united nations educational, scientific and cultural organization
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the **abdus salam** international centre for theoretical physics
40th anniversary 1964 2004

H4.SMR/1586-19

"7th Workshop on Three-Dimensional Modelling of Seismic Waves Generation and their Propagation"

25 October - 5 November 2004

Parametric Studies for the Definition of the Seismic Input: A Case Study

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7th Workshop on Three-Dimensional Modelling of Seismic Waves Generation, Propagation and their Inversion
Miramar, 2004

Parametric studies for the definition of the seismic input: a case study

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VAB Project (EC)

ADVANCED METHODS FOR ASSESSING
THE SEISMIC VULNERABILITY
OF EXISTING MOTORWAY BRIDGES

ARSENAL RESEARCH, Vienna, Austria; **ISMES S.P.A**,. Bergamo, Italy; **ICTP**, Trieste, Italy; **UPORTO**, Porto, Portugal; **CIMNE**, Barcelona, Spain; **SETRA**, Bagneaux, France; **JRC-ISPRA**, EU.

Effects on bridge seismic response of
asynchronous motion at the base of bridge piers

Source models

1) Database of focal mechanism

Longitude (°)	Latitude (°)	Focal Depth (km)	Strike (°)	Dip (°)	Rake (°)	Magnitude Ms (Mb)
16.200	48.030		180	20	90	
15.920	47.730	3	90	81	311	(4.7)
15.950	47.850	1	100	70	31	(5.4)
16.120	47.730	18	190	70	324	5.5 (4.9)
16.020	47.730	19	127	80	190	4.4

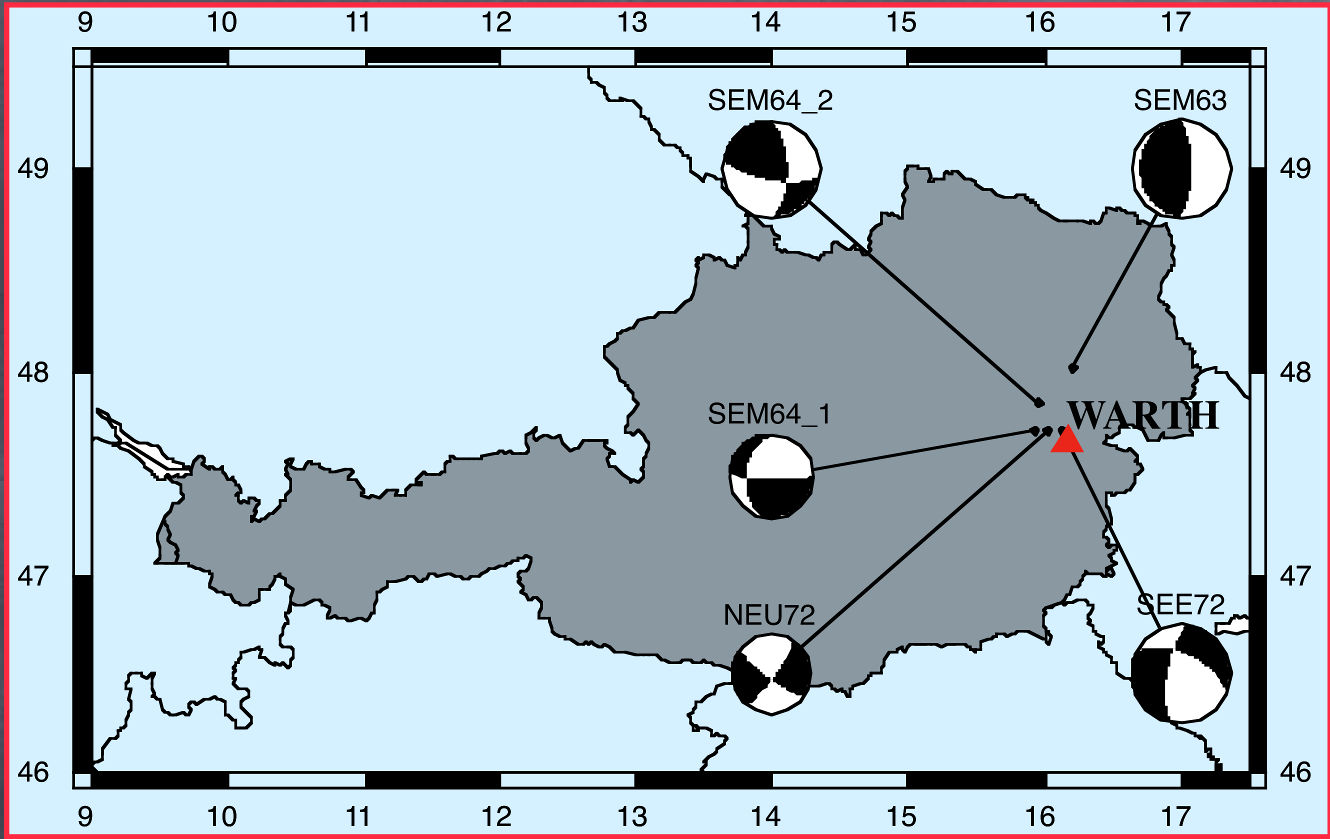
Maximum Historical Earthquake

2) Parametric study on focal mechanism:

strike
dip
rake
depth

Maximum Credible Earthquake

Maximum Design Earthquake



S1
Seebenstein 1972

Strike = 190°
Dip = 70°
Rake = 324°
Depth = 5 km
Mw = 5.5
Distance = 8.7 km

Definition of sources

Structural models

STRUCTURAL MODELS

Bedrock model

1) EUR-I Data set

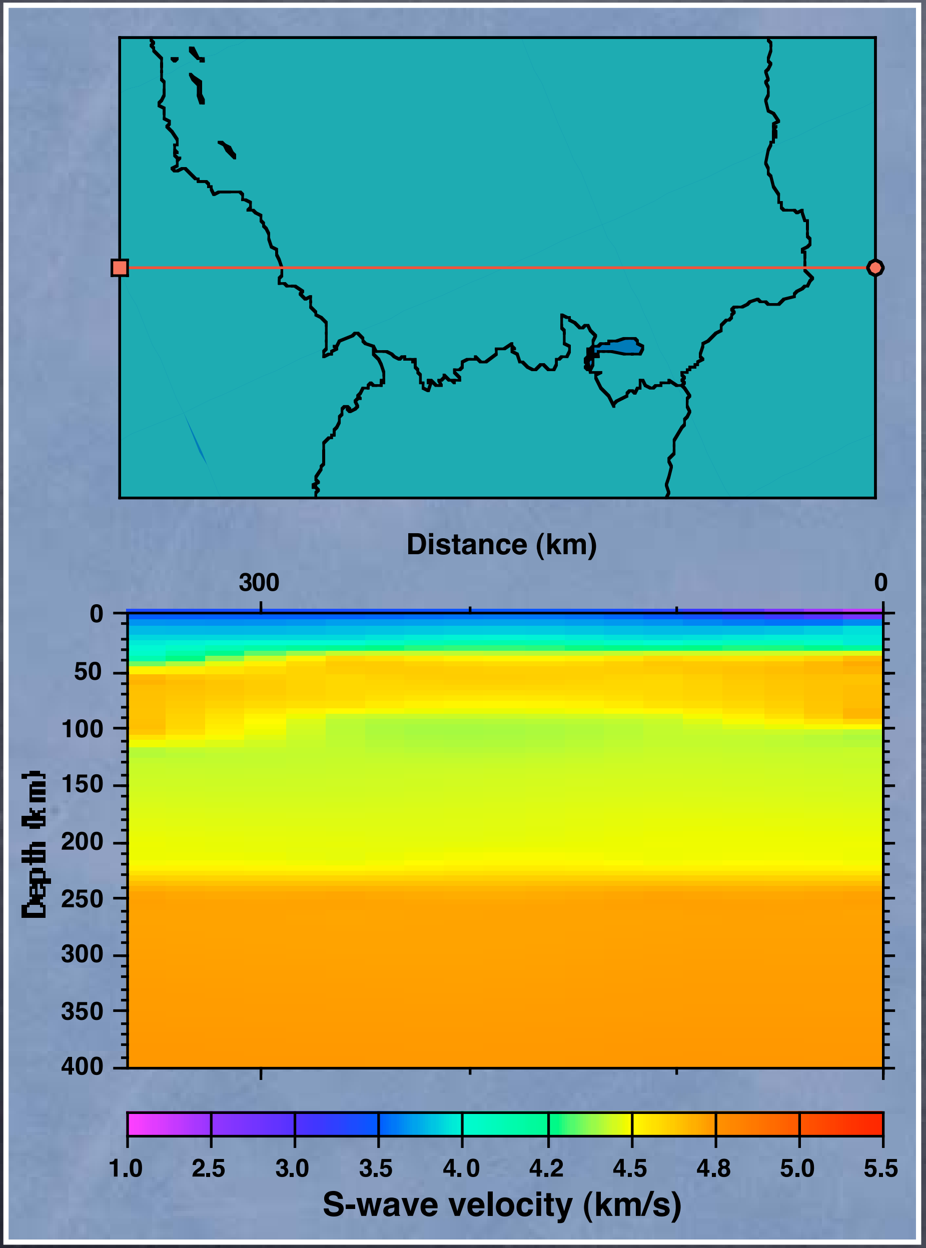
2) updated on the basis of the geological informations collected by CIMG

Local LHET model

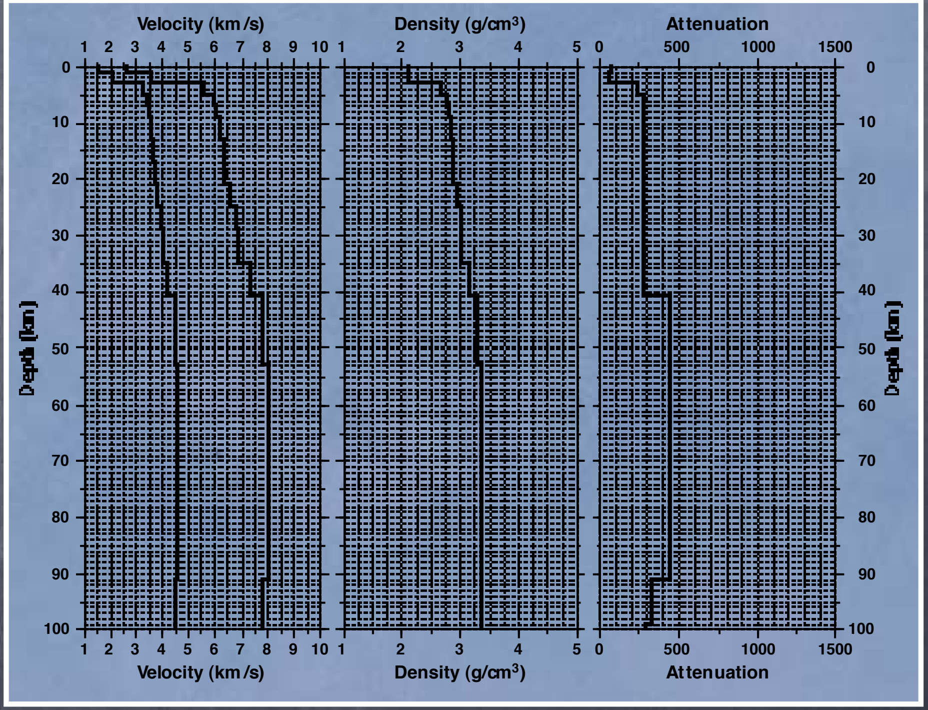
1) available Warth bridge section plan

2) updated on the basis of the refraction surveys by CIMG

Initial regional model

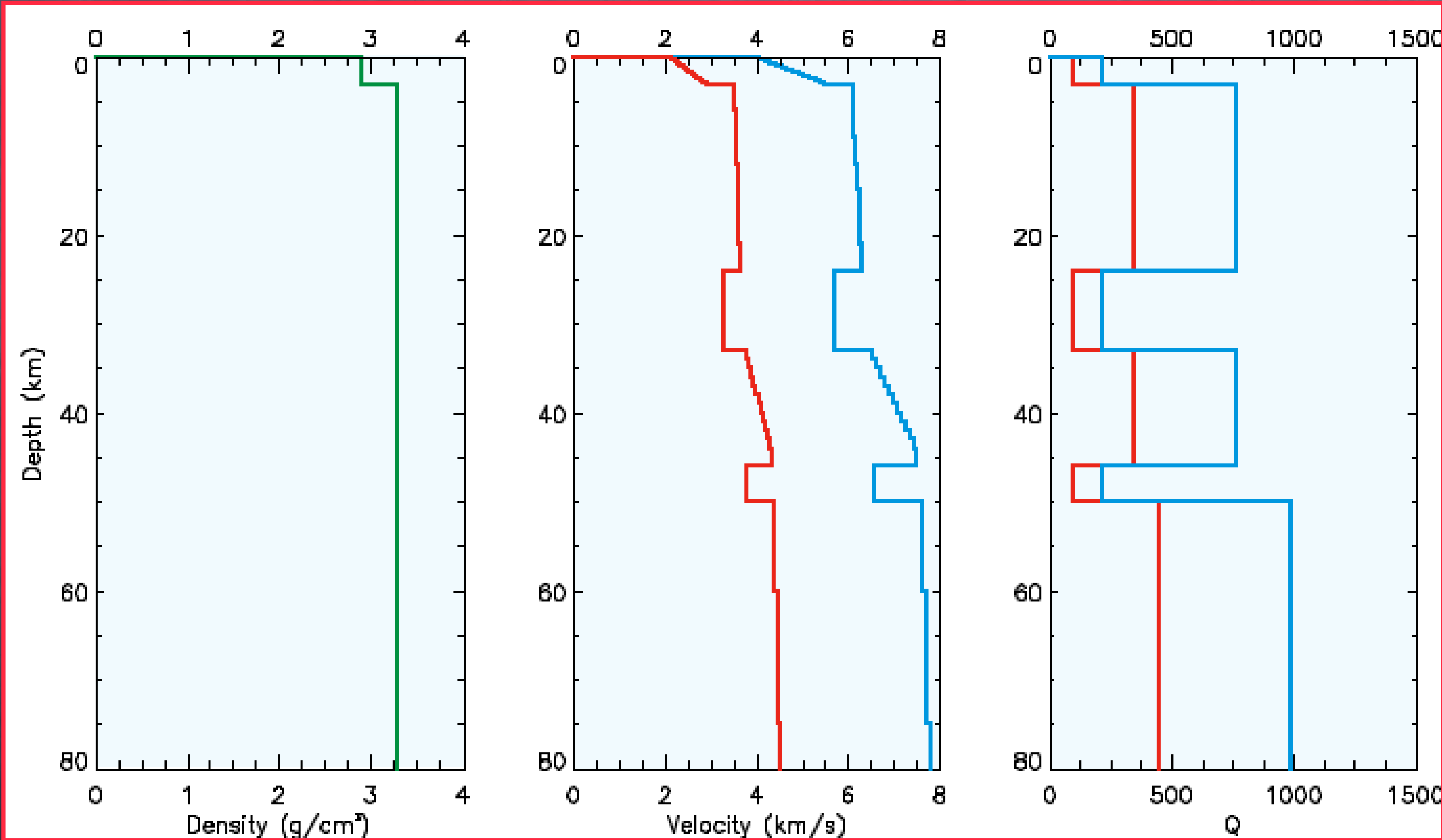


EUR I data set



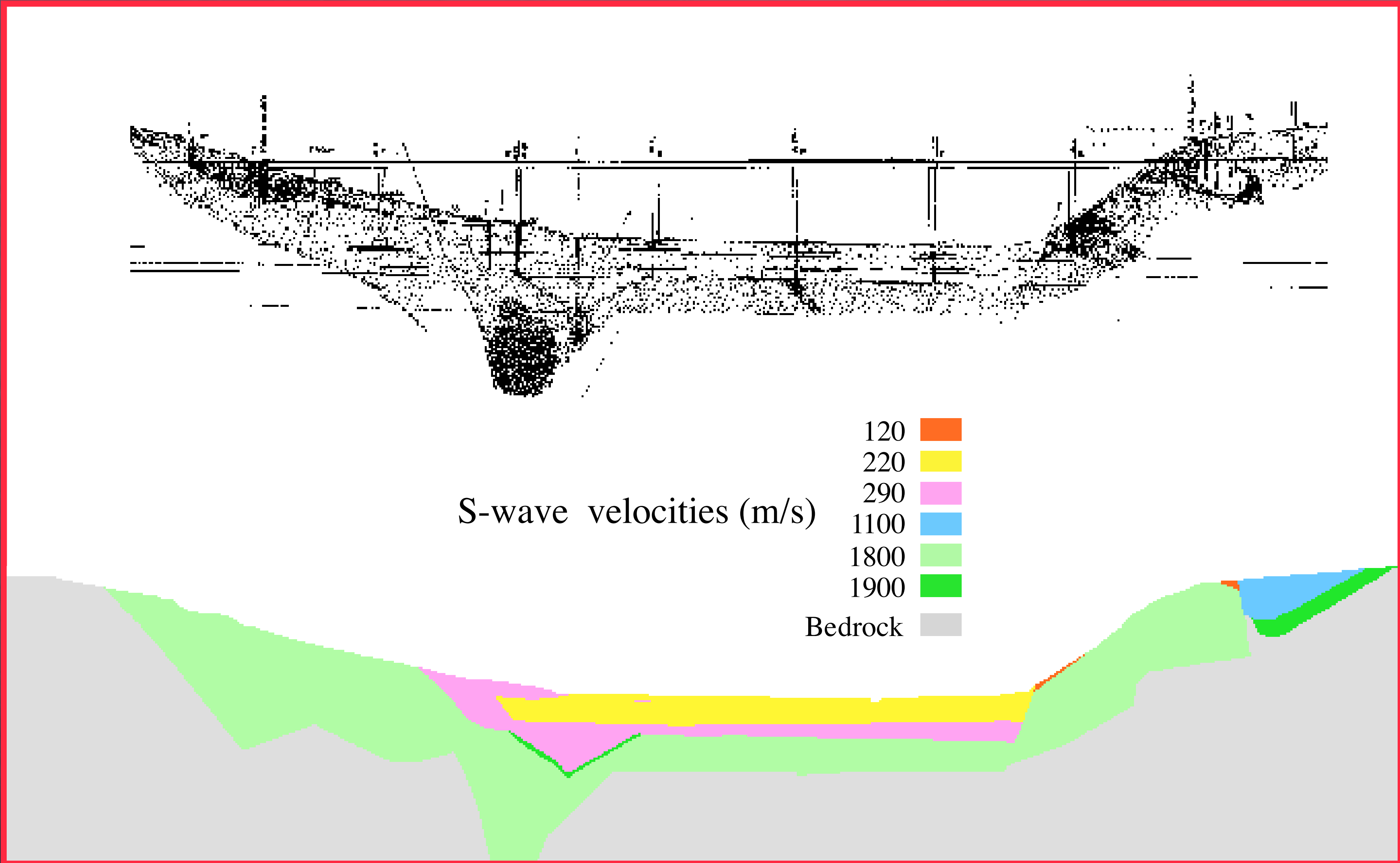
Definition of str. models

Final bedrock model



Definition of str. models

Initial LHM - Warth bridge - model



COMPUTATION OF SEISMIC INPUT

PRELIMINARY COMPUTATION

INITIAL source and structural models
3 components of motion
Displacement, velocity, acceleration

FINAL COMPUTATION

FINAL source and structural models
3 components of motion
Displacement, velocity, acceleration

