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Noise measurements along fault zones in central Appenines

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Abstract: *Normal fault systems, outcropping or hidden below Quaternary covers in intermountain basins, are the expression of the Neogene-Quaternary evolution of central Italy, characterized by an extensional tectonic regime following the fold and thrust structuring of the Appenninic orogen. The presence of these features plays an important role in seismic risk evaluation of an area. In this work we deal with the use of single-station seismic noise measurements to detect sudden lateral variations of the geometries and/or properties of subsoil connected to the presence of tectonic elements (fault zones). Ambient noise data were collected along transects perpendicular to the strike of hypothetical fault lines for 3 test sites within the Abruzzi Region. The proposed approach is suitable for detecting in a fast and simple way local lateral changes in the subsoil characteristics close to geological structures and can be very effective to properly address more expensive and time consuming classical geophysical and paleoseismological approaches.*

Key words: *Ambient noise, fault trace.*

INTRODUCTION

In the paper we analyse single station ambient noise H/V spectral ratios (HVNSR) (Konno and Ohmachi, 1998) to detect the presence of buried tectonic discontinuities in three case studies characterized by a different a priori knowledge of the presence of an outcropping fault. All the test sites (Figure 1) are located in the central part of Abruzzi region (Central Italy).

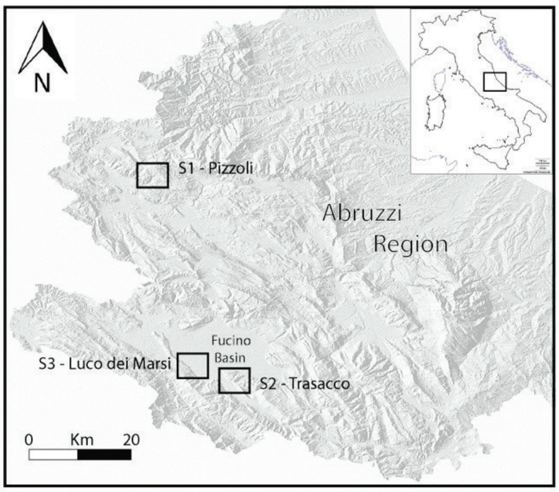

Figure 1: Geographical setting of the study area.

DISCUSSION

The first HVNSR analysis was performed in a site close to the Pizzoli village were a paleoseismological trench pointed out the presence of a dislocation in the very shallow sedimentary layers, probably correlated to an active and capable fault. The trench is located on recent slope sediments at the base of a NW-SE trending mountainside characterized by an important normal fault system recognized as active by several authors (Moro et al., 2002, Gori et al., this meeting).

Four HVNSR measurements were performed along a N20 trending transect deployed on a gentle slope parallel to the paleoseismological trench.

The inter-station distance was of about 20 meters. Two of the measuring points were located North of the dislocation found in the trench, on the hypothetical footwall (TRC1 – TRC2), while the two remaining on the hangingwall.

The HVNSR results are shown in Figure 2 were the rotate H/V ratio (Spudich et al., 1996) is presented. For all the analyzed stations spectral ratios detect a clear resonance peak with amplitude ranging from 3 to 5. Despite to the short station distance the resonance frequency present a quick and regular variation from North to South with f_0 values shifting from 7.0 to 4.1 Hz. The shape of resonance peak is quite sharp at the two sites located close to the edges of the trench (TRC1 and TRC4), while for the other two sites (TRC2 and TRC3) the peaks are broader with lower amplitude.

An important difference can be found also in terms of signals polarization with the polarization angle moving from about 0-20° for TRC1 and TRC2 to 45-50° for TRC3 and TRC4. In conclusion we can sustain that for this case study HVNSR results clearly show significative variations passing across the discontinuity revealed by the trench.

The step forward was, then, to verify if this approach could be applied in different areas with similar geological characteristics.

