Site characterization report at the seismic station IT.FOS – Foligno (PG)

Report di caratterizzazione di sito presso la stazione sismica IT.FOS – Foligno (PG)

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Subject: **Final report illustrating the site characterization for seismic station IT.FOS**	

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Introduction 3

A. Geological setting 3-12

1. Topographic and geological information 3
2. Geological map 5
3. Lithotechnical map 6
4. Survey map 7
5. Geological model 8
   5.1 General description
   5.2 Geological section
   5.3 Subsoil model

B. V_S profile 13-20

1. Geophysical Investigations 13
   1. Ambient noise HVSR analysis
   2. Dispersion curves from passive and active array measurements
2. Seismic Velocity Model 18
3. Conclusions 21

References 22

Disclaimer and limits of use of information 24

INTRODUCTION

Convenzione DPC-INGV 2019-21, All.B2- WP1, Task 2: "Caratterizzazione siti accelerometrici" (Coord.: G.Cultrera, F. Pacor)
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In this report we present the geological setting, geophysical measurements and results obtained in the framework of the 2019-2021 agreement between INGV and DPC, called *Allegato B2: Obiettivo 1 - TASK 2: Caratterizzazione siti accelerometrici (Responsabili: G. Cultrera, F. Pacor)* for the site characterization of station IT.FOS (Foligno).

Location and coordinates are reported in Table 1.

Table 1.

CODE	NAME	LAT [°]	LON [°]	ELEVATION [m]
IT.FOS	Seggio (fraz. Foligno)	43.01459*	12.83513*	954*
ADDRESS	Località Seggio, 1, (Foligno) 06034 PG, Italy			

* Reference table from ITACA (December 2020)

A. Geological setting

A1. TOPOGRAPHIC AND GEOLOGICAL INFORMATION

Topographic information related to the site is reported in Table 2.

Table 3 summarizes all available geological maps from literature for geological analyses.

Table 2.

Topography	Description	Topography Class	Morphology Class	EC8 Class
	Flat top of isolated relief with slope i<=15°	T1	VC*	B

* According to nomenclature of ITACA (December 2020)

Table 3.

Geological map	Source	Scale
IT.FOS	Geological map of Italy sheet *N.131* (Foligno)	1:100.000
IT.FOS	Geological Map - Umbria Region, Servizio Geologico, sheet N.314010 (Foligno) - 2014	1:10.000
IT.FOS	CARTA GEOLOGICA D'ITALIA alla scala 1:50.000 - Barchi and Lemmi, 2015 (Foglio 324 - FOLIGNO)	1:50.000
IT.FOS	Litho-morphological map – Seismic Microzonation (Foligno / PG)	1:5.000
IT.FOS	Carta geologica dell'area di Colfiorito-Geologica map of the Colfiorito area. 1:25000 Servizio Geologico e Sismico-Regione Umbria - Barchi et al., 2012	

In Table 4 Geological and Lithotechnical Units (according to Seismic Microzonation classification; Technical Commission SM, 2015) are described and are concerned with maps of following chapters. The term "original" means the result comes from a pre-existing cartography (Table 3); the term "deduced" means the result comes from an interpretation of a pre-existing cartography according to the nomenclature of corresponding cartography.

Table 4

GEOLOGICAL UNITS		LITHOTECHNICAL UNITS	
Carta Geologica Regione dell'Umbria, Servizio Geologico, 2014 (original)		Carta Geologico-Tecnica Microzonazione Sisr di Liv. III Comune di Foligno (MZS) (original)	
code	**description**	**code**	**description**
a	Landslide deposit. For shallow landslides it includes the scarp area	GW	Washed gravels with well-matched particle size, mixture of gravel and sand.
b	Coarse-grained, fan- shaped debris deposits, loose sand and gravel in a silty matrix.	GMca	Silty gravels, mixture of alluvial fa gravel, sand and silt - moderately thickened
b2	Fine-grained floodplain sediments made of clays and sandy clays	GC	Fine grained deposits with clasts variable size, mainly derived fr weathering of the substratu accumulated in situ (eluvium) emplaced due to diffuse (colluvium). These deposits oc both on the flanks and in the bott of minor valleys.
SAA	Scaglia Rossa	SFLPS	Lapideo, stratificato fratturato/ alterato
SBI	Scaglia Bianca	SFLPS	Lapideo, stratificato fratturato/ alterato
FUC	Marne a Fucoidi	CO	cohesive overconsolidated marls
MAI	Maiolica	LPS	Stony, stratified

A2. GEOLOGICAL MAP

In Figure 1 Geological Map is reported in a 1km x 1km square around the station.

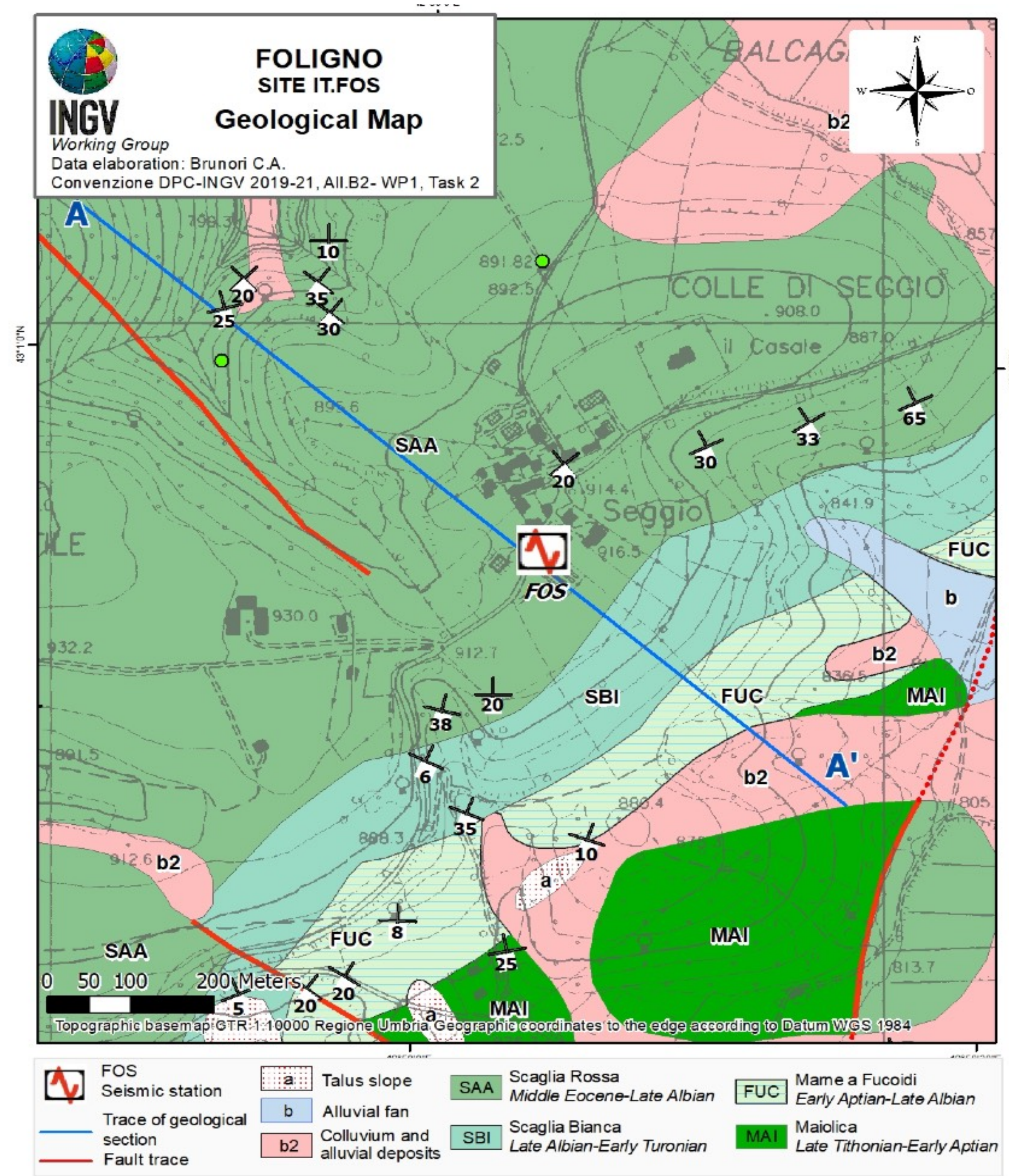

Figure 1. Geological map of seismic station IT.FOCC. Scale 1:10.000. Geological units come "Carta Geologica 1:10.000, Regione dell'Umbria Servizio Geologico, 2014 ”.

A3. LITHOTECHNICAL MAP

In Figure 2 Lithotechnical Map is reported in a 1km x 1km square around the station.

