Characterization of Italian strong-motion recording sites in the perspective of a new soil classification

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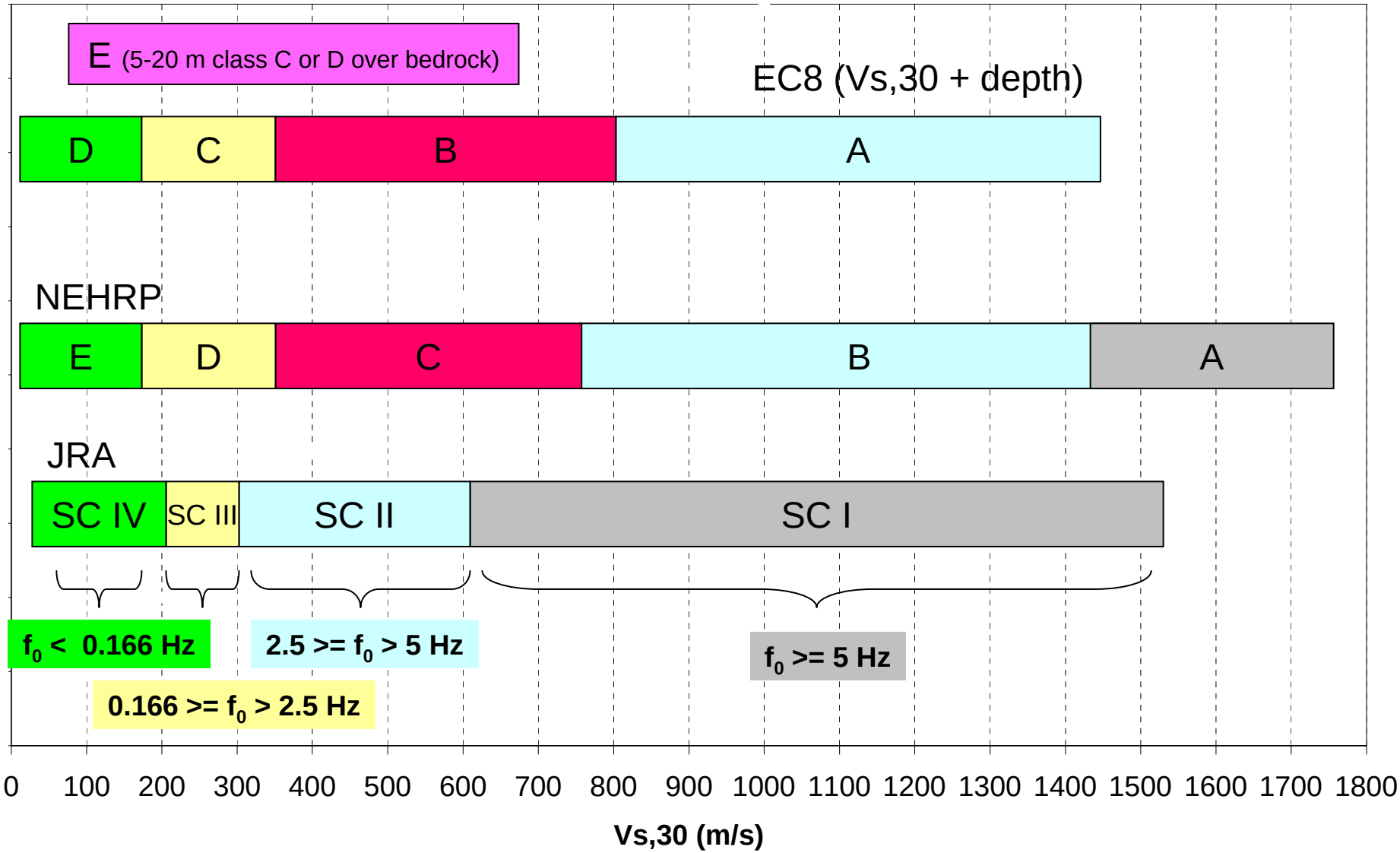
State of the art

Site are generally classified on the base of the $Vs,_{30}$ value (EC8, NEHRP) or a combination of $Vs,_{30}$/ $Vs,_{h}$ and resonance frequency (JRA, 1981; Cadet et al, 2008). Other classifications are based on the predominant site period, obtained from the average response spectral ratios of the horizontal and vertical components (Zhao et al., 2006) or both on average shear wave velocity and predominant period (Pitilakis et al., 2003; Bray and Rodriguez Marek, 1997)


E (5-20 m class C or D over bedrock)
EC8 (Vs,30 + depth)
D
C
B
A
NEHRP
E
D
C
B
A
JRA
SC IV
SC III
SC II
SC I
f0 < 0.166 Hz
2.5 >= f0 > 5 Hz
f0 >= 5 Hz
0.166 >= f0 > 2.5 Hz
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
Vs,30 (m/s)

Discussion

- NEHRP classification lacks class E of EC8, not identifiable on the bases of $Vs,_{30}$ (class E has similar $Vs,_{30}$ as class B, but a higher resonance frequency and higher impedance ratio with evident amplification peaks) and has 2 classes for rock
- JRA uses $Vs,_{30}$ and f_0, so that class E_{EC8} can be identified by a combination of frequency and $Vs,_{30}$. Rock sites have $Vs,_{30} > 600$ m/s

Discussion (2)

- Classifications which make use of 2 variables (i.e. $Vs_{,30}$ and f_0) categorize both, that is there is no overlap of $Vs_{,30}$ and f_0 between classes
- we will see that is not entirely true

Our approach (data driven)

1. Collection of a set of well documented recording station
2. Evaluation of soil parameters correlated to site effects
3. Classification through statistical data analysis
4. Soil classification test through error distribution in GMPE