SEISMIC INPUT

1) 1D 10 Hz Parametric study
2) 2D 8Hz

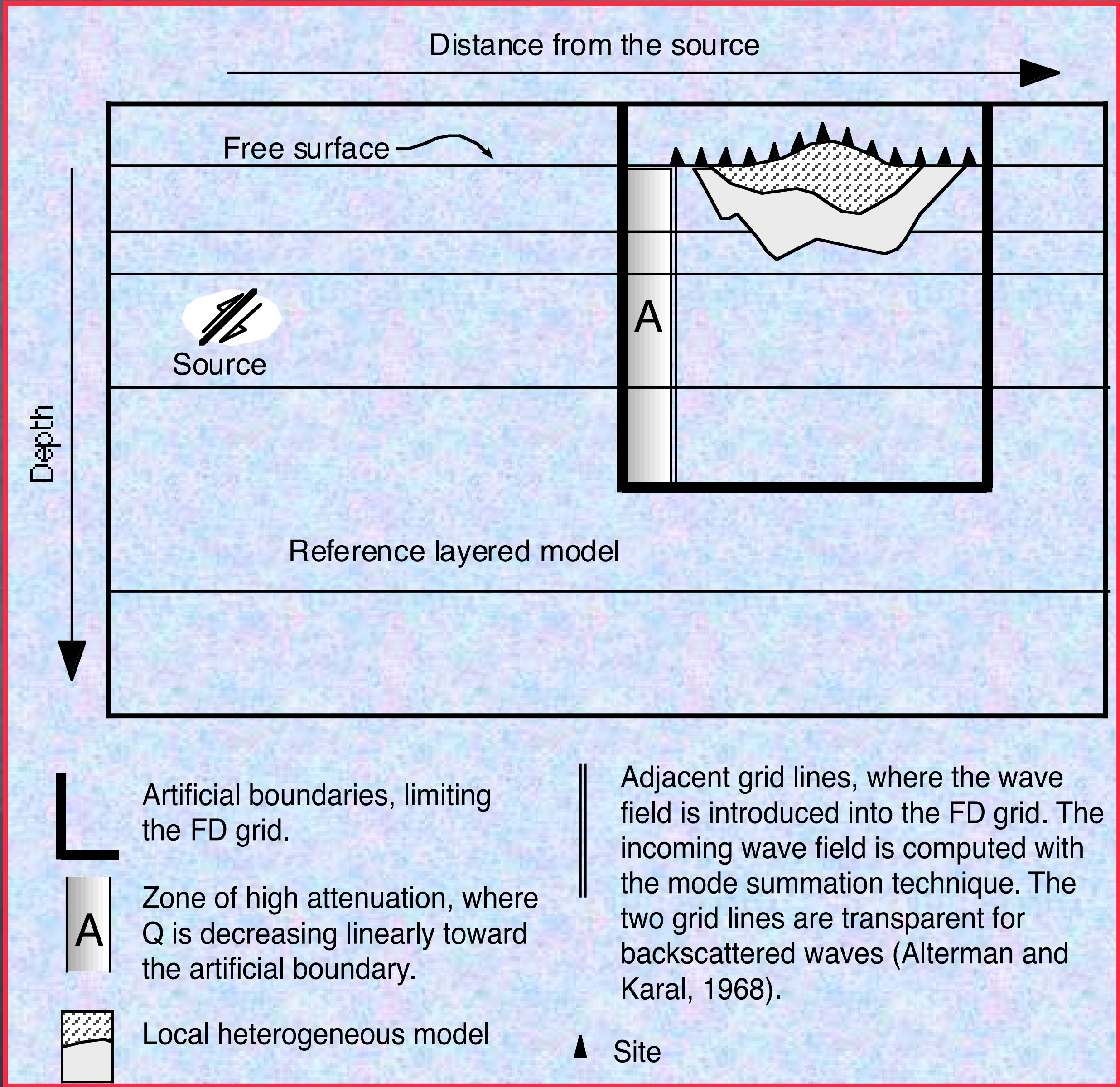
DIFFERENTIAL MOTION

1) time domain
2) spectral domain

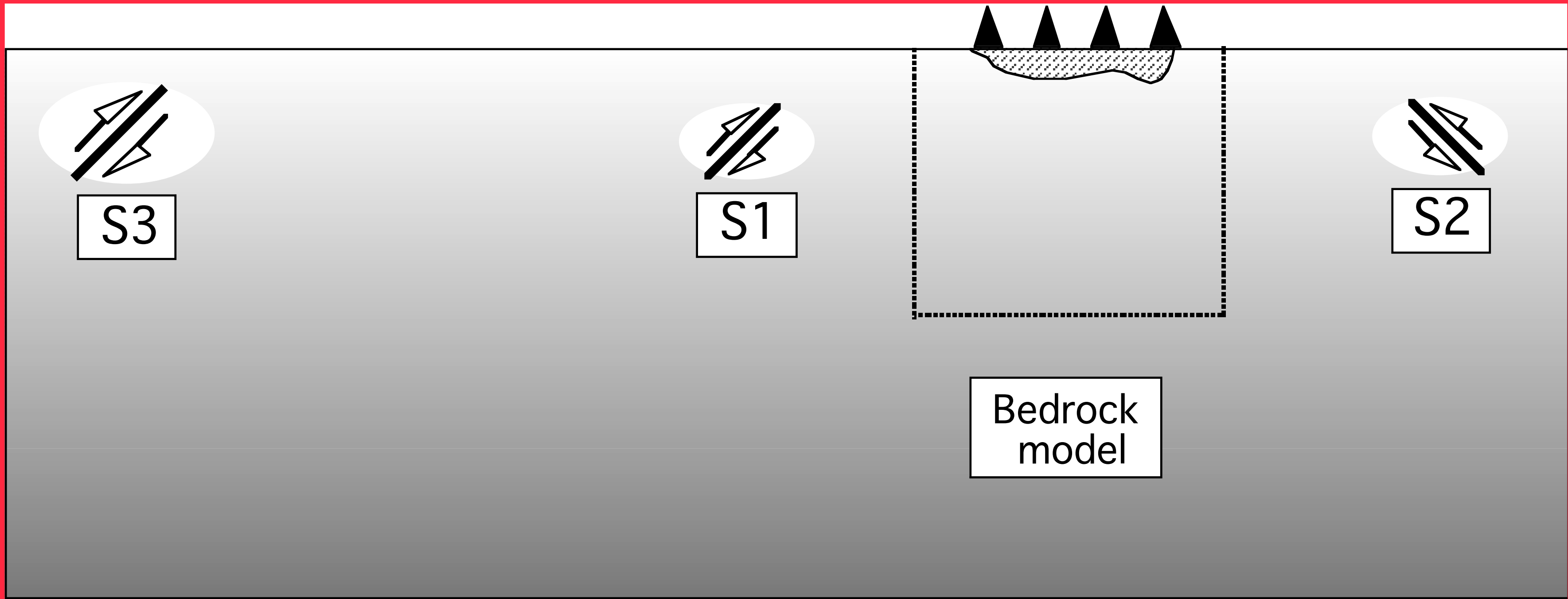
SITE RESPONSE

1) Fourier spectral ratios
2) Response spectral ratios

Hybrid method: MS-FD



Different source-section configurations

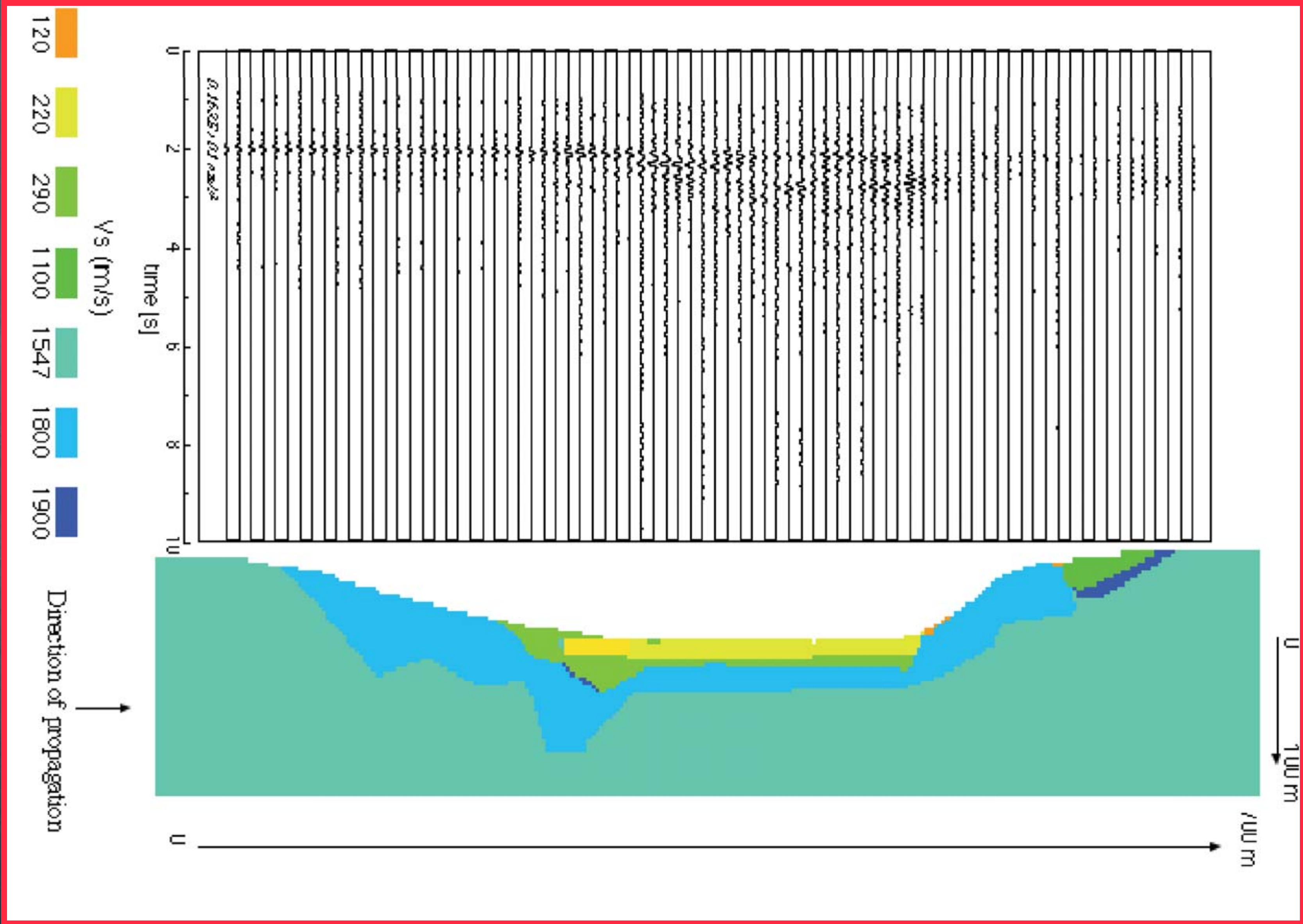


S3
Mw = 6.0
Distance = 50 km

S1
Strike = 190°
Dip = 70°
Rake = 324°
Depth = 5 km
Mw = 5.5
Distance = 8.7 km

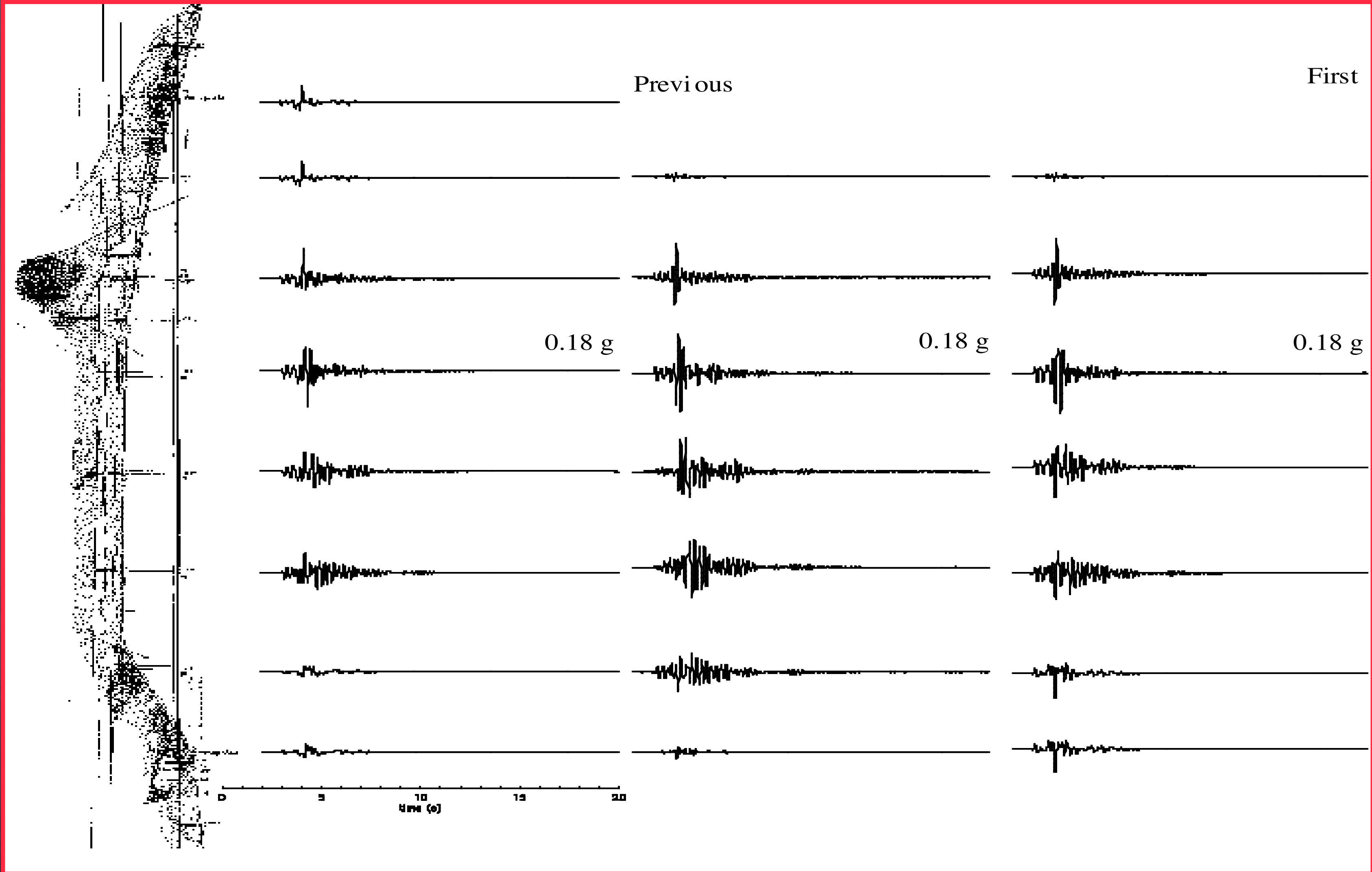
S2
Mw = 5.5
Distance = reverse

Initial synthesis - radial



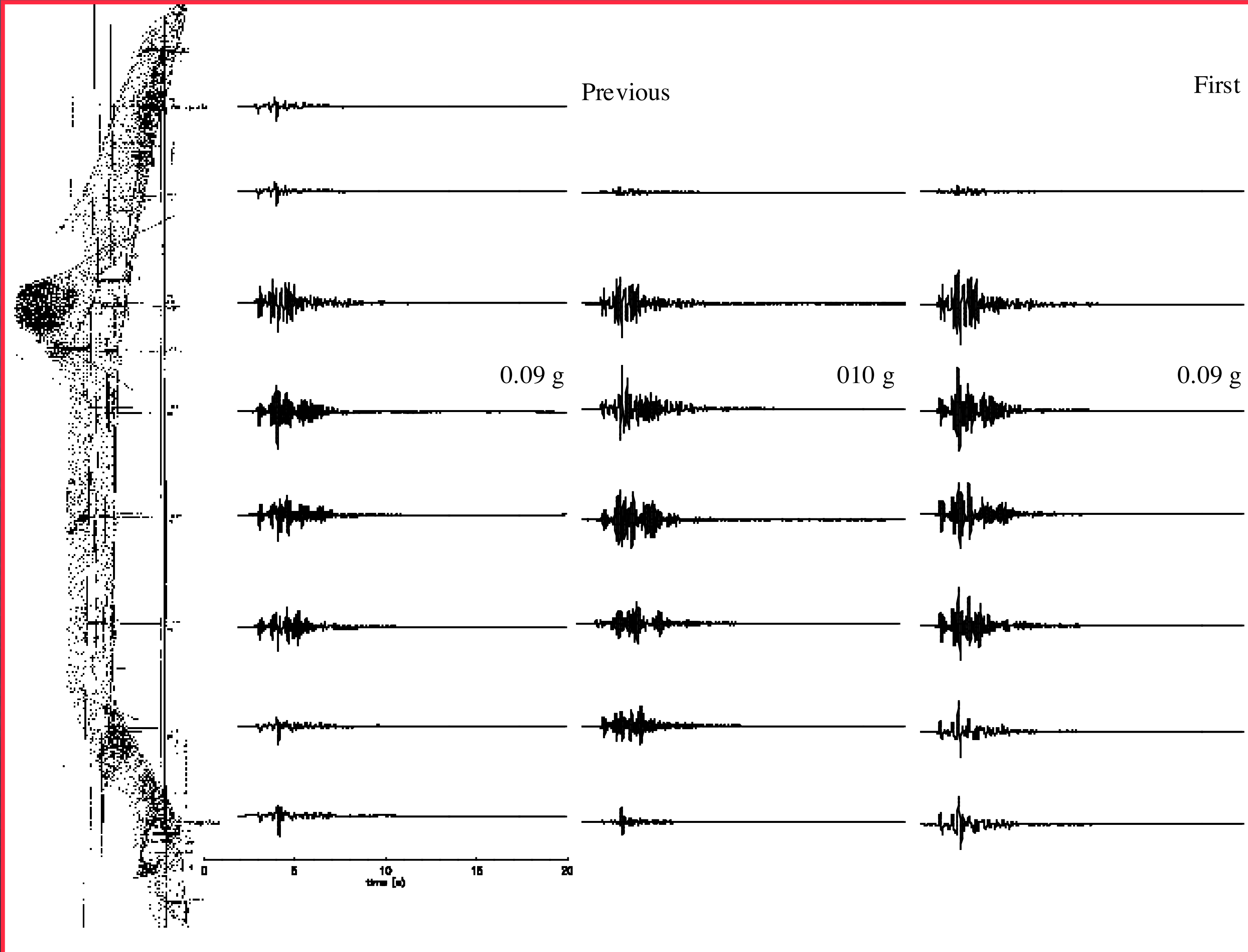
Definition of seismic input

Synthetic accelerations and diffograms



radial

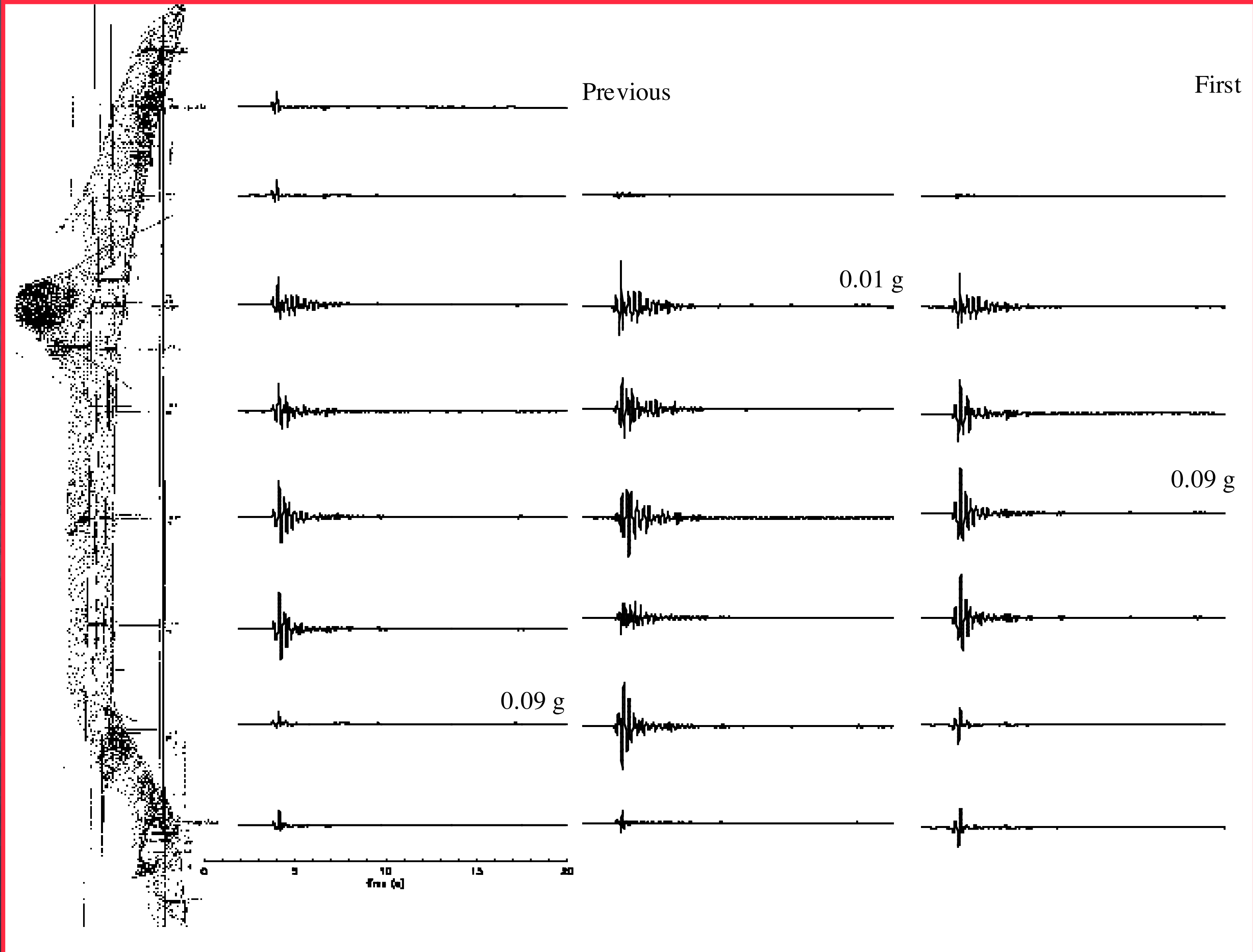
Synthetic accelerations and diffograms



vertical

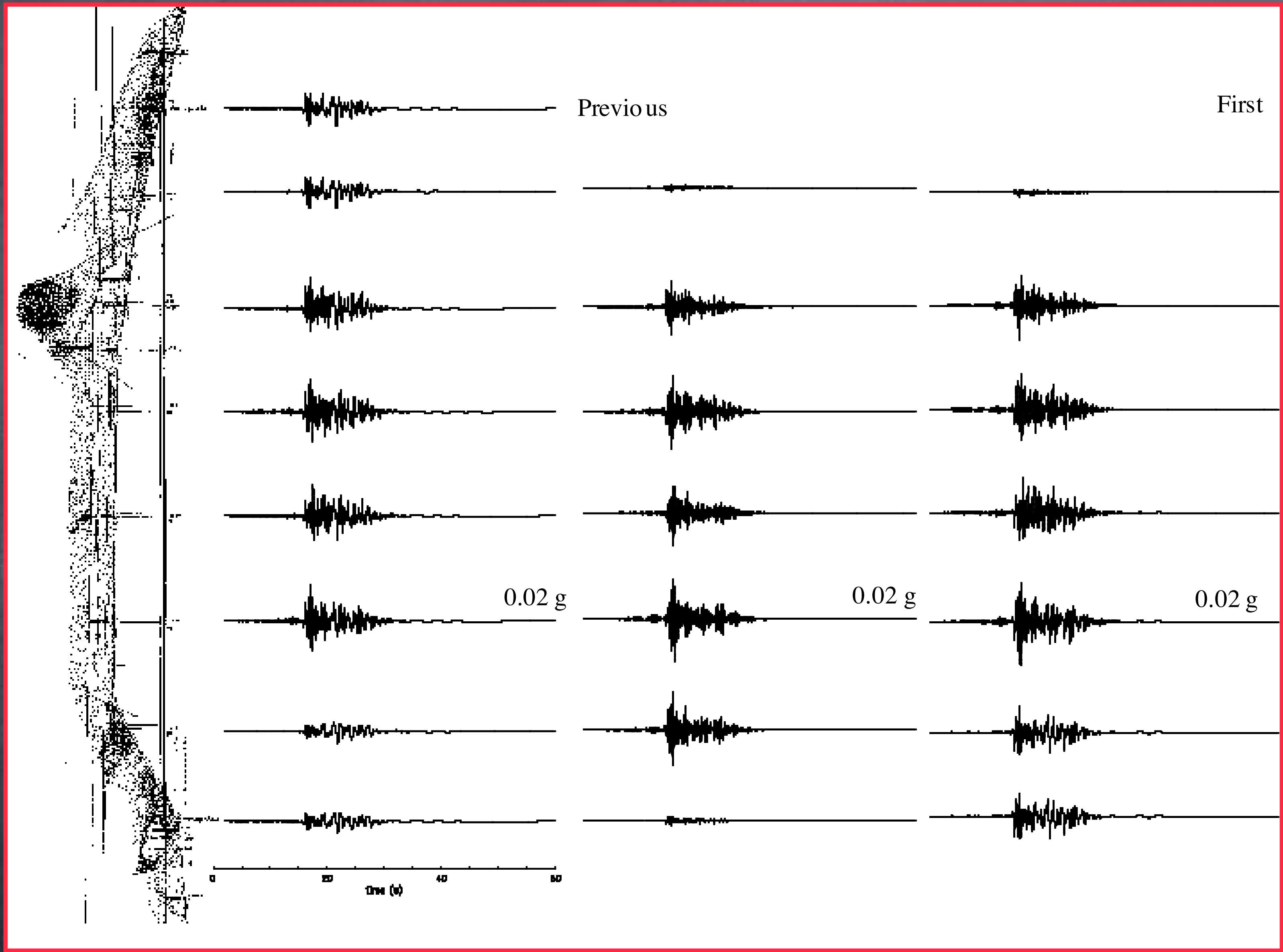
Definition of seismic input

Synthetic accelerations and diffograms



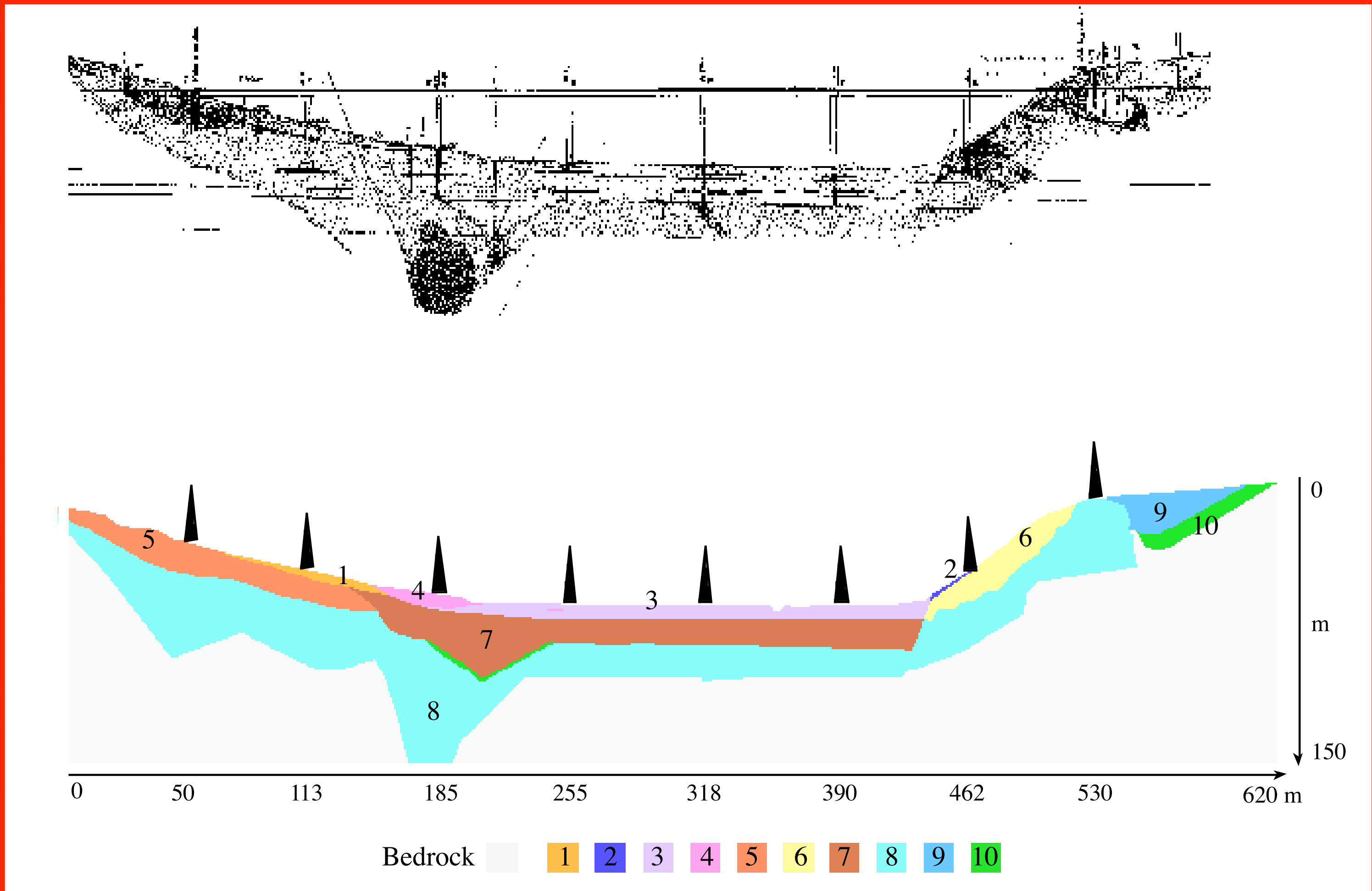
transverse

Synthetic accelerations and diffograms



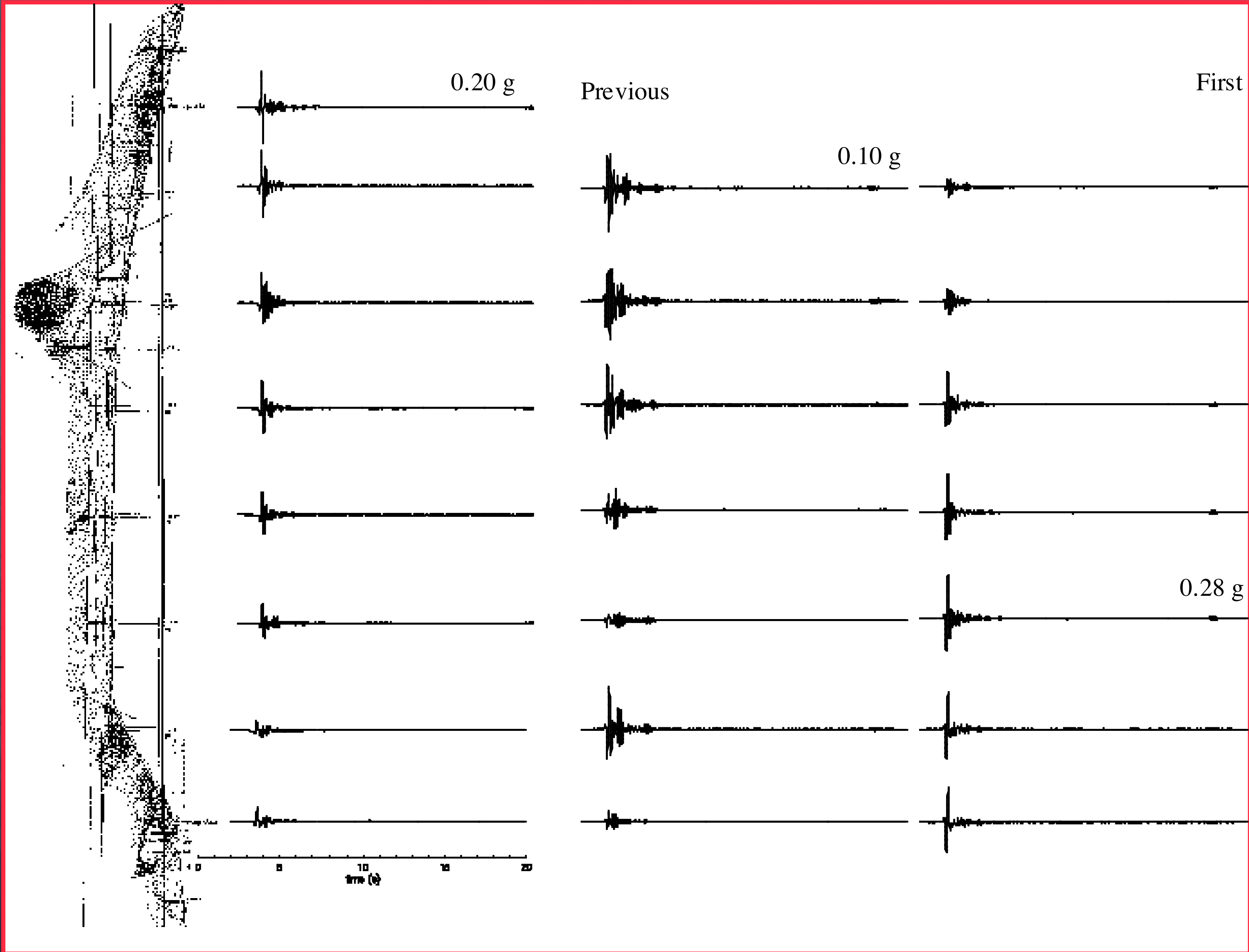
