



UNIVERSITÀ  
DEGLI STUDI  
DI TRIESTE

# Elementi di geofisica per la Protezione Civile

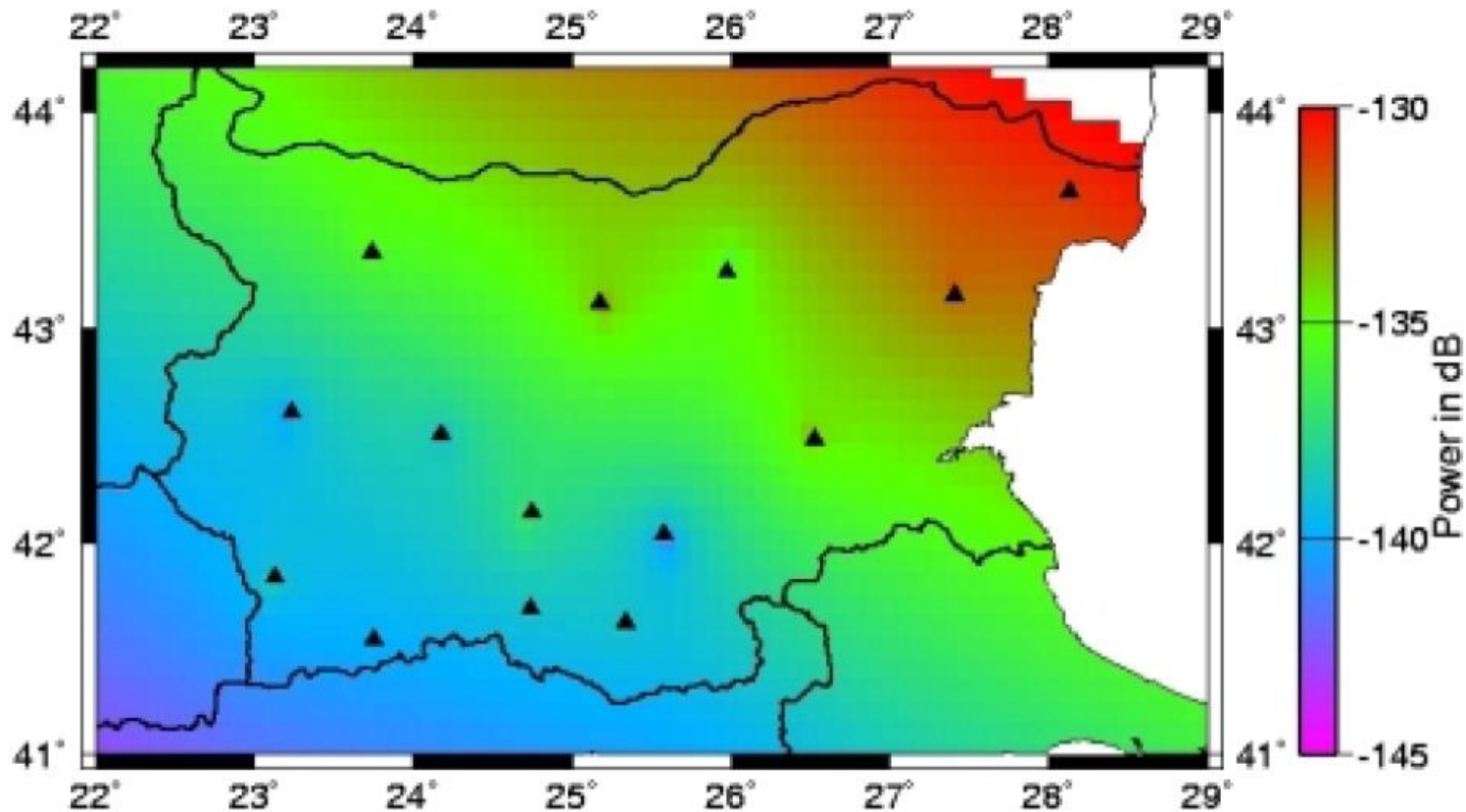
GMPE

Giovanni Costa - [costa@units.it](mailto:costa@units.it)

- Alle basse frequenze ( $f < f_{nh} \gg 1\text{Hz}$ ), l'origine è essenzialmente naturale, con particolare enfasi sulle onde oceaniche, che emettono la loro energia massima intorno a 0,2 Hz. Queste onde possono essere viste molto facilmente sulle isole e/o durante le tempeste oceaniche. Le frequenze più alte (intorno a 0,5 Hz) vengono emesse lungo le zone costiere a causa dell'interazione tra le onde del mare e le coste. Alcune onde a frequenza più bassa ( $f \ll 0,1\text{ Hz}$ ) sono anche associate alla forzatura atmosferica, ma questa gamma di frequenze ha scarso interesse per la sismologia ingegneristica. Frequenze più alte ( $> 1\text{ Hz}$ ) possono anche essere associate a flussi di vento e acqua
- Alle alte frequenze ( $f > f_{nh} \gg 1\text{Hz}$ ), l'origine è prevalentemente legata all'attività umana (traffico, macchinari); le sorgenti sono per lo più localizzate sulla superficie terrestre (tranne alcune sorgenti come le metropolitane) e spesso mostrano una forte variabilità giorno/notte e settimana/fine settimana.

	<b>Natural</b>	<b>Human</b>
<b>Name</b>	Microseism	Microtremor
<b>Frequency</b>	$0.1 - f_{nh}$ (0.5 Hz to 1 Hz)	$f_{nh}$ (0.5 Hz to 1 Hz) – > 10 Hz
<b>Origin</b>	Ocean	Traffic / Industry / Human activity
<b>Incident wavefield</b>	Surface waves	Surface + body
<b>Amplitude variability</b>	Related to oceanic storms	Day/ Night, Week / week-end
<b>Rayleigh / Love issue</b>	Incident wavefield predominantly Rayleigh	Comparable amplitude – slight indication that Love waves carry a little more energy
<b>Fundamental / Higher mode issue</b>	Mainly Fundamental	Possibility of higher modes at high frequencies (at least for 2-layer case)
<b>Further Comments</b>	Local wavefield may be different from incident wavefield	Some monochromatic waves related to machines and engines. The proximity of sources, as well as the short wavelength, probably limits the quantitative importance of waves generated by diffraction at depth

## 8 - 1.8sec Band [0.12 - 0.55Hz]



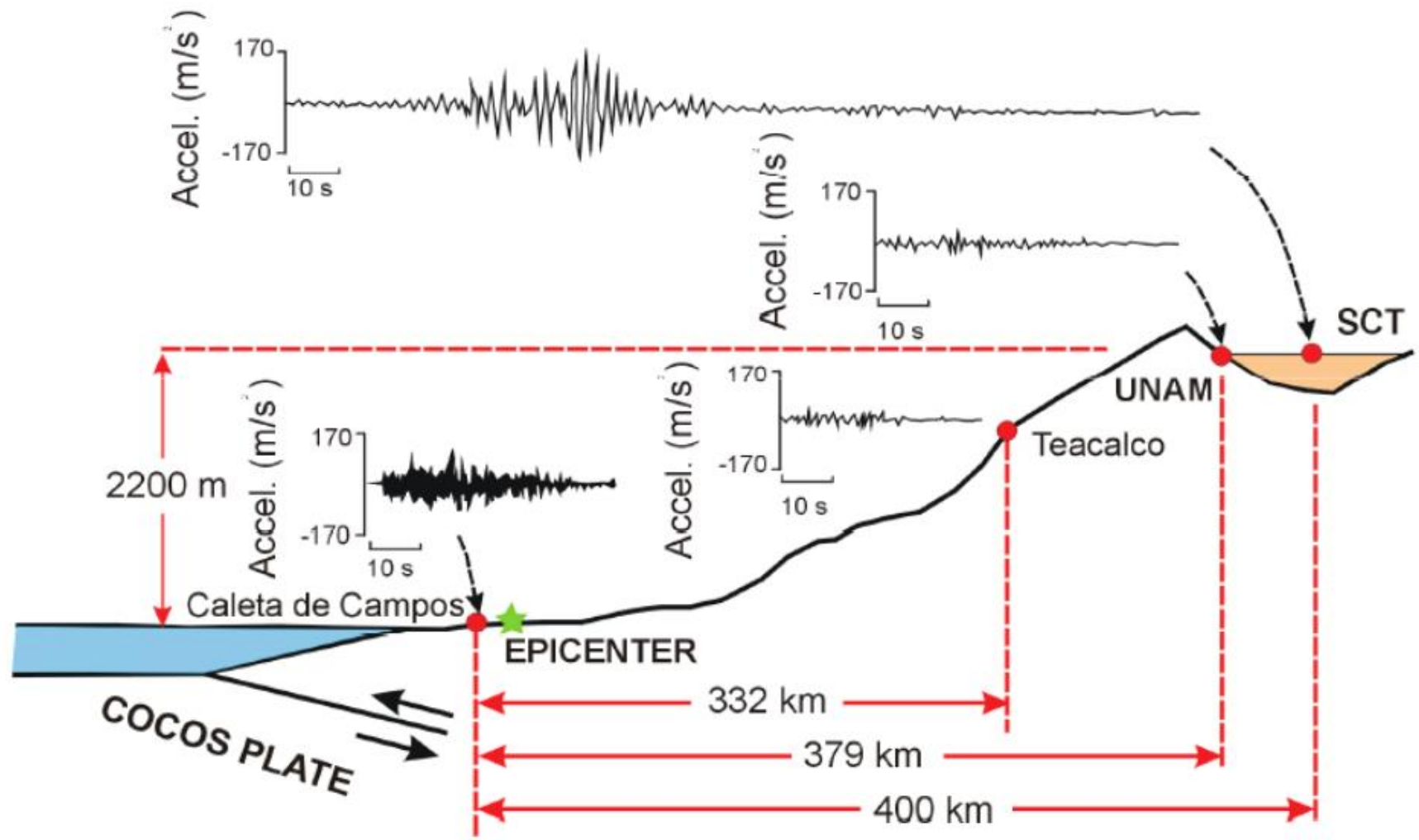
Distribuzione del rumore sismico dalla media delle curve PDF nell'intervallo da 1.8s a 8s per la rete sismologica bulgara.

STATION SITE NAME: _____ _____		SITE #: _____			DATE OF ANALYSIS: _ / _ / _			ACTUAL DISTANCE
COORDINATES:  N    °   '   '' W    °   '   ''		HARD MASSIVE ROCK, GRANITE, QUARTZITE, ETC.			HARDPAN HARD CLAY, ETC.			
		RECOMMENDED MINIMAL DISTANCES [km]						
		A	B	C	A	B	C	[km]
1. Oceans, with coastal mountains system		300	50	1	300	50	1	
2. Oceans, with broad coastal plains		1000	200	10	1000	200	20	
3. Inland seas, bays, very large lakes, with coastal mountain system		150	25	1	150	25	1	
4. Inland seas, bays, very large lakes, with broad coastal plains		500	100	5	500	100	5	
5. Large dams, high waterfalls, large cataracts		a	40	10	1	50	15	5
		b	60	15	5	150	25	10
6. Large oil or gas pipelines		a	20	10	5	30	15	5
		b	100	30	10	100	30	10
7. Small lakes		a	20	10	1	20	10	1
		b	50	15	1	50	15	1
8. Heavy reciprocating machinery, machinery		a	15	3	1	20	5	2
		b	25	5	2	40	15	3
9. Low waterfalls, rapids of a large river, intermittent flow over large dams		a	5	2	0.5	15	5	1
		b	15	3	1	25	8	2
10. Railway, frequent operation		a	6	3	1	10	5	1
		b	15	5	1	20	10	1
11. Airport, air ways heavy traffic		6	3	1	6	3	1	
12. Non-reciprocating power plant machinery, balanced industrial machinery		a	2	0.5	0.1	10	4	1
		b	4	1	0.2	15	6	1
13. Busy highway, mechanized farms		1	0.3	0.1	6	1	0.5	
14. Country roads, high buildings		0.3	0.2	0.05	2	1	0.5	
15. Low buildings, high trees and masts		0.1	0.03	0.01	0.3	0.1	0.05	
16. High fences, low trees, high bushes, large rocks		0.05	0.03	5 m	0.06	0.03	0.01	

Topic	Recommended minimal distances of seismic sites from sources of seismic noise
Author	Amadej Trnkoczy (formerly Kinometrics SA); E-mail: <a href="mailto:amadej.trnkoczy@siol.net">amadej.trnkoczy@siol.net</a>
Version	Sept. 1999

#### LEGEND:

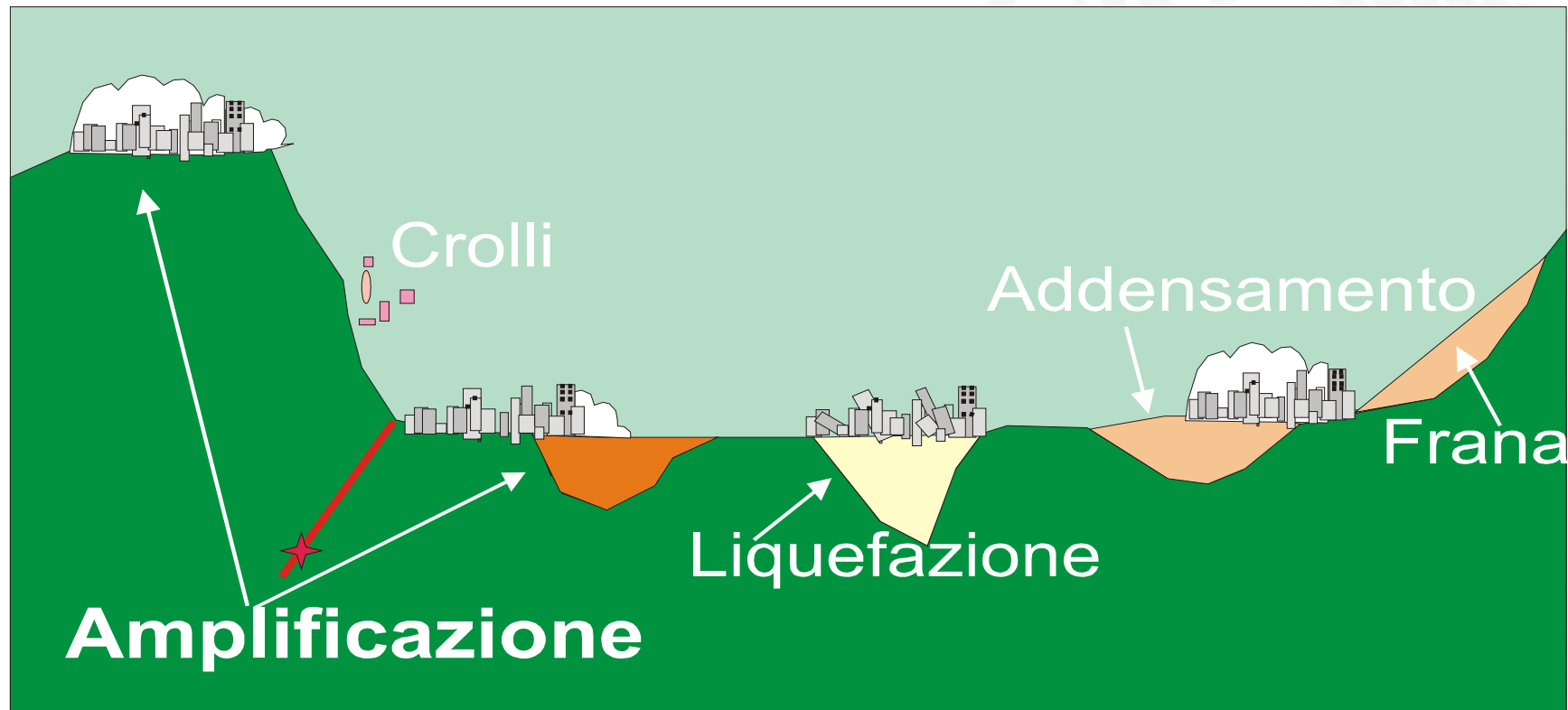
- A SP seismic station with a gain of about 200,000 or more at 1 Hz
- B SP seismic station with a gain from 50,000 to 150,000 at 1 Hz
- C SP seismic station with a gain of approximately 25,000 or less at 1 Hz
- a Source and seismometer on widely different geological formations or that mountain ranges or valleys intervene
- b Source and seismometer on the same geological formation and with no intervening alluvial valley or mountain range



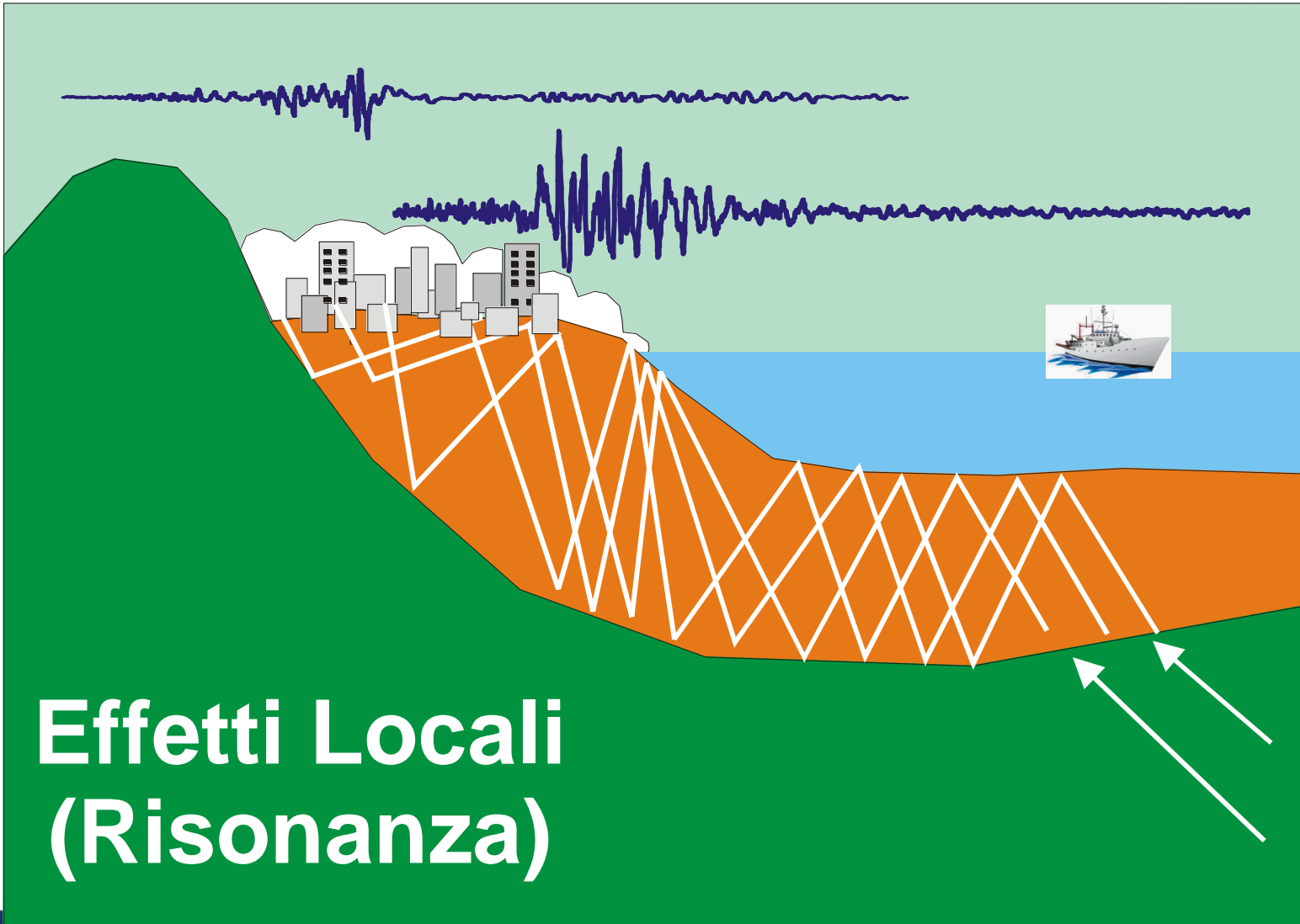
*Schema sismogrammi relativi alla città del Messico che mostrano l'amplificazione del bacino dove sorge Città del Messico.*

Un terremoto genera delle oscillazioni del suolo, indotte dalla propagazione di onde sismiche attraverso il terreno. Le onde sismiche, propagandosi nello strato più superficiale della crosta terrestre, subiscono riflessioni e rifrazioni causate dalle eterogeneità della crosta stessa. In certe condizioni ed in presenza dei suoli superficiali le onde sismiche vengono amplificate o attenuate a seconda delle caratteristiche meccaniche del mezzo.

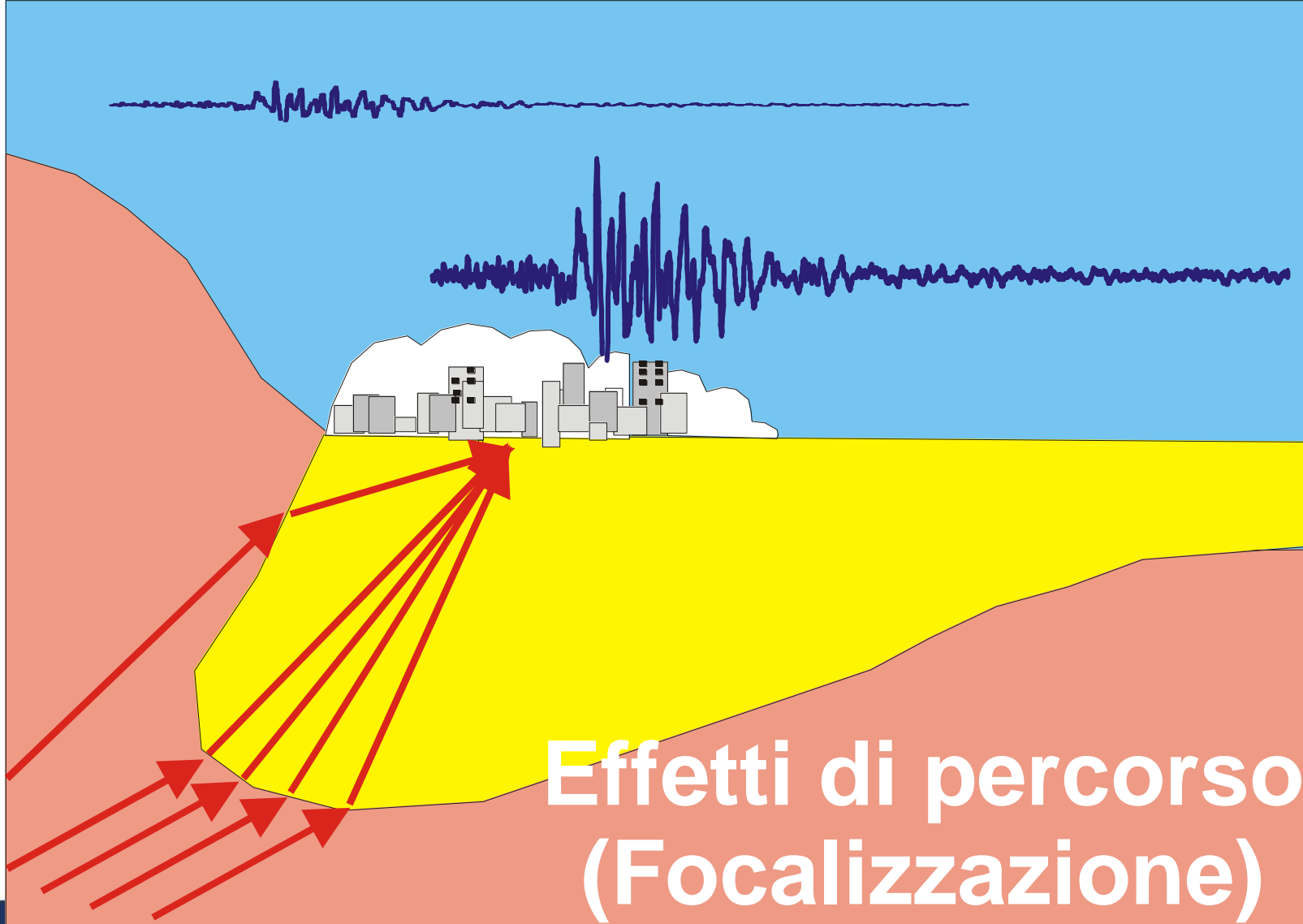




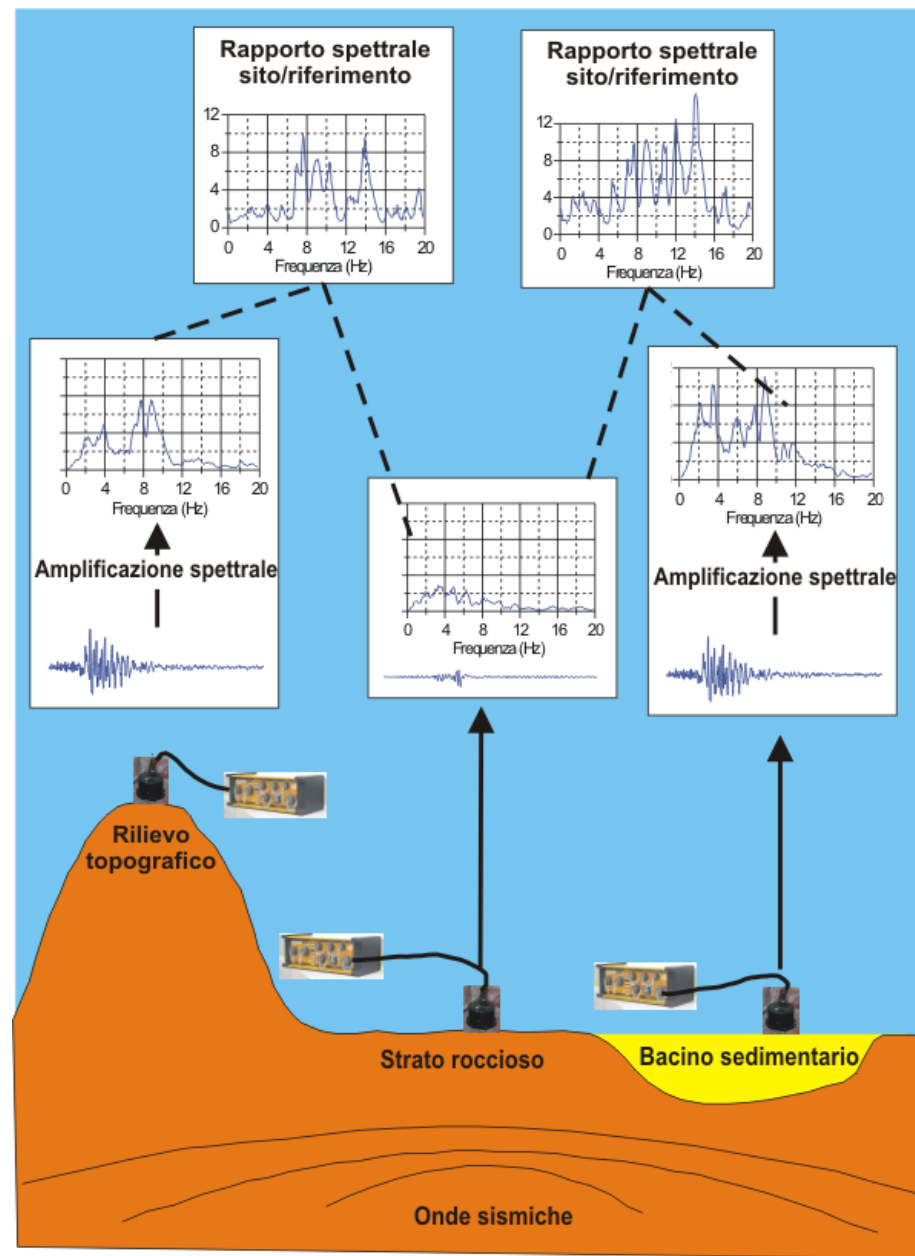


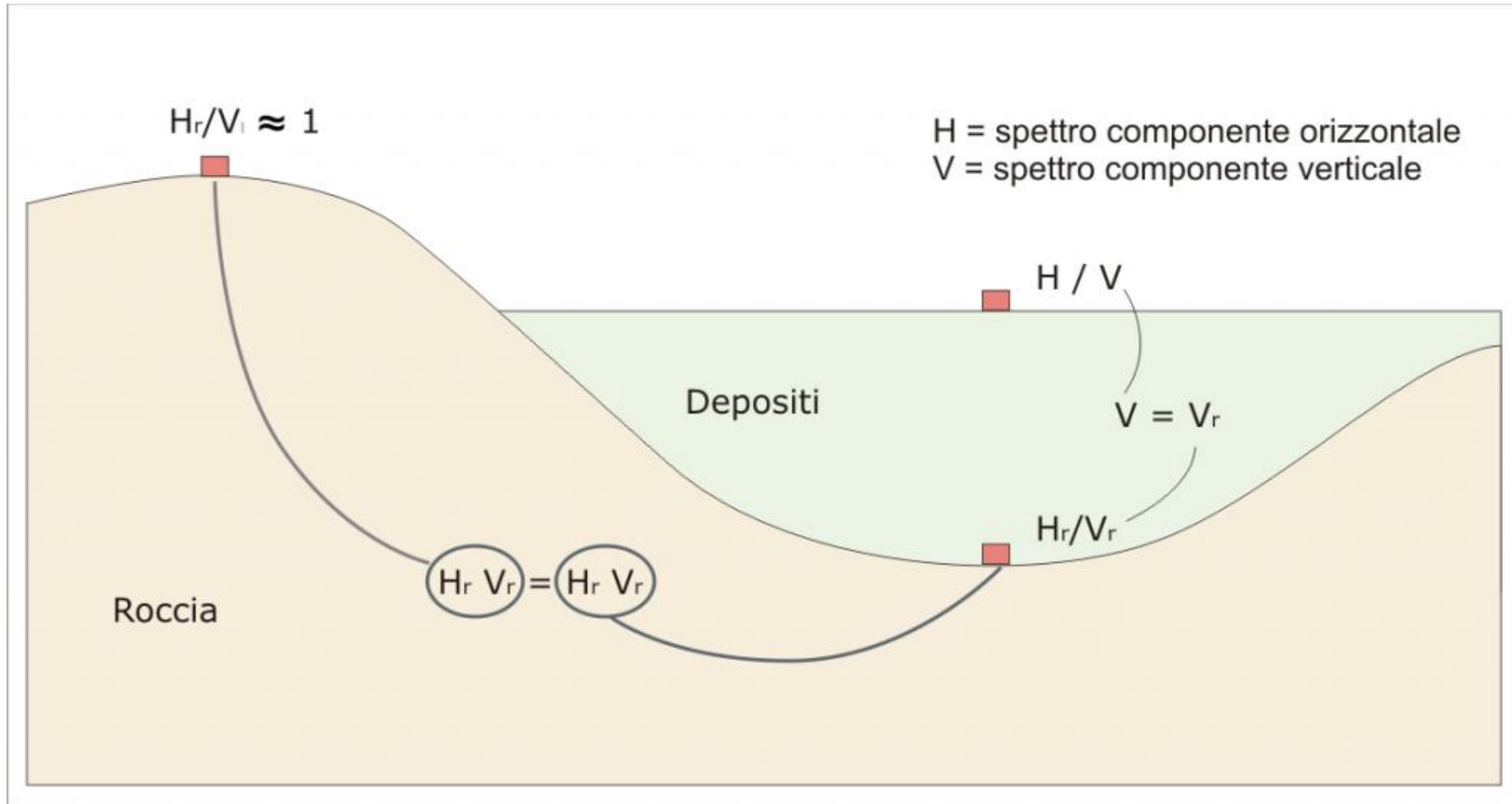


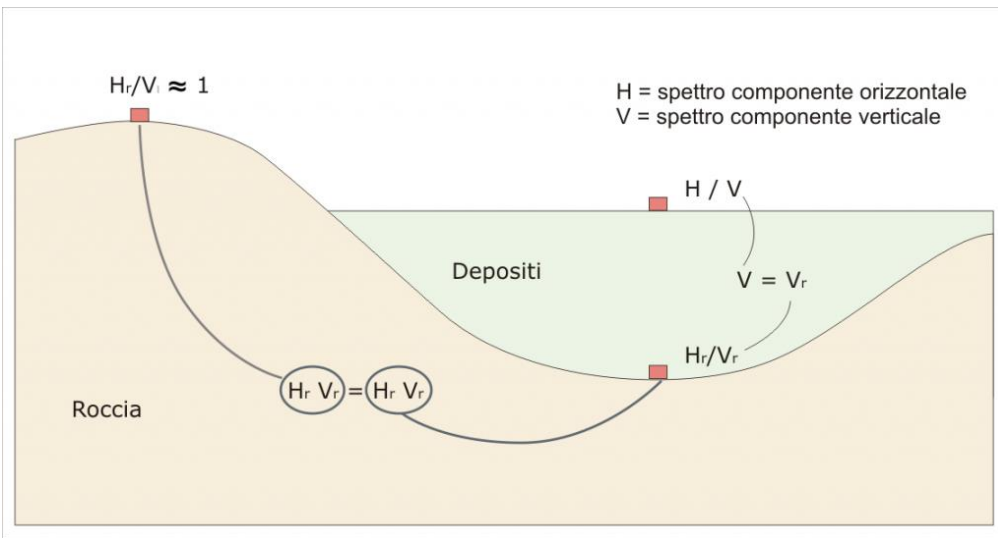
## Effetti Locali (Risonanza)



