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Controlling factors of turf-banked solifluction lobe evolution in the Turtmann glacier forefield (Switzerland)

Daniel Draebing (1) and Jana Eichel (2)

(1) Bonn, Germany (daniel.draebing@gmx.de), (2) Department of Geography, University of Bonn, Bonn, Germany

Soil structure and moisture, thermal conditions and vegetation control solifluction movement, however, the spatial distribution of controlling factors and resultant spatial variability of movement are poorly understood. We use a (1) geomorphological and vegetation mapping of solifluction lobe properties, (2) temperature loggers to quantify thermal conditions, (3) 2D Electrical Resistivity Tomography (ERT), Puerkhauer drilling and TDR measurements to evaluate material properties as well as (4) 3D Time-Lapse ERT to quantify spatial variability of material properties. Our results are used to (5) evaluate the influence of potential controlling factors on solifluction movement. Investigations took place on three turf-banked lobes (TBL) located at proximal and distal slopes of Little Ice Age and 1920s lateral moraines in the Turtmann glacier forefield, Swiss Alps.

(1) Vegetation is spatially differentiated at TBLs. The treads are mostly covered by the ecosystem engineer Dryas octopetala, while other dwarf shrubs, shrubs and pioneer species were found at the high lobe risers (0.8-1.8 m). In contrast, less vegetated ridge-like features at the upper part of the treads are colonized by frost-tolerant species. Large blocks are located at the lobe fronts, probably impeding the lobe movement.

(2) Temperature loggers show a lack of ground cooling due to snow isolation at the vegetated lower tread between 2014 and 2015. Thus, significant ground cooling in winter is reduced to the wind-exposed upper parts (ridges).

(3) TBL material consists of sandy silt, thus, lobe material is much finer than subjacent moraine till and indicates former colluviation. As a consequence, 2D ERT demonstrates low-resistant areas until depths equal to riser height, thus, the finer TBL body is higher saturated than the coarser surrounding parent slope and more susceptible to gelifluction. On the contrary, risers show high resistivities indicating dry conditions which are supported by TDR results. Furthermore, ERT demonstrates the absence of permafrost in all measured TBLs.

(4) Time-Lapse 3D ERT shows low-resistant areas at the rim of lobes in contrast to the high-resistant treads. In addition, resistivity increases with TBL depth. Thus, resistivity values indicate higher saturated conditions along the lobe axis with decreasing saturated conditions at the rim.

(5) High-saturated conditions favour gelifluction movement while low-freezing activity and dense vegetation cover result in a lack of ice lenses and absence of permafrost and, thus, impermeable layers. Therefore, the highly permeable material favours drainage and seepage without development of critical pore water pressures. The D. octopetala mat on the tread increases near-surface shear strength, which decreases near-surface movement. In addition, later successional shrubs species colonizing the risers indicate limited frontal movement. As a consequence, our results suggest that solifluction movement is limited to the low- vegetation cover, highly saturated parts of the lobe affected by winter ground cooling.

However, the large riser height reflects high past solifluction activity. Location of the lobes at the foot of slopes and large riser height indicate that TBLs are close to their final cycle of development. Due to the moraine age, the length of the cycle can be assumed to be maximum 100 years.