Velocity profile report at the seismic station IV.CIMA - CIVITANOVA MARCHE

Working Group: **Claudia MASCANDOLA** **Sara LOVATI** **Marco MASSA** **Chiara LADINA** **Massimo FRAPICCINI**	Date: December 2018

Subject: **Final report illustrating measurements, analysis and results for station IV.CIMA**

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

Cite as: Working group INGV "Agreement DPC-INGV 2018, Allegato B2, Obiettivo 1 - TASK B", (2018). Velocity profile report at the seismic station IV.CIMA-CIVITANOVA MARCHE. doi: 10.5281/zenodo.2222307

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

Cite as: Working group INGV "Agreement DPC-INGV 2018, Allegato B2, Obiettivo 1 - TASK B", (2018). Velocity profile report at the seismic station IV.CIMA-CIVITANOVA MARCHE. doi: 10.5281/zenodo.2222307

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 (Coord. G. Cultrera, F. Pacor).* In this report, the results for station IV.CIMA, belonging to the Italian National Seismic Network (RSN-INGV), are presented.

Geophysical measurements consist in a 2D array in passive configuration that provide results 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).

Cite as: Working group INGV "Agreement DPC-INGV 2018, Allegato B2, Obiettivo 1 - TASK B", (2018). Velocity profile report at the seismic station IV.CIMA-CIVITANOVA MARCHE. doi: 10.5281/zenodo.2222307

2. Geophysical investigations

Figure 1 shows the location of the stations used for the 2D array and Tab. 1 the corresponding geographic coordinates.

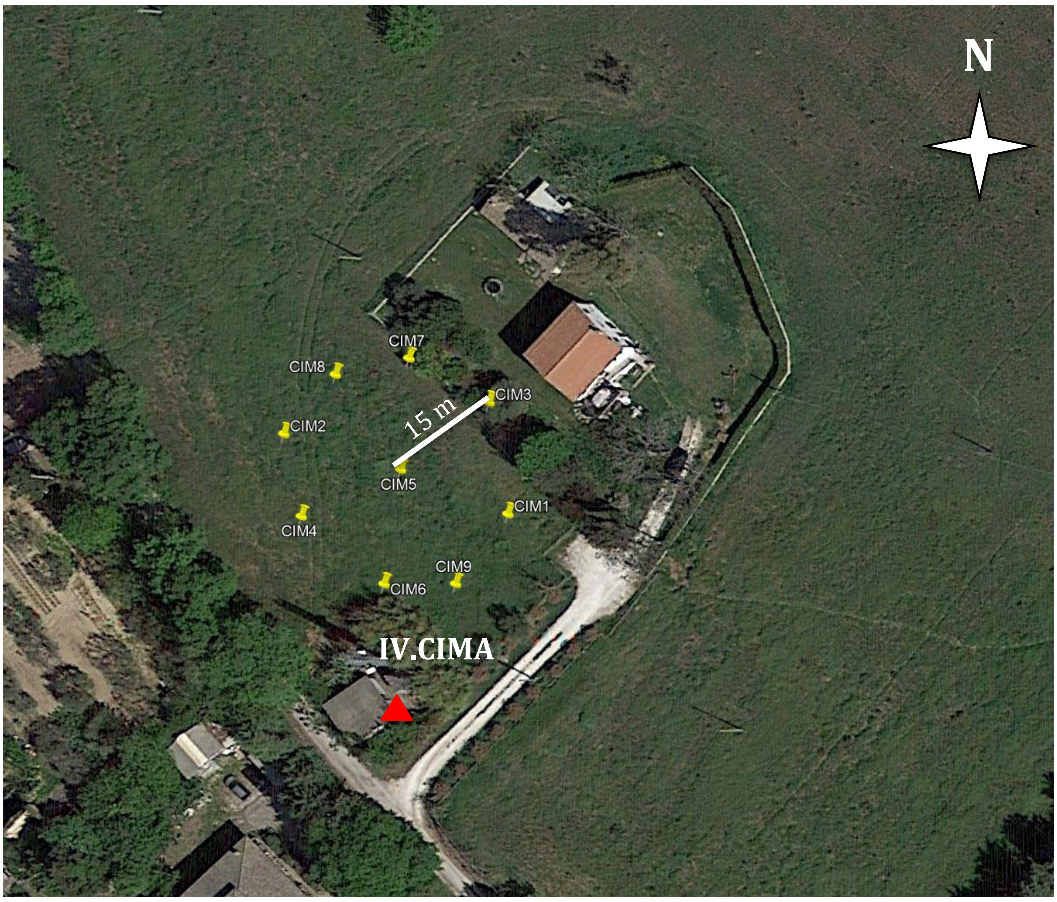


Figure 1: Map of the geophysical measurements performed at IV.CIMA site. The yellow points are the nine stations of the 2D array in passive configuration (all stations are equipped with Reftek-130 digitizer and Lennartz 3D-5sec velocimetric sensors). The red triangle indicates station IV.CIMA.