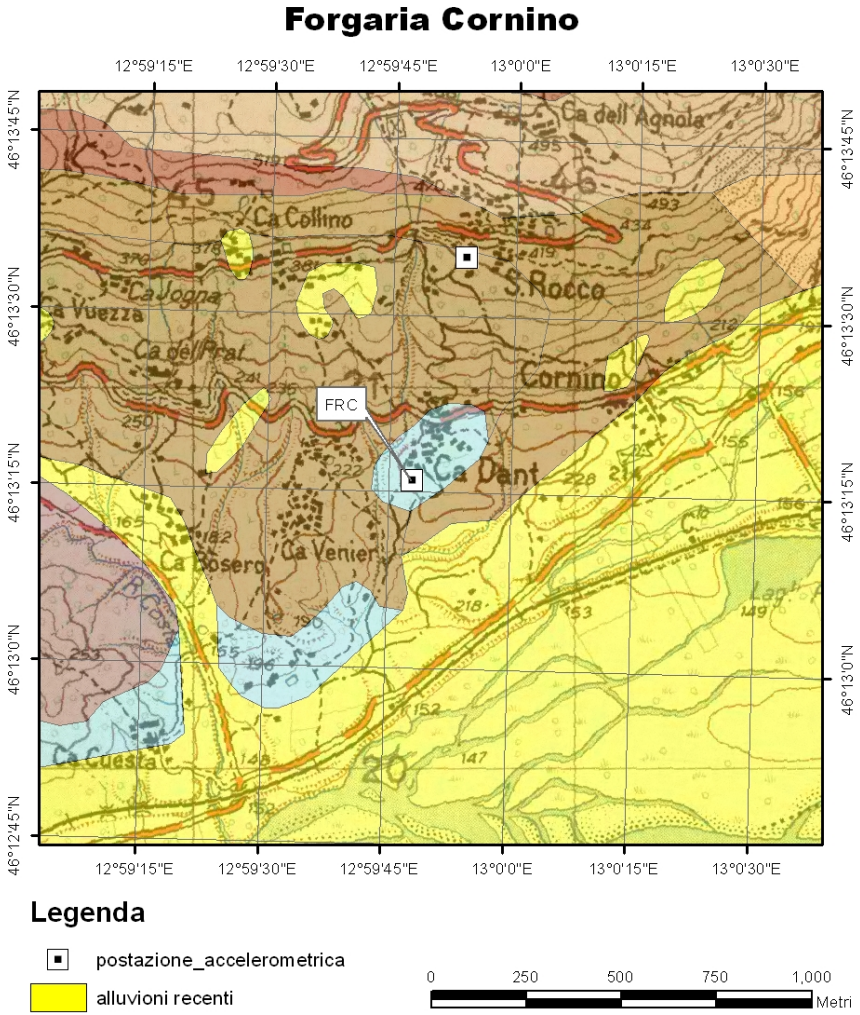
Data set

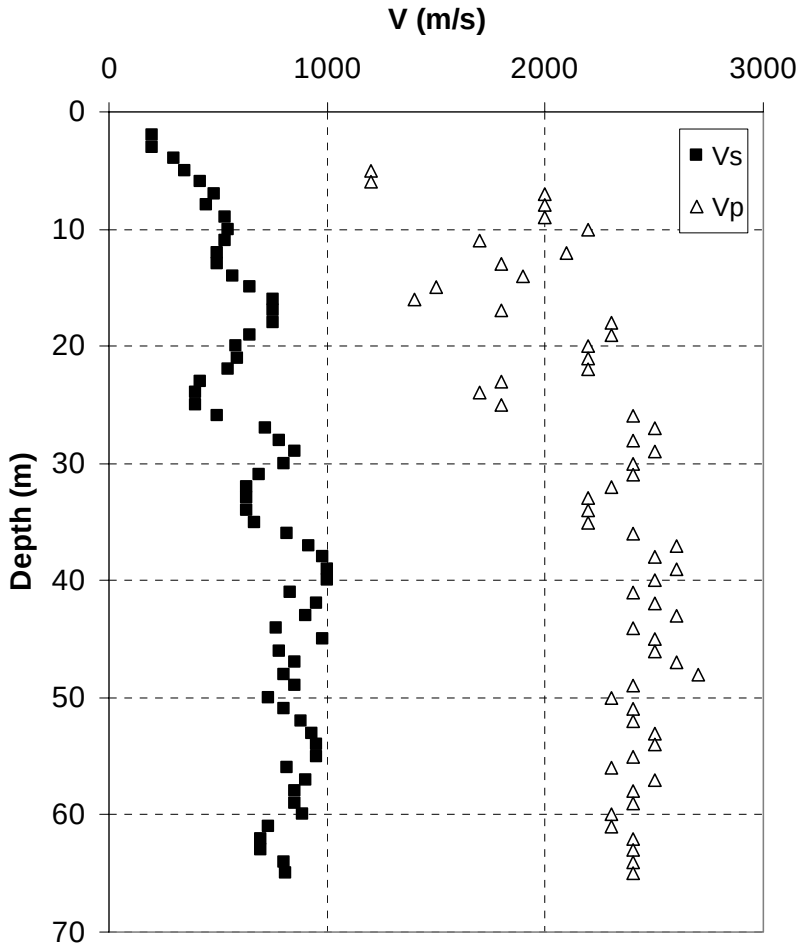
Recording stations which belong to the RAN (national strong-motion network) + recording stations managed by the University of Basilicata characterized by:

i) reliable geotechnical and geophysical information;

