ISTITUTO NAZIONALE DI GEOFISICA E VULCANOLOGIA

Site characterization report at the seismic station IT.BVT – Borgo Val di Taro (PR)

Report di caratterizzazione di sito presso la stazione sismica IT.BVT – Borgo Val di Taro (PR)

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

Convenzione DPC-INGV 2019-21, All. B2- WP1, Task 2: "Caratterizzazione siti accelerometrici" (Coord.: G. Cultrera, F. Pacor)
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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 IT.BVT (Borgo Val di Taro).

Location and coordinates are reported in Table 1.

Table 1

CODE	NAME	LAT [°]	LON [°]	ELEVATION [m]
IT.BVT	Borgo Val di Taro	44.530400 *	9.742800 *	807 **
ADDRESS	Località Porcigatone, 43043 Borgo Val di Taro (PR), Italy			

* Coordinates from ITACA (November 2021)   ** 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.

Table 2

Topography	Description	Topography Class	Morphology Class
	Slopes with average slope angle i ≥ 15°	T2	Slope (SL)

Table 3

Geological map	Source	Scale
IT.BVT	Geological Map of Italy (CARG Project), sheet 216 (Borgo Val di Taro)	1:50.000
IT.BVT	Geologic Technical Map of Borgo Val di Taro Municipality (A_7 Porcigatone) - Seismic Microzonation	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		**LITHOLOGICAL UNITS**		**LITHOTECHNICAL UNITS**	
Geological Map of Italy 1:50.000, sheet 216 (Borgo Val di Taro) *original*		Amanti *et al.* (2008) *deduced*		(MZS) *original*	
code	**description**	**code**	**description**	**code**	**description**
AMR	Palombini Clays of Monte Rizzone	A3-A7	Marly limestone, marl-mudstone	NR	Non-rigid geological substrate
RAN_2	Val Pessola Member (Ranzano Formation)	A9	Sandstone	NRS	Stratified non-rigid geological substrate

