Spatial variability and geomorphic controls of denudation rates in the Alpine Rhine Basin (Switzerland)

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Abstract

Mountain landscapes exhibit significant spatial heterogeneity in denudation rates, yet it remains debated where, how rapidly, and which processes control sediment production and transport through fluvial systems. Here, we aim to quantify sediment sources and investigate the factors controlling denudation rates in the 4,300 km^2 Alpine Rhine basin.
We utilize concentrations of in-situ cosmogenic 10Be from riverine quartz at 76 sites, supplemented by paired 10Be-26Al data from 46 locations, to quantify denudation rates and distinguish between different erosional mechanisms. These data are integrated with bulk geochemical compositions to evaluate how lithological and topographic parameters influence sediment generation.

Our results reveal that denudation rates vary by nearly an order of magnitude, ranging from 0.3 to 2 mm yr-1. The paired isotope data indicate that this variability is primarily driven by the competition between steady-state overland flow erosion and landsliding processes. In basins with high denudation rates ($>$ 1.2 mm/yr), sediment production is accomplished by localized sediment sources driven by glacial erosion or mass wasting, often under dip-slope conditions that promote frequent slope failures.
Our integrated geochemical and cosmogenic analysis demonstrates that distinct sedimentary signatures are primarily established within headwater catchments smaller than 200 km^2. While larger drainage systems $>$ 200 km^2 typically act as integrators that homogenize these diverse inputs, the downstream record remains susceptible to the disproportionate influence of localized sediment pulses that can effectively overprint broader basin-scale signals with high-magnitude contributions.

Keywords: denudation rates, paired cosmogenic nuclides, catchment, geomorphology, European Alps

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