ii) availability of records of weak and strong events

In total: 84 stations



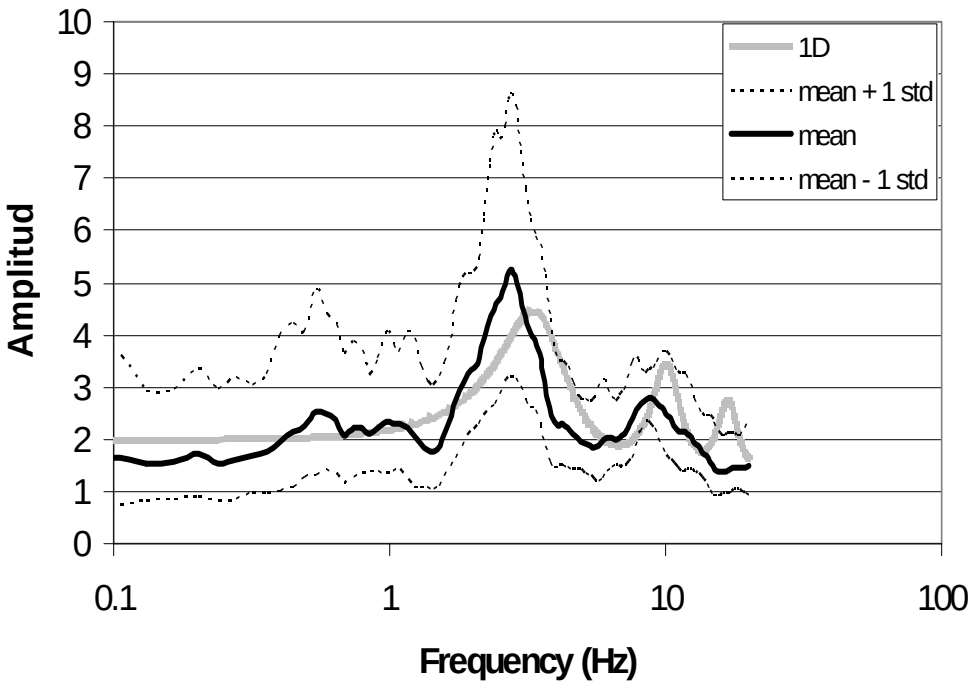


Geologic map and shear and compression wave velocity profile Of the station **Forgaria Cornino** (Friuli, northern Italy)

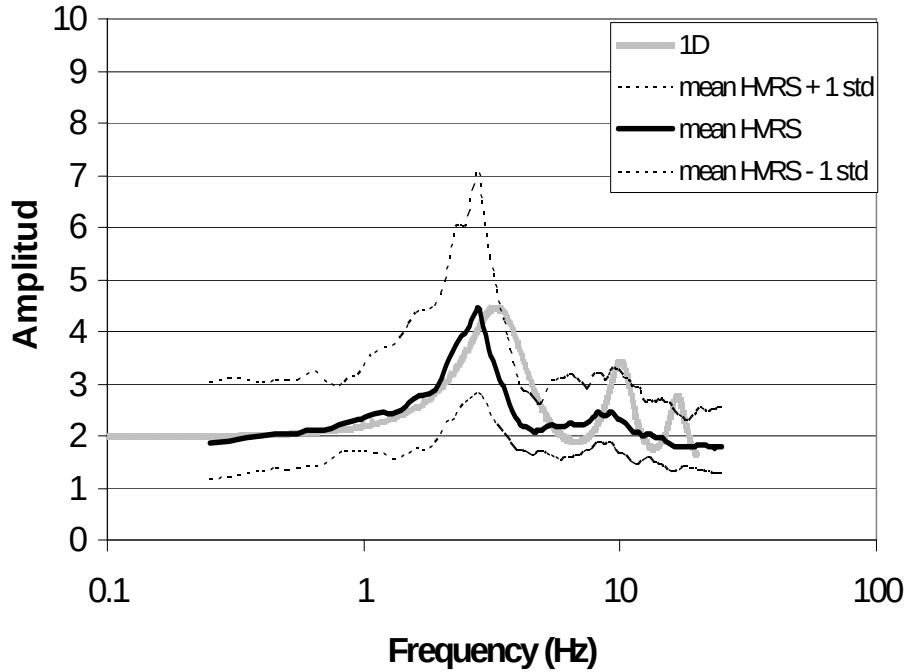
Forgaria Cornino (RAN)

$Vs_{,30}$ (m/s)	Classe EC8	$Vs_{,28}$ (m/s)
455	B	440

HVSR (smooth Konno Ohmachi, b = 20)

