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Influence of rock strength variations on interpretation of thermochronologic data

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Low temperature thermochronologic datasets are the primary means for estimating the timing, magnitude, and rates of erosion over extended (10s to 100s of Ma) timescales. Typically, abrupt shifts in cooling rates recorded by thermochronologic data are interpreted as changes in erosion rates caused by shifts in uplift rates, drainage patterns, or climate. However, recent work shows that different rock types vary in strength and erodibility by as much as several orders of magnitude, therefore implying that lithology should be an important control on how landscapes change through time and the thermochronometer record of erosion histories. Attention in the surface processes community has begun to focus on rock strength as a critical control on short-term (Ka to Ma) landscape evolution, but there has been less consideration of the influence of this factor on landscapes over longer intervals. If intrinsic lithologic variability can strongly modify erosion rates without changes in external factors, this result would have important implications for how thermochronologic datasets are interpreted.

Here we evaluate the importance of rock strength for interpreting thermochronologic datasets by examining erosion rates and total denudation magnitudes across sedimentary rock-crystalline basement rock interfaces. We particularly focus on the ‘Great Unconformity’, a global stratigraphic surface between Phanerozoic sedimentary rocks and Precambrian crystalline basement, which based on rock strength studies marks a dramatic rock erodibility contrast across which erosion rates should decelerate. In the Rocky Mountain basement uplifts of the western U.S., thermochronologic data and geologic observations indicate that erosion rates were high during latest Cretaceous-early Tertiary denudation of the sedimentary cover (3-4 km over ∼10 m.y., 300-400 m/m.y.) but dramatically decelerated when less erodible basement rocks were encountered (0.1-0.5 km over ∼55 m.y., 2-9 m/m.y.). Similarly, the western Canadian shield underwent multiple Phanerozoic episodes of substantial (1-4 km) sedimentary rock burial and erosion, but total Phanerozoic erosion of the crystalline basement below the Great Unconformity was no more than a few hundred meters. We use published low temperature thermochronologic dates, the LandLab landscape evolution model, and 1D thermokinematic and erosion (Pecube) models to assess whether the observed deceleration of erosion can be explained by measured variations in rock strength alone. We use these results to consider the extent to which rock strength can change the cooling history recorded by thermochronologic datasets.