ISTITUTO NAZIONALE DI GEOFISICA E VULCANOLOGIA

Site characterization report at the seismic station IV.MOCO – Biccari Monte Cornacchia (FG)

Report di caratterizzazione di sito per la stazione sismica IV.MOCO – Biccari Monte Cornacchia (FG)

Working Group **Geology:** Luigi ZARRILLI, Raffaele MOSCHILLO **Geophysics**: Maurizio VASSALLO, Giuseppe DI GIULIO, Stefania PUCILLO, Rocco COGLIANO, Gaetano RICCIO	Date: December 2021
Subject: **Final report illustrating the site characterization for seismic station IV.MOCO**	

Convenzione DPC-INGV 2019-21, All.B2- WP1, Task 2: "Caratterizzazione siti accelerometrici" (Coord.: G.Cultrera, F. Pacor)
Cite as: Working group INGV "Agreement DPC-INGV 2019-21, All.B2- WP1, Task 2", (2021). Site characterization report at the seismic station IV.MOCO – Biccari Monte Cornacchia (FG) http://hdl.handle.net/2122/15101

INDEX

Introduction 3

A. Geological setting 4-12

1. Topographic and geological information 4
2. Geological map 6
3. Lithotechnical map 7
4. Survey map 8
5. Geological model 9

B. Vs profile 13-23

1. Geophysical Investigations 13
2. Seismic Velocity Model 20
3. Conclusions 22

References 24

Disclaimer and limits of use of information 25

Appendix: Summary Report 26

INTRODUCTION

In this report we present the geological setting and the 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 IV.MOCO (Biccari Monte Cornacchia - FG).

Location and coordinates are reported in Table A1.

Table A1.

CODE	NAME	LAT [°]	LON [°]	ELEVATION [m]
IV.MOCO	BICCARI - MONTE CORNACCHIA (FG)	41.37000* 41.370980***	15.15800* 15.158541***	1049** 1034***
ADDRESS	SP129, Biccari FG, Italy			

* Coordinates from ITACA (Nov. 2019) **Elevation from CTR 5k Regione Lazio
*** Coordinates measured during the geophysical survey (for the station site characterization) performed on 12 October 2021

A. Geological setting

A1. TOPOGRAPHIC AND GEOLOGICAL INFORMATION

Topographic information related to the site are reported in Table A2. Table A3 summarizes all available geological maps from literature for geological analyses.

Table A2.

Topography	Description	Topography Class	Morphology Class	EC8 Class
	Slopes with average slope angle i>15°	T2	SL	B

Table A3.

Geological map	Source	Scale
IV.MOCO	Geological map of Italy 1:100.000- sheet 163- Lucera	1:100.000

In Table A4 Geological, Lithotechnical Units are described and are concerned to maps of following chapters. The term “deduced” means the result comes from an interpretation of a preexisting data according to the nomenclature of Seismic Microzonation classification; Technical Commission MS, 2015.

Table A4

GEOLOGICAL UNITS		LITHOTECHNICAL UNIT	
deduced. According to the nomenclature of geological map of Italy 1:100.000- sheet 163 - Lucera.		(MZS) *original*	
code	**description**	**code**	**description**
bcD	Daunia Formation (Lower Miocene). On the top: White limestones with intercalations of compact or leafy calcarenites. in the middle part: calcareous marls with brown flint lenses alternating with gray clays. Lower part: quartz sandstones with intercalations of calcarenites and clayey marls.	SFLPS	layerd stone, fractured/altered

A2. GEOLOGICAL MAP

In Figure A1 Geological Map is reported in a 1kmx1km square around the station.

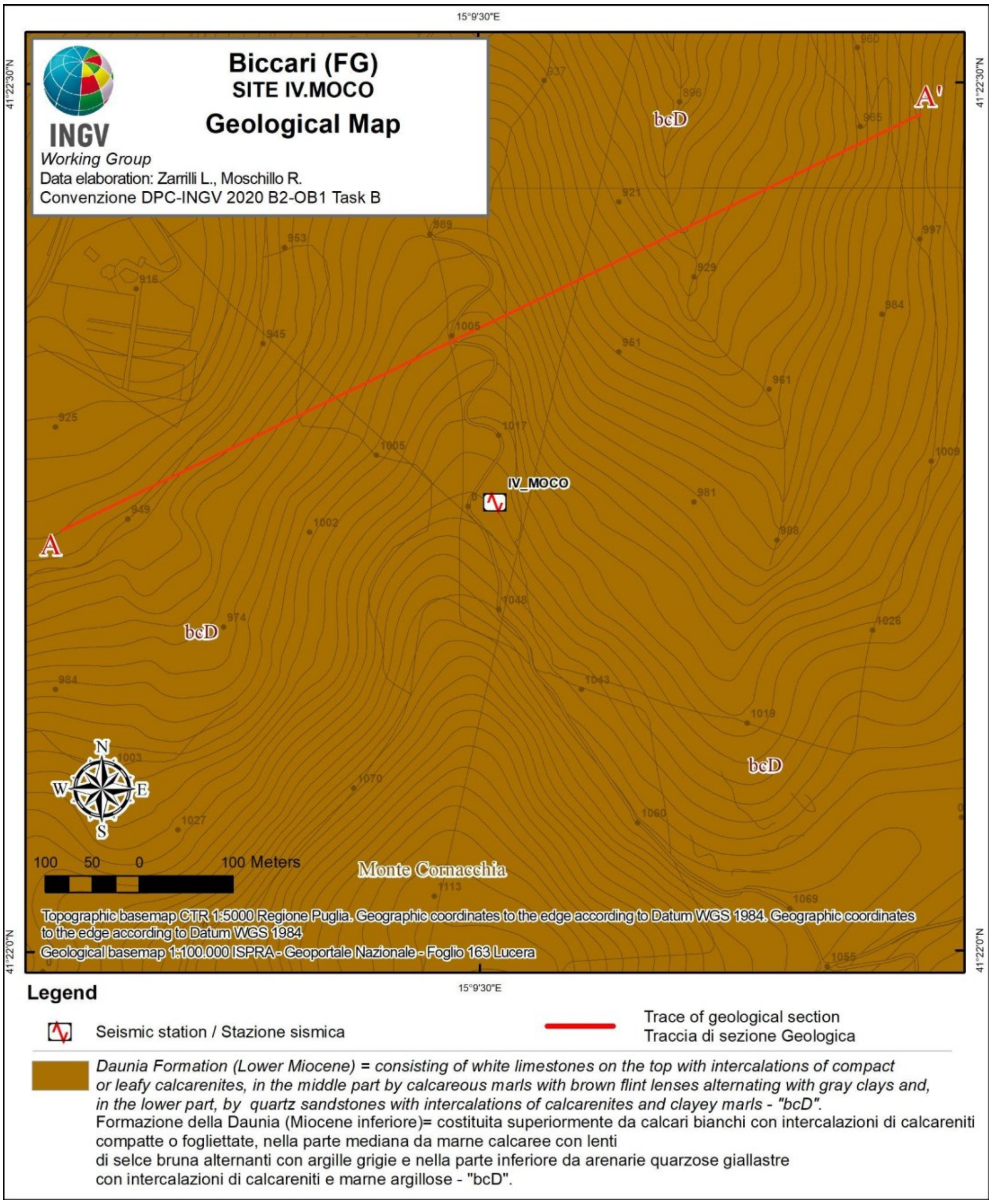


Figure A1. Geological map of seismic station IV.MOCO. Scale 1:5.000. Geological units are established according to the nomenclature of geological map of Italy 1:100.000 (Sheet 163-Lucera).

A3. LITHOTECHNICAL MAP

In Figure A2 Lithotechnical Map is reported in a 1kmx1km square around the station.

