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Roughness, off-fault damage and frictional melt distribution in an exhumed seismogenic fault: quantitative high resolution data from a Digital Outcrop Model study

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The topography of fault surfaces causes significant variations in the near fault stress field, thus controlling fault plane processes such as nucleation, propagation and arrest of earthquake ruptures, off-fault damage and production and redistribution of frictional melts during coseismic slip. All these processes affect the earthquake energy budget and the pattern of the radiated energy. Here, we quantify the 2D relationships between fault surface topography, coseismic off-fault damage and melt distribution on a well-exposed seismogenic fault reproduced in a high-resolution photogrammetric digital outcrop model.

The fault surface is about 20 m long along strike and 3 m high, strikes EW and dips of 50° to the South, and is part of a wide fault zone composed of hundreds of fault segments crosscutting the granodiorite of the Avio pluton in the northern Adamello batholith (Italy). The fault experienced dextral transpressive activity, and, since one pseudotachylyte fault vein with average thickness of 3 mm could be identified from field and microstructural observations, it likely hosted only one main seismic rupture. The coseismic offset could not be measured in the field, but, based on a wide dataset of coseismic offsets measured on similar fault strands in the area, it was likely on the order of 1 m. An unknown amount of slip was accumulated at subseismic slip rate before the earthquake propagation, as suggested by the occurrence of a cataclasite layer crosscut by the pseudotachylyte vein. The fault footwall crops out on a recently deglaciated rock cliff and preserves thin patches of hanging wall, where it is possible to measure the thickness of the pseudotachylyte fault vein. The footwall is crosscut by swarms of pseudotachylyte injection veins aligned in direction roughly perpendicular to the slip vector.

The digital outcrop model was reconstructed from 2972 photographs by using the VSFM software. The resulting point cloud has sub-millimeter resolution and millimeter accuracy. We extracted several profiles from the point cloud, both parallel and perpendicular to the slip vector, and characterized their topography and roughness by Fourier power spectral analysis. The point cloud was also interpolated to obtain a triangulated mesh, successively textured with selected high-resolution field pictures and used to digitize the relevant structures, i.e. injection vein traces, hanging wall and pseudotachylyte patches.

Our preliminary analysis suggests that fault wavy topography controls the position of injection veins clusters and the thickness of the pseudotachylyte fault vein. Injection veins swarms are located along the restraining side of asperities with wavelength of around 1m. The thickness of the pseudotachylyte fault vein ranges between less than 1 mm in restraining segments, to more than 1 cm in releasing bands over similar wavelengths. A significant volume of frictional melt, between 1.3 and 1.7 l/m2, is drained within injection veins swarms. We propose that the length scale of fault waviness controlling the distribution of macroscopic off-fault damage and the thickness of the coseismic frictional melt layer has a scale comparable with that of the coseismic slip.