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Landslides in vibrating sand-box: what controls types of slope-failure and frequency magnitude relations?

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Although landslides are a worldwide significant natural hazard, their physics is not well understood. This study focuses on aspects of landslide failure mechanisms and controls on their frequency-magnitude relations. Landslides were induced in a vibrating box filled with wet (practically cohesive) sand, simulating natural slope failure. The questions addressed in this study were (a) what controls the type of slope-failure and (b) what controls frequency magnitude relations of landslides.

Accelerations were applied separately in the vertical and horizontal directions. Two parallel processes were observed to occur during shaking: (a) development of a slope parallel failure plane, causing slumping that encompass the whole box, and (b) development of a set of tensile cracks normal to the slope, that dissect the whole slope into fragments. It appears that the more significant process of these two processes controls the type of slope failure as well as the final size-distribution. Under applied horizontal acceleration, a slope-parallel failure plane develops rapidly, and a box-sized slump always occurs. In contrast, under applied vertical acceleration, the more significant process is formation of Mode I fractures vertical to the slope. The fractures cause strength heterogeneity and promote block sliding as the slope failure mechanism. The experiments show a power-law size distribution of blocks controlled by this fracture distribution.

We argue that the above two processes also control the size distribution of natural landslide inventories (Malamud et al., 2004). Natural slides may be divided into two end members: large and small. We think that the processes controlling their formation is different, where each size is controlled by one of the mechanisms observed in our experiments:

1. The smaller natural landslides occur as slumps within unconsolidated sediments typical of the upper few meters close to the surface. They fail by a process equivalent to the whole box landslides observed in our experiments and show a characteristic landslide size, which is the largest slide size possible in the system. The size of the characteristic slide is determined by a dependence of slide depth (h) and slide area (A) (Hovius et al., 1997). In the experiments A is constrained by the box size and h is thus determined, while in nature h is constrained by the depth of unconsolidated sediments and a characteristic slide area A is thus obtained.

2. In contrast to the homogeneous upper layer, rock mass below the unconsolidated sediment is always heterogeneous due to fractures, layers and bedding. Thus, for deep slides, material heterogeneity dominates over sliding and slumping processes in controlling the size distribution of deep-seated landslides. This preexisting heterogeneity is the source of the power law decay observed for the large landslide portion in natural slide distributions. Our model rules out SOC dynamics as the dominant mechanism responsible for the power-law decay in natural landslides.