INGV Istituto Nazionale di Geofisica e Vulcanologia

# Velocity profile report at the seismic station IT.CSA (Castelnuovo - Assisi)

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|---|---|
| Subject: **Final report illustrating measurements, analysis and results for station IT.CSA** | |



**Convenzione DPC-INGV 2018, Allegato B2: Obiettivo 1 - TASK B**: "Caratterizzazione siti accelerometrici" (Coord.: G.Cultrera, F. Pacor)
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## 1. Introduction

In this report, we present the geophysical measurements and the results obtained in the framework of the 2018 agreement between INGV and DPC, called *Allegato B2: Obiettivo 1 - TASK B: Caratterizzazione siti accelerometrici (Responsabili: G. Cultrera, F. Pacor)* for the site characterization of the Italian accelerometric stations. Here the results for station IT.CSA (Latitude: 43.00802, Longitude: 12.59060), belonging to the Italian Strong Motion Network (RAN-DPC), are presented.

Geophysical measurements are usually 2D arrays or 1D linear arrays in active or passive configuration (MAWS) and provide results in terms of dispersion curves that are inverted to obtain shear-wave velocity ($V_s$) profiles for the studied area and suitable for assigning the EC8 class. For this site we decided to use the results of two 2D arrays of different aperture.


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## 2. Geophysical investigations

Figure 1 shows the location of the stations used for the two 2D arrays.