**Effetti di percorso  
(Focalizzazione)**







In genere, l'effetto di amplificazione è dovuto alla geologia superficiale e viene espresso come rapporto tra l'ampiezza dello spettro di Fourier della componente orizzontale del moto in superficie ( $H_s$ ) e quella alla base dello strato ( $H_r$ ):

$$T_s = \frac{H_s}{H_r}$$

Il fattore di amplificazione può essere ottenuto tramite la relazione:

$$S = \frac{T_s}{T_r} = \frac{H_s}{H_r} * \frac{V_r}{V_s}$$

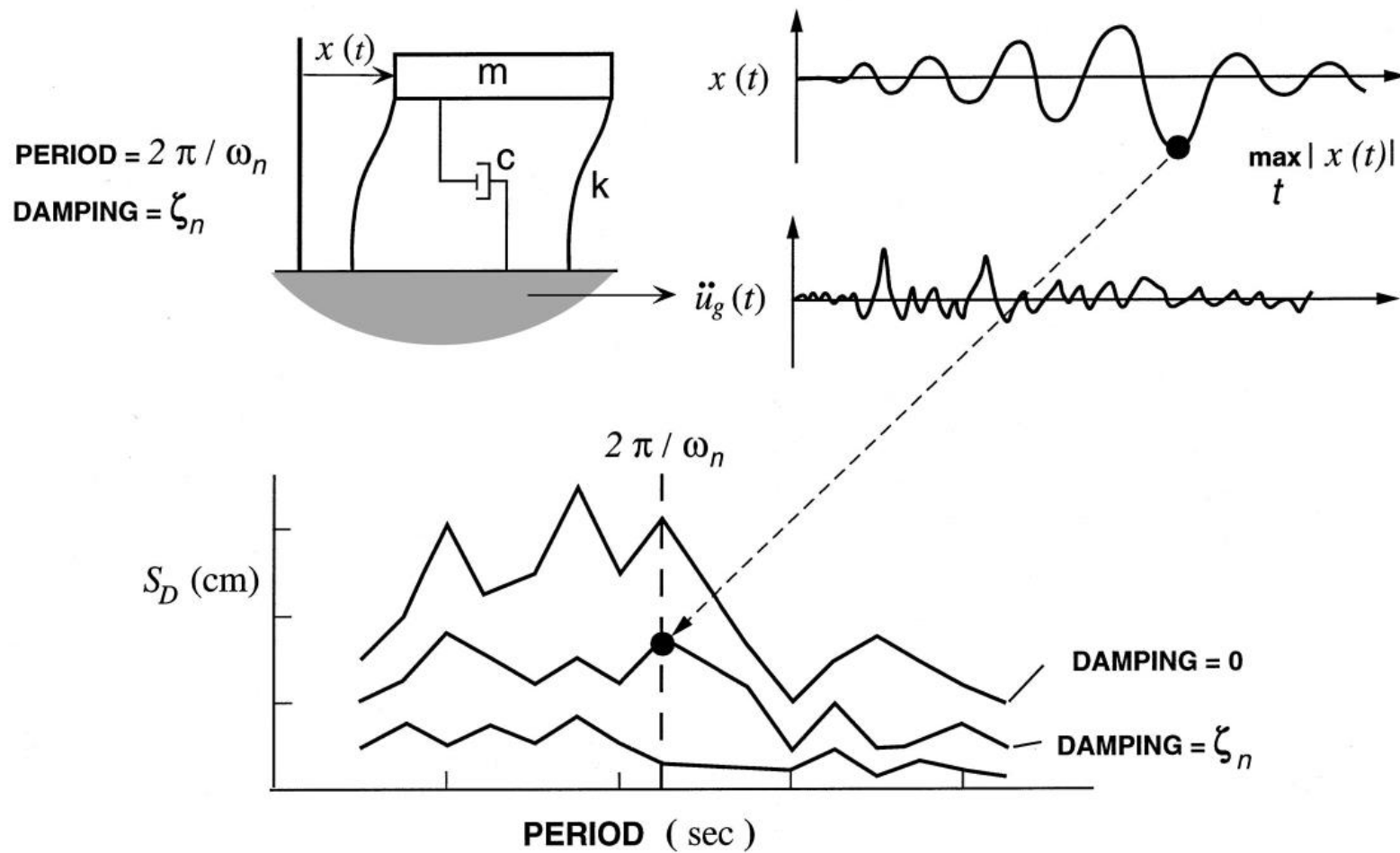
Ed essendo:

$$\frac{V_r}{H_r} = 1$$

Risulta:

$$S = \frac{H_s}{V_s}$$

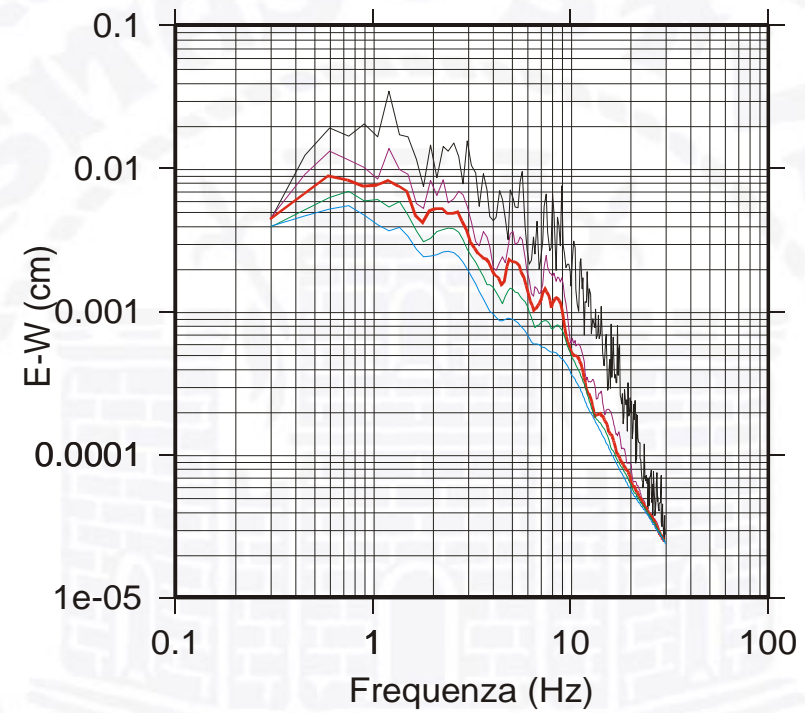
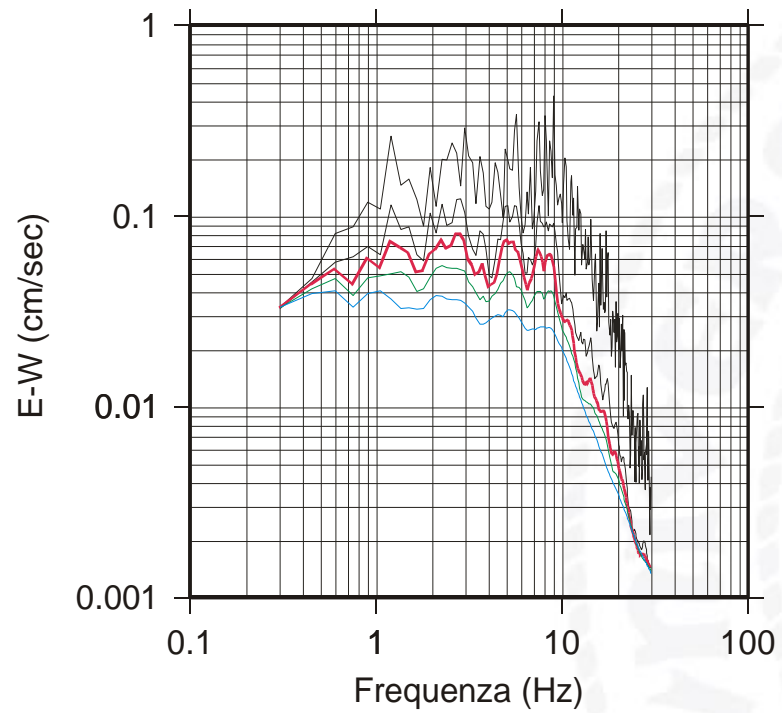
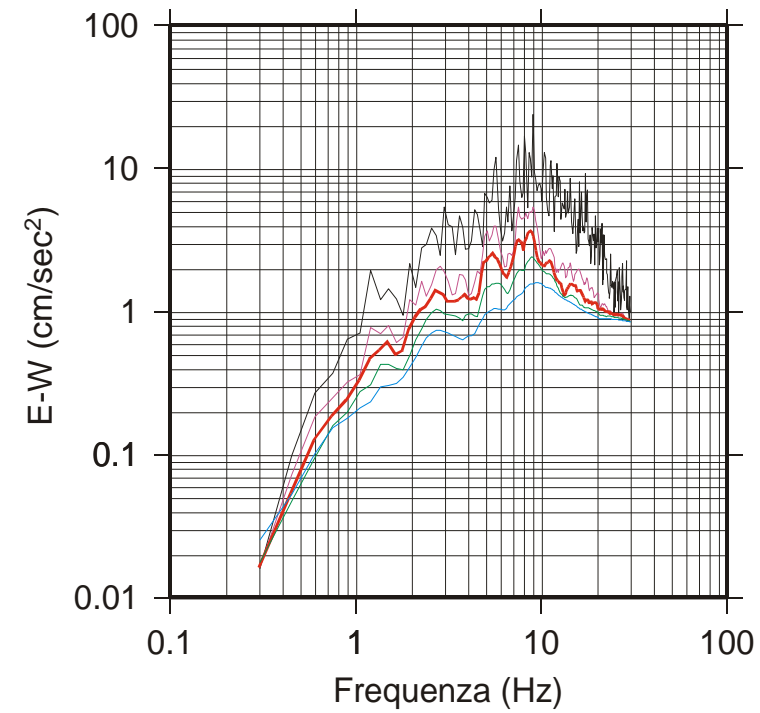
Nakamura afferma che il picco massimo nel grafico H/V permette di identificare la frequenza di risonanza con l'amplificazione ad essa correlata.



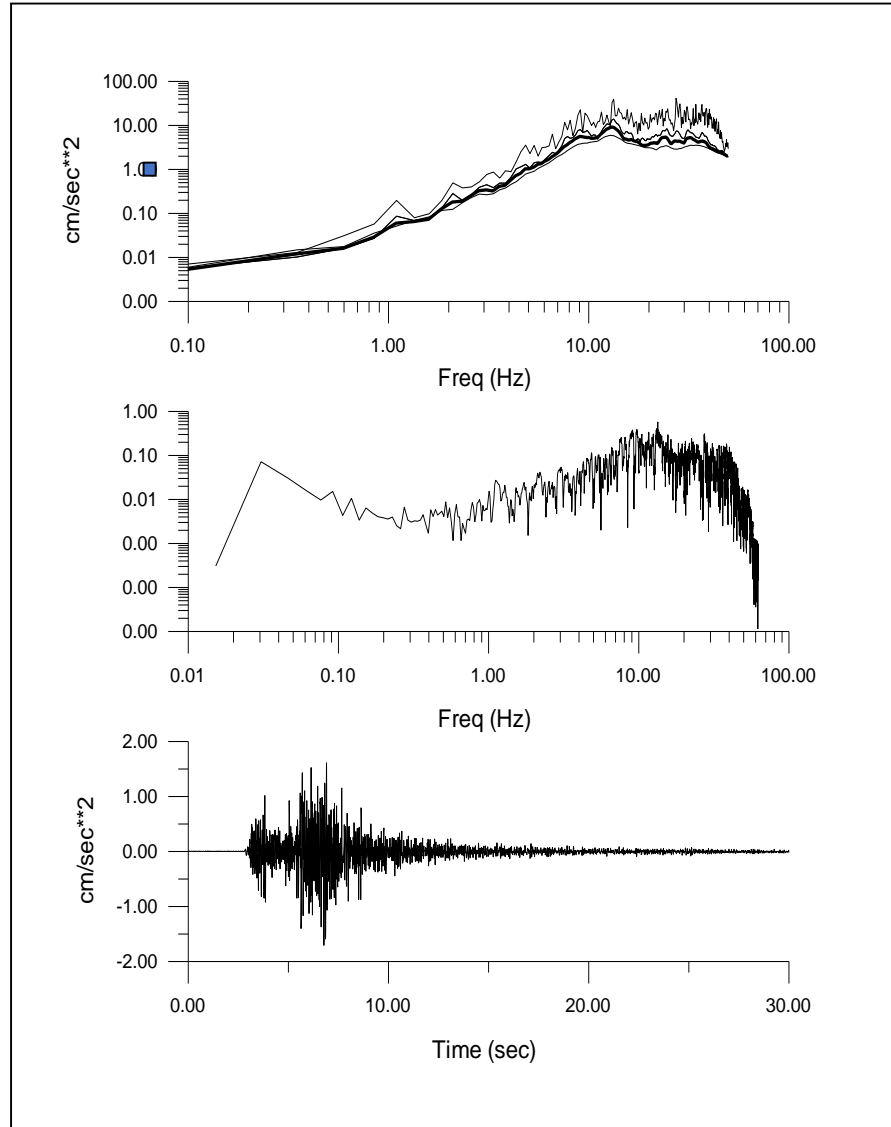
Se con  $x_g(t)$  si indica lo spostamento impresso al suolo dal terremoto e con  $x(t)$  lo spostamento della massa  $m$  rispetto al suolo, l'equazione differenziale che governa il problema delle oscillazioni forzate si scrive:

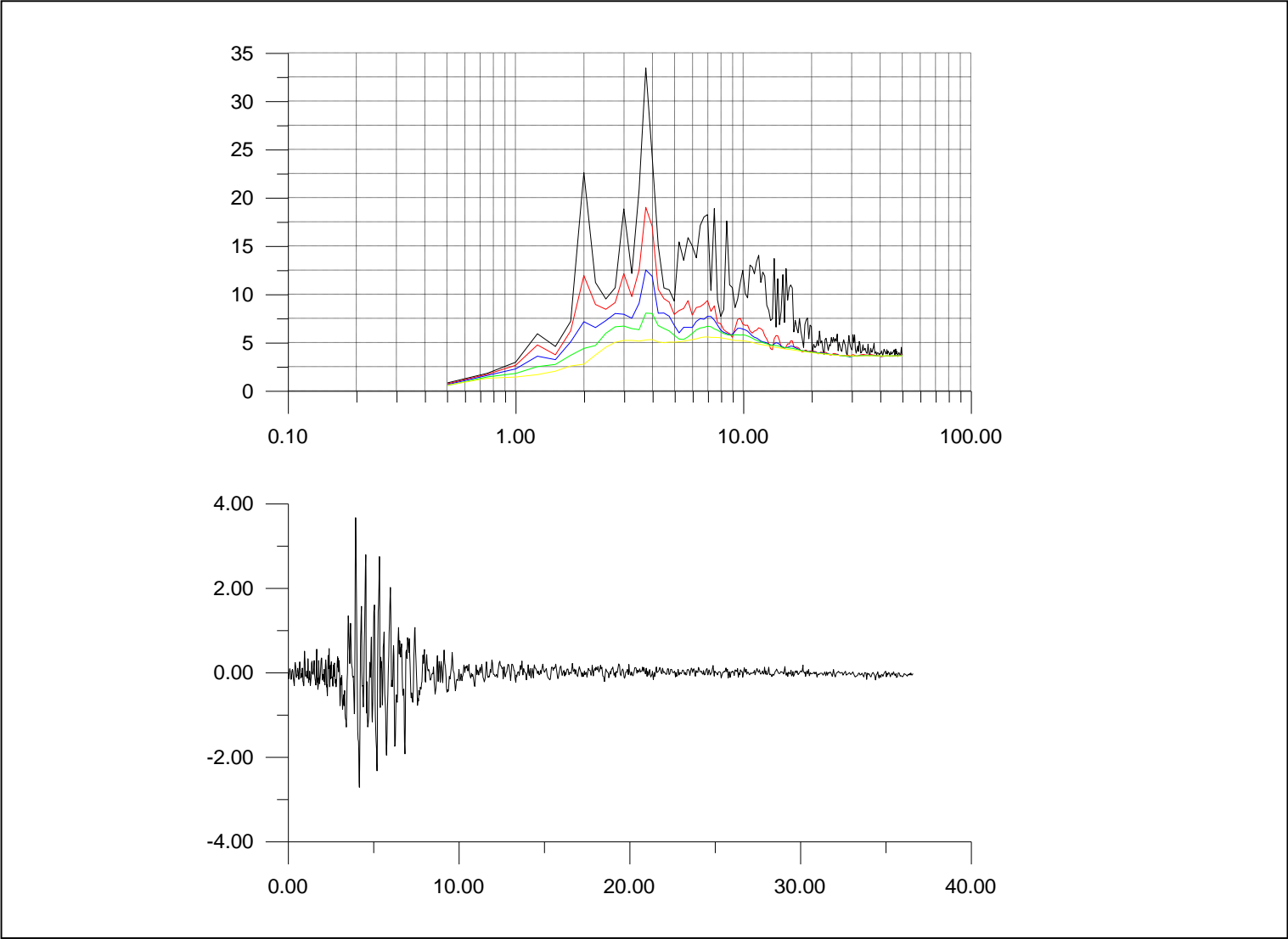
$$m\ddot{x}(t) + b\dot{x}(t) + kx(t) = -m\ddot{x}_g(t)$$

in cui la costante  $k$  è la rigidezza del sistema e  $b$  è la costante associata allo smorzatore del sistema di tipo viscoso.



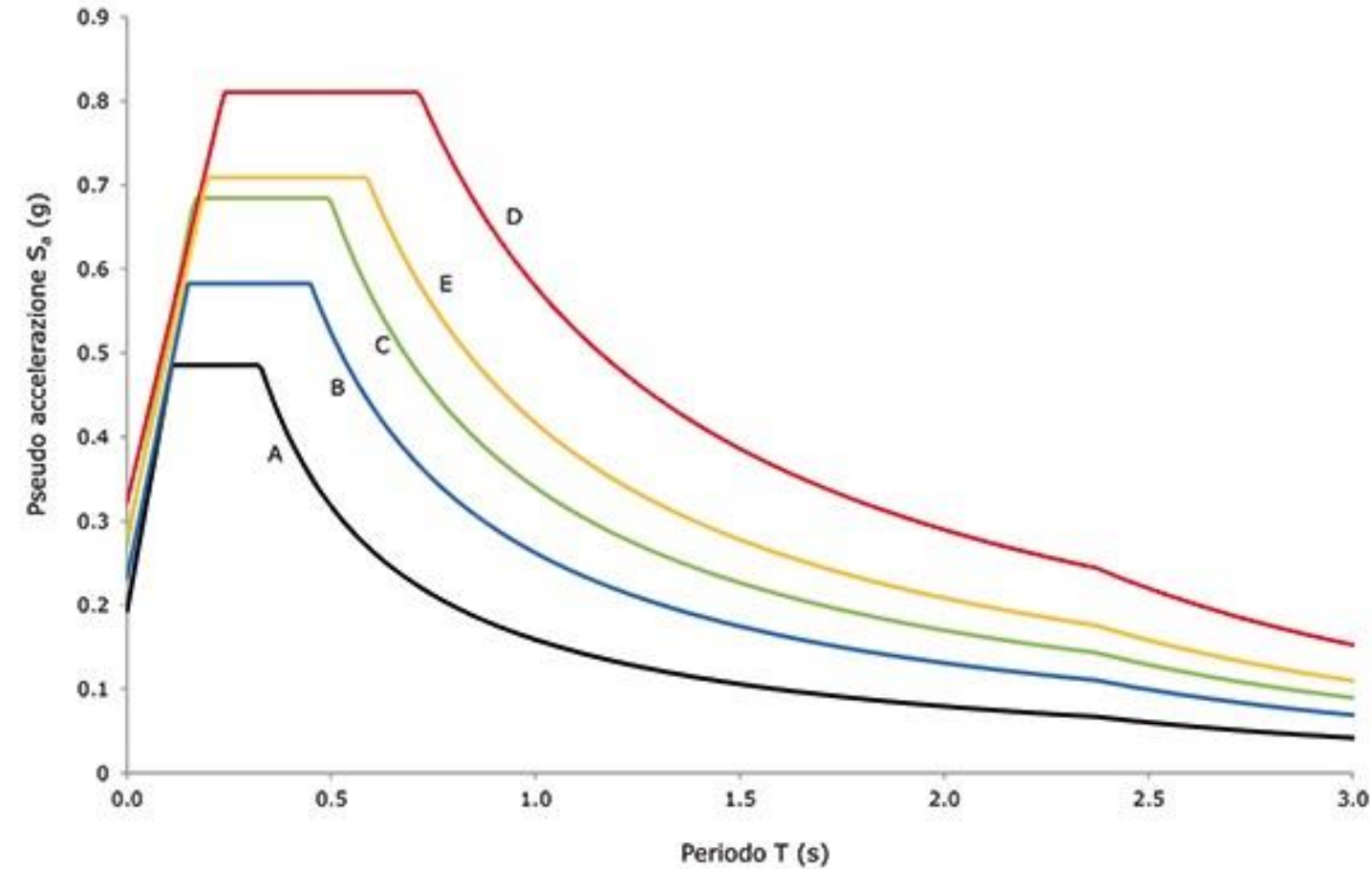




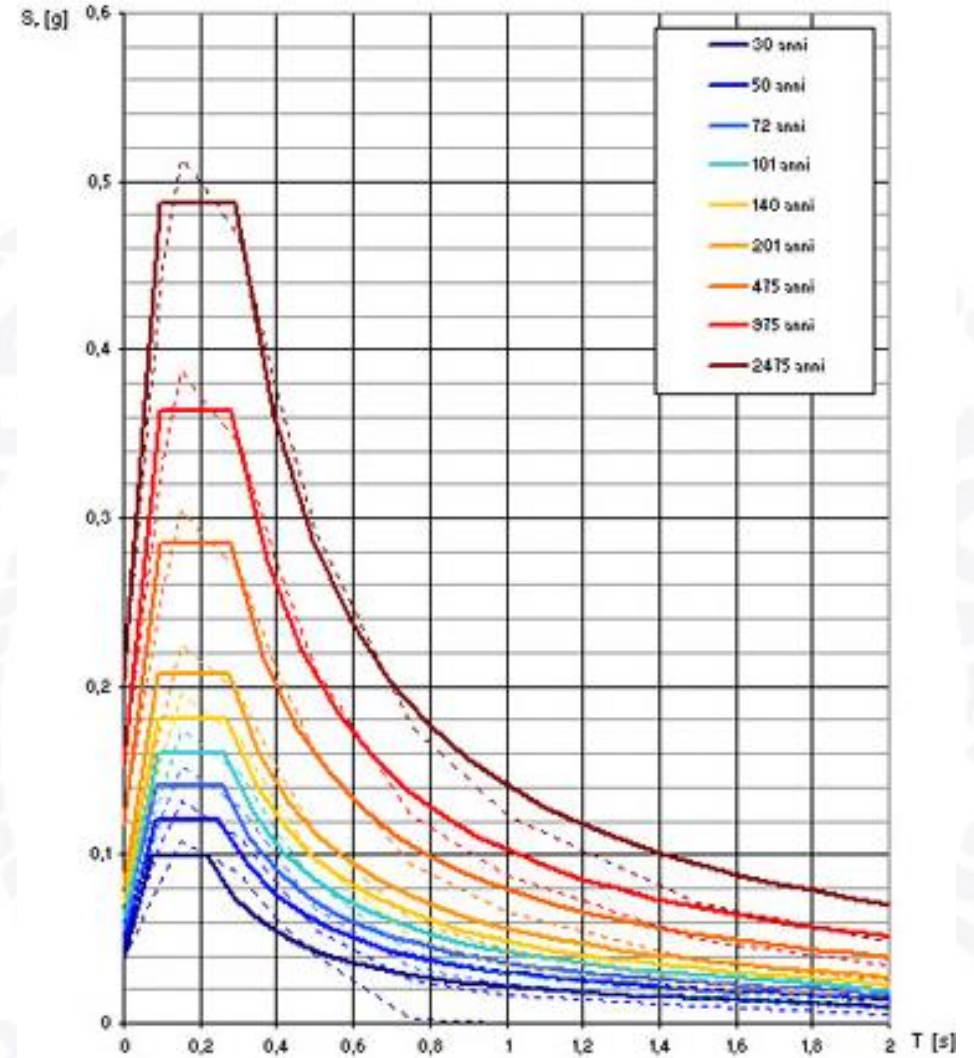


## Categorie di sottosuolo nelle NTC-08

- A** *Ammassi rocciosi affioranti o terreni molto rigidi* caratterizzati da valori di  $V_{s30}$  superiori a 800 m/s, eventualmente comprendenti in superficie uno strato di alterazione, con spessore massimo pari a 3 m.
- B** *Depositi di terreni a grana grossa molto addensati o terreni a grana fina molto consistenti*, con spessori superiori a 30 m, caratterizzati da un graduale miglioramento delle proprietà meccaniche con la profondità e da valori di  $V_{s30}$  compresi tra 360 m/s e 800 m/s (ovvero  $N_{SPT,30} > 50$  nei terreni a grana grossa e  $c_{u,30} > 250$  kPa nei terreni a grana fina).
- C** *Depositi di terreni a grana grossa mediamente addensati o terreni a grana fina mediamente consistenti*, con spessori superiori a 30 m, caratterizzati da un graduale miglioramento delle proprietà meccaniche con la profondità e da valori di  $V_{s,30}$  compresi tra 180 m/s e 360 m/s (ovvero  $15 < N_{SPT,30} < 50$  nei terreni a grana grossa e  $70 < c_{u,30} < 250$  kPa nei terreni a grana fina).
- D** *Depositi di terreni a grana grossa scarsamente addensati o terreni a grana fina scarsamente consistenti*, con spessori superiori a 30m, caratterizzati da un graduale miglioramento delle proprietà meccaniche con la profondità e da valori di  $V_{s,30}$  inferiori a 180 m/s (ovvero  $N_{SPT,30} < 15$  nei terreni a grana grossa e  $c_{u,30} < 70$  kPa nei terreni a grana fina).
- E** Terreni dei sottosuoli di tipo C o D per spessore non superiore a 20 m posti sul substrato di riferimento (con  $V_s > 800$  m/s).
- S1** Depositi di terreni caratterizzati da valori di  $V_{s30}$  inferiori a 100 m/s (ovvero  $10 < c_{u30} < 20$  kPa), che includono uno strato di almeno 8 m di terreni a grana fina di bassa consistenza, oppure che includono almeno 3 m di torba o di argille altamente organiche
- S2** Depositi di terreni suscettibili di liquefazione, di argille sensitive o qualsiasi altra categoria di terreno non classificabile nei tipi precedenti

