ISTITUTO NAZIONALE DI GEOFISICA E VULCANOLOGIA

Site characterization report at the seismic station IV.NEVI – Neviano degli Arduini (PR)

Report di caratterizzazione di sito presso la stazione sismica IV.NEVI – Neviano degli Arduini (PR)

Working Group **Geology:** Sara LOVATI, Paolo MANGANELLO **Geophysics**: Sara LOVATI, Paolo MANGANELLO, Alessio LORENZETTI, Rodolfo PUGLIA, Marco MASSA	Date: December 2020
Subject: **Final report illustrating the site characterization for seismic station IV.NEVI**	

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", (2020). Geological report at the seismic station *IV.NEVI – Neviano degli Arduini,* http://hdl.handle.net/2122/14044

INDEX

Introduction 3

A. Geological setting 4-13

1. Topographic and geological information 4
2. Geological map 6
3. Lithological map 7
4. Lithotechnical map 8
5. Survey map 9
6. Geological model 10
6.1 General description 10
6.2 Geological section 11
6.3 Subsoil model 12

B. Vs profile 14-21

1. Geophysical Investigations 14
2. Seismic Velocity Model 18
3. Conclusions 21

References 22

Disclaimer and limits of use of information 24

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.NEVI (Neviano degli Arduini).

Location and coordinates are reported in Table 1.

Table 1

CODE	NAME	LAT [°]	LON [°]	ELEVATION [m]
IV.NEVI	Neviano degli Arduini	44.580900 *	10.313000 *	517 **
ADDRESS	Via Chiesa, Neviano degli Arduini (PR), Italy			

* Coordinates from ITACA (Nov. 2020) ** Elevation from CTR 5k Regione Emilia-Romagna

A. Geological setting

A1. TOPOGRAPHIC AND GEOLOGICAL INFORMATION

Topographic information related to the site are reported in Table 2. Table 3 summarizes all available geological maps from literature for geological analyses.

Topography	Description	Topography Class	Morphology Class	EC8 Class
	Relief with top wider than base and slope with $15° \leq i \leq 30°$	T3	R	B

Table 2

*Reference table from ITACA (Nov. 2020)

Table 3

Geological map	Source	Scale
IV.NEVI	Geological map of Italy sheet *085* (Castelnovo nè Monti)	1:100.000
IV.NEVI	Geological map of Italy sheet 217 (Neviano degli Arduini)	1:50.000
IV.NEVI	Geological map from Emilia Romagna Region database	1:10.000
IV.NEVI	Geological and technical maps – Seismic Microzonation *level 3*	1:5.000

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

Table 4

GEOLOGICAL UNITS (10k Regione Emilia Romagna) *original*		**LITHOLOGICAL UNITS** (Amanti et al., 2008) *deduced*		**LITHOTECHNICAL UNITS** (MZS) *original*	
code	**description**	**code**	**description**	**code**	**description**
MR01	Limestone, marly limestone, marls	A3	marly limestone	NRS	Stratified bedrock

A2. GEOLOGICAL MAP

In Figure 1 Geological Map is reported in a 1 $km \times 1$ km square around the station.

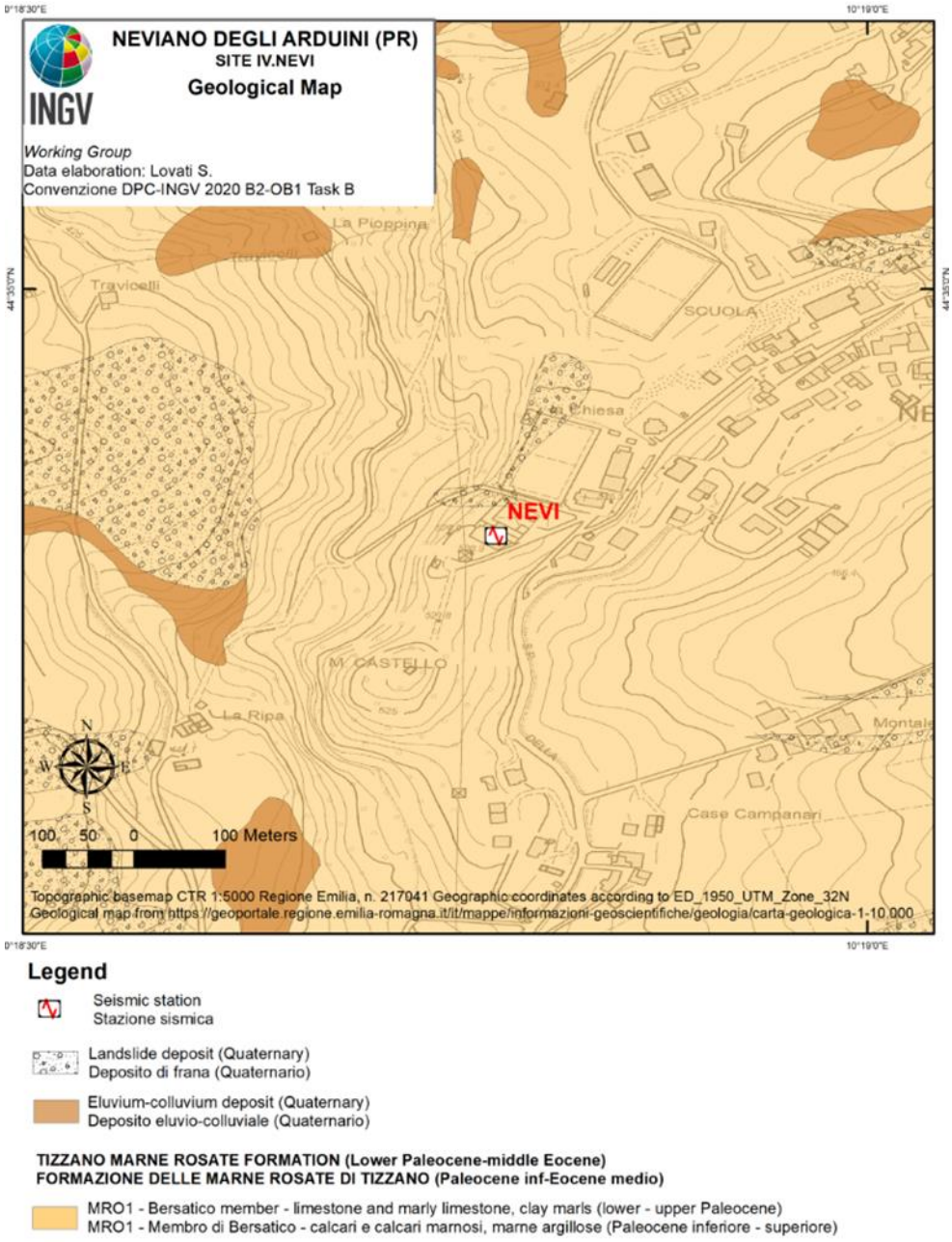

Figure 1: Geological map of seismic station IV.NEVI. Scale 1:5.000. Geological units are established according to the nomenclature of geological map 1:10.000 of Emilia-Romagna Region.