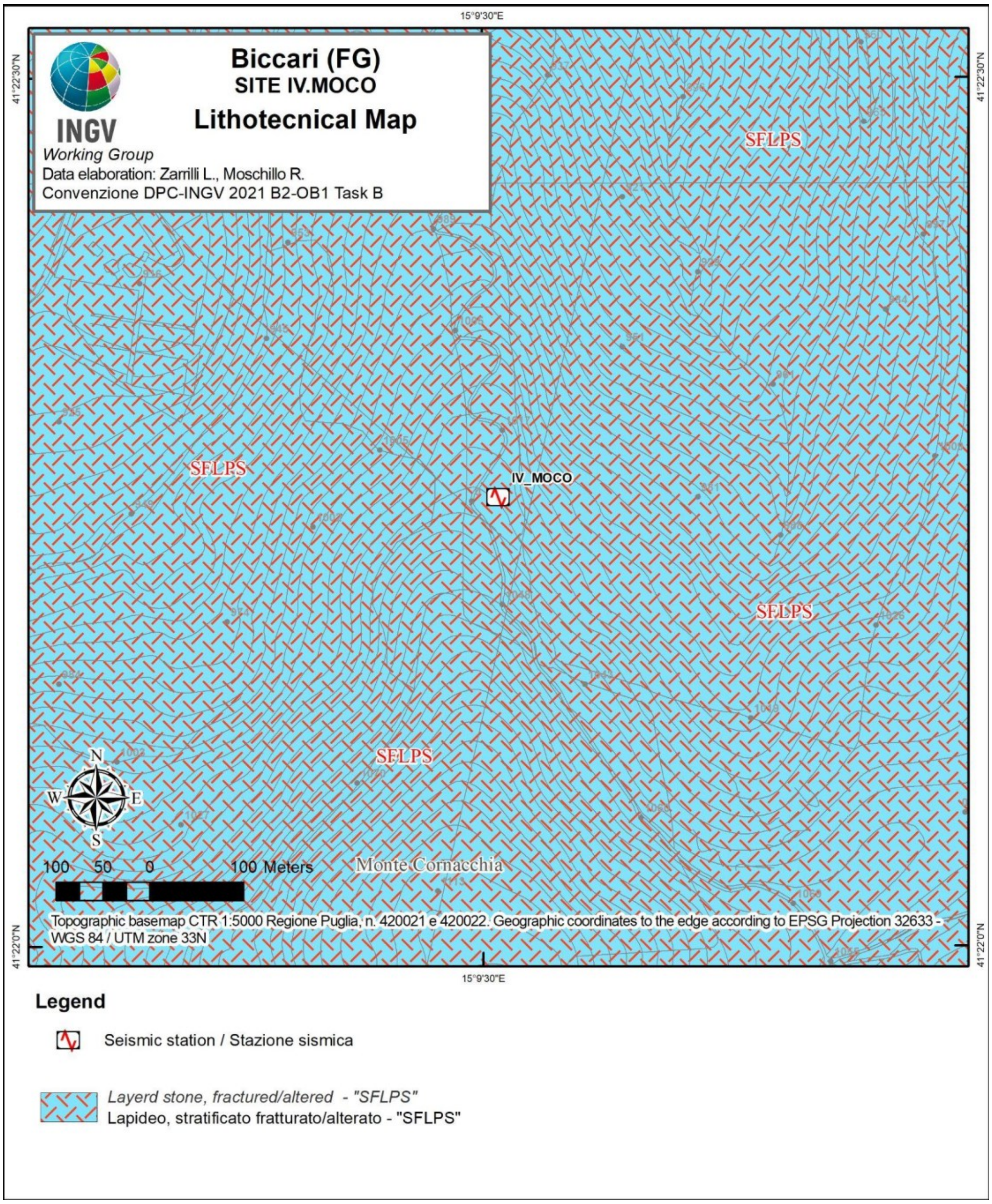


Figure A2: Lithotechnical map of the seismic station IT.MOCO. Scale 1:5.000. The lithotechnical units are deduced according to the nomenclature of Seismic Microzonation (Technical Commission MS, 2015).

A4. SURVEY MAP

Figure A3 shows the survey Map reported seismological investigations (geophysical measurements) realized by the INGV working group, and finalized to the realization of the geophysical report for the seismic station IV.MOCO.
So, have been installed a 2D array of seismic stations in passive configuration on the mountainside of Monte Cornacchia for studies of site seismic characterization of IV.MOCO station.

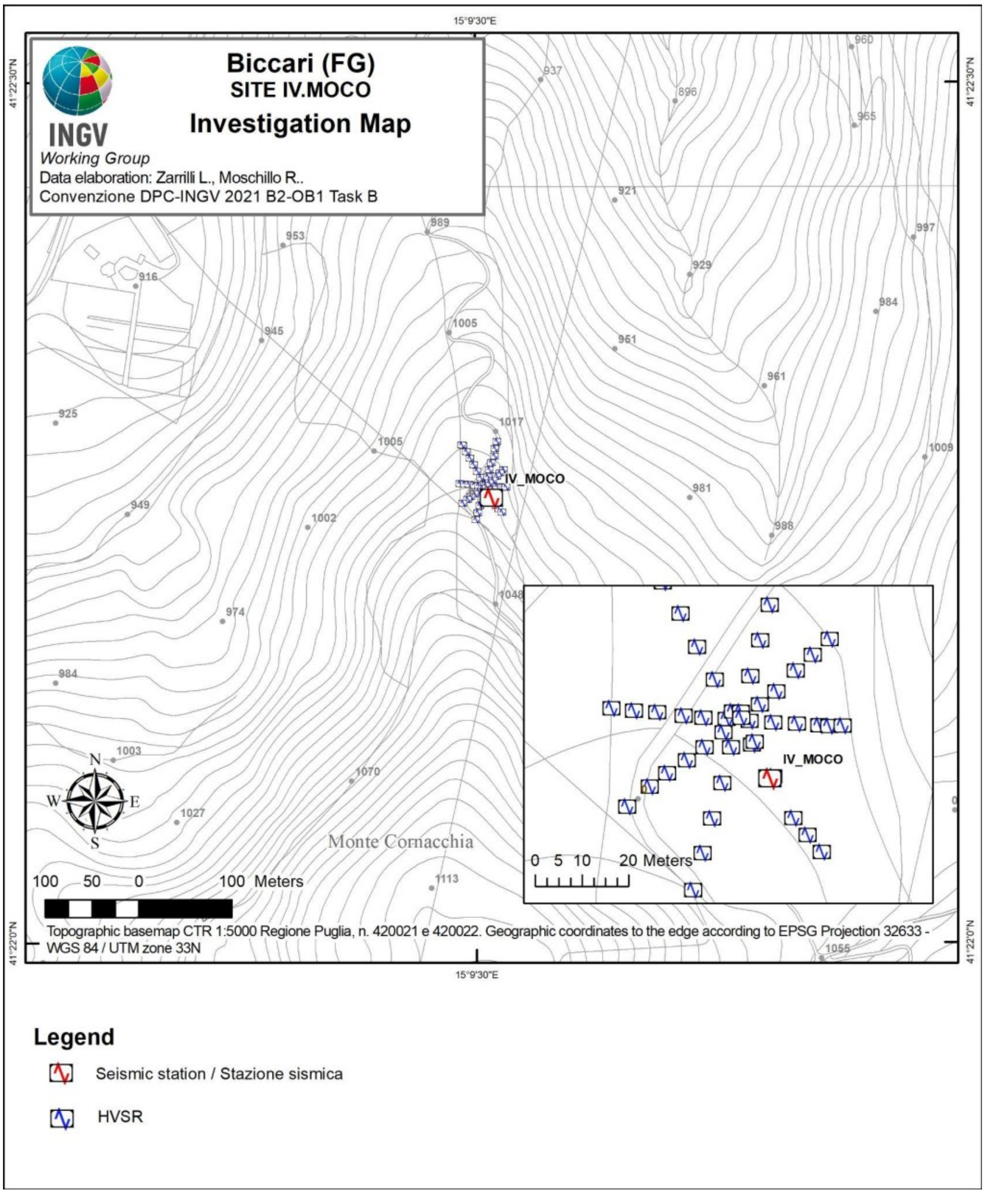


Figure A3: Map of the surveys near the station IV.MOCO. Scale 1: 10.000. The box at the bottom right contains a zoom of the area with the detail of the inside investigations conduced in the area.

A5. GEOLOGICAL MODEL

A5.1 General description

The area affected by the present work is characterized by the presence of continental colluvial Olocene deposits resting on Miocene marine sediments.

A5.2 Geology of the area.

During the geological survey of the area the following stratigraphic terms were identified:

- Continental Quaternary deposits - Olocene. Colluvial materials.

This kind of continental deposits derive from the disintegration of the materials of the Daunia formation, which constitutes the slopes under study.

The geologic characteristics of the “Daunia Formation” are clarified below.

- “Daunia Formation” (Lower Miocene). Marine Miocene deposits.

Consisting of white limestones on the top with intercalations of compact or leafy calcarenites, in the middle part by calcareous marls with brown flint lenses alternating with gray clays and, in the lower part, by quartz sandstones with intercalations of calcarenites and clayey marls.

So, generally, we can say that the reliefs of the area are characterized, for the most part, by colluvial materials, in the middle-upper part of the slopes resting on Miocene marine sediments known as “Daina Formation” (Lower MIocene).

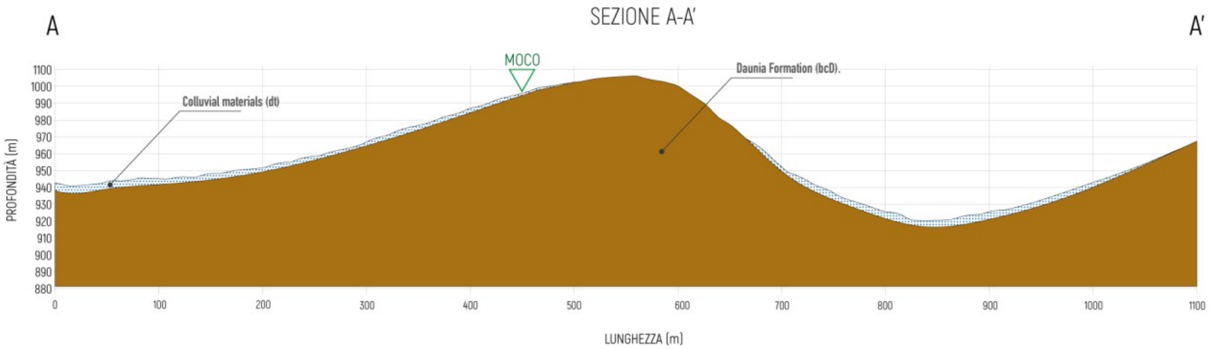


Figure A4: Geological cross section: A-A'.

