



**The Abdus Salam  
International Centre for Theoretical Physics**



**2142-25**

**Advanced Conference on Seismic Risk Mitigation and Sustainable  
Development**

*10 - 14 May 2010*

**SISMA Project  
Local scale scenarios  
of ground motion**

Franco Vaccari  
*University of Trieste  
Dept. of Geoscience/ICTP  
Trieste*

# SISMA Project

## *Local scale scenarios of ground motion*

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**Advanced Conference on Seismic Risk Mitigation & Sustainable Development**

*10-14 May 2010, The Abdus Salam International Centre for Theoretical Physics*

**Miramare - Trieste**



# Regional Scale - Bedrock

- Seismic zonation based on the computation of synthetic seismograms on the nodes of a grid that covers the study area
- Average structural properties
- Simple source model (scaled point source)
- Cut-off frequency 1 Hz
- Maps of peak displacement, velocity and Design Ground Acceleration

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# Local Scale - Bedrock

- Seismic zonation based on the computation of synthetic seismograms on the nodes of a grid that covers the study area
- Average structural properties
- Detailed source model (rupture directivity included)
- Cut-off frequency up to 10 Hz
- Maps of peak displacement, velocity and Design Ground Acceleration

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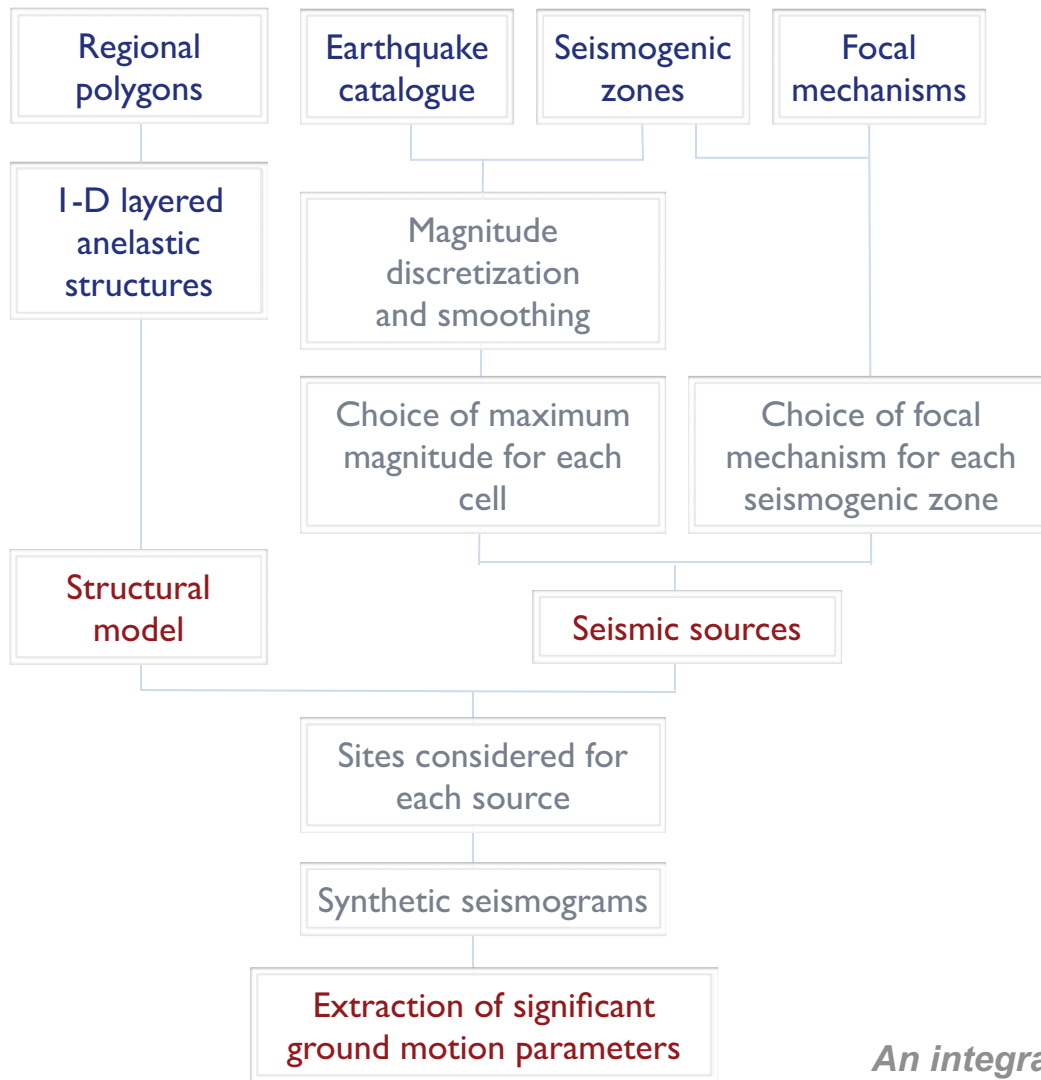
# Local Scale - 2D Models

- Synthetic seismograms computed along selected profiles
- Laterally heterogeneous structural models
- Detailed source model (rupture directivity included)
- Cut-off frequency up to 10 Hz
- Maps of ground motion amplification

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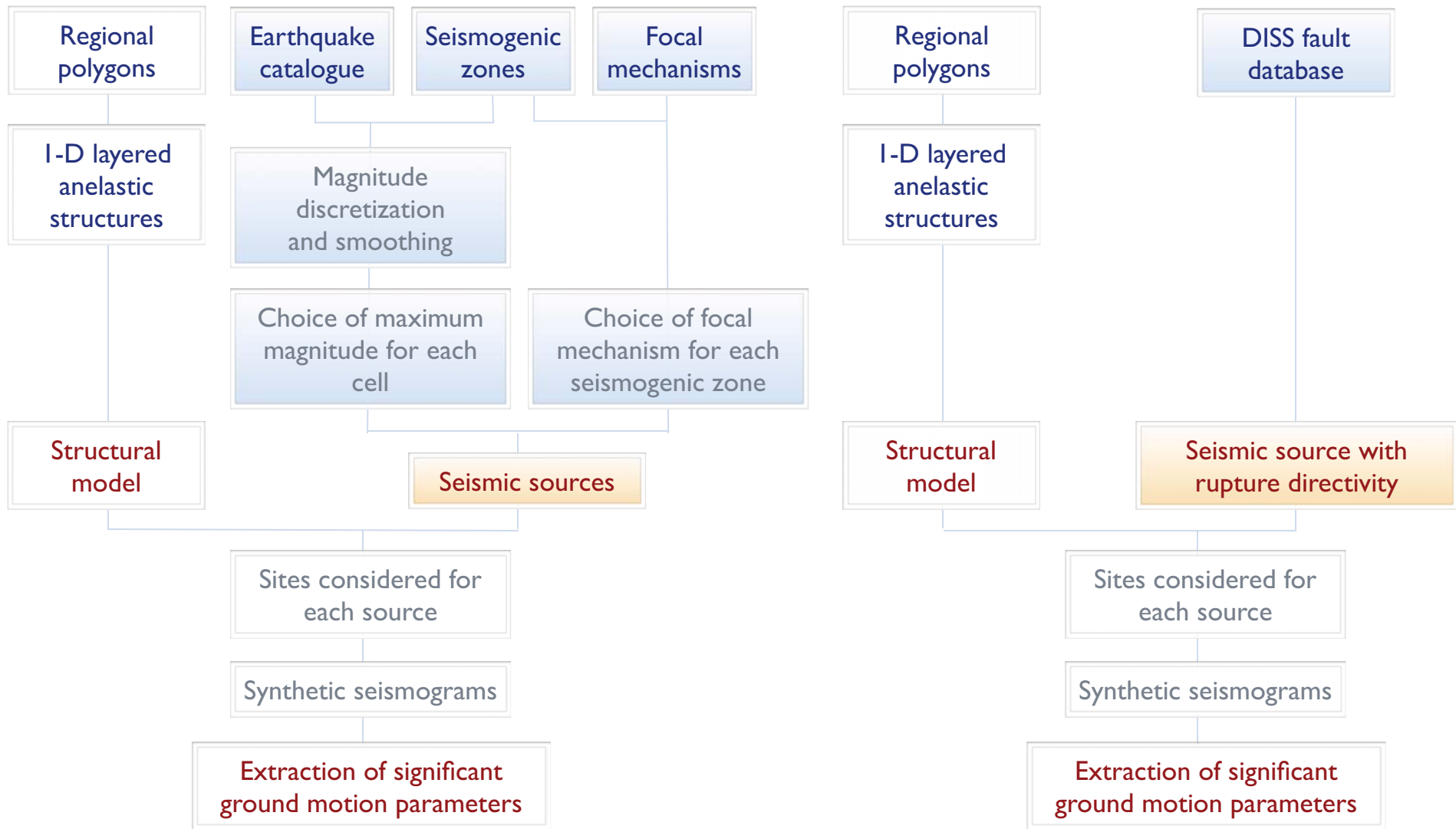
# Regional Scale



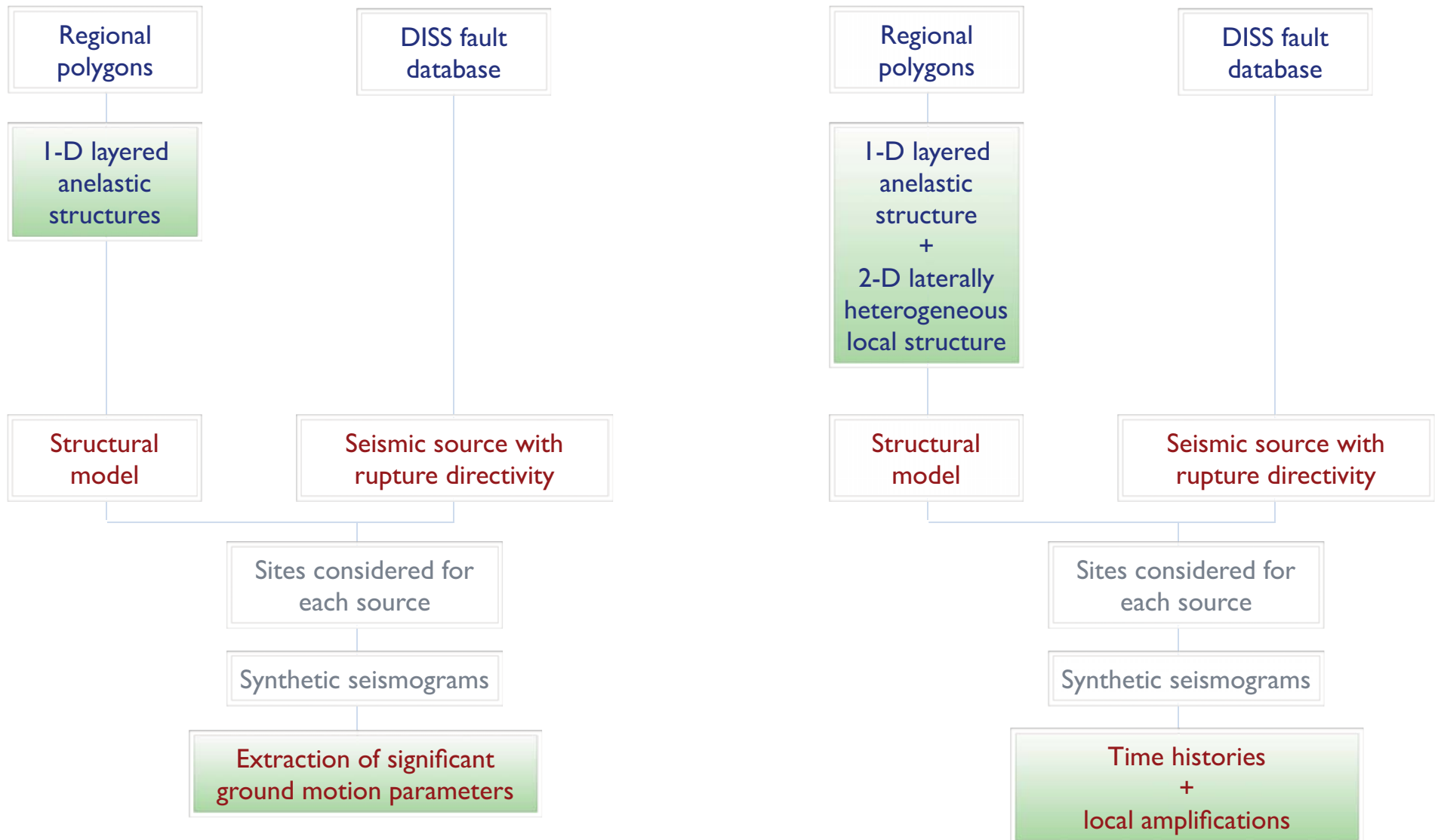
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# Regional Scale

# → Local scale (bedrock)



# Local scale (bedrock) → Local scale (2D)





# Methodology

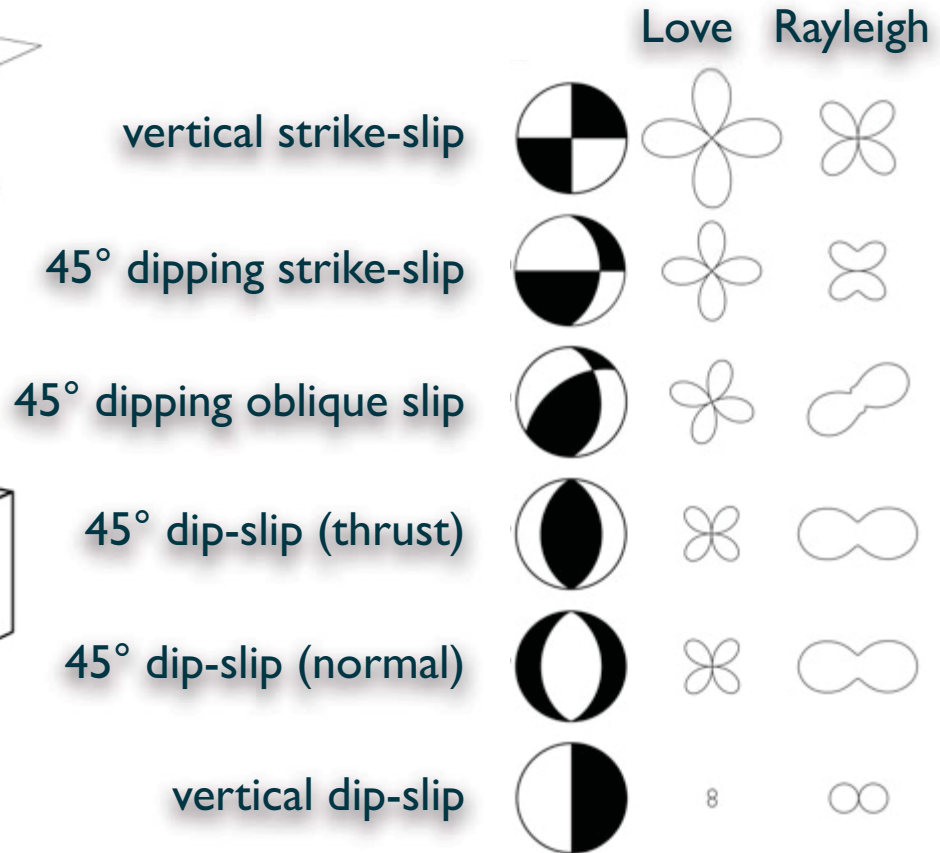
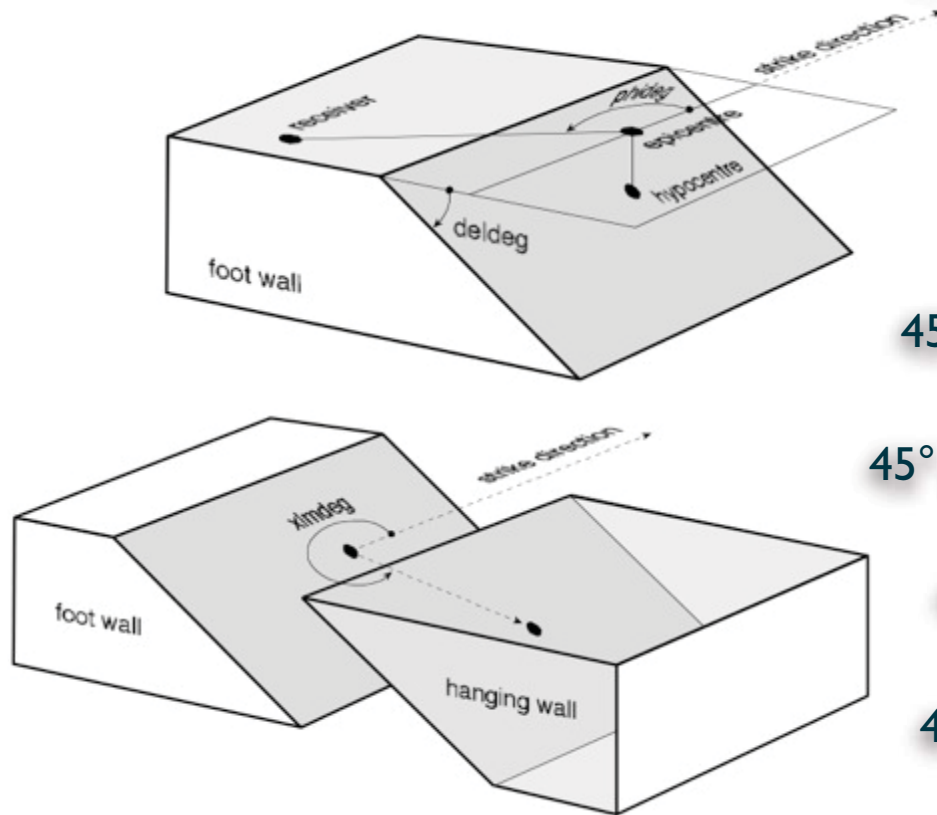
- Regional scale: modal summation technique
- Local scale (bedrock): modal summation technique
- Local scale (2D models): hybrid technique (modal summation + finite difference)

