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Dynamic rock fragmentation in grain flow: application to large mass movements

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Mechanical explanations for large-scale, hypermobile, geophysical phenomena (long-runout debris avalanches, low-angle blockslides, faulting) have had limited success. These phenomena all involve shearing of comminuted grain strata, but the flow mechanics of rigid grains provide no mechanism for reducing frictional resistance to grain shearing. We outline a mechanical explanation for reduced frictional resistance to debris motion, based on the fact that provided strain rate and confining stress are sufficient, the shearing grain strata in these situations experience intense comminution by dynamic rock fragmentation throughout the motion. Much of the energy used in fragmenting the grains is returned to the situation as kinetic energy of the fragments; this recycled energy generates instantaneous local isotropic pressures in the GPa range.

We distinguish two classes of geological mass movement, in which grain fragmentation has different roles. In *confined shear* the fragmenting grain layer is thin and bounded by non-fragmenting material (blocksliding, basal shear of volcanic debris avalanches). Under high ambient stresses and strain rates, shear concentrates in thin "shear bands"; fragmentation reduces the confining stress in a band, and so reduces its effective intergranular direct stress and ability to resist boundary shear with a conventional friction coefficient. Thus we quantitatively explain the motion of the Waikaremoana blockslide and the Socompa volcanic debris avalanche.

In *less confined* shear (dry debris avalanches) the fragmenting layer is initially thin, but thickens during runout until it extends through the whole depth of the

mass except for a $\sim$ 10-m thick less-fragmented surface carapace. The shear rate is thus lower and shear banding is less prominent than in confined shearing; we suggest that motion is affected by reduced internal friction due to myriads of local, transient shear bands and by the integrated effect of the isotropic fragmentation pressures. The Falling Mountain and Acheron rock avalanche deposits (NZ) are quantitatively explained this way.

Comminution cannot reduce all the available grains to unrealistically small sizes before motion is complete. If fresh material is recruited from adjacent rock or debris during motion, blockslides, volcanic debris avalanches and faults do not violate this constraint. Dry debris avalanches cannot recruit new material, but if initial block size is based on proximal carapace grain-size, fragmentation can endure for the duration of motion.