

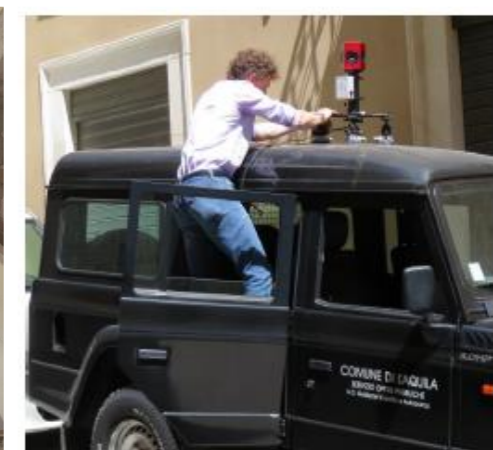
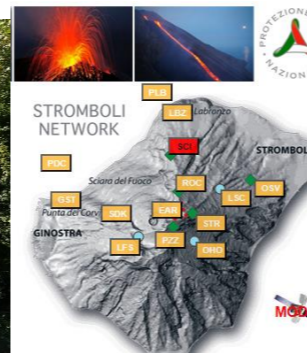
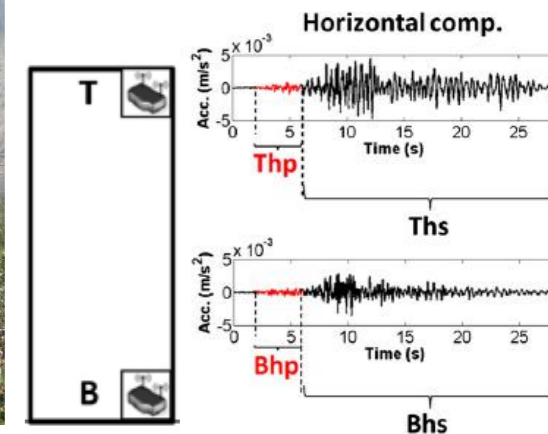
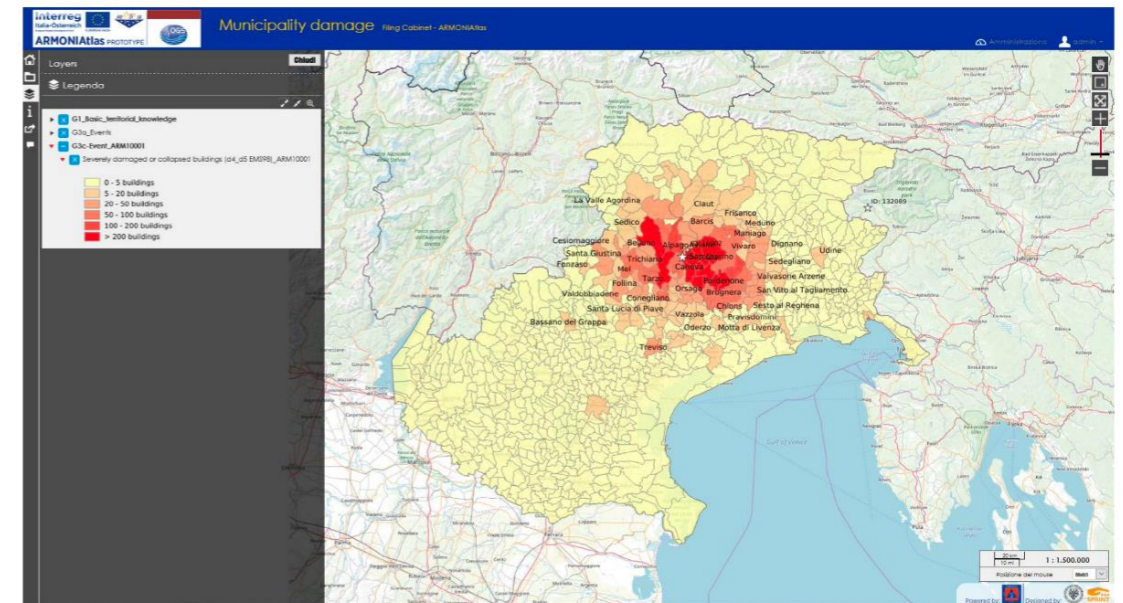
# Elementi di Geofisica per la Protezione Civile

## SM60 Geologia CFU 6.0

### TEMI

- Cenni storici sull'evoluzione e l'organizzazione della protezione civile a livello locale, regionale, nazionale ed internazionale
- Concetti generali quali il rischio, la pericolosità, la vulnerabilità, il danno (stati limite di esercizio) la prevenzione, la protezione
- Accenni sul ruolo della ricerca nell'ambito della protezione civile
- Geofisica per il rischio sismico: reti di monitoraggio permanenti (nazionali e transfrontaliere), accenni di microzonazione sismica e CLE (condizioni limite per l'emergenza), reti sismiche temporanee ed interventi post evento, misure sulle strutture per la quantificazione del danno, uso di mobile mapping per un rapida stima di impatto post evento
- Geofisica per il rischio idrogeologico: reti di monitoraggio multiparametriche
- Geofisica per il rischio vulcanico: reti di monitoraggio multiparametriche

**Nell'ambito del corso sono inoltre previste almeno due visite a sedi di protezione civile o enti di ricerca che hanno attivi contratti di collaborazione con la Protezione Civile Nazionale**



# Interventi per migliorare la fase di PREPARAZIONE

- Reti temporanee (studio degli effetti di sito e microzonazioni)
- Studi per migliorare i modelli di esposizione (analisi di immagini)

# Interventi Post-evento

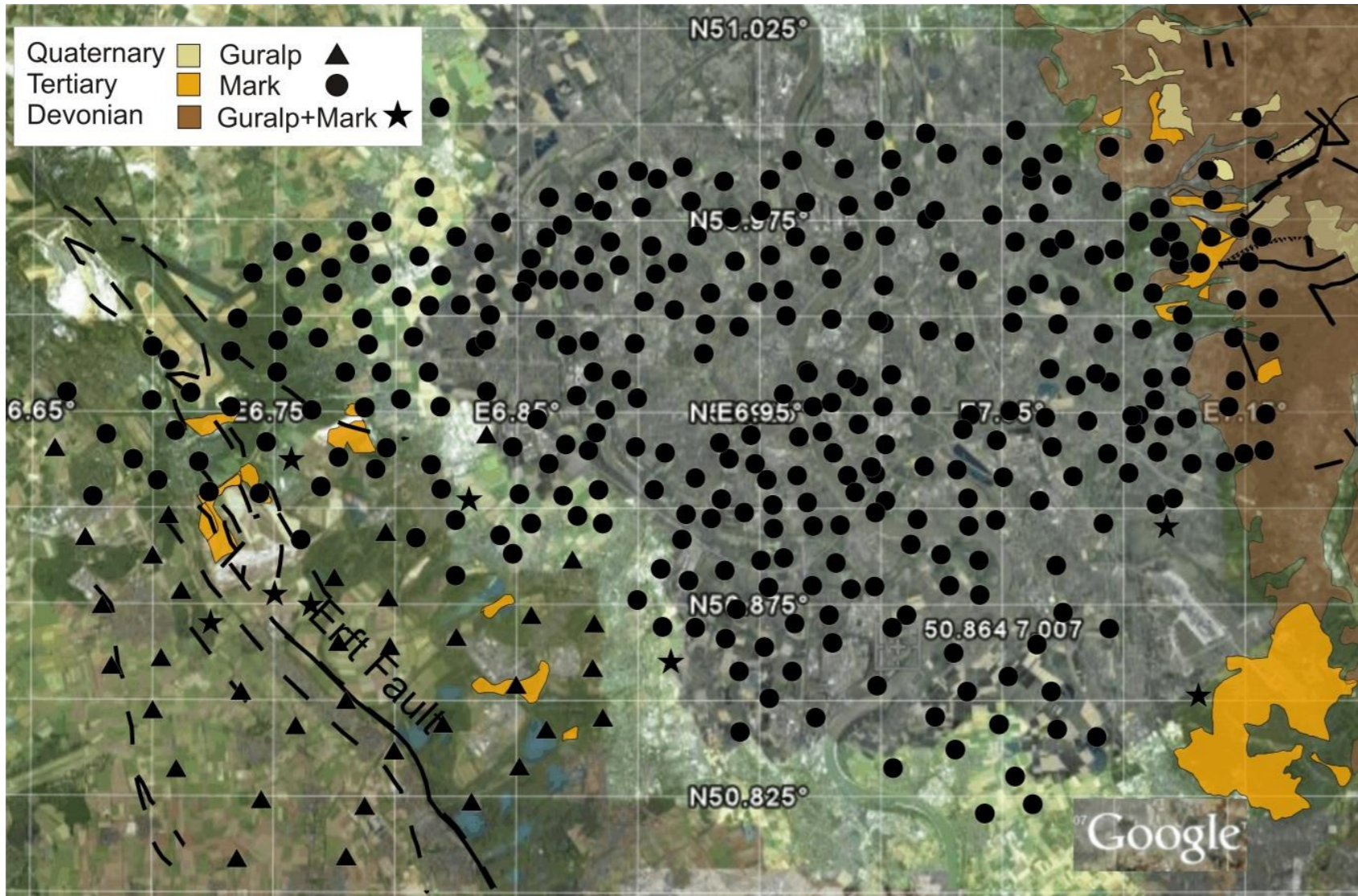
- Reti temporanee (studio degli effetti di sito e microzonazioni, analisi della sismicità e monitoraggio)
- Stima rapida del danneggiamento (analisi di immagini)

# Interventi per migliorare la fase di PREPARAZIONE

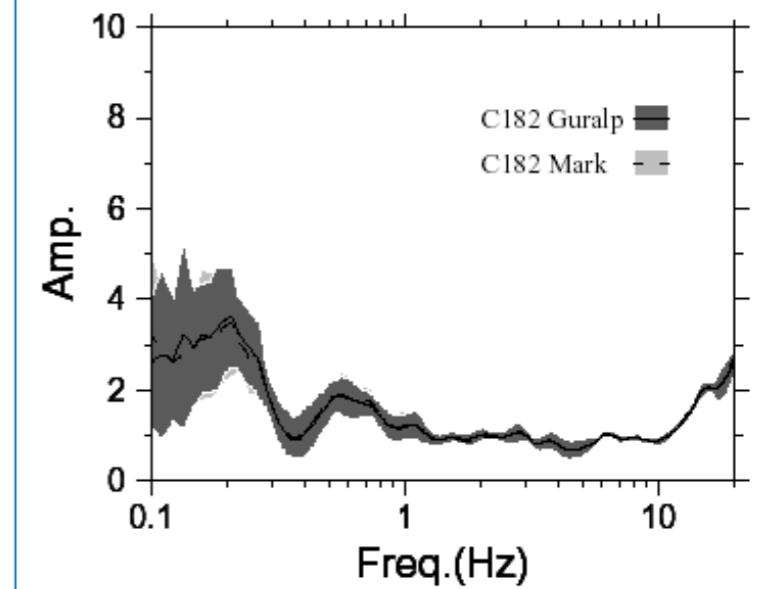
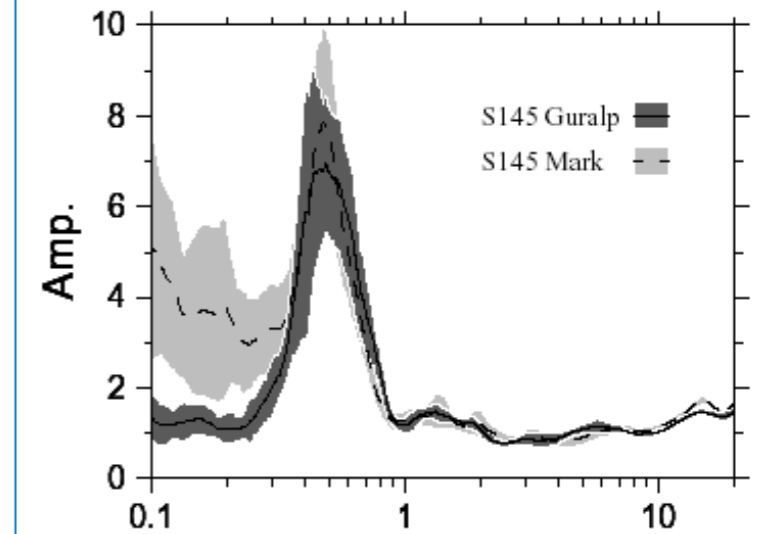
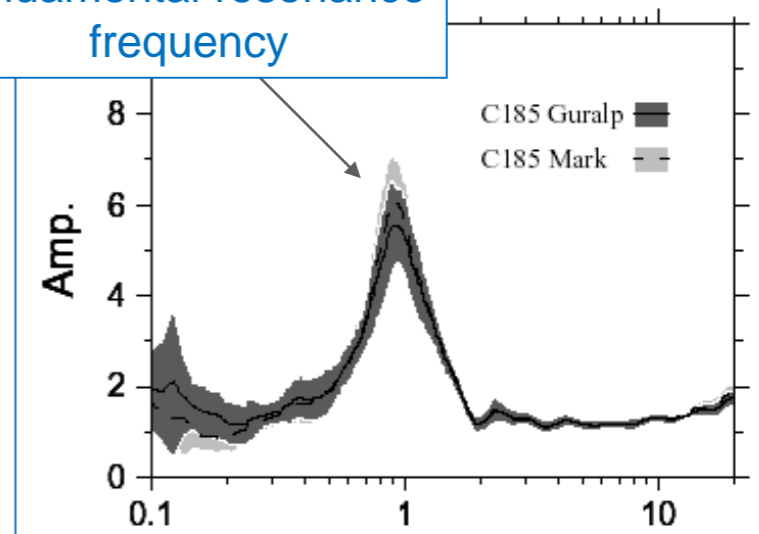
# Interventi per migliorare la fase di PREPARAZIONE

## H/V spectral ratios

Ambient Seismic Noise



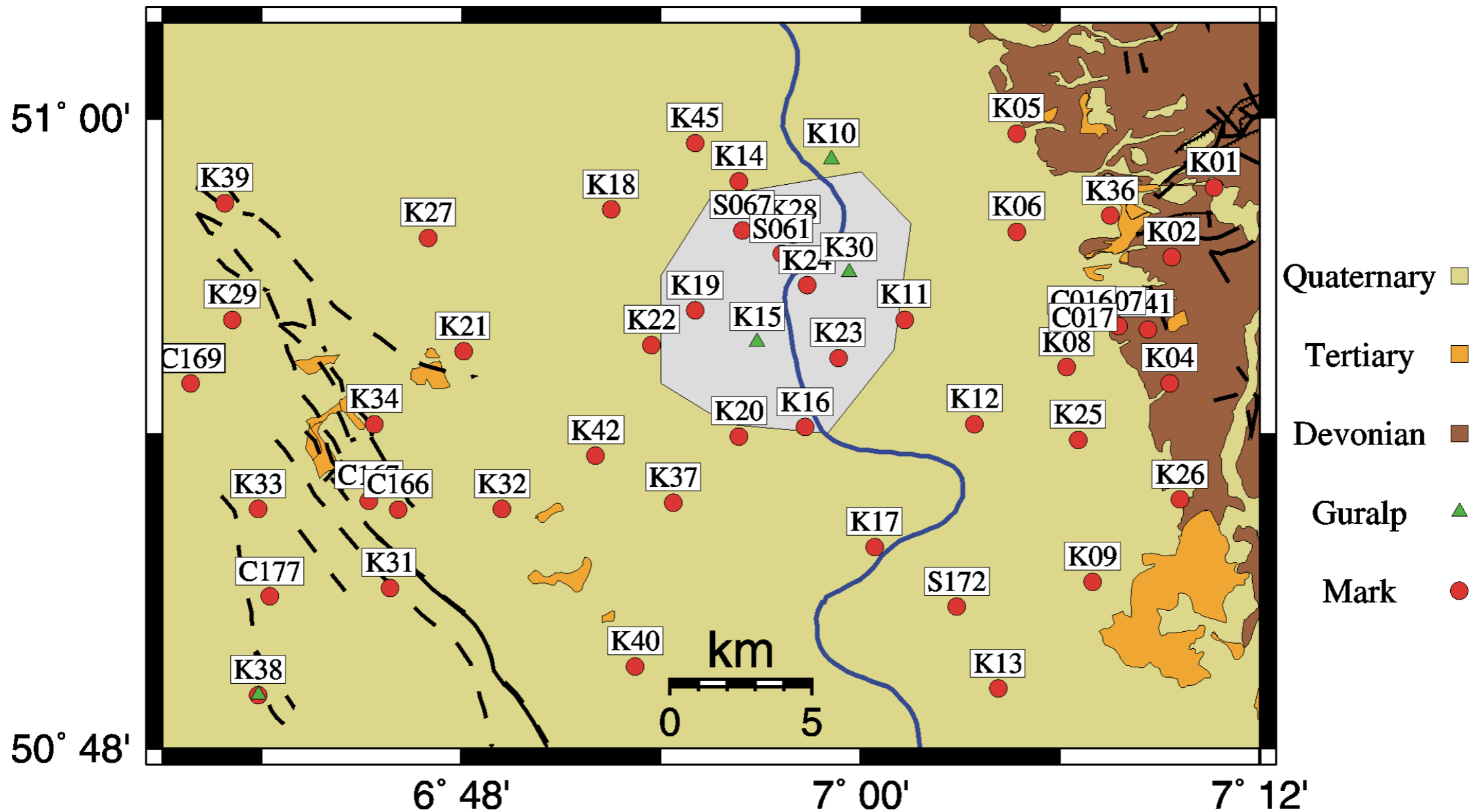
fundamental resonance frequency



Parolai et al. (2001)

# Interventi per migliorare la fase di PREPARAZIONE

## Seismological network: April-June 2001; November 2001



# Pianificazione dell'esperimento e della logistica!



# Condivisione degli spazi e socialità





# Preparazione al lavoro di campagna



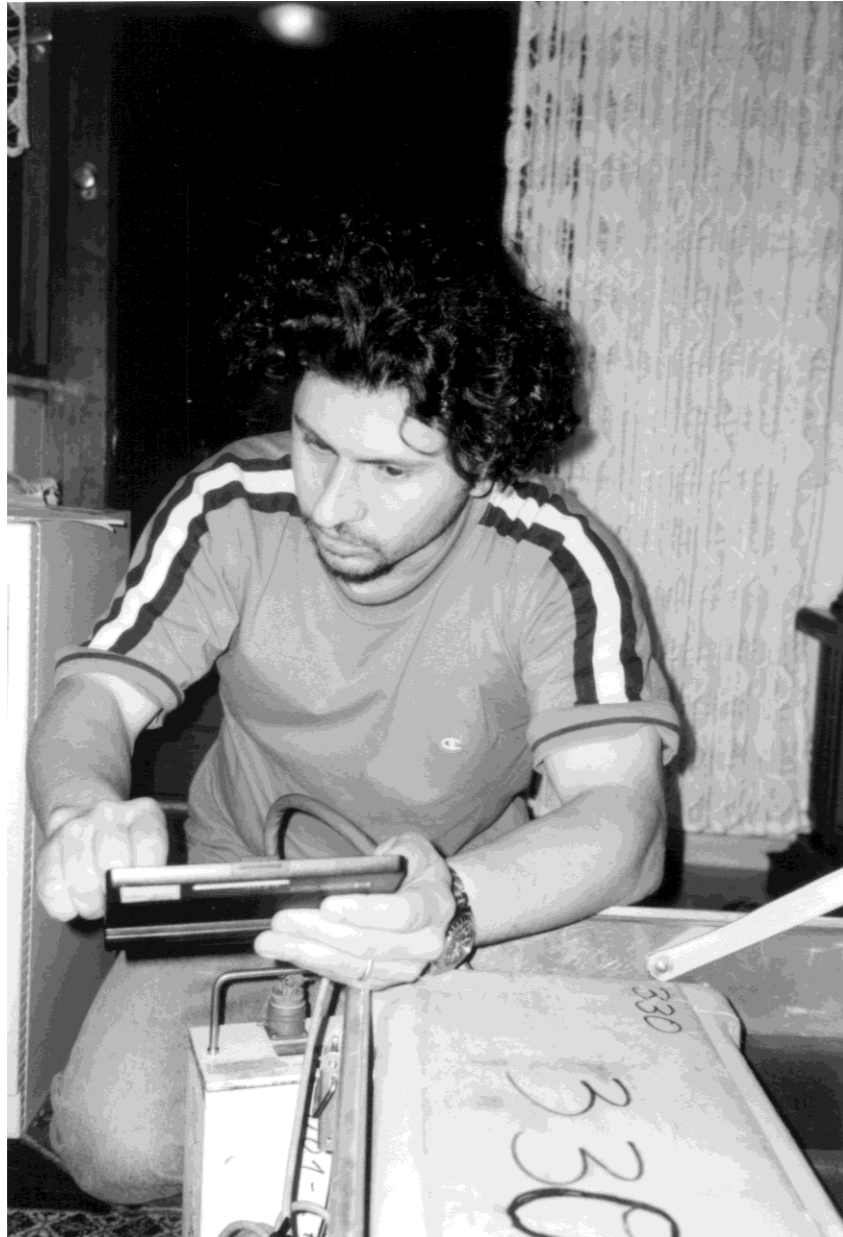


## Installazioni all'interno di aree urbane

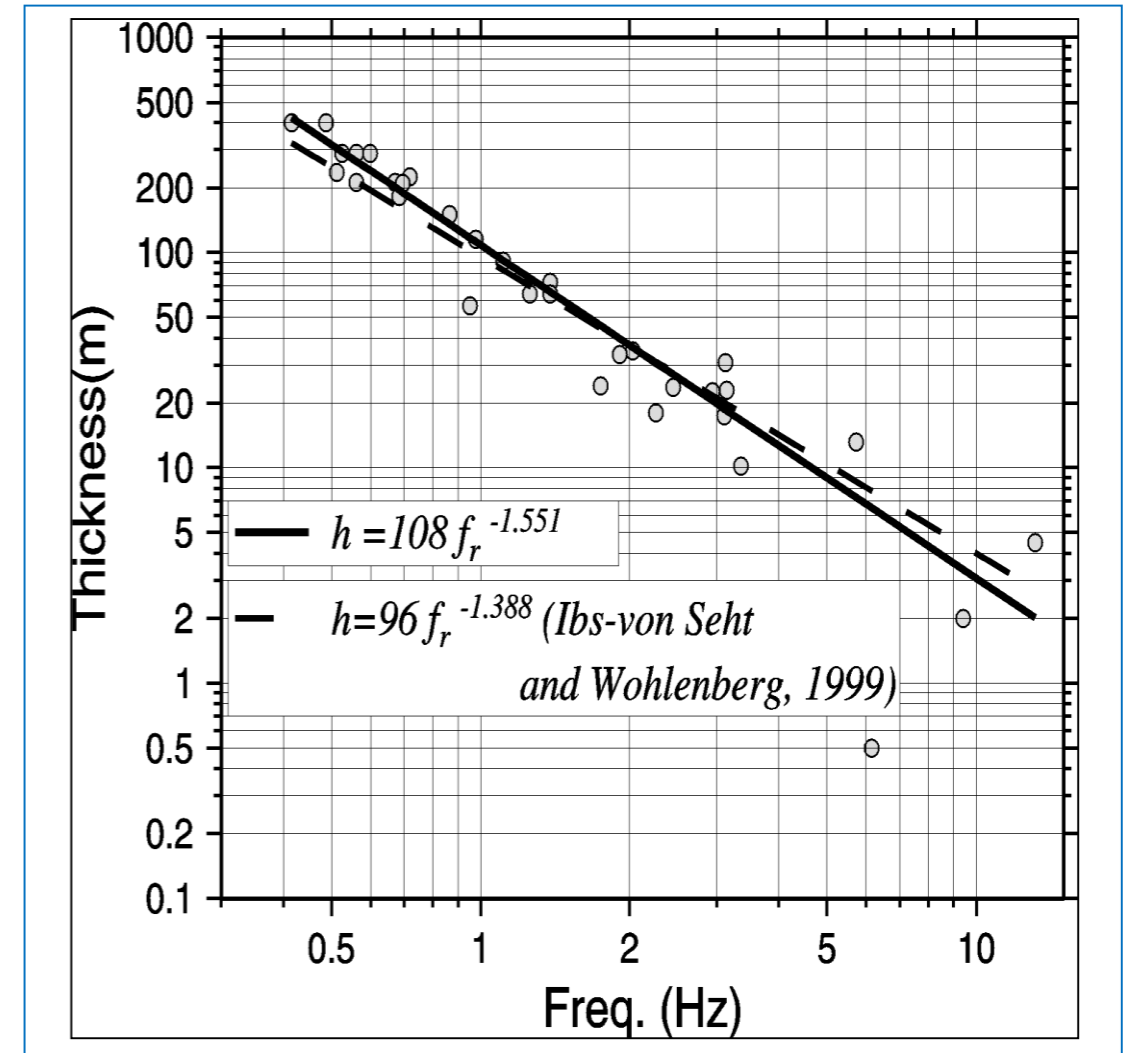
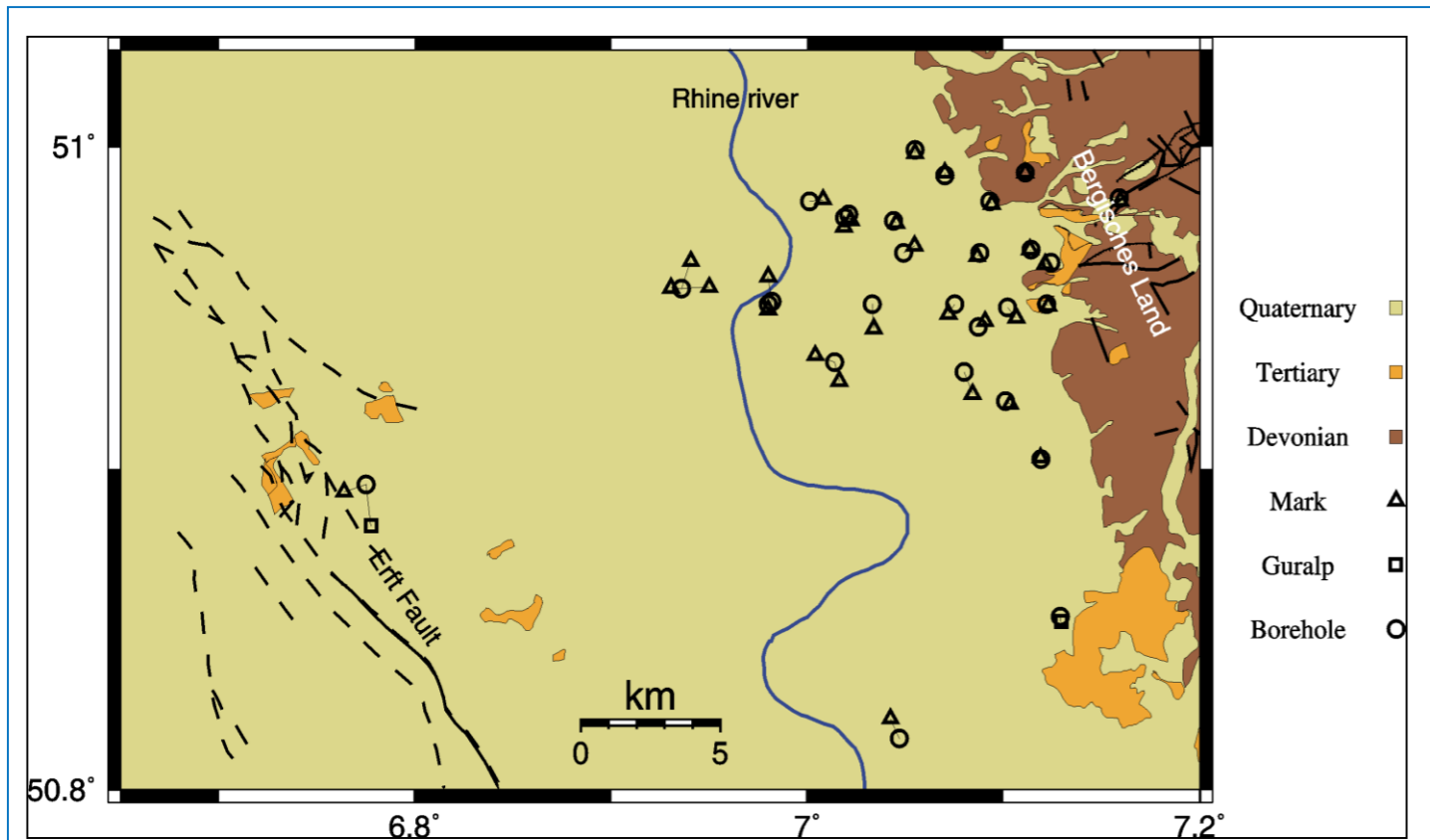
Cantine  
Chiese  
Cimiteri

Attenzione alle antenne GPS e  
alimentazione!

