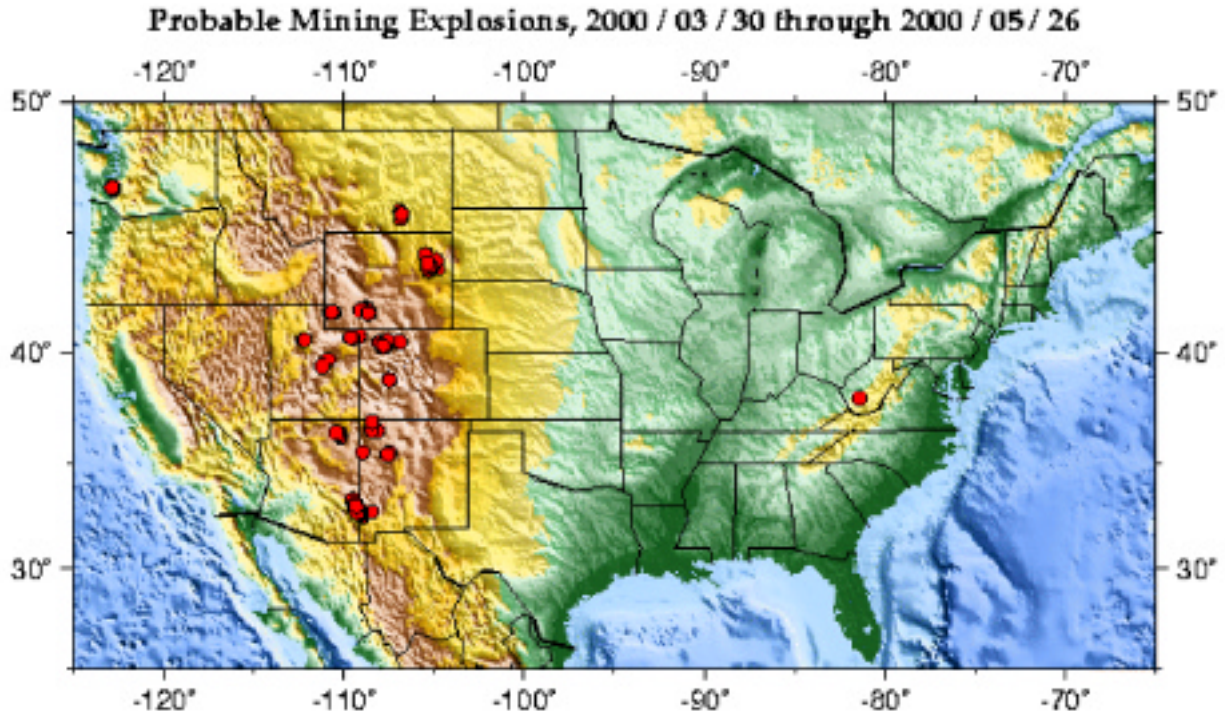
IMPROVED IDENTIFICATION OF MINING EXPLOSION SIGNALS

Utilization of Calibration Explosions, Ground Truth and Infrasound

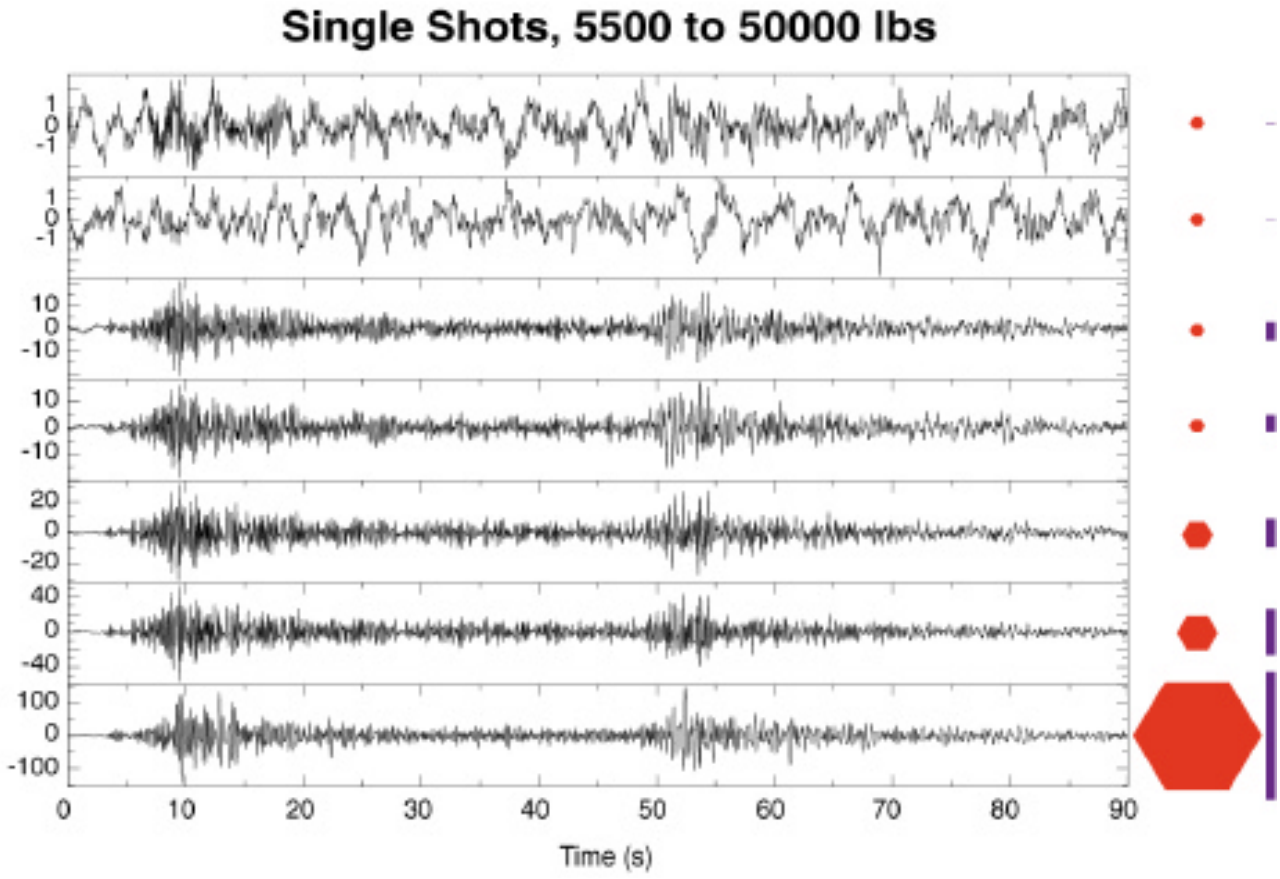
THE ROLE OF GROUND TRUTH IN IMPROVED IDENTIFICATION OF MINING EXPLOSION SIGNALS



OVERVIEW

- Calibration Explosions for Identification
- Utilization of Array Measurements
- Empirical Ground Truth
- Seismo-Acoustic Array Results

CALIBRATION SHOTS FOR IDENTIFICATION



CALIBRATION SHOTS FOR IDENTIFICATION

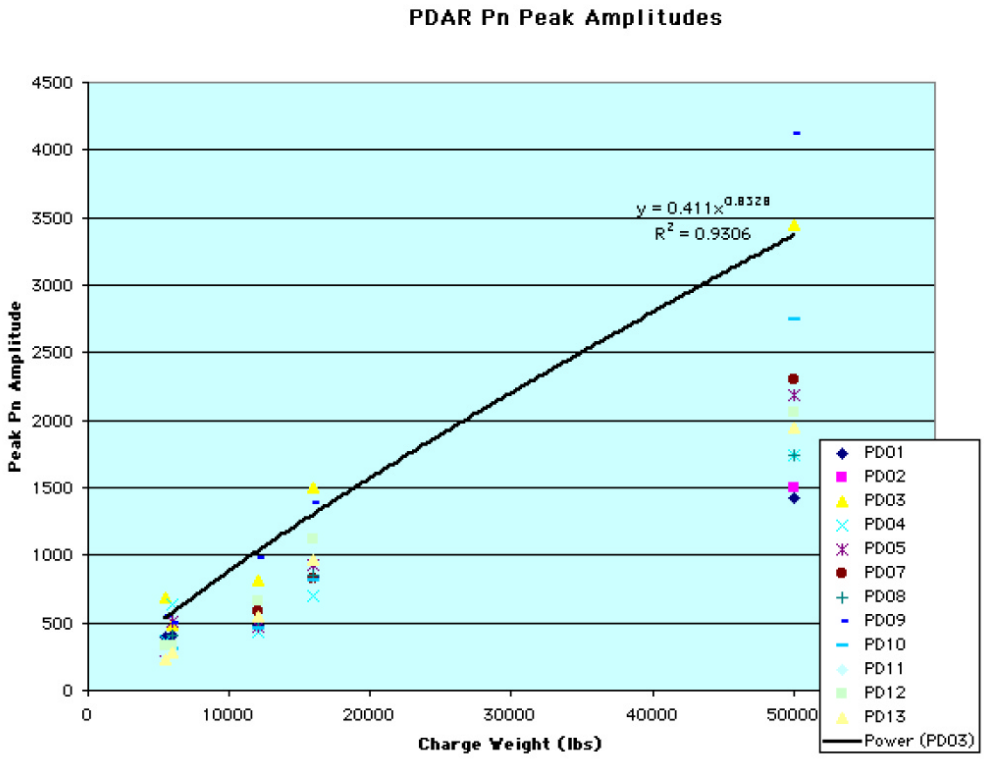
CALIBRATION SHOTS FOR IDENTIFICATION

SINGLE-FIRED EXPLOSIONS

SHOT	SIZE	# BOREHOLES	DISTANCE TO S1
S1	5500 lb	1	-
S2	5500	1	30 m
S3	5500	1	70
S4	6000	1	90
S5	12000	3	390
S6	16000	4	420
24Aug	50000	10	3820

