ISTITUTO NAZIONALE DI GEOFISICA E VULCANOLOGIA

Site characterization report at the seismic station IT.PAR – Parma

Report di caratterizzazione di sito presso la stazione sismica IT.PAR – Parma

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 IT.PAR**	

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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.PAR (Parma).

Location and coordinates are reported in Table 1.

Table 1

CODE	NAME	LAT [°]	LON [°]	ELEVATION [m]
IT.PAR	Parma	44.82892 *	10.27939 *	47 **
ADDRESS	Str. Chiesa di Fognano, 23, 43126 Parma (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
	Flat surfaces, isolated slope and reliefs with slope i ≤ 15°	T1	P	C

Table 2

Table 3

Geological map	Source	Scale
IT.PAR	Geological Map of Italy (CARG Project), sheet 181 (Parma Nord)	1:50.000
IT.PAR	Geologic Technical Map of Parma Municipality (sheet 1) – Seismic Microzonation	1:10.000

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 181) *original*		(Amanti *et al.*, 2008) *deduced*		(MZS) *original*	
code	**description**	**code**	**description**	**code**	**description**
AES_8	Alluvial deposits	B1-B2	Fine-medium granulometry	MH pd	Inorganic silt, fine sand

A2. GEOLOGICAL MAP

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

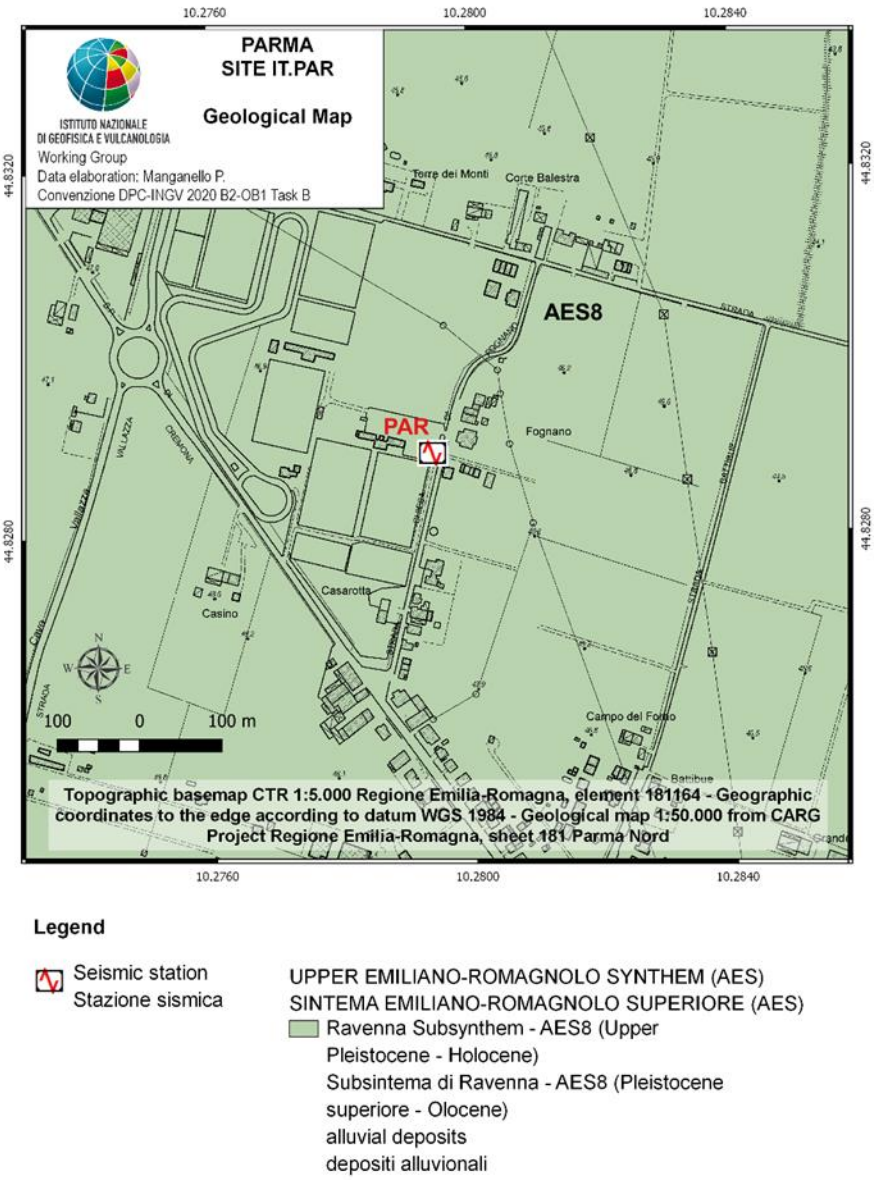

Figure 1: Geological map of seismic station IT.PAR. Scale 1:5.000. Geological units are established according to the nomenclature of the Geological Map of Italy 1:50.000 (CARG Project – sheet 181 Parma Nord).