A2. GEOLOGICAL MAP

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

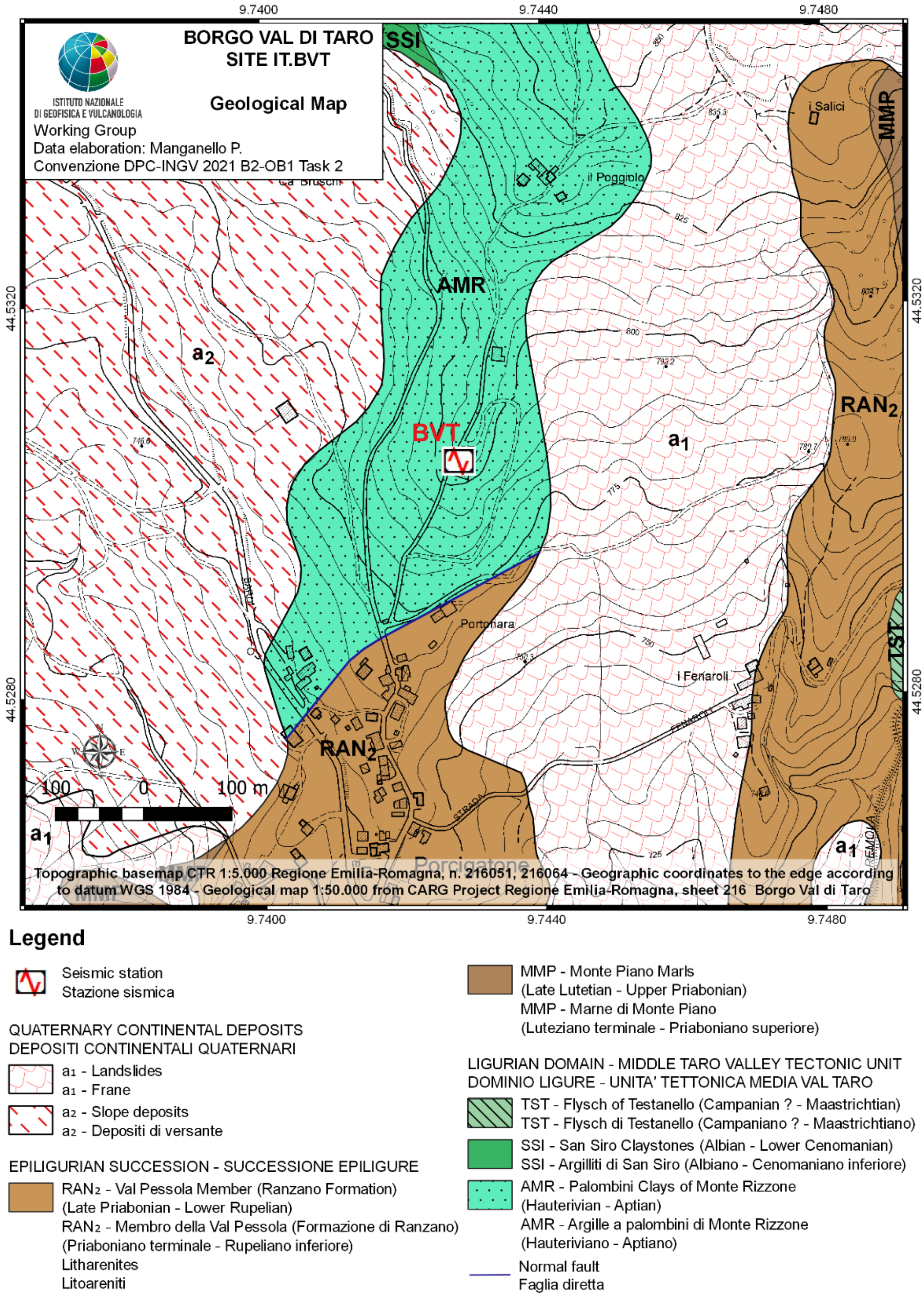

Figure 1: Geological map of the seismic station IT.BVT. Scale 1:5.000. The geological units are established according to the nomenclature of the Geological Map of Italy 1:50.000 (CARG Project – sheet 216).

A3. LITHOLOGICAL MAP

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

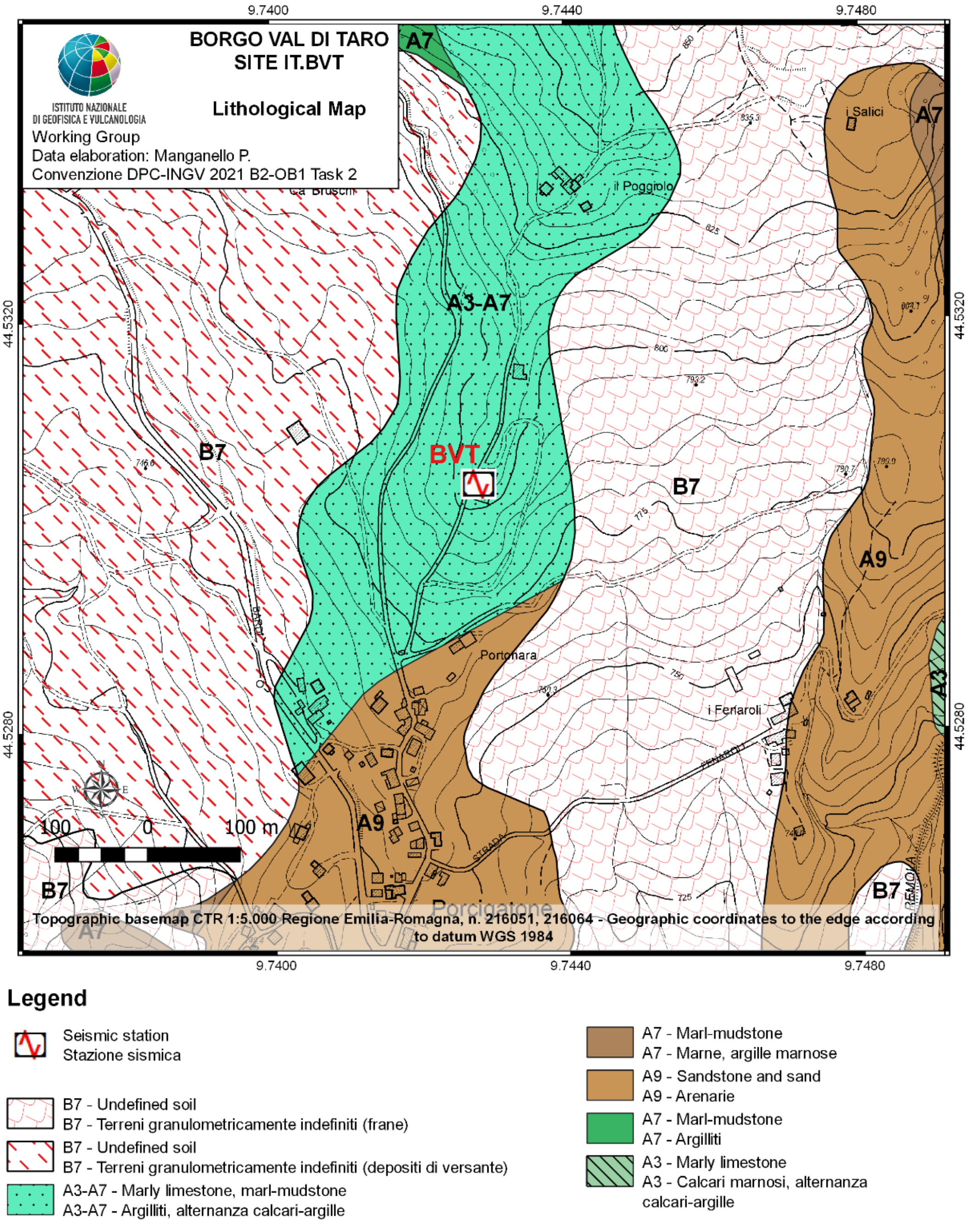

Figure 2: Lithological map of the seismic station IT.BVT. Scale 1:5.000. The codes of the lithological units are assigned according to the nomenclature of the Lithological map of Italy ISPRA 1:100.000 (Amanti *et al.*, 2008).