S3 - radial

LHM - Warth bridge - model



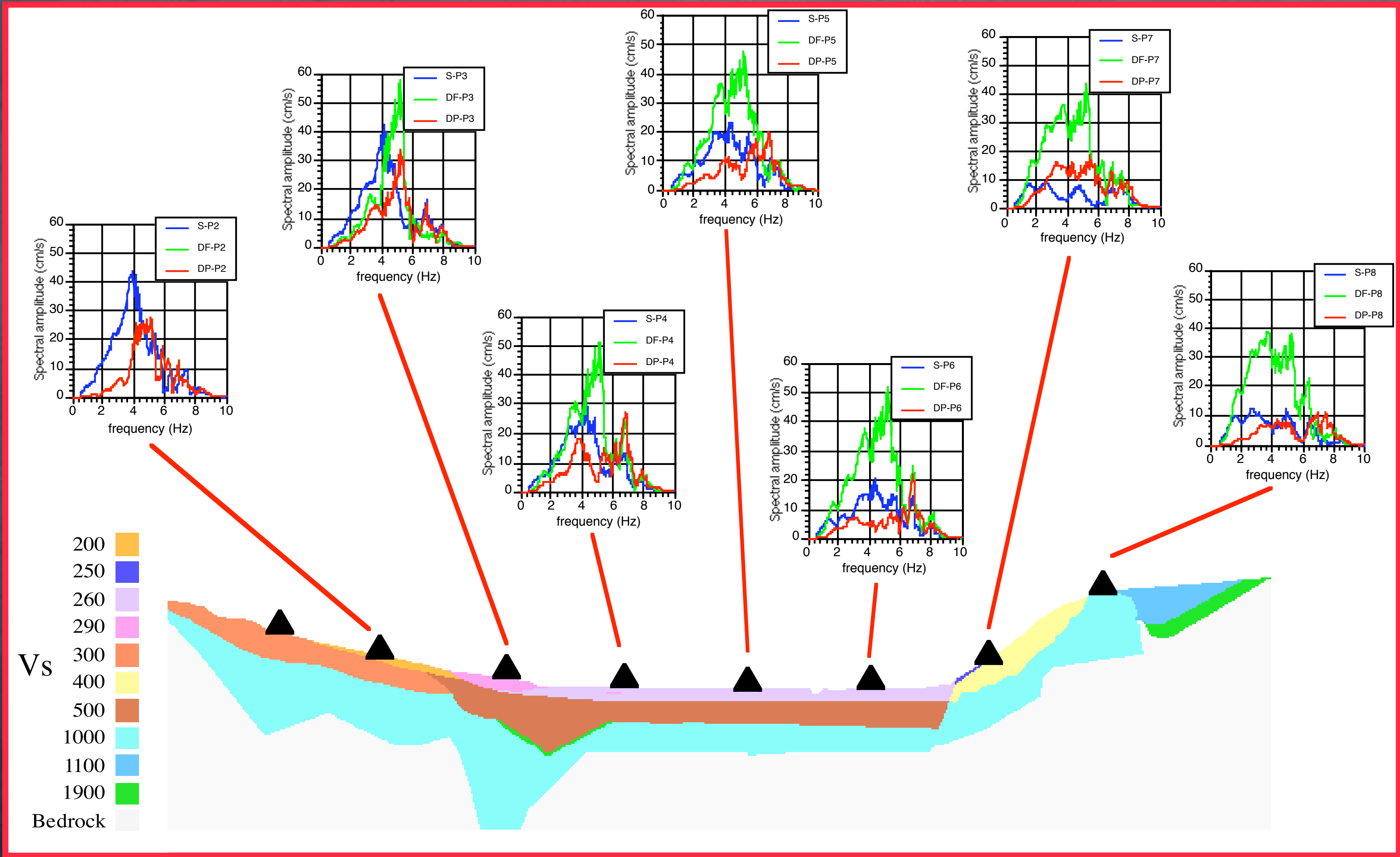
Unit	Density g/cm^3	P-wave velocity km/s	Q_P	S-wave velocity km/s	Q_S
1	1.5	0.30	40.0	0.20	15.0
2	1.7	0.49	40.0	0.25	15.0
3	2.0	0.70	50.0	0.26	20.0
4	1.8	0.70	50.0	0.29	20.0
5	2.3	0.80	50.0	0.30	20.0
6	2.3	0.80	50.0	0.40	20.0
7	1.8	1.70	50.0	0.50	20.0
8	2.3	2.10	150.0	1.00	60.0
9	2.3	3.00	150.0	1.90	60.0
10	2.2	1.80	100.0	1.10	40.0

Synthetic accelerations and diffograms



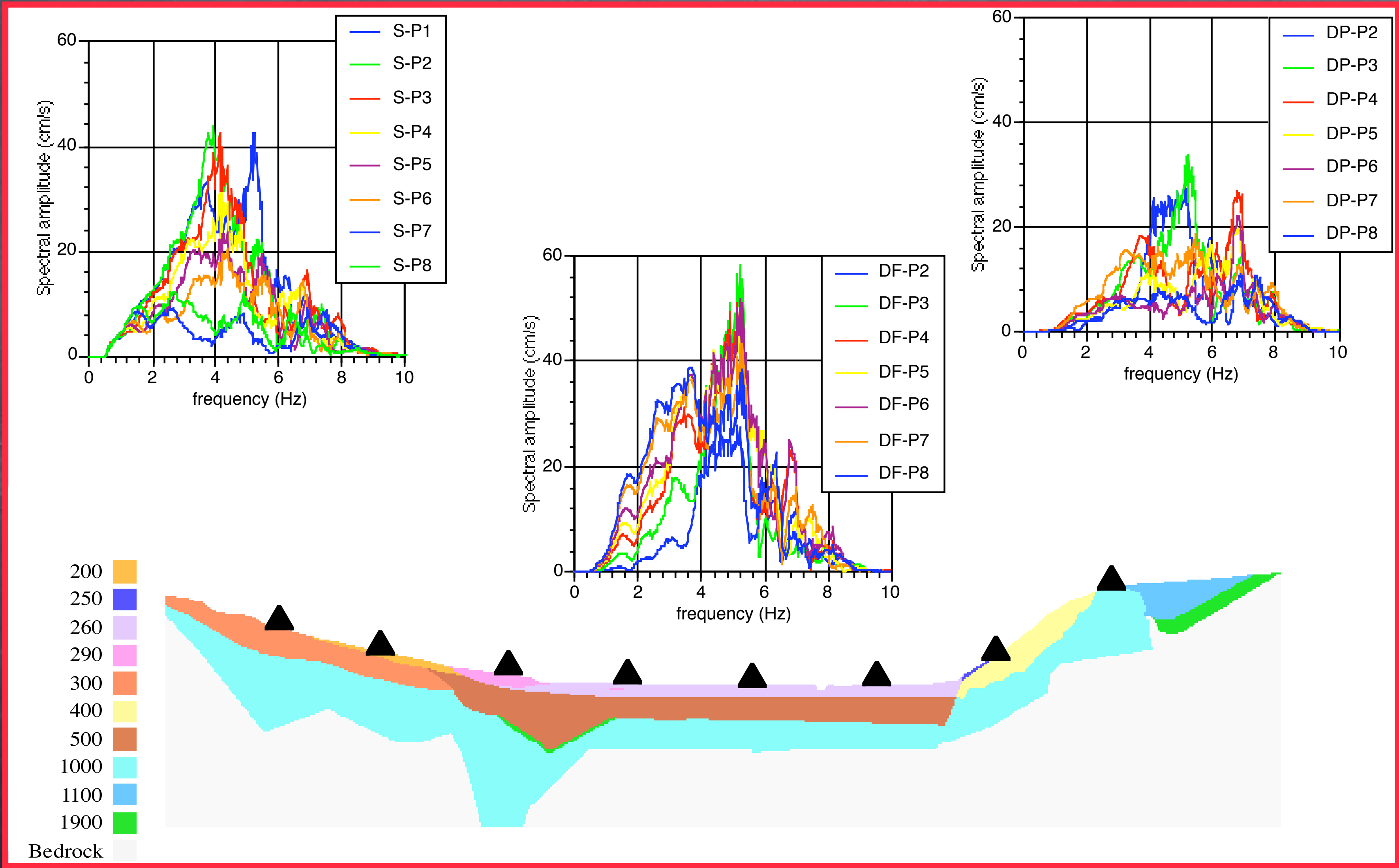
new - radial

Synthetic accelerations and diffograms
Frequency domain - Amplitude spectra



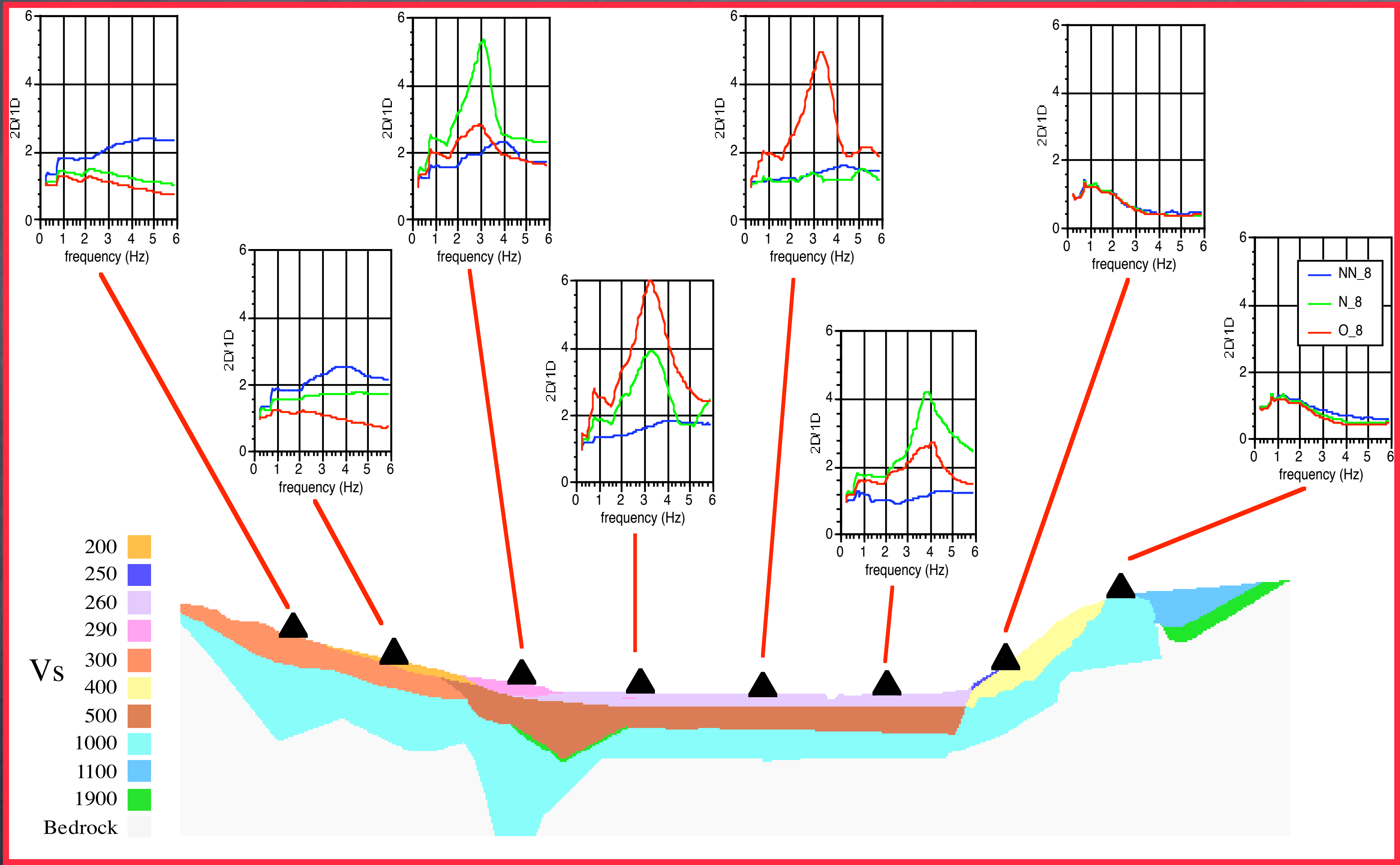
Seismic input-Fourier

Synthetic accelerations and diffograms
Frequency domain - Amplitude spectra



Seismic input-Fourier

Synthetic accelerations
RS domain - Amplification



Seismic input-RSR

PARAMETRIC STUDY - Fp towards MCE

All the focal mechanism parameters of the original source model have been varied in order to find the combination producing the maximum amplitude of the various ground motion components.