A3. LITHOLOGICAL MAP

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

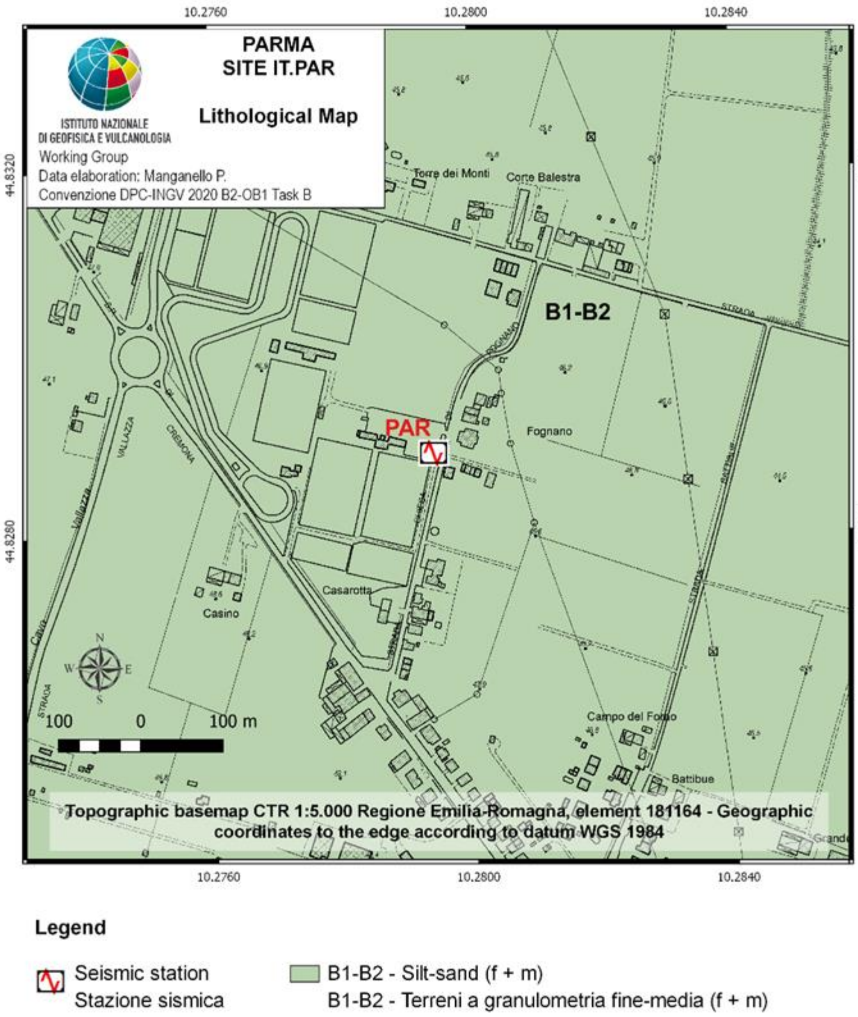

Figure 2: Lithological map of seismic station IT.PAR. Scale 1:5.000. Codes of the lithological units are assigned according to the nomenclature of the Lithological map of Italy ISPRA 1:100.000 (Amanti *et al.*, 2008).

