Seismic noise measurements along the slope of the L'Aquila terrace

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Sessione 22
Natural Hazards – E11. From L'Aquila to Emilia: Comparison of seismic microzonation experiences

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Observation:

- L'Aquila downtown is built on the top of a hill characterized by steep slopes toward the Aterno River Valley

- Many collapses and strong damages on buildings (including “Casa dello Studente”) were observed in proximity of the slopes (southern edge of the downtown) during the 2009 L'Aquila earthquake

Aim:

- To investigate the variation of site effects along the flanks of the L'Aquila terrace
- Role of the topographic effects ??
- Effect of the caves ??

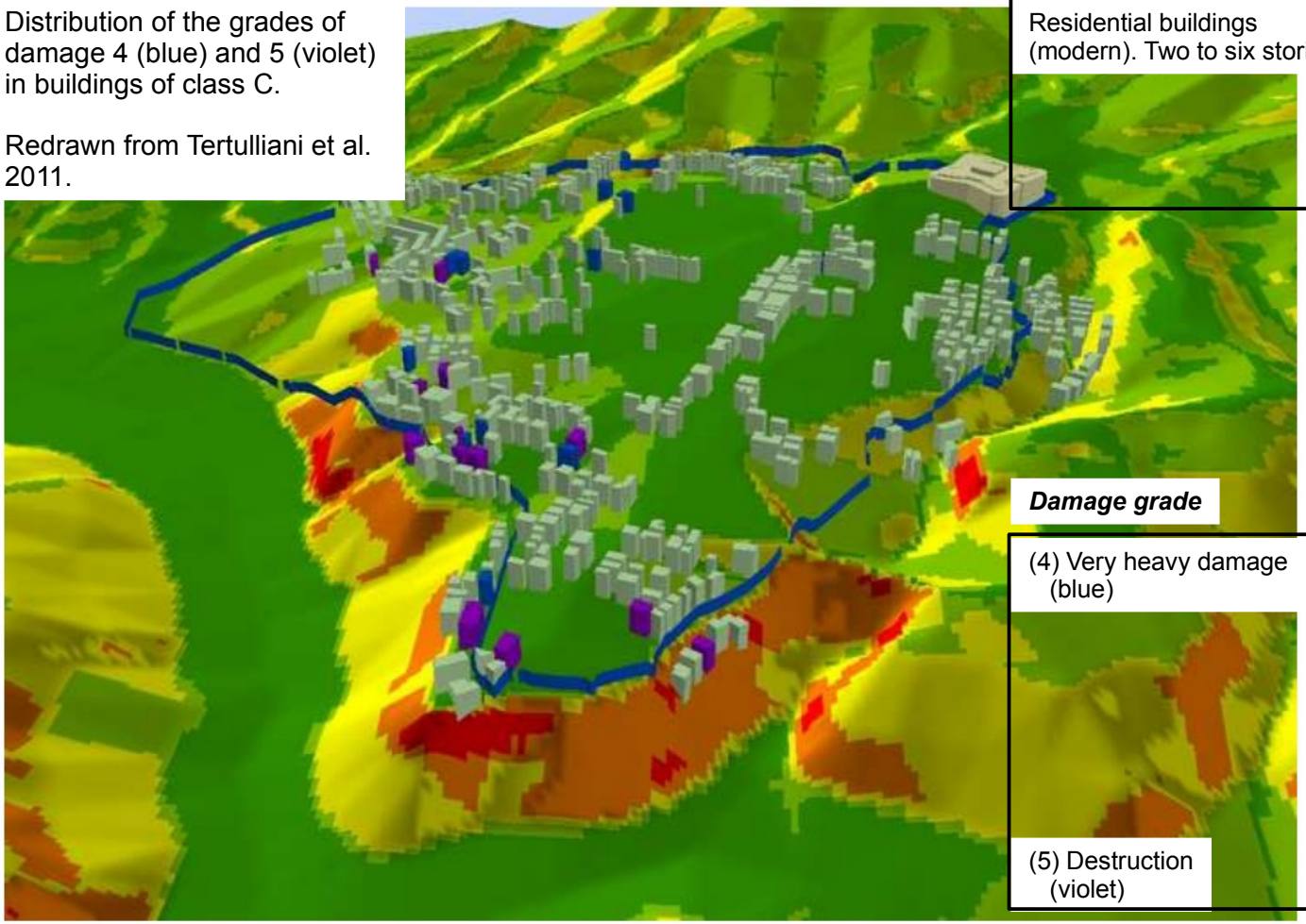
Method of analysis:

- Ambient noise analysis (HVSR)
- Aftershock data
- Numerical modeling (in progress)

Damage distribution

Distribution of the grades of damage 4 (blue) and 5 (violet) in buildings of class C.

Redrawn from Tertulliani et al. 2011.



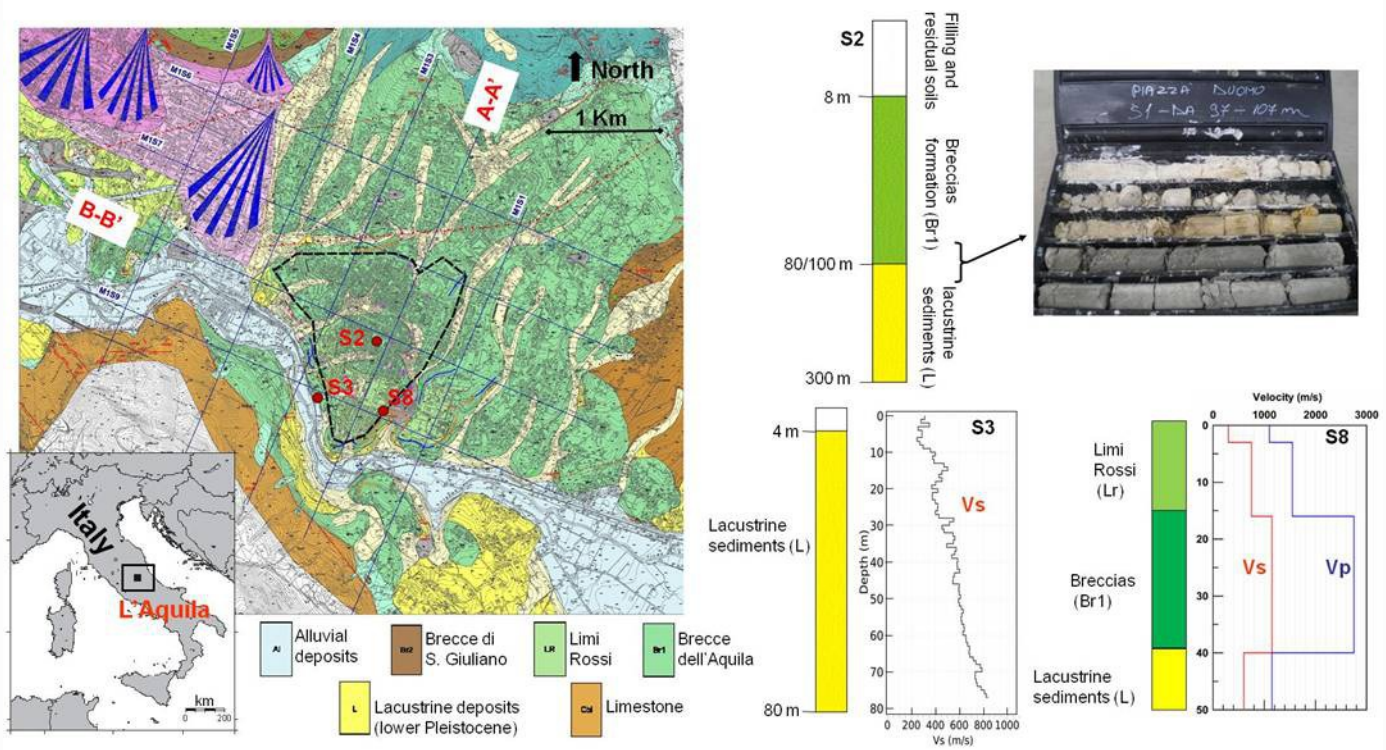
Type of building	*Characteristics*	*Vulnerability Class (EMS 98)*
Residential buildings (modern). Two to six stories	Masonry construction in manufactured stone units. Brick with RC floors buildings, RC structure without anti-seismic design. Generally in good state of preservation	C

Damage grade	*Masonry buildings*	*RC buildings*
(4) Very heavy damage (blue)	Serious failure of walls and roofs, partial structural failure	Large cracks in strucutral elements, damage to the joints of the skeleton, destruction of concrete floors, protrusion of reinforcing nods, tilting of columns
(5) Destruction (violet)	Very total or near total collapse	Very total or near total collapse

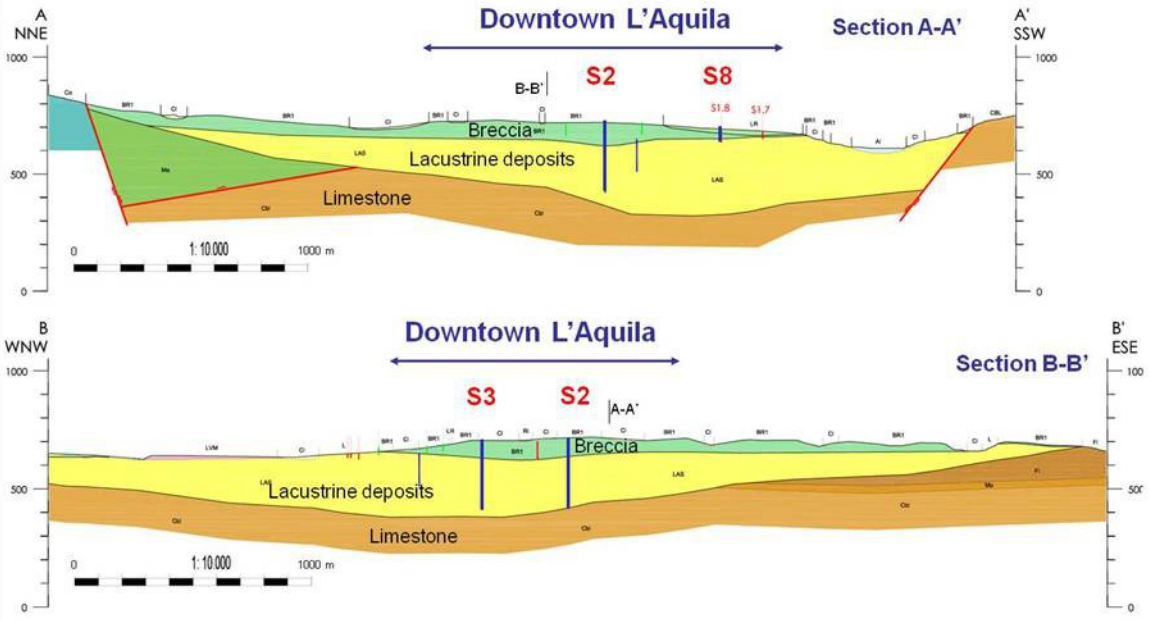
"...This area is very close to the lithological contact between the alluvial sediments of the Aterno Valley and the conglomerates (Megabrecce) on which L'Aquila downtown is settled ,and coincides with a remarkable morphological slope . Moreover the same area was the site of large embankments in the first decades of 1900. Thus this geomorphologic feature can be considered as a probable factor that increased the damage...." from Tertulliani et al., 2011

