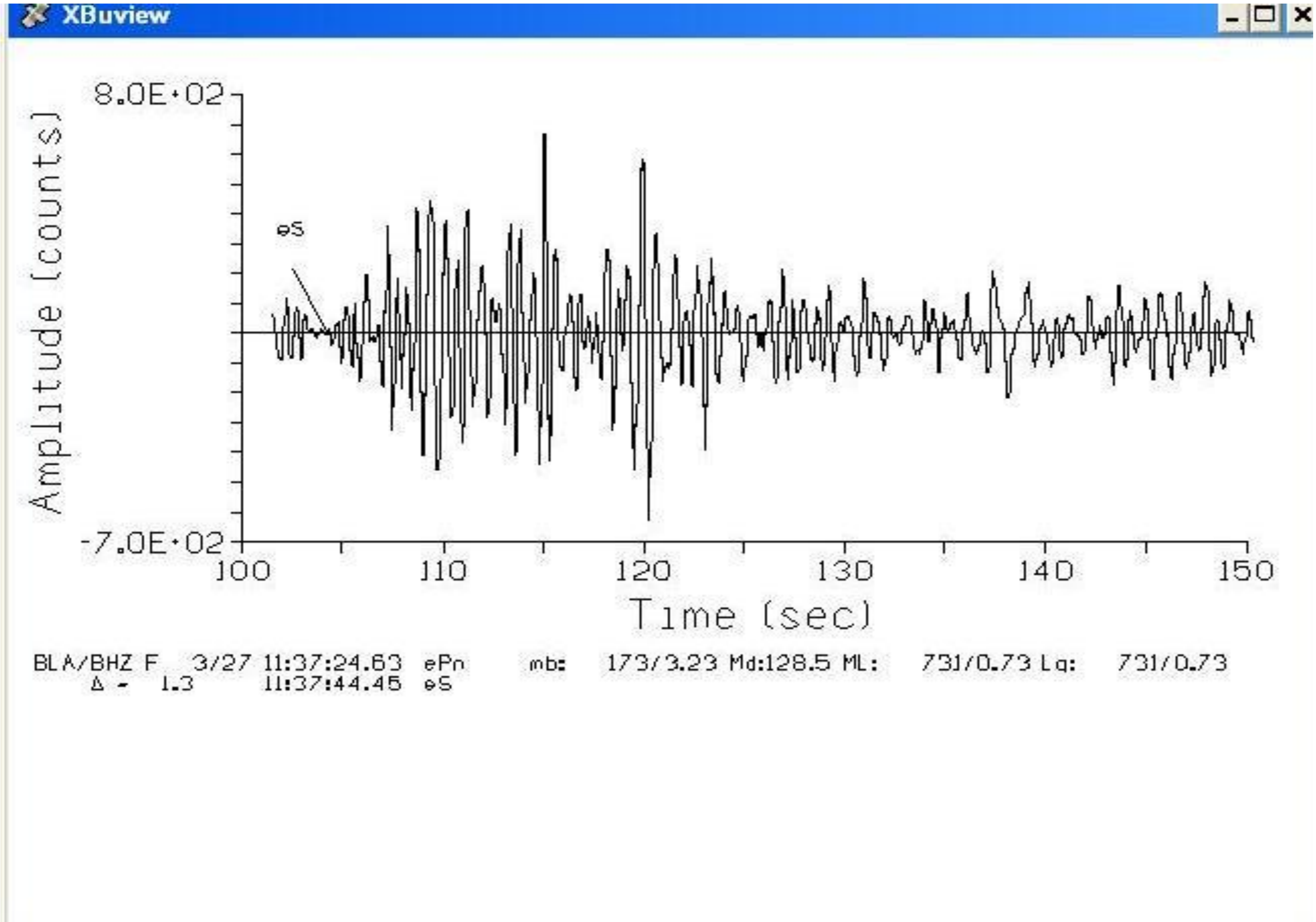
In this example, the timing marks represent 0.1 sec (100 ms) and the measured period is about 88 percent of the time between marks

Period (T): 0.88 x 0.1 sec = .088 sec
Frequency (f): 1/.088 = 11.4 Hz

Earthquakes & Vibrations

- Vibrations of the Earth-caused by the sudden release of energy, usually as a result of displacement of rock along faults.
- Strain builds up until the elastic limit (strength) of the rock is exceeded. The rock then rupture (fails) at a point, snapping back toward an unstrained position, releasing the elastic energy as seismic waves radiating outward.
- The greater the stored strain, the greater the release of energy.


XBuview
6.0E+02
Amplitude (counts)
ePn
eS
-4.0E+02
80
85
90
95
100
105
110
Time (sec)
BLA/BHZ F 3/27 11:37:24.63 ePn mb: 173/3.23 Md:128.5 ML: 731/0.73 Lg: 731/0.73
Δ = 1.3 11:37:44.45 eS


XBuview
8.0E+02
-7.0E+02
Amplitude (counts)
eS
100
110
120
130
140
150
Time (sec)
BLA/BHZ F 3/27 11:37:24.63 ePn mb: 173/3.23 Md:128.5 ML: 731/0.73 Lg: 731/0.73
Δ = 1.3 11:37:44.45 eS

Magnitude & Intensity

- Magnitude : a measure of the size (energy release), on the Richter – defined as seismograph reading 100 kilometers from epicenter.
- Intensity: a measure of the strength of a earthquake as felt at a particular location (severity of shaking or damage), the Modified Mercalli.
- Note: There is no way to make a direct measurement of released energy

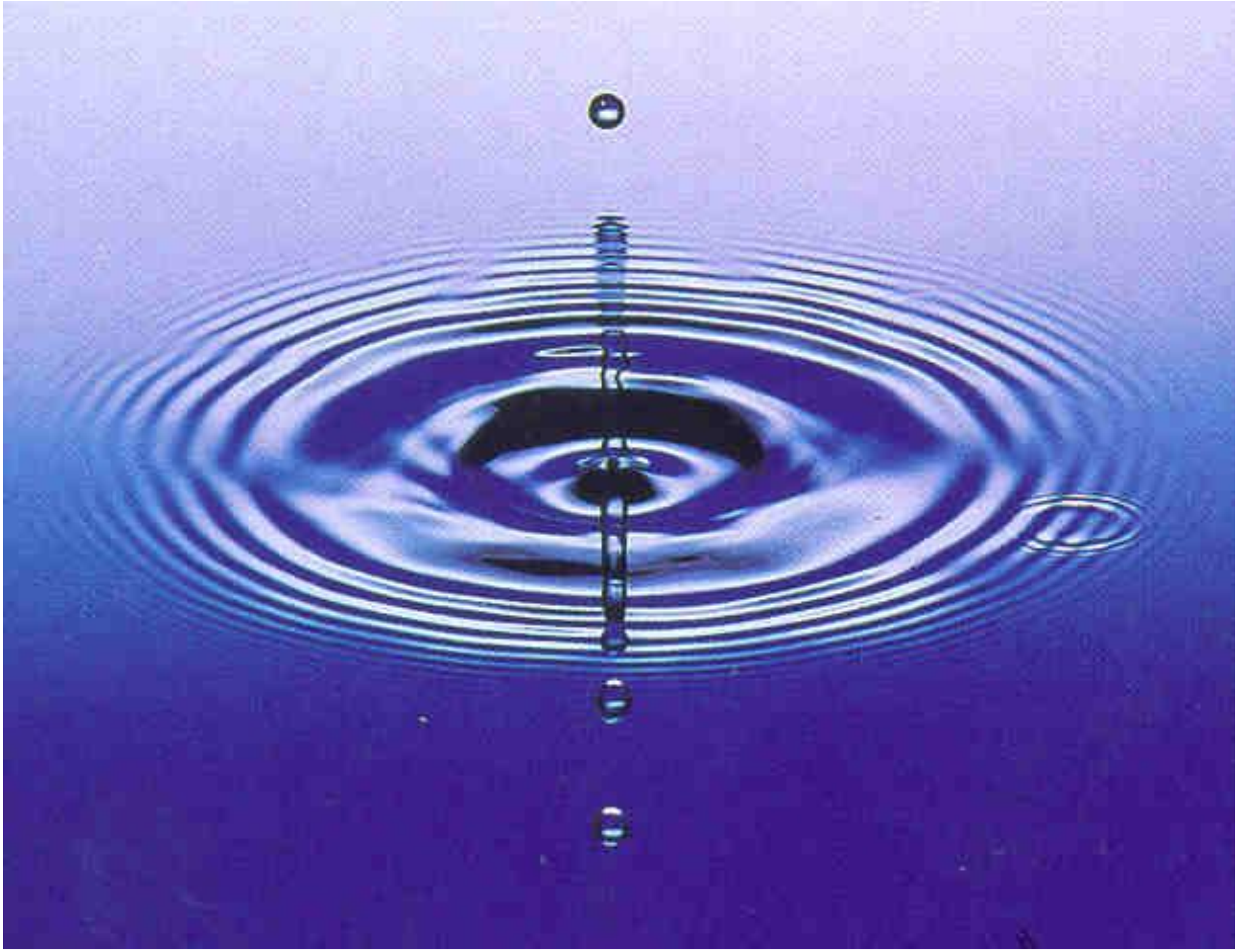
Equivalent/Comparison Mercalli-Richter

Intensity - Mercalli	**Magnitude - Richter**	**Observations**
1 to II	1.0 to 3.0	Felt by few, barely noticeable, upper floors
III to IV	3 to 4 & 4	Noticeable indoors?, many in-few outside
V to VI	4 to 5 & 5 to 6	Felt by everyone, objects move, hard to stand, some damage to structures
VII to VIII	6.0 & 6.0 to 7.0	Poor construction, ordinary structures all effected
IX	7.0	Landsides, wholesale destruction
X	7.0 to 8.0	Ground failures -cracked
XI	8.0	Total damage, waves on ground seen

Seismic Waves

- Body Waves: with rock depth speeds up
  - Primary (P) Wave – compressional & vibrates parallel to direction of movement. Fastest seismic wave.
  - Secondary (S) Wave - known as a shear wave, vibrates perpendicular to the P Wave. Only travels in solids.
- Surface Waves: rolling, shaking motion
  - Rayleigh (R) Waves – Behaves like water waves with an elliptical motion
  - Love (L) Waves – Shear motion in a horizontal plane, therefore most destructive & fastest of the surface waves.