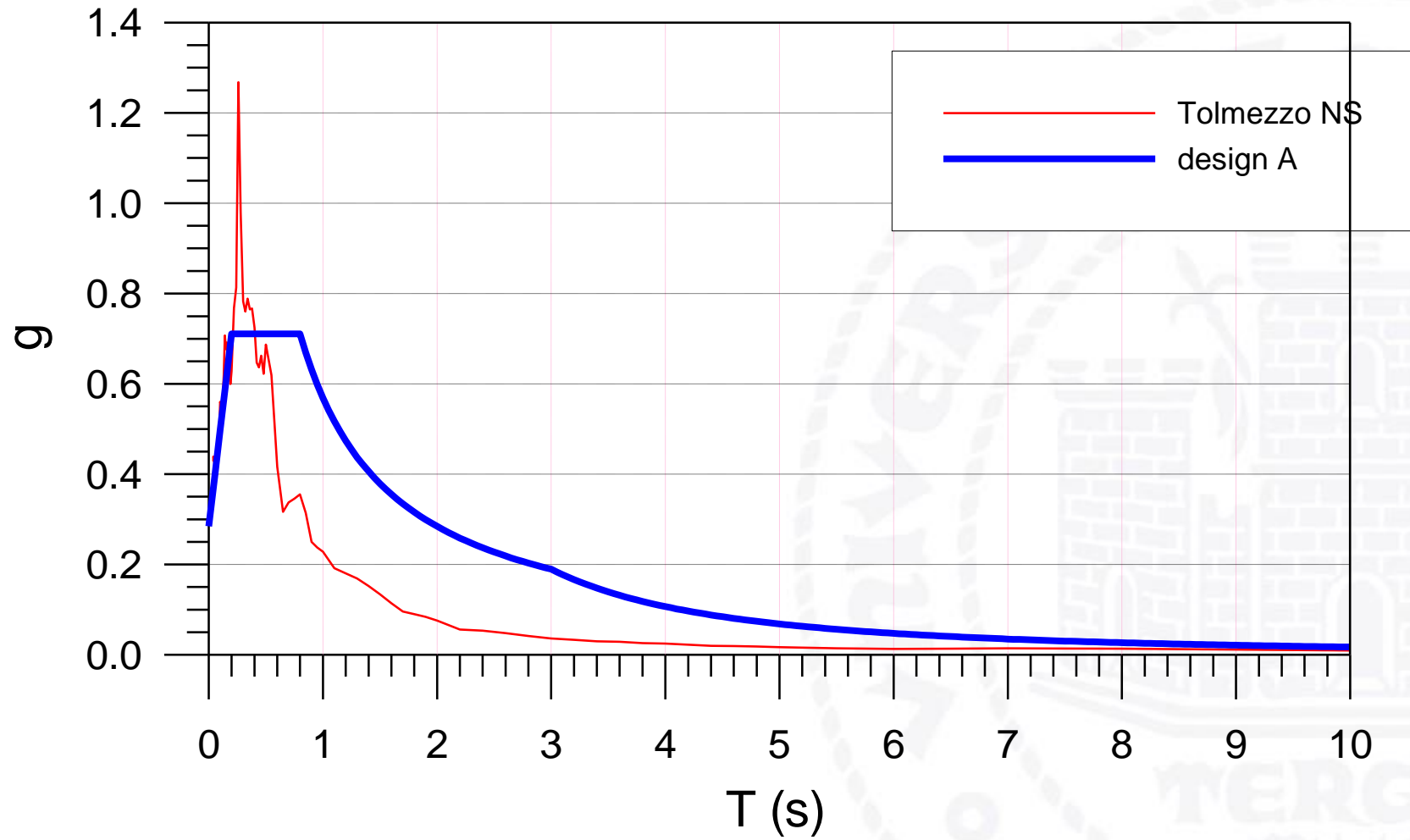


Spettri di normativa per le diverse classi di suolo



NOTA:  
Con linea continua si rappresentano gli spettri di Normativa, con linea tratteggiata gli spettri del progetto S1-INGV da cui sono derivati.

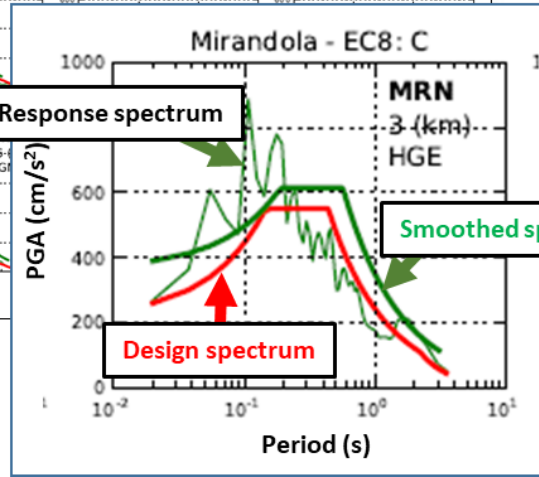
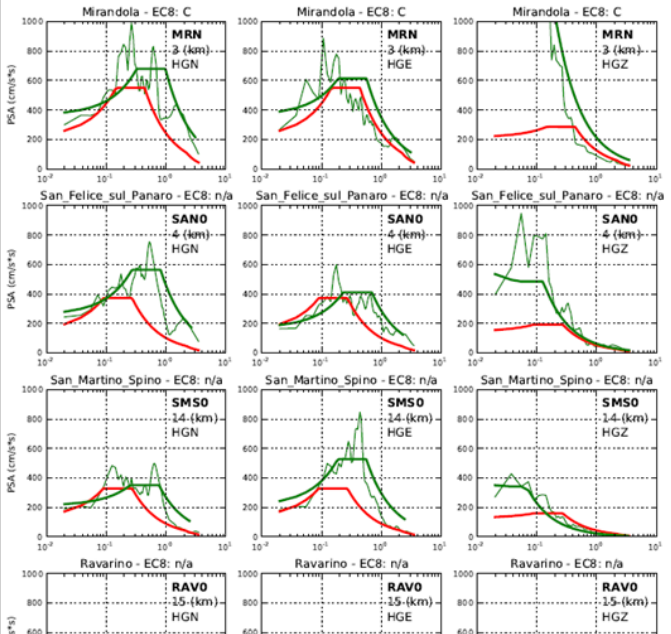
SOIL A  
ACCELERATION RESPONSE SPECTRA  
(5% damping)



DESIGN GROUND ACCELERATION: 0.28 g



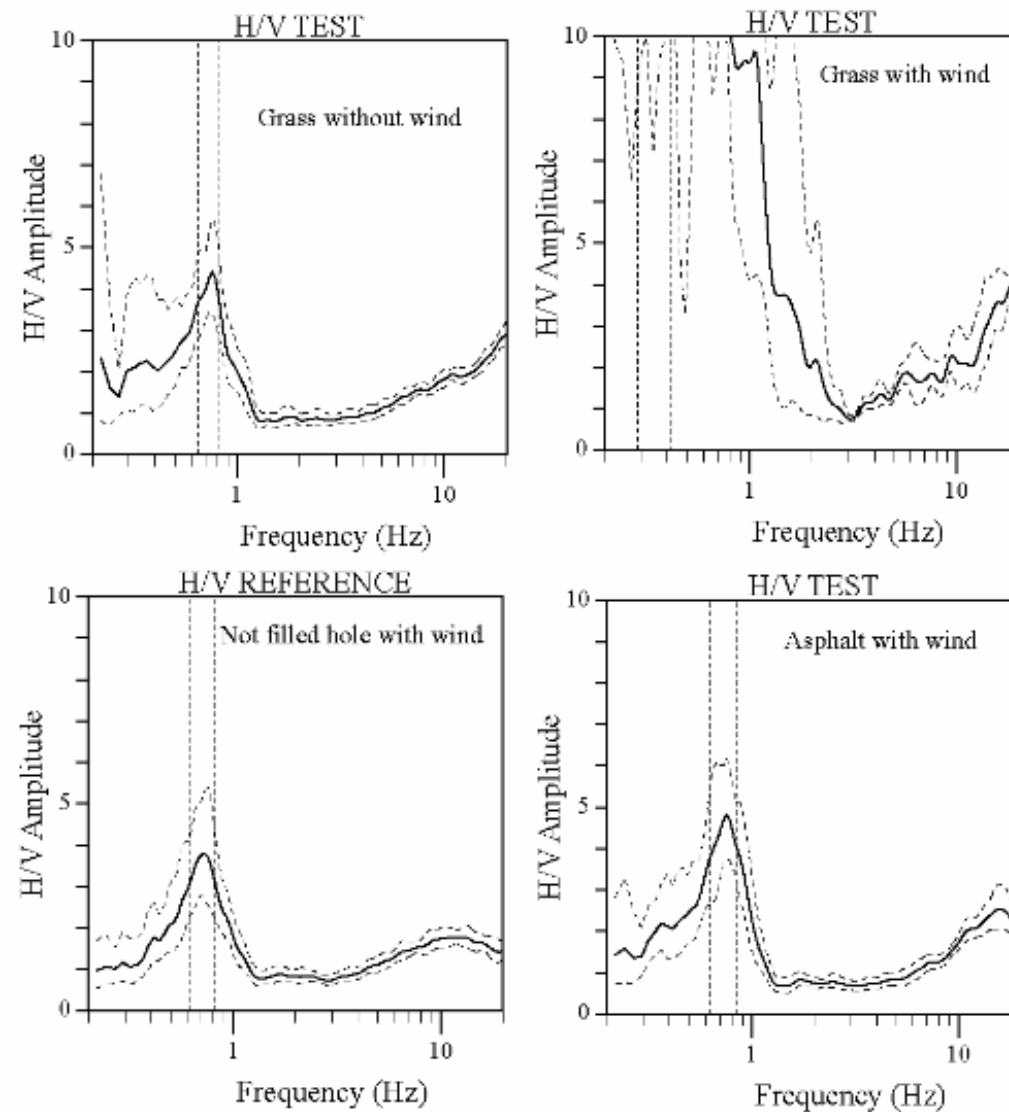
Event: NORTHERN - Origin time: 2012/05/29 07:00:03 Lat:44.851 Lon:11.086 MI = 5.8



## 1. EXPERIMENTAL CONDITIONS + MEASUREMENT FIELD SHEET

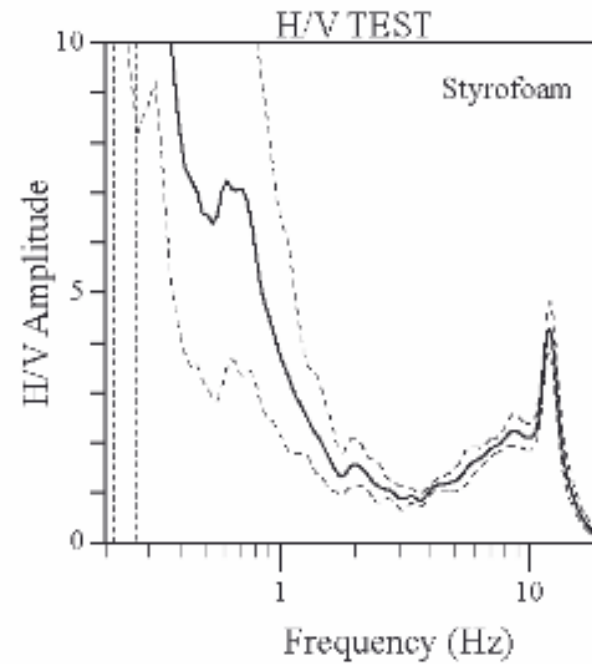
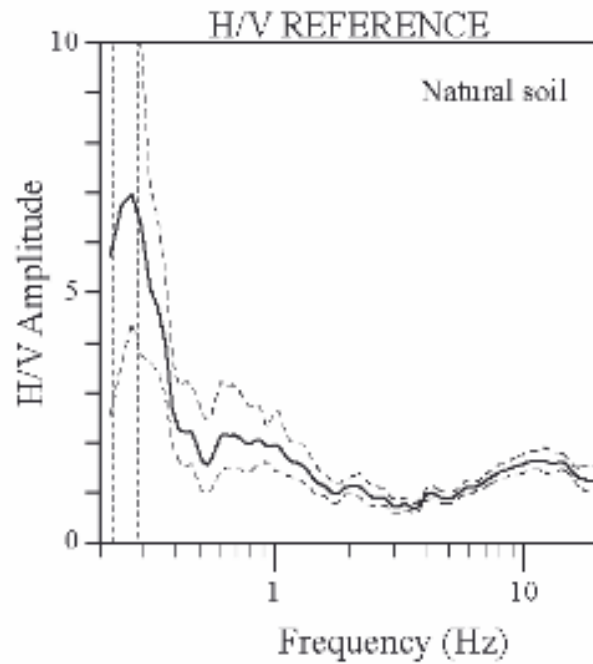
→ This sheet is only a quick field reference. It is highly recommended that the complete guidelines be read before going out to perform the recordings. A field sheet is also provided on the next page. This page, containing two identical sheets can be printed and be taken in the field.

Type of parameter	Main recommendations	
	Minimum expected $f_0$ [Hz]	Recommended minimum recording duration [min]
Recording duration	0.2	30'
	0.5	20'
	1	10'
	2	5'
	5	3'
	10	2'
Measurement spacing	→ <u>Microzonation</u> : start with a large spacing (for example a 500 m grid) and, in case of lateral variation of the results, densify the grid point spacing, down to 250 m, for example. → <u>Single site response</u> : never use a single measurement point to derive an $f_0$ value, make at least three measurement points.	
Recording parameters	→ level the sensor as recommended by the manufacturer. → fix the gain level at the maximum possible without signal saturation.	
In situ soil-sensor coupling	→ set the sensor down directly on the ground, whenever possible. → avoid setting the sensor on "soft grounds" (mud, ploughed soil, tall grass, etc.), or soil saturated after rain.	
Artificial soil-sensor coupling	→ avoid plates from "soft" materials such as foam rubber, cardboard, etc. → on steep slopes that do not allow correct sensor levelling, install the sensor in a sand pile or in a container filled with sand. → on snow or ice, install a metallic or wooden plate or a container filled with sand to avoid sensor tilting due to local melting.	
Nearby structures	→ Avoid recording near structures such as buildings, trees, etc. in case of wind blowing (faster than approx. 5 m/s). It may strongly influence H/V results by introducing some low frequencies in the curves → Avoid measuring above underground structures such as car parks, pipes, sewer lids, etc.	
Weather conditions	→ <u>Wind</u> : Protect the sensor from the wind (faster than approx. 5 m/s). This only helps if there are no nearby structures. → <u>Rain</u> : avoid measurements under heavy rain. Slight rain has no noticeable influence. → <u>Temperature</u> : check sensor and recorder manufacturer's instructions. → <u>Meteorological perturbations</u> : indicate on the field sheet whether the measurements are performed during a low-pressure meteorological event.	
Disturbances	→ <u>Monochromatic sources</u> : avoid measurements near construction machines, industrial machines, pumps, generators, etc. → <u>Transients</u> : In case of transients (steps, cars,...), increase the recording duration to allow for enough windows for the analysis, after transient removal.	



Confronto delle curve H/V ottenute nello stesso sito su erba con e senza vento (in alto), e in una buca, su asfalto (in basso) e di nuovo su erba con vento. Questo confronto mostra il forte effetto del vento combinato con l'erba, mentre sull'asfalto o in una buca il vento non ha effetti significativi (se lontano da qualsiasi struttura)

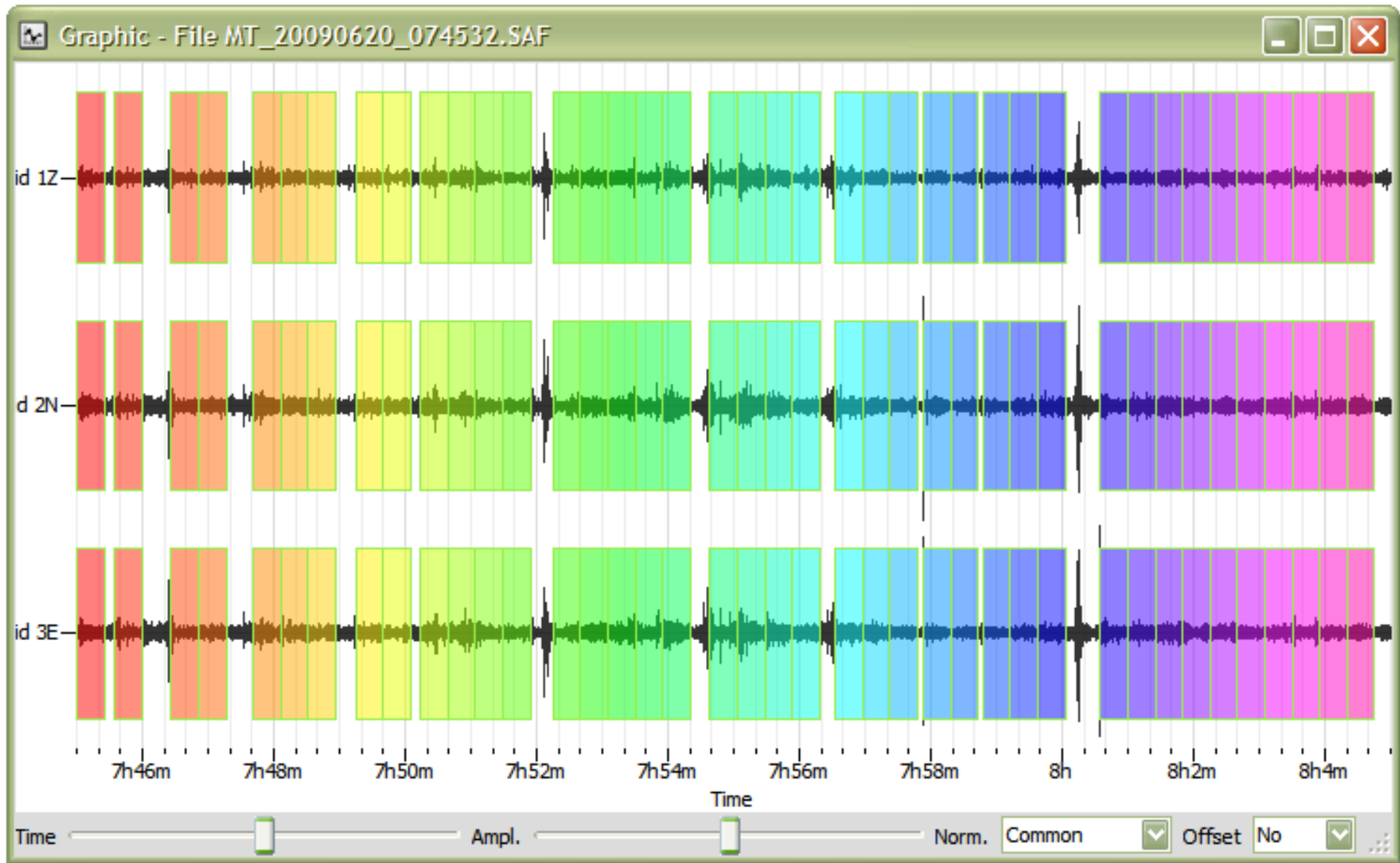


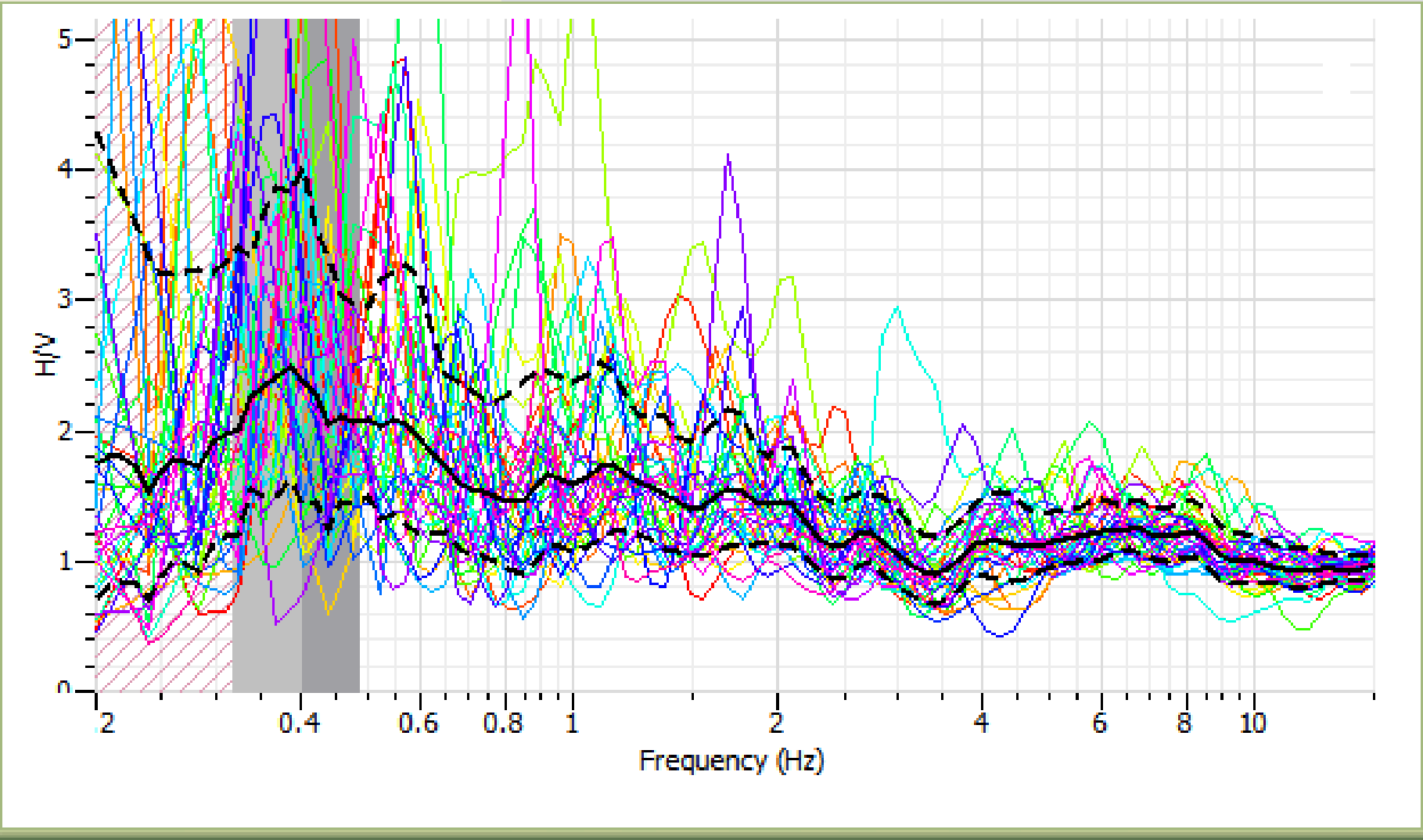


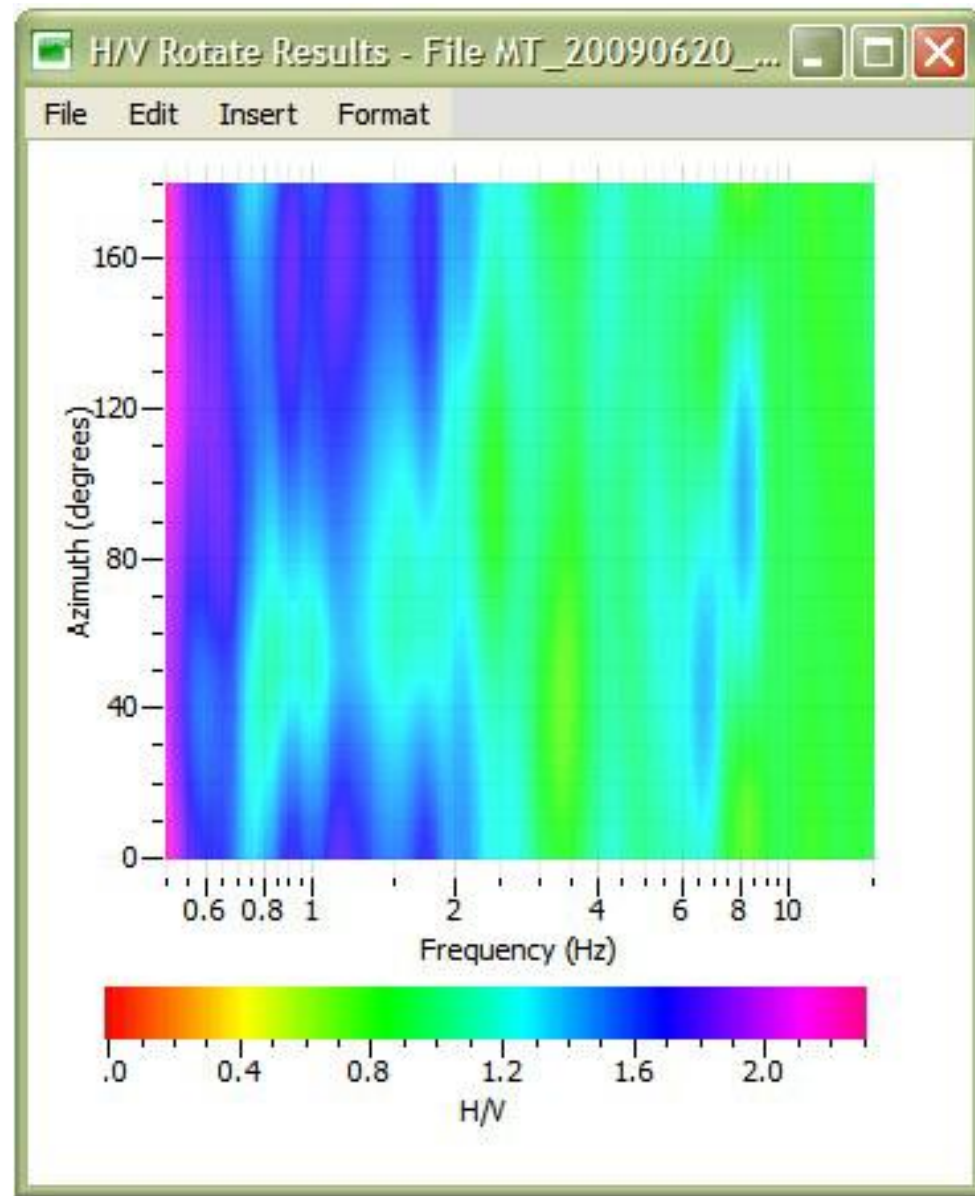
Confronto delle curve H/V ottenute con e senza una piastra di polistirolo sotto il sensore, nello stesso sito, è evidente un forte effetto del polistirolo.