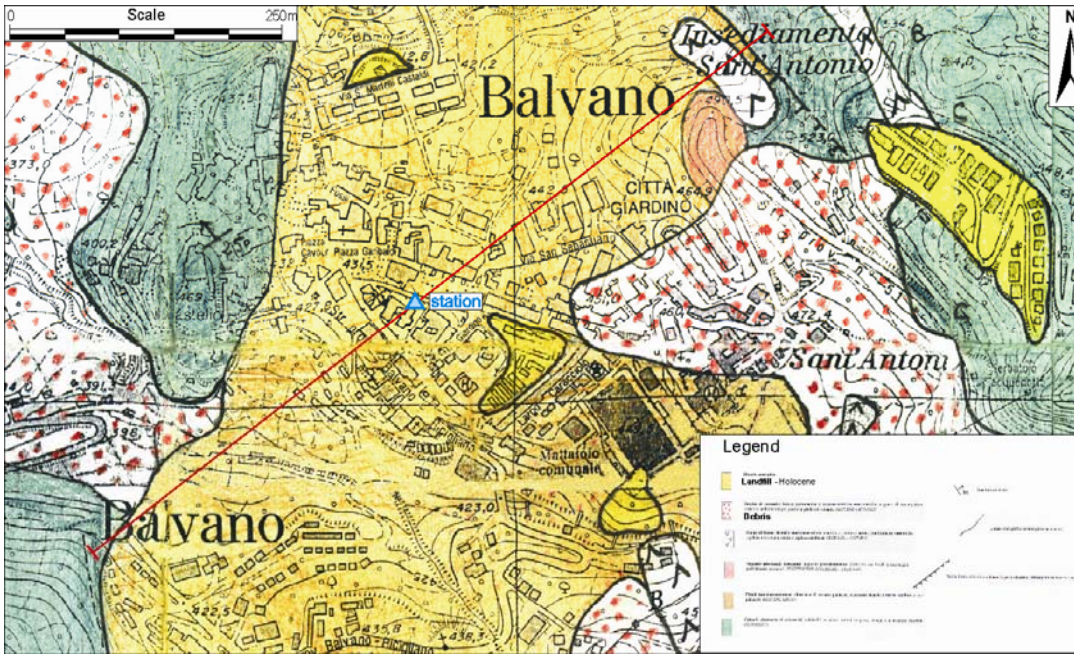


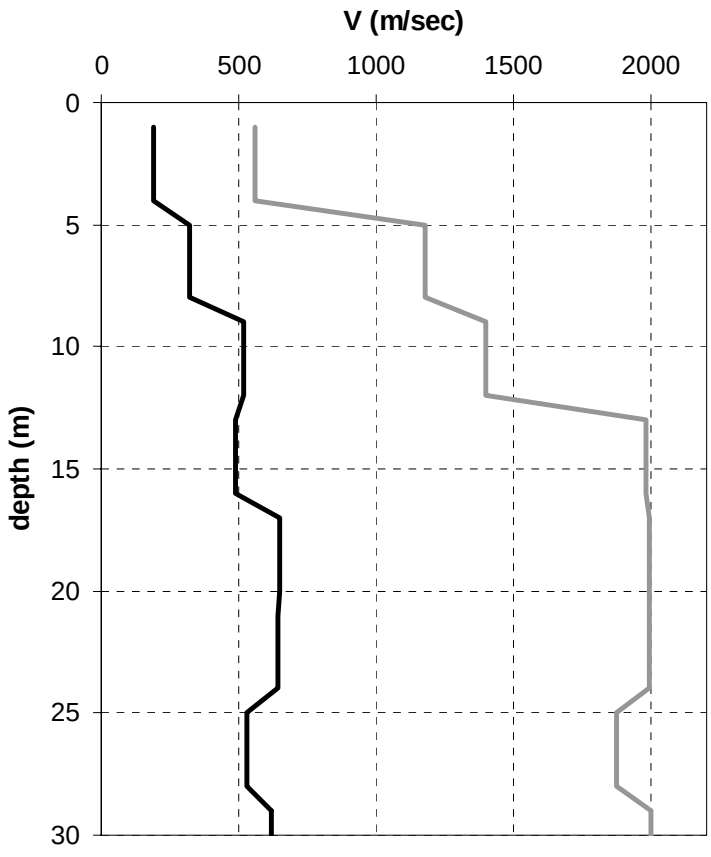
HV response spectra 5% damping

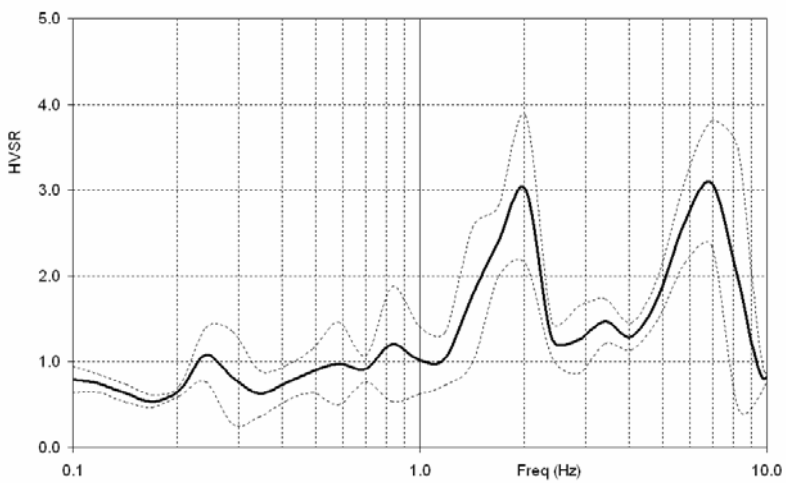


HVSR (2.75, 5.2) **1D** (3.5, 4.3) **HVRS** (2.8, 4.4)

Balvano (UNIBAS)





