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# Surface roughness of ancient seismic faults exhumed from seismogenic depths (Gole Larghe Fault, Italian Alps)

Andrea Bistacchi (1), William Ashley Griffith (2), Stefan Nielsen (3), Steven A. Smith (3), and Giulio Di Toro (4)

(1) Dipartimento di Scienze Geologiche e Geotecnologie, Universita' di Milano Bicocca, Milano, Italy (andrea.bistacchi@unimib.it), (2) Department of Geology and Environmental Science, University of Akron, Akron (OH), USA, (3) Istituto Nazionale di Geofisica e Vulcanologia, Roma, Italy, (4) Dipartimento di Geoscienze, Universita' degli Studi di Padova, Padova, Italy

Fault surface roughness is a principal factor controlling earthquake rupture nucleation, propagation and arrest, and, possibly, dynamic friction during seismic slip. However, the characterization of fault roughness is limited to a few examples of fault zones exhumed from <5 km depth and generally hosted in sedimentary and volcanic lithologies. Here we investigate the roughness of slip surfaces from the seismogenic strike-slip Gole Larghe Fault Zone, exhumed from ca. 10 km depth and hosted in granitoid rocks of the Adamello batholith (Italian Alps). This fault zone is composed of numerous sub-parallel and interconnected slip surfaces that are exposed in continuous glacier-polished outcrops with undulating topography, providing 1D fault traces oriented at a variety of angles relative to the net slip vector. Ancient seismicity is corroborated by the occurrence of continuous layers of pseudotachylyte which very often line the slip surfaces.

We determined the geometry of fault traces over five orders of magnitude using terrestrial laser-scanning (LIDAR, 100 m to 1 m scale), and 3D mosaics of high-resolution rectified digital photographs (10 m to 1 mm scale). LIDAR scans and photomosaics were georeferenced in 3D using a Differential Global Positioning System, allowing detailed multiscalar reconstruction of fault traces in gOcad®. Fault surfaces are almost perpendicular to outcrop surfaces, hence roughness of fault traces represents the real roughness of fault surfaces, sampled along different directions. Fourier's power spectrum analysis revealed a self-affine behavior over 3 to 5 orders of magnitude, with Hurst exponents ranging between 0.5 and 0.8. Also RMS roughness and equivalent parameters can be defined. The availability of fault traces collected along different directions allowed us to define roughness anisotropy, which is always small to negligible for the Gole Larghe Fault Zone.

From a methodological point of view, the technique used here has the advantage over direct measurements of exposed fault surfaces in that: (1) both hangingwall and footwall are preserved and separations and displacements can be easily measured (using markers separated by the slip surfaces); (2) fault rocks (pseudotachylyte and cataclasite) are well preserved and can be related to roughness and offset; (3) the measured roughness is not affected by weathering processes; (4) data collected with LIDAR and photomosaics can be merged to reconstruct power spectra spanning five orders of magnitude.

Regarding the Gole Larghe Fault, our preliminary conclusions are that (1) faults do not show significant roughness anisotropy, and (2) roughness of pre-existing joints is almost the same as that of seismogenic fault surfaces. These observations seem to be consistent with the generally small offsets shown by individual seismogenic fault surfaces, and in general indicate that precursor joints have a strong influence on the roughness of the fault surfaces in this setting.

Finally, parameters issued from Fourier's analysis have been used to reconstruct synthetic fault surfaces with an equivalent roughness by means of 2D Fourier synthesis. These surfaces can be used as input for highly realistic dynamic fracture propagation numerical models.