CALIBRATION SHOTS FOR IDENTIFICATION

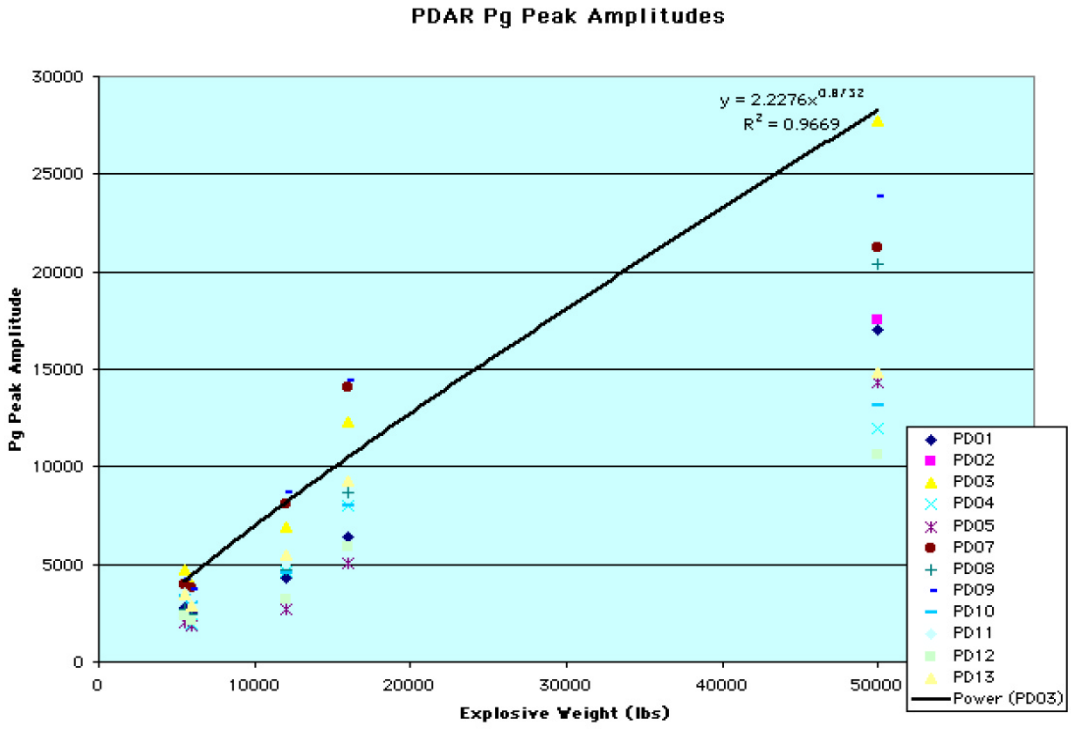
Amplitude = A W^b Pn: b = 0.84 ± 0.14



CALIBRATION SHOTS FOR IDENTIFICATION

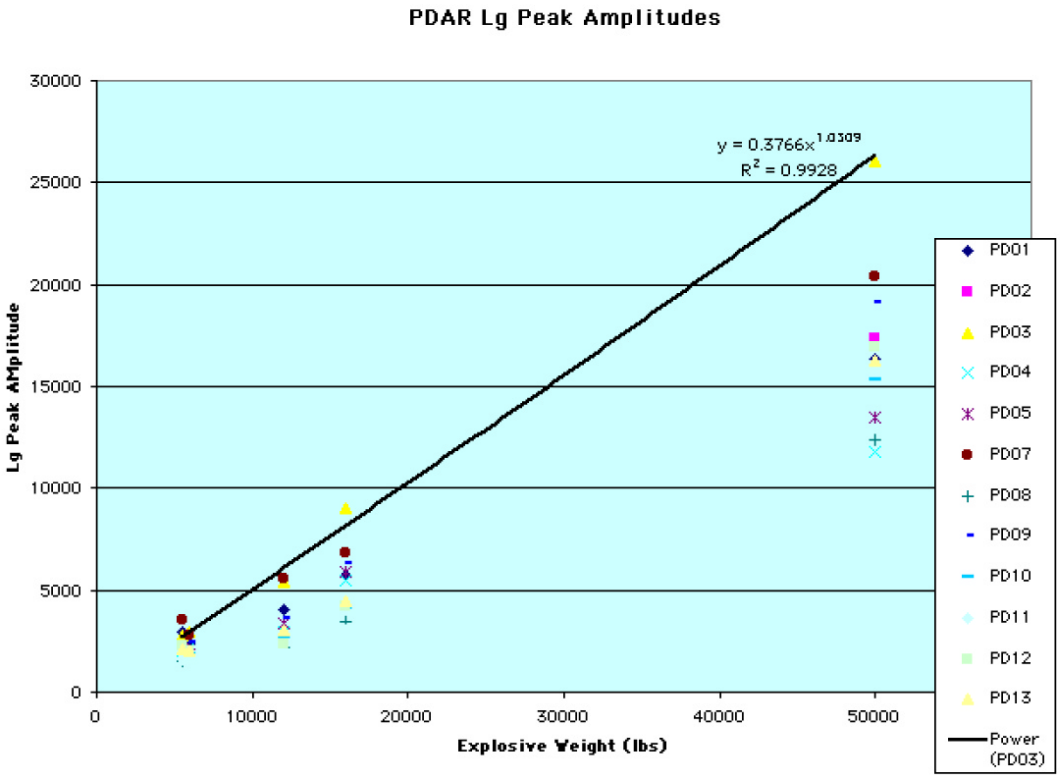
Amplitude = A W^b

Pg: b = 0.84 ± 0.09

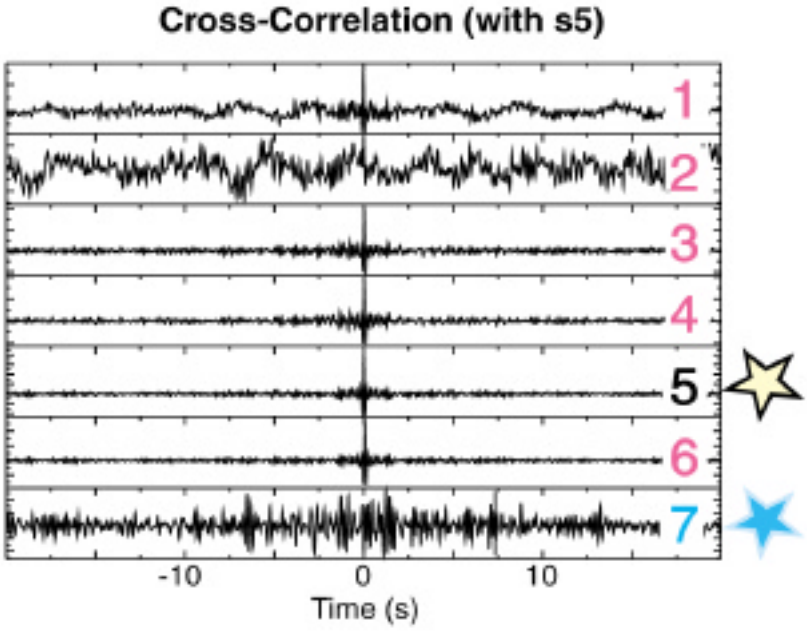


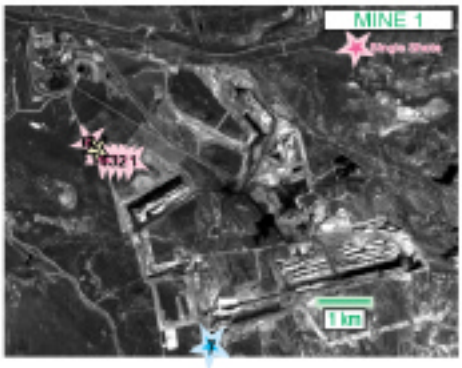
CALIBRATION SHOTS FOR IDENTIFICATION

Amplitude = A W^b Lg: b = 0.91 ± 0.08

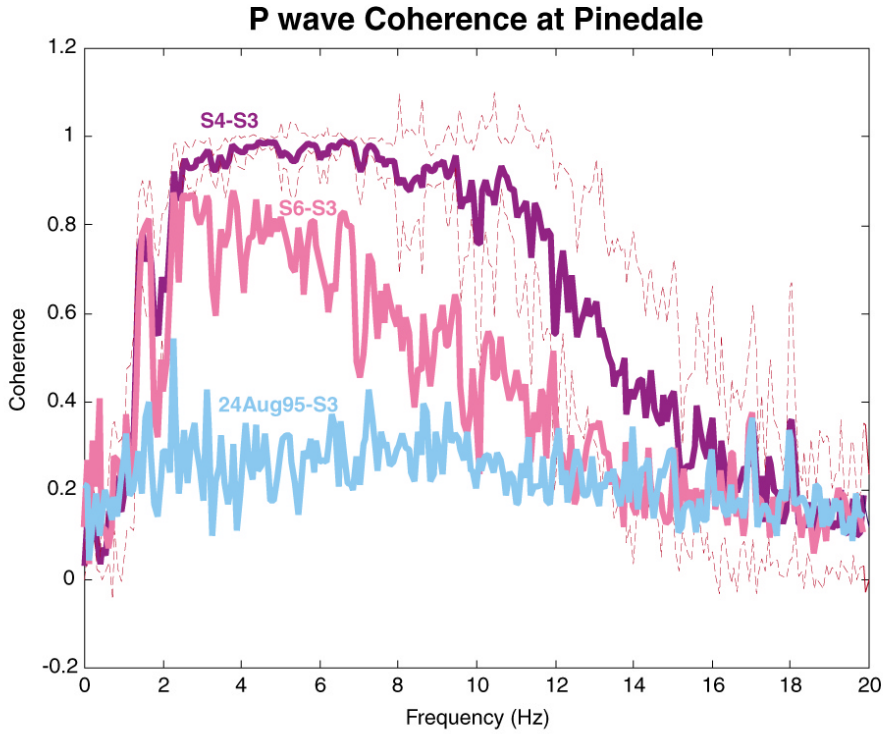


CALIBRATION SHOTS FOR IDENTIFICATION

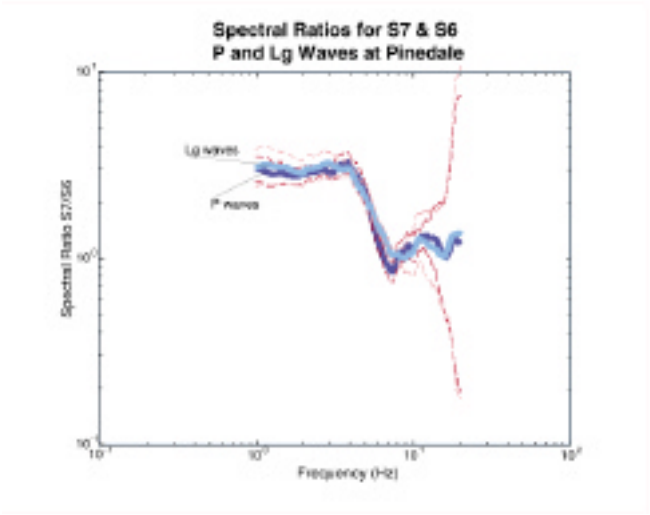


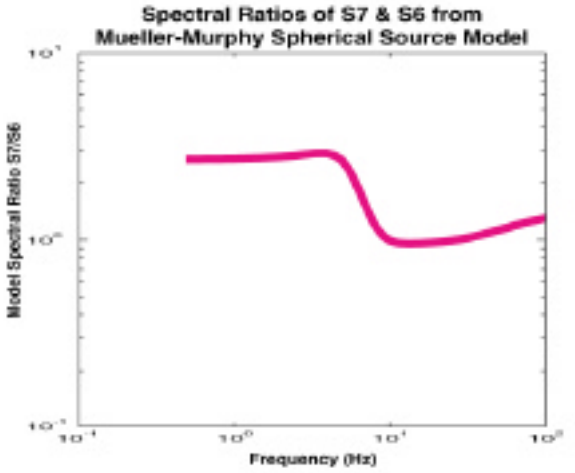


CALIBRATION SHOTS FOR IDENTIFICATION



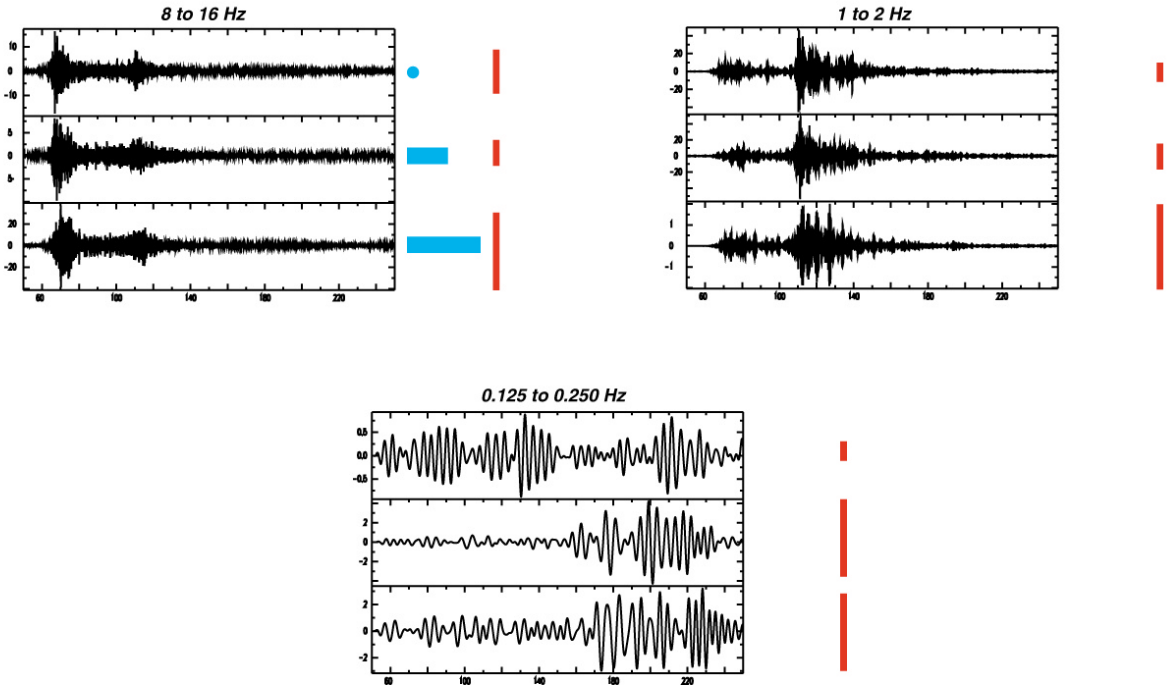
CALIBRATION SHOTS FOR IDENTIFICATION



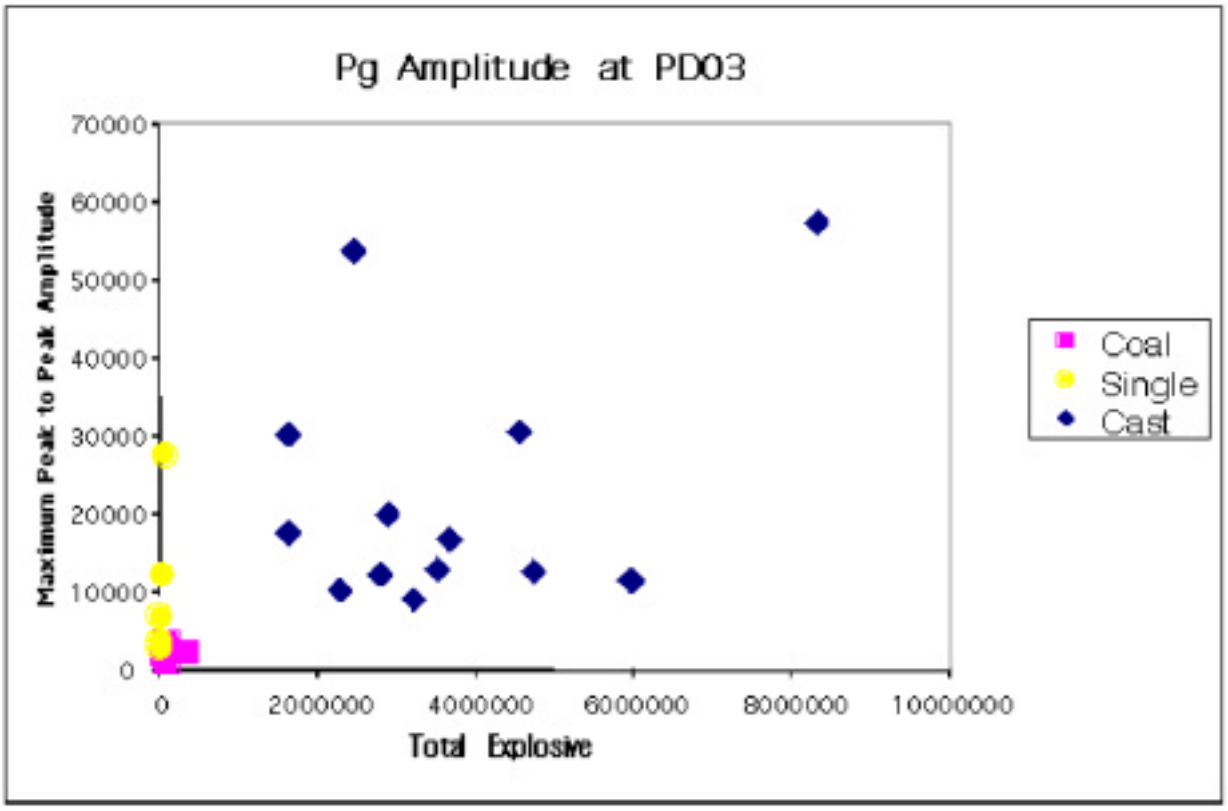


CALIBRATION SHOTS FOR IDENTIFICATION

Single Shot and Cast Shots Comparison
Mine 1 at 360 km