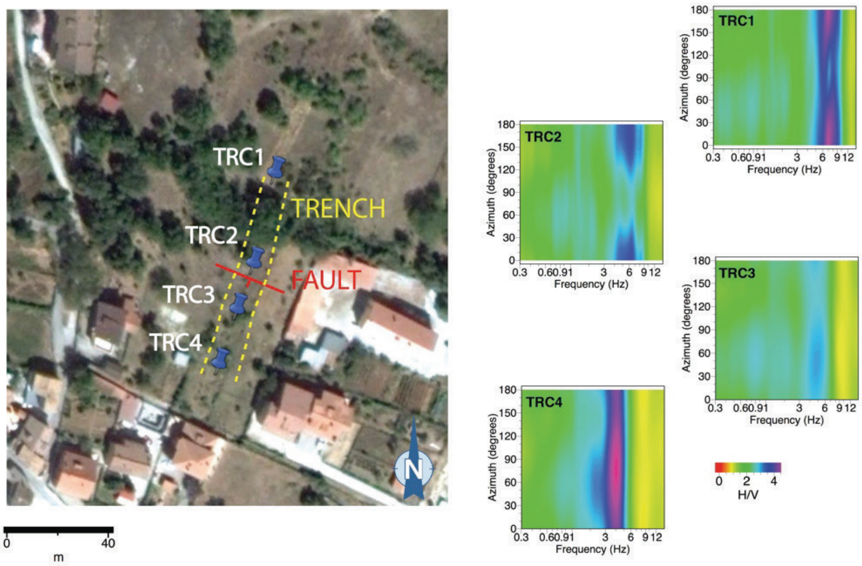

Figure 2: S1 Pizzoli test site.

The second test site is located in the Trasacco municipality, in the NW-SE trending Vallelonga valley that merges into the southern edge of Fucino Basin. It is characterized by fluvio-glacial deposits (gravels) that progressively thickens moving away from the foot of a rocky slope. Previous works (Galadini and Messina, 1999) defined this area as a tectonic valley due to the presence of the Vallelonga fault system that seem to have played an important role in the depositional history of the southern portion of the Fucino basin.

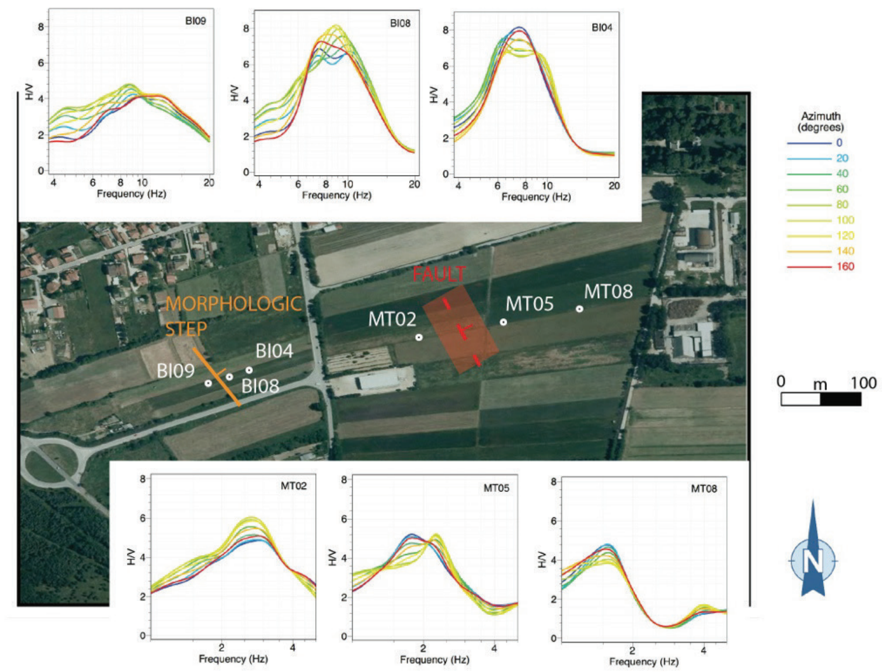

Figure 3: S2 Trasacco test site.

