Thermochronologic approaches to paleotopography

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Low-temperature thermochronology constrains paleotopographic relief by relating spatial and temporal variations in cooling ages, erosion rates, and topographic or paleotopographic relief. Bedrock-based approaches use models of topographic effects on shallow-crustal thermal fields to invert relationships between modern topography and cooling ages for relief evolution. This approach has provided provocative evidence for ancient paleorelief and its change through time, which indirectly constrains paleoelevation.

Detrital low-temperature thermochronology has proliferated recently, motivated by the potential for entire-catchment sampling by rivers, and the opportunity to constrain paleotopography in older sediments. To first order, the population of cooling ages in a detrital sample is a function of three characteristics of its source catchment: 1) hypsometry (and topographic relief); 2) spatial variation in erosion rate; 3) temporal variation of erosion rate. Thus, single-grain cooling ages can be combined with constraints or assumptions on any two of these, to solve for the third.

Using this approach we measured detrital apatite He ages in modern and Eocene fluvial sediment from the western Sierra Nevada (San Joaquin, Kings, ancestral Yuba rivers) and eastern Washington Cascades (Icicle Creek). In modern Cascades sediment, observed detrital ages, catchment hypsometry, and the assumption of spatially uniform erosion, yield a synthetic age-elevation relationship suggesting slow erosion rates (~0.05 km/Myr) in the Oligocene, followed by a roughly eight-fold increase in the late Miocene. Modern San Joaquin river sediment shows a much narrower probability distribution (65±6 Ma) than spatially uniform erosion predicts from projecting existing bedrock ages through observed hypsometry. These data suggest focused erosion at intermediate elevations in the catchment, near margins of deeply incised and relatively low-relief upland regions. Finally, Eocene fluvial sediments in the ancestral Yuba drainage yield apatite He ages ranging from 40-115 Ma, with a probability peak at ~80 Ma. Together with estimates of erosion rates during this time (which are rapid in the Eocene, as evidenced by approximately syndepositional cooling ages) from multiple thermochronometric systems, this yields estimates of paleorelief in the ancestral Yuba drainage, and therefore adds constraints to paleoelevation of the early Cenozoic Sierra Nevada.