## Check dei dati in campagna

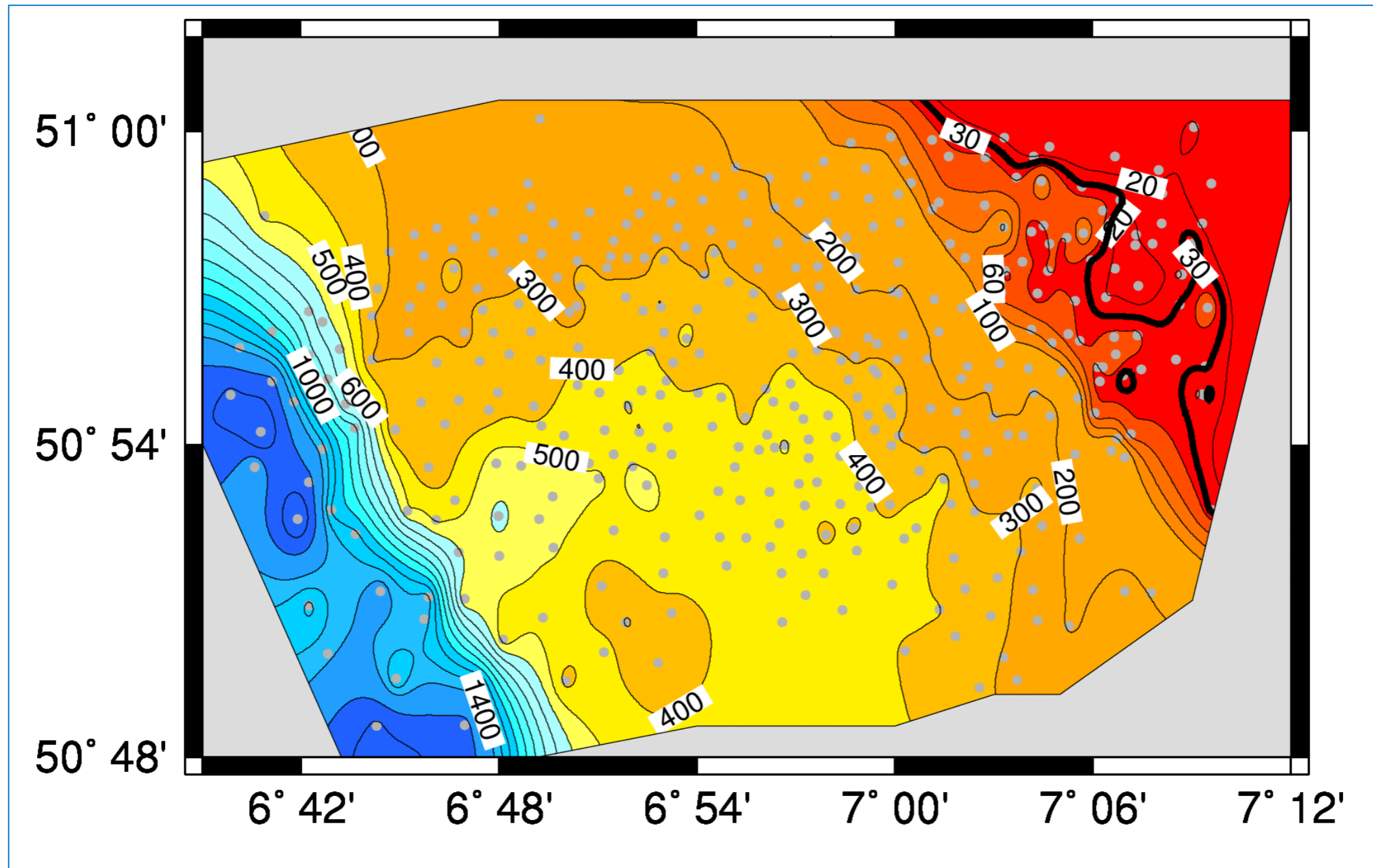


# H/V as geophysical investigation tool: H/V versus sedimentary cover thickness



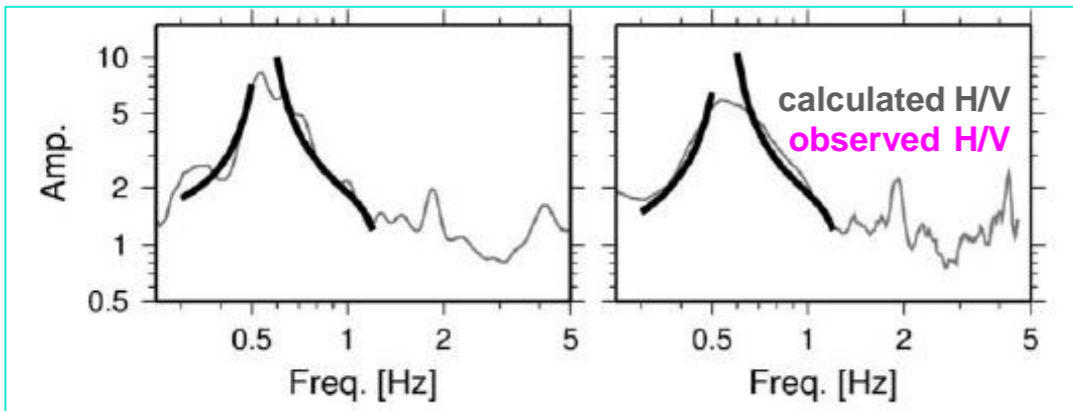
Parolai et al. (2002)

# Sedimentary cover thickness

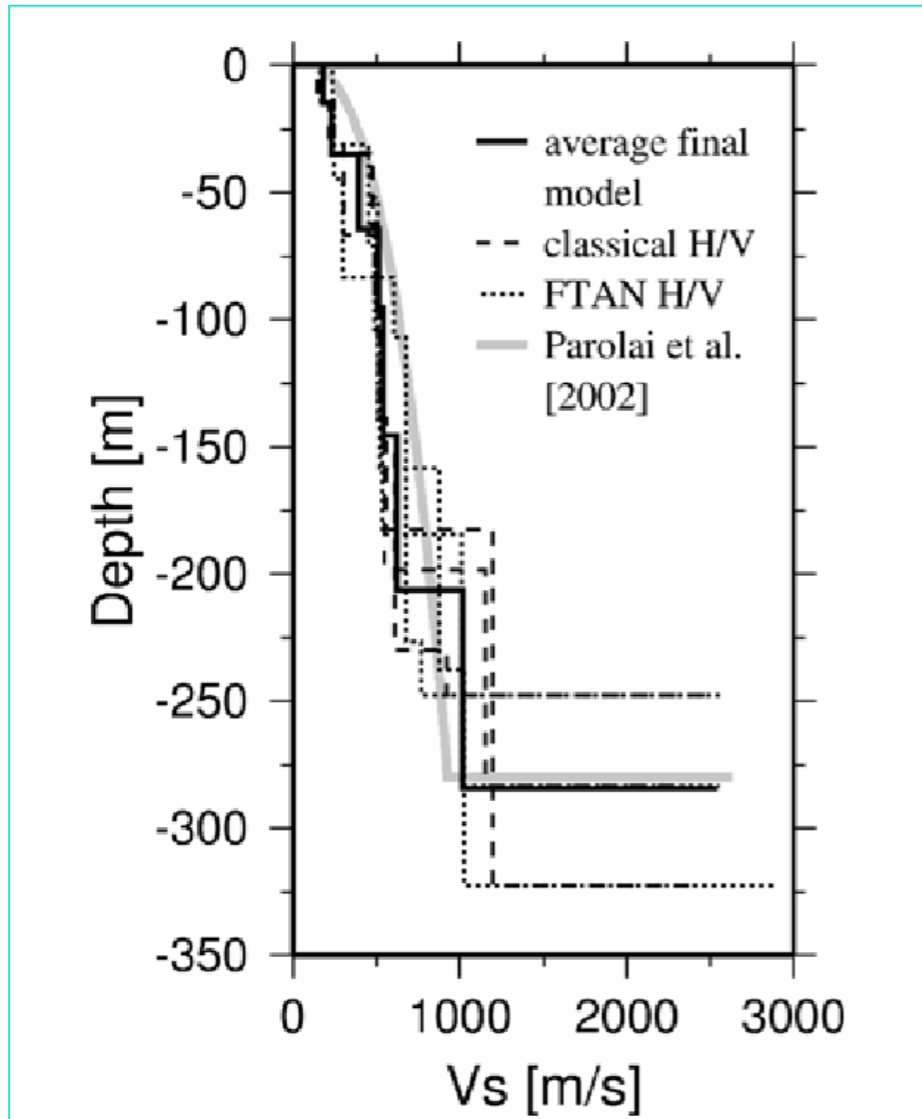


Parolai et al. (2002)

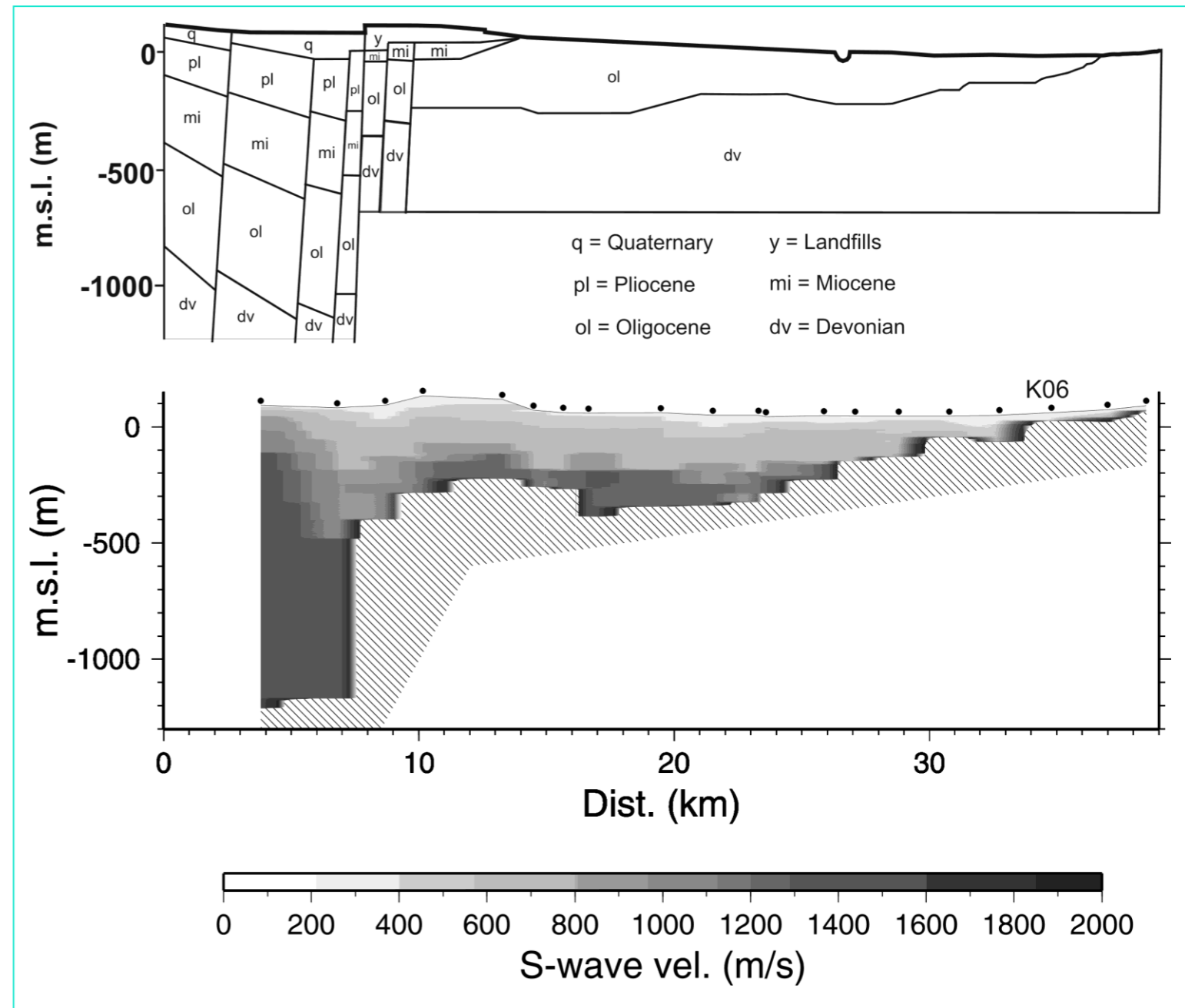
# H/V as geophysical investigation tool: H/V inversion



S-wave velocity profile

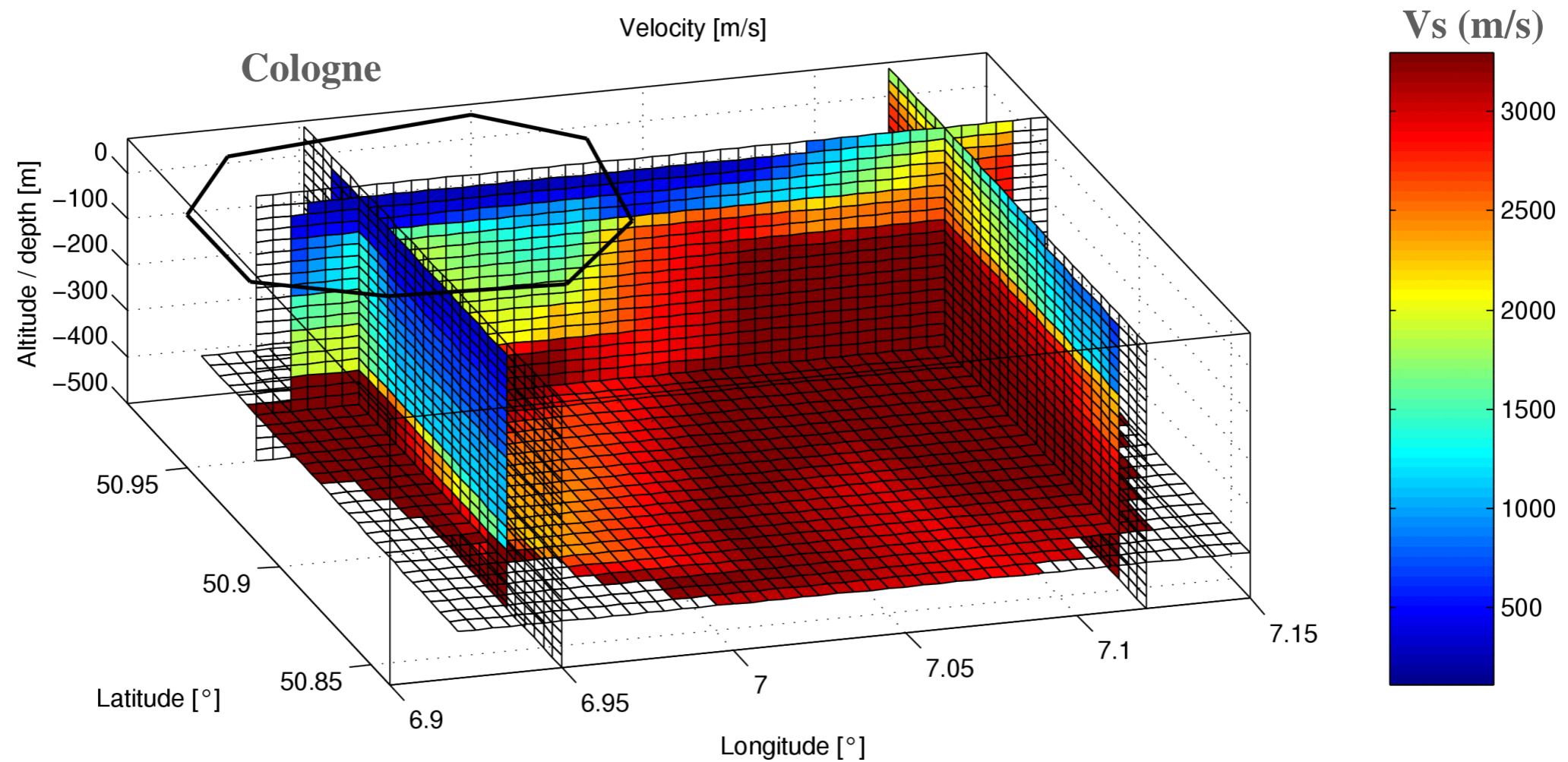


2D S-wave velocity section



# H/V as geophysical investigation tool: H/V inversion

2D-3D models can be used for numerical simulations of ground motion!

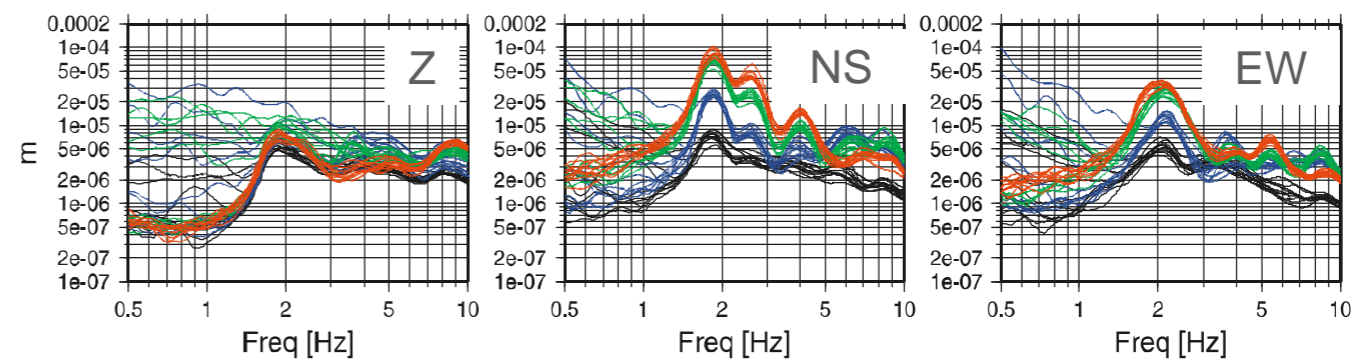


# Investigating the frequency of vibration of buildings with seismic noise

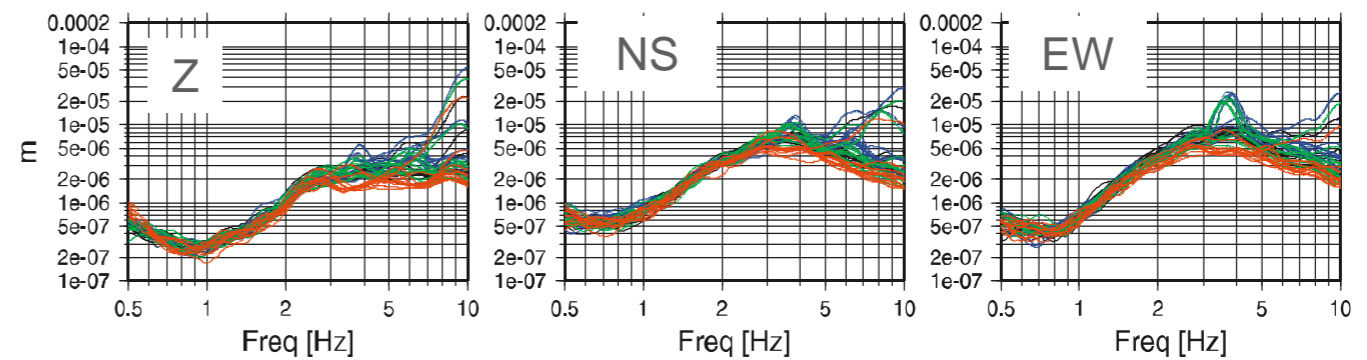
Hospital Holweide



Inside



outside



movie



# Seismic noise measurements : investigating the resonance frequencies of buildings



Table 1. Comparison of resonance frequencies at Holweide Hospital from FE modelling and ambient seismic noise measurements using the H/V ratio and spectral ratio (RSM) technique.

Mode	1	2	3	4	5	6
FE frequency (Hz)	1.78	1.94	2.34	2.78	4.15	5.83
NS modal mass (%)	59	10	1	1	0	3
EW modal mass (%)	1	16	59	0	1	0
H/V frequency (Hz)	1.75 NS	–	2.2 EW	2.65 NS	3.95 NS	5.45 EW
RSM frequency (Hz)	1.8 NS	–	2.0 EW	2.5 NS	4.0 NS	5.45 EW

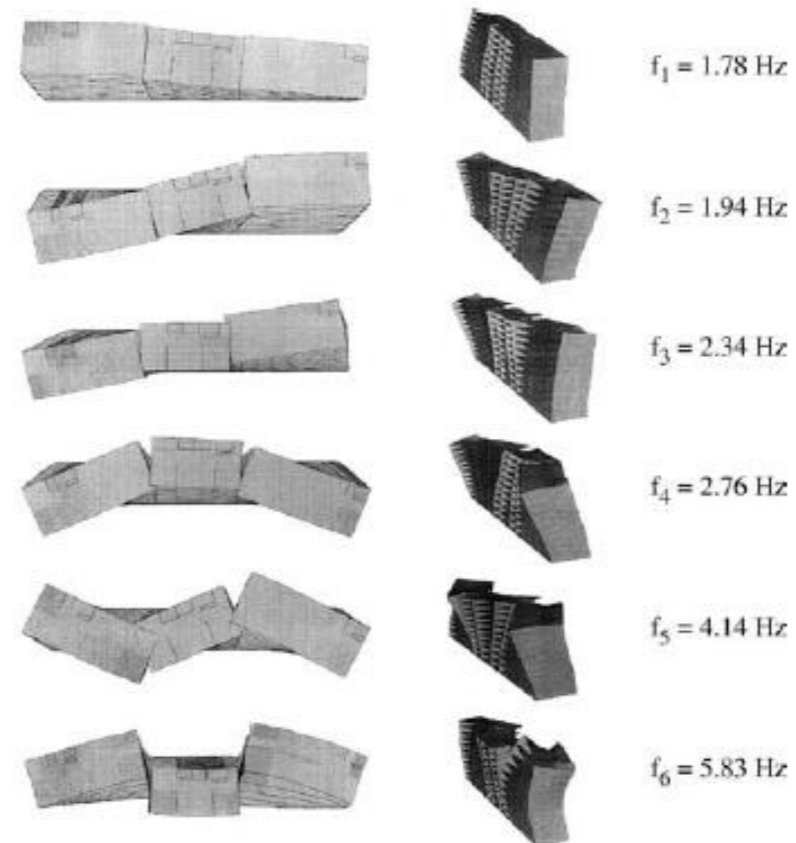


Figure 7. Top view (left) and perspective view (middle) with eigenfrequencies for the first six eigenmodes using the second model with springs in separation joints leading to coupled building sections.



Parolai et al. (2005)

# Seismic noise measurements : investigating the resonance frequencies of buildings

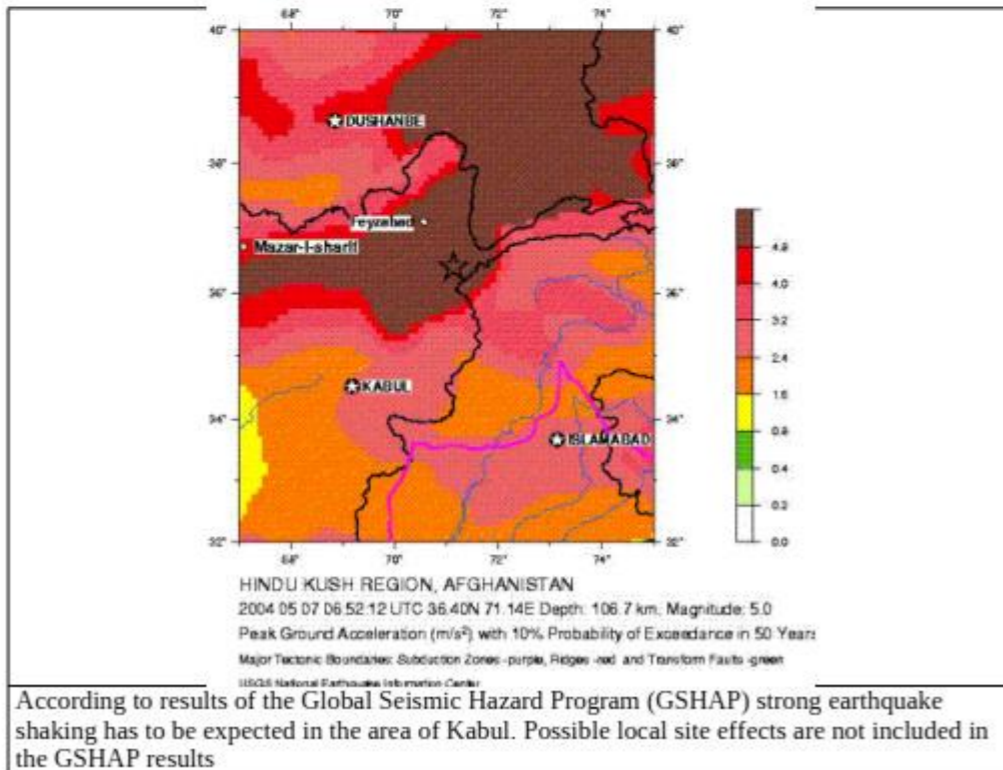


	GeoForschungsZentrum Potsdam Prof. Dr. J. Zschau Telegrafenberg Haus E D 14473 Potsdam Germany
	Tel: +49 331 2881201 Fax: +49 331 2881204 Email <a href="mailto:zschau@gfz-potsdam.de">zschau@gfz-potsdam.de</a>

Potsdam, 12.5.2005

**Final Report: „Earthquake Hazard Assessment“, Afghanistan 2003-2004**

Following Myslil and Eqrar (1982), the city of Kabul is located inside a basin (inter-mountains tertiary-quaternary sedimentary basin) surrounded by mountains composed by pre-tertiary metamorphic and sedimentary rocks. The thickness of the sedimentary cover was estimated to reach hundred of meters but is generally unknown. Considering the high seismic hazard estimated by the GSHAP project (Global Seismic Hazard Assessment Program) for the city of Kabul and the possible amplification of the ground motion due to the thickness of the sedimentary cover and the morphology of the bedrock, a seismic microzonation of the area is required. This necessity is becoming even stronger due to the continuous expansion of the city, occupying new areas and extending on the surrounding hills.



# Interventi per prevenzione, preparazione e capacity building



View from the Institute of Geosciences of the Kabul University to the North. Kabul has been built on top of a basin with soft soil where at some places hard rock outcrops. Strong site effects have to be expected during an earthquake.



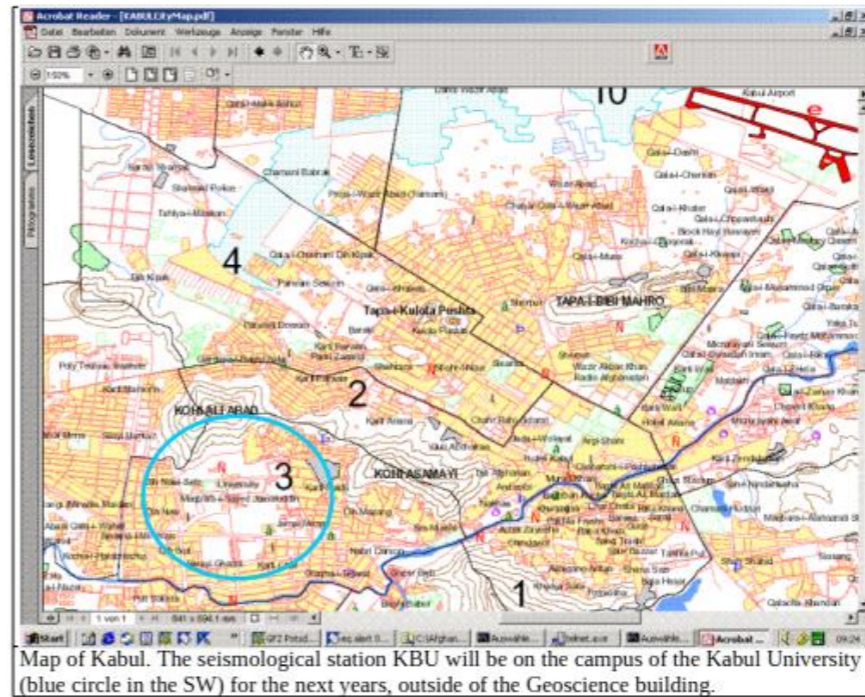
During introductory lessons the state of understanding of local site effects during earthquakes were explained and the role of microzonation studies formulated.



During practicals in instrumental microzonation the use of the geofon and seismic recording system has been exercised and measurements were taken in the building and outside on the campus.



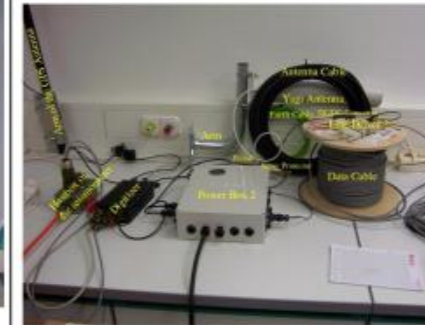
Measurements were analysed by the H/V method on the project computer.