staz	Lat (°)	Lon (°)	El (m)
CIM1	43.30612	13.67023	172
CIM2	43.30622	13.66986	168
CIM3	43.30625	13.6702	179
CIM4	43.30612	13.66988	167
CIM5	43.30617	13.67005	169
CIM6	43.30603	13.67002	168
CIM7	43.30631	13.67006	172
CIM8	43.30629	13.66994	171
CIM9	43.30603	13.67014	173

Tab. 1: array stations coordinates (WGS84)

Cite as: Working group INGV "Agreement DPC-INGV 2018, Allegato B2, Obiettivo 1 - TASK B”, (2018). Velocity profile report at the seismic station IV.CIMA-CIVITANOVA MARCHE. doi: 10.5281/zenodo.2222307

2.1 Array measurements results

A 2D array was performed using nine seismic stations equipped with Reftek 130 digitizers and Lennartz 3D-5s velocimetric sensors. The noise recording lasted about 2 hours.

A view of the 2D passive array survey is shown in Figure 2.

The seismic sensors were positioned in a circular geometry with a radius of 15 m, as shown in Figure 1 and 2.

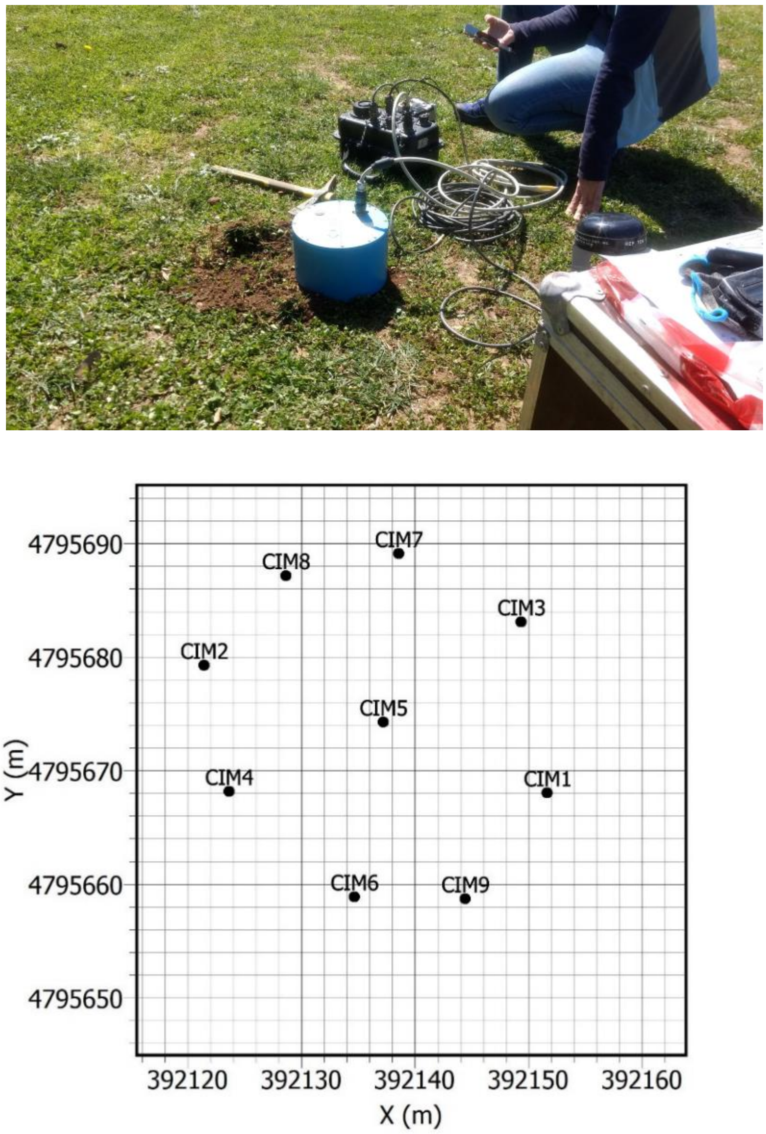


Figure 2: Top: example for the installation of an array station. Bottom: 2D Array geometry with UTM coordinates.

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

Cite as: Working group INGV "Agreement DPC-INGV 2018, Allegato B2, Obiettivo 1 - TASK B", (2018). Velocity profile report at the seismic station IV.CIMA-CIVITANOVA MARCHE. doi: 10.5281/zenodo.2222307

The geometry of the array controls the response in terms of theoretical transfer function as described in Figure 3.