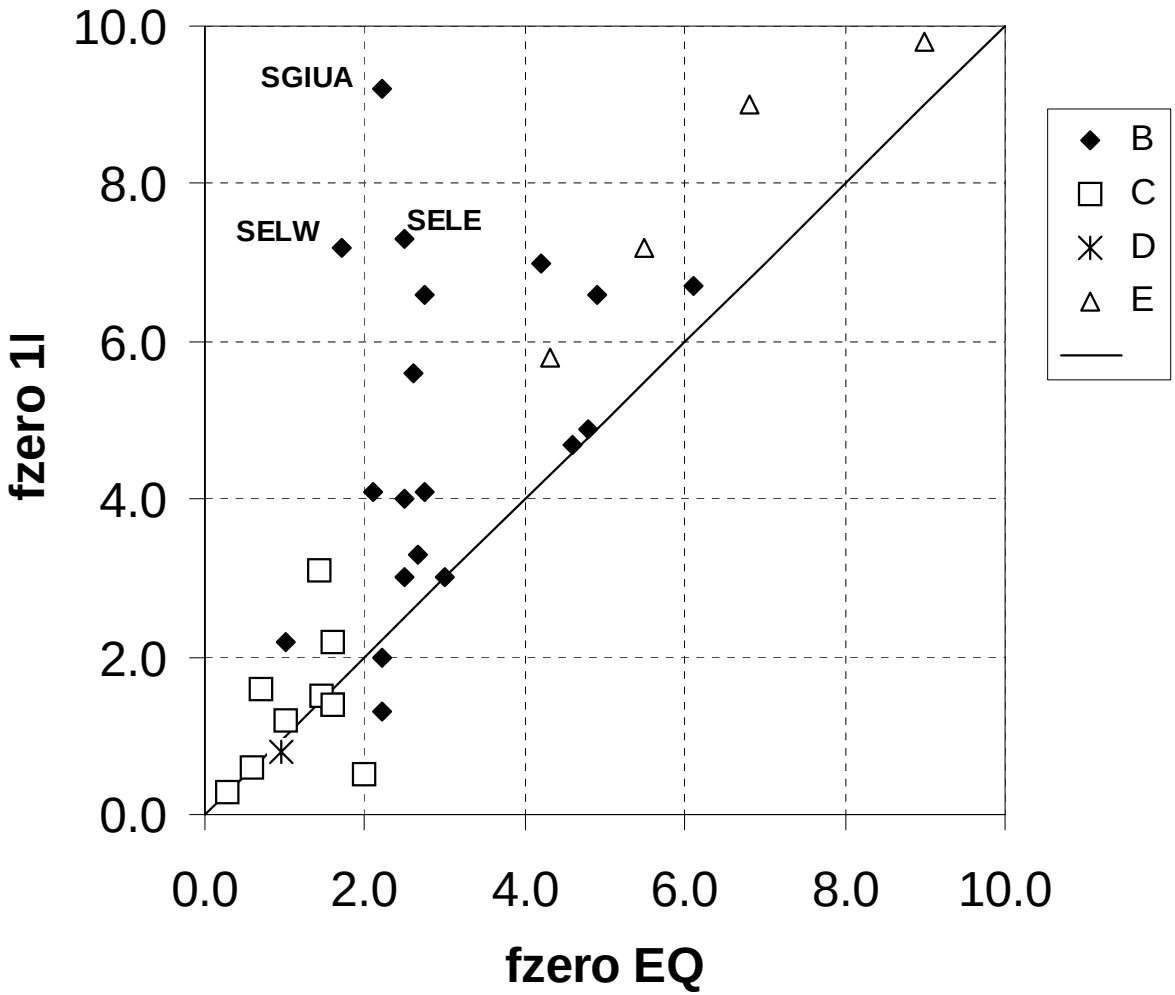


Vs30	EC8
413	*B*

Parameters

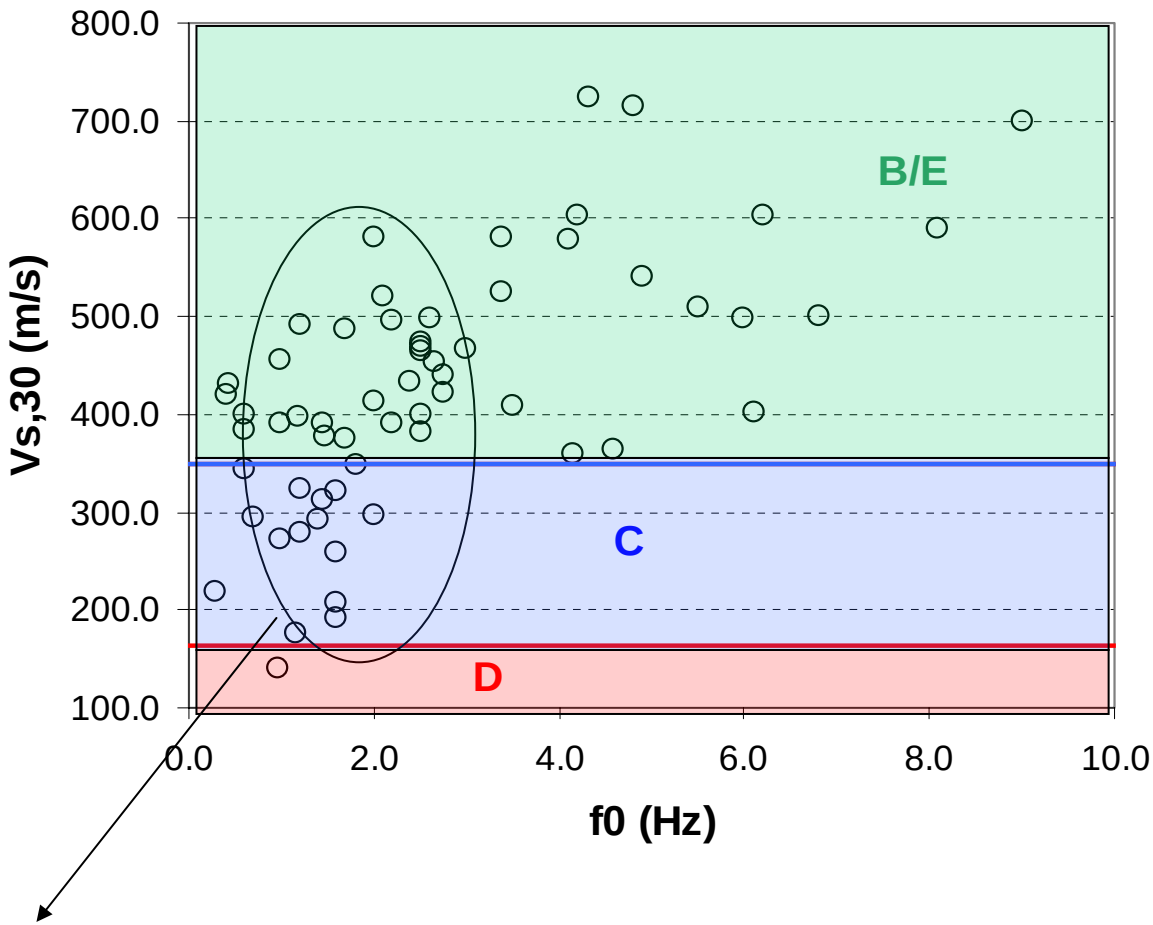
Vs30	Average shear wave velocity of the topmost 30 m
Vs,bedrock	Average velocity to the bedrock depth
Vs,H	Average shear wave velocity for different depths
f_{0hvsr}	Resonance frequency obtained for HVSR (earthquakes, microtremors)
f_{01D}	Resonance frequency obtained using 1D models
A_{hvsr}	Amplitude at $f0_{hvsr}$
A_{1D}	Amplitude at $f0_{1D}$
Ec8	Ec8 class