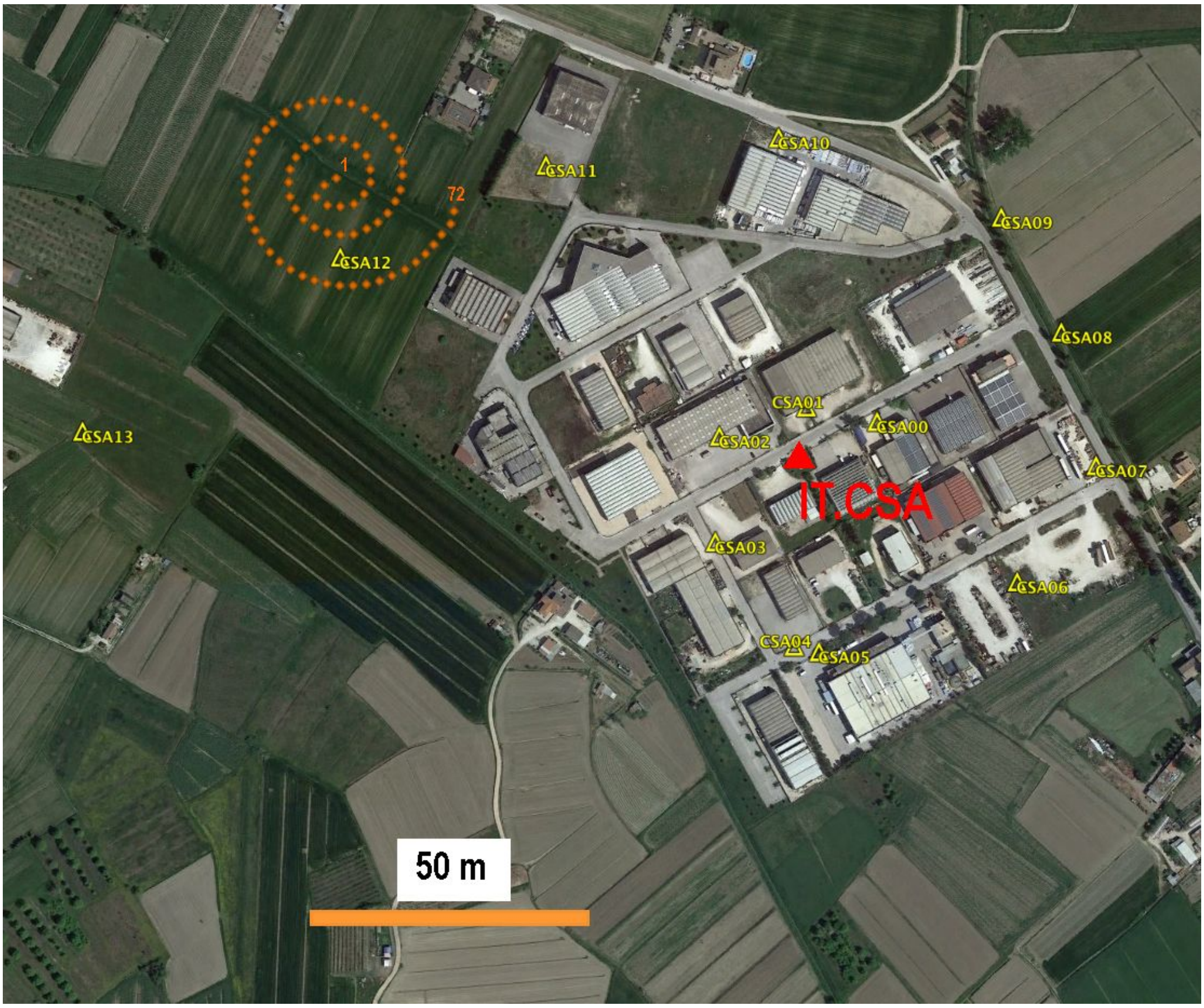


**Figure 1: Map of Castelnuovo showing the two 2D arrays performed close to IT.CSA station. The yellow points are the fourteen stations of the large 2D array in passive configuration. All stations are equipped with Reftek R130 digitizer and Lennartz 3D-5sec velocimetric sensors. The orange points are the seventy-two 4.5Hz geophones used for the passive small 2D array. The instrumentation is the Geometric Geode, the same used for passive and active MASW. The red triangle indicates the station IT.CSA.**



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## 2.1 ARRAY MEASUREMENTS RESULTS

The large 2D array was performed using 14 single seismic stations equipped with Reftek 130 digitizers and Lennartz 3d-5s velocimetric sensors. The common noise recording lasted about 2 hours. The seismic sensors were positioned along spiral geometry with irregular spacing and centered around station IT.CSA. The aperture of this array is about 1000mt as shown in Figure 2.

The small 2D array was performed using 72 4.5Hz geophones connected through cables to three Geode digitizers. We recorded 10 windows of 8 minutes, for a total length of 1h20’. The geophones were positioned along spiral geometry. The aperture of this array is about 200mt as shown in Figure 2. The area of this experiment is about 400mt far from station IT.CSA but in similar geological conditions.

The topography of the entire shown in Figure 1 is absolutely flat and the level of anthropic disturbances was acceptable during the experiment.

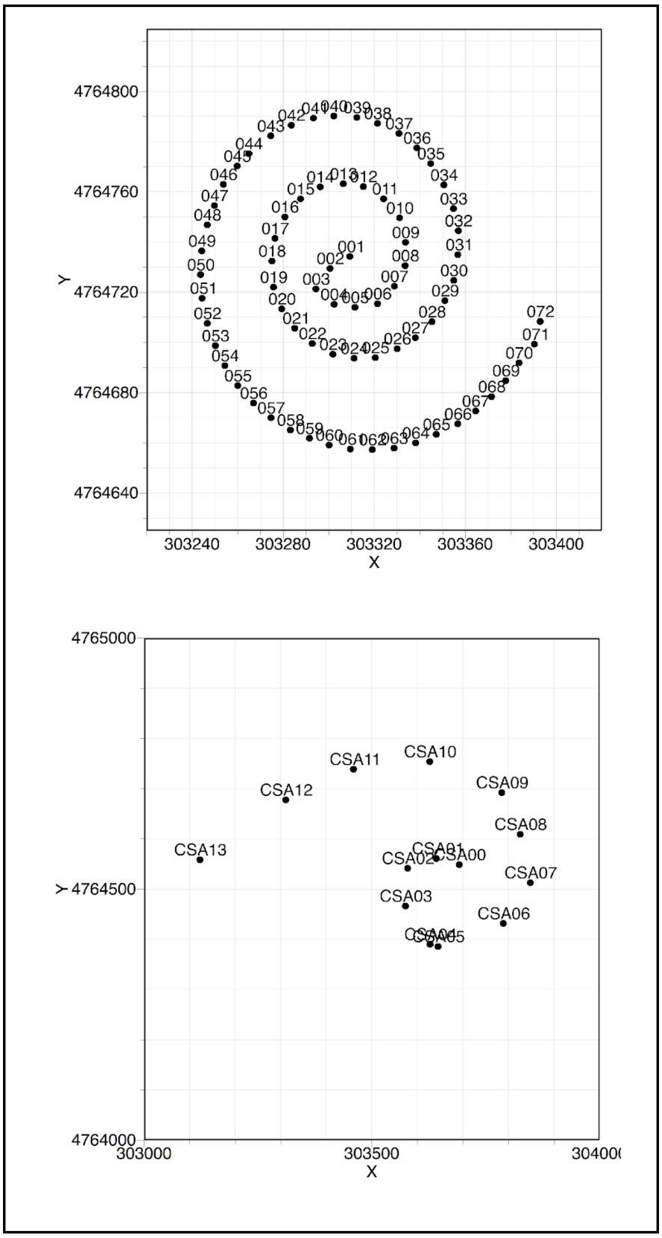


**Figure 2: Top: geometry of the 2D array performed with 4.5Hz geophones. Bottom: geometry of the 2D array performed with seismic sensors.**

The geometry controls the response of the arrays in terms of theoretical transfer function. In particular, Figure 3 shows the array transfer function for the large 2D array.

