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The role of frontal buttress for submarine landslides: Lake Lucerne as natural laboratory

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For the investigation of a subaqueous landslide in oceans as well as in lakes, the geotechnical characterization of the undisturbed sediments upslope the slide scar is a fundamental task, providing information about pre-conditioning, trigger mechanisms, and failure evolution. The basin sediments, on the contrary, are generally not taken into consideration for the stability analysis, as the slope sequence is often considered as an "infinite slope". The key question of our study is whether the geotechnical properties of sediments at the base of the slope can play an important role in failure initiation and in frontal emplacement style of the mass-transport deposit (MTD; frontally emergent or frontally confined). Furthermore, we aim to learn more about confined landslides, whose kinematics and mechanisms are still poorly understood.

For addressing these scientific questions, we chose the already well-investigated Lake Lucerne as natural laboratory and small-scale model for submarine basin-to-slope studies. We collected new seismic profiles, cores and free-fall Cone Penetration Test (FF-CPTU) data for three main case studies: i) a basin-to-slope setting, where almost the entire slope collapsed during a nearby Mw 5.9 earthquake in 1601 AD, generating several frontally-confined MTDs, ii) another 1601 AD earthquake-triggered confined landslide in a nearby basin, and iii) a basin-to-slope transect across a wide slope area that did not fail during this earthquake.
We integrate geophysical data and geotechnical data, derived from core analysis and CPT profiles, in order to obtain a multidisciplinary characterization of each study area. Geotechnical properties of sediments at the base of failed and unfailed slopes are then compared to understand if the frontal buttress plays a role in the slope failure development.

Our investigation along the transect of confined landslides shows that the sediments inside the MTD have higher values of CPT-derived undrained shear strength than the basin sediments (e.g. difference of up to 5 kPa at a depth of 6 m). Moreover, the data highlight an internal variability within the MTDs, with the inner part being more compressed, and therefore characterised by higher shear-strength values, than the outer part. In the toe region, frontal thrusts divide intact blocks of sediments, which show undrained shear strength values and trends similar to the ones of basin undisturbed sediments, suggesting a lower level of compression and deformation.
Furthermore, the comparison of the case studies shows that sediments at the base of stable slopes have higher values of undrained shear strength than sediments at the base of failed slopes. This hints at basin-sediment properties to play a role in controlling slope stability upslope. The new data and initial findings are discussed with respect to the role of other factors, such as slope geometry, presence of gas, and lithology of sediments.