Source Scaling of Single-Fired and Delay-Fired Explosions

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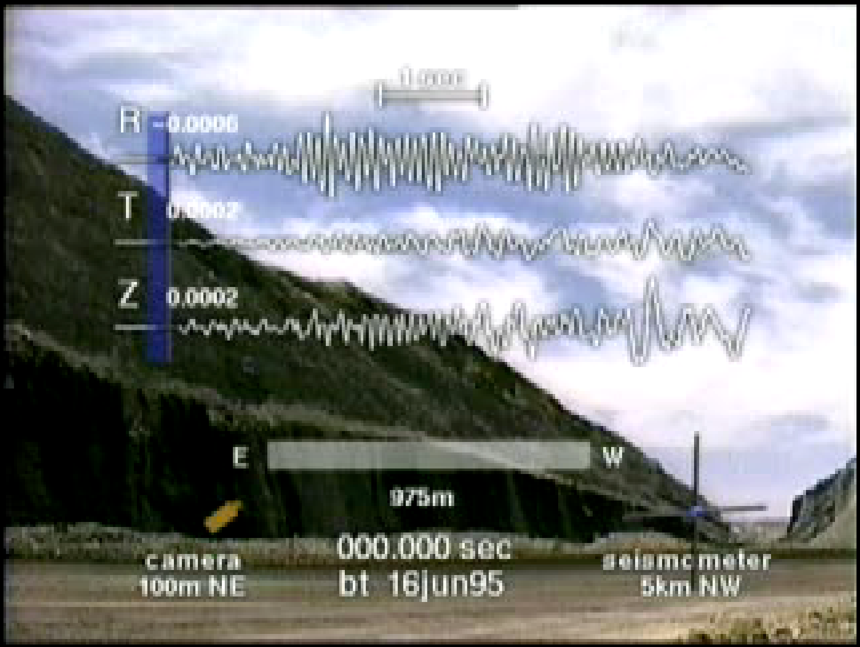

Types of Explosions

Contained, Single-Fired: Cylindrical borehole with enough stemming to maintain containment of explosion. All explosives simultaneously detonated

Delay-fired Explosions: Cast shots with multiple boreholes detonated in time sequence to maximize the casting overburden. Coal shots with multiple boreholes detonated in time sequence to maximize the fragmentation of coal without casting.

PURPOSE

• Quantify Relationship Between Peak Seismic Amplitudes and Total Amount of Explosives for Contained, Single-Fired Explosions

• Quantify Relationship Between Peak Seismic Amplitudes and Total Amount of Explosives for Delay-Fired Explosions

• Compare Seismic Coupling In-Mine (kilometers) and at Regional Distances (100's kilometers)

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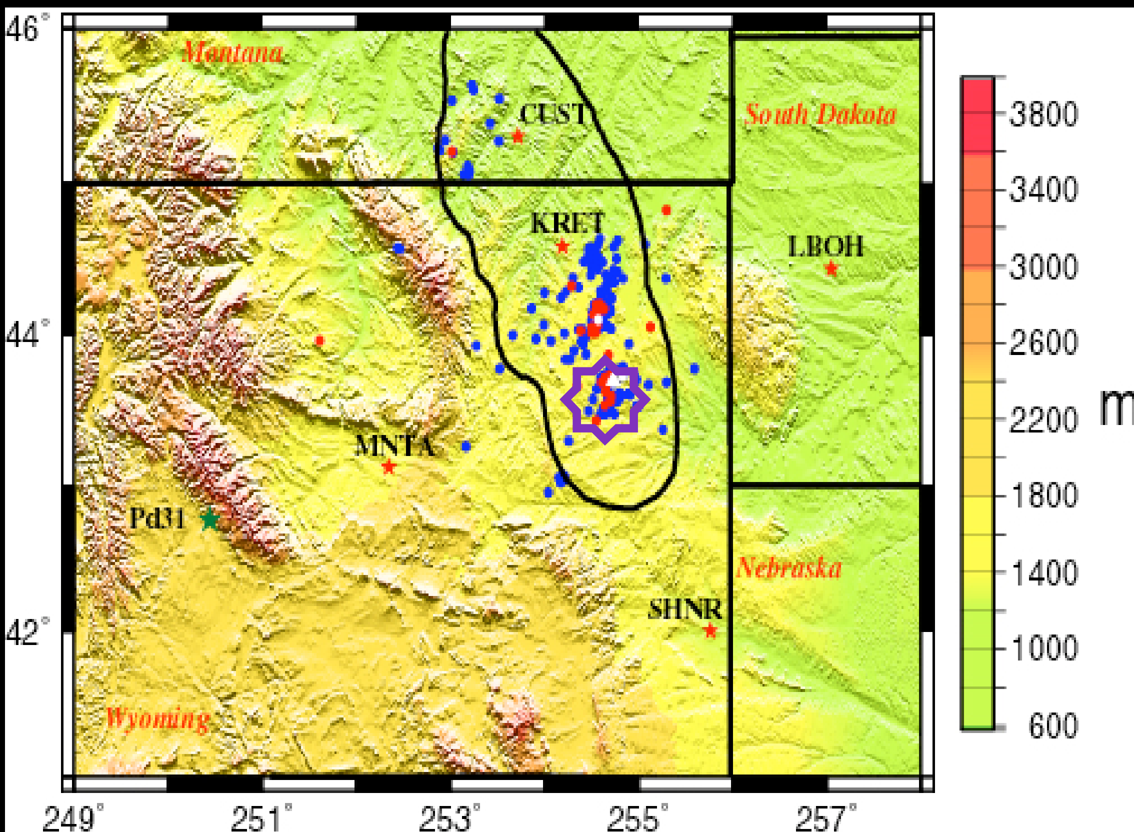
EXPERIMENT LOCATION
REGIONAL