A4. LITHOTECHNICAL MAP

In Figure 3 Lithotechnical Map is reported in a $1\ km \times 1\ km$ square around the station.

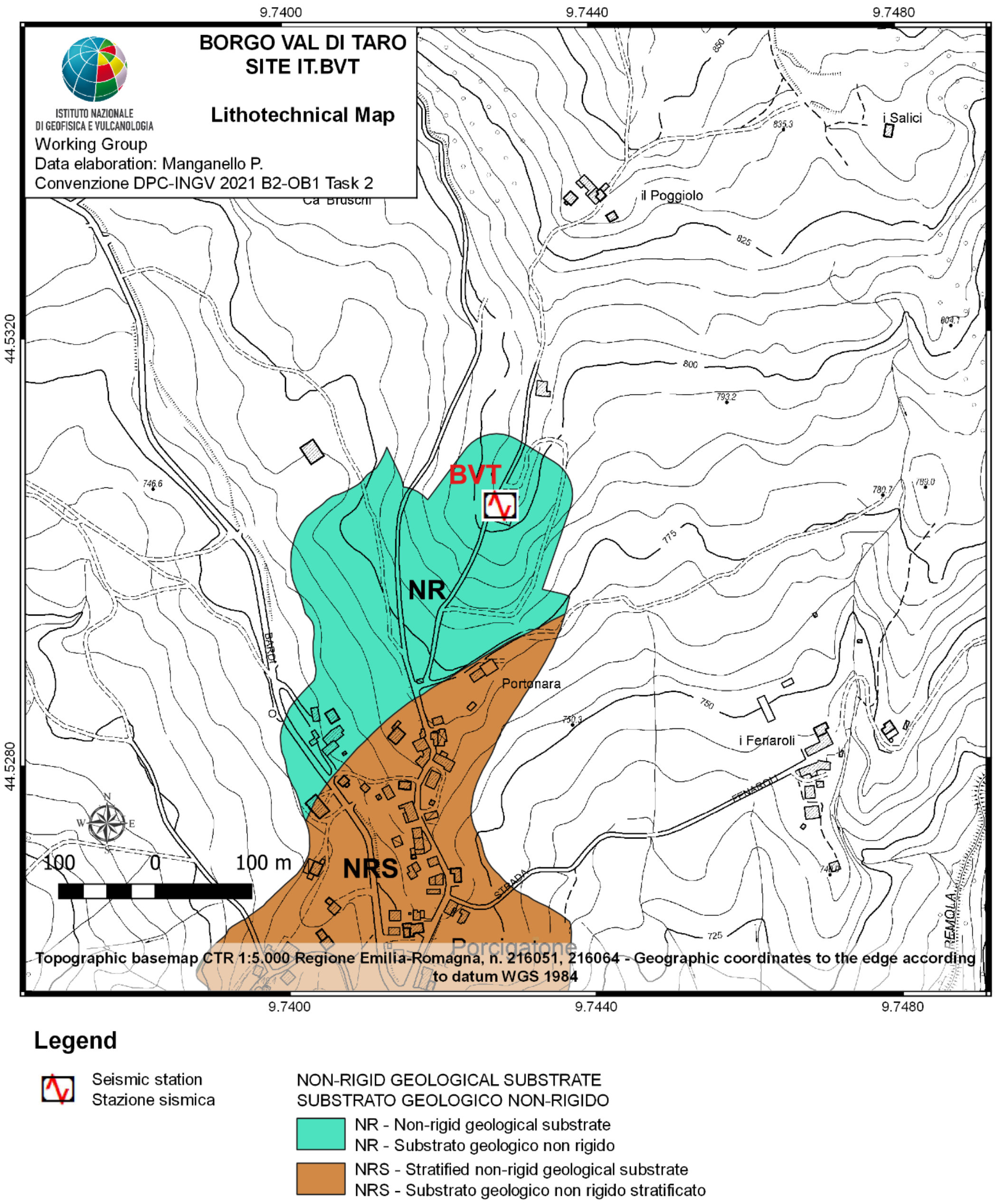

Figure 3: Lithotechnical map of the seismic station IT.BVT. Scale 1:5.000. The lithotechnical units are assigned according to the nomenclature of Seismic Microzonation (Technical Commission SM, 2015).

