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Reappraisal Of A XVI Century Earthquake Combining Historical, Geological And Instrumental Information

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Introduction

The earthquake occurred during 1561 in Southern Italy heavily struck a zone known as Vallo di Diano. This is the only destructive earthquake whose epicentre is attributed to that valley. Two problems arise about this epicentral location:

1) the distribution of reported effect is highly asymmetrical, possibly reflecting population distribution at that time,
2) some geologist maintain that there is no evidence for ongoing active tectonics in the Vallo di Diano area.

The basic question behind our work is the following: Is it possible that both expert judgement and computer techniques have up to now placed the 1561 epicentre in the wrong place, driven by asymmetrical distribution of observations and by site effects enhancing damage in the alluvial valley?

We know from previous studies that site effects are a dominant factor in seismic hazard estimates performed using site seismic histories (Mucciarelli, Peruzza and Caroli, 1999) and that there is a correlation between ground motion amplification in the building frequency range and a systematic increases in hazard values (Gallipoli et al., 1999) or damage enhancements (Mucciarelli and Monachesi, 1998, 1999, Mucciarelli, Monachesi and Gallipoli, 1999).

To try to answer the previous question, we performed site amplification measurements to have a sort of "station correction" for each locality involved, so to be able to understand if the intensity assigned on the basis of historical information is somehow biased by the presence of local effects. Then we studied some plausible scenarios of rupture propagation on finite faults to derive the best fit possible between observed intensity and theoretical models compatible with geological information.

The activities performed are the following:

1- Comparison of different interpretation from historical seismology studies
2 - Site amplification measurements using the HVSR technique
3 - Residual analysis between observed and predicted using:

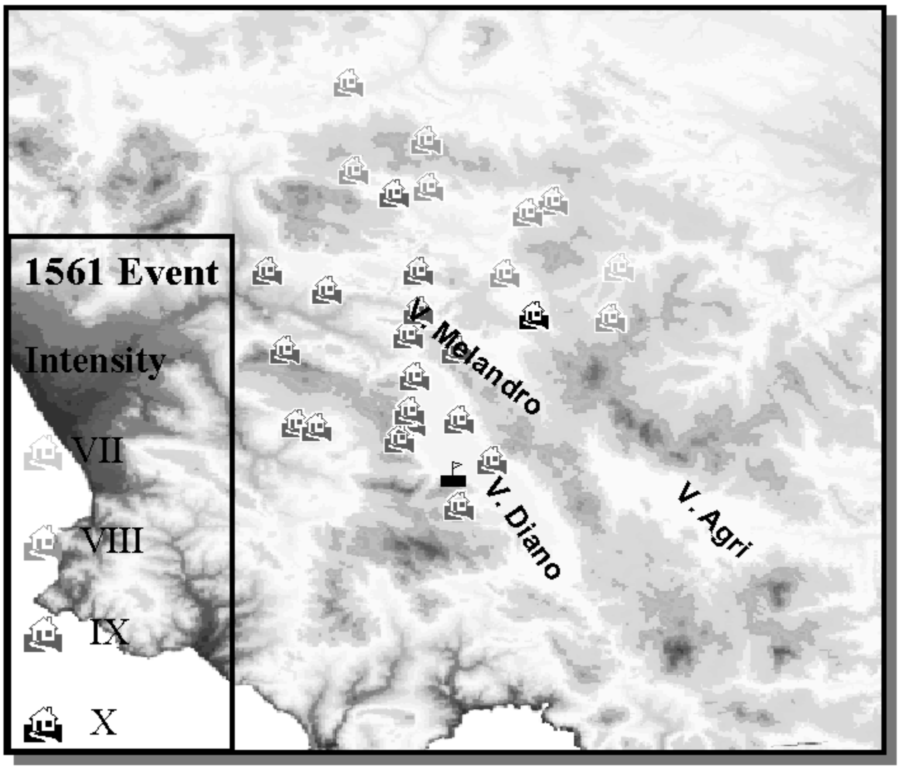
- Isotropic Model
- BOXER Model
- WINTENSO Model