A4. LITHOTECHNICAL MAP

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

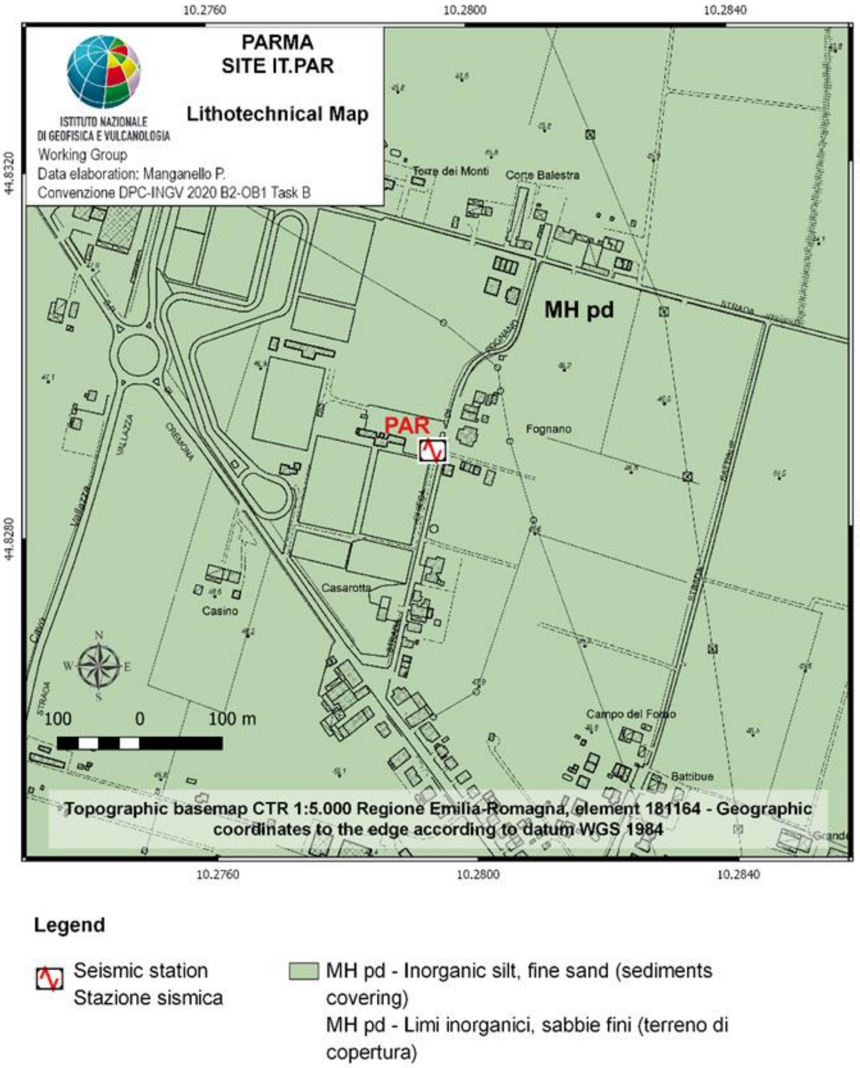

Figure 3: Lithotechnical map of the seismic station IT.PAR. Scale 1:5.000. The lithotechnical units are assigned according to the nomenclature of Seismic Microzonation (Technical Commission SM, 2015).

A5. SURVEY MAP

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

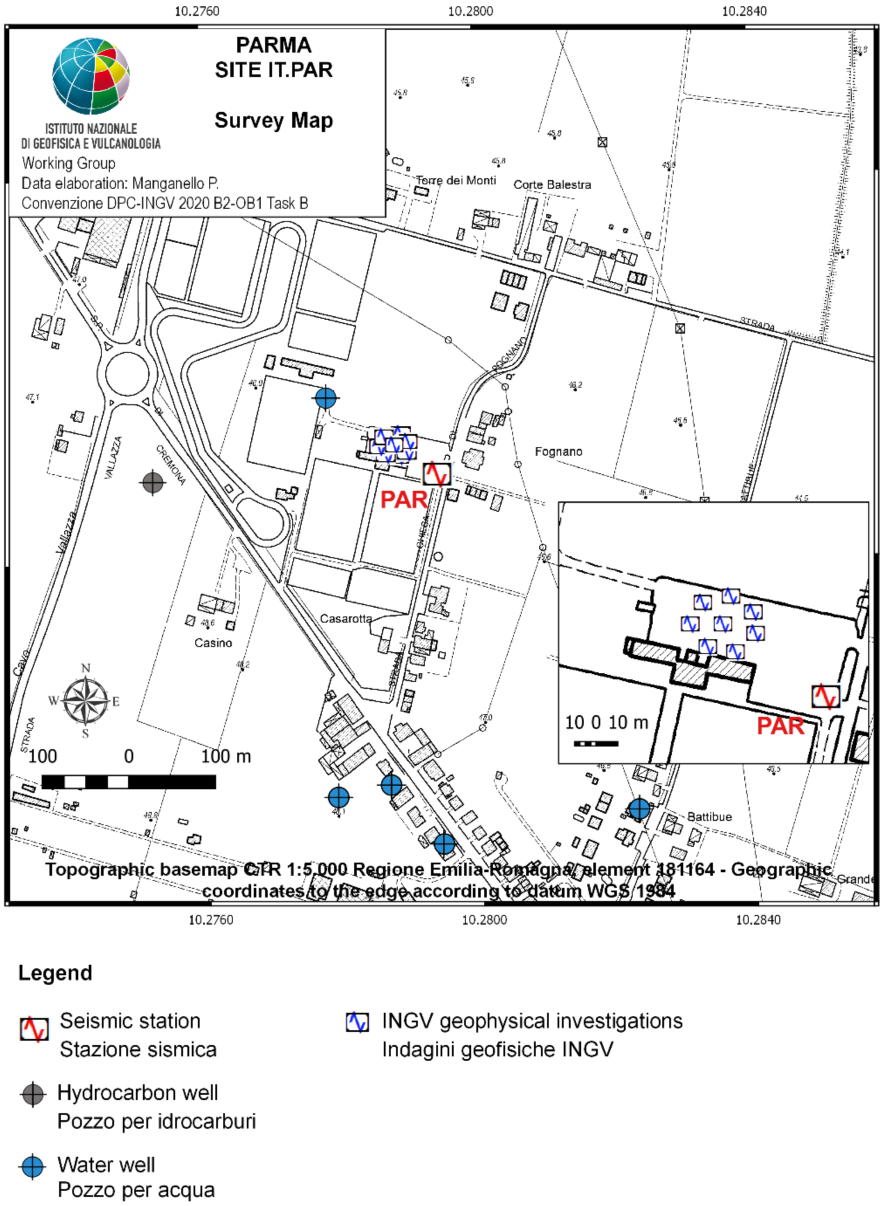

Figure 4: Map of the surveys in the surroundings of the station IT.PAR. Scale 1:5.000. The box at the bottom right contains a zoom of the area with the detail of the geophysical survey conducted by INGV Working Group for the seismic characterization of the site (Agreement DPC-INGV 2019-21, All. B2, WP1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

A6. GEOLOGICAL MODEL

6.1 General description

The studied area is located in the territory of the Parma Municipality (Northern Italy), to the north-west of the city center, and is characterized by a flat morphology.

