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A 3-D velocity model for earthquake location from combined geological and geophysical data: a case study from the TABOO near fault observatory (Northern Apennines, Italy)

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Accurate hypocenter location at the crustal scale strongly depends on our knowledge of the 3D velocity structure. The integration of geological and geophysical data, when available, should contribute to a reliable seismic velocity model in order to guarantee high quality earthquake locations as well as their consistency with the geological structure.

Here we present a 3D, P- and S-wave velocity model of the Upper Tiber valley region (Northern Apennines) retrieved by combining an extremely robust dataset of surface and sub-surface geological data (seismic reflection profiles and boreholes), in situ and laboratory velocity measurements, and earthquake data.

The study area is a portion of the Apennine belt undergoing active extension where a set of high-angle normal faults is detached on the Altotiberina low-angle normal fault (ATF). From 2010, this area hosts a scientific infrastructure (the Alto Tiberina Near Fault Observatory, TABOO; http://taboo.rm.ingv.it/), consisting of a dense array of multi-sensor stations, devoted to studying the earthquakes preparatory phase and the deformation processes along the ATF fault system.

The proposed 3D velocity model is a layered model in which irregular shaped surfaces limit the boundaries between main lithological units. The model has been constructed by interpolating depth converted seismic horizons interpreted along 40 seismic reflection profiles (down to 4s two way travel times) that have been calibrated with 6 deep boreholes (down to 5 km depth) and constrained by detailed geological maps and structural surveys data. The layers of the model are characterized by similar rock types and seismic velocity properties. The P- and S-waves velocities for each layer have been derived from velocity measurements coming from both boreholes (sonic logs) and laboratory, where measurements have been performed on analogue natural samples increasing confining pressure in order to simulate crustal conditions.

In order to test the 3D velocity model, we located a selected dataset of the 2010-2013 TABOO catalogue, which is composed of about 30,000 micro-earthquakes (see Valoroso et al., same session). Earthquake location was performed by applying the global-search earthquake location method NonLinLoc, which is able to manage strong velocity contrasts as that observed in the study area. The model volume is 65km x 55km x 20km and is parameterized by constant velocity, cubic cells of side 100 m. For comparison, we applied the same inversion code by using the best 1D model of the area obtained with earthquake data. The results show a significant quality improvement with the 3D model both in terms of location parameters and correlation between seismicity distribution and known geological structures.