A3. LITHOLOGICAL MAP

In Figure 2 Lithological Map is reported in a 1 $km \times 1$ km square around the station.

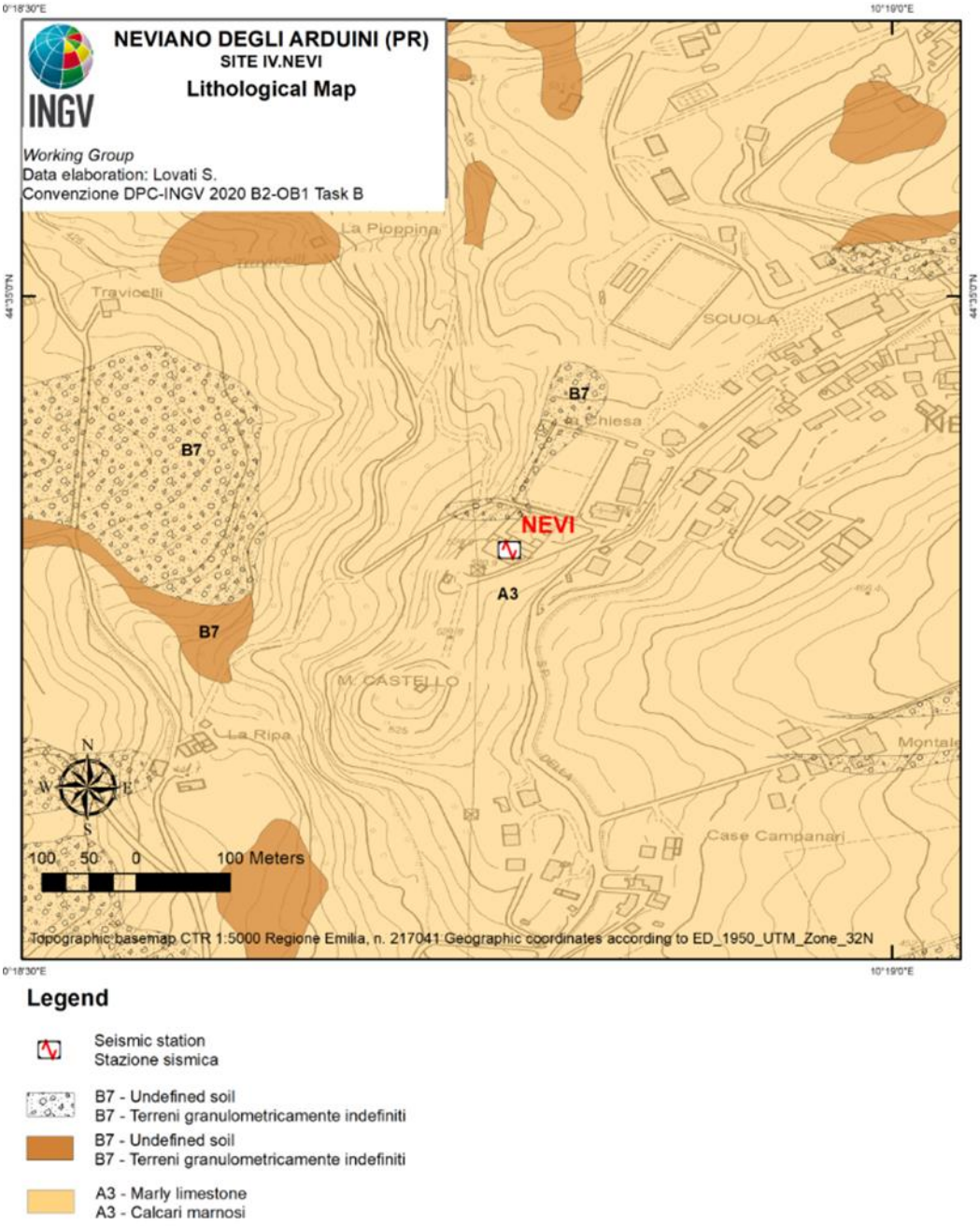

Figure 2: Lithological map of seismic station IV.NEVI. Scale 1:5.000. The codes of the lithological units are assigned according to the nomenclature of the Lithological map ISPRA 1:100.000 (Amanti *et al.*, 2008).

A4. LITHOTECHNICAL MAP

In Figure 3 Lithotechnical Map is reported in a 1 *km* × 1 *km* square around the station.

