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Structural characterization of fault damage zones in carbonates (Central Apennines, Italy)

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The Italian Central Apennines are one of the most seismically active areas in the Mediterranean (e.g., L'Aquila 2009, Mw 6.3 earthquake). The mainshocks and the aftershocks of these earthquake sequences propagate and often nucleate in fault zones cutting km-thick limestones and dolostones formations. An impressive feature of these faults is the presence, at their footwall, of few meters to hundreds of meters thick damage zones. However, the mechanism of formation of these damage zones and their role during (1) individual seismic ruptures (e.g., rupture arrest), (2) seismic sequences (e.g., aftershock evolution) and (3) seismic cycle (e.g., long term fault zone healing) are unknown. This limitation is also due to the lack of knowledge regarding the distribution, along strike and with depth, of damage with wall rock lithology, geometrical characteristics (fault length, inherited structures, etc.) and kinematic properties (cumulative displacement, strain rate, etc.) of the associated main faults.

Previous high-resolution field structural surveys were performed on the Vado di Corno Fault Zone, a segment of the ca. 20 km long Campo Imperatore normal fault system, which accommodated ~ 1500 m of vertical displacement (Fondriest et al., 2020). The damage zone was up to 400 m thick and dominated by intensely fractured (1-2 cm spaced joints) dolomitized limestones with the thickest volumes at fault oversteps and where the fault cuts through an older thrust zone. Here we describe two minor faults located in the same area (Central Apennines), but with shorter length along strike. They both strike NNW-SSE and accommodated a vertical displacement of ~300 m.

The Subequana Valley Fault is about 9 km long and consists of multiple segments disposed in an en-echelon array. The fault juxtaposes pelagic limestones at the footwall and quaternary deposits at the hanging wall. The damage zone is < 25 m thick and comprises fractured (1-2 cm spaced joints) limestones beds with decreasing fracture intensity moving away from the master fault. However, the damage zone thickness increases up to □100 m in proximity of subsidiary faults striking NNE-SSW. The latter could be reactivated inherited structures.

The Monte Capo di Serre Fault is about 8 km long and characterized by a sharp ultra-polished master fault surface which cuts locally dolomitized Jurassic platform limestones. The damage zone is up to 120 m thick and cut by 10-20 cm spaced joints, but it reaches an higher fracture intensity where is cut by subsidiary, possibly inherited, faults striking NNE-SSW.

Based on these preliminary observations, faults with similar displacement show comparable damage zone thicknesses. The most relevant damage zone thickness variations are related to geometrical complexities rather than changes in lithology (platform vs pelagic carbonates). In particular, the largest values of damage zone thickness and fracture intensity occur at fault overstep or are associated to inherited structures. The latter, by acting as strong or weak barriers (sensu Das and Aki, 1977) during the propagation of seismic ruptures, have a key role in the formation of damage zones and the growth of normal faults.