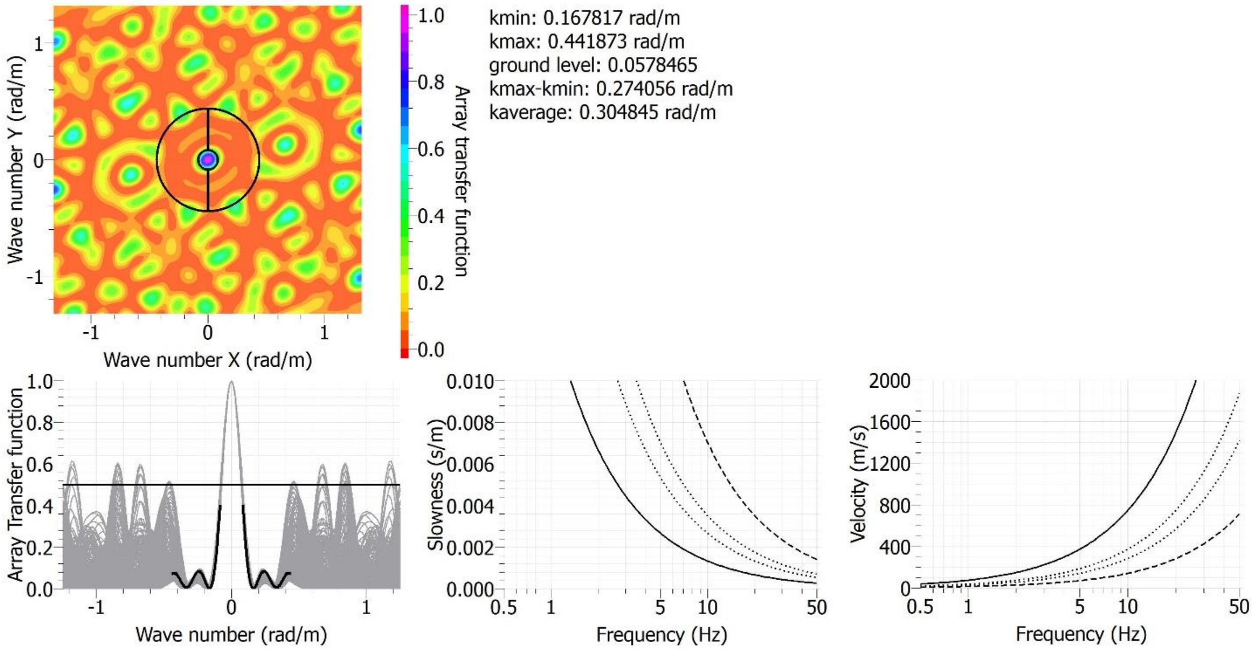
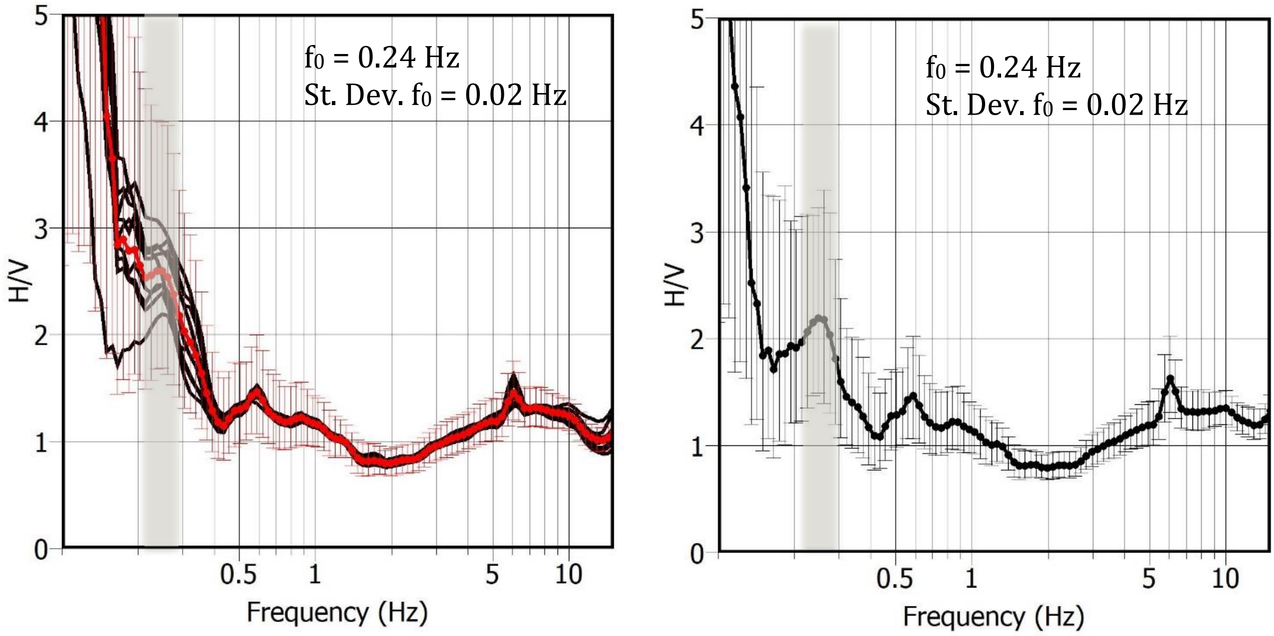


Figure 3: Theoretical Array Transfer function for the 2D array at IV.CIMA

In Figure 4a, the H/V curves of the nine stations are superimposed on each other. The average H/V curve is reported in red. All the H/V curves present a good agreement, but the sensors instability at low frequency (around 0.2 Hz) does not always allow to clearly define the f_0 value. For this reason, a representative H/V curve (CIM6) is selected between the nine stations of the array and reported in Figure 4b. This curve is in good agreement with the H/V analysis at the station IV.CIMA.