A5. SURVEY MAP

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

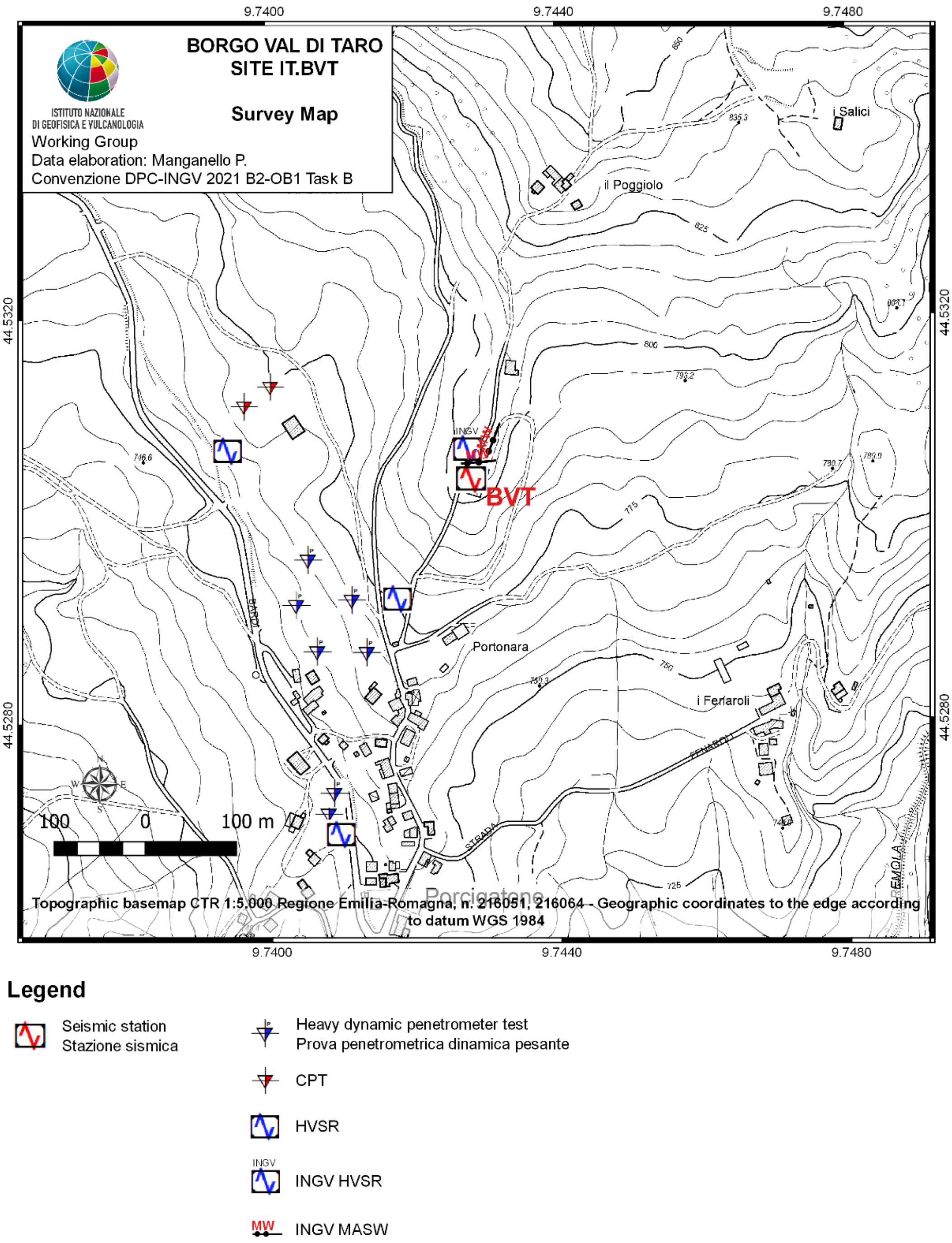

Figure 4: Map of the surveys in the surroundings of the station IT.BVT. Scale 1:5.000.