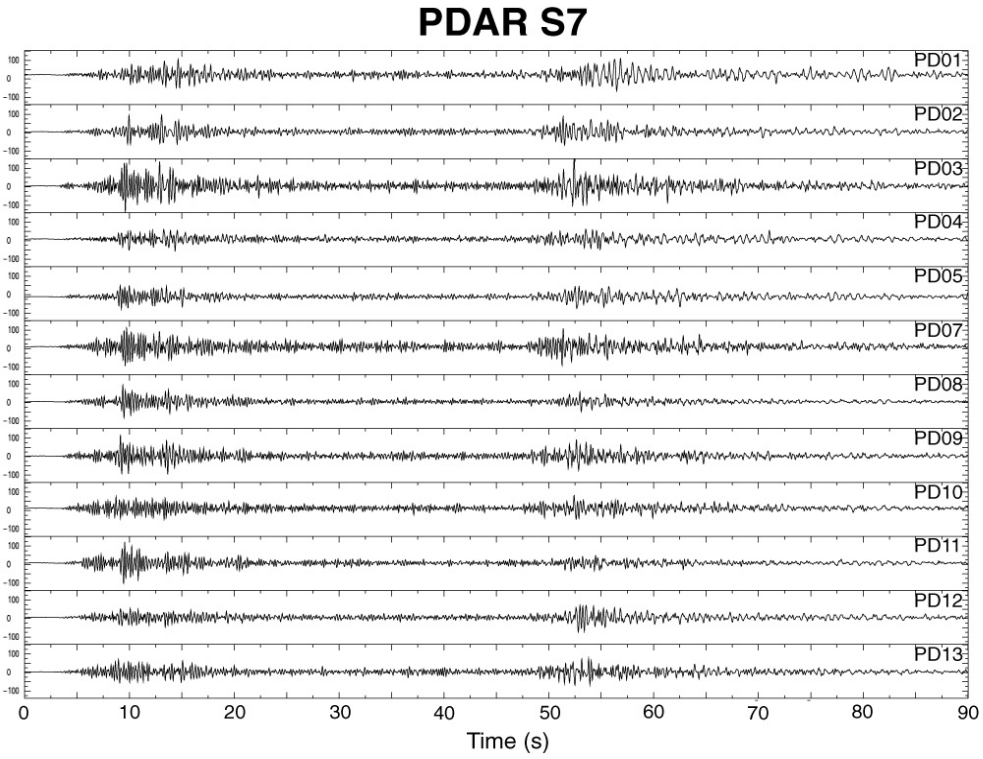
CALIBRATION SHOTS FOR IDENTIFICATION



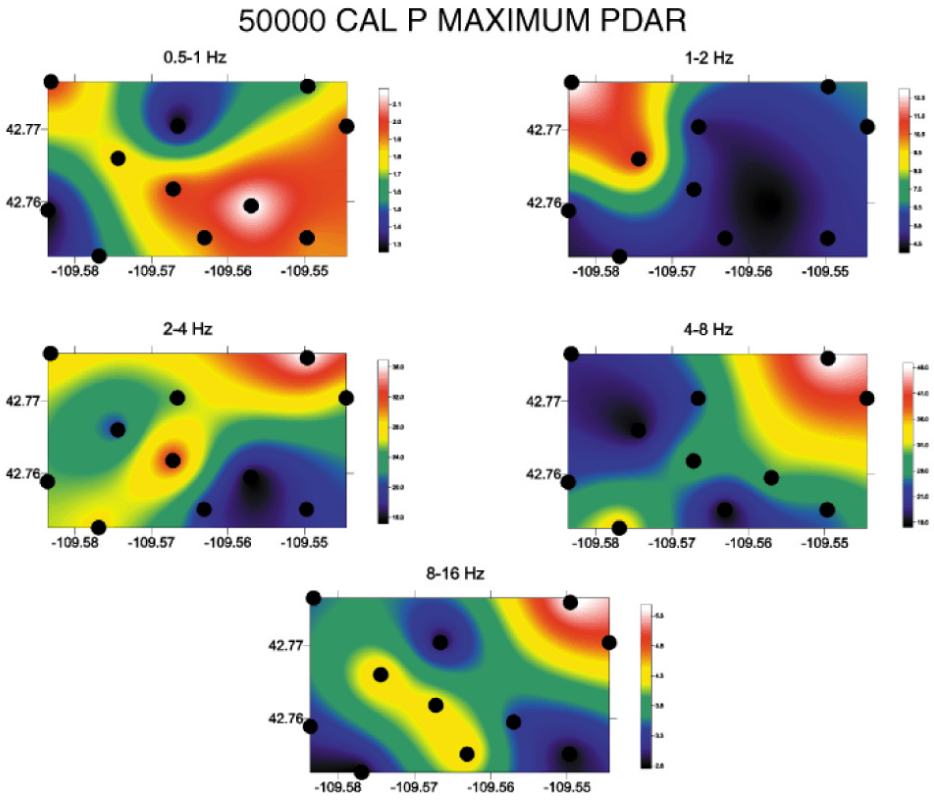
CALIBRATION SHOTS FOR IDENTIFICATION

- Regional amplitude scaling for contained, single-fired explosions follows power law
- Waveform coherence decays with source separation
- Empirical spectral ratios matched with a Mueller-Murphy source model
- Significant waveform shape and amplitude variations observed across the regional array

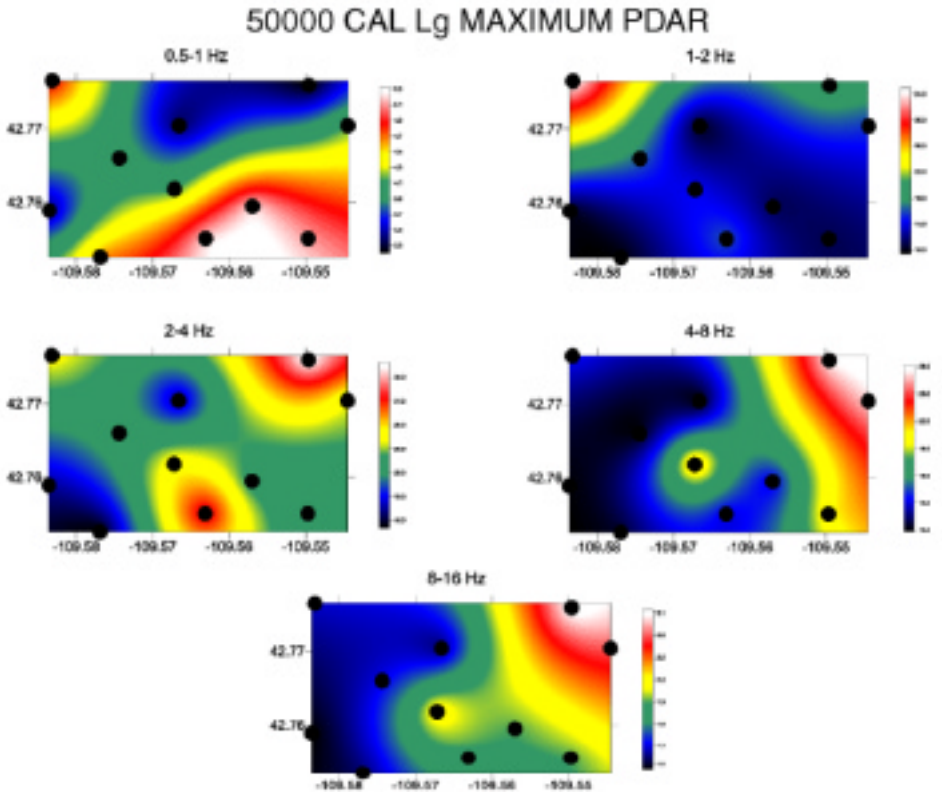
ARRAY MEASUREMENTS



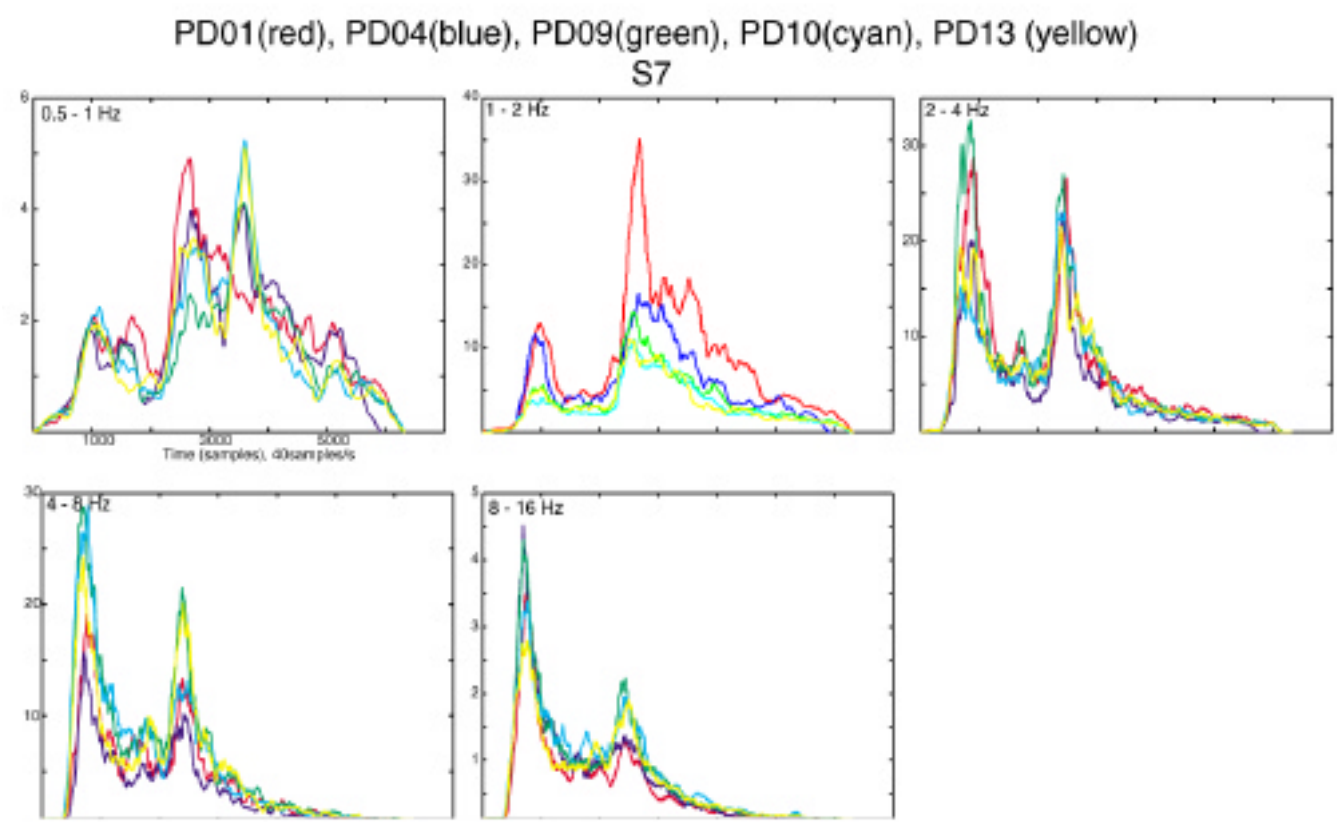
ARRAY MEASUREMENTS



ARRAY MEASUREMENTS



ARRAY MEASUREMENTS



ARRAY MEASUREMENTS

- Frequency dependent amplitude variations quantified for regional arrays
- Spatial patterns of variation similar for Pn, Pg and Lg
- Variation appears to correlate with shallow geology