Map of Kabul. The seismological station KBU will be on the campus of the Kabul University (blue circle in the SW) for the next years, outside of the Geoscience building.



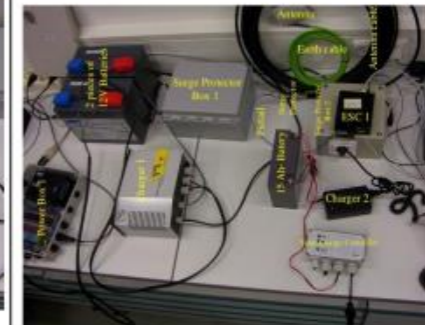
First 1/4 Equipment



Second 1/4 Equipment



Third 1/4 Equipment



Fourth 1/4 Equipment

Seismological equipment for Kabul station KBU: Beside the broadband seismological sensor the other equipment is used for power supply, data transmission and protection. The station has been set-up several times during the training courses in September 2004 and January 2005 by the participants from Afghanistan and background information about Observatory Practice was part of the programme during the International Training course 2004 in Germany

# Interventi per prevenzione, preparazione e capacity building



Interventi per prevenzione, preparazione e capacity building



# Interventi per prevenzione, preparazione e capacity building



## Interventi per prevenzione, preparazione e capacity building



## Working in urban areas



Materiale fotografico fornito da A. Stollo



## Comparison of Empirical and Numerical Site Responses at the Tito Test Site, Southern Italy

by S. Parolai, M. Mucciarelli, M. R. Gallipoli, S. M. Richwalski, and A. Strollo

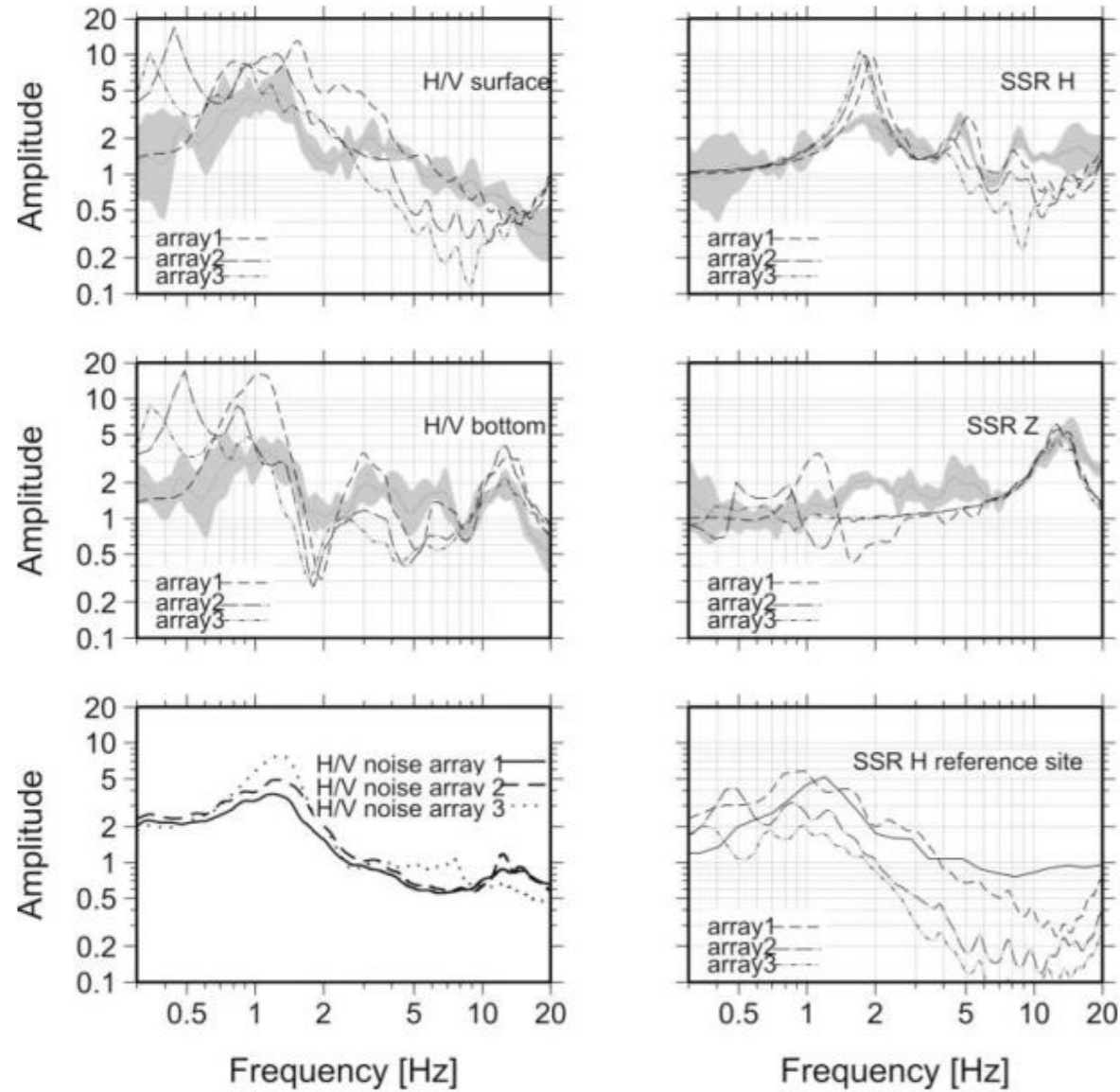


Figure 16. (top left) H/V ratios at the surface station. (top right) SSR H spectral ratios (surface to bottom). (middle left) H/V ratios at the borehole station. (middle right) SSR Z spectral ratios (surface to bottom). All figures show averaged results from earthquake recordings (black line), and the gray area indicates the 95% confidence interval. Ratios from synthetic seismograms are shown considering the model obtained by array 1 (dashed line), array 2 (dashed-dotted line), and array 3 (dotted-dashed line). (bottom left) Array-averaged H/V spectral ratio of seismic noise for array 1 (continuous line), array 2 (dashed line), and array 3 (dotted line). (bottom right) SSR H spectral ratio with respect to a reference site from earthquake recordings (black line). SSR H spectral ratio with respect to a reference site from synthetic seismograms considering the model obtained by array 1 (dashed line), array 2 (dashed-dotted line), and array 3 (dotted-dashed line).

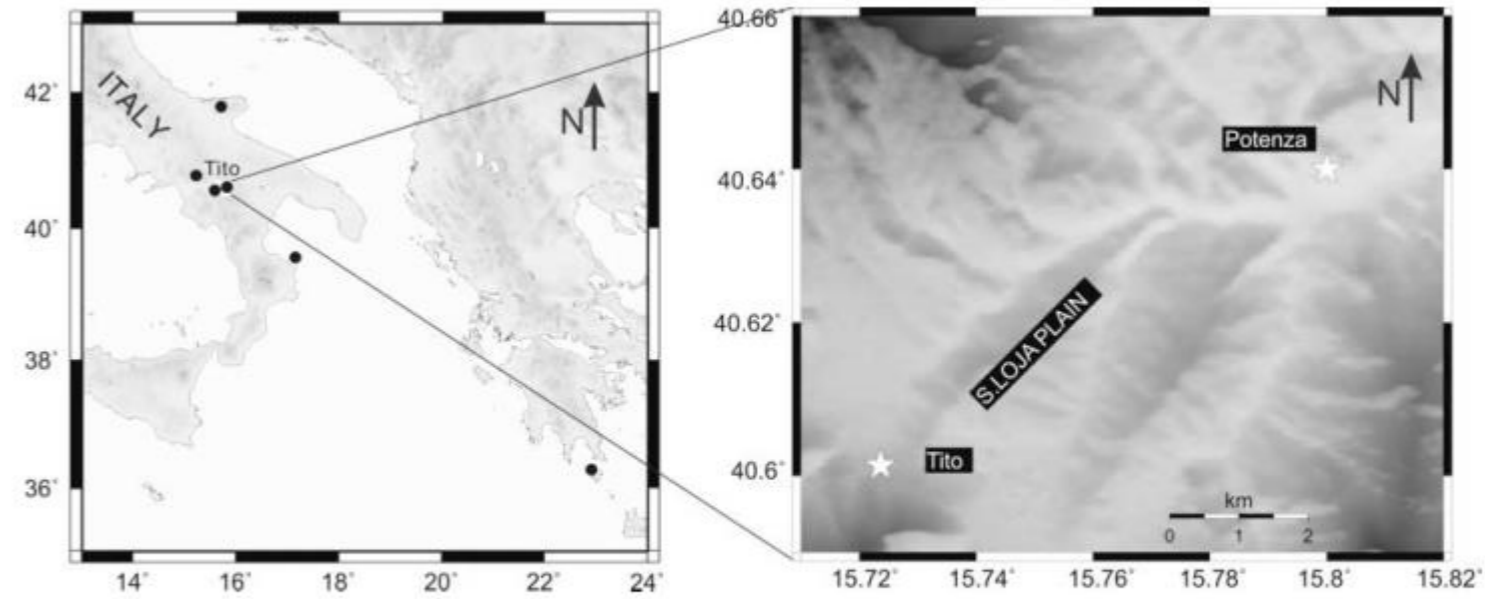


Figure 1. Location of the Tito test site. The epicentral locations of the earthquakes analyzed in this study are indicated by filled circles.

## Microzonation of Potenza (Southern Italy) in terms of spectral intensity ratio using joint analysis of earthquakes and ambient noise

Angelo Strollo · Stefano Parolai · Dino Bindi ·  
 Leonardo Chiauzzi · Rossella Pagliuca ·  
 Marco Mucciarelli · Jochen Zschau

Received: 30 September 2010 / Accepted: 26 February 2011 / Published online: 23 March 2011

$$r_{jk} = \frac{c v_{jk}}{\sigma_j \cdot \sigma_k} = \frac{\left( \frac{\sum_{i=1}^n (x_{ij} - \bar{x}_j) \cdot (x_{ik} - \bar{x}_k)}{(n_i - 1)} \right)}{\left( \sqrt{\frac{\sum_{i=1}^n (x_{ij} - \bar{x}_j)^2}{(n_i - 1)}} \right) \cdot \left( \sqrt{\frac{\sum_{i=1}^n (x_{ik} - \bar{x}_k)^2}{(n_i - 1)}} \right)}$$

$$f_{jk} = \frac{1}{\sqrt{\frac{\sum_{i=1}^n (x_{ij} - x_{ik})^2}{n_i}}}$$

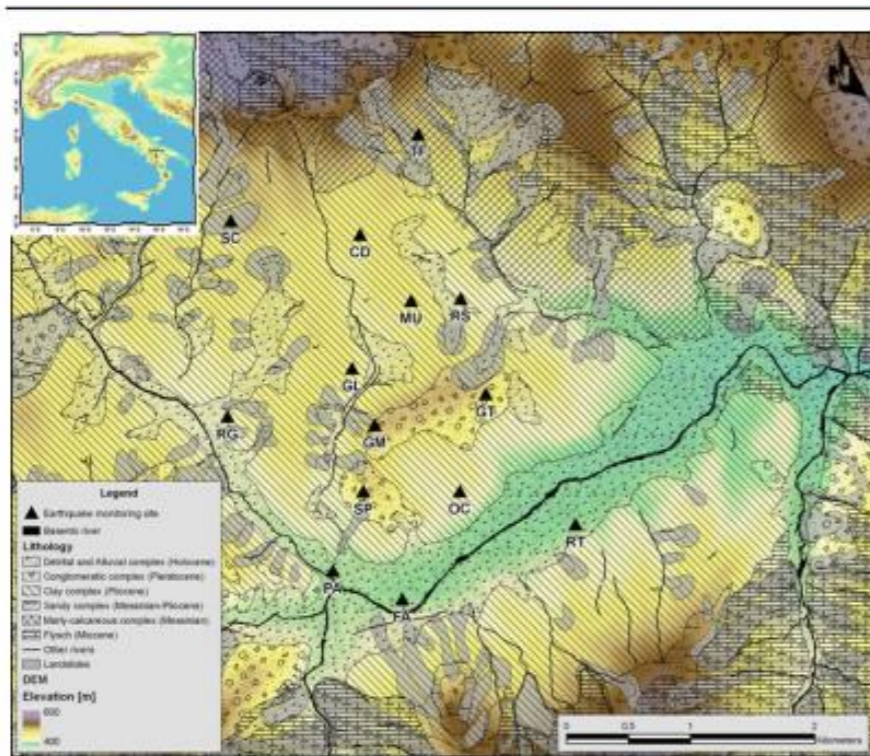


Fig. 1 Simplified lithological map. The black triangles indicate the location of the selected earthquake monitoring sites

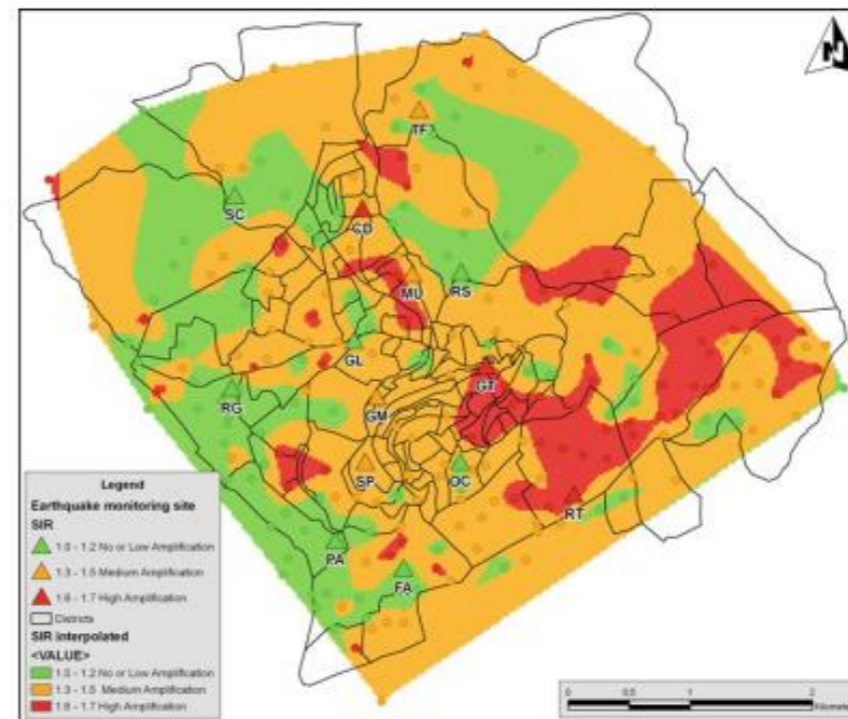
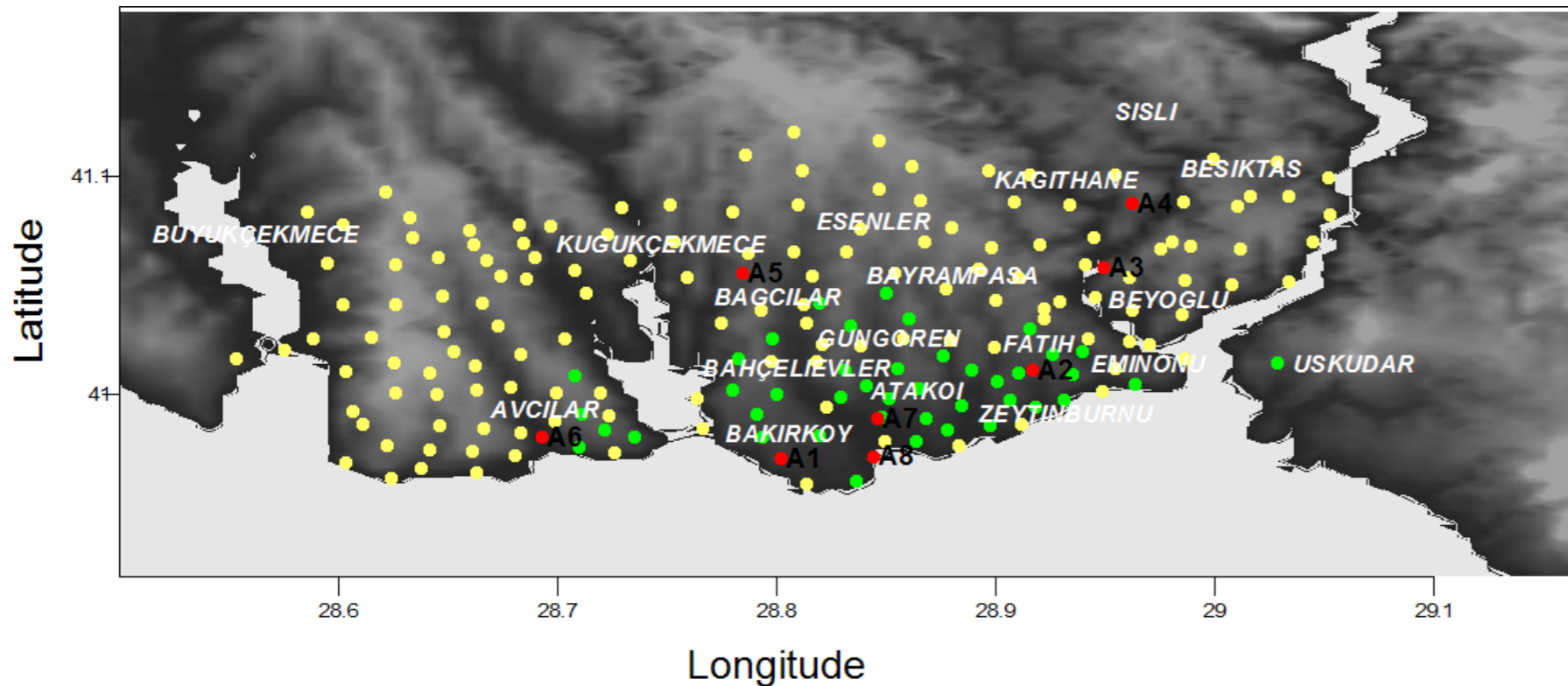


Fig. 11 Natural neighbours interpolation of the SIR values

## Interventi per prevenzione, preparazione e capacity building

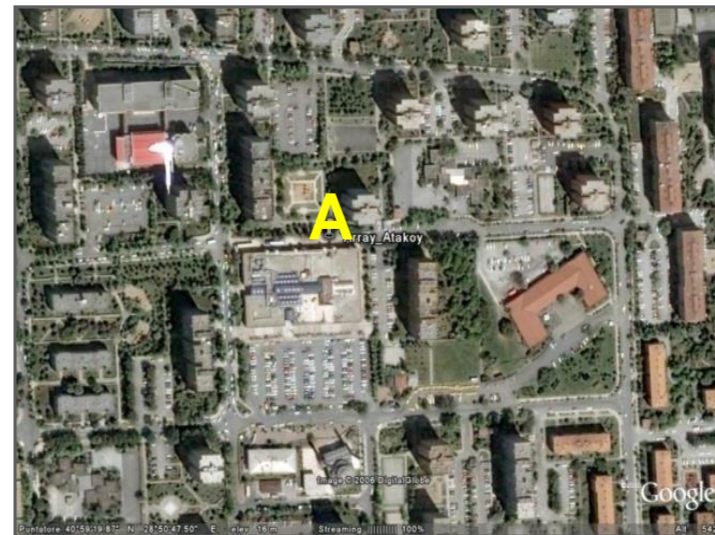
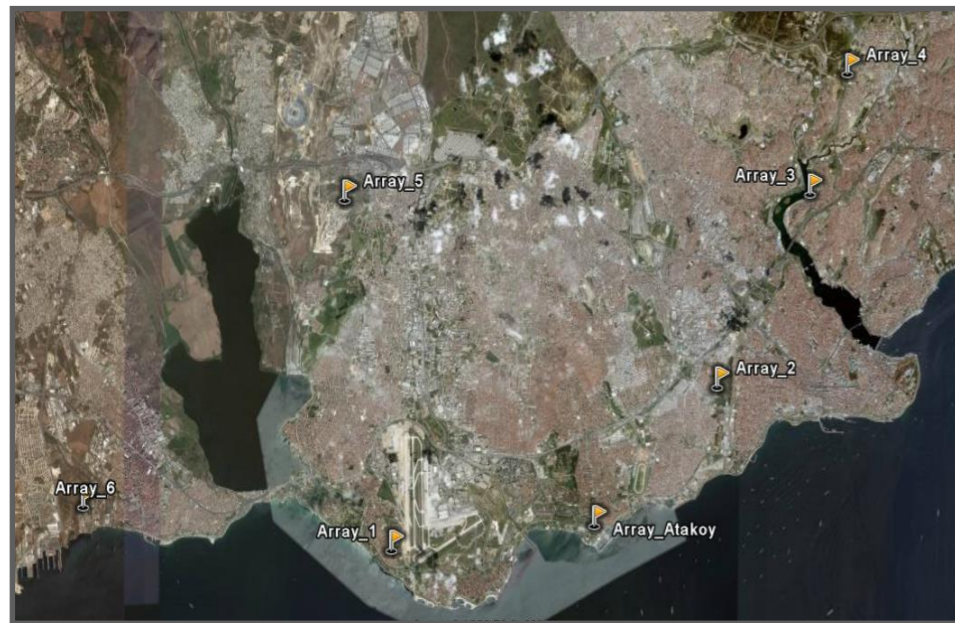
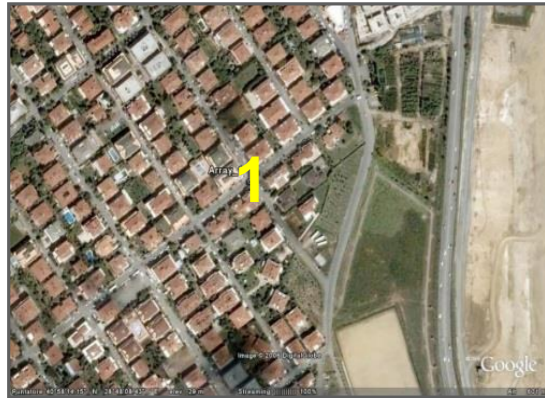
- Single station measurement ( $H/V \Rightarrow f_0$ )  $\Rightarrow$  192 sites
- Istanbul Earthquake Rapid Response System (IERRS)
  - 2-D Array measurement ( $V_R \Rightarrow V_S$ )  $\Rightarrow$  8 sites



**Working in urban  
areas: Istanbul a  
megacity**

Instrumentation used for noise measurements: *EDL 24bit*  $\Leftrightarrow$  *Mark L-4C-3D 1Hz*

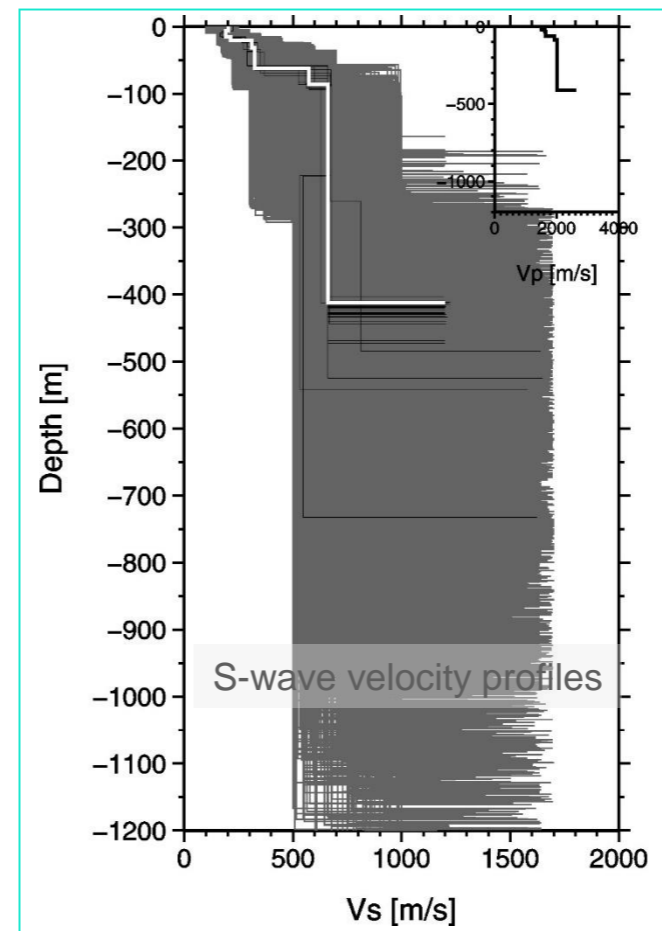
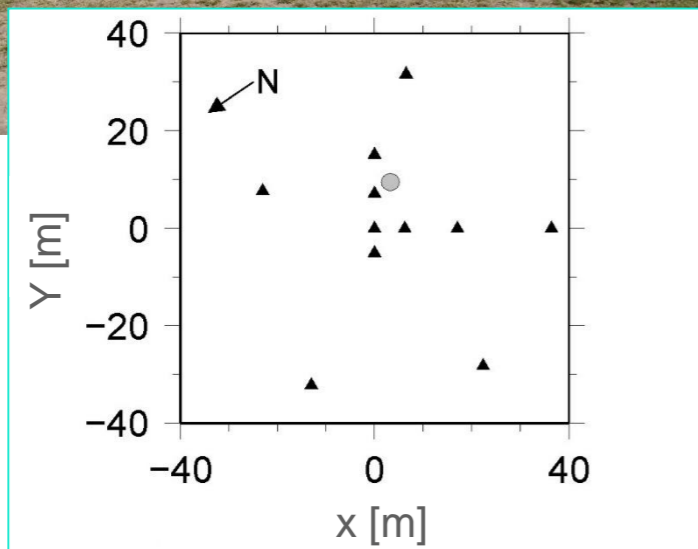
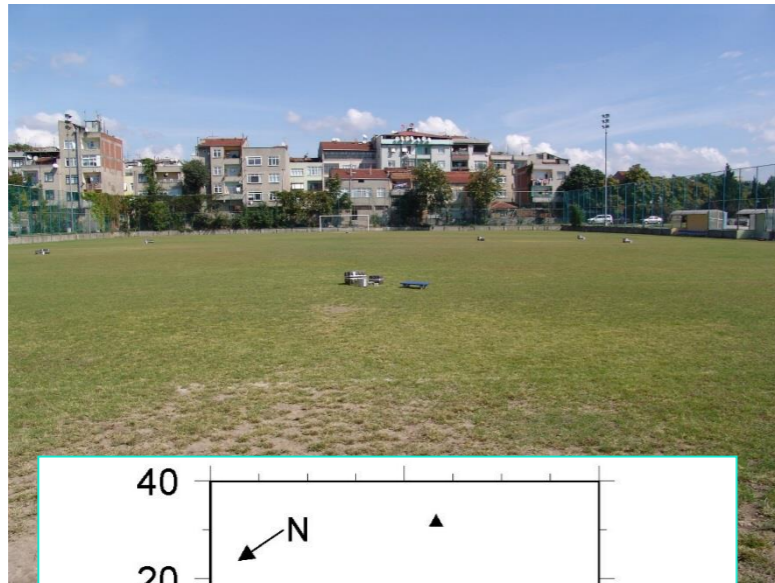
# Using seismic noise to estimate the characteristics of a site : Istanbul



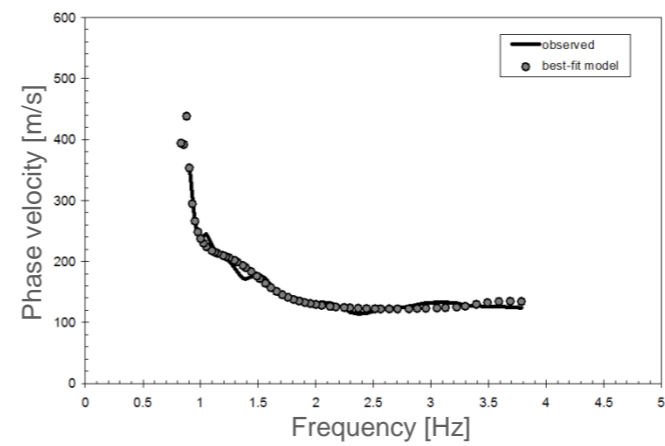
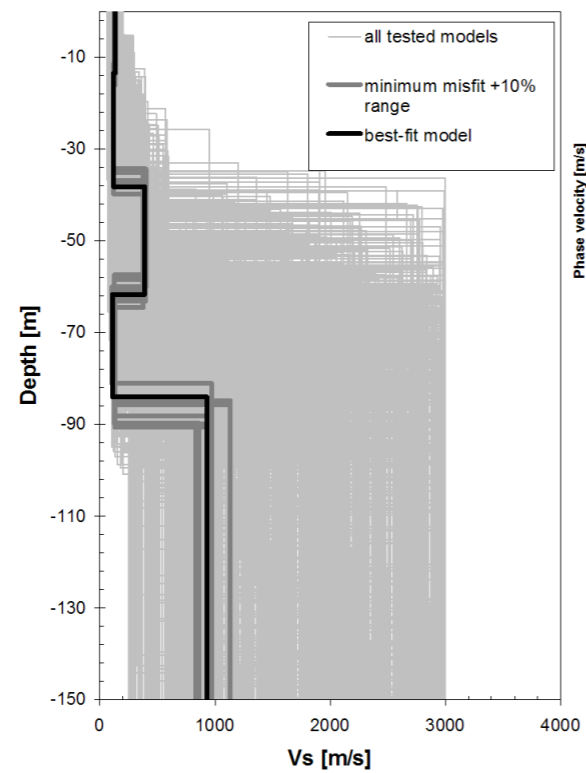
**Working in urban areas: Istanbul a megacity  
Finding investigation sites**