Structural Geology

According to what reported in the official geological cartography (Geological Map of Italy scale 1: 100.000 - 163 -Lucera) the area under examination is not affected by large tectonic discontinuities and, during the surface geological survey, no faults were identified or other tectonic elements, that could compromise the stability of the area.

The only contact of probable tectonic origin is present in the East North-East part of the surveyed area, and puts the lithotypes of the early Miocene Daunian formation in contact with the clayey sands of the Middle Pliocene (Geological map of Italy sheet 163 - Lucera).

A5.3 Geological Section

A knowledge of the station site subsurface is available, thanks to:

1. geological knowledge of the area
2. drilling for the installation of the MOCO geodetic station, for the INGV GPS integrated National GPS network (RING).
3. seismological investigations (geophysical measurements) realized from the INGV geophysic working group, and finalized to the realization of the geophysical report for the seismic station of MOCO (Biccari, FG).

Looking at results we can see that the shallower portion (2-2,5 m) consists in altered and pedogenizedsandy clayey gravels deriving from the alteration of the lithotypes that make up the reliefs and slopes and, as already mentioned, belong to the "Daunia Formation".
Under these colluvial materials there are white limestones with intercalations of compact or leafy calcarenites up to the depth of 17-20 meters, followed by calcareous marls with flint lenses alternating with greyish clays and then quartz sandstones with intercalations of calcarenites and clayey marls, up to a depth of about 60 meters.
Ultimately, the "Daunia Formation" consists of a continuous calcareous-clastic succession from the Upper Cretaceous to the Upper Messinian, mostly turbiditic, originating in an environment of transition between slope and basin.

A5.4 Subsoil model

A subsoil model is built up a depth of 50-60 m for the area around the IV.MOCO station (Figure A5) based on geological information and on results obtained from the geophysical survey performed around the IV.MOCO station by INGV Working Group on 12 October 2021 (described below in this report). In according to geophysical results, the substrate consists of layered stone, fractured/altered, belonging to the "Daunia Formation".

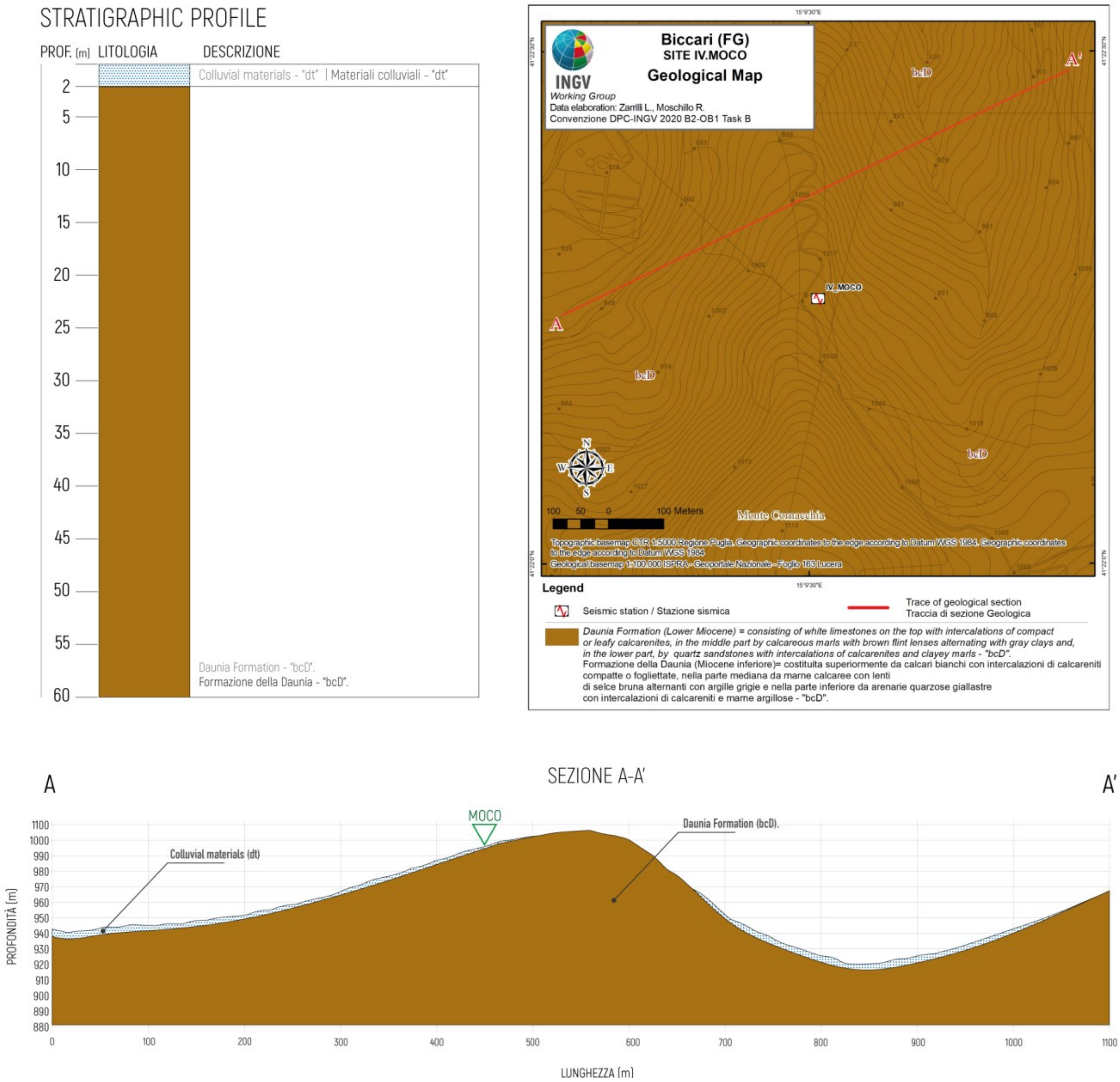


Figure A5: Geological Map (a). Subsoil model under the IT.MOCO seismic station according to seismic and geotechnical investigations (b). Geological cross section (c).

B. Vs profile

B1. GEOPHYSICAL INVESTIGATIONS

With the aim of determining a 1D-velocity model representing the subsoil underlying the seismic station, we performed geophysical investigations in the area around the IV.MOCO seismic station. We installed a 2D array of seismic stations in passive configuration on the mountainside of Monte Cornacchia (Biccari - FG) for studies of site seismic characterization of IV.MOCO station (the permanent station is locate in the center of the 2D array). Figure B1 shows the location of 2D array and of two temporary seismic stations deployed in the target area near to the IV.MOCO station (red triangle).

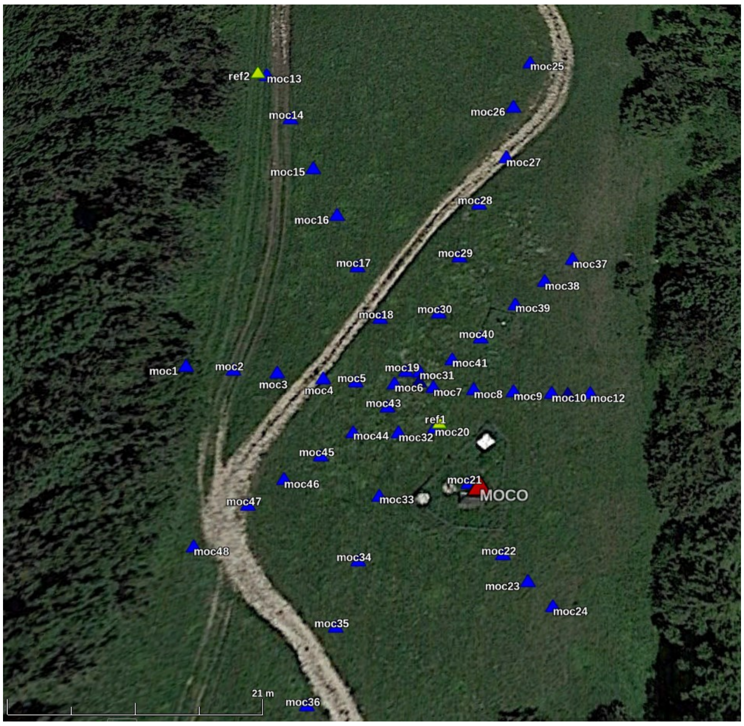


Figure B1: Map of Biccari Monte Cornacchia - FG (image from Google Earth http://www.earth.google.com) showing: the position of IV.MOCO station (red triangle), the temporary 2D array composed by 48 geophonic tri-axial stations (blue triangles) and the positions of temporary seismic stations installed during the survey (green triangles).

The geophysical survey were performed around the permanent seismic station, the temporary seismic instruments were installed trying to make the most efficient use of the area around the station. The array stations were located in the investigated area following a two-dimensional geometry with irregular spacing, as shown in Figure B1. The survey was performed using the data acquired by 48 tri-axial geophones (named as mocXX in figure B1, with natural frequency of 4.5 Hz) and two temporary seismic stations equipped by a Lennartz-5s sensor and a Reftek130 digitizer (named as REFX in Figure B1). Measurements were acquired on 12 October 2021 with unstable weather, initially sunny and then cloudy with the occurrence of moderate wind. Figure B2 shows some pictures taken during the performed measurements.

