Constraining the mid-to-low temperature thermal history of the Central Appalachian Mountains using zircon (U-Th)/He thermochronology

Luke Basler, 2020

The Appalachians Mountains are an ancient range formed between 250 and 500 million years ago (mya) through multiple collisions of tectonic plates that uplifted them to heights comparable with the modern-day Himalayas. The old age of the Appalachians stands in apparent contrast to the prevailing geologic belief that the erosive power of rivers and glaciers can level mountains in a mere 100 million years. Even today, the range exceeds 6,500 feet in elevation, and geologists have proposed that non-tectonic forces may have caused the longevity of the Appalachians, and, controversially, that topographic uplift continues to occur today.

The recent uplift hypothesis is debated in part because the Appalachian Mountains are currently located among a passive, tectonically quiet margin. While topographic development is often limited to active tectonism, when the geologically violent collision of plates builds mountains, some believe that the unique lithospheric structure of the Appalachians may be responsible for recent uplift. Specifically, lithospheric delamination, a process by which a piece of the brittle lithosphere breaks off and sinks into the semi-viscous asthenosphere below, is a commonly proposed mechanism. While a wide array of geologic data, including geomorphic and geophysical data, supports modern-day lithospheric delamination as an uplift mechanism, the thermal history of the region remains poorly constrained. The thermal history of a region documents the time at which certain rocks experienced a specific temperature, and allows for geologists to draw interpretations about the development and erosion of mountains. Although both the low and high temperature history is known, a ~300 million year gap currently exists in the thermal record, precluding interpretations about the long term uplift and erosional history of the Appalachians. To bridge this gap, we applied zircon (U-Th)/He thermochronology, a mid-temperature geologic dating technique, to rocks from the Appalachian Mountains.

Thermochronology is employed to determine the thermal history of a region, which can uncover the uplift and erosional past of a mountain range. Thermochronology takes advantage of the natural radioactive decay of trace elements, such as uranium, found within specific mineral types. As uranium decays, it releases helium at a predictable rate into a mineral grain. Deep within the earth, where temperatures are hotter than the surface, the helium easily diffuses out of the mineral. However, as rocks are exhumed to the surface, via uplift or erosion, temperature cools to a point at which helium is retained with the mineral grain. This temperature is known as the closure temperature. By measuring the amount of uranium and helium present, geologists can thus pinpoint the date at which the rock reached its closure temperature. Since temperature is correlated with depth within the crust, these data provide evidence for the vertical movement of rocks, thereby revealing the timing of uplift or erosion. The closure temperature of the zircon (U/Th)-He thermochronometer is 150-220 C, allowing it to document exhumation through the upper ~10 km of crust. The closure temperature of this system depends on both the size of the zircon grain and the amount of self-induced radiation damage of the grain, enabling the construction of detailed thermal histories.

Our sampling strategy targeted the Appalachian Mountains in Virginia, West Virginia, and Vermont. Prior geophysical work indicates that the Earth below these regions is unusually warm, signaling that uplift may also be occurring. The presence of hot springs, recent (~50 Ma) Virginia volcanism, and river profiles and topography lacking erosional equilibrium also suggests that topographic rejuvenation is occuring. In both sites, we collected rock samples on a transect across the axis of the Appalachian Mountains, and then processed the samples to isolate the mineral zircon. At the University of Colorado Thermochronology and Instrumentation Laboratory, high quality zircon grains were selected and processed for thermochonologic dates. Results of the study are forthcoming.

Advisor: Professor Jaclyn Baughman
Funded by the Hughes Family Summer Research Fellowship