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Some physics of landslide distributions and their consequences for mountain landscapes

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Landslides large and small are the principal sources of sediment in many mountain landscapes. Their quantitative role can be estimated through integration of their size-frequency distribution, but the shape and physical origin of this distribution are not well understood. After careful study of a large number of landslide inventories, we have concluded that only in rare cases can the entire distribution be characterized reliably, the power-law tail analyzed robustly, and the mean landslide size measured without bias. These rare inventories are nevertheless encouraging, because they point to a simple mechanical origin for the famous self-similarity of landslide areas. The whole size distribution, not just the power-law tail, can be predicted correctly by a model of landslide rupture that accounts for topographic stresses and their stochasticity. The basis of the model is a kind of random walk of the principal stresses acting on the soil and shallow bedrock above a growing rupture. Rupture termination is considered to occur when the landslide breaks the surface and "pops out", which happens when the stress random walk breaches a Mohr-Coulomb yield envelope. We have used a combination of elastoplastic mechanics and probability theory to solve this stochastic model and to produce a closed-form equation for the landslide size distribution. The beauty of the model is that it predicts that the power-law tail scaling is an inverse function of the internal angle of friction of the soil or bedrock: the weaker the substrate, the steeper the power-law tail, the larger its scaling exponent, and the rarer the large landslides. Mean cohesion, on the other hand, appears to set the mean landslide area. Our analysis of the best landslide inventories vindicates the shape of the size distribution predicted by the model, while its mechanical predictions continue to be tested. If they prove correct, the model insights will help a great deal in the bid to understand landslide sediment budgets and mountain landscape evolution in general.