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The Mechanics of Landslide Mobility with Erosion

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Erosion can dramatically change the dynamics and deposition morphology and escalate the destructive power of a landslide by rapidly amplifying its volume, turning it into a catastrophic event. Mobility is the direct measure of the thread posed by an erosive landslide as it plays a dominant role in controlling the enormous impact energy. However, no clear-cut mechanical condition has been presented so far for when and how the erosive landslide gains or loses energy resulting in enhanced or reduced mobility. We pioneer a mechanical model for the energy budget of an erosive landslide that delineates the enhanced or reduced mobility. A fundamentally new understanding is that the increased inertia due to the increased mass is not related to the landslide velocity, but it is associated with the distinctly different entrainment velocity emerging from the inertial frame of reference. The true inertia can be much less than incorrectly proposed previously. We eliminate the existing erroneous perception and make a breakthrough in correctly determining the mobility of the erosive landslide. We reveal that the erosion velocity plays an outstanding role in appropriately determining the energy budget of the erosive landslide. Crucially, whether the erosion related mass flow mobility will be enhanced, reduced or remains unaltered depends exclusively on whether the newly constructed energy generator is positive, negative or zero. This provides a first-ever explicit mechanical quantification of the state of energy, and thus, the precise description of mobility. This becomes a game-changer and fully addresses the long-standing scientific question of why and when some erosive landslides have higher mobility, while others have their mobility reduced. By introducing three important novel mechanical concepts: erosion-velocity, entrainment-velocity and energy-velocity, we demonstrate that the erosion and entrainment are essentially different processes. With this, we draw a central inference: that the landslide gains energy and enhances its mobility if the erosion velocity is greater than the entrainment velocity. The energy velocity delineates the three excess energy regimes: positive, negative and zero. We establish a mechanism of landslide-propulsion that emerges from the net momentum production, providing the erosion-thrust to the landslide. Analytically obtained velocity quantifies the effect of erosion in landslide mobility and indicates the fact that erosion can have the major control on the landslide dynamics. We have also presented a full set of dynamical equations in conservative form in which the momentum balance correctly includes the erosion induced change in inertia and the momentum production. This is a great advancement in legitimate simulation of landslide motion with erosion.