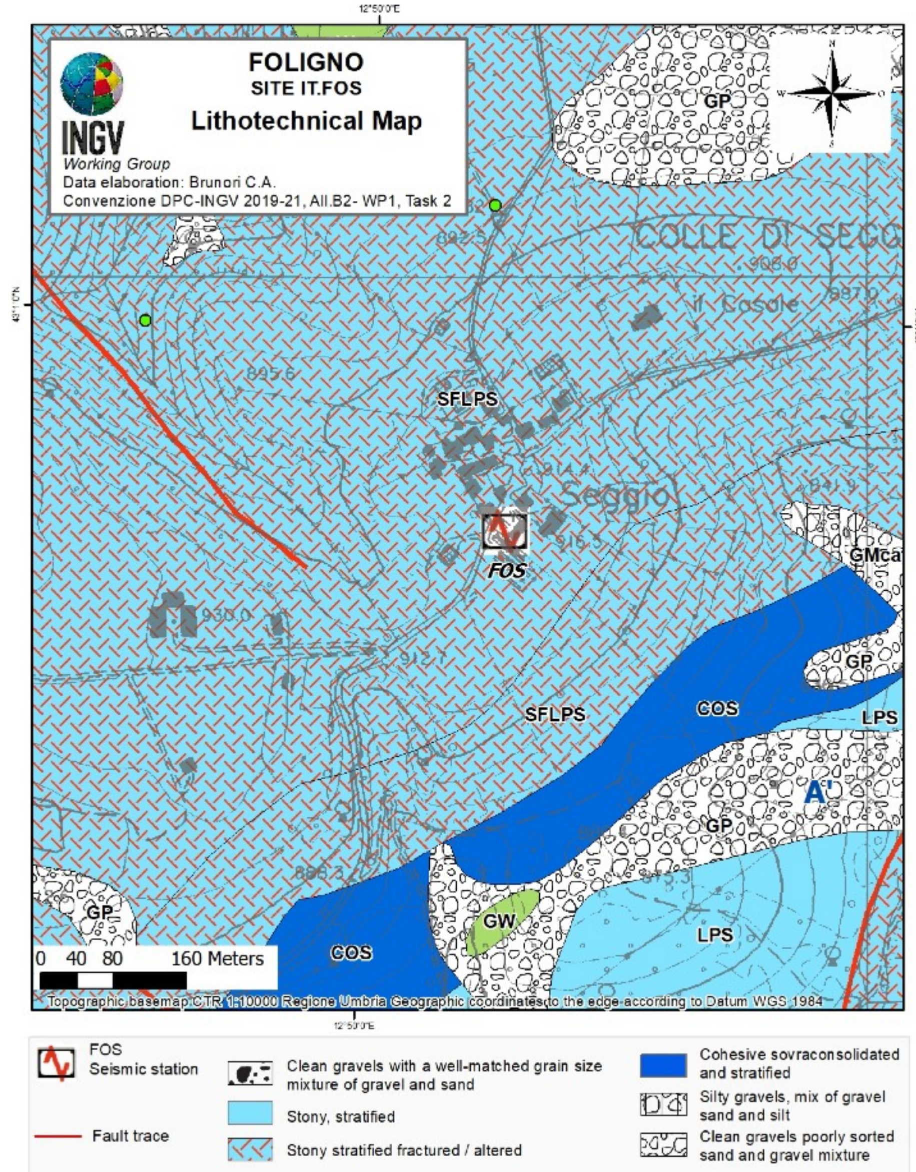

Figure 2: Lithotechnical map of the seismic station site IT.FOS - scale 1:5.000. The lithotechnical units are attributed according to the nomenclature of Seismic Microzonation study (Technical Commission SM, 2015).

A4. SURVEY MAP

Figure 3 shows the Survey Map reporting both previous investigations and geophysical surveys conducted by INGV Working Group.

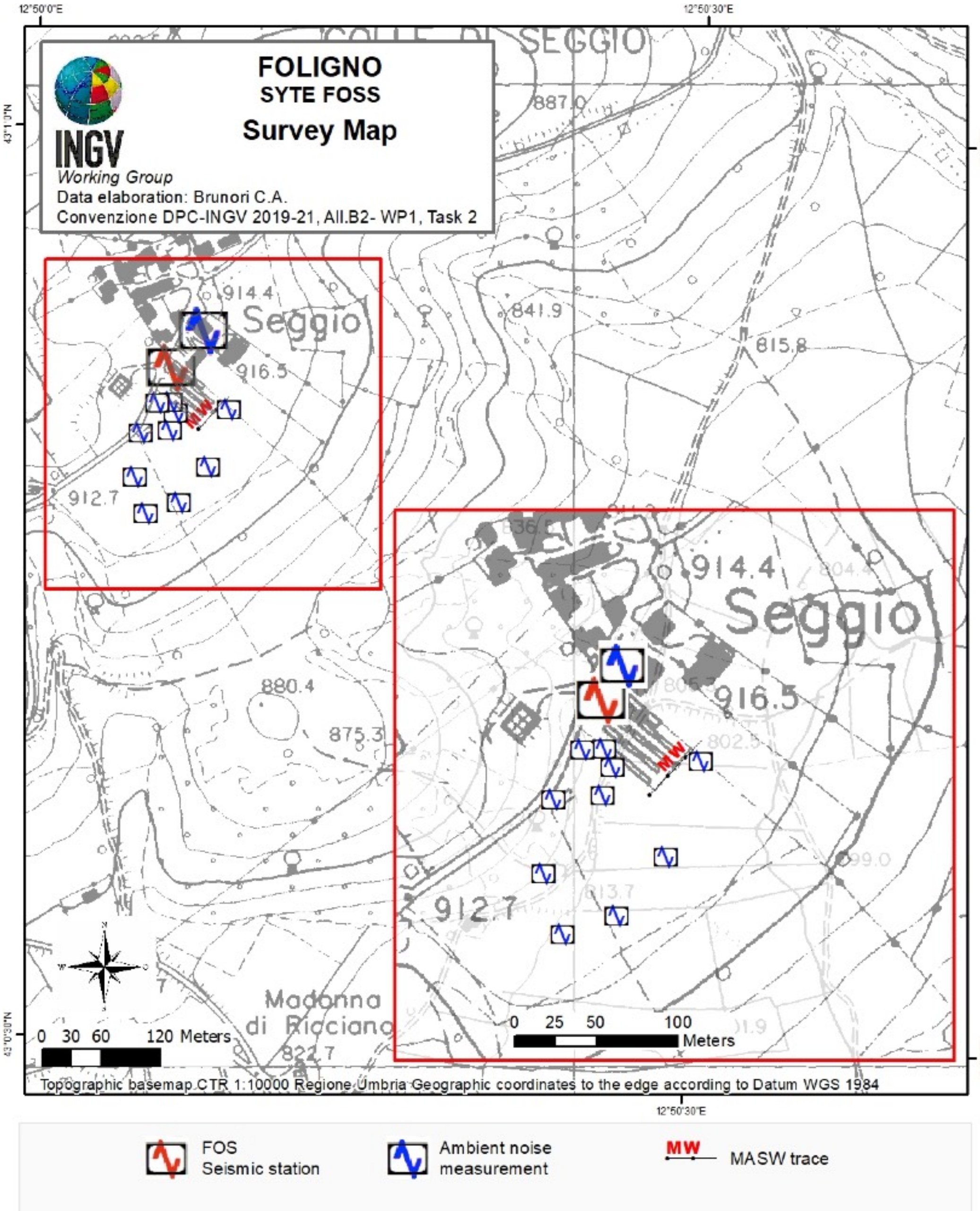

Figure 3: Map of the geophysical surveys made in the sectors around the seismic station IT.FOS - scale 1: 5.000. The box at the bottom right contains a zoom of the area with the detail of the geophysical investigation conducted by INGV Working Group for the seismic characterization of the site (Convenzione DPC-INGV 2019-21, Allegato B2-WP1, Task B, Velocity profile at the seismic station report IT.FOS).

A5. GEOLOGICAL MODEL

5.1 General description

The investigated area is located in the Colfiorito 1997 seismic sequence region and within the Umbria-Marche Apennines, upon a Late Miocene fold-and-thrust sheet (the 'Inner Anticlinorium' of Lavecchia and Pialli, 1980) bounded eastward by a thrust plane (Figure EE). The Quaternary normal faults here outcropping cross-cut and dislocate the pre-existing fold-and-thrust belt structures. The maximum displacement along the normal faults is of the order of 400–500 m (Calamita et al., 1999).

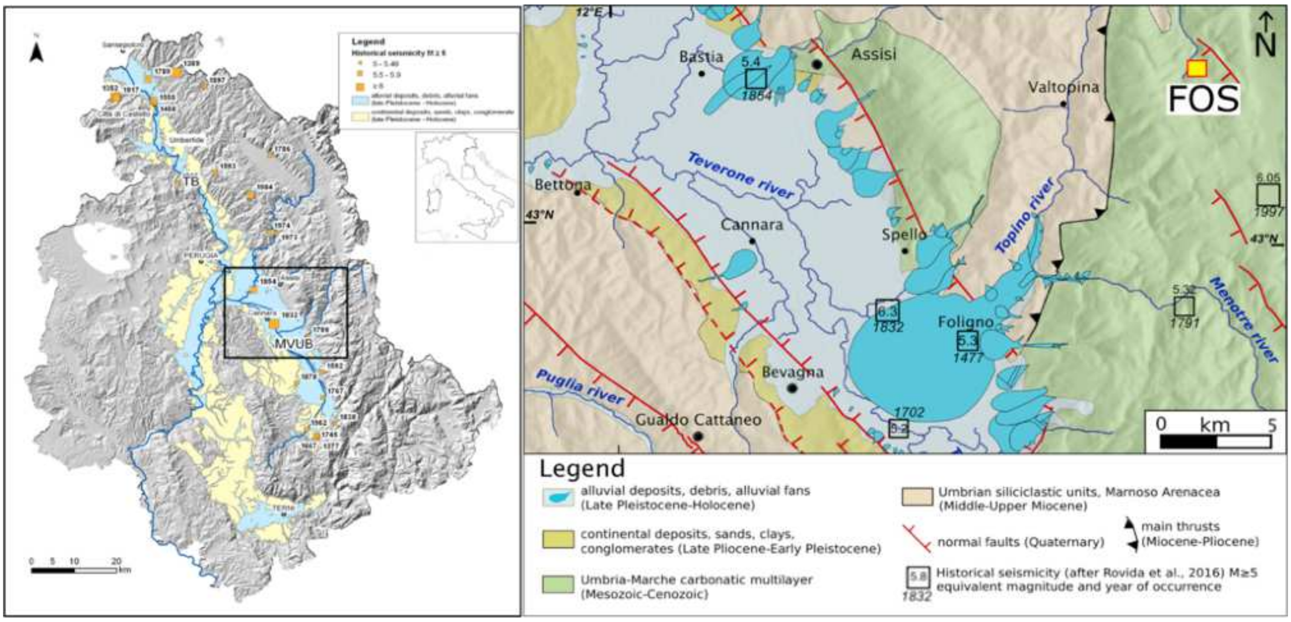

Figure 4: Left panel: Umbria Region, in background, the shaded relief derived from DTM 10 m (TINItaly, Tarquini et al.,), in yellow and light blue the recent and quaternary formations filling the Tiberina Valley (TB) and the Middle Umbria valley Basin (MVUB). The study site is located in the eastern carbonatic ridge. Right panel: simplified geological map of the Umbria valley and Appennine ridge. The FOS station is located in the inner edge of Appennine carbonatic ridge. The black boxes (in the left panel the same are represented with orange boxes), locate the zoomed area on the right panel showing principal formations of this Appeninic sector and the small black box locates historical earthquakes of this sector of Italy (CPTI15; Rovida et al., 2016)

