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Glacial reorganization of topography in a tectonically active mountain range

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Tests of the interactions between tectonic and climate forcing on Earth's topography often focus on the concept of steady-state whereby processes of rock deformation and erosion are opposing and equal. However, when conditions change such as the climate or tectonic rock uplift, then surface processes act to restore the balance between rock deformation and erosion by adjusting topography. Most examples of canonical steady-state mountain ranges lie within the northern hemisphere, which underwent a radical change in the Quaternary due to the onset of widespread glaciation. The activity of glaciers changed erosion rates and topography in many of these mountain ranges, which likely violates steady-state assumptions. With new topographic analysis, and existing patterns of climate and rock uplift, we explore a mountain range previously considered to be in steady-state, the Olympic Mountains, USA. The details of our analysis suggest the dominant topographic signal in the Olympic Mountains is a spatial, and likely temporal, variation in erosional efficiency dictated by orographic precipitation, and Pleistocene glacier ELA patterns, and not tectonic rock uplift rates.

Alpine glaciers drastically altered the relief structure of the Olympic Mountains. The details of these relief changes are recorded in channel profiles as overdeepenings, reduced slopes, and associated knickpoints. We find the position of these relief changes within the orogen is dependent on the position of the Pleistocene ELA. While alpine glaciers overdeepened valleys in regions near the Pleistocene ELA (which has a tendency to increase relief), headward erosion of west and north flowing glacier systems captured significant area from opposing systems and caused drainage divide lowering. This divide lowering reduced relief throughout the range. We demonstrate similar topographic effects recorded in the basin hypsometries of other Cenozoic mountain ranges around the world. The significant glacial overprint on topography makes the argument of mountain range steadiness untenable in significantly glaciated settings. Furthermore, our results suggest that most glaciated Cenozoic ranges are likely still in a mode of readjustment as fluvial systems change topography and erosion rates to equilibrate with rock uplift rates.