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Experimental constraints on the origin of in-situ shattered dolostones

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Many seismically active regions on Earth include thick sequences (up to 4-10 km) of sedimentary carbonate-bearing rocks (mainly limestones and dolostones) in the brittle upper crust. This implies that most moderate to large in size earthquakes (e.g. L'Aquila 2009 Mw = 6.1 in central Italy) and their aftershocks, nucleate within and propagate through carbonate rocks.

In the last years several field and experimental studies focused on the characterization of carbonate-bearing fault zone rocks to determine earthquake-related deformation processes. In particular, the occurrence of thick belts (10-100s m) of low-strain fault-related breccias (average size of rock fragments >1 cm), which is relatively common within carbonate-bearing damage zones, was generally interpreted as resulting from quasi-static growth of the fault zones (e.g. Billi et al., 2003; Salvini et al., 1999) rather than from the cumulative effect of multiple earthquake ruptures.

Here we report the occurrence of up to hundreds of meters thick belts of intensely fragmented dolostones along the major transpressive Foiana Fault Zone (FFZ, Italian Southern Alps) which was exhumed from 1.5-2 km depth. Such dolostones are reduced into fragments ranging from few centimeters down to few millimeters in size and are reduced to ultrafine-grained layers in proximity to the principal slipping zones. Preservation of the original bedding indicates a lack of significant shear strain in the fragmented dolostones which seem to have been shattered in situ.

To understand the origin of the in-situ shattered rocks, dolostones of the Mendola Formation (i.e. host rock of the FFZ) were deformed in uniaxial compression both under low-strain rate (∼10-3 s-1) quasi-static loading and high-strain rate (>50 s-1) dynamic loading. Dolostones deformed up to failure under low-strain rate loading were affected by single to multiple discrete (i.e. not interconnected) extensional fractures sub-parallel to the loading direction. Dolostones deformed under high-strain rate loading were shattered over a strain rate threshold of ∼200 s-1 (strain >1.2%) while they were split in few fragments or were macroscopically intact for lower strain rates. Experimentally shattered dolostones were reduced into a non-cohesive material with rock fragments mostly of few millimeters in size elongated parallel to the loading direction. Diffuse microfracturing exploiting grain boundaries and cleavage planes occurred along the main fractures. Three-dimensional fracture network analysis based on X-ray microtomographic data showed that the damage patterns produced at low- and high-strain rate were different, the latter being similar to that of natural in-situ shattered dolostones. Moreover,since shattered dolostones were produced only under high strain rate dynamic loading, the in-situ shattered dolostones of the FFZ are interpreted to be formed due to the cumulative effect of dynamic stress wave loading during the propagation of multiple earthquake ruptures.