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Tectonics, Climate and Earth's highest peaks

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Prominent peaks characterized by high relief and steep slopes are among the most spectacular morphological features on Earth. In collisional orogens they result from the interplay of tectonically driven crustal thickening and climatically induced destruction of overthickened crust by erosional surface processes. The glacial buzz-saw hypothesis proposes a superior status of climate in limiting mountain relief and peak altitude due to glacial erosion. It implies that peak altitude declines with duration of glacial occupation, i.e. towards high latitudes. This is in strong contrast with high peaks existing in high latitude mountain ranges (e.g. Mt. St. Elias range) and the idea of peak uplift due to isostatic compensation of spatially variable erosional unloading an over-thickened orogenic crust.

In this study we investigate landscape dissection, crustal thickness and vertical strain rates in tectonically active mountain ranges to evaluate the influence of erosion on (latitudinal) variations in peak altitude. We analyze the spatial distribution of serval thousand prominent peaks on Earth extracted from the global ETOPO1 digital elevation model with a novel numerical tool. We compare this dataset to crustal thickness, thickening rate (vertical strain rate) and mean elevation. We use the ratios of mean elevation to peak elevation (landscape dissection) and peak elevation to crustal thickness (long-term impact of erosion on crustal thickness) as indicators for the influence of erosional surface processes on peak uplift and the vertical strain rate as a proxy for the mechanical state of the orogen.

Our analysis reveals that crustal thickness and peak elevation correlate well in orogens that have reached a mechanically limited state (vertical strain rate near zero) where plate convergence is already balanced by lateral extrusion and gravitational collapse and plateaus are formed. On the Tibetan Plateau crustal thickness serves to predict peak elevation up to an altitude of about 5000 m suggesting that the topography is fairly well supported by local isostasy. In contrast, the highest peaks of the India-Asia collision zone seam the plateau rim and exceed the surface elevation predicted by crustal thickness and local isostasy. They are likely supported by the lithospheric strength of the northern and southern foreland basins and further uplifted by spatially variable unloading of the orogen due to major rivers and glaciers. Peak altitude, landscape dissection and the long-term impact of erosion on crustal thickness increase from the center of the Tibetan Plateau to the rim. However, we found evidence for a similar trend on a global scale from mid- to high-latitude orogens. Towards high latitudes, peaks of similar height are characterized by a more dissected landscape and supported by a thinner crust compared to mid-latitude mountain ranges. This however, would imply that the recent glacial period has already influenced orogens on their crustal level.

We propose that long-term glacial erosion in high latitudes may have already thinned the orogenic crust and conclude that (a) over-thickened crust in zones of plate convergence can buffer intense erosion and maintain high mountain topography over millions of years even in heavily glaciated orogens, (b) high peaks may persist or may even be uplifted due to glacial erosion and (c) glacial erosion limiting mountain topography may NOT work as simple as a buzz-saw applied to fluvial topography supported by a thick mountain root.