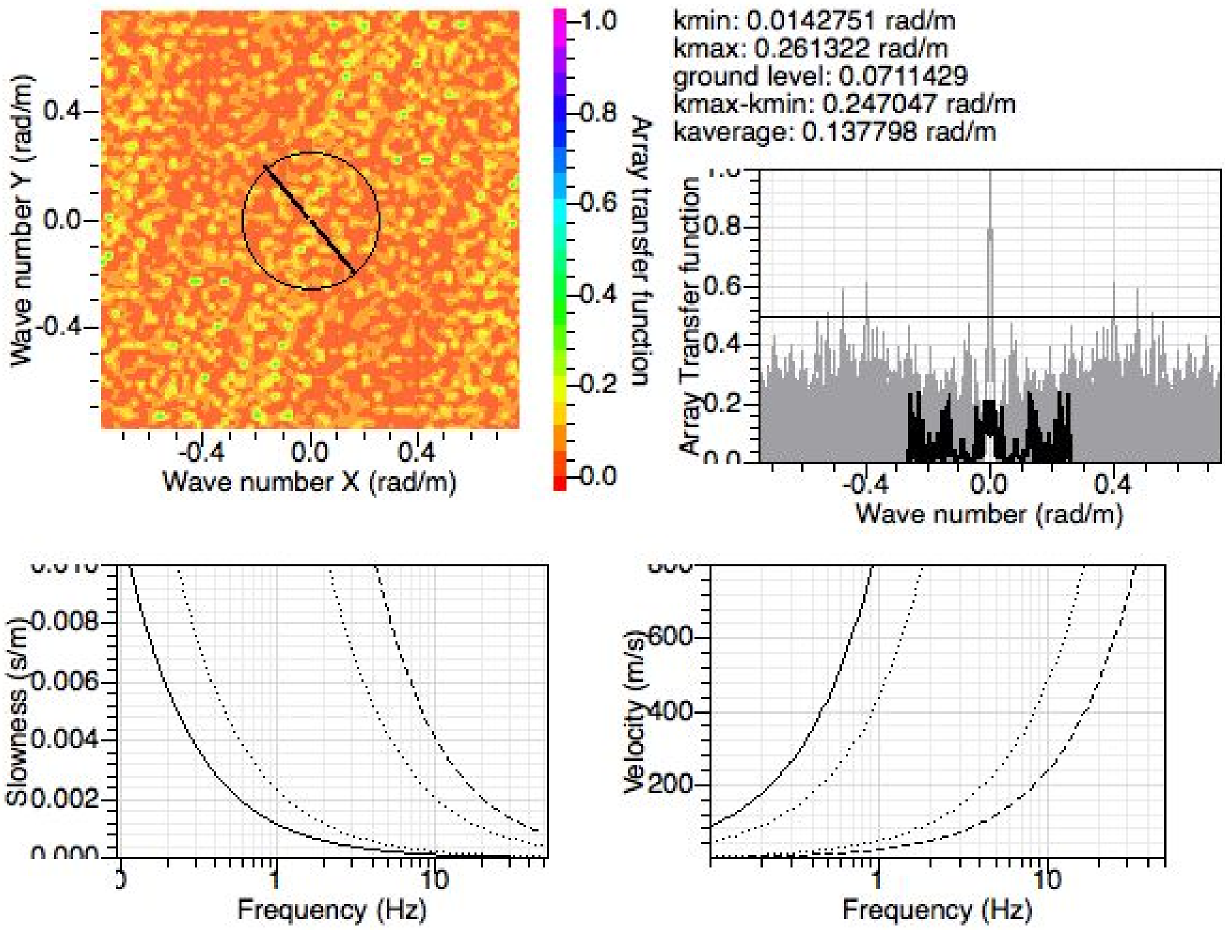


**Figure 3: Theoretical Array Transfer function for the large 2D array at IT.CSA**

In Figure 4 (top-left side) the average H/V curves of the 14 stations of the large 2D array are overimposed each other. There is a very good agreement among the measurement points in a wide frequency range. There is also a good agreement with the H/V published in the IT.CSA station monography (Fig. 4 bottom) of ITACA (http://itaca.mi.ingv.it) or ESM (http://esm.mi.ingv.it), even if with lower amplitudes.

For the small array it wasn't possible to perform the H/V analysis because the 4.5Hz geophones are only vertical. Anyhow, one seismic stations of the large array (CSA12) falls into the area of this small 2D array and it is consistent with the other measurement points.