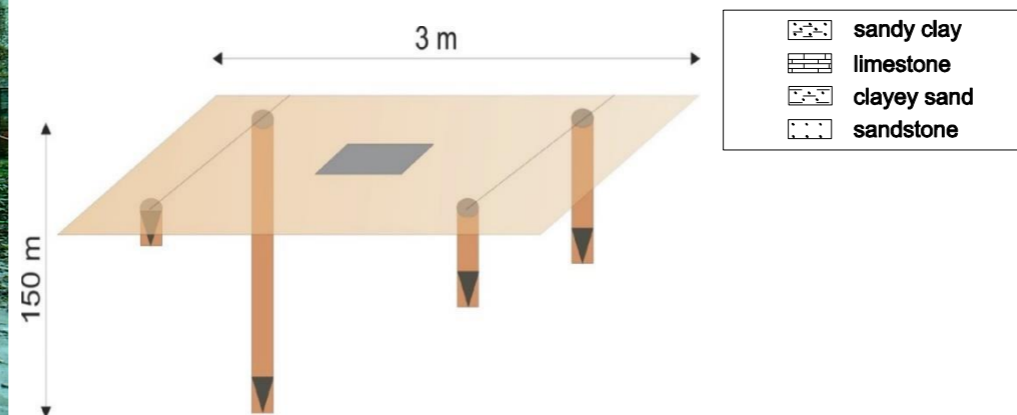
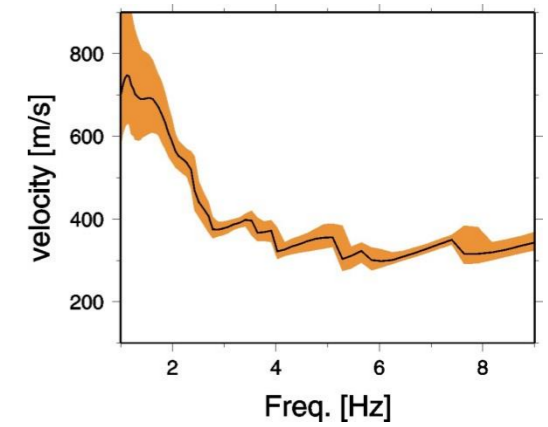
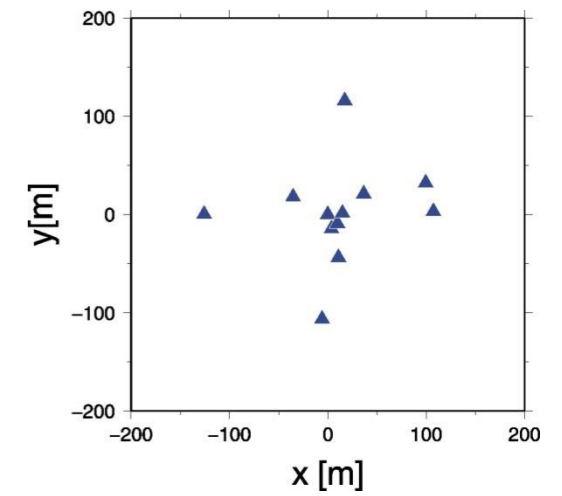
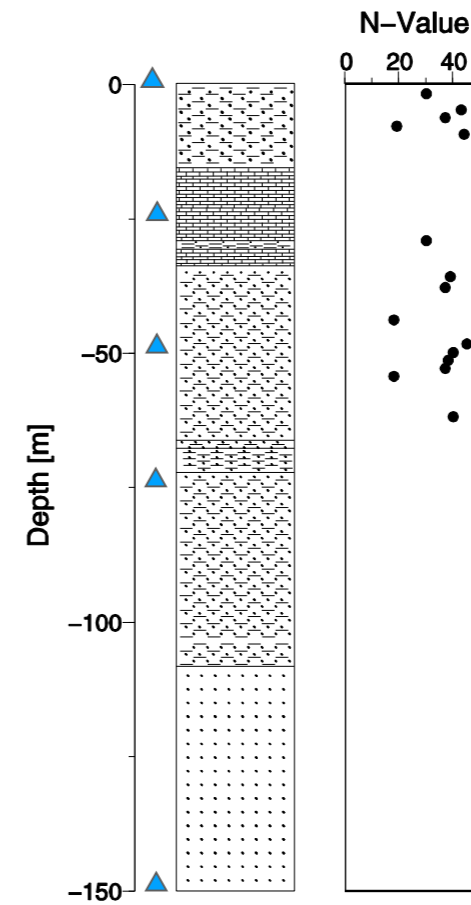
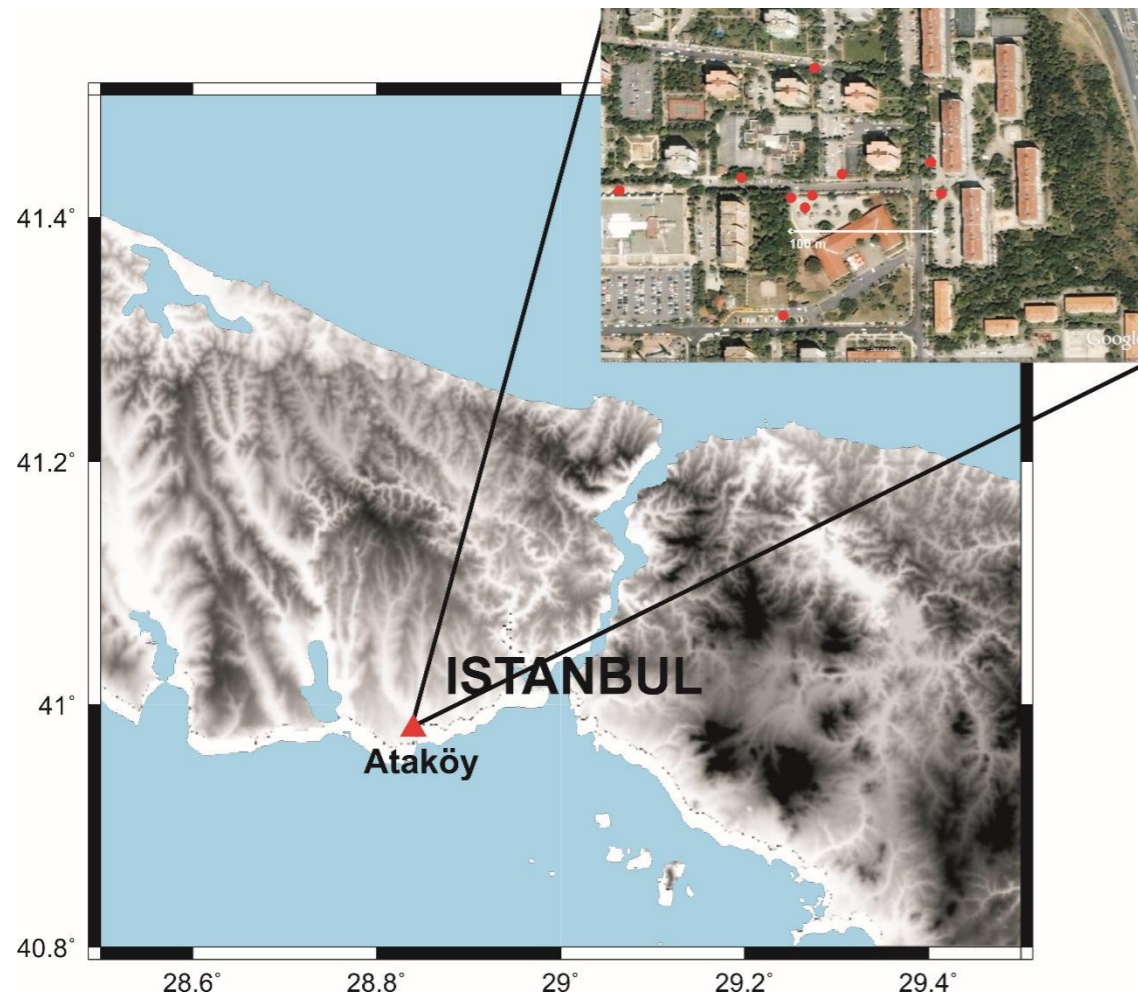
## Seismic noise array measurements: investigating the subsoil S-wave velocity structure



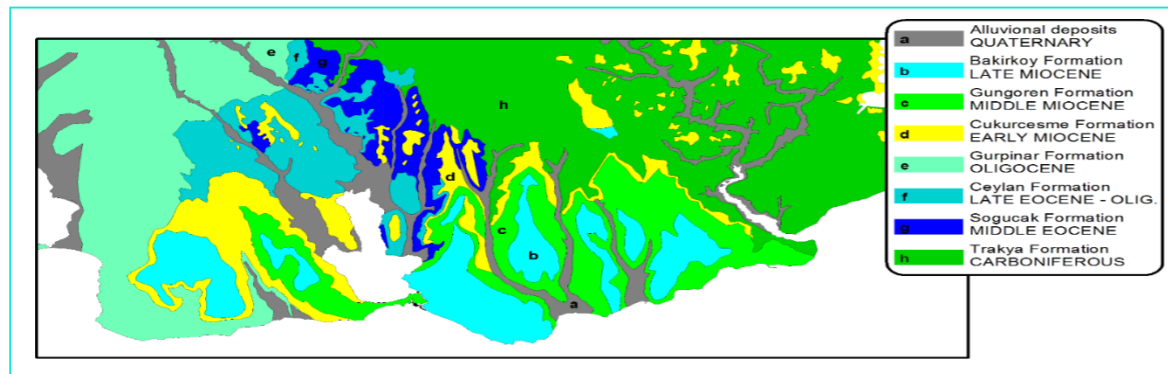
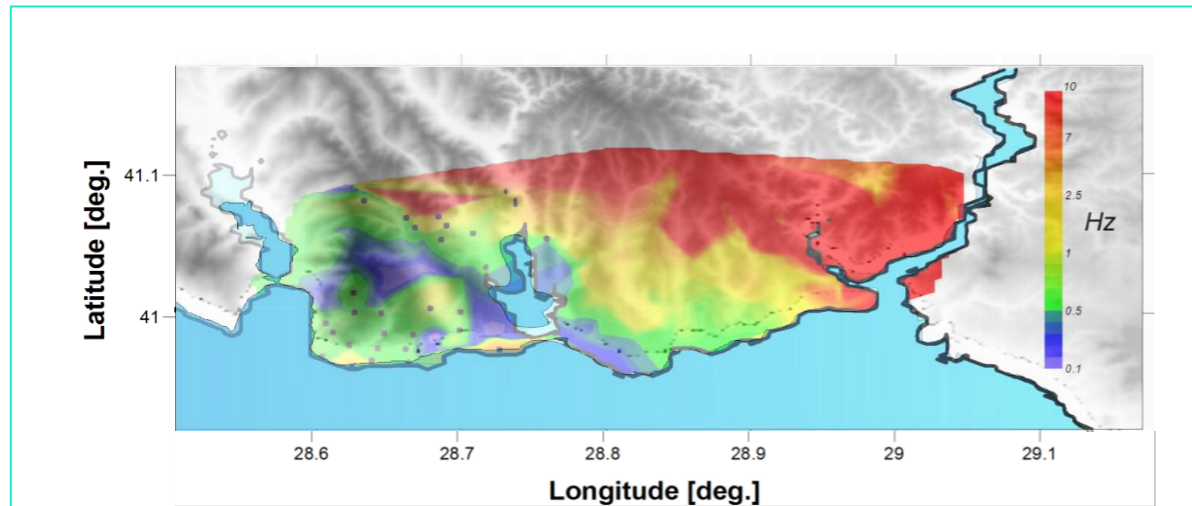
# Interventi per prevenzione, preparazione e capacity building



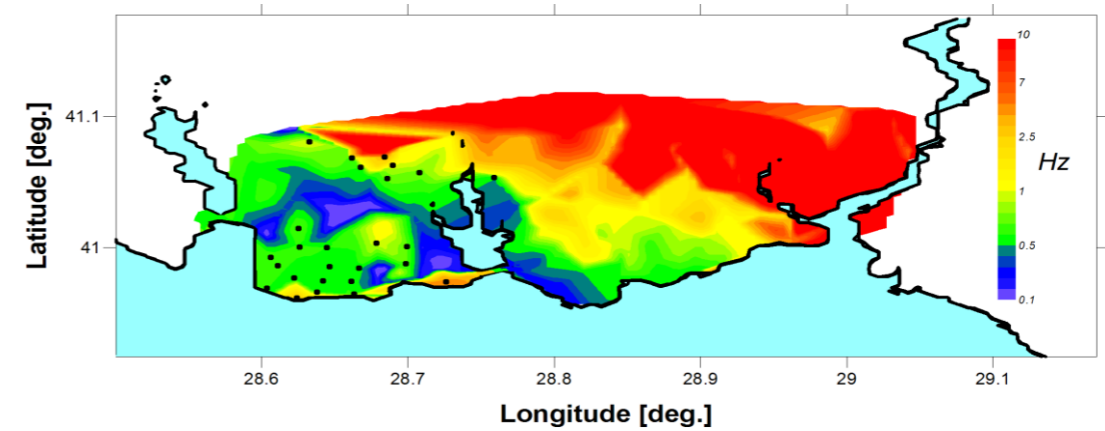
# Interventi per prevenzione, preparazione e capacity building



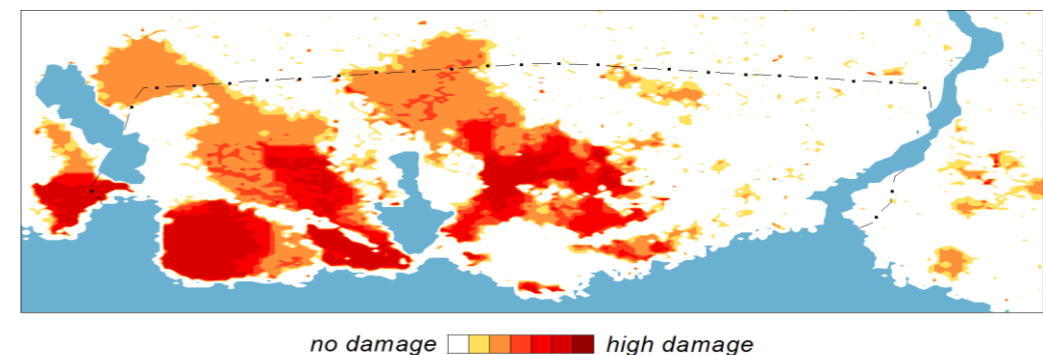
# Interventi per prevenzione, preparazione e capacity building



Stefano Parolai



Distribution of damage in Istanbul 17-08-1999 Kocaeli Earthquake





## Progetto S3

### Scenari di scuotimento in aree di interesse prioritario e/o strategico

*coordinatori: Francesca Pacor (INGV-MI) e Marco Mucciarelli (UNIBas)*

#### **Task 6– Scenari, area 4: Gubbio**

*Partecipanti: UR1, UR2, UR3, UR4, UR6, UR9, UR10, UR11 - Le UR partecipano a tutte le attività, tranne dove diversamente specificato*

*Obiettivi: Scenari di scuotimento al bedrock e al sito nell'abita e nella piana di Gubbio (PG).*

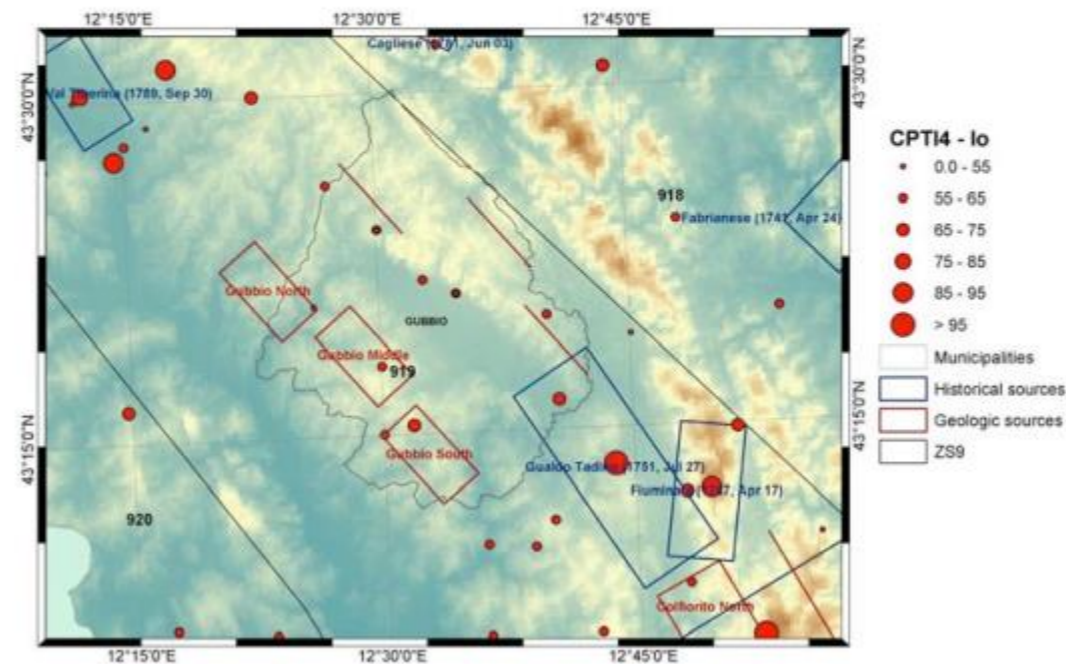
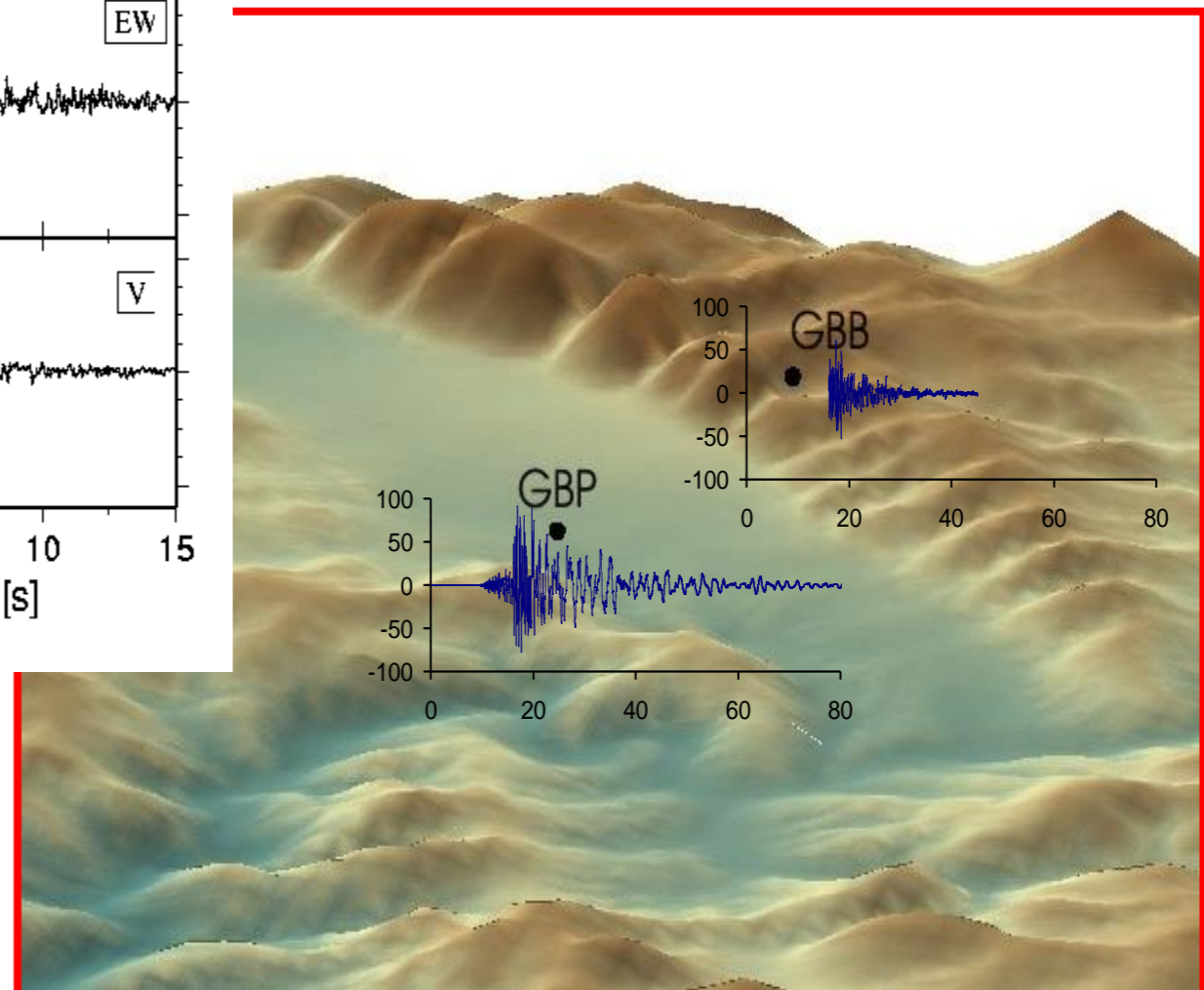
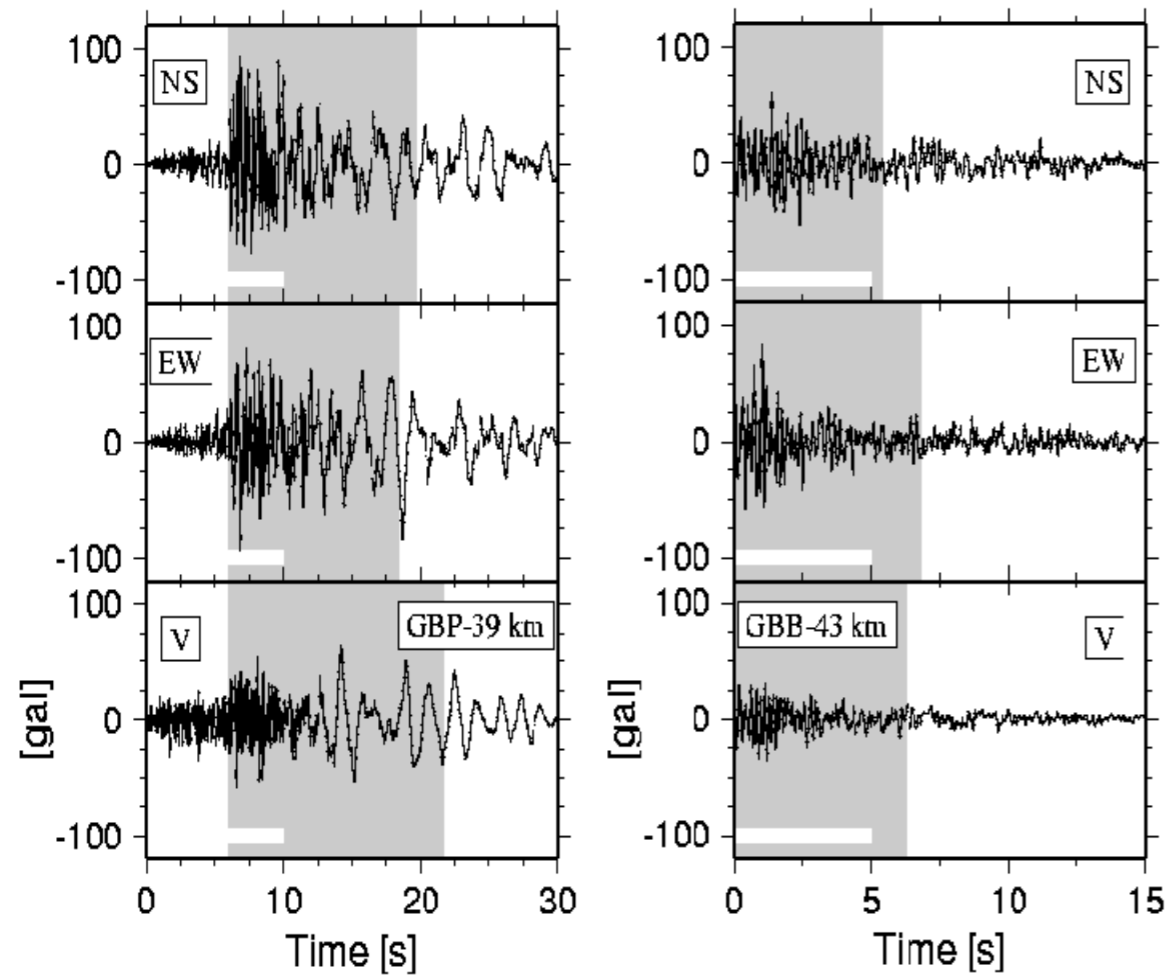


FIGURA 4 – AREA 4

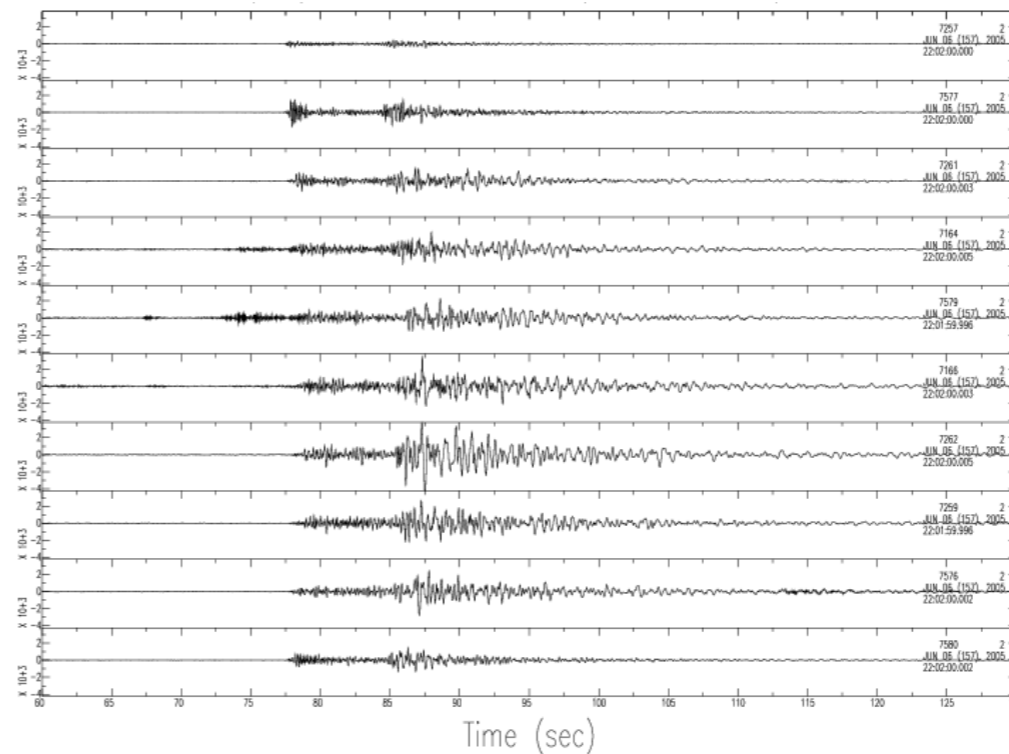
# Interventi per prevenzione, preparazione e capacity building



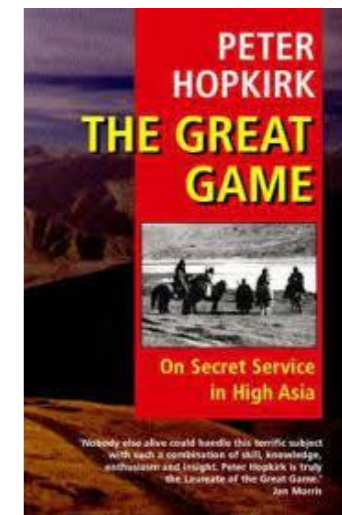
# Interventi per prevenzione, preparazione e capacity building



