Spatial variability of denudation rates and transient landscape adjustment in low-deforming mountains (the Strengbach catchment, Vosges Mountains, France)

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Abstract

Mid-altitude mountain belts often preserve pronounced relief contrasts even with low present-day deformation. Yet catchment-wide 10Be denudation (CWD) rates may record only modest variations despite clear internal geomorphic contrasts. Here, we combine morphometric analysis with a dense nested 10Be dataset from the Strengbach catchment (Vosges Mountains, France) to examine how erosion is spatially partitioned.

CWD rates range from 39 to 84 mm/ka across the catchment. Along the main trunk, rates increase from 41 to 48 mm/ka from source to outlet, whereas tributaries are systematically higher, ranging from 42 to 84 mm/ka. To discuss the origin of these variations, we apportion each sub-catchment among litho-morphological landscape types combining four lithological units and three morphological classes: hillslopes adjusting to fluvial incision, gentle hillslopes, and steep hillslopes or cliffs. A Monte Carlo adjustment method based on a Quantum-behaved Particle Swarm Optimization (QPSO) algorithm is then applied to retrieve the optimal denudation rates of each landscape type contributing to each sub-catchment CWD rate.

The results show that some zones denude up to an order of magnitude faster than others, indicating out-of-equilibrium relief evolution. Using these domain-scale rates, we quantify the pace of landscape adjustment, including knickpoint migration and cliff retreat. Together, the inversion and retreat-rate estimates show that modest CWD variations can coexist with large internal denudation contrasts controlled by lithology and transient landscape adjustment. This approach makes it possible to discuss CWD variations in slowly evolving environments and to quantify the spatial pattern of transient landscape response, with implications for long-term relief persistence.

Keywords: 10Be, catchment–wide denudation rate, Monte Carlo inversion, denudation partitioning, knickpoint migration, cliff retreat, low–deforming mountains

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