Site characterization of the INGV station IV.CDCA – Città di Castello

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Subject: **Final report illustrating measurements, analysis and results at IV.CDCA station**	

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1. Introduction

In this report, we present the geophysical measurements and the results obtained in the framework of the 2016 agreement between INGV and DPC, named "*Allegato B2: Obiettivo 1 (Responsabile: C. Meletti) - TASK B: Caratterizzazione siti accelerometrici (Responsabili: P. Bordoni, F. Pacor)*" for the characterization of sites of the Italian National Seismic Network (RSN) with accelerometers.

Here the results for station IV-CDCA are presented.

Geophysical measurements are two 2D arrays of seismic stations in passive configuration. Using surface-wave analysis, we provide results in terms of dispersion curves that are inverted to obtain shear-wave velocity (V_s) profiles for the studied area. The inverted models are suitable for computing the average Vs velocity in the uppermost 30 m (Vs30) and assegning then the EC8 soil class category.

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2. Geophysical investigation

IV.CDCA station is situated in the park ("Parco Ansa del Tevere") of Città di Castello (Perugia, Italy).

Figure 1 shows the location of the seismic stations used for the two 2D arrays deployed in the target area surrounding IV.CDCA.

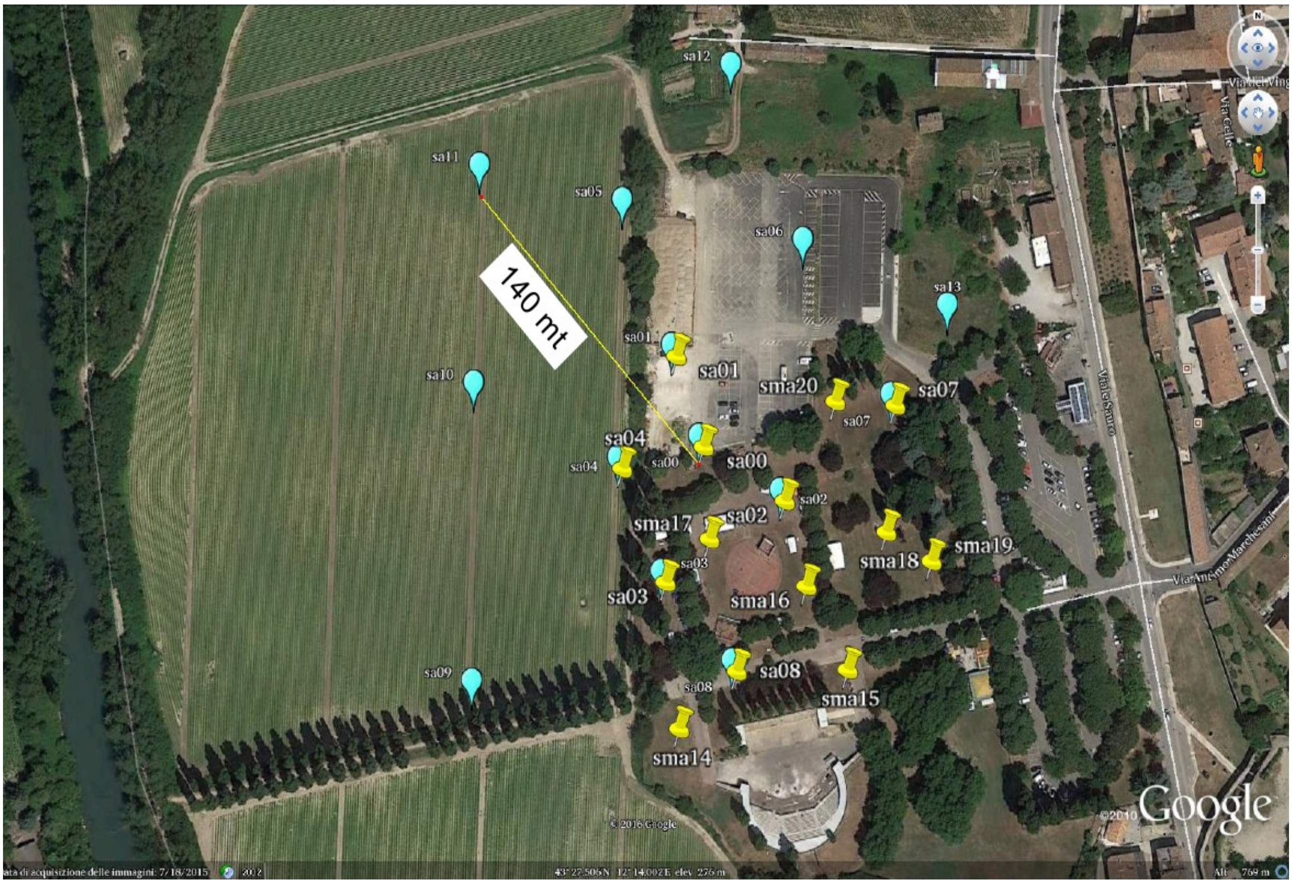

Figure 1: Plan view of the two 2D seismic arrays deployed around IV-CMPO site. The yellow and cyan points indicate the fourteen stations of the 2D array in passive configuration (named "*small*" and "*big*" array, respectively). All stations are equipped with Reftek R130 digitizer and Lennartz 3D-5sec velocimetric sensors. IV-CDCA station is situated in proximity of the sa00 station.