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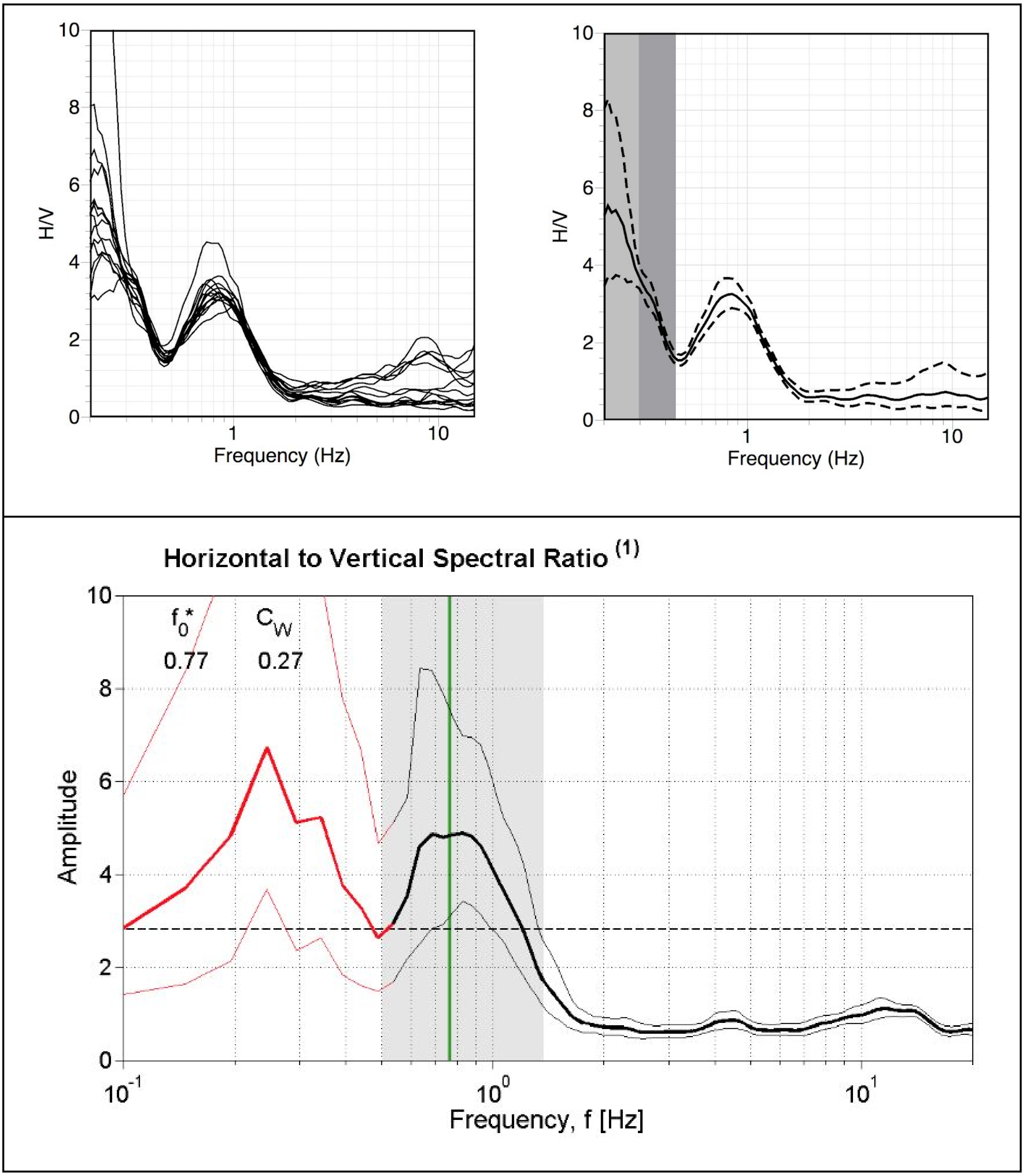


**Figure 4: Top-left: H/V curves of the 14 stations of the large 2D array. Top-right: Average and standard deviation of H/V. Bottom: H/V of IT.CSA as published in ITACA or ESM websites**

Data from the two 2D arrays have been analysed in terms of FK, high-resolution FK (HRFK) and SPAC techniques. Because the three methods lead to very similar results, we decided to maintain only the results coming from the conventional FK analysis.

All the methods lead to a very good determination of the dispersion curves (Figure 5). The picking of the dc was easy (Figure 5). For the analysis we used the code GEOPSY (http://www.geopsy.org)