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# Methodology - Source (regional and local scale)

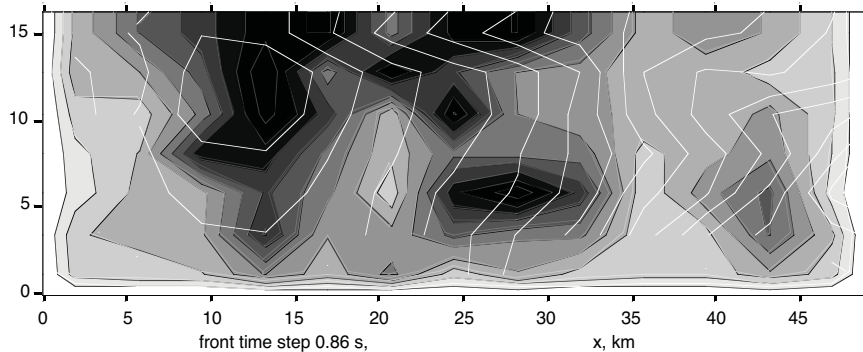
## Source definition and examples of radiation pattern



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# Methodology - Source (local bedrock and 2D)

## Source kinematic model

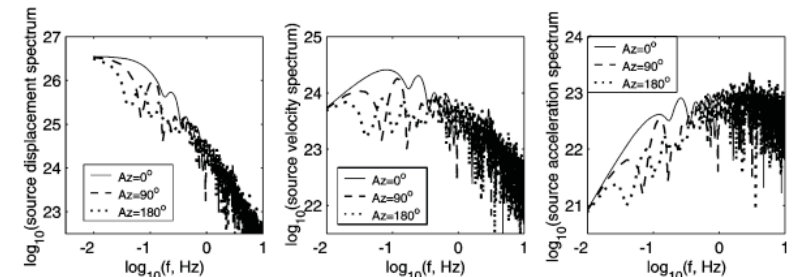
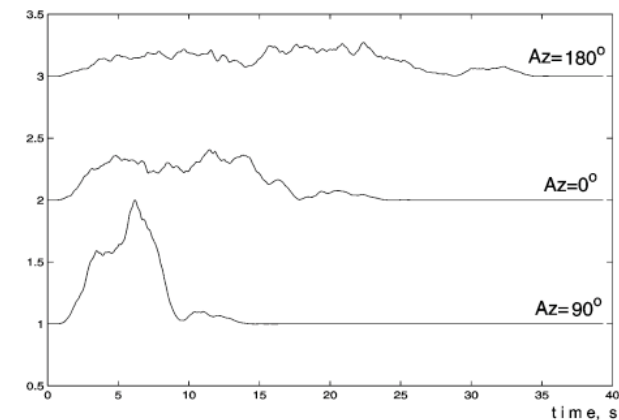


2-dimensional final slip distribution over a source rectangle, shown as a density plot (Mw=7.0).

Rupture front evolution was simulated kinematically from random rupture velocity field.

Far-field source time histories and their spectra.

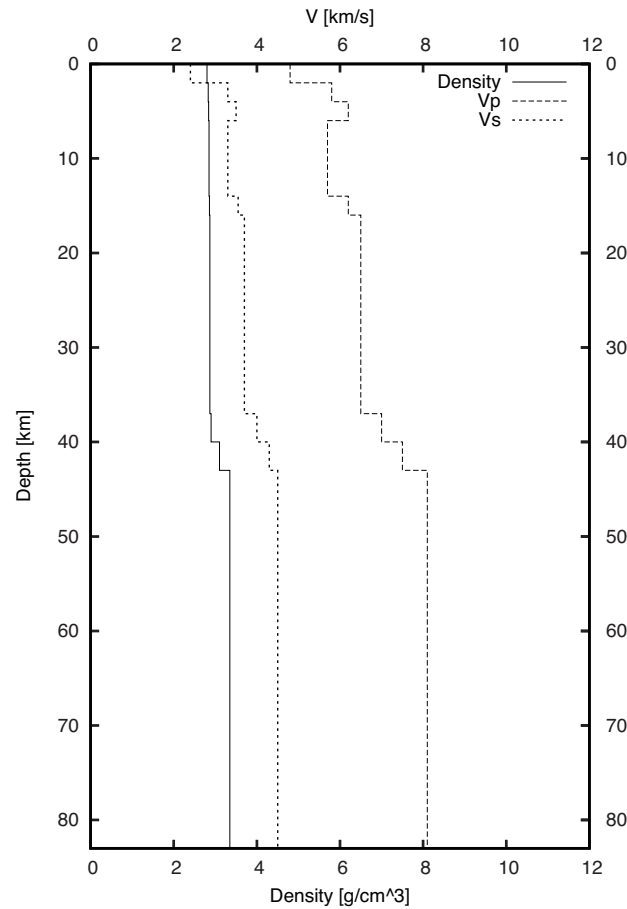
“Displacement” far-field functions (arbitrary scale) for the simulated case of mostly unilateral rupture propagation



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# Methodology - Structure (bedrock)

## Modal summation

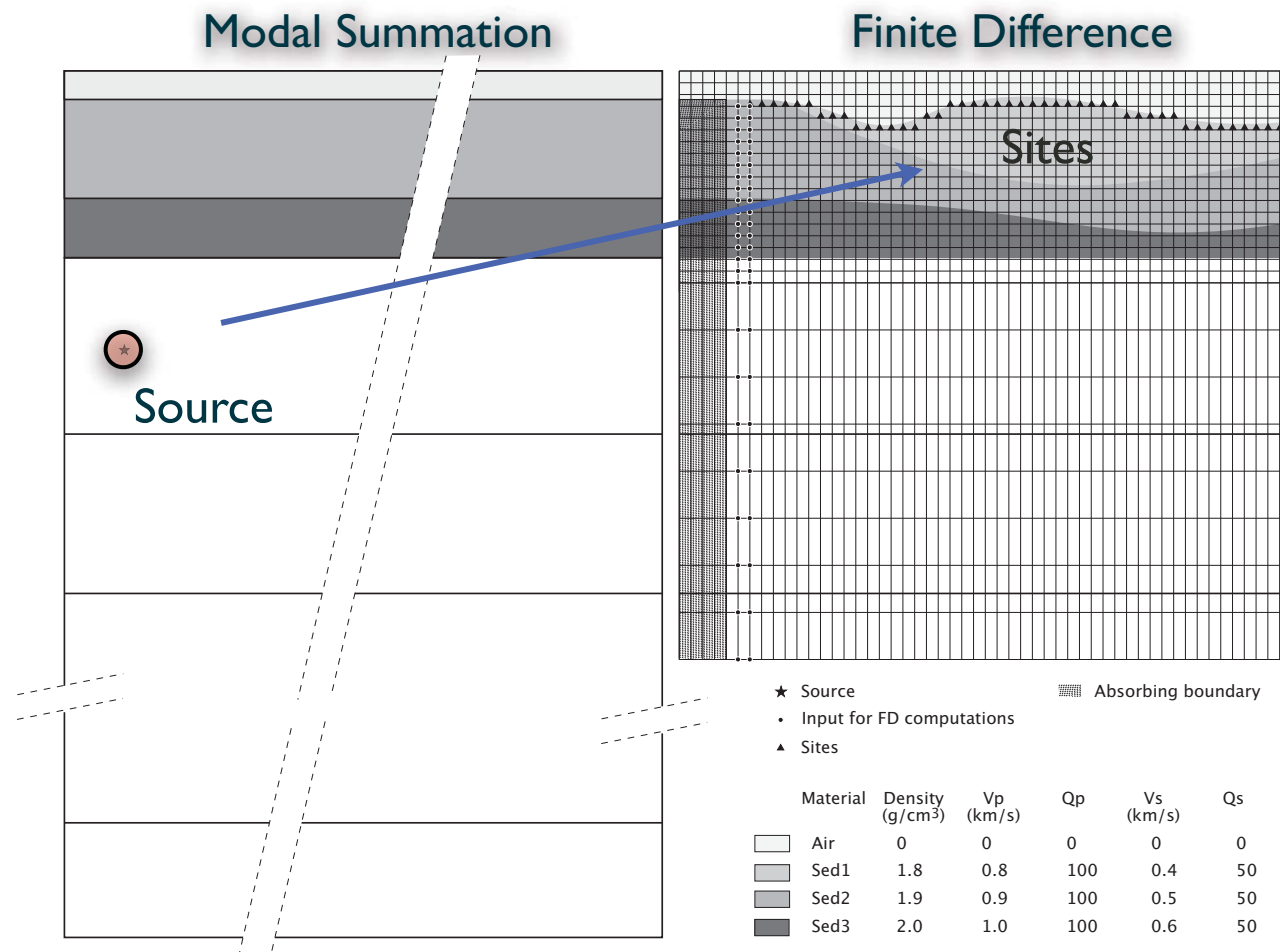


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# Methodology - Structure (2D profiles)

Hybrid technique



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# Local scale (bedrock) scenario

Source mechanism used for the ground shaking scenario (DISS ITIS038, M=6)

<http://diss.rm.ingv.it/diss/>

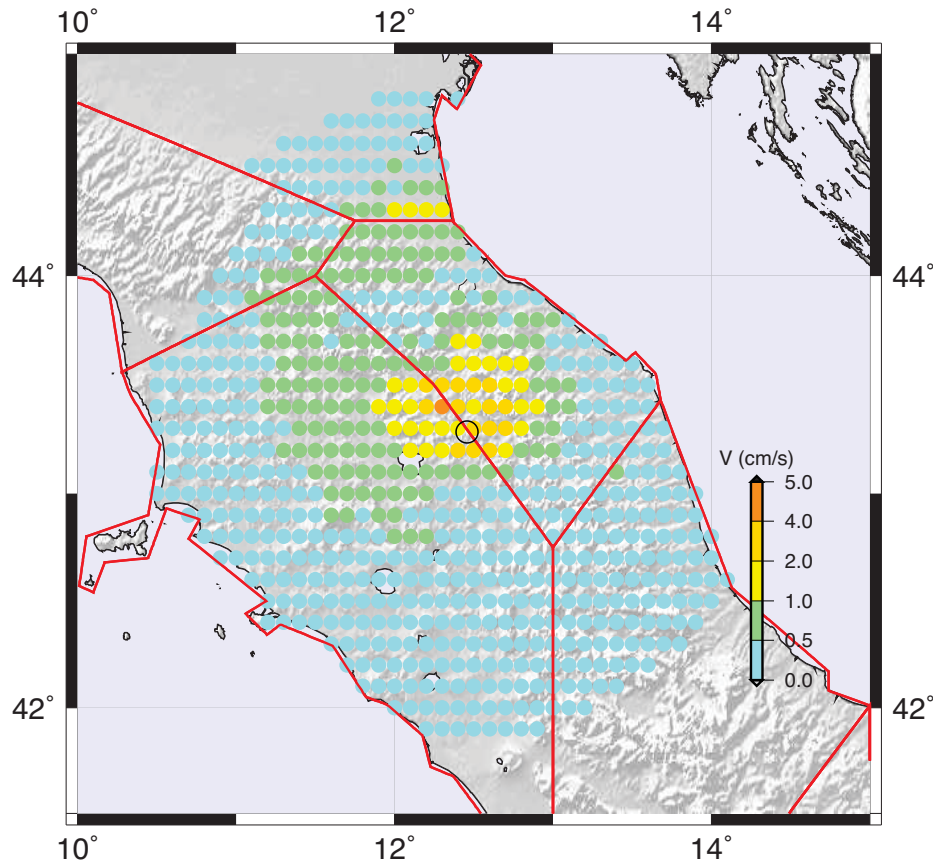


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# Local scale (bedrock) scenario - Directivity

Ground shaking scenario (velocity), directivity **north-west**

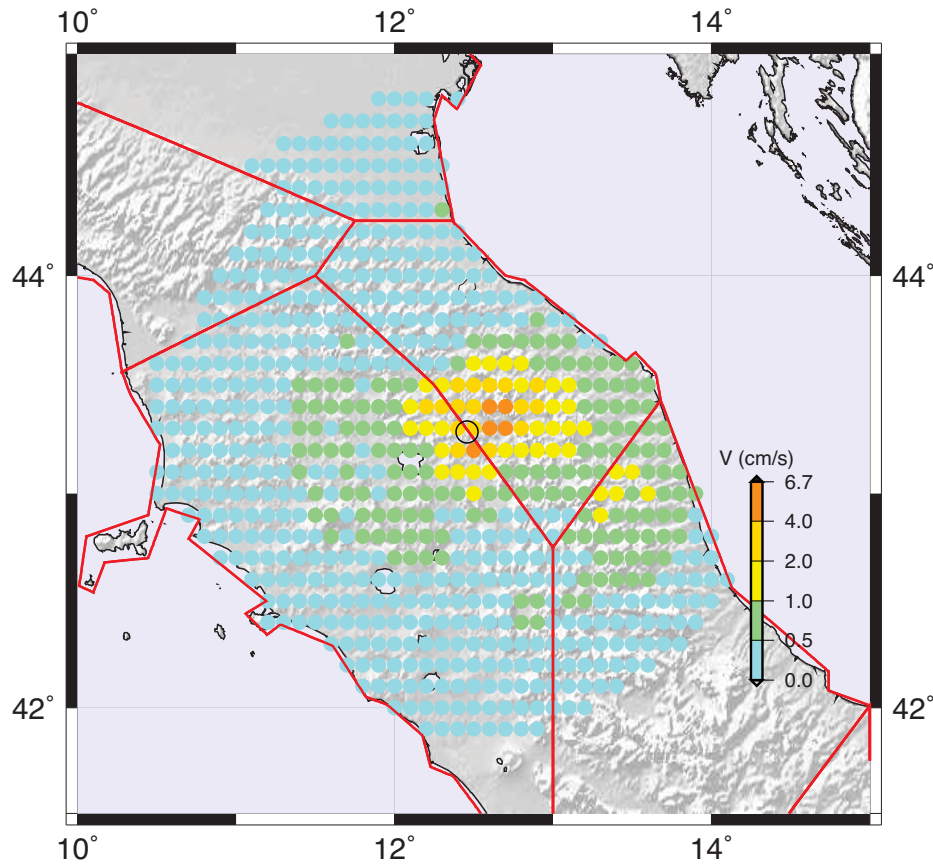


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# Local scale (bedrock) scenario - Directivity