A.Tertulliani, L. Arcoraci, M. Berardi, F. Bernardini and R. Camassi, et al., 2011,
An application of EMS98 in a medium-sized city: The case of L'Aquila (Central Italy) after the April 6, 2009 Mw 6.3 earthquake,
Bulletin of Earthquake Engineering, Volume 9, Number 1, pp. 67-80, doi 10.1007/s10518-010-9188-4

Geological sketch



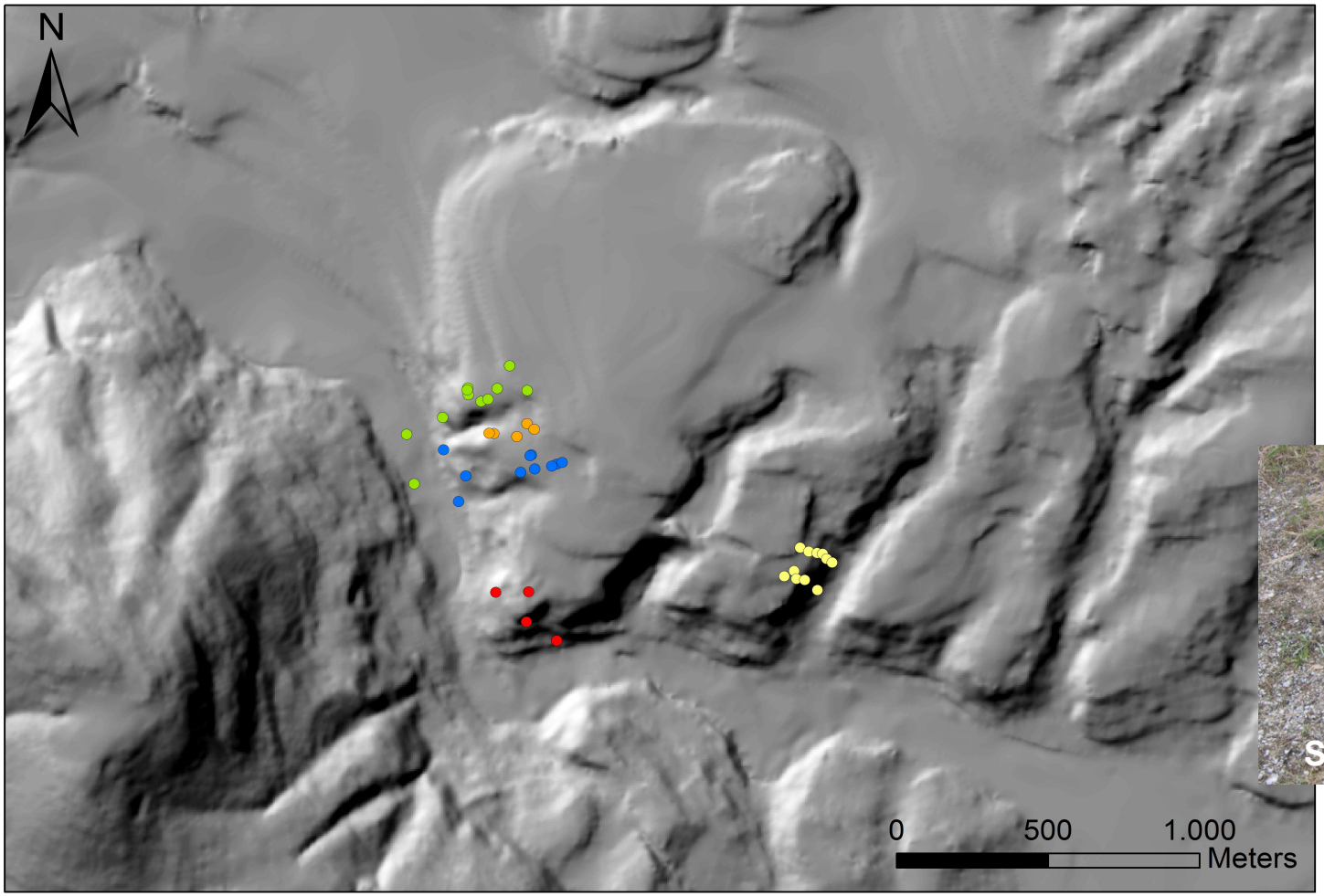
MS-AQ Working Group, 2010. Microzonazione sismica per la ricostruzione dell'area aquilana, Ed. Regione Abruzzo- Dipartimento della Protezione Civile, pp. 1-796, 3 vol & CD-rom, in Italian.



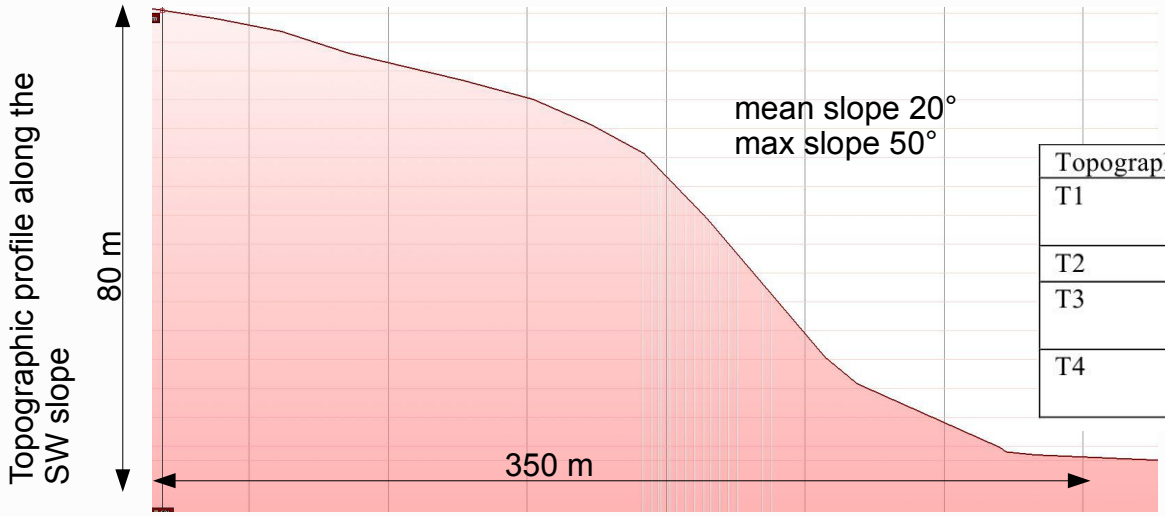
The downtown is settled on a calcareous terrace, mainly composed of a Pleistocene stiff calcareous breccia over-imposed to ancient lacustrine sediments.

The upper portion of the L'Aquila breccia is irregularly affected by the presence of residual soft soils known as "red soils" or filling material.

The shear-wave velocity profile is characterized by a velocity inversion at a depth ranging from few tens up to one hundred meters (contact between Breccia and Lacustrine deposits).

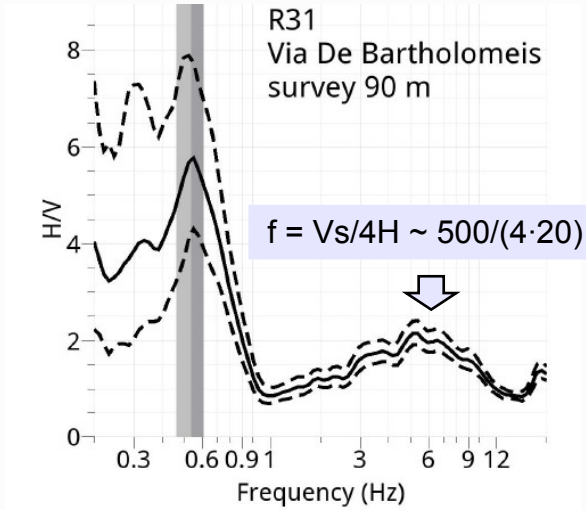


Symbols: ambient noise measurements located considering also the available investigations (boreholes and Vs data)

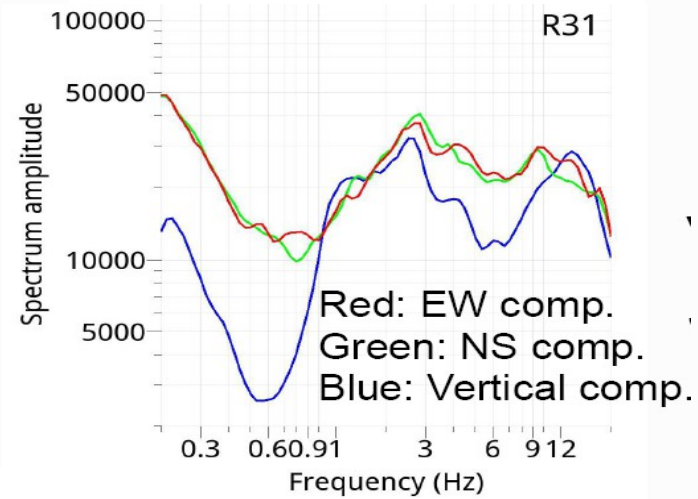


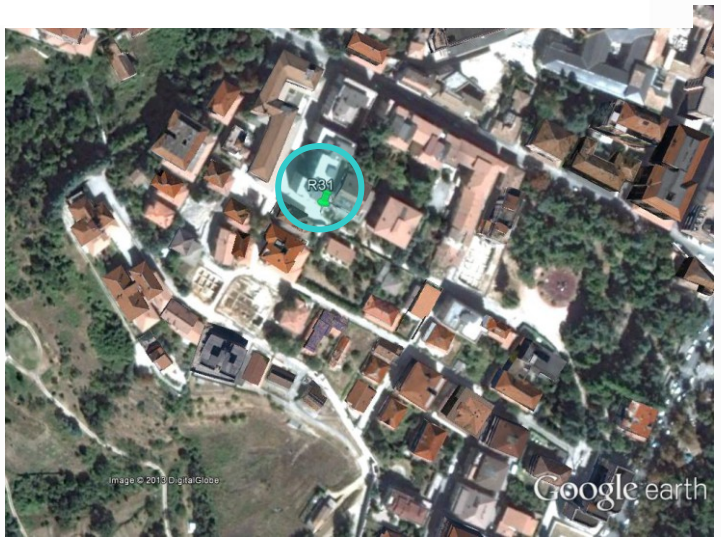
Topographic amplifications factors
(Italian Building Code NTC08)