06/06/05 M 3 22:03 H 57km Comp. Ns



# Interventi per prevenzione, preparazione e capacity building

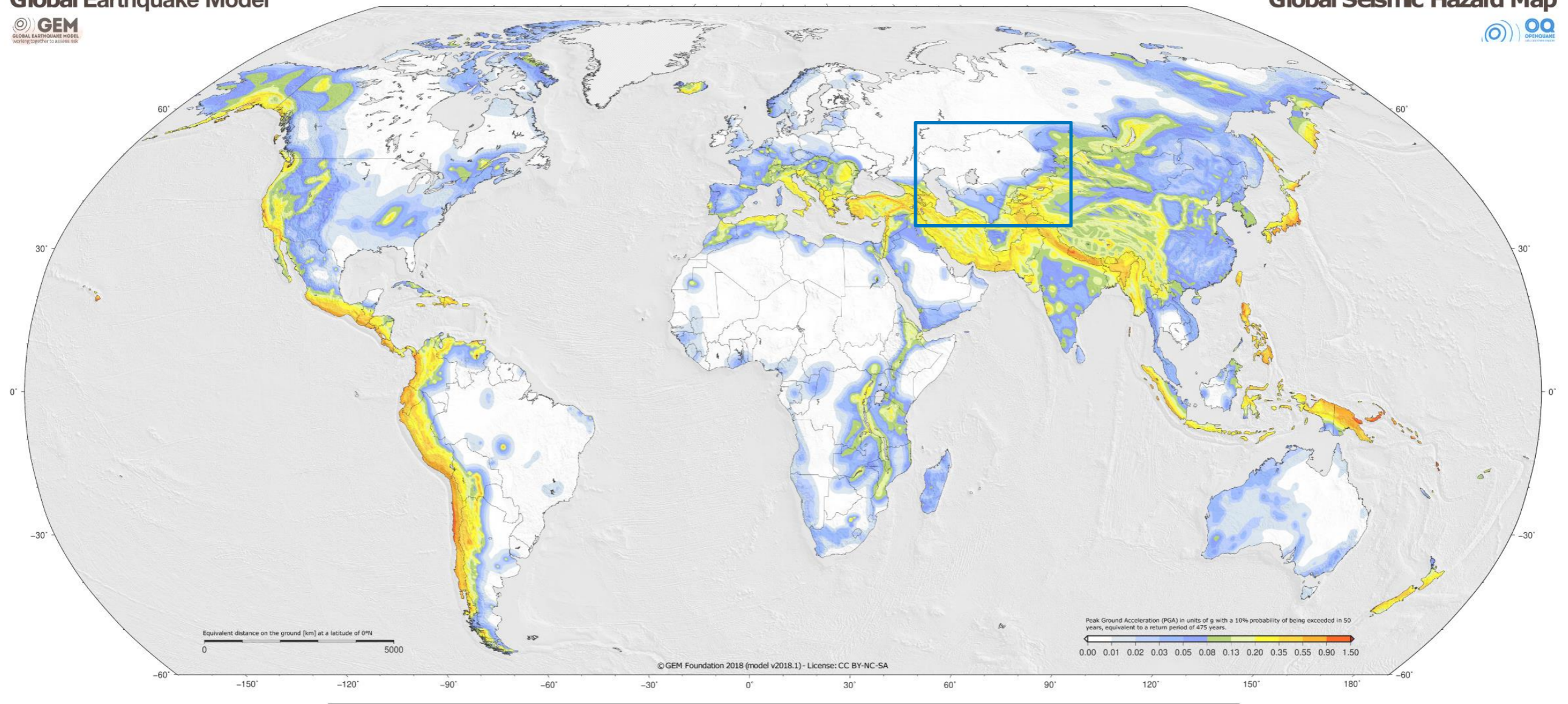


# Interventi per prevenzione, preparazione e capacity building

Global Earthquake Model



Global Seismic Hazard Map



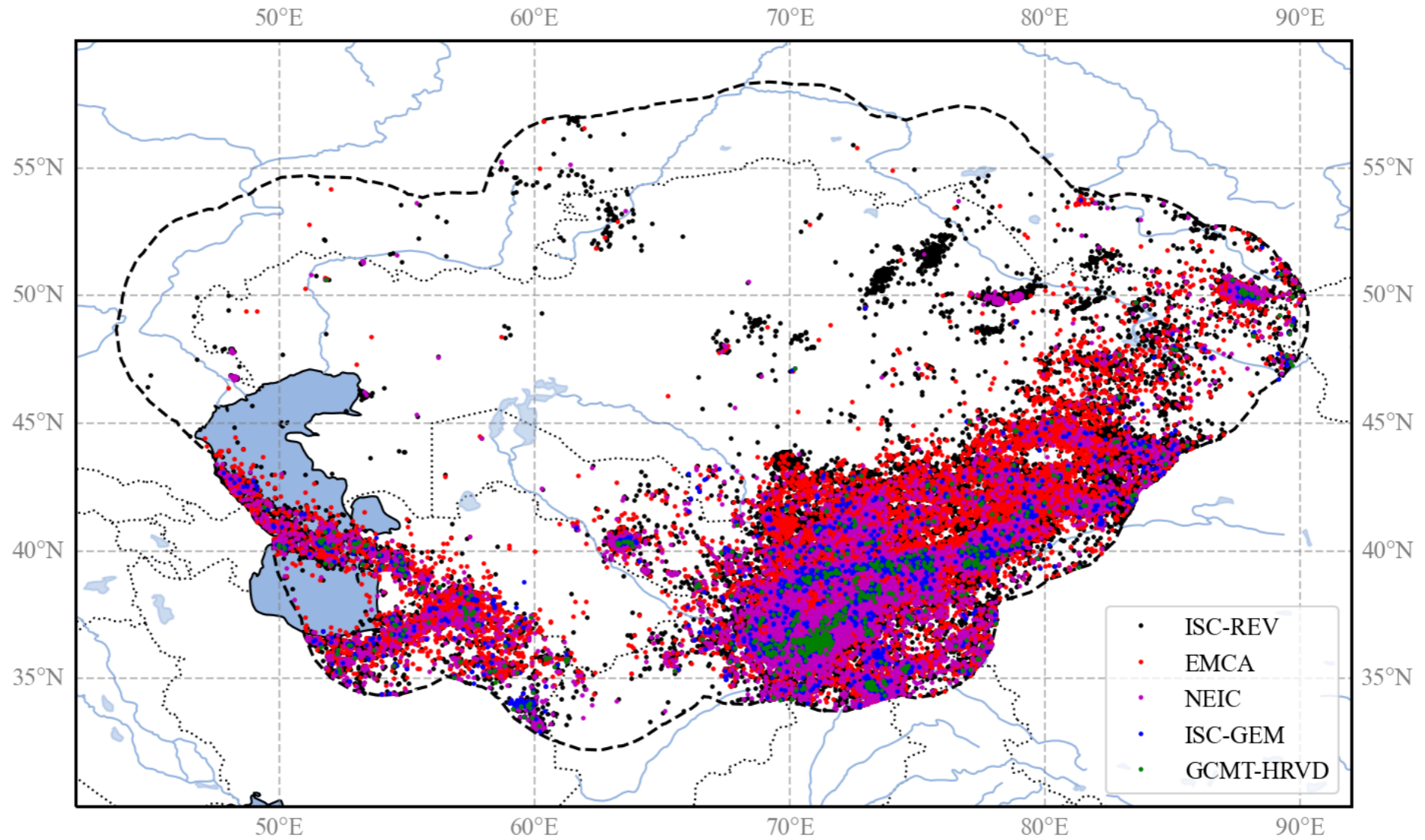
© GEM Foundation 2018 (model v2018.1) - License: CC BY-NC-SA

# Interventi per prevenzione, preparazione e capacity building

## Harmonized Earthquake Catalogue for Central Asia (HECCA)

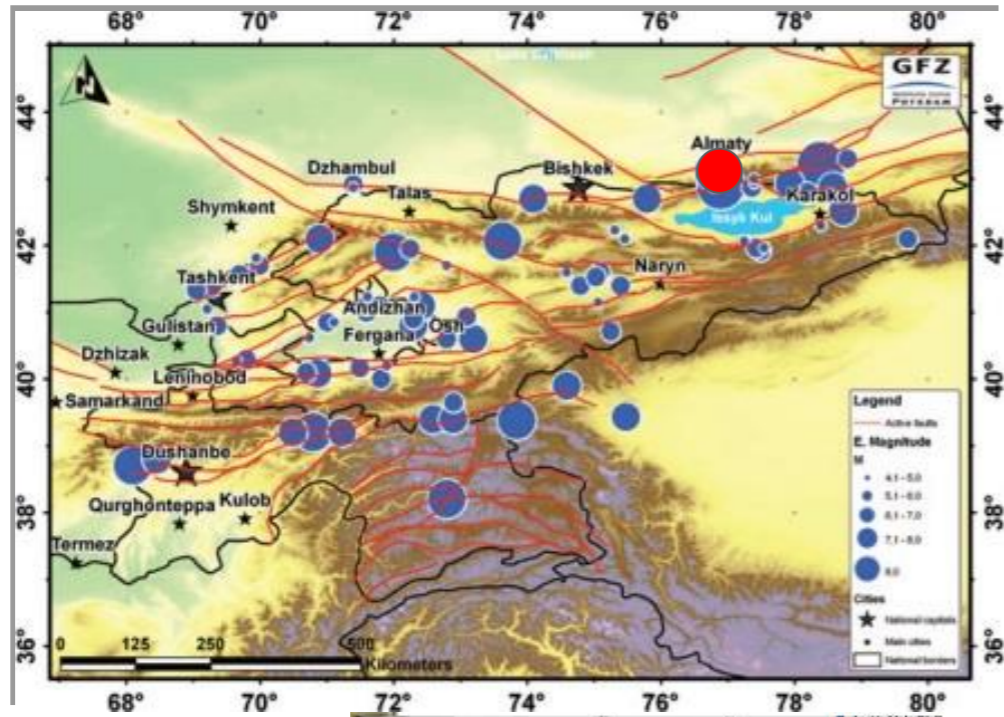
Project “Regionally consistent risk assessment for earthquakes and floods and selective landslide scenario analysis for strengthening financial resilience and accelerating risk reduction in Central Asia”

EU-funded Program  
“Strengthening Financial Resilience and Accelerating Risk Reduction in Central Asia” (SFRARR).

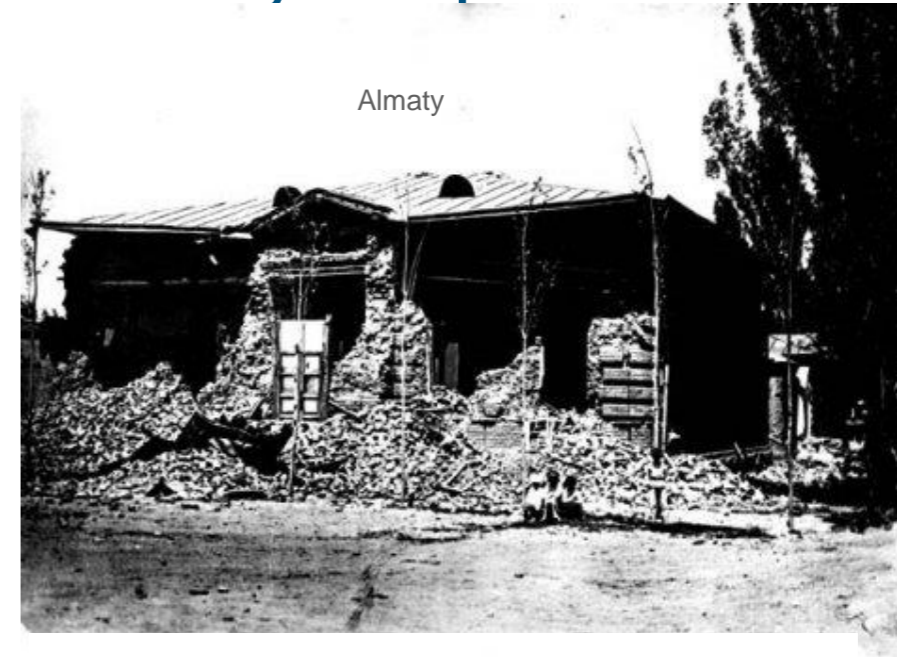


Poggi et al, (2022)

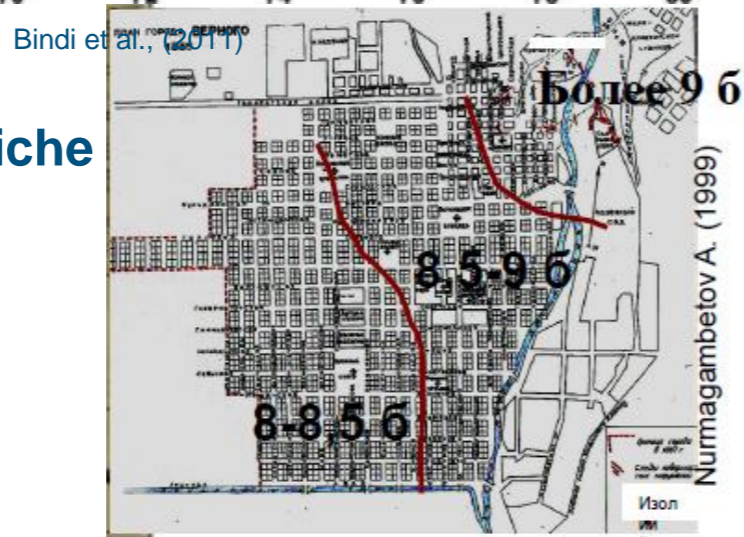
# Interventi per prevenzione, preparazione e capacity building



## 1887 Verny Earthquake M=7.3



Nurmagambetov (1999)



Intensità macrosismiche  
ad Almaty

~300 morti



Nurmagambetov (1999)

# Interventi per prevenzione, preparazione e capacity building

## 1911 Kemin Earthquake M=7.8-8.0



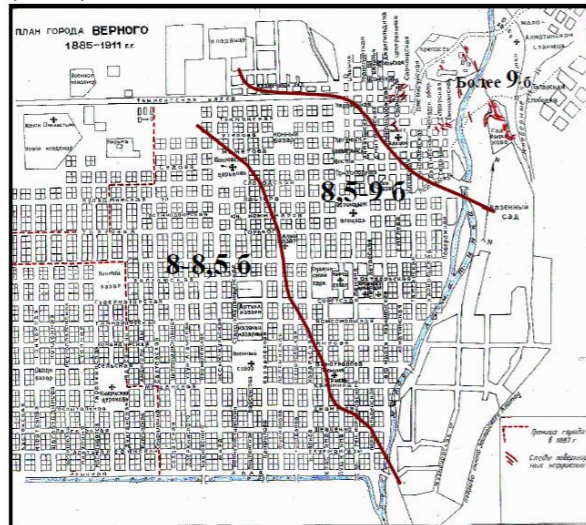
Le sorgenti storiche indicano che il terremoto generò forti danni e devastazione a Pishpek (l'attuale Bishkek)

Bindi et al. (2011)

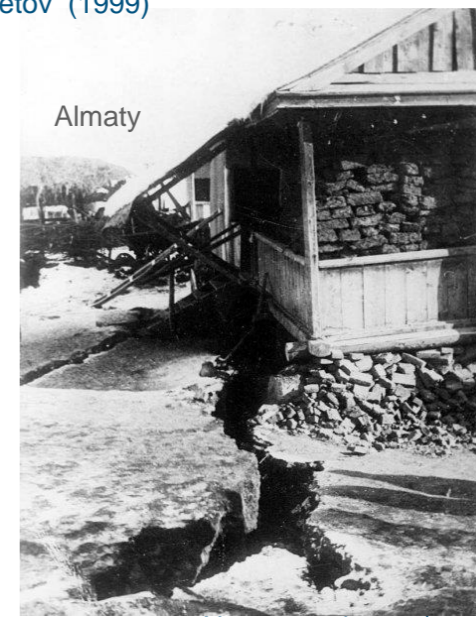


Nurmagambetov (1999)

Intensità  
macroismich  
e a Almaty  
~390 morti



Nurmagambetov (1999)

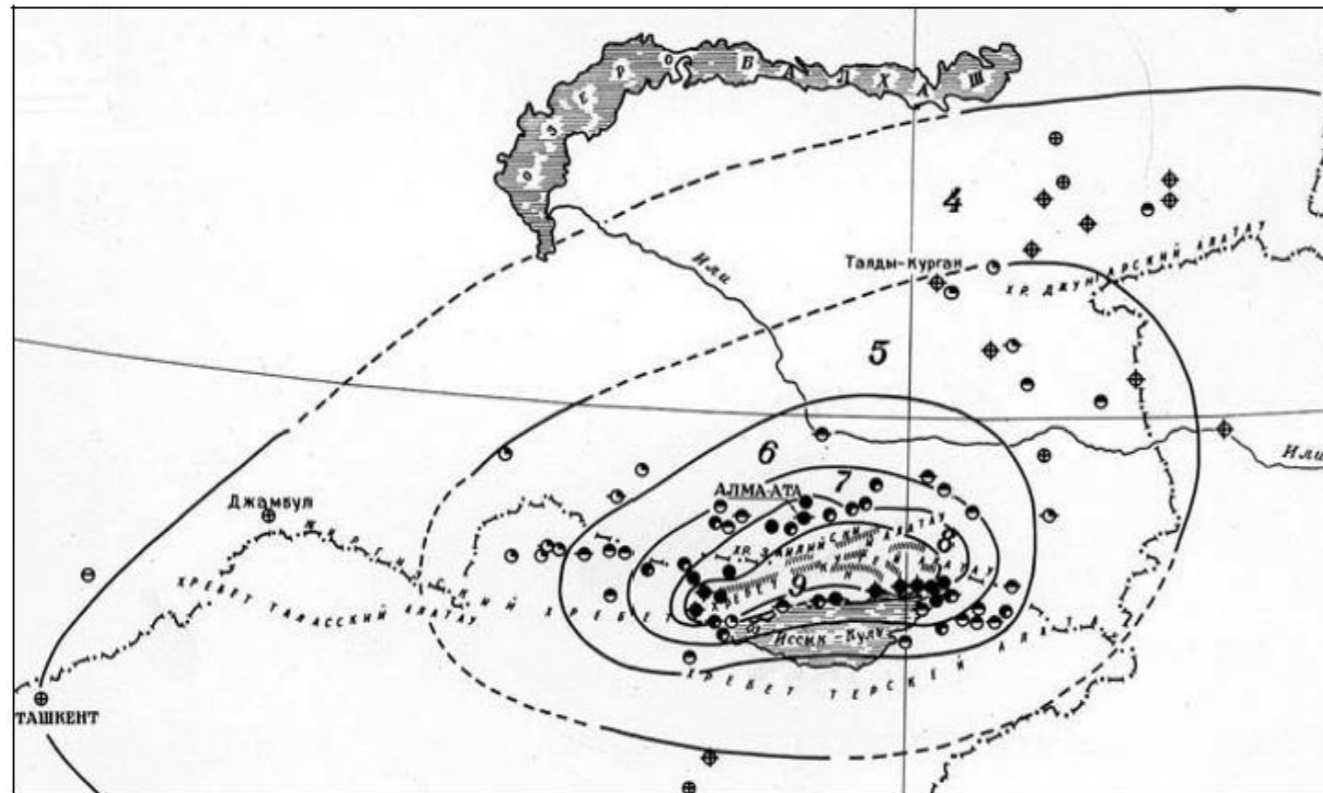


Nurmagambetov (1999)



## Interventi per prevenzione, preparazione e capacity building

Verny, è situata su una conoide, e **notevoli depositi di potenza di ghiaia e sabbia grossolana mista a massi, talvolta di notevoli dimensioni, che rappresentano, in condizioni di livello profondo delle acque sotterranee, un materiale in grado di assorbire rapidamente le onde elastiche** soddisfacente in termini di condizioni sismiche. A.P. Zenkov



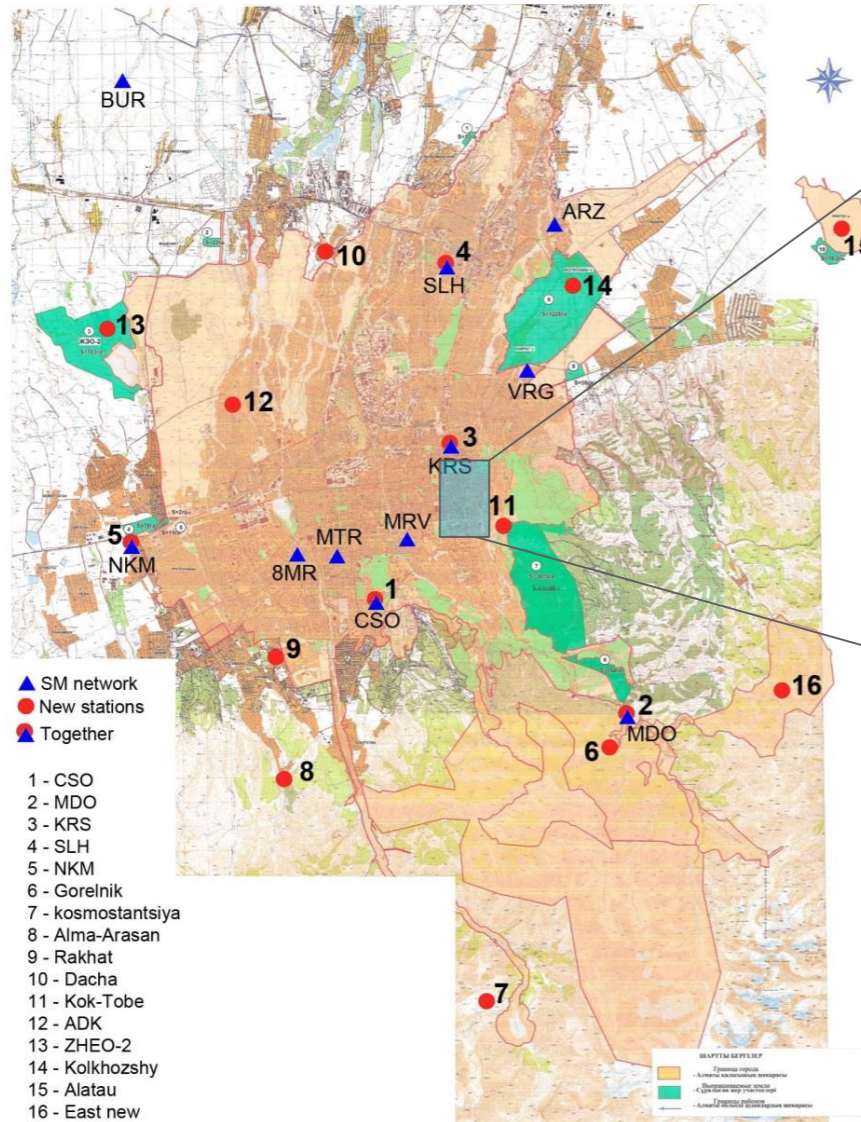
Nurmagambetov (1999)



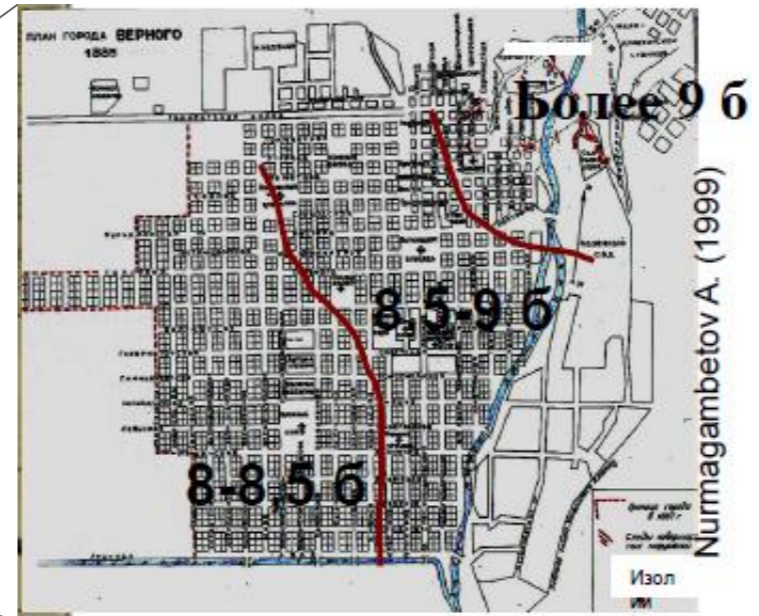
K. Bogdanovich

Spedizione di 4 mesi con rilievo di dettaglio!

Rischi molto alto considerando la dinamica dell'urbanizzazione



Parolai et al (2015)



City	Population (millions)	Estimated deaths (thousands)	Estimated Injuries (thousands)
Almaty	1.5	75	300
Bishkek	0.8 (now ~1)	40	160

GeoHazards IBt.Tucker, pers. comm.

