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Interplay between tectonics and climate in orogenic growth: insights from the Alborz Mountains (N Iran)

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Physical calculations, field-based studies, analog experiments, and numerical simulations have shown that erosional efficiency in actively deforming orogens correlates with high near-surface rock-uplift rates. Such a correlation would call either for surface uplift caused by high precipitation or for orographic precipitation induced by high topography. This complex feedback highlights our difficulty in documenting unambiguously the causal links between tectonics and climate changes.

Located on the southern coast of the Caspian Sea, the Alborz Mountains (N Iran) are a sinuous, approximately E-W-striking, double-verging, orogen of the Arabia-Eurasia collision zone. With a length of 700-800 km, a width of 60-130 km, and peak elevations up to $\sim$5.6 km, this orogen forms an orographic barrier to moisture-bearing northerly winds. The northern flank is densely vegetated and receives > 2 m/yr of rainfall while the southern flank is sparsely vegetated and receives < 0.5 m/yr of rain. The range is characterized by a strong topographic asymmetry with the drainage divide shifted towards the south. The northern flank is steep and has a base level < 0 m a.s.l. (Caspian Sea) while the southern flank is less steep and is connected with Central Iran at an elevation of ca. 700-800 m a.s.l.. North-draining rivers show higher normalized steepness indices (ksn), often associated with pronounced knickpoints or transition zones separating steep upper segments from even steeper lower segments. Conversely, south-draining rivers are characterized by lower ksn values and few knickpoints, while the transversal drainages exhibit the lowest ksn values. The presence of segmented river profiles suggests that river channels are undergoing a transient response to change in forcing mechanisms. Furthermore, the northern flank seems to be characterized by higher rock-uplift rates than the southern flank. Interestingly, high ksn correlate positively with high rainfall. Considering that higher precipitation rates, and hence higher efficiency of surface processes at constant rates of rock uplift will favor a diminution in channel steepness, such a positive correlation suggests positive feedback between orographically induced precipitation and the near-surface rock-uplift rates.

Long-term uplift rates, however, do not seem to agree with this pattern in modern uplift rates. Our new zircon and apatite (U-Th)/He cooling ages together with available geologic data suggest that contractional deformation in the Alborz Mountains: 1) started at low rates during the latest Eocene-earliest Oligocene, 2) accelerated diachronously across different structures of the orogen during the early-middle Miocene, and 3) was renewed at ca. 6-4 Ma. Spatially, these data show that the greatest amount of exhumation occurred along the inner and southern sectors of the orogen. Moreover, paleoclimate data suggest that the range became an efficient orographic barrier during the early-middle Miocene. This indicates that although a strong climatic difference may have persisted since the middle Miocene, the Alborz range does not show strong gradients in exhumation as expected in orogens characterized by orographic precipitation, but rather a negative correlation on time scales > 106 yr.

This implies that for some reasons, which might include internal wedge dynamics, threshold effects, structural anisotropies, rheological properties or a combination of them, the positive feedback between orographically induced precipitation and rock-uplift rates must have been established only recently.