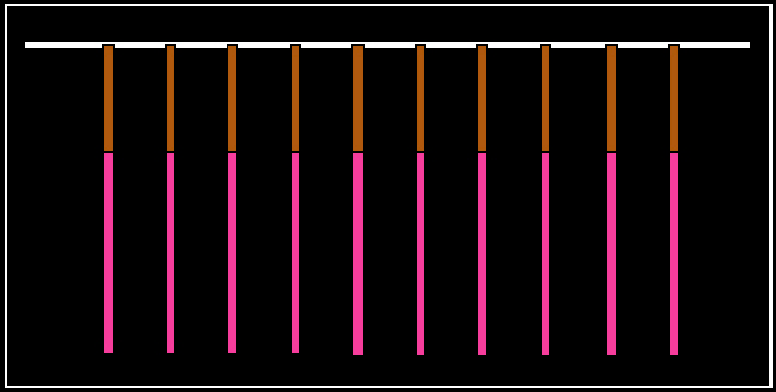


- Sources in Powder River Basin in NE Wyoming
- Regional Stations at 100-360 km

EXPERIMENT LOCATION IN-MINE

- Contained single-fired shots marked by stars
- Largest blasts were cast shots
- Also conducted coal shots for fragmentation

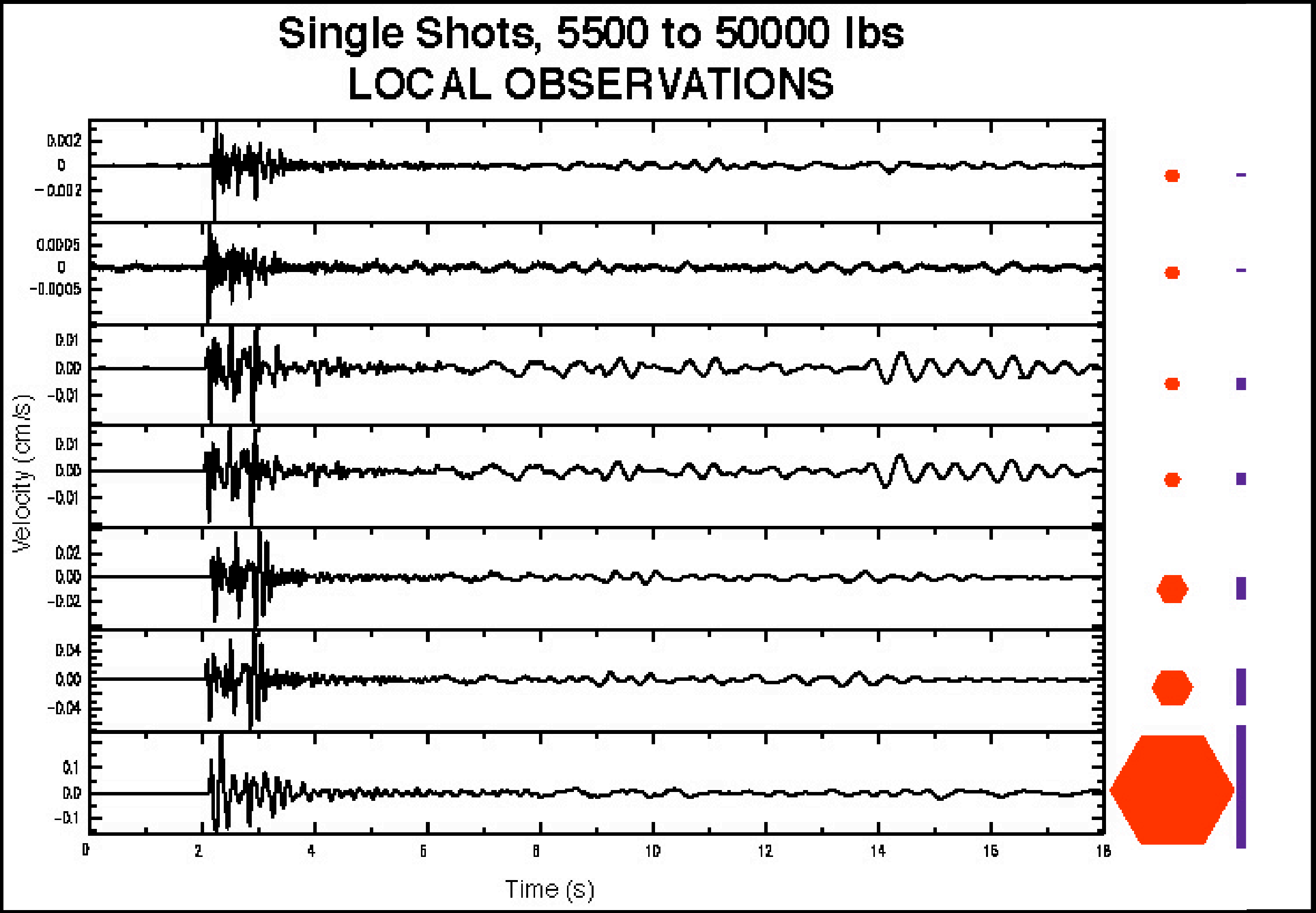
Contained Single-Fired Explosions