Cite as: Working group INGV "Agreement DPC-INGV 2018, Allegato B2, Obiettivo 1 - TASK B", (2018). Velocity profile report at the seismic station IV.CIMA-CIVITANOVA MARCHE. doi: 10.5281/zenodo.2222307

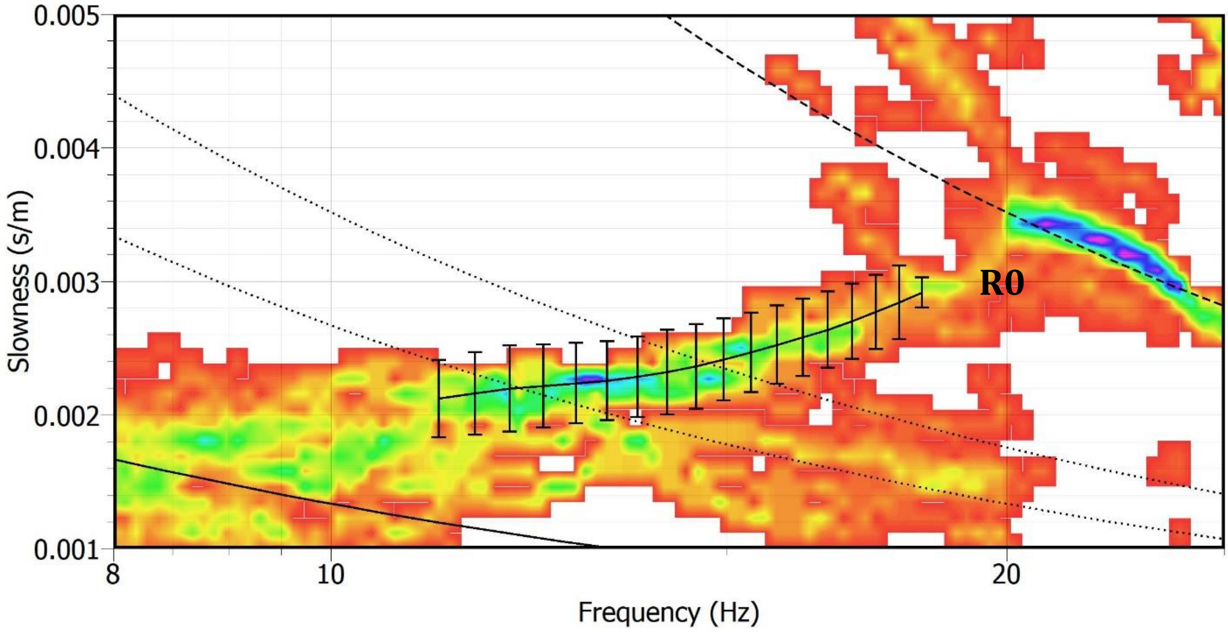


a) b)