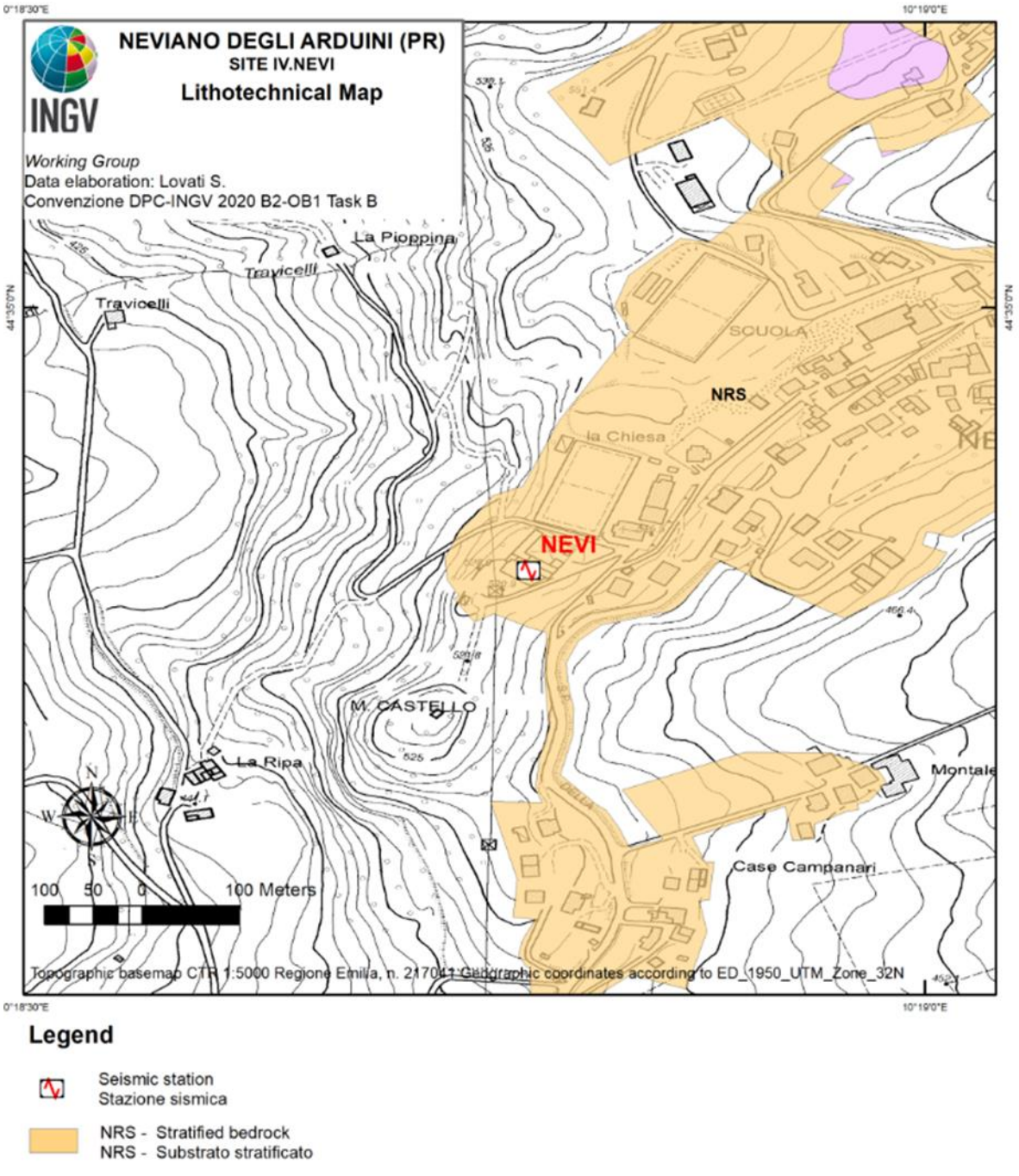

Figure 3: Lithotechnical map of the seismic station IV.NEVI. Scale 1:5.000. The lithotechnical units are assigned according to the nomenclature of Seismic Microzonation (Technical Commission SM, 2015).

A5. SURVEY MAP

Figure 4 shows the Survey Map reporting both previous investigations and geophysical surveys conducted by INGV Working Group.