The geological setting of the studied area is closely related with the evolution of the Po Plain, which represents the foreland basin of the Northern Apennines and the retroforeland basin of the Alps. The Po Plain sedimentary basin originates, since the Late Cretaceous, as a consequence of the thrusting of the south verging Southern Alps and the north-northeast verging Northern Apennines belts, that loaded and bended the continental crust giving rise to a foreland basin characterized by a thick synorogenic clastic sequence and complex buried tectonic structures (Doglioni, 1993; Carminati & Doglioni, 2012; Bresciani & Perotti, 2014; Castaldini *et al.*, 2019).

Since Oligocene to Late Miocene the Po basin recorded the Neoalpine inflection toward the Southern Alps, with phenomena of uplift and compression (Frantoni & Franciosi, 2010). In the Pliocene till the Lower Pleistocene the sea still covered the area of the current Po Plain forming a marine gulf between the Alps and the Apennines affected by a quite deep sedimentation controlled by subsidence. Plio-Pleistocene sea sediments, generally consisting of clays, silts and sands, have very high thicknesses, in some areas of the orders of some kilometers. Subsequently the transition from Marine Quaternary to Continental Quaternary took place with the sedimentation of fluvial sediments, controlled by tectonic processes and climate changes, until the deposition of exclusively continental Holocene sediments, with a gradually filling of the sedimentary basin from West to East (Carminati & Doglioni, 2012; Bresciani & Perotti, 2014).

The studied area is located on the southern border of Po sedimentary basin and is geologically characterized by the alluvial deposits of Ravenna Subsynthem (Upper Pleistocene – Holocene), which represents the most recent subsynthem of the Upper Emiliano-Romagnolo Synthem (AES). In particular alluvial deposits of the studied area belong to an alluvial fan ascribable to the activity of Taro river.

6.2 Geological Section

In the surroundings of IT.PAR seismic station, stratigraphic data are represented by a deep drilling of AGIP – Direzione Mineraria (Figure 5) of the 1966 exploratory well "Roncopascolo 2" (1898 *m* deep, about 330 *m* far from IT.PAR), which crossed the Continental Quaternary (up to 370-380 *m*) consisting of alluvial deposits (sandy gravels with clayey intercalations), the Marine Quaternary (up to 1220 *m*) consisting of clays, clayey sands, sands and silty clays, the Medium-Upper Pliocene sediments (up to 1565 *m*) consisting of clays, clayey sands and sands, and the silty-sandy marls of Upper Miocene (from about 1845 to 1898 *m*), and by five water wells, the nearest 155 *m* far from IT.PAR (Figure 5 upper left).

The collected data allow to draw the schematic geological section A-A' crossing the RAN seismic station IT.PAR from NW to SE (Figure 5 bottom left).

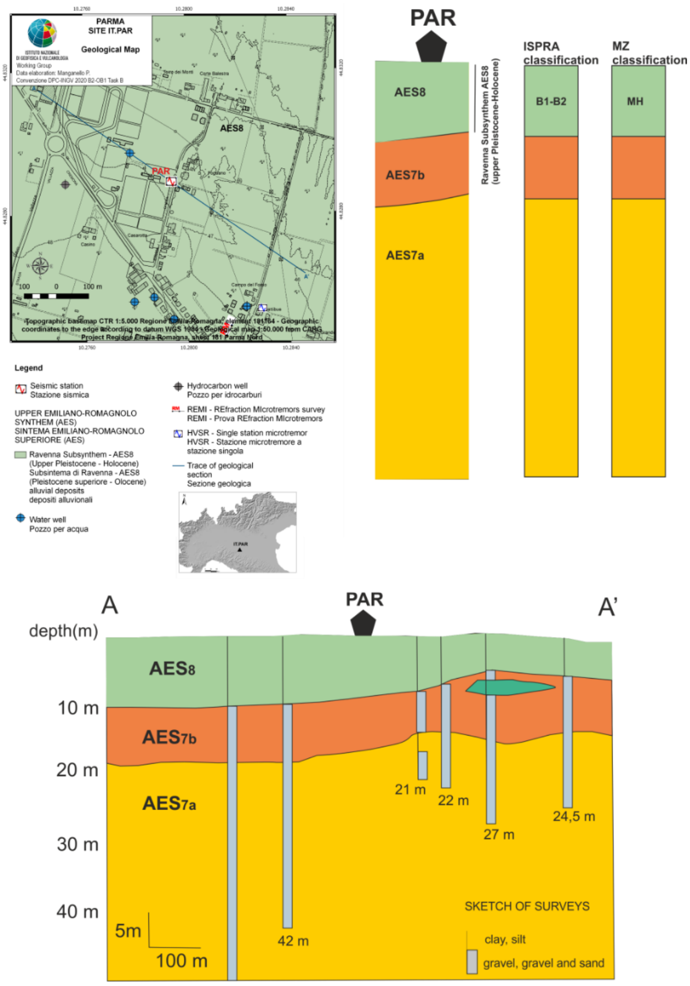

Figure 5: Left: Geological map of the study area where is installed IT.PAR seismic station; Right: (top) geological section; Bottom: subsoil model for the site.