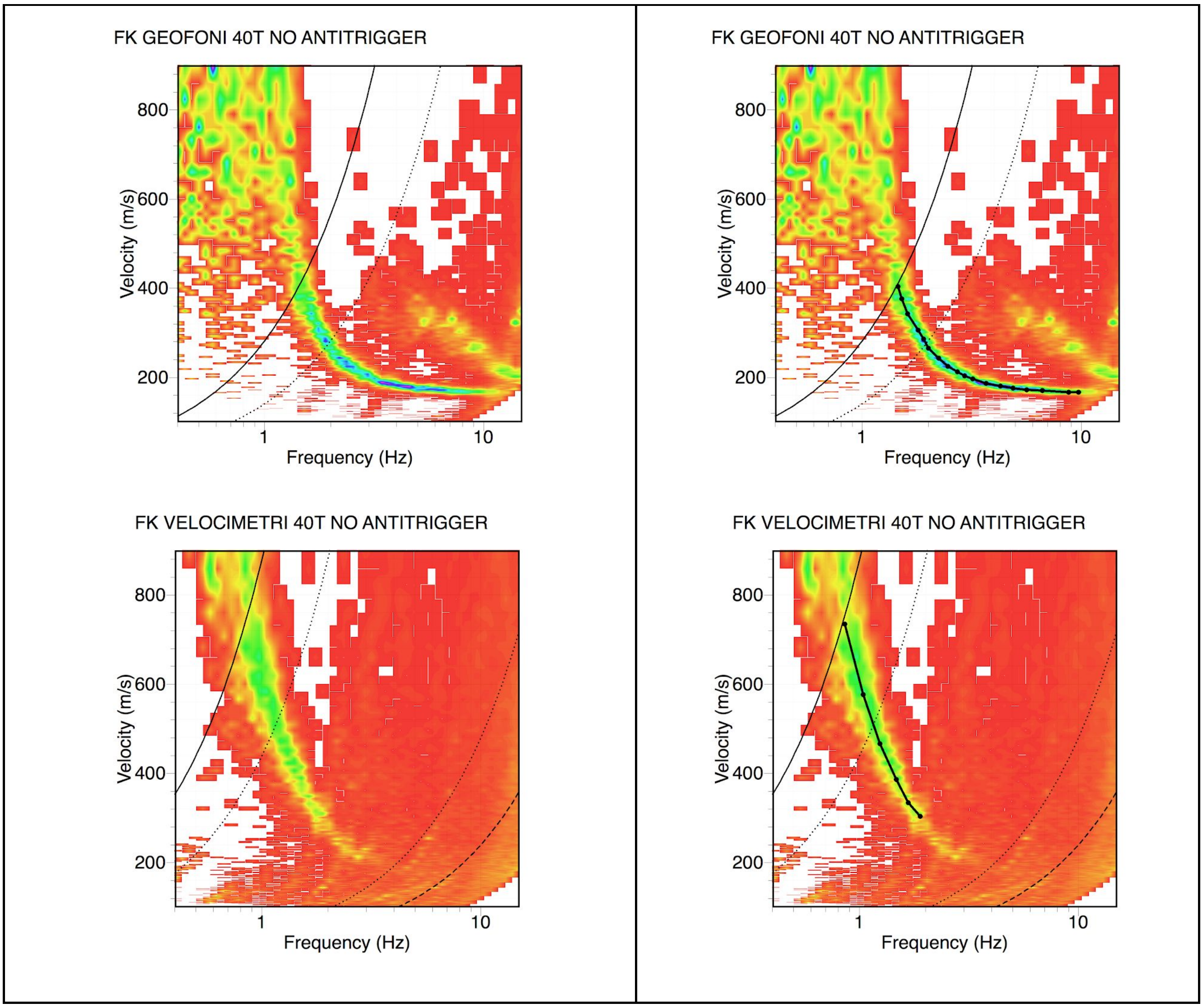


**Figure 5: Left: FK analysis of the small 2D array of geophones (top) and of the vertical components of the large 2D array (bottom). Right: Picking of the corresponding dispersion curves on the left.**

The two picked dispersion curves were then compared, merged and finally resampled and for each point an estimate of the error was added (Figure 6).