S7
10 boreholes
42.5 m depth
15.25 m stemming
10.4 m spacing

Shot	# boreholes	Weight
3	1	5500
4	1	6000
5	3	12000
6	4	16000
7	10	50000

Comparison of In-Mine Data



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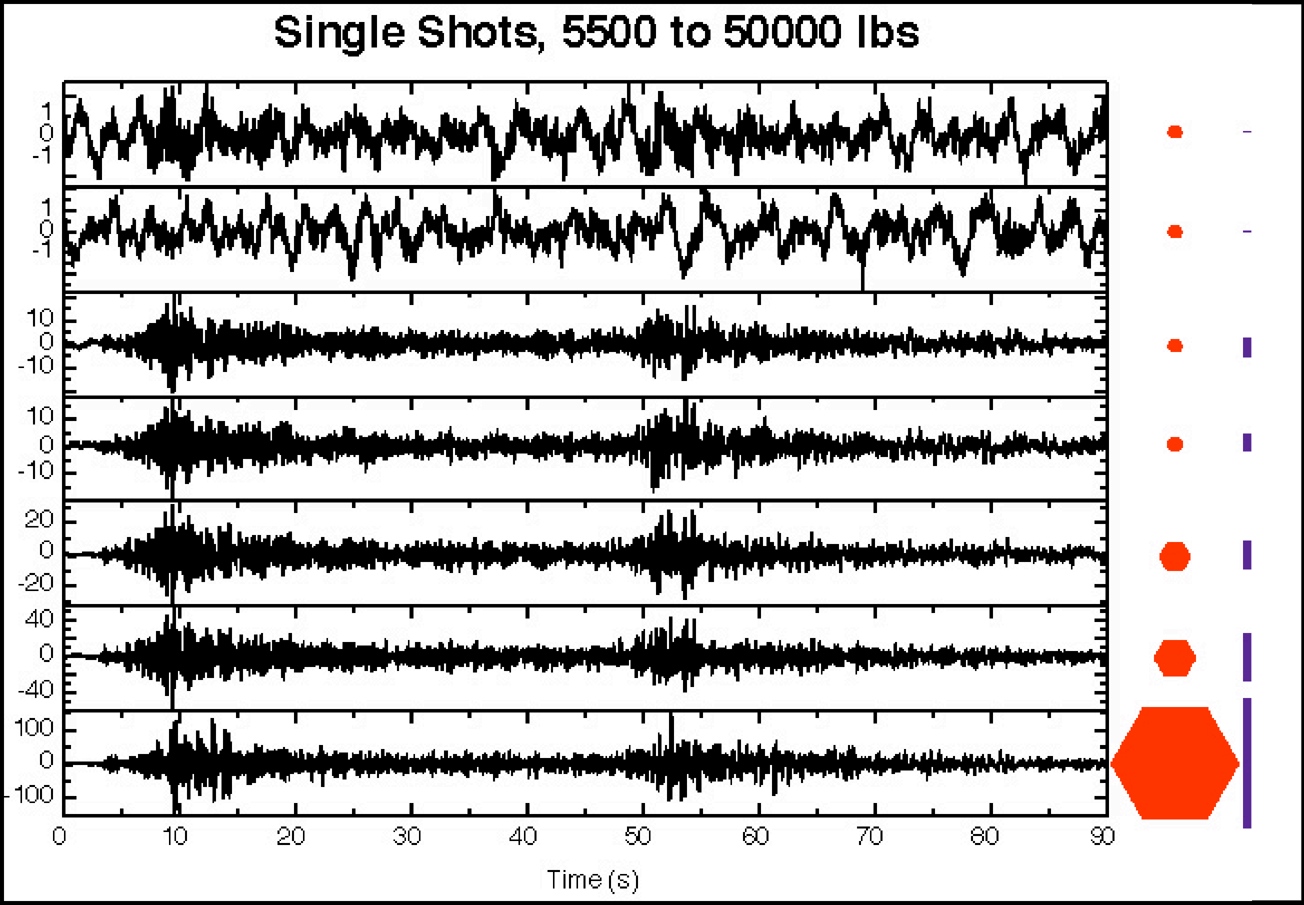
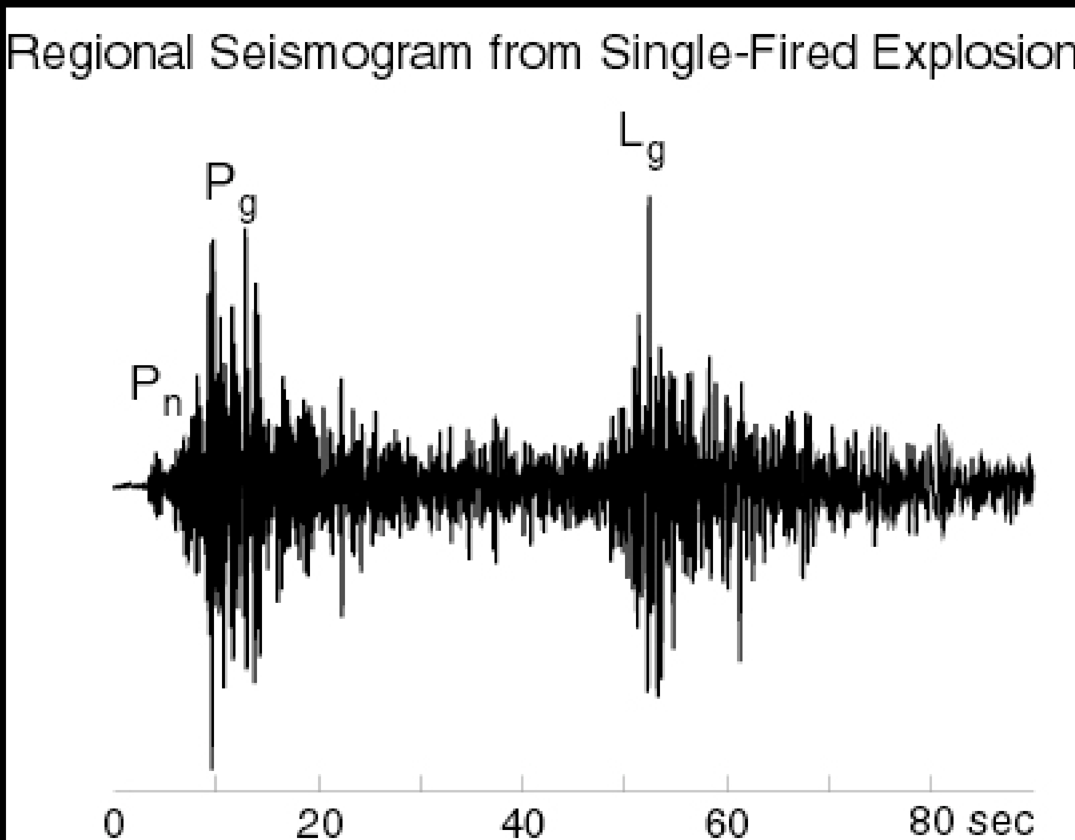
Comparison of Regional Data



