Bulldozer-like soil erosion at the front of a rockglacier indicates change in advance dynamics: Case study from the Furggentälti, Vallais, Switzerland

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Several active rockglaciers in the Alps have increased their creep velocity in the last few decades. An example for such a rockglacier is the well-studied Furggentälti rockglacier near the Gemmi Pass in the Valais Alps in Switzerland. If a rockglacier flows onto soil, erosion can occur forming peculiar landforms. At the Furggentälti, a bulldozer-like soil erosion takes place and therefore a bulge is developing in front of the rockglacier (Figure 1a).

The aim of our study was to simulate the dynamical creep behavior of the Furggentälti rockglacier and in particular to reproduce the erosional process at the rockglacier front. For this, we used the finite-element code presented in Frehner et al. (2015). We assume the rockglacier movement to be governed by purely viscous creep behavior, which is driven downhill by gravity. To design a realistic model representing the Furgentälti rockglacier as well as possible, we used the swissALTI3D digital elevation model for the rockglacier topography and the interpreted seismic refraction data of Nussbaum (2008) for the internal structure (i.e., thickness of active layer and depth to bedrock). In addition, we added a 1 m thick soil layer in front of the rockglacier and beneath the frontal 30 m of the rockglacier. The extent and dimensions of this soil layer are based on local observations and areal images.

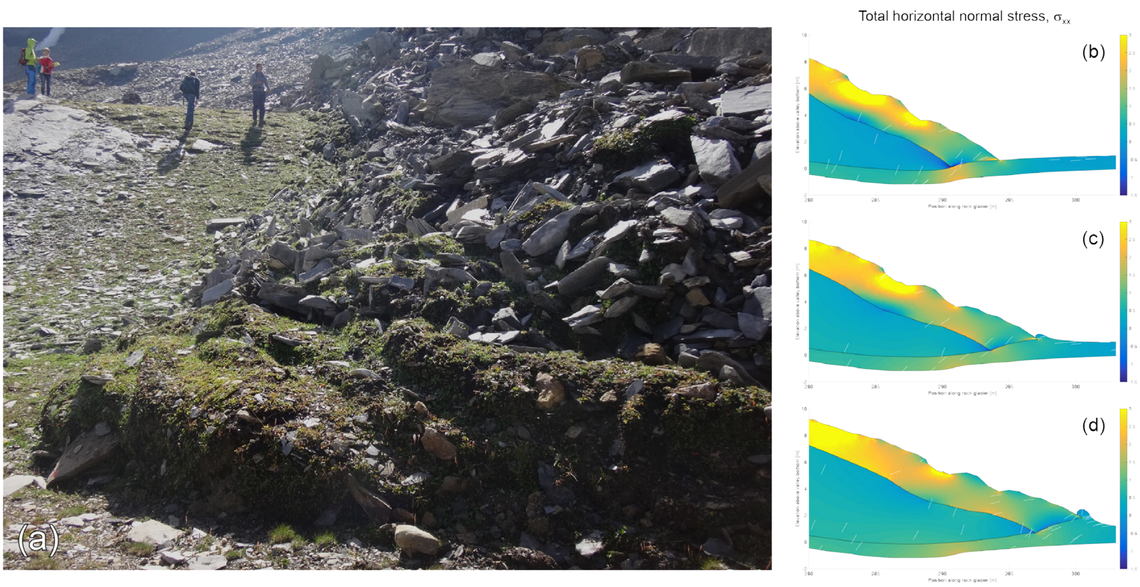

Figure 1. a) Bulldozer-like soil erosion at the front of the Furggentälti rockglacier. People for scale. b)–d) Progressive snapshots of numerical simulation. Shown in color is the total horizontal normal stress. The bulge in the soil forms immediately in front of the advancing rockglacier.

The numerical simulation (Figure 1b–d) results in the development of a bulge in the soil in front of the rockglacier. Several key observations from the Furggentälti rockglacier are very well reproduced by the model:

(i) The position and shape of the bulge.
(ii) The amplitude of the bulge.
(iii) The fact that only one bulge forms in the soil, and not several with a distinct wavelength (as compared to the furrow-and-ridge morphology on top of the rockglacier, see Frehner et al., 2015).

Our study also led to various new thoughts and speculations, which we summarized in a conceptual model of a rockglacier moving onto soil (Figure 2). At the rockglacier front, we observe several discrete packages of soil that are incorporated into the rockglacier. Therefore, we assume that a bulge can only reach a certain size (Figure 2b) before it is sheared off and incorporated into the rockglacier (Figure 2c), after which a new bulge forms. This cycle repeats continuously while the sheared-off soil packages are transported up the rockglacier front (Figure 2d). This observation contradicts the commonly accepted caterpillar-like dynamics of a rockglacier, which is characterized by a frontal movement downwards, not upwards. Therefore, we propose that the entire frontal dynamics changes when a rockglacier moves from bedrock onto soil, from caterpillar-like (Figure 2a) to sliding (Figure 2d).

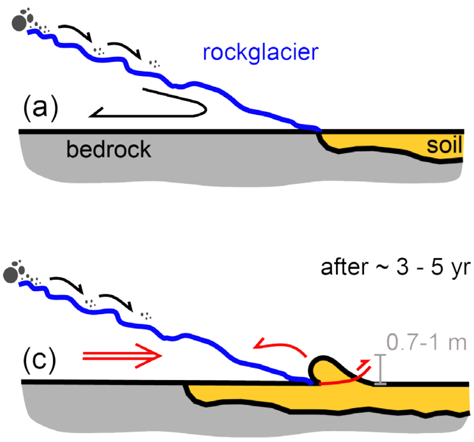

Figure 2. Schematic model of a rockglacier moving from bedrock onto soil. The frontal dynamics changes from caterpillar-like to sliding.

It is interesting to note that the point in time when the Furggentälti rockglacier increased its creep velocity coincides with the moment it moved from bedrock onto soil. Therefore, we also propose that the two different movement dynamics have two different speeds. The increase in creep velocity might be triggered by the change in substrate and the corresponding change in movement dynamics of the rockglacier front, from caterpillar-like movement to sliding.

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