Ground shaking scenario (velocity), directivity **south-east**



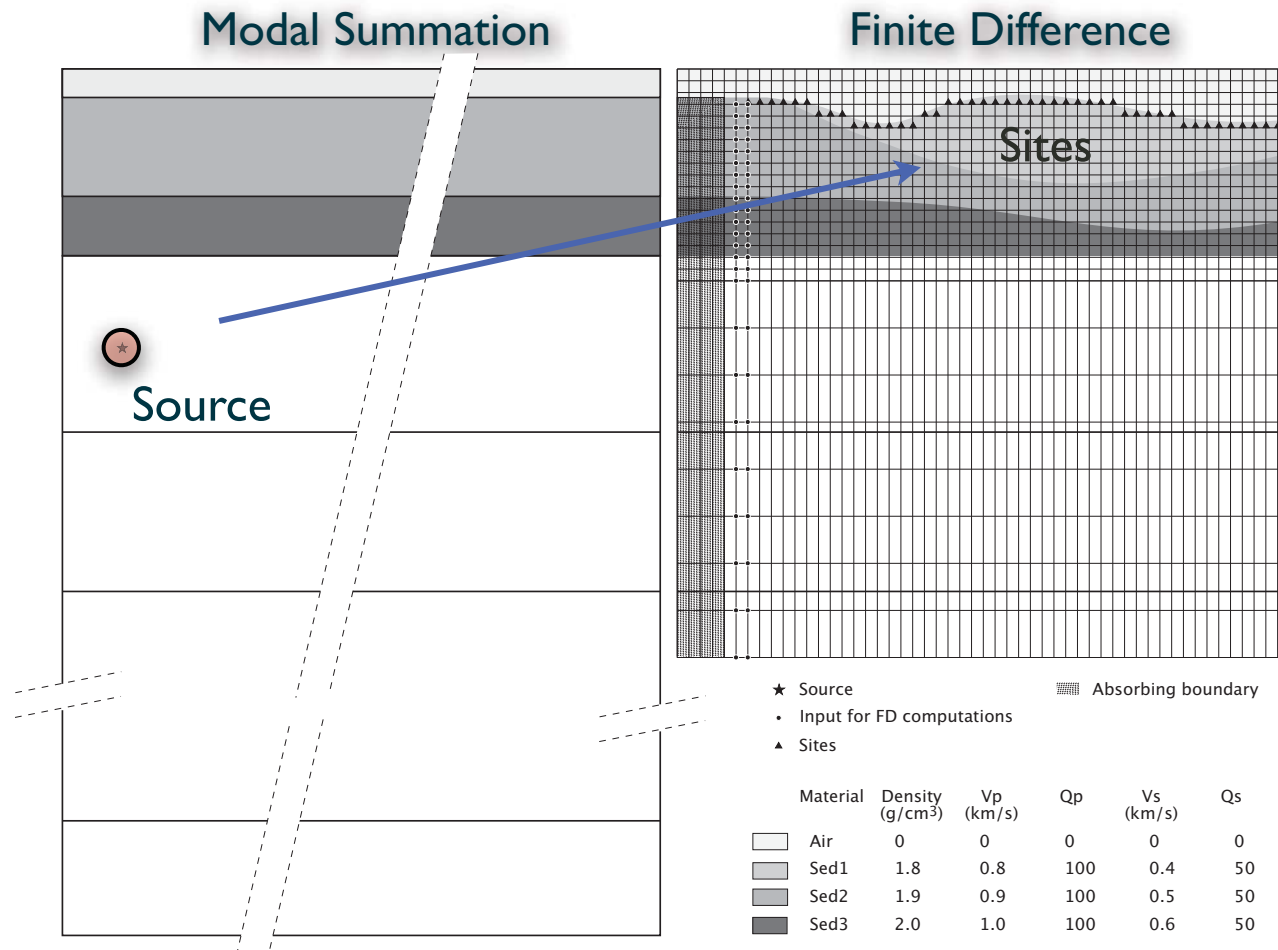
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# Hybrid technique - Structure (2D profiles)

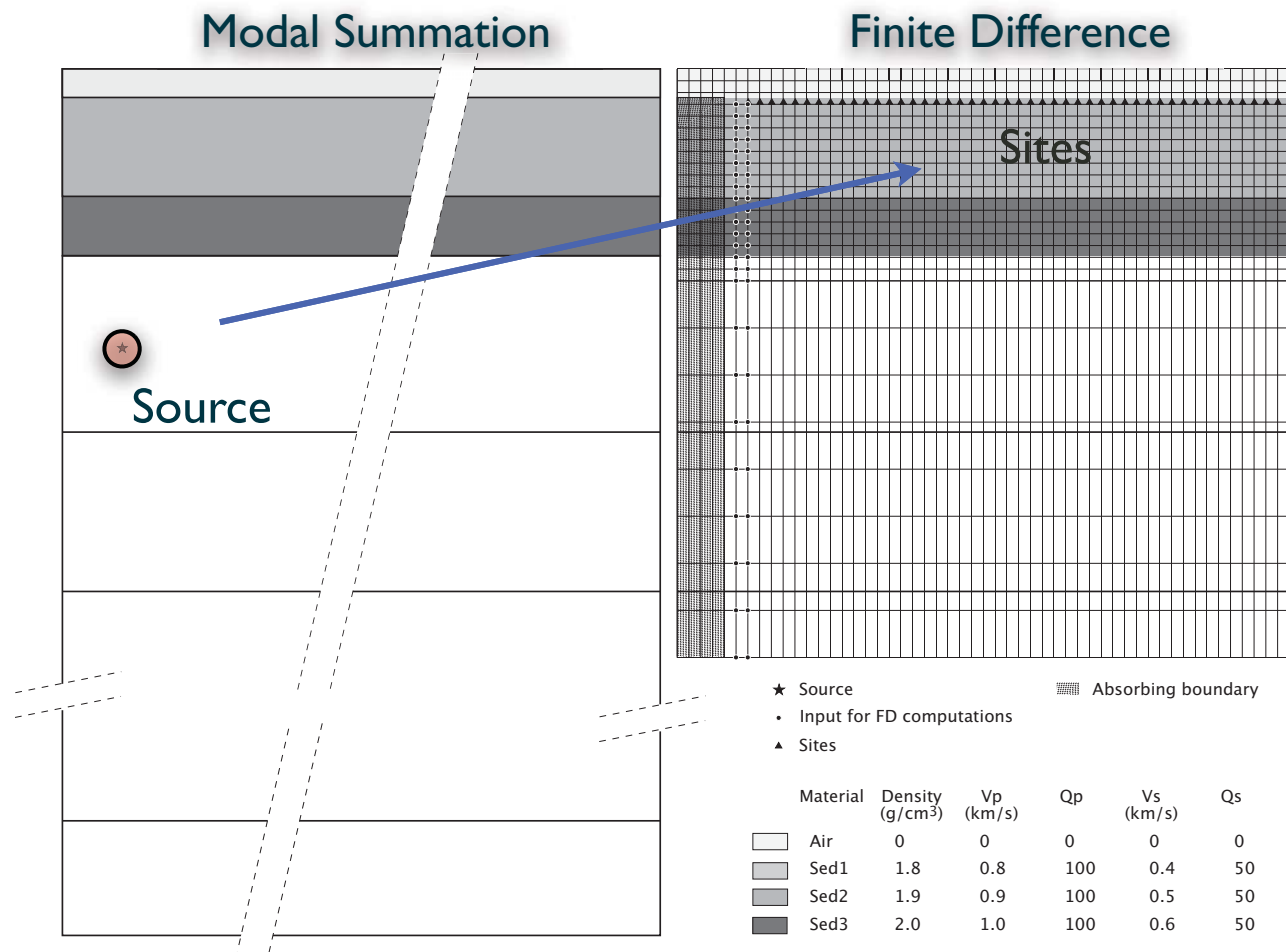
2D



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# Hybrid technique - Testing the model

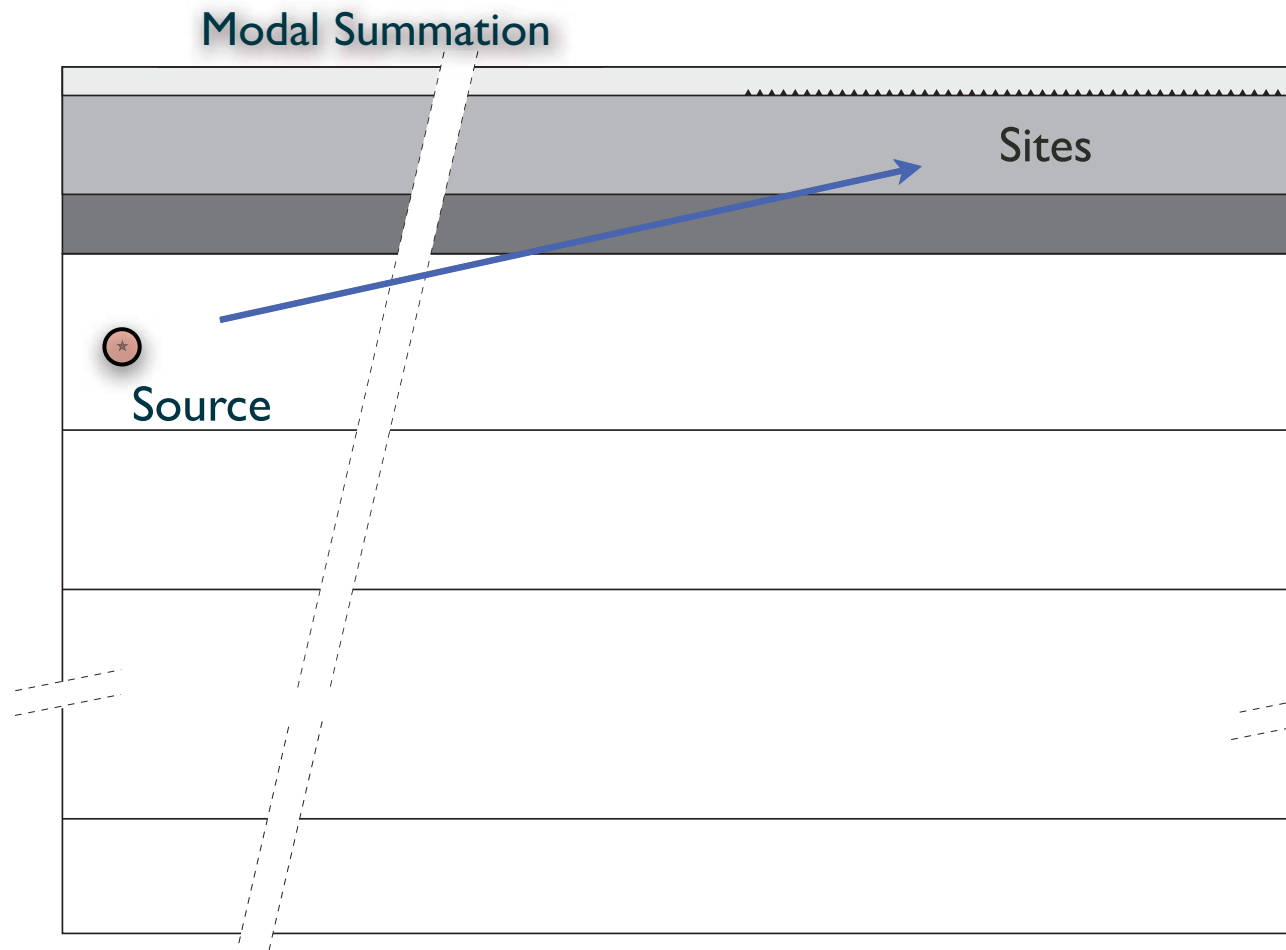
## ● ID HT



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# Hybrid technique - Testing the model

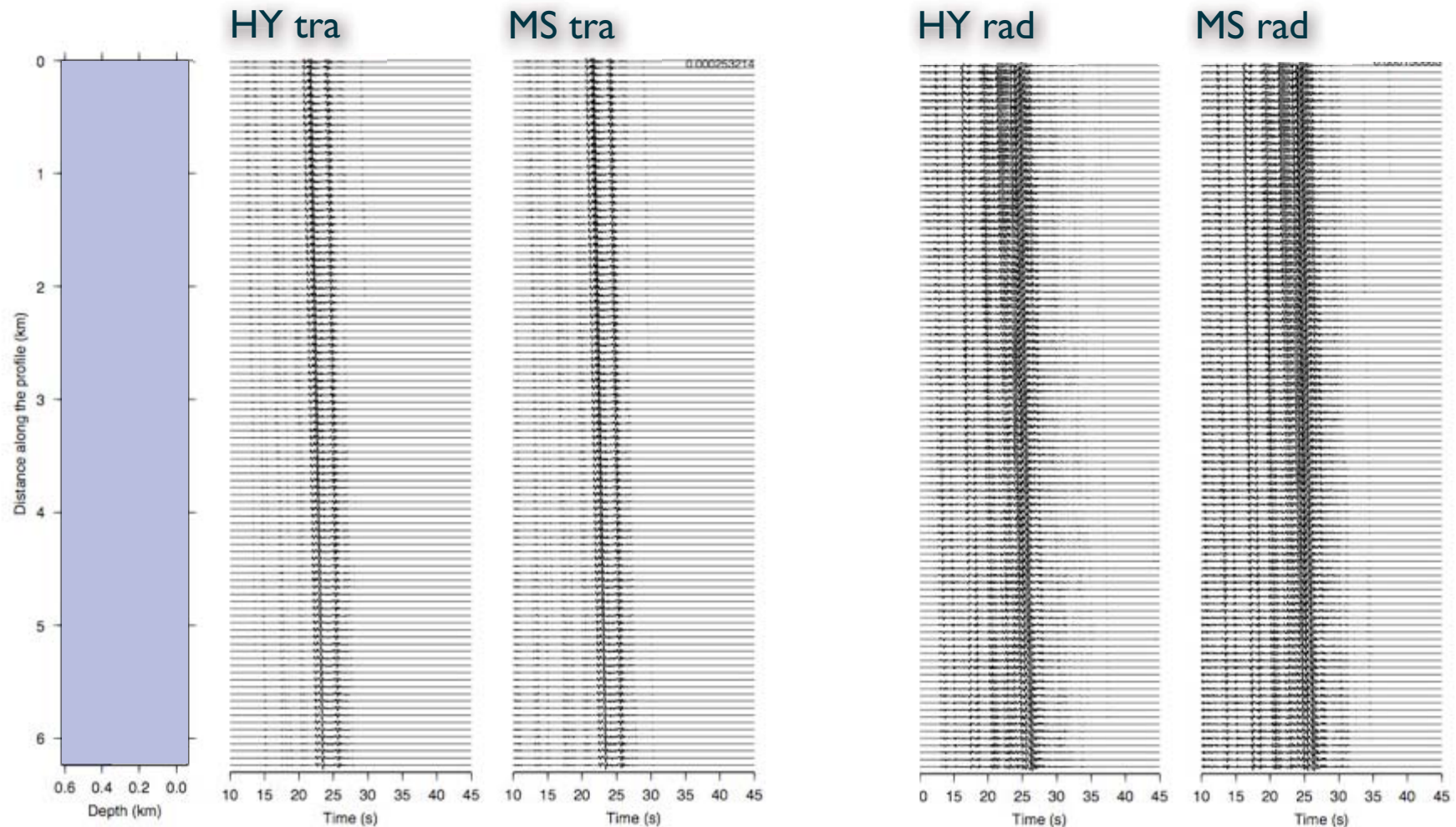
● ID MS



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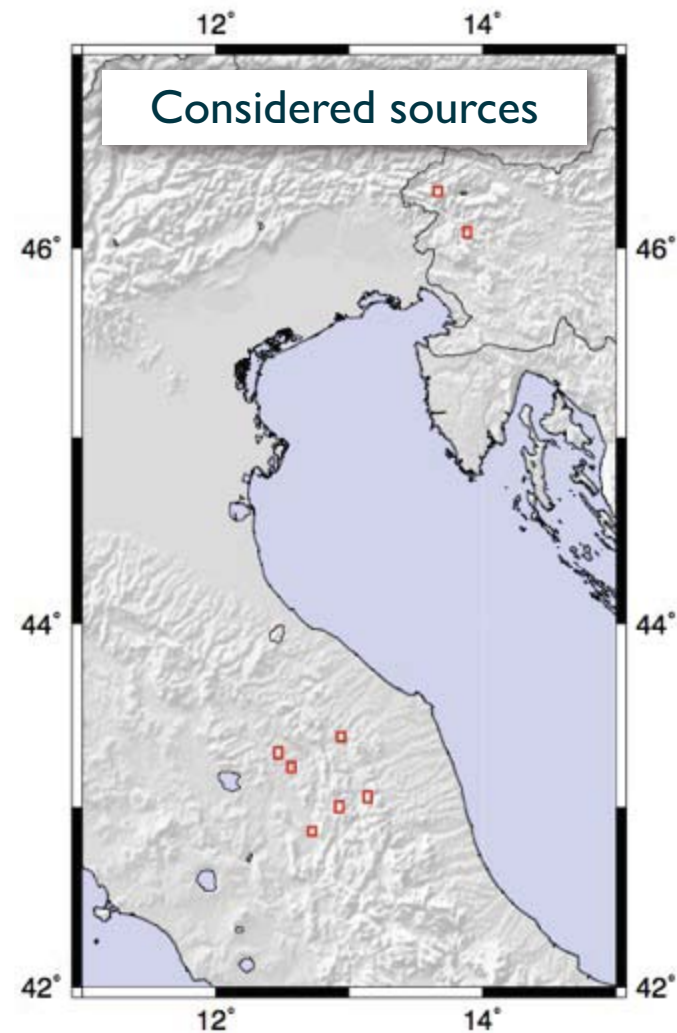
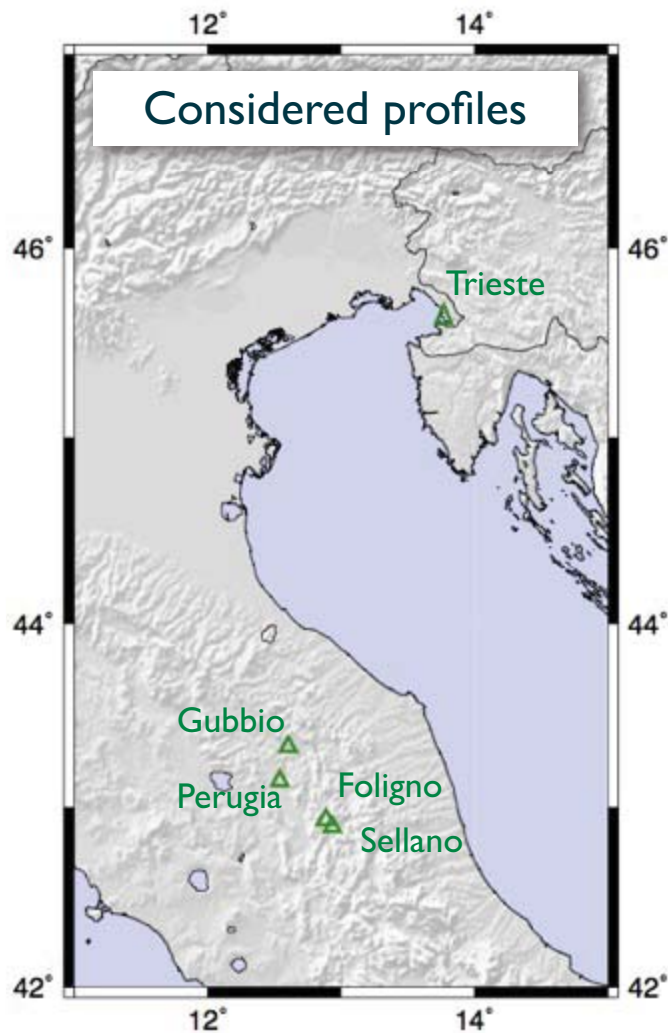
# Hybrid technique - Testing the model