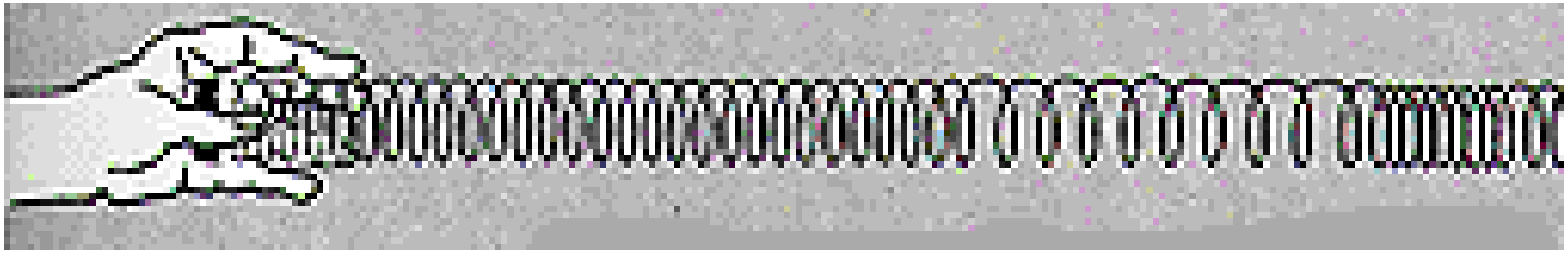
Vibrations or Waves



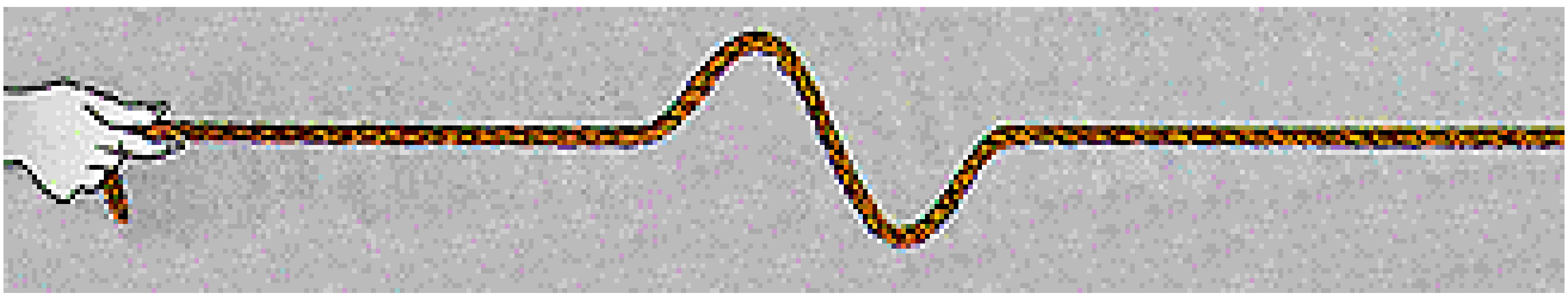
Typical Values of P & S Velocities

Material	P Velocity	S Velocity	Density
Granite	13,000-20,000	7,000-11,000	2.70
Sandstone	8,000-14,000	3,000-10,000	2.45
Limestone	10,000-20,000	9,000-10,500	2.65
Shale	6,000-13,000	3,500-7,500	2.35
Marble	19,000	11,500	2.75
Clay	3,700-8,200	1,900	1.40
Soil	500-2,500	300-1,800	1.1-2.0

Compression Waves



Shear Waves



Blasting & Vibrations

- Vibrations that result from mining, quarrying, and engineering operations.
- Of the hemisphere of rock around a blast, only a small fraction of the volume is bounded by a free face close enough to the explosion to be fractured by the pressure front. In the rest of the rock , the pressure front rapidly decays into elastic waves.
- The greater the confinement of the explosive, the less the fragmentation and the greater the formation of elastic waves.

29S2-HW

8th May 2002

Limits to Rock Breakage

- The zone (critical radius) of non-elastic effects is equal to cube root of the explosive charge weight.
- Examples: 100 lbs ~ 4.6 ft. & 800 lbs ~ 9.3 ft.
- Micro-Fractures – change the elastic properties of the rock, therefore has an effect on the strength & stability of the mass. Can extend for tens of feet.
- Examples: Rules of Thumb – 10 times the borehole diameter, 3″ hole ≈ 30 ft. & 8″ ≈ 80ft.

Rock Velocities & Impedance

Longitudinal (P) wave speed

• Granite:	18,200 ft/sec
• Marlstone:	11,500 ft/sec
• Sandstone:	10,600 ft/sec
• Chalk:	9,100 ft/sec
• Shale:	6,400 ft/sec

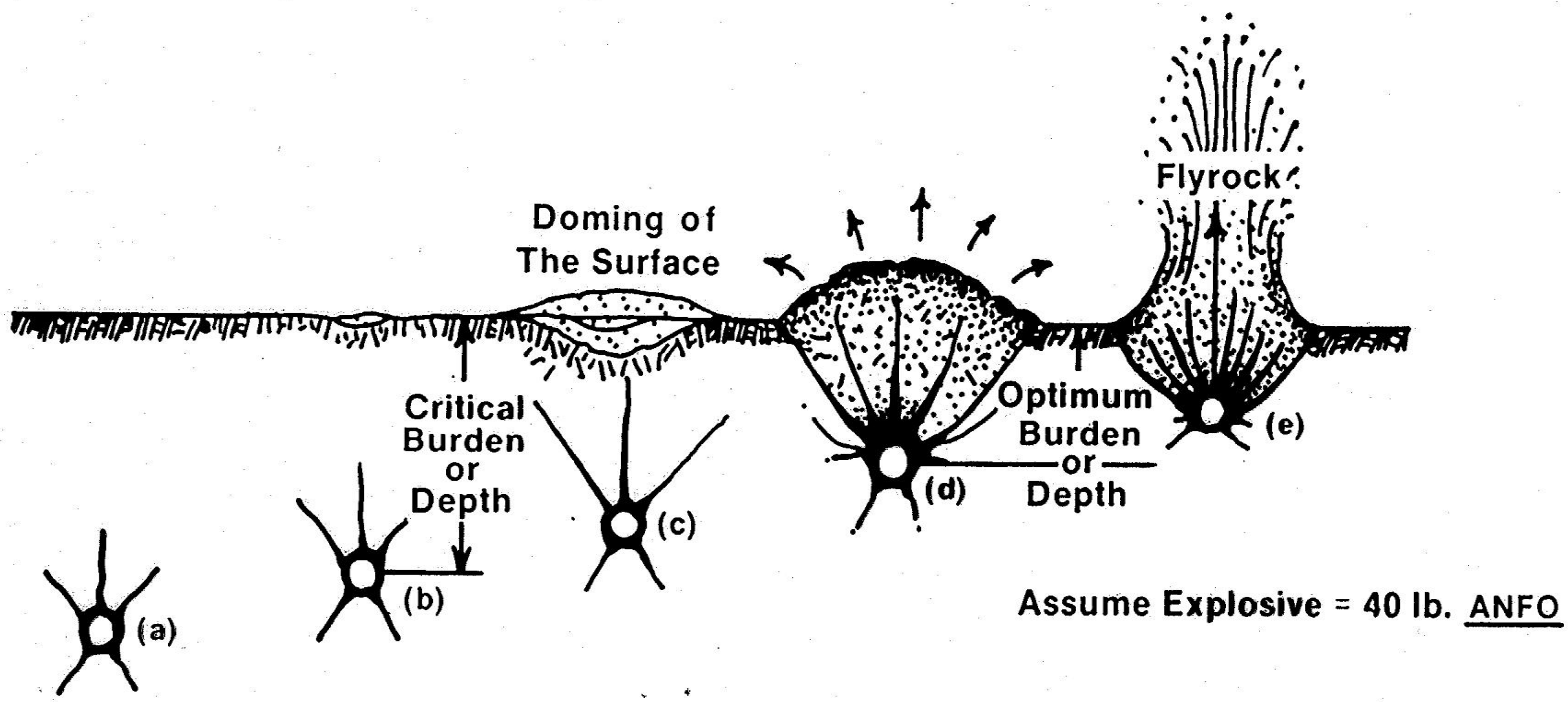
Impedance: rk density x velocity

• Granite:	54 lb sec/in^3
• Marlstone:	27 lb sec/in^3
• Sandstone:	26 lb sec/in^3
• Chalk:	22 lb sec/in^3
• Shale:	15 lb sec/in^3

Particle Velocity Damage Criteria for Rock Mass

- 10 in/sec. - no fracturing of intact rock
- 10-25 in/sec.- minor tensile slabbing will occur
- 25-100 in/sec.- strong tensile & some radial cracking
- 100 in/sec.- complete breakup of rock mass will occur

Confinement



(a) B = 15′

Completely contained, only failure is pulverisation near the charge and radial tensile failure running out from it.

(b) B = 12′

Start of surface failure. Burden not broken. Some doming of the surface.

