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Shallow architecture of the 2009 Mw 6.1 L'Aquila earthquake fault (Central Italy): Insights from high-resolution multiscale refraction tomography and reflection profiles

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Central Apennines (Italy) is affected by repeated large normal-faulting crustal earthquakes. The 6th April 2009 Mw 6.1 event damaged L'Aquila town and surroundings, causing 308 deaths. Seismological, geodetic and geological analyses have defined the geometry and kinematics of the source of the 2009 mainshock (Paganica Fault) and of the structures activated during the seismic sequence. They form a $\sim$ 40 km long NW-trending and SW-dipping normal fault system featuring two main right-stepping strands. The hangingwall of the Paganica Fault hosts a deep Quaternary basin (Middle Aterno basin). However, the basin geometry and internal structure, as well as the internal architecture and the fault-system, are poorly unknown. This hinders the reconstruction of the long-term evolution of the fault-system and related basin.

With the aim of illuminating the shallow crust, in 2010 we collected 5 dense wide-aperture seismic profiles that run NE-SW across the Middle Aterno basin and the Paganica Fault, for a total survey length of 8 km. Multi-scale refraction tomography and reflection data were merged to investigate extremely complex fault structures. A 216-channel geophone array (5 m spacing) was used to record a narrow spaced (5-10 m) vibratory source progression. The spread is 1075 m long, 3-4 times larger than the presumed depth of the basin substratum. For each line we provide Vp models and stack migrated sections. The overall profiles allowed to depict a reliable cross-section of the Middle Aterno basin and of the normal fault-system, including the source of the 2009 mainshock.

Multi-scale tomography details the Vp structure down to $\sim$ 350 m depth, identifying low Vp (1500-2000 m/s) lacustrine sediments (up to 200 m thick) and coarse fluvial and alluvial fan deposits (Vp $\sim$ 3000 m/s) sited above high-Vp regions (Vp > 3500-4000 m/s) corresponding to an articulated Meso-Cenozoic substratum. The main basin depocenter, $\sim$ 350 m deep, is in the SW sector of the basin. It matches the area of maximum coseismic subsidence observed after the 2009 earthquake, suggesting that the 2009 deformation pattern is coherent with the Quaternary evolution of the L'Aquila fault-system. Strong lateral Vp changes unravel large steps in the substratum and in the continental infill, which can be related to the Paganica Fault and to two unreported synthetic buried faults with $\sim$ 250 m associated cumulative vertical throw.

Reflectivity images have a greater penetration (up to $\sim$ 1 km) and provide insight on Tertiary contractional structures affecting the Meso-Cenozoic substratum. Stack migrated sections provide information about the stratigraphic architecture of the continental infill, depicting the main unconformities separating old lacustrine bodies from younger fluvial sediments, and pin-point the normal-fault system. Besides, reflection data allow to obtain refined estimates of the cumulative deformation along the faults.