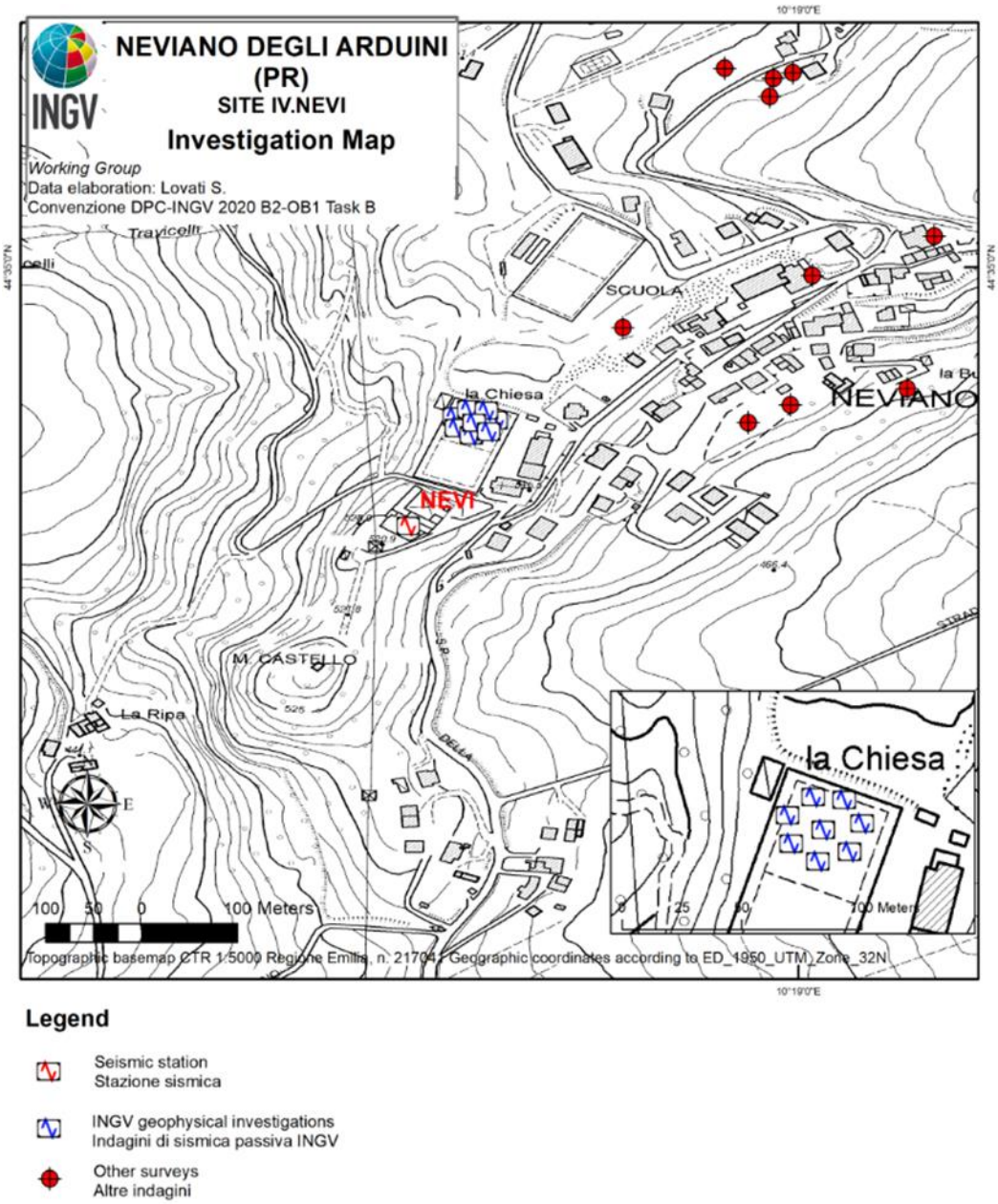

Figure 4: Map of the surveys in the surroundings of the station IV.NEVI. Scale 1:5.000. The box at the bottom right contains a zoom of the area with the detail of the geophysical survey conducted by INGV Working Group for the seismic characterization of the site (Agreement DPC-INGV 2019-21, All. B2, WP1 - TASK 2, Velocity profile report IV.NEVI).

A6. GEOLOGICAL MODEL

6.1 General description

The studied area is located immediately South-West of the Church of Neviano degli Arduini "Santa Eufemia", in the southern sector of the municipality.

The survey area is in correspondence of a ridge with axis in the south-west – north-east direction, with average altitudes ranging between 525 and 530 m s.l.m. and average slopes of 25 - 30 ° on the north west side and about 20° in the one east of the cemetery. The ridge tends to widen rapidly in correspondence with the town of Neviano.

The area belongs to the middle Emilian Apennines, the formations belonging to the tectonic unit of *Falda Toscana*, emerge broadly in the Apennine ridge and cover the Autochthonous Apuan, with azimuth towards north-east. These formations, are below the Allochthonous Sub-Ligurian and Ligurian Units that constitute the middle - medium-high part of the Parma Apennines, characterized by the outcrop of predominantly clayey formations, of various colors, containing ophiolites and extensive limbs of calcareous and arenaceous flysch, very tectonized (Crete-Eocene). The latter ones are covered, in a discontinuous way, by the sequences of the Epiligure Succession.

In detail, the rock formations belonging to the Epiligurian Succession prevail in the southwestern sector of the Neviano municipality, between Monte Fuso and Vetto of Reggio Emilia, while, in the northern direction, the oldest units of Ligurian formations emerge.

The lithostratigraphic units that constitute the belt of the middle Parma Apennines (to which Neviano degli Arduini belongs) are Continental Quaternary Units (top) and Ligurian domain (bottom) with *Marne Rosate di Tizzano* Formation (Lower Paleocene-middle Eocene) and *Argille Varicolori della Val Samoggia* Formation (upper Hauterivian-Cenomanian).

As concern Quaternary units, they are represented by a predominant silty-clay lithology that includes stone blocks of various sizes that form thick layers covering the slopes and include both eluvium/colluvium deposits and active gravitational movements.

The ridge area on which the town of Neviano is located, is characterized by *Marne Rosate di Tizzano* Formation (MRO), in particular the sub-unit of the Bersatico Member (MRO1), consisting of very thick white and pink limestone and marly limestone, marl and clayey marl,

in banks alternating with thick and medium layers of fine turbidite sandstones; marly limestones, silty sandstone and brown-gray silt.

The formation dip in the south east direction with incline between 30 and 50 °. The relative lying regularity indicates a moderate or low tectonic disturbance in that area.

From a structural point of view the territory around Neviano degli Arduini is characterized by a compressive tectonic that determined a wide shortening of Apennine belt edge through two important parallel imbrication structure in NO-SE direction and NE dipping, whom detachment surface interested Mesozoic and Tertiary covers (Boccaletti *et al.*, 1985).

The northern front ("External Thrust Front" - ETF), coinciding with the Cremona - Parma - Reggio Emilia alignment, belongs to the arc of the so-called "Emilian Folds" which extend from the Vogherese Apennines to the "T. Sillaro "; this beam is made up of a system of blind and arched thrusts, affected by transverse discontinuities with a probable component of transcurrent movement.

The southern front ("Pedeapenninic Thrust Front" - PTF), coinciding with the Apennine morphological margin, develops underground in correspondence with the prewurmian terraces. This front is also involved by transversal discontinuities coinciding with some of the main Apennine watercourses (Stirone river, Taro river, Baganza river and Enza river) which delimit sectors with different tectonic - sedimentary behavior.

6.2 Geological Section

Closing at IV.NEVI station a schematic geological section A-A' crossing the INGV seismic station IT.BNO from NW to SE (Figure 6 bottom) following the dipping of layer towards SE.

Along the section Bersatico Member (MRO1, lower - upper Paleocene) well outcrops Pleistocene) (Figure 6 bottom).

Also the geological map of Italy 1:100.000 (sheet *085* Castelnovo nè Monti) shows a section crossing the municipality of Neviano degli Arduini in SW-NE direction where Neviano Limestone Formation (cN, upper Cretaceous-Paleocene) outcrops (Figure 5).

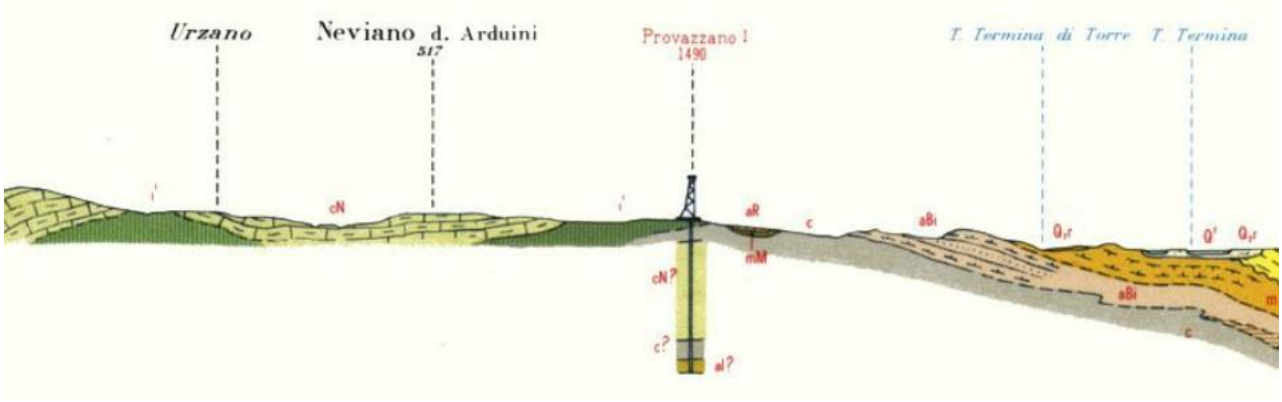

Figure 5: Deep geological section crossing the municipality of Neviano degli Arduini (1:100.000 geological map of Italy, sheet 085 CASTELNOVO NE MONTI). Legend: cN (Neviano Limestone, upper Cretaceous-Paleocene).