(c) B = 9′

Surface and subsurface failure almost meet. There will be a shelf of unbroken rock between the two. Doming or surface bulging.

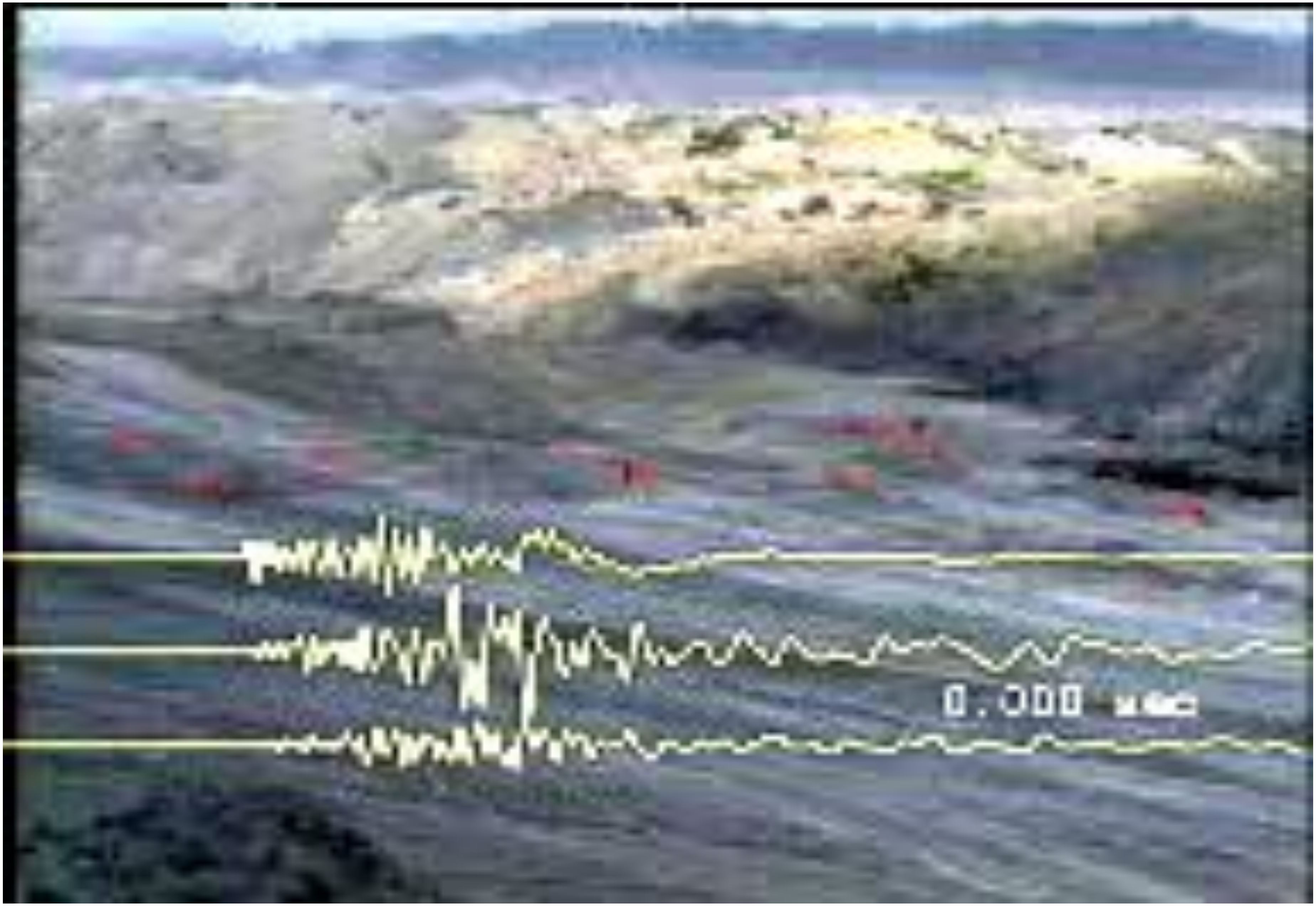
(d) B = 6′

Full crater, burden completely broken out. Surface and subsurface failures run through to the surface.

(e) B = 3′

Full crater, lower volume than optimum fine fragmentation. Noise, flyrock, bowl shaped crater.

Figure 7.17. Schematic of the Effect of Decreasing the Burden on Charges Fired in Rock.


0.000 sec

Scaled Distance

- Scaling of distance is necessary to predict ppv when both charge weight per delay (W), and the distance (D), vary.
- W is the maximum Lbs. of explosive detonated at one instant of time within a 8 ms time frame, within a total blast or shot. There can be one or many equal charges within a single blast, but none will exceed it.
- D is the distance in feet from that source (W) to the structure of concern.

Scaled Distance: SD = D/√W

Blast of 40 holes, 200#/h & 3 holes/8ms with structure @ 1,000 ft from blast

- W = 200#/h x 3 holes/8ms = 600 #/8ms
- √W = √600 =24.5
- D =1,000 ft.
- SD = 1,000/24.5
- SD = 40.8

Blast of 65 holes, 765#/h & 5 holes/8ms with structure @ 1,500 ft from blast

- W = 750#/h x 5 holes/8ms = 3,750#/8ms
- √W = √3,750 =61.2
- D =1,500 ft.
- SD = 1,500/61.2
- SD = 24.5

OSM Ground Vibration Criteria

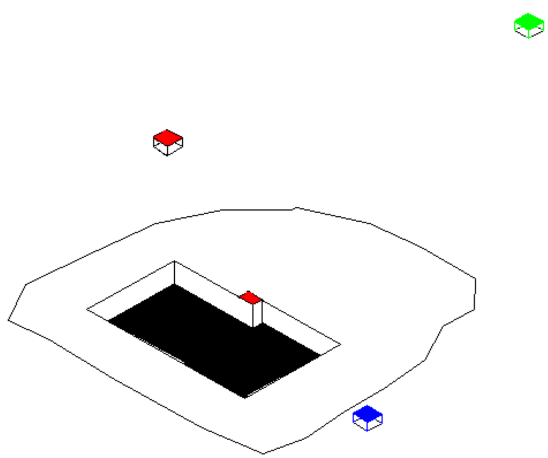
Distance	SD	PPV
< 301	50	1.25
301 – 5000	55	1.00
>5001	65	0.75

-

$$\mathbf{PPV = 438\,(SD)^{-1.52}}$$

What are the Most Important Parameters in Evaluating the Adverse Effects?

- Location of the blast
- Location of the compliance structure
- Distance between the two
- Charge weight per delay
- Confinement
- Type of blast



Damage Criteria – Wave Motion

- Frequency (f) and amplitude (A) are the basic elements of harmonic motion, acceleration (a) results from both, while the force (ma) which moves a structure is defined in terms of the velocity (v or ppv) of the motion it produces.
- Kinetic energy (KE) is energy of motion
- $a = (4\pi^2)(f^2A)$
- $ma = W/a_g\ (a)$
- v or $ppv = (2\pi)(fA)$
- $KE = Wv^2/2a_g$
- Note: acceleration of gravity (a_g) = 32.2 ft/sec^2 or 386 in/sec^2

Comparison: A Blast to A Quake
Sandstone-Shale: V = 8,500 fps

Blast

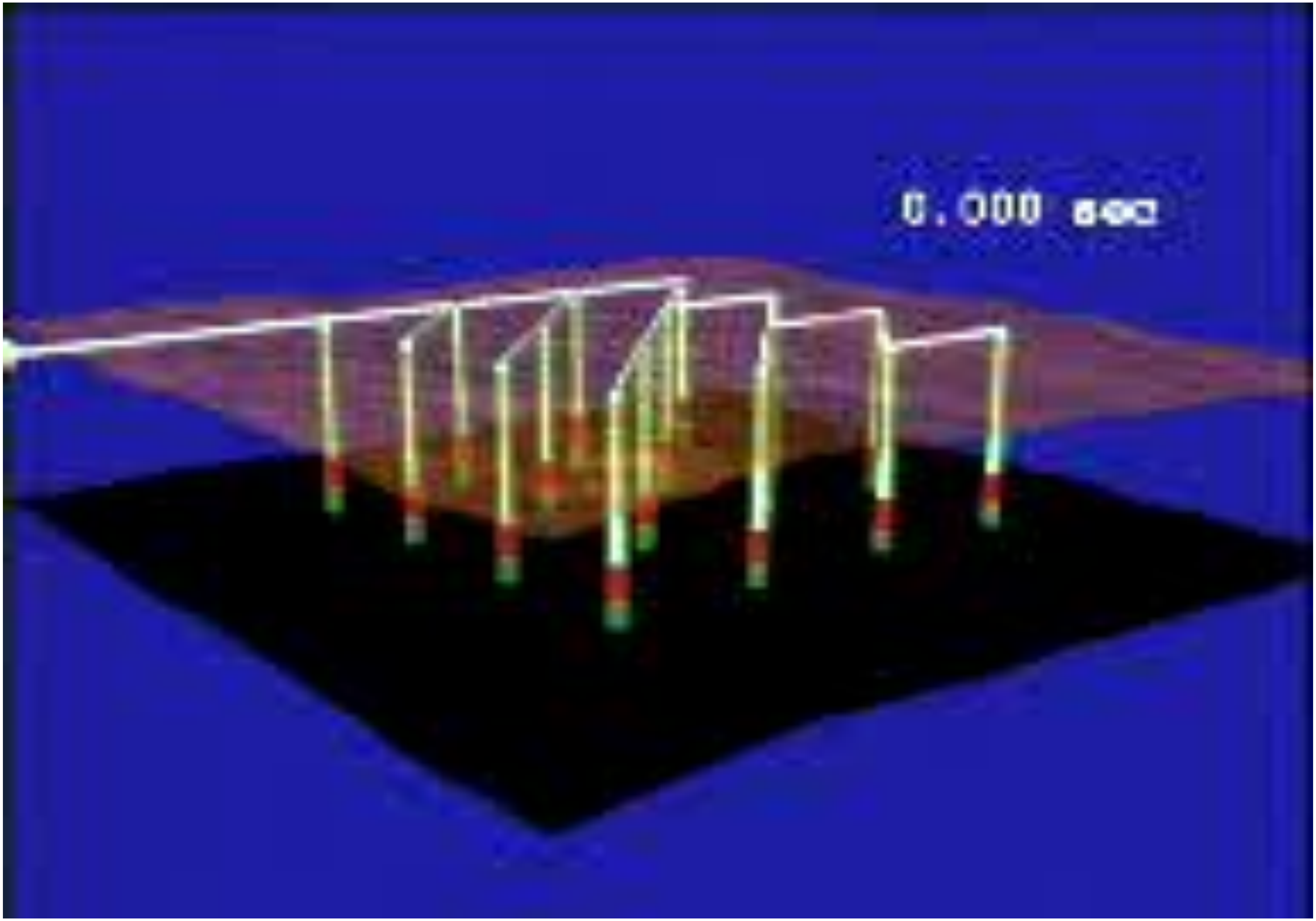
- f (cps) = 10
- A (in) = 0.0090
- a (in/sec^2) = 36 ~ 0.093 g's
- Ratio of a = 1.0
- ppv (in/sec) = 0.57
- Ratio of v = 1.0
- f^2A^2 = 0.0080
- KE = 0.000410W
- Ratio of KE = 1.0
- E.R. = 0.09
- L = 8,500/10 =850 ft.

