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Sedimentary processes and triggering mechanisms of debris flows in subaquatic canyons in Rhone delta (Lake Geneva, Switzerland, France)

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Subaquatic canyons in deltas are major pathways for the transport of particles from land to the deep basins. They represent active environments with frequent deltaic failures and mass-movement deposits potentially leading to hazardous (tsunami waves) and economic (infrastructure damages) implications. Understanding sedimentary processes and mass-movement triggering mechanisms is crucial to assess related consequences and to carry out geological risk assessments.

The Rhone River delta in Lake Geneva (Switzerland, France) is a complex underwater structure with several active and inactive subaquatic canyons, similar to marine deltas but at a smaller scale. The difference between two bathymetric surveys in 1986 and 2002 revealed an inversion in the topography of the distal active canyon, as a former distal canyon was transformed into a mound-like structure. A 12 m-thick layer was deposited in the canyon and modified the sediment transfer conduit. Sediment cores from this deposit were retrieved in-situ in 2002 and 2011 via the "F.-A. Forel" and Russian MIR submersibles, respectively. These cores contained a homogeneous, sandy material. Its sediment texture, grain-size, high density and shear strength, and low water content suggests that it corresponds to a debris-flow deposit that possibly took place after the initiation of a mass movement due to a scarp failure in proximal areas of the canyon. In addition, in-situ geotechnical tests on the modern canyon floor have shown a soft top layer above a stiffer substratum. This soft layer, which increases in thickness towards distal areas, may act as a basal surface for hydroplaning, and might have allowed the debrite to be transported $\sim$9 km away from the source of the scarp failure. Similarities in textures and grain-size of the debris flow and levee deposits hints at proximal northern levee as the source of this material. Rapid sediment loading in this area, at the rate of >3cm/yr, steep slopes in the canyon walls and increased pore pressure due to high methane concentrations may have reduced the stability of the canyon wall in this area. Discrete sandy intervals show very high methane concentrations and thus could correspond to potentially weak layers prone to scarp failures. Nevertheless, the probable cause for the 2000 AD Rhone delta event was an exceptional flood in October 2000 which undercut the slope, and subsequently decreased the stability by increasing the shear stress and triggered the mass failure in the already unstable canyon walls. Besides economic and hazardous implications, such mass failures represent significant and underestimated causes in morphological evolution of underwater canyons by damming the channel and, eventually, forming short-term meanders susceptible to further erosion.