Wave propagation and shaking in deep sedimentary basins: Po Plain case of study.

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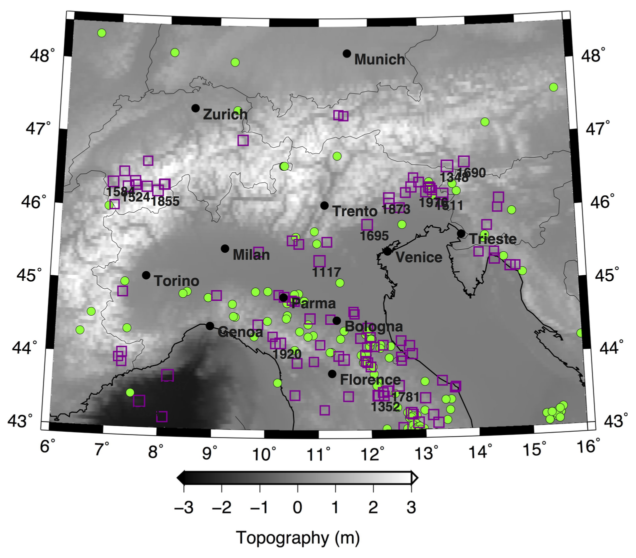
WHY PO PLAIN?

The Po Plain area is affected by relatively infrequent and moderate-magnitude seismicity. However, it has experienced quite strong earthquakes historically (up to estimated M ~ 7), and it is characterized by high vulnerability and exposure given by dense population and large industrial and touristic districts. Crustal structure is strongly heterogeneous, with a deep sedimentary basin up to 8 km deep, and sometimes rough terrain in the surrounding Alps and Apennines. In such circumstances, assessment of local seismic amplification and shaking scenarios using deterministic calculations is, at the same time, both very challenging and highly relevant.

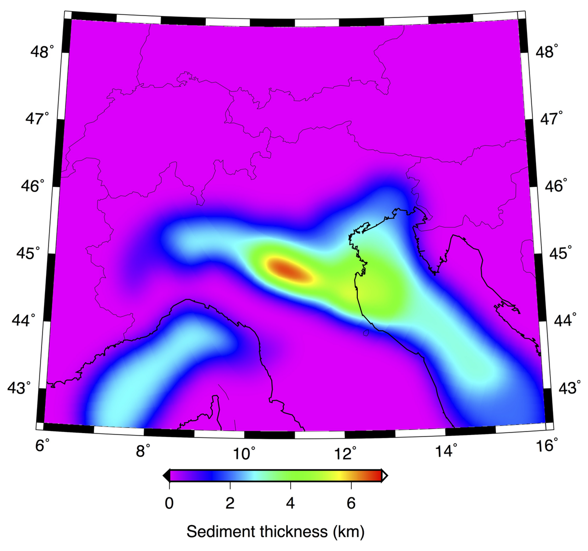
In order to simulate seismic wave propagation for sample earthquakes with SPECFEM3D-SESAME (Peter et al., 2012) we need to set up a 3D model of the earth's crust with appropriate detail. This would allow to compute shaking maps for recent and ancient earthquakes, and compare them with available seismic records and macroseismic intensity maps, with the aim of understanding the effects of the sedimentary basin on local seismic amplification. A detailed geological model, and a very large mesh, will be necessary to produce realistic simulations. We illustrate early results obtained with a preliminary earth model.

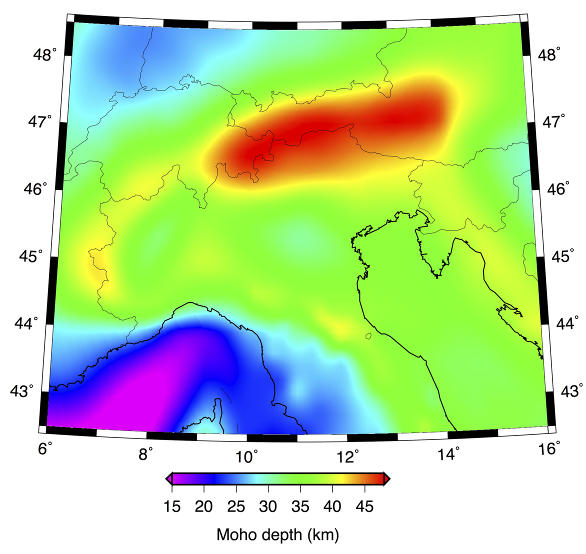


Historical seismicity between 1000 AD to 1970 AD with intensity larger than 5.5. Green dots represent the instrumental earthquakes recorded from 1970 to 2012 with magnitude bigger than 4.

