ISTITUTO NAZIONALE DI GEOFISICA E VULCANOLOGIA

Velocity profile report at the seismic station IT.BNO – Breno (BS)

Report sul profilo di velocità sismica per il sito della stazione sismica IT.BNO – Breno (BS)

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Subject: **Final report illustrating measurements, analysis and results for Vs profile at station IT.BNO**	

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1. INTRODUCTION

In this report, we present the geophysical measurements and the results obtained in the framework of the 2019-2021 agreement between INGV and DPC, Allegato B2, WP1 - TASK 2: "Caratterizzazione siti accelerometrici" (Coord.: G. Cultrera, F. Pacor). In this report, the results for station IT.BNO, belonging to the Italian Strong Motion Network (RAN-DPC), are presented. The recording station is located in Val Camonica (Central Alps), specifically in the town of Breno that is part of the Brescia province.
Geophysical measurements 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).

2. GEOPHYSICAL INVESTIGATIONS

Figure 1 shows the location of the IT.BNO seismic station (in red) and the location of the seismic stations used for the 2D array (in yellow). The distance between IT.BNO seismic station and the center of the 2D array is 20 m. The seismic sensors were positioned in a circular geometry with a radius of 10 m, as shown in Figure 1. The corresponding geographic coordinates are reported in Table 1.

Figure 1: Map of the geophysical measurements performed at the IT.BNO site. The yellow points are the nine stations of the 2D array in passive configuration. The red point indicates the IT.BNO seismic station.

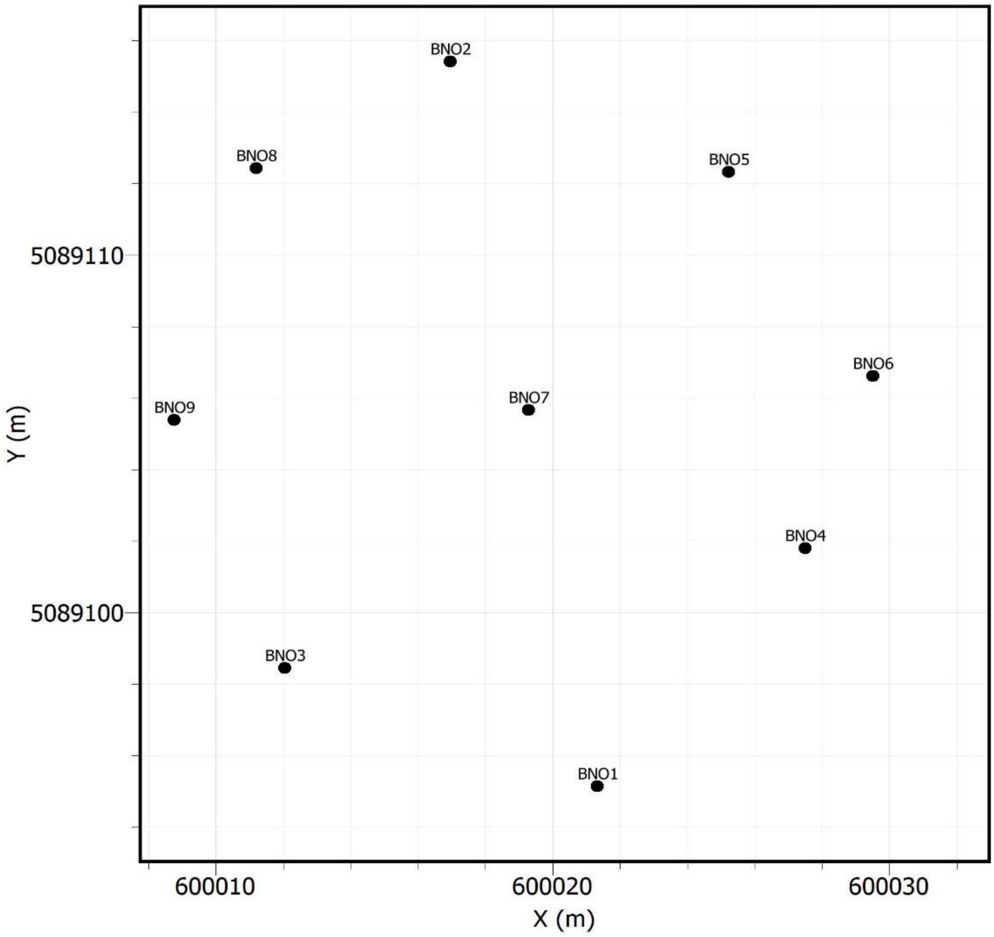
Station	Lat. (°)	Lon. (°)	El. (m)
BNO1	45.948140	10.290524	392
BNO2	45.948323	10.290472	409
BNO3	45.948171	10.290405	399
BNO4	45.948199	10.290605	402
BNO5	45.948294	10.290578	397
BNO6	45.948242	10.290632	394
BNO7	45.948235	10.290500	400
BNO8	45.948297	10.290397	402
BNO9	45.948234	10.290364	402

Table 1: geographic coordinates of the array stations (WGS84).

All stations of the array are equipped with Reftek-130 digitizer and Lennartz 3D-5s velocimetric sensors. The measurements were recorded in June and lasted about an hour and a half.

A view of the fieldwork is shown in Figure 2. The seismic sensors were positioned in a circular geometry in order to have a homogeneous azimuthal coverage that allows a better performance of the array techniques.

a)



b)

Figure 2: a) fieldwork at the IT.BNO seismic station. b) 2D array geometry (UTM coordinates).

The geometry of the array controls the response in terms of theoretical transfer function as described in Figure 3. On the left, the array transfer function is shown. On the right, the limits for the aliasing conditions are reported both in slowness and in velocity domains.