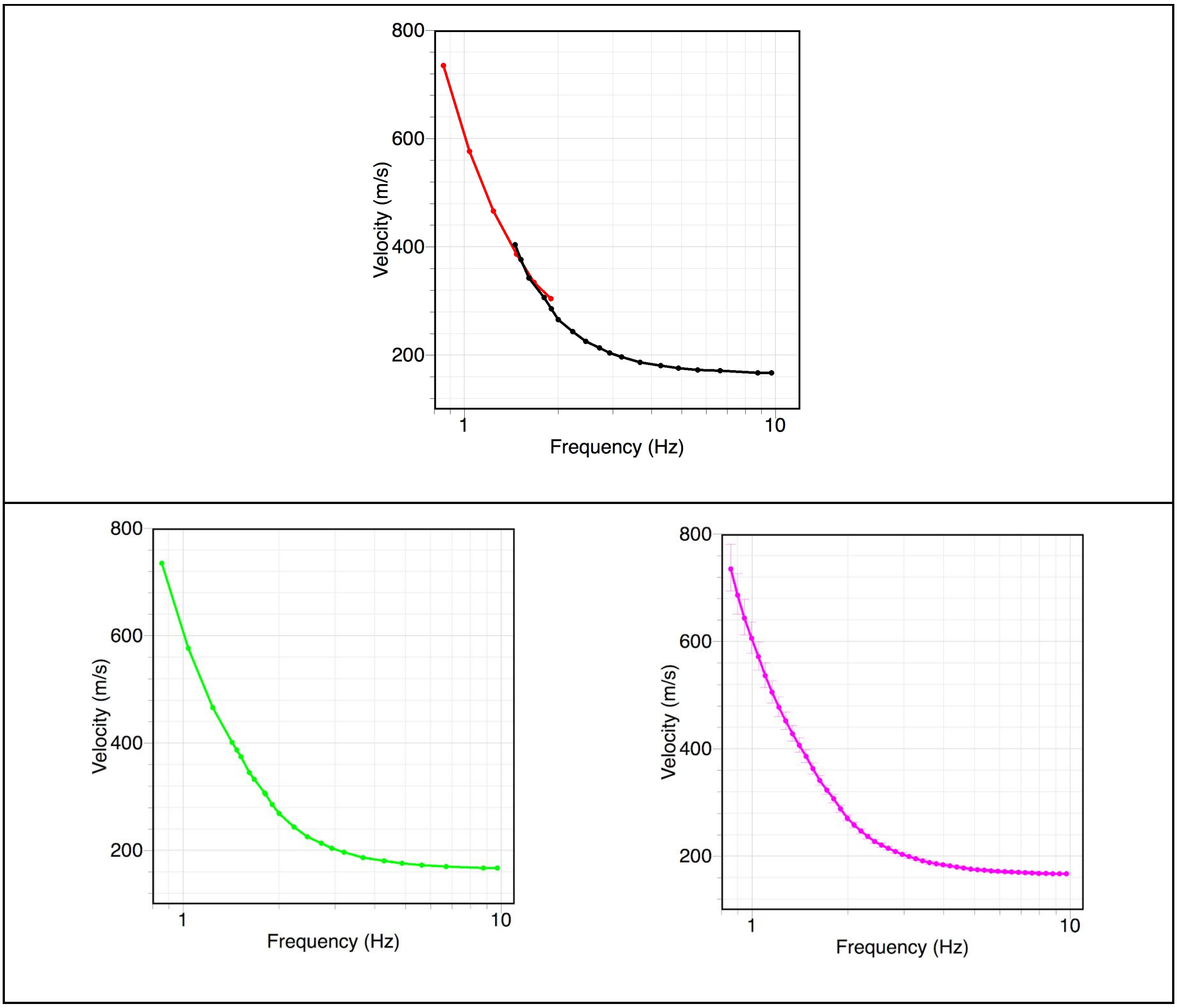


**Figure 6: Top: comparison between the dispersion curves coming from the FK analysis of the two arrays (red and black curves). Bottom-left: merging of the two dispersion curves (in green). Bottom-right: resampling of the merged dc and adding of an error to each point of the magenta curve (in magenta).**

We interpret and assume that the final merged dispersion curve is relative to the fundamental mode of the Rayleigh dispersive waves. The dispersion curve show velocities ranging from 800 m/s at frequency of about 1Hz to 150 m/s at frequency of 10Hz.



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## 3. $V_s$ Model

To proceed with the inversion, we decided to:

1) Invert the dispersion curve
2) Invert jointly with the ellipticity constrain, in particular the peak at 0.9Hz has been considered well recognizable on the data. On the other hand the peak at low frequency on H/V (f=0.25Hz) has a large variability on the measurement points and then we preferred not to include it on the inversion.

After several tests and using different starting models, we focused on 2-layers models over a stiff bedrock. The first layer has been imposed to have a linear increase of velocity with depth. The best result of the inversion is shown in Figure 7.

