Geophysical Research Abstracts
Vol. 17, EGU2015-6798, 2015
EGU General Assembly 2015

Spontaneous, large stick-slip events in rotary-shear experiments as analogous to earthquake rupture

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Experimental stick-slips are commonly envisioned as laboratory analogues of the spontaneous faults slip during natural earthquakes (Brace & Byerlee, 1966). However, typical experimental stick-slips are tiny events of slip distances up to a few tens of microns. To close the gap between such events and natural earthquakes, we develop a new method that produces spontaneous stick-slips with large displacements on our rotary shear apparatus (Reches & Lockner, 2010). In this method, the controlling program continuously calculates the real-time power-density (PD = slip-velocity times shear stress) of the experimental fault. Then, a feedback loop modifies the slip-velocity to match the real-time PD with the requested PD. In this method, the stick-slips occur spontaneously while slip velocity and duration are not controlled by the operator.

We present a series of tens stick-slip events along granite and diorite experimental faults with 0.0001-1.3 m of total slip and slip-velocity up to 0.45 m/s. Depending on the magnitude of the requested PD, we recognized three types of events: (1) Stick-slips with a nucleation slip that initiates $\sim$0.1 sec before the main slip which is characterized by temporal increase of shear stress, normal stress, and fault dilation; (2) Events resembling slip-pulse behavior of abrupt acceleration and intense dynamic weakening and subsequent strength recovery; and (3) Small, creep events during quasi-continuous, low- velocity slip with tiny changes of stress and dilation. The energy-displacement catalog of types (1) and (2) events shows good agreement with previous slip-pulse experiments and natural earthquakes (Chang et al., 2012). The present experiments indicate that power-density control is a promising experimental approach for earthquake simulations.