4- Comparison of non-parametric correlation

Available studies:

The historical seismology studies considered are those of Chiodo (1994), Castelli, (1996), CFTI (ING-SGA), 1998, DOM (Monachesi and Stucchi, 1998)

All these studies are mainly based on the interpretation of a single manuscript by C. A. Pacca (Discorso dei terremoti, 1563). The intensity assignments coincides for most of the localities, with some minor discrepancies. The intensity map used is shown in the figure below



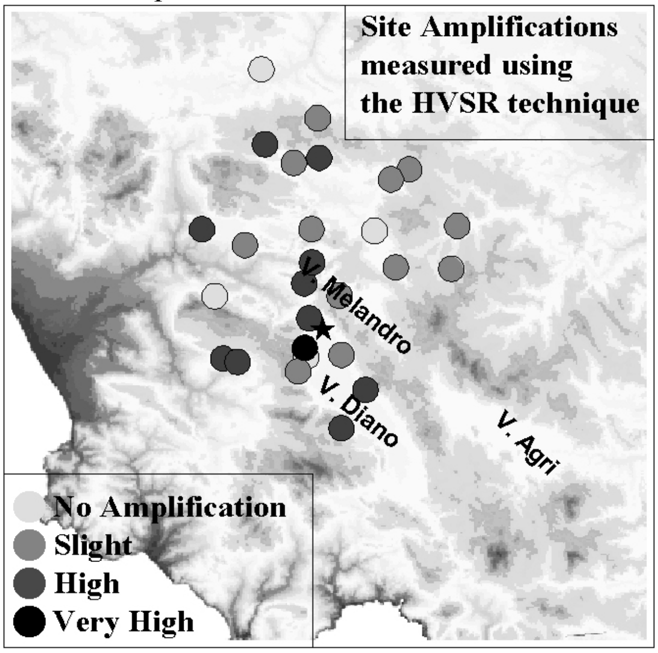
HVSR measurements

The proposed procedure, essentially based on a few number of microtremors measurements is actually an application of the measuring technique set up by Nakamura (1989) for site effects. This methodology has the great advantage to exploit specific properties of the measured structures in the filtering of the signals, avoiding the typical dependency of ambient vibration measures from the spectrum of the applied vibration (wind, traffic, etc.)

For each site one measuring point was selected trying to identify the oldest part of the town an possibly near a building that was already built at the time of the earthquake (usually the oldest church). One measurement point should be enough on a first approach considering the limited extension of settlements at the time of the earthquake considered.

The signals used have been recorded with a tridirectional sensor Lennartz 3D-Lite (1 Hz period), connected with a 24 bit digital acquisition unit PRAXS-10 and a Pentium personal

The site transfer functions have been computed in the following way. First a set of at least 5 time series of 60 s each, sampled at 125 Hz, have been recorded. Time series have been corrected for the base-line and for anomalous trends, tapered with a cosine function to the first and last 5% of the signal and band-pass filtered from 0.1 to 20 Hz, with cut off frequencies at 0.05 and 25 Hz. Fast Fourier transforms have been applied in order to compute spectra for 25 predefined values of frequency, equally spaced in a logarithmic scale between 0.1 and 20 Hz, selected in order to preserve energy. The arithmetical average of all horizontal to vertical component ratios have been taken to be the amplification function. Full details of the methodology and its limits are given by Mucciarelli (1998). For this specific application, we then considered only the frequency band form 1 to 10 hz, supposing that buildings at that time should not have fundamental modes at lower frequencies. It is known that the Nakamura technique can well identify soil fundamental frequency but some doubts are cast on its capability to correctly estimate the magnitude of amplification. For this reason we considered only classes of amplification: No Amplification (HVSR value below 2), Slight Amplification (between 2 and 2.5) Amplification (between 2.5.and 3.5) and High Amplification (over 3.5). The results are reported in the map below:



Fault Models

We considered first a point-source model. This model is based on the determination of the epicentre as the minimum of the residuals of all the intensity points with respect to an isotropic attenuation model for Italy (CRAM model as described in Magri et al. 1994). Then we estimate the residuals between the observed data and the fault model proposed by the program BOXER (Gasperini et al, 1998). Finally, we performed six different forward models: two on the Val d'Agri Fault (Apenninic strike, dipping toward the Tyrrenian Sea at 60 degrees, with propagation NE-SW or vice-versa) and four imposing a fault in the Melandro Valley (Apenninic strike, dipping toward the Tyrrenian Sea or the Adriatic Sea at 60 degrees, with propagation NE-SW or vice-versa, see following figure). For this forward modelling we used WINTENSO. The WINTENSO software package embodies a methodology for relating site intensity information collected during historical or contemporary earthquakes with parameters derived from a physical description of earthquake rupture on extended fault planes, based on the algorithm described by Mendez et al.(1996). All the programs used are shareware, and can be downloaded from http:\faust.ingv.it, the site of FAUST, a project funded by EC ENV4 framework. We then correlated each residual with the site amplification, using the Spearman's rank correlation index. The results are reported in the following table:

Model	Correlation
Isotropic	-0.0043
Boxer	-0.1142
Melandro Adriatic Dip - Propagation South	0.0269
Melandro Adriatic Dip - Propagation North	-0.0421
Melandro Thyrrhenian Dip - Propagation South	0.1294
Melandro Thyrrhenian Dip - Propagation North	0.1581
Vallo di Diano - Propagation South	-0.0336
Vallo di Diano - Propagation North	-0.0220

Some models have negative, unphysical residuals. The preferred model is Melandro

Thyrrhenian Dip - Propagation North, which is significative at about 80% confidence level.

Conclusions

It was possible to demonstrate that, when site amplification are taken into account, the location of an historical earthquake can vary significantly. This applies not only to epicentre but especially to extended seismogenic faults connected to large events. The main open question regards the town of Tito, which is always the most uncorrelated site. Did we measure amplification in a more recent historical downtown? Was the location of Tito in 1561 different from today? More help from historians and more HVSR measurements are needed to solve this problem. From the seismogenic point of view, we demonstrate that the location of the 1561 in the Melandro valley is more statistically significant than the one up to know proposed. More detailed geological data are however needed to lend support to the Val Melandro fault hypothesis.

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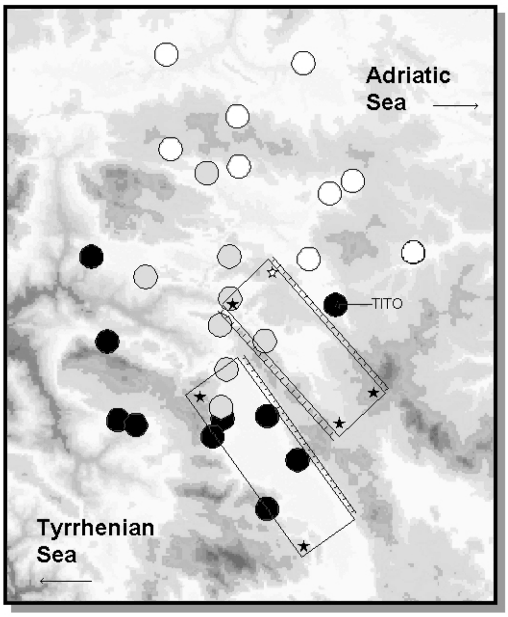

The left figure shows the fault models: the Val d'Agri (below) and Val Melandro (upper), with stars marking the rupture starting points and the barbed lines indicating the sense of dip. The white stars mark the rupture propagation for this simulation. The dots indicate the residuals with respect to observed data, indicating which kind of amplification is expected for the best fit: No amplification (white), Slight (gray) and High (Black). This simulation is the one giving the smallest residuals, as it can be seen matching the expected amplification here with the observed one, showing maxima in the alluvial plain of Val d'Agri.