5.3 Subsoil model

A subsoil model is built up to a depth of 50 *m* in the area around the IT.PAR seismic station on the basis of geological and stratigraphic information (Figure 5 right).

The stratigraphy shows the presence of yellow clays until a depth of about 5-10 *m*, and from about 5-10 *m* to 50 *m* gravels and sandy gravels belonging to the Ravenna Subsynthem (AES_8 – Upper Pleistocene-Holocene) and to the two stratigraphic units of the Villa Verucchio Subsynthem, Vignola Unit (AES_{7b} – Upper Pleistocene) and Niviano Unit (AES_{7a} – Upper Pleistocene).

B. V_S profile

B1. GEOPHYSICAL INVESTIGATIONS

Geophysical measurements executed next to the station IT.PAR (Italian Accelerometric Network, RAN-DPC) 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 6 shows the location of the station IT.PAR (Latitude 44.82892, Longitude 10.27939 WGS84) installed on a pillar inside a ENEL fiberglass box. 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 6: Map of the geophysical measurements performed at the IT.PAR site. The yellow placemarkers in circular geometry are the 8 stations of the 2D array in passive configuration. The red triangle indicates the IT.PAR accelerometric station (image from Google Earth http://www.earth.google.com).

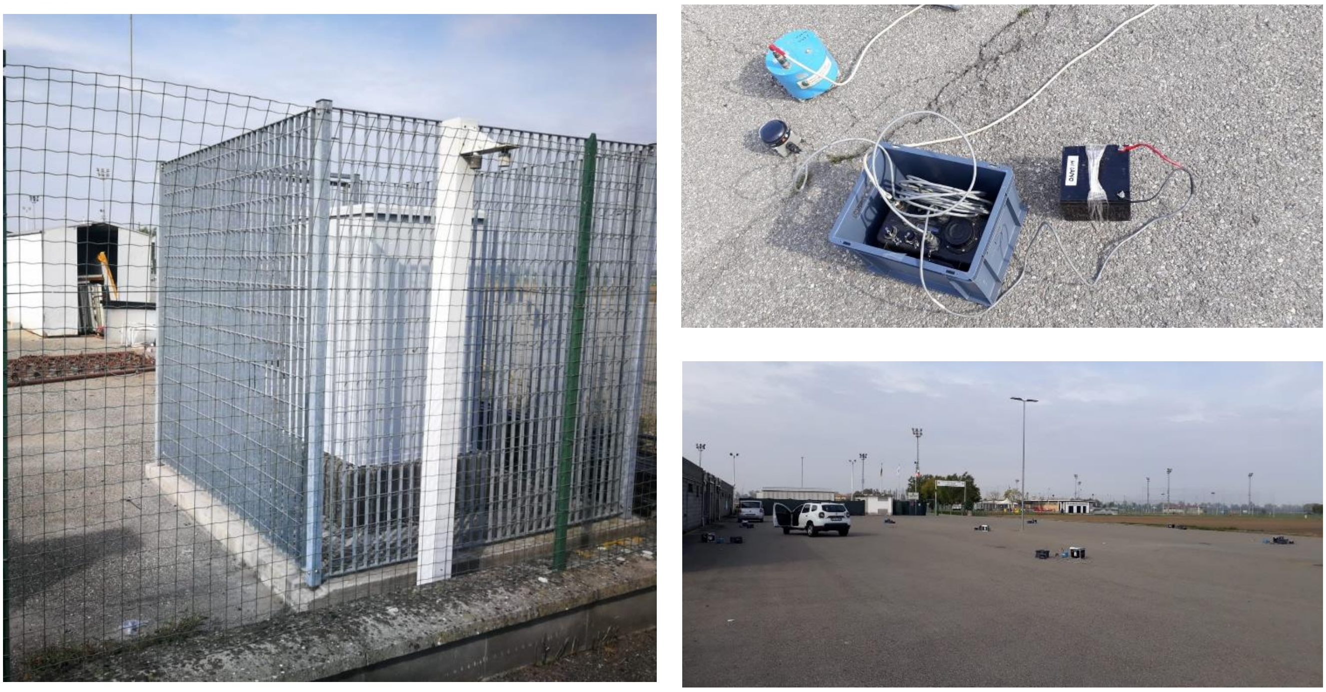

Figure 7: Left: IT.PAR accelerometric station installed on a pillar inside a ENEL fiberglass (Parma). Upper right: single station ambient noise measurement performed at IT.PAR station. Bottom right: 2D passive ambient noise array installed close to the PAR station.

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 duration of about two hours. The sampling rate was set to 200 sps.

