Using Apatite Helium Thermochronology to Constrain the Thermal History of the Northern Appalachian Mountains of Vermont

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Around 450 million years ago, a series of tectonic collisions created the Appalachian Mountains of North America. These tectonic activities ceased around 350 million years ago and since then, the Appalachian Mountains have been situated within the passive margin of eastern North America, three thousand kilometers away from the tectonically active mid-Atlantic ridge. While we expect the mountain's modern passive setting to forecast quiescence for the Appalachians, studies in the region portray a contrasting picture.

Unusual observations in eastern North America imply activity contrary to what geologists expect from passive margins. Seismic imaging of sub-surface structures reveals a recent development of anomalously hot upper mantle under the Northern Appalachians (1). And sedimentary basins along the Appalachians have seen pulses of sediment accumulation, suggesting that the Appalachians have been uplifting (2).

My research uses apatite helium thermochronology to characterize the exhumation history of the Northern Appalachians and determine the timing and magnitude of potential uplift of the mountains in order to interpret the geologic processes that have been governing eastern North America since it became a passive margin.

Apatite helium thermochronology exploits the mineral apatite's ability to retain or release helium in response to thermal conditions. When a rock is deeper underground, it is exposed to higher temperatures, causing its composing apatite minerals to release helium. As a rock reaches the surface, through erosion of overlying rock, it reaches relatively lower temperatures, causing its composing apatite minerals to hold onto helium. Taking advantage of the known rate of helium production through radioactive decay, the effect of mineral size on helium diffusion, and the effect of radiation on helium retention, we can determine the date when a rock reached a depth that is cool enough to retain helium. In this way, apatite minerals essentially hold a record of any particular rock's journey to the surface.

My research focused on creating models that predicted the possible thermal histories of the four samples collected from varying elevations at the Green Mountains and identifying the tectonic and climatic mechanisms contributing to the mountains' exhumation history.

The resulting models suggest a period of rapid exhumation around 120 million years ago, which is consistent with the exhumation histories of surrounding mountains in New York and New Hampshire. The timing of exhumation is synchronous to North America's passage over a hotspot, whose thermal features could induce an uplift reaction. However, the extent of rapid exhumation ~100 million years ago favors a larger mechanism, such as a mantle anomaly that spanned the Atlantic Ocean at the time.

The resulting models also reveal very limited exhumation—only about 1.5 kilometers—in the last 90 million years, which disputes contributions from the seismically imaged modern, hot mantle anomaly to the Northern Appalachians' exhumation history.

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References
1. Menke, William, et al. “Crustal Heating and Lithospheric Alteration and Erosion Associated With Asthenospheric Upwelling Beneath Southern New England (USA).” *Journal of Geophysical Research: Solid Earth*, vol. 123, no. 10, June 2018, pp. 8995–9008, doi:10.1029/2018JB015921.
2. Poag, C. Wyli., and William D. Sevon. “A Record of Appalachian Denudation in Postrift Mesozoic and Cenozoic Sedimentary Deposits of the U.S. Middle Atlantic Continental Margin.” *Geomorphology*, vol. 2, no. 1, 1989, pp. 119–57, doi:10.1016/0169-555X(89)90009-3.