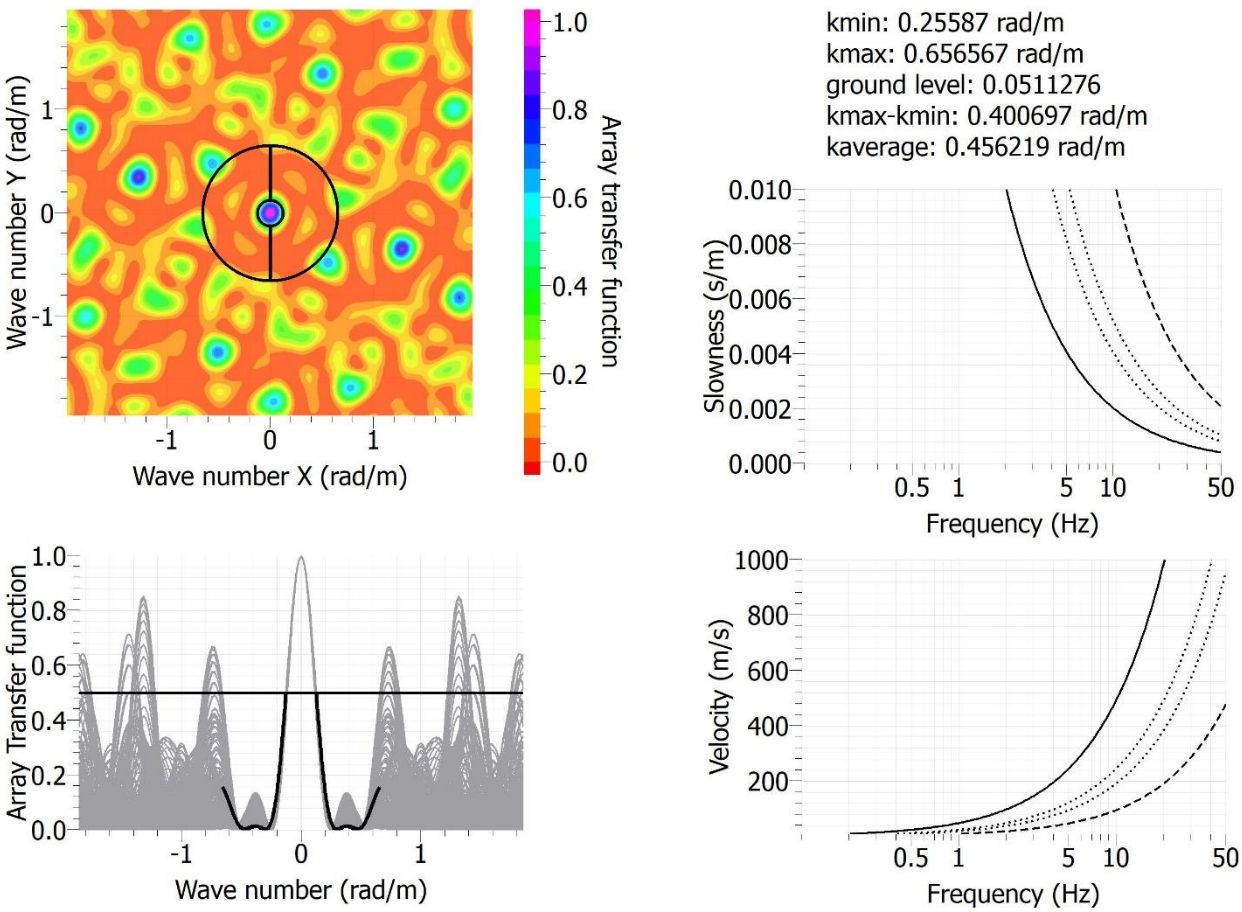


Figure 3: on the left, the theoretical array transfer function is reported for the 2D array. On the right, the aliasing conditions are reported in the slowness and velocity domains.

The H/V curves of the 9 stations are superimposed on each other in Figure 4, where the average H/V is reported in red. There is a general agreement of the H/V shapes showing a good overlapping in the frequency range 1-15 Hz. On the other hand, the H/V curves show a high variability at lower frequency (< 1Hz) probably due to the sensors instability. The H/V peak observed at 1.3 Hz most likely has an anthropic origin, as deduced by the local narrow peak observed on both the H/V (Figure 4) and the Fourier spectra (Figure 5), with a small polarization around 150°-180° (Figure 6). Moreover, a slight amplification is observed on the H/V curve at 7.5 Hz (Figure 4), presenting a small polarization around 150°-180° (Figure 6).

