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Field study of permafrost molards from diverse origins of landslides in Matanuska Valley, Alaska

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Permafrost is receding and warming globally due to current climate change trends. Mountain regions with areas of discontinuous to isolated permafrost are especially sensitive to these changes. In high relief mountainsides, ground ice can be essential in stabilising mountain slopes and can result in slope failures if this ice degrades. To determine the state of degrading permafrost and related slope failures, we studied the Matanuska Valley in Alaska (USA), an area characterised by a high density of landslides with permafrost molards .

Permafrost molards are cones of loose debris that can be found in landslide deposits in periglacial terrains, originating from ice-cemented blocks of debris that are transported down-slope within the landslide. These ice-cemented blocks are fragmented parts of the frozen material initially located in the landslide source area. Therefore, they can indicate the presence of degrading permafrost at the level of the detachment zone. Landslides containing permafrost molards have been detected in geographically and geologically diverse regions such as Argentina, Canada, Colorado, the European Alps, Greenland, Iceland, and Norway.

Our Alaskan field site contains 9 molard landslides within only a 15 km radius. These densely clustered landslides have a unique variety of geological, geomorphological and dynamic characteristics. This allows us to study a large parameter space of permafrost slope instabilities within a small region. Therefore, we studied the following five molard landslides in detail: Amulet, East and West Index Lake, Yellowjacket, and Matanuska River 2021 landslide.

These landslides are diverse in terms of landslide type, transported volume, run-out length, source materials, expositions, and altitudes. For instance, the Matanuska River 2021 landslide is a rotational slide of initially forested terrain with the head scarp at 780 m.a.s.l., and with a length of ~400 m plunging into the Matanuska River. In contrast, the Amulet landslide is a channelized debris slide with the head scarp at 1500 m.a.s.l., a run out length of ~2100 m, and with hundreds

of molards with diameters ranging up to 44 m in the landslide deposits.

To document the variability between these landslides, we performed traditional geomorphological and geological field measurements, dug transects in the molards, took samples, and we obtained digital terrain models of the landslides by drone-based photogrammetry. We acquired drone-based photogrammetry data of Yellowjacket landslide only two weeks after the failure, before the initial ice-cemented blocks fully degraded, as well as four years after the slope failure. For the first time, this allows us to compare spatial data of permafrost molards before and after the degradation of the initial ice-cemented blocks and to perform statistical analysis on this data.

We investigated molard shape, size, and size-distribution parameters to compare these to variables such as source material and expected permafrost conditions. This allows us to confine the composition of the initially ice-cemented blocks of debris, which will help us to understand under what conditions molards can form. In the future, this will allow us to quantify the currently often uncertain state of mountain permafrost more precisely.