Longitude (°)	Latitude (°)	Focal Depth (km)	Strike (°)	Dip (°)	Rake (°)	Magnitude Ms (Mb)
16.120	**47.730**	**18**	**190**	**70**	**324**	**5.5 (4.9)**

1) Strike angle (Depth=5km)

2) Rake angle

3) Strike-Rake angles variation (Dip=45°)

4) Strike-Rake angles variation (Dip=70°)

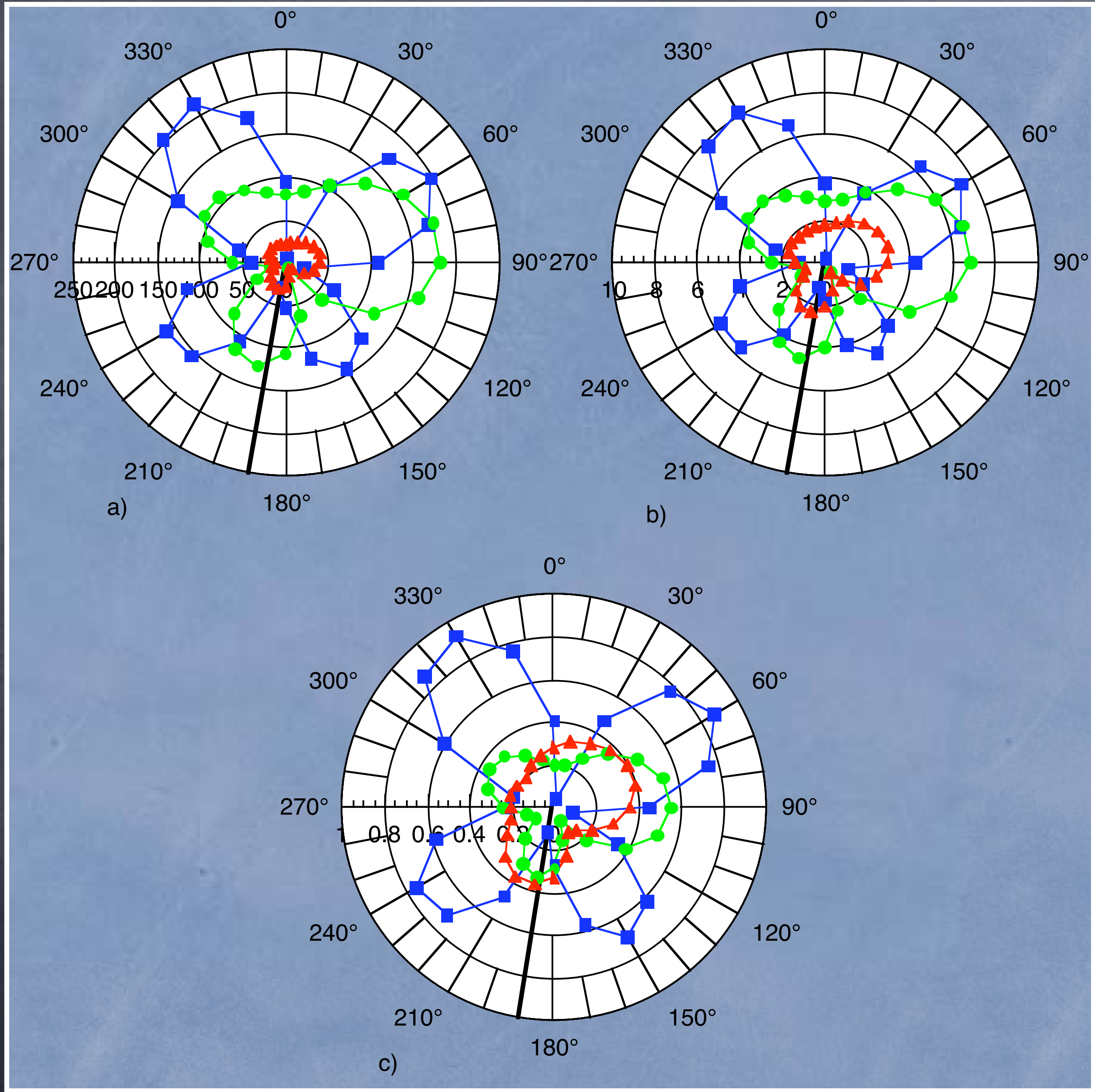
5) Strike-Rake angles variation (Dip=90°)

6) Depth-Distance variation

(Strike=60°, Dip=70°,Rake=0, 90°)

The computations of synthetic seismograms (displacements, velocities and accelerations for the radial, transverse and vertical components) have been carried out with cut-off frequency 10 Hz.

Parametric study 1: strike

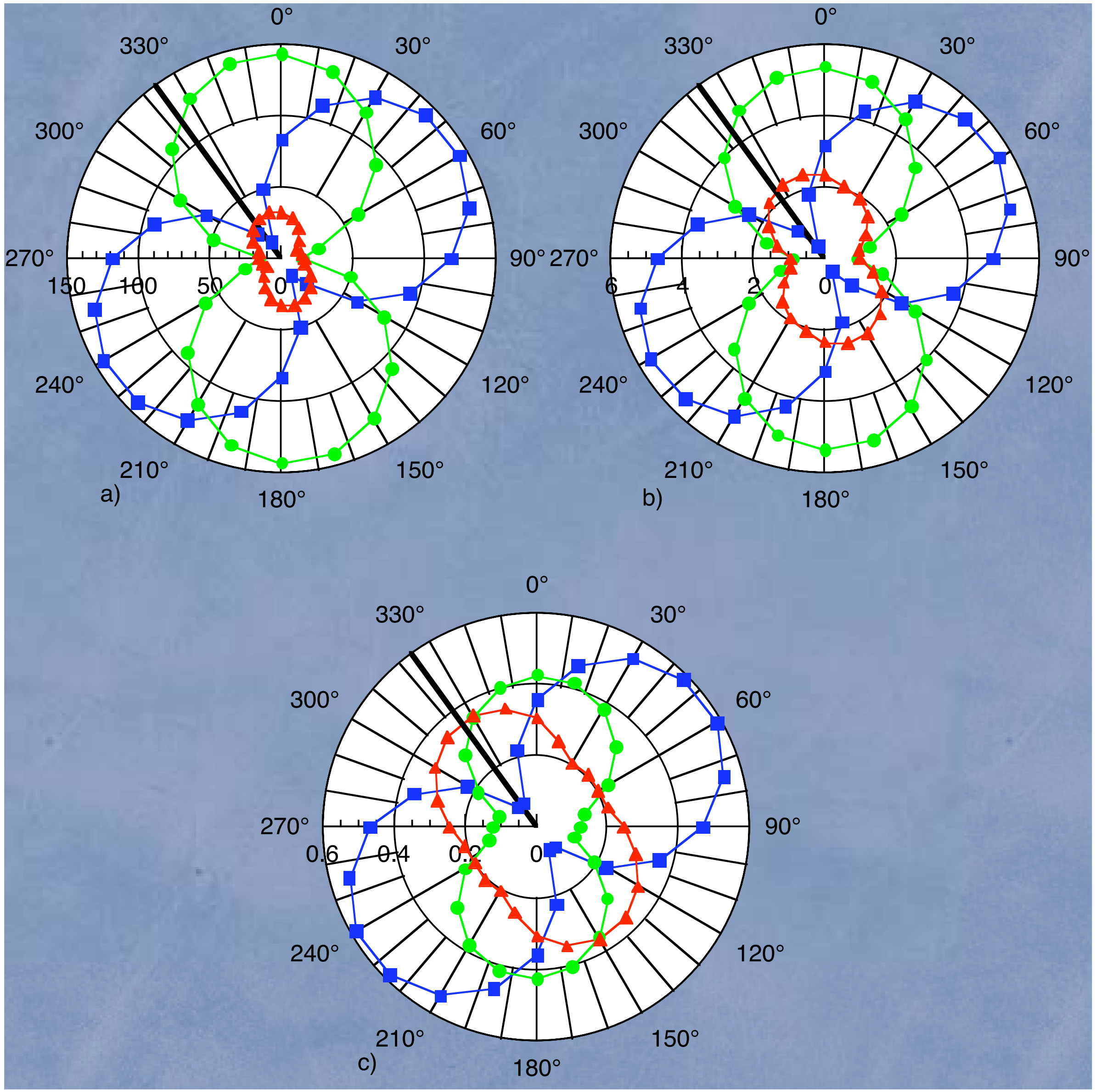


Polar plot of the maximum amplitude of the ground motion:
a) acceleration (cm/s^2)
b) velocity (cm/s)
c) displacement (cm)

versus the strike angle

for the three components:
transverse (squares);
radial (circles);
vertical (triangles)

Parametric study 1: rake

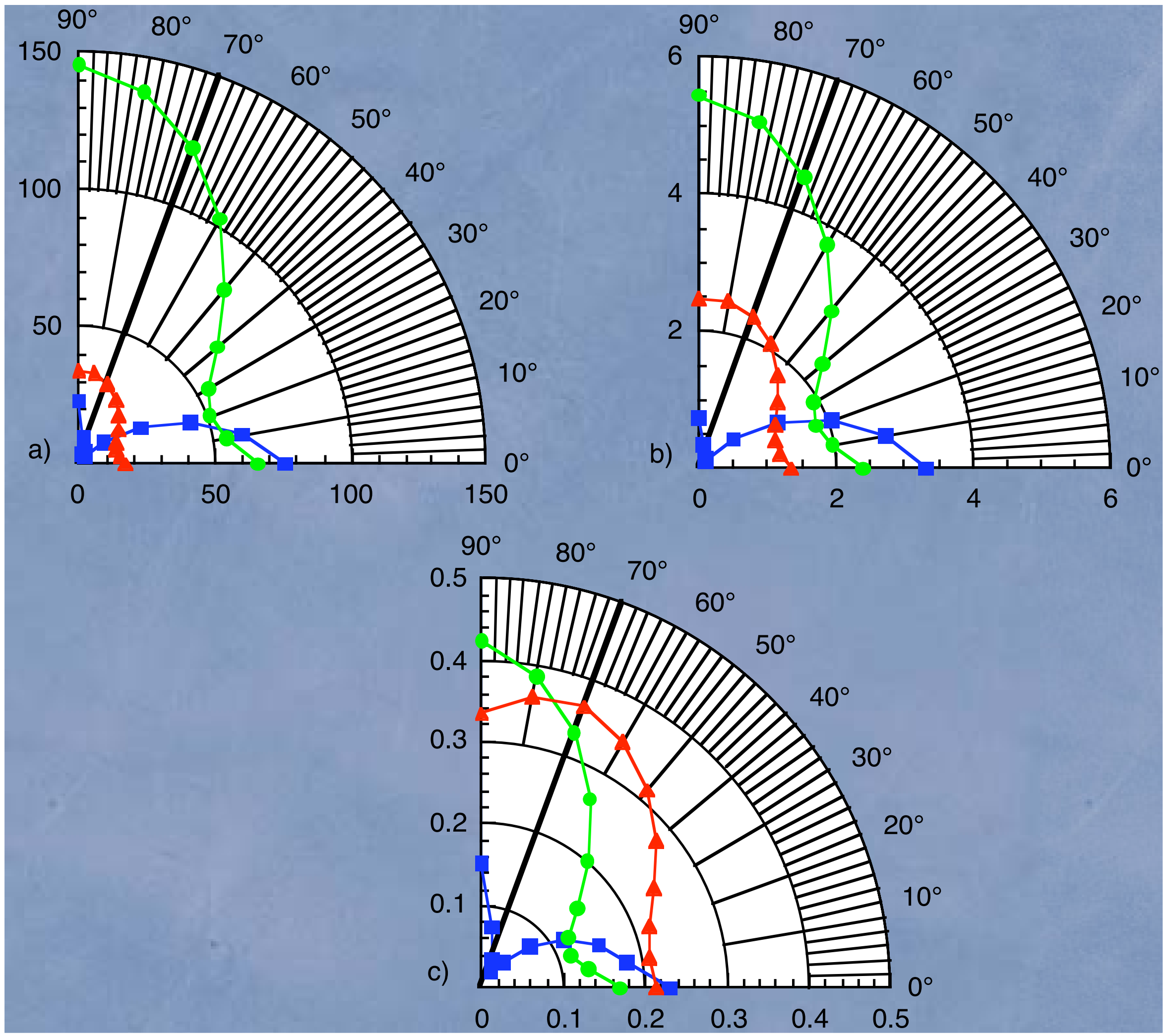


Polar plot of the maximum amplitude of the ground motion:
a) acceleration (cm/s^2)
b) velocity (cm/s)
c) displacement (cm)

versus the rake angle

for the three components:
transverse (squares);
radial (circles);
vertical (triangles)

Parametric study 1: dip



Polar plot of the maximum amplitude of the ground motion:

a) acceleration (cm/s^2)

b) velocity (cm/s);

c) displacement (cm)

versus the dip angle

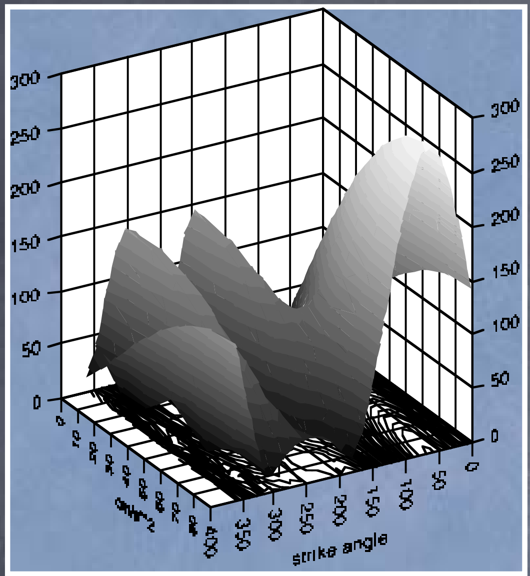
for the three components:

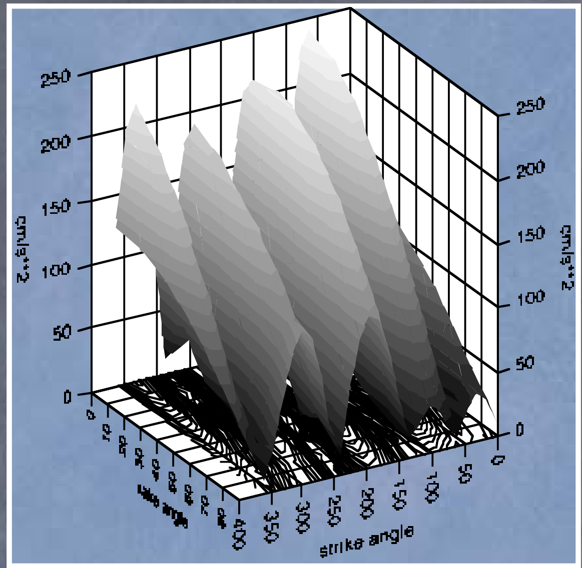
transverse (squares);

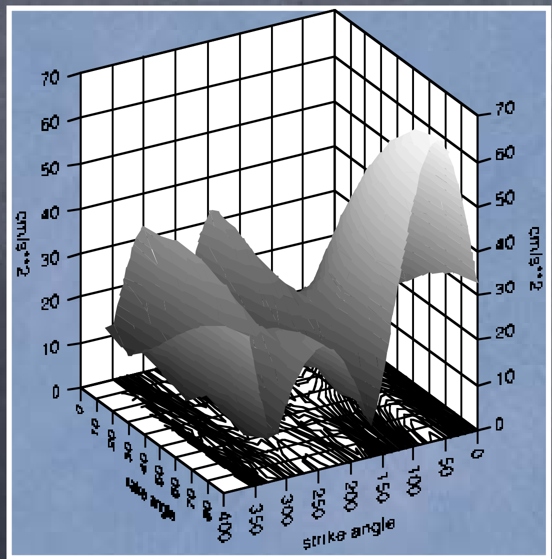
radial (circles);

vertical (triangles)

Parametric study 1: s&r





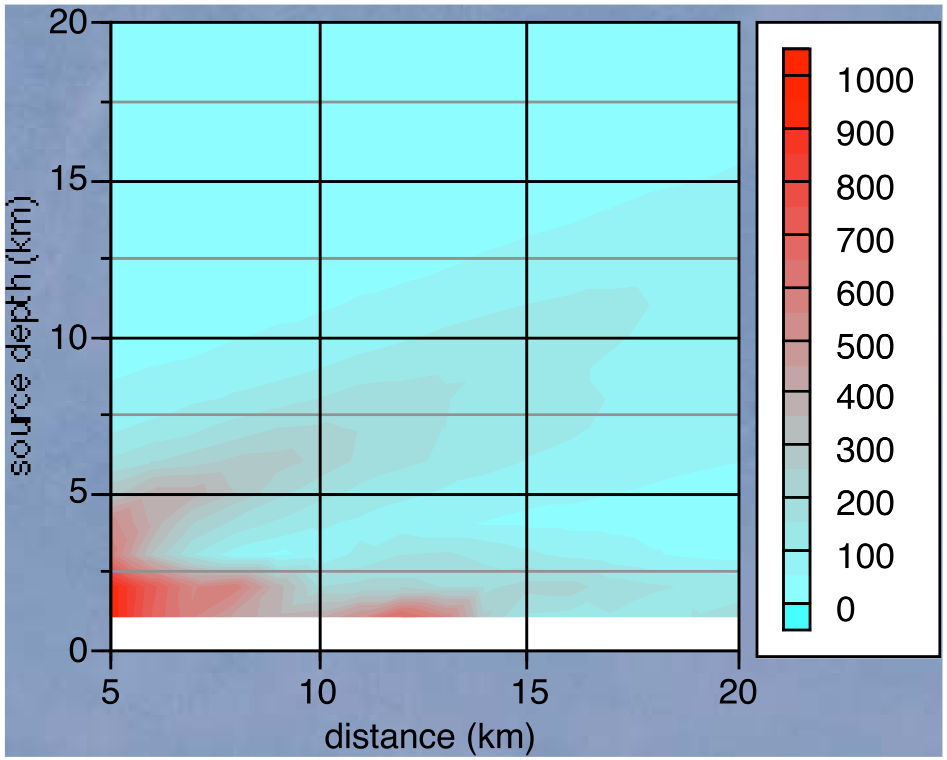


Polar plot of the maximum amplitude of the acceleration ground motion - dip angle is 70°

