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Mobility and Energy Budget of Fragmenting Rockfalls and Rockslides

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The mobility of rockfalls and rockslides can be difficult to predict due to complex interactions of numerous physical processes, such as fragmentation of the rock mass and its effect on the energy dissipation of basal and internal friction. Despite its occurrence in all types of gravitational rock movements for a wide range of sizes, the process of fragmentation is largely neglected in models of rockfalls and rockslides. Typically, these models assume the movements to be of rigid bodies or granular flows. However, there exists a wide spectrum of brittle, fragmenting bodies in between these end-members which are not captured by existing models. Here, we present a model aimed at closing that gap: a quantitative description of the mobility and energy budget of fragmenting rock masses.

Fragmentation is generally recognized to consume energy at the cost of kinetic energy. Nevertheless, fragmentation has been suggested to increase mobility of rockfalls and rockslides. This suggests a complex interplay between the fragmentation process and the other energy dissipative processes (e.g. friction), which is not yet understood. To gain basic insights into the effects of fragmentation on rockfalls and rockslides, we perform simple experiments of fragmenting analogue rocks. From these, we aim to answer: (1) what controls the degree of fragmentation? (2) How is the mobility of gravitational rock movements affected by the process of fragmentation? (3) How is the energy budget changed?

Using dimensional analysis, we derive a set of dimensionless parameters that characterize the role of fragmentation in rockfalls and rockslides. Taking advantage of a newly developed rock analogue material, we perform a parameter study over the material strength, potential energy, initial geometry of samples and basal coefficient of friction to study their effect on the mobility and energy budget of gravitational rock movements. Our results show that the travel length of the center of mass decreases with the degree of fragmentation. In contrast, the area and the runout of the front of the deposits increase with a higher amount of fragmentation. The energy consumed by fragmentation increases with the degree of fragmentation and follows a logarithmic curve, with values of fragmentation energy ranging from 0 % to 25 % of the potential energy. Despite the energy consumption by fragmentation, an increased degree of fragmentation causes a larger amount of spreading of the material, causing an increased mobility.