EMPIRICAL GROUND TRUTH

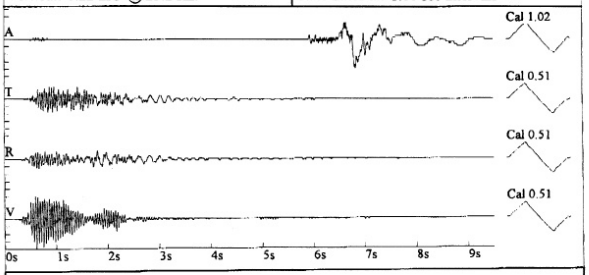
213 Holes
673,245 Total Tons
357,820 lbs Blasting Agent
14,000 lbs delay

00033 & 00045 39 MW3P
D. MALENIUS KINNEY 6882 FEET
SE 135 10 MPH
14000 LBS. DELAY

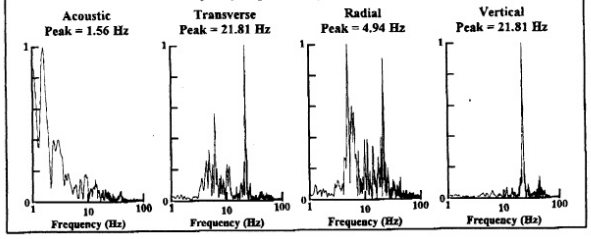
Fax Note 7671 | Date 5/16/00 | # of pages 1
To BRYAN STUMP
Phone 214-768-2701
From D. THOMPSON
Phone USX-MINNTAC

Event Number: 195 Date: 5/16/00 Time: 11.04
Acoustic Trigger: 114 dB Seismic Trigger: 0.10 in/s Serial Number: 1336

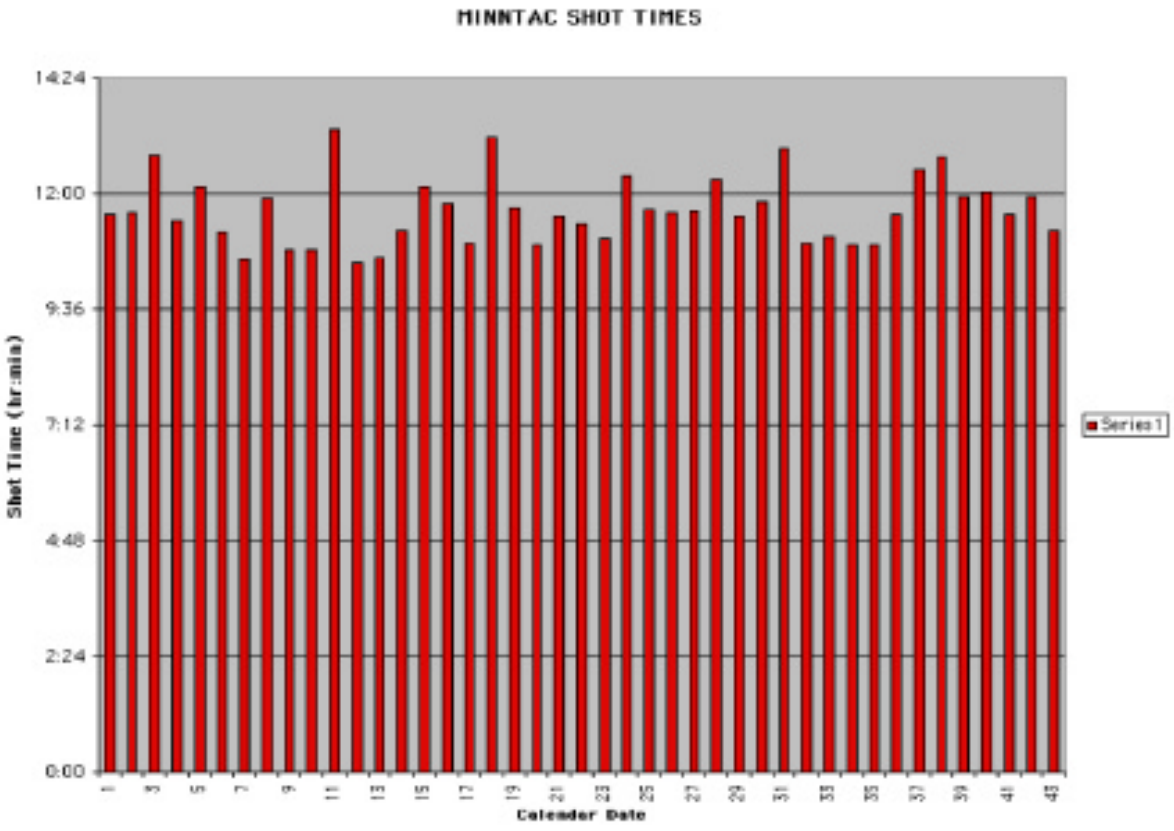
Amplitudes and Frequencies	Graph Information
Acoustic: 123 dB @ 2.4 Hz.	*Duration:* 0.000 sec To: 9.500 sec
Transverse: 0.10 in/s @ 20.4 Hz.	*Acoustic:* 0.28 Mb (0.07 Mb/div)
Radial: 0.07 in/s @ 28.4 Hz.	*Seismic:* 0.22 in/s (0.055 in/s/div)
Vertical: 0.22 in/s @ 23.2 Hz.	*Time Lines at:* 1.00 sec intervals



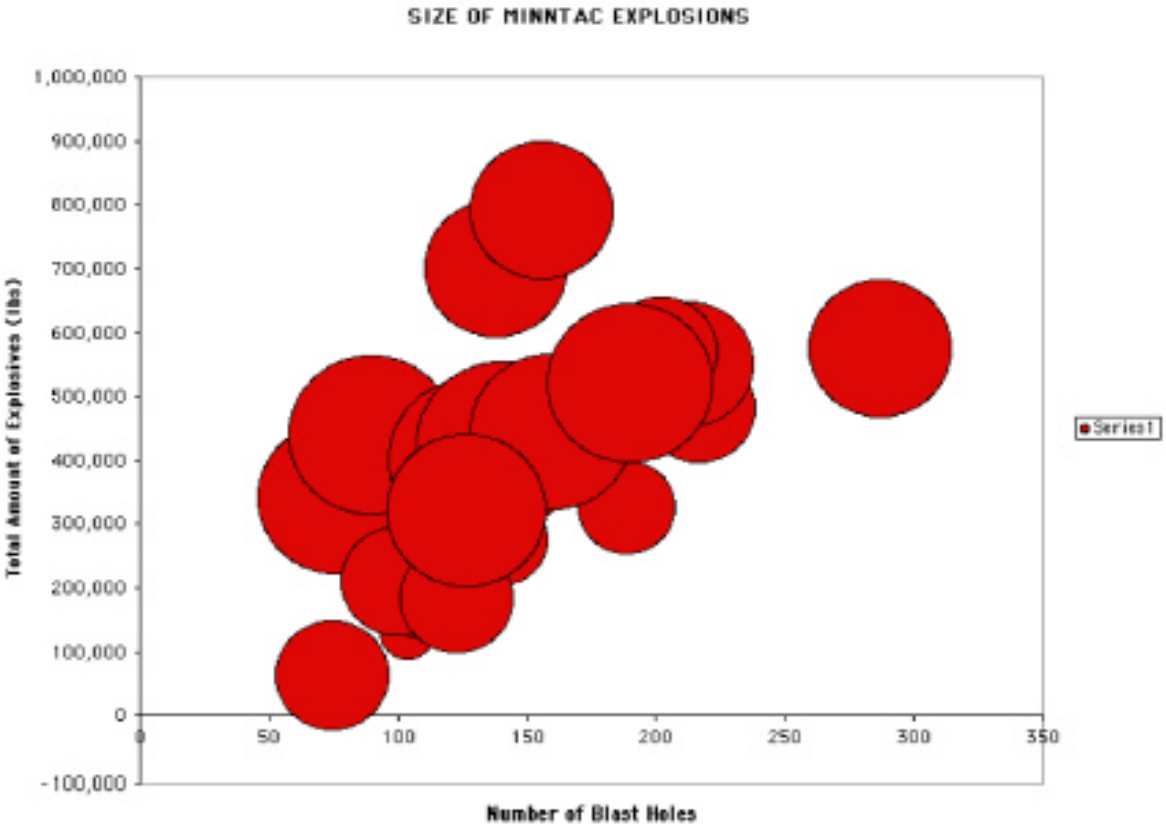
Fourier Analysis (Amplitude Spectrum - Box Window)



EMPIRICAL GROUND TRUTH



EMPIRICAL GROUND TRUTH



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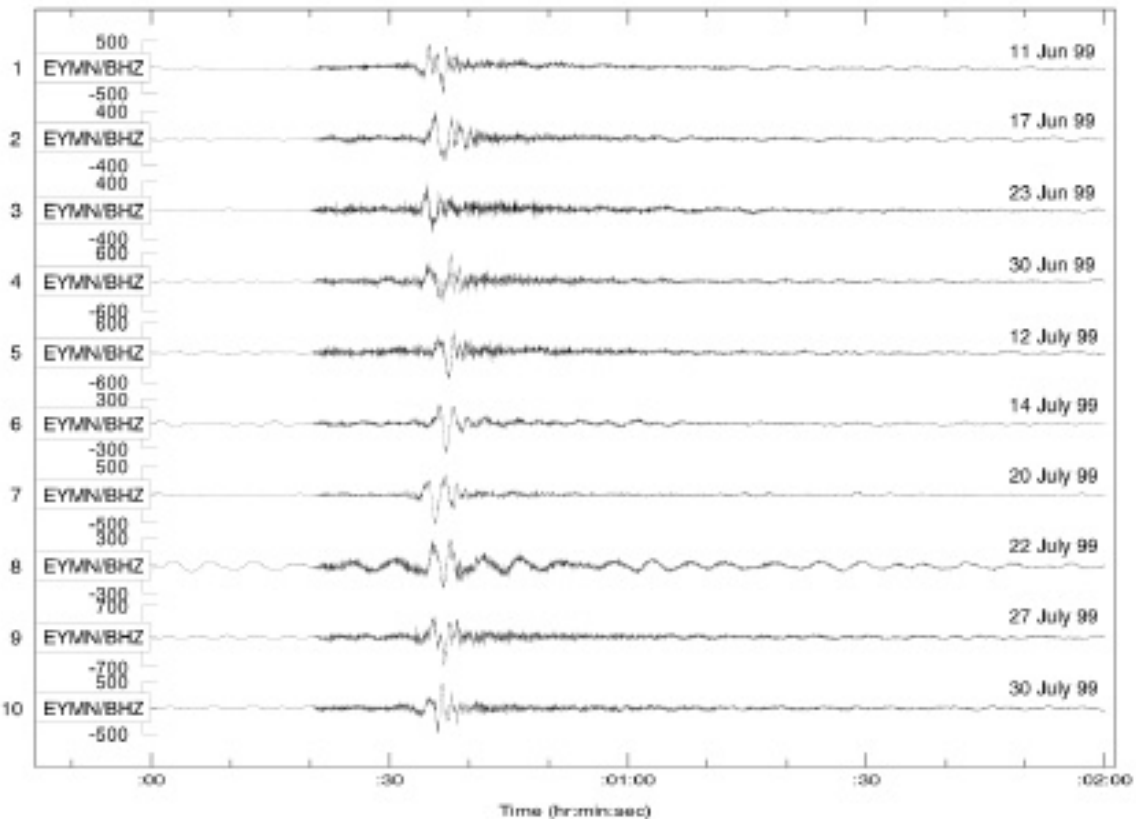