versus the strike and rake angle

for the three components of motion

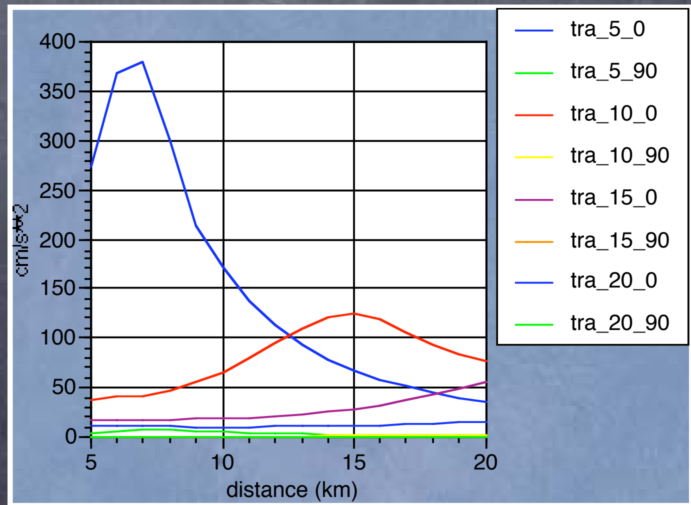
Parametric study 1: h&d



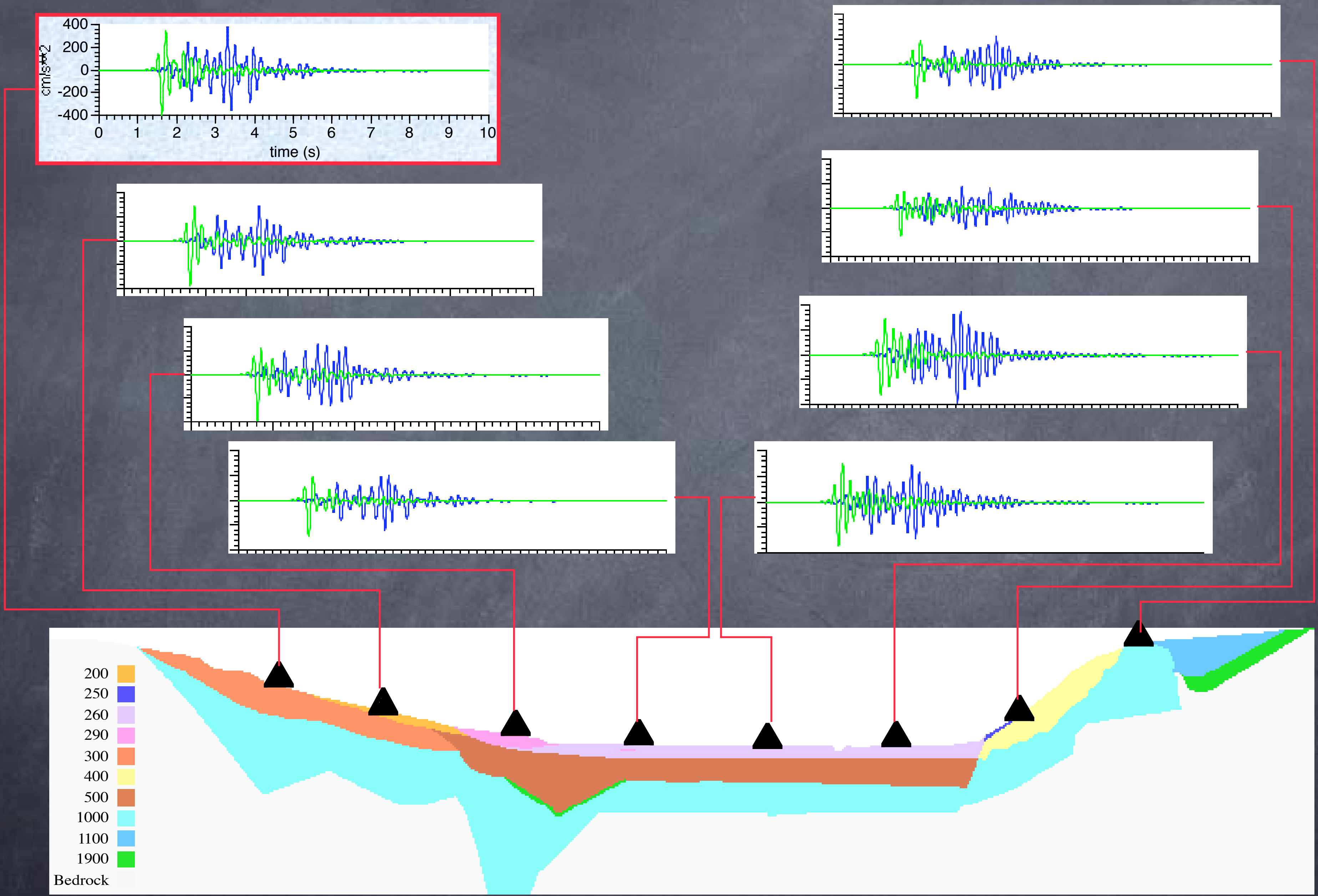
Plot of the maximum amplitude of the acceleration ground motion - cm/s^2 - versus the

epicentral distance
and
source depth

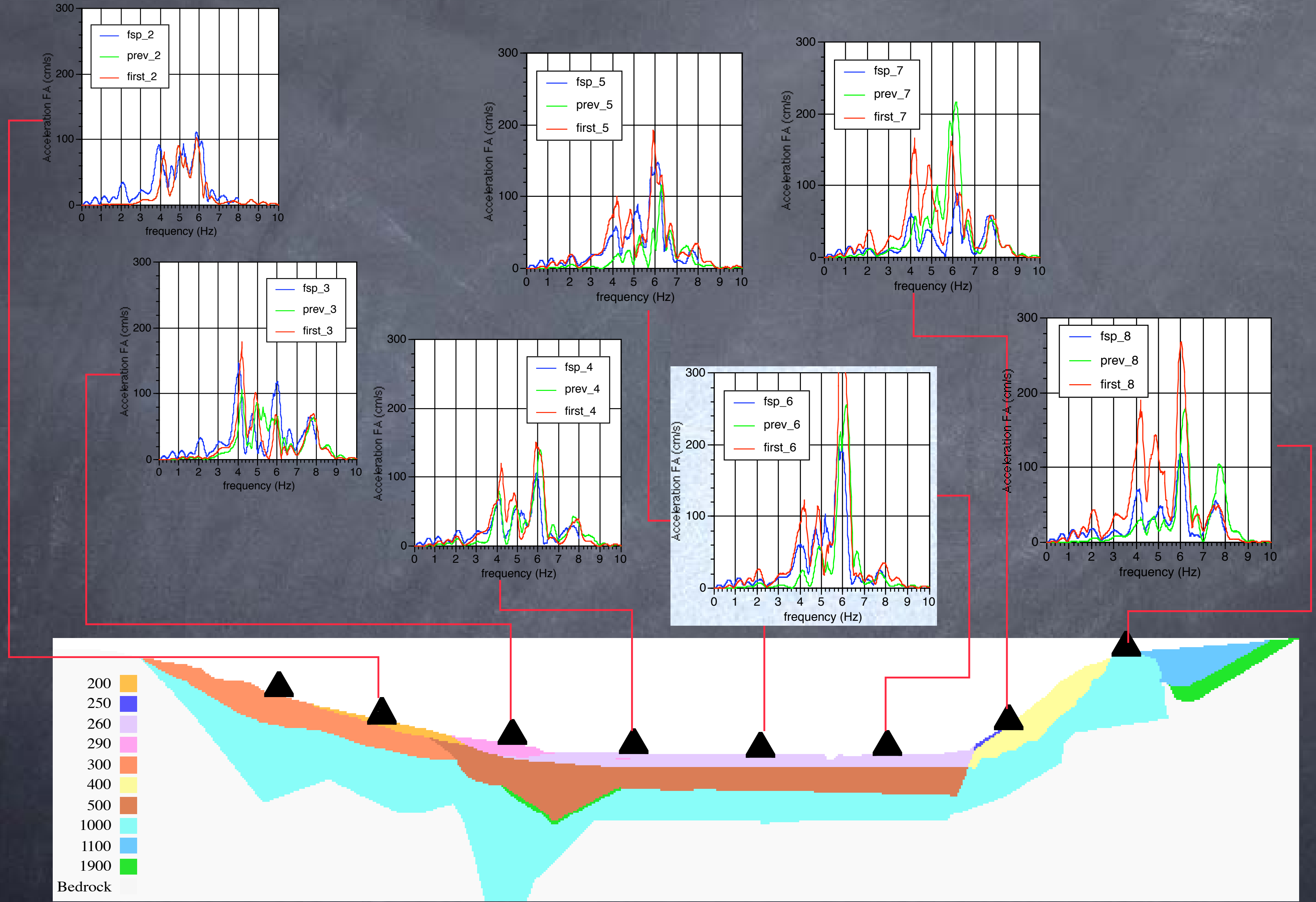
transverse component
dip angle=70°



Tranverse accelerograms M=5.5

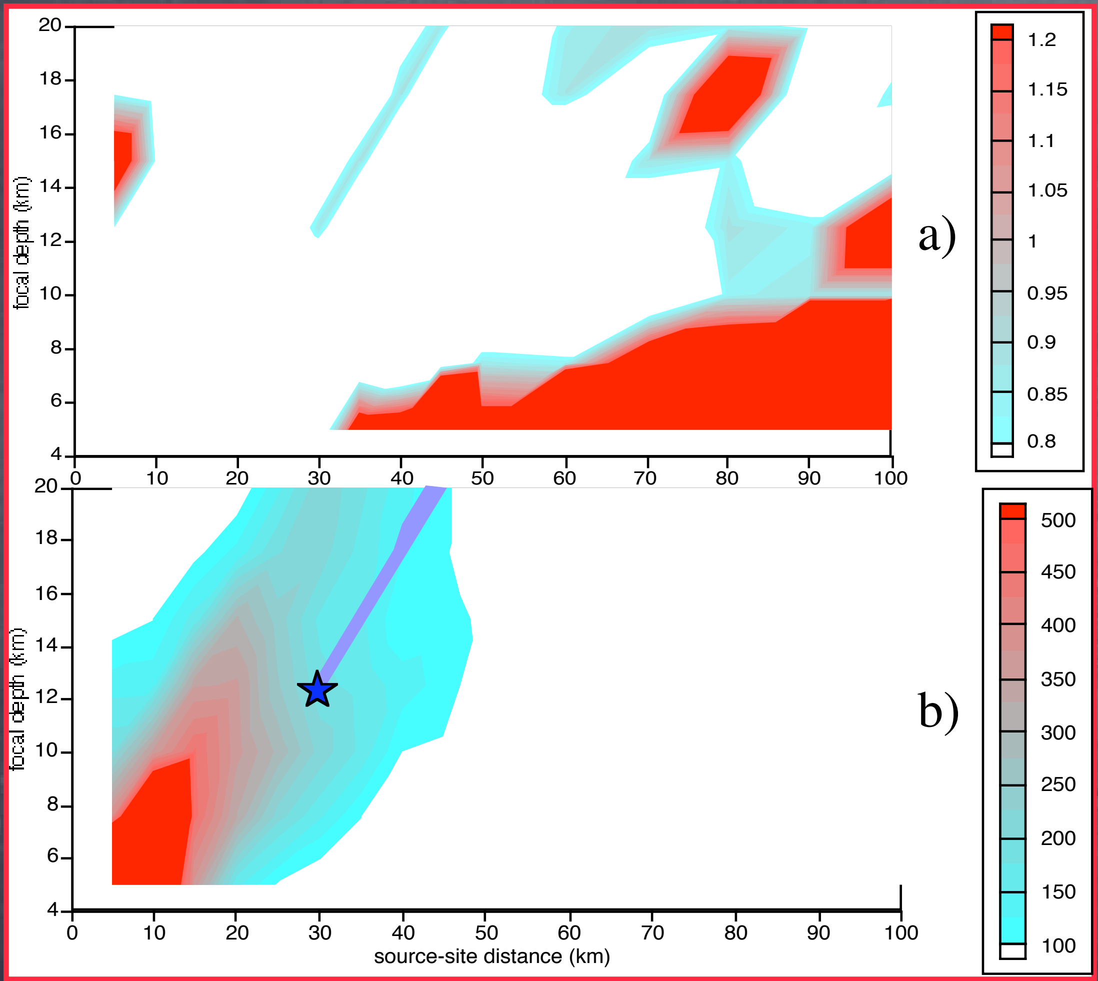


Tranverse acceleration spectra



Parametric study 1 - SI

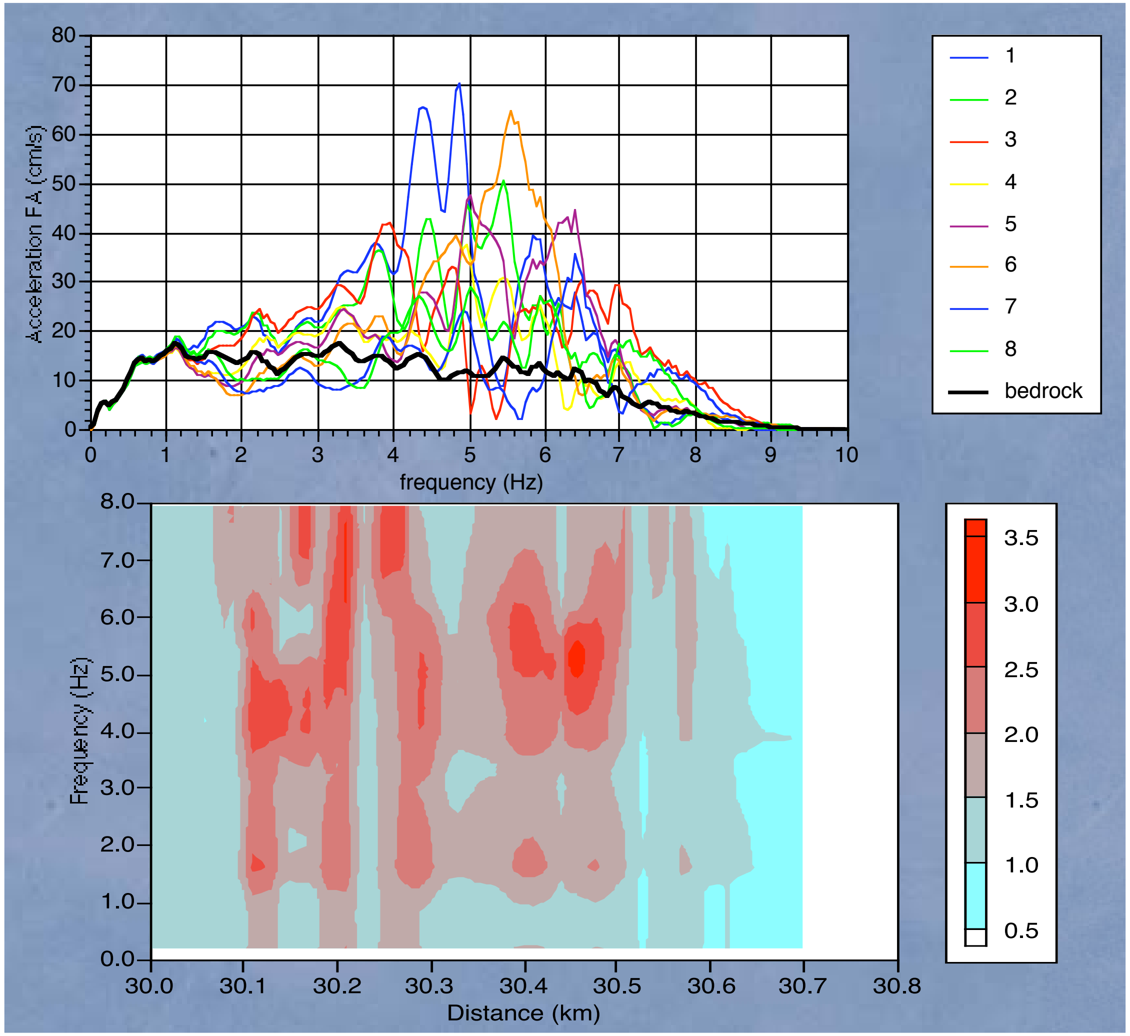
PARAMETRIC STUDY 2 - Fp towards 1Hz



Another parametric study has been performed in order to find a seismic source-Warth site configuration providing a set of signals whose seismic energy is concentrated around 1 Hz, frequency that corresponds approximately to that of the fundamental transverse mode of oscillation of the bridge.

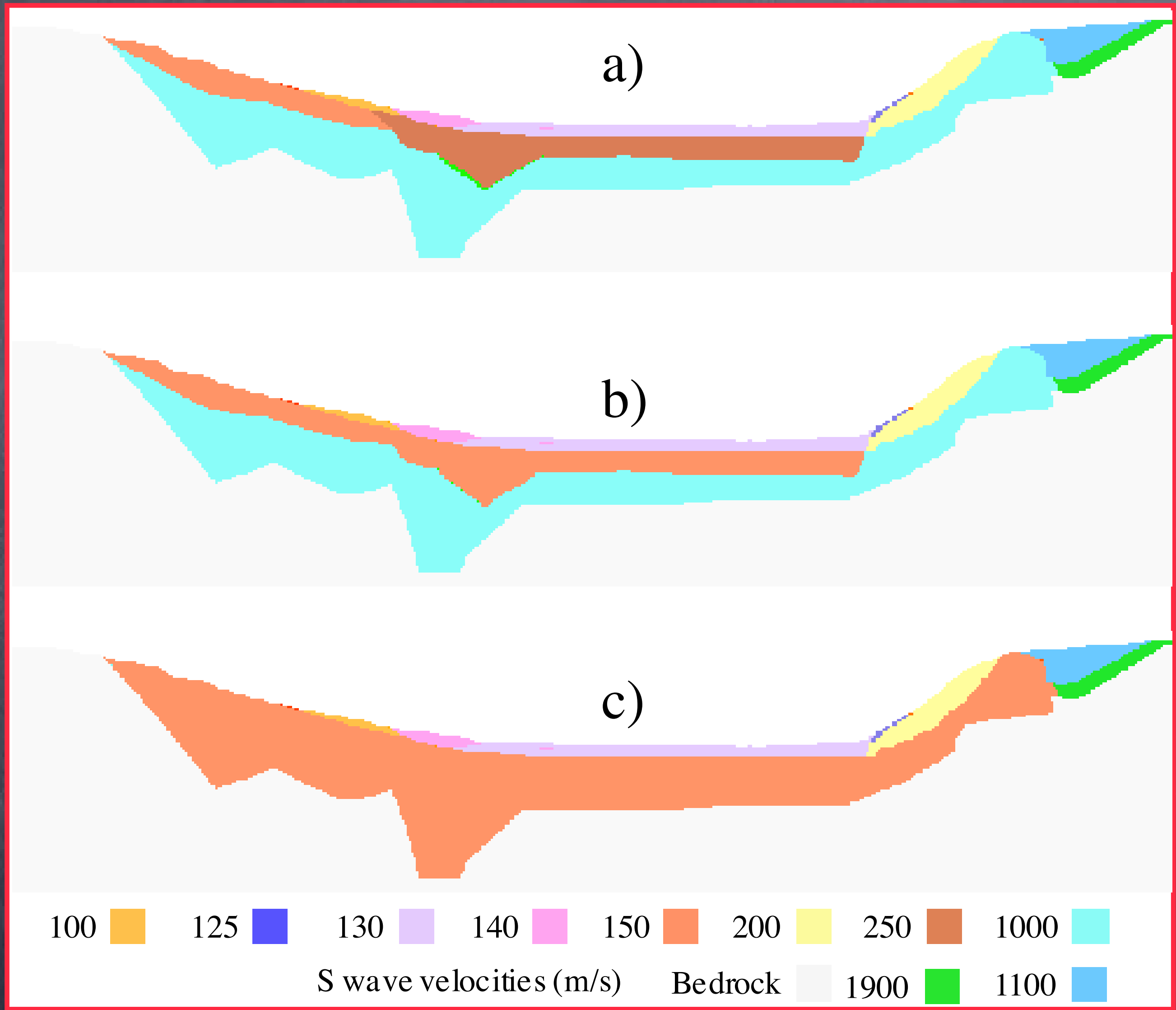
The results show that, in order to reach a relevant value of PGA (e.g. greater than 0.1g) in the desired period range (i.e. 0.8-1.2 s), an alternative and suitable configuration is a source
12 km deep at an epicentral distance of 30 km.

