Shallow structural setting of an active normal fault zone in the 30 October 2016 Mw 6.5 central Italy earthquake imaged through a multidisciplinary geophysical approach.

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We investigate the shallow structure of an active normal fault-zone that ruptured the surface during the 30 October 2016 Mw 6.5 Norcia earthquake (central Italy) using a multidisciplinary geophysical approach. The survey site is located in the Castelluccio basin, an intramontane Quaternary depression in the hangingwall of the SW-dipping Vettore-Bove fault system. The Norcia earthquake caused widespread surface faulting affecting also the Castelluccio basin, where the rupture trace follows the 2 km-long Valle delle Fonti fault (VF), displaying a ~3 m-high fault scarp due to cumulative surface slip of Holocene paleo-earthquakes. We explored the subsurface of the VF fault along a 2-D transect orthogonal to the coseismic rupture on recent alluvial fan deposits, combining very high-resolution seismic refraction tomography, multichannel analysis of surface waves (MASW), reflection seismology and electrical resistivity tomography (ERT).

We acquired the ERT profile using an array of 64 steel electrodes, 2 m-spaced. Apparent resistivity data were then modeled via a linearized inversion algorithm with smoothness constraints to recover the subsurface resistivity distribution. The seismic data were recorded by a 190 m-long single array centered on the surface rupture, using 96 vertical geophones 2 m-spaced and a 5 kg hammer source.

Input data for refraction tomography are ~9000 handpicked first arrival travel-times, inverted through a fully non-linear multi-scale algorithm based on a finite-difference Eikonal solver. The data for MASW were extracted from common receiver configurations with 24 geophones; the dispersion curves were inverted to generate several S-wave 1-D profiles, subsequently interpolated to generate a pseudo-2D Vs section. For reflection data, after a pre-processing flow, the picking of the maximum of semblance on CMP super-gathers was used to define a velocity model (VNMO) for CMP ensemble stack; the final stack velocity macro-model (VNMO) from the CMP processing was smoothed and used for post-stack depth conversion. We further processed Vp, Vs and resistivity models through the K-means algorithm, which performs a cluster analysis for the bivariate data set to individuate relationships between the two sets of variables. The result is an integrated model with a finite number of homogeneous clusters.
In the depth converted reflection section, the subsurface of the VF fault displays abrupt reflection truncations in the 5-60 m depth range suggesting a cumulative fault throw of ~30 m. Furthermore, another normal fault appears in the footwall. The reflection image points out alternating high-amplitude reflections that we interpret as a stack of alluvial sandy-gravels layers that thickens in the hangingwall of the VF fault. Resistivity, Vp and Vs models provide hints on the physical properties of the active fault zone, appearing as a moderately conductive (< 150 $\Omega$m) elongated body with relatively high-Vp (~1500 m/s) and low-Vs (< 500 m/s). The Vp/Vs ratio > 3 and the Poisson's coefficient > 0.4 in the fault zone suggest this is a granular nearly-saturated medium, probably related to the increase of permeability due to fracturing and shearing. The results from the K-means cluster analysis also identify a homogeneous cluster in correspondence of the saturated fault zone.