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A mechanical explanation for slip weakening

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At low pressures and strain rates, rock-on-rock friction has a coefficient μ of 0.6-0.8 ("Byerlee" friction). This applies also to the intergranular friction of dry non-comminuting grain-flows. At the higher stresses and strain rates found in earthquakes, and in some recent small-scale laboratory rock-on-rock friction experiments, however, apparent μ values of the order of 0.1 are common. A wide variety of explanations has been proposed for these low friction values, including high-pressure pore water, rock melting and silica gel formation, but all seem to be restricted to particular circumstances.

We note that all the situations in which low apparent μ values are found involve intense comminution of rock fragments forming "gouge"; and where these conditions are not met, rock friction appears to be normal. We outline a mechanical explanation for reduced frictional resistance to shear, based on the shearing grain strata in these situations being continuously, rapidly and intensely comminuted by dynamic rock fragmentation. Some of the work done in straining grains to failure may be lost to fracture-surface energy, but much of the strain energy generated is recycled to the motion of the grain mass as instantaneous local isotropic dispersive pressures (which can be in the GPa range) derived from the kinetic energy of the fragments. At high ambient stresses and strain rates, granular shear concentrates in thin "shear bands"; the pressures resulting from fragmentation events act on the shear band boundaries to reduce the confining stress within a band, and so reduce its effective intergranular direct stress and ability to resist boundary shear with a conventional friction coefficient. In this way we quantitatively explain the resistance to shear measured for the San Andreas fault, and the laboratory data of Di Toro *et al* (2004).

Comminution cannot reduce all the available grains to unrealistically small sizes before motion is complete. If fresh material can be recruited from adjacent rock or debris during motion, fault ruptures do not violate this constraint.