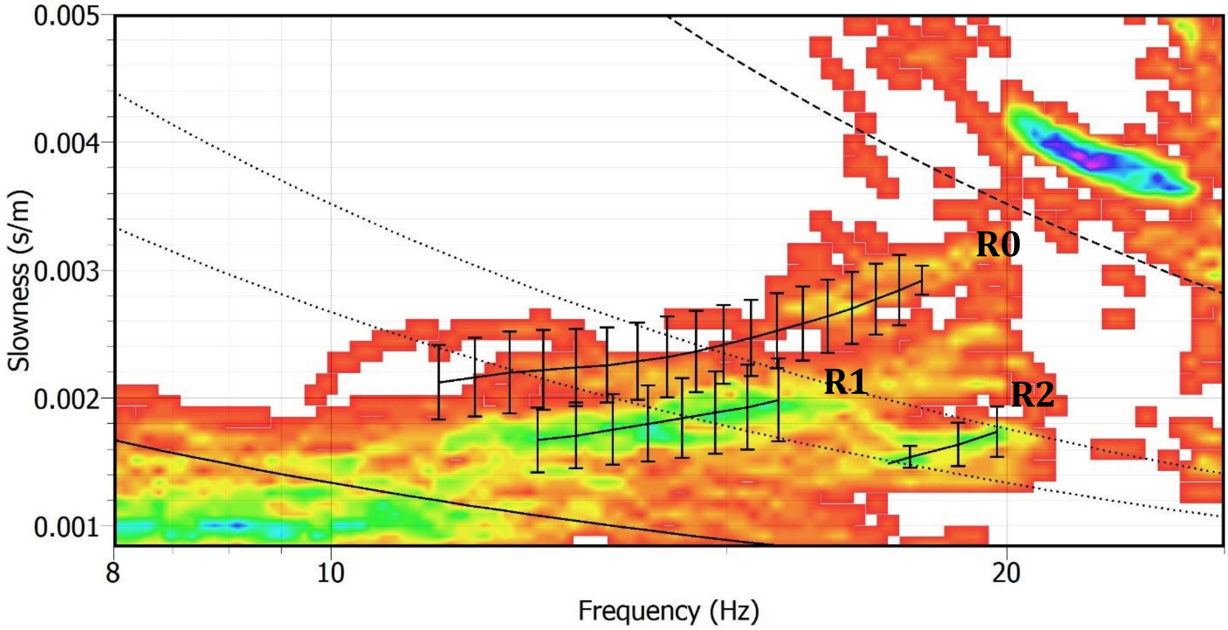
Figure 4: a) H/V curves of the nine stations. The red curve is the average H/V and the red bars estimate the uncertainty of the average H/V. b) Representative H/V curve for the nine stations of the array.

Data from the 2D array have been analysed in terms of FK analysis and high-resolution FK analysis. Because the two techniques lead to similar results, hereinafter we consider only the high-resolution FK method. For the analysis we use the code GEOPSY (http://www.geopsy.org). The dispersion curve is shown in Figure 5.

Cite as: Working group INGV "Agreement DPC-INGV 2018, Allegato B2, Obiettivo 1 - TASK B", (2018). Velocity profile report at the seismic station IV.CIMA-CIVITANOVA MARCHE. doi: 10.5281/zenodo.2222307



a)



b)

Figure 5: Picked dispersion curves in the slowness domain with the high-resolution FK analysis. a) vertical components b) radial components. R0, R1, R2 = Rayleigh wave fundamental, first, and second mode respectively.

Cite as: Working group INGV "Agreement DPC-INGV 2018, Allegato B2, Obiettivo 1 - TASK B", (2018). Velocity profile report at the seismic station IV.CIMA-CIVITANOVA MARCHE. doi: 10.5281/zenodo.2222307

We interpret and assume that the dispersion curve obtained with the vertical components of the array stations is relative to the fundamental mode of the Rayleigh dispersive waves (Figure 5a). On the other hand, we interpret the dispersion curves obtained with the radial components of the array stations as relative to the first and the second mode of the Rayleigh waves (Figure 5b).

3. V_S Model

At the IV.CIMA site, the high-resolution FK analysis allows to define the Rayleigh wave dispersion curves relative to the fundamental, first and second mode.

The fundamental mode is defined between 11.2 to 18.3 Hz, whereas the first mode between 12.3 and 15.8 Hz, and the second mode between 17.7 and 19.8 Hz.

In Figure 6, the dispersion curves adopted for the inversion process are shown.

