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Examining microroughness evolution in natural and experimental pseudotachylyte-bearing fault surfaces

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Fault surfaces are rough at all wavelengths, and power dissipation is therefore also likely to be highly heterogeneous during seismic slip along a single fault. We explore the relationship between the evolution of fault surface microroughness and power density, the product of slip rate with shear stress, taking two complimentary approaches: 1) measurement of roughness on experimentally generated pseudotachylytes (solidified frictional melts) where physical conditions can be carefully controlled and monitored and 2) 3D imaging of intact pseudotachylyte-bearing fault surfaces along a wavy fault surface where fault normal stress is inferred to vary with local fault orientation.
Dynamic friction experiments performed with SHIVA, a rotary shear apparatus at the Instituto Nazionale di Geofisica in Rome, Italy, produce artificial pseudotachylyte under controlled conditions. The roughness of slip surfaces associated with these artificial pseudotachylytes was analyzed using images of thin sections produced from optical microscope and scanning electron microscopes (SEM). The edge of the pseudotachylyte was digitized and the characteristic height and radii of asperities were quantified. Analysis of the roughness of experimental pseudotachylytes suggests a decrease in characteristic asperity height with an increase in frictional power density.
Natural pseudotachylyte-bearing faults preserve a record of roughness and, potentially, processes of wear and roughening during earthquake slip. By studying a fault with a relatively uniform slip magnitude but different orientation we can approximate the controlled conditions of dynamic friction experiments. In order to quantify fault surface microroughness and understand its evolution during slip we have examined the 3D geometry of samples from a single fault with approximately 110-200 mm of slip from within the Gole Larghe Fault Zone, Italy. At the outcrop scale, this fault is distinctly wavy with contractional and extensional fault bends as well as relatively straight sections. We quantified the micro-scale roughness for six samples from a range of geometric positions along the fault that we infer to have experienced different fault normal stress during slip. High-resolution x-ray computed tomography (CT) was used to image the internal geometry of the intact sample cores (2-3.5 cm in diameter, 4-6 cm in length). The surfaces of the fault zone were then extracted from the CT volume using an edge detection algorithm. The microroughness (sub mm to 10 cm scale) of the surfaces was then quantified using a Fourier spectral analysis. Samples from relatively planar sections of the fault show similar roughness on both sides, as do samples from contractional bends. Samples from extensional bends, however display distinctly different microroughness on each surface. Thus, samples from natural faults show an evolution of microroughness in response to changing conditions along the fault.