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2.1 ARRAY MEASUREMENTS RESULTS

Two 2D arrays were performed using 14 single seismic stations equipped with Reftek 130 digitizers and Lennartz 3d-5s velocimetric sensors. Figure 1 shows their position, and hereinafter we referred to these two arrays as “*big*” and “*small*” array. The common noise recording lasted approximately 2 hours for both arrays. The measurements were recorded the 15th of June 2016. The *small* and *big* array are characterized by a maximum aperture of 145 and 260 m, respectively. A view of field work is shown in Figure 2. The seismic sensors were positioned in a two-dimensional geometry with irregular spacing, as shown in Figure 2 (some stations of the two arrays shared the same position).

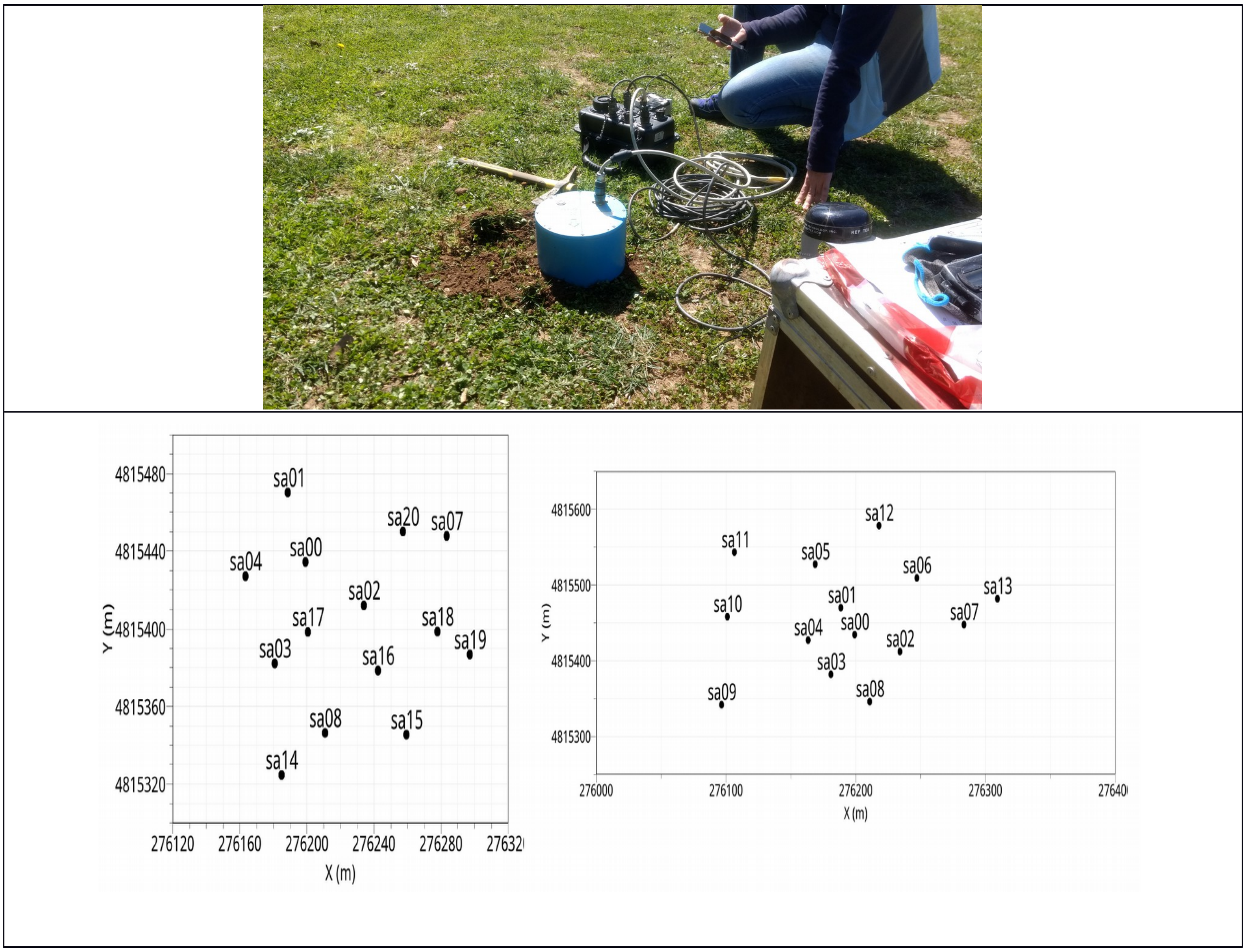

Figure 2: Top: Example of an installation of a seismic station. Bottom: 2D Array geometry of the *small* (left panel) and *big* (right panel) array.