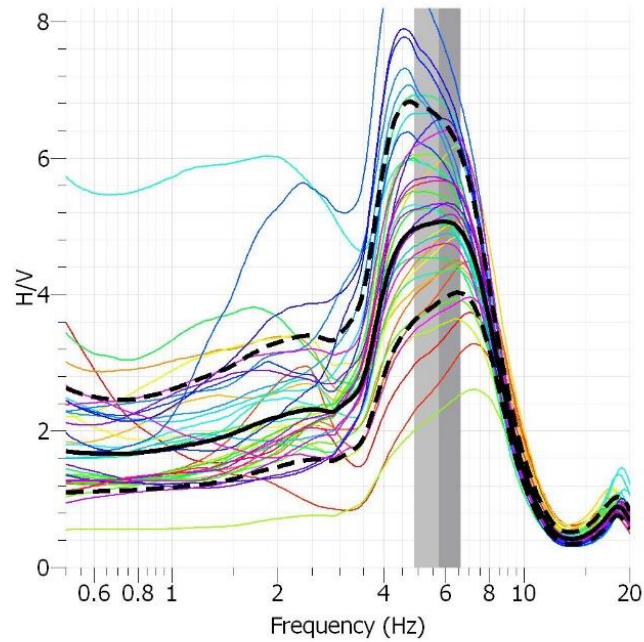
DATE		HOUR		PLACE	
OPERATOR			GPS TYPE and #		
LATITUDE		LONGITUDE		ALTITUDE	
STATION TYPE		SENSOR TYPE			
STATION #		SENSOR #		DISK #	
FILE NAME				POINT #	
GAIN		SAMPL. FRBQ Hz		REC. DURATION <small>minutes seconds</small>	
WEATHER		WIND <input type="checkbox"/> none <input type="checkbox"/> weak (5m/s) <input type="checkbox"/> medium <input type="checkbox"/> strong Measurement (if any): _____			
CONDITIONS		RAIN <input type="checkbox"/> none <input type="checkbox"/> weak <input type="checkbox"/> medium <input type="checkbox"/> strong Measurement (if any): _____			
		Temperature (approx): _____		Remarks _____	
GROUND		<input type="checkbox"/> earth ( <input type="checkbox"/> hard <input type="checkbox"/> soft) <input type="checkbox"/> gravel <input type="checkbox"/> sand <input type="checkbox"/> rock <input type="checkbox"/> grass = ( <input type="checkbox"/> short <input type="checkbox"/> tall)			
TYPE		<input type="checkbox"/> asphalt <input type="checkbox"/> cement <input type="checkbox"/> concrete <input type="checkbox"/> paved <input type="checkbox"/> other _____			
		<input type="checkbox"/> dry soil <input type="checkbox"/> wet soil		Remarks _____	
ARTIFICIAL GROUND-SENSOR COUPLING <input type="checkbox"/> no <input type="checkbox"/> yes, type _____					
BUILDING DENSITY <input type="checkbox"/> none <input type="checkbox"/> scattered <input type="checkbox"/> dense <input type="checkbox"/> other, type _____					
TRANSIENTS		MONOCHROMATIC NOISE SOURCES (factories, works, pumps, rivers...)			
		<input type="checkbox"/> no <input type="checkbox"/> yes, type _____			
		NEARBY STRUCTURES (description, height, distance) (trees, polls, buildings, bridges, underground structures...)			
	<small>none</small>	<small>few</small>	<small>moderate</small>	<small>many</small>	<small>very dense</small>
cars					distance
trucks					
pedestrians					
other					
OBSERVATIONS				FREQUENCY: _____ Hz <small>(if computed in the field)</small>	

DATE		HOUR		PLACE	
OPERATOR			GPS TYPE and #		
LATITUDE		LONGITUDE		ALTITUDE	
STATION TYPE		SENSOR TYPE			
STATION #		SENSOR #		DISK #	
FILE NAME				POINT #	
GAIN		SAMPL. FRBQ Hz		REC. DURATION <small>minutes seconds</small>	
WEATHER		WIND <input type="checkbox"/> none <input type="checkbox"/> weak (5m/s) <input type="checkbox"/> medium <input type="checkbox"/> strong Measurement (if any): _____			
CONDITIONS		RAIN <input type="checkbox"/> none <input type="checkbox"/> weak <input type="checkbox"/> medium <input type="checkbox"/> strong Measurement (if any): _____			
		Temperature (approx): _____		Remarks _____	
GROUND		<input type="checkbox"/> earth ( <input type="checkbox"/> hard <input type="checkbox"/> soft) <input type="checkbox"/> gravel <input type="checkbox"/> sand <input type="checkbox"/> rock <input type="checkbox"/> grass = ( <input type="checkbox"/> short <input type="checkbox"/> tall)			
TYPE		<input type="checkbox"/> asphalt <input type="checkbox"/> cement <input type="checkbox"/> concrete <input type="checkbox"/> paved <input type="checkbox"/> other _____			
		<input type="checkbox"/> dry soil <input type="checkbox"/> wet soil		Remarks _____	
ARTIFICIAL GROUND-SENSOR COUPLING <input type="checkbox"/> no <input type="checkbox"/> yes, type _____					
BUILDING DENSITY <input type="checkbox"/> none <input type="checkbox"/> scattered <input type="checkbox"/> dense <input type="checkbox"/> other, type _____					
TRANSIENTS		MONOCHROMATIC NOISE SOURCES (factories, works, pumps, rivers...)			
		<input type="checkbox"/> no <input type="checkbox"/> yes, type _____			
		NEARBY STRUCTURES (description, height, distance) (trees, polls, buildings, bridges, underground structures...)			
	<small>none</small>	<small>few</small>	<small>moderate</small>	<small>many</small>	<small>very dense</small>
cars					distance
trucks					
pedestrians					
other					
OBSERVATIONS				FREQUENCY: _____ Hz <small>(if computed in the field)</small>	









$L_w$ =Lunghezza finestra.  
 $n_w$ =Numero di finestre selezionate per la media della curva H/V.  
 $n_c=L_w*n_w*f_0$ =Numero di cicli significativi.  
 $f$ =Frequenza corrente.  
 $f_0$ =Picco di frequenza H/V.  
 $\sigma f$ =Deviazione standard del picco di frequenza H/V ( $f_0 \pm \sigma f$ ).  
 $\sigma(f_0)$ =Valore di soglia per la condizione di stabilità  $\sigma f < \sigma(f_0)$ .  
 $A_0$ =Ampiezza del picco H/V alla frequenza  $f_0$ .  
 $A_{H/V}(f)$ =Ampiezza della curva H/V alla frequenza  $f_0$ .  
 $f^-$ =Frequenza tra  $f_0/4$  e  $f_0$  per cui  $A_{H/V}(f^-) < A_0/2$ .  
 $f^+$ =Frequenza tra  $f_0$  e  $4f_0$  per cui  $A_{H/V}(f^+) < A_0/2$ .  
 $\sigma A(f_0)$ =Deviazione standard di  $A_{H/V}(f)$ ,  $\sigma A(f)$  è il valore per il quale la  $A_{H/V}(f)$  va moltiplicata o divisa.  
 $\sigma \text{Log H/V}(f)$ =Dev. Standard della curva  $\text{Log AH/V}(f)$ ,  $\sigma \text{Log H/V}(f)$  è il valore assoluto da sottrarre o aggiungere alla curva media  $\text{Log AH/V}(f)$ .  
 $\theta(f_0)$ =Valore di soglia per la condizione di stabilità  $\sigma f < \theta(f_0)$ .

Criteri per una H/V affidabile  
(devono essere rispettati tutti e tre i parametri)

$$f_0 > 10/L_w$$

$$n_c(f_0) > 200$$

$$\sigma_A < 2 \text{ per } 0.5f_0 < f < 2f_0 \text{ se } f_0 > 0.5 \text{ Hz}$$

oppure

$$\sigma_A < 3 \text{ per } 0.5f_0 < f < 2f_0 \text{ se } f_0 < 0.5 \text{ Hz}$$

Criteri per un picco H/V chiaro  
(almeno 5 su 6 devono essere rispettati)

$$\text{Esiste } f^- \text{ in } [f_0/4, f_0] \mid A_{H/V}(f^-) < A_0/2$$

$$\text{Esiste } f^+ \text{ in } [f_0, 4f_0] \mid A_{H/V}(f^+) < A_0/2$$

$$A_0 > 2$$

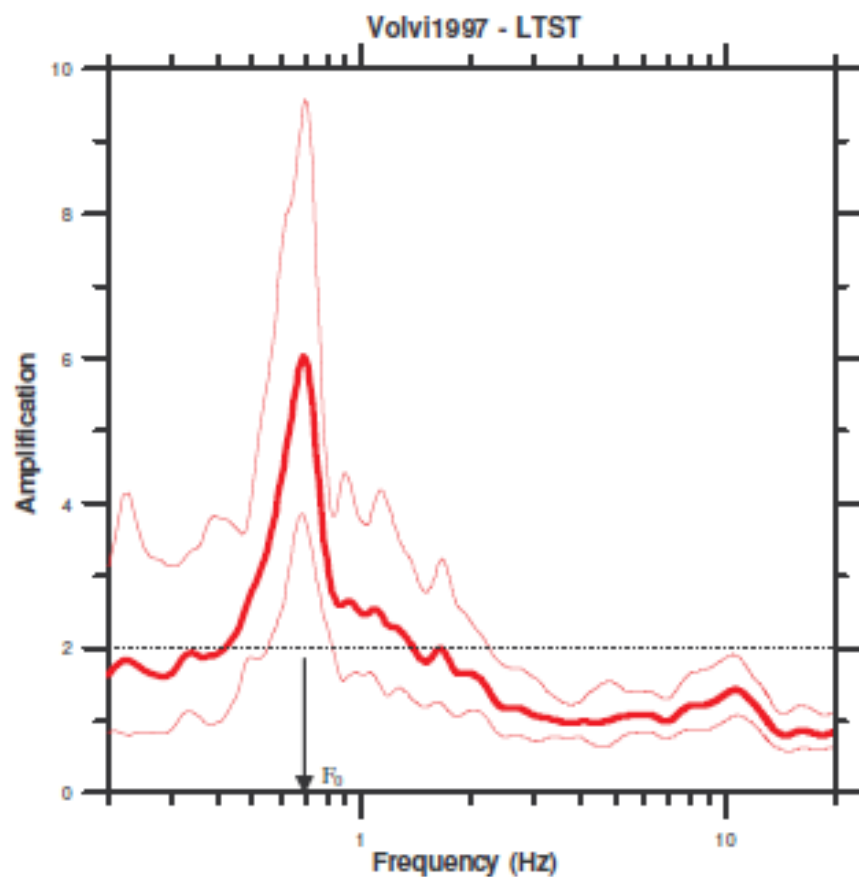
$$f_{\text{picco}} [A_{H/V}(f) \pm \sigma_A(f)] = f_0 \pm 5\%$$

$$\sigma_f < \sigma(f_0)$$

$$\sigma_A(f_0) < \theta(f_0)$$

Valori di soglia per le condizioni di stabilità

Range di frequenza [Hz]	<0,2	0,2-0,5	0,5-1,0	1,0-2,0	>2,0
$\sigma(f_0)$ [Hz]	0,25 $f_0$	0,20 $f_0$	0,15 $f_0$	0,10 $f_0$	0,05 $f_0$
$\theta(f_0)$ per $\sigma_A(f_0)$	3	2,5	2	1,78	1,58
$\text{Log } \theta(f_0)$ per $\sigma_{\text{Log H/V}}(f_0)$	0,48	0,4	0,3	0,25	0,2



**Basin geometry:** Elongated alluvial valley, width~5km, length~40km, Depth~200m

#### Site Information

LTST site depth to bedrock: 196m

Type of bedrock: Gneiss

Average shear wave velocity of deposits: 570m/s

#### Comments

Criteria for a reliable H/V curve are fulfilled, that is:

$$f_0 > 10 / l_w$$

$$n_c(f_0) > 200$$

$$\sigma_A(f) < \log_{10}(2)$$

Criteria for an ideal H/V peak are also fulfilled:

$$A_0 (=6) > 2$$

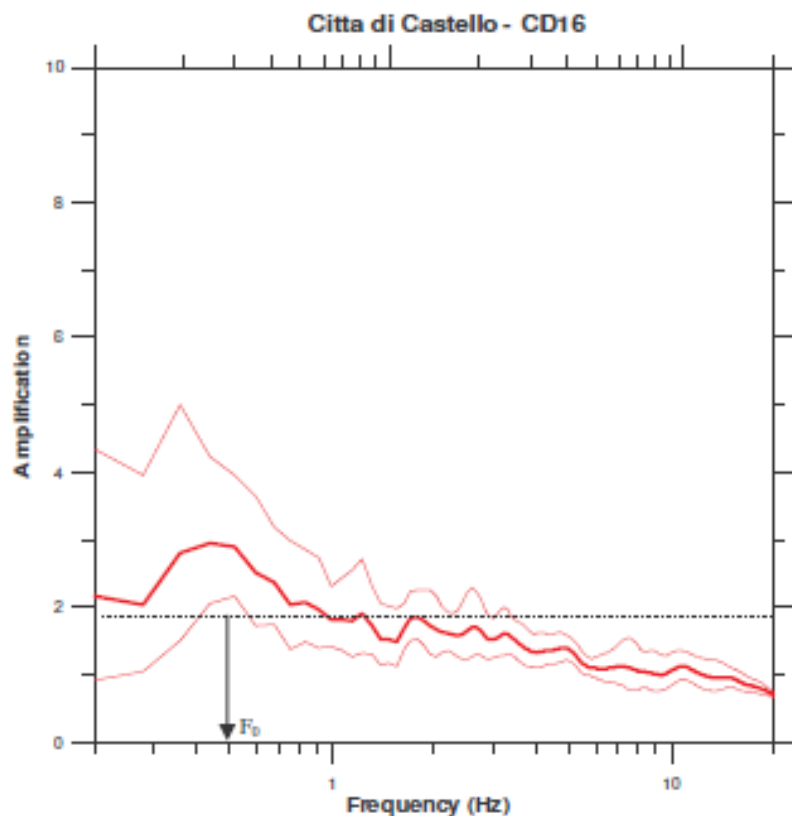
$$\exists f \in [f_0/4, f_0] \mid A_{HV}(f) < A_0/2$$

$$\exists f^* \in [f_0, 4f_0] \mid A_{HV}(f^*) < A_0/2$$

$$\sigma_f (=14\%) < \varepsilon(f_0) (=15\%)$$

$$\sigma_A(f_0) (=1.6) < \theta(f_0) (=2)$$

Interpretation : All criteria are fulfilled, the fundamental frequency of the site may be reliably estimated at 0.7 Hz.



**Basin geometry:** Elliptical alluvium valley, width~10km, length~25km, depth~0.1km

#### Site Information

CD16 site is situated on soft alluvium sediments and silty clay.  
Type of bedrock: Sandstone (Middle Miocene).

#### Comments

Criteria for a reliable H/V curve are fulfilled, that is:

$$f_0 > 10 / l_w$$
$$n_c(f_0) > 200$$
$$\sigma_A(f) < \log_{10}(2)$$

In addition:

Although  $A_0(=2.9) > 2$ , the peak cannot be qualified "clear" since the amplitude is not decreasing rapidly on each side.

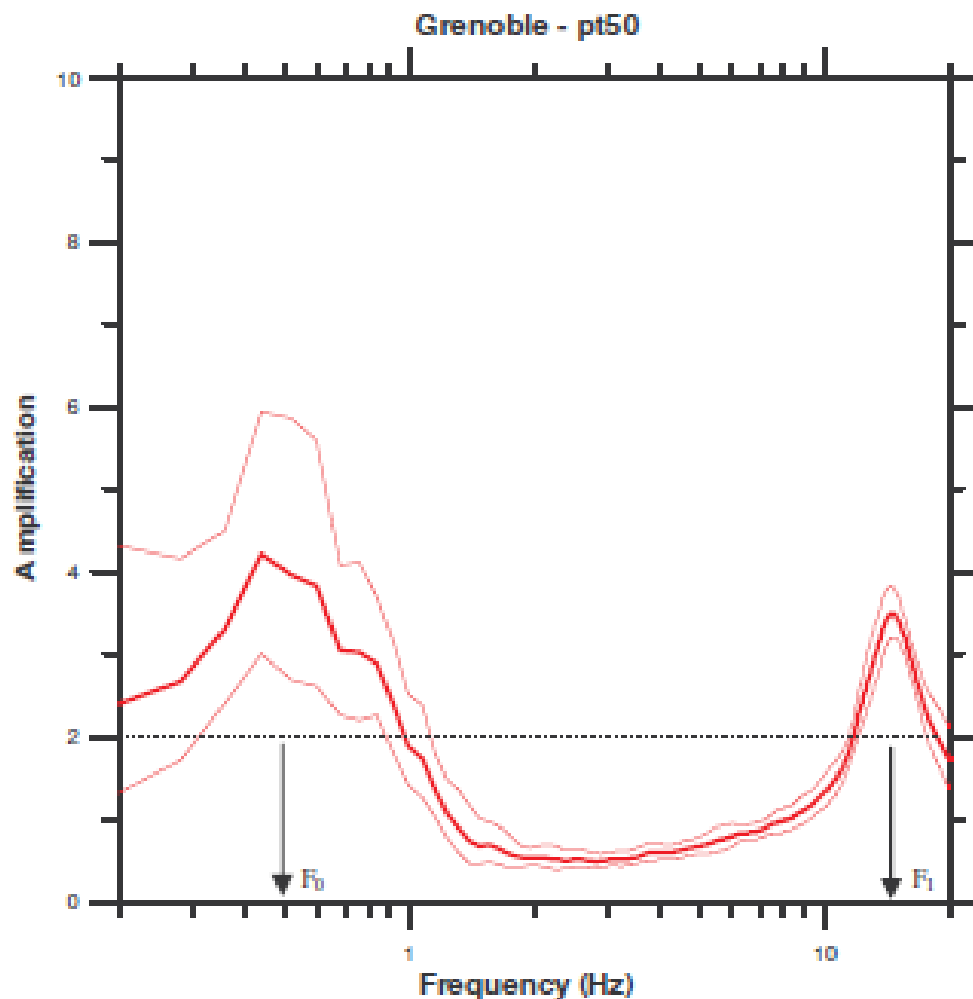
None  $f_1 \in [f_0/4, f_0] \mid A_{HV}(f_1) < A_0/2$

None  $f_2 \in [f_0, 4f_0] \mid A_{HV}(f_2) < A_0/2$

Interpretation : further tests should be performed as listed in section II-3.3.2-b







**Basin geometry:** Y-shaped sedimentary valley, Depth~800m

#### Site Information

PT50 site is situated on late quaternary post-glacial deposits.  
Type of bedrock: Jurassic marls and marly limestone.

#### Comments

Criteria for a reliable H/V curve are fulfilled, that is:

$$f_0 > 10 / l_w$$

$$n_c(f_0) > 200$$

$$\sigma_A(f) < \log_{10}(2)$$

Interpretation :

For the low frequency peak,  $A_0(=4.0) > 2$  and  $\exists f_2 \in [f_0, 4f_0] \mid A_{HV}(f_2) < A_0/2$

Although, strictly speaking, one cannot find  $f_1 \in [f_0/4, f_0] \mid A_{HV}(f_1) < A_0/2$ , the general trend of the curve, together with the known geology of the site, allow the meaning of the low frequency peak to be assigned with confidence; another processing with more narrow band smoothing would satisfy the criteria

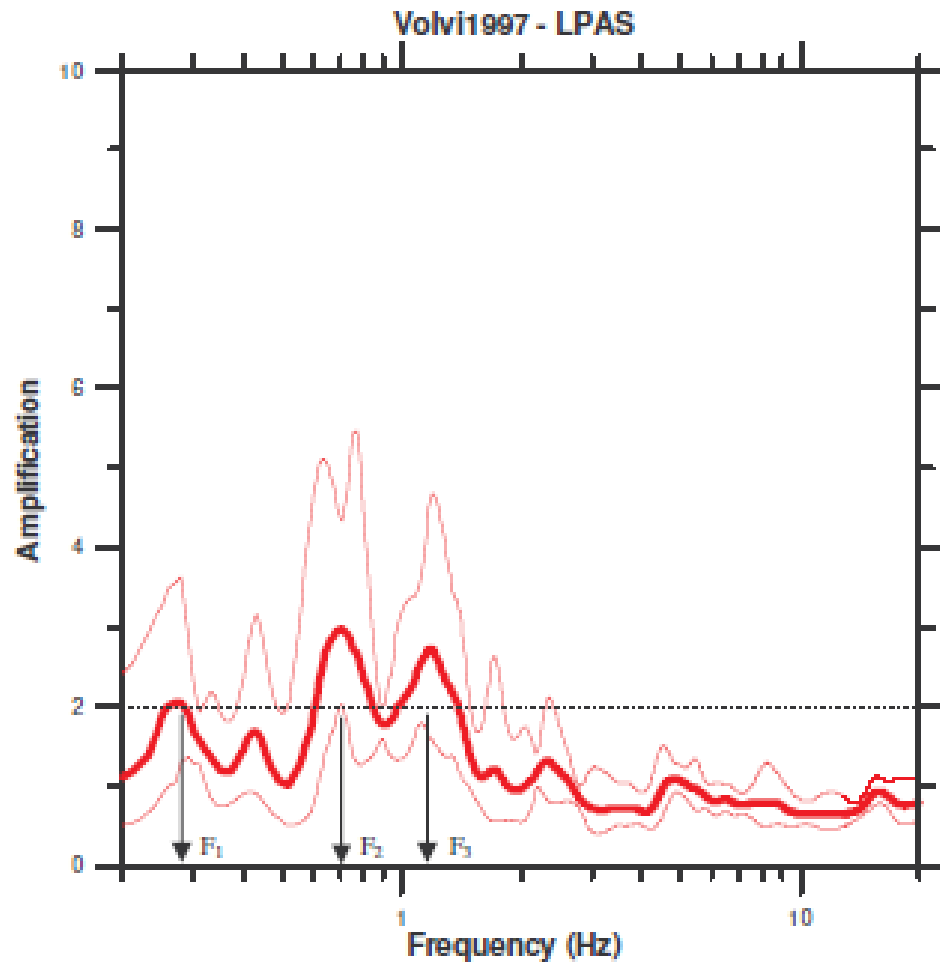
For the second peak, all the criteria are fulfilled:

$$A_1(=3.5) > 2$$

$$\exists f_1 \in [f_1/4, f_1] \mid A_{HV}(f_1) < A_1/2$$

$$\exists f_2 \in [f_1, 4f_1] \mid A_{HV}(f_2) < A_1/2$$

This second peak around 13 Hz is certainly associated with a very shallow structure.



**Basin geometry:** Elongated alluvial valley, width~5km, length~40km, Depth~200m

#### Site Information

LTST site depth to bedrock: ~180m

Type of bedrock: Gneiss

Average shear wave velocity of deposits: 570m/s

#### Comments

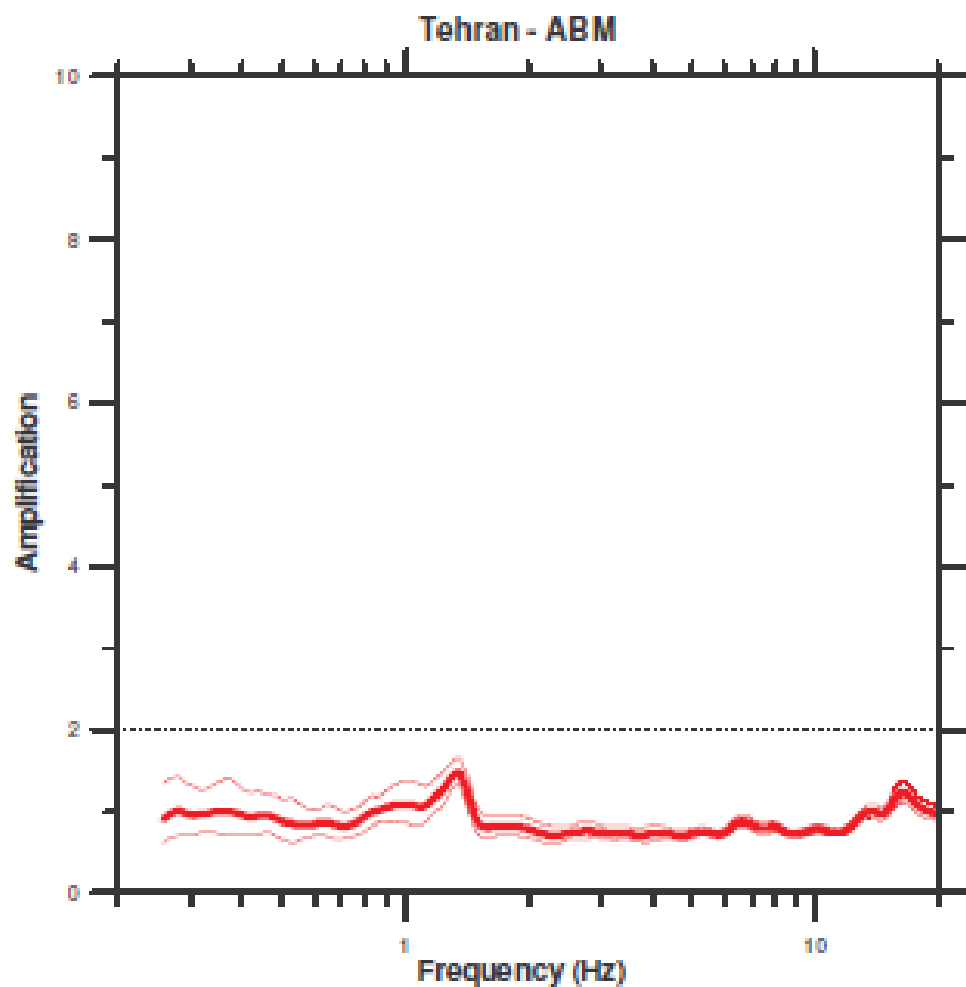
Criteria for a reliable H/V curve are fulfilled, that is:

$$f_0 > 10 / l_w$$

$$n_c(f_0) > 200$$

$$\sigma_A(f) < \log_{10}(2)$$

Interpretation : All three peaks fulfil the criterion for amplitude,  $A_i > 2$ . However, only the peaks  $F_2$  and  $F_3$  fulfil all "clarity" criteria (3.3.1). The availability of other information (geology, deposit thickness, geophysics) in that area allows us to identify  $f_2$  as the fundamental frequency of the site. The location of this site close to a valley edge may explain the presence of these two peaks with rather low amplitude, while another nearby site (LTST, see above the "clear peak" example") exhibits a clear peak with larger amplitude: the latter is located in the central, part of the graben.



**Basin geometry:** Unknown

#### Site Information

ABM site is characterised by stiff soil (coarse grained alluvium) overlying bedrock at an unknown depth.

#### Comments

Criteria for a reliable H/V curve are fulfilled, that is:

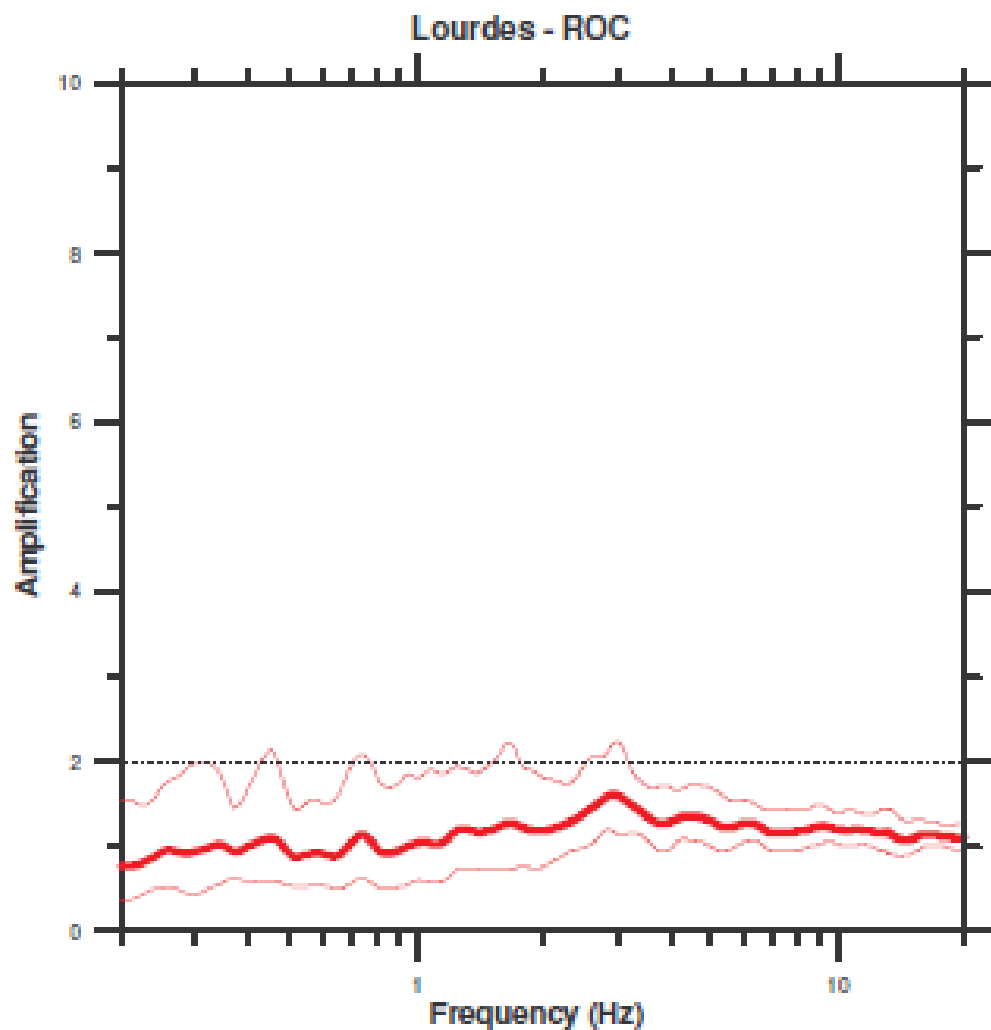
$$f_0 > 10 / l_w$$

$$n_c(f_0) > 200$$

$$\sigma_A(f) < \log_{10}(2)$$

Significant low frequency amplification ( $F < 1.0$  Hz) was found for the ABM sedimentary site using earthquake data, which does not appear in the H/V ratio. This site is one of the few examples of non-rock sites exhibiting a flat H/V curve though also exhibiting a significant low frequency amplification (less than 5% of the total number of sites studied, as can be seen on Figure 8, section 3.1)

Note: the peak around 1.3 Hz was shown to have an industrial origin.