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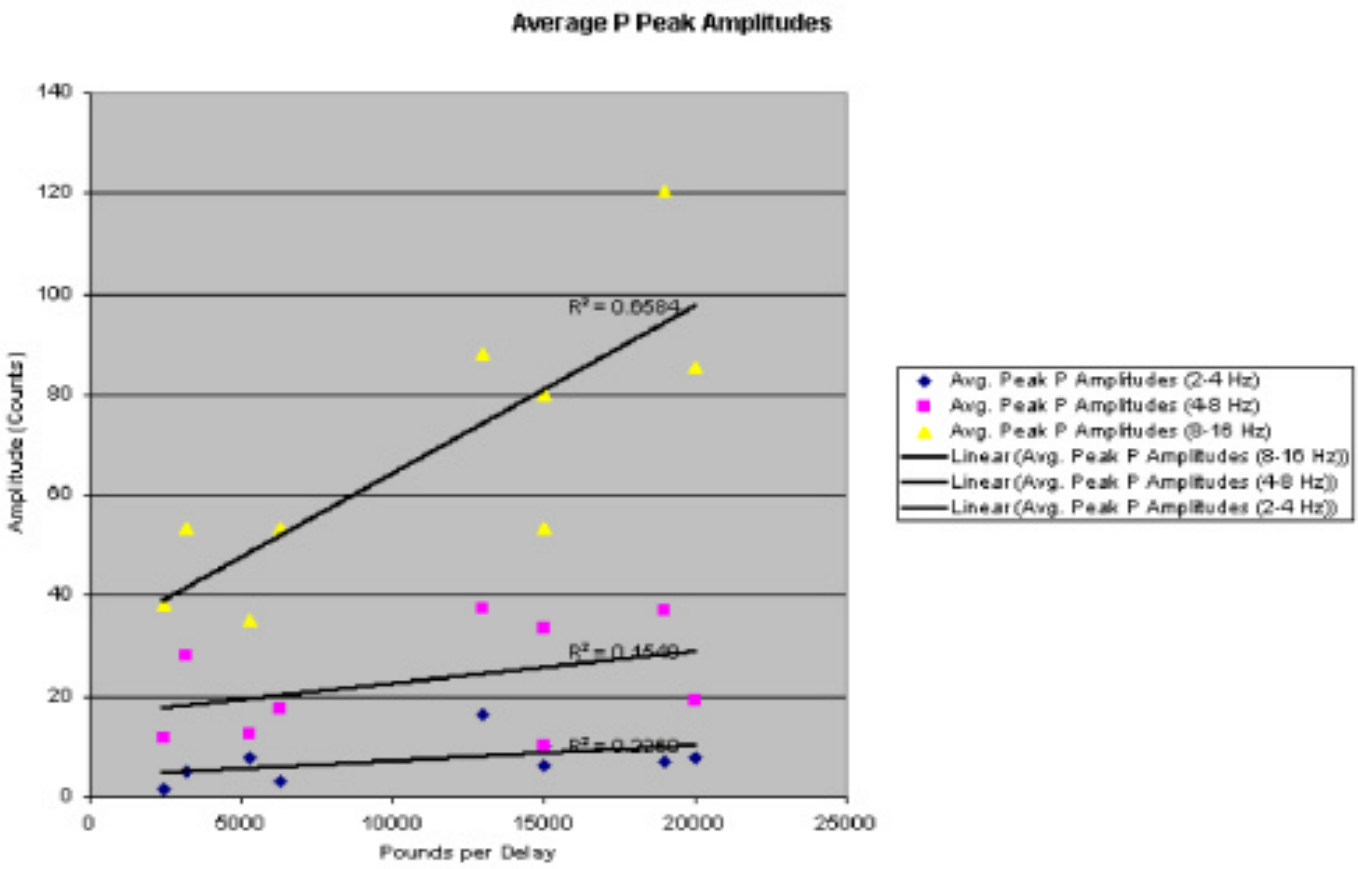

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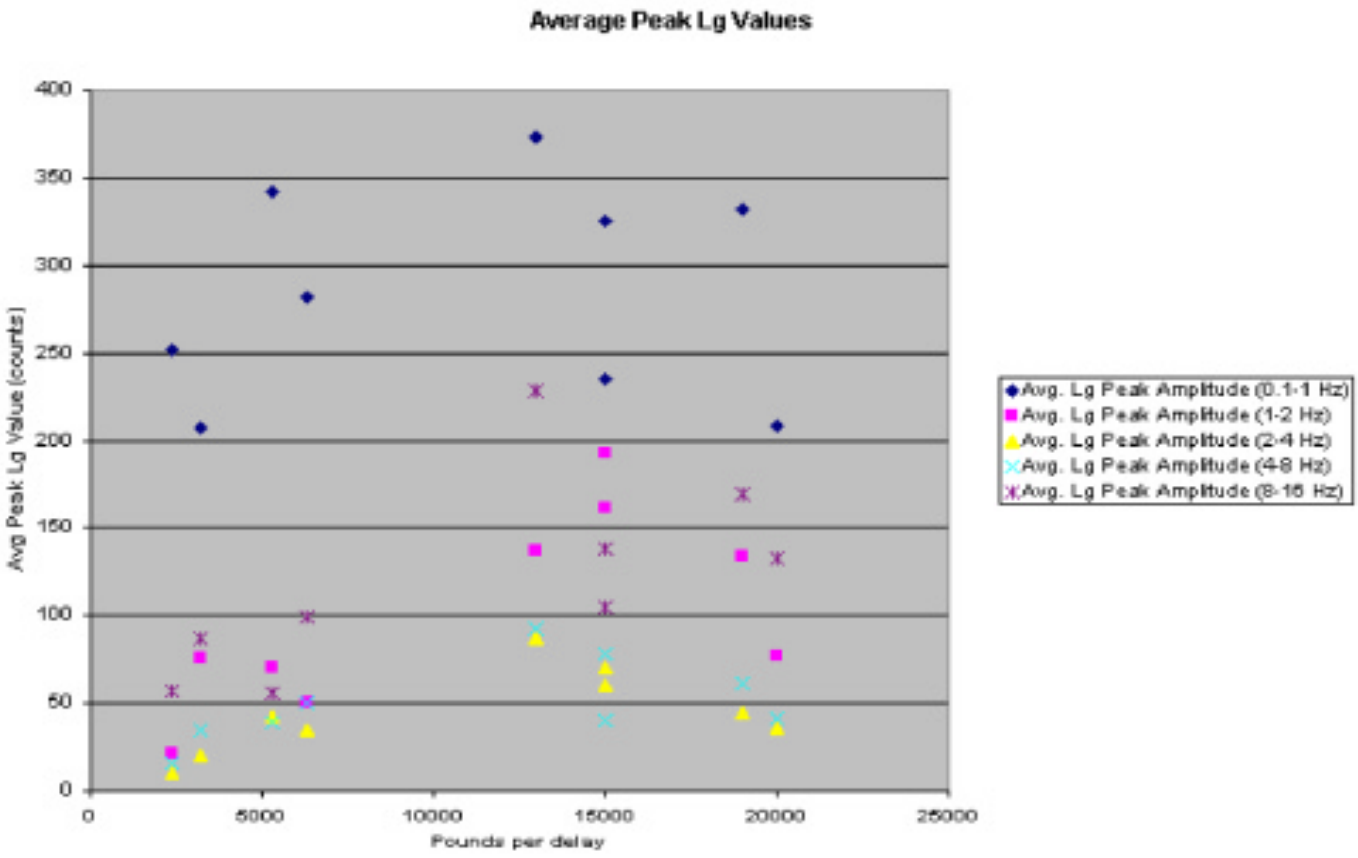

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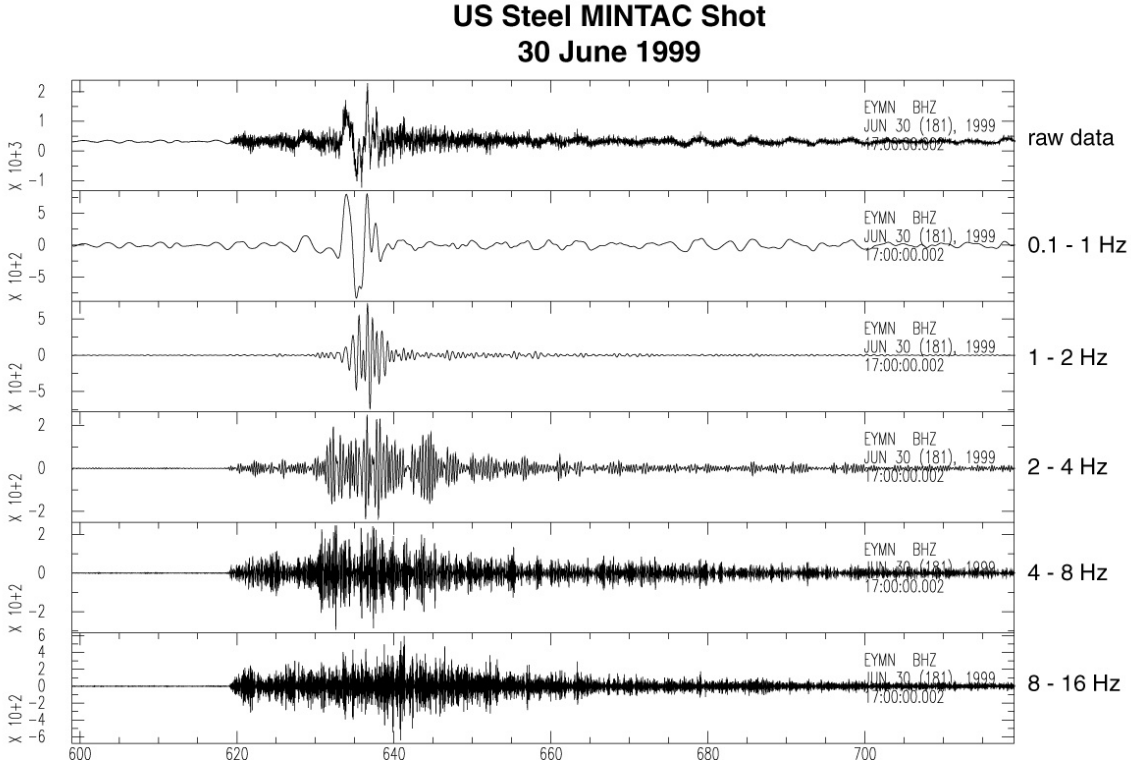

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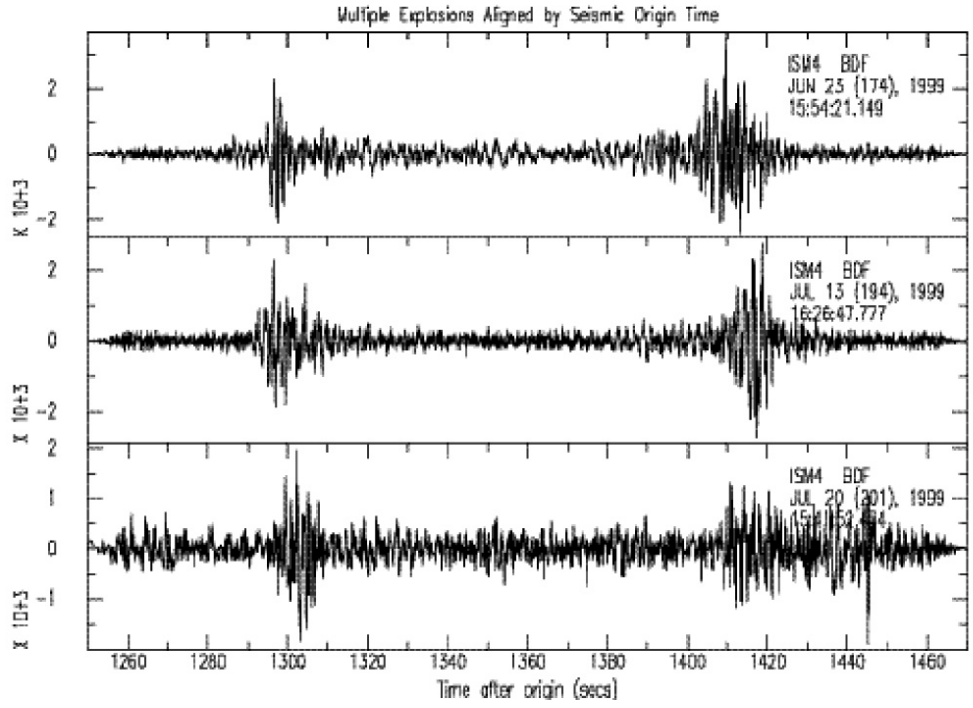

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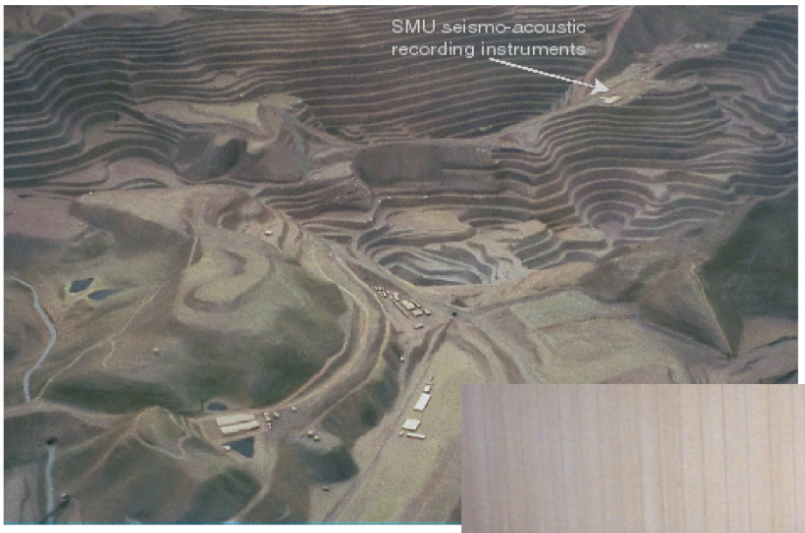