A6. GEOLOGICAL MODEL

6.1 General description

The studied area is located in the territory of Borgo Val di Taro municipality (south-western sector of the Parma Province). The town center of Borgo Val di Taro is situated on the flood plain of Taro river. The IT.BVT seismic station is located in the village of Porcigatone (northwestward from the town center of Borgo Val di Taro), which is situated on a rock slope.
The geological setting of the studied area is related to the origin of Northern Apennines, an active NW-SE trending fold-and-thrust belt originated during the Late Cretaceous - Present convergence between the European plate and the African plate and characterized by the piling of several nappes. The main orogenic phases and the piling of nappes started in the Oligocene - Miocene limit (Abbate *et al.*, 1970; Carlini *et al.*, 2012). The Apennines have been characterized by uplift since the Pliocene, with a significant increase in the uplift rate in Late Pliocene and Middle - Late Pleistocene (Carlini *et al.*, 2012).
In the Western portion of Northern Apennines the overthrusting of the Ligurian Units (magmatic-sedimentary successions consisting in the remnants of the Piedmont-Ligurian ocean) occurred, through the interposition of the Subligurian Units (Paleocene - lowermost Miocene), on the units of the Tuscan Domain (Triassic - early Miocene), which represents the succession of the continental margin of Adria plate. Starting from the Late Oligocene the Tuscan Domain represents the foredeep basin of the developing and migrating Apennine orogen. Thereafter the sedimentation of the Epiligurian Succession (wedge-top sediments) started in the Middle-Late Eocene, indicating that the Apenninic wedge grew in submarine environment until the Late Miocene. This succession lies on top of the Ligurian Succession through a regional angular unconformity and it is not importantly deformed by the Ligurian tectonic phases (Abbate *et al.*, 1970; Boccaletti *et al.*, 1971; Carlini *et al.*, 2012; Conti *et al.*, 2020). The Plio-Pleistocene has been characterized by the sedimentation of continental deposits, which filled the intermontane lacustrine basins mainly by clays and sands (Abbate *et al.*, 1970).

The North-Western Apennines represent a seismically active area as a consequence of the complex pattern of tectonic lineaments, oriented either NW-SE or ENE-WSW. One of the most important tectonic lineaments is the NE-SW oriented strike-slip Taro Line (Elter *et al.,* 2012).
In the village of Porcigatone an active fault marks the contact between Epiligurian deposits, represented by the Ranzano Formation (Val Pessola Member) and the Monte Piano Marls, and Ligurian units, represented by the Palombini Clays of Monte Rizzone and the Scabiazza Sandstones (Comune di Borgo Val di Taro, 2013).

6.2 Geological Section

In the surroundings of IT.BVT seismic station there are not boreholes, and the executed surveys are represented by Dynamic Cone Penetrometer Tests (DCPT), Cone Penetrometer Tests (CPT) and single station noise measurements (HVSR).
The SW-NE oriented geological section is reported and highlights the geological and structural setting of the IT.BVT site.
The trace with location of the section is reported as a black line in the geological map (Fig. 5 Upper left).

6.3 Subsoil model

A subsoil model is built up to a depth of about 70 *m* in the area around the IT.BVT seismic station on the basis of geological and stratigraphic information (Figure 5 bottom). The stratigraphy shows the presence of the Palombini Clays of Monte Rizzone (Ligurian Domain – Middle Taro Valley Tectonic Unit).