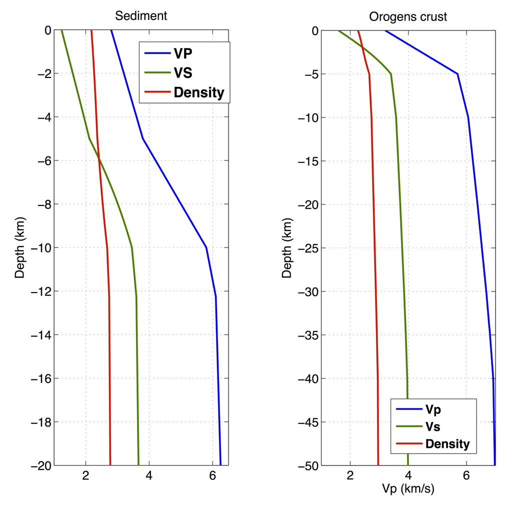
PRELIMINARY CRUSTAL MODEL

Despite the lack of knowledge of Po Plain crust and the geological complexity of the structure, we set up a preliminary model of the North Italian crustal structure: the sediment thickness is derived from Vuan et, al, 2010, CROP seismic lines (Finetti, 2005 and Cassano et al, 1986), whereas the Moho depth is taken from model EPcrust (Molinari & Morelli, 2011). The topography is from ETOPO1 (NOAA database). VP-wave velocity structure of both sediment and crystalline crust follows a 1D depth dependent profile from Ogniben et, al, 1975 and Mooney, respectively. VS-wave speed and density are derived from VP using the Brocher relations (Brocher, 2006). The upper mantle is from Shaefer et al. 2011. This crustal model is sampled with a resolution of 0.01˚x 0.01˚.





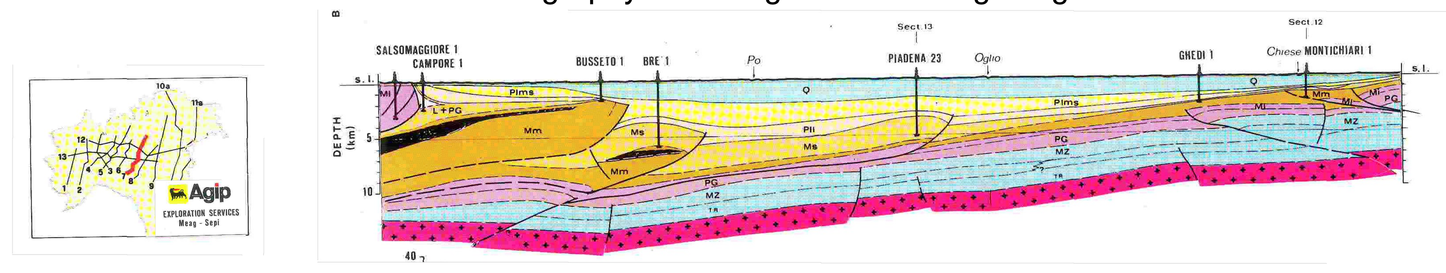
(left) Sediment layer thickness (km) arranged from literatures, (right) Moho deph taken from EPcrust (Molinari & Morelli, 2011)