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The geometries of the arrays allow the performance in terms of wavenumbers described in Figure 3, where the theoretical Array Transfer Function is reported for each array.

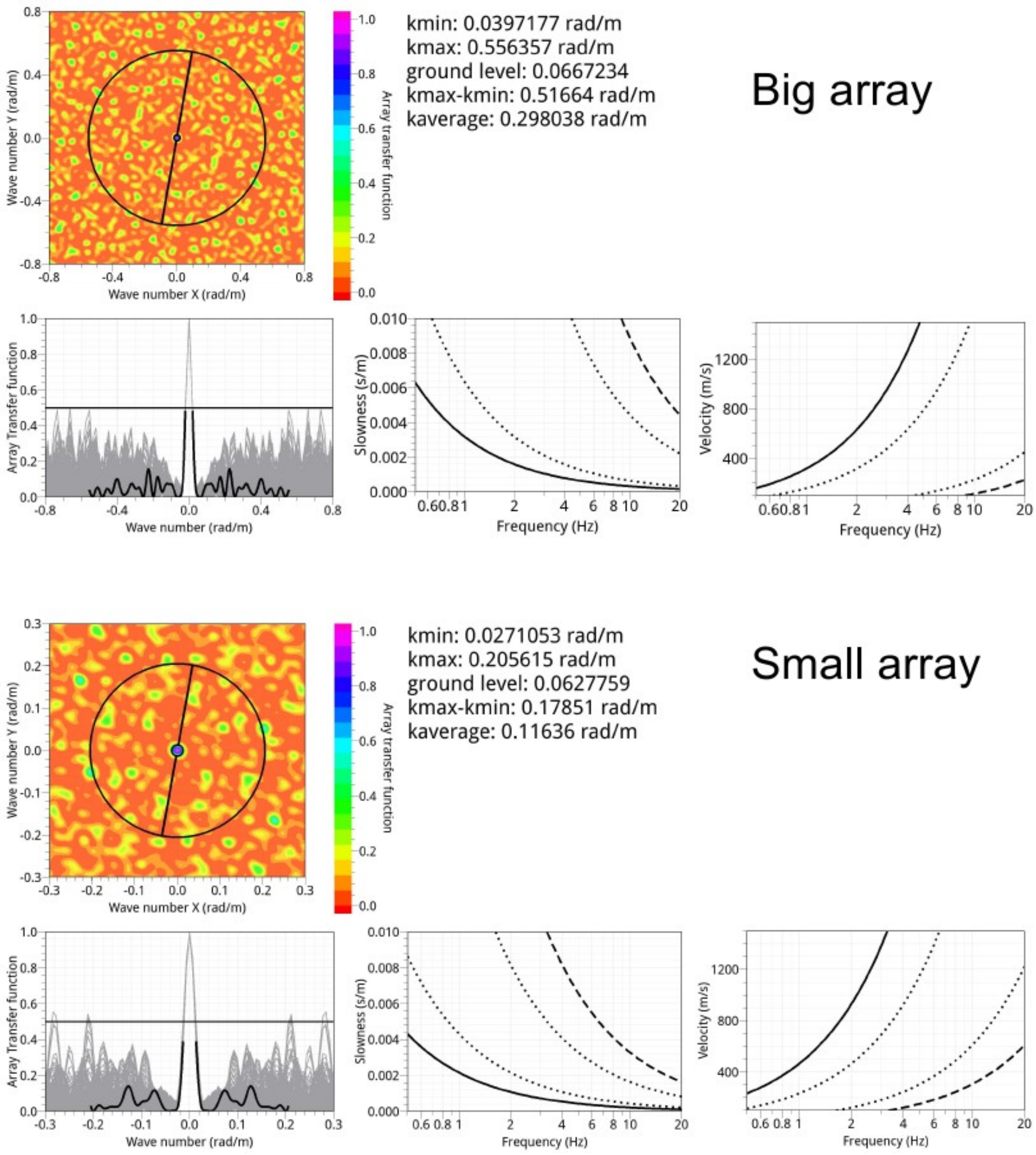

Figure 3: Theoretical Array Transfer function of the two 2D arrays installed in the target area of IV-CDCA. Alias and resolution curves are also reported in the slowness(or velocity)-frequency representation.

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The computed H/V curves of the 14 stations are overimposed for each array in Figure 4. There is a general agreement of the H/V shapes in almost the entire reliable frequency band (eigen-frequency of the velocimetric sensor is 0.2 Hz). The resonance frequency (Fo) can be assigned to 0.42 Hz, even if the H/V curves show an amplified band up to 0.6 Hz. The rotated HV spectral ratios show consistently amplification in this frequency band (see Figure 5 where we show for semplicity only the results of the *big* array).