Comparison f_0 1D / HVSR (RAN sites)



Comment: the velocity profiles are generally reliable, with few exception (probable topographic effects, SELE, SELW and SGIUA)

f_0 versus Vs,30



Frequency overlap between class C and B/E

Data driven classification (Cluster analysis)

A partitioning which minimizes the sum, over all clusters, of the within-cluster sums of point-to-cluster-centroid distances. Different combinations of variables are tested:

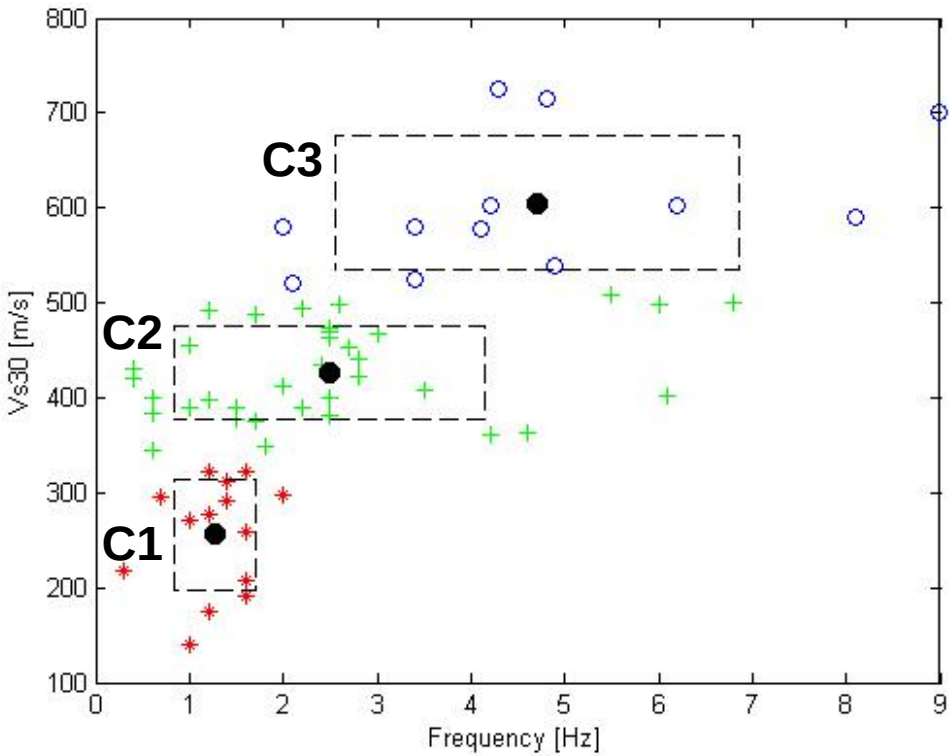
$$Vs,_{30} - f_0$$

$$Vs,_{H} - f_0$$

$$Vs,_{10} - Vs,_{30} - f_0$$

$$f_0$$

Data driven classification (Cluster analysis)



	Mean f_0	Std f_0
C1	1.27	0.43
C2	2.48	1.65
C3	4.70	2.14

	Mean Vs30	Std Vs30
C1	255.77	58.96
C2	426.70	48.96
C3	605.11	71.11

The error of each cluster is calculated as the mean point – to – centroid distance (normalized to the standard deviation of the cluster)

Degree of membership to a class

- Assuming that the variables of the points in a cluster are normally distributed, the membership to a soil class can be evaluated as probability density
- For a N variable normal distribution, the probability density function is

