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Intense pulverization of quartz single crystal in associated with possible super-shear stick-slips

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Intensely pulverized rocks have been reported from large scale strike slip faults such as San Andreas Fault (e.g., Dor et al., 2006, EPSL). Microstructural characteristics of pulverized rocks with apparent lack of shear suggests shattering and comminuation of grains possibly resulting from a rapid decrease in normal stress and perhaps transient fault opening during passage of the dynamic rupture front. Recently, Doan and Gary (2009, Nature Geoscience) experimentally reported that the pulverization of granite requires high strain rates greater than 150 /s and could be explained by a super shear rupture.
In order to clarify how rupture propagates during a stick-slip, we have undertaken an experimental study on a stick-slip with a single crystal of synthetic quartz. We used a gas apparatus, and performed the experiments at confining pressures of 120-180 MPa and axial strain rate of 10^{-3}/s. Single crystals of dry synthetic quartz were cored parallel to c-axis and a-axis with a diameter of 20 mm and cut to a length of about 40 mm. Then the cores were cut 50 deg to the long axis of the core, and the precut surfaces were mirror polished. Displacements, axial stresses and shear strains along the fault surfaces were measured by strain gauges glued on the sample surface, and the data were sampled at 2 MHz.
Our experimental results yielded two different frictional behaviors and final states of samples: 1) simple fracturing state associated with multiple small stick-slips at the confining pressure less than 160 MPa, where samples were split into fragments but no intense pulverization, 2) intense pulverization state associated with large stick-slips at the confining pressure of 180 MPa, where samples were intensely pulverized into numerous small fragments. TEM analysis shows that the size of the fragments extends down to submicron in the vicinity of the slip plane. In pulverized samples, the axial stress abruptly decreased as large as 700 MPa and the slip distance attained up to 2mm during the main shock of the stick-slip. The pulverized fragments show polygonal column irrespective of their sizes, and the fractographic textures suggest them to be a tensile fracture origin. The peak stresses and strain rates exceed the range of a transition from fracturing state to intense pulverization reported by Doan and Gary (2009).
The mechanical data and the mode of intense pulverization of synthetic quartz imply the super-shear ruptures radiated supersonic waves during the stick-slips caused by anomalously high strain rates and peak stresses. Synthetic single crystals of quartz are very brittle and the stress drops in our experiments are much larger than earthquakes, but mosaic textures of pulverized rocks with lack of distinct shear deformation are not rare in natural faults. Therefore, it is likely that the pulverization by super-shear would be a mechanism to widen the damaged zones of seismic faults.

Keywords: super-shear, stick-slip experiment, quartz single crystal, pulverization, fault, damage zone