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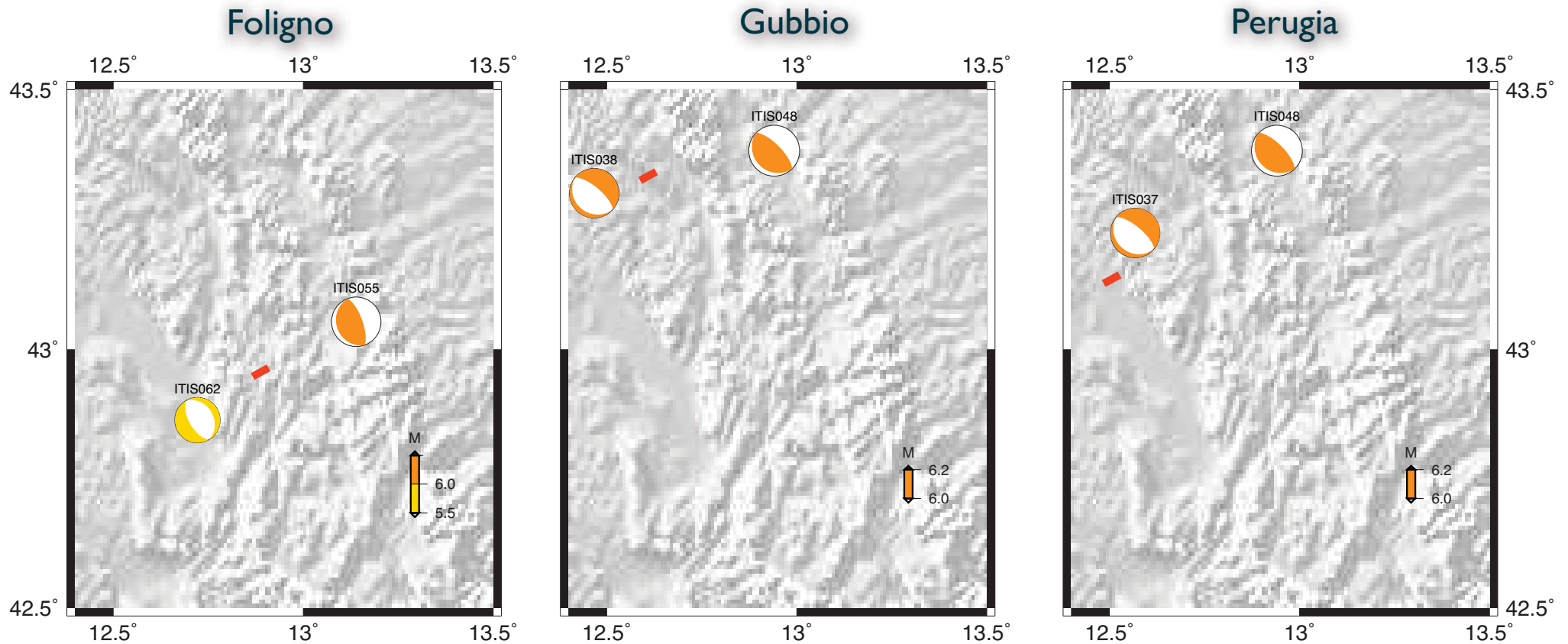


# Local scale (2D) - Selected sites



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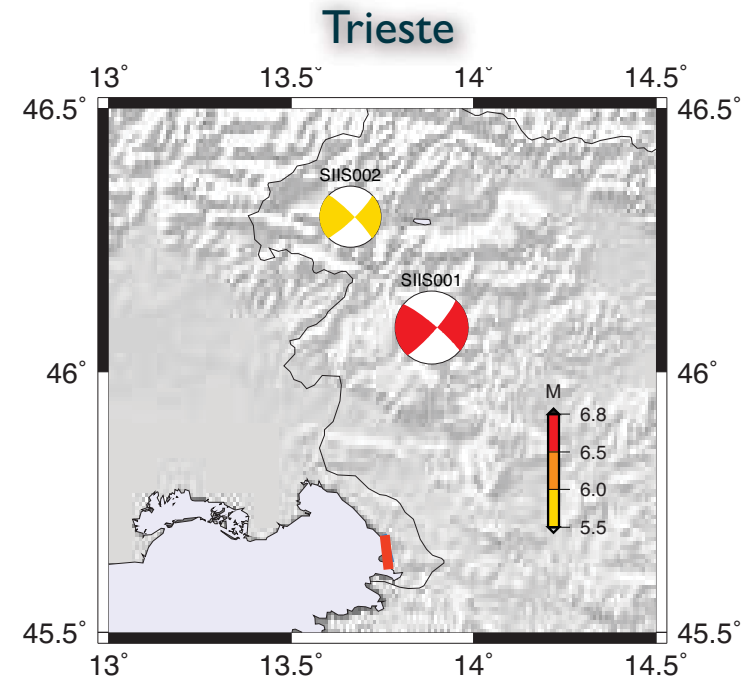
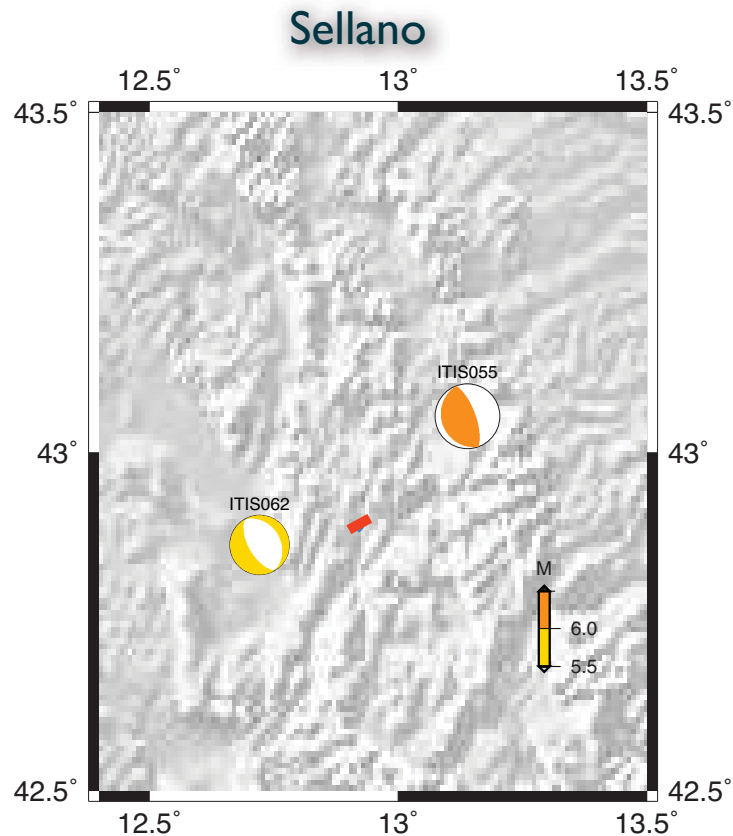
# Local scale (2D) - Selected profiles and sources



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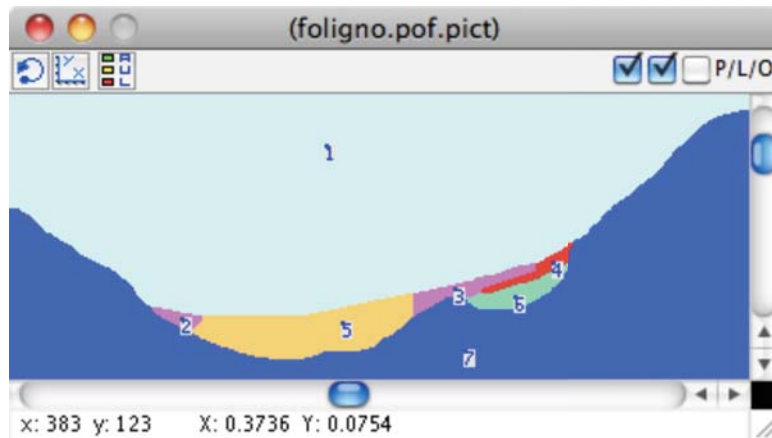
# Local scale (2D) - Selected profiles and sources



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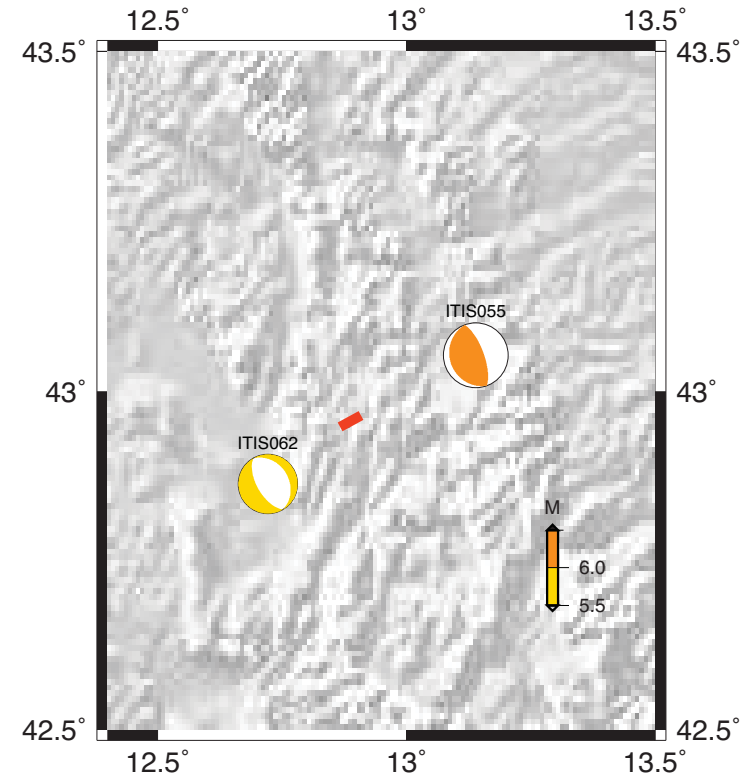
# Local scale (2D) - Foligno



(520x193 m)

(foligno.pof.pict) Legend

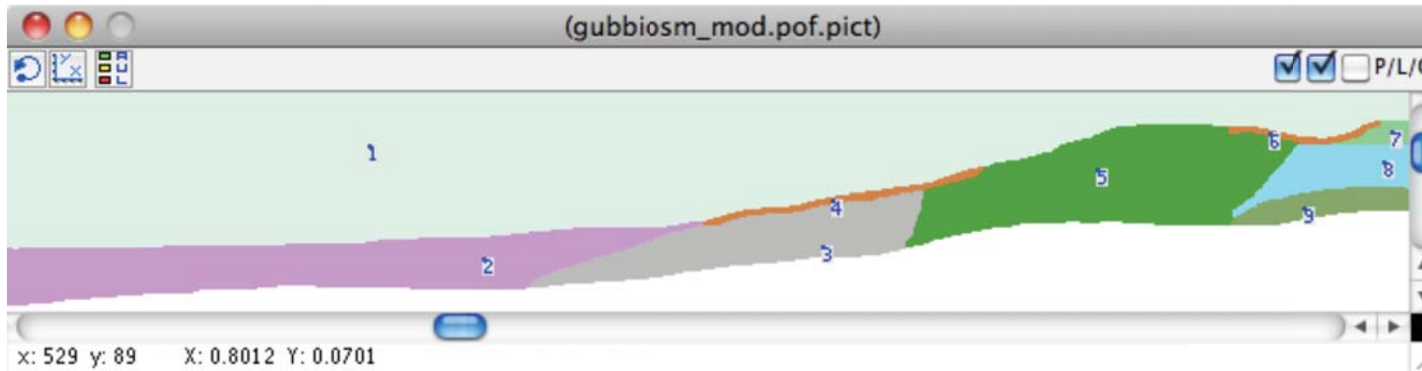
6 items	Descr.	Rho	Vp	Qp	Vs	Qs
	Aria					
	Colluvi	1.850	0.700	44.000	0.300	20.000
	Detriti	1.900	0.800	44.000	0.400	20.000
	Alluvioni	1.950	1.000	44.000	0.500	20.000
	Marne fuocoidi	2.100	2.000	220.000	1.200	100.0...
	Calcare rupestre	2.300	2.650	220.000	1.400	100.0...



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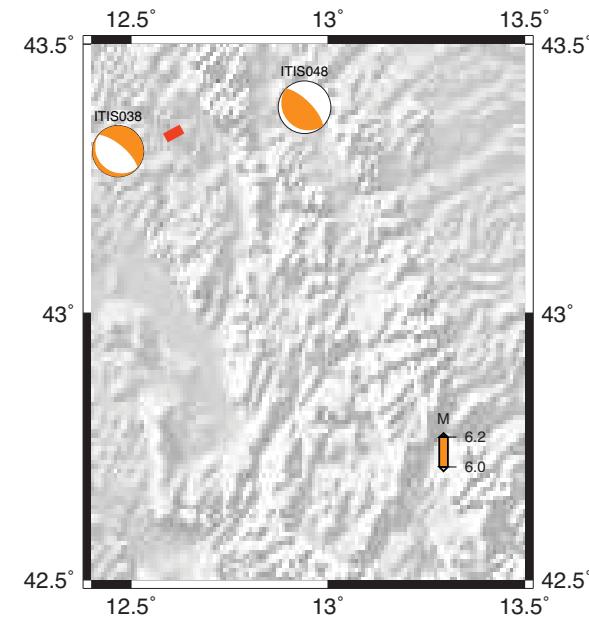
# Local scale (2D) - Gubbio



(1200x160 m)

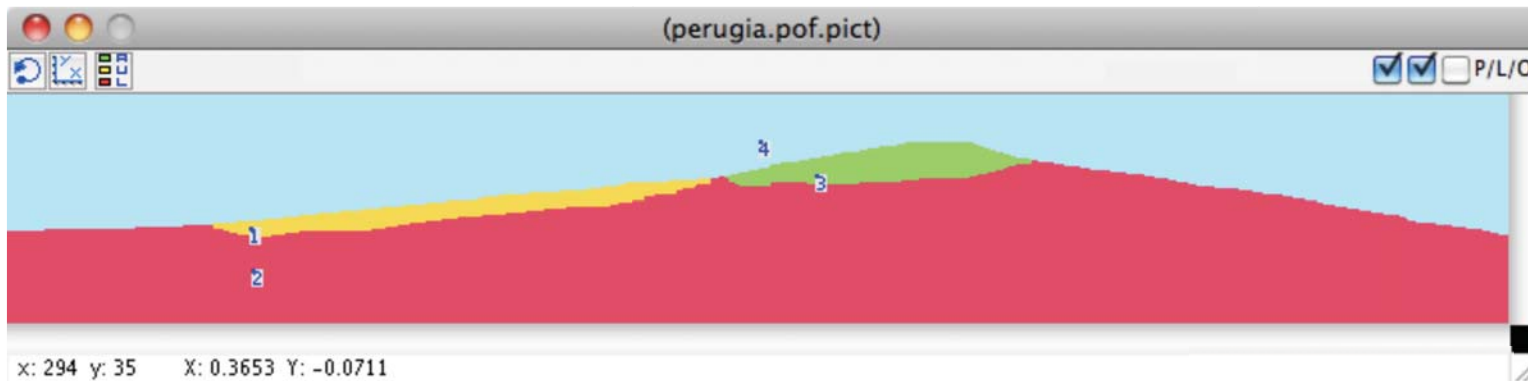
(gubbiosm\_mod.pof.pict) Legend

8 items	Descr.	Rho	Vp	Qp	Vs	Qs
	Air					
	drr	1.850	0.700	44.000	0.350	20.000
	detriti	1.900	0.800	44.000	0.400	20.000
	ter	1.800	0.600	66.000	0.300	30.000
	ma	2.400	2.500	220.000	1.500	100.0...
	sc	2.000	1.800	220.000	1.000	100.0...
	sv	2.100	2.000	220.000	1.200	100.0...
	sr	2.400	2.500	220.000	1.500	100.0...



