Sensitivity and uncertainty in nanoscale geochronology by atom probe tomography

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Atom probe tomography (APT) provides new insight into the nanoscale behavior of trace components in zircon, and their relationship to cryptic thermal histories [1]. Spectral analysis of APT data requires identification of each peak and integration of counts between user-defined range bounds. For major elements, concentrations are relatively insensitive to the fine adjustment of range bounds; however, nanoscale $^{207}Pb/^{206}Pb$ geochronology utilizes the ratio of isotopes present at trace levels, and thus is more sensitive to the details of ranging and background correction. We present a systematic ranging and error propagation protocol to assess (1) the uncertainty in $^{207}Pb/^{206}Pb$ resulting from spectral analysis including placement of peak integration bounds, count binning, and counting statistics, and (2) how spatial identification of clusters may influence observed ratios. This analysis utilizes three APT data sets for a 3.77 Ga zircon from the Beartooth Mountains, Montana, USA. This zircon possesses two, 100% concordant U-Pb analyses by ion microprobe, indicative of a closed U-Pb system on the micron scale since crystallization. APT data sets contain a small number of sub-spherical Pb-rich (>0.25% atomic) domains with diameter <15 nm, which are isolated using six different cluster identification protocols. Each of these cluster ID algorithms define broadly consistent regions within the data sets, though the exact number, and size, of clusters varies. $^{207}Pb/^{206}Pb$ within clusters varies between 0.80 ± 0.12 (±2 SD; 737 total Pb atoms) to 0.72 ± 0.06 (2678 total Pb atoms), depending on cluster definition protocol, and number of clusters interrogated. In all cases here, errors are dominated by counting statistics. These ratios are consistent with the clustering of Pb culminating at ~2.8Ga, during metamorphism in the Beartooth mountains [2,3]. We expand upon these results with modeling of anticipated matrix and cluster Pb concentrations and isotope relations for a variety of time-temperature histories to evaluate the utility of APT in nanoscale zircon geochronology throughout earth's history.

[1] Valley et al. (2015) *Am. Min.* **100**, 1355-1377. [2] Henry et al. (1982) *Mont. Bur. of Mines and Geol. Spec. Pub.* **84** 147-156. [3] Mueller et al. (1992) *Geology* **20** 327-330.