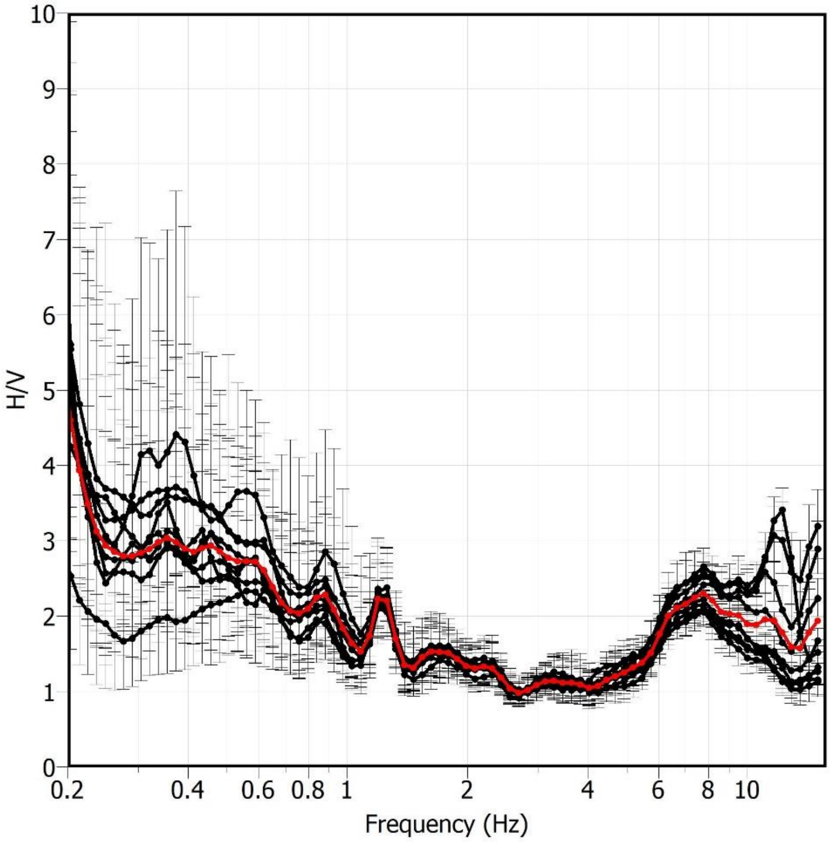


Figure 4: H/V curves of the 9 stations of the 2D array. The average is reported in red. The vertical bars estimate the H/V uncertainties.

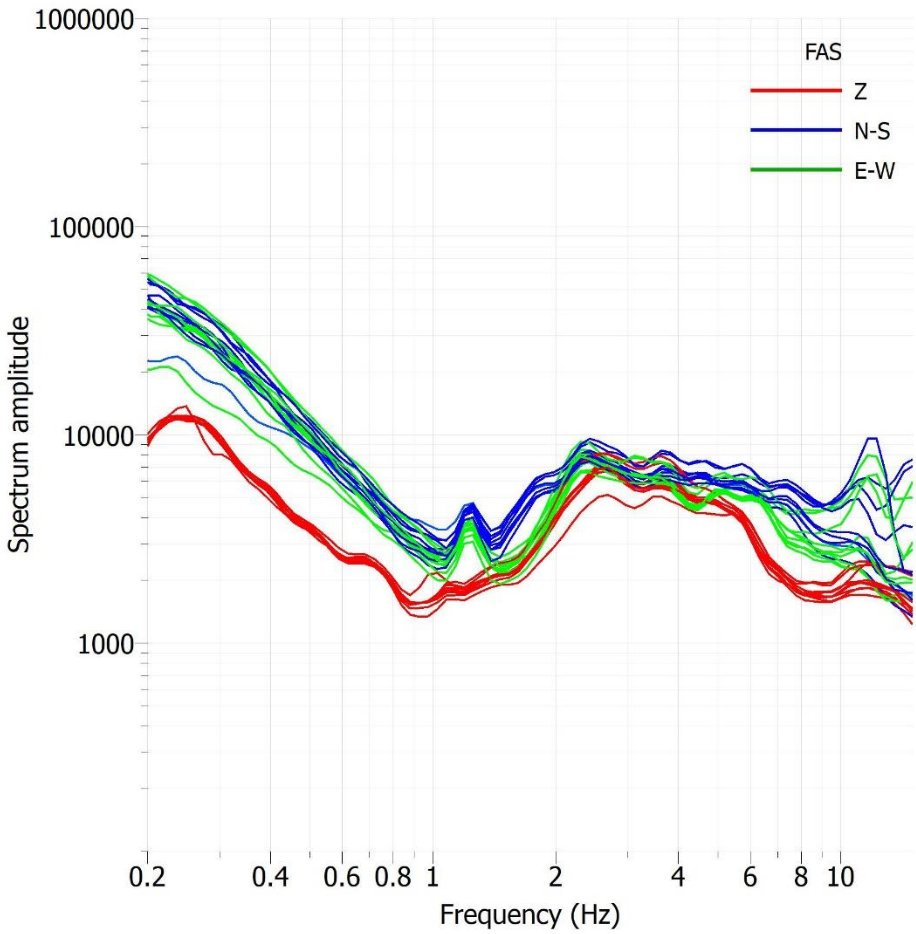


Figure 5: Fourier amplitude spectra of the 9 stations of the 2D array. The red curves are the vertical components, whereas the blue and green curves are the N-S and E-W components respectively.