To assess the resonant frequency at IT.SSU 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 peak at 5.85 Hz (f_0), with amplitude around 3. The directional H/V show for the f_0 a slight polarization effect around 20°N. The results are summarized in figure 8.

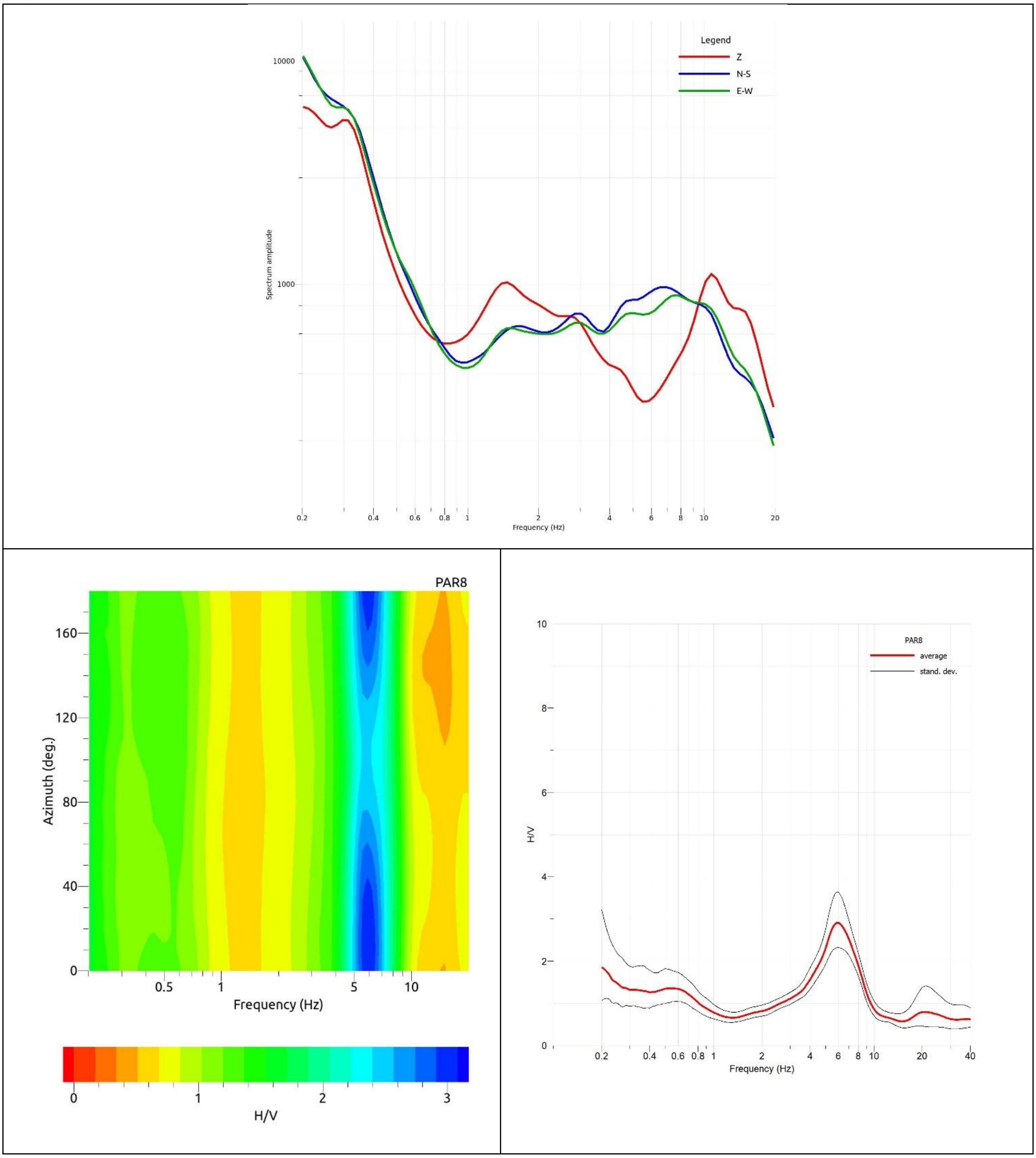

Figure 8: H/V results at IT.PAR station. Top: Fourier spectra of the three components. Bottom left: directional H/V. Bottom right: H/V curve (with mean and standard deviation).

Data from the 2D array have been analyzed with the GEOPSY code (http://www.geopsy.org) in terms of high-resolution FK analysis. The FK dispersion curve obtained from the vertical components is shown in Figure 9 (top panel). We interpret and assume that the dispersion curve obtained in Figure 9 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.

In this case also the modified spatial autocorrelation technique (MSPAC, fig. 9 bottom panel) and the ESAC (Extended Spatial AutoCorrelation) method have been considered to expand the confidence interval of the FK dispersion curve.