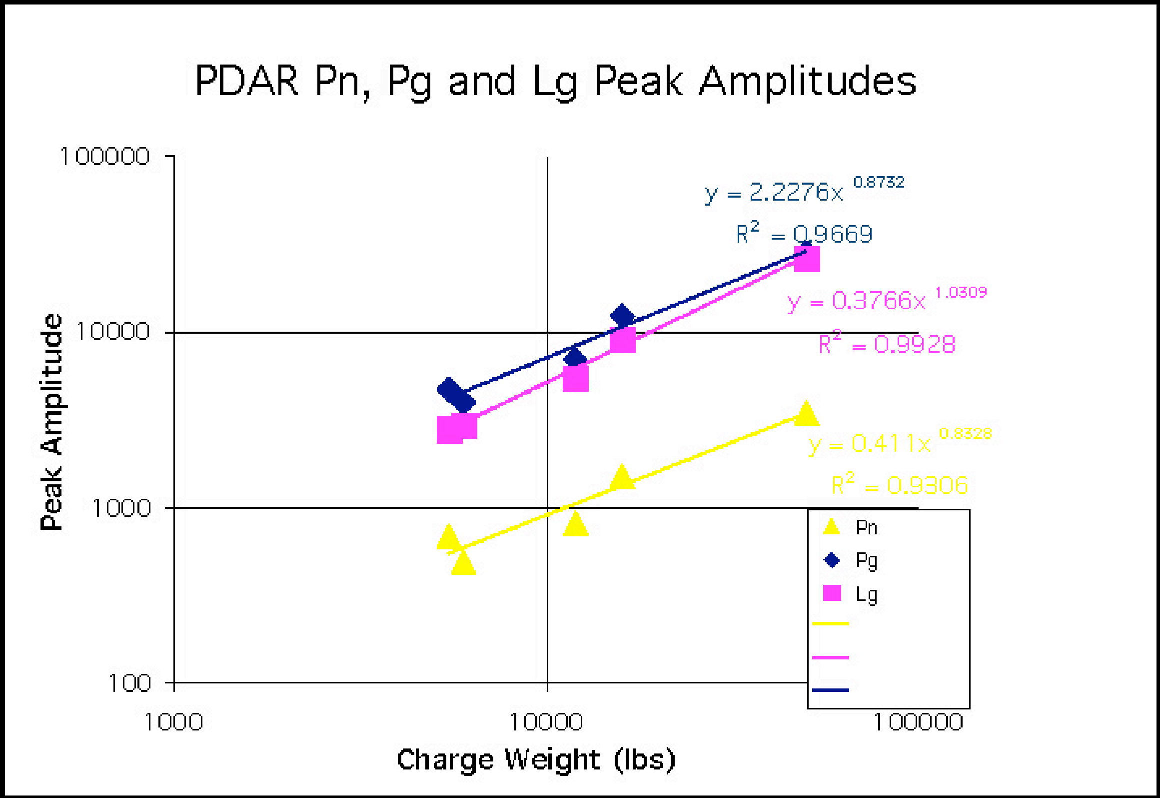
Regional Seismogram



- P_n : Mantle P wave
- P_g : Crustal P wave
- L_g : Crustal S wave

Peak Amplitudes of Regional Data

Power Law Scaling: Amplitude = AW^b



P_n b = 0.83

P_g b = 0.87

L_g b = 1.03

Peak Regional Amplitude Scaling

Amplitude $= AW^b$

All three of the high frequency regional phases (P_n, P_g, and L_g) have peak amplitudes that scale according to a Power Law:

$b_{Pn} = 0.83$, $b_{Pg} = 0.87$, $b_{Lg} = 1.03$ THIS STUDY

Scaling using in-mine data produced similar results

$b_{in\text{-}mine} = 0.73 - 0.94$ YANG 1999

Scaling of regional amplitudes from large-scale nuclear explosions in studied in Western US

$b_{nuclear} = 0.8$ VERGIN0 1983

Spectral Ratios - Theory
Scaling at All Frequencies

$U_j(f) = R(f)\, P(f)\, S_j\,(f)$

$U_j(f)$ *observation*
$R(f)$ *receiver function*
$P(f)$ *path effect*
$S_j\,(f)$ *source*

$$U_1(f)/\,U_2(f) = [R(f)\, P(f)\, S_1\,(f)]/\,[R(f)\, P(f)\, S_2\,(f)]$$
$$= S_1\,(f)/\,S_2\,(f)$$