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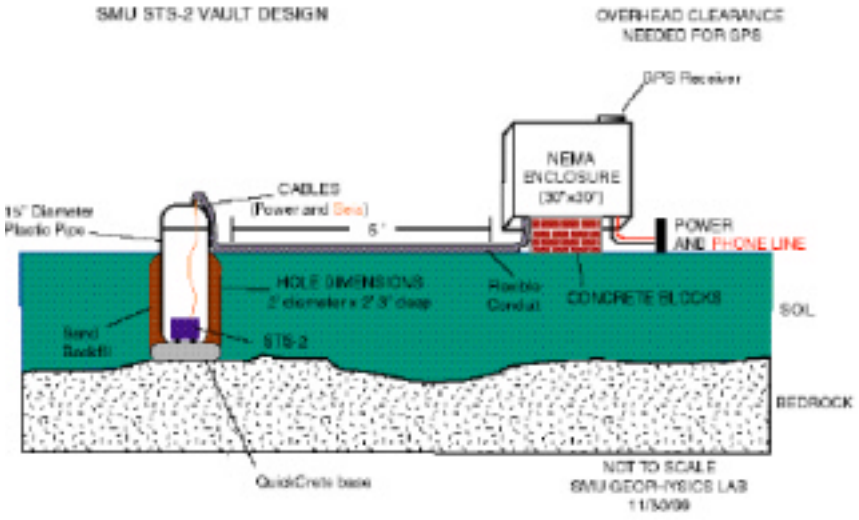

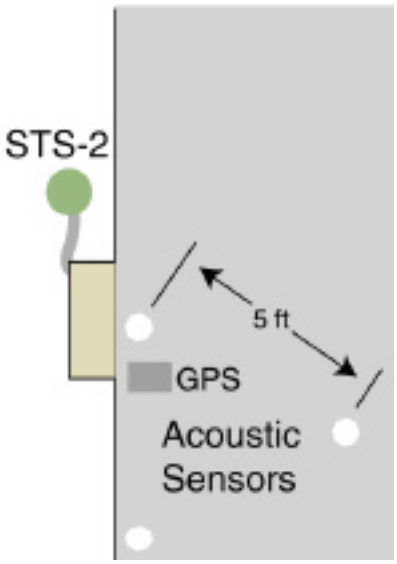

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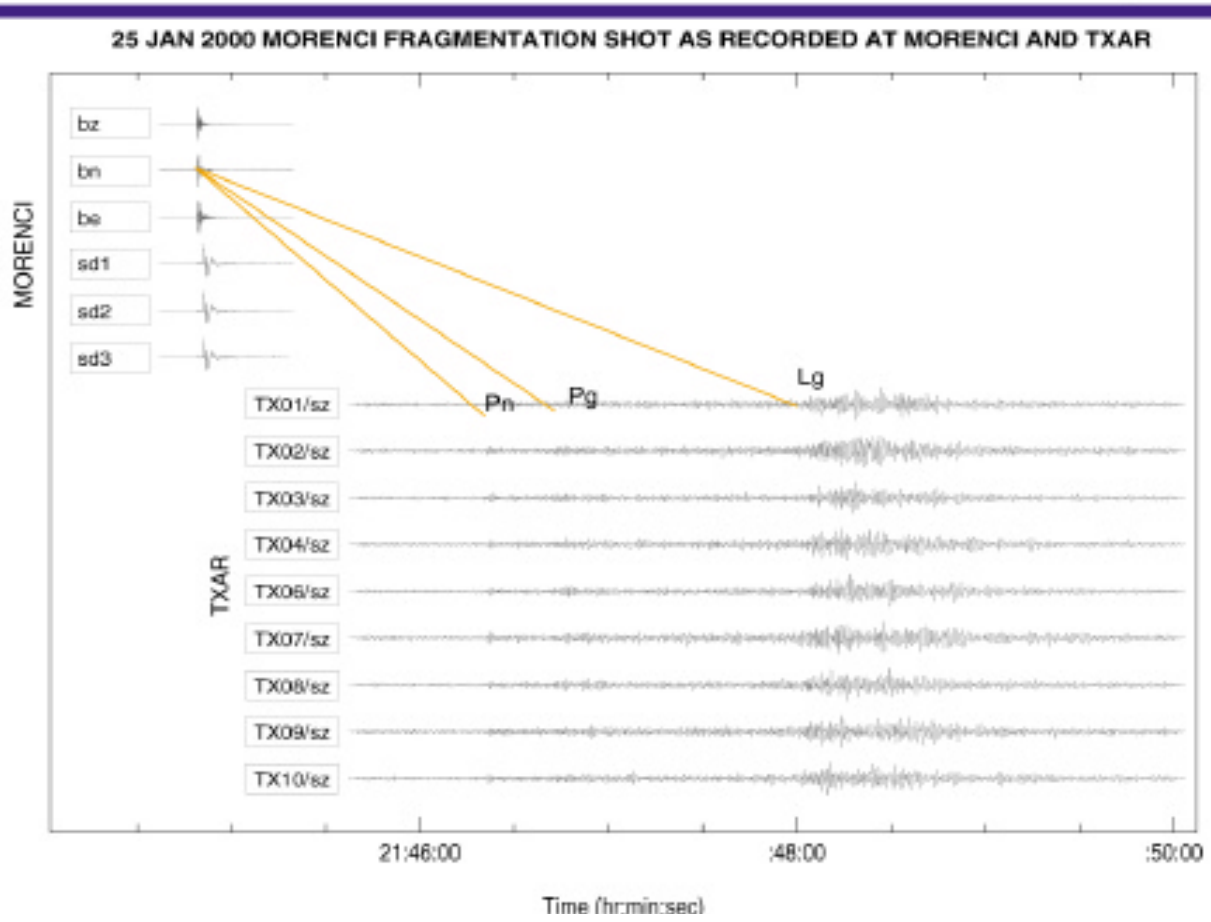

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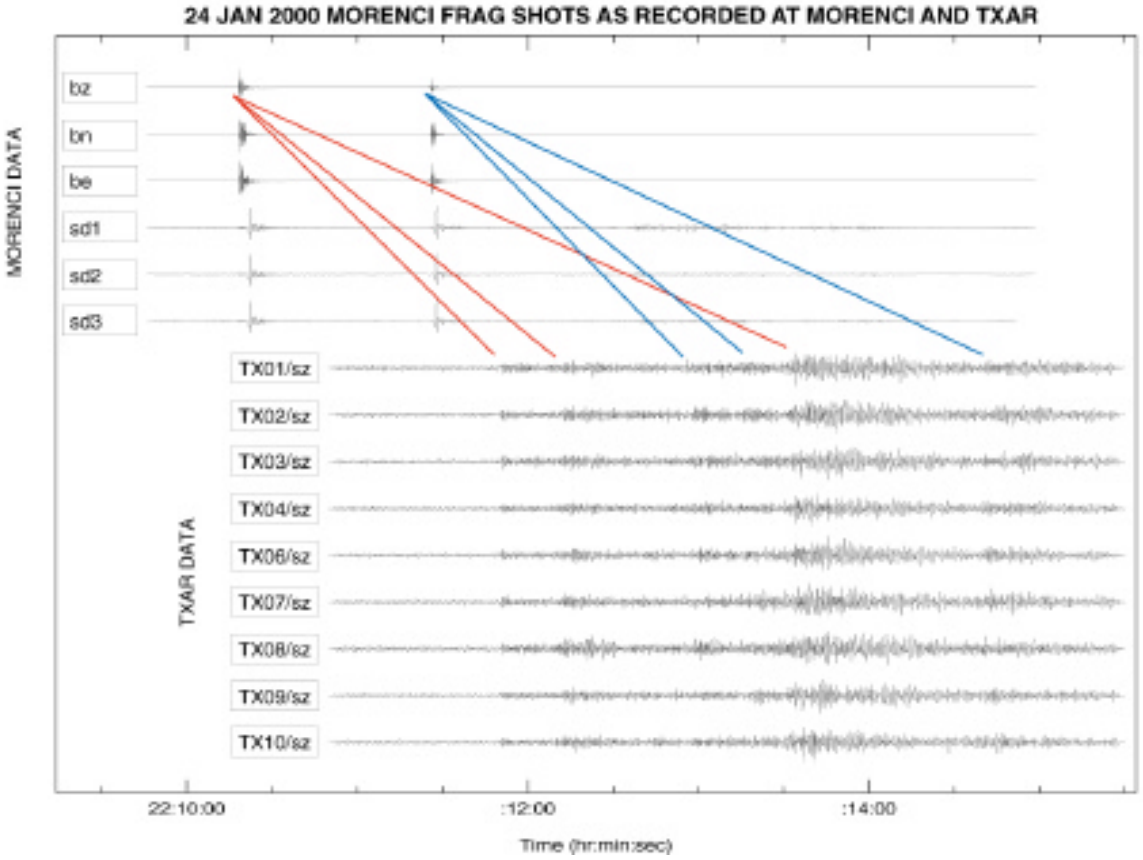

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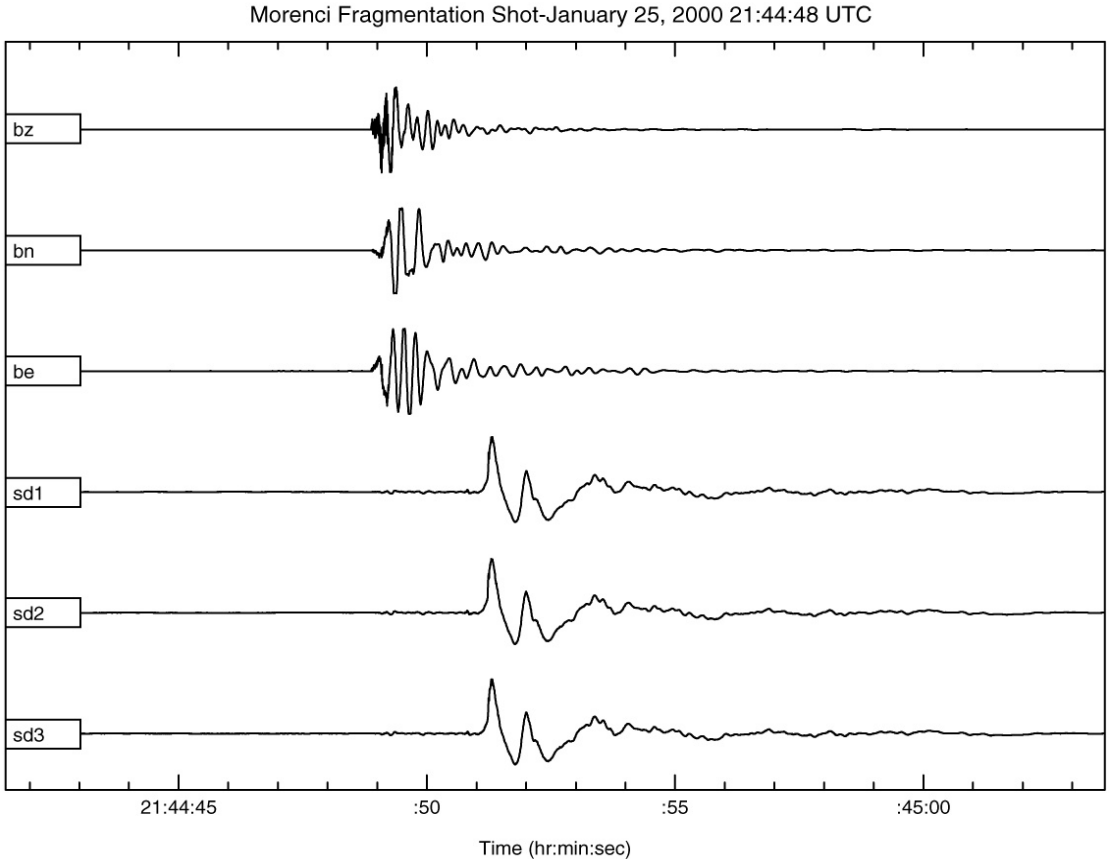

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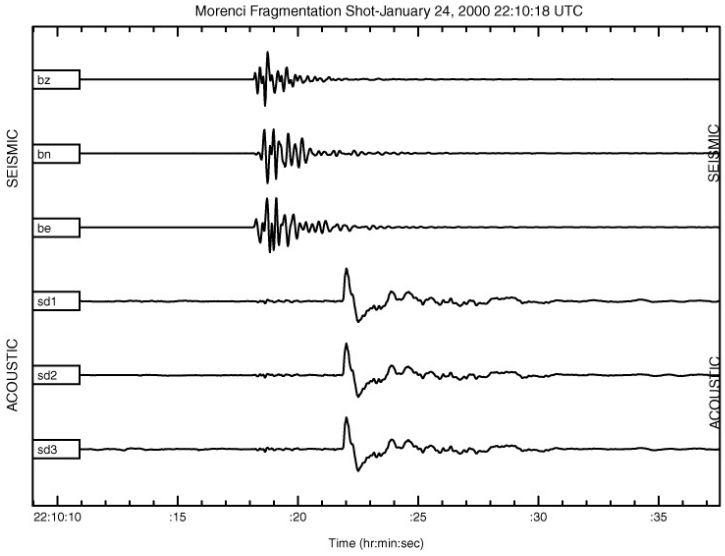