5.2 Geological Section

The FOS station is located in the Seggio village, on the top of reliefs bordering the Northern side of the Piano di Ricciano basin. The latter basin is the southern termination of the Colfiorito and Annifo basins, edged in its north-Eastern side by the fault systems responsible for the 1997 seismic sequence (main shock 26/09/1997, 5.7 and 6.0-- Ml). The stratigraphy of the FOS subsoil is represented by Late Thithonian to Late Albian formations of the Umbria Marche carbonatic sequence. These limestones are stratified with the thickness of the strata decreasing from 40 cm of the Maiolica (MAI) to the 50-70 cm of the Scaglia Bianca (SBI) and 30 cm of the upper Scaglia Rossa. Between MAI and SBI the Marne a Fucoid marls consists of varicoloured pelagic marlstones and marly limestones, with diffuse Chondrites (informally called fucoids), and frequent interbedded black shales. in The Figure 5 the geological profile. In the first 200 m of the FOS station area are not present tectonic structures cutting the limestone sequence above described.

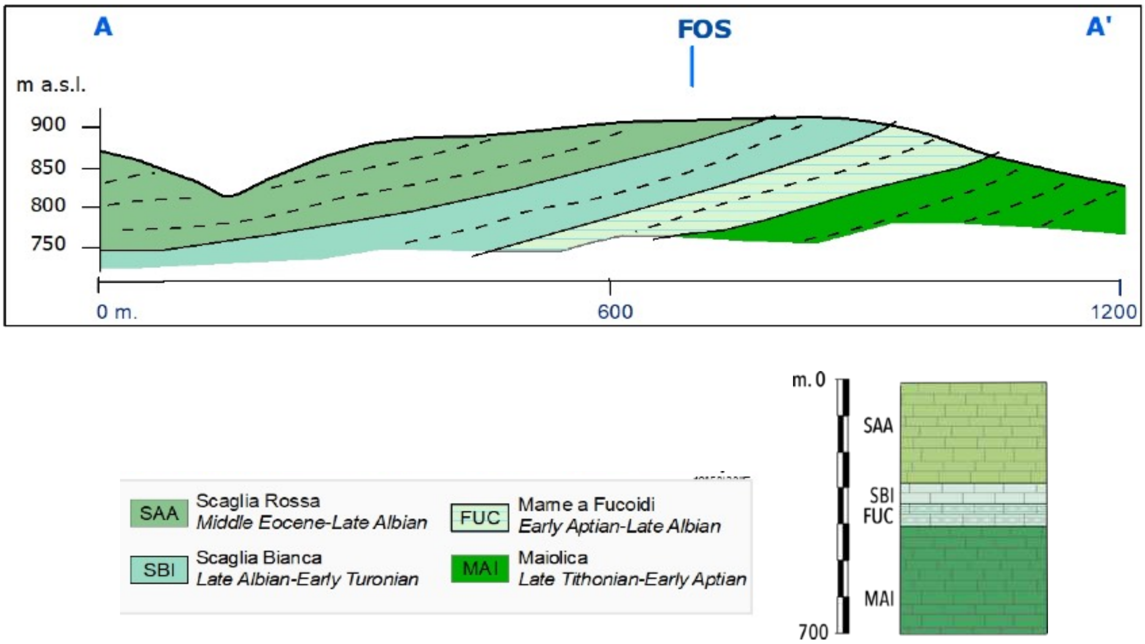

Figure 5: Schematic geological cross section, oriented NE-SE (seet the A-A' trace in the Fig. 1), showing the stratification of carbonatic units of the Umbria-Marche sequence.

5.3 Subsoil model

The FOS station is located in the central-Northern sector of the Apennines chain. In this sector of the Apennines the upper crust is made up of four main lithological units each about 1.5–2 m. thick. From bottom to top there is a phyllitic basement (not exposed at the surface), UpperTriassic evaporites (alternated and dolostones), Jurassic to Oligocene multilayered carbonates (Figs. 5 and 6). The present-day tectonic setting derives from the superimposition of two main tectonic phases, compressional structures related to arc-shaped folds and thrusts (Late Miocene) and extensional structures related to NW-SE trending normal faults (Late Pliocene-Quaternary). The easternmost and more recent NW-SE extensional structures have been named as the Umbria Fault System. These SW dipping normal faults represent the prominent extensional structures of the region, controlling the onset and evolution of neo-autochthonous continental intermountain basins located on the hanging wall of the subsiding areas.

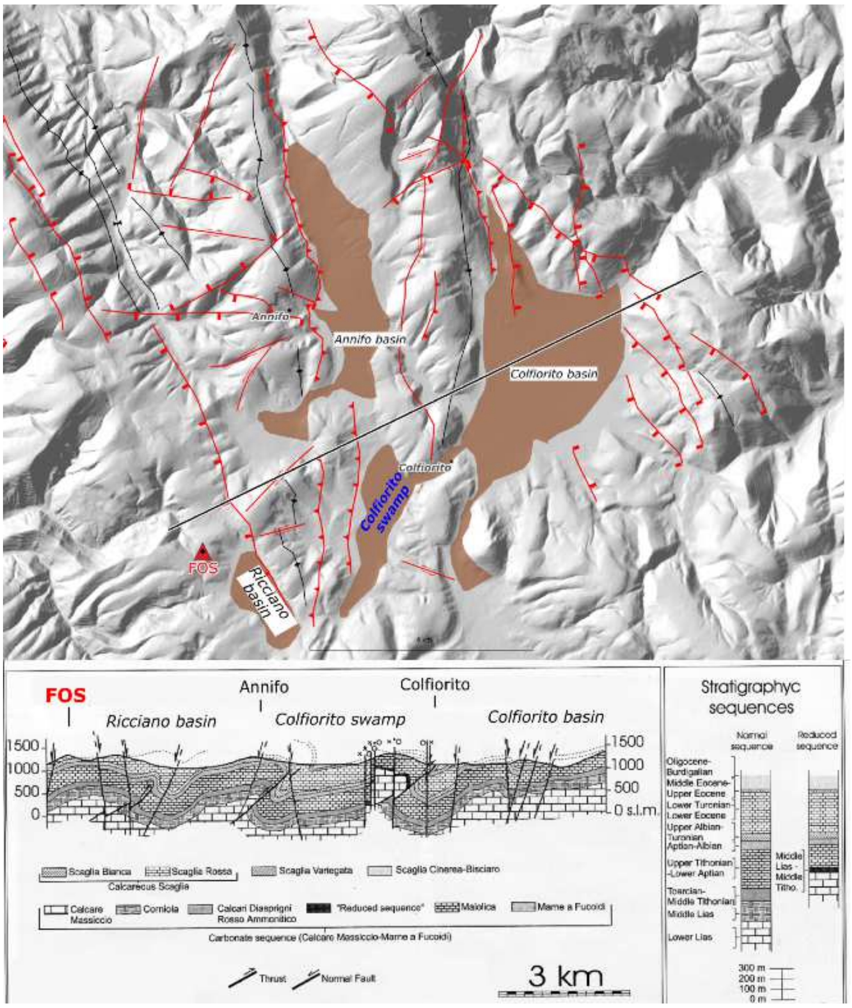

Figure 6: **Top** panel - Tectonic structures mapped in the Colfiorito and FOS - Seggio area; the NE-SW black line is the trace of the geological section in the **Bottom** panel - Geological section and stratigraphy of the Colfiorito area. The Geological map and profile are by Mirabella and Pucci (2002).

B. Vs profile

B1. GEOPHYSICAL INVESTIGATIONS

The collected geophysical measurements consist in:

i) one ambient-vibration measurement executed next to the station IT.FOS :

ii) a 1D linear array of geophones close to the station in active acquisition (MASW);

iii) a 2D array of velocimeters with spiral shape and passive acquisition. During data analysis we selected a sub-array configuration made by the following stations :1, 2, 3, 4, 5, 10. These measurements provide results in terms of dispersion curves that are inverted to obtain the shear-wave velocity (V_S) profile for the studied area. The obtained results are suitable for assigning the soil class according to the current Italian seismic code (NTC18) and the current Eurocode (EC08).