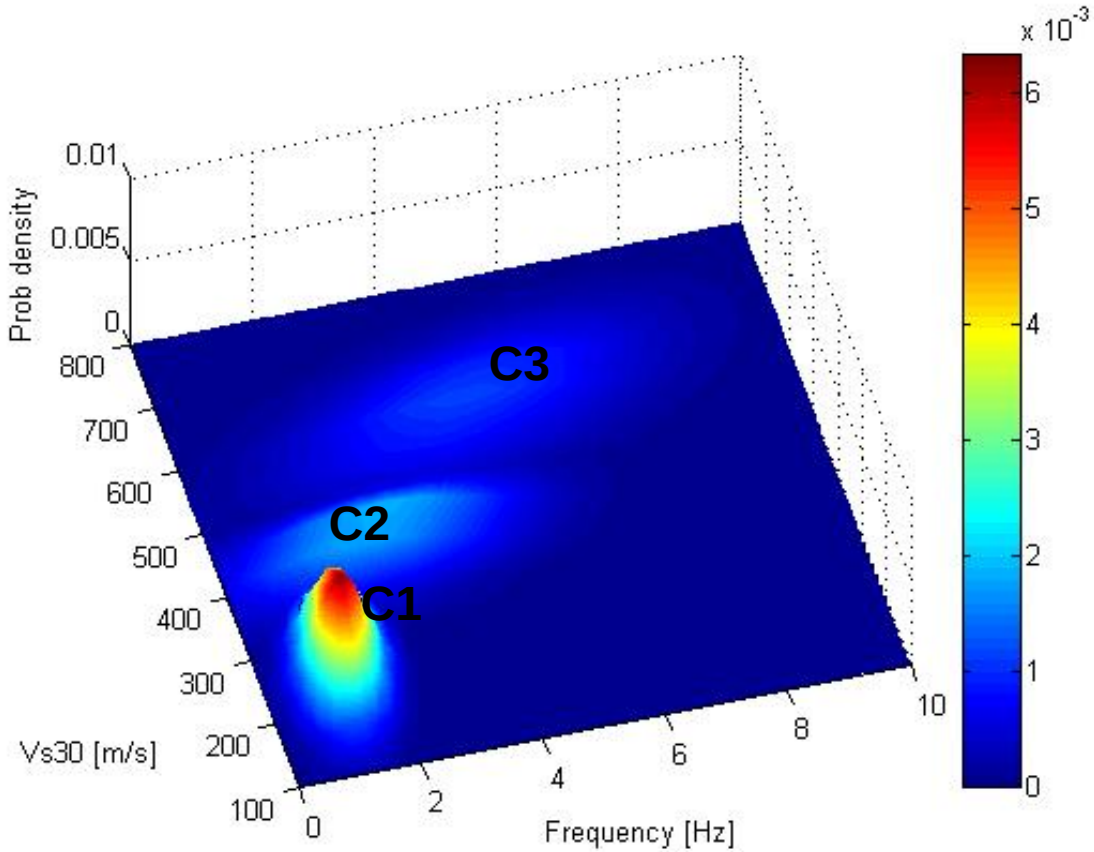
$$f(x) = \frac{1}{(2\pi)^{N/2}\left|\Sigma\right|^{1/2}} e^{-\frac{1}{2}(x-\mu)^T \Sigma^{-1}(x-\mu)}$$

where:

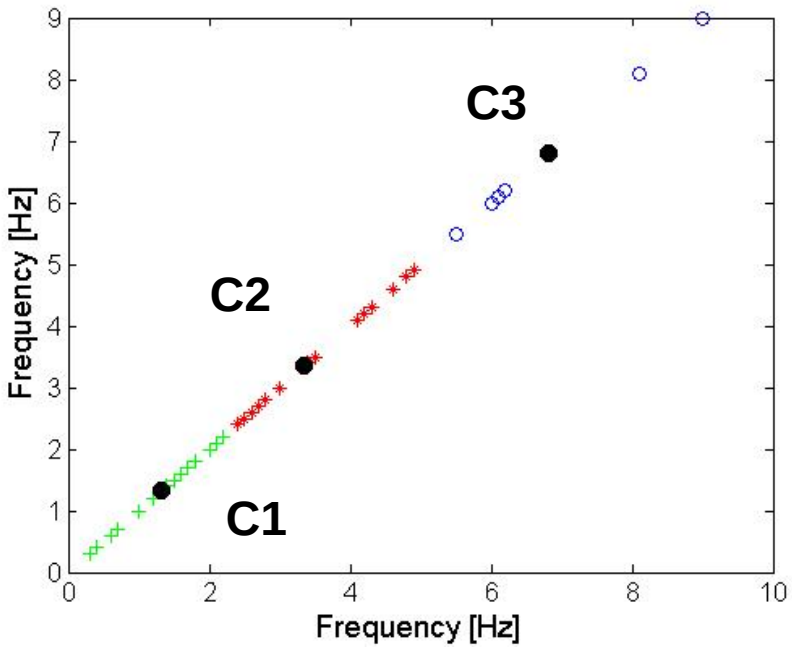
$\mu = [\mu_1, \mu_2, ...\mu_N]^T$ is the vector of variable mean

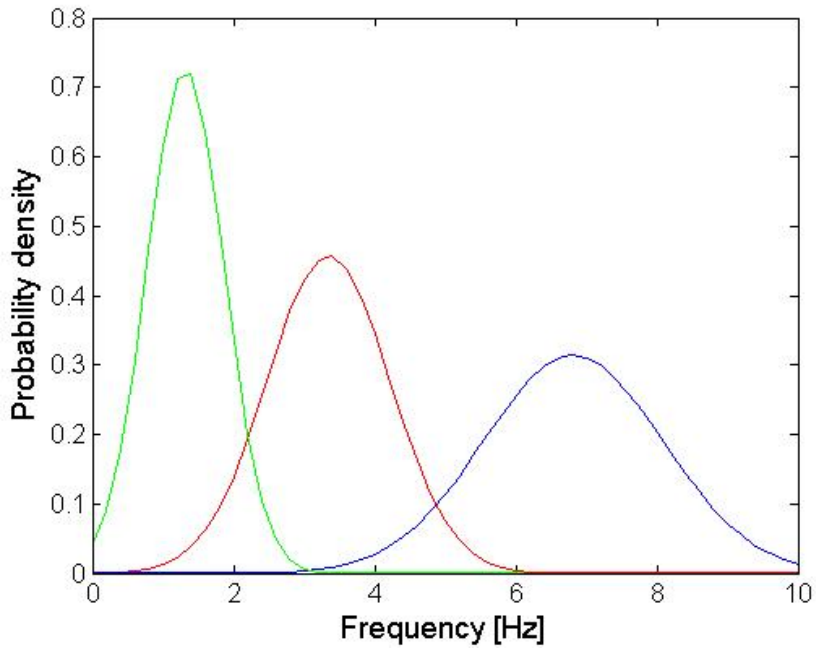
Σ is the covariance matrix (NxN matrix)