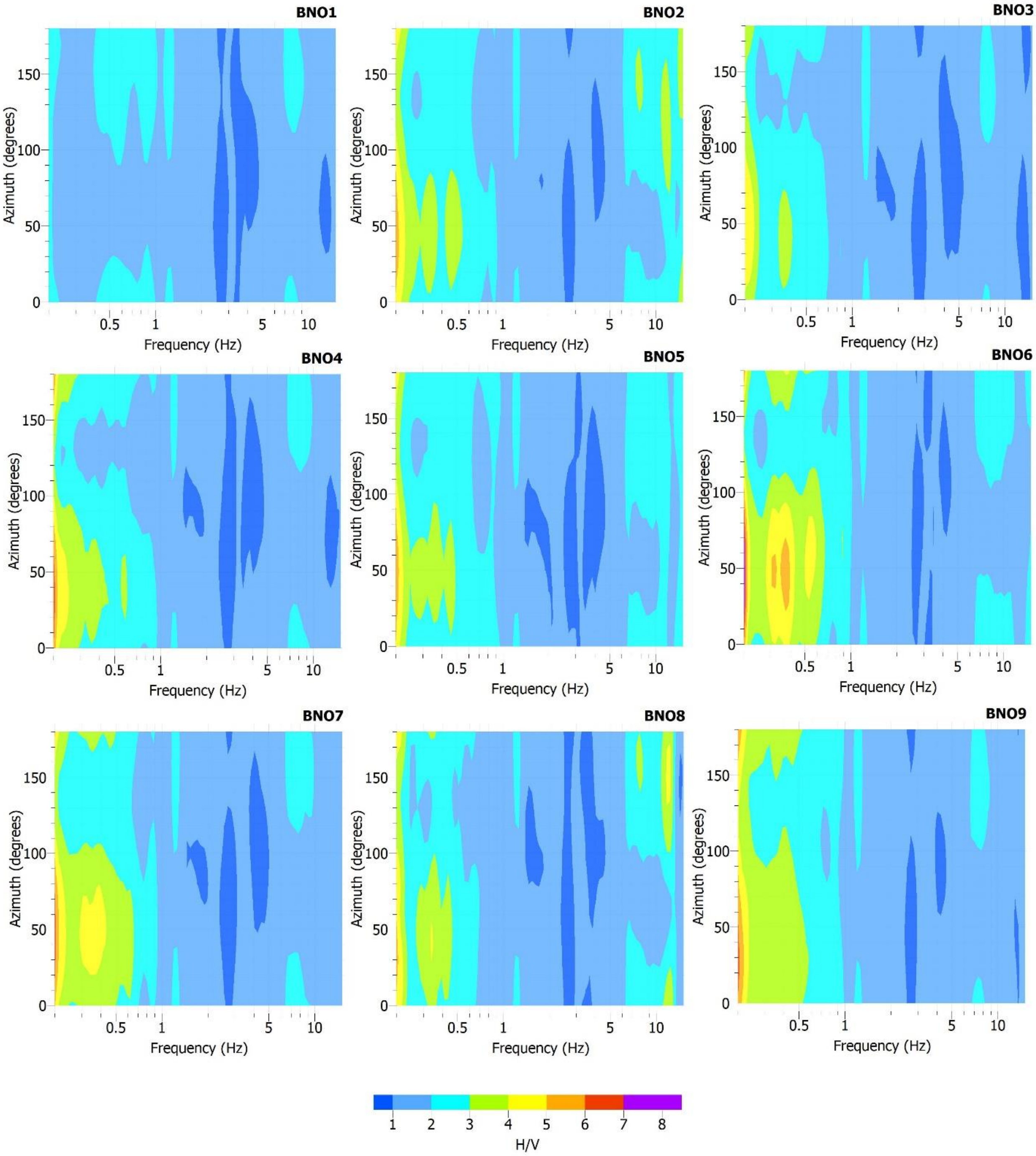
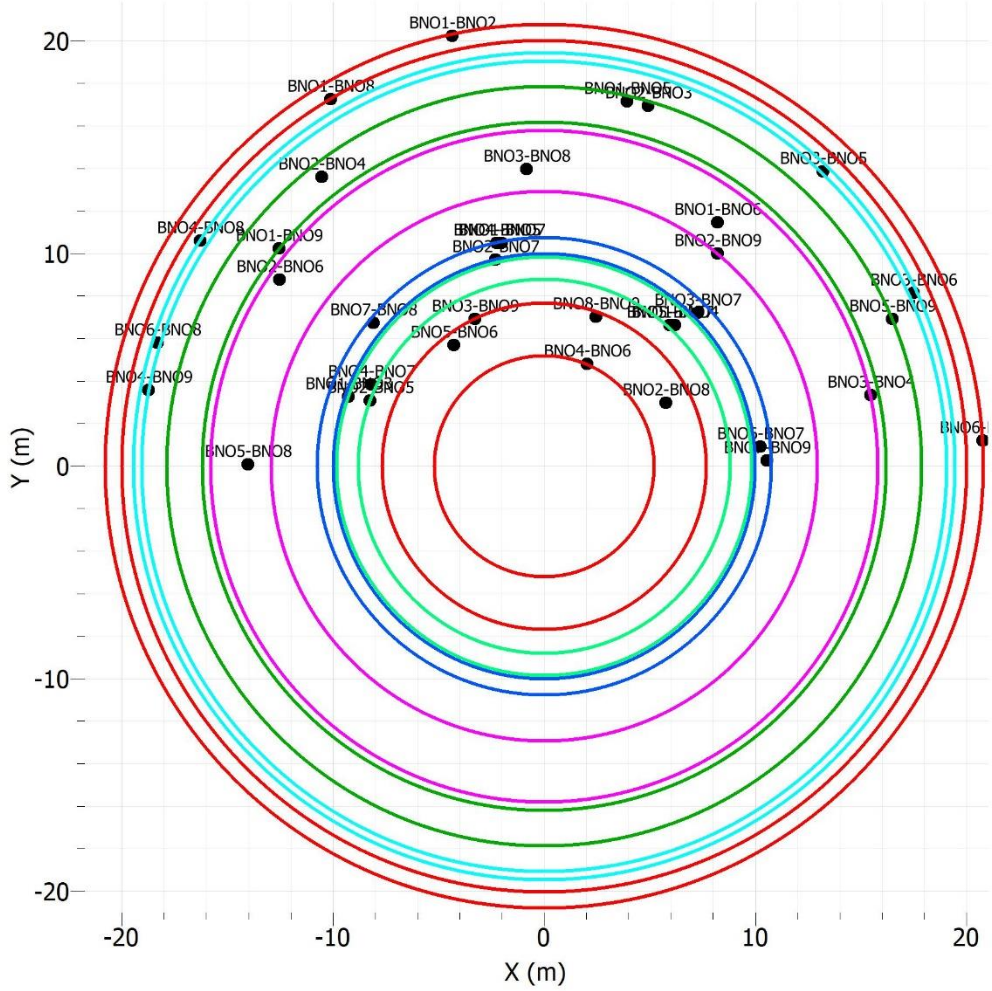


Figure 6: rotated H/V curves for the 9 stations of the 2D array.