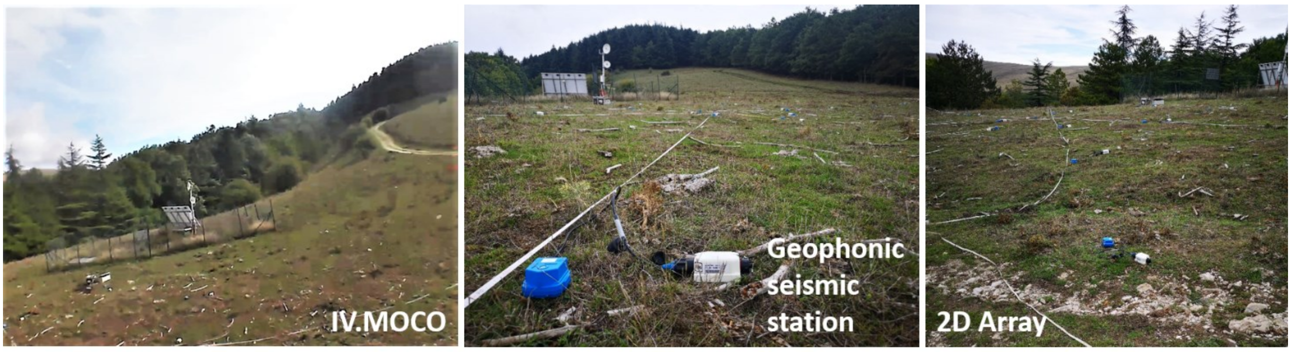


Figure B2. Pictures taken during the measurements day: (left) site hosting the IV.MOCO seismic station; (middle) examples of temporary seismic stations in ambient noise acquisition installed on 12 October 2021; (left) 2D array installed in the same date.

B1.1 HV noise spectral ratios

The temporary seismic stations acquired the data for about 3.5 hours that were used to compute the H/V spectral ratios at different measurement points. Figure B3 shows the H/V computed for all the 48 geophonic stations, for the 2 temporary seismic stations (REFX in figure B1) and for IV.MOCO permanent seismic station. The amplitudes of the H/V spectral ratios are very different from each other with the stations equipped with the geophonic sensors (mocXX) providing, on average, larger spectral ratio amplitudes than stations equipped with the 5s sensor (REFX) and IV.MOCO station. This could be related to the instrumental bandwidth that for geophonic sensors is more limited (starts from 4.5 Hz upwards) compared to the other sensors. Beyond the amplitudes, the spectral shapes of the different H/V results are quite similar to each other and emphasize a broad peak at frequencies between 1 Hz and 1.7 Hz. The figure B4 shows the areal distribution of peak amplitudes for the different measurement points. The areal distribution shows that the anomalous peak frequencies are not focused in one or a few limited areas but they appear in a scattered manner in different positions of the array. This observation supports the hypothesis that these differences can be attributed to the type of sensor used in survey and its limited bandwidth.
Figure B5 shows the results of directional H/V spectral ratios performed for all the temporary stations and IV.MOCO permanent station. For IV.MOCO, REF1 and REF2 stations the results of rotated H/V spectral ratios evidence a quite coherent polarization effect (Figure B4) with

maximum amplification along between N70° and N100° direction. Also considering the other temporary geophonic stations (mocXX), we can note that, in most cases, also for them the peak between 1 Hz and 1.7 Hz has a polarization effect whose maximum appears in the EW direction, consistent with the previously cited broader bandwidth stations (REFXX and IV.MOCO). Considering the information collected from directional analysis, as well as the absence of a deep stratigraphic log, in this stage, we exclude that the peak between 1 Hz and 1.7 Hz could be caused by a stratigraphic effect with a velocity contrast at depth.

Unfortunately, the results obtained by H/V on geophonic temporary station do not provide usable results for studying areal variability in spectral ratios. The interpretation of the patterns of the H/V curves needs to be thorough studied in further investigations that are beyond the goal of the present report.

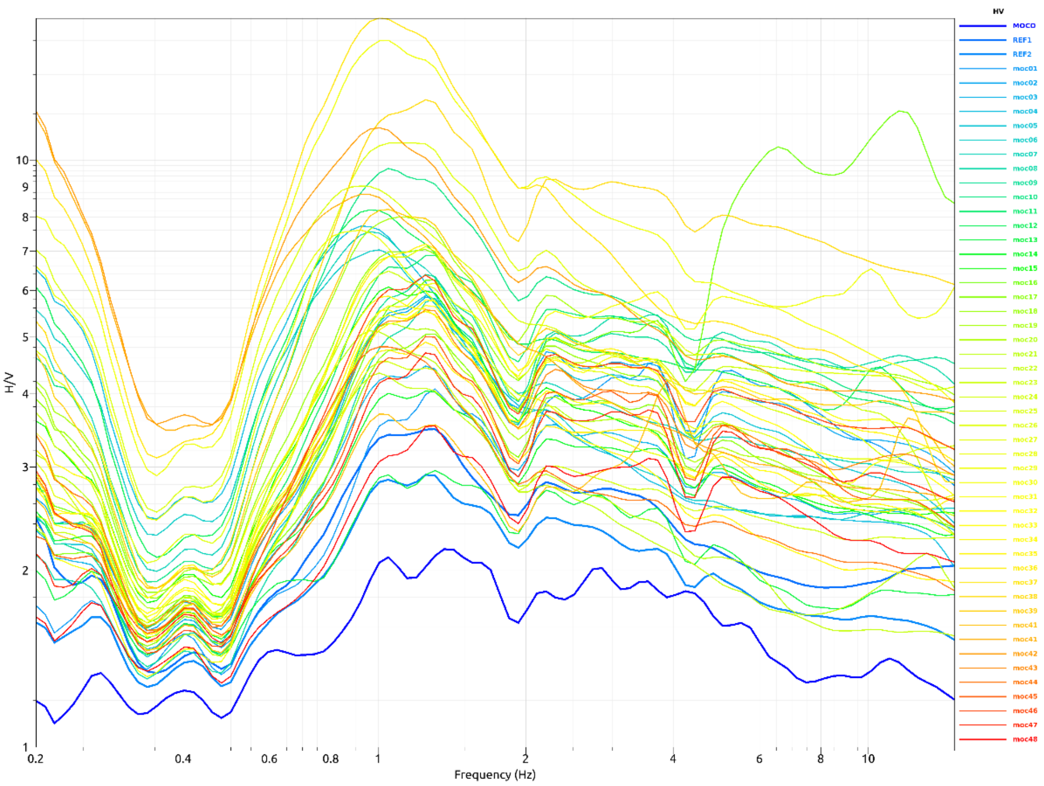


Figure B3. Results of H/V analysis performed on data acquired at 50 temporary seismic stations and at IV.MOCO station, during the geophysical survey. The mean H/V spectra are shown in different colors associated to the measuring stations.

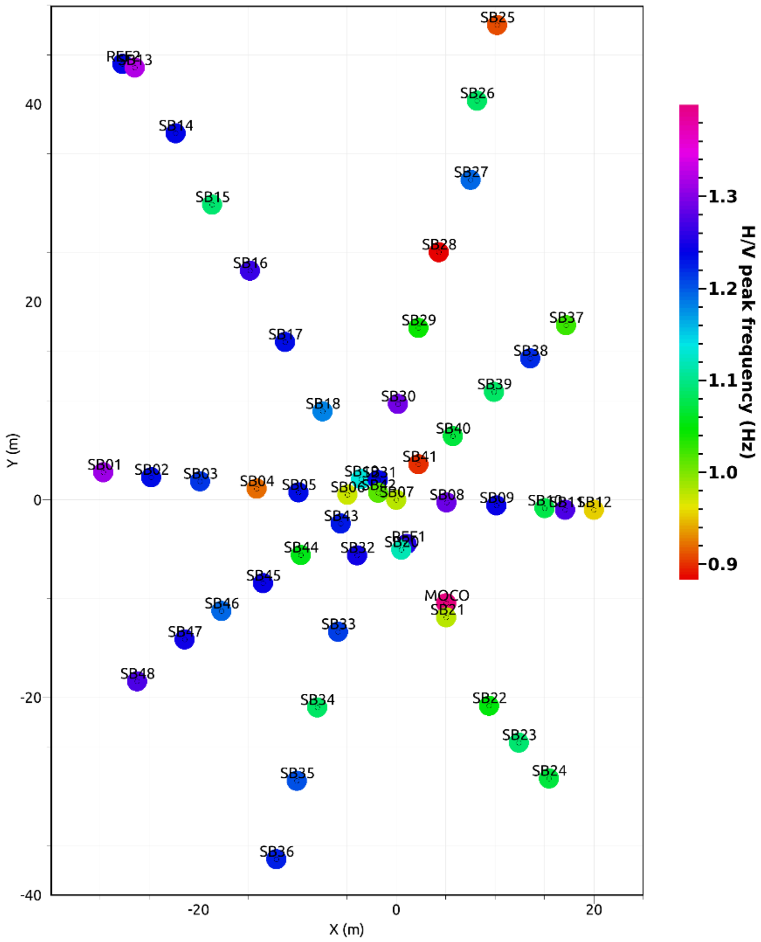


Figure B4. Areal distribution of peak frequencies for the different measurement points.