6.3 Subsoil model

A subsoil model is built up to a depth of 50 m in the area around the IV.NEVI station on the basis of geological information from literature, oil drilling, and public databases (Figure 6).
The comparison between the data obtained from the heavy dynamic penetrometric surveys (DPSH) and the seismic stratum units determined by the refraction geophysical prospecting BS, Re.Mi./MASW, single station HVSR (Comune di Neviano, 2019) and our passive seismic investigation (8 stations array) highlighted the presence of low thickened landfill up to 1.6 m in depth. Beyond this depth substrate lithotypes (Formation of the Pink Marls of Tizzano - Member of Bersatico, MRO1) are present. They are locally characterized by turbidite successions and by the presence of alternations of lightly cemented sandstones and silty limestone levels, altered up to about 7 m in depth. The degree of alteration decreases rapidly with depth.

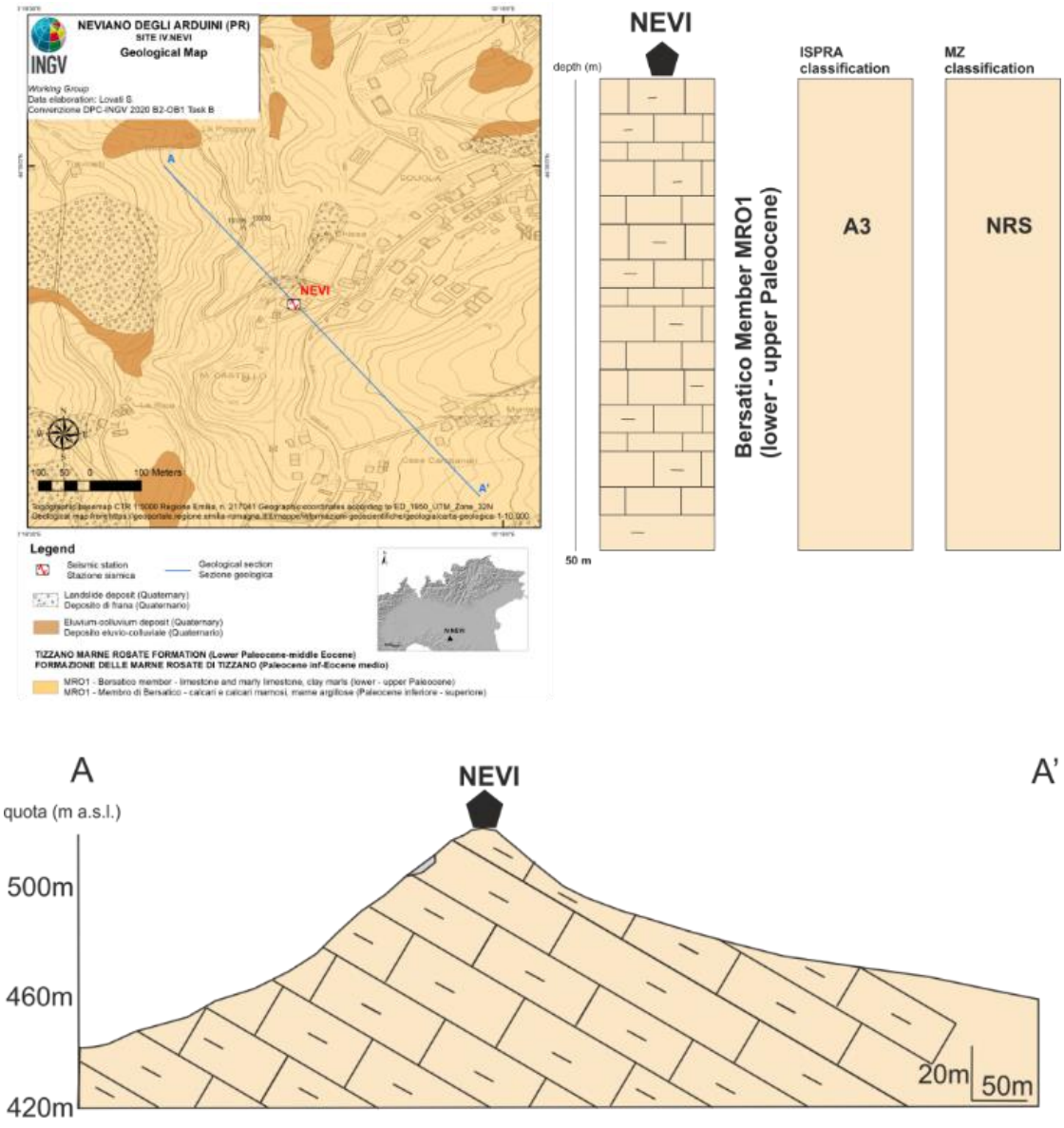

Figure 6: Bottom left: Geological section A-A' crossing seismic station IV.NEVI. Top right: Subsoil model under the IV.NEVI seismic station and classification according to ISPRA: A3: marly limestone; according to MZ: NRS: stratified bedrock.

B. V_S profile

B1. GEOPHYSICAL INVESTIGATIONS

Geophysical measurements executed next to the station IV.NEVI (Italian National Seismic Network, RSN-INGV) consist in ambient-vibration measurements in both single-station and 2D array configuration that provide results in terms of resonance frequency of the soil deposits and in terms of dispersion curves of surface waves. These curves are inverted to obtain a shear-wave velocity (Vs) profile that is suitable for assigning the soil class according to the current Italian seismic code (NTC 2018) and the current Eurocode (EC8).

Figure 7 shows the location of the station IV.NEVI (Latitude 44.580900, Longitude 10.313000 WGS84) installed inside the municipal cemetery of Neviano degli Arduini (PR). The seismic sensors were positioned in a circular geometry with a radius of 15 m, in order to have a homogeneous azimuthal coverage that allows a better performance of the array techniques.

