Was Archean crust hot?

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The assumption that continental crust was hot in the Archean largely stems from the fact that the global budget of heat producing elements was higher in the Archean. Petrologic and theoretical studies indicate higher mantle potential temperatures in the Archean, and these estimates result in the generation of basalts through higher degree melting of mantle lithologies. Though the magnitude of these estimates come with large uncertainties, for a given mantle composition, basalts created through higher degrees of partial melting should have lower concentrations of heat producing elements compared to basalts created through low degrees of partial melting. And thus arises a hypothesized negative feedback between a hotter mantle and lower heat production in a crust spawned by basalt accumulation and subsequent differentiation.

To test this hypothesis we assembled a large database of several hundred thousand igneous rock samples spanning in age from the Archean to the present. We used statistical tools to automate outlier rejection and reduce sampling biases from the global database to arrive at our best estimate for concentrations of heat producing elements in igneous lithologies over earth history. The results confirm the hypothesis that heat production in low silica igneous rocks at the time of their formation has not changed over geologic time. However, modest differences exist at higher silica, perhaps arising from igneous differentiation within the crust.

By combining our dataset with global databases for geophysical characteristics of the crust, we attempt to quantify the distribution of heat producing elements within the upper, middle, and lower crust through time. These estimates are used as inputs into a finite difference thermal model for lithospheric thermal evolution to compare the temperature-time histories through a modern orogeny dominated by igneous lithologies to an Archean one. The results show that differences in heat production are inadequate to explain any observed differences, on average, between modern and Archean mountain belts, and permit the existence of thick, buoyant, continental crust in the Archean capable of sustaining high topography.