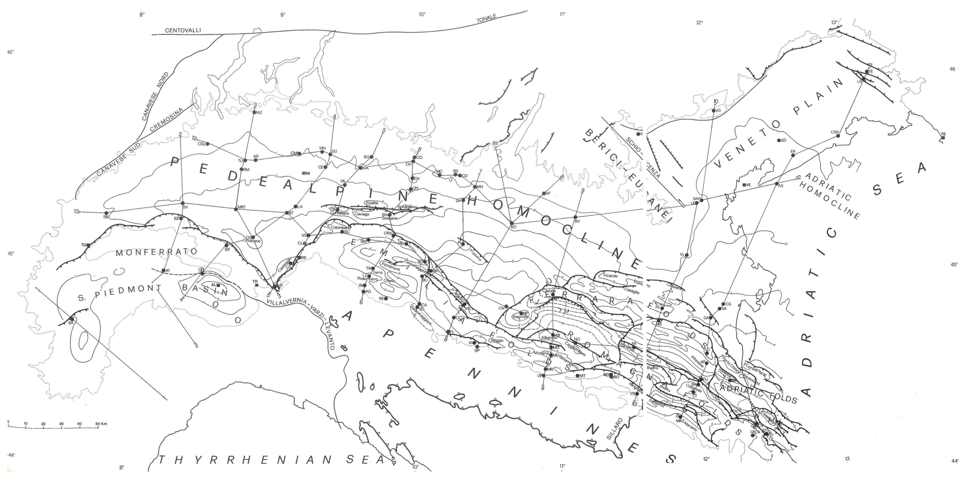
Vp-depth profile used to describe the sediment layer (left) and the crystalline crust (right).

REFINING THE MODEL

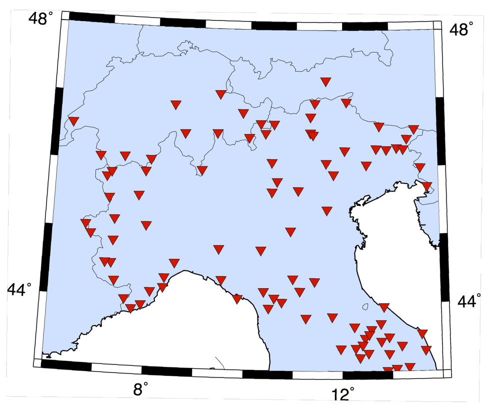
We plan to refine our preliminar model (with a particular attention on the sediment layer) integrating geological and geophysical data together with seismic tomography results. In particular, we are collecting interpreted seismic profiles, borehole data, information from geological studies and seismic noise modeling data for a high resolution surface waves noise tomography of the region based on geological constraints.



Geological profile from seismic refraction/reflection lines (Pieri & Groppi, 1975) interpreted in the frame of hydrocarbon exploration surveys (Agip company). In this section, we can appreciate the complexity of the characteristic Appenine folds and the sharpness of the basement boundary.



Simplified structural map of Pliocene-Quaternary sequence in the Po Plain Basin, Scale 1:1.000.000 (Pieri & Groppi, 1975).