Parametric study 2nd - FS & RSR



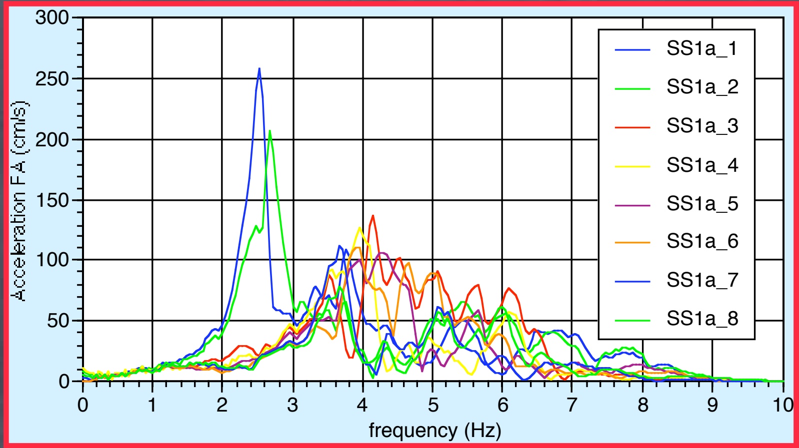
The results show that, even if the seismic energy around 1 Hz can be relevant (see bedrock curves), the local structure beneath the Warth bridge greatly amplifies the frequency components between 3 and 7 Hz, i.e. a frequency range not corresponding to the fundamental transverse mode of oscillation of the bridge (about 0.8 Hz)

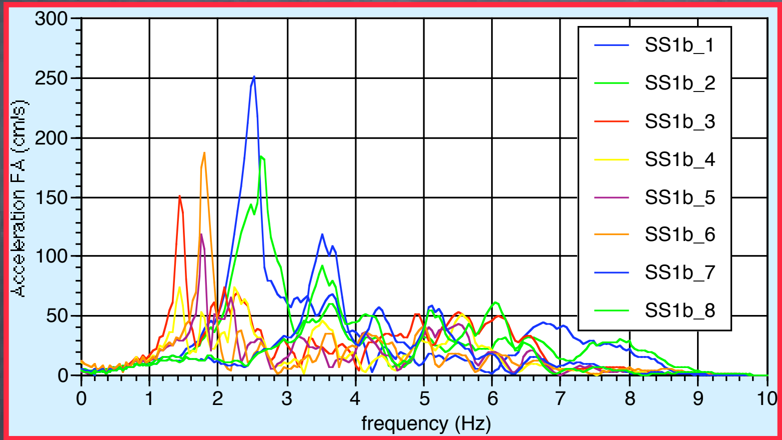
Parametric study 3 - LMp towards 1Hz

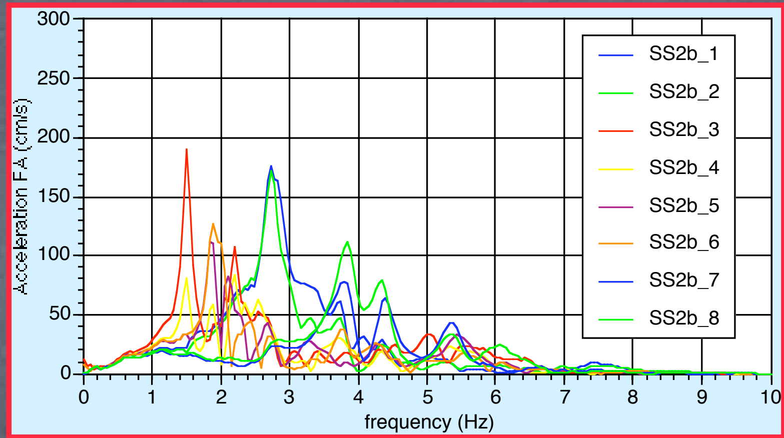


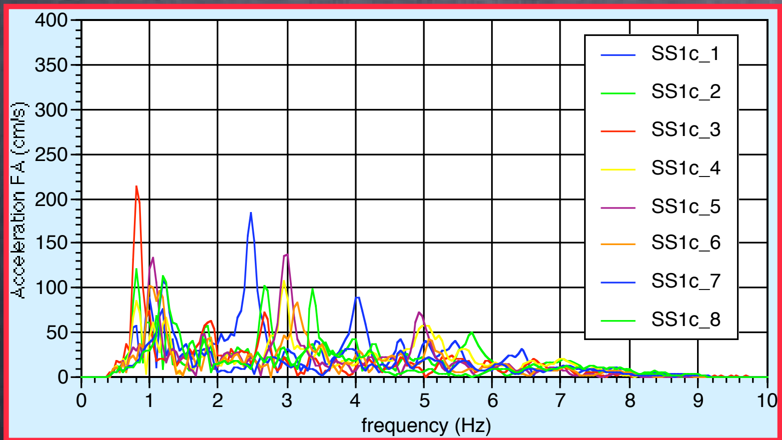
Local geotechnical models of Warth bridge section obtained lowering successively the S-wave velocities of the uppermost units

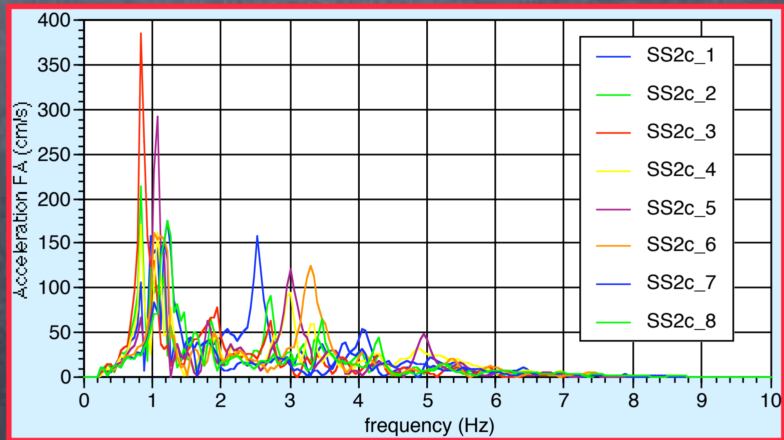
Parametric study 3rd FAS



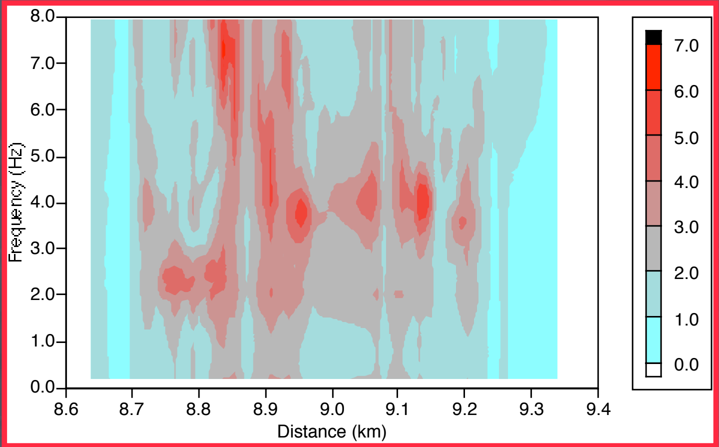


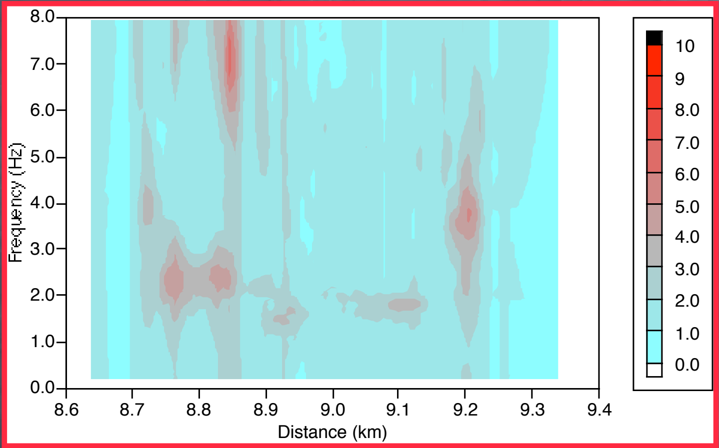


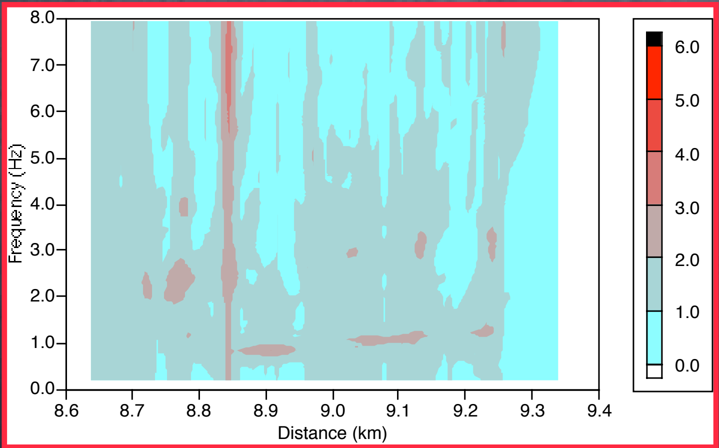


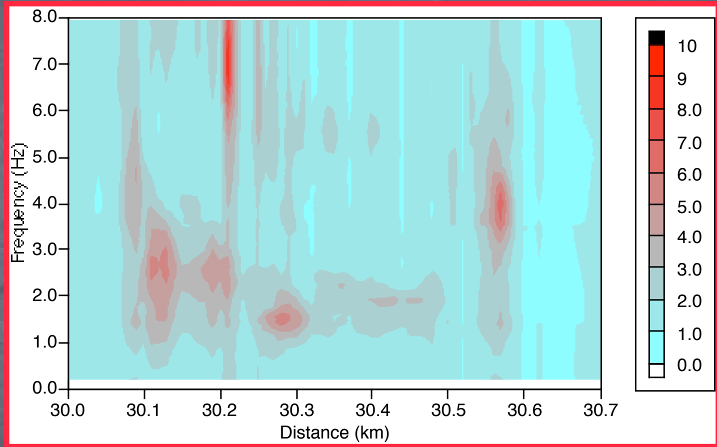


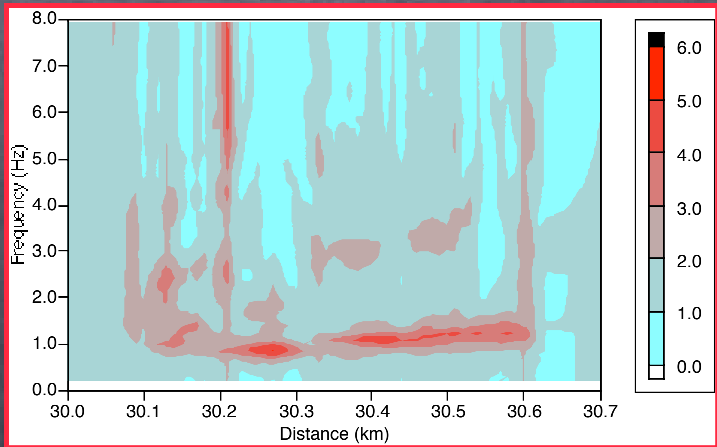
Parametric study 3rd RSR



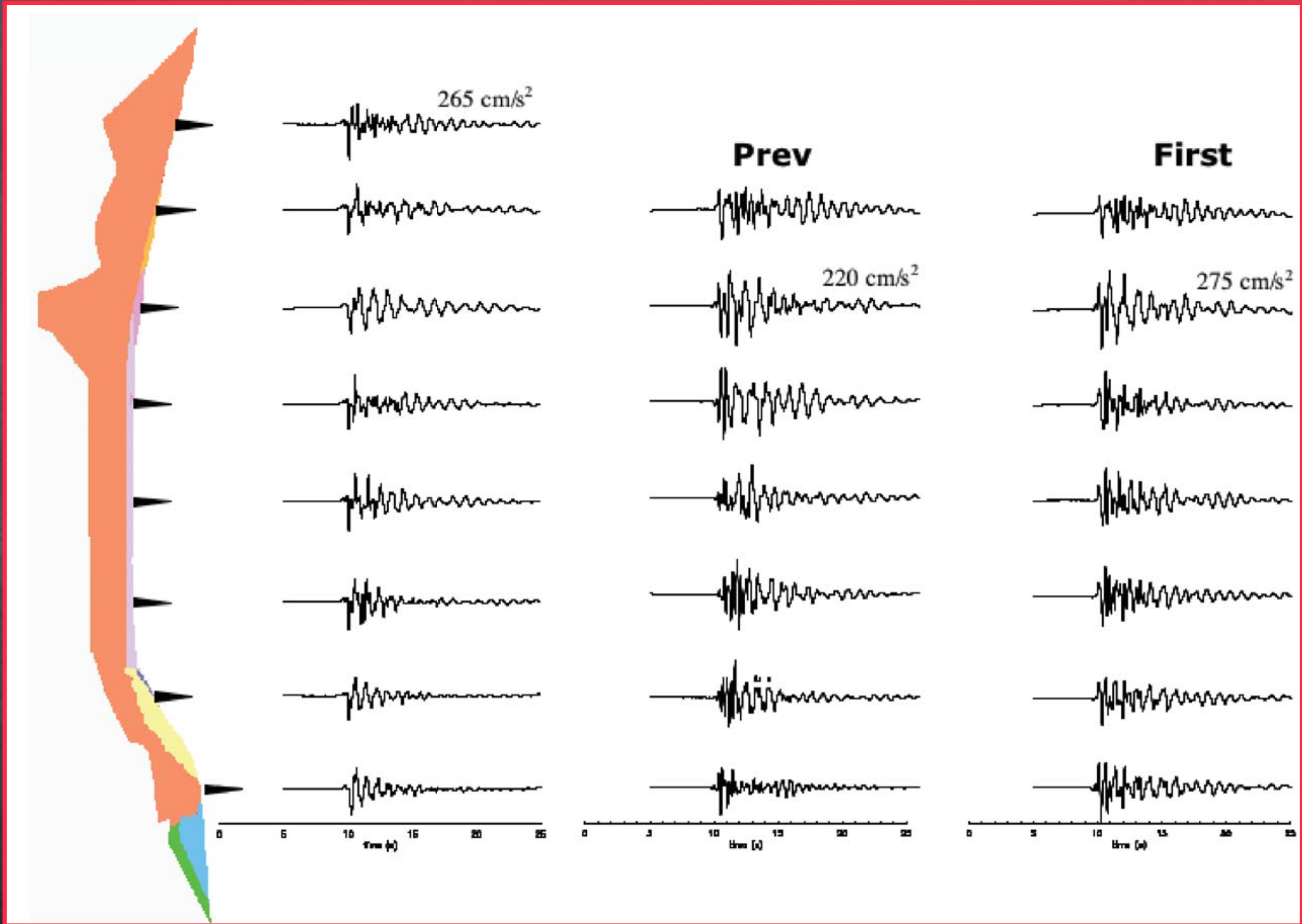




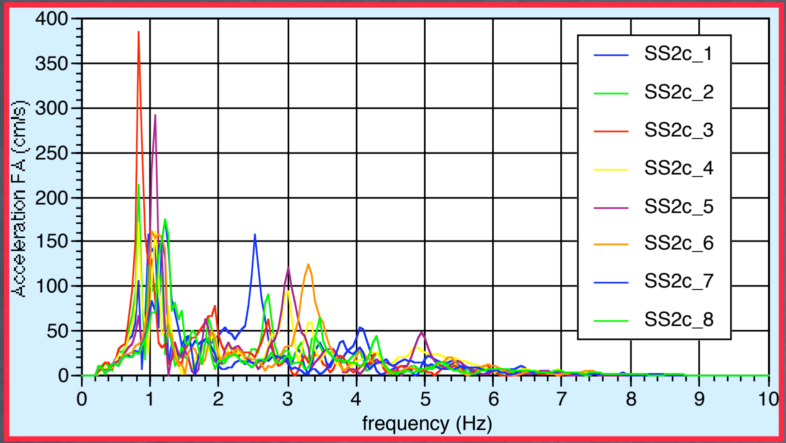


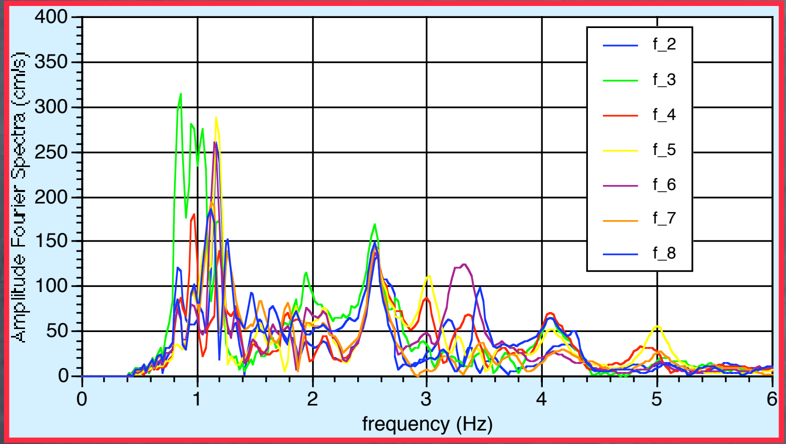


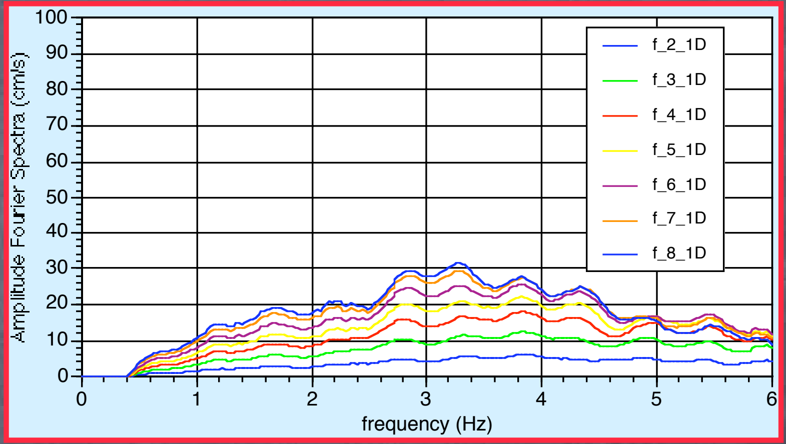
Synthetic accelerations and diffograms

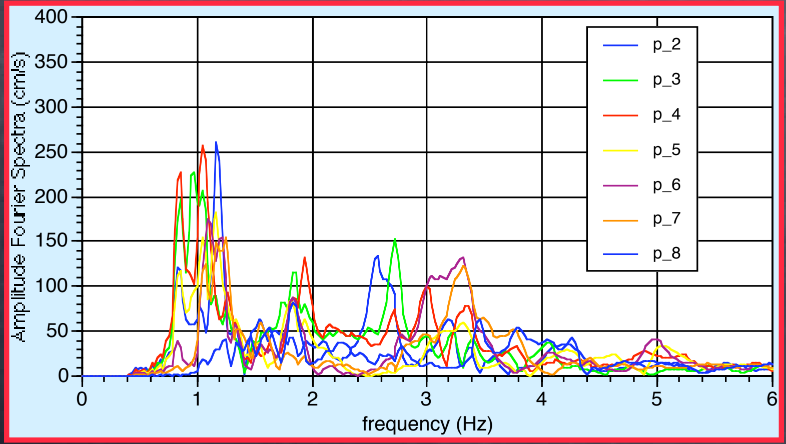


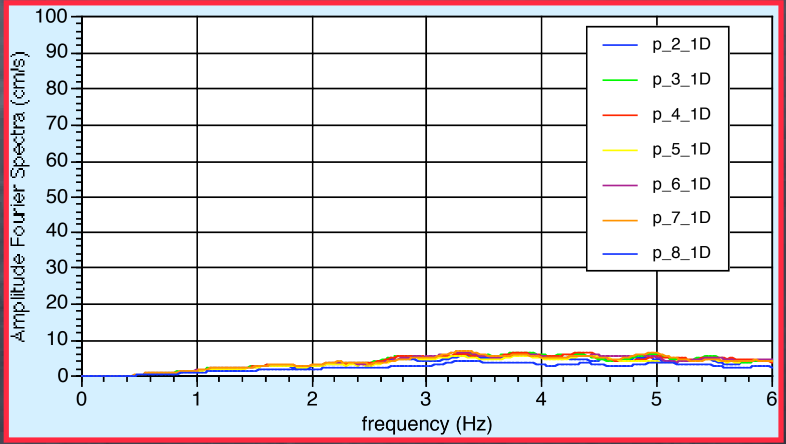
Synthetic accelerations and diffograms FAS