Figure 7: Map of the geophysical measurements performed at the IV.NEVI site. The red placemarkers in circular geometry are the 8 stations of the 2D array in passive configuration. The triangle indicates the IV.NEVI accelerometric station (image from Google Earth http://www.earth.google.com).

Figure 8: Left: IV.NEVI accelerometric station installed inside the municipal cemetery of Neviano degli Arduini (PR). Upper right: single station ambient noise measurement performed at IV.NEVI station. Bottom right: 2D passive ambient noise array installed close to the IV.NEVI station.

Figure 8 shows the site where the accelerometric station IV.NEVI is deployed and the velocimetric sensor used for the ambient noise measurement.

Both for single and 2D array passive measurements, the ambient noise vibrations have been acquired with Lennartz-5s velocimetric sensor coupled to the Reftek-130 (24 bits) digitizer. For 2D passive array the measurement has a duration of about two hours. The sampling rate was set to 200 sps.

To assess the resonant frequency at IV.NEVI station, the horizontal-to-vertical spectral ratio (H/V) has been calculated, using the *Geopsy* software (http://www.geopsy.org). The H/V analyses show a clear resonance peak at 6.53 Hz (f_o), with amplitude higher than 4 and a smoother second peak around 20 Hz. The directional H/V does not show any significant polarization effect. The results are shown in figure 9.

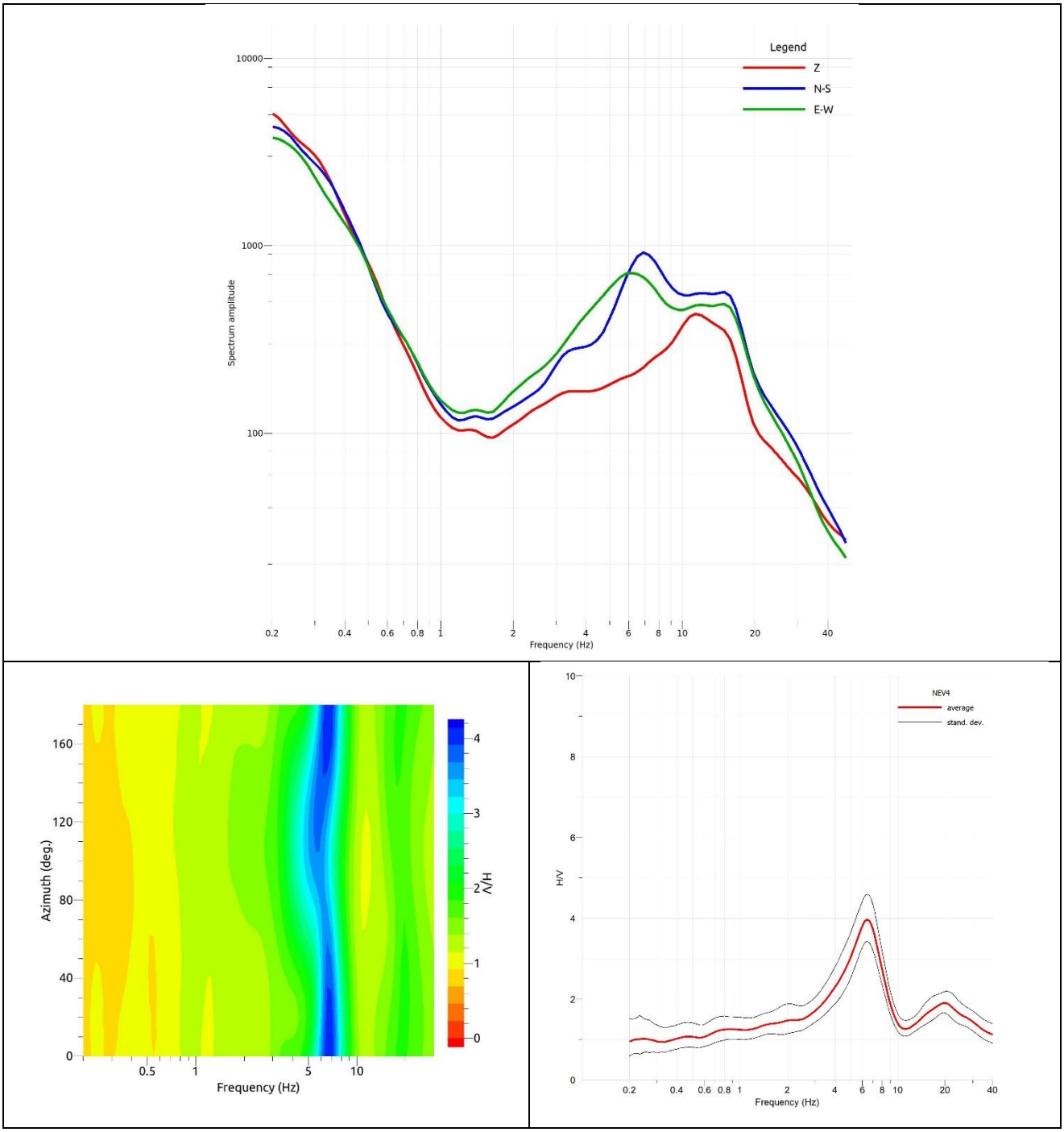

Figure 9: H/V results at IV.NEVI station. Top: Fourier spectra of the three components. Bottom left: directional H/V. Bottom right: H/V curve (with mean and standard deviation in red and grey rispectively).

Data from the 2D array have been analyzed with the GEOPSY code (http://www.geopsy.org) in terms of high-resolution FK analysis. In this case other methods (e.g MSPAC or ESAC) do not provide reliable results. The dispersion curve from FK (in this case not clear) obtained from the vertical components is shown in Figure 10. We interpret and assume that the dispersion curve is relative to the fundamental mode of the Rayleigh dispersive waves. The aliasing conditions (black lines) constrain the validity range of the picked dispersion curves in the frequency range 10-15 Hz.

