Geophysical Research Abstracts
Vol. 20, EGU2018-14984, 2018
EGU General Assembly 2018

Anatomy of an active seismic source: kinematic complexity and structural inheritance constrained by field observations and present-day seismic activity (Central Apennines, Italy)

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The mechanics and seismogenic behaviour of fault zones are strongly influenced by their internal structure, in terms of both fault geometry and fault rock constitutive properties. In recent years, high-resolution seismological techniques yielded new constraints on the geometry and velocity structure of seismogenic faults down to 10s meters length scales. This reduced the gap between geophysical imaging of active seismic sources and field observations of exhumed fault zones. Nevertheless, fundamental questions such as the origin of geometrical and kinematic complexities (e.g., variable slip vector directions, highly heterogeneous slip distributions) associated to seismic faulting remain open.

We addressed these topics by characterizing the internal structure of the Vado di Corno Fault Zone, an active seismogenic normal fault cutting carbonates in the Central Apennines of Italy and comparing it with the present-day seismicity of the area. The fault footwall block, which was exhumed from < 2 km depth, was mapped with high detail (< 1 m spatial resolution) for $\sim$ 2 km of exposure along strike, combining field structural data and photogrammetric surveys in a three dimensional structural model. Three main structural units separated by principal fault strands, were recognized: (i) cataclastic unit (20-100 m thick), (ii) damage zone ($\leq$ 300 m thick), (iii) breccia unit ($\geq$ 20 m thick). The cataclastic unit lines the master fault and represents the core of the normal fault zone. In-situ shattering together with evidence of extreme (possibly coseismic) shear strain localization (e.g., mirror-like faults with truncated clasts, ultrafine-grained sheared veins) was recognized. The breccia unit is an inherited low-angle thrust zone affected by pervasive veining and secondary dolomitization. It strikes subparallel to the active normal fault and is characterized by a non-cylindrical geometry with 10-100 m long frontal and lateral ramps. The cataclastic unit cuts through thrust flats within the breccia unit, whereas normal to oblique inversion occur on frontal and lateral ramps. The topology of the extensional fault/fracture network was quantified in section parallel to the strike and perpendicular to the dip of the fault zone. Both fracture branch intensity and connectivity were measured and related to the kinematic complexity (i.e. slip vector dispersion) and fault rock spatial distribution, to investigate the origin of fault linkage and segmentation within the fault zone.

A comparable structural setting was imaged South-West of the study area, during the 2009 L'Aquila seismic sequence. Here at $\sim$ 2 km depth in equivalent carbonate lithologies, the master normal fault cross-cuts a 10 km long flat structure and clear lateral ramps are "illuminated" by hypocentral distributions, suggesting the superposition of normal seismic faulting on inherited compressional structures. This suggest that the exhumed Vado di Corno Fault Zone is a good analogue for the shallow structure of active seismic sources in the region, thus providing (i) unique information on deformation processes active at depth and (ii) a representative structural framework to be tested in various fault reactivation models.