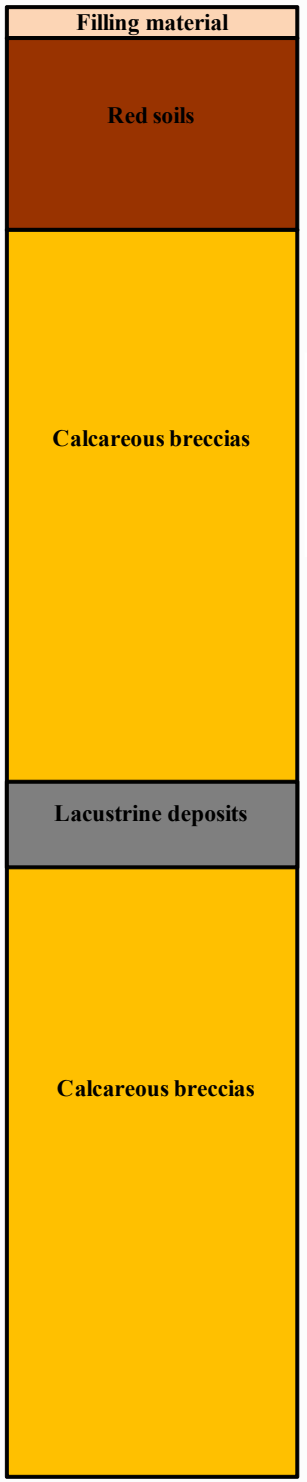
Topographic class	Description	Amplification factor
T1	Flat surface; isolated slopes and cliffs with average slope angle $i < 15°$	1
T2	Slopes with $i > 15°$	1.2
T3	Ridges with crest width significantly less than the base width and $15° < i < 30°$	1.2
T4	Ridges with crest width significantly less than the base width and $i > 30°$	1.4