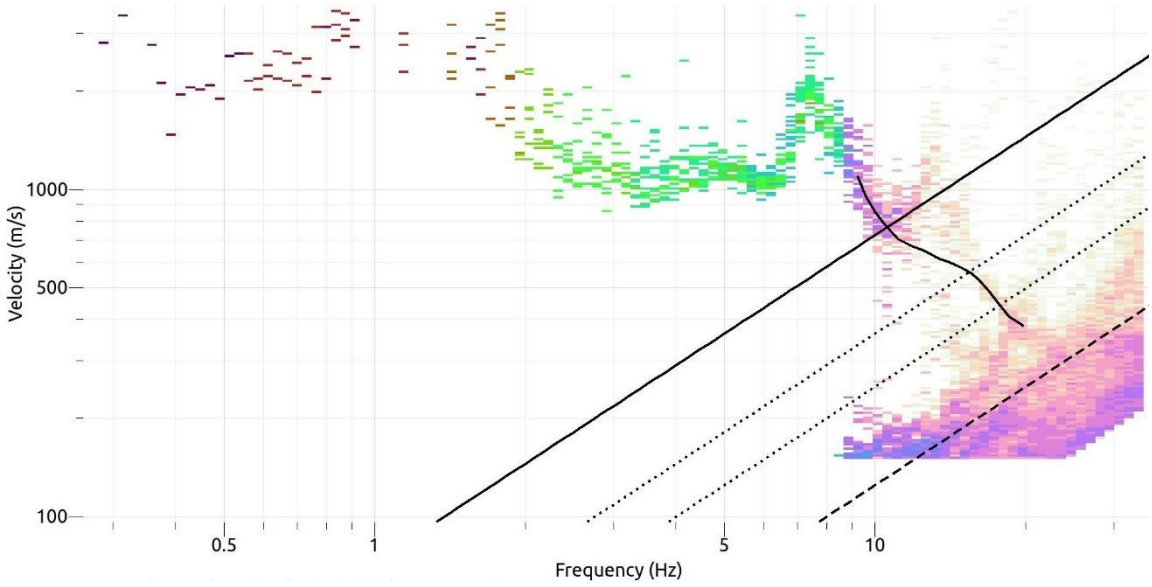

Figure 10: FK analysis and picked dispersion curve for the array.

To obtain the shear wave velocity profile (V_s) for the area, the FK dispersion curve has been inverted together the right flank of the H/V curve showed in figure 9 (right bottom panel).

B2. SEISMIC VELOCITY MODEL

After a low thickened landfill up to 1.6 m in depth, the geology of the area where the IV.NEVI station is installed, highlights the presence of lithotypes of Formation of the Pink Marls of Tizzano (Member of Bersatico, MRO1). They are locally characterized by turbidite successions and by the presence of alternations of lightly cemented sandstones and silty limestone levels, altered in an interval between 7 and 10 m in depth as the Vs profile shows. After this depth the degree of alteration decreases rapidly with depth. We have no information about geological surveys at depth deeper of 10-12 m. On the basis of the geological map (1:100.000, sheet 085) available for the area (ISPRA), it is possible suppose that the change in velocity around 25 m is probably due to the transition at the Indifferenziato Argilloso Varicolore, *Formation i* (Cretaceous), composed of grey green black and red shale with some limestone layers.

The resulting velocity model after the inversion step is shown in Figure 11. We obtained a fairly good fit between experimental and theoretical curves using a model parameterization composed of two main layers over the half space. The final result of the inversion is shown in Figure 11. The best -fit model of V_s is represented in Figure 12 and Table 5.

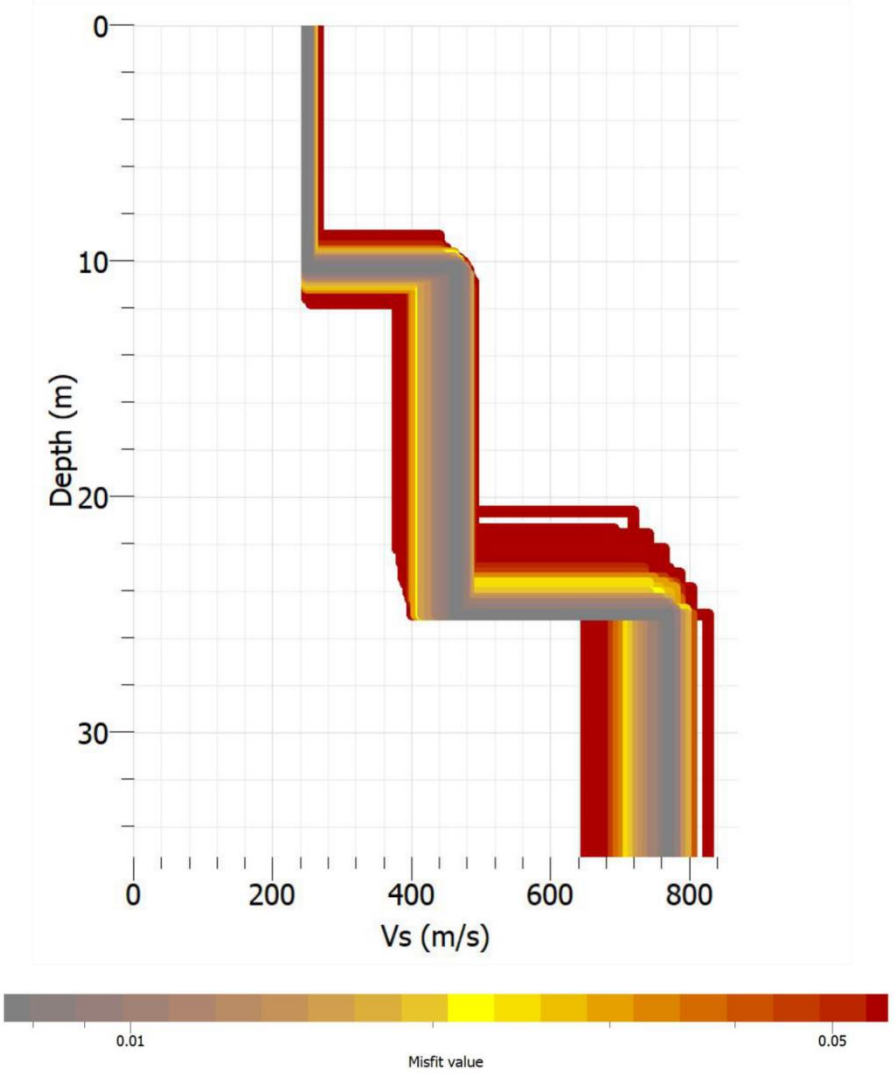

Figure 11: V_s velocity profile obtained through the inversion of the FK dispersion curves reported in in figure 10 and the the right flank of HVSR curve. The best-fit model is shown in grey.