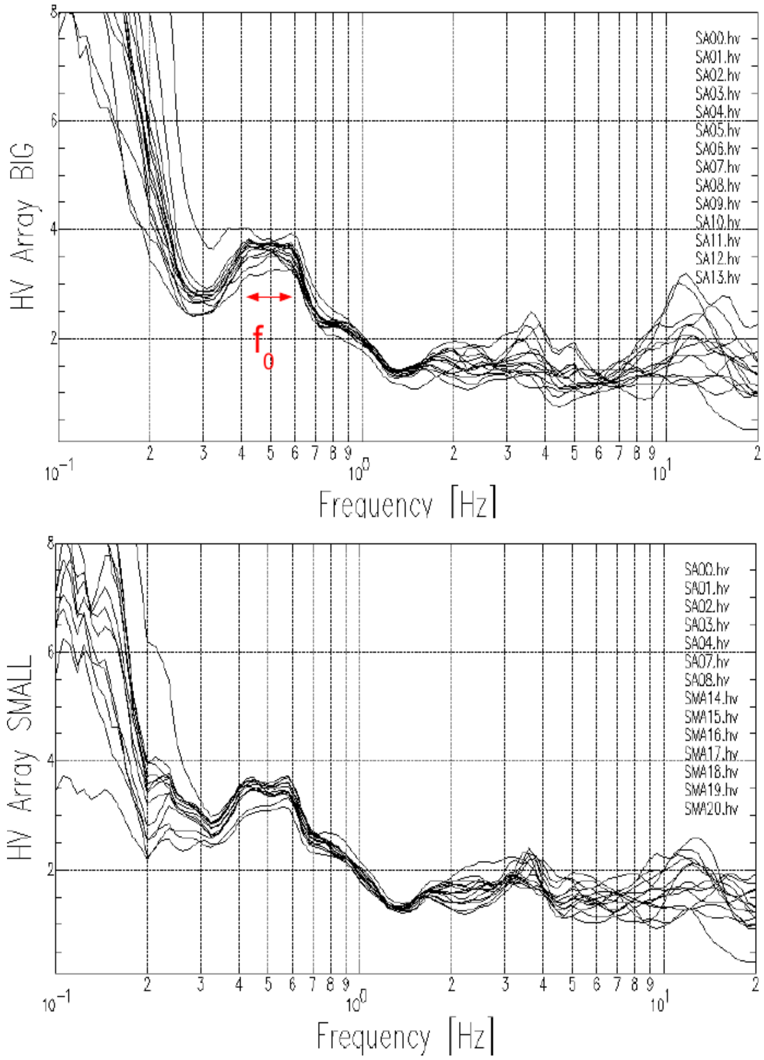

Figure 4: H/V curves of the 14 stations for the *big* (top panel) and *small* array (bottom panel).

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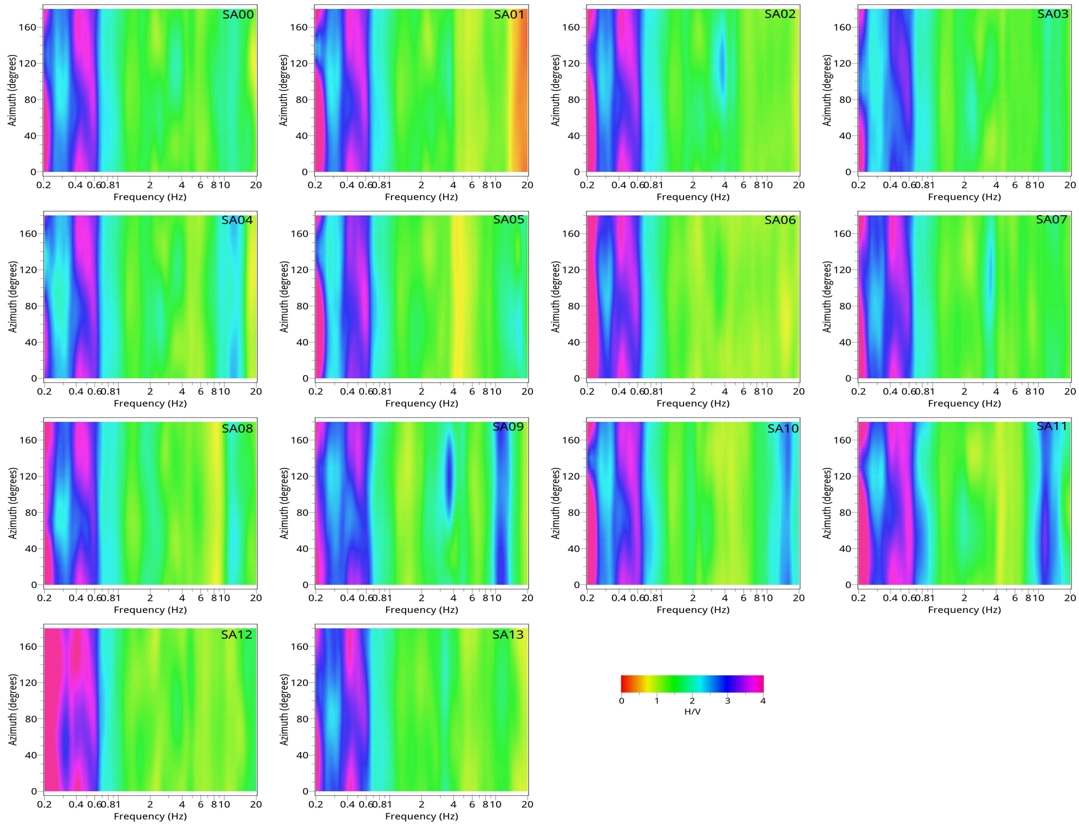