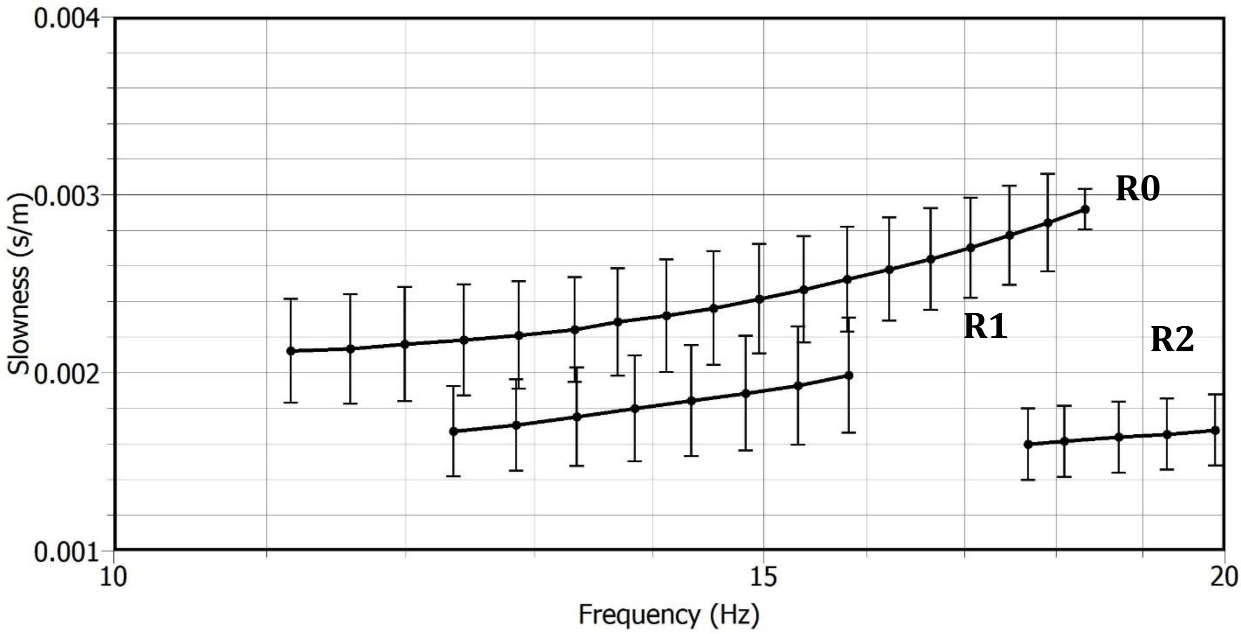


Figure 6: Rayleigh wave dispersion curves adopted for the inversion process. R0= fundamental mode, R1= first mode, R2= second mode.

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

Cite as: Working group INGV "Agreement DPC-INGV 2018, Allegato B2, Obiettivo 1 - TASK B", (2018). Velocity profile report at the seismic station IV.CIMA-CIVITANOVA MARCHE. doi: 10.5281/zenodo.2222307

In this case, in order to focus on the shallow (first tens of meters) Vs model, we invert the Rayleigh wave dispersion curves in Figure 6, not considering the low frequency H/V peak at 0.24 Hz.

Figure 7 shows the comparison between the experimental targets and the ones expected for the best models coming from the inversion process.

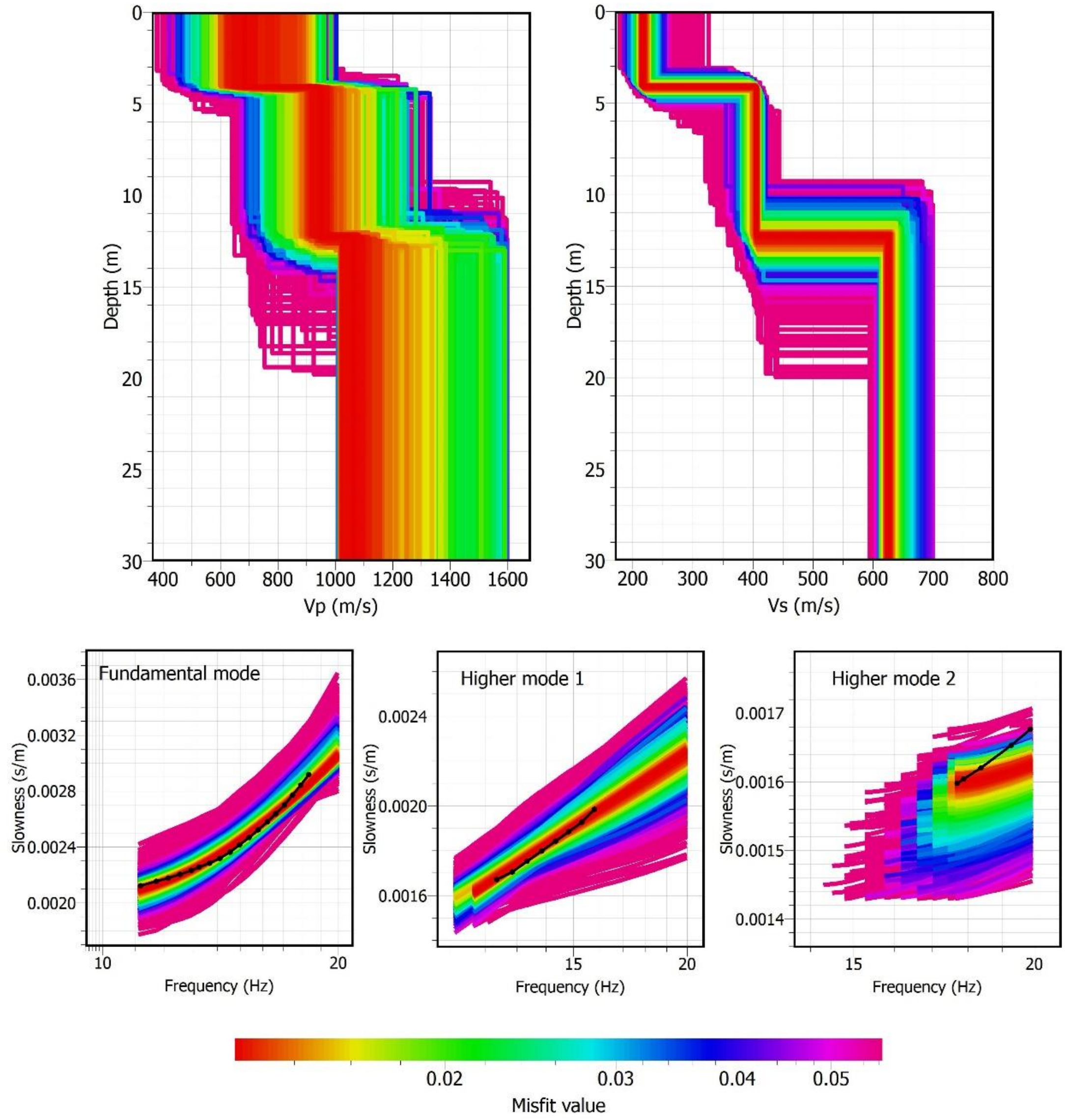


Figure 7: Inversion of the dispersion curves obtained with the 2D passive array.