**Inizio della cooperazione nella regione: Tashkent, Uzbekistan 2008**



Installazione di una rete sismometrica in tempo reale (CAREMON, CASCADE)

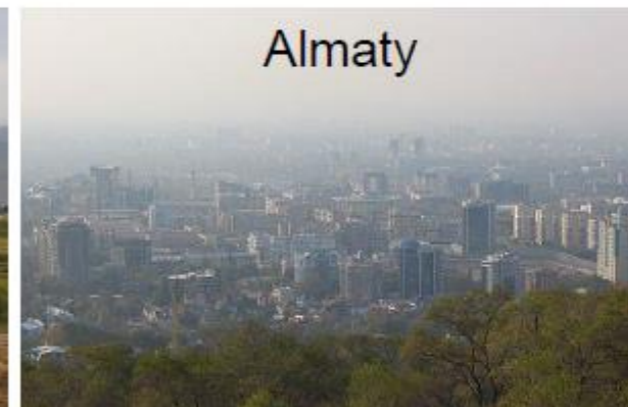
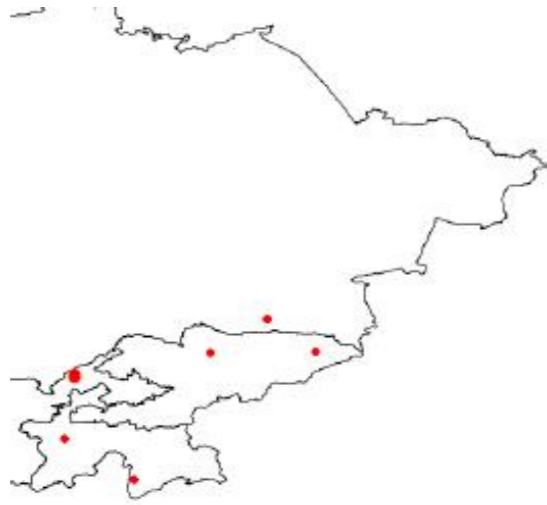
Risposta di sito in aree urbane

Stima della pericolosità e del rischio sismico (EMCA)

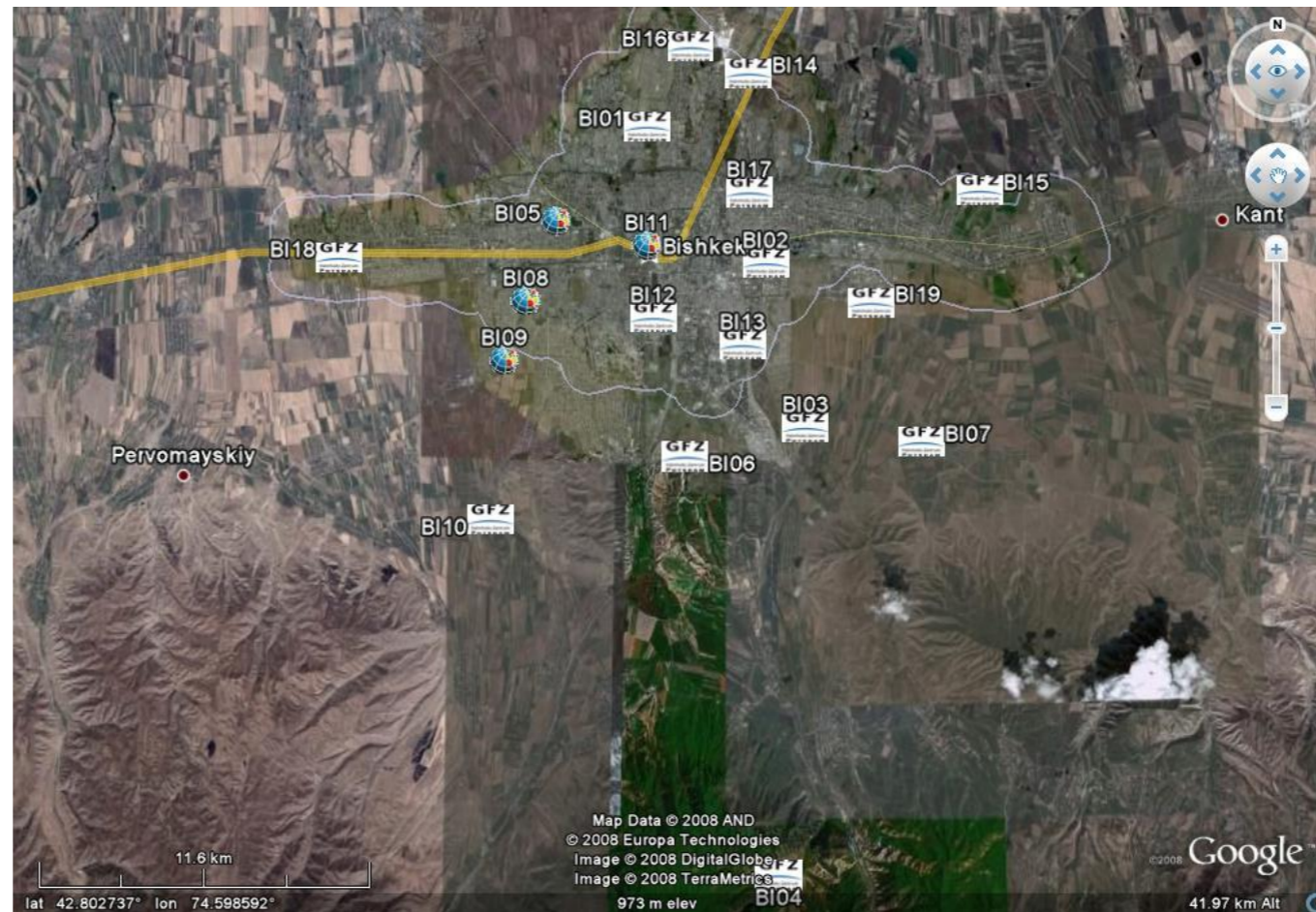


## Stima degli effetti di sito

Identificazione di hot spots per la valutazione del rischio



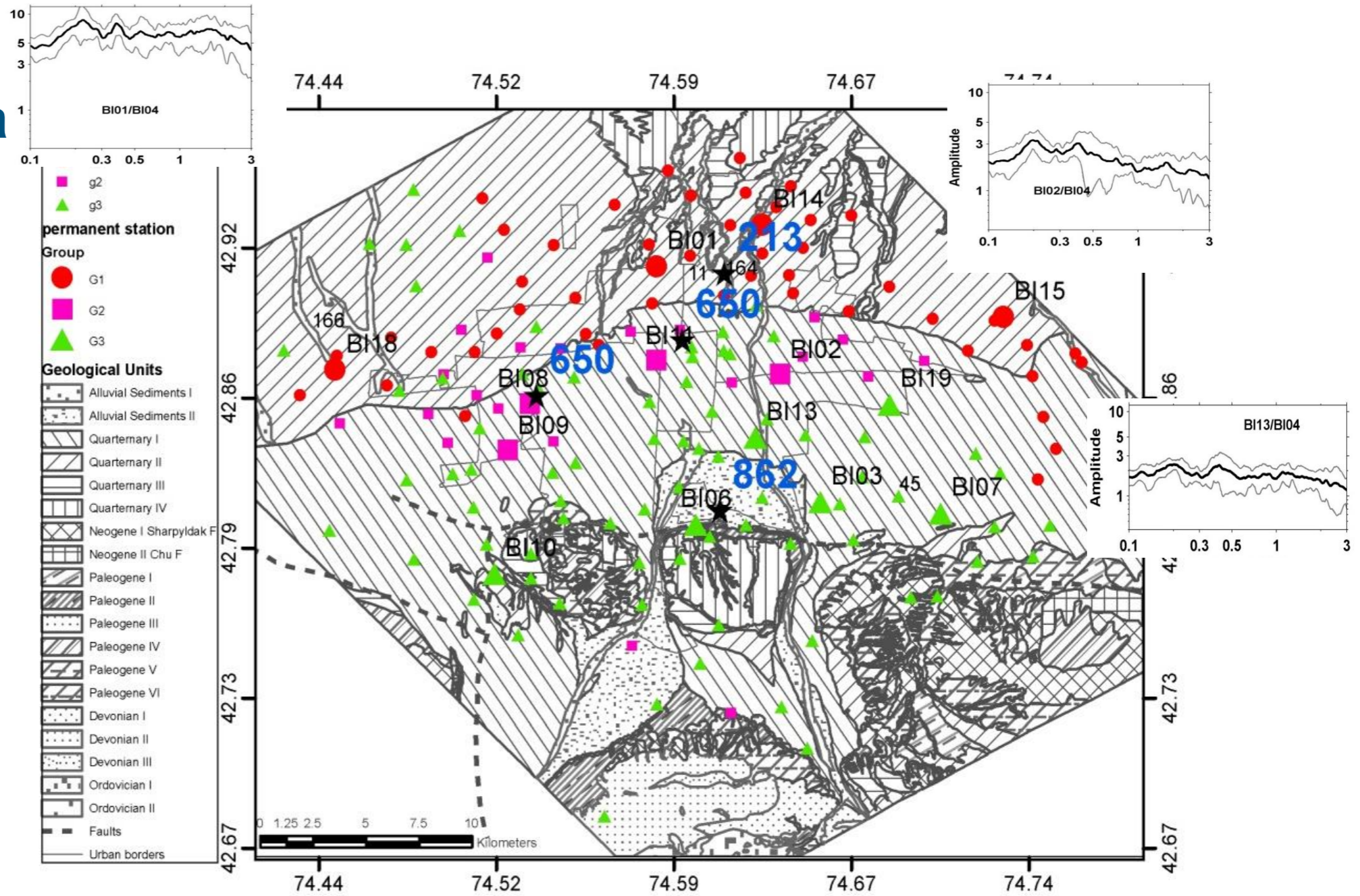
## Studio della risposta di sito a Bishkek



Installazione di una rete sismometrica temporanea di 19 stazioni

196 misure di rumore sismico a stazione singola

# Stima della risposta di sito a Bishkek



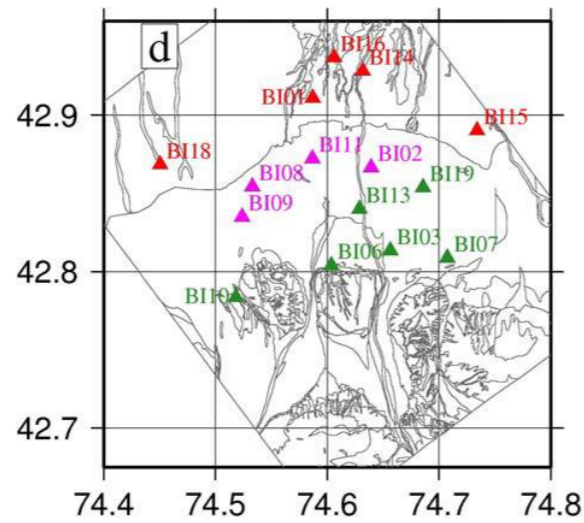
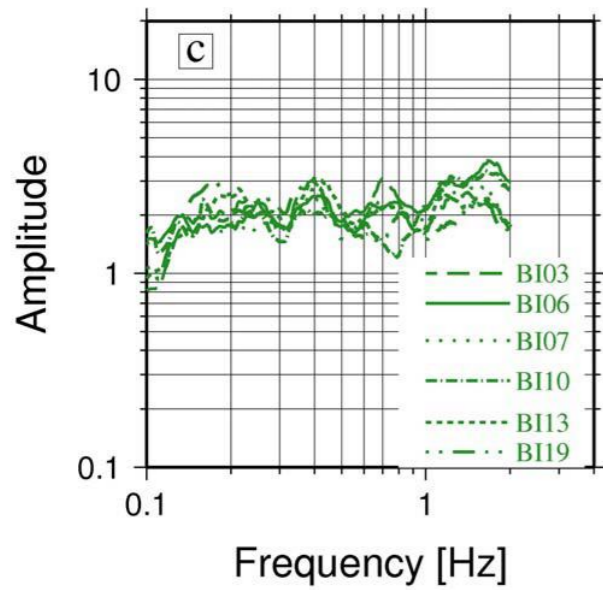
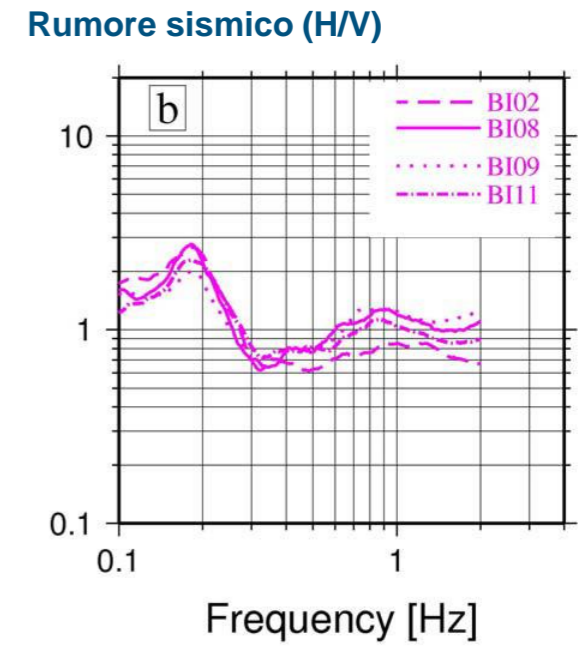
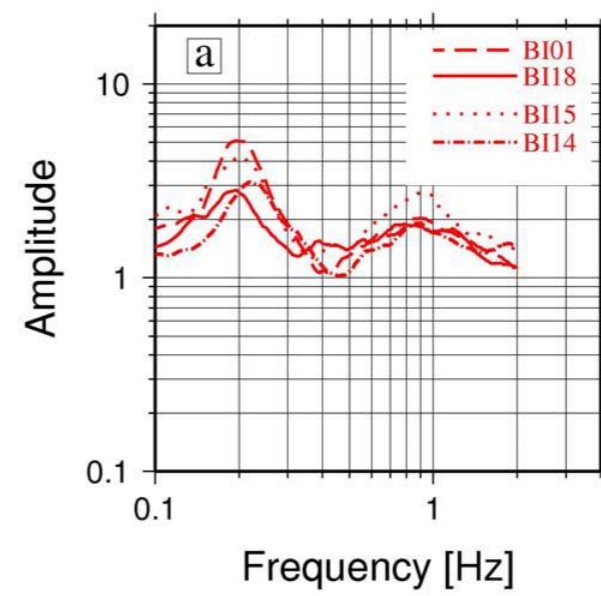
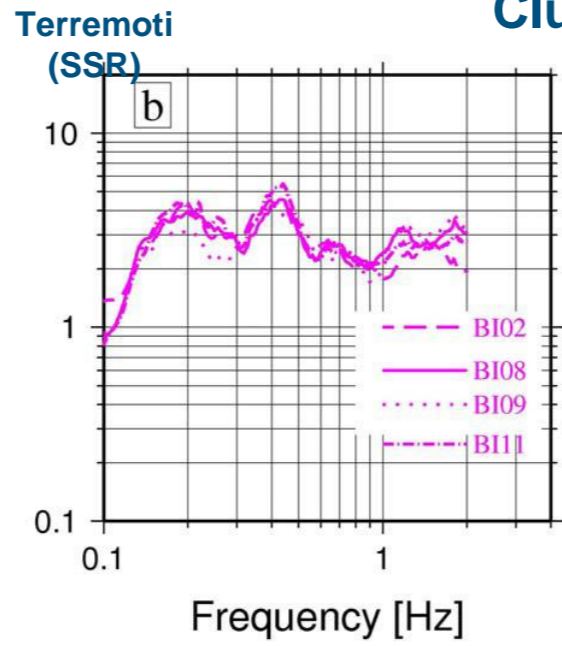
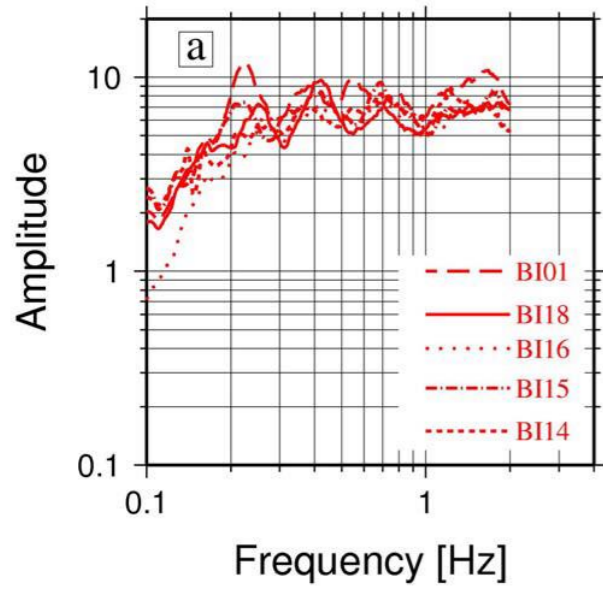
Ullah et al (2013)

## Interventi per prevenzione, preparazione e capacity building

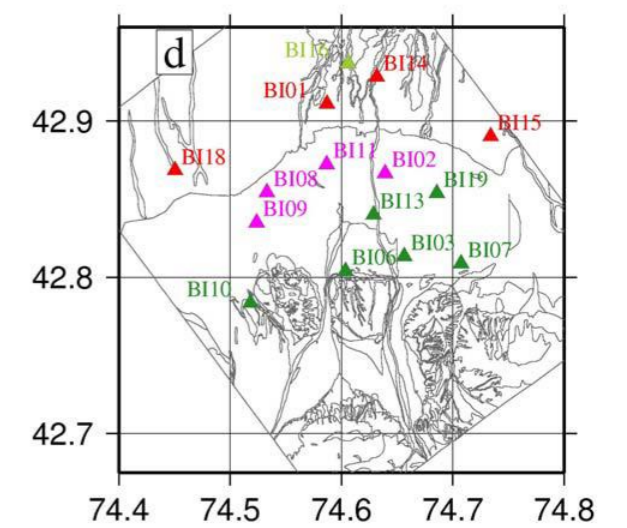
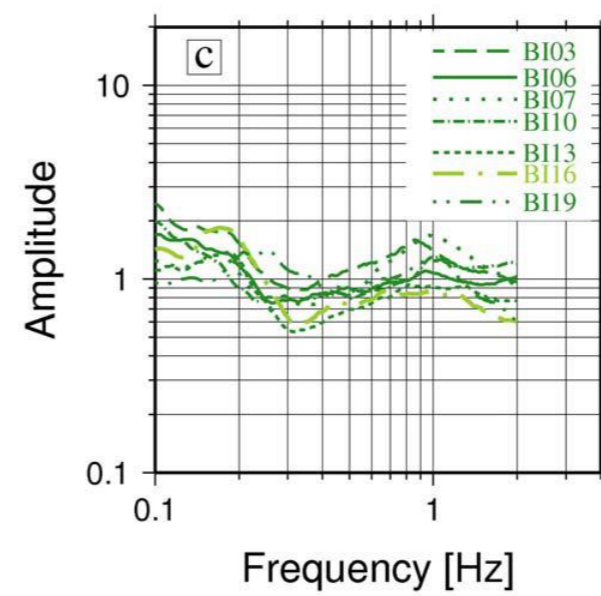


# Interventi per prevenzione, preparazione e capacity building

## Clustering analysis

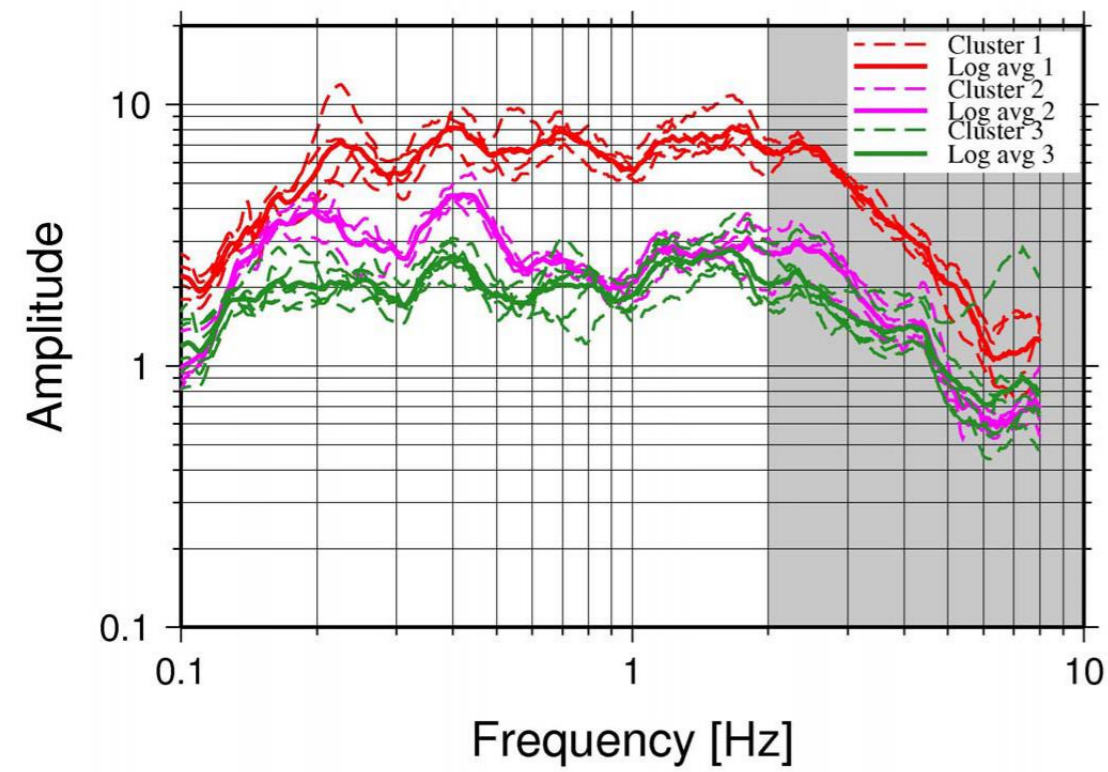


Ullah et al (2013)

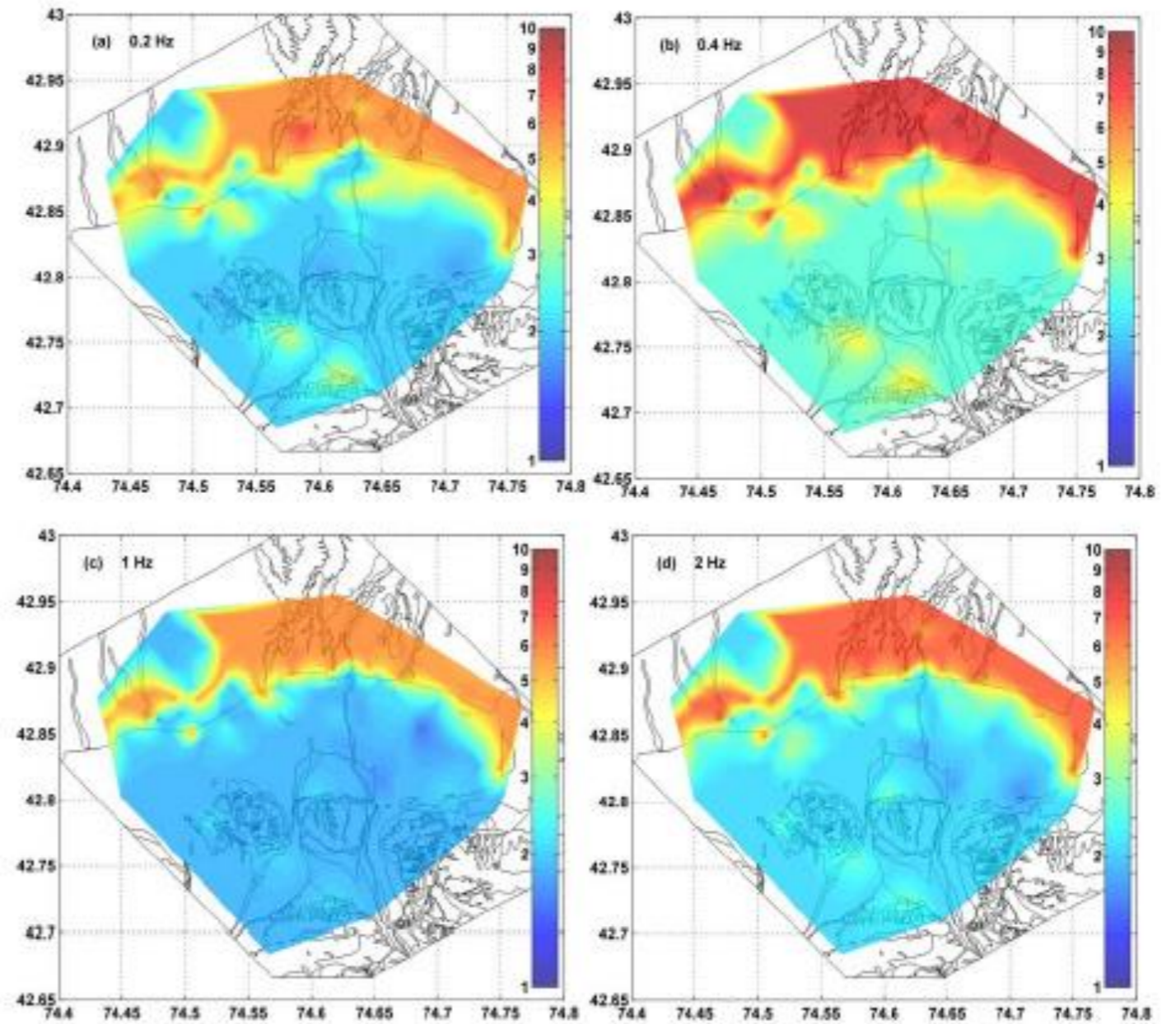




## Clustering analysis

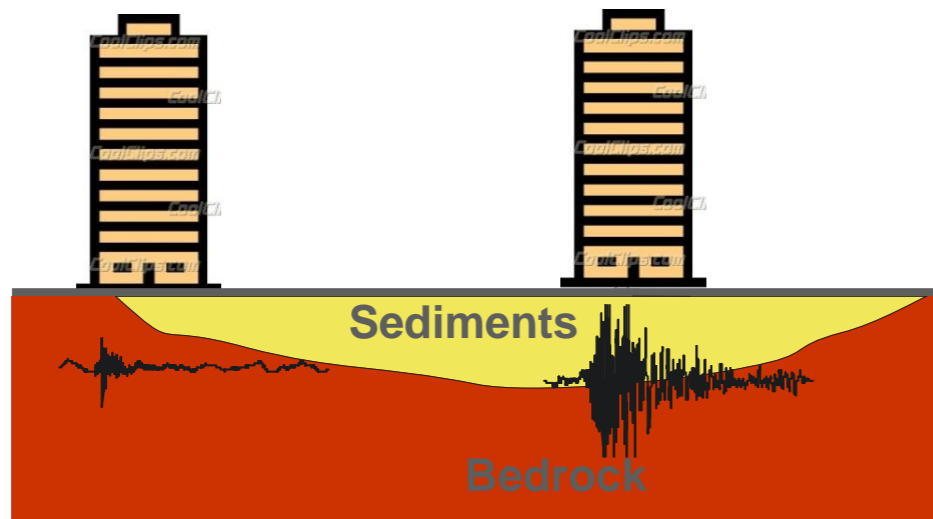


Ullah et al (2013)



## Stima degli effetti di sito

Bulletin of the Seismological Society of America, Vol. 100, No. 6, pp. 3068–3082, December 2010, doi: 10.1785/012010004



### Site Effects Assessment in Bishkek (Kyrgyzstan) Using Earthquake and Noise Recording Data

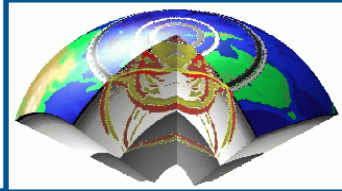
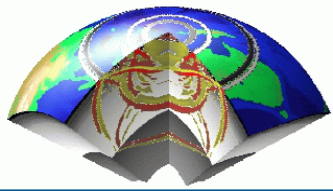
by S. Parolai, S. Orunbaev, D. Bindi,\* A. Strollo,† S. Usupaev, M. Picozzi, D. Di Giacomo,† P. Augliera, E. D'Alema, C. Milkereit, B. Moldobekov, and J. Zschau

**Abstract** Kyrgyzstan, which is located in the collision zone between the Eurasian and Indo-Australian lithosphere plates, is prone to large earthquakes as shown by its historical seismicity. Hence, an increase in the knowledge and awareness by local authorities and decision makers of the possible consequence of a large earthquake, based on improved seismic hazard assessments and realistic earthquake risk scenarios,

“On the other hand, the velocity (*..estimated from the slope of topography..*) in the northern part seems to be **underestimated** ....”

