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Tectonics, Climate, and Mountain Topography

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By regressing simple, independent variables that describe climate and tectonic processes against measures of topography and relief of 69 mountain ranges worldwide, we quantify the relative importance of these processes in shaping observed landscapes. Climate variables include latitude (as a surrogate for mean annual temperature and insolation, but most importantly for the likelihood of glaciation) and mean annual precipitation. To quantify tectonics we use shortening rates across each range. As a measure of topography, we use mean and maximum elevations and relief calculated over different length scales. We show that the combination of climate (negative correlation) and tectonics (positive correlation) explain substantial fractions (> 25%, but < 50%) of mean and maximum elevations of mountain ranges, but that shortening rates account for smaller portions, <25%, of the variance in most measures of topography and relief (i.e. with low correlations and large scatter). Relief is insensitive to mean annual precipitation, but does depend on latitude, especially for relief calculated over small ($\sim$1 km) length scales, which we infer to reflect the importance of glacial erosion. Larger-scale (averaged over length scales of $\sim$10 km) relief, however, correlates positively with tectonic shortening rate. Moreover, the ratio between small-scale and large-scale relief, as well as the relative relief (the relief normalized by the mean elevation of the region) varies most strongly with latitude (strong positive correlation). Therefore, the location of a mountain range on Earth and corresponding climatic conditions, not just tectonic forcing, appears to be a key factor in determining its shape and size. In any case, the combination of tectonics and climate, as quantified here, can account for approximately half of the variance in these measures of topography. The failure of present-day shortening rates to account for more than 25% of most measures of relief raises the question: Is active tectonics overrated in attempts to account for present-day relief and exhumation rates of high terrain?
The following points are of particular importance:
1) Elevations of ranges directly reflect the interaction between tectonics, which thickens the crust, and therefore increases elevations, and climate (through erosion), which thins the crust, and hence decreases the elevation. The importance of tectonics appears to be modest in most cases, and suggests that although tectonics is obviously essential for mountain building, but the shapes of mature ranges appear to be controlled mostly by climate factors, that cause a large scatter.
2) Relief is not sensitive to mean annual precipitation amounts, but increases with shortening rates and latitude (hence glacial erosion). Relief averaged over large areas is not affected much by climatic factors, and more by tectonics, but relief measured on short distance scales correlates best with a combination of tectonics and latitude. Relief in high-latitude mountain ranges result largely from glacial excavation at valley scale of the topography created by tectonics.
3) The location of a mountain range on Earth appears to be an important factor in determining its elevation. Latitude also correlates with relief measured on short distance scales and the relative relief (the amount of relief scaled to the mean elevation of the range). Presumably, the climatic differences that vary with latitude, glaciers in particular, play a crucial role in shaping that relief.