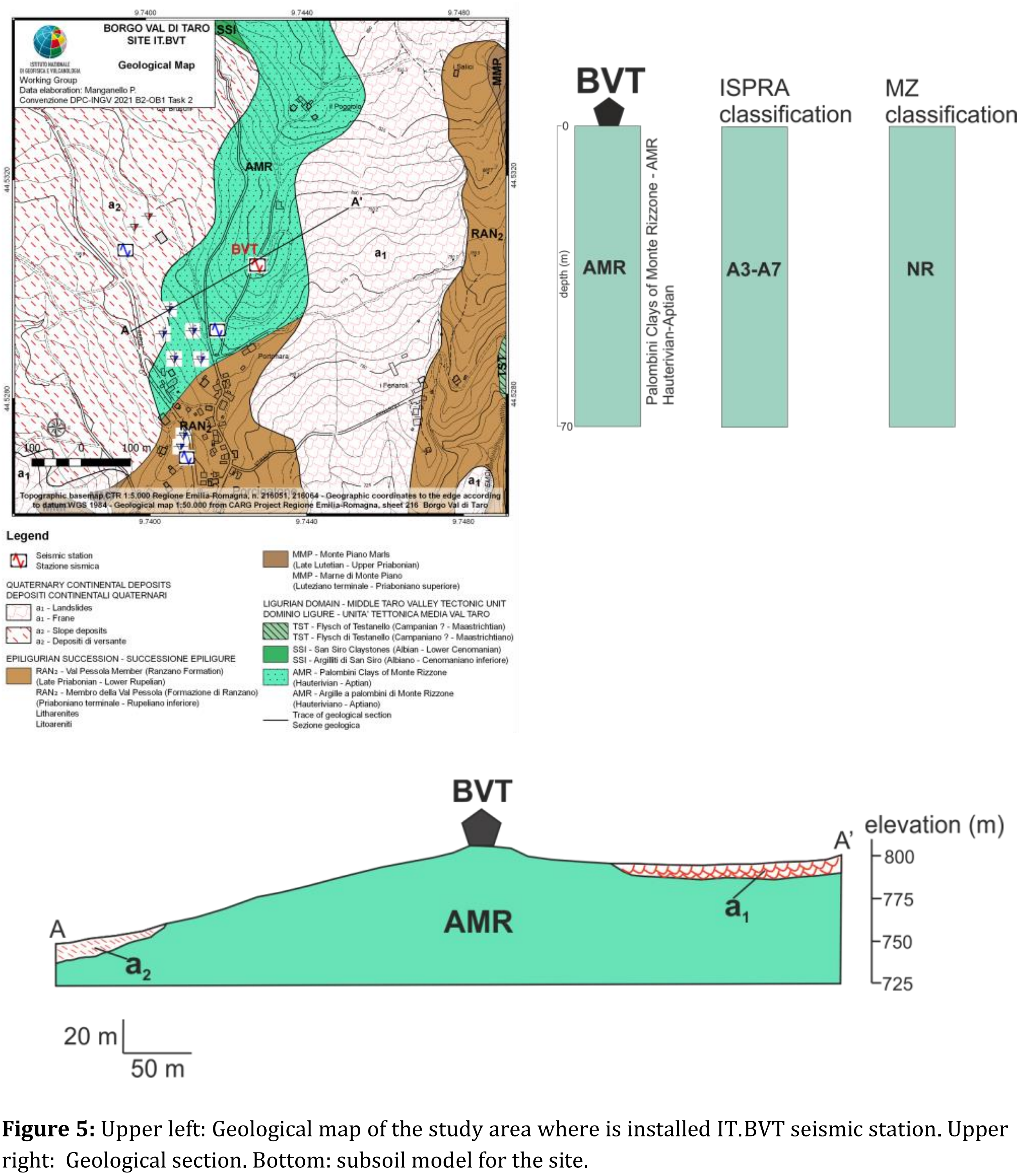

Figure 5: Upper left: Geological map of the study area where is installed IT.BVT seismic station. Upper right: Geological section. Bottom: subsoil model for the site.

B. V_S profile

B1. GEOPHYSICAL INVESTIGATIONS

Geophysical measurements executed nearby the station BVT of the network IT (PCM-DPC, 1972) consist in: a) ambient-vibration measurements in single-station configuration and b) Multi-channel Analysis of Surface Waves (MASW) surveys (Figure 6), that provide results in terms of H/V curve (HVSR) and in terms of Rayleigh dispersion curve. These curves are inverted to obtain a shear-wave velocity (V_S) profile that, together with the geological study at section A, is suitable for assigning the soil class according to the current Italian seismic code (NTC18) and Eurocode (EC8).

Figure 7 shows the location of the station IT.BVT (Latitude 44.5304, Longitude 9.7428 WGS84) installed in the municipality of Borgo Val di Taro (PR).

Seismic microtremor is acquired using 8 Reftek-130 24-bits recording systems equipped with short-period Lennartz LE-3D/5s sensors and GPS timing (Figure 7). The sampling rate is fixed to 100 *Hz*, while the gain is set as “high”.

The MASW survey is based on the simultaneous analysis of surface wave traces recorded by an equally spaced array of receivers (Foti *et al.*, 2017). The used acquisition device has been a Geometrics Geode seismograph (24 channel) and the acquisition lines consisted in 24 vertical geophones (4.5 *Hz* natural frequency) with receiver spacing of 1 *m* and 2 *m* (Figure 7). One shot has been performed with offset equal to 4 *m*. These ranges allow the analysis of a range of wavelengths that guarantee sufficient shallow resolution in order to estimate the $V_{S,30}$ and the site-class according to current building codes (i.e. NTC18 and EC8). The used source has been a sledgehammer striking on a metal plate. The chosen data acquisition parameters have been a time window of 2 *s* and a sampling frequency of 2 *kHz*.

The Rayleigh-wave dispersion curve (Figure 9) is estimated by picking the maximum amplitudes on the phase velocity – frequency plot obtained from recorded data. We interpret and assume that the final dispersion curve consists of the fundamental mode of the Rayleigh dispersive waves.

Figure 6: Map of the geophysical measurements performed at the IT.BVT site. The yellow place-marker indicates the single station ambient vibration measurement. The red line and the orange line indicate the lines of 24 geophones used for MASW, respectively with 1 *m* and 2 *m* receiver spacing. The red triangle indicates the IT.BVT accelerometric station (image from Google Earth http://www.earth.google.com).

Figure 7: Left: IT.BVT accelerometric station installed in the municipality of Borgo Val di Taro (PR) and single station ambient noise measurement. Upper right: MASW acquisition line with 1 *m* receiver spacing. Bottom right: MASW acquisition line with 2 *m* receiver spacing.

Figure 8 shows HVSR recorded close to the station IT.BVT, while Figure 9 depict Rayleigh dispersion curve obtained from the MASW.