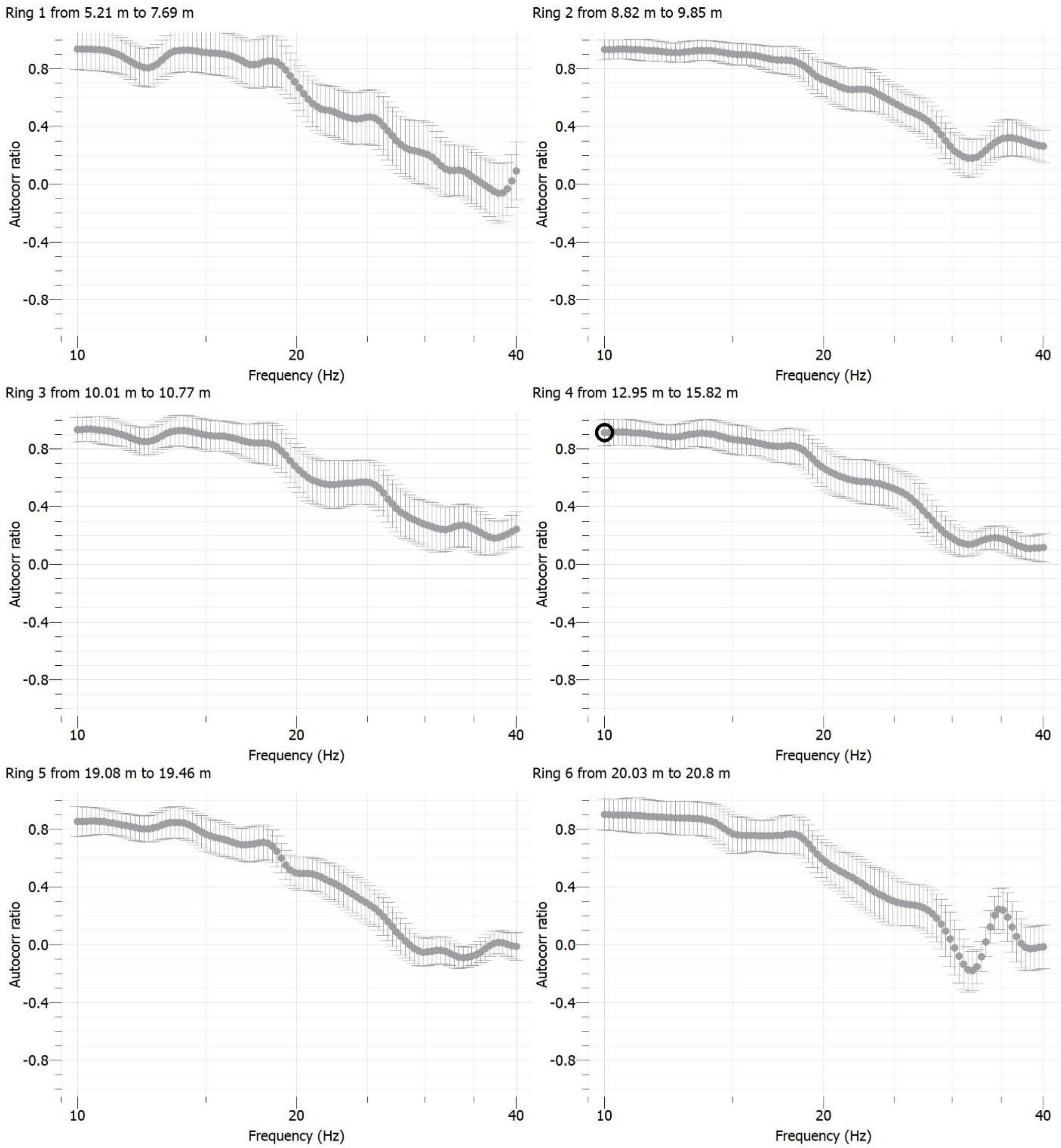
Data from the 2D array have been analyzed with the GEOPSY code (http://www.geopsy.org) using both the high-resolution FK analysis and the modified spatial autocorrelation technique (MSPAC). However, being the site located on rock, the dispersion of surface waves is not easy to observe and the high-resolution FK analysis could not detect any dispersion of surface waves. On the other hand, the modified spatial autocorrelation technique (MSPAC) allowed roughly assessing the Vs of the site. The modified spatial autocorrelation technique (MSPAC) has been applied to the passive data to obtain the autocorrelation curves. Figure 7a shows the 7 rings adopted for the MSPAC analysis, whose geometries are reported in Table 2. Figure 7b shows the spatial autocorrelation curves computed for each ring.

Ring	R min	R max	Pairs
1	5.21	7.69	5
2	8.82	9.85	5
3	10.01	10.77	7
4	12.95	15.82	6
5	16.21	17.88	5
6	19.08	19.46	5
7	20.03	20.8	3

Table 2: geometry of the 7 rings adopted for the MSPAC analysis.


BNO1-BNO2
BNO1-BNO8
BNO3-BNO8
BNO2-BNO4
BNO1-BNO6
BNO4-BNO8
BNO1-BNO9
BNO2-BNO7
BNO2-BNO9
BNO2-BNO6
BNO7-BNO8
BNO3-BNO9
BNO3-BNO7
BNO5-BNO9
BNO6-BNO8
BNO5-BNO6
BNO4-BNO6
BNO4-BNO9
BNO4-BNO7
BNO2-BNO8
BNO3-BNO4
BNO5-BNO7
BNO5-BNO8
20
10
0
-10
-20
Y (m)
X (m)

a)



b)

Figure 7: a) rings selected for the MSPAC analysis; b) autocorrelation curves of the selected rings.