**Basin geometry:** Confluence of two valleys

**Site Information**

ROC site is situated on rock outcrop at the confluence of two valleys (reference site). (Dubos et al., 2003; Dubos, 2003)

**Comments**

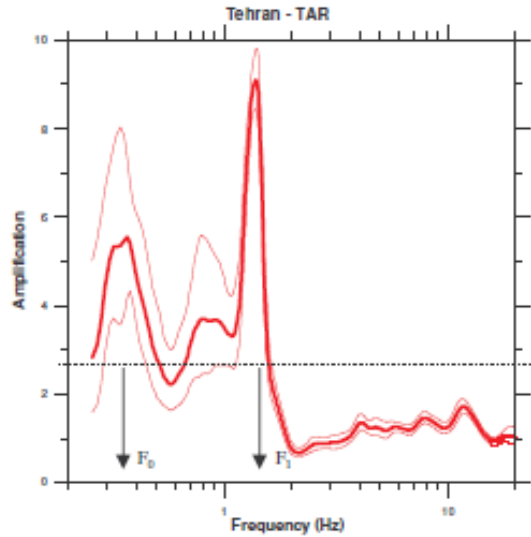
Criteria for a reliable H/V curve are fulfilled, that is:

$$f_0 > 10 / l_w$$

$$n_c(f_0) > 200$$

$$\sigma_A(f) < \log_{10}(2)$$

The H/V ratio is flat over the whole frequency range examined. As the available geological information unambiguously indicates that it is a hard rock site, this flat H/V curve may be interpreted as indicative of a good, non weathered reference site free of any amplification even at high frequencies.



### Site Information

TAR site is overlain with stiff soil (coarse grained alluvium).

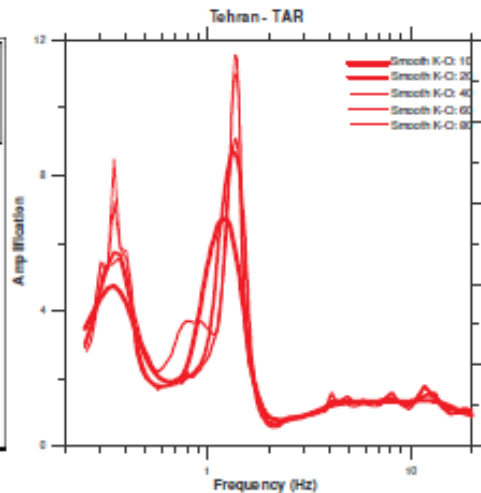
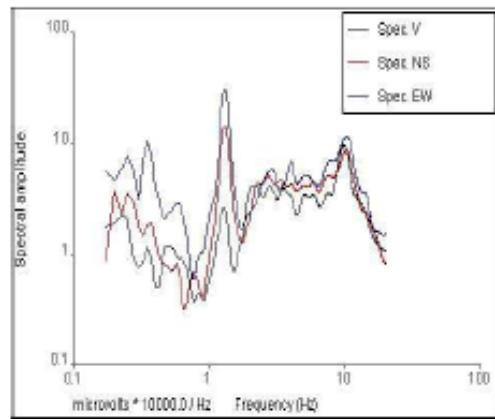
### Comments

Criteria for a reliable H/V curve are fulfilled, that is:

$$f_0 > 10 / l_w$$

$$n_c(f_0) > 200$$

$$\sigma_A(f) < \log_{10}(2)$$

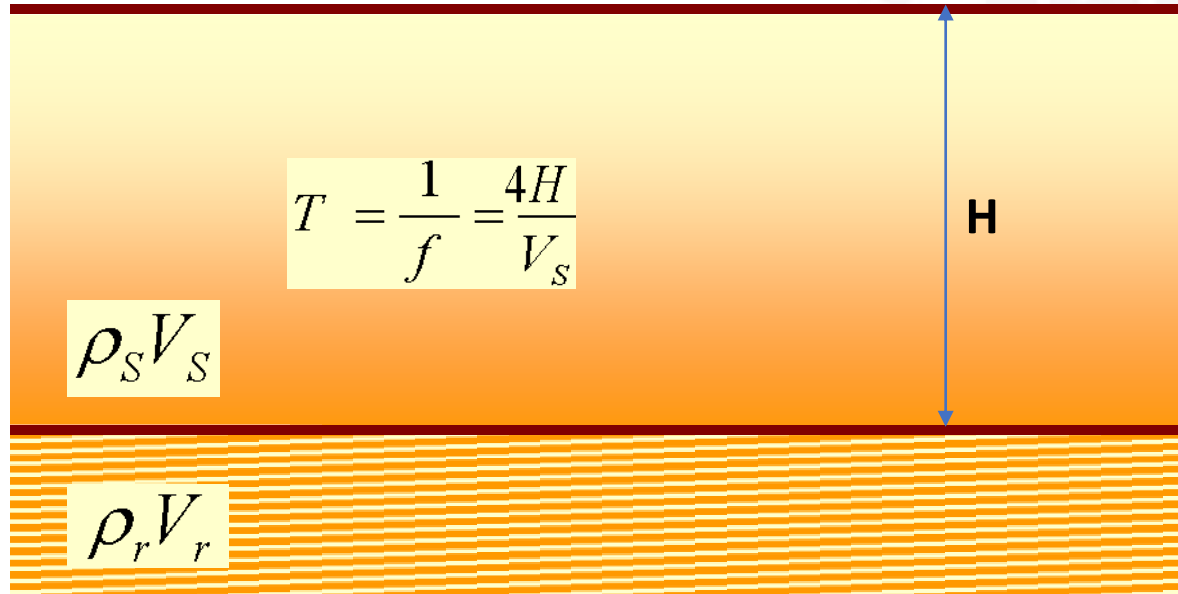


The  $F_1$  local narrow peak has an industrial origin. This (H/V) spectral ratio peak is due to manmade noise/machinery; the reprocessing with different smoothing parameters (bottom right) shows it becomes narrower and narrower, with a larger and larger amplitude when the b-value (Konno-Ohmachi smoothing approach) is increasing: this behaviour is typical of industrial origin. Another confirmation is obtained from the fact this narrow peak occurs at the same frequency in the Fourier spectra of all three components (Figure on bottom left).

Basin geometry: Unknown

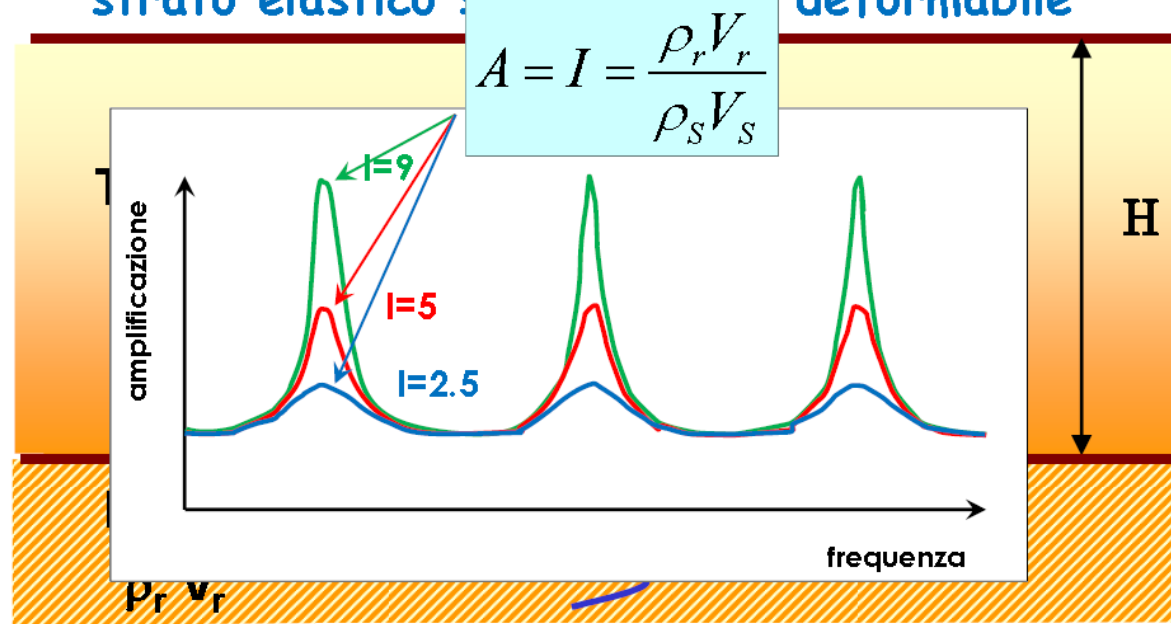
## Amplificazione 1D

Strato elastico su basamento deformabile



# Amplificazione 1D

## strato elastico su basamento deformabile



$$I = \frac{\rho_r V_r}{\rho_s V_s}$$

rapporto di  
impedenza  
roccia-terreno

$$T_n = \frac{1}{f_n} = \frac{4H}{V_s(2n+1)}$$

periodi naturali

Da: "Le categorie di sottosuolo delle NTC08: limiti applicabilità  $V_{s30}$ " - Giuseppe Lanza

## Amplificazione 1D

Le due variabili di controllo:

$$I = \frac{\rho_r V_r}{\rho_s V_s}$$

$$T_0 = \frac{1}{f_0} = \frac{4H}{V_s}$$

Studi di Borcherdt (1992, 1994, 2002) hanno mostrato per siti:

- di comparabile spessore  $H$  del basamento
- di comparabile velocità  $V_r$

l'amplificazione media cresce al crescere di  $V_s$

**In queste condizioni  $V_s$  può essere considerato un parametro efficace per la caratterizzazione sismica**

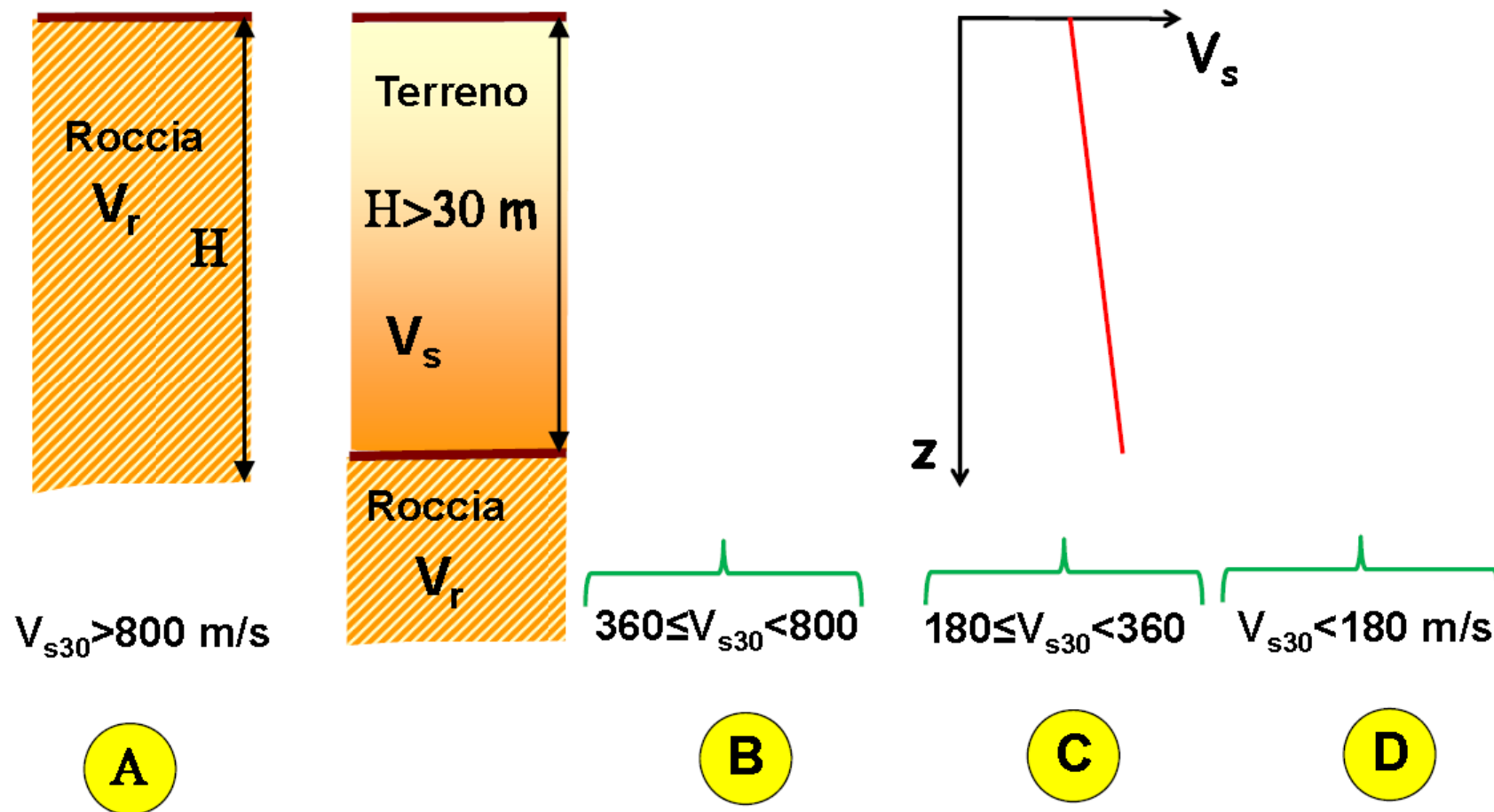
$$V_{s30} = \frac{30}{\sum_{i=1}^n \frac{h_i}{V_{si}}} \Rightarrow \sum_{i=1}^n t_i \Rightarrow \text{Strato } i \text{ } h_i$$

Da: "Le categorie di sottosuolo delle NTC08: limiti applicabilità  $V_{s30}$ " - Giuseppe Lanza



# Classi di sottosuolo

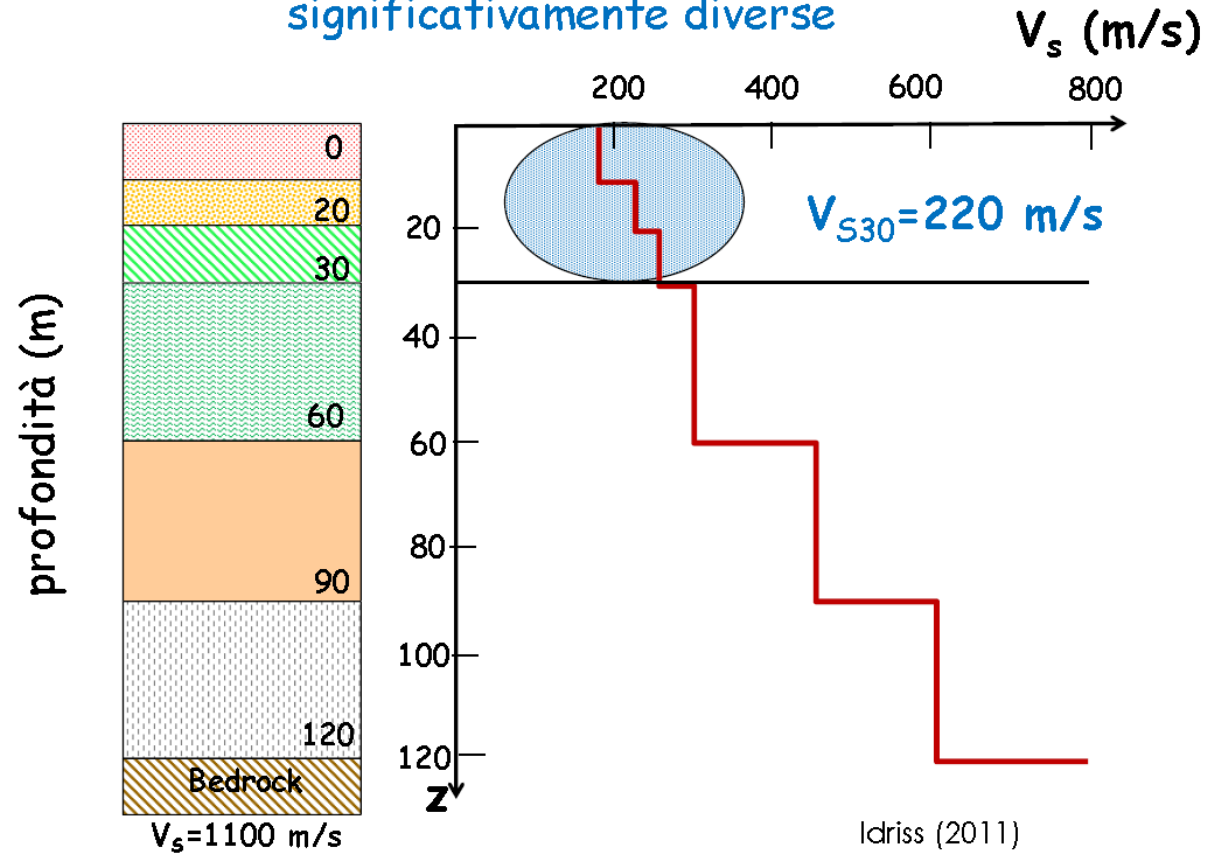
Per le classi di sottosuolo da A ad E si calcola il  $V_{s,30}$  :



Da: "Le categorie di sottosuolo delle NTC08: limiti applicabilità  $V_{s30}$ " - Giuseppe Lanza

## Limiti della $V_{S30}$

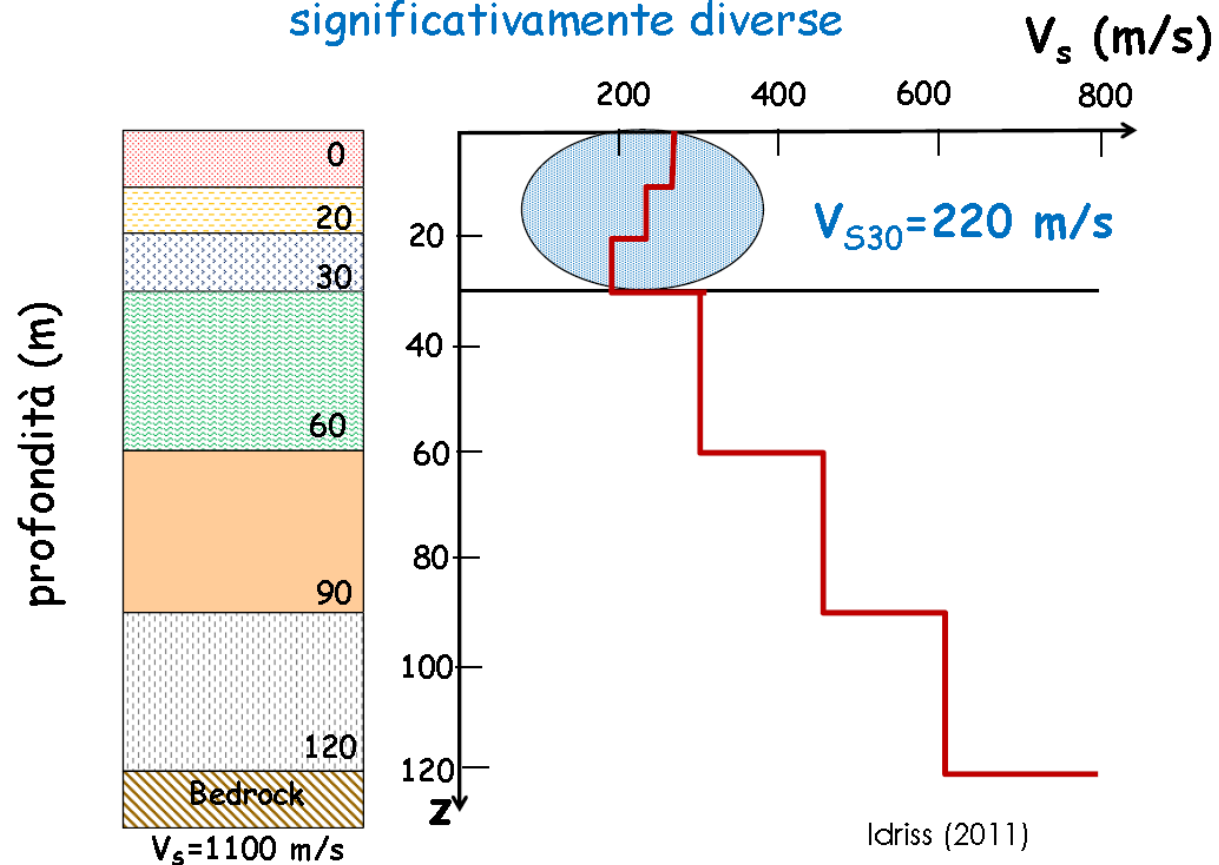
Siti con la stessa  $V_{S30}$  possono avere risposte significativamente diverse



Da: "Le categorie di sottosuolo delle NTC08: limiti applicabilità  $V_{S30}$ " - Giuseppe Lanza

## Limiti della $V_{S30}$

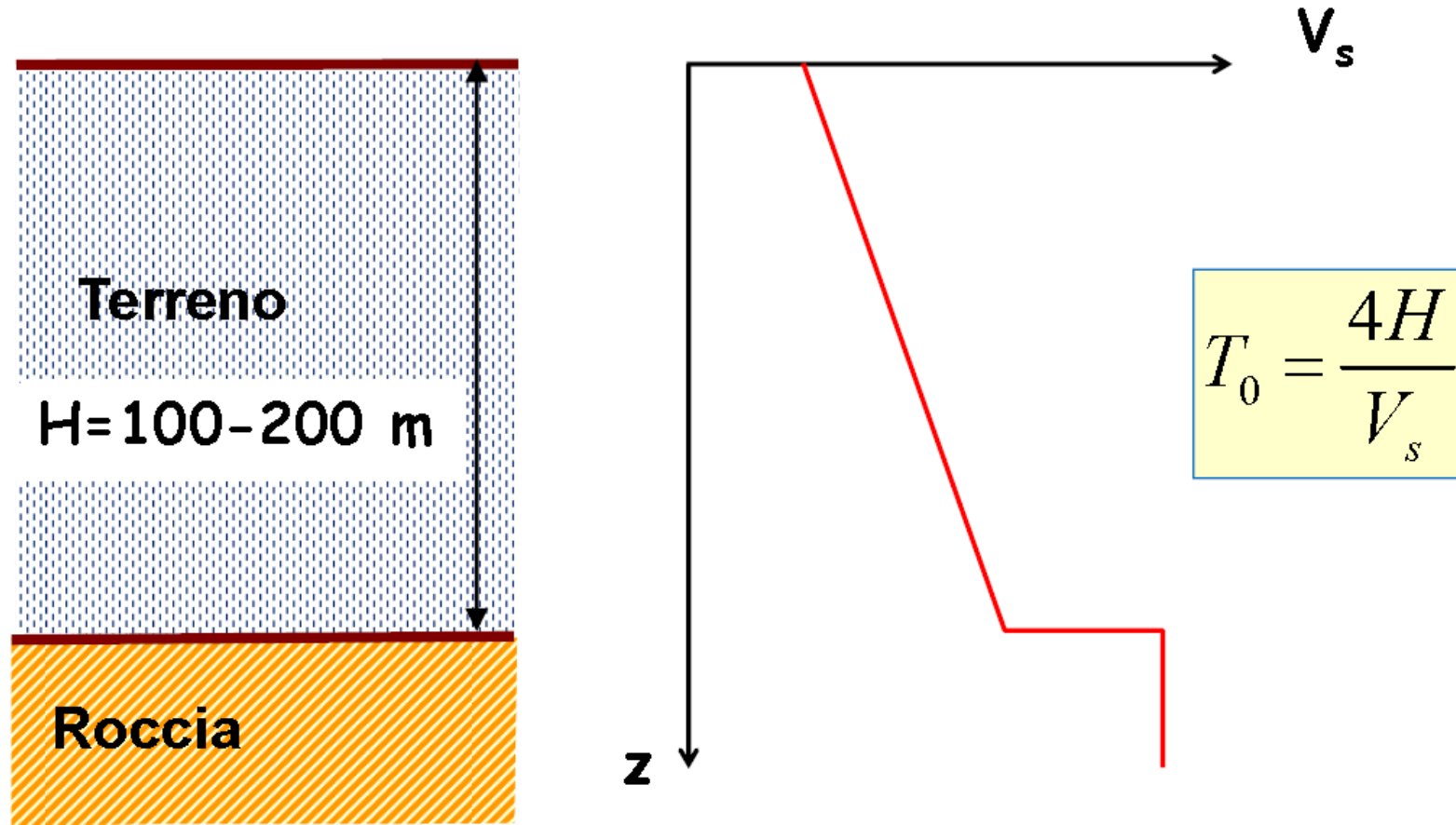
Siti con la stessa  $V_{S30}$  possono avere risposte significativamente diverse



Da: "Le categorie di sottosuolo delle NTC08: limiti applicabilità  $V_{S30}$ " - Giuseppe Lanza

# Limiti della $V_{s30}$

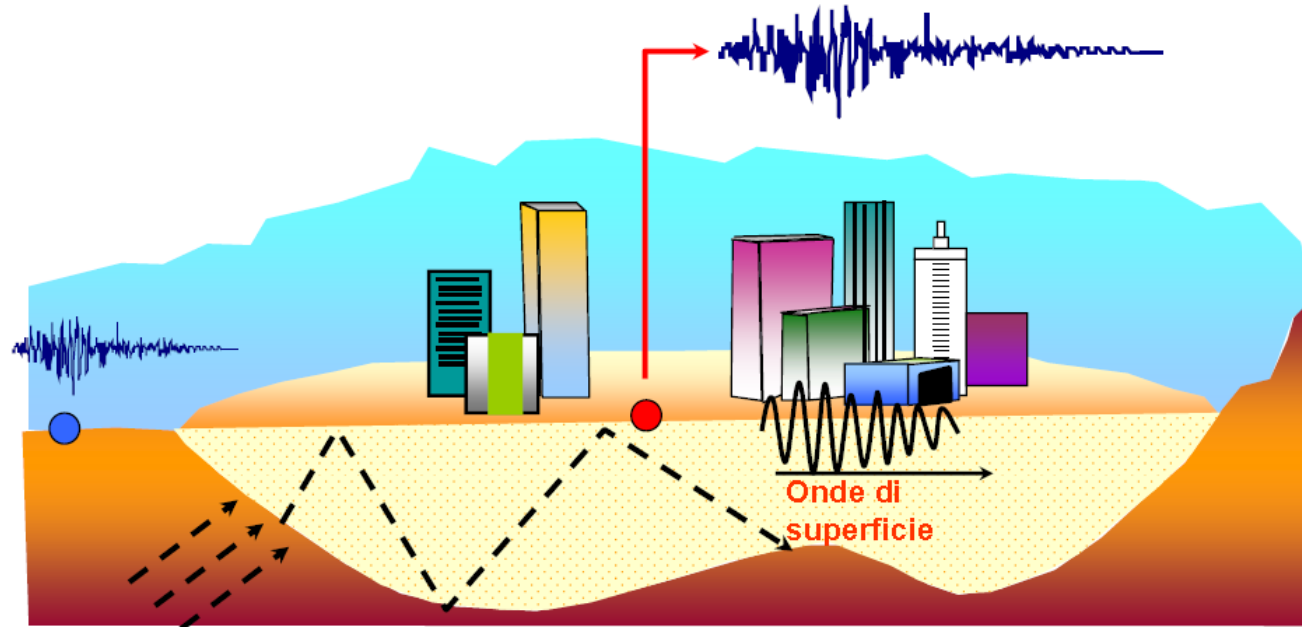
Depositi di terreno di elevato spessore



Da: "Le categorie di sottosuolo delle NTC08: limiti applicabilità  $V_{s30}$ " - Giuseppe Lanza

# Limiti della $V_{s30}$

## Amplificazione 2D



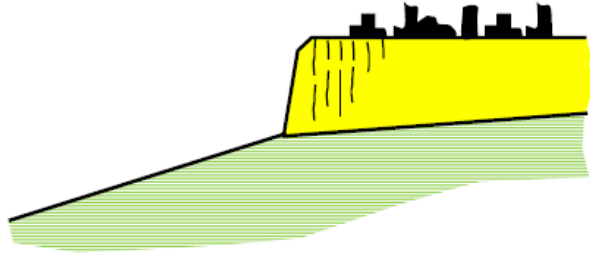
Rispetto alle condizioni 1D:

- aumento dell'amplificazione
- incremento di durata
- amplificazione a larga banda
- variazione spaziale del moto

Da: "Le categorie di sottosuolo delle NTC08: limiti applicabilità  $V_{s30}$ " - Giuseppe Lanza

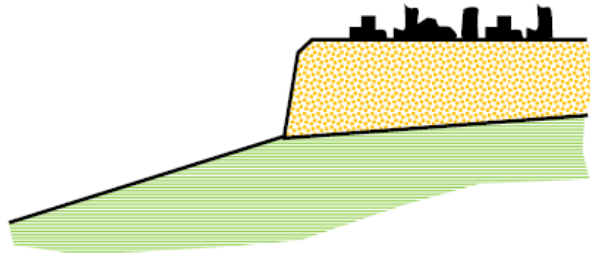
# Limiti della $V_{s30}$

## Configurazioni tipo "rupe"



### Piastroni di rocce su substrato di argille

- Orvieto (TR) (tufo litoide su argille marine OC)
- Agrigento (calcareni su argille marine OC)
- Gerace (RC) (calcareni su argille varicolori)

