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Imaging the 3D geometry of pseudotachylyte-bearing faults

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Dynamic friction experiments in granitoid or gabbroic rocks that achieve earthquake slip velocities reveal significant weakening by melt-lubrication of the sliding surfaces. Extrapolation of these experimental results to seismic source depths (> 7 km) suggests that the slip weakening distance (Dw) over which this transition occurs is < 10 cm. The physics of this lubrication in the presence of a fluid (melt) is controlled by surface micro-topography. In order to characterize fault surface microroughness and its evolution during dynamic slip events on natural faults, we have undertaken an analysis of three-dimensional (3D) fault surface microtopography and its causes on a suite of pseudotachylyte-bearing fault strands from the Gole Larghe fault zone, Italy.

The solidification of frictional melt soon after seismic slip ceases “freezes in” earthquake source geometries, however it also precludes the development of extensive fault surface exposures that have enabled direct studies of fault surface roughness. We have overcome this difficulty by imaging the intact 3D geometry of the fault using high-resolution X-ray computed tomography (CT). We collected a suite of 2-3.5 cm diameter cores (2-8 cm long) from individual faults within the Gole Larghe fault zone with a range of orientations (+/- 45 degrees from average strike) and slip magnitudes (0-1 m). Samples were scanned at the University of Texas High Resolution X-ray CT Facility, using an Xradia MicroCT scanner with a 70 kV X-ray source. Individual voxels (3D pixels) are $\sim$36 μm across. Fault geometry is thus imaged over $\sim$4 orders of magnitude from the micron scale up to $\sim$Dw.

Pseudotachylyte-bearing fault zones are imaged as tabular bodies of intermediate X-ray attenuation cross-cutting high attenuation biotite and low attenuation quartz and feldspar of the surrounding tonalite. We extract the fault surfaces (contact between the pseudotachylyte bearing fault zone and the wall rock) using integrated manual mapping, automated edge detection, and statistical evaluation. This approach results in a digital elevation model for each side of the fault zone that we use to quantify melt thickness and volume as well as surface microroughness and explore the relationship between these properties and the geometry, slip magnitude, and wall rock mineralogy of the fault.