The auto-correlation curves in Figure 7b have been inverted to obtain the corresponding dispersion curve (Figure 8) that we assume as relative to the fundamental mode of the Rayleigh dispersive waves in the frequency range 10-30 Hz. The MSPAC technique is affected by a low resolution, but indicates a hard rock site with shear-wave velocity of approximately 1700 m/s.

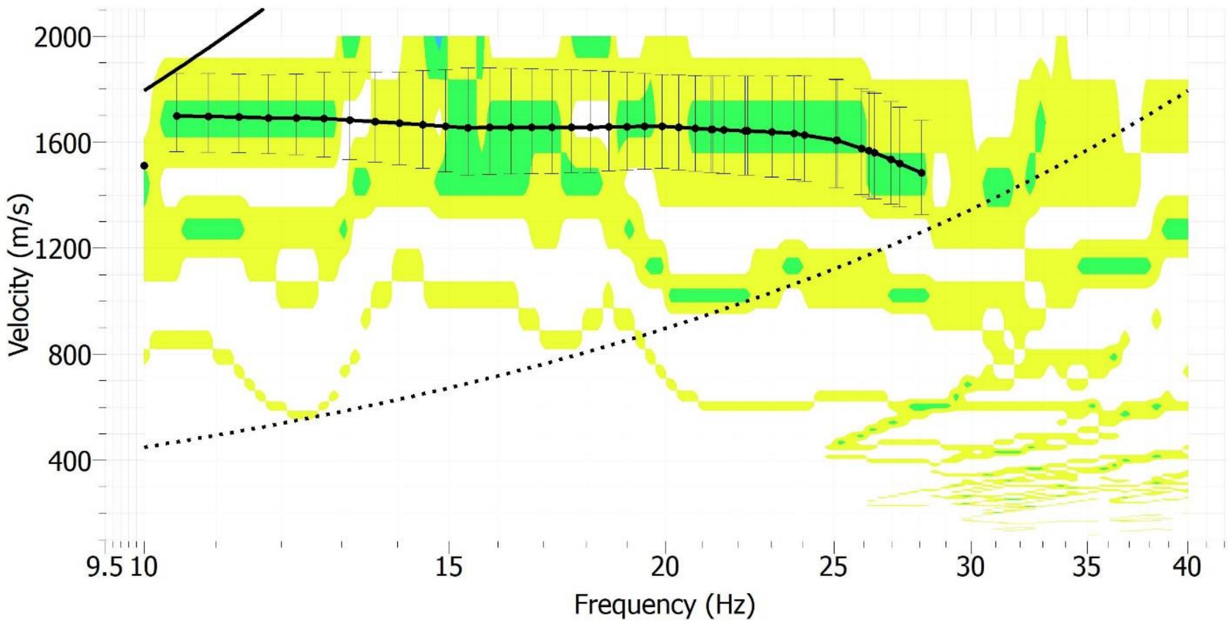
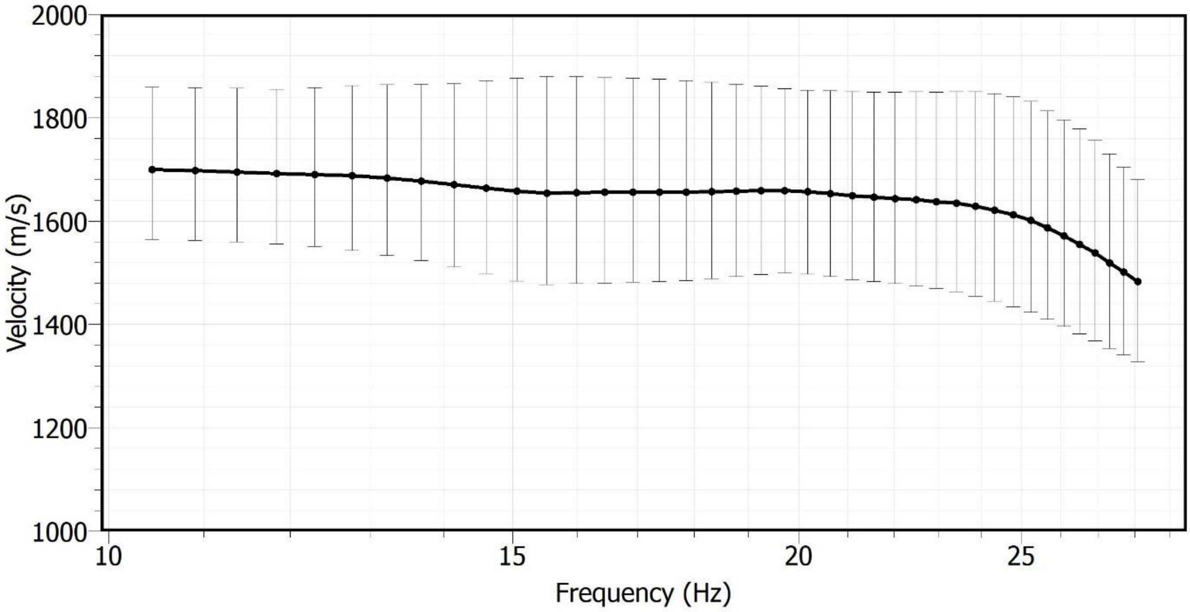


Figure 8: picked dispersion curve with the MSPAC method.