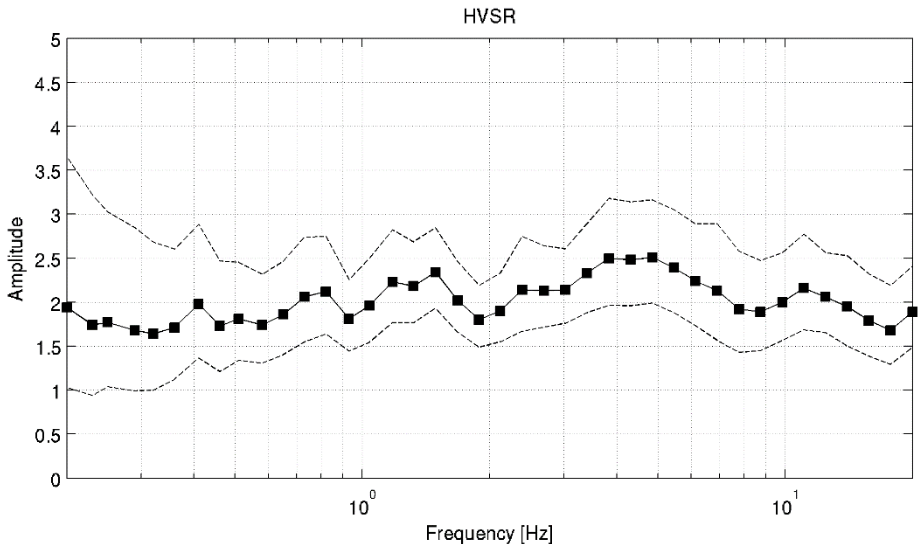

Figure 8: HVSR representative for the site. Dashed lines represent +/- one standard deviation.

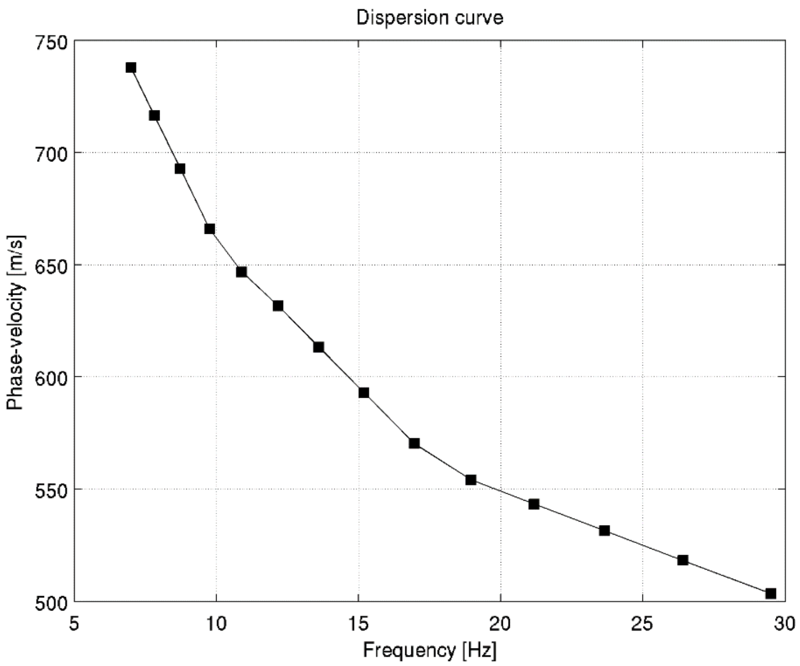

Figure 9: Rayleigh dispersion curve obtained from the MASW.

B2. SEISMIC VELOCITY MODEL

The non-linear inversions are performed using the software *joinv6* (Parolai *et al.*, 2005; Giustiniani *et al.*, 2020), which adopt a genetic algorithm (Yamanaka and Ishida, 1996). The forward modelling of Rayleigh wave phase velocities and HVSR curves is performed under the assumption of a vertically heterogeneous 1D Earth model using the modified Thomson-Haskell method proposed by Wang (1999) and following the suggestions of Arai and Tokimatsu (2004) and Tokimatsu *et al.* (1992). The modelling is not restricted to the fundamental mode, preserving the possibility that higher modes participate in simulating the observed dispersion and HVSR curves.

The experimental dispersion curve used as input for inversions is the one estimated from the MASW analysis in the frequency interval 7-30 *Hz*. The experimental HVSR is used between about 2 and 9 *Hz*. In the left panel of Figure 10 tested models are shown in different colors according to their cost value: the more reliable model (minimum cost) is in white, the models lying inside the 10% range of the minimum cost are in black and the other tested models are shown in grey. In the right-central and right-bottom panels of Figure 10, agreement between experimental and theoretical (grey and open circles, respectively) Rayleigh-wave dispersion curves and HVSR are shown. The agreement is good and, considering the wavelengths related to the dispersion curve frequency range, the V_S profile between about 5-45 *m* is very well constrained. Table 5 reports the minimum-cost shear-wave velocity model.