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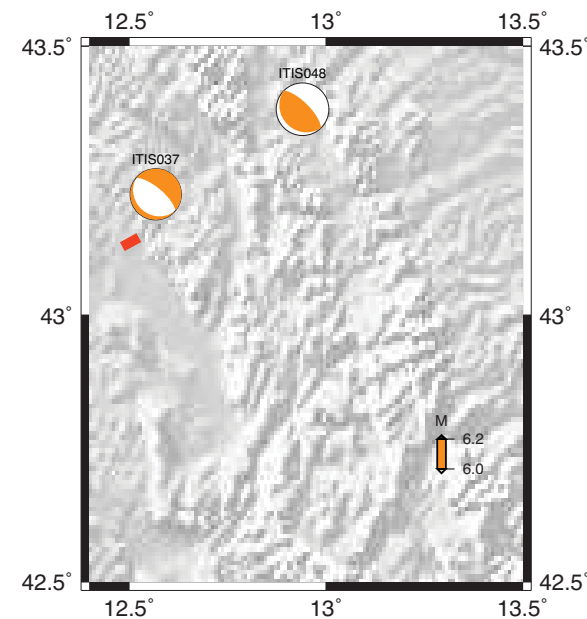
# Local scale (2D) - Perugia



(930x200 m)

(perugia.pof.pict) Legend

4 items	Descr.	Rho	Vp	Qp	Vs	Qs
	frana	1.600	0.600	220.0...	0.400	100.0...
	argille	1.950	1.900	220.0...	0.950	100.0...
	conglomerati	2.000	1.200	220.0...	0.700	100.0...
	aria	---	---	---	---	---

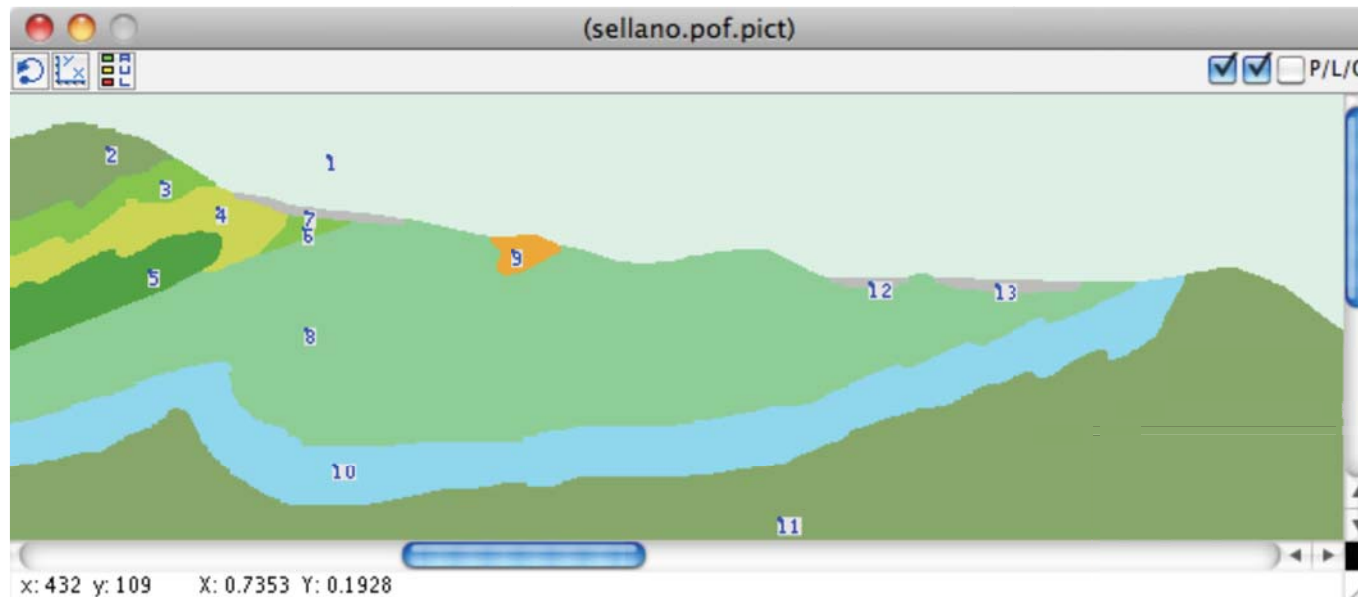


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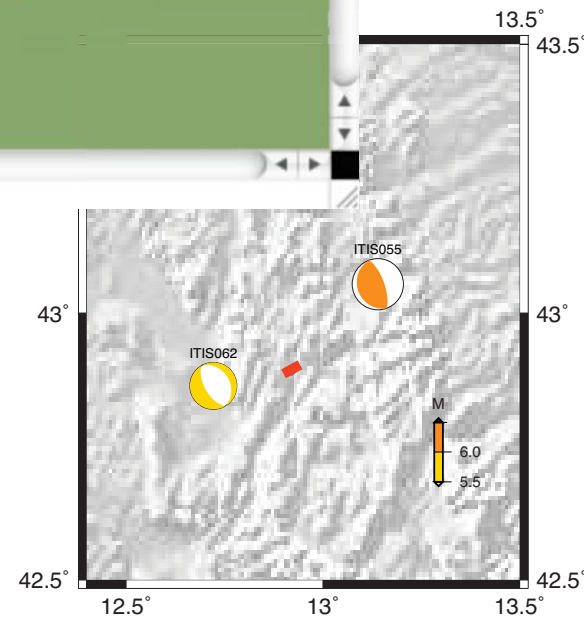
# Local scale (2D) - Sellano



(1170x365 m)

(sellano.pof.pict) Legend

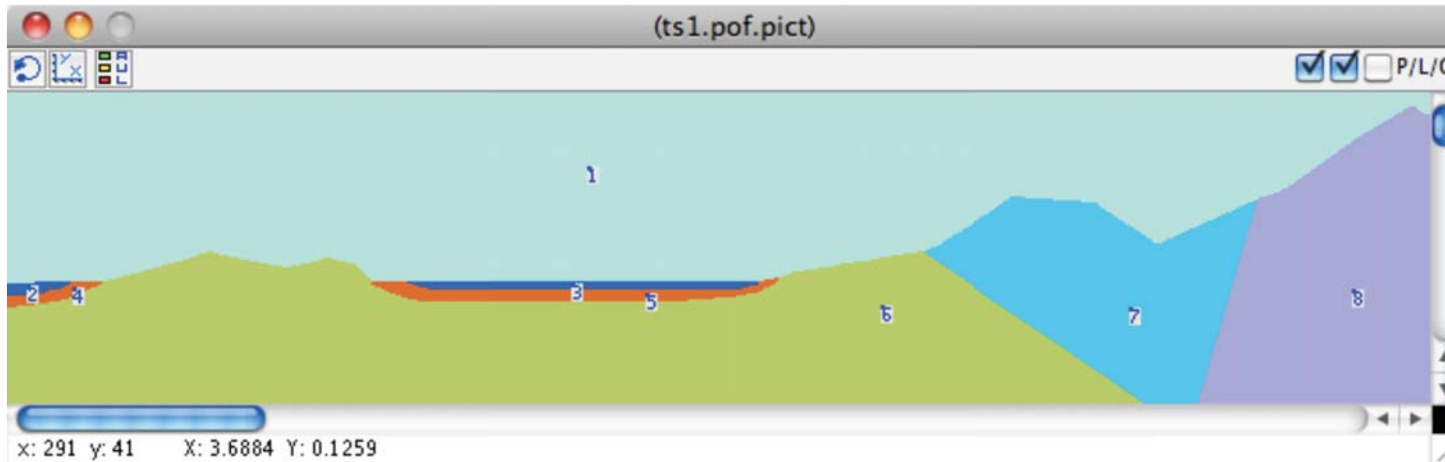
9 items	Descr.	Rho	Vp	Qp	Vs	Qs
	Air					
	sr	2.400	2.500	220.000	1.500	100.0...
	sb	2.300	2.300	220.000	1.300	100.0...
	MF	2.100	2.000	220.000	1.200	100.0...
	ma	2.400	2.500	220.000	1.500	100.0...
	detriti	1.900	0.800	44.000	0.400	20.000
	sc	2.000	1.800	220.000	1.000	100.0...
	bi	2.100	2.000	220.000	1.200	100.0...
	sv	2.100	2.000	220.000	1.200	100.0...



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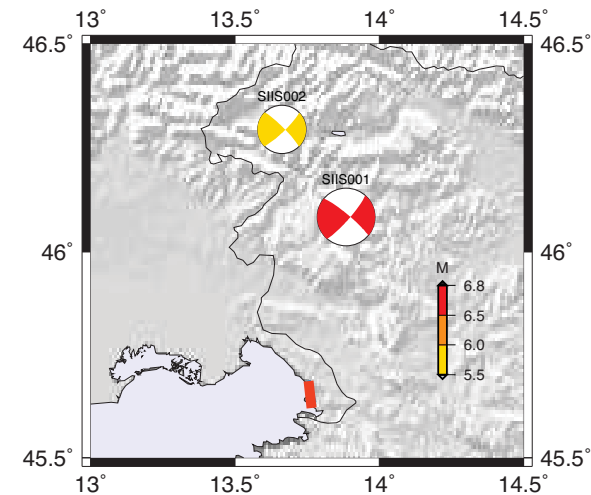
# Local scale (2D) - Trieste



(6250x617 m)

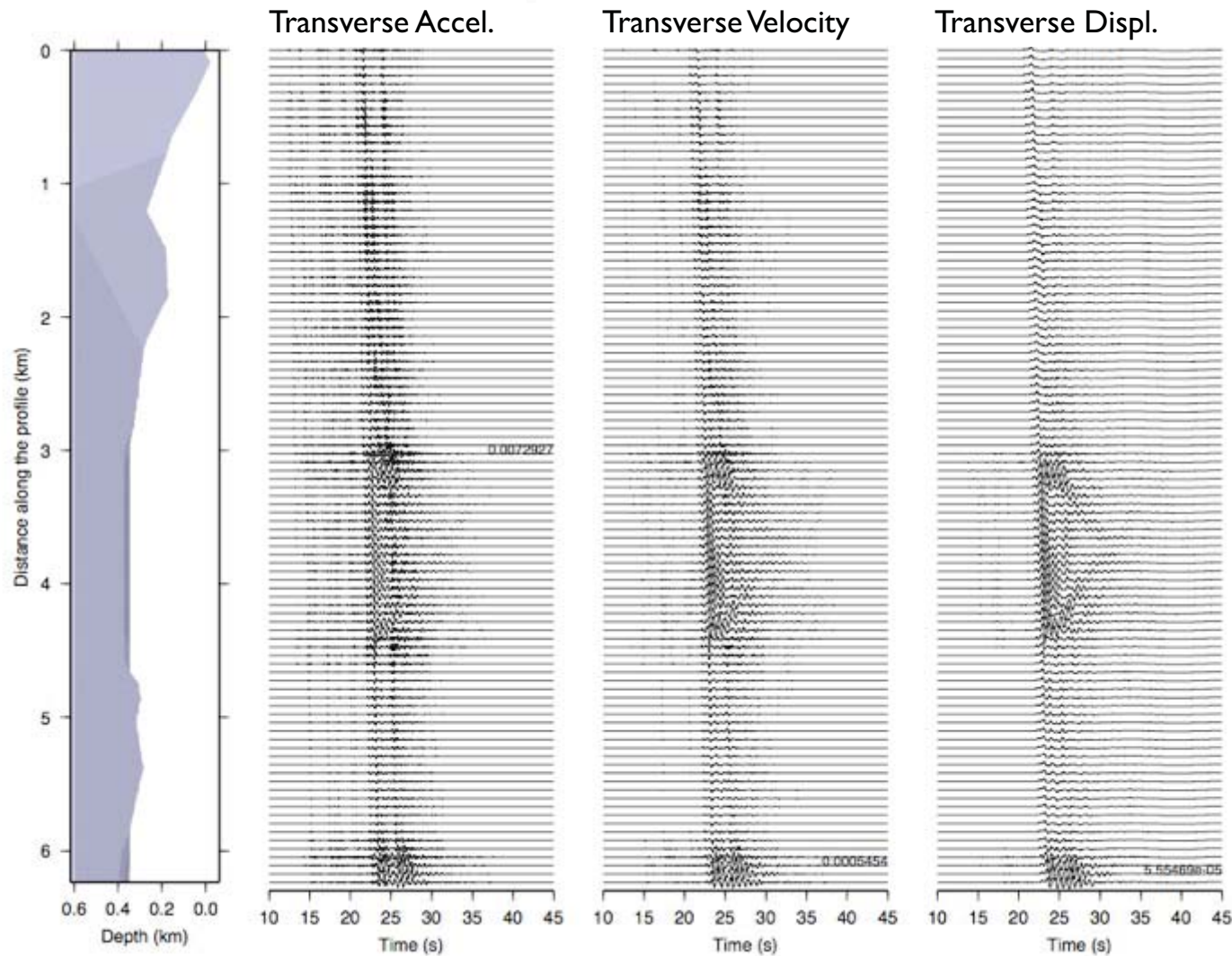
(ts1.pof.pict) Legend

6 items	Descr.	Rho	Vp	Qp	Vs	Qs
	Aria					
	Riporti	1.800	0.420	30.000	0.200	15.000
	Sed. marini	1.900	0.800	40.000	0.400	20.000
	Flysch	2.000	1.800	100.000	1.000	50.000
	Arenarie	2.100	2.000	200.000	1.200	100.0...
	Calcari	2.300	2.500	200.000	1.400	100.0...