Results from spectral ratio analysis on data acquired at permanent IV.MOCO station during the ongoing geophysical survey are in fair agreement with those produced for the two temporary broader band stations REFXX. The differences between these latter stations mainly concern the HV amplitude associated with the peak between 1 Hz and 1.7 Hz. We can hypothesize that the different type of installation of the stations (for the permanent one, the sensor is in a shallow well and placed on a pillar embedded in the ground) may influence the recording, but this hypothesis needs future investigations. For now, we prefer to consider the results produced analyzing the permanent station data more robust than the temporary stations. In the following, we will therefore consider the spectral ratio of the permanent station IV.MOCO as representative of the investigated area.

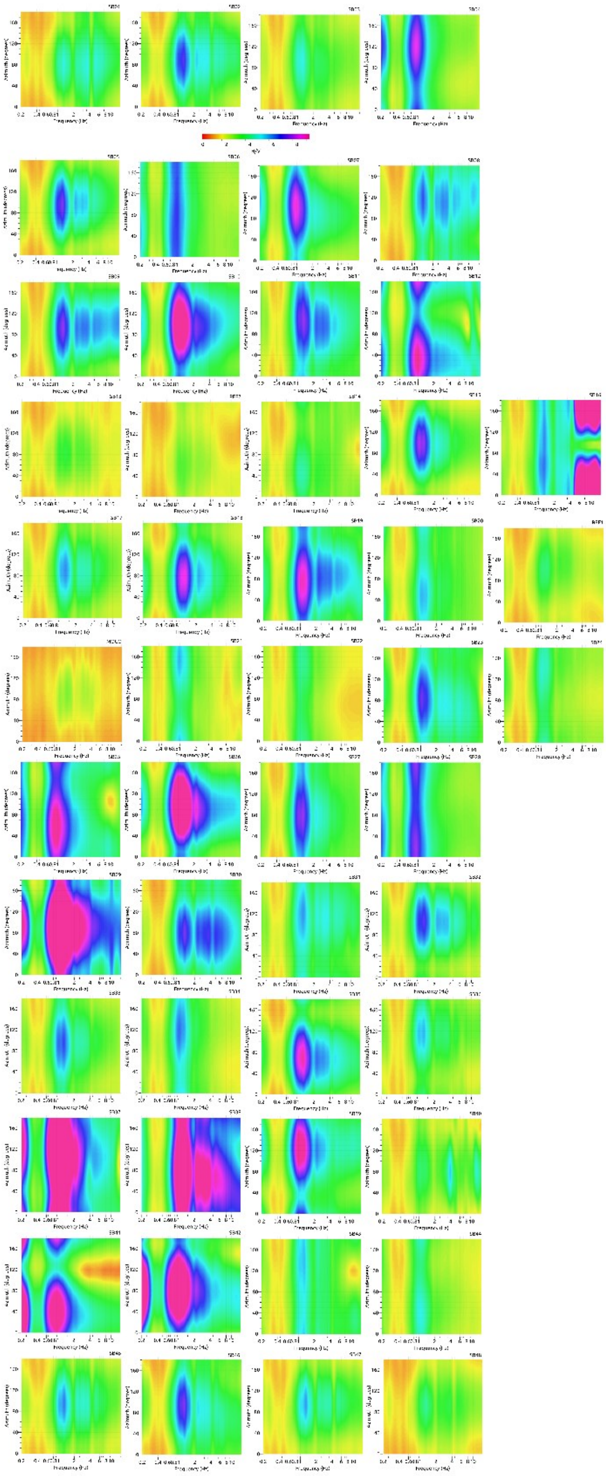


Figure B5: H/V spectral ratios obtained after rotating the two horizontal components by steps of 10°, from 0° to 180°. We show results obtained at all temporary seismic stations installed during the survey (the related name is shown at the top right of each sub-figure) and at the IV.MOCO permanent station.

B1.2 Dispersion curves from 2D array

The ambient vibration data acquired by 48 temporary geophonic stations (mocXX) were processed using the *GEOPSY* software tools (www.geopsy.org) in order to extract the surface-wave dispersion by applying to the seismic signals frequency-wavenumber (FK). The data of the array were analysed in terms of conventional frequency-wavenumber (FK) analysis applied to the vertical component. Figure B6 shows the dispersion results; the apparent phase-velocities are varying from about 1100 m/s (at 10 Hz) to about 500 m/s (at 36 Hz).
In order to obtain a new dispersion curve in a complementary way respect to the FK technique, a Cross-Correlation (CC) analysis was also applied to the vertical components of recordings and using an ad hoc software for velocity reconstruction (Vassallo et. al. 2019). Fig. B7 shows the computed cross-correlations functions (organized according to the distance between station pairs) and the results of the velocity analysis performed on CCs.

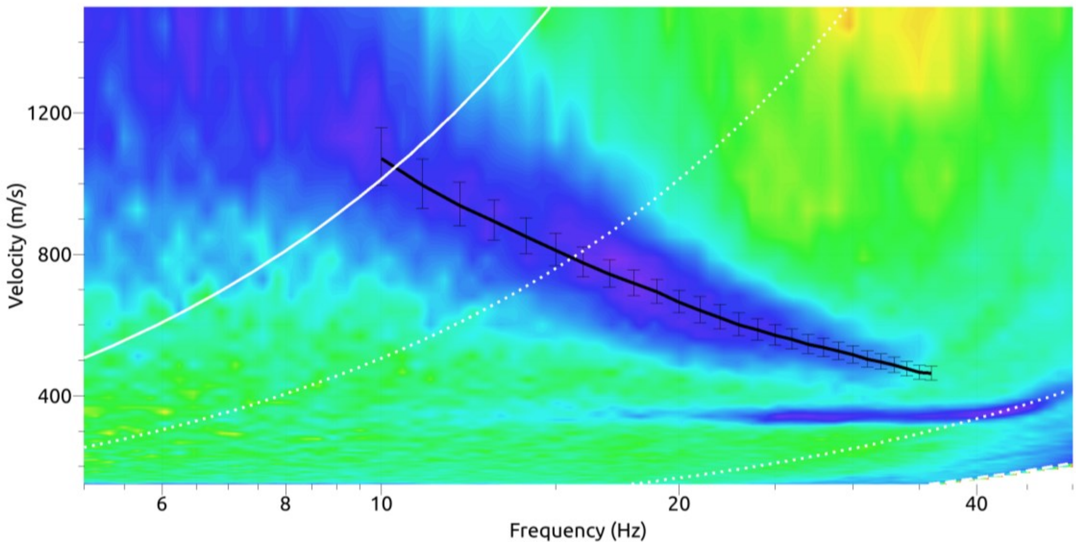


Figure B6: Picked dispersion curve (black line) in the velocity-frequency plan from the FK analysis applied to the vertical component of array measurements. The theoretical resolution (Kmin/2, Kmin) and alias limits (Kmax/2, Kmax) are overlaid as white (continuous and dashed) curves.

Specifically, the array data were processed using one-bit normalization and spectral whitening (Bensen et al. 2007). Then, the cross-correlation functions were computed for the processed traces at the different station pairs of arrays (Fig. B7 top panel). To compute the dispersion curve of the seismic signals, we applied a Constant Velocity Stack (CVS) analysis (Yilmaz, 1987) to the CCs functions (Fig. 7 bottom panel). The cross-correlation functions were filtered in different frequency bands starting from 5 to 50 Hz. For each band, the cross-correlation functions were shifted back in time according to different constant velocities starting from 200 m/s until 2500 m/s using a velocity step of 10 m/s. For each frequency band and velocity correction, a Phase-Weighted Stack was computed, and the maximum of the stack function provided the velocity of surface waves at the considered frequency. The dispersion curve (black line in Fig. B7bottom) is identified on the basis of the maximum value of the stack function at each frequency, and shows a good agreement with the results of the f-k analysis. This method allowed us to extract information on the dispersion in the frequency band 8-30 Hz.

