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Experimental constraints on the energy budget of dynamic gouge formation: effects of rock strength, material heterogeneity, and initial flaw characteristics

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Fault core materials are characterized by substantial grain size reduction relative to host and damage zone rocks. The properties of these materials control fault strength and frictional behavior, and they record valuable information about rupture and slip processes. At high strain rates and large stress amplitudes characteristic of earthquake rupture tips, rock failure passes through a fragmentation transition from discrete fracture to pulverization; therefore much of the observed grain size reduction at the leading edge of propagating earthquake ruptures. Past examinations of particle size distributions in gouge formed in the cores of natural faults have led to contrasting conclusions that during a single event, the energy associated with creation of new surface area during this grain size reduction can be as large as 50%, or as little as <1% of the earthquake energy budget; however these estimates are difficult to confirm due to (A) challenges associated with accurate particle size measurement and (B) uncertainty regarding the variety of (not-necessarily coseismic) physico-chemical processes that may contribute to the observed grain size reduction. Here we study the micromechanics and energy budget of dynamic rock fragmentation under impulsive compressive loads using a Split Hopkinson Pressure Bar. We present new experimental results on Arkansas Novaculite and Westerly Granite coupled with microstructural observations and BET surface area measurements of post-mortem specimens. We show that the energy partitioned into creation of new surface areas approaches a significant portion of the total dissipated energy during our experiments, but this partitioning can be buffered by the presence of flaws and/or significant material heterogeneity. The results of this work have important implications for lithologic controls on gouge formation and energy partitioning during earthquakes.