Quake

- f (cps) = 1.3
- A (in) = 1.42
- a (in/sec^2) = 101 ~ 0.262 g's
- Ratio of a = 2.8
- ppv (in/sec) = 11.60
- Ratio of v =20.3
- f^2A^2 = 3.6300
- KE = 0.185000W
- Ratio of KE = 451.2
- E.R. = 37.96
- L = 8,500/1.3 = 6,540 ft.

Summary: Blast or Quake

- Total energy-governed by the duration,
  - Blast: seconds = to the total detonation time plus decay period
  - Quake: minutes for earthquakes waves near their source
- There is an inadequacy in using acceleration as a criterion of damage, there can be no damage/failure unless there is sufficient energy.
- Per the comparison example "a" of quake is only 3 times blast (no harm), but quake did extensive damage.
- Not shown is the quakes' total energy & duration of significant vibration.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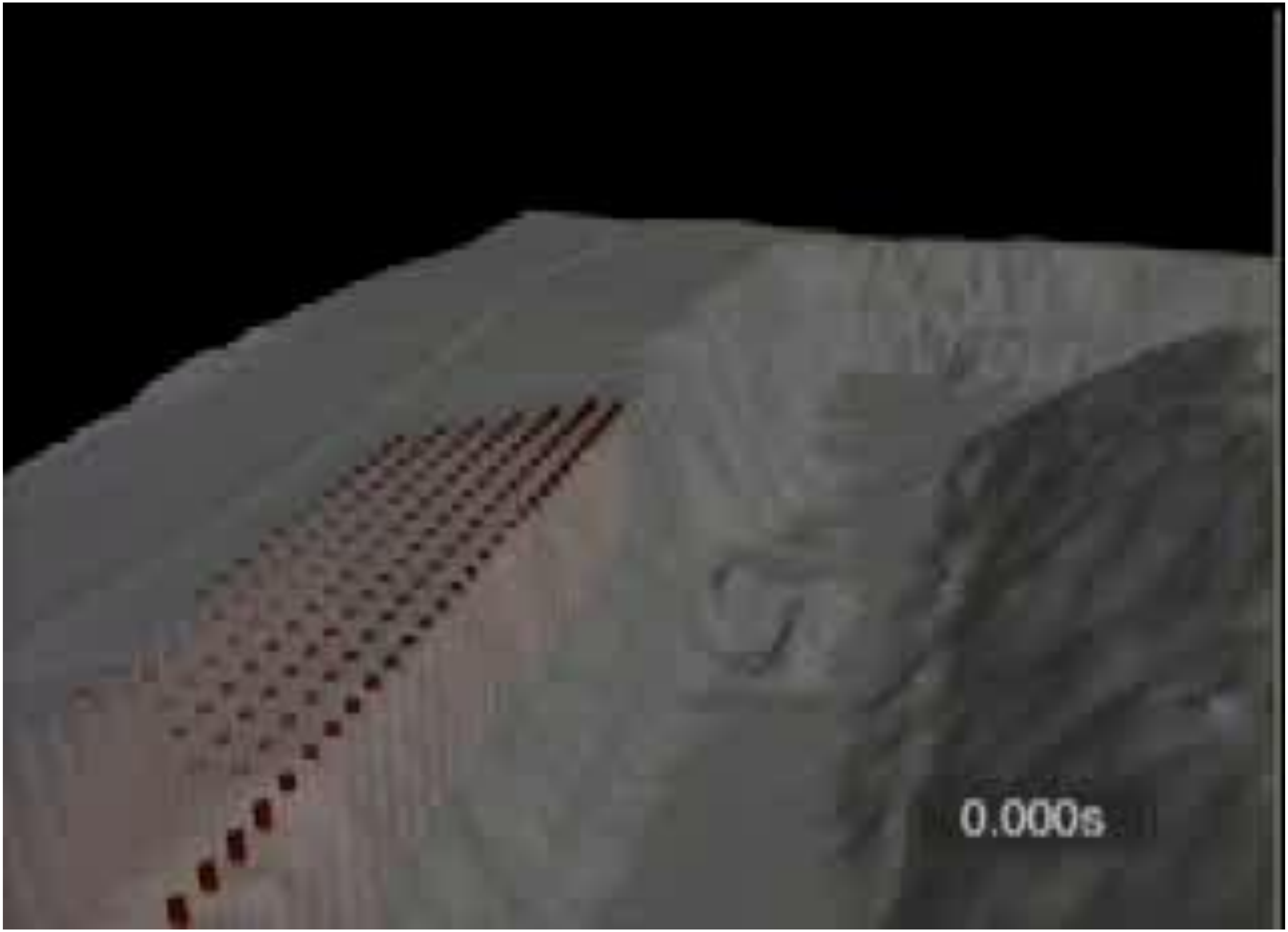
Blast or Quake #2

Mining/Construction Blasting

- Medium to High Frequency
- Highly Transient
- Short Duration
- Transient Waves Die out rapidly
- Short Wave Lengths
- Motion in Various Parts of the Embankment ***are not*** in Phase

Earthquake

- Very Low Frequency
- Very Large Displacements
- Long Duration
- Generate Large Strains
- Generate a Strong Lunching Action
- Long Waves Shake Dam as a Unit, simultaneously.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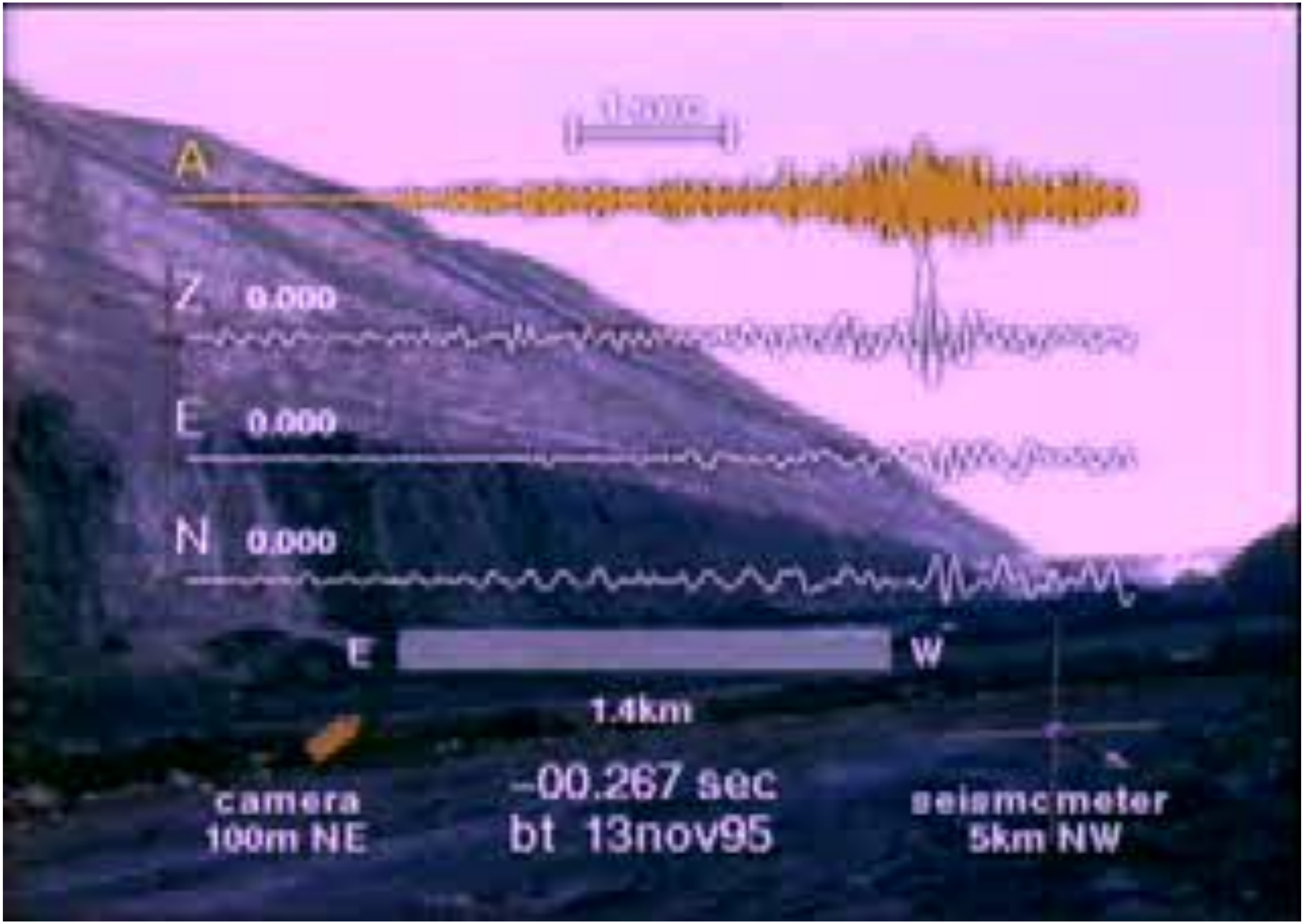