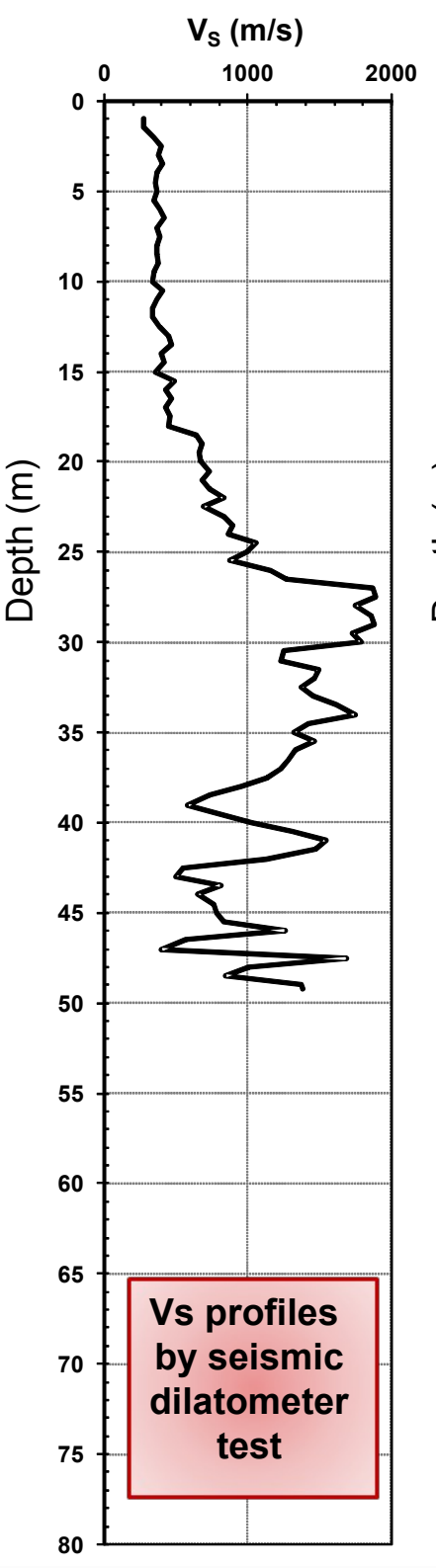


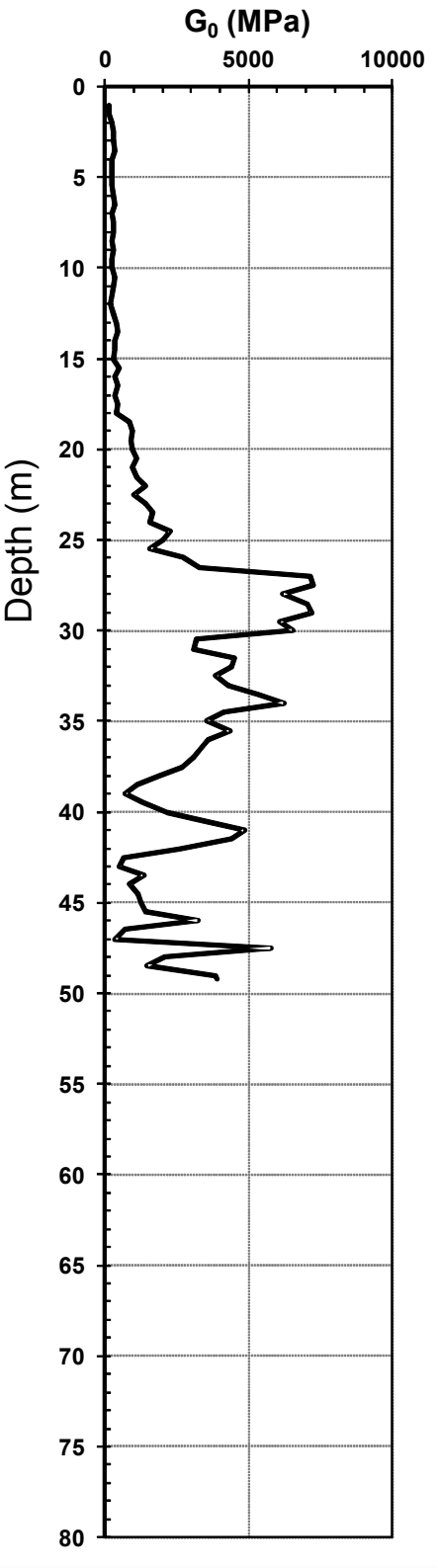
f = Vs/4H ~ 500/(4·20) ~ 6Hz



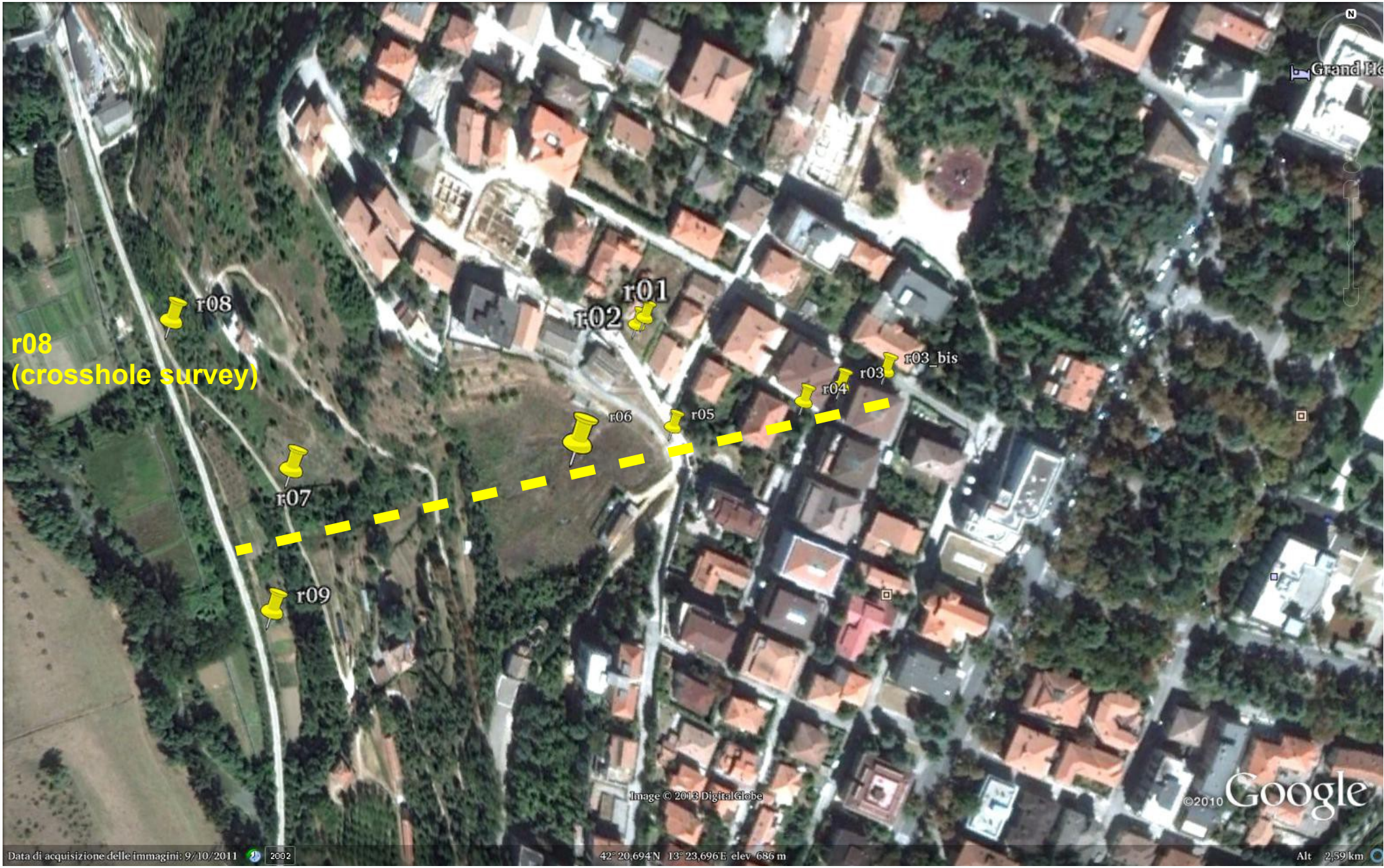




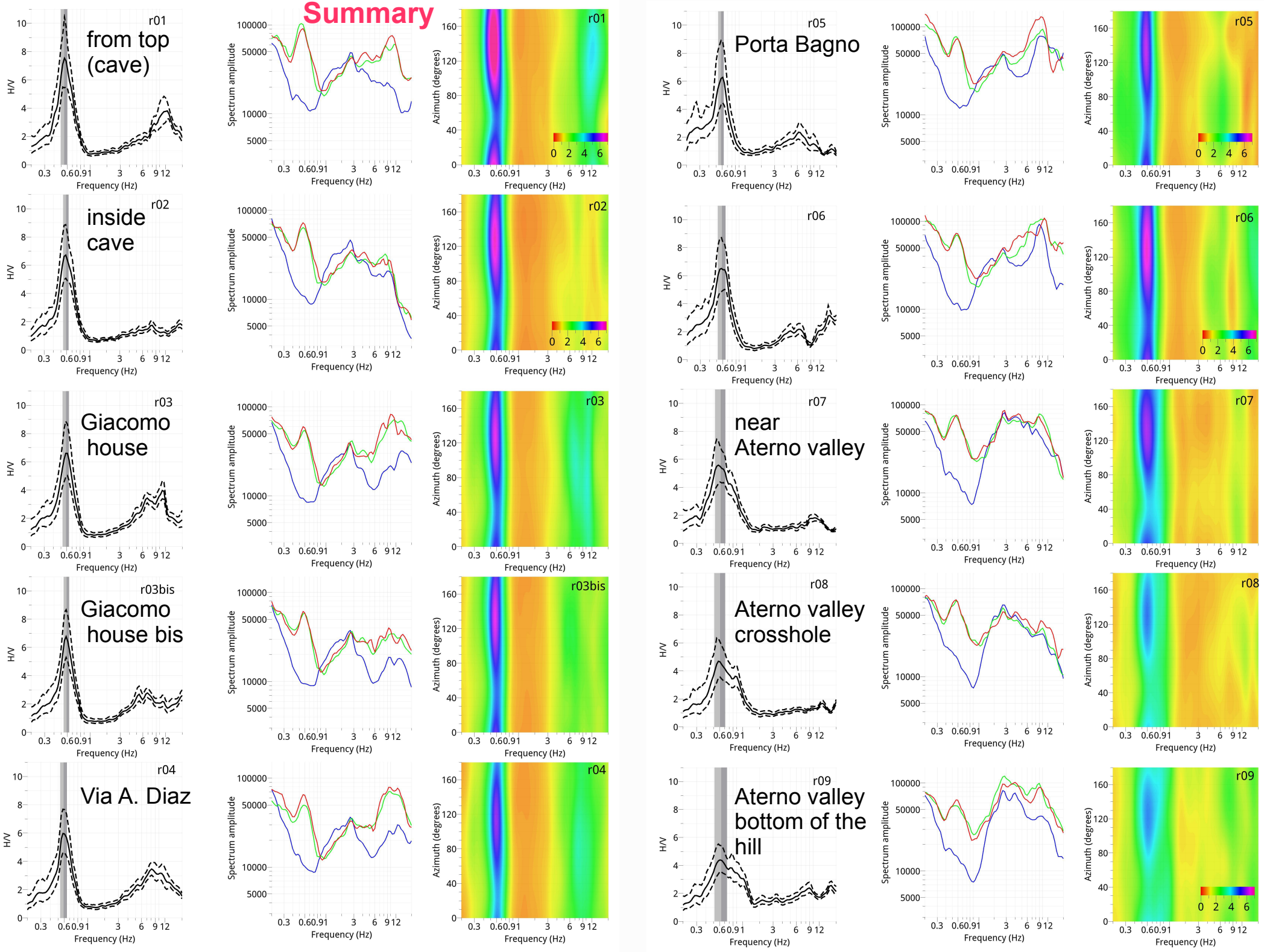




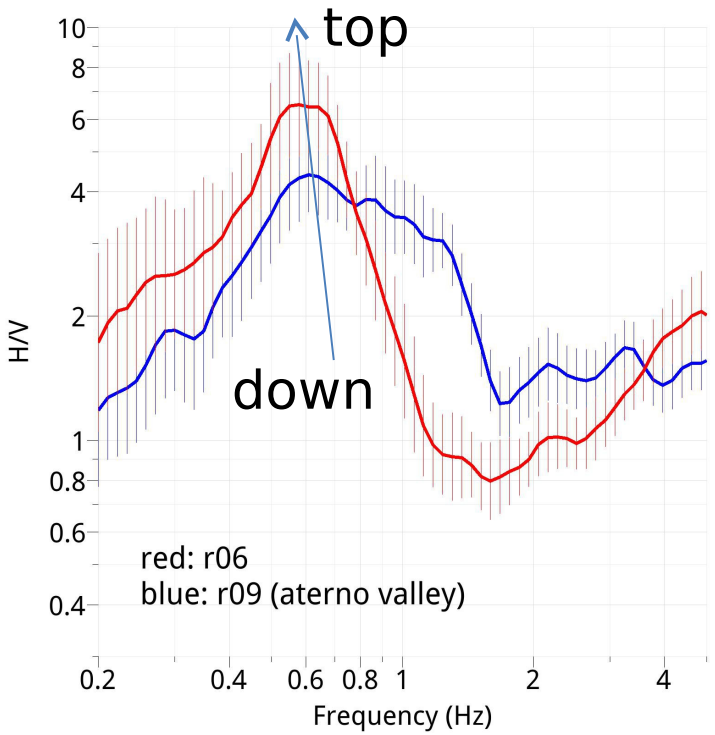
Noise Section “Fosso Porta di Bagno”



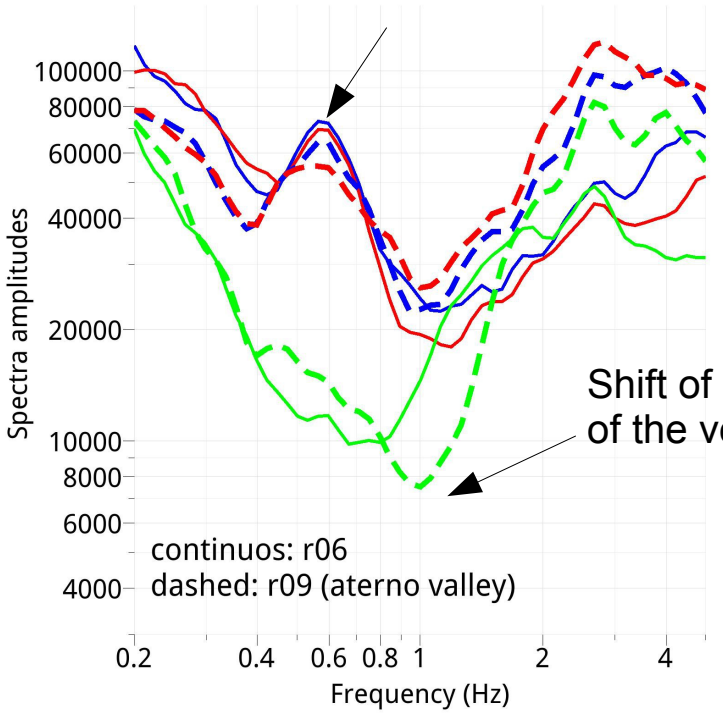
Summary


r01
from top (cave)
r02
inside cave
r03
Giacomo house
r03bis
Giacomo house bis
r04
Via A. Diaz
r05
Porta Bagno
r06
r07
near Aterno valley
r08
Aterno valley crosshole
r09
Aterno valley bottom of the hill
H/V
Frequency (Hz)
Spectrum amplitude
Azimuth (degrees)

Noise Transect “Fosso Porta di Bagno”

