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Climatic and tectonic influence on exhumation rates in the Olympic Mountains (USA): New thermochronometer data and thermo-kinematic modelling results

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The interplay between both climatic and tectonic processes and their effects on mountain building is still a matter of debate. Numerical modelling studies predict the strong response of the mechanics of mountain ranges to variation in denudation rates. Measurements and observations from mountain ranges in Alaska, Chile and Europe demonstrate the plausibility of these models, and show that topography, exhumation rates and exhumation patterns are heavily influenced by Pleistocene glaciation. Here, we present new thermochronometer data and results from thermo-kinematic modelling, in order to analyse the competing effects of both climate and tectonics on the development of the Olympic Mountains (USA). Situated at the Cascadia Subduction zone where the Juan de Fuca plate subducts beneath North America, the Olympic Mountains represent the exhumed portion of the subduction zone's accretionary wedge. Exhumation of the mountain range started at around 18 Ma and a strong spatial variation in exhumation rates can be observed. This is related to the location of the mountain range within an orogenic syntaxis, where the curvature of the subducted slab governs the exhumation pattern. Superimposed on the surface expression of the tectonic setting is the strong effect of Plio-Pleistocene glacial sculpturing of the mountains' topography.

To the existing thermochronometer dataset, we add several multi-dated thermochronometer samples, which allows resolving temporal variations in exhumation rates. We present 28 new apatite and zircon (U-Th)/He (AHe and ZHe, respectively), and apatite and zircon fission track (AFT and ZFT, respectively) ages for seven bedrock samples. AHe ages are generally young and AFT ages overlap with ZHe ages for five of the samples. We perform 1D thermo-kinematic modelling in order to obtain possible exhumation histories from our cooling ages. The best-fit histories suggest fast exhumation rates (>3 km/Ma) for five of the samples, starting at 7 – 8 Ma, followed by a strong drop in rates at $\sim$5 – 6 Ma with slow exhumation rates (<0.3 km/Ma) prevailing until $\sim$2 Ma. An increase towards faster rates (>1 km/Ma) is observed after 2 Ma for several of the samples. We interpret the observed drop in exhumation rates at 5 – 6 Ma to be a response to changes in the tectonic parameters, because our observed reduction in exhumation rates agrees with a decrease in subduction rates of the Juan de Fuca plate at around 6 – 7 Ma. The increase in exhumation rates at 2 Ma is contemporaneous with the onset of glaciation in the Olympic Mountains and we interpret it as glacial erosion signal.

Taken together, these results demonstrate the Olympic Mountains show rapid responses to both changes in the tectonic and climatic circumstances, suggesting that both "fluid" and "solid" earth contribute to the evolution of this mountain range.