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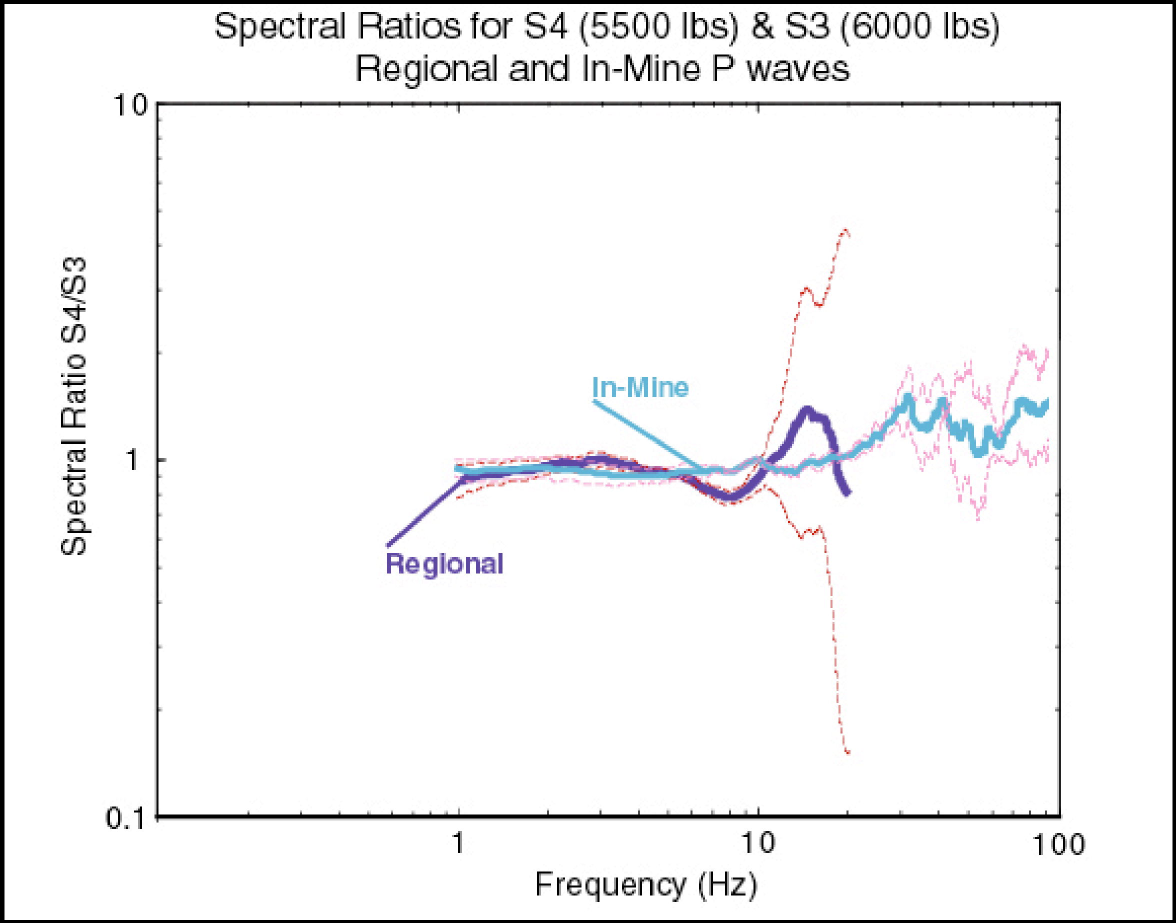
Spectral Ratios - Observations

$U_4(f)/ U_3(f) = S_4 (f)/ S_3 (f)$



Single-Fired

S3 - 5500 lbs

S4 - 6000 lbs

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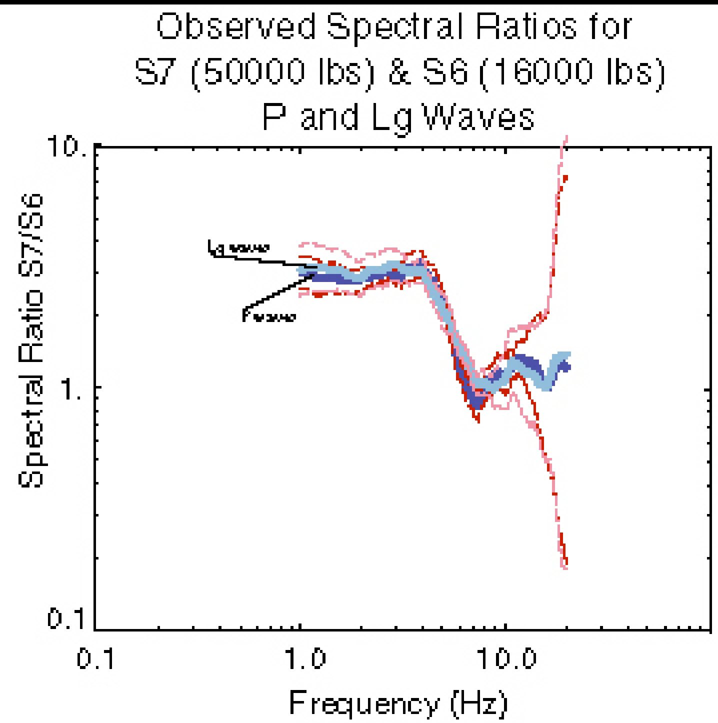
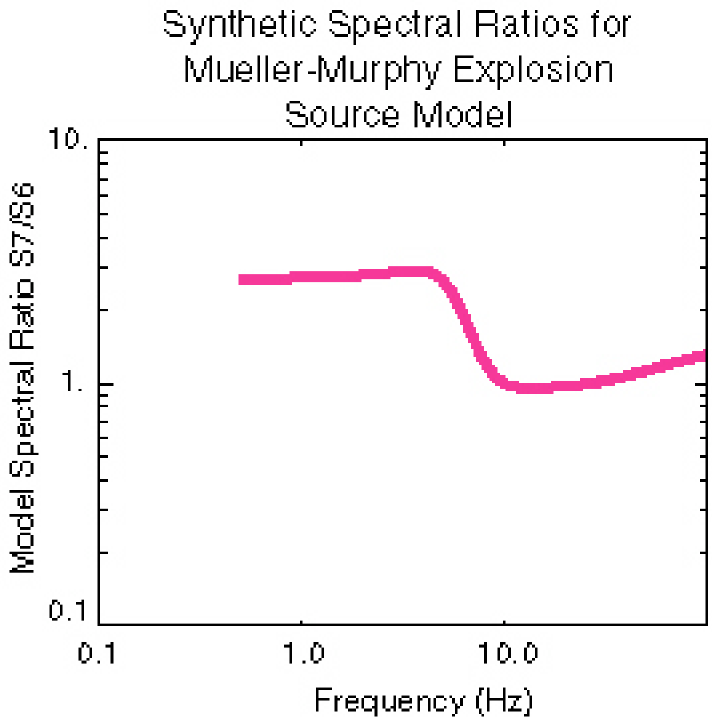
Spectral Ratios - Data and Model