A
Z 0.000
E 0.000
N 0.000
E
W
1.4km
camera
100m NE
-00.267 sec
bt 13nov95
seismometer
5km NW

Vibration Parameters @ Different Frequencies

Acceleration	Frequency	Velocity-ppv	Amplitude	"L" in Soils 2000 fps	"L" in Rock 10,000 fps
0.12 g	0.1 cps	75 in/s	120 in	20,000 ft	100,000 ft
0.12 g	1.0 cps	7.5 in/s	1.2 in	2,000 ft	10,000 ft
0.12 g	10 cps	0.75 in/s	0.012 in	200 ft	1,000 ft
0.12 g	50 cps	0.15 in/s	0.0005 in	40 ft	200 ft
0.12 g	100 cps	0.075 in/s	0.00012 in	20 ft	100 ft
0.12 g	10,00 cps	0.0075 in/s	0.0000012 in	2 ft	10 ft
0.12g	10,000 cps	0.00075 in/s	0 000000012	0.2 ft	1 ft

Impoundment or Tailings Dam

- The concept of impounding slurry behind an engineered embankment is the same, coarse refuse versus waste rock, fine refuse versus tailings.
- Note: since MSHAs’ establishment there has been no incidents of embankment instability , which with seismic effects dominate failure causes for upstream dams.

Recent Past Vibration Concerns
at
Coal Waste Impoundments

- Martin County Coal: What were the effects of “construction' blasting on the integrity of the coal barrier and roof of the abandoned underground works below the slurry pool?
- Brushy Fork Slurry Impoundment: Is surface mine blasting detrimental to the embankment?

NRC Comments

- "Monitoring of potential failure modes of embankments typically measures _ _ _, and vibrations, especially if blasting is being conducted nearby."

- ***"The committee recommends that MSHA and OSM consider requiring additional continuous monitoring in specific instances and evaluate automation of monitoring instrumentation."***

Martin County Coal

- Blasting had prior to the failure taking place, above & within 1,000 ft. of the point of failure.
- No monitoring had taken place (ground motion)
- Review based on Old Jenny Mine in Kentucky results by USBM

Old Jenny Mine

- Jenny Mine Entry ~ 140 ft. below bottom of holes
- Underground roof reading ~ 40% less than surface – body waves underground ~ ½ the intensity of surface motion.
- Maximum mine roof readings ~ 18 in/s
- "Since no observable damage occurred, it was not possible to say at what exact level damage would have occurred for individual events."

Brushy Fork Slurry Impoundment

- Citizens regarded blasting within a few 1,000ft. of the impoundment embankment as a reason for concern.
- Instrumentation (blasting seismographs) were placed between blasts & structure, plus on the embankment.
- No instability has been seen, & instrument on “dam” has not been triggered.

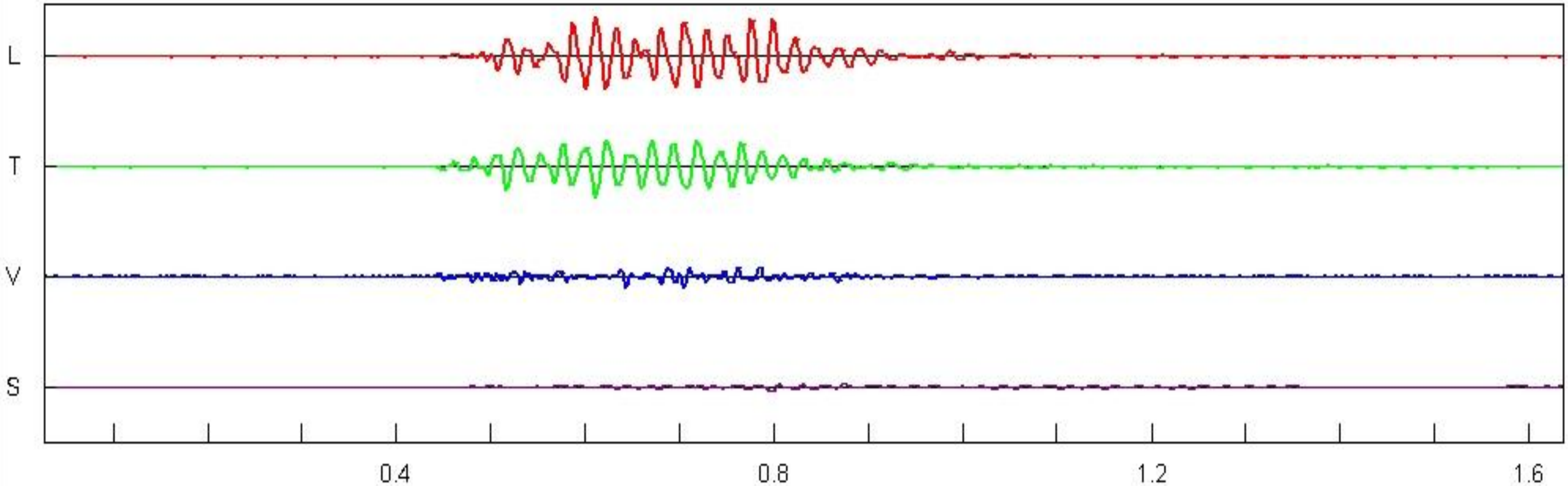
May 23, 2007 1:21:22 pm
P2
P5
GW34
27a
26
27b
ISGL
21
29
20
28
23
24
14
25
bee tree
Power
GW32
GLMP
12
17
19
15
13
18
GW15
GW31
Image USDA Farm Service Agency
©2009 Google
© 2010 Google
Imagery Date: Aug 25, 2007
37°54'54.52" N 81°27'59.46" W elev 2380 ft
Eye alt 6348 ft

Seismic Results in Vicinity of Brushy Fork

- No results on dam
- Seismic readings along ridge by a gas wells and gas lines SAFE per the lines and wells, therefore are below any known threshold for ‘earthen’ dam embankments.
- Criteria recommended for ‘dam’ is acceleration, peak particle velocity and Energy Ratio

SN: 3210 v2.69

Date:	10/30/2003	Time: 17:11:40				
Event:	9	Record Time: 5.0 s		Summary Data		
Client:	Jimmy Clem			L	T	V
Operation:	Harrod UG		PPV (in/s)	0.115	0.090	0.030
Location:			PD (.001")	0.42	0.32	0.09
Distance:	0.		PPA (g)	0.098	0.072	0.039
Operator:	Ralph King DSMRE		FREQ (Hz)	41.7	45.5	83.3
Comment:	distance variable		Resultant PPV:		0.145 in/s	
Trigger Level:	0.020 in/s		Peak Air Pressure:		89 db	
	133 db				0.0002 psi	



Velocity Waveform

Velocity Waveform Graph Scale:
Time   = 0.100 s
Seismic = +/- 0.160 in/s
Sound   = +/- 0.0023 psi

Version 3.0.0 Suite
Executable Date: 17Jun08

File: C:\Seismic Downloads\AutoDial\Marfork\Gas Line Monitoring Point\10565-10.NSZ

Nomis Seismographs, Inc.

406'

SuperGraphics - Report

Telephone: (205)592-2488 x 23

Company: Marfork Mining | Unit #: 10565 | **04-Nov-09 at 15:57:49 Event # 10**

Operator: Tommy Crabtree

Location: Gas Line Monitoring Point

Notes: N37 54.882 W81 27.645

Distance: N | Wgt. Per Delay: N | Scaled Distance: 0.0

Record Duration: 10.0 sec
Sample Rate: 1024/sec
Last Calibration: 16Oct09

Seismic

Gain: 1 Trigger: .05 in/s

Channel	Radial	Transverse	Vertical
○ Velocity (in/s)	0.445	0.275	0.205
Frequency (Hz)	10.40	13.10	11.10
Displacement (in)	0.0068	0.0033	0.0029
Acceleration (g's)	0.075	0.059	0.037
Trigger >>> Peak	1043.9	1033.2	405.3