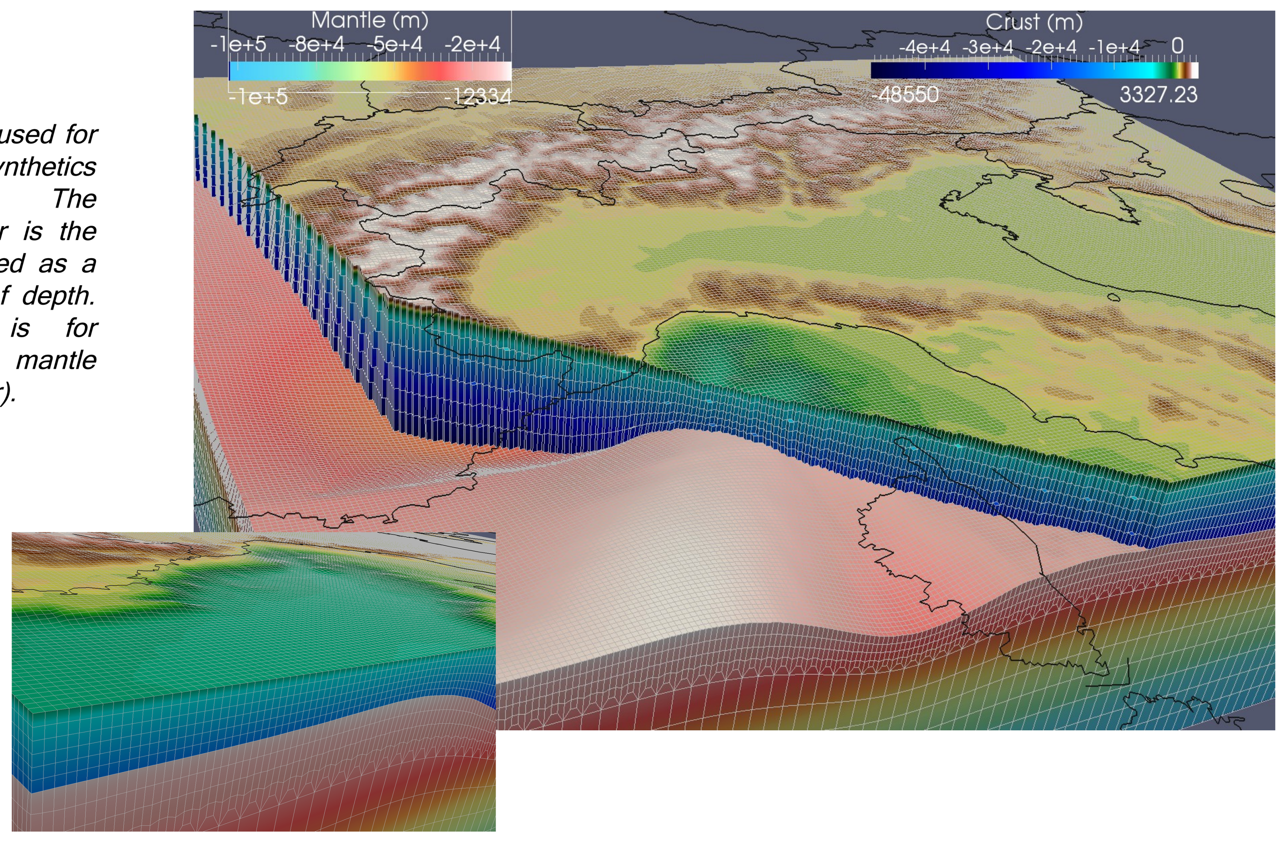


Seismic station distribution in the Po Plain area, available for a noise tomographic study. .

MESHING

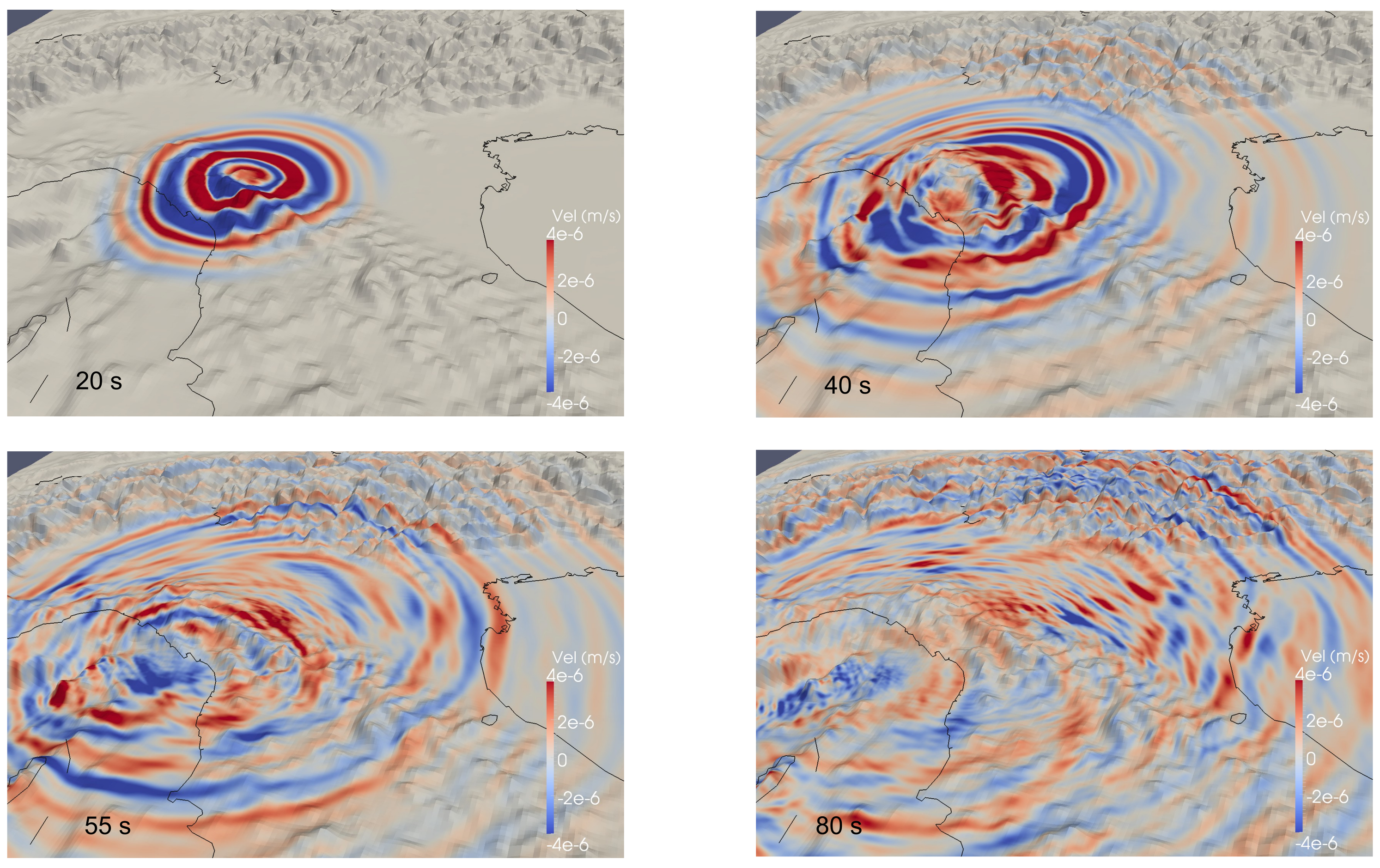
The region covers the whole Northern part of Italy, from 42 to 48 latitude and from 7 to 16 of longitude and 245 km of depth . We mesh the model using Cubit, honoring the topography and the Moho depth as main discontinuities. The element width was set to 3 km in the crust and 9 km in the upper mantle. This allows us to reach a minimum accurate period in the simulations of 4-5 seconds. The mesh has 1 milion of spectral elements.