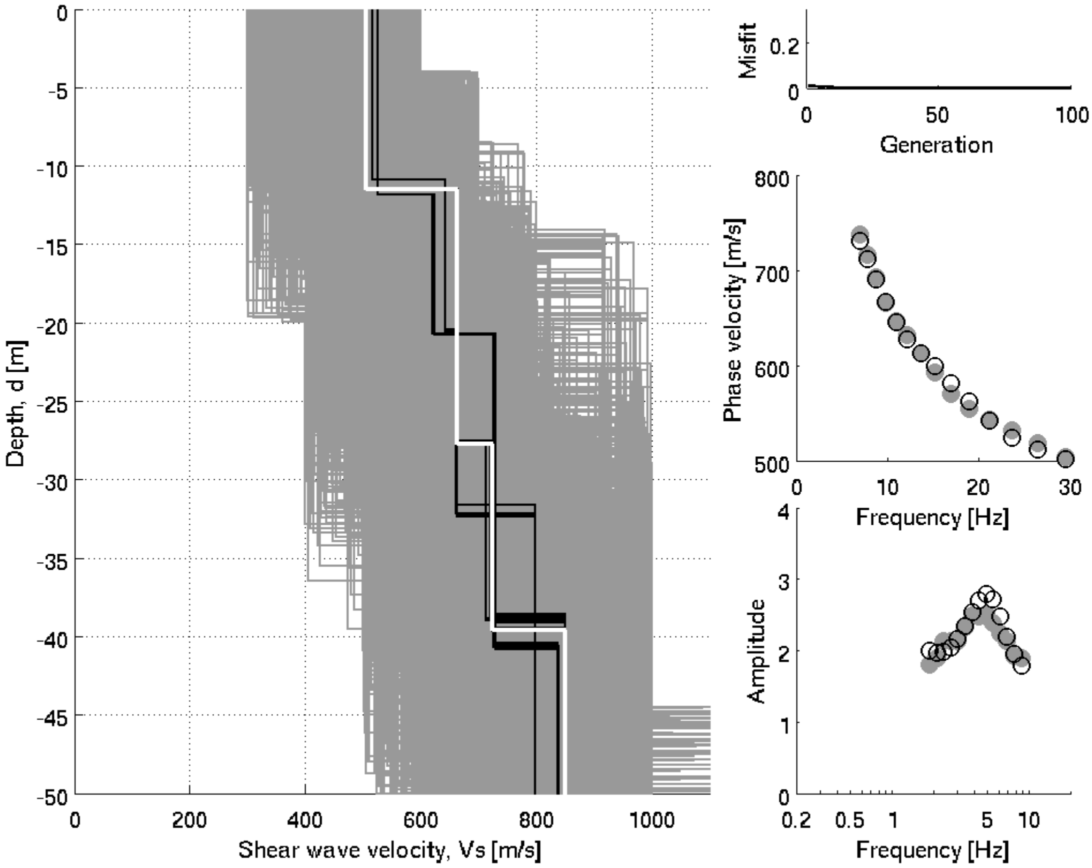

Figure 10: Shear-wave velocity models modeled during the inversion procedure (left panel): tested models (grey lines), the minimum cost model (white line) and models lying inside the minimum cost + 10% range (black lines); the generation values versus misfit (right-upper panel); the fitting of experimental data (grey circles) and empirical values relative to the minimum cost model (white circles) relevant to the dispersion curve (right-central panel) and to HVSR (right-bottom panel).

Table 5: Best-fit shear-wave velocity model

From [*m*]	To [*m*]	Thickness [*m*]	V_S [*m/s*]
0	11.5	11.5	506
11.5	27.7	16.2	664
27.7	39.6	11.9	725
39.6	-	-	851

B3. CONCLUSIONS

As evinced from results of geophysical investigations carried out by INGV Working Group, we can attribute to the Palombini Clays of Monte Rizzone (AMR) V_S values from 506 to 851 m/s, compatible with EC8 class assigned at the site according to geological evidences.
According to the current Italian seismic code (NTC18), if the bedrock (V_S > 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 10, the velocity of 800 m/s is reached at 39.6 m of depth, i.e. below the depth of 30 m.
Therefore, in this case, both $V_{S,eq}$ and $V_{S,30}$ are equal to 596 m/s. Of consequence, IT.BVT site is classified in the soil category B, for both the NTC18 and EC8 seismic codes (Table 6).

Table 6: $V_{S,eq}$,$V_{S,30}$ and soil classes

$V_{S,eq}$ = $V_{S,30}$ [m/s]	Soil class (NTC18)	Soil class (EC8)
596	B	B

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