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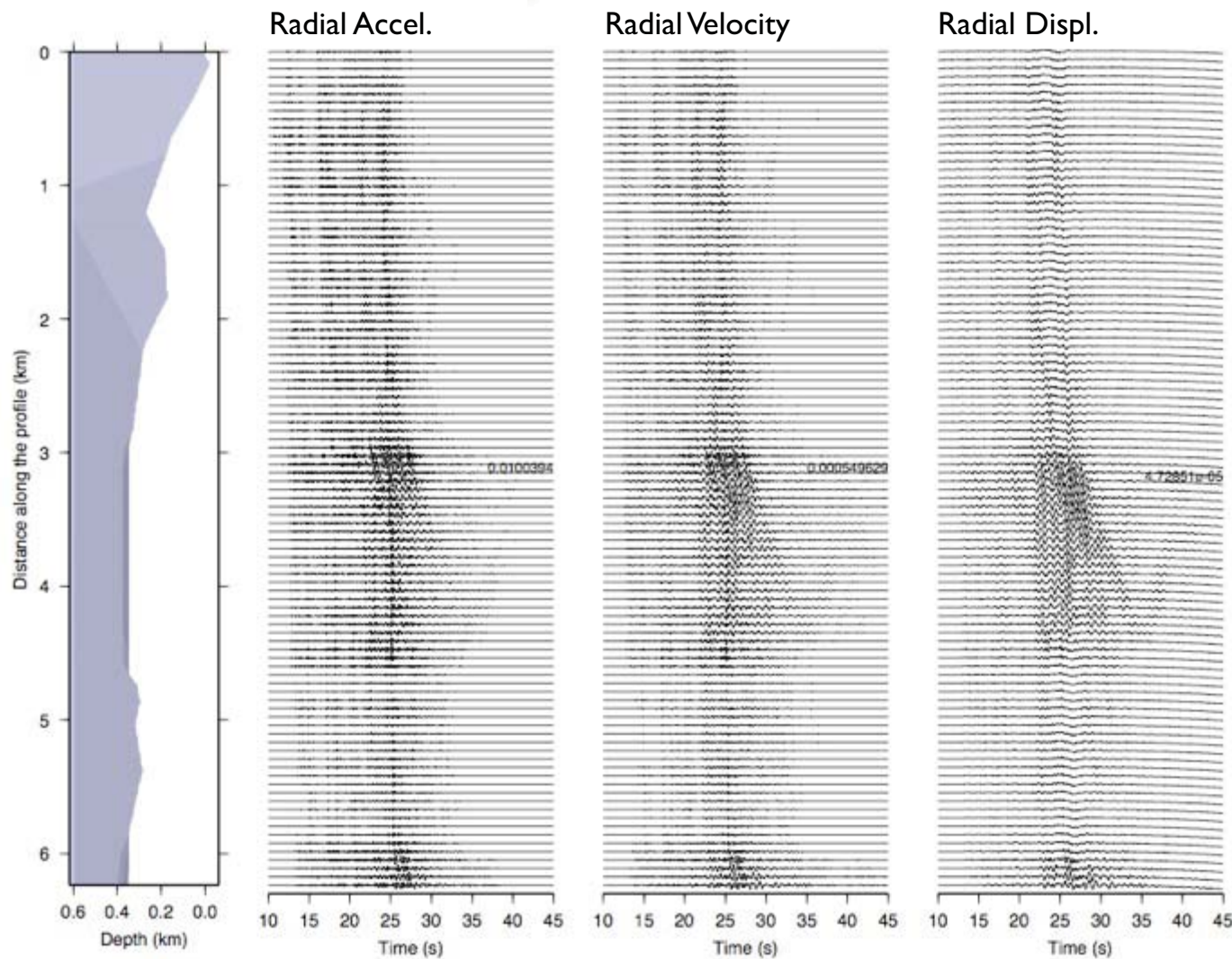
# Local scale (2D) - Trieste



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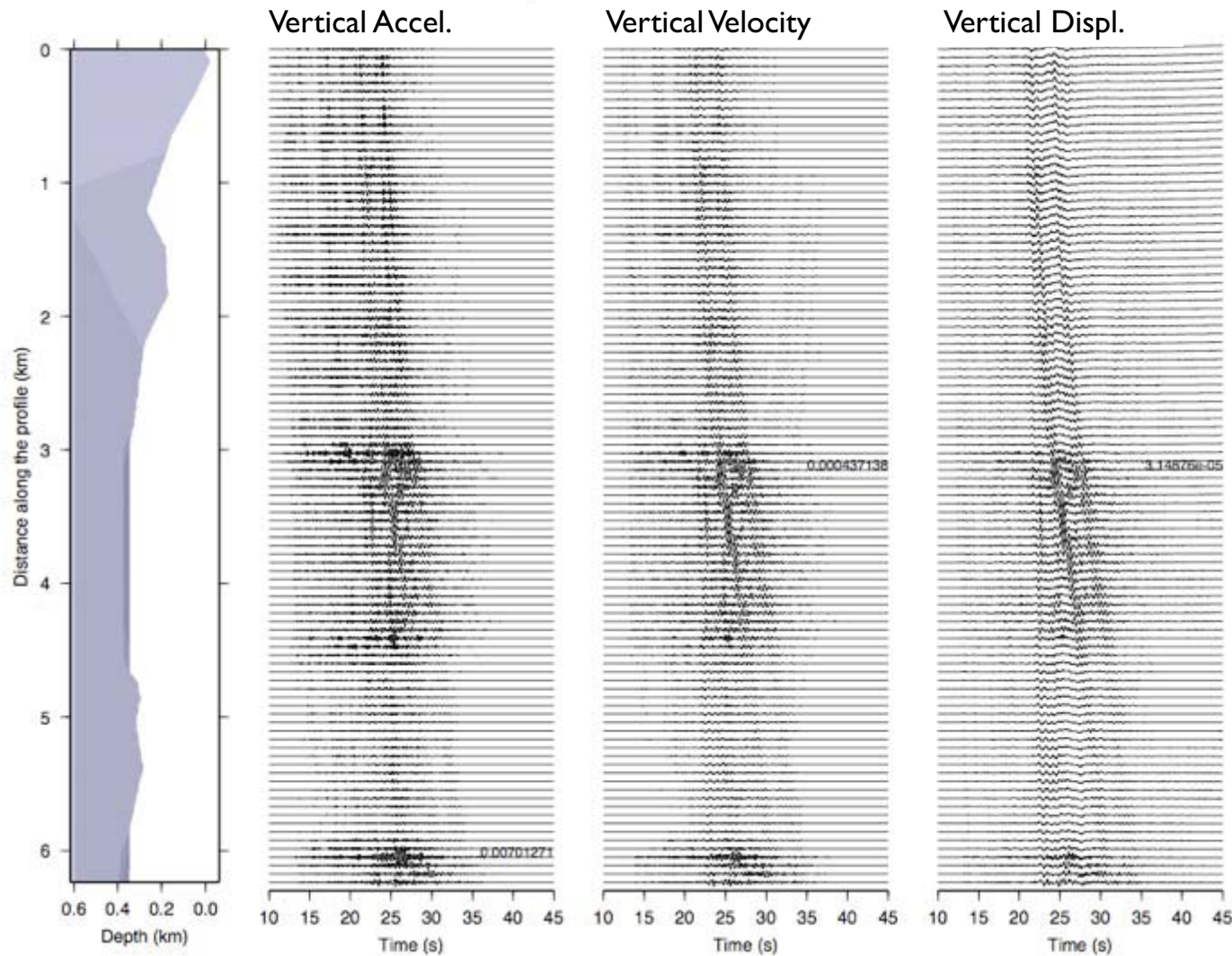
# Local scale (2D) - Trieste



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# Local scale (2D) - Trieste

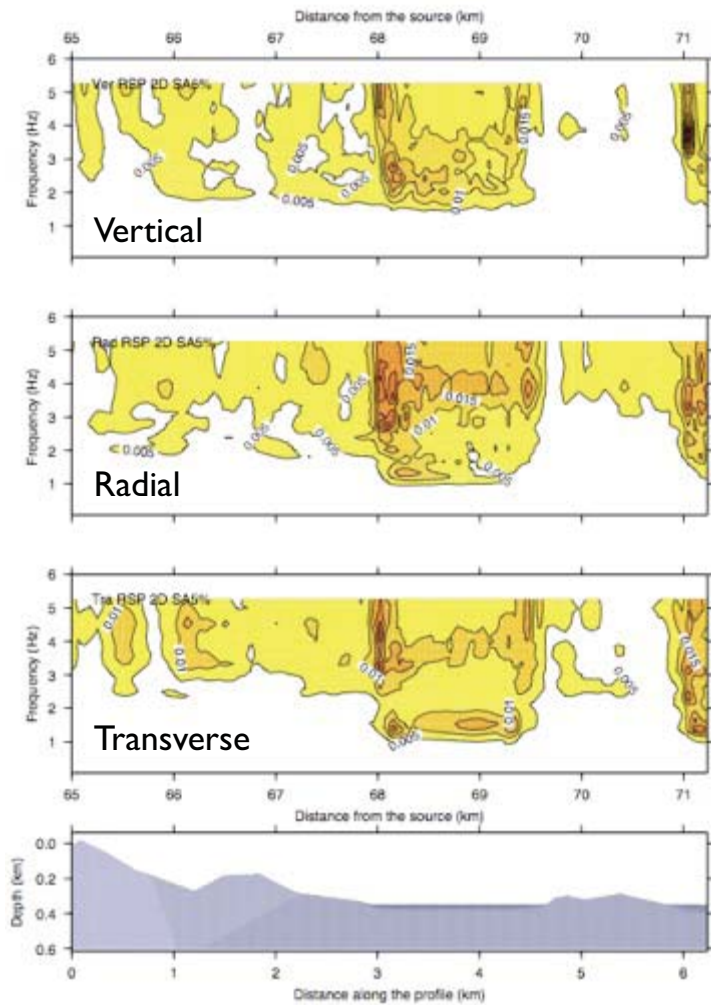


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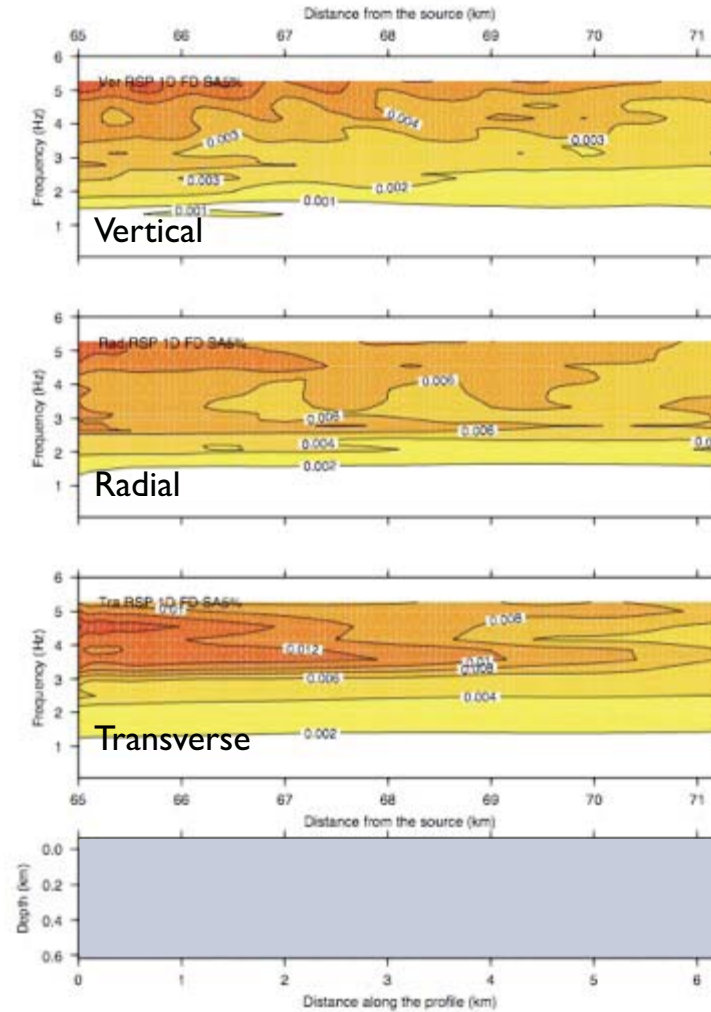


# Local scale (2D) - Trieste

2D Response Spectra



1D Response Spectra

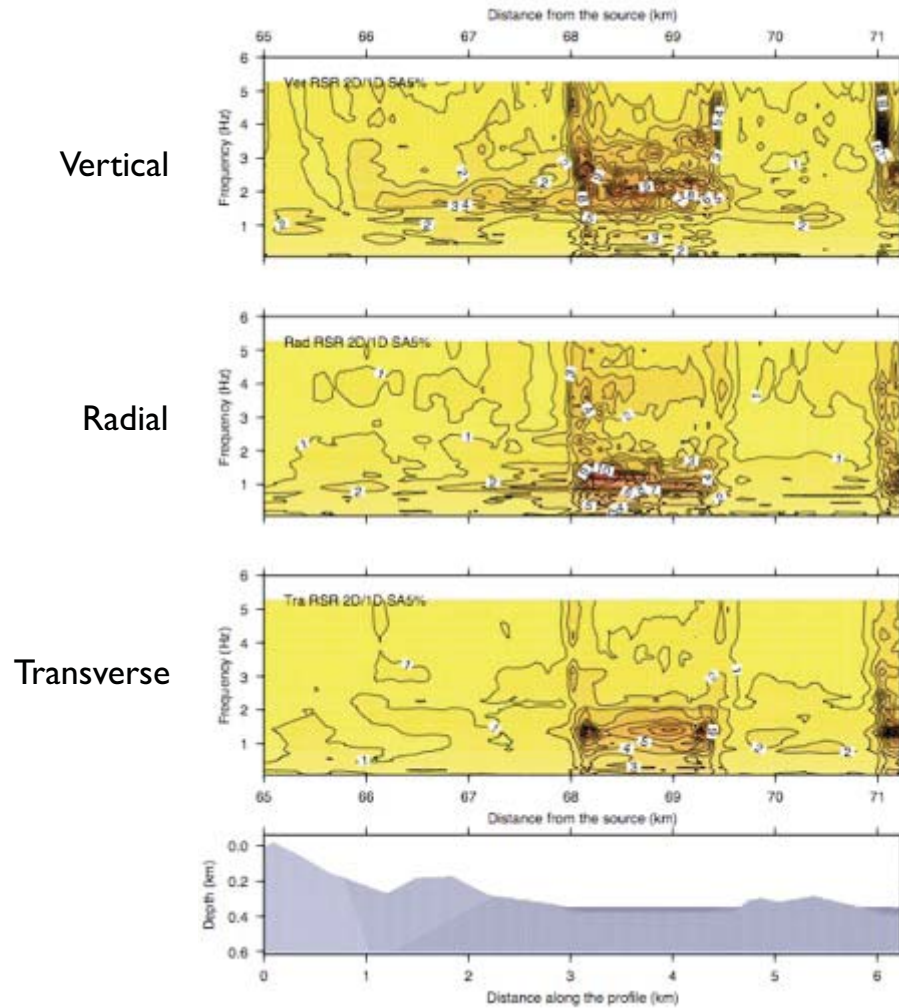


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# Local scale (2D) - Trieste

2D/1D Response Spectra Ratios (Amplifications)



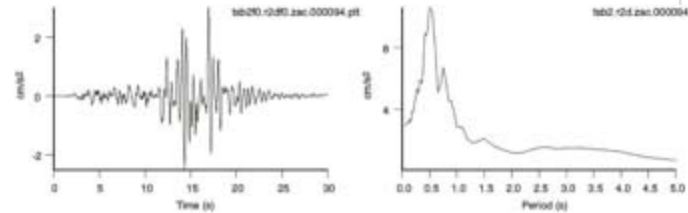
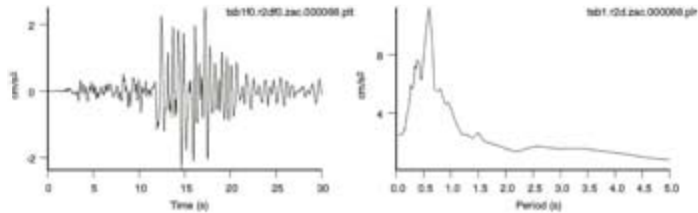
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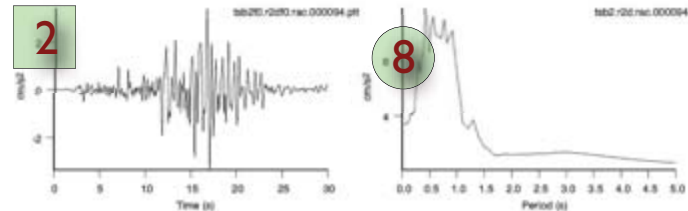
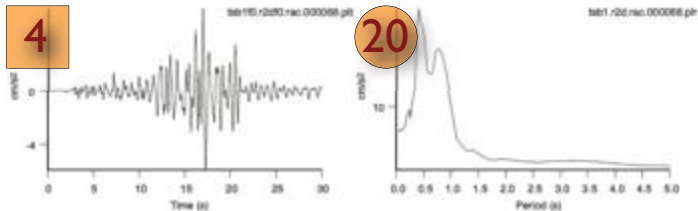
# Local scale (2D) - Trieste

