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Outsize fan evolution in the Upper Rhone Valley, Switzerland – gradual or catastrophic?

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What dominates geomorphic process effectiveness: high-frequency or high-magnitude? Especially in the European Alps, where slopes adjust to postglacial conditions, this question has important implications for natural hazard assessment and for understanding postglacial landscape development. In the Upper Rhone Valley, Switzerland, three large fan systems (footprint area $\sim$1 km^2 each) are fed by catchments of just about similar size.

Grounding on three different methods, geomorphometric analysis of high-resolution digital topography, geophysical surveys (GPR & ERT), and surface exposure dating using cosmogenic radionuclides, we seek to analyze 1) the morphology of the fans and their feeder basins, 2) the sedimentary facies and architecture of the deposits, and 3) the chronology of the events that lead to the formation of the fans.

The sediment source regions for the three fans, all coming down from the northern valley flank, are well defined consisting mainly of gneissic lithologies. Based on morphometric analysis, we estimate the volume eroded from the feeder catchments to range between 50 and 62 x 10^6 m^3, translating to minimum uniform denudation rates of $\sim$5-6 mm yr^{-1} averaged over 15 kyr (when deglaciation exposed the valley), outranging ^{10}Be-derived denudation rates from adjacent catchments by factor 2 to 15. Ground penetrating radar surveys ($>$ 10 km length), measured with 40 and 200 MHz antennas, reveal a predominance of large boulders in the subsurface and clearly identify levees and channels, pointing towards high-magnitude debris flow events as the dominant generation process. This finding is supported by ERT surveys, drillings on the margin of one of the fans, as well as a series of m-sized subangular boulders covering parts of the fans. Using cosmogenic nuclide abundances, the exposure ages of selected large boulders as well as bedrock outcrops within the feeder catchment were determined to establish a chronology of fan generation. Exposure ages in the catchment range dominantly between 5800 and 6000 a BP with single ages dated around 3900 and 1100 a BP. Boulders exposed at the surface of the fan exhibit preliminary ages between c. 1000 and 4500 a BP. These ages indicate fan formation took place over several thousands of years during the Holocene. However, the catchment was already formed ca. 6000 a BP. Settlements on the fan (14th century) and a minimum exposure age of c. 830 a BP indicate geomorphic activity ceased several hundred years ago.