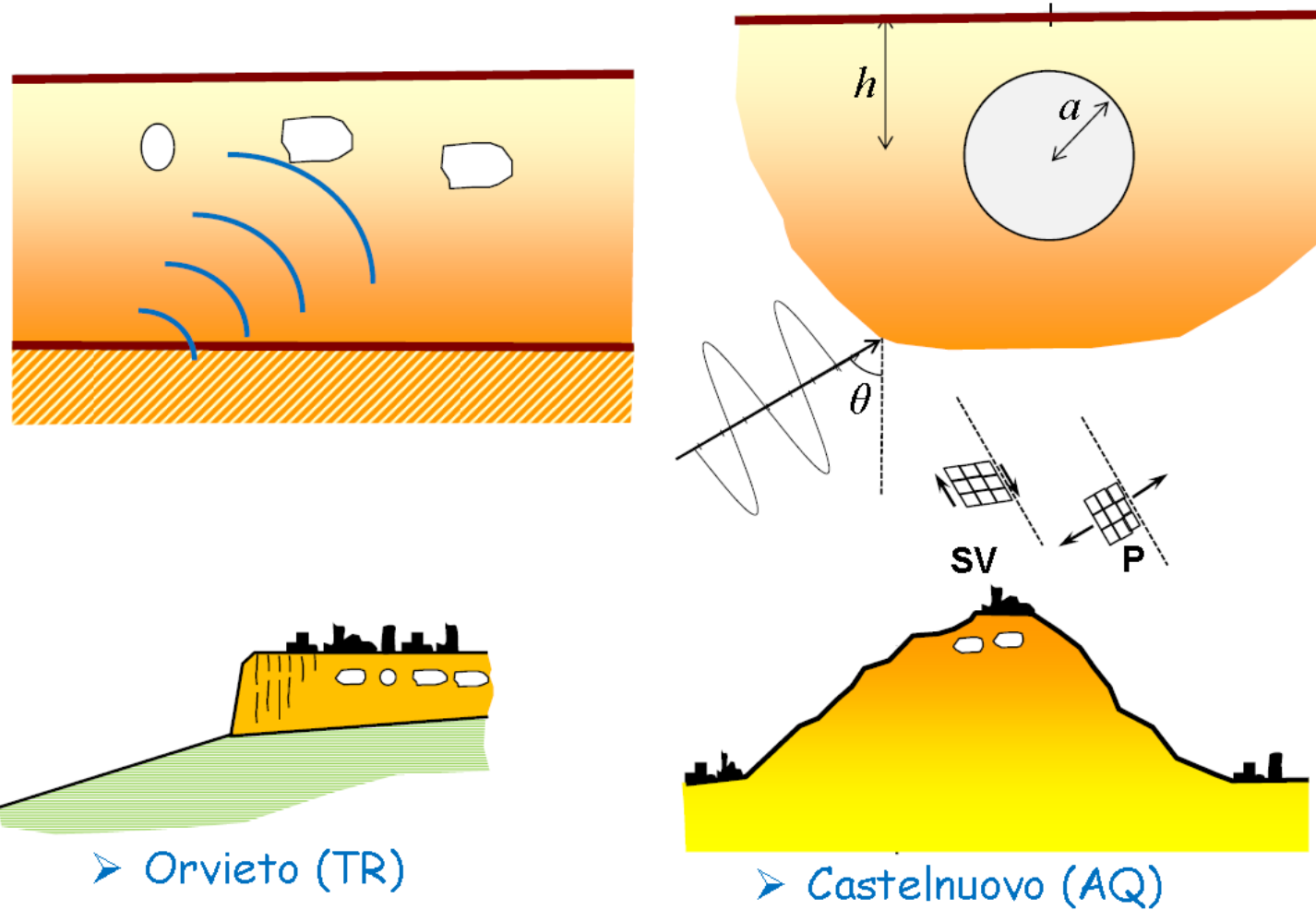


### Banchi di terreni sabbiosi e ghiaiosi su substrato di argille

- Bisaccia (AV) (conglomerati su argille plioceniche a scaglie)

Da: "Le categorie di sottosuolo delle NTC08: limiti applicabilità  $V_{s30}$ " - Giuseppe Lanza

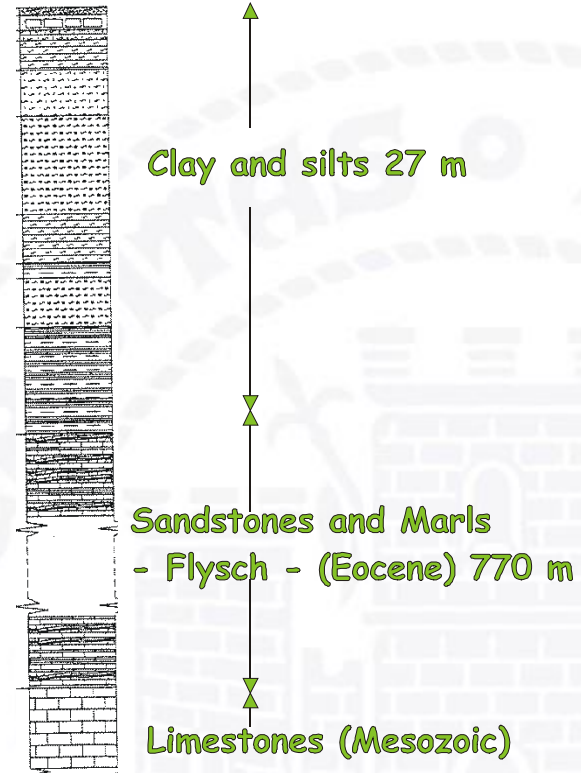
# Limiti della $V_{S30}$ Presenza di cavità



Da: "Le categorie di sottosuolo delle NTC08: limiti applicabilità  $V_{S30}$ " - Giuseppe Lanza

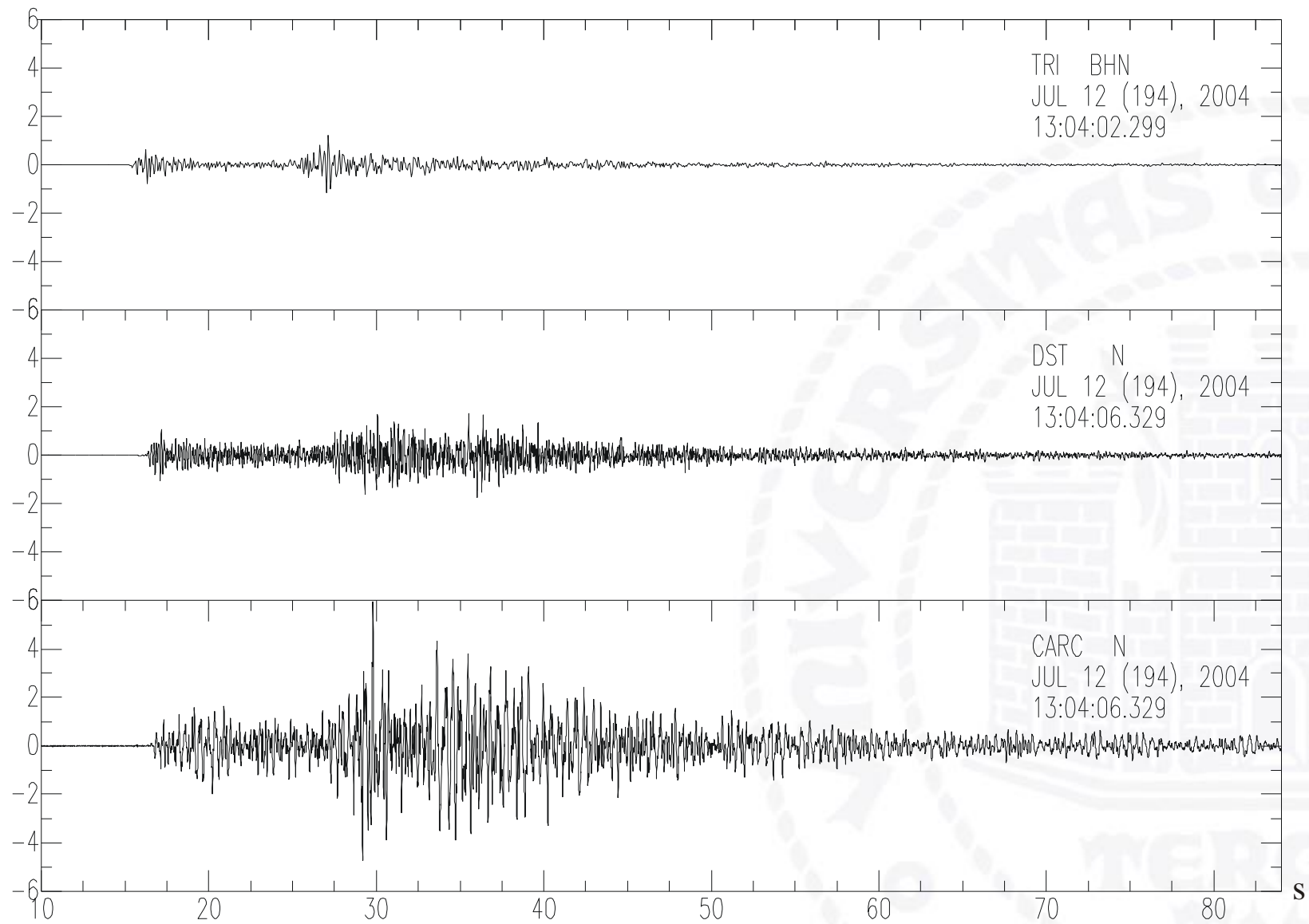
# The station CARC

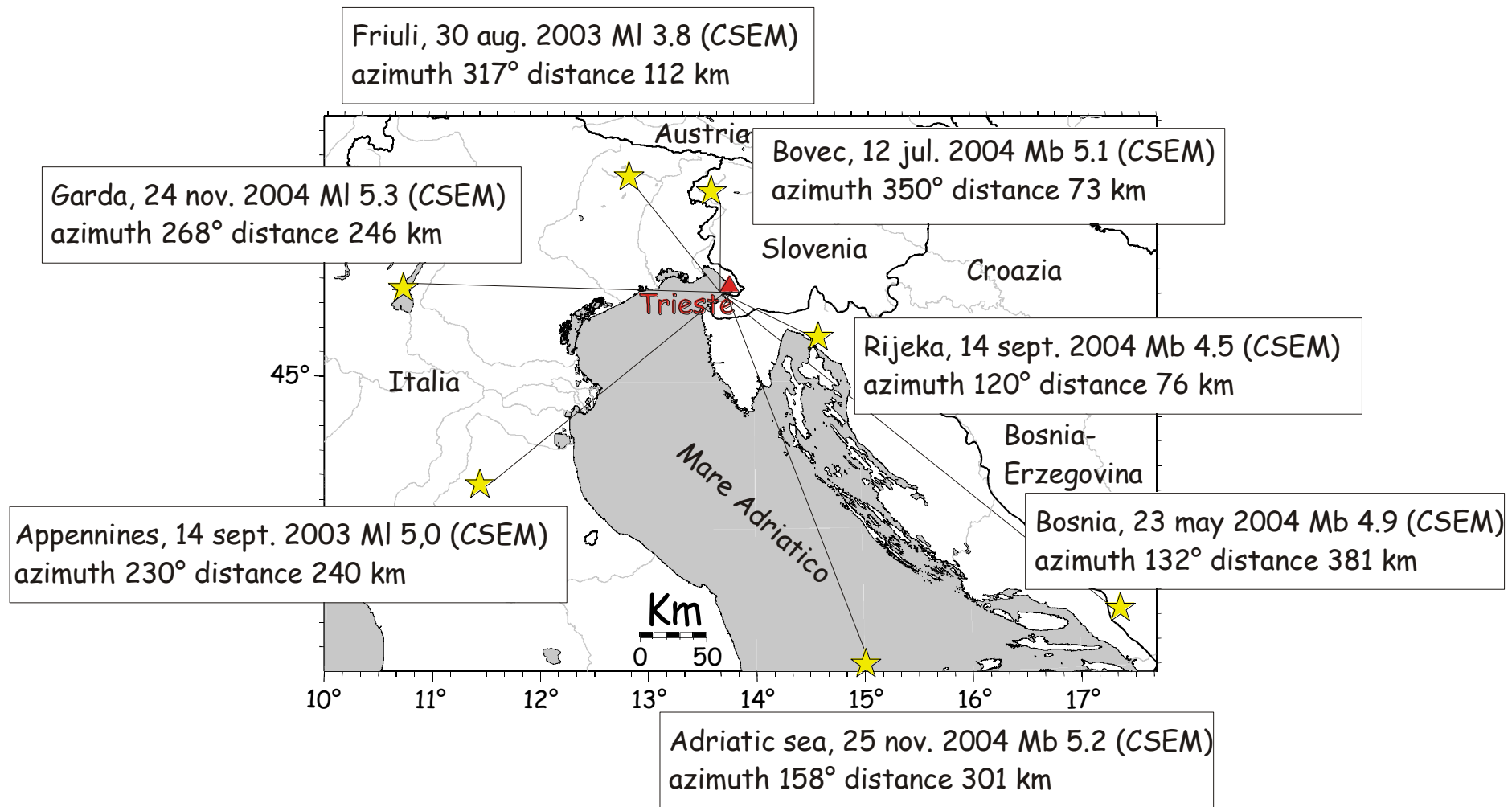
GURALP CMG5-T  
Lennartz MARS88

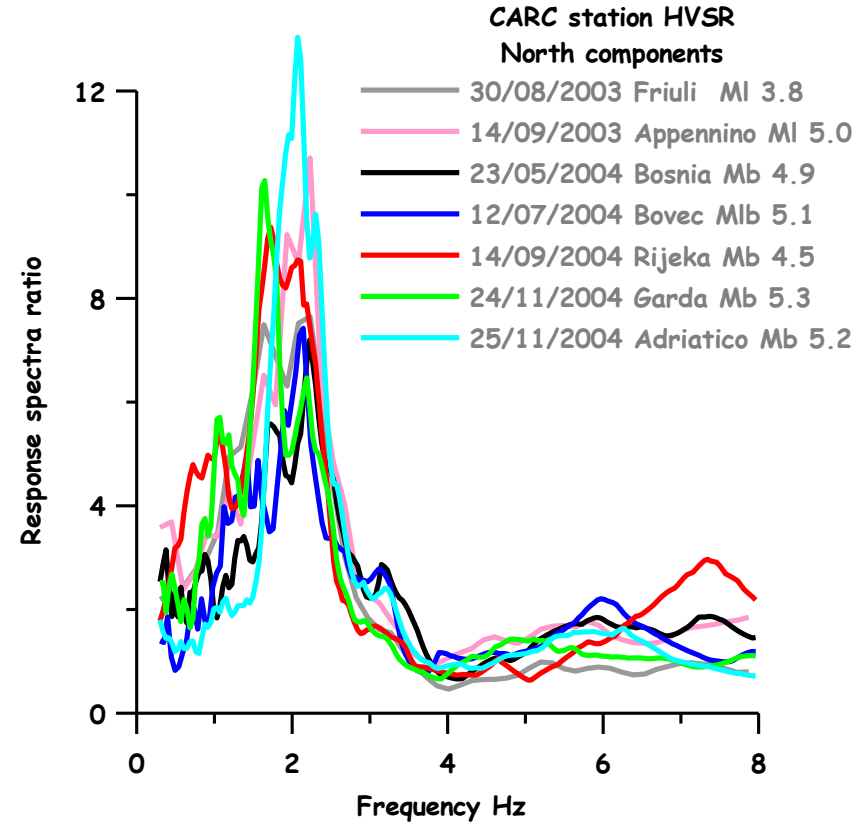
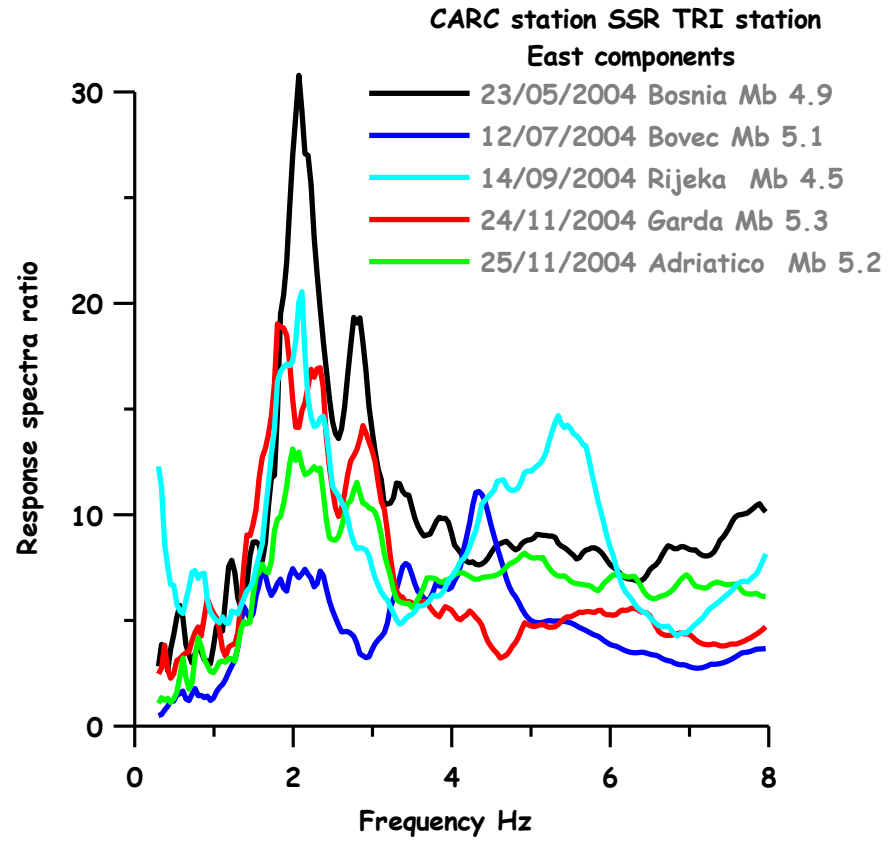


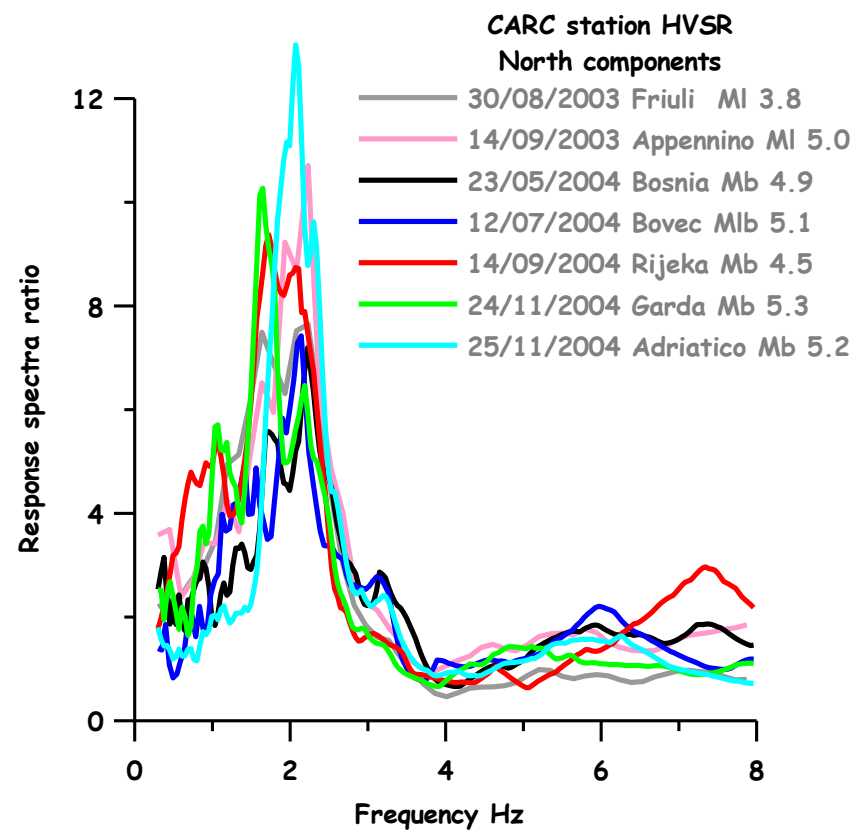
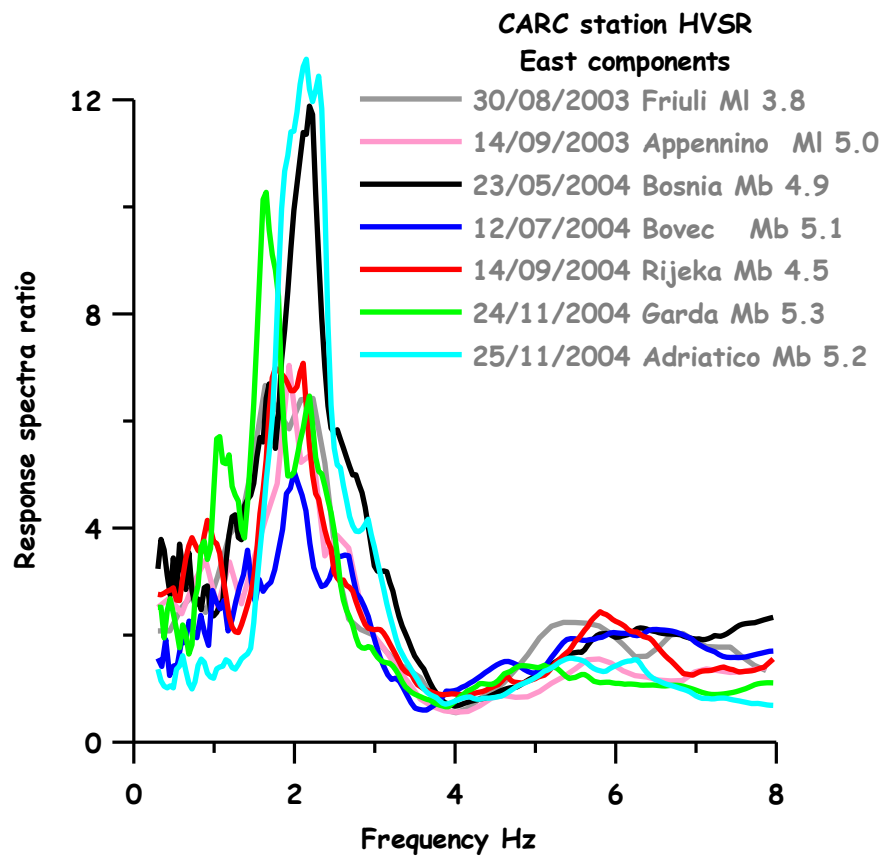


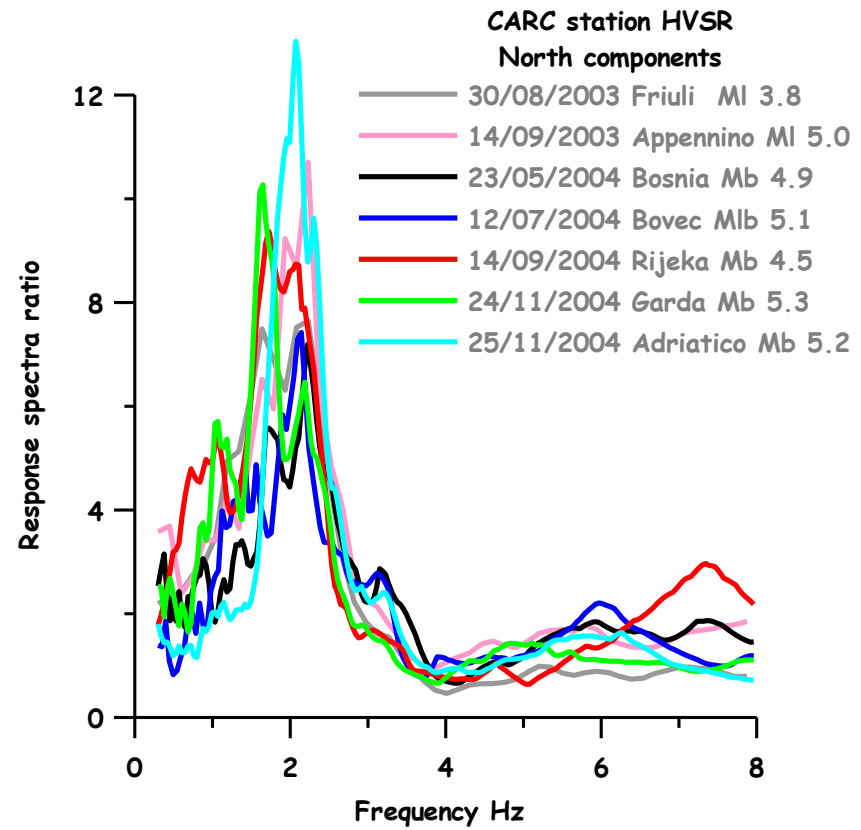
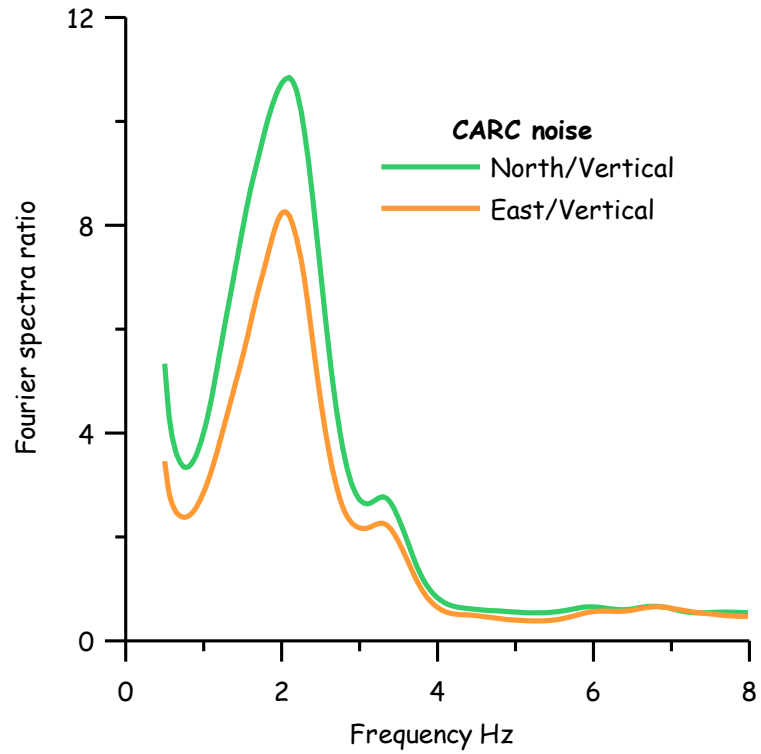
cm/s<sup>2</sup>

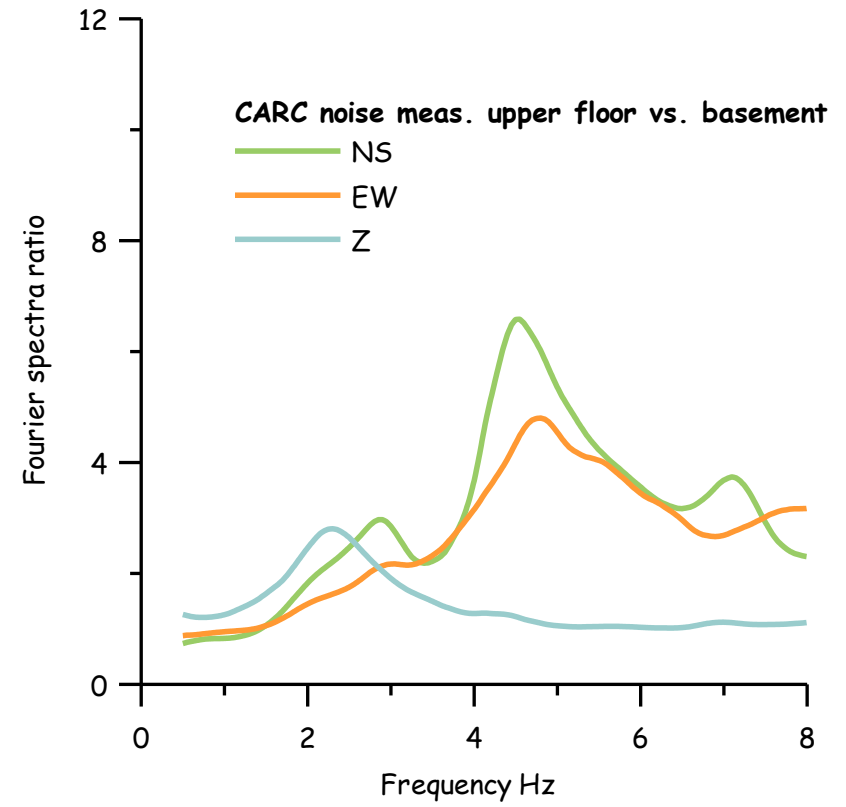
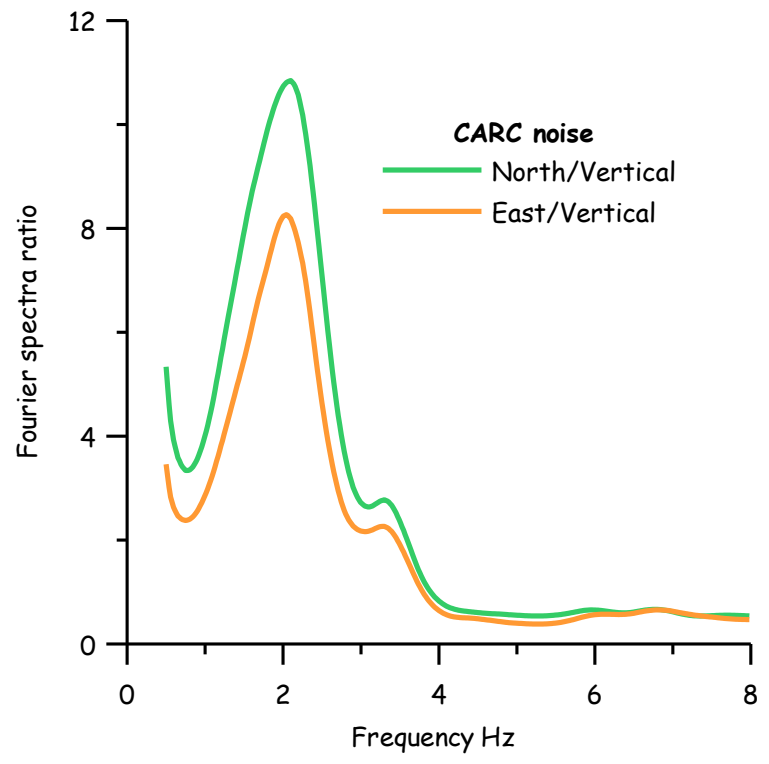












Per strutture 1D, con un solo strato su un semispazio, la frequenza fondamentale per lo strato è data da:

$$f_0 = \frac{\beta_1}{4h}$$

$\beta_1$  = velocità delle onde S nello strato superficiale

$h$  = spessore dello strato

le armoniche superiori da:

$$f_n = (2n + 1)f_0$$

dove  $n$  è l'intero che indica l'ordine dell'armonica.



