Trace element clustering in Jack Hills zircons: New results and future directions

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Atom probe tomography (APT), and its ability to characterize the atomic-scale distribution of trace elements and isotopes in three dimensions, represents a novel means to understand the cryptic thermal histories of ancient zircons. This is particularly relevant for detrital grains, many of which are known to possess complex histories, but are missing the compositional, textural and mineralogical context of their protolith. We present data for two new Jack Hills zircons, bringing the total number of Jack Hills zircons studied by APT to four. Zircons in this study possess $^{207}Pb/^{206}Pb$ core and rim ages of 3904±3 (core) and 3589±5 Ma (rim), and 4265±4 Ma (core) and 4089±6 Ma (rim), respectively. The two zircons contain distinct styles of nanoscale clustering: (1) a small number of clusters (<2 clusters/10^6 nm^3) enriched primarily in Pb and (2) numerous clusters (22-36 clusters/10^6 nm^3) enriched in Y and other trace elements with smaller Pb enrichments. In both cases, the textural and isotopic trends observed on the micron scale by SIMS are recorded on the nanoscale and, like other APT studies in the Jack Hills, these nanoscale features have persisted since their formation.

These observations add to a growing body of zircon APT data documenting nm-scale trace-element-rich domains in zircon. In aggregate, these data provide empirical context for using APT to extract cryptic time, temperature and structural information not seen on coarser spatial scales [1]. To better understand the opportunities and limitations for APT in zircon nanogeochronology, we model how cluster detection, and uncertainties for Pb isotope ratios vary as a function of several variables, including U and Th content, crystallization age, cluster formation age(s), and cluster volume fraction. The physical manifestation of clusters directly influences both their detection and the precision of Pb isotope ratios; this has implications for where and when in geologic history APT analysis may be advantageous.

[1] Blum et al. (2018) AGU Monograph, 232, 327–349.