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Research Article

On the morphological characteristics of overdeepenings in high-mountain glacier beds

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Abstract

Overdeepenings, i.e. closed topographic depressions with adverse slopes in the direction of flow, are characteristic for glacier beds and glacially sculpted landscapes. Quantitative information about their morphological characteristics, however, has so far hardly been available. The present study provides such information by combining the analysis of (a) numerous bed overdeepenings below still existing glaciers of the Swiss Alps and the Himalaya-Karakoram region modelled with a robust shear stress approximation and (b) detailed bathymetries from recently exposed lakes in the Peruvian Andes. The investigated overdeepenings exist where glacier surface slopes are low (< 5°–10°), occur in bedrock or morainic material and are most commonly a fraction of a kilometre squared in surface area, hundreds of metres long, about half the length in width and tens of metres deep. They form under conditions of low to high basal shear stresses, at cirque, confluence, trunk valley and terminus positions. The most striking phenomenon, however, is the high variability of their geometries: Depths, surface areas, lengths and widths of the overdeepenings vary over orders of magnitude and are only weakly – if at all – interrelated. Inclinations of adverse slopes do not differ significantly from those of forward slopes and are in many cases higher than so far assumed theoretical limits for supercooling of ascending water and corresponding closure of sub-glacial channels. Such steep adverse slopes are a robust observation and in support of recently developed new concepts concerning the question about where supercooling of sub-glacial water and closure of ice channels can or must occur. However, the question of when and under what climatic, topographic and ice conditions the overdeepenings had formed remains unanswered. This open question constitutes a key problem concerning the interpretation of observed overdeepenings, the understanding of the involved glacio-hydraulic processes and the possibility of realistic predictive modelling of overdeepening formation.