Cite as: Working group INGV "Agreement DPC-INGV 2018, Allegato B2, Obiettivo 1 - TASK B", (2018). Velocity profile report at the seismic station IV.CIMA-CIVITANOVA MARCHE. doi: 10.5281/zenodo.2222307

The best fit models of V_p and V_s are represented in Figure 8 and Tab. 2.

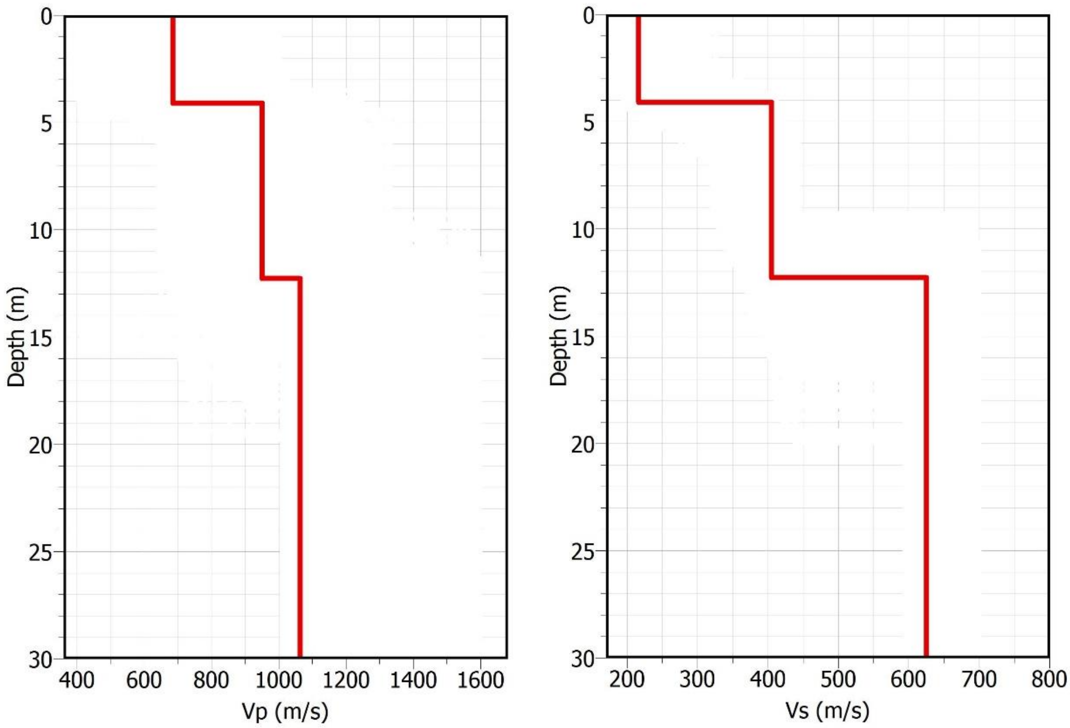


Figure 8: Best-fit models of Vp (left panel) and Vs (right panel) values

From	*To*	*Thickness (m)*	*V_s (m/s)*	*V_p (m/s)*
0	4	4	214	693
4	12	8	400	947
12	?	?	621	1059

Tab. 2: Best-fit model

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

Cite as: Working group INGV "Agreement DPC-INGV 2018, Allegato B2, Obiettivo 1 - TASK B", (2018). Velocity profile report at the seismic station IV.CIMA-CIVITANOVA MARCHE. doi: 10.5281/zenodo.2222307

4. Conclusions

The H/V analysis for site IV.CIMA shows a low frequency peak at 0.24 Hz. However, in order to focus on the shallow Vs model of the site, this H/V peak is not considered in the analysis.
We can propose an interpretation of the velocity profile based on the nearest available borehole stratigraphy, at a distance of 100 m from the study site (Agreement DPC-INGV 2018, Allegato B2: Obiettivo 1 - TASK B, Geological report IV.CIMA). The very first 4 meters could be linked to the presence of a superficial fine-grained soil layer. The second layer, from 4 to 12 m depth, could be related to the gravel deposits observed at the same depths in the nearest boreholes. The third layer could corresponds to the stiff clay observed around 14-16 m depth up to around 28 m depth in correspondence with the substratum (Agreement DPC-INGV 2018, Allegato B2: Obiettivo 1 - TASK B, Geological report IV.CIMA).