## simple 1D model

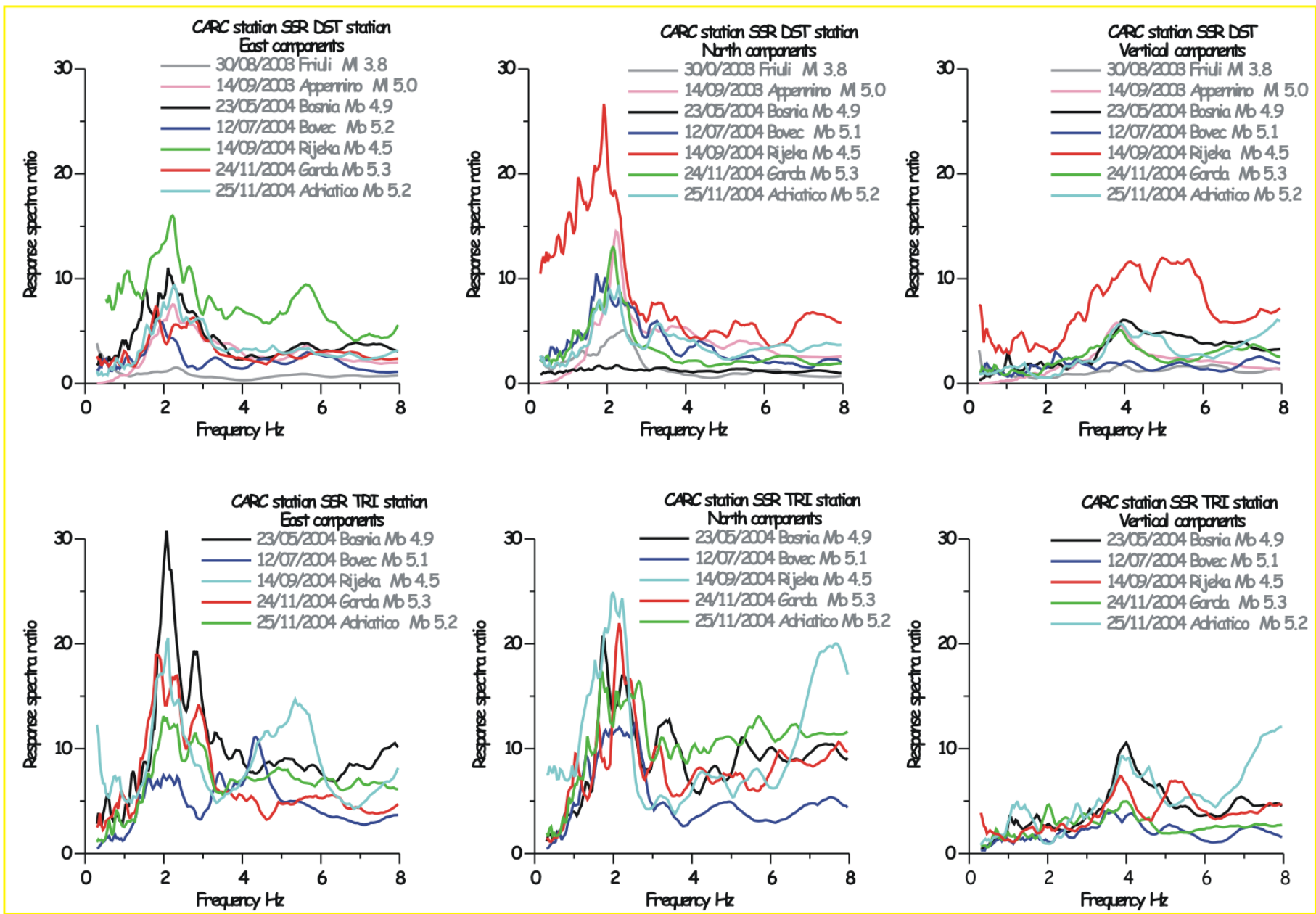
$f=v/4H$ ,  $f$  frequency Hz,  $V$  s-waves velocity  $m/s^2$ ,  $H$  sediments thickness m [Bard and Bouchon, 1985]

## Uniform Building Code (1985)

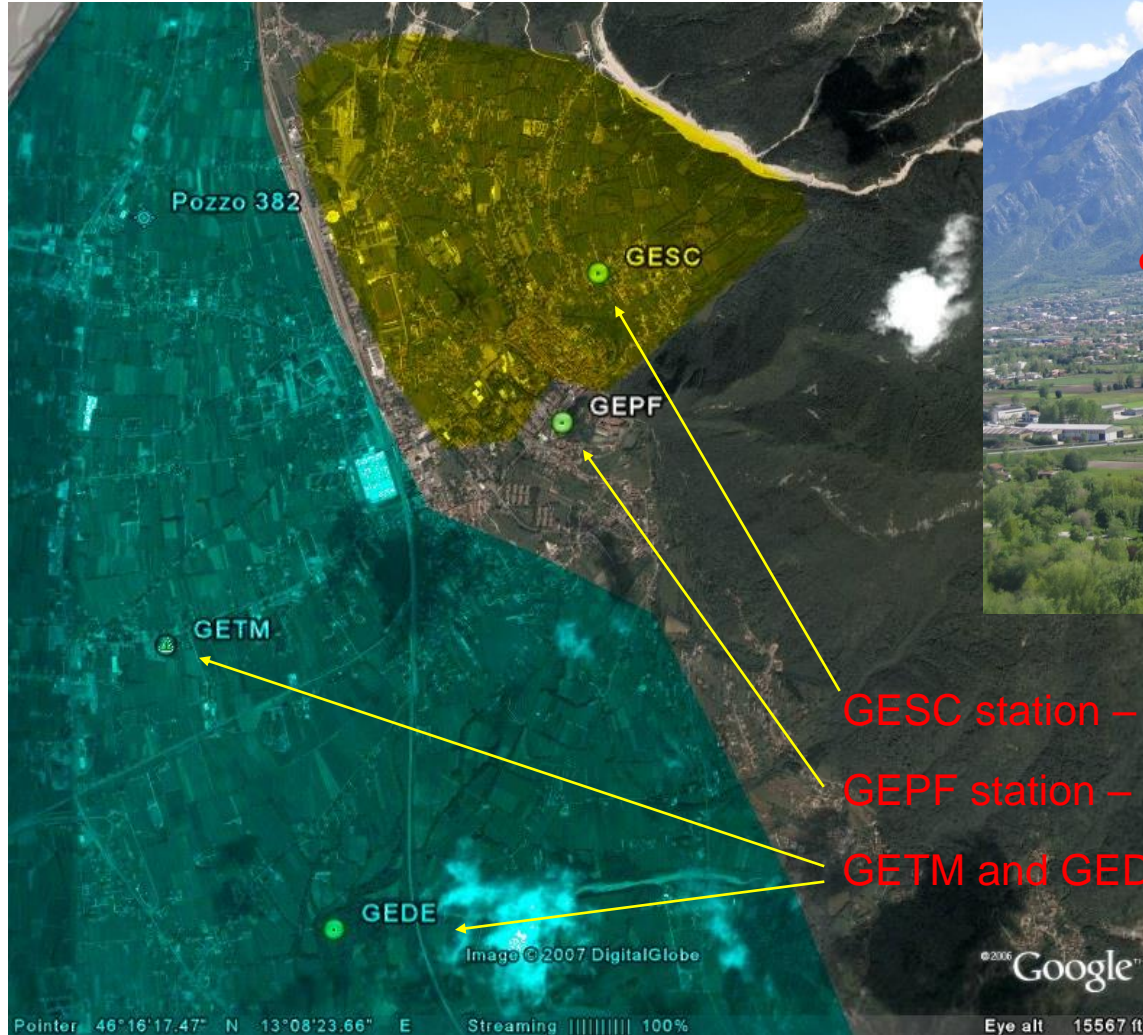
$T=0.09H*[D]^{-1/2}$   $T$  period s,  $H$  height m and  $D$  building basement dimension







# Gemona del Friuli

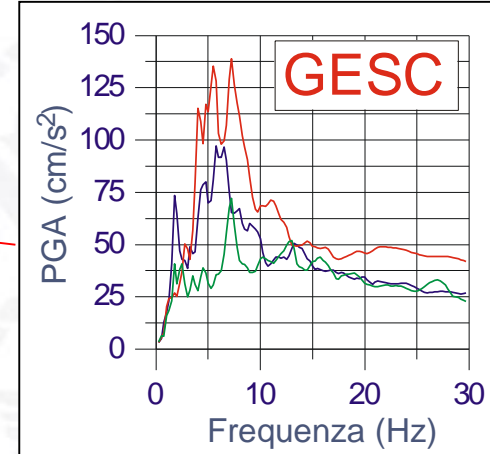
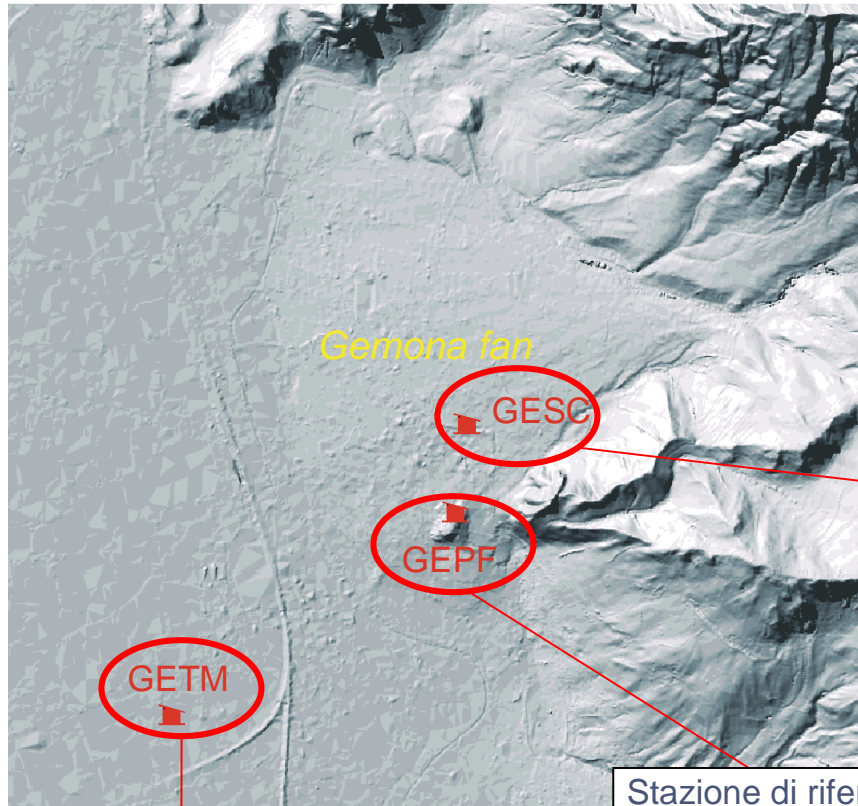


GESC station – alluvial fan

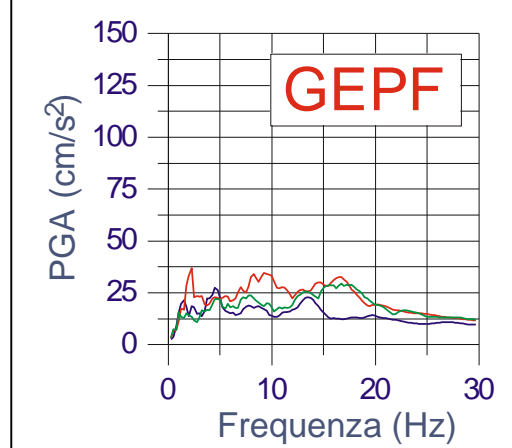
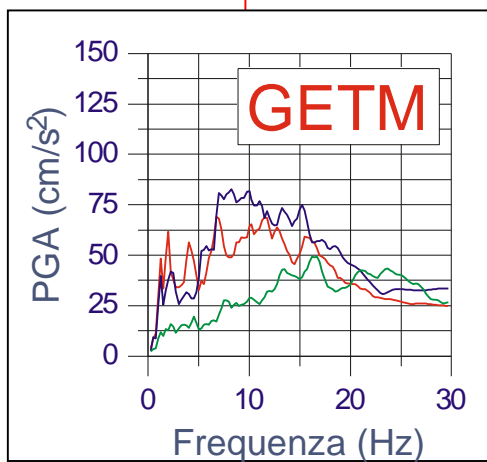
GEPF station – reference station

GETM and GEDE stations – sedimentary basin

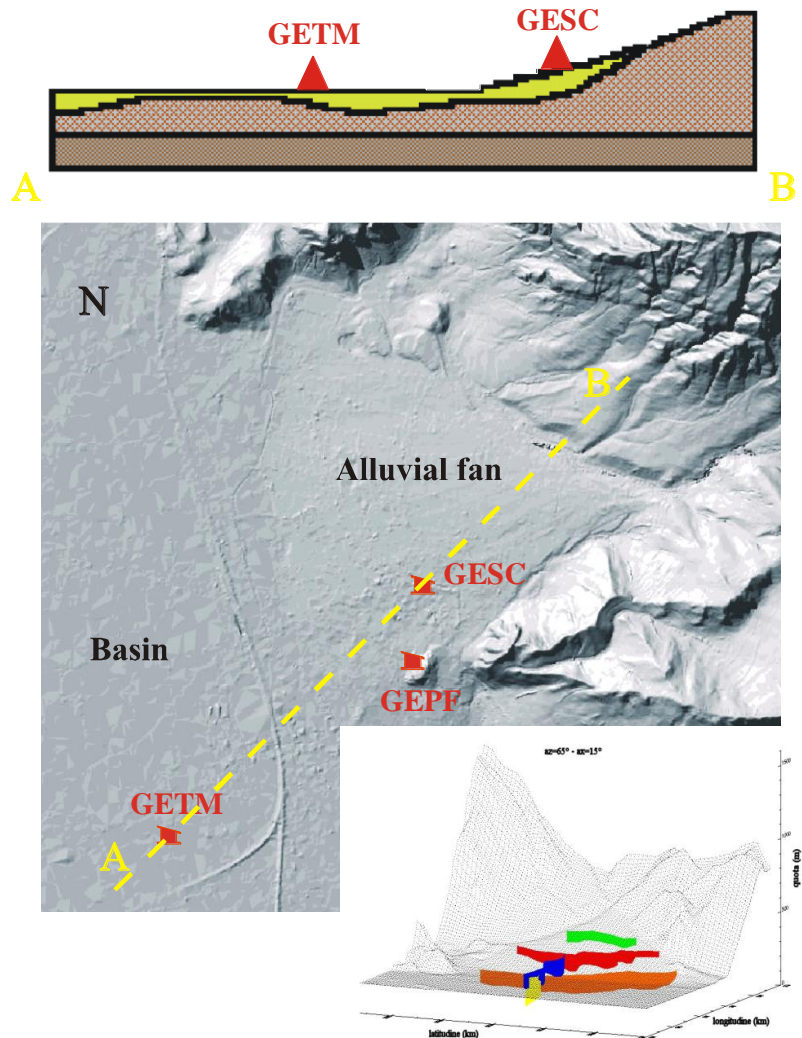




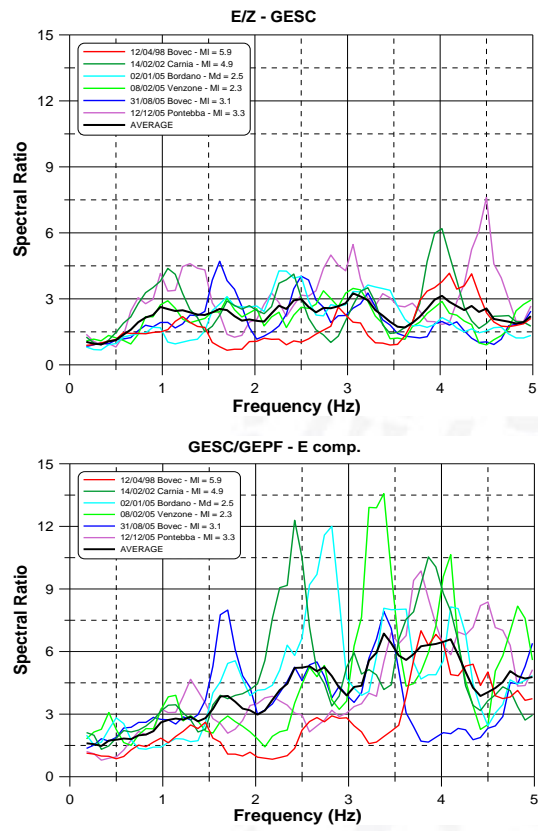
Stazione di riferimento su roccia



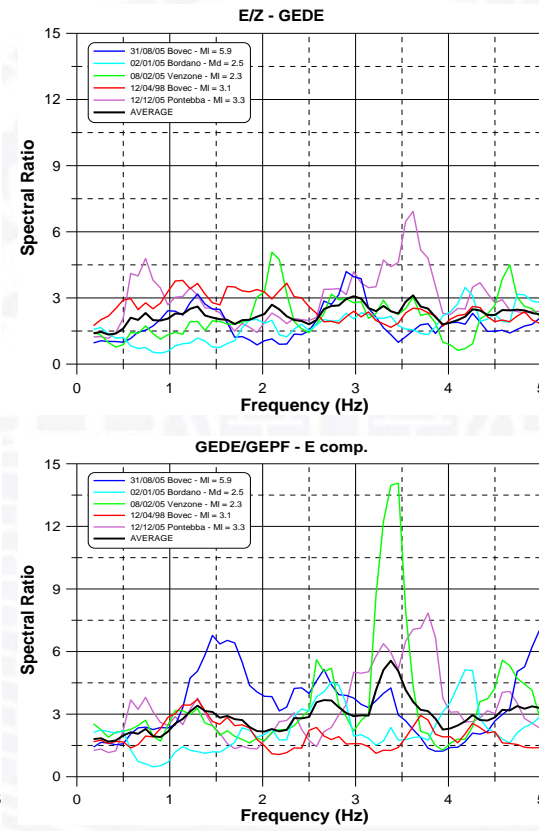
# EFFETTI DI SITO A GEMONA



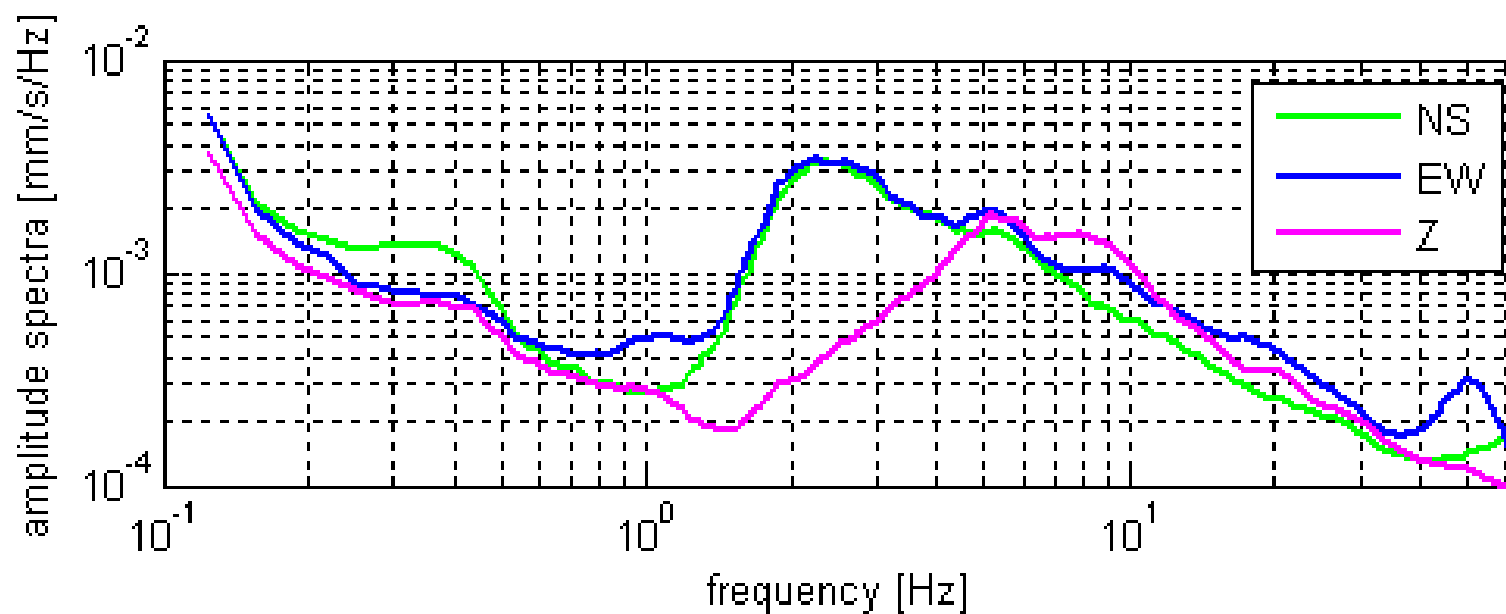
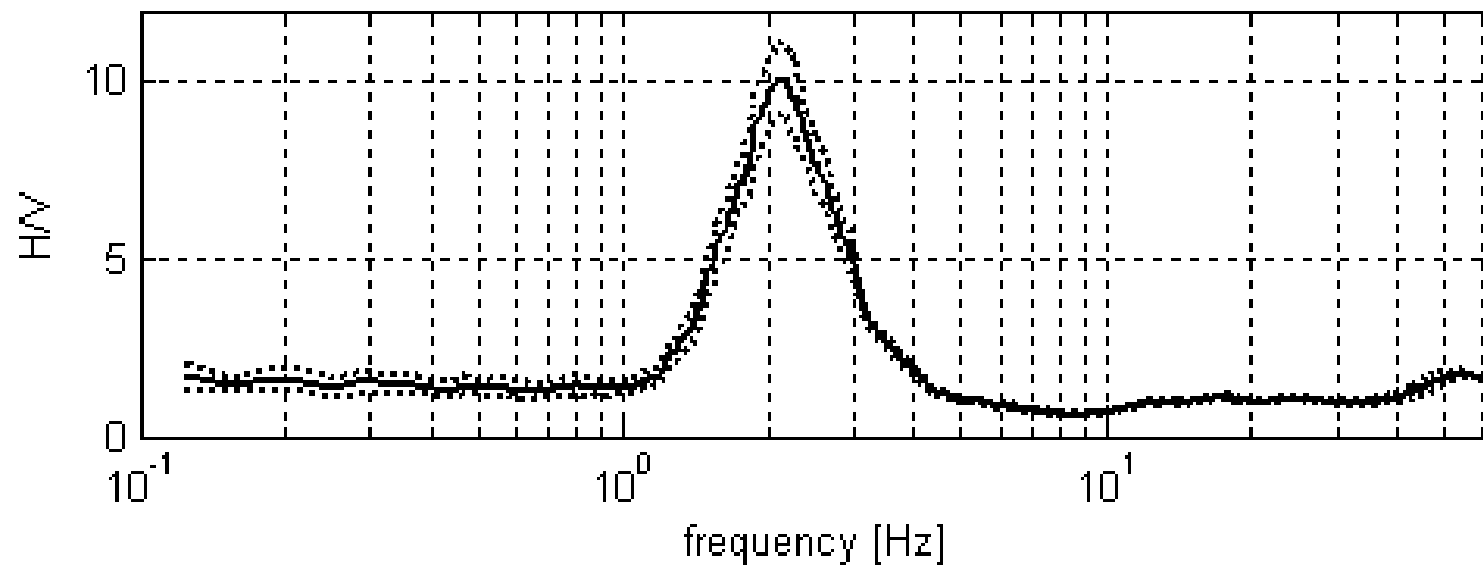
## GESC