“Finally, a site classification only based on VS30 **is not** adequate to account for the broadband site amplification





## Strong motion vertical array

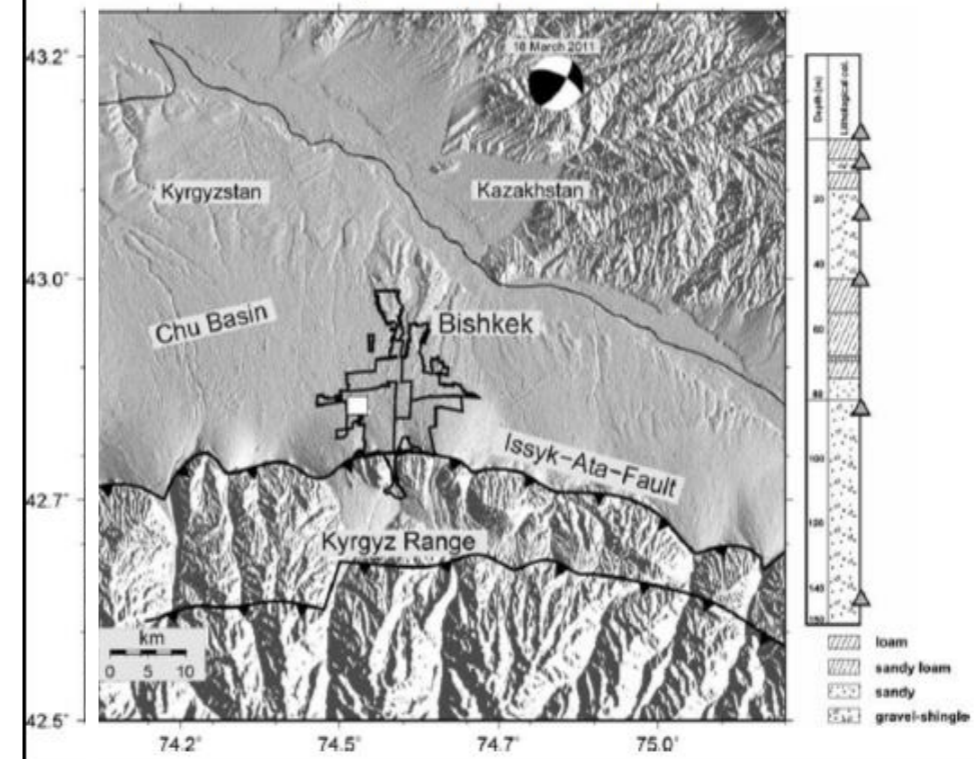


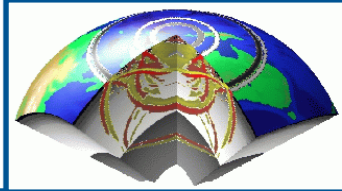
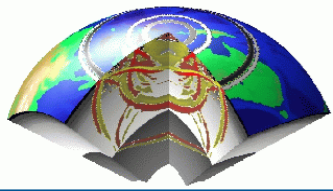
J Seismol (2013) 17:707–719  
DOI 10.1007/s10950-012-9347-y

ORIGINAL ARTICLE

### The Bishkek vertical array (BIVA): acquiring strong motion data in Kyrgyzstan and first results

S. Parolai • D. Bindi • S. Ullah • S. Orunbaev •  
S. Usupaev • B. Moldobekov • H. Echtler

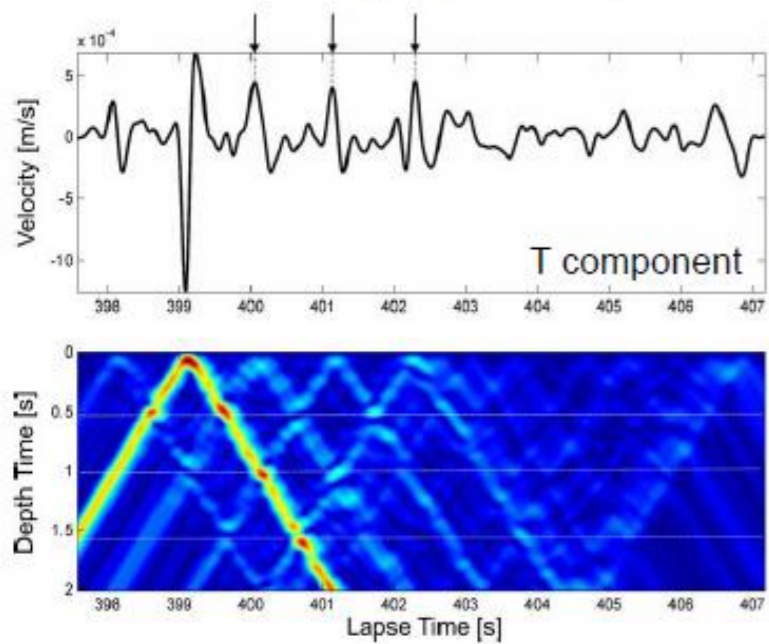




# Strong motion vertical array

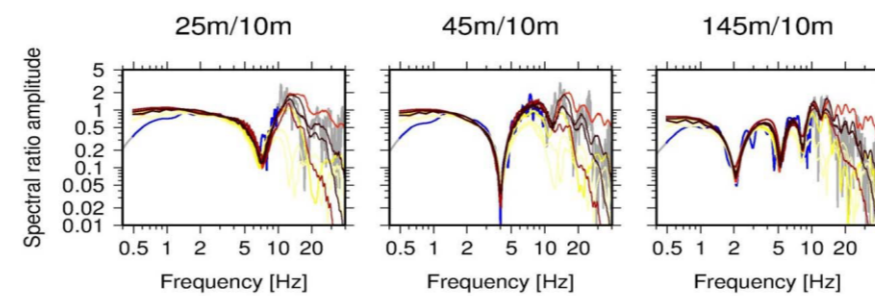
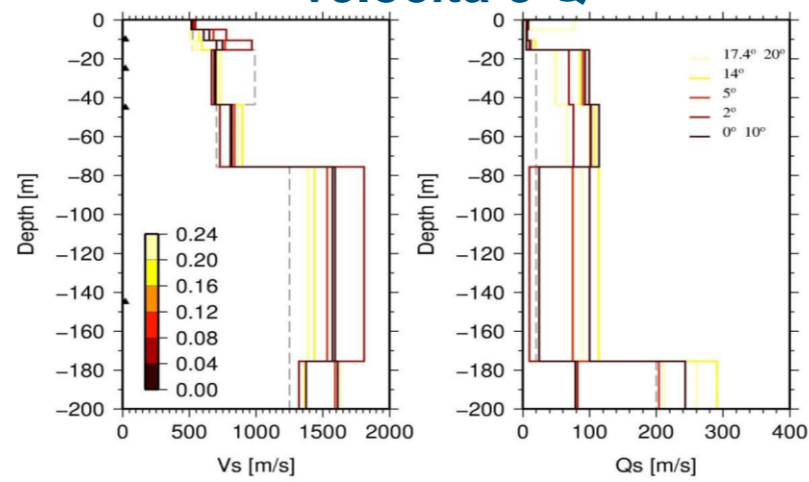
## Studio della struttura del bacino

Non stationary ray decomposition



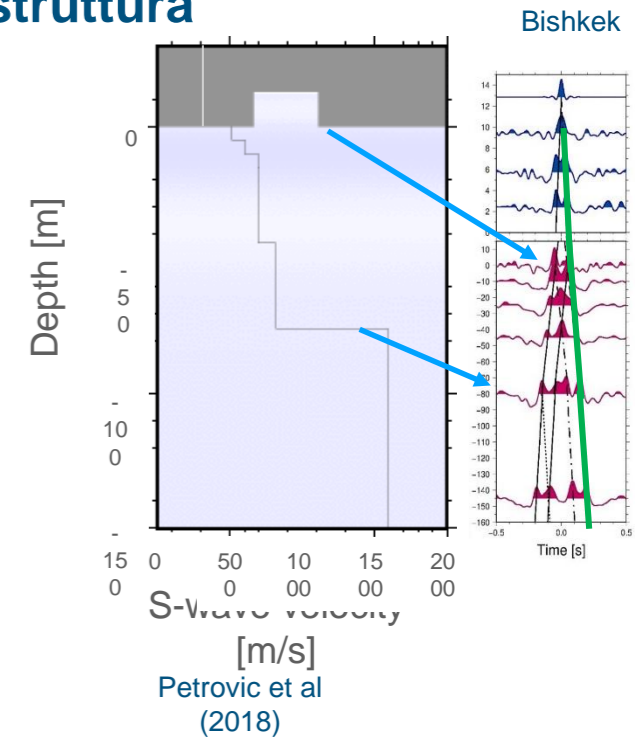
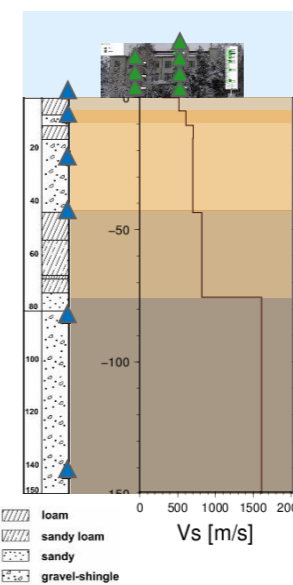
Parolai et al (2013)

## Inversione della struttura di velocità e Q

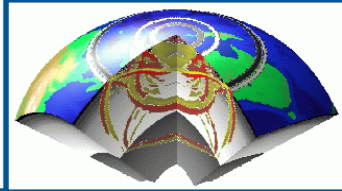
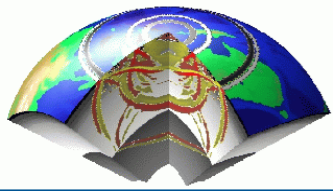


Parolai et al (2013)

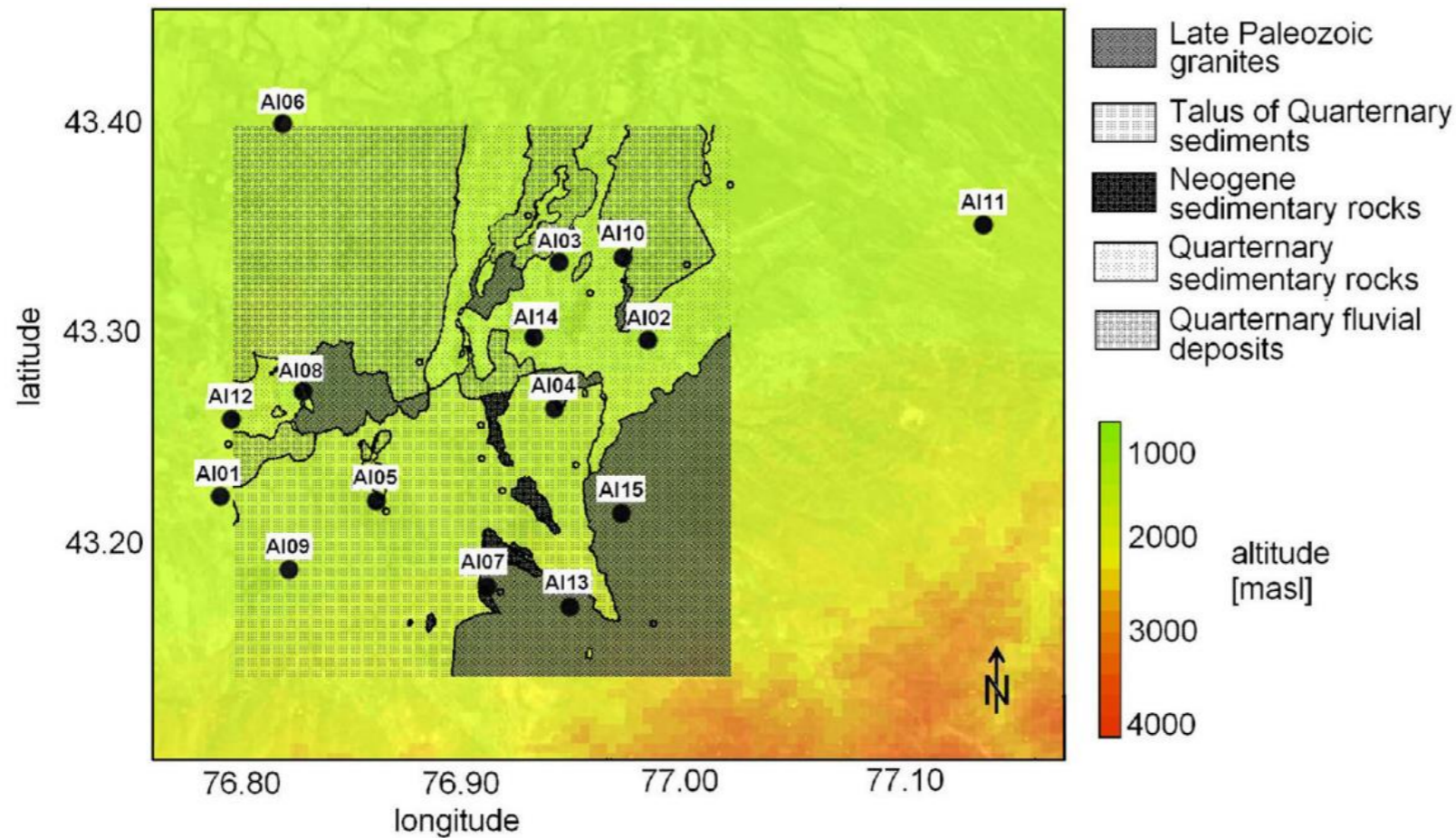
## Studio dell'interazione suolo struttura



Petrovic et al (2018)



## Studio degli effetti di sito a Almaty



Pilz et al (2018)

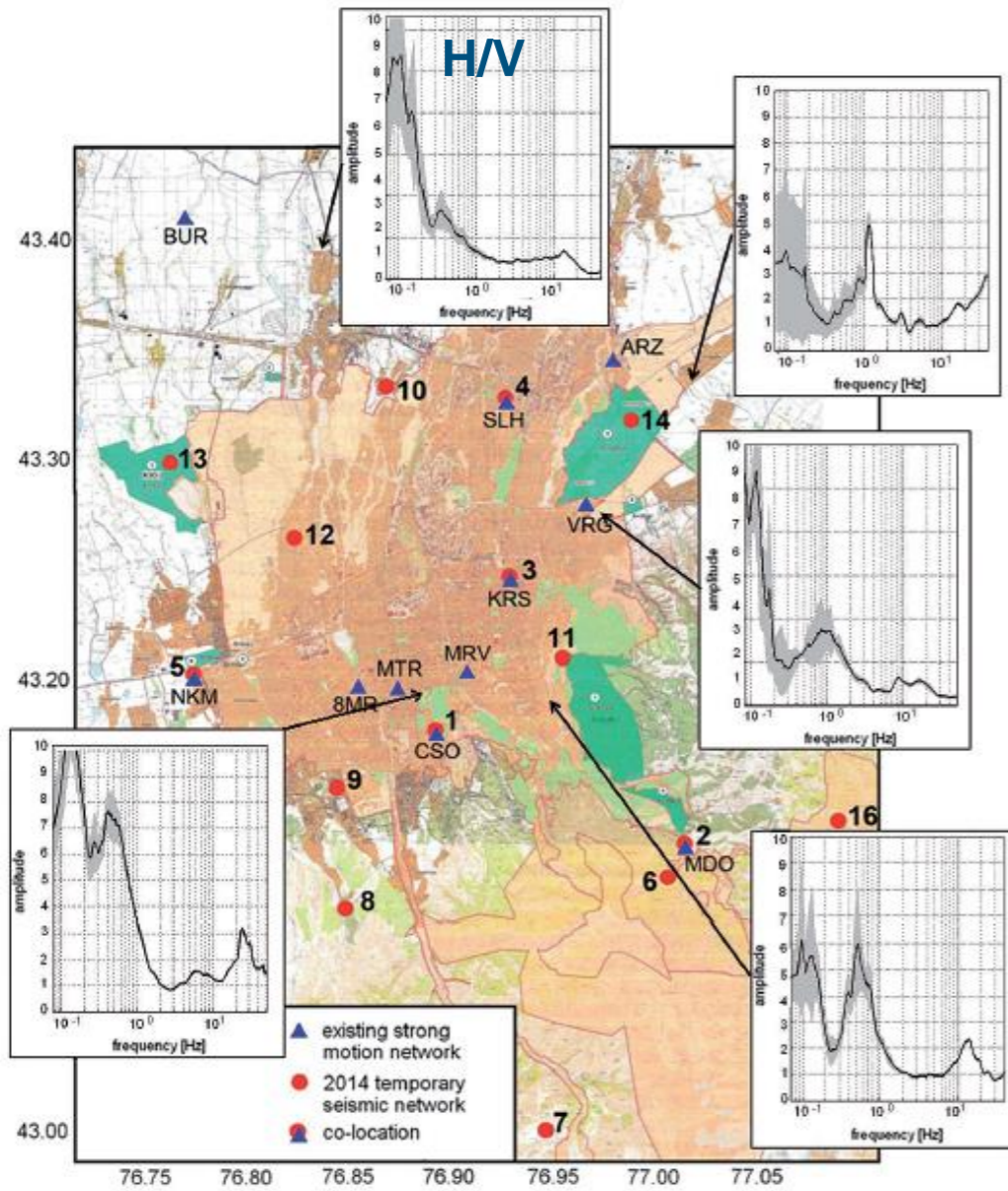
Rete temporanea di 15 stazioni  
Temporary network

15 stazioni strong motion  
permanenti

220 misure di rumore  
ambientale a singola stazione

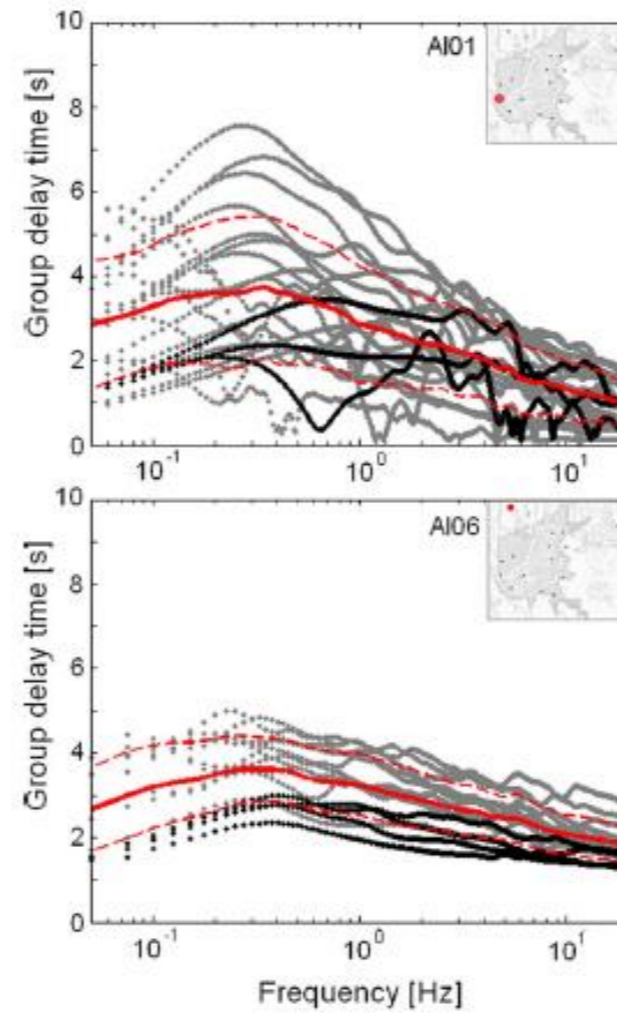
3 arrays

# Interventi per prevenzione, preparazione e capacity building

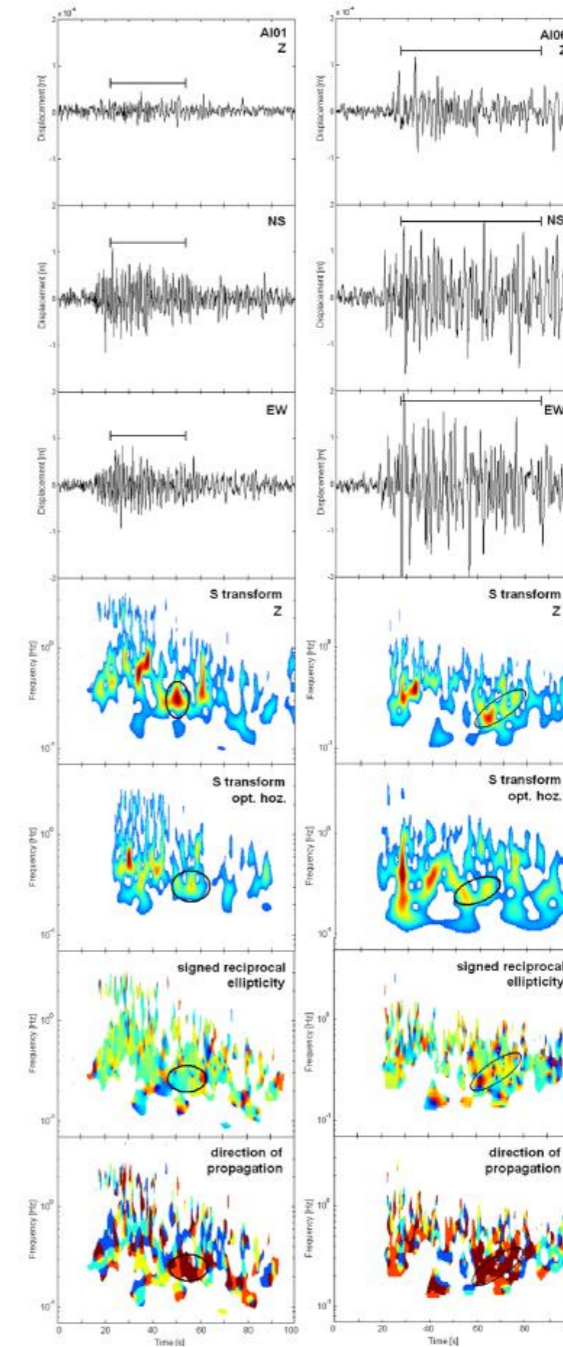


Pilz et al (2015)

## Studio della durata

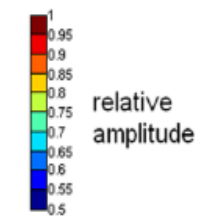
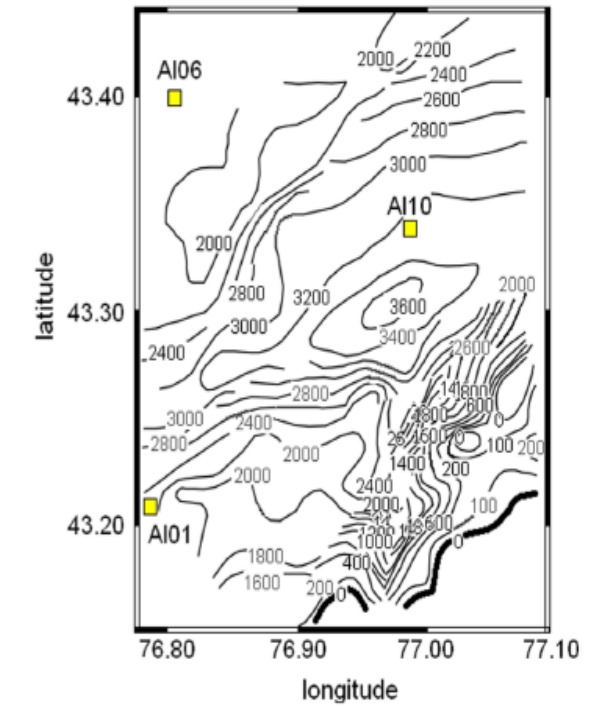
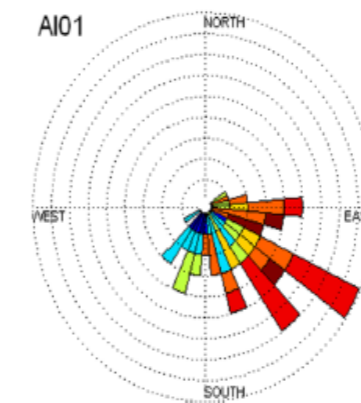
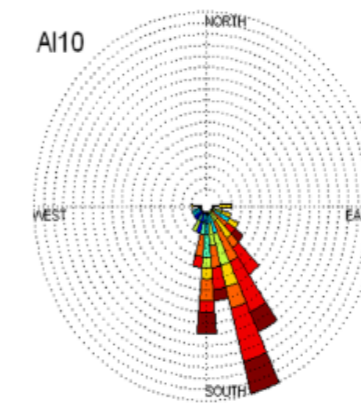
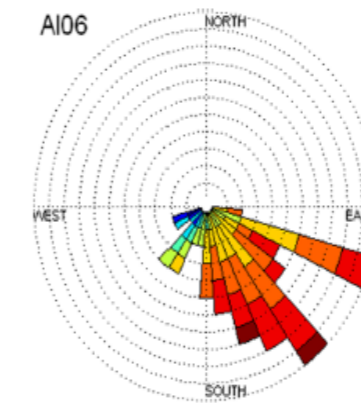
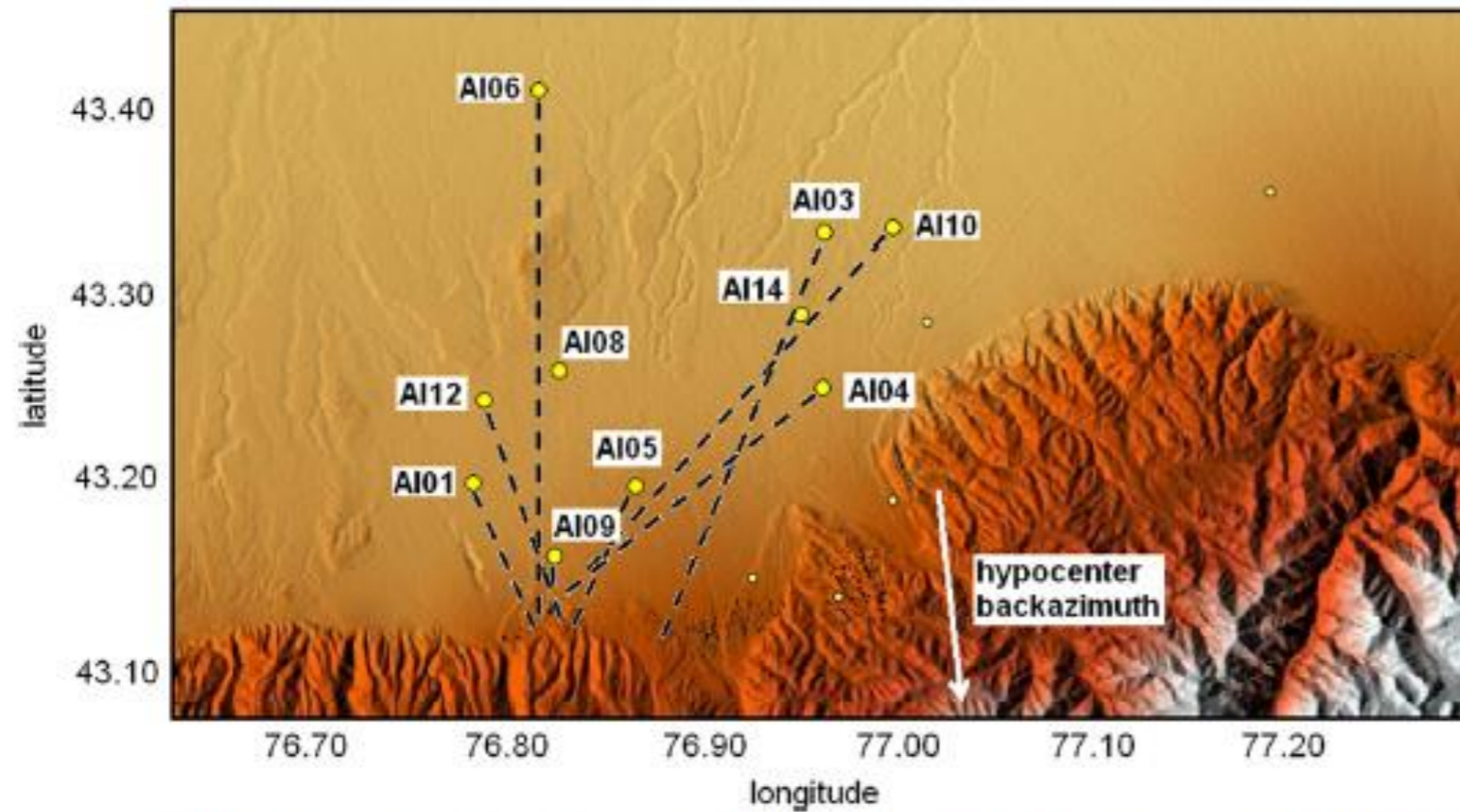


Pilz et al (2018)



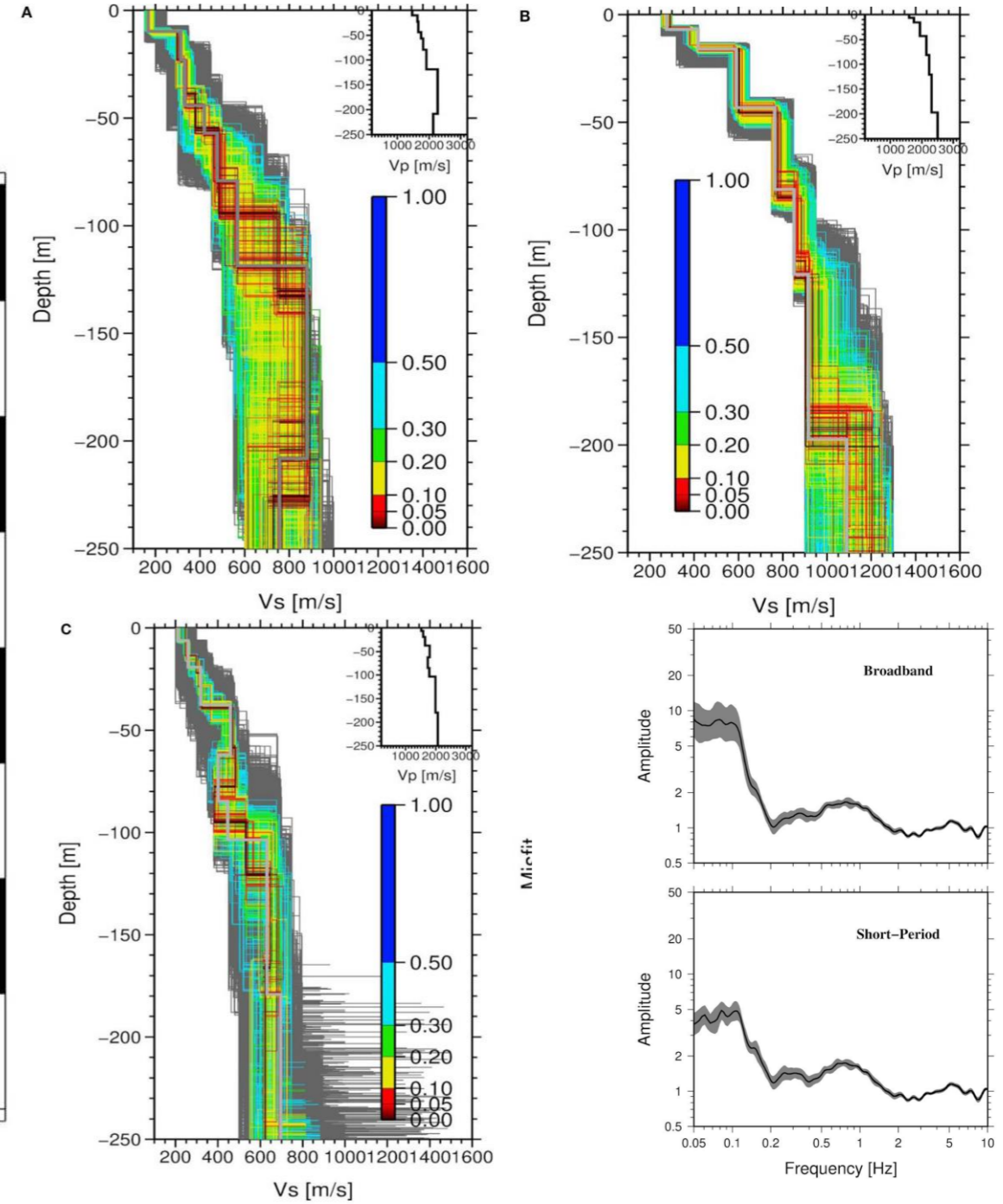
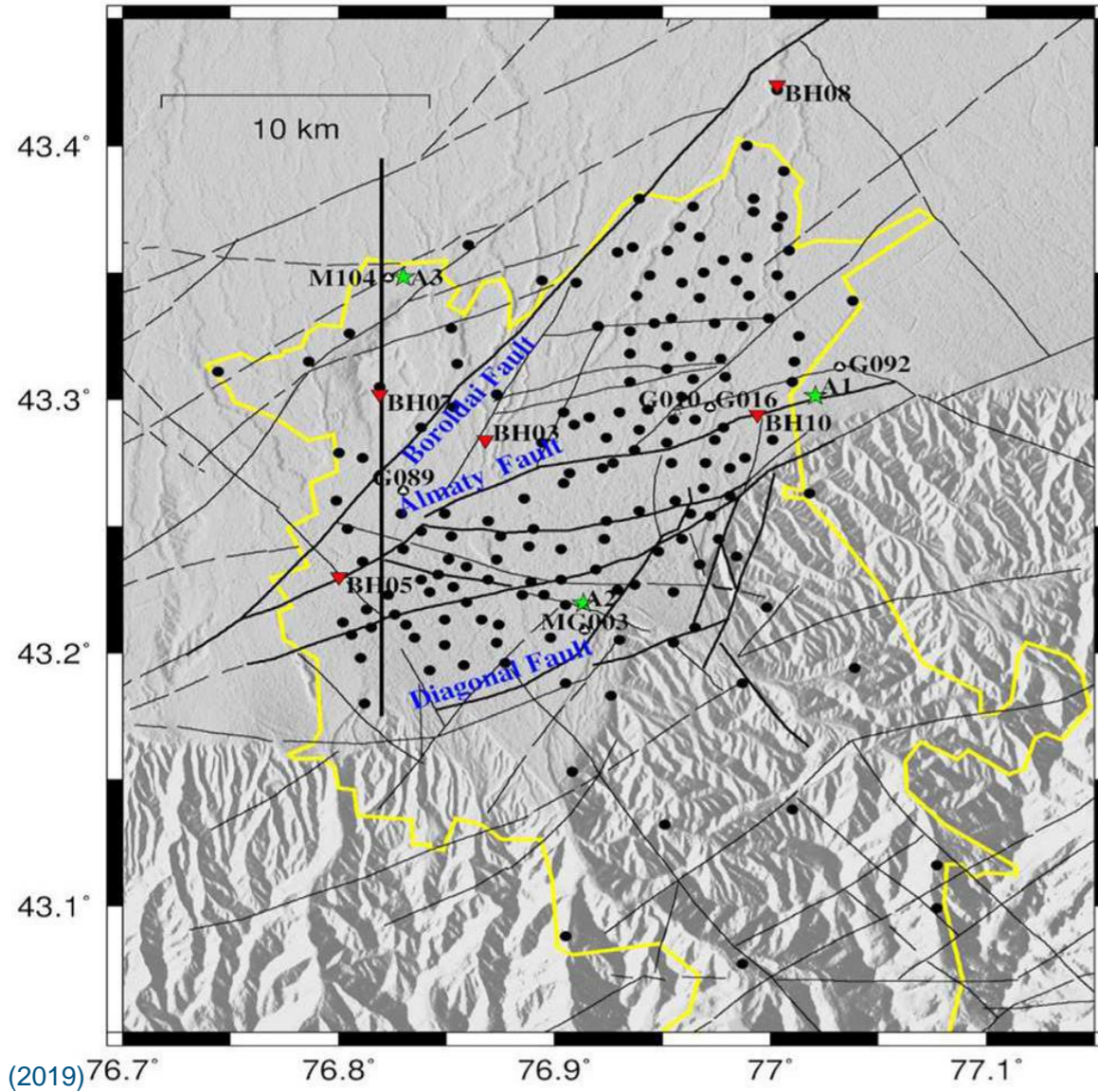
## Analisi della polarizzazione e nel dominio tempo-frequenza