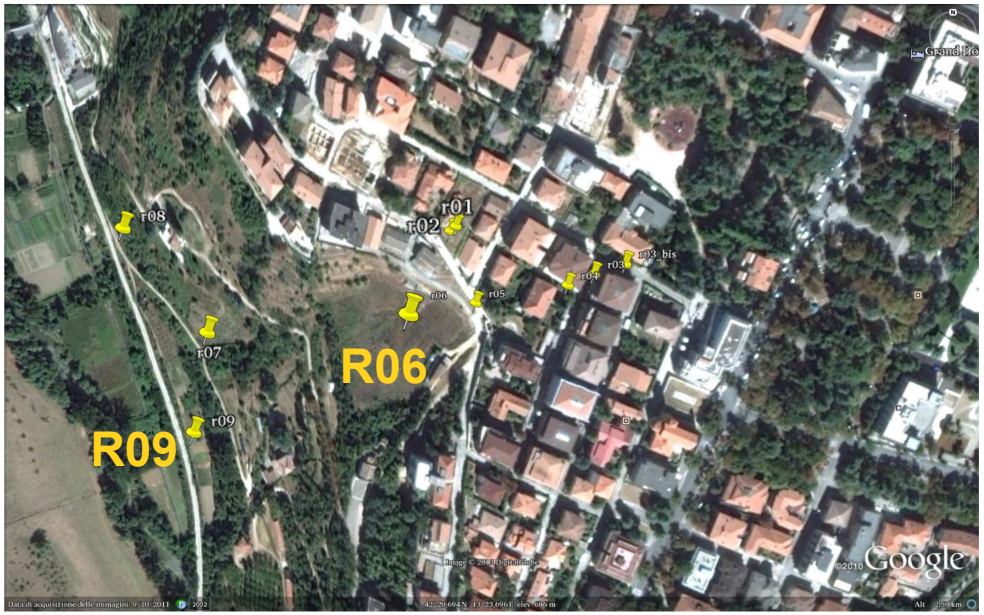


horizontal components

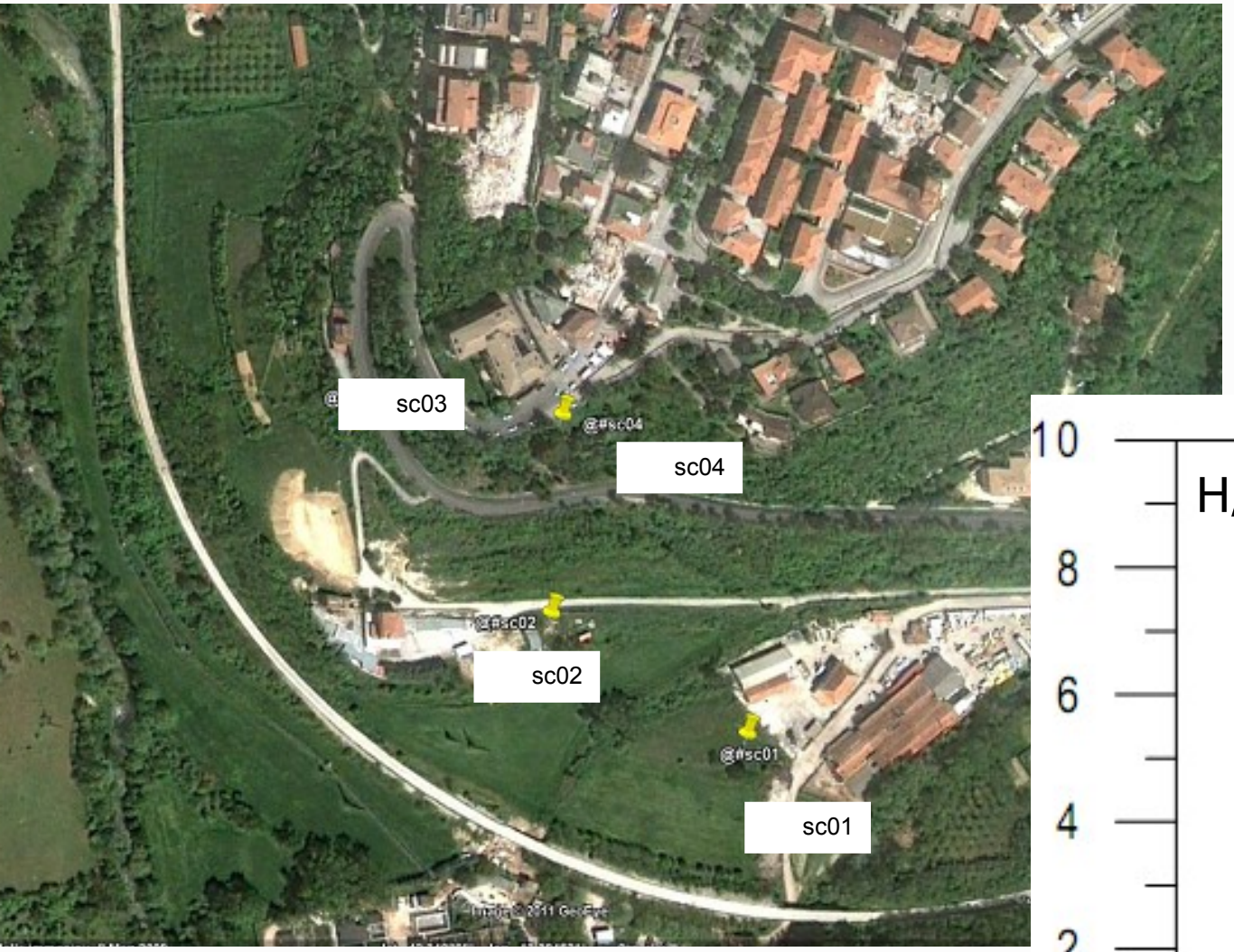


Dashed curves: bottom
Continuous curves: top

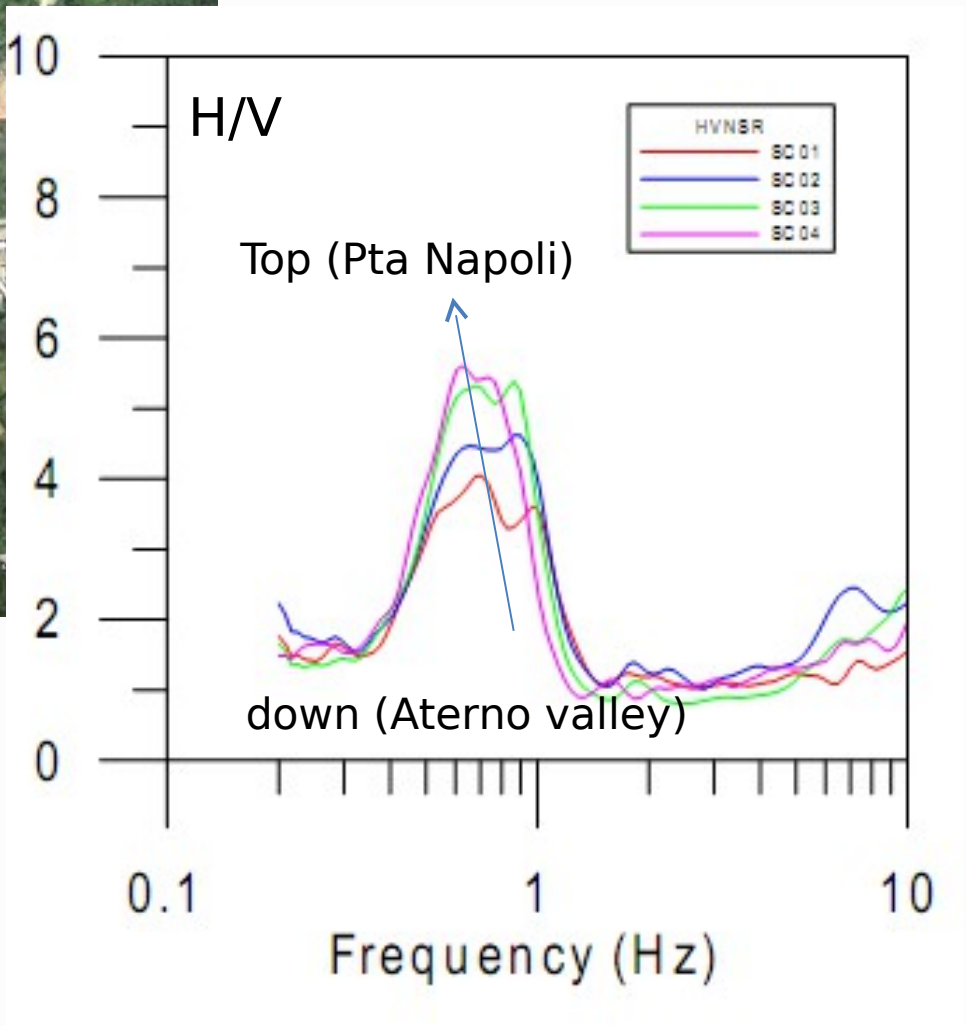
Shift of the spectral minimun of the vertical component



From top to down (Section “Fosso Porta Napoli”)

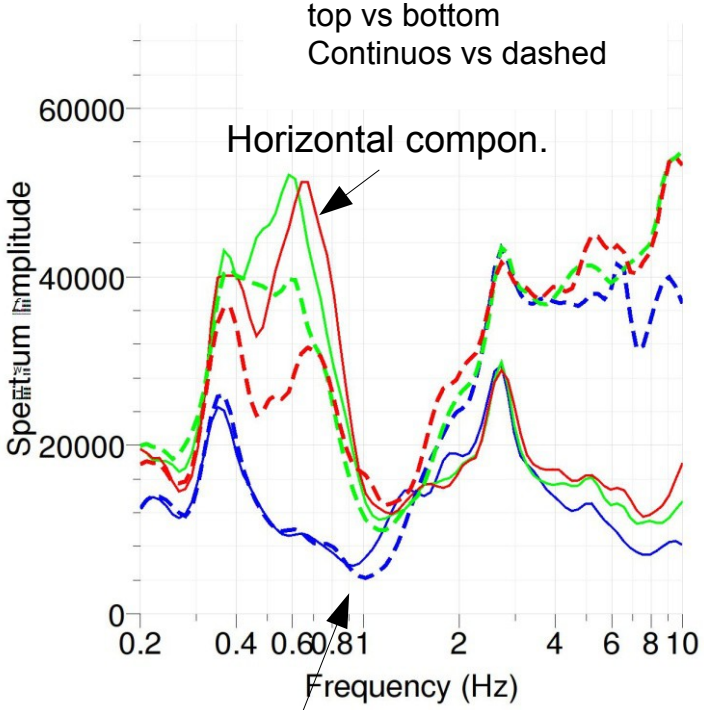


The noise measurements at the base of the hill show a broader peak and a lower amplitude in comparison with the measurements at the top

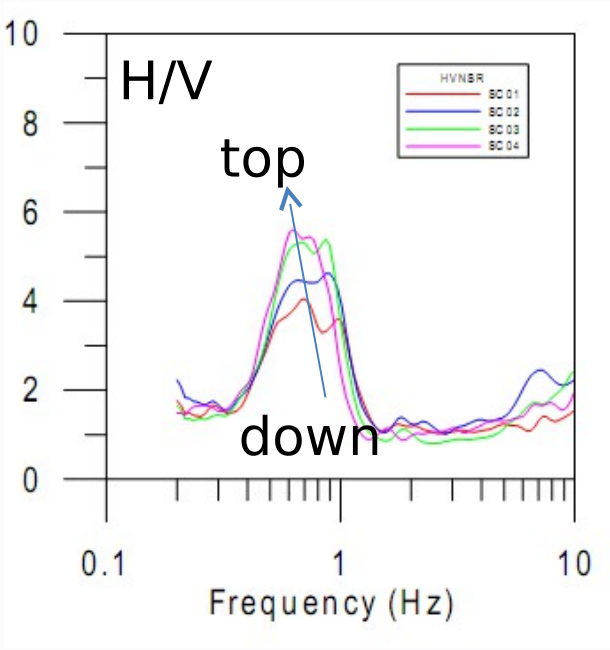


Section Porta Napoli

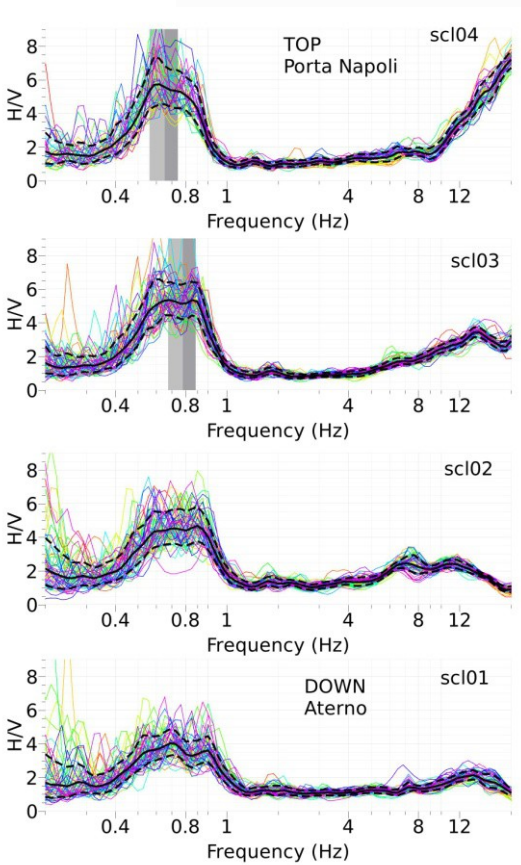
sc04 vs sc01
top vs bottom
Continuos vs dashed

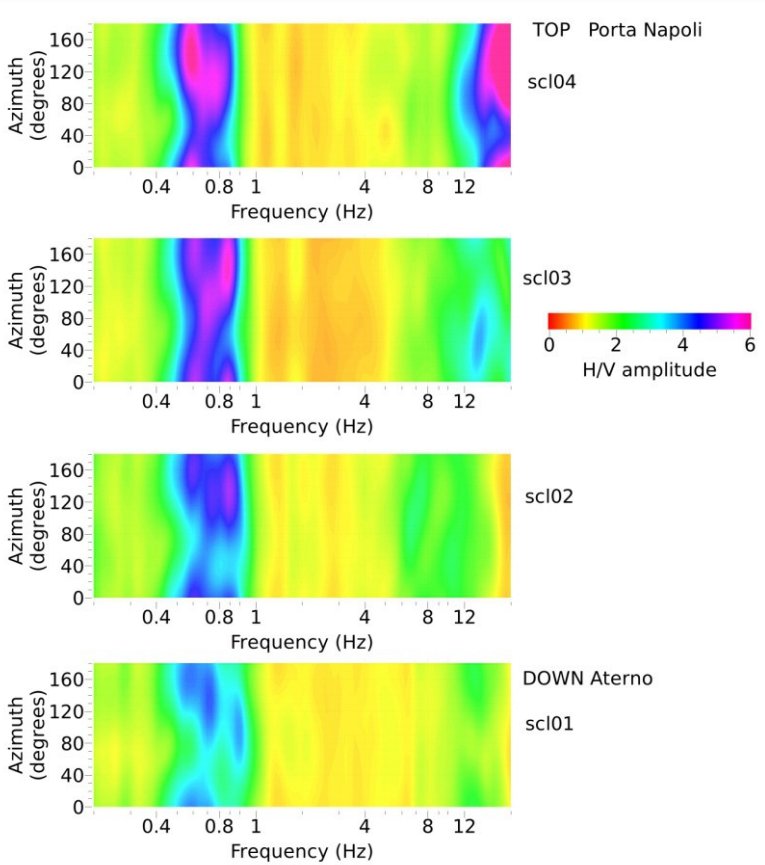


green: NS
red: EW
blu: UP



Shift of the spectral minimun
of the vertical component





Measurements Borgo Rivera/Santa Chiara/Casa dello Studente

AQ13, AQ09 and AQ04 recorded many aftershocks of the L'Aquila sequence

Milana et al. (2011)
The contribution of seismic data in microzonation studies for downtown L'Aquila,
Bull. Earth. Engin. 9(3) 741-759.

