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Reconstructing the pace and pattern of glacial erosion with detrital thermochronology, Southern Alps of New Zealand

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Erosion by the expansion of mountain glaciers can fundamentally reshape mountain topography to alter local climate dynamics, reorganize river drainages and force allopatric speciation events. Characteristic U-shaped glacial valleys and well-preserved glacial landforms across the eastern flanks of the Southern Alps of New Zealand attest to the dramatic impact of Quaternary glaciation on this dynamic landscape. However, the progressive influence of glacial erosion on the evolution of this landscape, and the redistribution of glacial sediment at its peripheries, remains difficult to constrain from morphological analyses alone. To reconstruct the pace and pattern of glacial erosion within the Southern Alps, we present a comprehensive detrital thermochronological dataset including apatite fission-track and (U-Th)/He analyses from samples of modern river sediment and sedimentary basin units preserved along the eastern flanks of the mountains.

We interpret erosion patterns in five catchments east of the main drainage divide from detrital cooling age populations in samples of modern river sediment. Published bedrock analyses demonstrate that partial annealing and partial retention zones for the apatite fission-track and (U-Th)/He mineral systems, respectively, have been exhumed within each catchment area. Consequently, cooling ages predictably increase from fully reset ages (typically <5 Ma) to partially reset ages (up to ~ 80 Ma) with eastward distance from the Alpine Fault and increasing elevation. We exploit this predictive relationship between cooling age, eastward distance and elevation to map the source of modern sediment across the eastern flanks of the range. Exhumation of these partial annealing and retention zones east of the main drainage divide is further manifest in the appearance of reset cooling ages within peripheral basin sediments. To reconstruct the pace of Southern Alps exhumation, we further analyze detrital mineral lag-times preserved in late Miocene-Pleistocene peripheral basin sequences.

Detrital cooling ages from modern sediment samples indicate that erosion is preferentially focused at elevations near reconstructions of the late Pleistocene equilibrium line. We interpret this observation to suggest that eastern catchments remain in a topographic disequilibrium as relict glacial deposits continue to be recycled in deep glacial valleys, armoring the valley bottom and extending the timescale of landscape readjustment between glacial-interglacial periods. The absence of relatively young detrital mineral lag-time in late Miocene-Pliocene sedimentary basin units constrains a maximum of 2-4 km of pre-Quaternary rock exhumation, and suggests that 50-85% of the total mountain exhumation occurred during mountain glaciation. Thermo-kinematic modeling further suggests that lag-time observations may alternatively be explained by a progressive westward migration of the main drainage divide, reflecting an early exchange between topographic advection and the asymmetric erosion of mountain glaciers across a developing rainshadow.

Our observations are broadly consistent with global data compilations and decades of regional studies that demonstrate the power of glaciation to reshape mountain topography. More specifically, this work attests to the lasting influence of glaciation on intermontane sediment production during interglacial periods. Ongoing analytical work and thermo-mechanical modeling will expand upon this work to evaluate potential complications arising from the tectonic isolation of intermontane sediments in response to antithetic faulting.