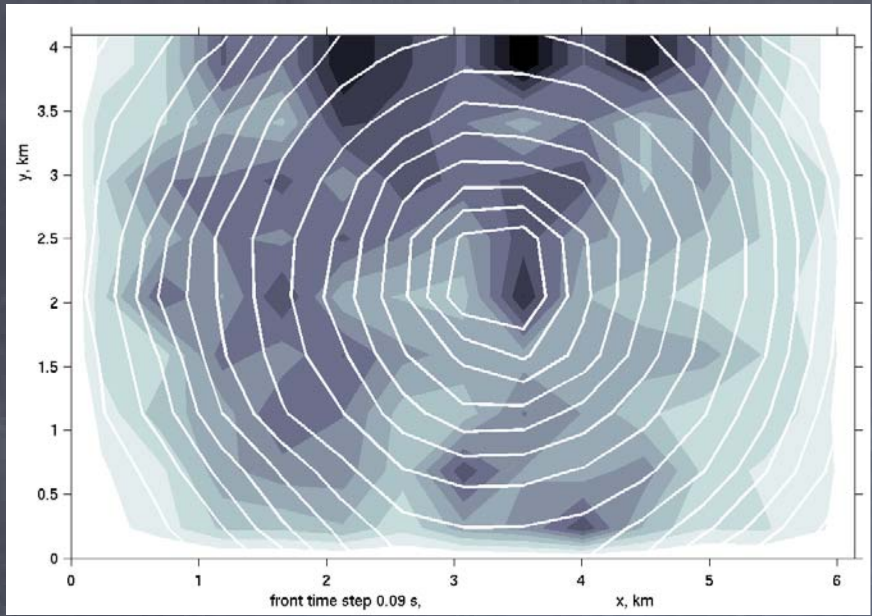


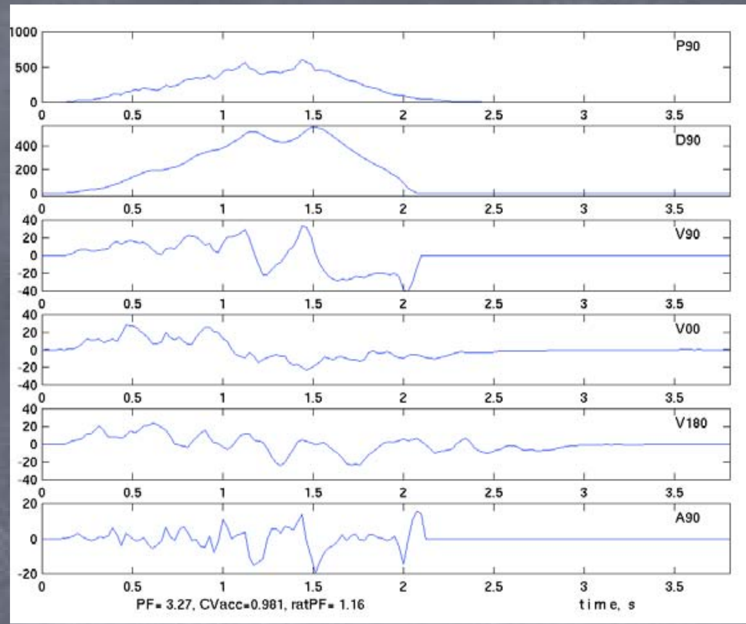


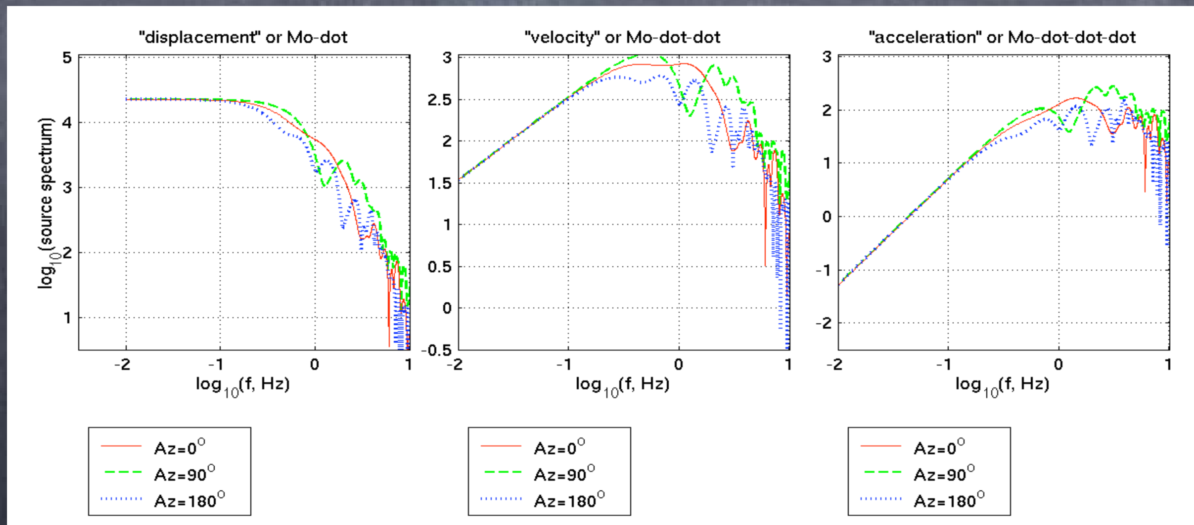




Parametric study 4 - ESp towards directivity

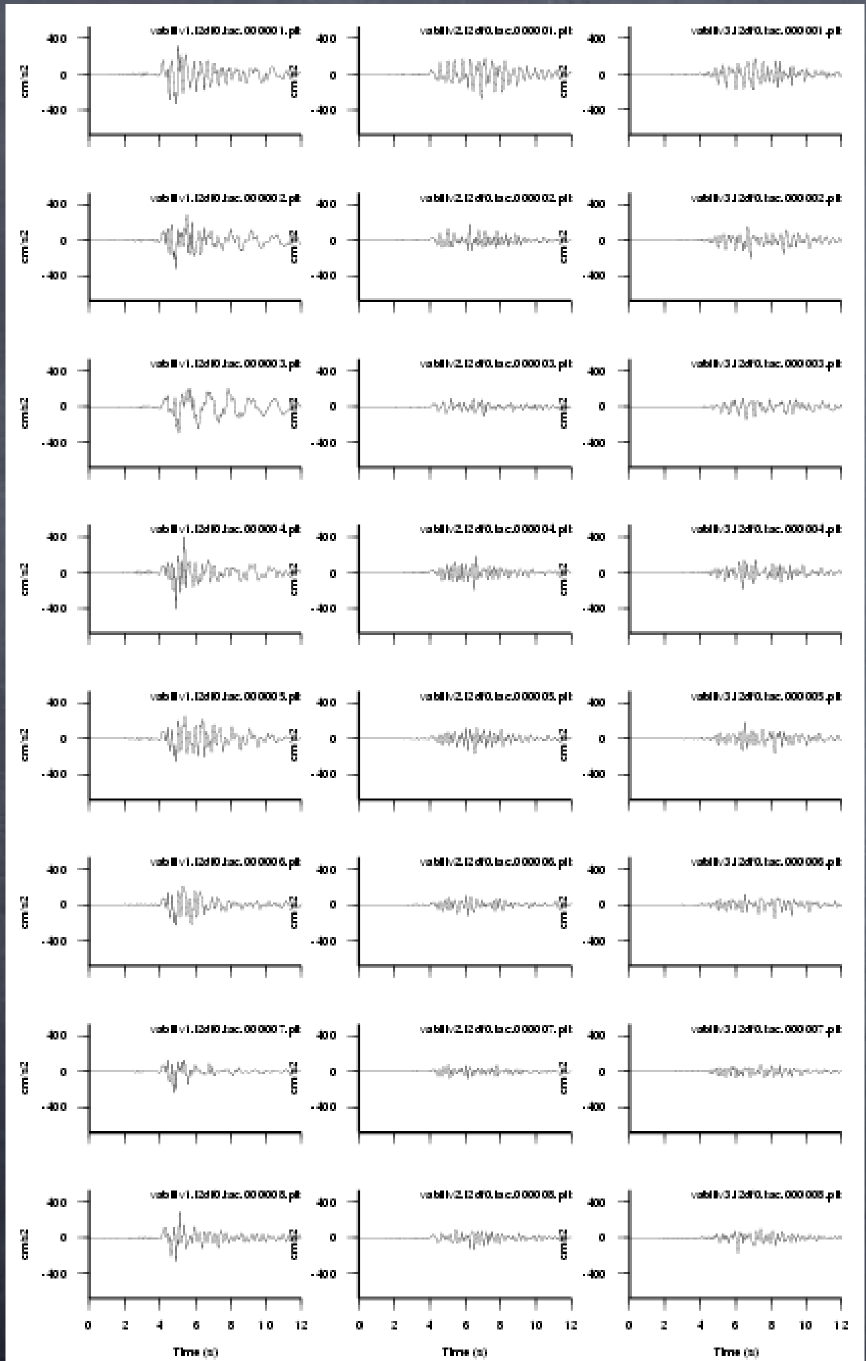


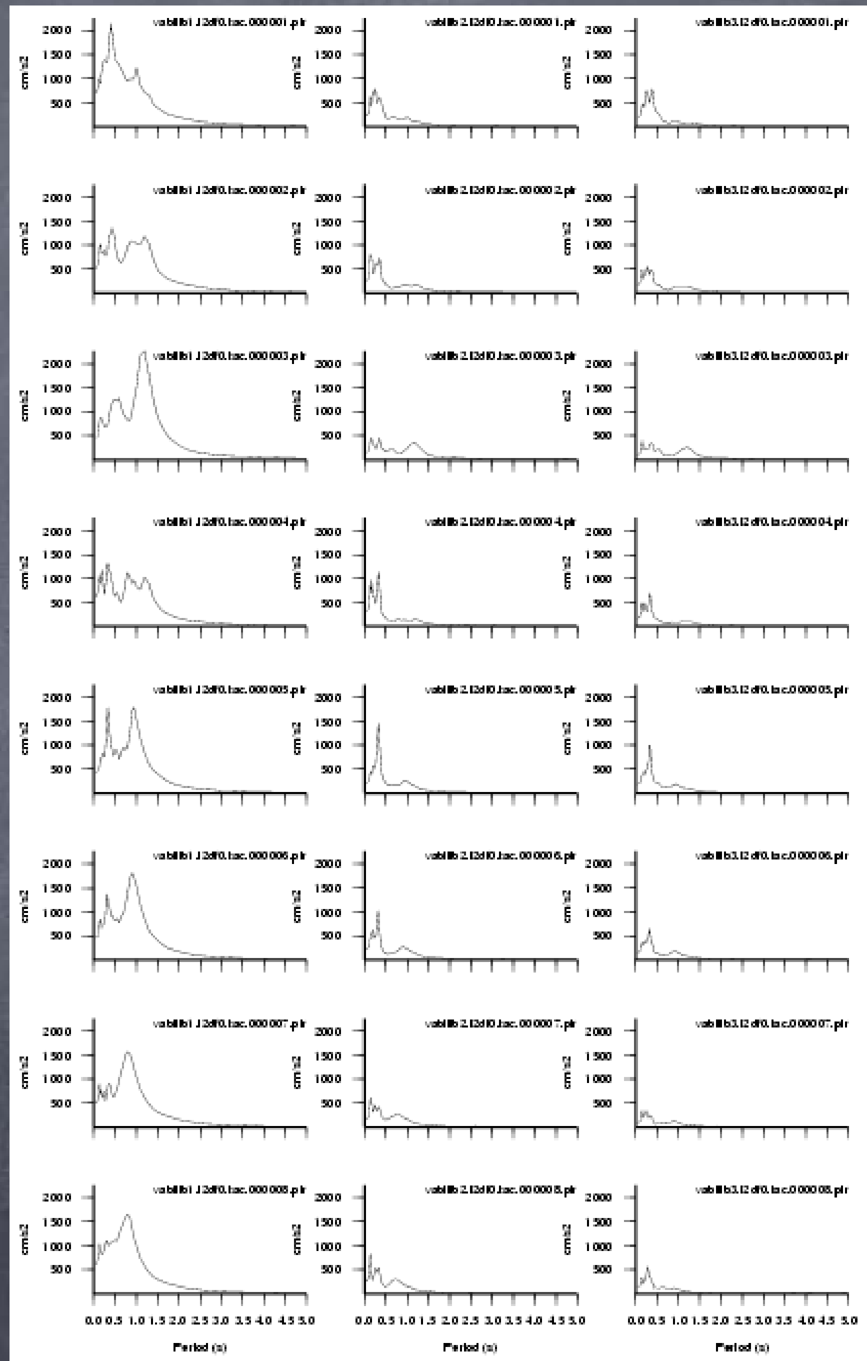




1st rupture model: bilateral at 3 positions

Accelerograms and response spectra

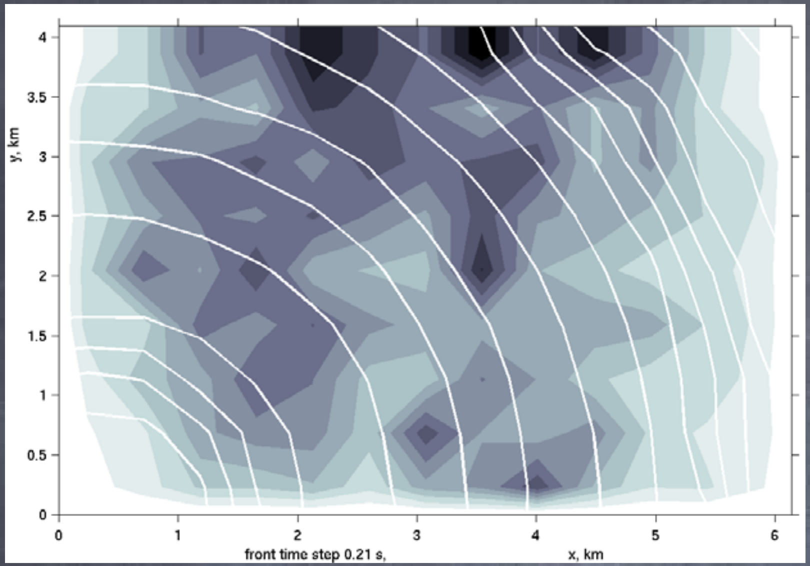


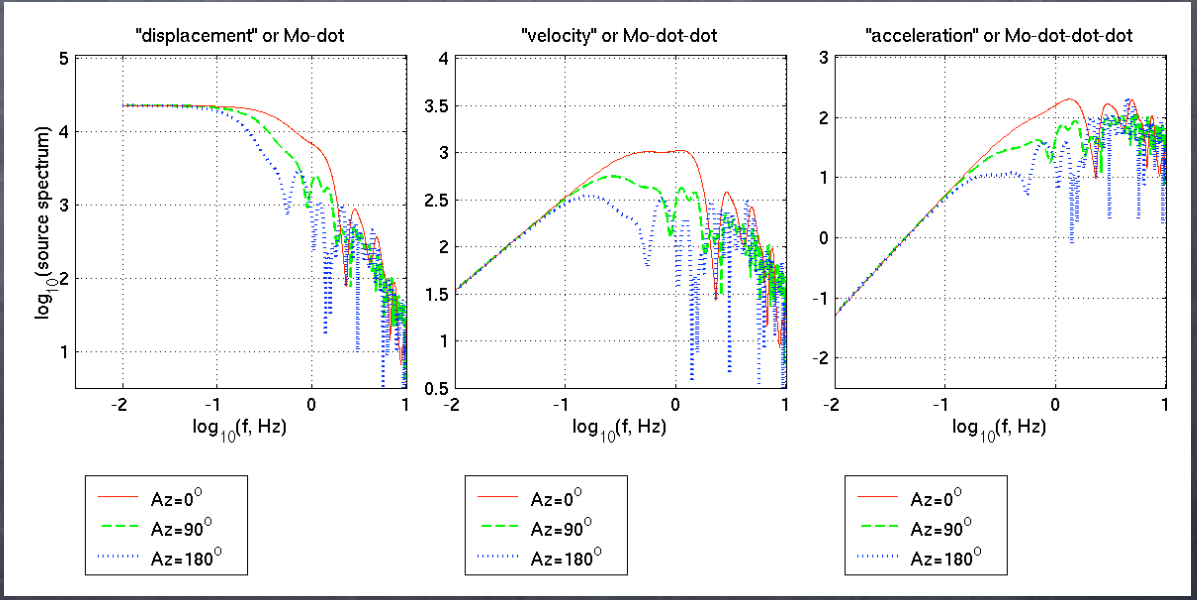


Parametric study 4 - ES

1st rupture model: bilateral at 3 positions

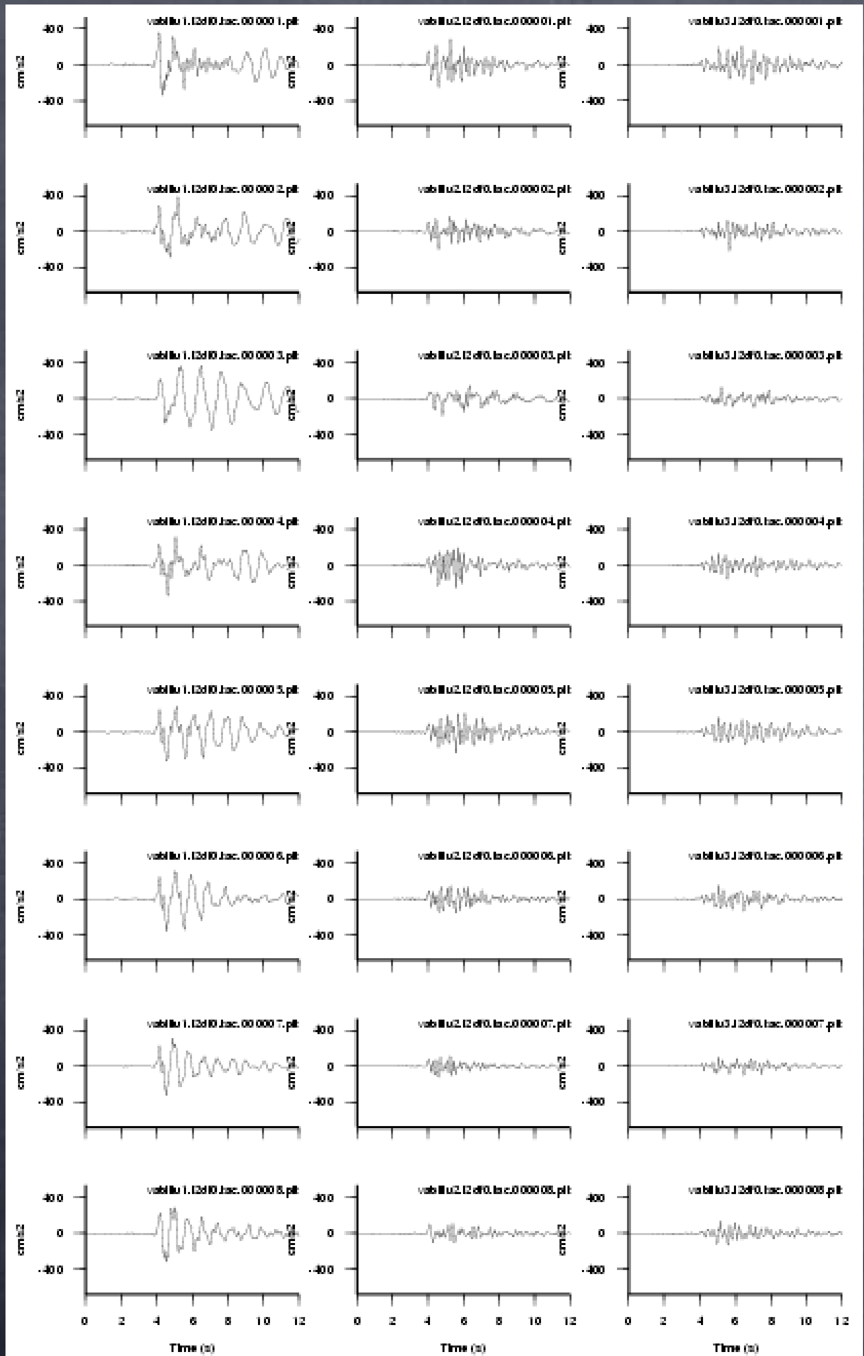
Parametric study 4 - ESp towards directivity

