EGU26-10254, updated on 07 Nov 2026
https://doi.org/10.5194/egusphere-egu26-10254
EGU General Assembly 2026
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Formation of Fault Damage Zones in Carbonates and Their Role in the Seismic Cycle

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Probably the most impressive geological feature of active fault zones hosted in carbonate rocks is the presence of several hundreds of meters thick damage zones, often composed of *in-situ* shattered rocks (ISRs, i.e. rocks fragmented into clasts < 1 cm in size). Despite their abundance, it remains unknown how ISRs form (during the propagation of seismic ruptures?), and how their presence affects (1) the propagation of individual mainshock seismic ruptures, (2) the near field wave radiation and associated strong ground motions, and (3) the evolution in space and time of aftershock seismic sequences. In this contribution, we will present preliminary results of a three-year Ph.D. project aimed at addressing these issues through an integrated field geology and numerical modelling approach.

We exploit existing and newly acquired field geology data on fault damage zone distributions in the Central Apennines (Italy), and perform dynamic rupture earthquake sequence simulations with SeisSol (https://seissol.org). The fully-dynamic individual earthquake simulations with SeisSol rely on the discontinuous Galerkin method, which allows treating complex 3D geological structures, nonlinear rheologies (including off-fault plastic yielding) and high-order accurate propagation of seismic waves (Käser et al., 2010). The earthquake modelling simulations integrate laboratory-derived frictional constitutive laws with simplified and realistic representations of fault zone geometry and surface topography. Currently, our study is focused on the 25 km long Campo Imperatore fault system in the Gran Sasso Massif area (Italian Central Apennines) where the damage zones are pronounced and well mapped (Demurtas et al., 2016; Fondriest et al., 2020).

We aim at using the dynamic rupture earthquake modelling simulations to discuss the formation and distribution of ISRs with respect to (1) the maximum magnitude (Mw 7.0) of the earthquake associated with the studied fault, (2) fault geometry (length, presence of step overs, fault bends, etc.), (3) topographic effects (valleys, etc.), and (4) lithology (limestones, dolostones, etc.) of the wall rocks. This approach is expected to identify the physical, geological, and loading conditions controlling seismic rupture propagation and the development of fault damage zones. The physically based, fully dynamic 3D simulations will also provide estimates of earthquake source parameters (e.g., fracture energy and seismic moment release rate) and synthetic seismograms (strong ground motions), which will be compared with seismological and strong-motion data from

earthquakes in the Central Apennines.

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