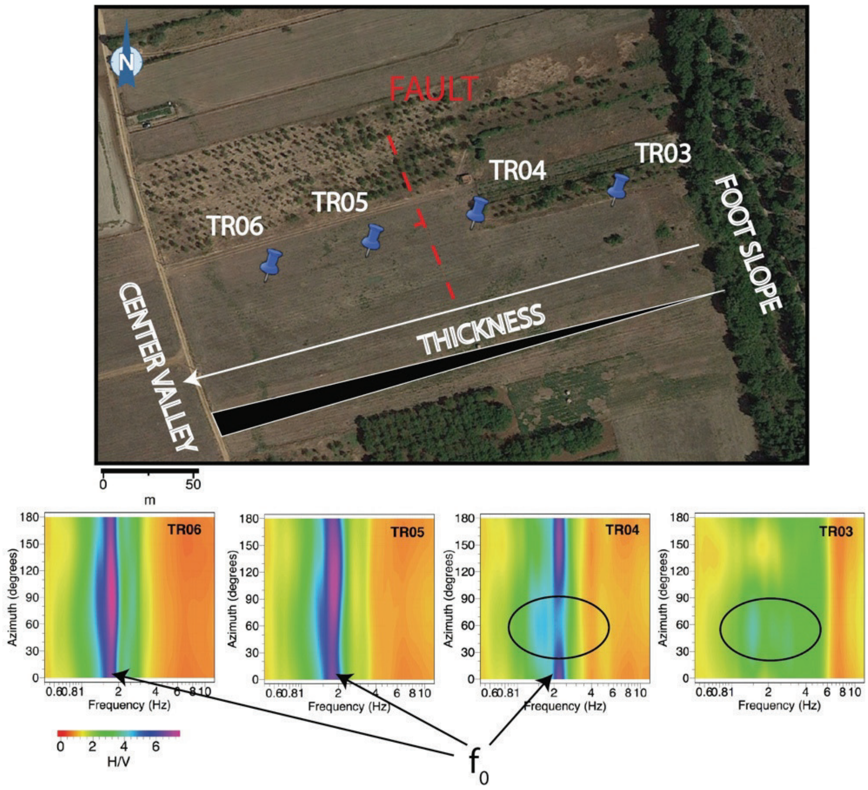

Figure 4: S3 Incile test site.

Single-station ambient noise measurements have been performed along a N75 trending transect, perpendicular to the elongation of the valley.

The inter-station distance in this case is of about 50-60 meters. Along this transect, spectral ratios results, shown in Figure 3, highlight the presence of a clear shift of resonance peak related to the quick variation of gravels thickness. In this case it is possible to notice a 60 degrees polarized energy at about 1.5Hz at stations close to the slope (TR03 - TR04) where HVNSR reaches amplitude values of 4-4.5.

Moving towards the center of the valley (TR05 and TR06), it disappears because is merged with the fundamental resonance peak. This complexity in HVNSR results can be ascribed to some 2D effect.

The third case study is located in the Incile hamlet, in the South-western margin of Avezzano municipality. The selection of this site has been addressed by the presence of the Luco dei Marsi fault together with the availability of a huge amount of previous multidisciplinary studies and investigations (Oddone 1915, Galadini et al., 1997, Giraudi 1988, Cavinato et al., 2002, Boncio et al., 2014). Besides the general knowledge of the geological and tectonic setting, previous investigations available for the area have to be considered in order to plan the geophysical survey. In fact, the interpretation of commercial seismic lines, evidences of superficial effects after the M 7.0 1915 Fucino earthquake and results of a paleoseismological trench has been useful to better locate the fault trace. Luco dei Marsi fault is a tectonic element buried by Quaternary deposits of Fucino basin, with NNW-SSE trend that borders the foot of Monte Salviano, dipping towards the central part of the basin. In this site we have deployed a transect of seismic stations, with minimum inter-station distance of 30 meters and a total length of 700 meters, perpendicularly to the hypothetical fault trace on a gently dipping sandy gravels slope. Once performed the noise spectral ratios analysis, some parts of the seismic station alignment showed-up features similar to S1 and S2 sites. In this case, to better show the polarization effect and the shift in frequency, we have plotted together spectral ratios curves calculated from 0 to 180 degrees with a step of 20 degrees.