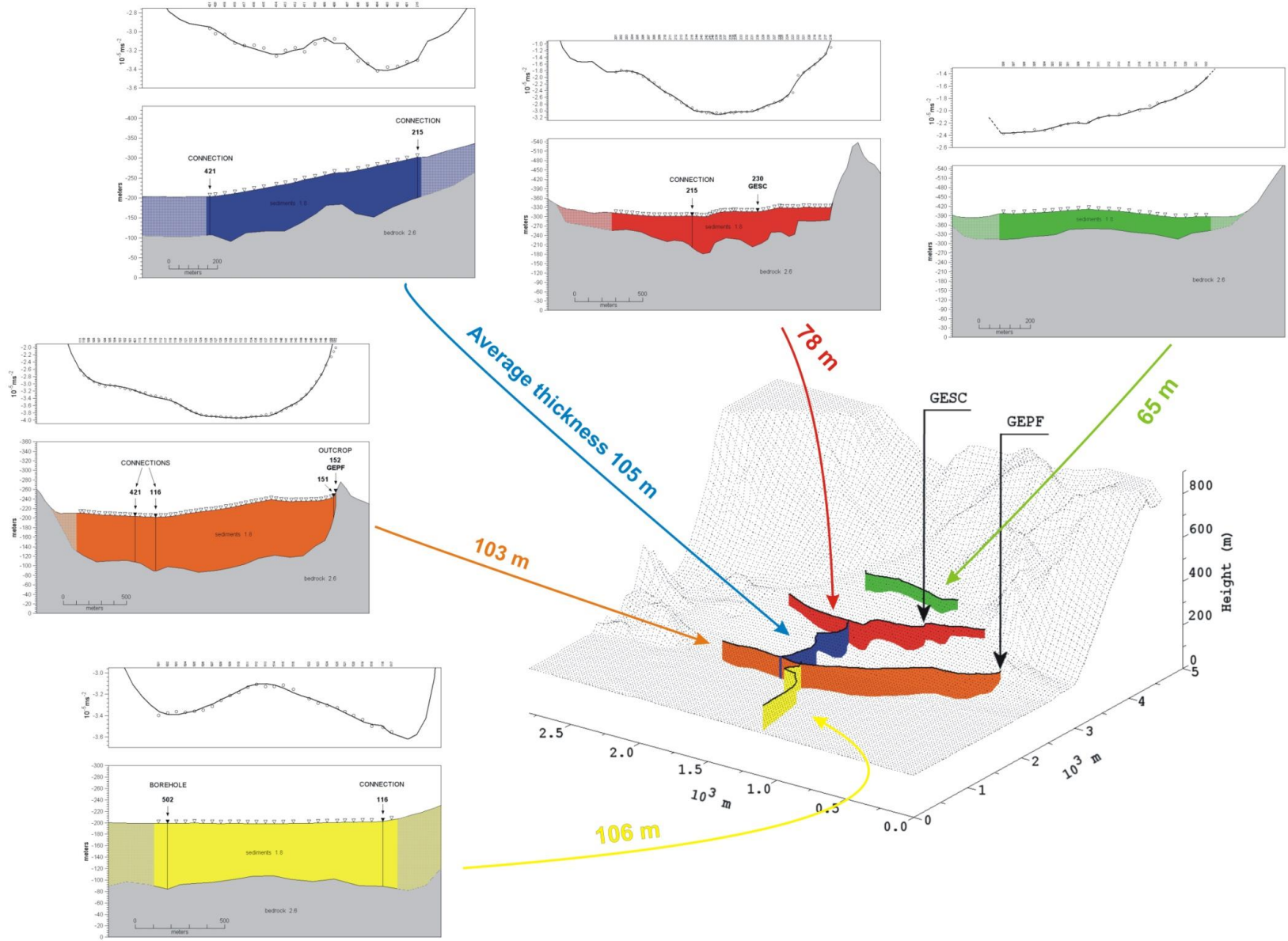


## GETM

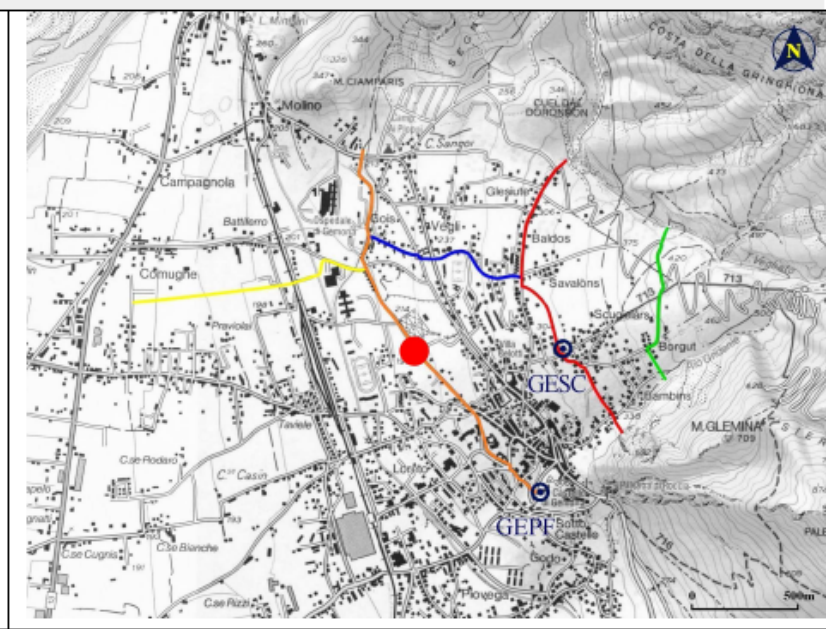
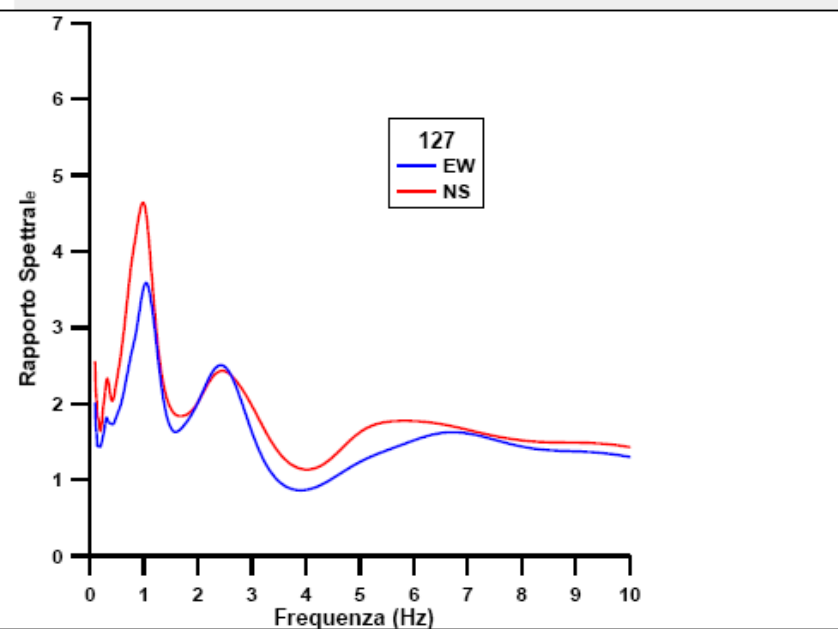
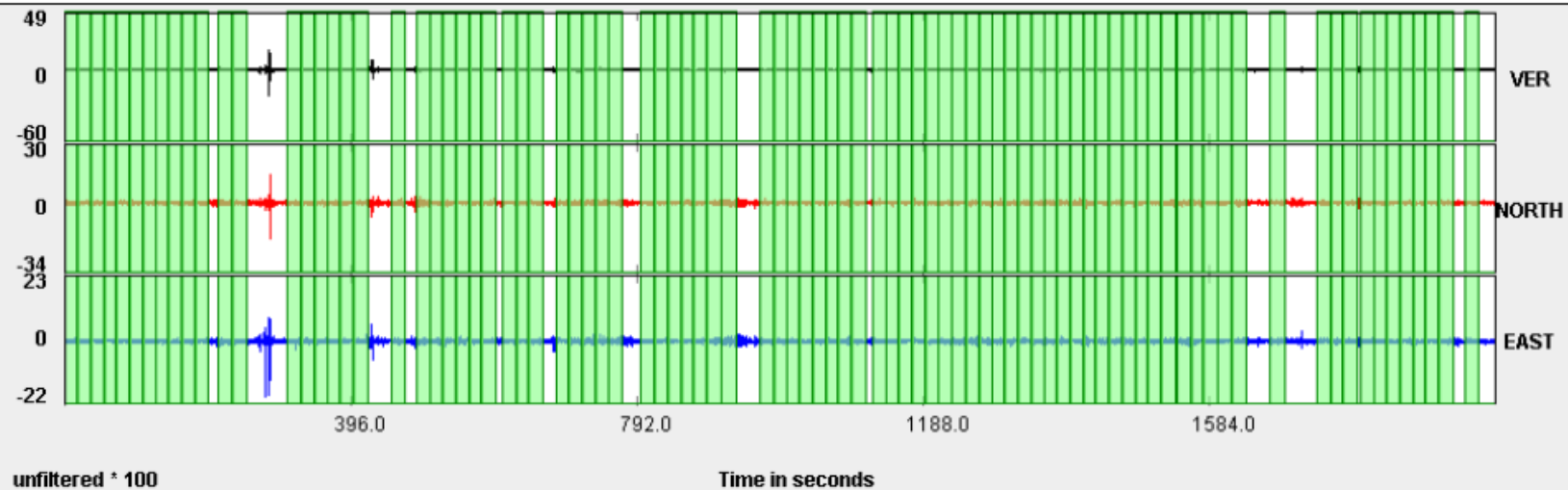


Progetto INTERREG IIIB Spazio Alpino  
"Sismoalp: Seismic risk in alpine valleys"

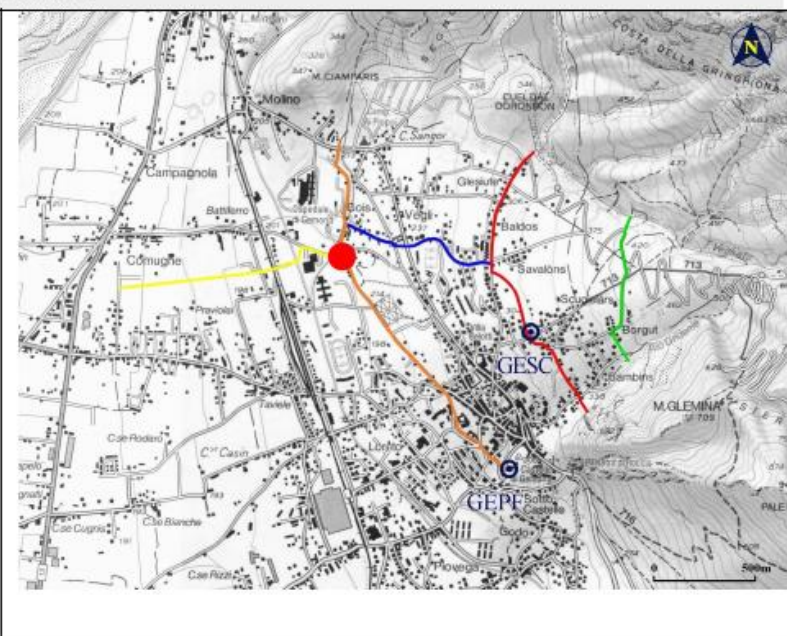
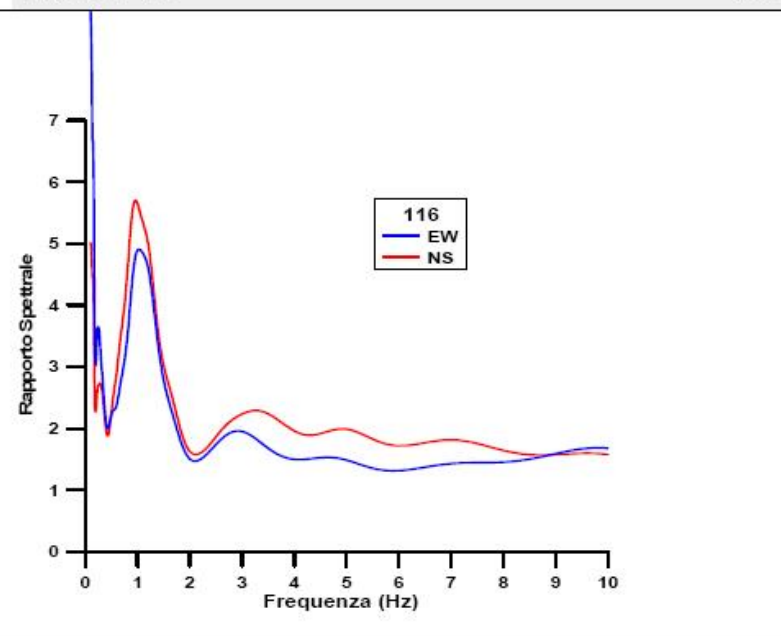
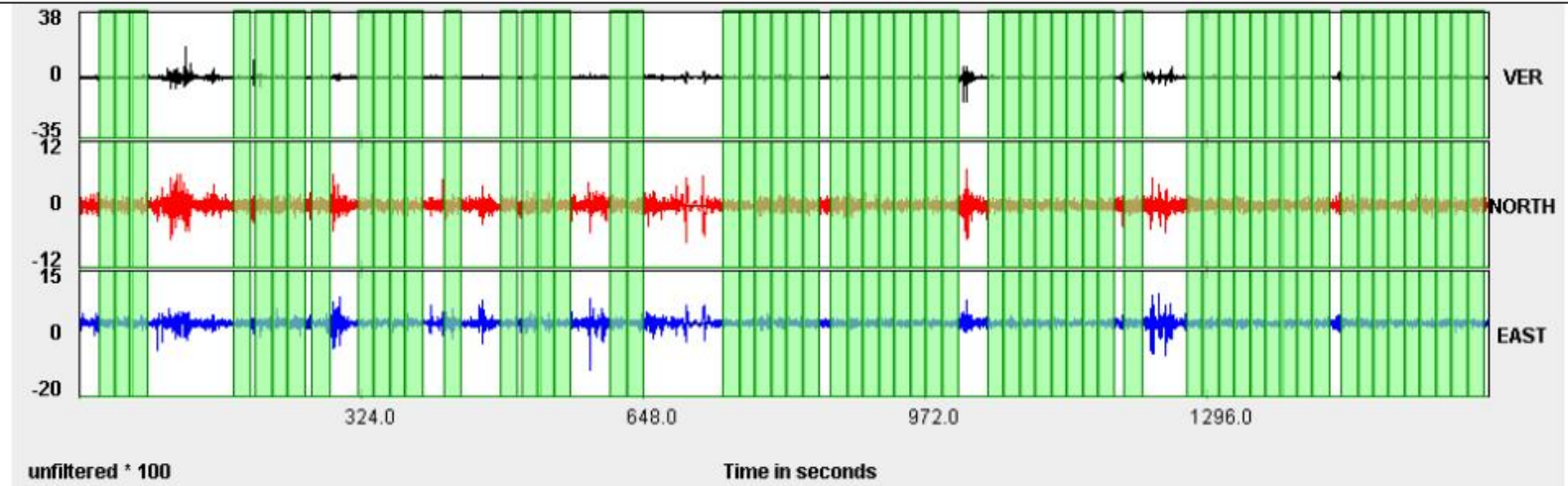




# PUNTO 127

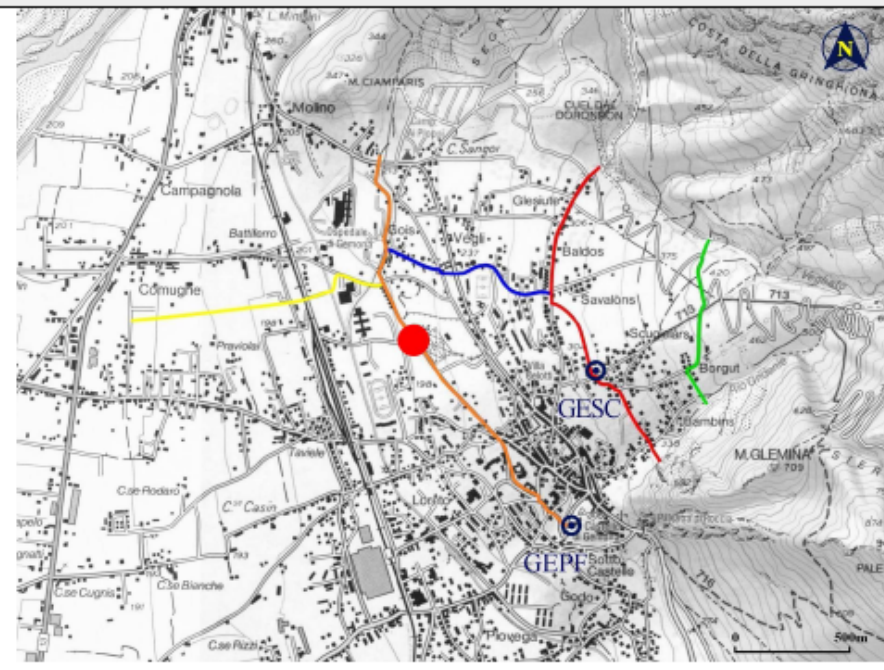
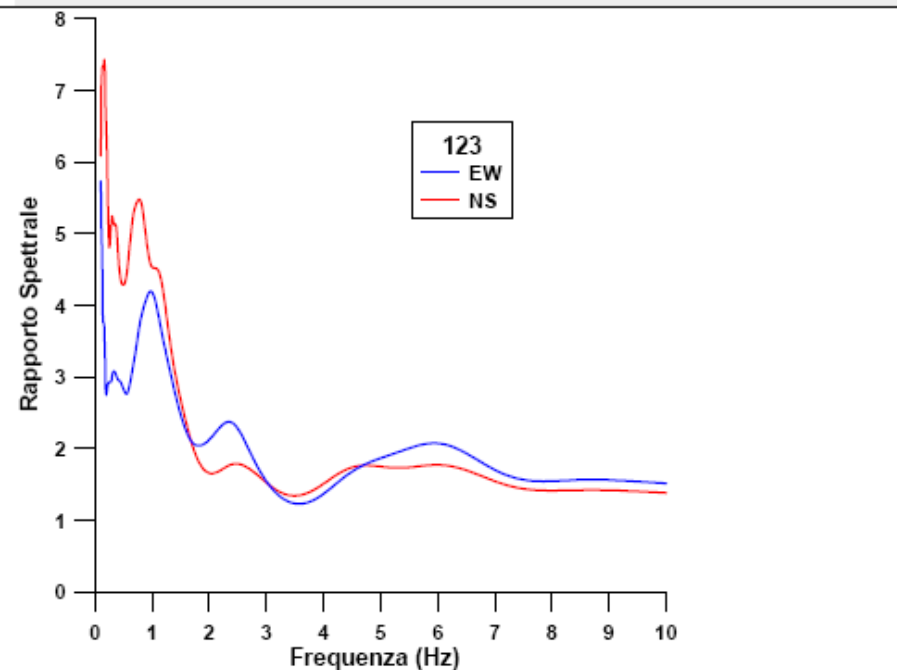
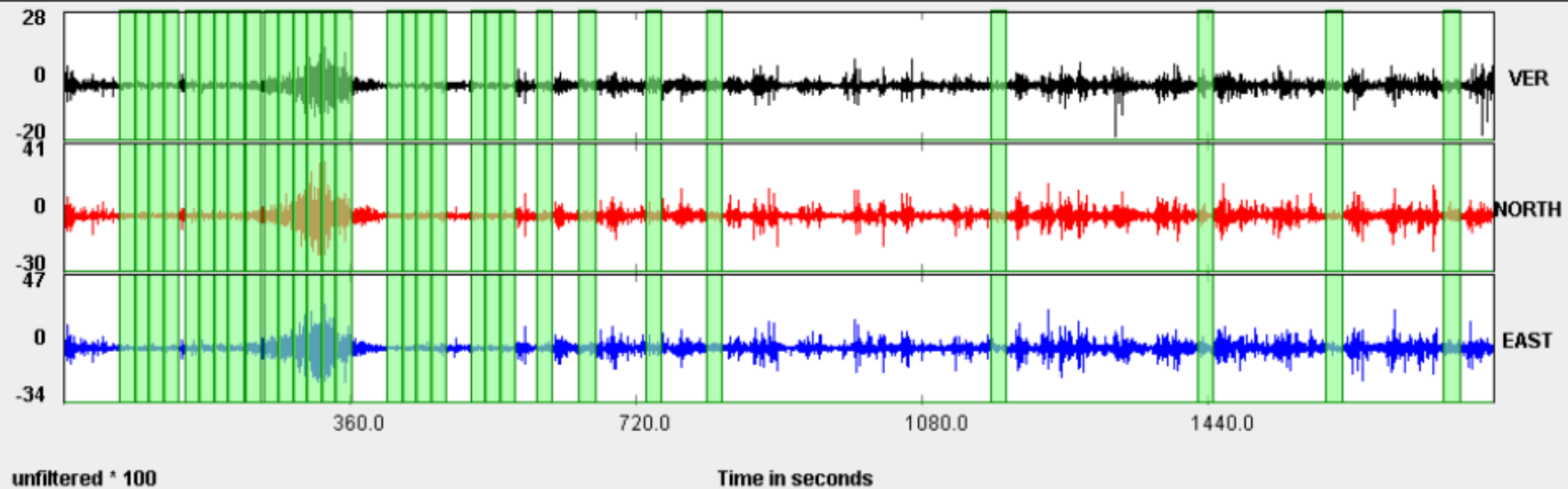


# PUNTO 116





# PUNTO 123

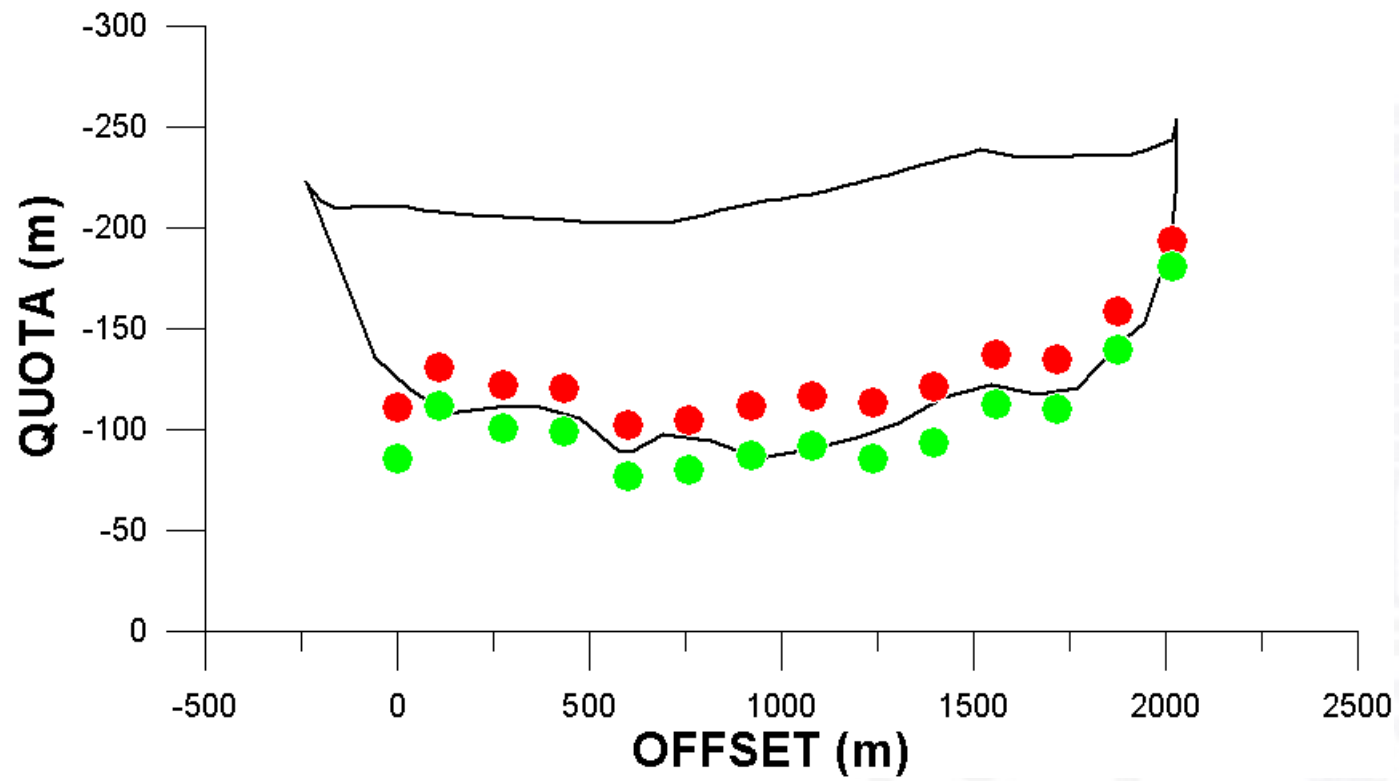


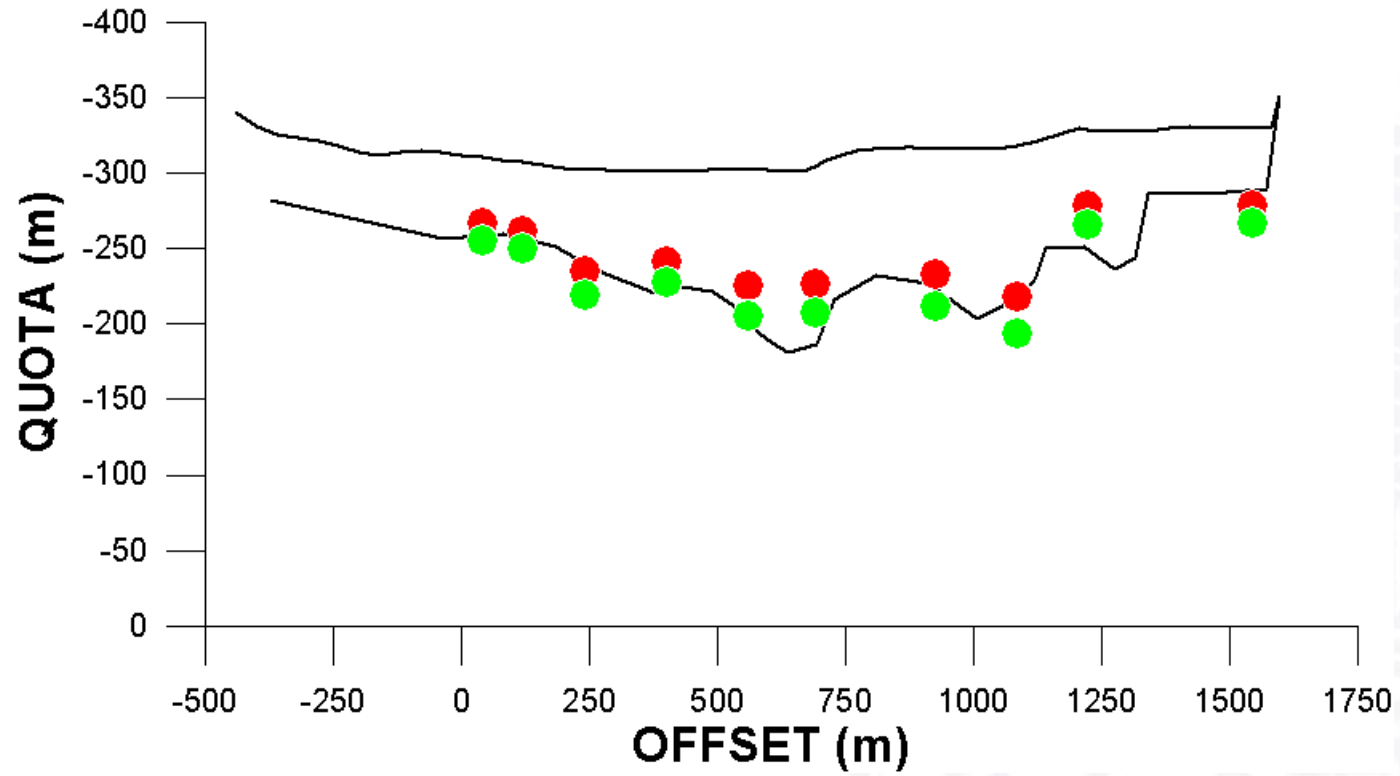
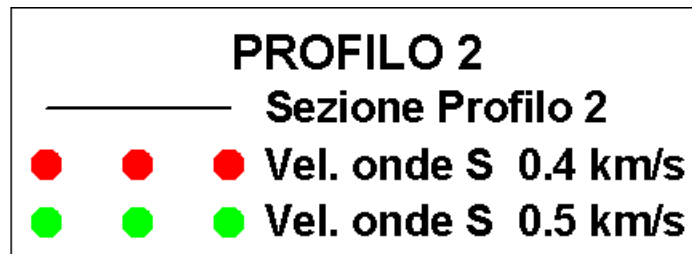
# PROFILO 1

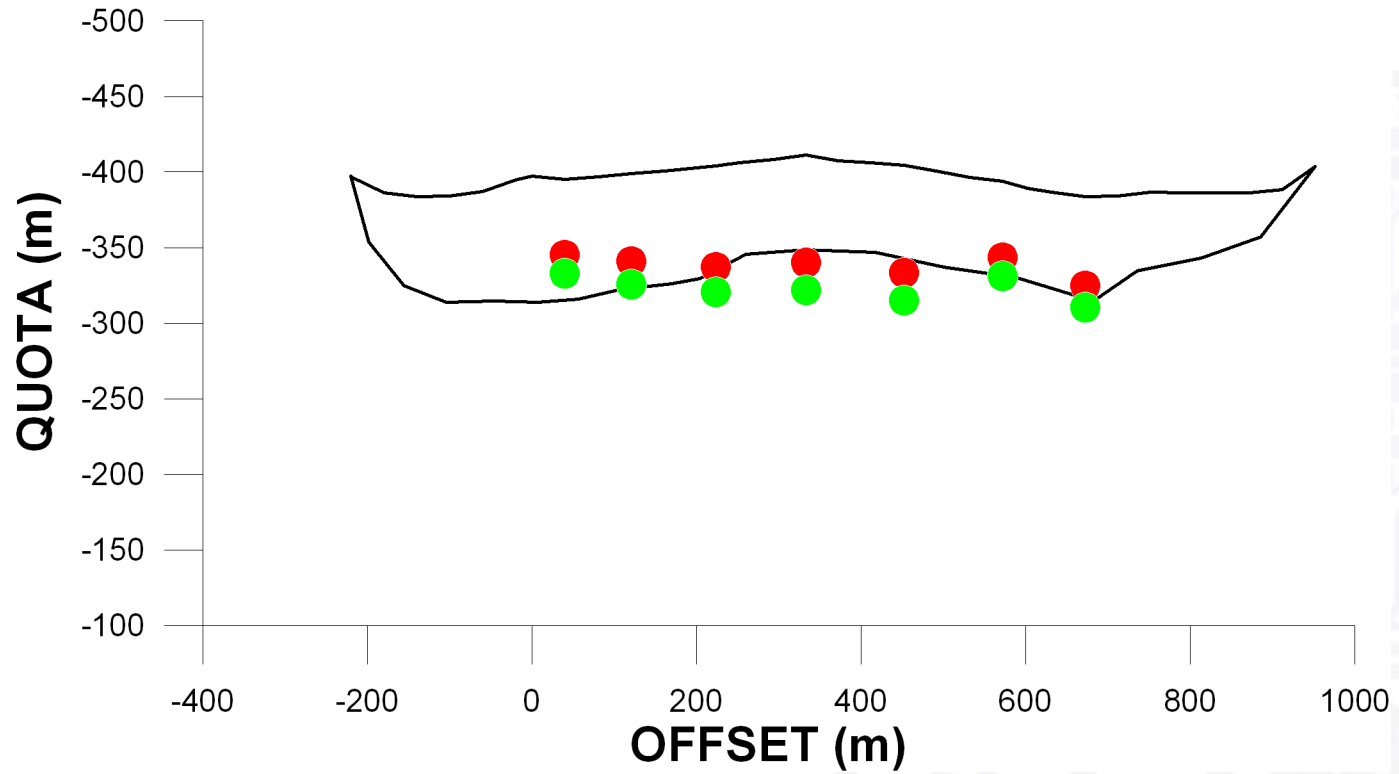
Sezione Profilo 1

● ● ● Vel. onde S 0.4 km/s

● ● ● Vel. onde S 0.5 km/s







## PROFILO 4

- Sezione Profilo 4
- ● ● Vel. onde S 0.4 km/s
- ● ● Vel. onde S 0.5 km/s