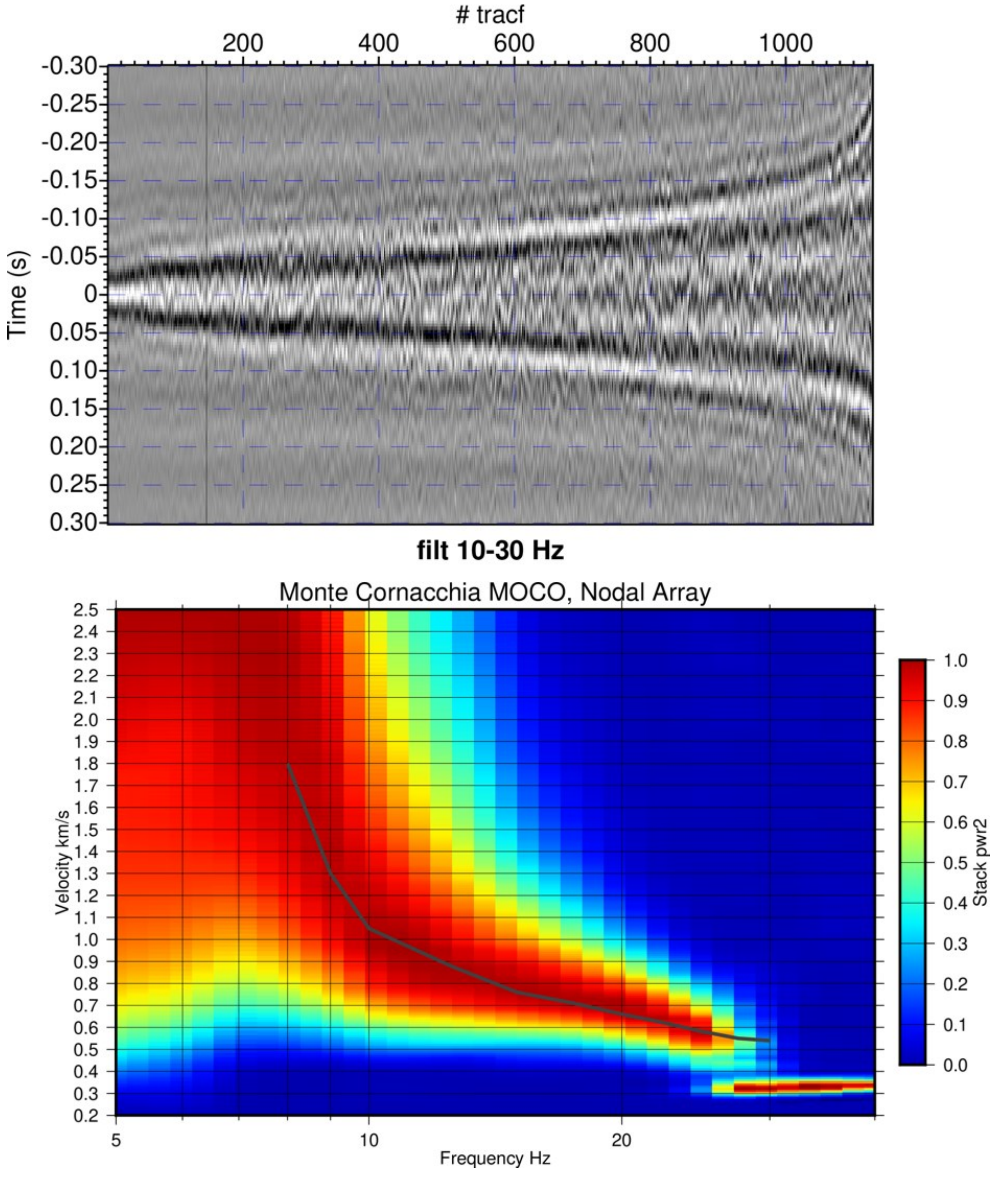


Figure B8. Results obtained by cross-correlation analysis performed on passive data acquired by vertical components of 48 geophones. Top: cross-correlation functions for the different station pairs and filtered in the band 10-30 Hz. Bottom: results obtained by Constant Velocity Stack analysis on cross-correlation functions, the black line represents the picked dispersion curve.

B2. Seismic Velocity Model

Figure B9 reports the two dispersion curves from the FK and CVS analyses performed on 2D array data. We combined all the picked dispersion curves from FK and cross-correlation analysis in order to obtain the final dispersion curve used as target in the inversion procedure (the green curve of Figure B9).

To proceed with the inversion step, the dispersion curve derived from the vertical component of motion was associated with the fundamental mode of surface Rayleigh-wave. Then, we inverted through the *GEOPSY* tool the apparent surface-wave dispersion curve for recovering the shear-wave velocity (Vs) model. We chose not to perform a join inversion of the dispersion and the H/V curve. In fact, the results from directional H/V analysis seems to suggest that the amplification peak at the site is not attributable to a stratigraphic effect with a velocity contrast at depth.

The resulting velocity models obtained from the inversion of the dispersion curve are shown in Figure B10. We tested several simple starting model-parameterization composed of different uniforms and linear velocity increase (with depth) layers over half-space, keeping in mind the limited depth of maximum investigation associated with our dispersion curve (in the range 70-100 m). The best Vp and Vs models (i.e. lowest misfit) resulting from the inversion are shown in Figure B11 and Table B1.

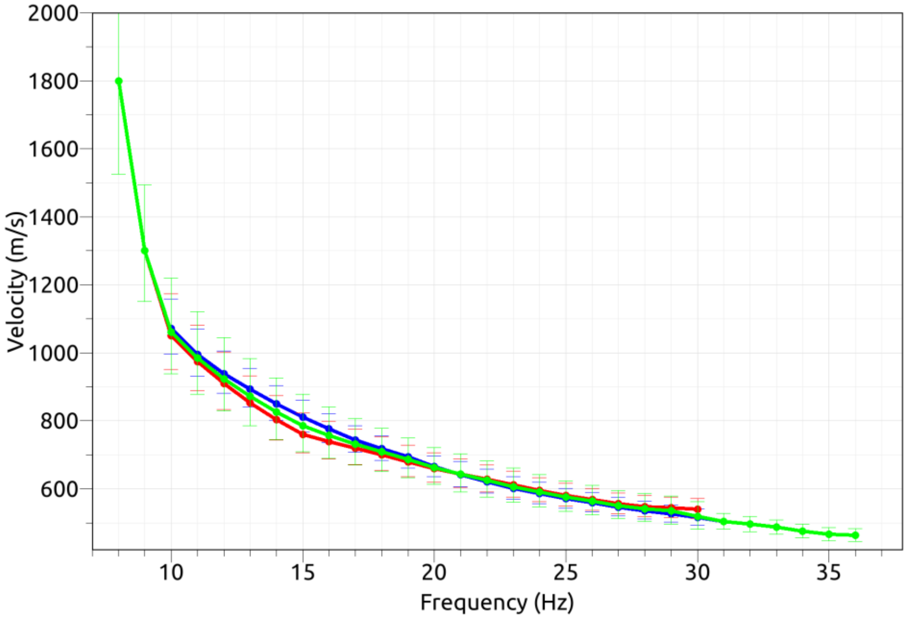


Figure B9. Dispersions curves from the FK (blue line) and CVS (red lines) results. The dispersion curve used as input data of inversion procedure (green line) is obtained by averaging the two dispersions from MASW (blue curve) and from CVS analysis (red curve).

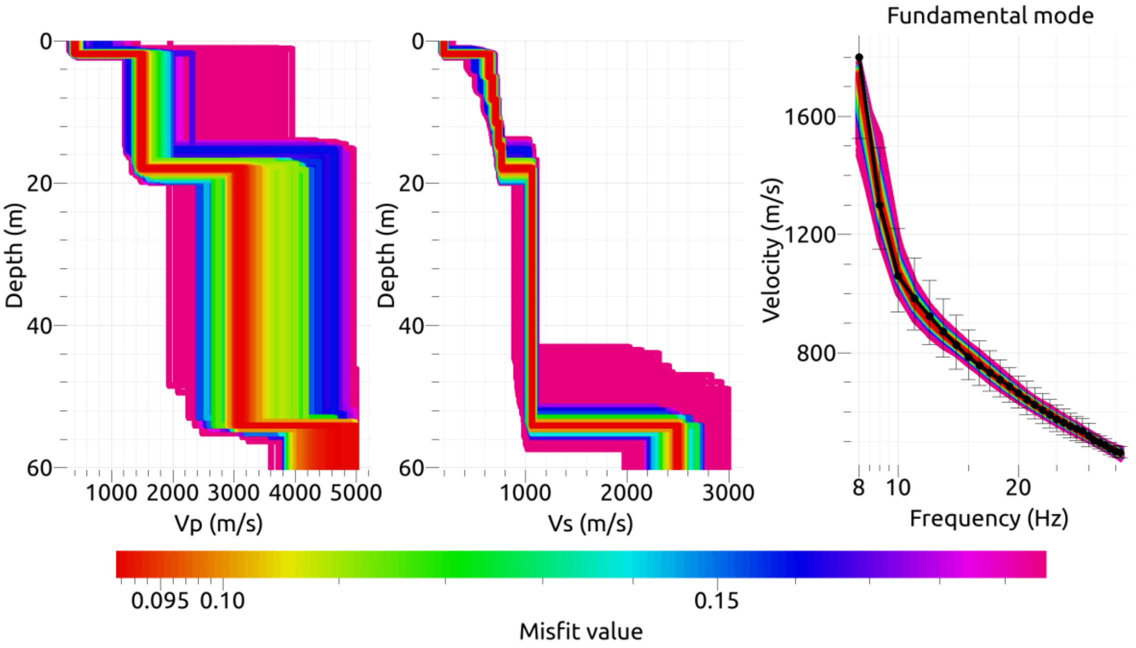


Figure B10. Models derived from the inversion of the experimental dispersion curve. Vp models on the left, Vs models in the middle and theoretical dispersion curves on the right (the experimental dispersion is shown in black). The color scale is proportional to the misfit between experimental curve and theoretical models. The best Vp and Vs model (i.e. lowest misfit) are presented in Figure B11.