$$U_7(f)/\,U_6(f) = S_7\,(f)/\,S_6\,(f)$$

S7 - 50000 lbs   S6 - 16000 lbs





Coal Shots

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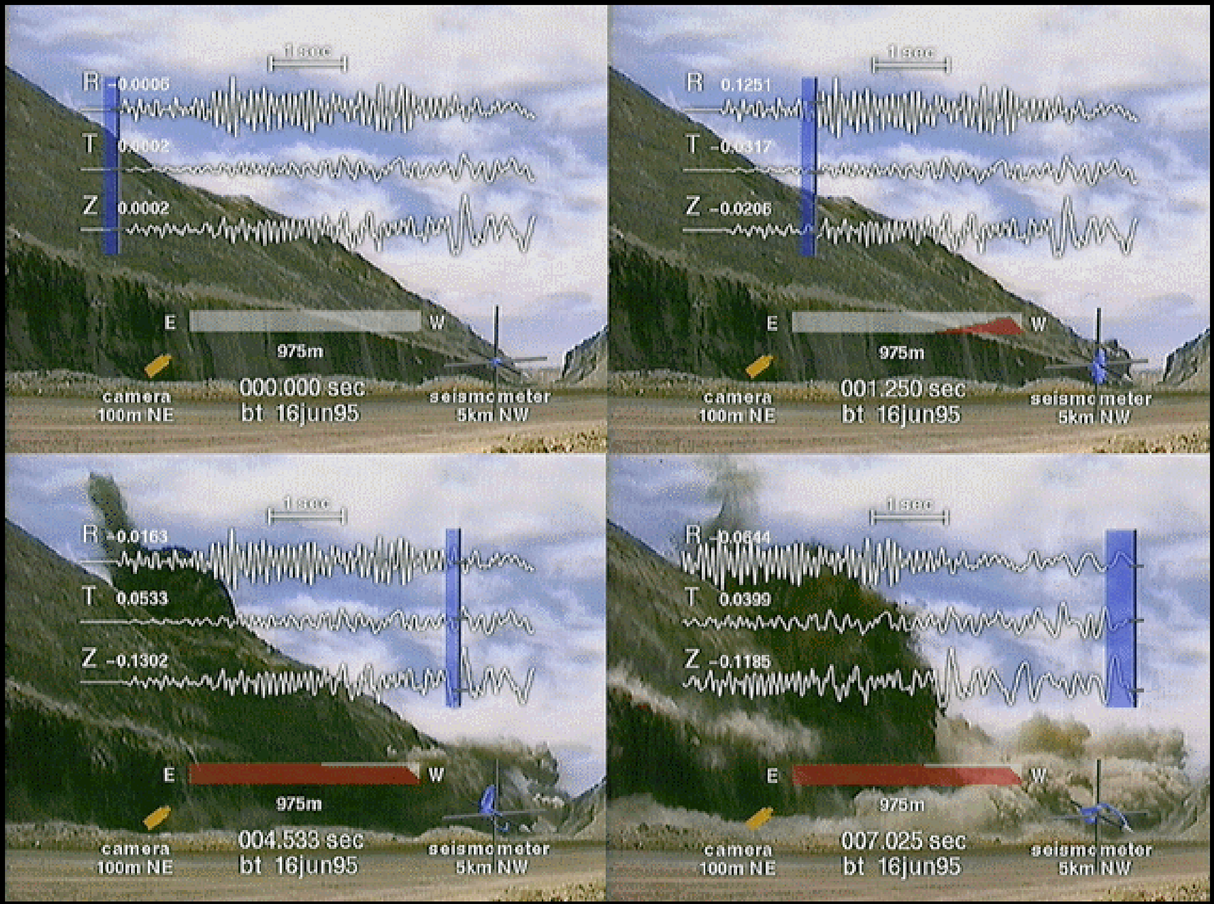
Cast Shots



