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A general law of fault wear and its implication to gouge zone evolution

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Fault wear and gouge production are universal components of frictional sliding. Wear models commonly consider fault roughness, normal stress and rock strength, but ignore the effects of gouge presence and slip-velocity. In contrast, our experimental observations indicate that wear continues while gouge layer is fully developed, and that wear-rates vary by orders-of-magnitude during slip along experimental faults made of carbonites, sandstones and granites (Boneh et al., 2013, 2014). We derive here a new universal law for fault wear by incorporating the gouge layer and slip-velocity. Slip between two rock-blocks undergoes a transition from a 'two-body' mode, during which the blocks interact at surface roughness contacts, to 'three-body' mode, during which a gouge layer separates the two blocks. Our wear model considers 'effective roughness' as the mechanism for failure at resisting, interacting sites that control the global wear. The effective roughness is comprised of a time dependent, dynamic asperities which are different in population and scale from original surfaces asperities. The model assumes that the intensity of this failure is proportional to the mechanical impulse, which is the integrated force over loading time at the interacting sites. We use this concept to calculate the wear-rate as function of the impulse-density, which is the ratio [shear-stress/slip-velocity], during fault slip. The compilation of experimental wear-rates in a large range of slip-velocities (10 μm/s – 1 m/s) and normal stresses (0.2 – 200 MPa) reveal very good agreement with the model predictions. The model provides the first explanation why fault slip at seismic velocity, e.g., $\sim$1 m/s, generates significantly less wear and gouge than fault slip at creeping velocity. Thus, the model provides a tool to use the gouge thickness of fault-zones for estimation of paleo-velocity.

Boneh, Y., Sagy, A., Reches, Z., 2013. Frictional strength and wear-rate of carbonate faults during high-velocity, steady-state sliding. Earth and Planetary Science Letters 381, 127-137.

Boneh, Y., Chang, J.C., Lockner, D.A., Reches, Z., 2014. Evolution of Wear and Friction Along Experimental Faults. Pure and Applied Geophysics, 1-17.