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Long-Term landscape evolution from apatite U-Th/He thermochronology in slowly eroding landscapes: Problems and potential from the southern Appalachians, U.S.A.

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Apatite U-Th/He thermochronology (AHe) is used extensively in tectonically active orogens to observe spatial and temporal variations in exhumation rates. As a result of the application of this tool much has been learned about linkages between tectonic, climatic, and erosive processes that have fundamentally changed our understanding of how these landscapes evolve and the drivers of that change. Despite the numerous successes of AHe dating in active regions, few researchers have attempted to use this tool to address questions of long-term landscape evolution in old, tectonically inactive regions. This disparity is unfortunate because decaying and dead orogens spatially account for a large portion of the surface of the earth, but our understanding of these landscapes lags behind their active counterparts. One reason for the lack research in areas characterized by slow exhumation rates (10s of m/Myr) is that AHe data from these settings typically suffer from varying degrees of poor age reproducibility, hindering interpretations of the processes driving landscape evolution. Here we propose several likely sources for the poor reproducibility observed, offer methods to mitigate or take advantage of the effects of these sources and present preliminary results from the Great Smoky Mountains of the southern Appalachians in eastern North America.

The accumulation of radiation damage within the apatite grain and implantation of He from radiogenic decay outside of the grain are both sources of age scatter that are exacerbated by the slow cooling experienced in regions of slow exhumation. He implantation can become a problem when the internal concentration of He producing radiogenic material (eU) is low. This causes ages to be too old because of the excess He, but the effects of implantation can be mitigated by abrading the outer 20 microns of the grain where externally produced He can be implanted. The accumulation of radiation damage impedes He diffusion and as a result the closure temperature for an individual grain is dependent upon the cooling rate and eU, slower cooling and higher eU results in greater damage and higher closure temperatures. A slowly cooled sample with aliquots spanning a wide range in eU will produce a range of ages which can be used as input for inverse modeling of the thermal history by taking advantage of the differences in closure temperatures those scattered ages represent.

In the Great Smoky Mountains of North Carolina the persistence of rugged topography and moderate relief in conjunction with significant accumulation of young sediment offshore is difficult to explain in the context of a decaying orogen. Short-term and and long-term estimates of erosion rates are equal and suggest steady and slow erosion at $\sim$20 m/Myr since the mid Cretaceous. Poor age reproducibility from traditional AHe analysis sheds little light on these conflicting evolution histories, however, physical abrasion of grains and accounting for radiation damage is showing promising results. Modeled thermal histories suggest unsteady behavior that corroborates geologic evidence for periods of increased erosion rates around 80 Ma and 20 Ma which were undetectable using other techniques. These results are intriguing for a landscape that typically is considered quite old and and illustrates the potential for AHe dating and these techniques in other slowly evolving landscapes.