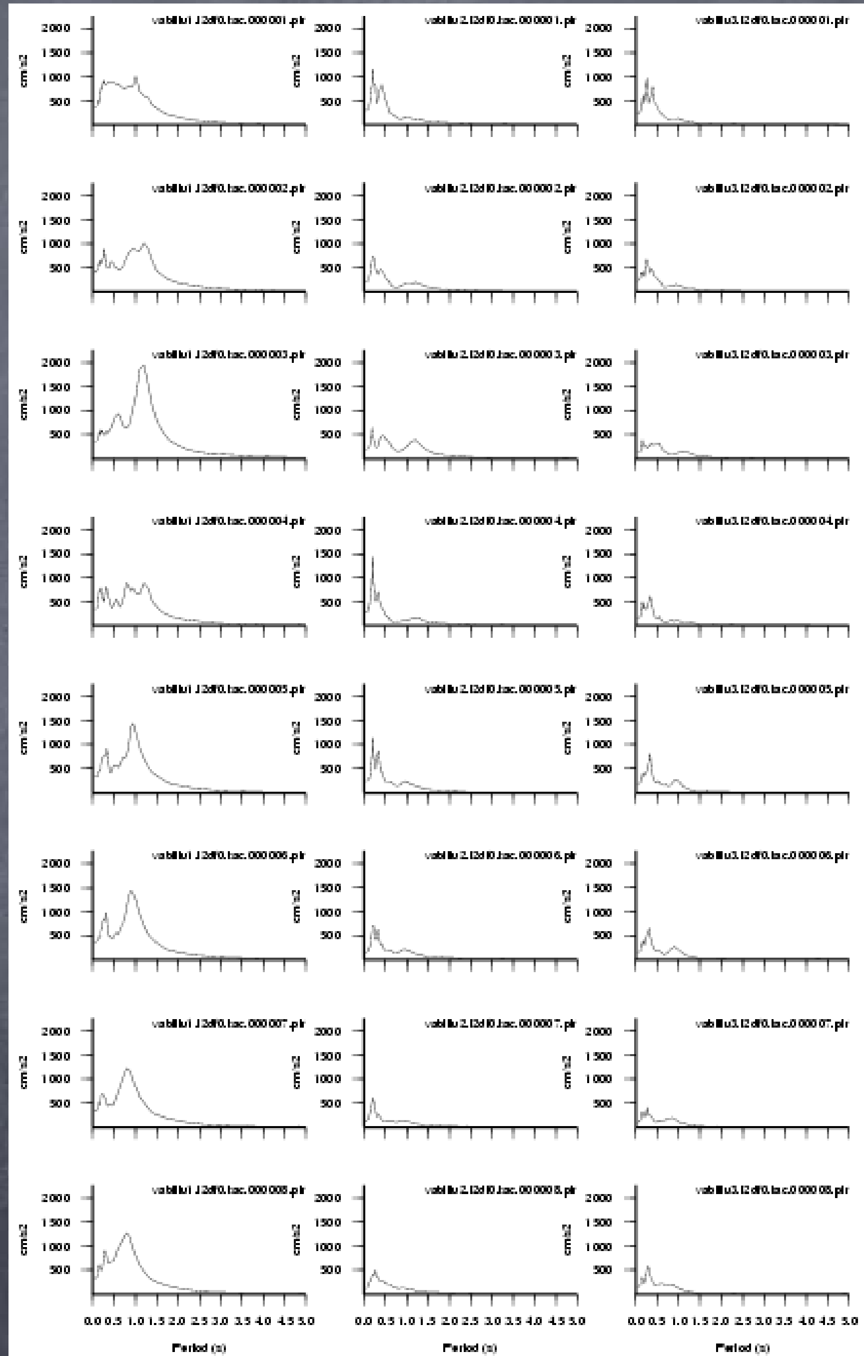




2nd rupture model: unilateral at 3 positions

Accelerograms and response spectra

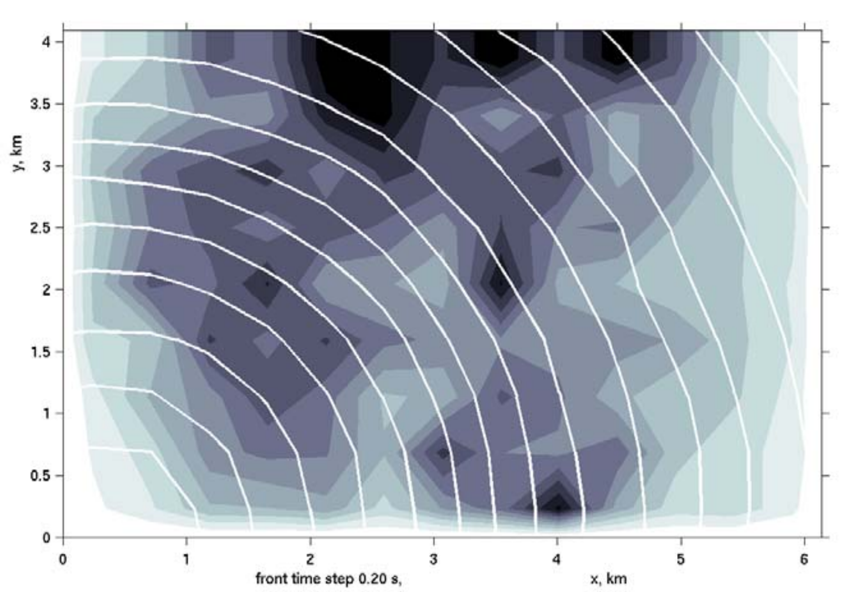


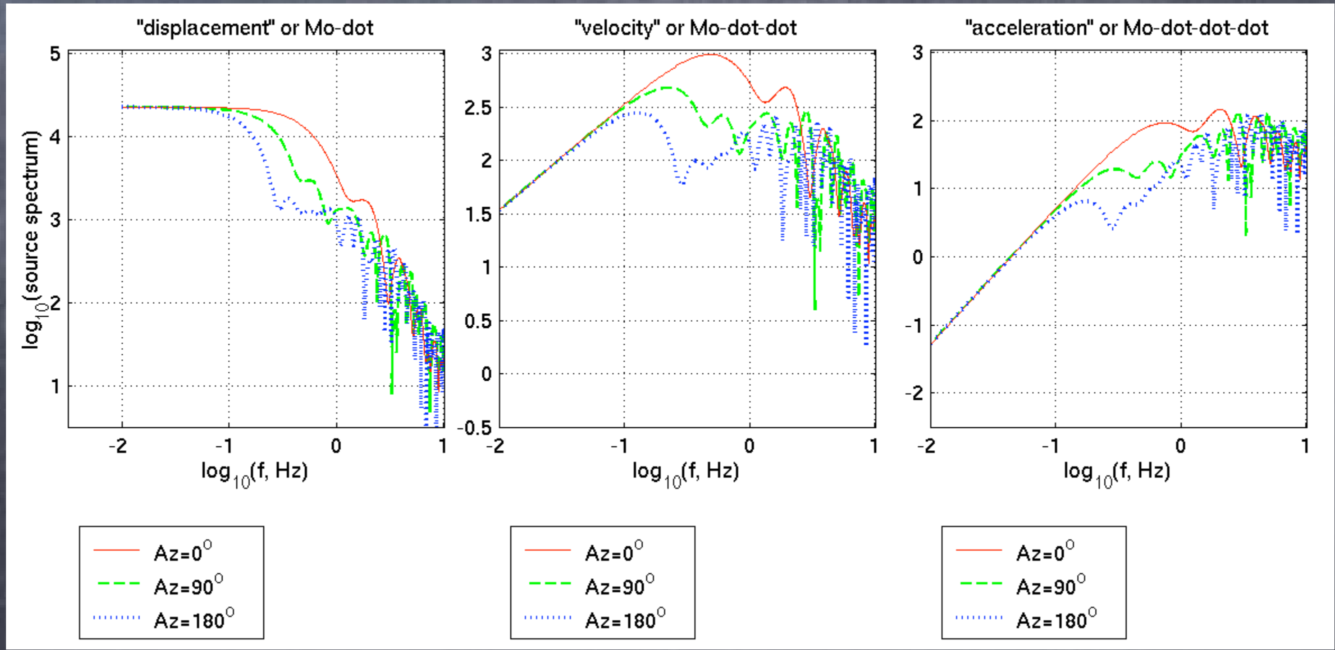


Parametric study 4 - ES

2nd rupture model: unilateral at 3 positions

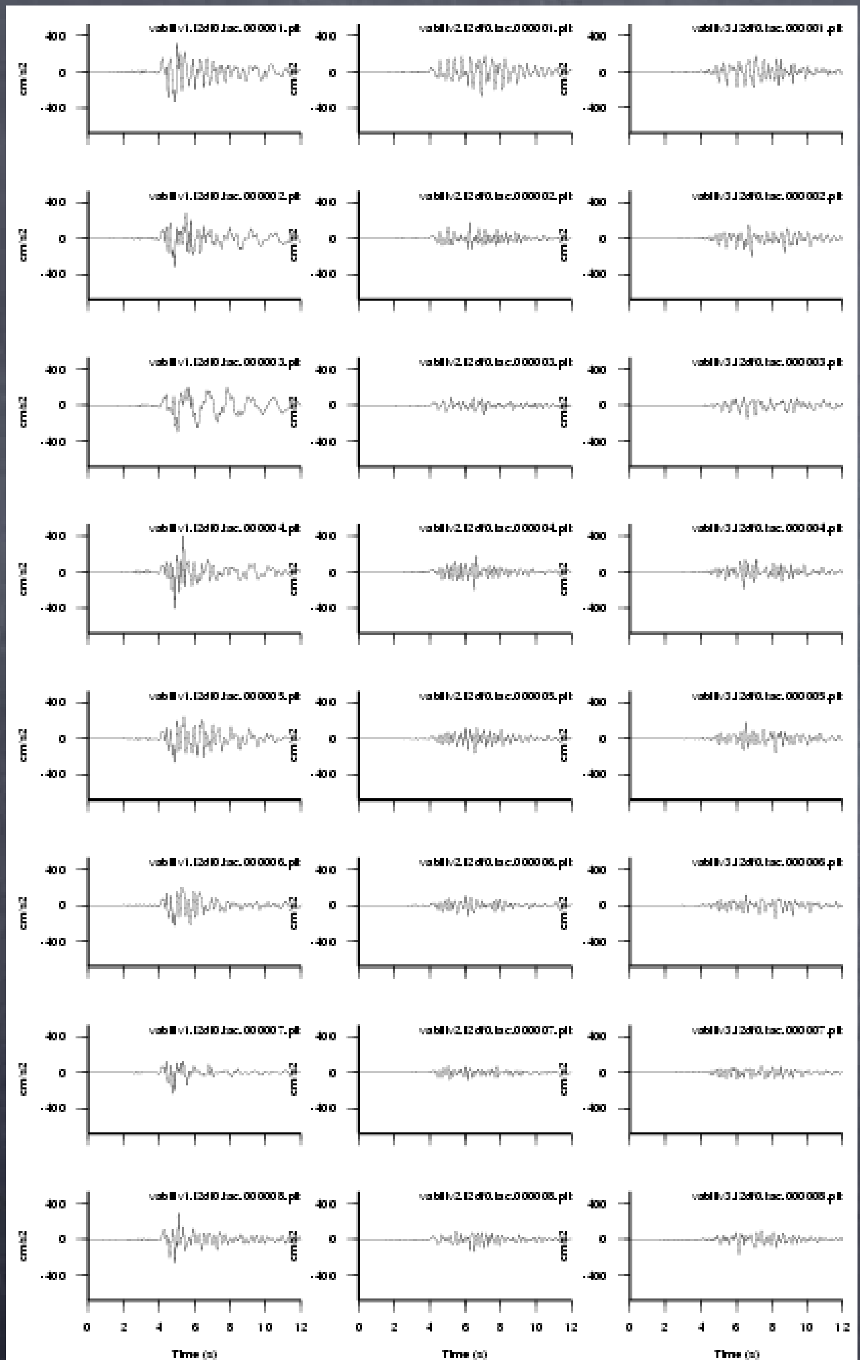
Parametric study 4 - ESp towards directivity

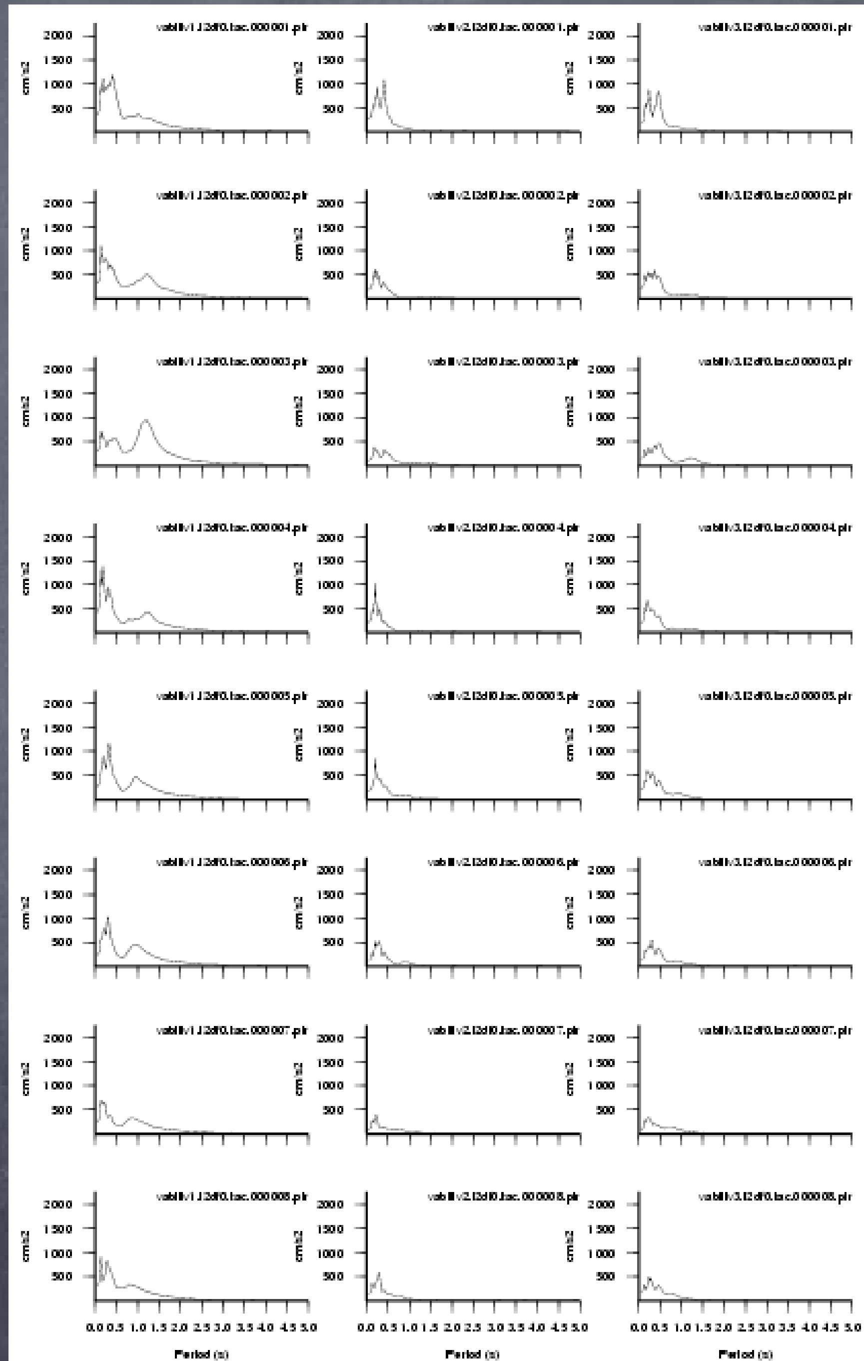




3rd rupture model: different v_r at 3 positions

Accelerograms and response spectra

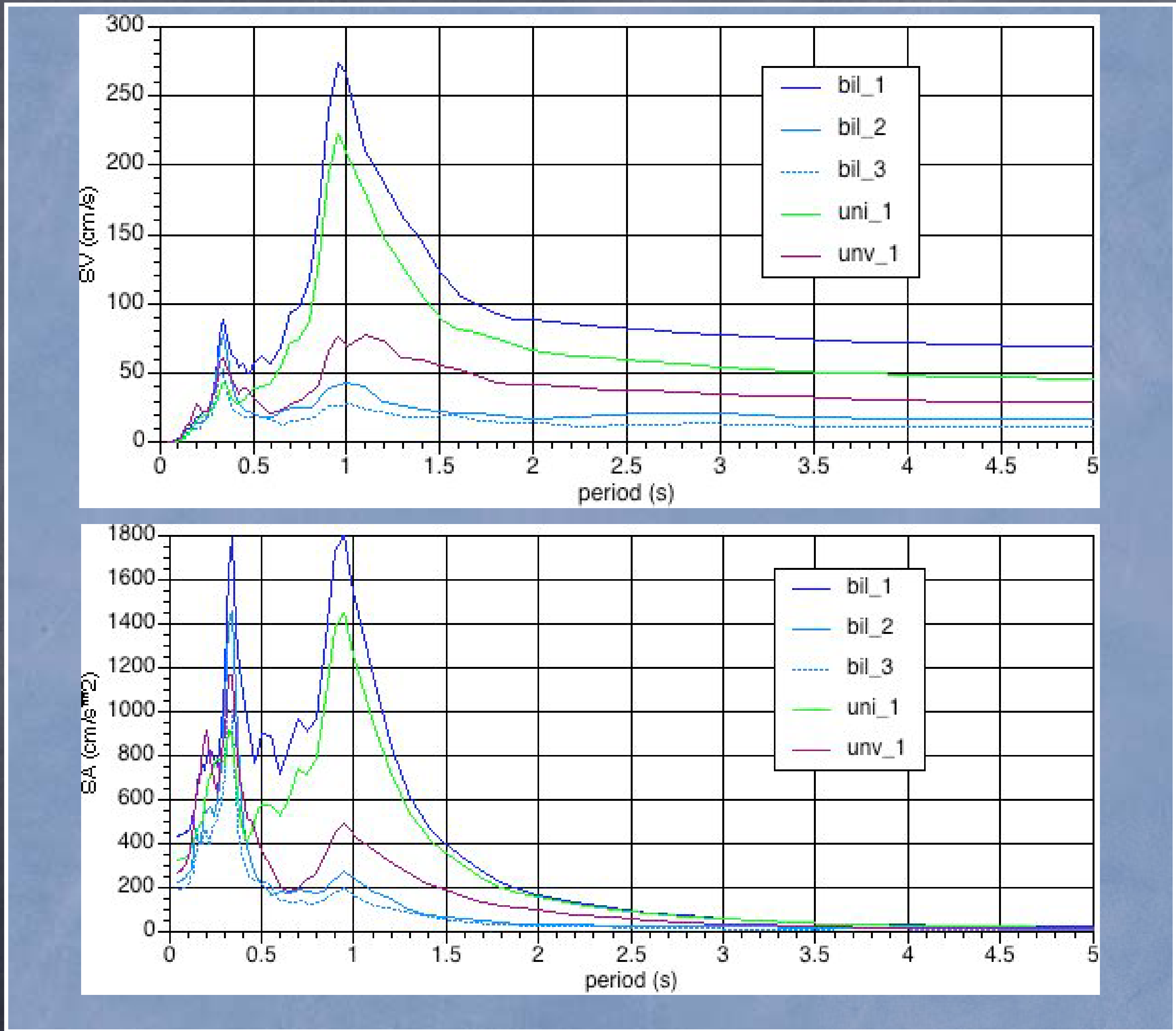




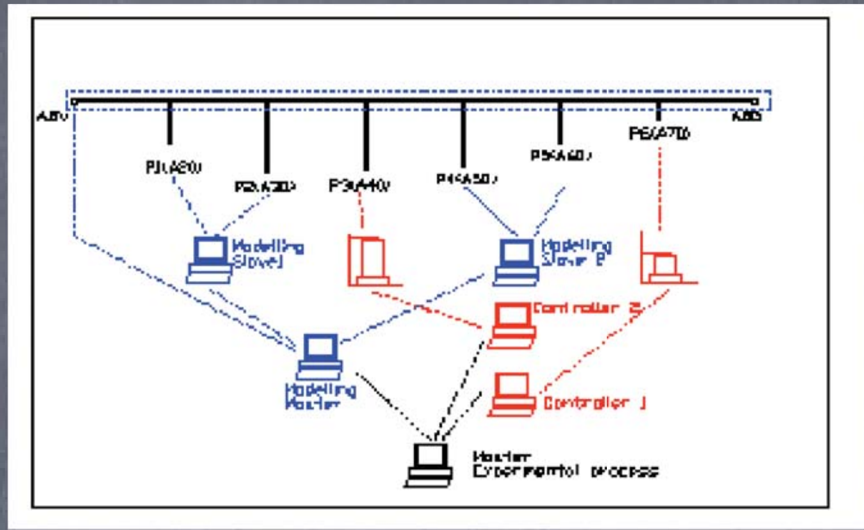
Parametric study 4 - ES

3rd rupture model: different v_r at 3 positions

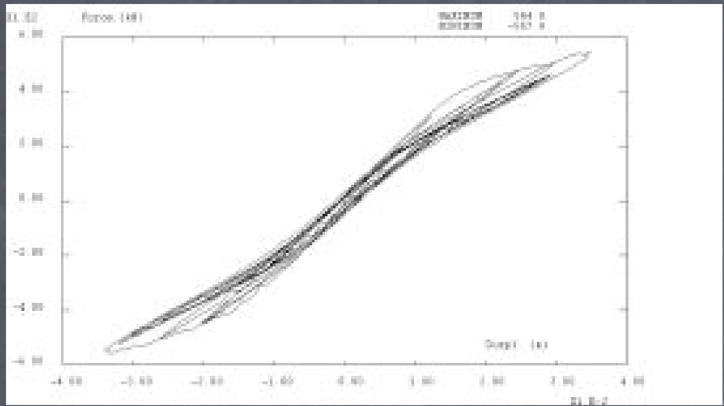
Parametric study - ESp towards directivity



Implementation of PSD tests

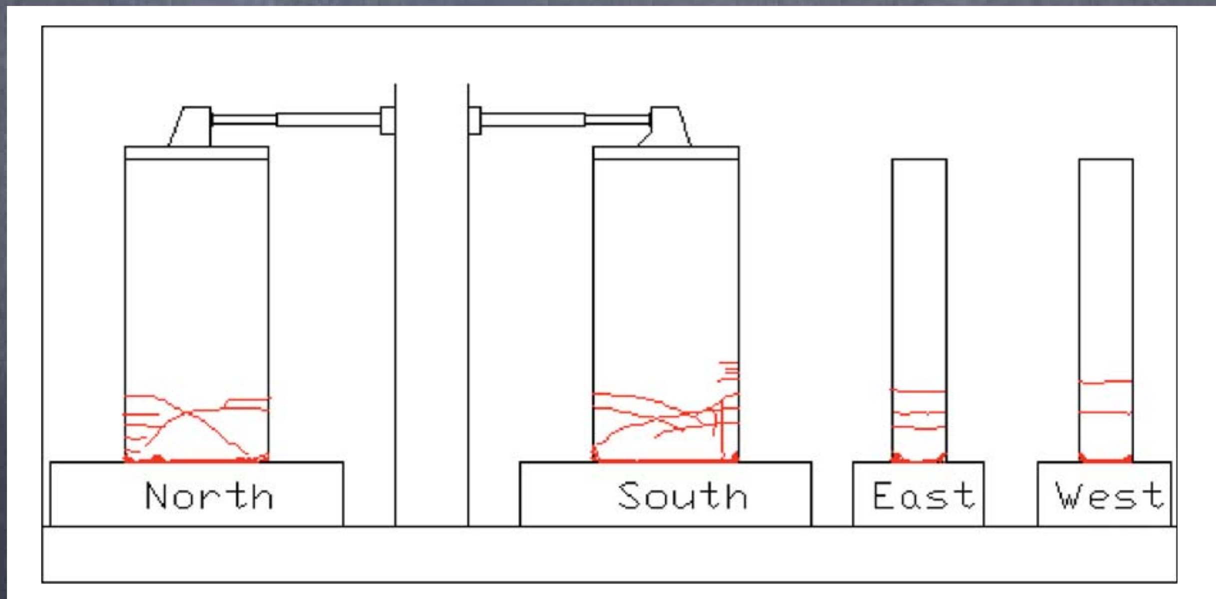


(a) physical piers in the lab, (b), schematic representation
(c) workstations running the PSD algorithm and controlling the test



Force-displacement for Low-level earthquake - experimental results Pier A40

Identification of insufficient seismic detailing. tall pier A40, buckling of longitudinal reinforcement at h = 3.5m



Damage pattern after the end of the High-Level Earthquake PSD test, short pier A70.

Conclusions - 1

- Different ground motions at the Warth site have been studied in order to define the maximum excitation in longitudinal and transverse direction, which are consistent both with the Maximum Credible Earthquake and with the Maximum Design.
- The main practical conclusion of our analysis, verified by laboratory experiments carried out at JRC-ISPRA, is that the Warth bridge is likely to well stand the most severe seismic input compatible with the seismic regime of the Eastern Alps.
- With the parametric study we have defined a seismic source-Warth site configuration that provides a set of signals whose seismic energy is concentrated around 1 Hz, frequency that corresponds approximately to that of the fundamental transverse mode of oscillation of the bridge.

Conclusions - 2

- The results show that lateral heterogeneity can produce strong spatial variations in the ground motion even at small incremental distances.

- Such variations can hardly be accounted for by the stochastic models commonly used in engineering practice.

- In absolute terms, the differential motion amplitude is comparable with the input motion amplitude when displacement, velocity and acceleration domains are considered.

- On the base of the existing empirical regression relations between Intensity and peak values of ground motion a general result of our modeling is that the effect of the differential motion can cause an increment greater than one unit in the seismic intensity experienced by the bridge, with respect to the average intensity affecting the area where the bridge is built.

References

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