Figure 1 shows the map of all the geophysical investigation performed by INGV: the location of station IT-FOS (Latitude 43.01459, Longitude 12.83513 WGS84) installed in Seggio hamlet (Foligno - PG) and the line of geophones used for the 1D linear array (MASW) and the 2D array.

Figure 1: Map of investigations for Foligno Seggio station (IT.FOS) (image from Google Earth http://www.earth.google.com): the position of IT-FOS station (red triangle) and the near noise measurement (green triangle), the line of 48 geophones (red line) used for the linear active survey and the spatial distribution of the seismic stations for the 2D-array. The spiral geometry of the ten 3-c velocimeters (yellow placemarks) used in passive acquisition. The green and red lines represent the shorter and longer interstation distances respectively

The ambient noise has been acquired with a medium-period seismometer (i.e., Lennartz Le3d-5s) and it lasted about an hour and twenty minutes. The sampling rate was set to 200sps.
To assess the resonant frequency of the site, the horizontal-to-vertical (H/V) spectral analysis has been calculated, using the *Geopsy* software (http://www.geopsy.org).
Figure 2 shows the Fourier spectra of the three components (NS, EW, UP), the directional H/V and the H/V curves (mean and plus/minus one standard deviation).

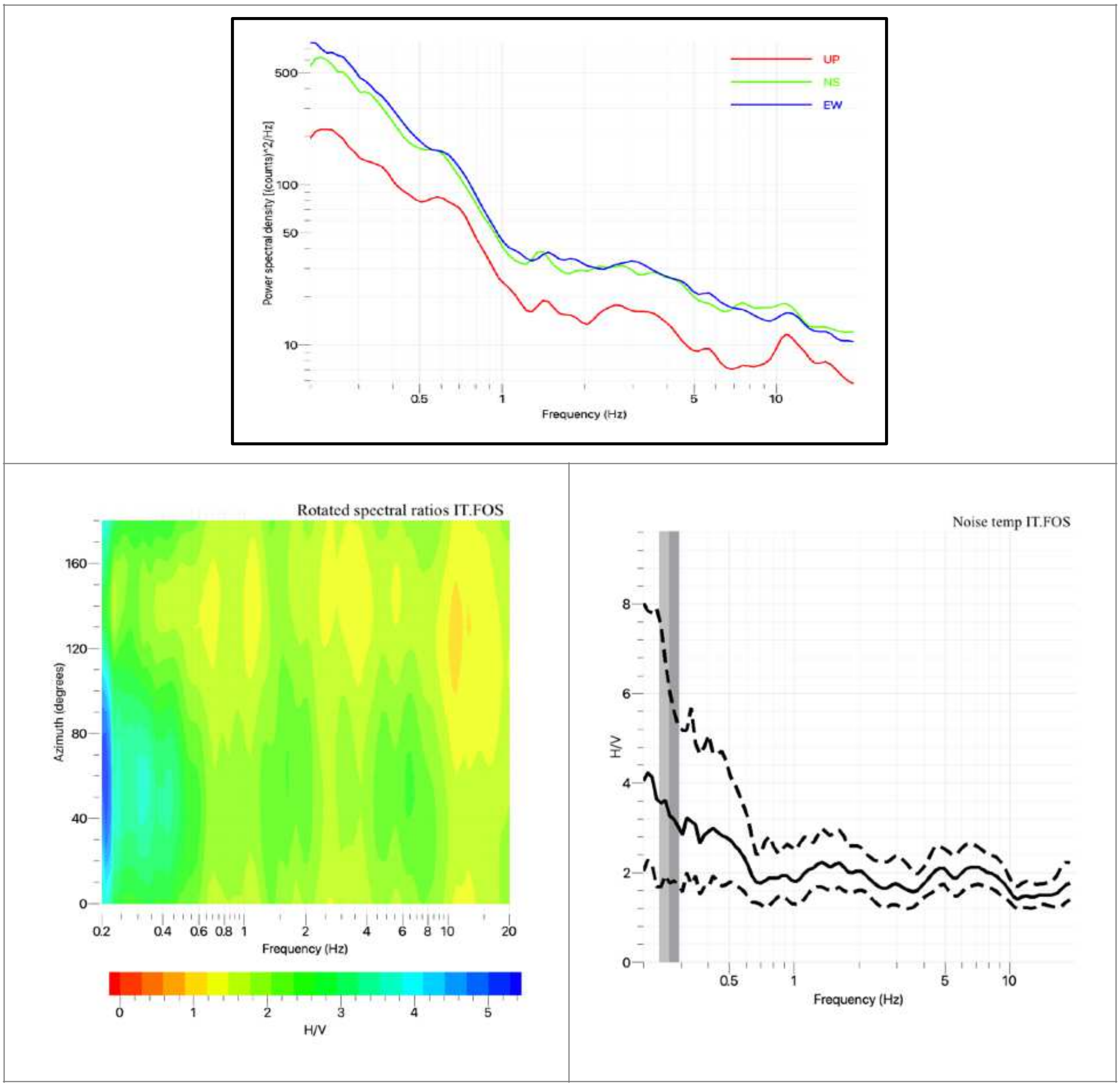

Figure 2: Summary of the analyses on the ambient-vibration measurement. Top: Fourier spectra of the three components. Bottom left: directional H/V. Bottom right: H/V curve (with mean and standard deviation).

The H/V curve is quite flat above 1 Hz and spectral ratios reach higher amplitudes for frequencies below 1 Hz, attesting the f0 at around 0.3 Hz according to SESAME criteria (SESAME Guidelines, 2004) but its shape is very broad and we consider it not meaningful.. The 3c-spectra show increasing energy of the ambient noise going towards low frequencies and rotated spectral ratios also highlight a slight polarization of the signal at these frequencies. This can also be observed for the ten 3-component stations installed for the 2d array in a nearby field. But in that case, the H/V peaks have slightly different frequencies (Figure 3). They may be more visible in the entire H/V curve because of the windy weather conditions during the investigation which increase the energy of the spectra in the horizontal components of the noise wavefield.

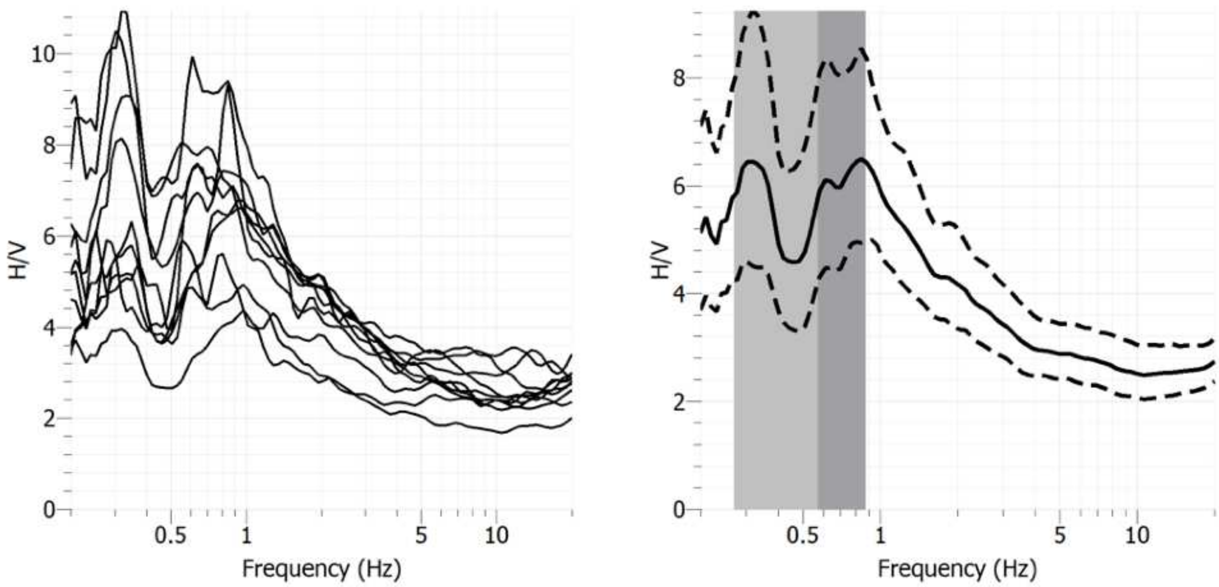

Figure 3: Ambient noise spectral ratios of the ten stations installed for the 2D array. Single plots (left) and average and standard deviations (right).

The 1D active linear array (red line in Figure 1) consisted of 48 vertical geophones (4.5Hz as natural frequency) placed at 1 mt of distance each other, for a total length of 47 mt. We used seven shot positions: -5mt from geophone #1, -1mt from geophone #1, at geophones #12, #24, #36, #48, +5mt from geophone #48. For each of them we hammered three times a metallic plate. We recorded signals with a sampling rate of 8000sps for 2 seconds. The 2D spiral array consisted of ten 3-component velocimetric stations. For this array we collected more than two hours of noise with a sampling rate of 200sps.

a. 1D linear active array

We first analyzed the 1D linear array in active acquisition. Figure 4 shows the comparison between the dispersion curves (DCs) obtained with the FK analysis for some shots located -5 mt from geophone #1, in central position, +5 m from geophone #48).