For both the "BI" and "MT" measurements (Figure 4), spectral ratios curves show for some stations a shift in frequency of the resonance peak as result of rotational analysis. By looking into further detail, for BI stations an electrical resistance tomography has been performed in order to detect and localize any possible lateral resistivity contrast. Results of this geophysical survey highlighted the presence of a high resistivity contrast related to a morphological step on shallow sediments generated by erosional process related to the fluctuations of the level of the Fucino lake (Giraudi et al., 1988, Boncio et al., 2014). Spectral ratios curves obtained show, for BI stations close to this geomorphologic element, a split of the frequency peak moving from a parallel to a perpendicular direction respect to its azimuth. Furthermore, we have observed that for parallel directions, the frequency values of the peak are compatible with the monodimensional response of the site (BI09 with lower and BI08 with higher thickness of the gravelly layer), while, moving to the perpendicular polarizations, the peak represents more a 2D effect due to the sudden variation of the shallow layer. BI09 station in fact, for perpendicular azimuths, shows a lowering of the frequency peak (from 11 to 8.5 Hz), while BI08, located on the other side of the step, highlights the opposite behavior. BI04 station (located few tens of meters away from BI08) confirms the general deepening trend of the area: the spectral ratios curve shows a double peak of resonance for perpendicular azimuths, reflecting the influence of the very rapid lateral thickness variation of the superficial layer. MT measurements have been deployed in order to better reconstruct the trend of subsoil geometries towards the center of the basin detecting a quick lateral variation connected to the presence of the Luco dei Marsi fault. For this part of the seismic station transect, thicker sandy silts characterize the superficial layer; therefore, the analyzed frequency range is lower. MT02 and MT08 show a sharp single resonance peak on the HVNSR curves (2.7 Hz for MT02 and 1.6 Hz for MT08) for almost all the azimuth considered in the rotational analysis, with a small variation only in amplitude values (from 5 to 6 for MT02 and from 3.5 to 5 for MT08). MT05 conversely, highlights a double frequency peak: the low frequency one (1.7 Hz) is obtained for NNW-SSE azimuths, while the other one (2.3 Hz) becomes clear for perpendicular directions. In conclusion, between MT02 and MT05 stations a lateral variation of the seismic response is clearly visible. In the light of the observations aforementioned, we can infer the presence of a hidden geologic feature is present close to them, which interrupts the normal progressive deepening of the basin eastward due to the gentle dipping of Monte Salviano buried slopes.

Electrical resistance tomography investigations are going to be deployed for this portion of the basin in order to better define the geometry of shallow deposits. To definitely assess the presence of Luco dei Marsi fault, further direct investigations (e.g. paleoseismological trench) are needed.

CONCLUSIONS

The use of HVNSR analysis become quite common in microzonation studies since it is quick, easy to perform and cost effective. The technique is very robust in simple 1D cases and for sites characterized by important impedance contrasts in the shallow sedimentary layers. In 2D geometrical situations H/V spectral ratios exhibit more complex features with broader amplification peaks. Some of these complexities can be explained, as suggested by other author (Matsushima et al., 2014), taking into account the signal polarization characteristics. The results shown in this paper confirm this hypothesis even if, in our opinion, some other case studies must be analyzed and some numerical models must be performed to fully support the proposed thesis.

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