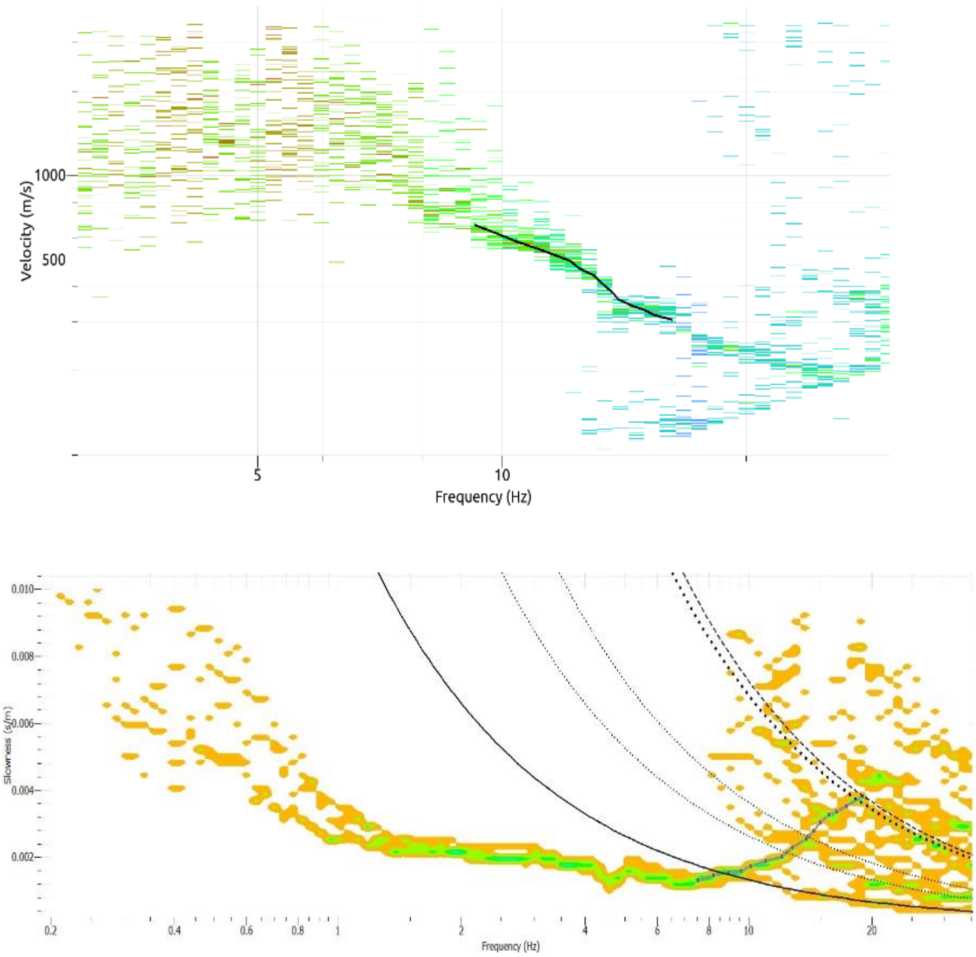

Figure 9: FK (top) and MSPAC (bottom) analysis dispersion curves for the 2D ambient noise passive array.

To obtain the shear wave velocity profile for the area the average among FK, MSPAC and ESAC dispersion curves has been inverted together the right flank of the H/V (first peak) curve showed in figure 8 (right bottom panel).

B2. SEISMIC VELOCITY MODEL

The final result of the inversion is shown in Figure 10 where we can observe two discontinuities at about 7 and 22 m as the subsoil model highlights. We obtained a fairly good fit between experimental and theoretical curves using a model parameterization composed of two main layers over half-space. The velocity is reported in table 5.

The first discontinuity is related to a yellow clay layer belonging to Ravenna Subsynthem (AES_8 – Upper Pleistocene-Holocene) until a depth of about 5-10 m passing to gravels and sandy gravels (Vignola Unit, AES_{7b} – Upper Pleistocene). The second discontinuity is probably related to the transition from Vignola Unit, AES_{7b} to Niviano Unit (AES_{7a} – Upper Pleistocene) due to a different density of deposits.

The best -fit model of V_s is represented in Figure 11 and Table 5.