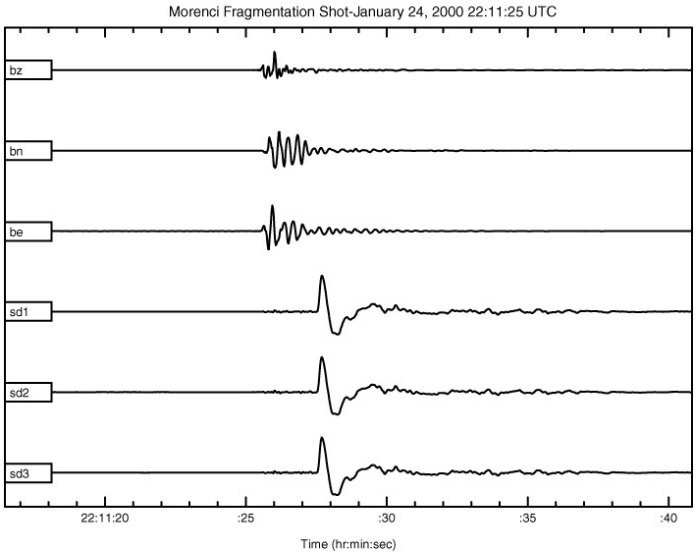

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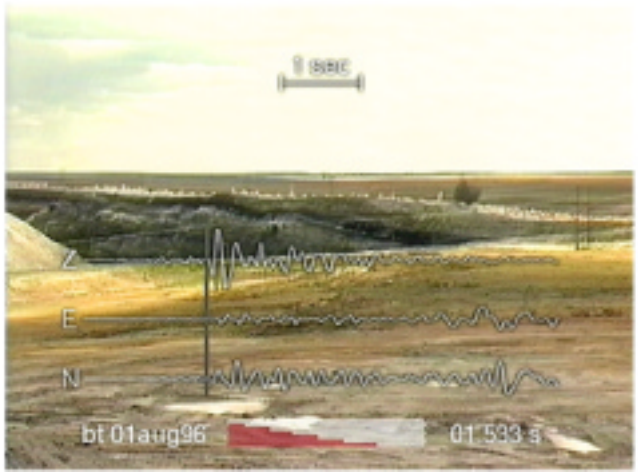
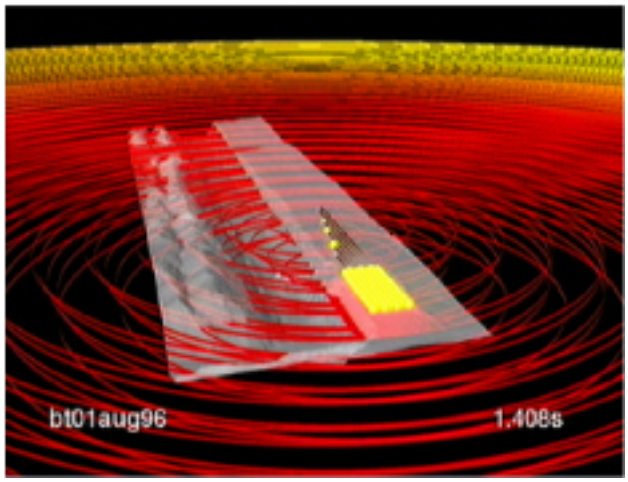




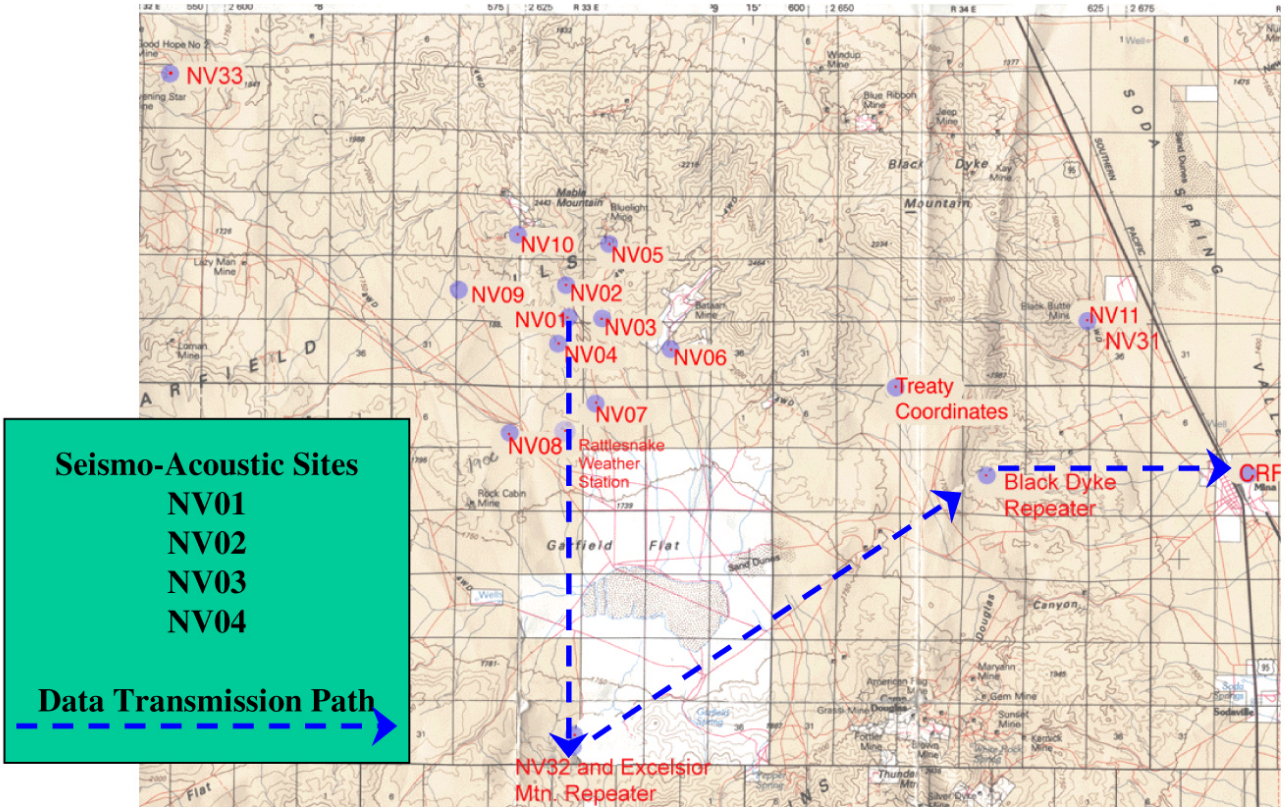
EMPIRICAL GROUND TRUTH

- Rapid availability of mine blasting records allows construction of database for regional analysis
- In-mine monitoring is useful in quantifying blasting anomalies
- In-mine seismic and acoustic observations provide additional constraints on regional data interpretation

SEISMO-ACOUSTIC ARRAY

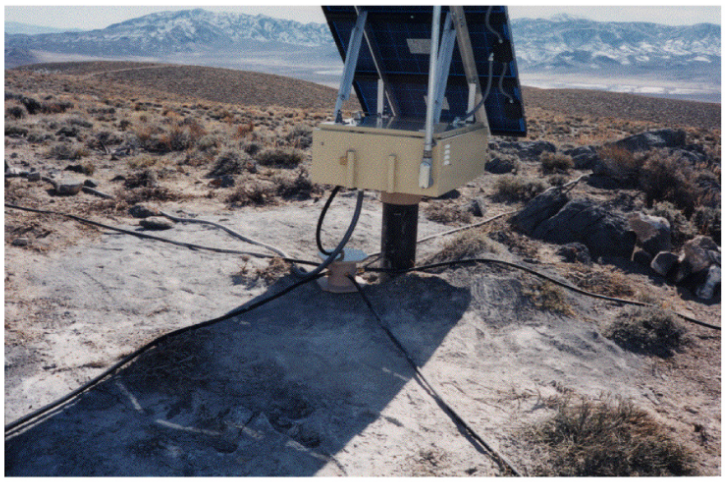
- **SENSOR**
  Validyn Model DP45 equivalent pressure sensor
  SMU CH5 Design
- **SPECIFICATIONS**
  Flat to sound pressure from 0.5 sec to
  50 sec period
  Sensitivity: 4400 microbars/volt
  Dynamic range: 90 dB
- **DATA ACQUISITION**
  40 samples/sec
  24 bit format
  19 bit resolution

SEISMO-ACOUSTIC ARRAY

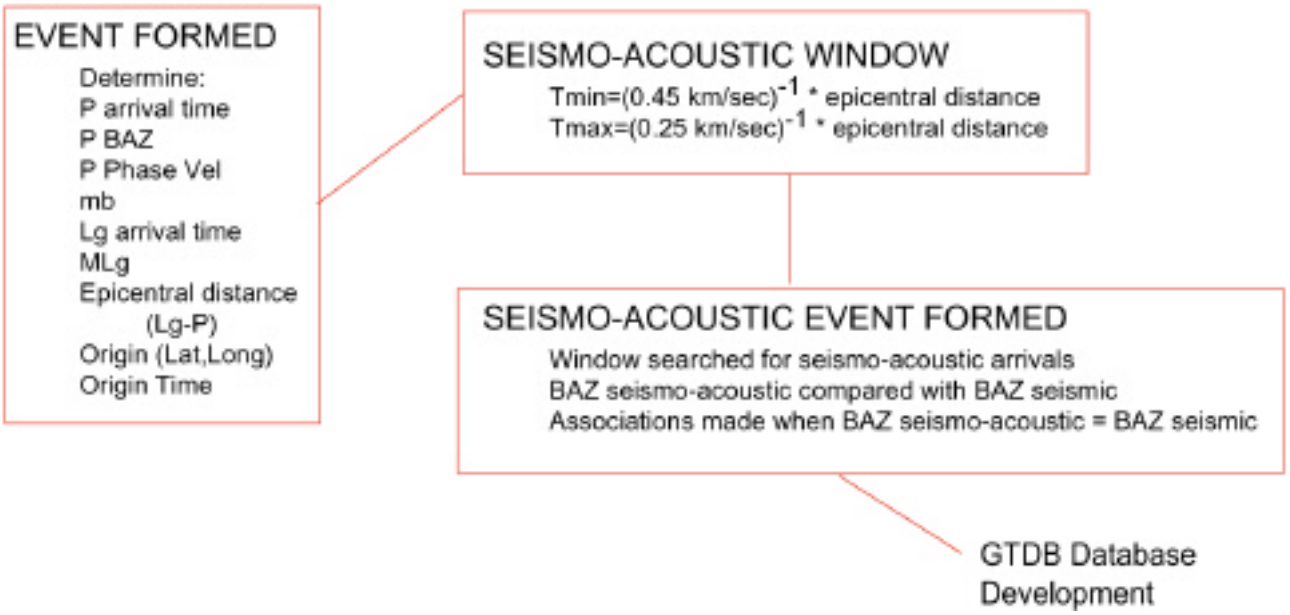


SEISMO-ACOUSTIC ARRAY

- **Solid Hoses**
  Five (5) 9m rubber hoses into summing volume
- **Porous Hoses**
  Five (5) 15m soaker hoses connected to solid hoses



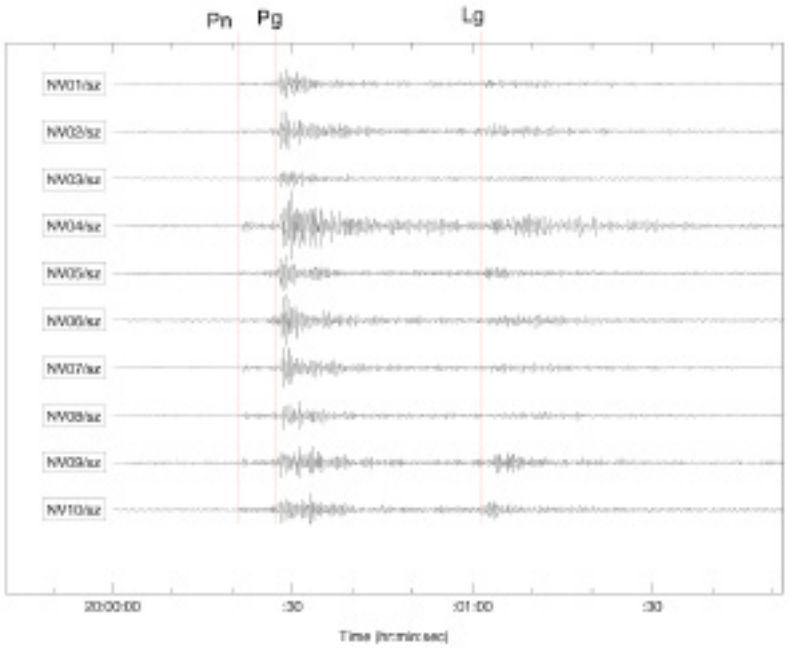
SEISMO-ACOUSTIC ARRAY



SEISMO-ACOUSTIC ARRAY

EVENT CHARACTERISTICS

Pn 20:00:21.7
Pn phase vel: 8.1
Pn BAZ 18.5 deg.
Pg 20:00:28.2
Pg phase vel: 6.5
Pg BAZ 15.1 deg.
Lg 20:01:03.2
Lg-Pn=41.5
mb Pn=2.5
mb Pg=3.1
mLg = 2.3
Epic. dist=295 km
Lat: 41.01
Long: -117.2
Origin time: 19:59:39