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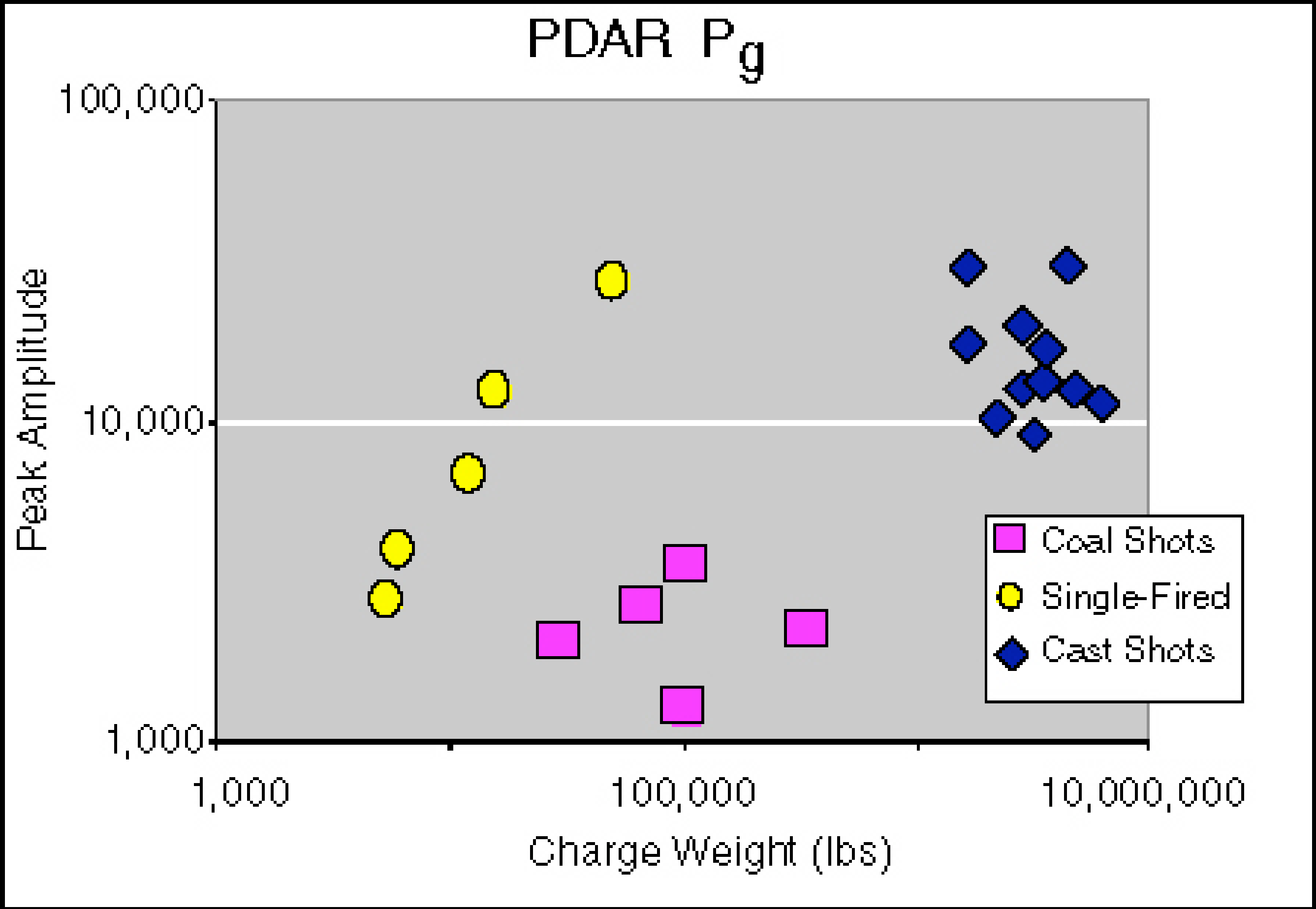
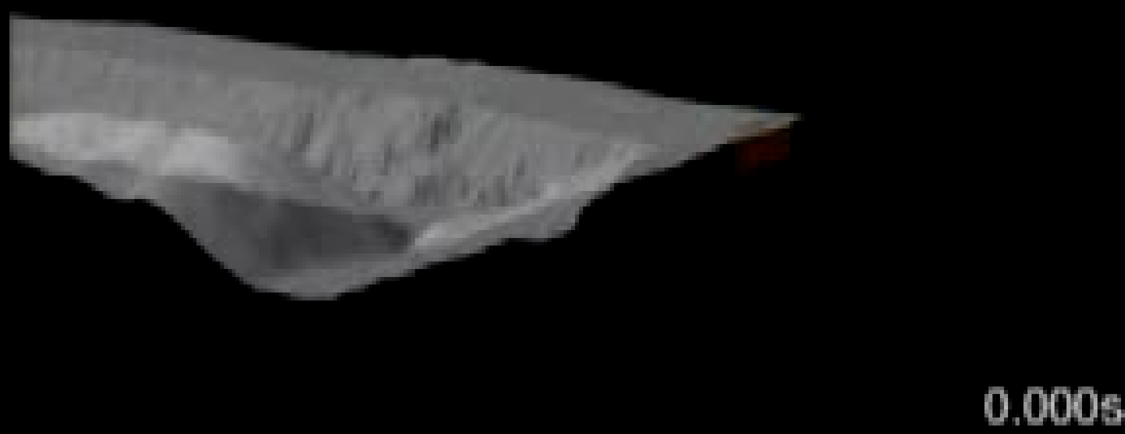
Peak Amplitudes for Coal, Cast and Single-Fired Shots



Models for Single-Fired Shots



Models for Cast Shots

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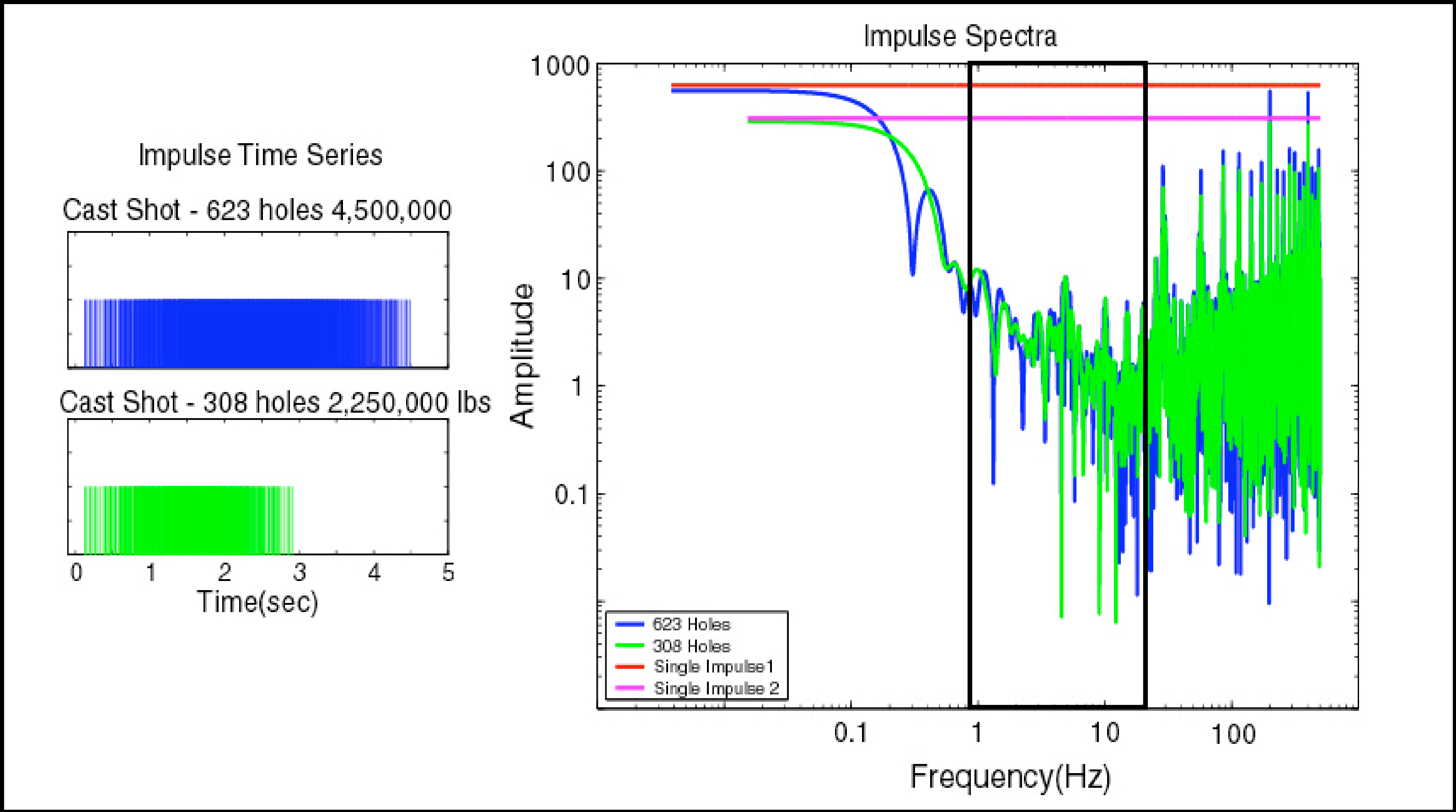
Spectral Model of Cast Shots



