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The use of HVSR measurements for investigating buried tectonic structures: the Mirandola Anticline, northern Italy, as a case study

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The Mirandola Anticline represents a buried fault-propagation fold that started forming during Quaternary due to the seismogenic activity of a blind segment of the broader Ferrara Arc (Italy). Its last reactivation was during May 2012 Emilia sequence. In correspondence with this structure the thickness of the marine and continental deposits of the Po Plain foredeep is particularly reduced. In order to better define the shallow geometry of this tectonic structure, and hence its recent activity, we investigated a depth range intermediate between the surficial morphological observations and seismic profiles information. Numerous passive seismic measurements for obtaining the horizontal-to-vertical spectral ratio (HVSR) were performed focusing on the amplitude of the peak value, A, and the corresponding frequency, f0. Based on these parameters we created two colour-shaded maps documenting the presence of an area characterized by very important resonance phenomena, marked gradients north and south and progressively fading ESE-wards. Position of the highest values and general trends in the two maps are due to laterally changing impedance contrast occurring in the Pliocene-Quaternary stratigraphic succession developed on top of the Mirandola Anticline. Accordingly, maps of natural frequency are of utmost importance allowing to recognize areas characterized by a high impedance contrast where a greater amplification in ground motion is expected to occur in case of seismic shaking. Indeed, if the amplified frequency at a site is close to that of a standing or planned building, a resonance effect may occur and therefore the risk for the building to suffer structural damage greatly increases. Based on a simplified inversion approach starting from boreholes (stratigraphy) and crosshole (Vs) data we succeeded to reproduce measured HVSR curves and particularly the major and meaningful peaks down to the interface separating the continental Middle Quaternary from the marine Early Quaternary-Late Pliocene deposits. The results of A and f0 nicely fit also the available geological information derived from seismic reflection profiles carried out for hydrocarbon purposes. This study also shows how the systematic application of the HVSR method generating a relatively dense grid of measurements over a wide area and strictly following as a standard the well tested SESAME criteria, could allow to laterally correlate specific amplification peaks and hence to interpolate with confidence the same impedance contrast surface. The application of the above procedure to the Mirandola case study also allowed to emphasize the persisting and recent growth of a major fault-propagation anticline, where both the causative thrust and the associated fold are completely buried by the Middle-Upper Pleistocene to Holocene continental deposits. At this regard, the obtained results clearly and independently document the presence of a folded surface in the shallow Mirandola subsoil; the crest is oriented ESE-WNW with a culmination towards the west and a periclinal setting eastwards in perfect agreement with the deeper tectonic structure reconstructed on the basis of seismic reflection profiles. The results of this methodological approach are quite encouraging and could be easily applied to other morphologically flat regions affected by blind faulting and folding.