Figure 5: Rotating H/V curves at the 14 stations of the *big* array..

Data from the 2D arrays have been analysed in terms of conventional frequency-wavenumber (FK) analysis and high-resolution FK analysis. Because the two techniques lead to similar results, we present hereinafter only the results of the conventional FK method.

The FK analysis was performed on the three-components of motion; the results using the horizontal and vertical components were interpreted in terms of Rayleigh and Love surface waves, respectively. We used the GEOPSY code (http://www.geopsy.org) for the H/V computation and surface-wave analysis. Figure 6a shows the dispersion curves derived from the f-k analysis using the vertical signal recorded by the *big* and *small* array. Because the picked dispersion curves of the two arrays show a sligth discrepancy in terms of apparent values (about 50 m/s; see Figure 6b), we decided to average them.

The surface-wave analysis performed on the horizonal signal provides the dispersion curves shown in Figure 7. Also in this case, the two curves were averaged to obtain a mean dispersion curve.

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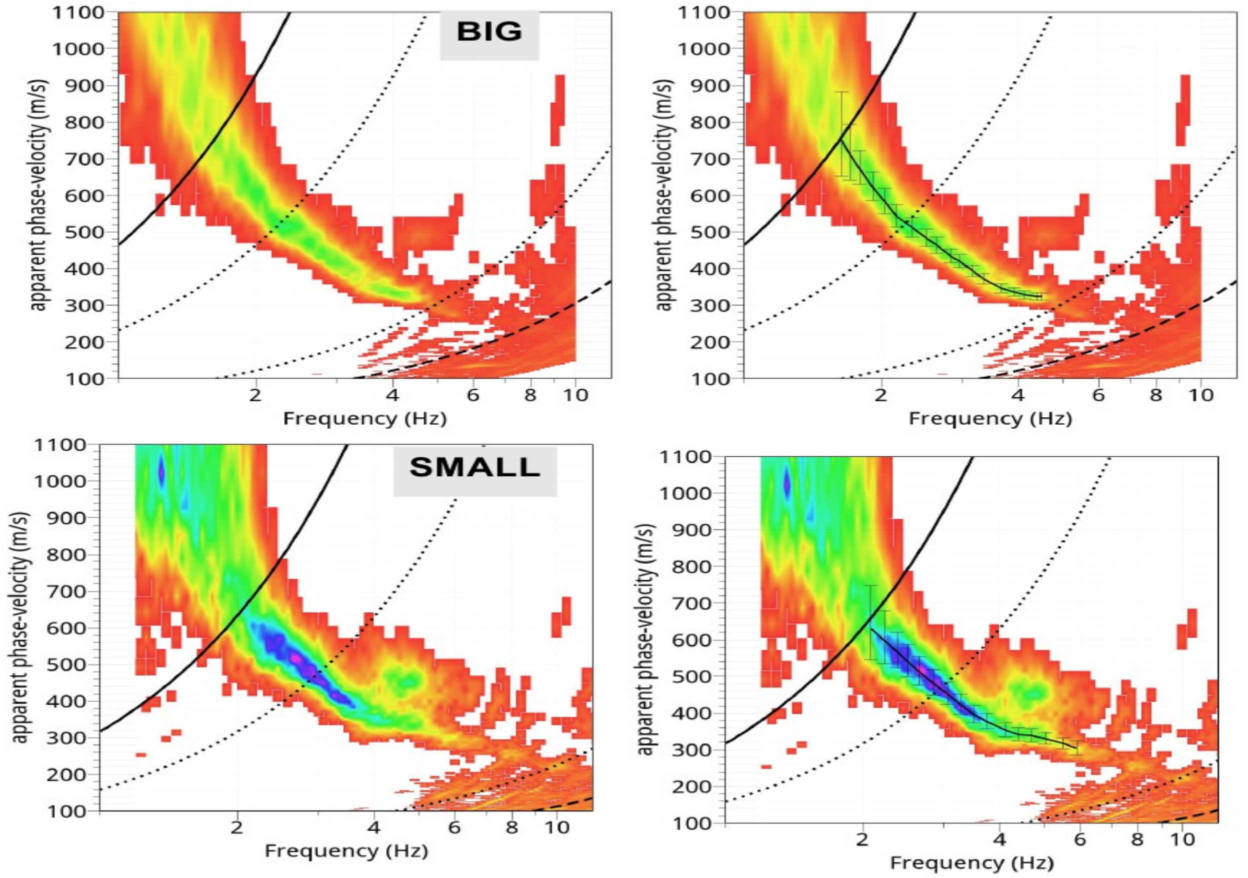

Figure 6a: Unpicked and picked dispersion curve in the velocity-frequency plan for the *big* (top) and *small* array (bottom panel) working with the vertical component.