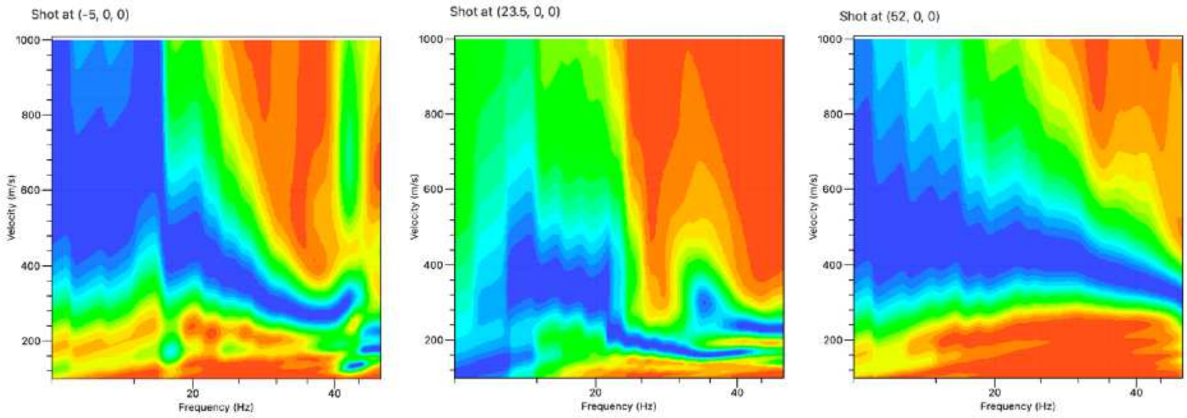

Figure 4: FK analysis for shots located -5 from geophone #1, at geophone #24 and +5 from geophone #48 (from left to right)

It is possible to notice that the shot at the middle of the line of geophones (central plot in Figure 4) does not give good results in terms of dispersion curve suggesting a superficial lateral heterogeneity along the line. To confirm that, the shots at the two edges of the line give a dispersion curve with same Vs values at around 20 Hz but lower velocities for higher frequencies. This difference can be due to the fact that the characteristics of the superficial soil are modified by the effect of decades of plowing for the first part of the line (plot on the left in Figure 4). The first part of the line is also closer to the 2D array performed for the same site. This condition leads us to consider more reliable the dispersion curve obtained stacking the shots located -5,0 mt from geophone #1. We stacked the three shots at -5m from geophone #1 and retrieved the auto-picked dispersion curve (Figure 5). The dark windows of the plot are discarded and the central part of the plot is considered reliable for the following inversion step.

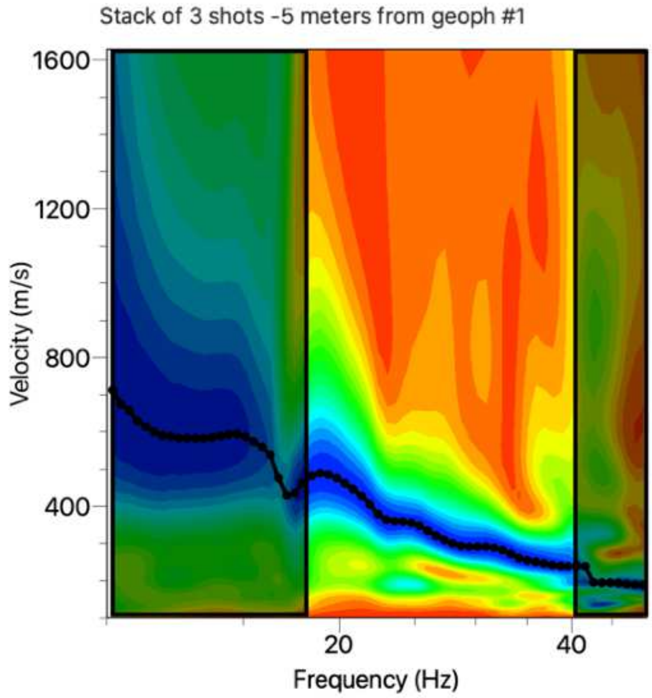

Figure 5: Stacked FK analyses and picked dispersion curve for shots in the first part of the 1D linear array.

We interpret and assume that the final dispersion curve consists of the fundamental mode of the Rayleigh dispersive waves. The lower part of the dispersion curve will be completed with results of the FK analysis on 2D array data.

b. 2D array

The 2D array installation was designed as a spiral geometry made by ten 3-component velocimetric stations. Data collected were first analyzed as single stations with the HVNSR technique to check the mono-dimensional hypothesis.

Results of HVNSR are reported in Figure 3 and show quite similar spectral ratios curves for almost all the stations.

FK analysis of data was performed in order to cover frequencies also below the limits of the linear active survey.

Using the entire number of stations for the FK analysis, the dispersion curve is poorly visible in the f-k domain (left plot in Figure 6), and only in the frequency band between 7 and 12 Hz (red lines in Figure 6). This could be due to the fact that in general for rock sites as this one, surface waves can hardly propagate for distances in the subsoil similar to the entire array aperture (130 m). For this reason, we decided to extract a subset of stations closer to each other (maximum aperture of 90 meters) and compute again the FK analysis (right plot in Figure 6). This time, results are more satisfactory at higher frequencies (12 and 16 Hz) and another branch of the DC curve is visible in black in the f-k domain as reported in the right plot of Figure 6.

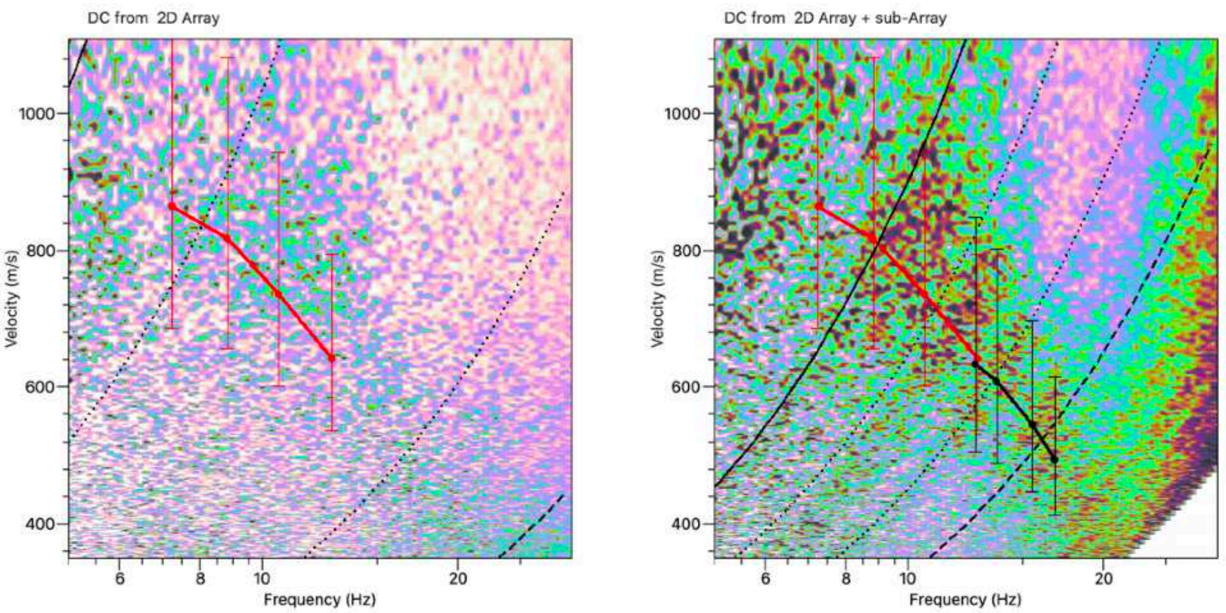

Figure 6: FK analyses of the 2D Array (left) and 2D sub-Array (right). The sub-array configuration optimized the DC detection at high frequency. The black curves are the limits of the array (left) and the sub-array (right) and the picked dispersion curves are plotted on the two figures.

B2 SEISMIC VELOCITY MODEL

To proceed with the inversion, we decided to:

1) Invert the dispersion curve shown in Figure 7;
2) Not to consider the ellipticity constrain, because the H/V curve shows a peak at low frequency which is not easy to interpret as a stratigraphic peak.

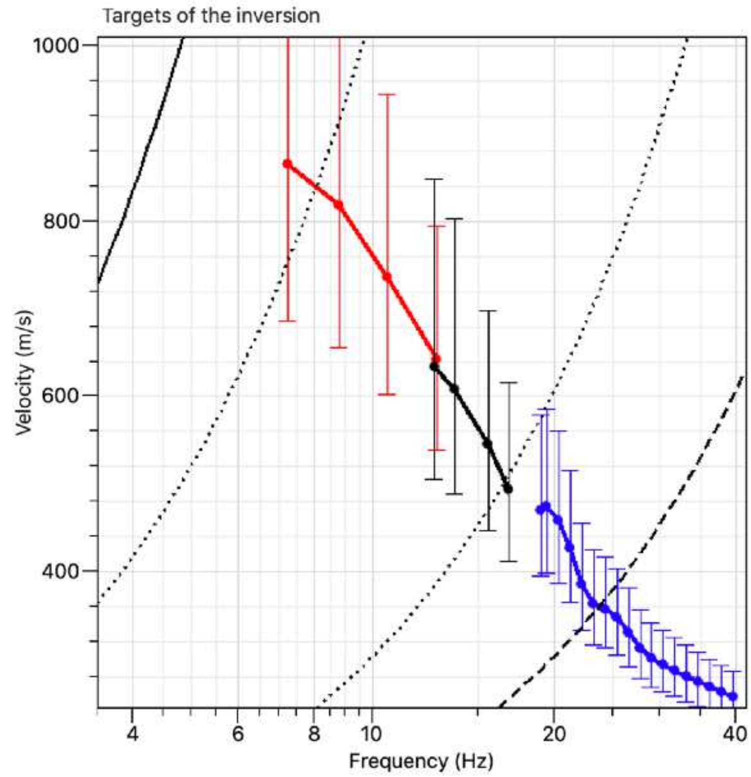

Figure 7: Targets of the inversion: in red the DC from 2D Array, in black the DC from the 2D sub-Array and in blue the DC from MASW.