According to the current Italian seismic code (NTC 2018), since the bedrock ($V_S > 800$ m/s) is > 30 m depth, the $V_{S,eq}$ is defined by the $V_{S,30}$. The $V_{S,30}$ retrieved from the inversion of the dispersion curves is 443 m/s (Tab. 3); therefore IV.CIMA is classified in the soil class B of NTC 2018 and EC8 seismic classifications.

$V_{s,eq} = V_{s,30}$ (m/s)	Soil class (NTC 2018)	Soil class (EC8)
443	B	B

Tab. 3: Soil Class

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

Cite as: Working group INGV "Agreement DPC-INGV 2018, Allegato B2, Obiettivo 1 - TASK B", (2018). Velocity profile report at the seismic station IV.CIMA-CIVITANOVA MARCHE. doi: 10.5281/zenodo.2222307

5. 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).

Working group INGV "Agreement DPC-INGV 2018, Allegato B2, Obiettivo 1 - TASK B" (2018). Geological report at the seismic station IV.CIMA-CIVITANOVA MARCHE.

Cite as: Working group INGV "Agreement DPC-INGV 2018, Allegato B2, Obiettivo 1 - TASK B", (2018). Velocity profile report at the seismic station IV.CIMA-CIVITANOVA MARCHE. doi: 10.5281/zenodo.2222307

Disclaimer and limits of use of information

The INGV, in accordance with the Article 2 of Decree Law 381/1999, carries out seismic and volcanic monitoring of the Italian national territory, providing for the organization of integrated national seismic network and the coordination of local and regional seismic networks as described in the agreement with the Department of Civil Protection.

INGV contributes, within the limits of its skills, to the evaluation of seismic and volcanic hazard in the Country, according to the mode agreed in the ten-year program between INGV and DPC February 2, 2012 (Prot. INGV 2052 of 27/2/2012), and to the activities planned as part of the National Civil Protection System.

In particular, this document1 has informative purposes concerning the observations and the data collected from the monitoring and observational networks managed by INGV.

INGV provides scientific information using the best scientific knowledge available at the time of the drafting of the documents produced; however, due to the complexity of natural phenomena in question, nothing can be blamed to INGV about the possible incompleteness and uncertainty of the reported data.

INGV is not responsible for any use, even partial, of the contents of this document by third parties and any damage caused to third parties resulting from its use.

The data contained in this document is the property of the INGV.

---

[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)"*

Cite as: Working group INGV "Agreement DPC-INGV 2018, Allegato B2, Obiettivo 1 - TASK B", (2018). Velocity profile report at the seismic station IV.CIMA-CIVITANOVA MARCHE. doi: 10.5281/zenodo.2222307

Esclusione di responsabilità e limiti di uso delle informazioni

L'INGV, in ottemperanza a quanto disposto dall'Art.2 del D.L. 381/1999, svolge funzioni di sorveglianza sismica e vulcanica del territorio nazionale, provvedendo all'organizzazione della rete sismica nazionale integrata e al coordinamento delle reti sismiche regionali e locali in regime di convenzione con il Dipartimento della Protezione Civile.

L'INGV concorre, nei limiti delle proprie competenze inerenti la valutazione della Pericolosità sismica e vulcanica nel territorio nazionale e secondo le modalità concordate dall'Accordo di programma decennale stipulato tra lo stesso INGV e il DPC in data 2 febbraio 2012 (Prot. INGV 2052 del 27/2/2012), alle attività previste nell'ambito del Sistema Nazionale di Protezione Civile.

In particolare, questo documento1 ha finalità informative circa le osservazioni e i dati acquisiti dalle Reti di monitoraggio e osservative gestite dall'INGV.

L'INGV fornisce informazioni scientifiche utilizzando le migliori conoscenze scientifiche disponibili al momento della stesura dei documenti prodotti; tuttavia, in conseguenza della complessità dei fenomeni naturali in oggetto, nulla può essere imputato all'INGV circa l'eventuale incompletezza ed incertezza dei dati riportati.

L'INGV non è responsabile dell'utilizzo, anche parziale, dei contenuti di questo documento da parte di terzi e di eventuali danni arrecati a terzi derivanti dal suo utilizzo.

La proprietà dei dati contenuti in questo documento è dell'INGV.

[1] *Questo documento rientra nella categoria di livello 3 come definita nei "Principi della politica dei dati dell'INGV (D.P. n. 200 del 26.04.2016)".*

Cite as: Working group INGV "Agreement DPC-INGV 2018, Allegato B2, Obiettivo 1 - TASK B", (2018). Velocity profile report at the seismic station IV.CIMA-CIVITANOVA MARCHE. doi: 10.5281/zenodo.2222307