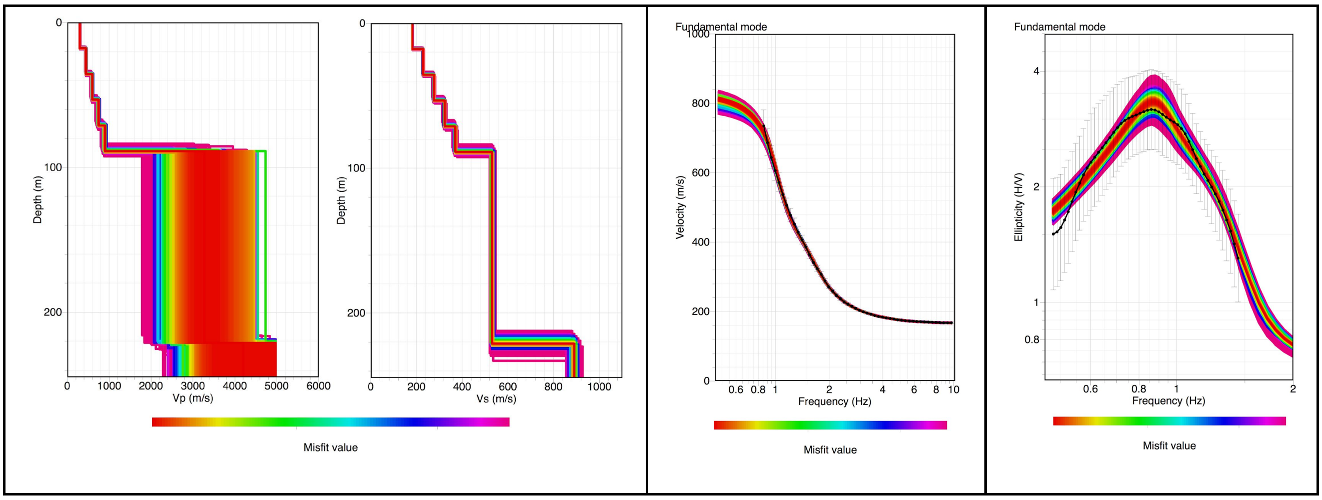


**Figure 7: Left: Vp and Vs profiles obtained through the inversion of the dispersion curve of Figure 7. Middle: fit between the experimental dispersion curve and the theoretical dispersion curves of the investigated models. Right: fit between the experimental H/V and the theoretical ellipticity of the investigated models.**

The inversion is able to reproduce fairly well both the experimental dispersion curve and the experimental H/V curve around the frequency of 0.9Hz.



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The obtained seismic model can be interpreted in terms of the known geology (Working group INGV "Agreement DPC-INGV 2018, Allegato B2, Obiettivo 1 - TASK B", 2018. Geological report at the seismic station IT.CSA-CASTELNUOVO ASSISI) of the area (Figure 8). The stratigraphy consists of a tick layer (about 220mt) of alluvial sediments with intercalation of gravels. The substratum consists of gray clays approximately 700mt thick and reaching the marly-arenaceous bedrock. Considering the uncertainties in the geological reconstruction, based on logs far from the investigated area (~1.5km), our results find that the passage from alluvial soft sediments to the gray clays should be found at a depth of about 220mt.

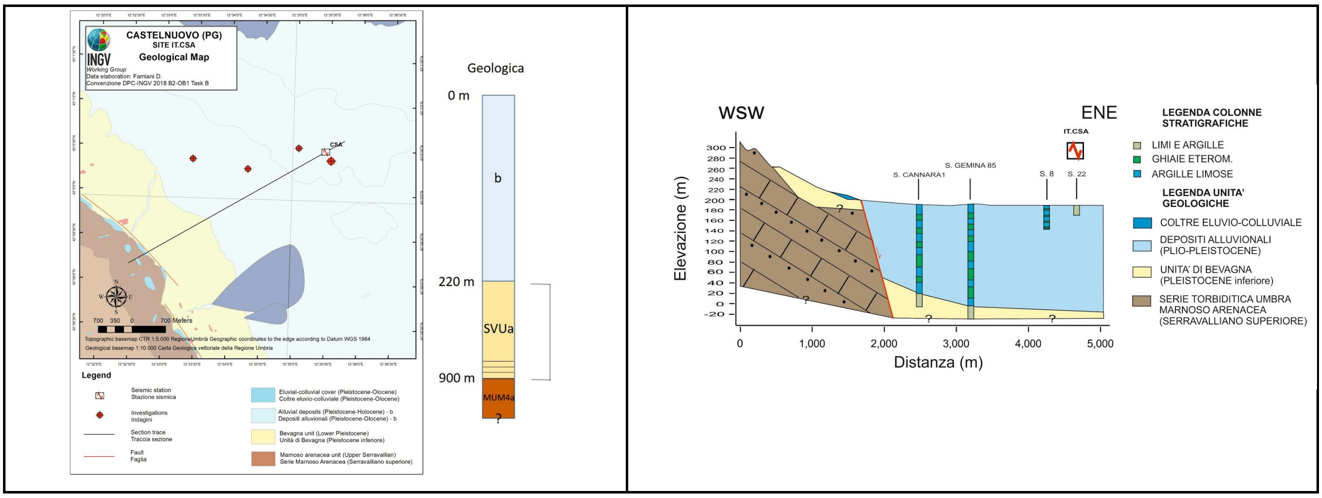


**Figure 8: Left: Geological map of Castelnuovo. Right: Geological section crossing the station IT.CSA**

The best -fit models of $V_p$ and $V_s$ are represented in Figure 9 and Tab 1.

