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Inverse Modeling of Earthquake Source Properties Constrained by Pseudotachylite Surface Roughness

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Under high rates of coseismic slip, frictional melt may be generated at the shear zone potentially altering the dynamics and rendering classical rate-and-state friction laws ineffective. Pseudotachylytes (solidified frictional melt) created in laboratories and found in natural fault zones thus provide thermal and mechanical information critical to the study of dynamic shear zone processes, including thermal runaway, stress drop, and viscous braking. While extensive geochemical and mineralogical evidence has suggested the occurrence of disequilibrium melting during pseudotachylite generation, few studies have leveraged it to resolve the kinematics of co-seismic slip.

In this study, we optimize the kinematic parameters of the regularized Yoffe source function using the topographic relief of a pseudotachylyte/wall rock surface in combination with a one-dimensional fluid-mechanical-thermal finite element model. The model consists of solving a two-phase moving boundary problem with an internal heat source constrained by the slip kinematics of the Yoffe function in tandem with the Couette flow problem as an approximation to the shearing of the viscous melt. The topographic relief data come from a pseudotachylyte-bearing fault within the Gole Larghe fault zone, Italy measured using high-resolution X-ray tomography. On this fault surface, biotites are ~260 (±100) micron lower than the mean surface height as a result of preferential melting associated with a lower fusion temperature than quartz or feldspar. Using Monte Carlo sampling of the relief data distribution and Bayesian optimization, we optimize the kinematic parameters of the regularized Yoffe functions and resolve the statistics of shear stress evolution.

Our preliminary results show that the displacement-averaged shear stress in frictional melt ranges from 2 to 7 MPa with a mean value of 5.5 MPa. This is much smaller than estimates based on pseudotachylyte thickness and laboratory experiments, indicating a more complete stress drop than previously thought. The optimal Yoffe source functions have a mean total rise time of ~4 seconds, which is longer than that inferred from scaling laws. Simulations are ongoing and we look forward to interpreting the results in the context of source properties, source models, and energy partitioning for pseudotachylyte-bearing faults.