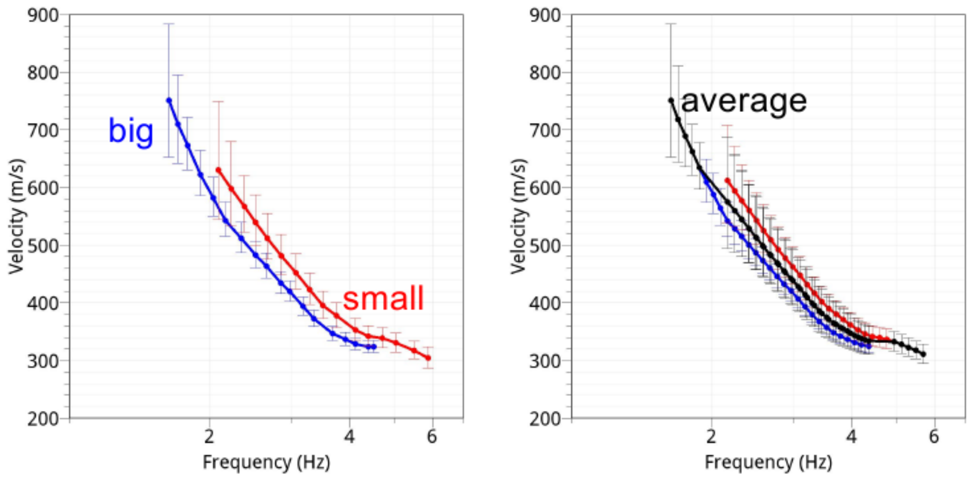

Figure 6b: Left) The picked dispersion curve from the *big* and *small* array are overimposed (blue and red curve, respectively). The vertical bars indicate uncertainties. Right) To proceed with the inversion step, we averaged the two dispersion curves: the black mean curve was considered during the inversion step.

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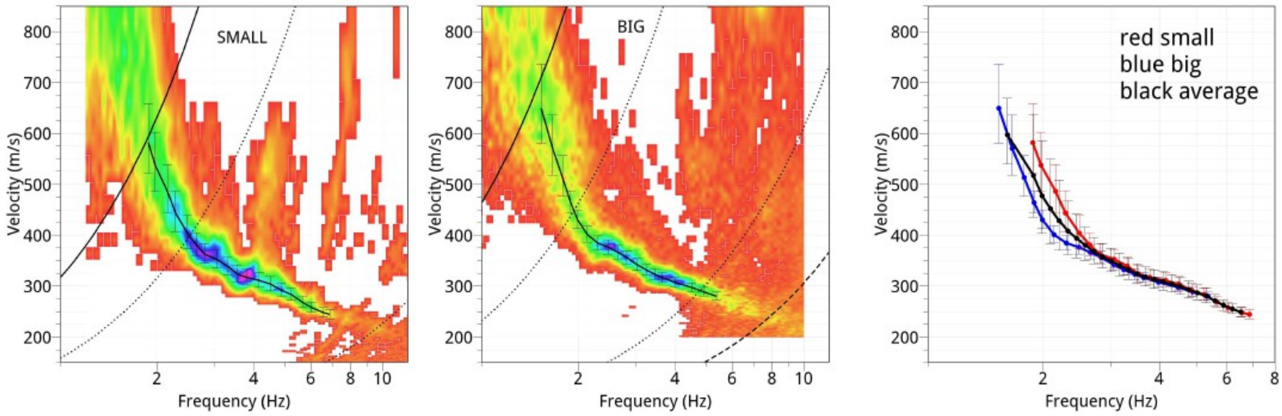

Figure 7: Picked dispersion curve for the *small* (left) and *big* array (middle panel) working with the horizontal component. The dispersion curves derived from these two arrays were compared in the right panel, where the black curve indicates the average curve.

The final dispersion curves selected for the inversion step are shown in Figure 8 assuming Rayleigh and Love fundamental mode (for vertical and horizontal components, respectively). The selected part of H/V curve to be considered in the ellipticity inversion is also shown.