The geology of the area where the IT.FOS station is installed is characterized by the presence of the Umbria-Marche stratigraphic sequence. This succession is made in general by limestones and marlstones which can be defined as a geologic bedrock. With this information in mind, we decided to use a simple starting model with three layers over half-space. Shear wave velocities (V_s) were set to vary for the three layers and half-space within the ranges of: 150-3500 m/s. Several tests have been carried out and the final result of the inversion is shown in Figure 8 along with the fit with the dispersion curve.

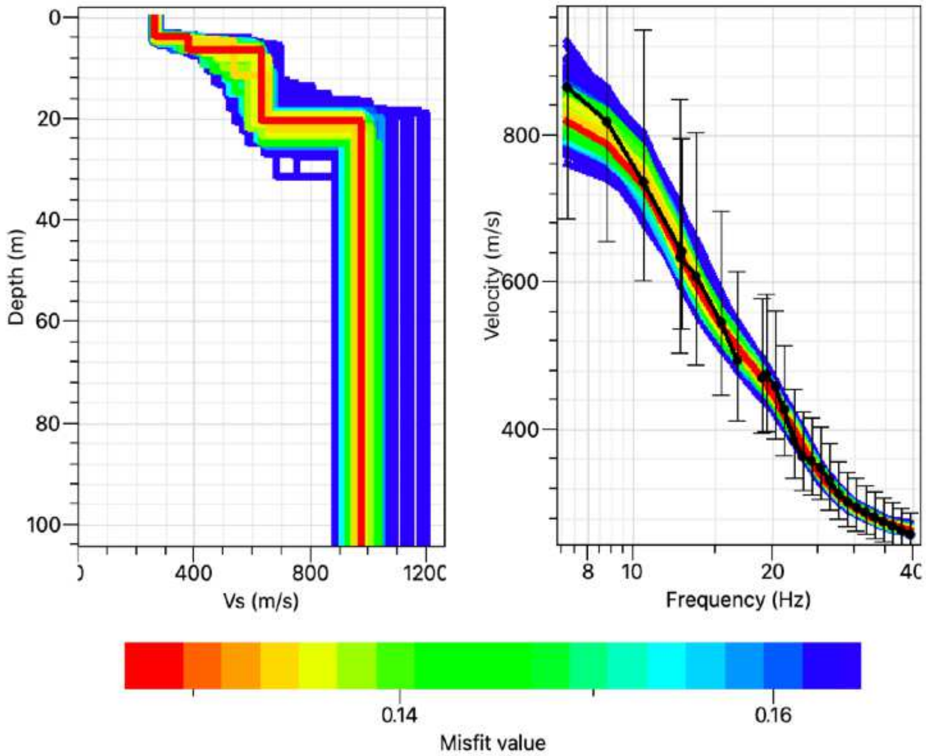

Figure 8: Left: Vs profile obtained through the inversion of the dispersion curve of Figure 7. Right: fit between the experimental dispersion curve and the theoretical dispersion curves of the investigated models.

The inversion is able to reproduce fairly well the experimental dispersion curve. The V_p profile is poorly constrained, and then we decided not to mention it in this report. The best -fit model of V_s is represented in Figure 9 and Table 1.

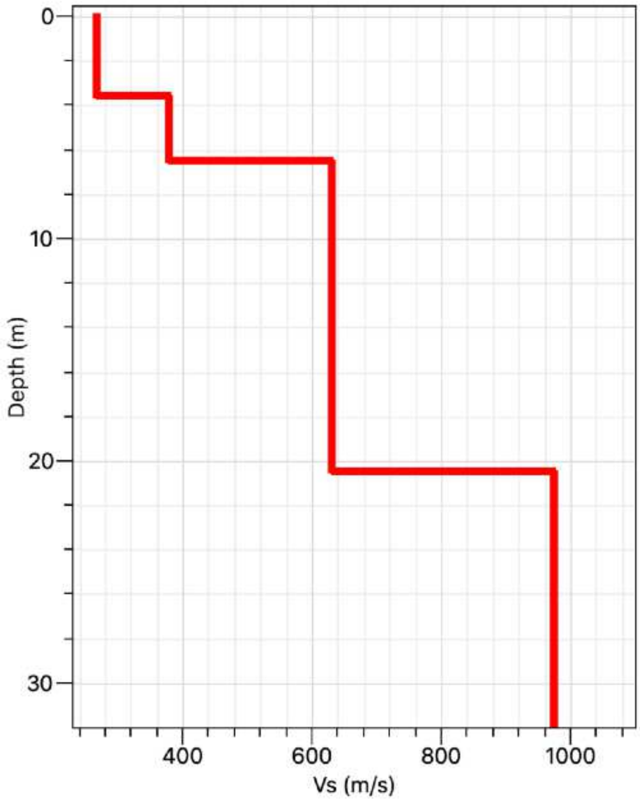

Figure 8: Best-fit model of Vs values

From	*To*	*Thickness (m)*	*V_s (m/s)*
0	3.53	3.53	264
3.53	6.42	2.89	378
6.42	20.39	13.97	628
20.39			973

Table 1: Best-fit model

B3. CONCLUSIONS

According to the current Italian seismic code [1], if the bedrock (Vs > 800 m/s) is more than 30 m in depth, the equivalent velocity ($V_{s,eq}$) is equal to the $V_{S,30}$. From Figure 8, the velocity of 800m/s is reached at 20.39 meters depth. Therefore $V_{S,30}$ retrieved from the inversion of the dispersion curves is 564.9 m/s, $V_{s,eq}$ computed at 20.4 meters depth is 469.4 m/s and the site is classified in the soil category B for both the NTC18 and EC8 seismic classifications (Table 2).

We have to take into account that the inversion process of the data array is poorly constrained by other independent information for this site. The results can change adding this info, whenever available.

***V_{s30}* [m/s]**	***V_{seq}* [m/s]**	***Soil class (NTC 2018)***	***Soil class (EC8)***
564.9	469.4	B	B

Table 2: Soil Class

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Umbria Region, Servizio Geologico (2014) Geological Map - Foglio N.314010 (Foligno)

GENERAL INFORMATION

Authors	Institutions	Contacts [email]	Compiling date [DD/MM/YY]
D. Famiani, C.A. Brunori	INGV	daniela.famiani@ingv.it, carloalberto.brunori@ingv.it	14/12/2021

Station description

Station name	Network code	Latitude [WGS84]	Longitude [WGS84]	Sensor depth [m]
FOS	IT	43.01459	12.83513	0

Site characterization summary

Indicators				
fo +/- std [Hz]	Value	none	Quality index Qi1	
	References			
	URL of report			
Velocity profiles [YES/NO]	Value	yes	Quality index Qi1	0.67
	References			
	URL of report			
Vs30 +/- std [m/]	Value	564.9	Quality index Qi1	0.67
	References			
	URL of report			
Surface geology [short description]	Value	Rock site	Quality index Qi1	1
	References	See this report		
	URL of report			
Seismological bedrock depth +/- std [m]	Value		Quality index Qi1	
	References			
	URL of report			
Site class EC8	Value	B	Quality index Qi1	0.67
	References			
	URL of report			
Engineering bedrock depth +/- std [m]	Value	20.4	Quality index Qi1	0.67
	References			
	URL of report			

Distance from the seismic station [m]		Final quality index (Final_QI)	Comments
min	min	0.46	QI2= 0.52 ;QI3 = 0.4

RESONANCE FREQUENCY

fo +/- STD [Hz]	none
Quality index 1	

Source	Earthquake	Ambient noise

Ambient noise

Method	H/V ✔	Ellipticity	Other
fo +/- std [Hz]	none		

Experiment date [DD/MM/YY]	Distance from station [m]	Lat. [WGS84]	Lon. [WGS84]
07/06/2021	10	40.014630	12.838258

Environment

Weather conditions	Sunny ✔	Windy	Rain
Soil-sensor coupling	Earth ✔	Asphalt	Artificial
Urbanization	None	Dense	Scattered ✔

Equipment

Sensor	Type [acc/vel]	manufacturer	cut-off frequency [Hz]
	vel	Lennartz	0.2
Digitizer	Type	Manufacturer	Sampling frequency [Hz]
	MarsLite	Lennartz	200
Measurement	Number	Duration [min]	
	1	148	

Analysis

Software	Geopsy
Smoothing type (e.g. triangular, Konno-Ohmachi, ...)	Window length [s]
Konno Ohmachi	40

Fo uncertainty estimate from

Fo from individual windows	H/V curve width	Manual picking

Earthquake

Method	HVSR	SSR	GIT	Other
fo +/- std [Hz]				

Recording period [DD/MM/YY]		Number of earthquakes	Epicentral distance [km]		Magnitude range	
from	to		from	to	from	to

HVSR

Seismic phase	P	S	Coda	S + coda	All

window duration [s]	Min	Max

SSR

Seismic phase	P	S	Coda	S + coda	All
Reference station	Lat. (WGS84)	Lon. (WGS84)			

window duration [s]	Min	Max

GIT

Parameters	Free (to be inverted)	Imposed
Reference paper		
Reference station	Lat. (WGS84)	Lon (WGS84)

Vs30

Vs30 +/- STD [m/s]	564.9
Quality index 1	0.67

Source	Geophysical measurements	Geotechnical measurements	Digital Elevation Model (DEM)	Geology	DEM & Geology

