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Longitudinal Ridges in Long Runout Landslides: on the Applicability of High-Speed Granular Flow Mechanisms.

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Long runout landslides are a particular type of mass-wasting phenomena that belongs to the category of surface processes associated with rapid strain rates. The reduction of friction that has to be invoked to explain their high velocities and exceptional travel distance over nearly horizontal surfaces has yet to find satisfactory explanation. Inspired by fault mechanics studies, thermally-activated mechanisms can explain the dynamic frictional strength loss during sliding along the initial failure surface and the early development of velocities higher than expected. However, as slides continue moving along nearly horizontal valley floors, the weakening mechanisms required to sustain their exceptional behaviour are less certain.

Long runout landslides are found ubiquitous in our solar system and the slow erosion rates that operate on extraterrestrial planetary bodies allow the preservation of their geomorphological record. The availability of the latest high-resolution imagery of the surface of Mars and the Moon allows to conduct detailed morphometric analysis not so granted on our planet. On the other hand, on Earth, the partial loss of the geomorphological record due to fast erosion rates is compensated by the accessibility of sites that enable us to conduct field work. In order to better understand the mechanisms responsible for the apparent friction weakening we use a comparative planetary geology approach, in the attempt to link the morphology and the internal structures of long runout landslide deposits to the mechanisms involved during the emplacement of such catastrophic events.

We focused on the distinctive longitudinal ridges that mark the surface of the landslide deposits. The formation mechanism of longitudinal ridges in long runout landslides has been proposed to require ice, as this low friction material would allow the spreading of the deposit, causing the development of longitudinal ridges by tensile deformation of the slide. However, ice-free laboratory experiments on rapid granular flows have demonstrated that longitudinal ridges can form as a consequence of helicoidal cells that generate from a mechanical instability, which onset requires a rough surface and a velocity threshold to be surpassed. Moreover, such experiments have showed that the wavelength of the longitudinal ridges is always 2 to 3 times the thickness of the flow.

We here present the results from three case studies: the 63-km-long Coprates Labe landslide in

Valles Marineris on Mars; the 4-km-long El Magnifico landslide in Chile, Earth; and the 50-km-long Tsiolkovskiy crater landslide, at the far side of the Moon. We found that the wavelength of the longitudinal ridges is consistently 2 to 3 times the thickness of the landslide deposit, in agreement with experimental work on rapid granular flows. The recurrence of such scaling relationship suggests a scale- and environment-independent mechanism. We discuss the applicability of high-speed granular flow convection-style mechanisms to long runout landslides and speculate on the existence of an alternative vibration-assisted mechanism.