Late Cenozoic Climate, Erosion, and the Topography of Mountain Belts

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Quantifying the feedbacks between tectonic processes in the lithosphere and climatic processes in the atmosphere is an overarching goal in Earth-Systems research. Long-term cooling during the Cenozoic has been linked to the growth of mountain belts, which enhanced erosion, chemical weathering, organic-carbon burial and drawdown of atmospheric CO_2. Conversely, it has been proposed that the cooler and more variable climate of the late Cenozoic led to increased topographic relief and erosion. However, the topographic and erosional response of mountainous topography to late-Cenozoic climatic cooling culminating in Quaternary glaciations, and the potential couplings and feedbacks between these processes, remain poorly constrained. Advancing our understanding requires the development of tools that record erosion rates and topographic relief changes with higher spatial and temporal resolution than the current state-of-the-art, and the integration of newly obtained data into next-generation numerical models that link observed erosion-rate and relief histories to potential driving mechanisms. Within the ERC-funded COOLER project, we have built a new $^4He/^3He$ thermochronology lab in Potsdam, developed numerical modelling tools that incorporate the latest insights in kinetics of thermochronological systems to make sample-specific predictions, coupled these tools to glacial landscape-evolution models to enable modelling of real landscapes with real thermochronology data as constraints and, finally, studyied potential couplings between glacial erosion, relief development, and tectonics in selected field areas. Here, we highlight some recent results focusing on newly obtained data from the European Alps, the Norwegian highlands, and the Kyrgyz Tian Shan, mountain belts that vary widely in both regional climatic setting and background tectonic activity. In all cases, the new $^4He/^3He$ thermochronology data provide evidence for localized Pliocene-Quaternary erosion of valley bottoms, attributed to glacial valley incision, that remained hidden or poorly constrained using conventional thermochronology data alone. Our data moreover highlight significant scale dependence of glacial valley incision, with larger, more heavily glaciated valleys recording a strong incision signal that is absent in adjacent smaller, less glaciated valleys.

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