# Studio degli effetti 2D-3D



Pilz et al (2018)

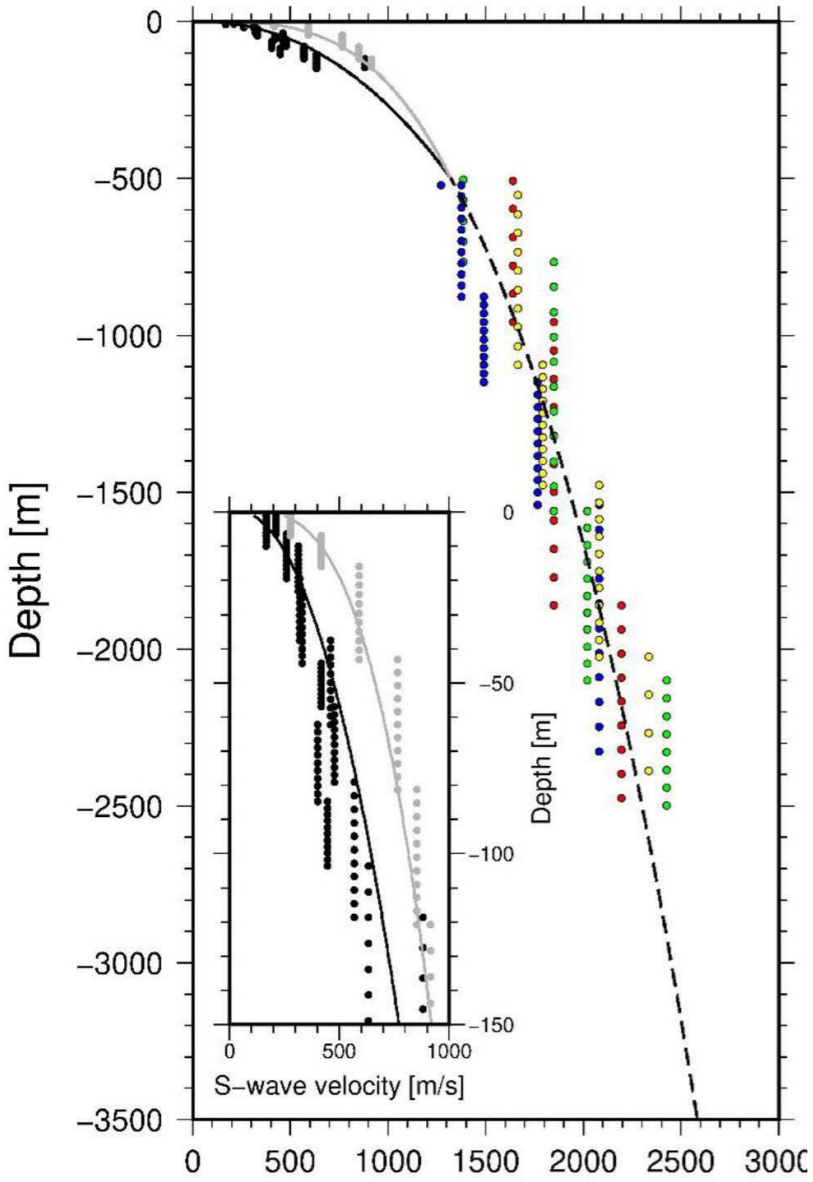
## Un nuovo modello della struttura del bacino



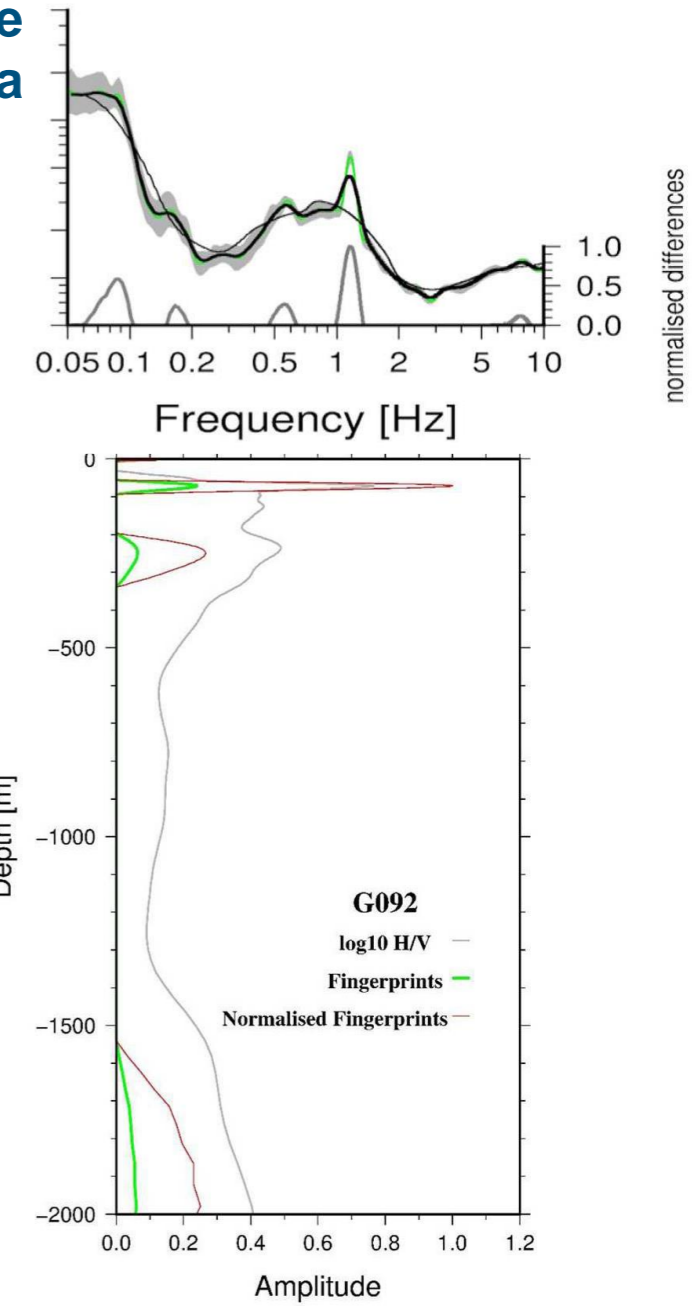
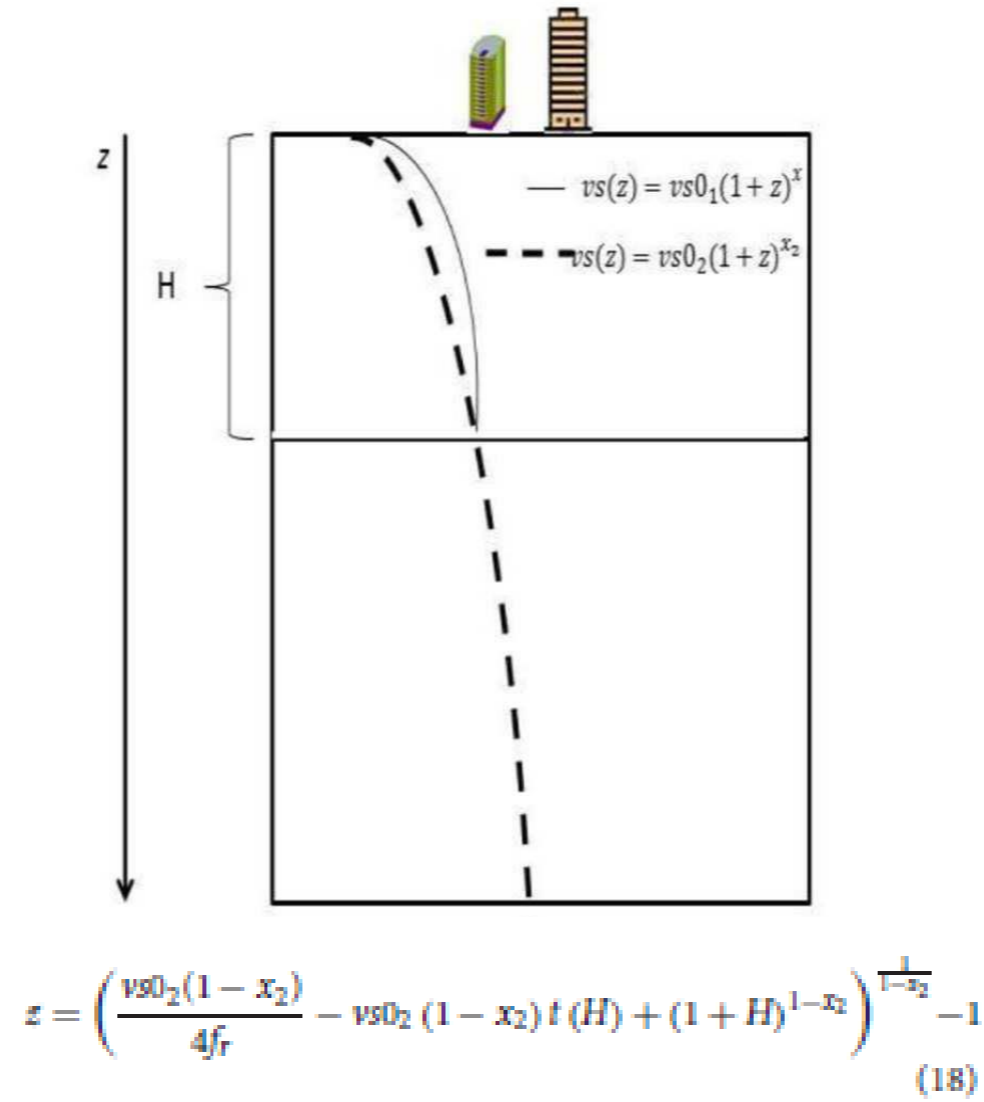
Parolai et al (2019)



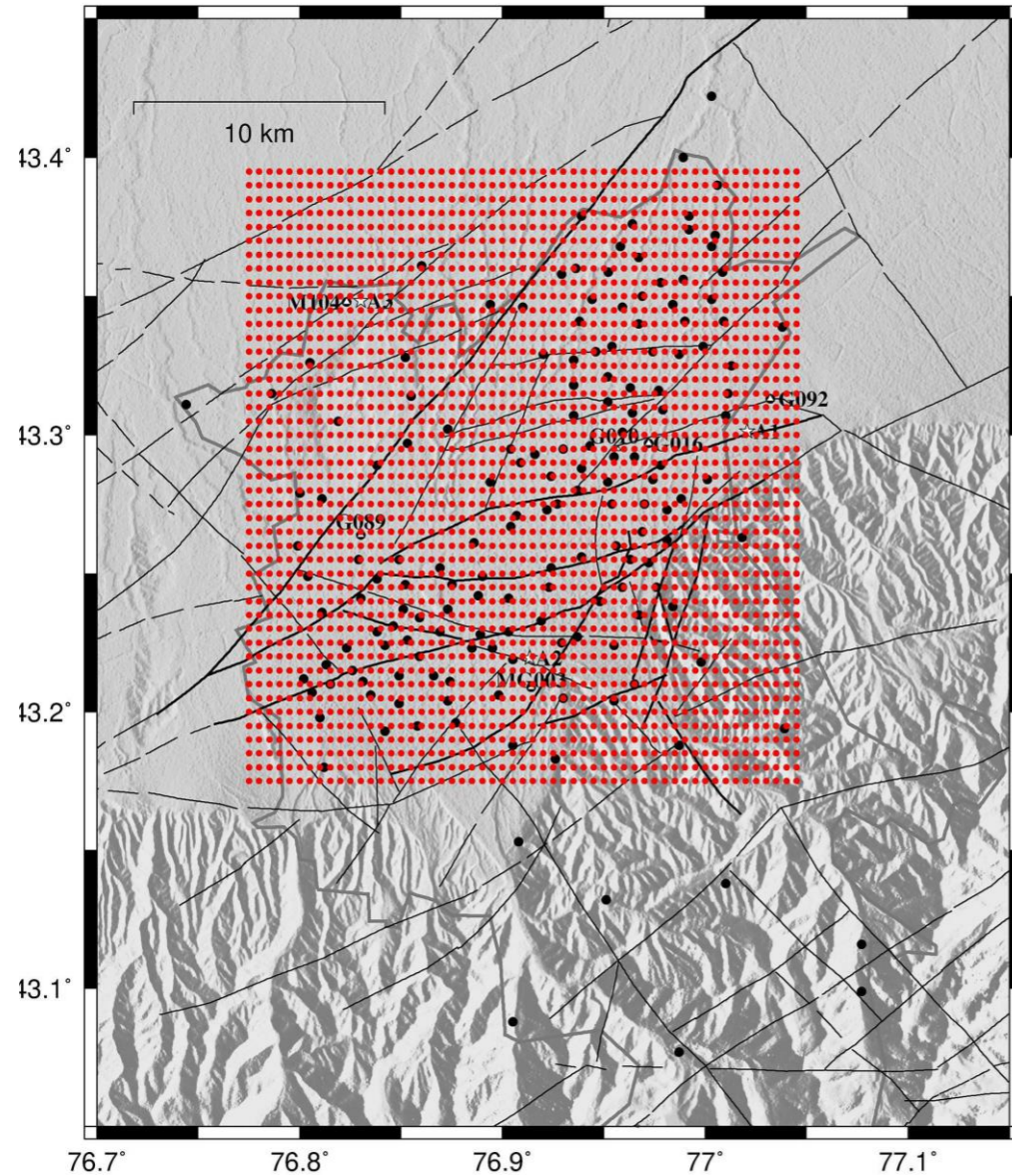
Migrazione dell'H/V in profondità e estrazione dell'impronta dei contrasti di impedenza significativi



Parolai et al (2019) S-wave velocity [m/s]



# Interpolazione e calibrazione con dati boreholes

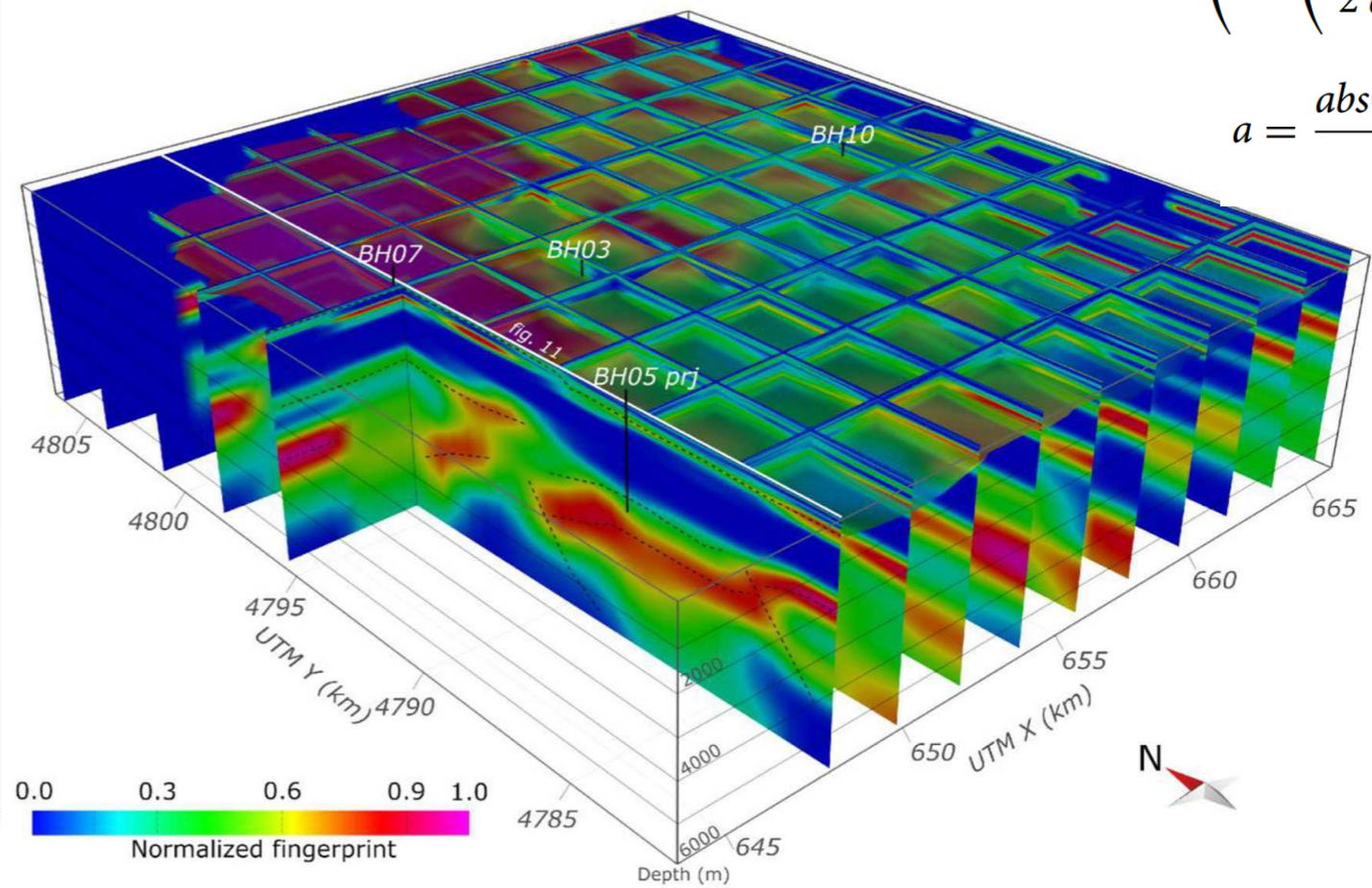


$$v_{est}(x, y, z) = \frac{\sum_{i=1}^{i=N} v(x_i, y_i, z_i) w_{0i} w_{1i} w_{2i}}{\sum_{i=1}^{i=N} w_{0i} w_{1i} w_{2i}}$$

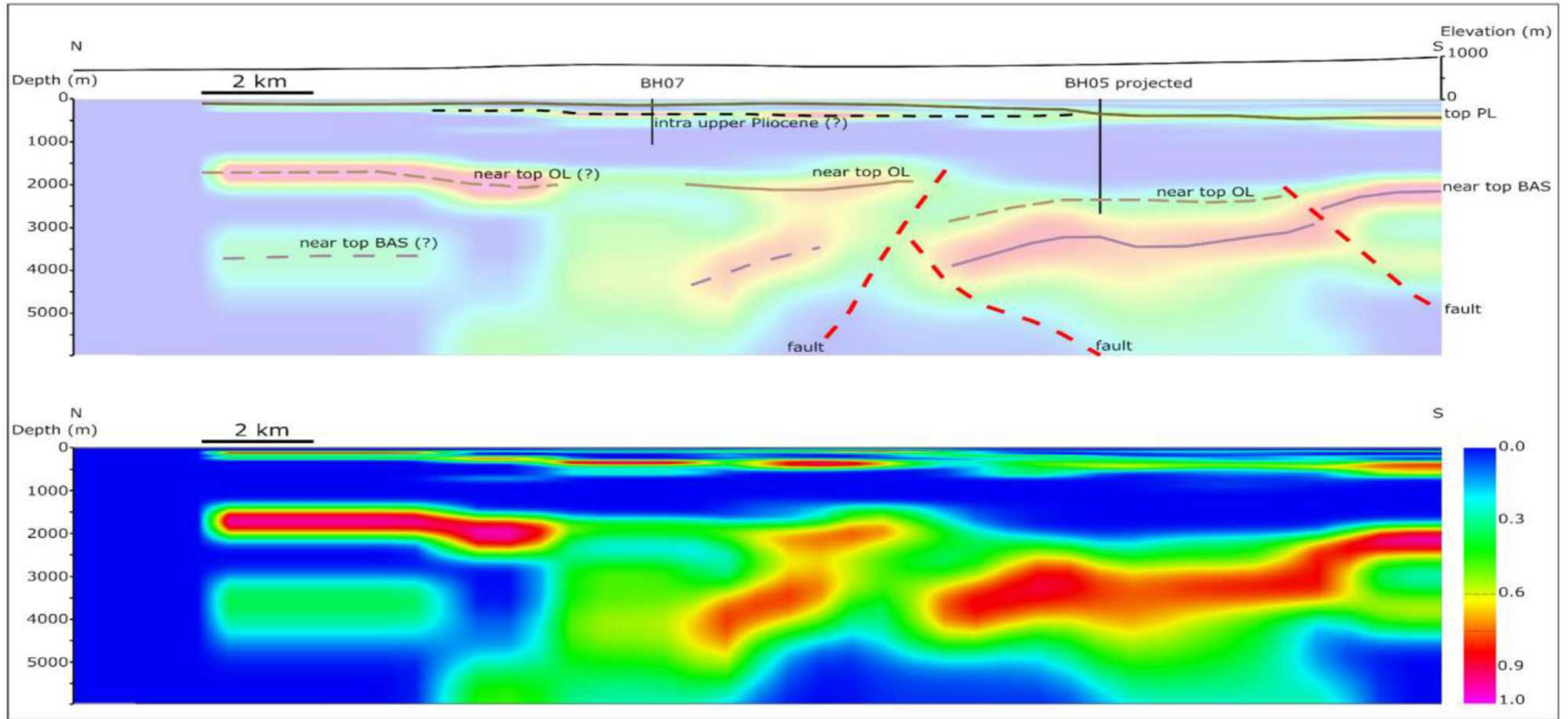
$$w_{1i} = \left( \cos \left( \frac{dh_i \pi}{2 d_{ref}} \right) \right)^6$$

$$w_{2i} = \left( \cos \left( \frac{a \pi}{2 a_{ref}} \right) \right)^4$$

$$a = \frac{abs(z_i - z)}{z_i}$$

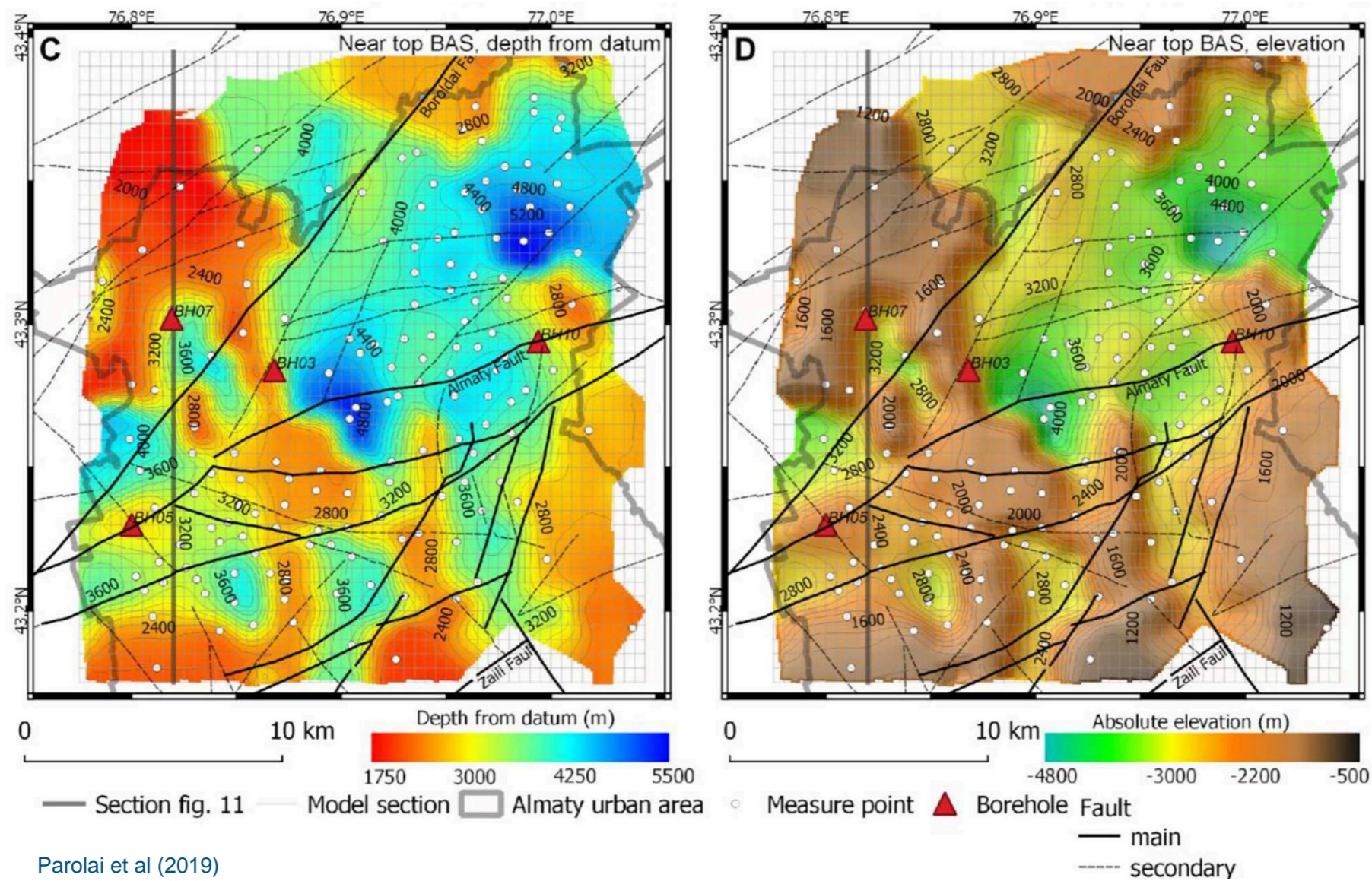


# Interpolazione e calibrazione con dati boreholes



Parolai et al (2019)

# Ricostruzione della topografia del basamento



Parolai et al (2019)