Formation mechanisms and scaling relationships of shattered fault damage zones in carbonates

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The Italian Central Apennines are one of the most seismically active areas in the Mediterranean (e.g., L'Aquila-Pizzoli Mw 6.7, 1703; Avezzano Mw 7.1, 1915; L'Aquila Mw 6.1, 2009) (Chiarabba et al., 2009). Most of this continuous seismic activity is produced by seismic ruptures propagating along normal faults hosted in carbonate rocks (dolostones and limestones) (Chiaraluce, 2012; Valoroso et al., 2013). Some of these active fault zones are well-exposed in the mountain belt (badland-type exposures, **Fig. 1**) and probably their most impressive structural feature is the presence of up to hundreds of meter thick *in-situ* shattered rocks (fault zone rocks made of fragments < 1 cm in size with little or no shear and often preserving their original sedimentary features such as bedding, stromatolites etc.: Fondriest et al., 2015, 2017, **Fig. 2**) within the footwall block (Demurtas et al., 2016). These thick shattered fault damage zones typically border meter to decameter thick cataclastic to ultracataclastic fault cores. Both the damage zone and the fault cores are cut by cm- to mm thick principal slipping zones frequently associated to mirror-like (i.e., highly polished) slip surfaces.

Figure 1. *Hundreds of meter thick shattered fault damage zone hosted in dolostones and exposed with badland-type morphology in the Italian Central Apennines (Pizzoli - Monte Marine Fault Zone).*

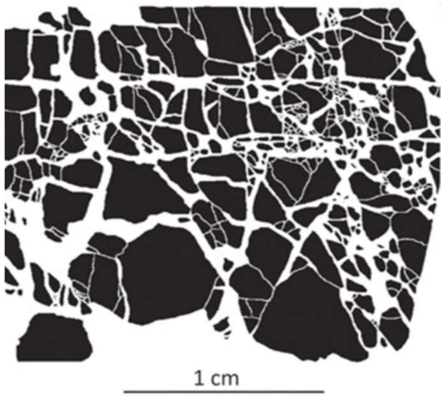

Figure 2. *Typical look-out of in-situ shattered fault zone rocks hosted hosted in dolostone (image analysis of polished sample, Fondriest et al., 2017).*

However, despite their common occurrence and impressive morphological expression, shattered fault damage zones in carbonates have been so far overlooked and several open questions regarding the origin of these peculiar fault products (i.e. *in-situ* shattered fault rocks) are still unanswered: How are they distributed along fault strike? - What are the geological, petrophysical (rock type, elastic properties, fracture toughness etc.) and geometrical (presence of step overs, fault bends, bedding etc.) factors controlling their formation? - At which depth are they produced? - How are they produced? - To which phase of the seismic cycle are they associated, perhaps to the propagation of seismic ruptures? - How their presence affects the evolution of individual seismic sequences (foreshocks, mainshock and aftershocks) and, more in general, the entire seismic cycle (fault healing, sealing and the interseismic phase)? - And, if their formation is associated to the propagation of seismic ruptures, how do they affect the energy budget of individual moderate to large in magnitude earthquakes?   Addressing these questions is clearly of relevant interest for earthquake mechanics and seismic hazard studies.

In this Ph.D. project we aim at investigating the distribution and geometry of shattered fault damage zones hosted in carbonates in the Central Italian Apennines to constrain their formation mechanism. The Ph.D. will quantify the thickness and distribution of these damage zones by means of remote sensing investigations (including images collected with drones) and detailed field geology structural surveys. The distribution of the *in-situ* shattered fault rocks will be discussed with respect to relevant structural, geological and seismological parameters including (i) the maximum magnitude of the earthquake associated to the studied fault zones, (ii) fault strain rate, (iii) fault length, displacement and geometry, (iv) lithology of the wall rocks etc.. This will allow the student to determine, if any, scaling relationships that might constrain the possible mechanism of formation of the *in-situ* shattered fault rocks.

The detailed field-based study will be supported by microstructural and dedicated experimental studies to be conducted also at INGV-Rome to individuate the deformation mechanisms associated to the formation of the *in-situ* shattered fault rocks. The analysis will include microstructural (Optical and Field-Emission Electron Scanning Microscopy, Electron Back-Scatter Diffraction, micro-CT, image analysis), mineralogical (X-ray Powder Diffraction, Micro-Raman Spectroscopy) and geochemical (micro-Cathodoluminescence, X-ray Fluorescence Spectroscopy, Electron Micro-Probe Analyzer, clumped isotopes) and rock mechanics experiments to be performed with the rotary machine SHIVA (Di Toro et al., 2010), permeameters, etc. to determine the evolution of petrophysical properties (permeability, Vp/Vs, seismic attenuation, etc.) of damage zones in experimental faults with progressive slip.

The above activities will require the PhD student, advised by the supervisors, to develop a collaborative network during the project, as the activities will be mostly performed at INGV-Rome and Padua University. Thanks to this approach, we anticipate the following results:

1) formation of a researcher with ability to exploit and integrate field, experimental and microanalytical methods (also for industrial applications) with strong background on earthquake geology;

2) submission to international peer-reviewed journals of three manuscripts on the topics discussed above.

References

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