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Progressive impact of glaciation on mountain erosion and topography: insights from in-situ thermochronometry

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Glacial processes have shaped conspicuous landscapes at the Earth surface. In alpine environments, glacial preconditioning of the topography exerts a strong control on the geomorphological response following glacier retreat. However, whether the late Cenozoic climate cooling and onset of glaciation have had a widespread impact on mountain erosion remains debated. Sediment budgets, in various mountain ranges and at a global scale, show an increase in sediment fluxes during the late Neogene, although their interpretation as proxy for increased erosion is challenged. In-situ low-temperature thermochronometry (including recent developments such as $^{4}He/^{3}He$ and OSL thermochronometry) records rock exhumation within the upper crust to quantify long-term erosion and relief histories. Here I will review some recent thermochronometric studies that investigate the mountain erosional and topographic response to glaciation, going from mid- to high-latitude regions.

In the European Alps, recent apatite $^{4}He/^{3}He$ data combined with thermal-kinematic modelling suggest a significant increase in topographic relief over the last ∼1 Myr, with 1-1.5 km of valley deepening by large and erosive glaciers. This episode is synchronous with the Mid-Pleistocene climatic transition from symmetric 40-kyr to strongly asymmetric 100-kyr glacial/interglacial cycles. Similar findings in other mountain ranges, as well as recent compilations at a global scale, point toward a globally averaged (but more pronounced at mid-latitudes) increase in erosion rates since 1-2 Ma. This would support the assumption that enhanced climatic variability during the Plio-Pleistocene, rather than cooling through the Late Cenozoic, has controlled mountain erosion and topography. However, in the high-latitude settings of the Patagonian Andes and southern Alaska, which have been glaciated since the late Miocene, new thermochronometric results show that a substantial increase in erosion had already occurred at ∼6-8 Ma, when alpine glaciers first appeared at these sites but under a less-oscillating climate. Interestingly, thermochronometric data also imply an increase in topographic relief since ∼1 Ma in these high-latitude settings.

These findings suggest that the erosional response to glaciation may have propagated equator-ward since the Late Miocene, quite simultaneously in both hemispheres. They also highlight threshold mechanisms in the erosional response to climate change, ultimately intensifying over the last 1-2 Myr when climate variability enhanced. Evaluating the influence of Plio-Pleistocene climatic oscillations on mountain erosion and topographic evolution now requires quantification of glacial erosion rates with higher temporal and spatial resolution.