Path effect at the same site

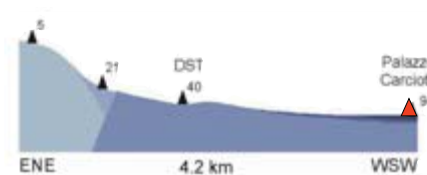
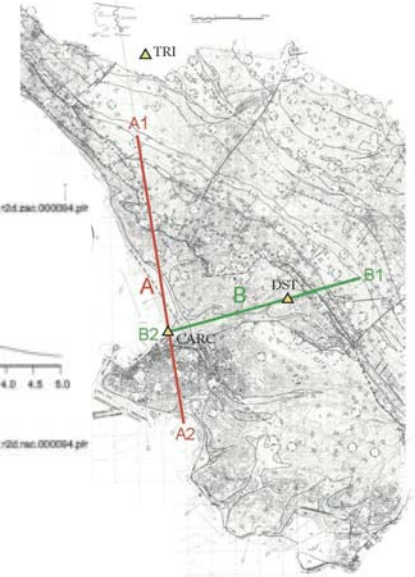
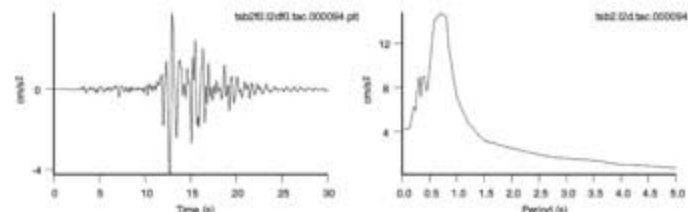
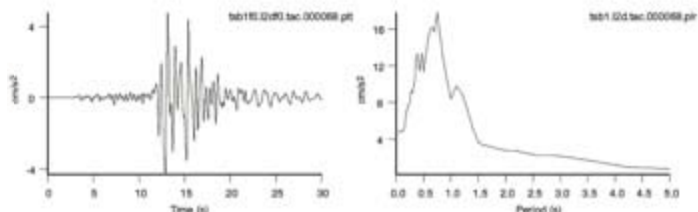
Z



R



T

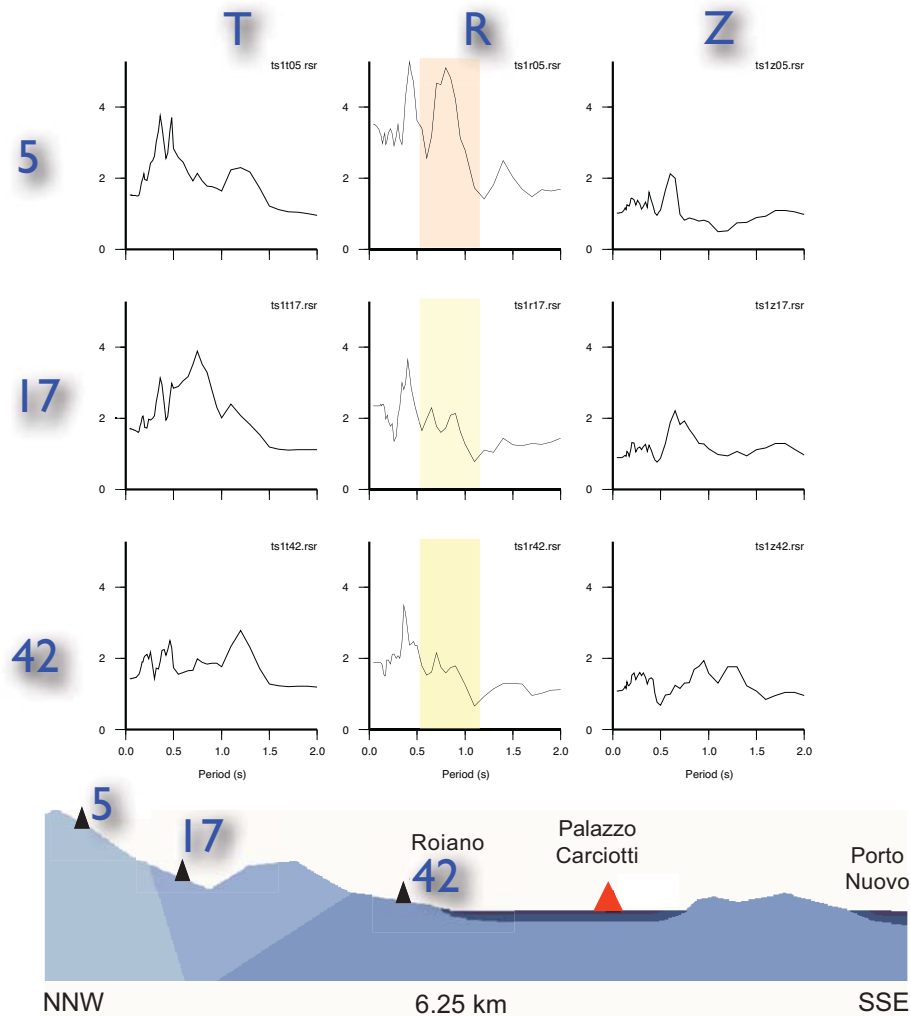


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# Local scale (2D) - Trieste

Choice of the reference site for amplification estimate

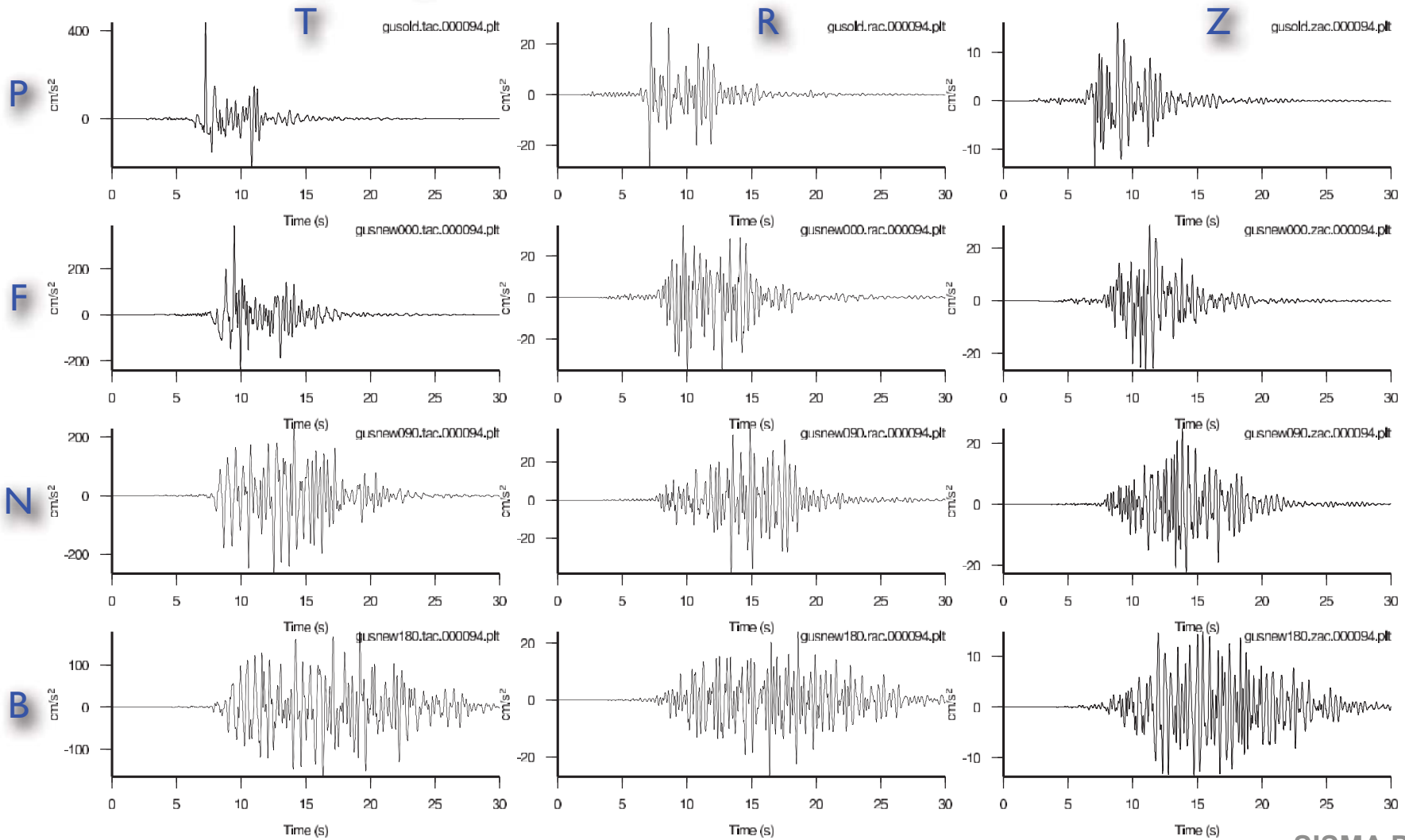


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# Local scale (2D) - Trieste

Directivity effects

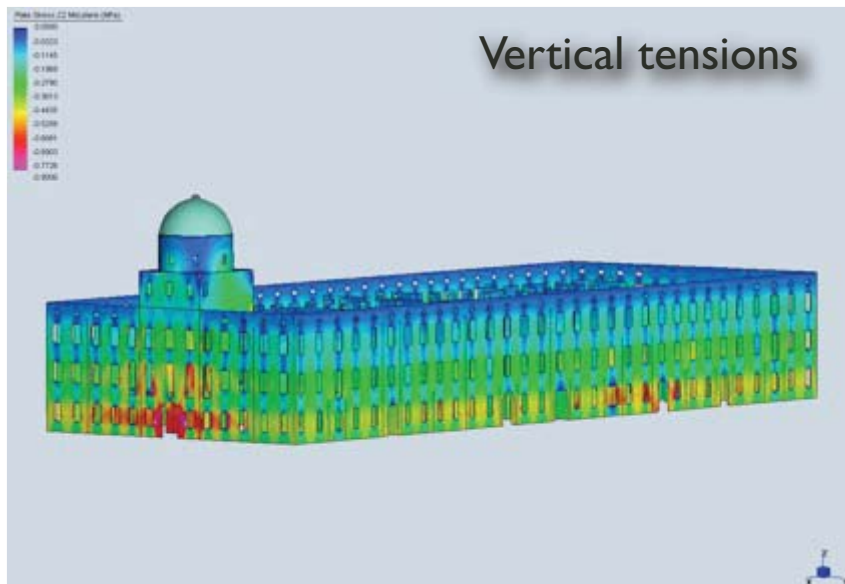


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# Local scale (2D) - Engineering Analysis

- The data set of synthetic seismograms can be used and analysed by civil engineers for design and reinforcement actions, and therefore supply a particularly powerful and economical tool for the prevention aspects of Civil Defence.



Palazzo Carciotti  
(masonry)

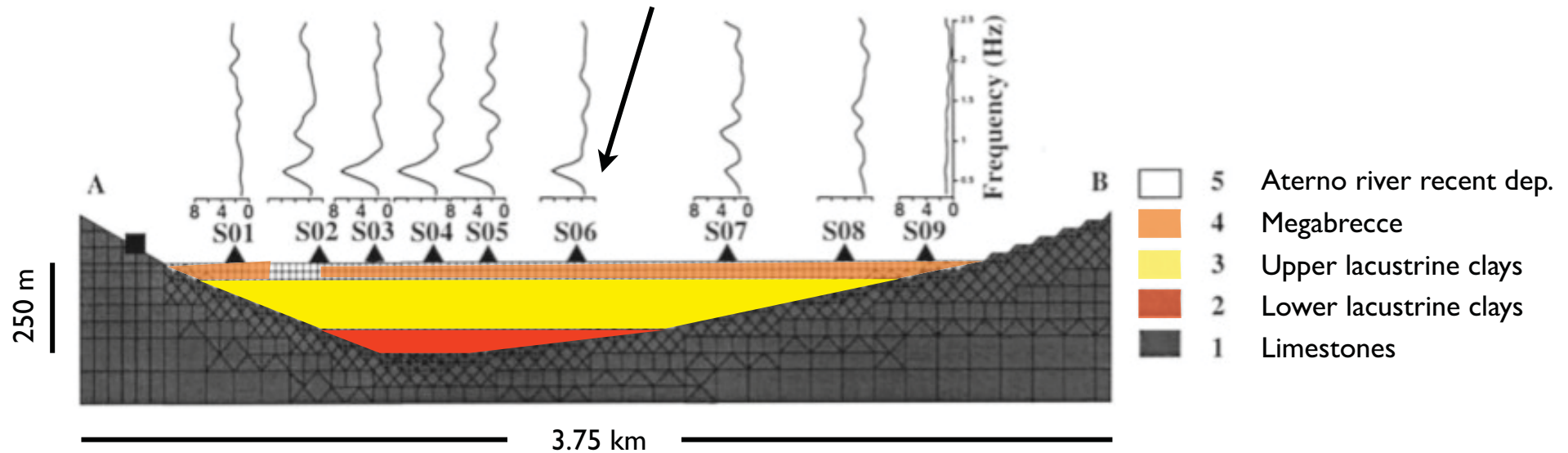


- Evaluate the response of relevant man-made structures, in terms of displacements and stresses, with respect to a set of possible scenario earthquakes

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# About H/V (L'Aquila) - H/V amplification

## Amplifications at 0.6 Hz



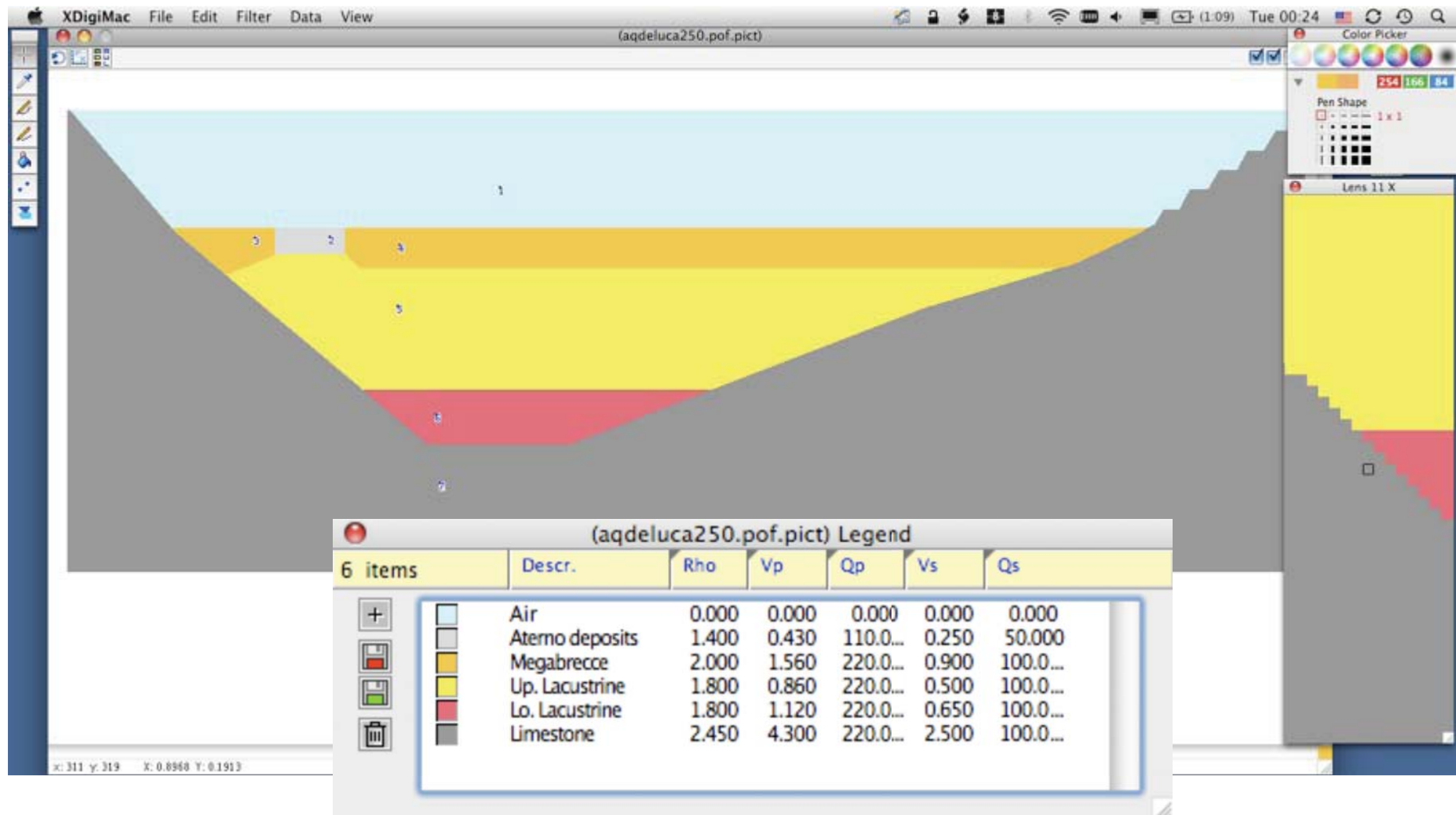
G. De Luca, S. Marcucci, G. Milana, and T. Sandò

*Evidence of Low-Frequency Amplification in the City of L'Aquila, Central Italy, through a Multidisciplinary Approach*

Bulletin of the Seismological Society of America, Vol. 95, No. 4, pp. 1469–1481, August 2005.