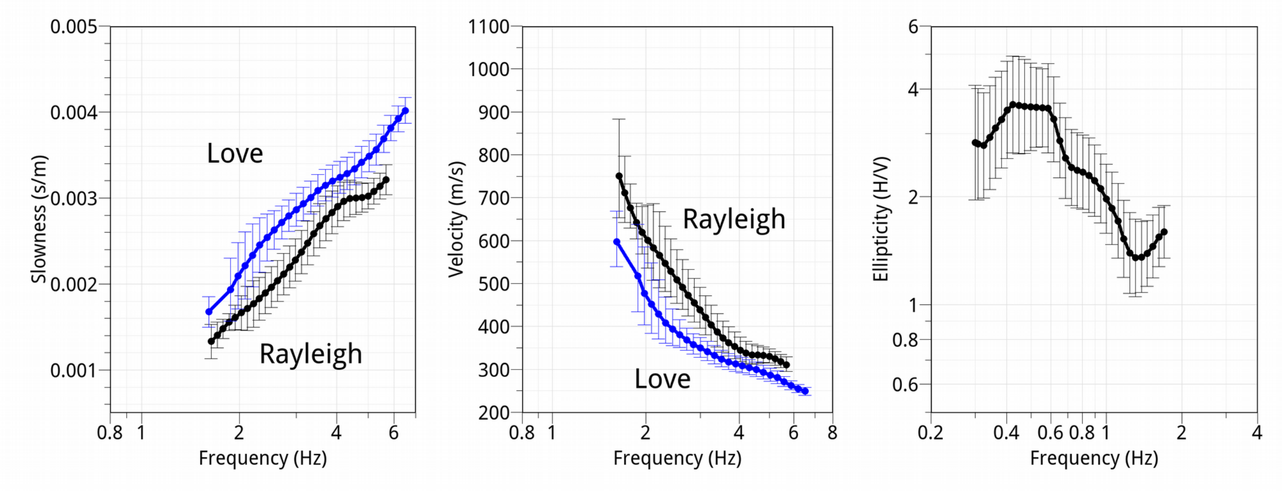

Figure 8: Dispersion and H/V curves considered during the inversion process. Rayleigh (black) and Love (blue curve) dispersions were derived from the analysis on vertical and horizontal component, respectively.

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3. Vs Model

To proceed with the inversion step, we assume that the dispersion curves derived from the vertical and horizontal component of motion are associated to the fundamental mode of Rayleigh and Love waves, respectively.

To summarize, the targets during our inversion process were:

1) Dispersion curves as shown in Figure 8.
2) Ellipticity curve in terms of Rayleigh fundamental mode extracted from the most similar part of the H/V curves (from 0.3 to 1.8 Hz; see the right panel of Figure 8)
3) Fundamental frequency (Fo=0.42 Hz)

The resulting models obtained after a preliminary inversion are shown in Figure 9. We used a simple model parameterization composed of two main layers over halfspace, where in the first layer a shear-wave velocity increasing with depth was allowed (following a power-law, see the zoomed view of Figure 9).

Focusing on the Vs models, the Vs is increasing from 110-150 to 600-700 m/s for the first layer (180 m thick); the Vs is of about 1000 m/s for the second layer (approximately from 180 to 650 m deep). The halfspace is found by the inversion at about 600-700 m deep.

However we noted some discrepancy between theoretical and field curve (Figure 9); this could indicate a too simple model space parameterization or some assumptions in the interpretation of the field curves not fully matched.

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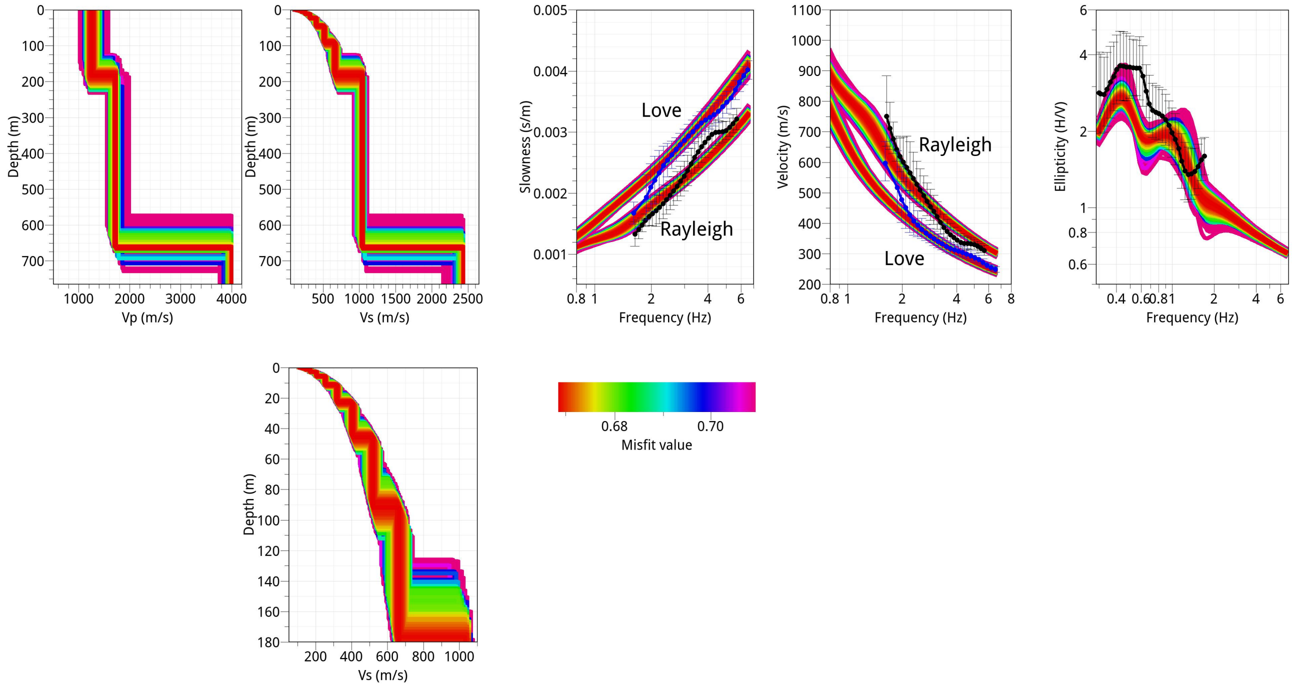