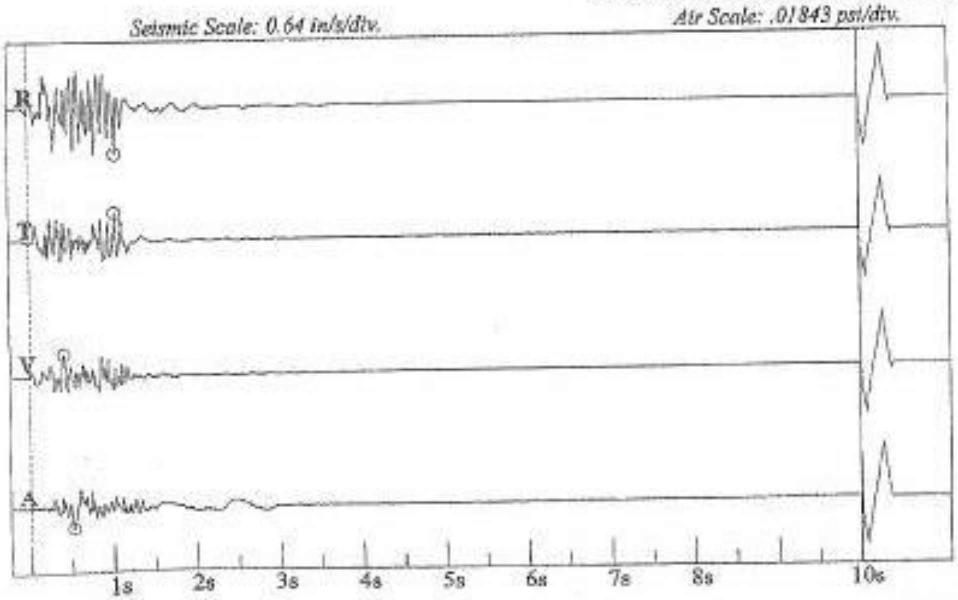
Air

Gain: 1 Trigger: 130 dBL

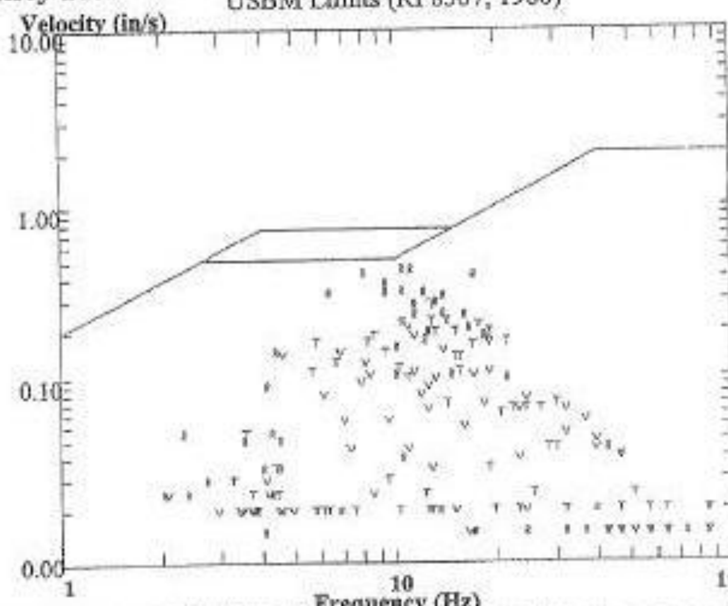
Measurement	Value	Trigger >>> Peak	
psi	.00609	514.6	
dBL	126		
Hz	5.7		

Waveform Analysis / Frequency Plot

Seismic Scale: 0.64 in/s/div. Air Scale: .01843 psi/div.



USBM Limits (RI 8507, 1980)



Version 3.0.6
Executable Date: 09Sep09

File: C:\Seismic Downloads\AutoDial\Marfork\Gas Well 34 bds\3.NSZ

Nomis Seismographs, .

SuperGraphics - Report

Telephone: (205)592-2488 x 23

Company: Marfork Mining

3520

Unit #: 10402

05-Nov-09 at ~~16~~ 15:55:03 Event # 3

Operator: Tommy Crabtree

Location: Gas Well #34 b.d.s

Notes: N37 55.028 W81 28.379

Record Duration: 10.0 sec
Sample Rate: 1024/sec
Last Calibration: 12Mar09

Distance: N | Wgt. Per Delay: N | Scaled Distance: 0.0

Seismic

Gain: 2 Trigger: .05 in/s

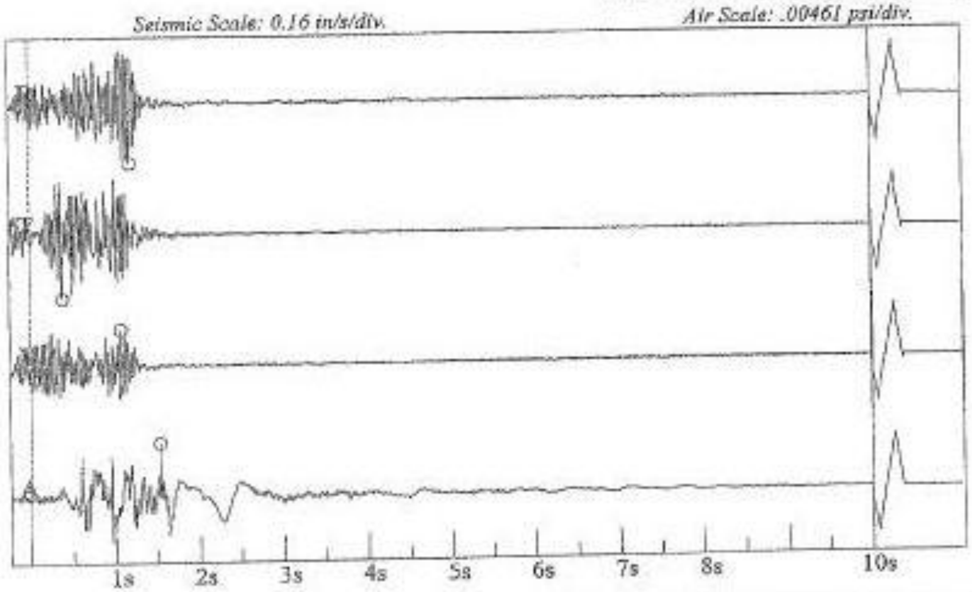
Channel	Radial	Transverse	Vertical
○ Velocity (in/s)	0.145	0.155	0.088
Frequency (Hz)	23.20	18.90	28.40
Displacement (in)	0.0010	0.0013	0.0005
Acceleration (g's)	0.055	0.048	0.040
Trigger >>> Peak	1197.3	381.8	1076.2

Air

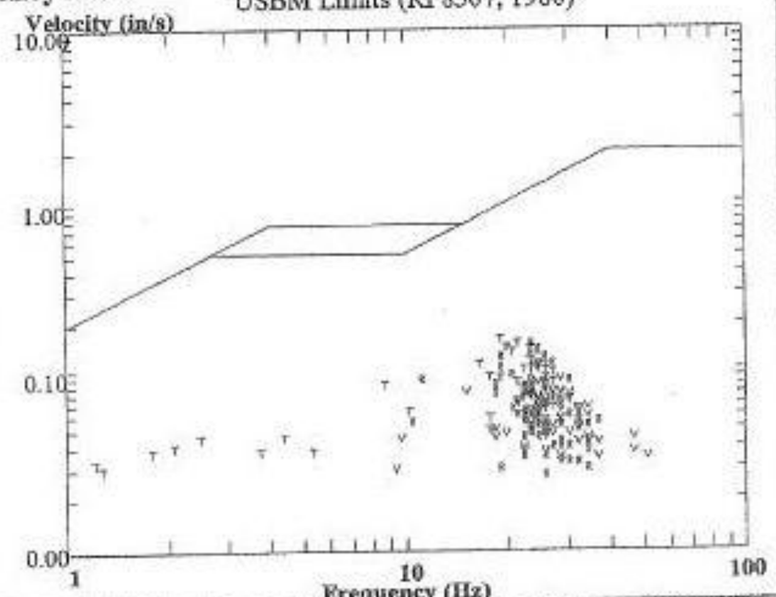
Gain: 1 Trigger: 130 dBL

Measurement	Value	Trigger >>> Peak	
		1534.2	
psi	.00381		
dBL	122		
Hz	19.6		

Waveform Analysis / Frequency Plot



USBM Limits (RI 8507, 1980)



Version 3.0.6
Executable Date: 09Sep09

File: C:\Seismic Downloads\AutoDial\Marfork\Gas Line Monitoring Point\10565-17.NSZ

4 38

Nomis Seismographs, Inc.

SuperGraphics - Report

Telephone: (205)592-2488 x 23

Company: Marfork Mining

Unit #: 10565

09-Nov-09 at 15:53:11 Event # 17

Location: Gas Line Monitoring Point

Operator: Tommy Crabtree

Notes: N37 54.882 W81 27.645

Record Duration: 10.0 sec
Sample Rate: 1024/sec
Last Calibration: 16Oct09

Distance: N *Wgt. Per Delay: N* *Scaled Distance: 0.0*

Seismic

Gain: 1 Trigger: .05 in/s

Channel	Radial	Transverse	Vertical
o Velocity (in/s)	0.550	0.175	0.235
Frequency (Hz)	3.50	13.40	11.60
Displacement (in)	0.0250	0.0021	0.0032
Acceleration (g's)	0.031	0.038	0.044
Trigger >>> Peak	1146.5	179.7	218.8