Conclusions
Contained Single-Fired Explosion

- Source scaling models developed for contained single-fired explosions in a coal mine.

- Regional seismograms (100’s km) support scaling models similar to those for in-mine ground motion.

- Frequency dependent scaling relations are consistent with a model developed for nuclear explosions.

Conclusions
Delay-Fired Explosion

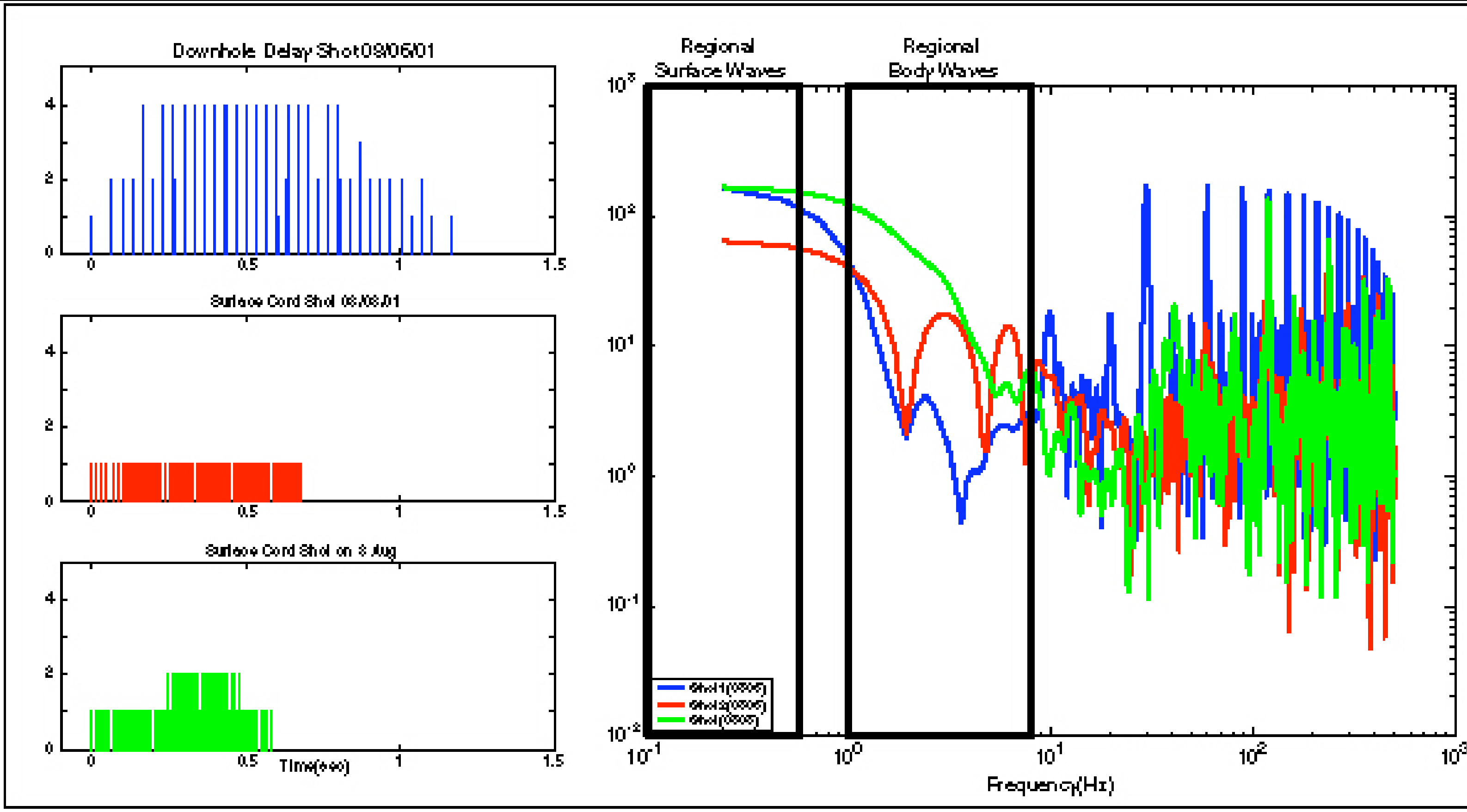
• Timing effects from delay-firing are modeled as impulse response.

• Significant destructive interference (factor of 60-300) found in the frequency band 1-20 Hz.

• Model predicts and data illustrates an insensitivity of peak amplitude in the 1-20 Hz band to the total amount of explosives.

Example from Another Mining Operation

Models of Three Blasts



Regional Data From the Three Blasts