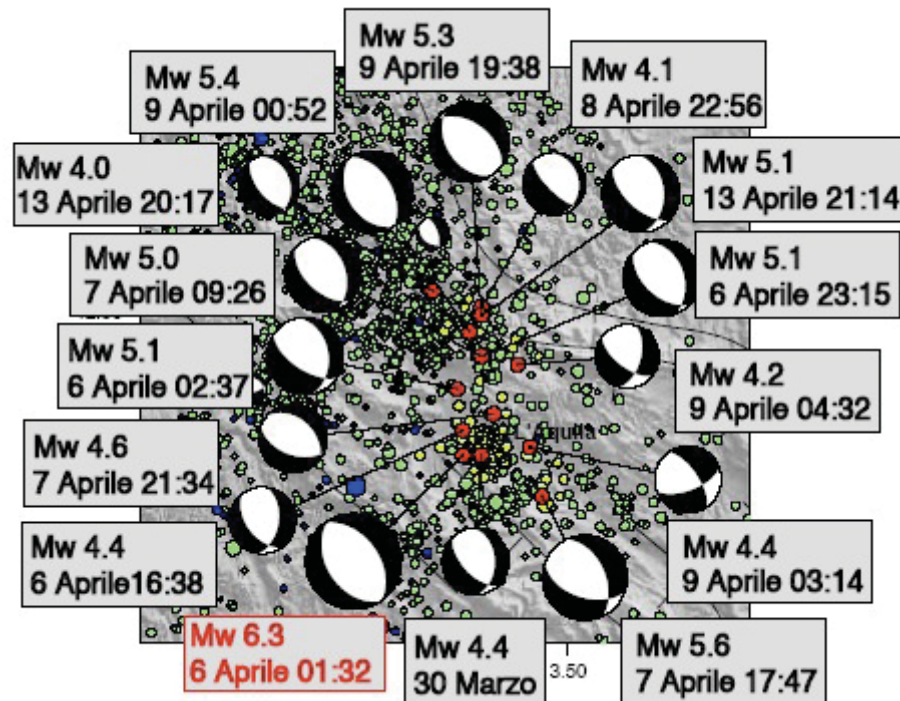
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# About H/V (L'Aquila) - Model



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# About H/V (L'Aquila) - Mechanism



Source: INGV

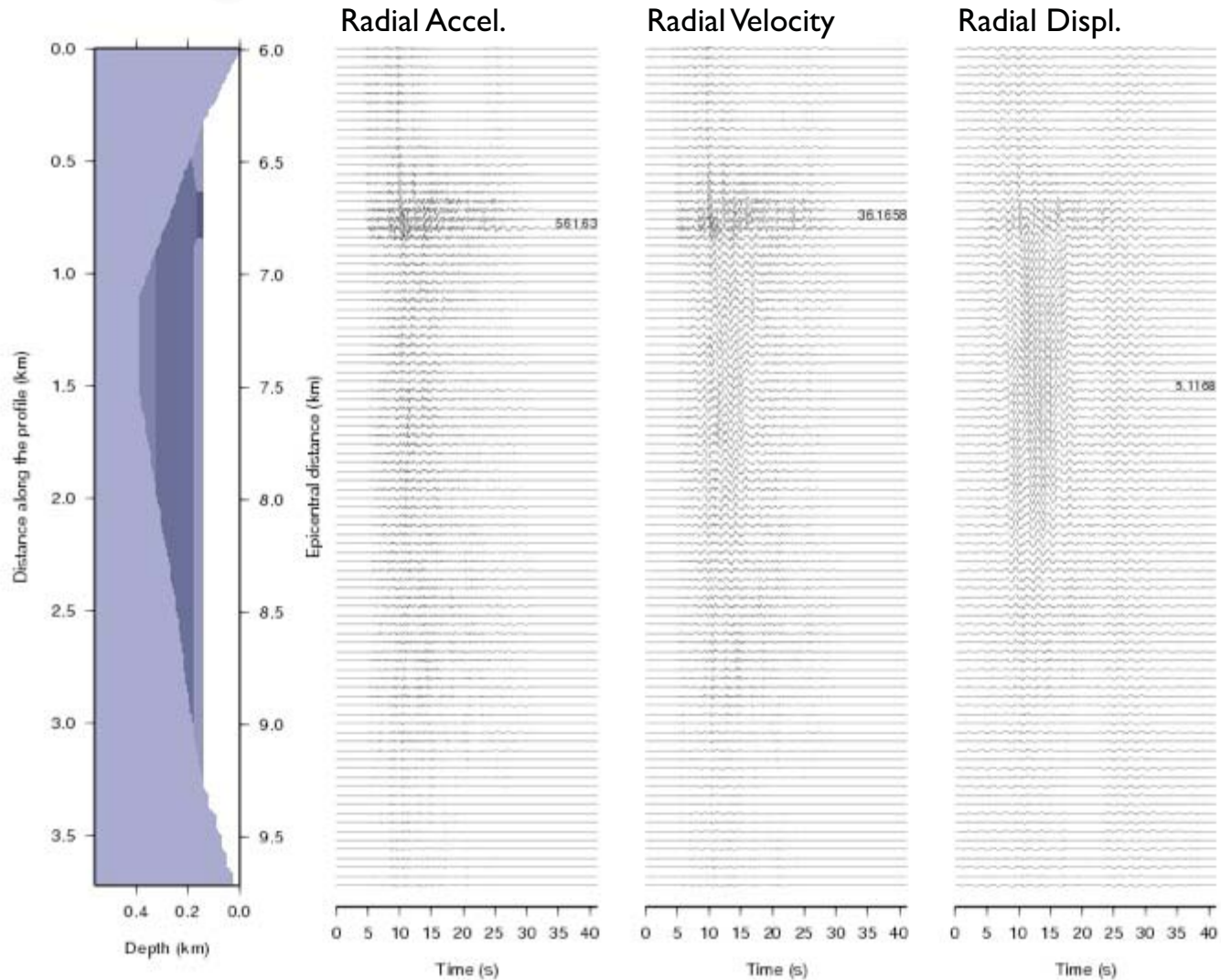
<http://portale.ingv.it/primo-piano/archivio-primo-piano/notizie2009/terremoto-6-aprile/meccanismi-focali>

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# About H/V (L'Aquila) - Radial component

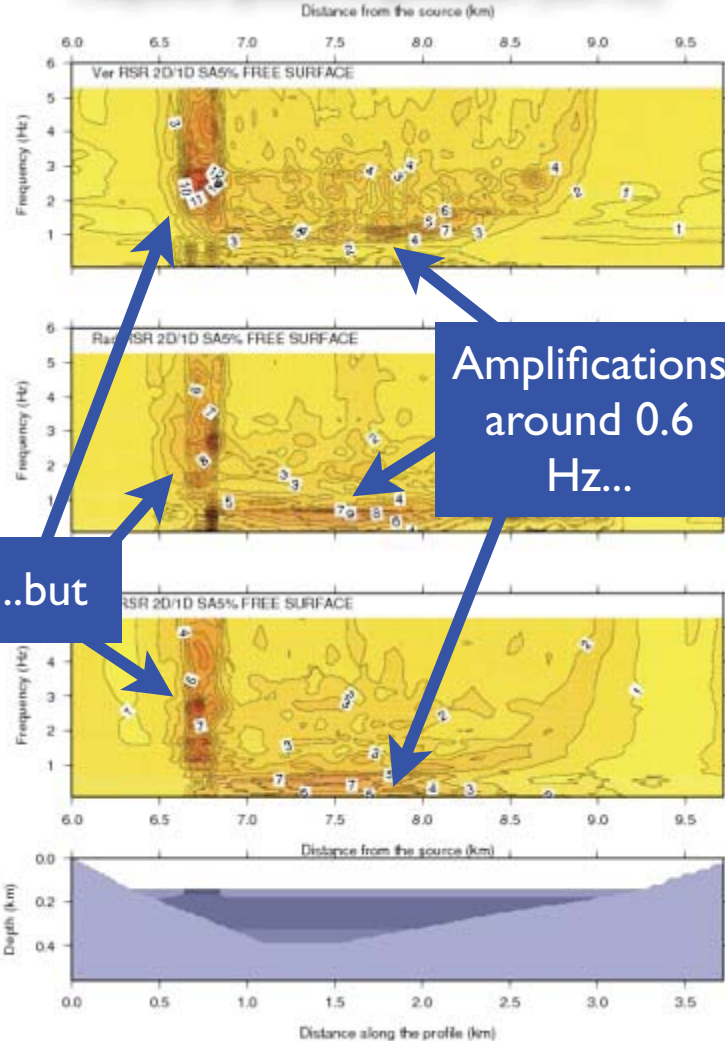


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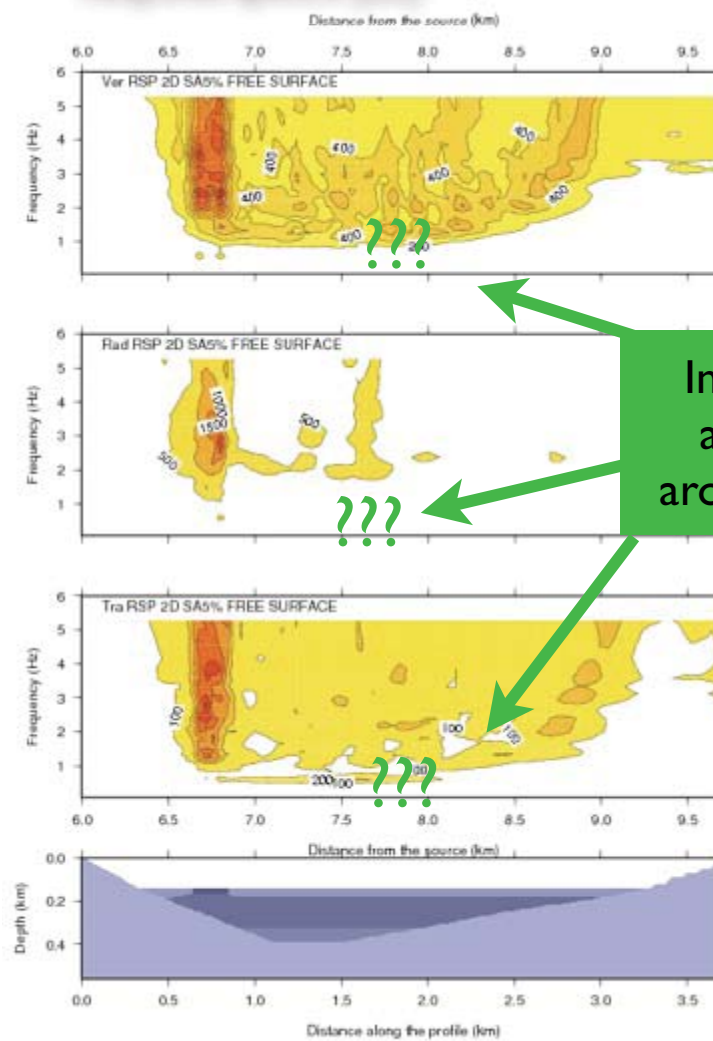


# About H/V (L'Aquila) - Amplification (2D/1D)

Response spectra amplification (2D/1D)



Response spectra (2D)

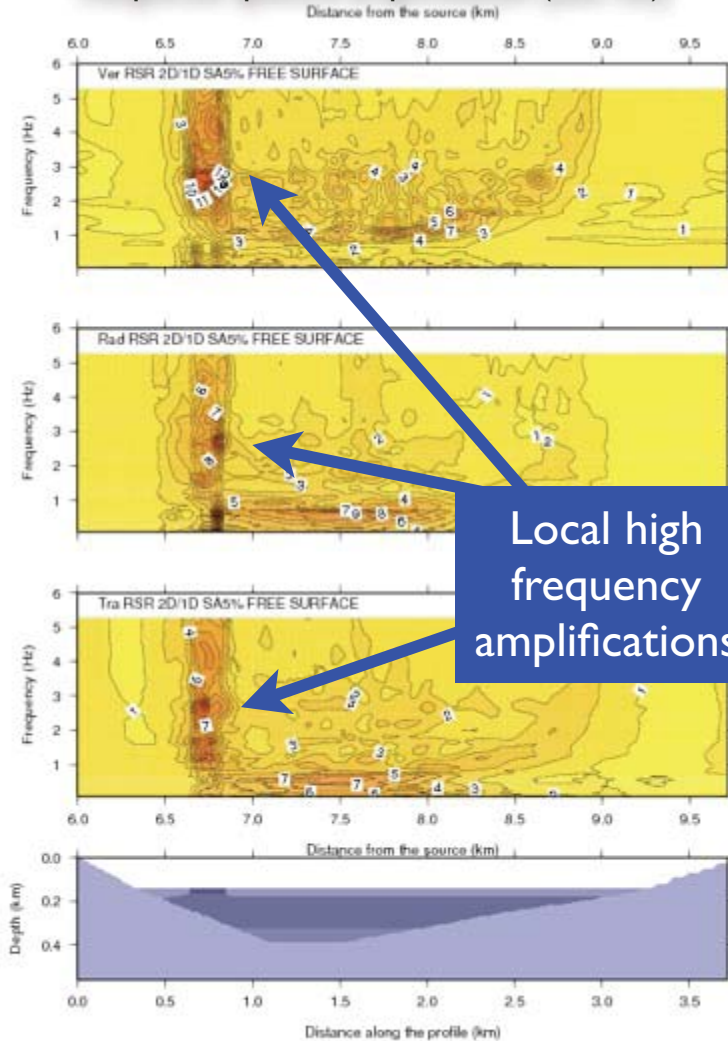


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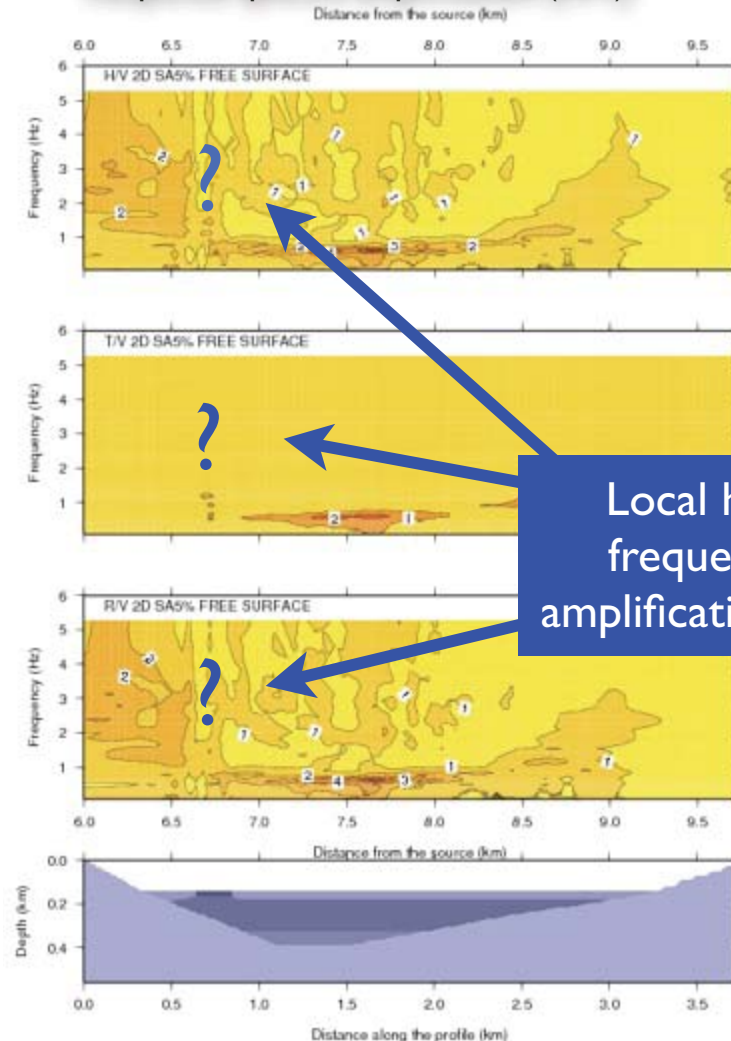


# About H/V (L'Aquila) - Amplification

Response spectra amplification (2D/1D)



Response spectra amplification (H/V)



Local high frequency amplifications

Local high frequency amplifications ???

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# Summary

- Choice of proper methodologies for ground shaking modelling at different scales
- Problem in the definition of actual “site effects”
- Problem in the definition of amplification

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# Thanks

- You
- Elisa Zuccolo
- Andrea Magrin

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