3. SEISMIC VELOCITY MODEL

The MSPAC dispersion curve, adopted for the inversion process, is reported in Figure 9, with the corresponding uncertainty. As previously observed, the uncertainty in the velocity assessment is high, but the array measurements indicate a rock site.



b)

Figure 9: Rayleigh wave dispersion curve adopted for the inversion process. The vertical bars indicates the uncertainty on the velocity estimates.

Since the site is located near outcropping limestone formations, with an H/V curve mostly flat, without a clear stratigraphic peak, we just invert the Rayleigh wave dispersion curve in Figure 9. The resulting models after the inversion step are shown in Figure 10. We obtained a fairly good fit between experimental and theoretical curves using a model parameterization composed of one shallow layer over halfspace. The *Vs* model of Figure 10 indicates a very thin soft layer with thickness of approximately 2 m and *Vs* around 249 m/s. The halfspace is found below 2 m in depth with Vs > 1600 m/s.

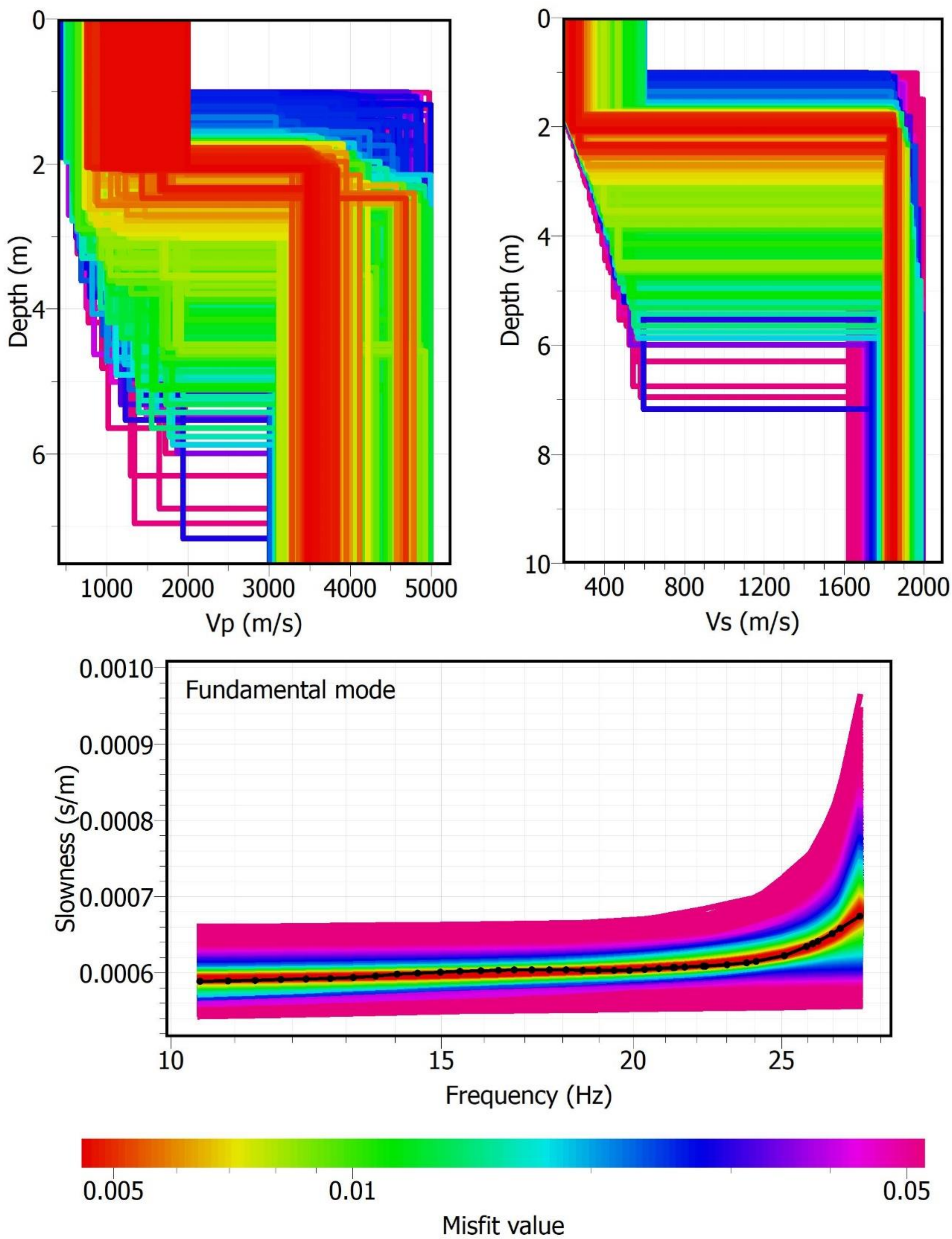


Figure 10: Inversion of the empirical dispersion curve (black curve) obtained with the 2D passive array.

The best Vp and Vs model (i.e. lowest misfit) resulting from the inversion are proposed in Figure 11 and reported in Table 3.