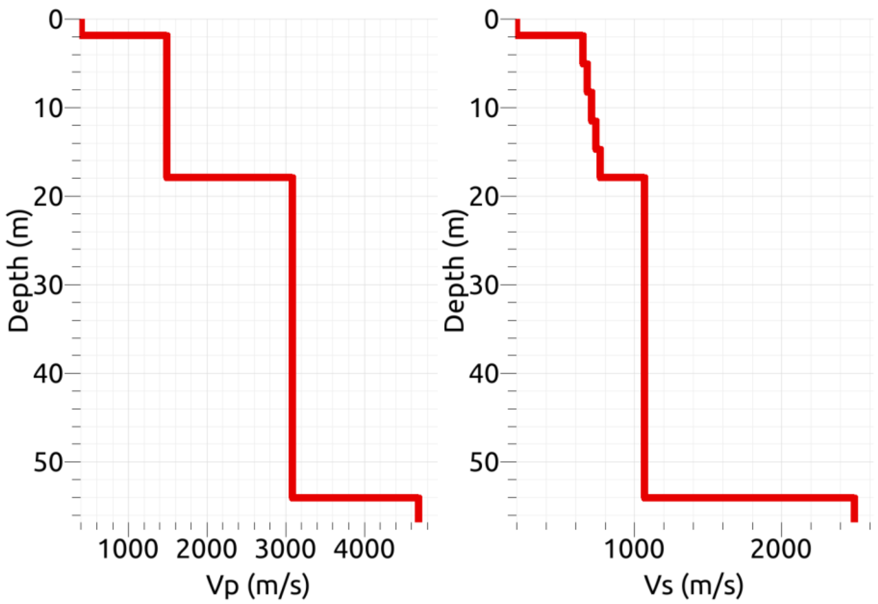


Figure B11. Best Vp and Vs models (among the models shown in Figure 15) obtained after the inversion of the experimental apparent surface-wave Rayleigh dispersion curve.

Table B1. Best-fit model

From (m)	To (m)	Thickness (m)	Vp (m/s)	Vs (m/s)
0	1.87	1.87	401.0	199.8
1.87	5.08	3.21	1489.7	649.9
5.08	8.29	3.21	1489.7	679.3
8.29	11.50	3.21	1489.7	708.8
11.5	14.71	3.21	1489.7	738.2
14.71	17.92	3.21	1489.7	767.7
17.92	54.09	36.2	3090.1	1068.1
54.09	--	--	4692.5	2498.0

B3. Conclusion

Surface-wave analysis performed at IV.MOCO station allow us to reconstruct the Vs velocity model for the characterization of the site. The best Vp and Vs models (i.e. lowest misfit) resulting from the inversion are shown in Figure B11 and Table B1.
The results from directional H/V analysis show that the peak from 1Hz and 1.7 Hz observed at temporary and permanent stations is characterized by a directional amplification effect with maximum amplification along between N70° and N100° direction. This suggests that the amplification peak at the site is not attributable to a stratigraphic effect with a velocity contrast at depth.
The analysis of passive data acquired at array of geophones provided a final dispersion curve from 8 Hz to 36 Hz (Figure B9), and the inversion procedure resulted in the Vs models of Figure B10 and B11 where the engineering bedrock is found at a depth of about 18 m (Table B1).
The V_{S30} retrieved from the best inverted model is 691.3 m/s (Table B2), therefore IV.MOCO is classified following EC8 or NTC08 as soil class B. Following the definition of $V_{S,eq}$ within NTC18, since the value of 800 m/s is reached at a depth of 17.92 m, $V_{S,eq}$ is equal to 558.6 m/s and the site can be related to class B.
We highlight that this site was already classified as B in the Itaca database, where in absence of direct velocity measurements the site classification was assigned only considering the outcropping lithotypes.
Further investigations will be needed to explore the disagreement in terms of H/V amplitude results obtained from the noise measurements at temporary stations and at the permanent IV.MOCO station. However, they are beyond the goal of the present study.

Table B2. f_0 value, and soil class following NTC08 and NTC18.

f_0 (Hz)	Note
1.4 Hz	The H/V peak is polarized between N70° and N100° directions.

V_{S30} (NTC08 or EC8)	Soil Class
691.3 m/s	B

$V_{S,eq}$ (NTC18)	Soil Class
558.6 m/s	B

REFERENCES

Bensen, G.D., Ritzwoller, M.H., Barmin, M.P., Levshin, A.L., Lin, F., Moschetti, M.P., Shapiro, N.M. and Yang, Y., (2007). "Processing seismic ambient noise data to obtain reliable broad-band surface wave dispersion measurements". Geophysical journal international, 169(3), pp.1239-1260.

Commissione Tecnica per la Microzonazione Sismica (2015). Microzonazione sismica. Standard di rappresentazione e archiviazione informatica, Versione 4.0b (Commissione tecnica inter-istituzionale per la MS nominata con DPCM 21 aprile 2011), PRG Comune di Biccari - Foggia - Italy

EC8: European Committee for Standardization (2004). Eurocode 8: design of structures for earthquake resistance. P1: General rules, seismic actions and rules for buildings. Draft 6, Doc CEN/TC250/SC8/N335.

Geological basemap 1:100.000 ISPRA - Geoportale Nazionale - Foglio 163 Lucera http://sgi.isprambiente.it/geologia100k/mostra_foglio.aspx?numero_foglio=163

Notes attached Geological map of Italy sheet 163 (Lucera) and geological survey

NTC 2018: 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).

Technical Commission SM, 2015 – Microzonazione sismica. Standard di rappresentazione e archiviazione informatica, Versione 4.0b (Commissione tecnica inter-istituzionale per la MS nominata con DPCM 21 aprile 2011).

Topographic basemap CTR 1:5000 Regione Puglia, n. 420021 e 420022. Geographic coordinates to the edge according to EPSG Projection 32633 - WGS 84 / UTM zone 33N

Vassallo, M., R. De Matteis, A. Bobbio, G. Di Giulio, G. M. Adinolfi, L. Cantore, R. Cogliano, A. Fodarella, R. Maresca, S. Pucillo and G. Riccio, (2019). Seismic noise cross-correlation in the urban area of Benevento city (Southern Italy). GEOPHYSICAL JOURNAL INTERNATIONAL, vol. 217, pp. 1524–1542, 2019. https://doi.org/10.1093/gji/ggz101

Yilmaz O. (1987). Seismic data processing in Investigations in Geophysics, 2: Soc. Expl. Geophys, series Eds., eds Doherty S.M., Neitzel E.B.

This study has benefited from funding provided by the Italian Presidenza del Consiglio dei Ministri - Dipartimento della Protezione Civile (DPC). This paper does not necessarily represent DPC official opinion and policies.

Lo studio presentato ha beneficiato del contributo finanziario della Presidenza del Consiglio dei Ministri - Dipartimento della Protezione Civile; la presente pubblicazione, tuttavia, non riflette necessariamente la posizione e le politiche ufficiali del Dipartimento.

[1]This document is level 3 as defined in the "Principi della politica dei dati dell'INGV (D.P. n. 200 del 26.04.2016)"

GENERAL INFORMATION

Authors	Institutions	Contacts [email]	Compiling date [DD/MM/YY]
Maurizio Vassall, Luigi Zarrilli	INGV	maurizio.vassallo@ingv.it	15/12/2021

Station description

Station name	Network code	Latitude [WGS84]	Longitude [WGS84]	Sensor depth [m]
MOCO	IV	41.370980	15.158541	

Site characterization summary

Indicators				
fo +/- std [Hz]	Value	1.4+/-0.2	Quality index Qi1	0.67
	References	This Document		
	URL of report	http://hdl.handle.net/2122/15101		
Velocity profiles [YES/NO]	Value	YES	Quality index Qi1	1
	References			
	URL of report			
Vs30 +/- std [m/]	Value	690+/-70	Quality index Qi1	1
	References			
	URL of report			
Surface geology [short description]	Value	hite limeston	Quality index Qi1	1
	References			
	URL of report			
Seismological bedrock depth +/- std [m]	Value	18+/-5	Quality index Qi1	1
	References			
	URL of report			
Site class EC8	Value	B	Quality index Qi1	1
	References			
	URL of report			
Engineering bedrock depth +/- std [m]	Value	18+/-5	Quality index Qi1	1
	References			
	URL of report			

Distance from the seismic station [m]		Final quality index (Final_QI)	Comments
min	min		
1	61	0.96	QI2=0.92 QI3=1

RESONANCE FREQUENCY

fo +/- STD [Hz]	1.4+/-0.2
Quality index 1	0.67

Source	Earthquake	☐	Ambient noise	✔

Ambient noise

Method	H/V	✔	Ellipticity	☐	Other	☐
fo +/- std [Hz]	1.4+/-0.2					

Experiment date [DD/MM/YY]	Distance from station [m]	Lat. [WGS84]	Lon. [WGS84]
12/10/2021	0	41.370980	15.158541

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	nometrics Trillium-	0.025
Digitizer	Type	Manufacturer	Sampling frequency [Hz]
	24 bit	Nanometrics Centau	100
Measurement	Number	Duration [min]	
		1440	

Analysis

Software	geopsy
Smoothing type (e.g. triangular, Konno-Ohmachi, ...)	Window length [s]
Konno-Ohmachi	60

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)