PDF of the three classes



1 variable: f_0



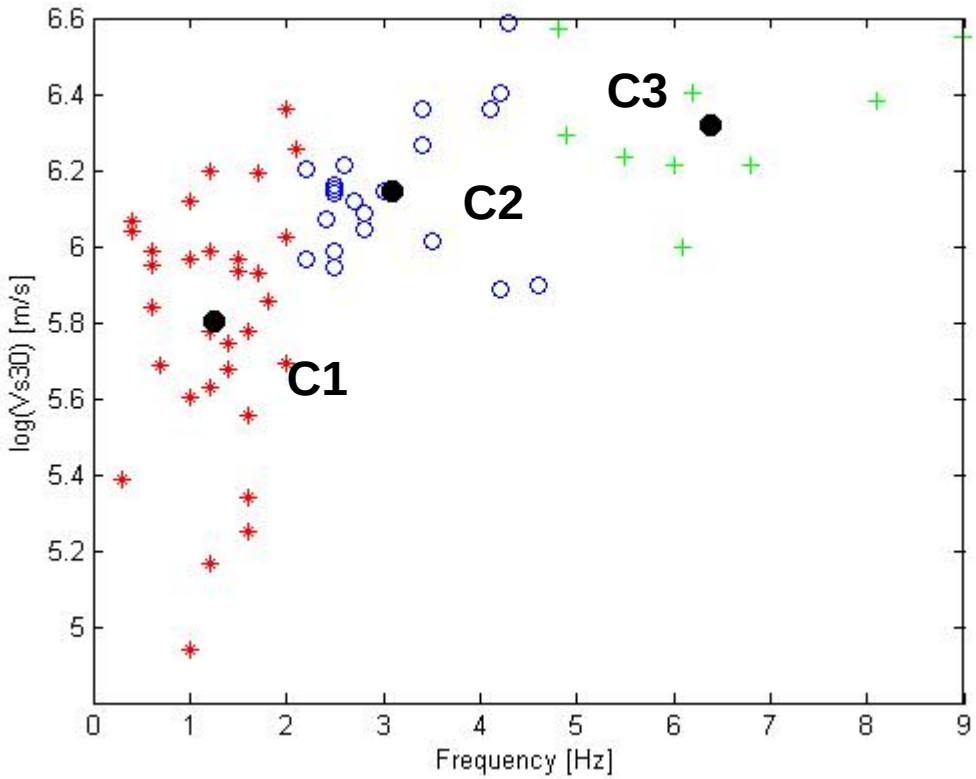


	Mean f_0	Std f_0
C1	1.31	0.54
C2	3.34	0.87
C3	6.81	1.27

Progress

- Test the classification estimating the residuals from GMPE
- Transform the dummy variables in GMPE in degree of membership to classes

Data driven classification (Cluster analysis)

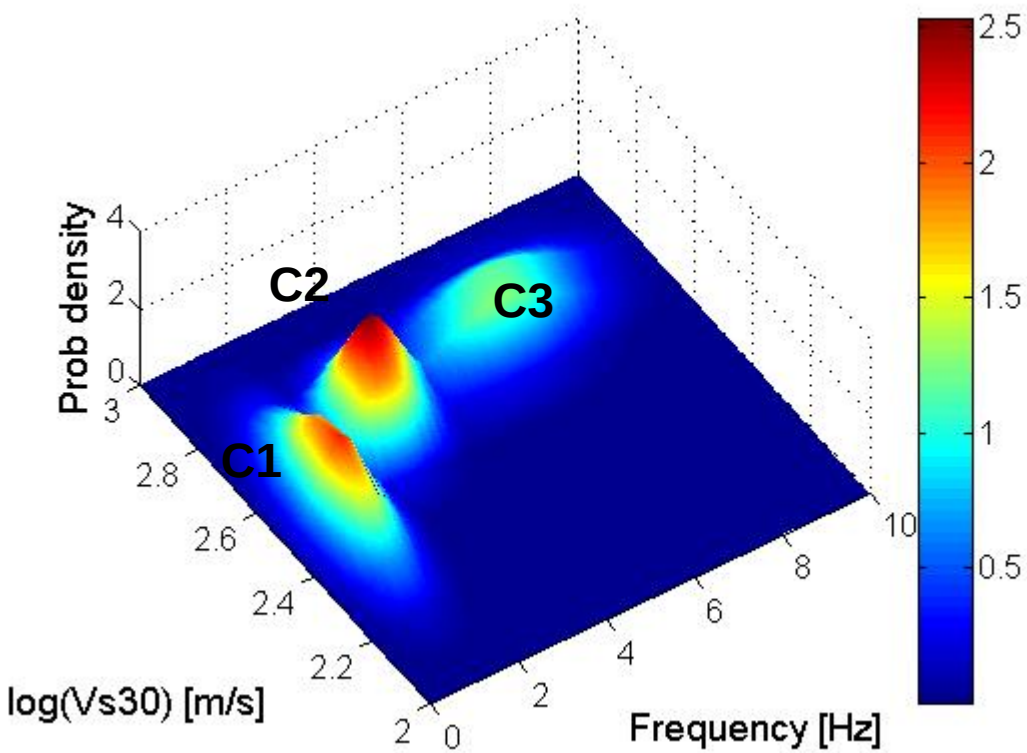


	Mean f_0	Std f_0
C1	1.2613	0.5149
C2	3.0905	0.7732
C3	6.3778	1.4016

	Mean Vs30	Std Vs30
C1	331.2884	93.5497
C2	465.4744	91.0291
C3	553.9174	110.421

The error of each cluster is calculated as the mean point – to – centroid distance (normalized to the standard deviation of the cluster)

PDF of the three classes



Cadet et al. (2008)

- A recent work by Cadet et al. (2008) tries to identify the main variables that can discriminate soil classes (Vs,H, where H = 5, 10, 15, 20, 25, 30 and site fundamental frequency f_0)
- They calculate the overall misfit between the actually measured amplification factors and the predicted ones using the KIK-NET dataset
- They found that the best combination is $Vs,_{30}$ - f_0