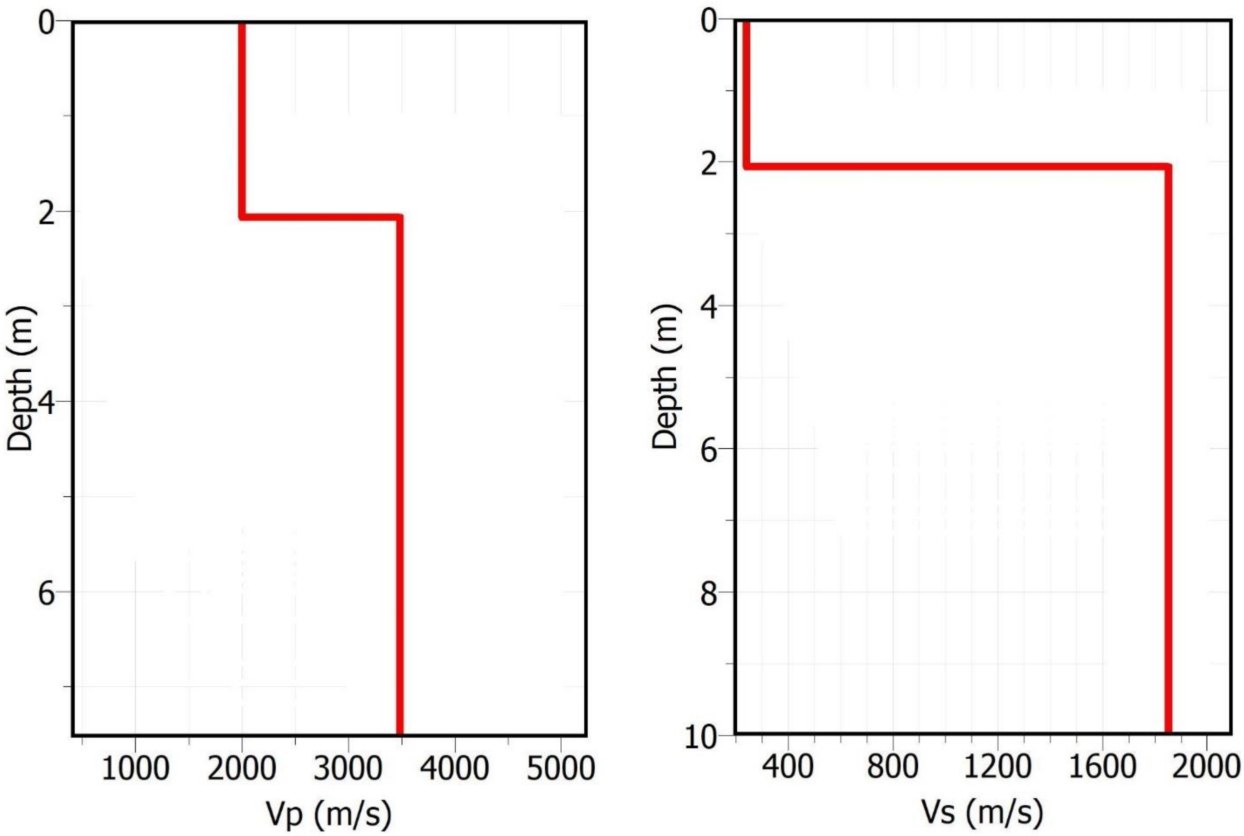


Figure 11: Best-fit models of Vp (left panel) and Vs (right panel) values.

From	*To*	*Thickness (m)*	*V_s (m/s)*	*V_p (m/s)*
0	2	7	249	2000
2	?	?	1852	3492

Table 3: Best-fit model

4. CONCLUSIONS

The H/V analyzes at the IT.BNO seismic station indicate a stiff site without any significant amplification in the frequency range 0.1-15 Hz.

The *Vs* profile obtained from the inversion of the Rayleigh wave dispersion curve retrieved in this study indicates a stiff bedrock (*Vs* > 1600 m/s) around 2 m in depth. The correlation with the stratigraphic column provided in the geological report at IT. BNO (Working group INGV (2019). Geological report at the seismic station IT. BNO) is shown in figure 12. The first 2 meters correlates with the morainic deposits of the Cantù Syntem, whereas the stiff bedrock corresponds to the Breno Formation, made of dolomia and dolomitic limestone (Figure 12).

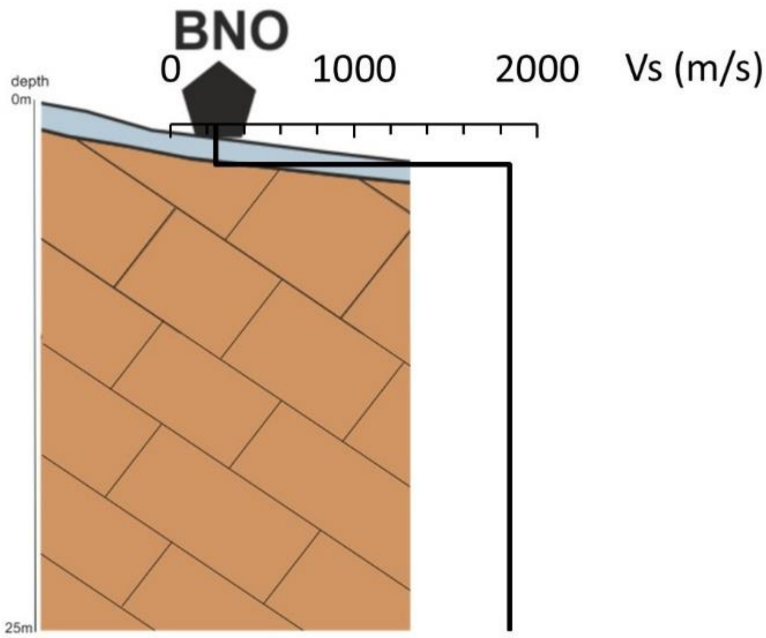


Figure 12: correlation between geological and geophysical information at the IT.BNO site (stratigraphic column from Working group INGV (2019). Geological report at the seismic station IT. BNO – Breno).

IT.BNO is classified in the soil category A following the NTC18 and EC8 seismic classifications (Table 4).

Soil class (NTC 2018)	***Soil class (EC8)***
A	A

Table 4: Soil Class

REFERENCES

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.

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).

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