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Multi-scale characterization of the seismogenic Gole Larghe Fault Zone (Southern Alps, Italy): methodology and results

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The Gole Larghe Fault Zone (GLFZ) in the Italian Southern Alps is characterized by the occurrence of cataclasites and pseudotachylytes (solidified frictional melts) formed along pre-existing magmatic cooling joints over a fault zone width of ca. 500 m, under ambient conditions of 9-11 km depth and 250-300°C (the “base” of the seismogenic zone in the crust). The fault zone is seamlessly exposed in glacier-polished outcrops both parallel and perpendicular to fault strike. We have studied in a very detailed way these outcrops, which are considered as a world-class natural laboratory for seismic faulting, combining two complementary strategies: (1) areal imaging/mapping and (2) linear transects. A considerable attention has been paid in order to make the results of these different strategies always coherent and consistent, thanks to a 3D spatial database where the entire dataset is stored.

Areal imaging and mapping of structures like individual fault traces was performed over almost five orders of magnitude (from km to mm scale) using high-resolution orthophotos, aerial and terrestrial laser-scanning, photogrammetry and 3D mosaics of high-resolution rectified digital photographs. LIDAR scans and imagery were georeferenced in 3D using a Differential Global Positioning System (DGPS), allowing centimetric precision. The analysis of these data has been performed in 3D with Gocad® and custom Matlab® toolboxes.

DGPS has been also used to collect linear transects across the fault zone, along which conventional structural measurements have been carried out. The particularity of these transects is that they allow an unprecedented > 100% coverage of the fault zone. In other words, each individual structure (visible with naked eyes), occurring along a continuous transect across the fault zone, has been measured, geolocated, and recorded in the database. In addition, 44 samples collected along the linear transect have been characterized for petrophysical parameters and much more samples have been collected in the area for microstructural and geochemical analysis.

Results of our project include the characterization of the self-affine fault surface roughness over five orders of magnitude. Thanks to the chosen approach, roughness evolution can be related to accumulated net slip, and this allowed us to develop a new forward model of wear and roughness evolution. This model has important implications for the modelling of realistic seismic sources.

Moreover, the architecture of the GLFZ have been quantitatively characterized, and hypotheses on its evolution have been tested with complementary datasets. This allowed to develop an evolutionary model where the fault zone architecture and permeability structure progressively change with accumulating net slip, and possibly also the seismic/aseismic character of the fault is subject to a progressive maturation.