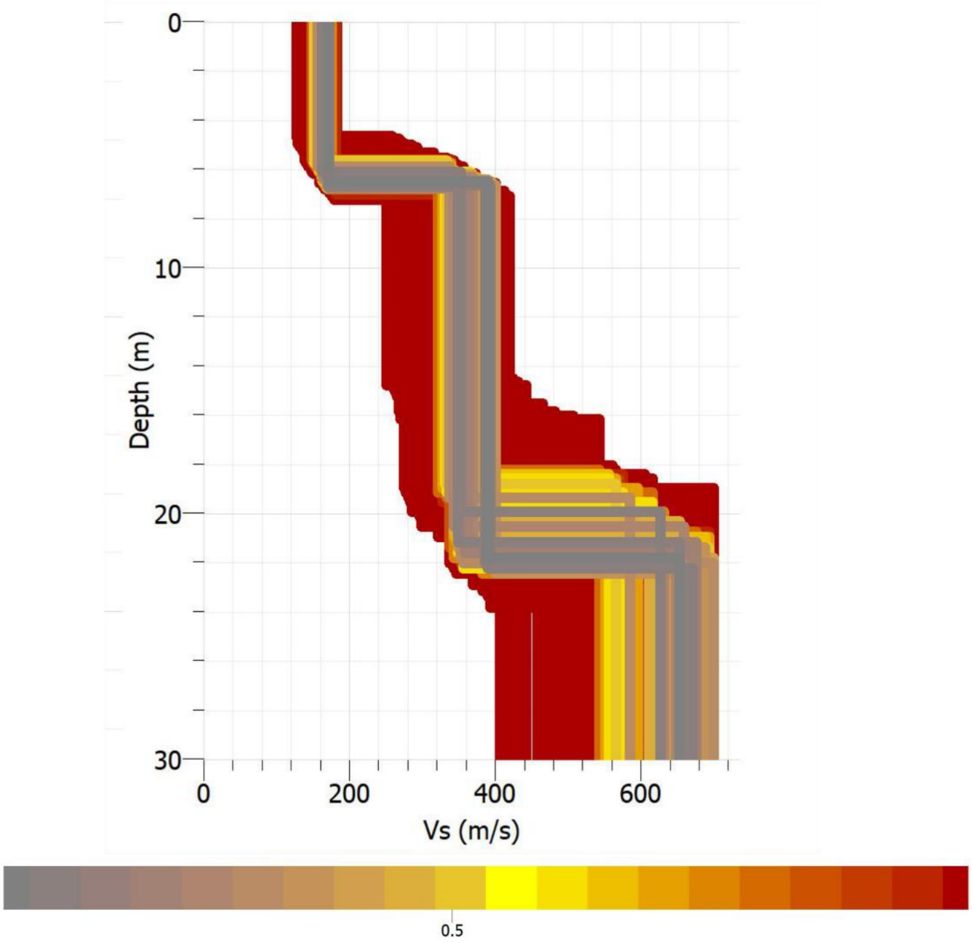

Figure 10: V_S profile obtained through the joint inversion of the FK, MSPAC and ESAC dispersion curves (Figure 9) together with the right flank of HVSR curve.

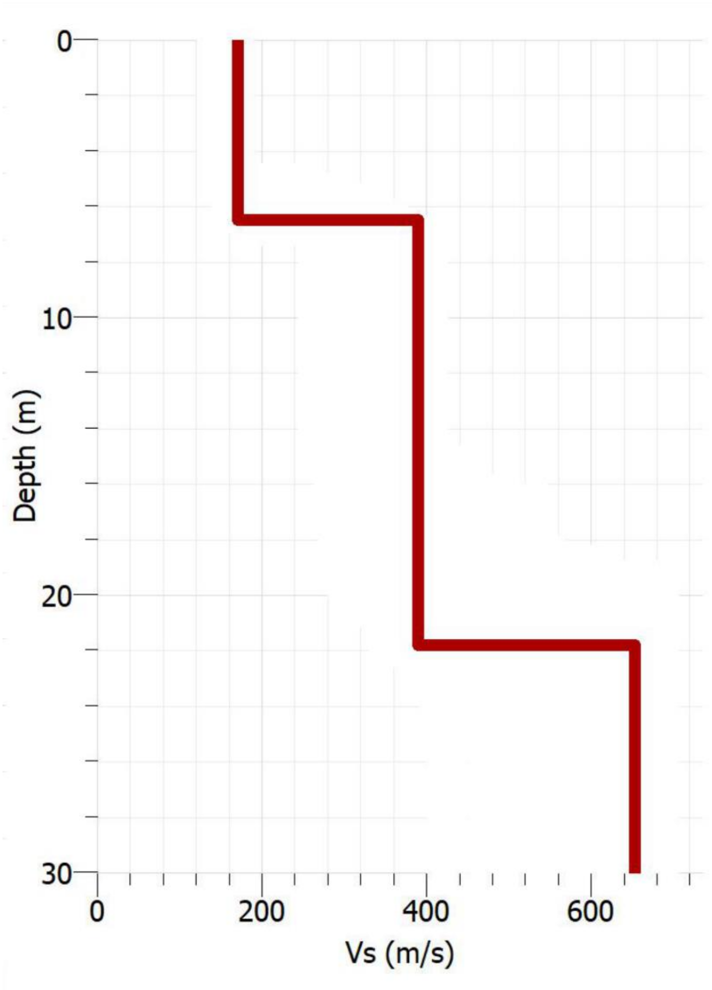

Figure 11: Best-fit model of V_s values

From	*To*	*Thickness (m)*	*V_s (m/s)*
0	6.51	6.51	170.07
6.51	21.81	15.30	395.94
21.81	30.00	8.19	653.08

Table 5: Best-fit model

B3. CONCLUSIONS

According to the current Italian seismic code (NTC 2018), 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 11, the velocity of 800 m/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 336 m/s. Of consequence, IT.PAR site is classified in the soil category C, for both the NTC18 and EC8 seismic codes (Table 6).

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

Table 6: Soil Class

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[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)"