The mesh used for the synthetics calculation. The upper layer is the crust colored as a functions of depth. The same is for the upper mantle (lower layer).



SIMULATIONS WITH SPECFEM3D

We implement the models in the seismic wave simulation code SPECFEM3D-SESAME (Peter et al., 2011) to calculate seismograms. We consider 2 recent earthquakes recorded at available Italian seismic stations: the 27 January 2012 Frignano earthquake (Mw = 5.4, depth= 55 km) and the 24/11/2004 Garda earthquake (Mw = 5.3, depth = 15 km). We plot here four snapshots for the Frignano earthquake, that was felt in the whole Po plain area even if it did not cause important damages. The effects of the topography and sediment are evident and causes reflections and amplification in the simulated wavefield.



Snapshots at 20 s. 40 s, 55s (left) and 80s (right) after the 27 Jan. 2012 earthquake (Mw=5.4) . Half duration was set to 1.8 s.

OUTLOOK

Preliminary results are encouraging but, of course, lack the resolution necessary for realistic simulation and higher frequencies.
High resolution knowledge of the crustal model of the region is a key point for computing realistic synthetic seismograms. Our plan is therefore to integrate information from geological studies, together with seismic tomography results. In particular:

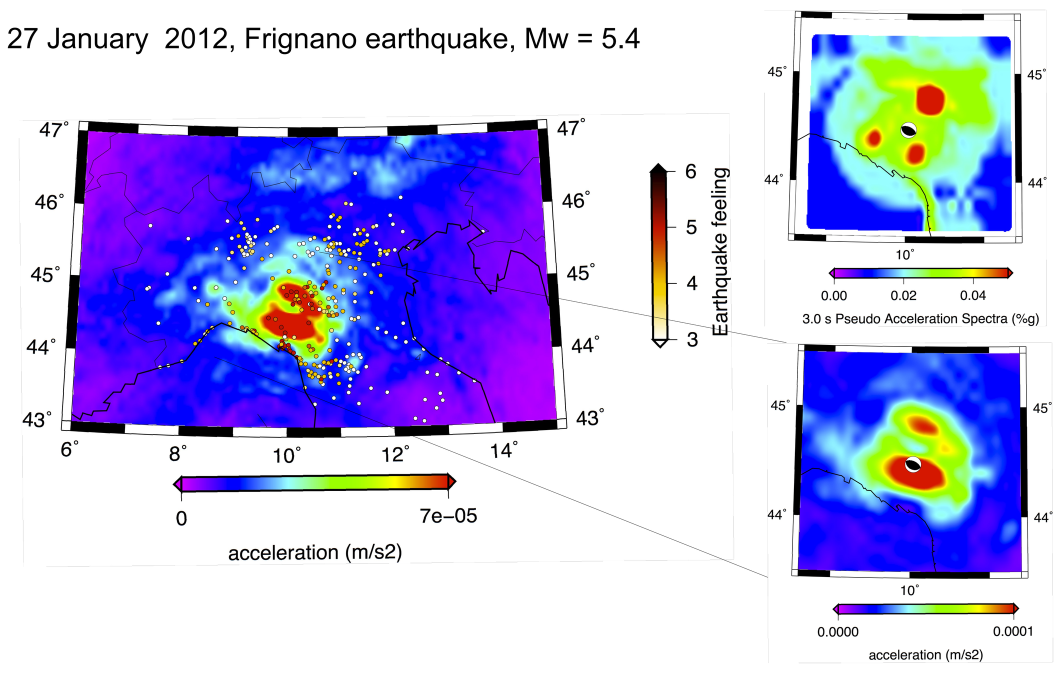
- Sediment layer structure, has to be described with higher precision in order to reach a good fit between data and synthetics.
- Reliable attenuation model for the area (not currently known)
- All the crust parameters need to be know with higher spatial resolution (at least 4 km x 4km) in order to reach higher frequencies (1-2 Hz).

High frequency deterministic shaking scenarios are important in a risk mitigation point of view. The actual estimations of shaking (Michelini et al, 2008) are based on regional attenuation relation and can be improved with the approach proposed here. The calculating shaking values depend on the highest resolved period by the mesh. An improving of the model will lead to a reilable shakemaps.

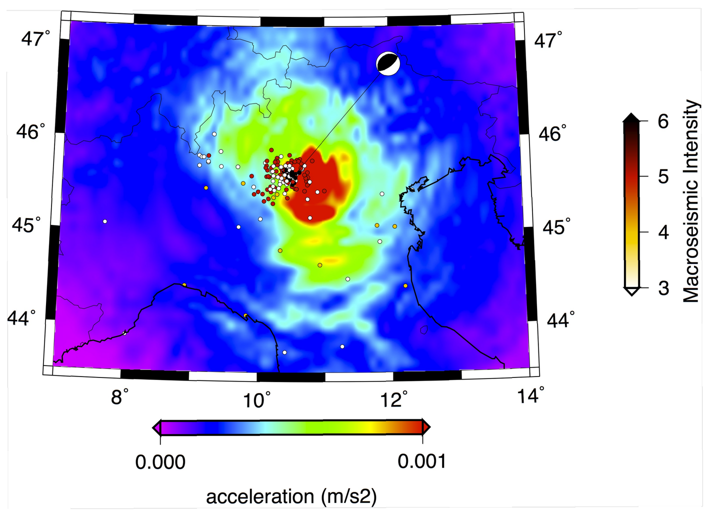
SHAKING SCENARIOS

We calculate the Shakemap® for the 27 January 2012 earthquake near Parma and for the December 2004 earthquake occured near Garda Lake. Since our calculations where done setting a half duration of the source equal to 1.8 s, we are able to appreciate the shaking at ~ 5 seconds. In the first case, we compare our preliminary results with the feeling intensity and with the 3.0 s pseudo-acceleration Spectra (*http://shakemap.rm.ingv.it,* Michelini et al, 2007) calculated at INGV, Rome. In the second case we qualitatively compare our shakemap with macroseismic intensity published in the CPTI11 (Macroseismic Italian Database, 2011*; http://emidius.mi.ingv.it/DBMI11/*).

27 January 2012, Frignano earthquake, Mw = 5.4



24 November 2004, Garda earthquake Mw = 5.3



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