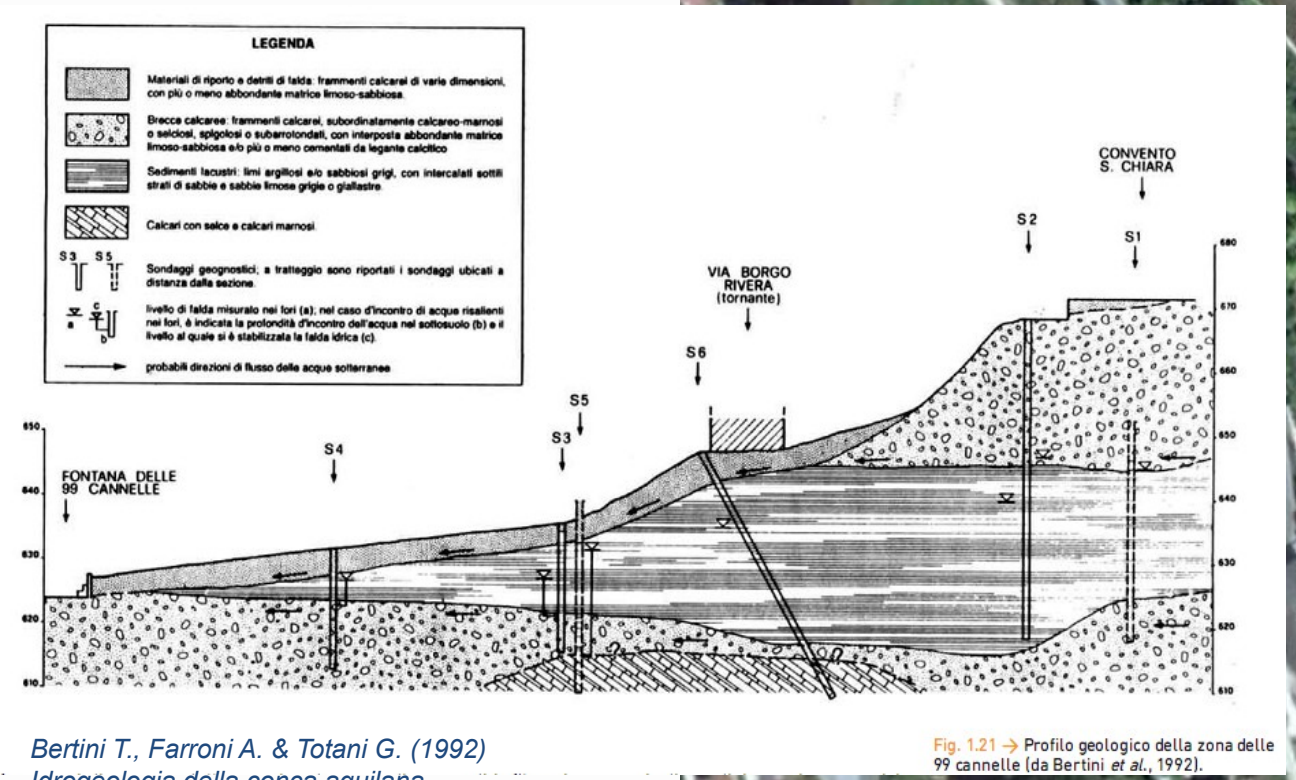
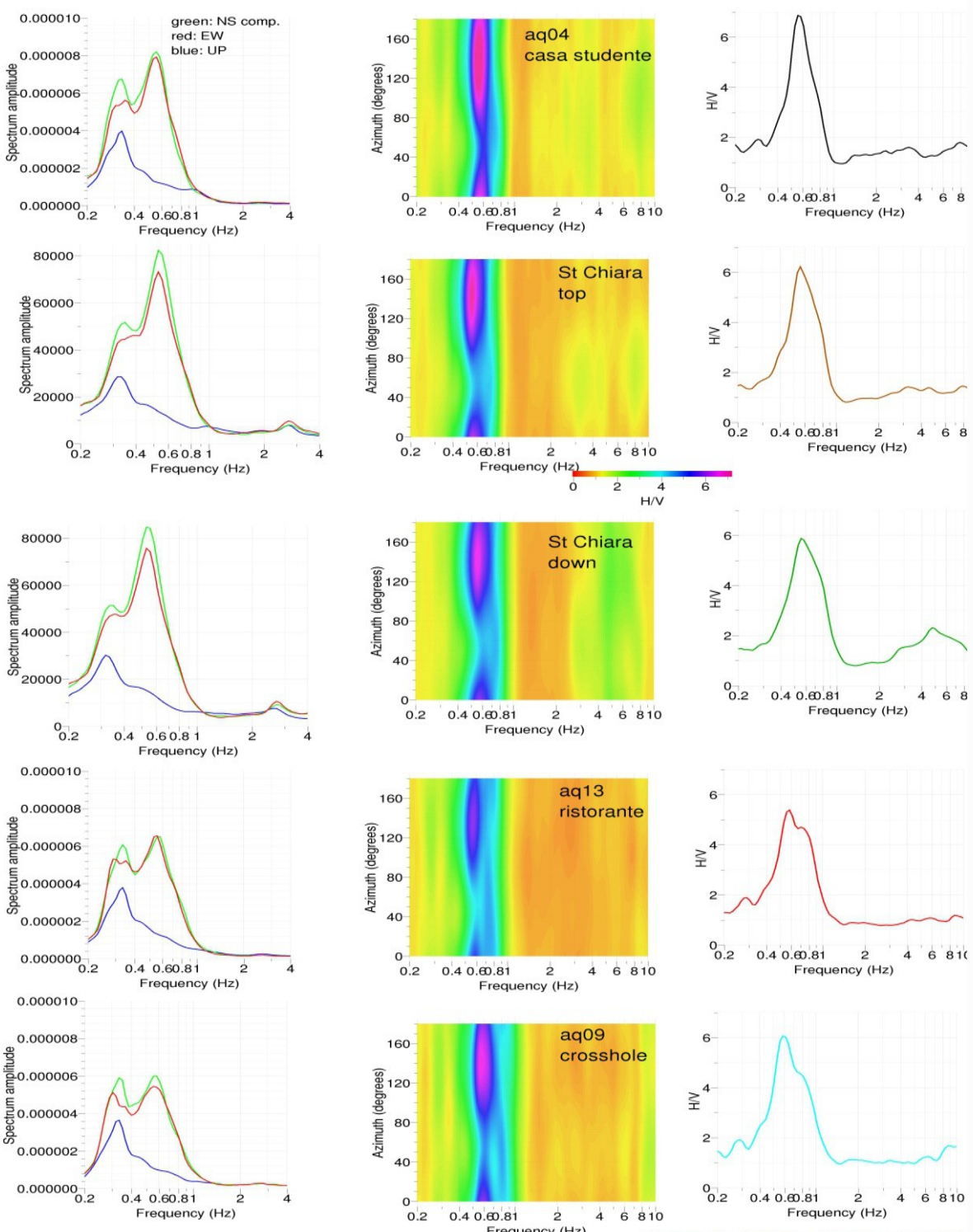


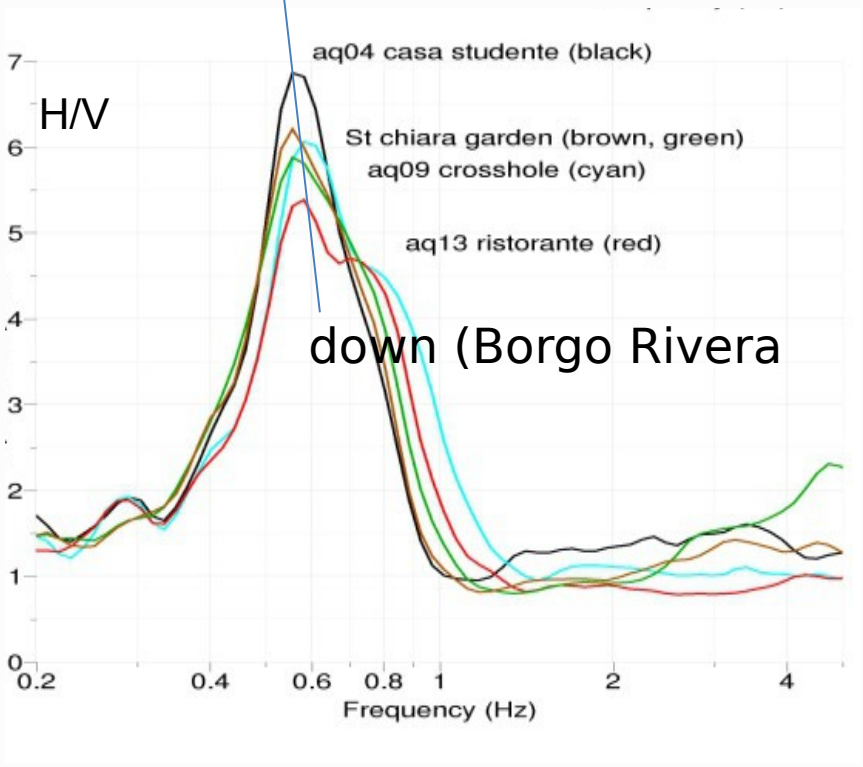
Fig. 1.21 → Profilo geologico della zona delle 99 cannelle (da Bertini *et al.*, 1992).

Bertini T., Farroni A. & Totani G. (1992)
Idrogeologia della conca aquilana.
Pubbl. DISAT, Università dell'Aquila,
92/6, 28 pp.