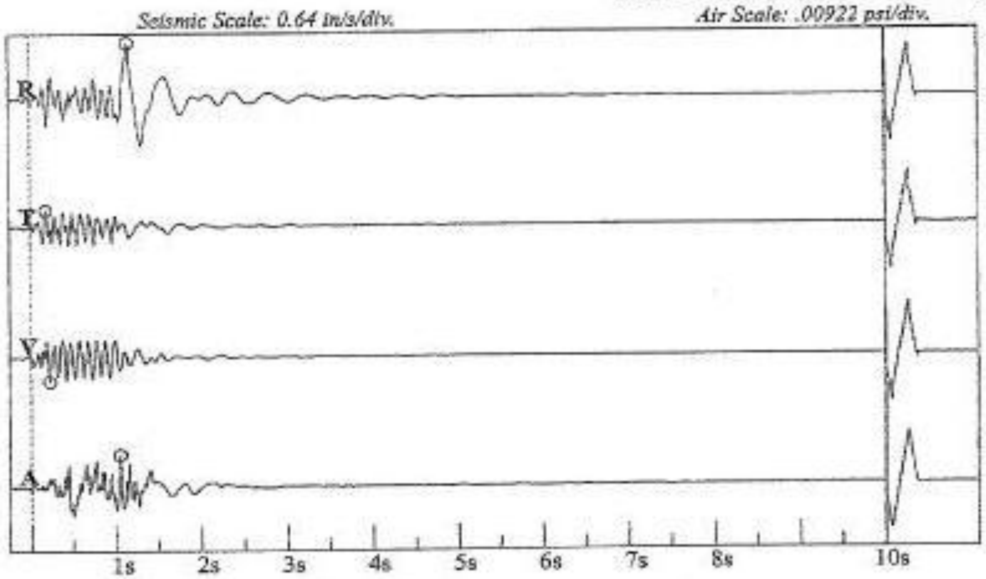
Air

Gain: 1 Trigger: 130 dBL

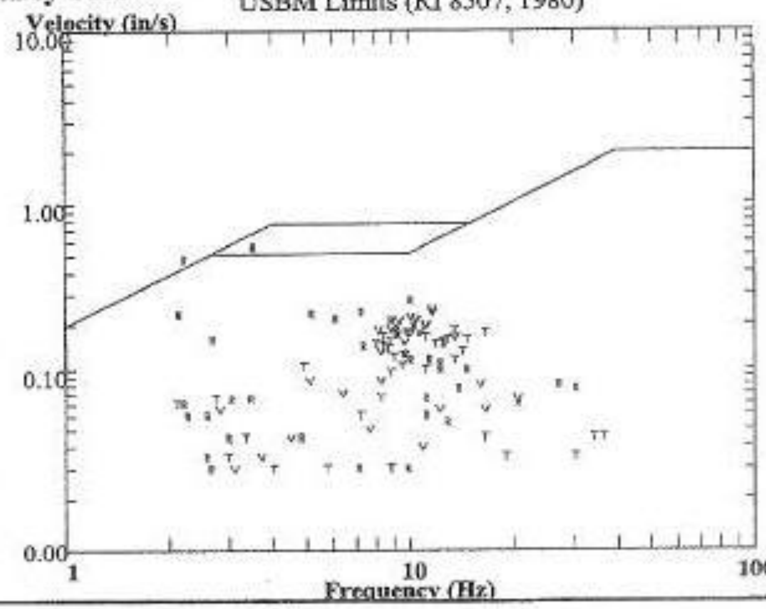
Measurement	Value	Trigger >>> Peak	
		1047.9	
psi	.00475		
dBL	124		
Hz	13.1		

Waveform Analysis / Frequency Plot

Seismic Scale: 0.64 in/s/div. *Air Scale: .00922 psi/div.*



USBM Limits (RI 8507, 1980)



Proposed Blast Monitoring Plan for Impoundments

- Place seismograph at impoundment- natural surface interface

- Place seismograph on surface near closest piezometer

- Place seismic transducers at depth near slurry – coarse refuse interface , parallel to piezometer

- Read and correlate all data after each blast

Conditions for a Observational Approach

- Sensitive Instruments could detect incremental changes that would indicate a tendency toward slope failure before any significant failure occurred

- Blasting could begin at inconsequential levels in a location easily recognized as safe, then increase in accord with instrumental observations

  – Lewis L. Oriard

What is a Safe Blasting Limit

- Remember: regardless of frequency, a vibration must reach a certain intensity before it has any damage potential
  - Should be Site Specific
  - Should be amplitude, frequency, acceleration, particle velocity related - in other words – an envelope on a log-log Tripartite relationship (the Z Curve)
  - Ground Shear Strain induces Liquefaction (~0.02%) and ***Strain = ppv/V*** (wave velocity)

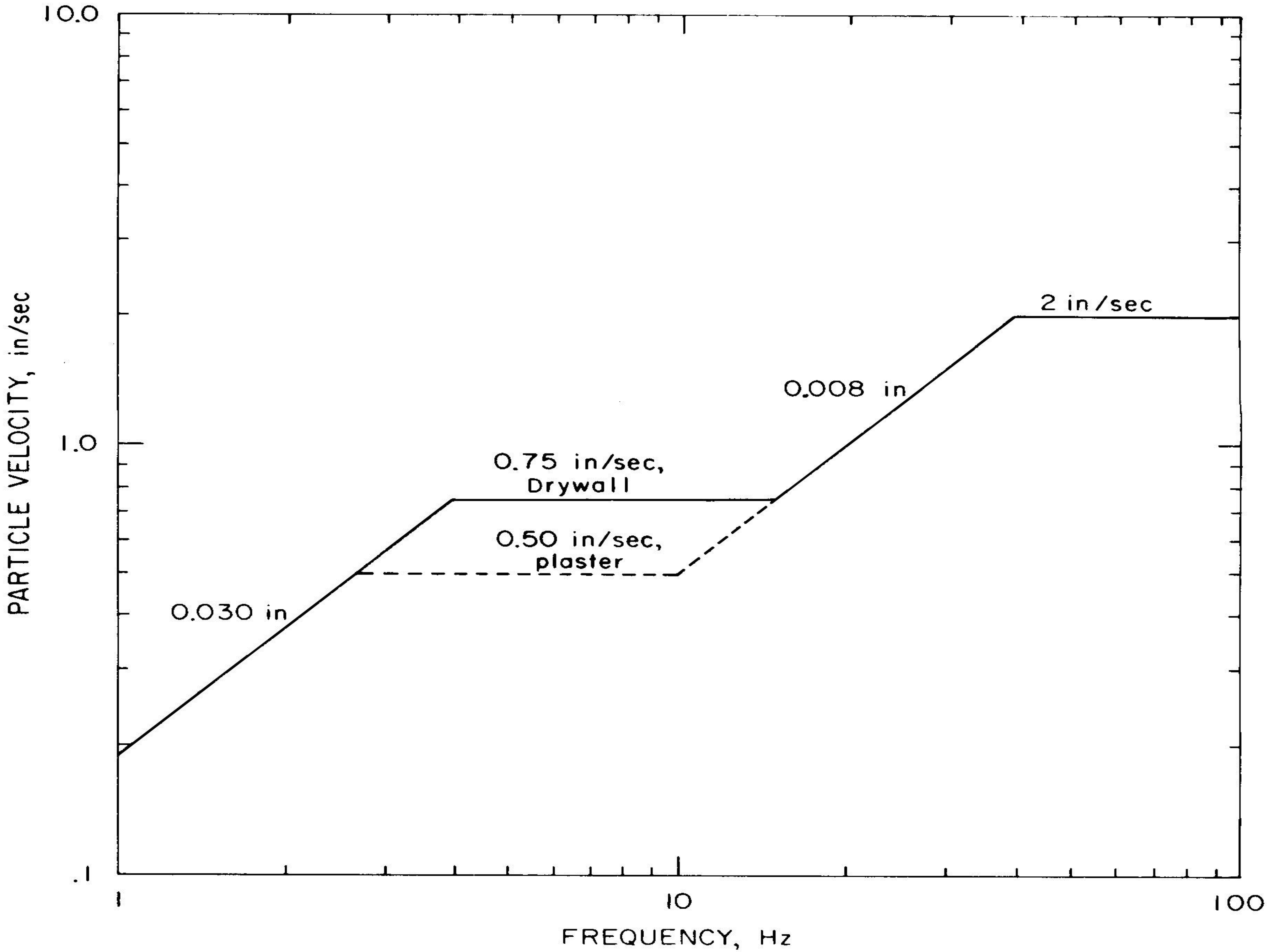


Figure B–1.—Safe levels of blasting vibration for houses using a combination of velocity and displacement.