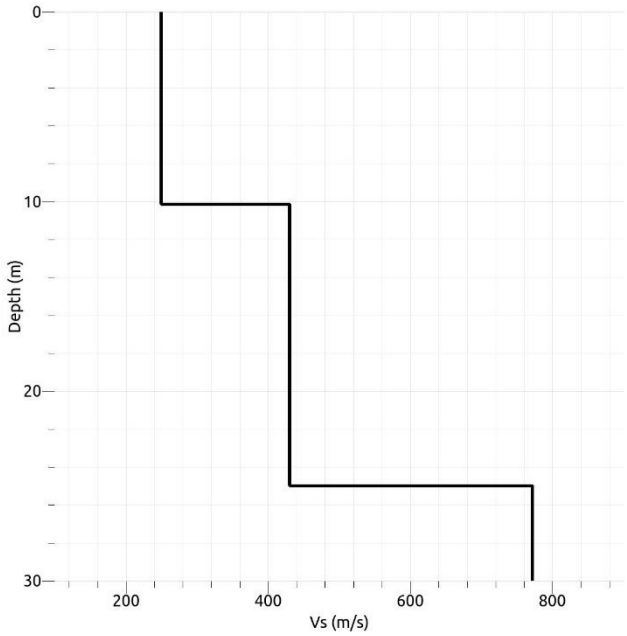

Figure 12: Best-fit model of Vs values

From	*To*	*Thickness (m)*	*V_S (m/s)*
0	10.16	10.16	250
10.16	25.00	14.84	430
25.00	30.00	5.00	771

Table 5: Best-fit model

B3. CONCLUSIONS

According to the current Italian seismic code (NTC 2018), 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 12, the velocity of 800m/s is reached for an unknown depth, well above the depth of 30 m. Therefore in this case both $V_{s,eq}$ and $V_{S,30}$ are equal to 367.5 m/s. Of consequence, IV.NEVI site is classified in the soil category B, for both the NTC18 and EC8 seismic codes (Table 6).

$V_{s,eq} = V_{s30}$ [m/s]	***Soil class (NTC 2018)***	***Soil class (EC8)***
367.5	B	B

Table 6: Soil Class

REFERENCES

Amanti M., Battaglini L., Campo V., Cipolloni C., Congi M.P., Conte G., Delogu D., Ventura R., Zonetti C. (2008). The Lithological map of Italy at 1:100.000 scale: An example of re-use of an existing paper geological map. 33rd International Geological Conference, IEI02310L – 6-14th August, Oslo (Norway).

Boccaletti M., Coli M., Eva C., Ferrari G., Giglia G., Lazzarotto A., Merlanti F., Nicolich R., Papani G. and Postpischl D. (1985). Considerations on the seismotectonics of the Northern Apennines, Tectonophysics, 117,7-38.

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).

Comune di Neviano degli Arduini (2019). Relazione geologica, geotecnica e determinazione dell'azione sismica.

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.

ISPRA - Geological Survey of Italy - Lithological map of Italy 1:100.000 - Geological Survey Portal http://sgi.isprambiente.it/geoportal/ Sheets 085 (Castelnovo ne Monti).

ISPRA (2014b) - Geological Survey of Italy - Geological Map of Italy 1: 50.000. Sheet 217 (Neviano degli Arduini).

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).

Regione Emilia Romagna – Geoportale - https://geoportale.regione.emilia-romagna.it/it.

Disclaimer and limits of use of information

The INGV, in accordance with the Article 2 of Decree Law 381/1999, carries out seismic and volcanic monitoring of the Italian national territory, providing for the organization of integrated national seismic network and the coordination of local and regional seismic networks as described in the agreement with the Department of Civil Protection.

INGV contributes, within the limits of its skills, to the evaluation of seismic and volcanic hazard in the Country, according to the mode agreed in the ten-year program between INGV and DPC February 2, 2012 (Prot. INGV 2052 of 27/2/2012), and to the activities planned as part of the National Civil Protection System. In particular, this document[1] has informative purposes concerning the observations and the data collected from the monitoring and observational networks managed by INGV.

INGV provides scientific information using the best scientific knowledge available at the time of the drafting of the documents produced; however, due to the complexity of natural phenomena in question, nothing can be blamed to INGV about the possible incompleteness and uncertainty of the reported data.

INGV is not responsible for any use, even partial, of the contents of this document by third parties and any damage caused to third parties resulting from its use.

The data contained in this document is the property of the INGV.

Esclusione di responsabilità e limiti di uso delle informazioni

L'INGV, in ottemperanza a quanto disposto dall'Art. 2 del D.L. 381/1999, svolge funzioni di sorveglianza sismica e vulcanica del territorio nazionale, provvedendo all'organizzazione della rete sismica nazionale integrata e al coordinamento delle reti sismiche regionali e locali in regime di convenzione con il Dipartimento della Protezione Civile.

L'INGV concorre, nei limiti delle proprie competenze inerenti la valutazione della Pericolosità sismica e vulcanica nel territorio nazionale e secondo le modalità concordate dall'Accordo di programma decennale stipulato tra lo stesso INGV e il DPC in data 2 febbraio 2012 (Prot. INGV 2052 del 27/2/2012), alle attività previste nell'ambito del Sistema Nazionale di Protezione Civile.

In particolare, questo documento[1] ha finalità informative circa le osservazioni e i dati acquisiti dalle Reti di monitoraggio e osservative gestite dall'INGV.

L'INGV fornisce informazioni scientifiche utilizzando le migliori conoscenze scientifiche disponibili al momento della stesura dei documenti prodotti; tuttavia, in conseguenza della complessità dei fenomeni naturali in oggetto, nulla può essere imputato all'INGV circa l'eventuale incompletezza ed incertezza dei dati riportati.

L'INGV non è responsabile dell'utilizzo, anche parziale, dei contenuti di questo documento da parte di terzi e di eventuali danni arrecati a terzi derivanti dal suo utilizzo.

La proprietà dei dati contenuti in questo documento è dell'INGV.

[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)"