Transect Borgo Rivera/Santa Chiara/Casa dello Studente

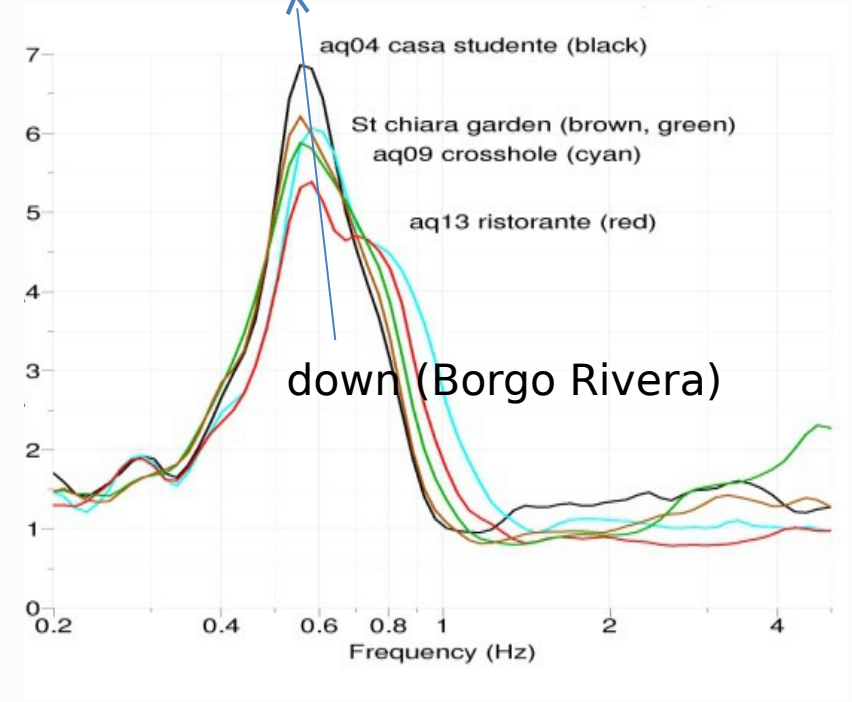


Top (Casa dello studente)



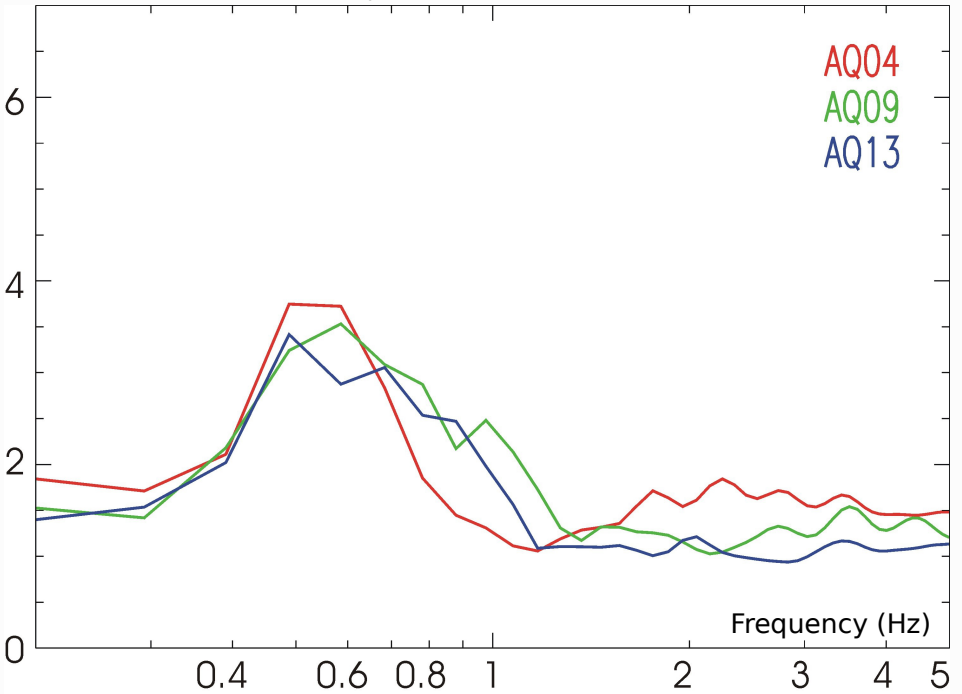
HV noise

Top (Casa dello studente)

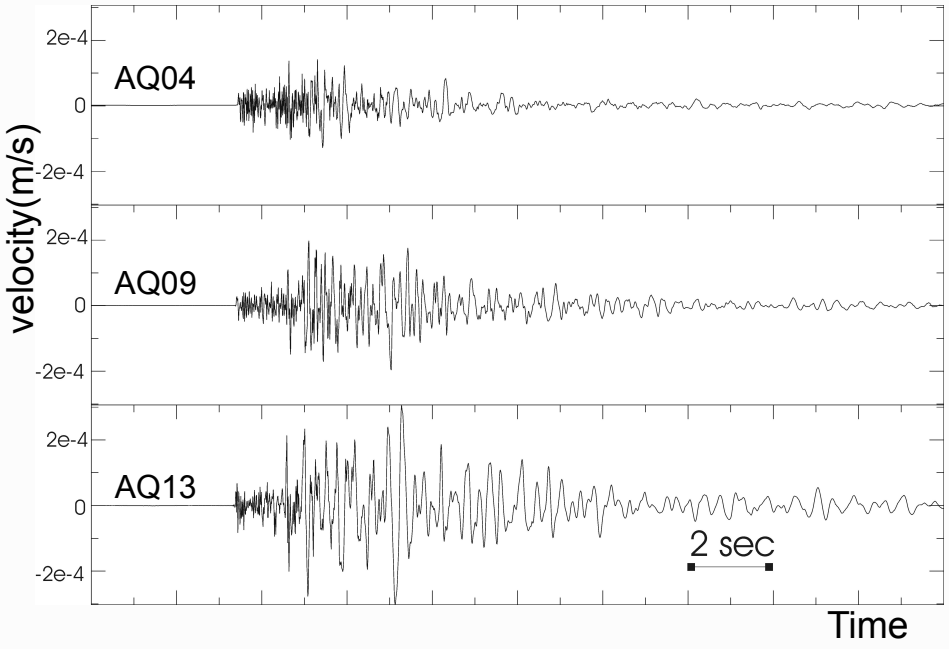


HV computed on about 250 aftershocks

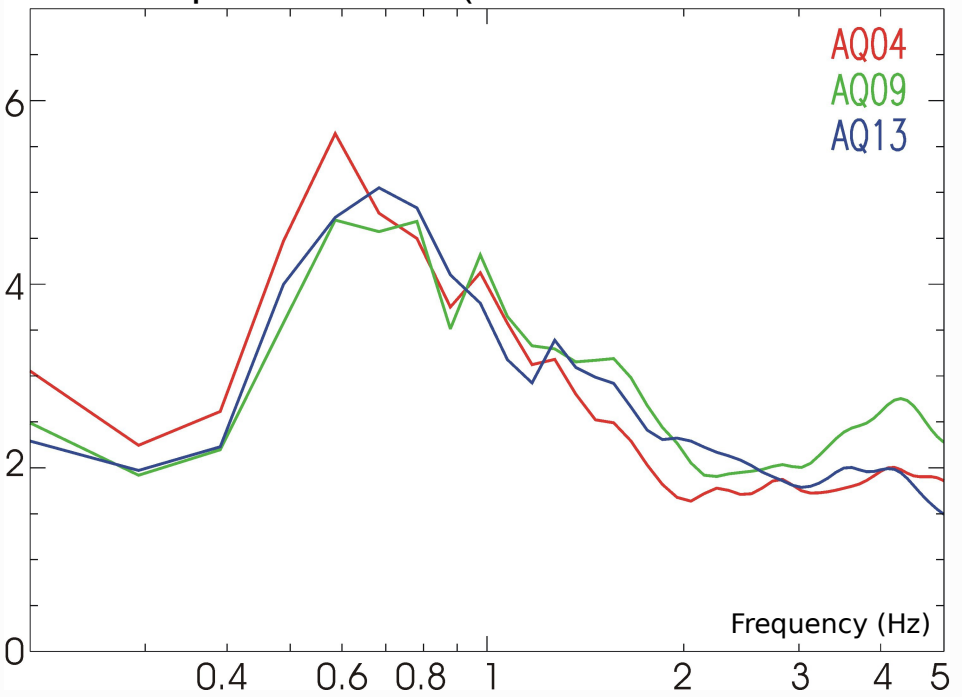
(AQ13 and AQ09 situated in proximity of the Aterno River Valley;
AQ04 nearby Casa dello Studente)



M 2.4, 30 May 2009, Compon. Z



Standard Spectral ratios (Roio site as reference site)



Measurements in caves (Breccias)

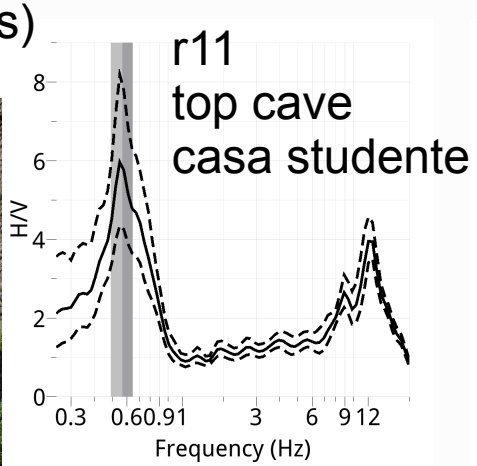
r12: inside cave

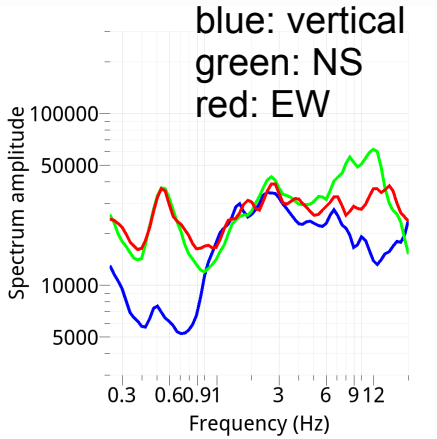
r12bis: just outside cave

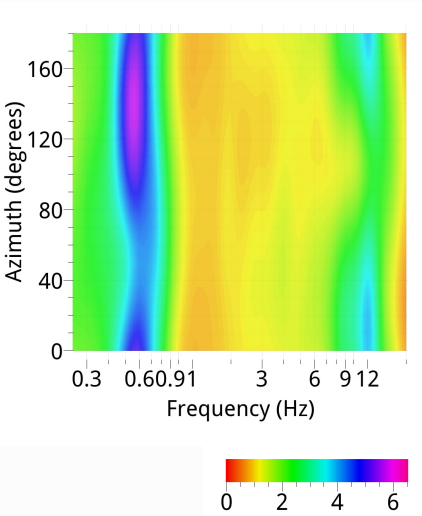
r12: inside the cave

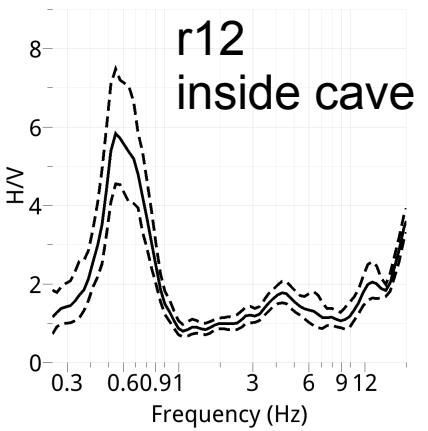
r12: inside the cave

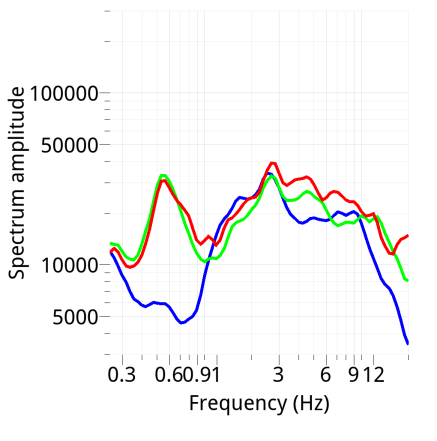
Measurements in caves (Breccias)

