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Outcrop-scale geometry and kinematics of a carbonate-hosted normal fault: The Tre Monti fault in Central Italy

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A multiscale geometrical and kinematic characterization of fault zones is the starting point to understand fault mechanics, in particular that of potentially seismogenic faults. Fieldwork and seismological studies can provide pictures and kinematic characterization of faults at sub-regional scale (i.e. tens of kilometers). Until the advent of Digital Outcrop Models (DOMs), fieldwork was the sole source of information about the outcrop-scale (i.e. hundreds of metres) internal structure.

Here, adopting the above-mentioned methodologies, we discuss the outcrop-scale geometrical and kinematic features of a seismogenic carbonate-hosted normal fault: the Tre Monti fault in Central Italy. In this area, NE-SW oriented extension is accommodated mainly by NW-SE faults, however rare ENE-WSW oriented faults, such as the Tre Monti fault, are also present. This fault crops out for $\sim$7 km with a series of SSE dipping right stepping fault scarps. It accommodates $\sim$1 km throw through a series of sub-parallel fault strands, and mostly shows dip-slip slickenlines. The outcrop-scale structure is well-exposed within an abandoned quarry and it is located between two right stepping fault segments.

The integration of classical fieldwork with manual interpretation of a laser-scanner derived DOM allowed us to build a very detailed map and a cross-section displaying minor fault distribution in the fault damage zone. In addition, we calculated the normalised slip tendency and the slickenlines compatibility of the minor faults under three stress fields: (1) a NE-SW extension (regional stress field), (2) a sub-regional NW-SE extension obtained from the kinematic inversion of the slickenlines collected on the Tre Monti fault (fault stress field), and (3) a right lateral transtension/transcurrent deformation defined by the slickenlines collected on the main fault in the quarry (local stress field).

Minor faults are heterogeneously distributed within the damage zone and are arranged in two main sets, (1) sub-parallel and (2) orthogonal to the main fault. The first set has the highest slip tendency values for the fault stress field, i.e. the geometry of the fault planes is optimally oriented within this stress field, but the slickenlines are more compatible with the local and regional stress fields. The geometry and kinematics of the second set are well-explained within the local stress field.

The overall structure of the Tre Monti fault zone at the outcrop-scale mimics the fault structure at the sub-regional scale and resembles the architecture of seismogenic normal faults obtained from high-precision relocated aftershocks occurred during seismic sequences. We propose that the complexity in minor fault orientation and kinematics is caused by the interaction between the two right stepping fault segments that border the outcrop.