Displacement/Velocity/Acceleration

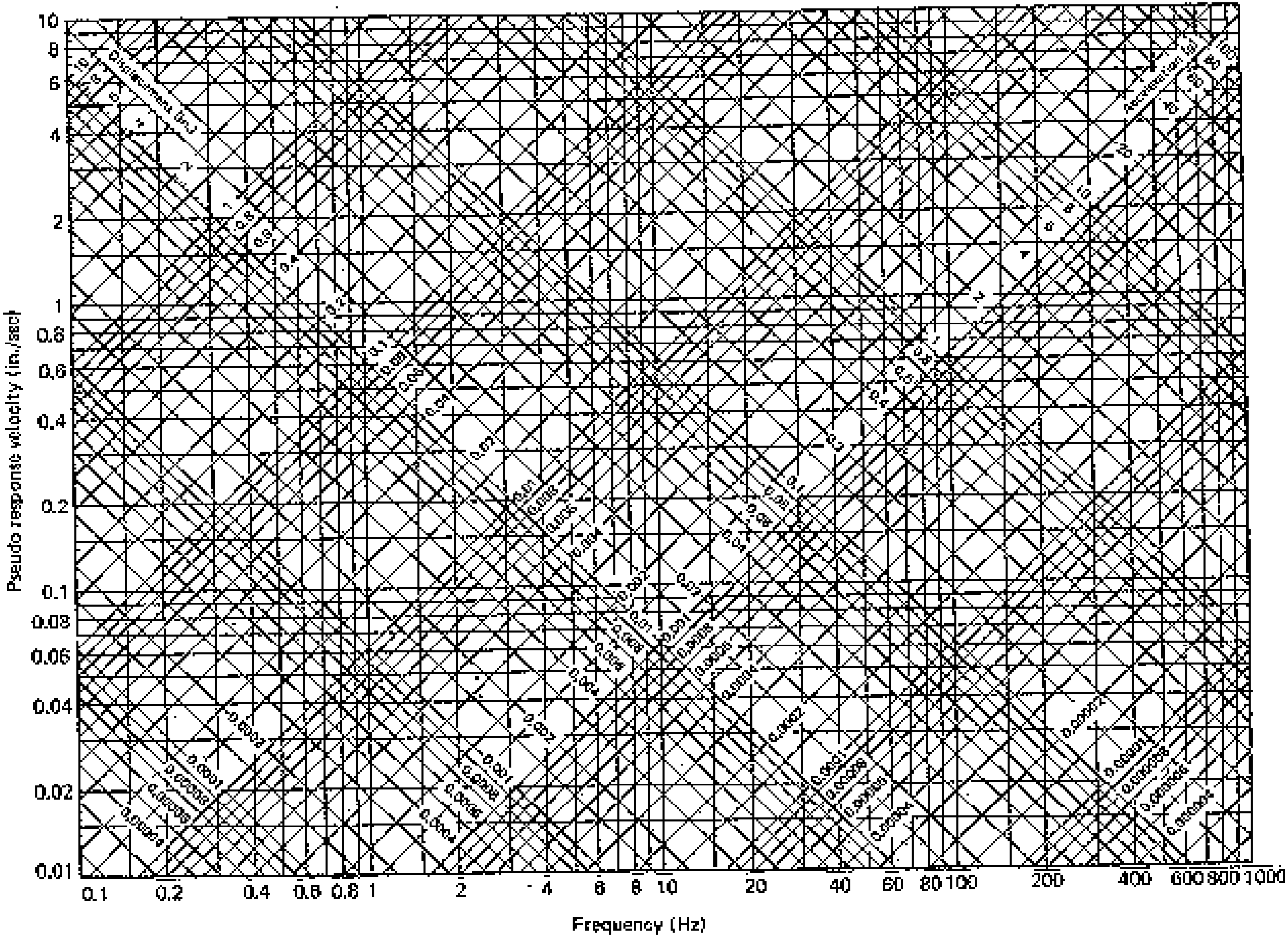


Figure 5-6 Blank tripartite paper.

An Old Criteria with a New Use

- Energy Ratio (E.R.) = a^2 / f^2
- Examples of Tests Near Brushy Fork
  - 01/10/09 E.R. = $0.42^2/10.6^2$ = 0.00156, g's = 0.013
  - 05/10/09 E.R. = $0.74^2/10.6^2$ = 0.00487, g's = 0.023
  - 03/11/09 E.R. = $1.22^2/4.20^2$ = 0.08438, g's = 0.038
- Examples of close –in Blast
  - f of 3.0 cps & A of 0.10 inches., therefore E.R. is:
  - E.R. = $2.96^2/3.0^2$ = 0.9735, g's = 0.092
  - f of 30.0 cps & A of 0.01 inches, therefore E.R. is:
  - E.R. = $29.49^2/30.0^2$ = 0.966, g's = 0.916

PPV for Quakes at Frequency ‘f’ of 1cps

magnitude	2	3	4	5	6	7	8
Avg. ‘gs’	0.0008	0.0029	0.01	0.038	0.13	0.48	1.6
PPV	0.02”/s	0.18”/s	0.63”/s	2.4”/s	8.2”/s	30.1”/s	101”/s
Caution	***‘f’ is not always***	***1.0 cps***	***& ‘v’***	***will vary accordin g***	***to energy***	***in the Source***	***but the***
Distance	***& Geology***	***as well!***					

Why Use Seismographs?

- *Establish Compliance with Rules*
- *Evaluate Blast Performance*
- *Provide Liability Protection*

Blasting Seismographs

- Measure ground velocity time histories
  - Component directions
- Measure airblast time history
  - Measured in pressure (psi)
  - Converted to Decibles (dB)
- Provide Summary information
- Conduct internal operations check

**** SAFEGUARD SEISMIC UNIT 2000DK ****
SN: 2243

DATE: 09/12/95 TIME: 15:18:06
Event: 009 Recording Time: 10
Client: ROBERTSON
Operation: BUCKEYE IND. MINING CO.
SSU Location: ROBERTSON YARD
Distance to blast: 1385
Operator: M.MANN/ODNR
Comments:
Trigger Level: .05 IN/SEC

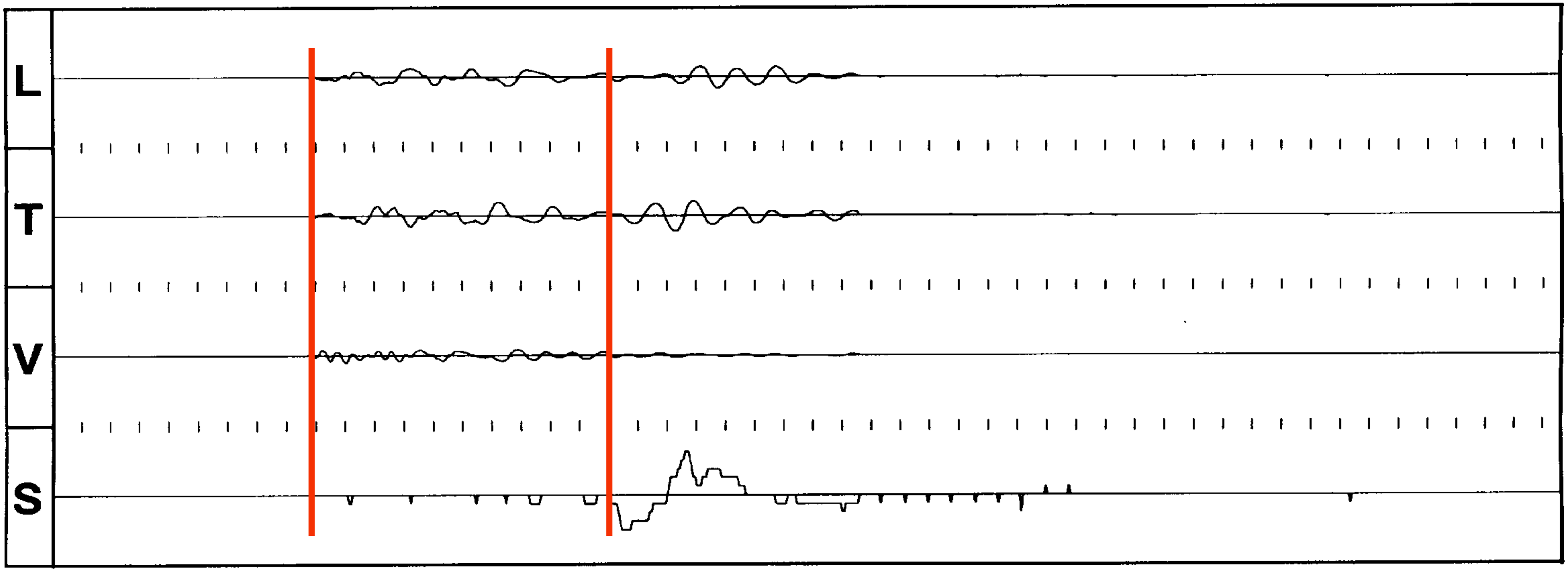
Summary

	L	T	V
PPV (in/sec)	0.10	0.14	0.07
PD (in x.001)	2.39	2.97	1.38
PPA (g)	.02	.02	.02
FREQ (Hz)	8.0	7.6	16.6

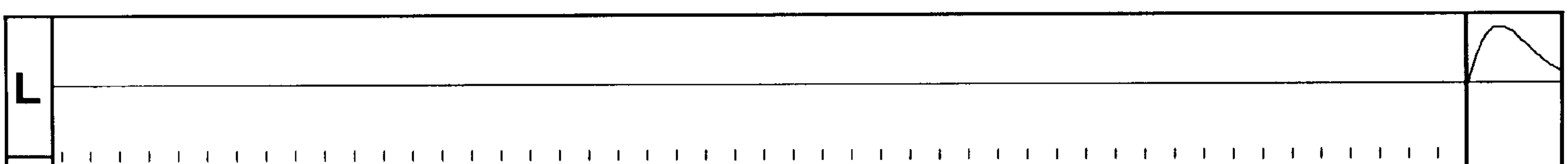
RESULTANT PPV (in/sec): 0.15
PEAK AIR PRESSURE: (dB) 114
(psi) 0.00145

VELOCITY WAVEFORM GRAPH SCALE
TIME = 100 MSEC PER MARK
SEISMIC = +/- .64 IN/SEC
SOUND = +/- 0.00232 PSI

SHAKETABLE CALIBRATED: 06/20/95
By GeoSonics, Inc.
Box 779, Warrendale, PA 15095 U.S.A.
TEL: 412.934.2900 FAX: 412.934.2999



CAL



Recordings are controlled by:

- How the seismograph is made
  - **ISEE Performance Specifications for Blasting Seismographs (2000)**
- How the seismograph is placed in the field
  - **ISEE Field Practice Guidelines for Blasting Seismographs (1999)**
- For specifications on each, go to: **http://www.isee.org/sections/blast.htm**

OSM Resources

- Appalachian Region Blasting Web Page
  - **www.ARblast.osmre.gov**
  - Reports and Publications

- Technical Innovation and Professional Services (TIPS)
  - **www.tips.osmre.gov**
  - Blast Log Evaluation Program (BLEP)

- keltschlager@osmre.gov or (412) 937-2169

THE END

- ANY QUESTIONS?
  - Dennis Clark @ OSM/KFO
  - dclark@osmre.gov
  - 865-545-4103, ext. #137