BP 0.6 4.5 Hz

ACOUSTIC WINDOW

MIN 19:59:39 + ((0.45 km/sec)$^{-1}$ * 296)=20:11:36
MAX 19:59:39 + ((0.25 km/sec)$^{-1}$ * 296)=20:20:21

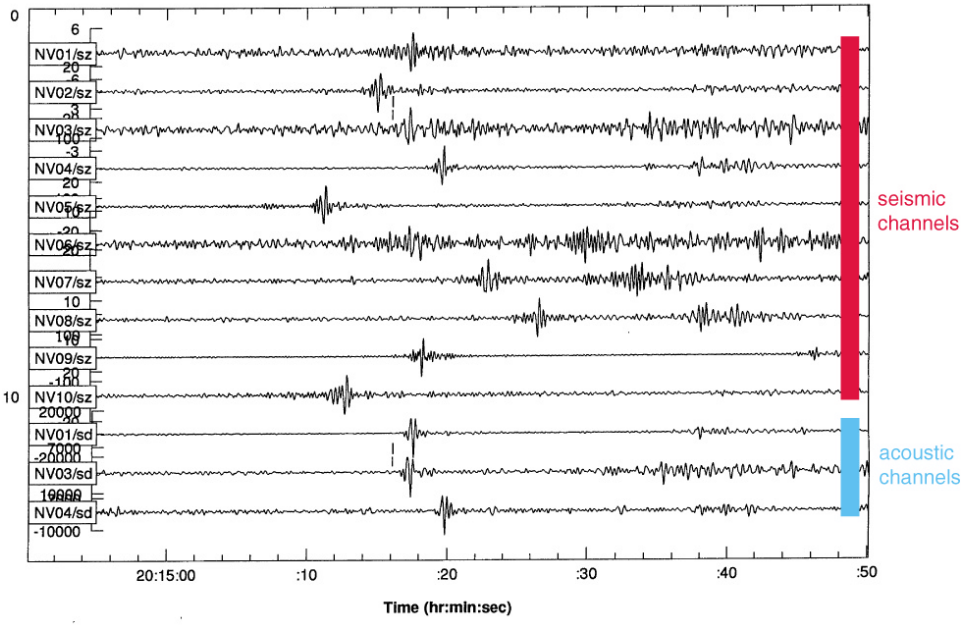
SEISMO-ACOUSTIC ARRAY

SEISMO-ACOUSTIC CHARACTERISTICS

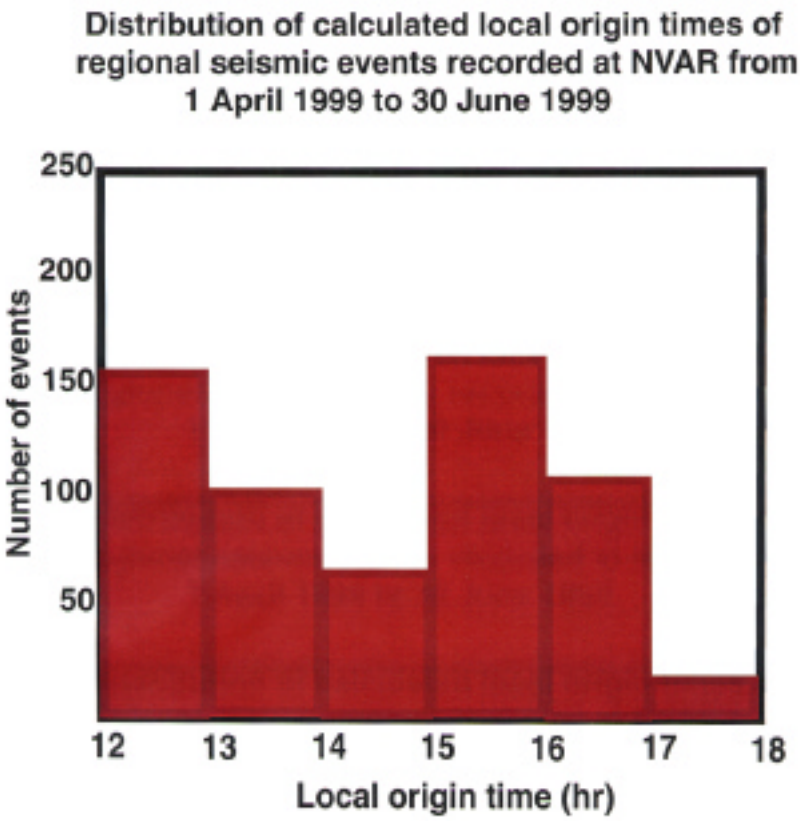
Phase Vel: 347 m/s
Group Vel: 270 m/s
Back Az: 17 degrees

Location of seismic event near Battle Mountain Gold Mining Complex

Good cross coupling from acoustic to seismic channels at some array sites.



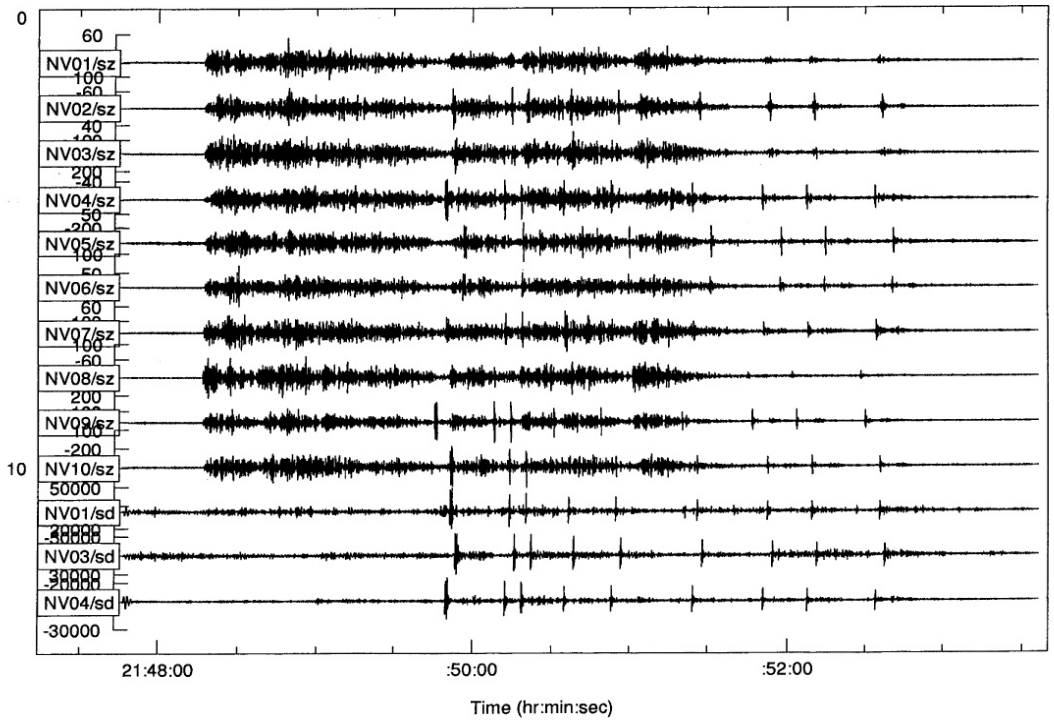
SEISMO-ACOUSTIC ARRAY



SEISMO-ACOUSTIC ARRAY

Acoustic Signals Observed in the 50-200 km Range

NVAR repetitive seismic-acoustic event sequence 15 June 1999



SEISMO-ACOUSTIC ARRAY

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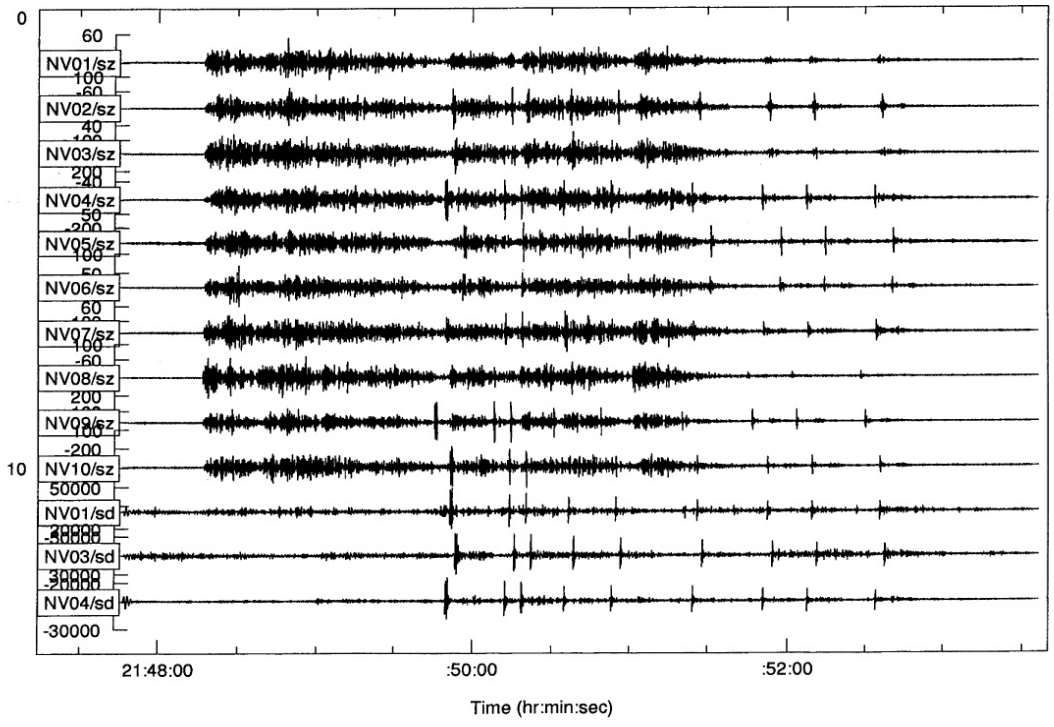
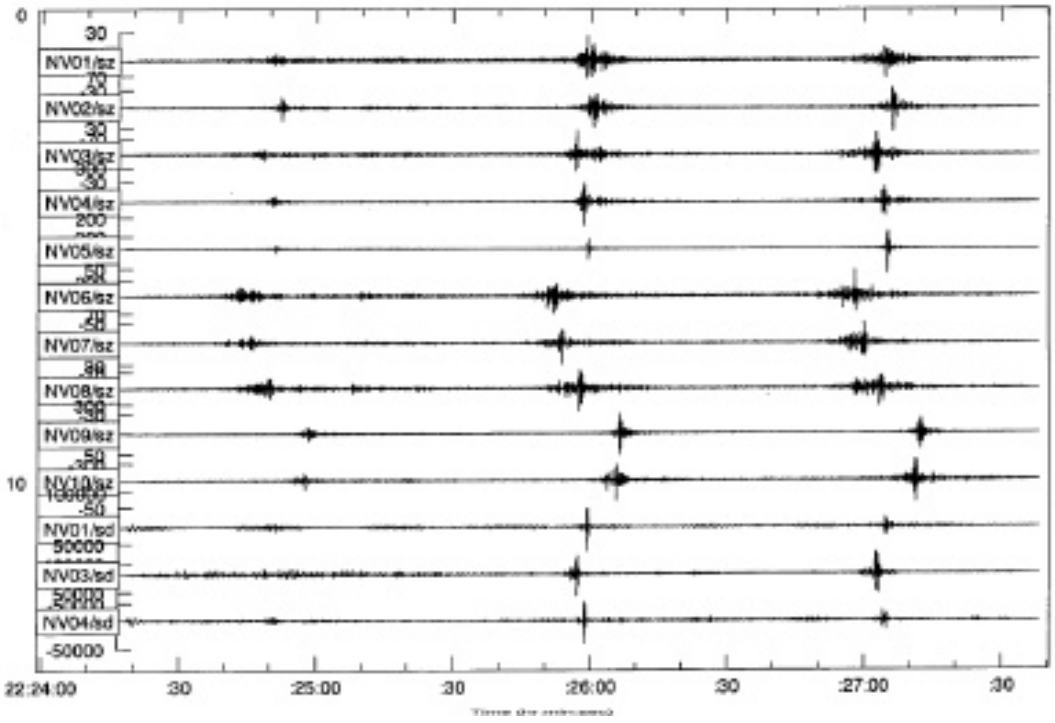


SEISMO-ACOUSTIC ARRAY

Many Unassociated Acoustic Signals

NVAR unassociated infrasonic arrivals 17 June 1999 127 deg 0.360 km/s



SEISMO-ACOUSTIC ARRAY

- Many unassociated acoustic signals
- Some acoustic signals observed in the 50-200 km
- Seasonal variations identified and under study
- Cross-coupling from acoustic to seismic channels observed for some geologic materials

SEISMO-ACOUSTIC ARRAY

- Co-located seismo-acoustic array is useful in event identification
- A few percent to a quarter of seismic signals have associated acoustic signals
- Regional event clusters identified
- Seismic waveform similarity within groups
- More variation in acoustic waveforms