Elevation, burial, and erosion history across the North American continental interior from low temperature thermochronometry

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Although cratons are the most stable portions of continents, it is increasingly appreciated that some cratonic interiors underwent a relatively dynamic history of burial, denudation, and elevation change. A classic example is the cratonic interior of the North American continent, where stratigraphic and hypsometric studies suggest that the craton has not remained static since cratonization. Low temperature thermochronometry is an especially powerful tool for deciphering this history, allowing resolution of depositional and erosional episodes even when the associated stratigraphic units are no longer preserved in the rock record. Here we present new and published low temperature thermochronometry data for ~65 samples, mostly of exposed Precambrian basement, from the western Canadian shield and northern and central U.S. midcontinent. These data are used to resolve the thickness, spatial extent, and evolution of missing portions of the Phanerozoic sedimentary record, and document distinct spatial heterogeneity in this history across ~3500 km of the North American continent. All data acquired across the Canadian shield and as far south as southern Minnesota record a pronounced heating and cooling event in Paleozoic–early Mesozoic time. This pattern, coupled with geologic observations, indicates that an extensive region of the continent was inundated and buried by 2.5 to ≥3.5 km of largely marine sedimentary rocks in Paleozoic time, with increasing depth of burial to the northwest, followed by significant Paleozoic–early Mesozoic unroofing that removed these strata from the rock record. Precambrian basement drillcore samples in Kansas, Missouri and Arkansas record an additional significant heating and cooling event in Cretaceous time that is absent or of lesser intensity in the Minnesotan and Canadian samples.

These thermochronometry data demand vertical motion of the craton to explain these patterns. The Paleozoic-early Mesozoic deposition and erosion history is opposite that expected from eustatic sea level chronologies, indicating that global sea level change is not the primary driver. Rather, a three-dimensional thermochemical convection model that explores the evolution of Earth's mantle structure during Pangea assembly and breakup predicts vertical motions due to dynamic topography that compare well with the long wavelength-low amplitude burial and unroofing history as recorded by our Canadian shield samples. This result is compatible with the notion that mantle flow associated with supercontinent evolution may have had an important influence on the hypsometry of the North American interior. The presence of 100 Ma marine sedimentary rocks in the Slave craton at modern elevations of ~500 m requires several hundred meters of post-100 Ma elevation gain, consistent with similar surface uplift after mid-Cretaceous time inferred across much of North America. The Cretaceous signal of burial and unroofing in the U.S. midcontinent appears spatially restricted, and indicates several km greater deposition and erosion in this time interval than the preserved record suggests. Full understanding of the significance of this history must integrate the tectonic evolution of the western U.S. plate boundary with mantle tomography, plate motion, and mantle dynamic models. Our work highlights the utility of thermochronometry to decipher otherwise inaccessible portions of the stratigraphic history in continental interiors and thereby place key constraints on the still poorly understood history and causes of elevation change in these settings.