Geophysical measurements

Method	Surface waves methods (active, passive methods)	Borehole methods (DH, CH, PS-Logging)
Vs30 +/- STD [m/s]	From Vs(z): 564.9	From Down-Hole
	From Vr40	From Cross-Hole
	From Vsz-Vs30 correlation	From PS Logging
Reference relationship Vsz - Vs30		

Geotechnical measurements

Method	N-SPT	CPT	Shear strength	OTHER
Vs30 +/- STD [m/s]				

Experiment date [DD/MM/YY]	Distance from station [m]	Lat. [WGS84]	Lon. [WGS84]

Reference relationship Vs30-geotechnical parameter	
	N-SPT
	CPT
	Shear strength
	Other

Geology

Method	Geological map	Stratigraphic log
Vs30 +/- STD [m/s]		
Geological map scale		
Geological unit name		

Stratigraphic log	Experiment date [DD/MM/YY]	Lat. [WGS84]	Lon. [WGS84]

Reference relationship Vs30-geology	
Reference relationship Vs30-Stratigraphic log	

Digital Elevation Model

Vs30 +/- STD [m/s]	
DEM resolution	
Reference relationship Slope - Vs30	

Slope range (degree)	
from	
to	

DEM & Geology

Vs30 +/- STD [m/s]	
Reference relationship Slope - Vs30 - geology	

Vs profile

Quality index 1	0.67

Source	Non-invasive methods (active and/or passive seismics)				Invasive methods (measurement in borehole)
	Active surface waves	✔	Refraction		Cross-hole / Down-hole
	Passive surface waves	✔	Refection		Geotechnical methods (CPT, SPT, ...)
	HV / ellipticity				PS-Logging

Non-invasive : surface waves methods

Experiment date [DD/MM/YY]	Distance from station [m]		Lat. [WGS84] center location	Lon. [WGS84] center location
	Min	Max		
28-09-2021	44	158	43.013923	12.835163

Active surface waves acquisition layout

Minimum receiver spacing (m)	1
Profile length (m)*	47
Geophones number	48
Number of profiles	1

** Provide the length for the various profiles (e.g. 46 m, 94 m)*

Geophone cut-off frequency (Hz)	4.5
Geophone type (vertical / horizontal)	vertical
Geophone manufacturer	GeospaceGS11
Source (hammer, vibrator, ...)	hammer
Digitizer type	geode
Digitizer manufacturer	Geometrics

Weather conditions	Sunny	Windy	Rain	Soil-sensor coupling	Earth	Asphalt	Artificial	Urbanization	None	Dense	Scattered
		✔			✔						✔

Passive surface waves acquisition layout

Number of sensors	10
Minimum array aperture	15
Maximum array aperture	130
Number of arrays	1
Minimum duration [min]	

Sensor cut-off frequency (Hz)	20
Sensor type (vertical / horizontal)	3C-velocimeter
Sensor manufacturer	Lennartz
Digitizer type	MarsLite
Digitizer manufacturer	Lennartz

Weather conditions	Sunny	Windy	Rain	Soil-sensor coupling	Earth	Asphalt	Artificial	Urbanization	None	Dense	Scattered
		✔			✔						✔

Type of dispersion and/or H/V estimates

	Reference paper (Name, Journal, DOI)
Rayleigh DC	3C-FK on passive data (geopsy code)
Love DC	3C-FK on passive data (geopsy code)
Ellipticity	
H/V (DFA, EHVR)	
H/V (SH)	

Dispersion curves

	Rayleigh	*Love*
Min wavelength (m)	10	
Max. wavelength (m)	121	
Min. phase vel. (m/s)	430	
Max. phase vel. (m/s)	850	
Modes (R0, L0, ...)	R0, L0	

H/V or Ellipticity curves

Min. frequency (Hz)	Max. frequency (Hz)

Inversion

Rayleigh waves	Love waves	Ellipticity curves	H/V (DFA, EHVR)	H/V (SH)	resonance frequency
✔					

A priori information used in inversion	seismic refraction	stratigraphic log	geotechnical information	water table depth
		✔		

Inversion algorithm/code	dinver
Reference	Wathelet M (2008) An improved neighborhood algorithm: parameter conditions and dynamic scaling. Geophys Res Lett 35(9) https://doi.org/10.1029/2008GL033256

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Non-invasive : body waves methods

Experiment date [DD/MM/YY]	Distance from station [m]		Lat. [WGS84] center location	Lon. [WGS84] center location
	Min	Max		

Acquisition layout

Receiver spacing (m)	
Profile length (m)*	
Geophones number	
Number of profiles	
Shot spacing (m) - reflection meas.	

** Provide the length for the various profiles (e.g. 46 m, 94 m)*

Geophone cut-off frequency (Hz)	
Geophone type (vertical / horizontal)	
Geophone manufacturer	
Source (hammer, vibrator, ...)	
Digitizer type	
Digitizer manufacturer	

Weather conditions	Sunny	Windy	Rain	Soil-sensor coupling	Earth	Asphalt	Artificial	Urbanization	None	Dense	Scattered

Processing methods

	Reference paper (Name, Journal, DOI)
classical refraction	
refraction tomography	
classical reflection	
advanced method	

Invasive methods

	Down-Hole	Cross-Hole	PS-Logging	SPT	CPT	OTHER
Borehole depth (m)						
Geophone type						
Source type						
Distance between wells						
Depth resolution (m)						
Latitude (WGS84)						
Longitude (WGS84)						
Distance from station (m)						
P-wave velocity						
S-wave velocity						

Processing methods

	Reference paper (Name, Journal, DOI) or ASTM norm
Down-Hole	
Cross-Hole	
PS-Logging	
SPT	
CPT	
OTHER	

Authoritative velocity profile

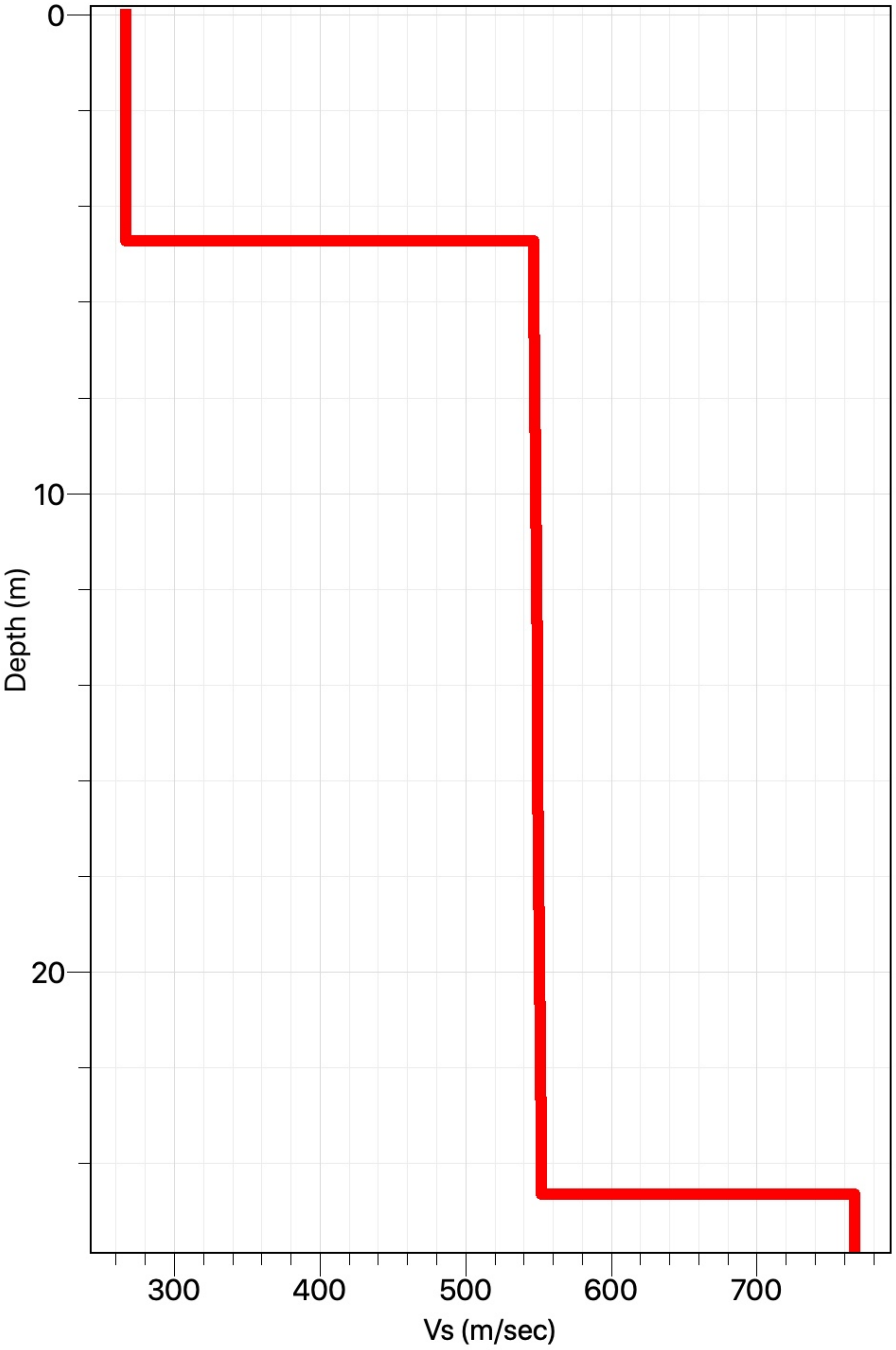
Note: You do not have to fill in all the columns. You can provide either single values for Vp or Vs (e.g. profiles derived from borehole measurements) or either a range for Vp and Vs (e.g. profiles derived from stochastic surface waves inversion)

