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Billion year thermal histories constrained by zircon (U-Th)/He age-eU correlations: Examples from the Laramide and Sevier Provinces of the western U.S.

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Recent advances in zircon (U-Th)/He low-temperature thermochronology have shown that radiation damage plays an important role in governing the kinetics of He diffusion in zircon and therefore affects ages. This effect manifests as positive and negative correlations between zircon He ages and effective uranium (eU), a proxy for relative damage. These correlations both explain dataset complexity and greatly expand the scope of time-temperature space that can be constrained with zircon He ages. Here, we present examples of both of these attributes with two datasets from the western United States. The first dataset comes from Wyoming craton crystalline rocks exposed in the hanging wall of a major Laramide thrust fault in the Wind River Range. Zircons (54 single grains) show a range of He ages from 540 Ma at low eU concentrations to an age-eU "pediment" of multiple ~40 Ma ages that span eU concentrations from 1000-7000 ppm. With a model that describes the coevolution of damage, diffusivity, and He age, this age-eU correlation is used to constrain the Proterozoic and Phanerozoic thermal history of Laurentian basement in the northern Rocky Mountain region. Our best fit history includes two phases of cooling at 1800-1600 Ma and 900-700 Ma followed by reheating during the Phanerozoic to maximum temperatures between 160-125°C, and final Laramide cooling to 50ºC between 60-40 Ma. This thermal history is therefore consistent with more recent cooling related to the Laramide orogeny, as well as cooling associated with Yavapai-Mazatazal tectonism and two phases of Mesoproterozoic-Neoproterozoic intracratonic extension.

The second dataset consists of detrital zircon grains collected from sedimentary units in the Oquirrh Mountains of central Utah. These data are complex and difficult to interpret as the samples contain grains that are only partially reset and possess different pre-depositional thermal histories. In order to explain this complexity and constrain burial and exhumation in this particular basin, we present an "inheritance envelope" approach for interpreting partially reset detrital zircon (U-Th)/He datasets. This approach uses forward modeling of thermal histories, combined with a damage-diffusivity model and a series of pre-depositional He ages to construct "inheritance envelopes". A forward modeled time-temperature path is a permissible thermal history if an inheritance envelope encompasses the observed age variation in a given dataset. For the Oquirrh dataset, a time-temperature path with a maximum burial temperature of ~170 °C and an initial Sevier-belt related exhumation event at 110 Ma successfully captures the large observed age variation. These results demonstrate that our inheritance envelope approach can be used to describe maximum burial temperatures and the timing of initial exhumation in detrital zircons from sedimentary basins.