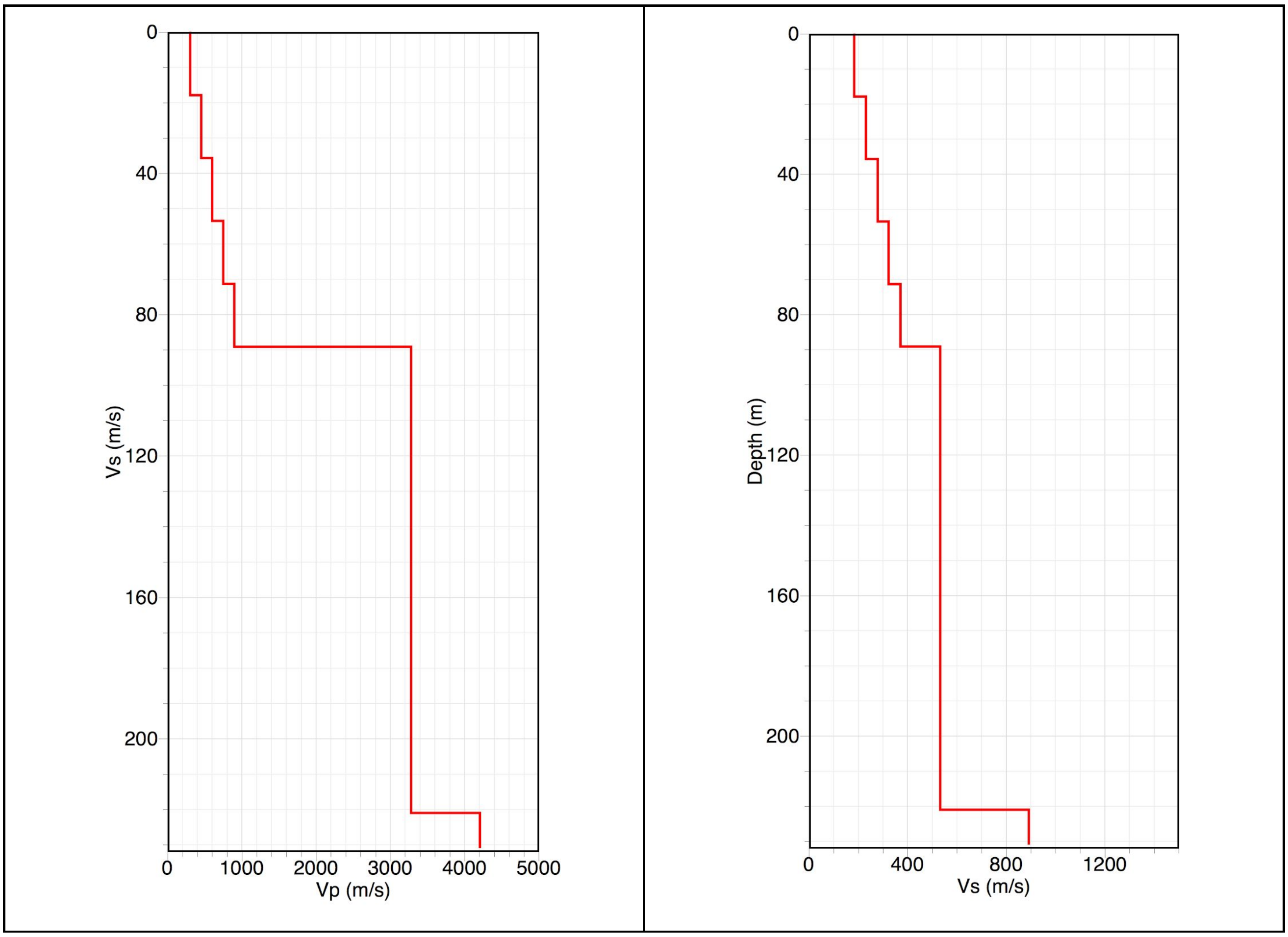


**Figure 9: Best-fit models of Vp (left panel) and Vs (right panel) values**

| *From* | *To* | *Thickness (m)* | $V_s$ *(m/s)* | $V_p$ *(m/s)* |
|---|---|---|---|---|
| 0 | 17.8 | 17.8 | 183 | 300 |
| 17.8 | 35.6 | 17.8 | 230 | 450 |
| 35.6 | 53.4 | 17.8 | 277 | 600 |
| 53.4 | 71.2 | 17.8 | 323 | 749 |
| 71.2 | 89 | 17.8 | 370 | 898 |
| 89 | 221 | 132 | 531 | 3276 |
| 221 | ? | ? | 891 | 4201 |

**Tab 1 Best-fit model**



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## 4. Conclusions

The $V_{s30}$ retrieved from the inversion of the dispersion curves is 199.2 m/s (Tab 2); therefore IT.CSA is classified as class C soil type in terms of NTC 08 seismic classification. The velocity of 800m/s is reached for depth of about 220mt, well above the depth of 30mt considered in the Italian seismic code. Therefore the $V_{s30}$ is enough for the classification of this site.

We have to take into account that the inversion process of the data array is poorly constrained by other independent information for this site, the results can change adding this info, if available.

| ***$V_{s30}$* (m/s)** | ***Soil class following NTC08*** |
|---|---|
| 199.2 | C |

**Tab 2: Soil Class**



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