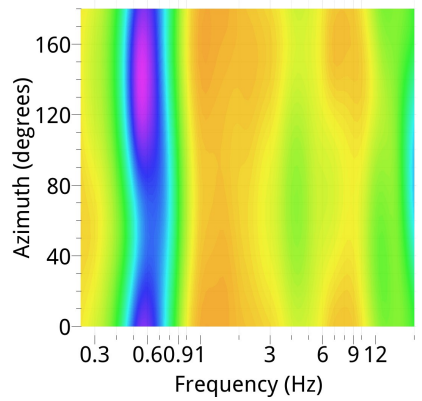


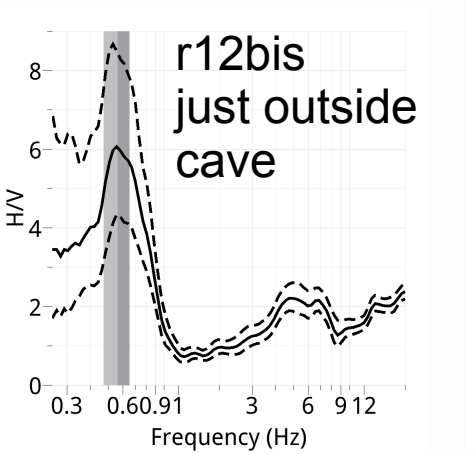


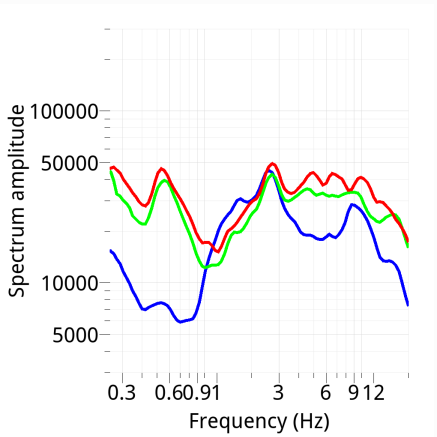


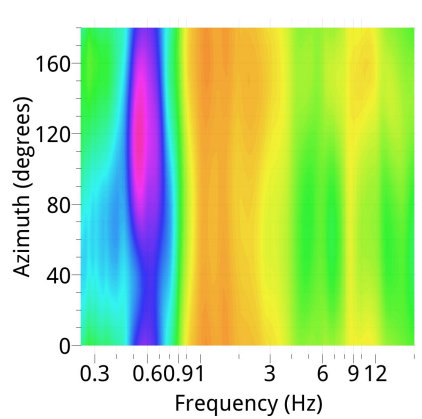




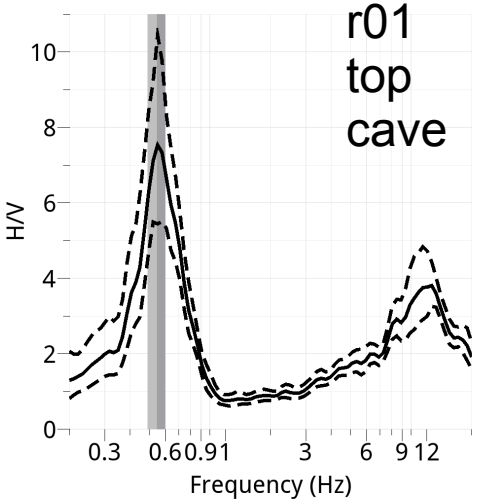


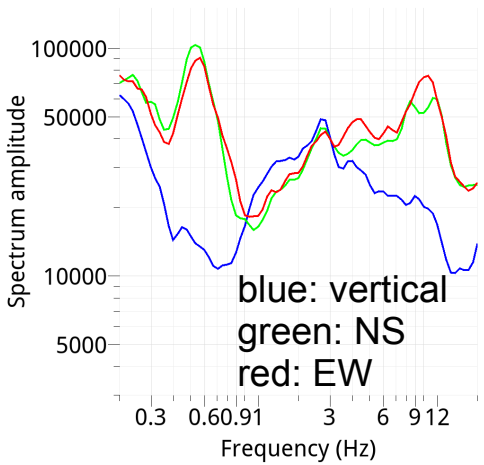


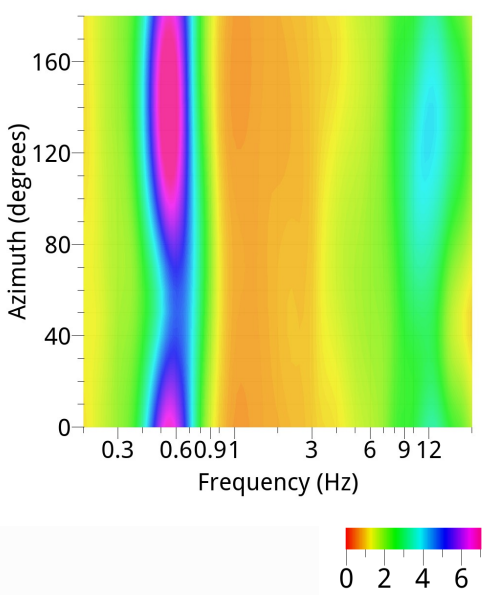


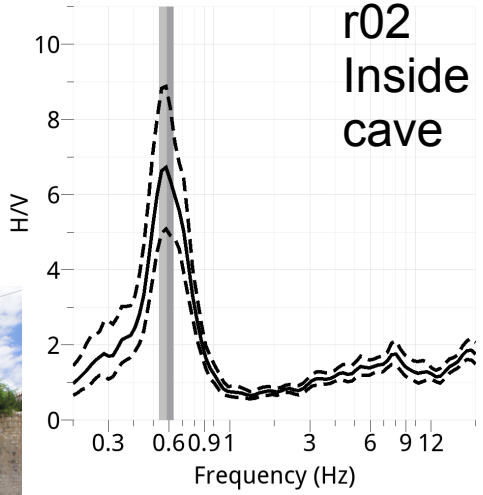


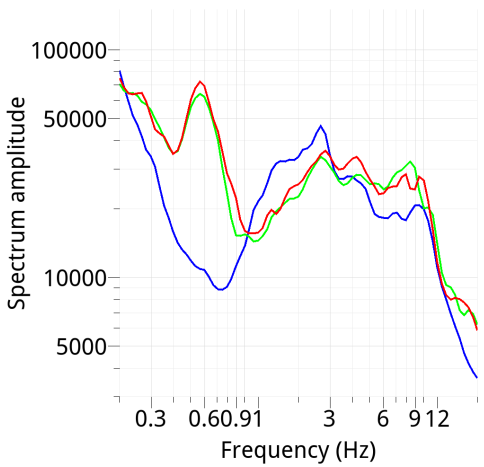
Measurements in caves (Breccias)

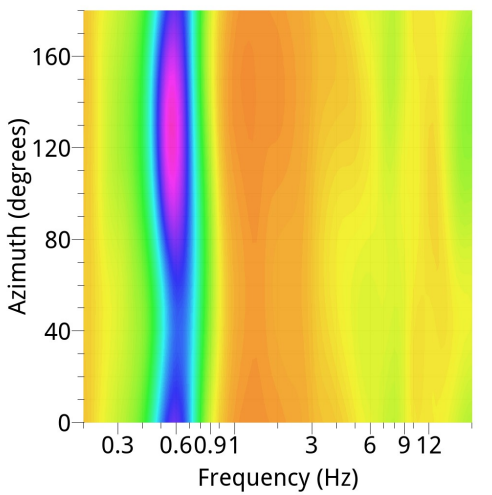








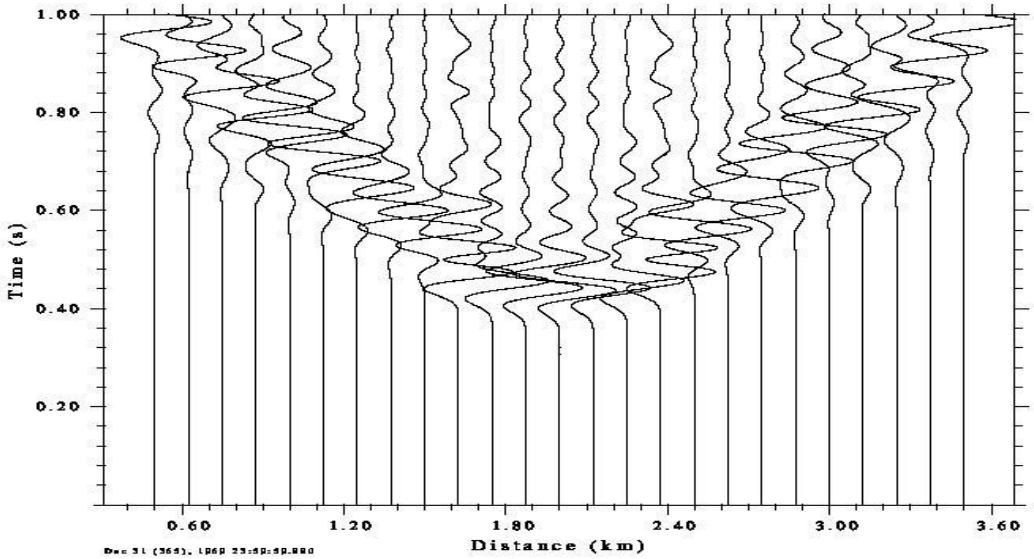




Terrazzo dell'Aquila

Thickness	Unit	Vp (m/s)	Vs (m/s)
80+50 m	breccia	2000	1000
120m	lacustrine deposit	1500	750
500m	basament	4500	2250

Compon Z



2D Numerical modelings are in progress to understand the role of topography on ground shaking

Conclusions:

- Because the variation of the spectral minimum of the vertical component, the noise H/V ratios at the bottom show a broader peak with lower amplitudes in comparison with the H/V curves at the top

- The H/V ratios computed on earthquakes seem to show the same behaviour of those computed on noise, although the differences between top and bottom are less clear

- The investigated caves cannot be recognized by noise measurements, likely related to the relative small dimensions and to the thickness (> 15 m) between the cave roof and the topographic surface

- The low-frequency resonance shows a N120°/N160° polarization.
  This direction is parallel to the main elongation of the Aterno River Valley
  and/or perpendicular to the main elongation of the L'Aquila hill

Transetto Collemaggio-Orto botanico