Is Vs derived from Vp ?	Yes	No ✔

Top depth (m)	Bottom depth (m)	Vp (m/s)	STD Vp (m/s)	Vs (m/s)	STD Vs (m/s)
0	3.53	480		260	
3.53	6.42	907		378	
6.42	20.39	1715		628	
20.39	30	2359		973	

Vs range		Vp range	
Vs min (m/s)	Vs max (m/s)	Vp min (m/s)	Vp max (m/s)

Figure with authoritative velocity profiles



0
10
20
Depth (m)
300
400
500
600
700
Vs (m/sec)

Surface geology

Quality index 1	1

Source	Cartography (geological, lithological, ...)	Field survey	Stratigraphic log

Geological map

Map reference	Carta geologica dell'area di Colfiorito-Geologica map of the Colfiorito area. 1:25000 Servizio Geologico e Sismico-Regione Umbria - Barchi et al., 201	
Map scale	1:25.000	
Map sheet	Carta geologica dell'area di Colfiorito-Geologica map of the Colfiorito area.	
Predominent geologic/lithologic unit	Name :	Scaglia Rossa
	Description :	Pink, dark red or white marly limestone, calcilutites and marls, with red or pink chert in nodules and ribbon. Thick grey or white calcarenites levels are also present.
	Age :	Turonian p.p. - Lutetian p.p.
	Thickness :	150-300 m
	Rock mass structure :	Decimeters rock strata
Fault presence		
Weathering		
Cross-section	✔	

Field survey

Map reference	Working group INGV "Agreement DPC-INGV 2019-21, All.B2- WP1, Task 2", (2020). Site characterization report at the seismic station IT.FOS - Foligno (PG)	
Map scale	1:25.000	
Predominent geologic/lithologic unit	Name :	Scaglia Rossa
	Description :	Pink, dark red or white marly limestone, calcilutites and marls, with red or pink chert in nodules and ribbon. Thick grey or white calcarenites levels are also present.
	Age :	Turonian p.p. - Lutetian p.p.
	Thickness :	150-300 m
	Rock mass structure :	Decimeters rock strata
Fault presence		
Weathering		
Cross-section	✔	

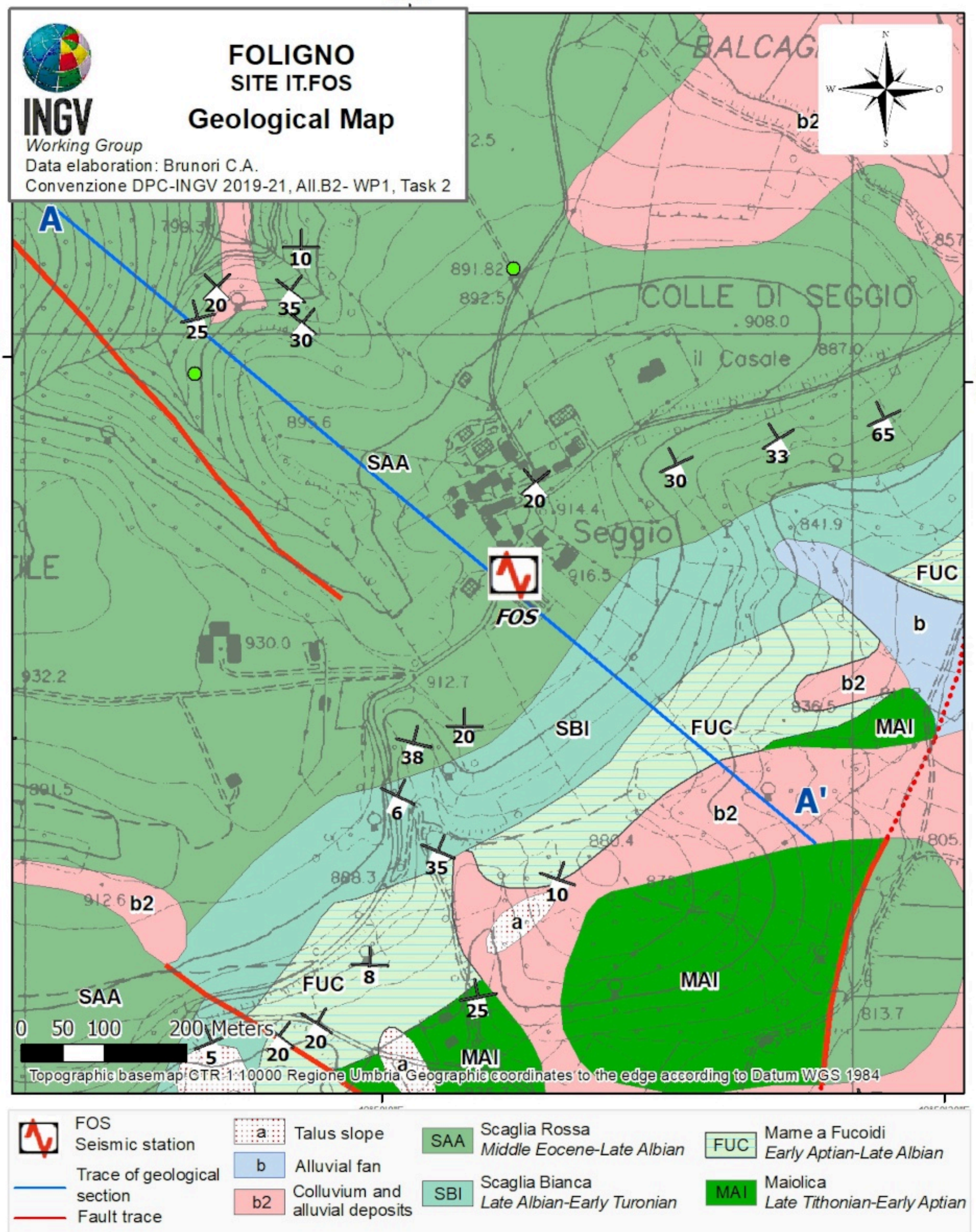
Stratigraphic log

log depth (m)	

Top depth (m)	Bottom depth (m)	Stratigraphic description
0	220	SAA - Scaglia Rossa
220	280	SBI - Scaglia Rossa
280	350	FUC - Marne a Fucoidi
350	600	MAI - Maiolica

Surface geology

Map


FOLIGNO
SITE IT.FOS
Geological Map
INGV
Working Group
Data elaboration: Brunori C.A.
Convenzione DPC-INGV 2019-21, All.B2- WP1, Task 2
A
A'
SAA
SBI
FUC
MAI
b2
b
a
FOS
COLLE DI SEGGIO
il Casale
Seggio
BALCAG
0 50 100 200 Meters
Topographic basemap CTR 1:10000 Regione Umbria Geographic coordinates to the edge according to Datum WGS 1984
FOS Seismic station
Trace of geological section
Fault trace
a Talus slope
b Alluvial fan
b2 Colluvium and alluvial deposits
SAA Scaglia Rossa Middle Eocene-Late Albian
SBI Scaglia Bianca Late Albian-Early Turonian
FUC Mame a Fucoidi Early Aptian-Late Albian
MAI Maiolica Late Tithonian-Early Aptian

Site class

Site class	B
Quality index 1	0.67

Reference building code for site classification (EC8-1, EC8-2, NEHRP, national code, ...)

Source	Geophysical measurements ✔	Geotechnical measurements	Digital Elevation Model (DEM)	Geology	DEM & Geology

Reference relationship geology - soil class	NTC18: Ministero delle Infrastrutture e dei Trasporti (2018). Aggiornamento delle Norme Tecniche per le Costruzioni. Part 3.2.2: Categorie di sottosuolo e condizioni topografiche, Gazzetta Ufficiale n. 42 del 20 febbraio 2018 (in Italian).
Reference relationship slope from DEM - soil class	
Reference relationship slope from DEM - geology - soil class	

Parameters for deriving soil class as prescribed in building code	Vs30, bedrock depth and its mean Vs (Vs equivalent)

Seismological bedrock depth

Depth +/- STD [m]	
Quality index 1	

Source	Vs profiles	Geology	Other (gravity, seismic refraction, TDEM, ...)
	Resonance frequency	Stratigraphic log	

Vs profile

	Non-invasive methods	Invasive seismic methods	Geotechnical methods
Bedrock depth +/- STD(m)			
Bedrock Vs +/- STD(m)			
Bedrock Vp +/- STD(m)			
Is Vs derived from Vp ?	Yes	No	

Resonance frequency

Bedrock depth +/- STD(m)	
Reference relationship Fo - bedrock depth	

Geology

Bedrock depth +/- STD(m)	
Bedrock geological unit	
Reference	

Stratigraphic log

Bedrock depth +/- STD(m)	
Bedrock geological unit	
Reference	

Other methods

	Bedrock depth +/- STD(m)	Reference
Gravity		
Seismic refraction		
Seismic reflection		
TDEM		

Engineering bedrock depth

Depth +/- STD [m]	20.4
Quality index 1	0.67

Reference Vs related to engineering bedrock in m/s	>=800

Reference building code for site classification (EC8-1, EC8-2, NEHRP, national code, ...)

Source	Vs profile	Geology	Stratigraphic log
	✔		

Vs profile

	Non-invasive methods	Invasive seismic methods	Geotechnical methods
Bedrock depth +/- STD(m)	20.4		

Is Vs derived from Vp ?	Yes	No ✔

Geology

Bedrock depth +/- STD(m)
Bedrock geological unit
Reference

Stratigraphic log

Bedrock depth +/- STD(m)
Bedrock geological unit
Reference

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