The role of frontal buttress in failure initiation and emplacement style of subaqueous landslides

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The investigation of subaqueous landslides, in ocean as well as in lakes, requires the geotechnical characterisation of undisturbed sediments located upslope of the slide scar such that information about pre-conditioning, trigger mechanisms, and failure evolution can be established. On the contrary, basin sediments are generally not investigated during stability analysis because the slope sequence is often considered as an “infinite slope”.

The main aim of our study is to establish whether the geotechnical properties of sediments at the base of a slope play an important role in failure initiation as well as in the frontal emplacement style of the mass-transport deposit (MTD; frontally emergent or frontally confined). Frontally emergent landslides can propagate rapidly and are able to generate destructive turbidity currents and tsunami. On the contrary, frontally confined landslides and related geohazards are still poorly understood. They can involve large volumes of sediments and generate an uplift of the seafloor in the toe region, but their kinematics and tsunamigenic potential are still not clear.

We chose the already well-investigated Lake Lucerne, Switzerland, as a natural laboratory. We collected new sub-bottom profiles, short gravity cores, and free-fall Cone Penetration Test (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 the 1601 AD earthquake.
The integration of geophysical data and geotechnical information, derived from core analysis and CPT processing, allows a multidisciplinary characterization of each study area. Geotechnical properties of sediments at the base of failed and unfailed slopes are compared, to understand if the frontal buttress plays a role in the slope failure development. Furthermore, we focus on geotechnical properties of confined-MTD sediments, comparing them to basin and unfailed-slope sediments, in order to understand how these landslides are propagating.

Our investigation shows that the sediments inside the confined MTDs have higher values of CPT- and core-derived undrained shear strength than the basin sediments. Moreover, the data highlight an internal variability within the MTDs, with the inner part being more compressed, and therefore stronger, 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 suggests basin-sediment properties 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 nature of sediments.