Figure 9: Resulting models after the inversion of the dispersion and H/V ellipticity curves (the field data are shown as black curves). A zoom of the Vs provile is shown in the bottom.

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The best Vp and Vs model (i.e. lowest misfit) resulting from the inversion are proposed in Figure 10 and Table 1.

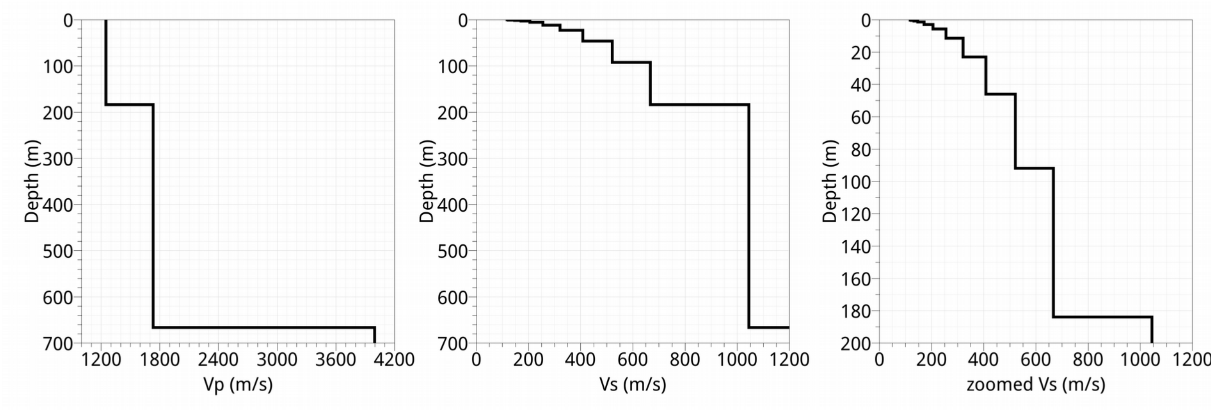

Figura 10: Best-fit model of Vp and Vs profiles [extracted from the ensemble of Fig. 9]. A zoomed view of Vs profile is shown on the right.

From (m)	*To(m)*	*Thickness (m)*	*Vs (m/s)*	*Vp (m/s)*
0	0,1	0,1	115	1248
0,1	0,17	0,07	118	1248
0,17	0,36	0,19	123	1248
0,36	0,7	0,34	132	1248
0,7	1,4	0,7	147	1248
1,4	2,9	1,5	171	1248
2,9	5,7	2,8	206	1248
5,7	11,4	5,7	255	1248
11,4	22,9	11,5	321	1248
22,9	45,9	23	408	1248
45,9	92	46,1	521	1248
92	184	92	667	1248
184	666	482	1044	1733
666	?	?	2433	4000

Table 1: Best-fit model

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4. Conclusions

The surface-wave analysis at IV.CDCA station indicates a soft site. Because the H/V curves show amplification from 0.42 to 0.6 Hz, a first resonant peak is found doubitatively at 0.42 Hz. However these low-frequency resonant values (< 1 Hz) suggest a bedrock relatively deep. The preliminary inversion shows Vs models with a significant seismic contrast at a depth of about 150-200 m, where the Vs increases from 650 to 1100 m/s (Figures 9, 10 and Table 1).

The uppermost layer shows low Vs value (< 350 m/s up to 23 m deep; see Table 1). The V_{s30} retrieved from the best inverted model is 275 m/s (Table 2), therefore IV-CMPO is classified as soil class C following the NTC08 seismic classification.

V_{s30} (m/s)	***Soil class***
275	C

Table 2: Soil Class

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