Contacts: Cecile.Cornou@univ-grenoble-alpes.fr Giovanna.Cultrera@ingv.it Giuseppe.Digulio@ingv.it

Vs30

Vs30 +/- STD [m/s]	690+/-70
Quality index 1	1

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)	✔	From Down-Hole	
	690+/-70			
	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		Slope range (degree)	from	
			to	
Reference relationship Slope - Vs30				

DEM & Geology

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

Vs profile

Quality index 1	1

Source

Non-invasive methods (active and/or passive seismics)			
Active surface waves	☐	Refraction	☐
Passive surface waves	✔	Refection	☐
HV / ellipticity	☐		

Invasive methods (measurement in borehole)	
Cross-hole / Down-hole	☐
Geotechnical methods (CPT, SPT, ...)	☐
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		
12/10/2021	1	61	41.371093	15.158459

Active surface waves acquisition layout

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

** 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

Passive surface waves acquisition layout

Number of sensors	48
Minimum array aperture	5
Maximum array aperture	95
Number of arrays	1
Minimum duration [min]	200

Sensor cut-off frequency (Hz)	4.5
Sensor type (vertical / horizontal)	vertical+horizontal
Sensor manufacturer	geospace
Digitizer type	GSB
Digitizer manufacturer	Geospace

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	✔	
Love DC		
Ellipticity		
H/V (DFA, EHVR)		
H/V (SH)		

Dispersion curves

	Rayleigh	*Love*
Min wavelength (m)	14	
Max. wavelength (m)	225	
Min. phase vel. (m/s)	500	
Max. phase vel. (m/s)	1800	
Modes (R0, L0, ...)	R0	

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 (Geopsy)
Reference	

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

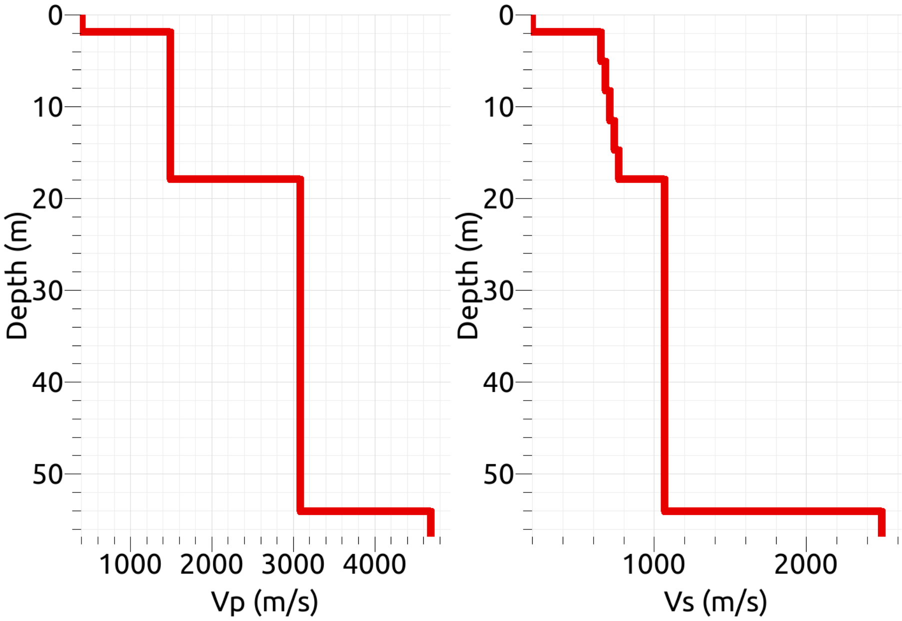
Note: You do not have to fill in all the columns. You can provide either single values for Vp or Vs (e.g. profiles derived from borehole measurements) or either a range for Vp and Vs (e.g. profiles derived from stochastic surface waves inversion)

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	1.87	401		199.8	
1.87	5.08	1489.7		649.9	
5.08	8.29	1489.7		679.3	
8.29	11.5	1489.7		708.8	
11.5	14.71	1489.7		738.2	
14.71	17.92	1489.7		767.7	
17.92	54.09	3090.1		1068.1	
54.09	--	4692.5		2498.0	

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



Surface geology

Quality index 1	1

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

Geological map

Map reference		
Map scale	1:5000	
Map sheet	sheet 163 - Lucera.	
Predominent geologic/lithologic unit	Name :	Daunia Formation
	Description :	white limestones with intercatations of clcarenites and clayey marls
	Age :	
	Thickness :	
	Rock mass structure :	
Fault presence		
Weathering		
Cross-section		

Field survey

Map reference		
Map scale		
Predominent geologic/lithologic unit	Name :	
	Description :	
	Age :	
	Thickness :	
	Rock mass structure :	
Fault presence		
Weathering		
Cross-section		

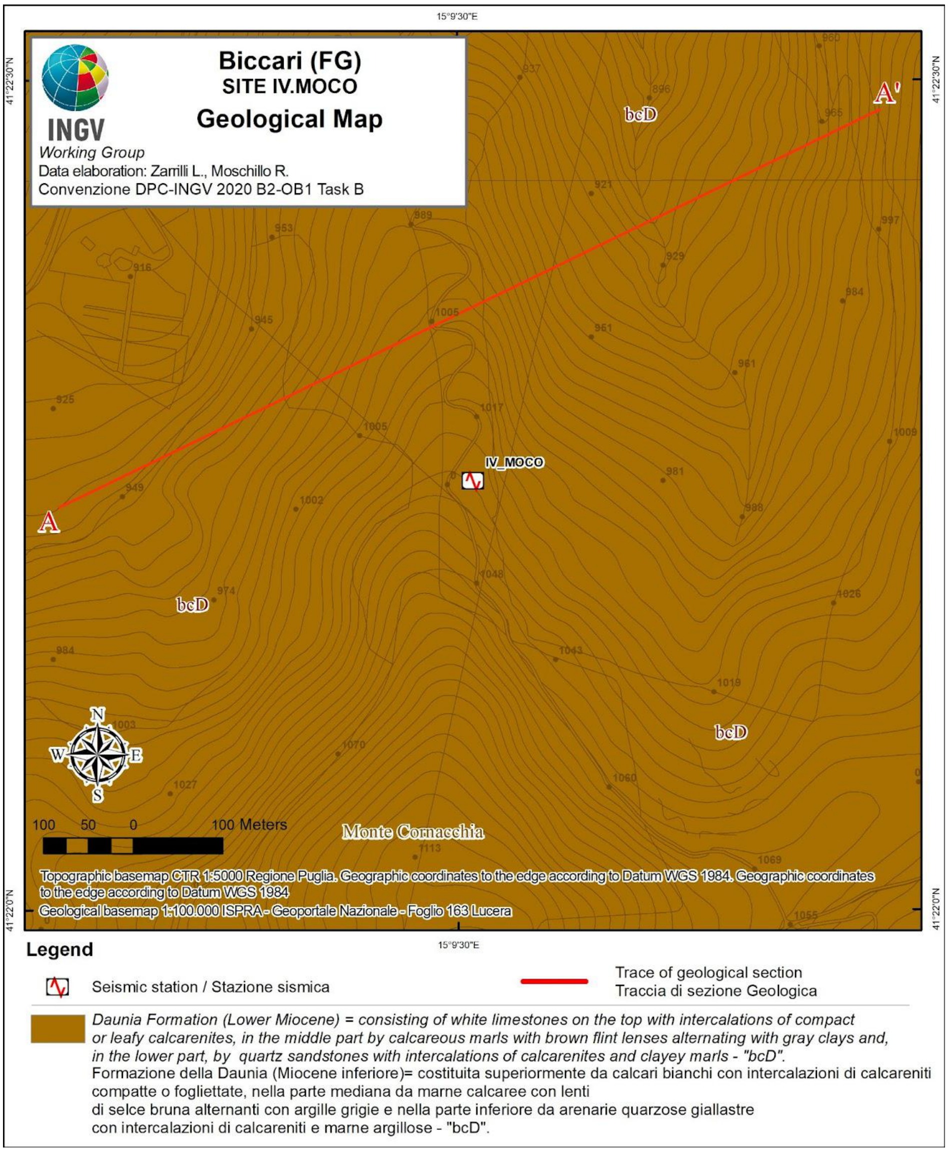
Stratigraphic log

log depth (m)	

Top depth (m)	Bottom depth (m)	Stratigraphic description

Surface geology

Map



Site class

Site class	B
Quality index 1	1

Reference building code for site classification (EC8-1, EC8-2, NEHRP, national code, ...)	EC8，NTC18

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

Reference relationship geology - soil class	
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	

Seismological bedrock depth

Depth +/- STD [m]	18+/-5
Quality index 1	1

Source						
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)	18+/-5		
Bedrock Vs +/- STD(m)	1068+/-100		
Bedrock Vp +/- STD(m)	3000+/-300		
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]	18+/-5
Quality index 1	1

Reference Vs related to engineering bedrock in m/s	1068	Reference building code for site classification (EC8-1, EC8-2, NEHRP, national code, ...)	EC8, NTC18

Source	Vs profile	✔	Geology		Stratigraphic log	

Vs profile

	Non-invasive methods	Invasive seismic methods	Geotechnical methods
Bedrock depth +/- STD(m)	18+/-5		

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	