Supplemental Info: Zircon trace element analytical methods using Stanford-USGS SHRIMP-RG

Zircon grains were separated from crushed and ground bulk igneous rock samples using standard magnetic and heavy liquid techniques (Strong and Driscoll, 2016), hand-picked under a binocular microscope, and mounted in 2.54-cm epoxy discs. Epoxy mounts were ground to expose grain interiors, polished, and imaged using cathodoluminescence (CL) for zircon on a scanning electron microscope (SEM) to identify internal structure (rims, core, etc.). A grain of Mad-1 zircon standard was also added to most mounts. LAICP-MS analyses were performed at the Geology, Geochemistry and Geophysics Science Center in Lakewood, CO prior to trace element work. Methodology, run parameters, and U/Pb geochronology data are available in Holm-Denoma et al. (2022. To ensure trace element (TE) analyses were targeting the correct zircon populations, careful spot selection was determined by matching the LA-ICP-MS laser pits to individual zircon grains in CL images. TE points were selected within the same internal zones (e.g. core, rim, or growth zone) on the CL images of each zircon grains included in the interpreted sample age presented in Holm-Denoma and others (2022). Whole rock geochemistry data for samplescontained within this dataset are also available in Todd and others (2022).

Samples were analyzed over multiple analytical sessions between 2019 and 2020 on the SHRIMP-RG. Secondary ions were generated from the target spot with a O2- primary beam varying from 1 to 5 nA. Mineral surfaces were rastered by the primary beam for 120-180 seconds before data were collected. The primary ion beam typically produced a spot diameter of 20-25 micrometers and a depth of 1–2 microns for an analysis time of approximately 15 minutes.

Trace elements (Li, B, F, Na, Al, P, K, Ca, Sc, Ti, Fe, Y, Nb, REE, Hf, Ta, Pb, Th, and U) were measured in mass order. Mounts were analyzed with one scan (peak-hopping cycles from mass 46 through 248) and measurements were made at mass resolutions of $M/\Delta M$ = 7500–8500 (10% peak height). Concentration data for all of the measured trace elements were normalized based on analyses (n=10 per mount) of the MAD-1 zircon (Coble et al., 2018) during the same sessions. Internal precision, based on the repeat analyses of MAD-1, is quantified by standard deviation (2σ) of about ± 30% for Li, ± 100% for B, ±100% for F, ± 75% Na, ± 10% for P, ± 65% for K, ± 50% for Ca, ± 15% for Sc, ± 5-10% for Ti, ± 20% for Fe, ± 3% for Y, ± 13% for Nb, ± 30% for La, ± 5% for Ce, ± 10% for Pr, ± 25% for Nd, ± 20% for Sm, ± 10% for Eu, ± 5% for Gd, ±5% for Ho, ± 15% for Tb, ± 15% for Dy, ± 5% for Er, ± 20% for Tm, ± 5% for Yb, ± 5% for Lu, ± 5% for Hf, ± 20% for Pb, ± 5% for Th, ± 5% for U, and ± 10% for Ta. Data reduction was done in Excel, using the Squid 2.51 (Ludwig, 2012) add-in. Equilibrium crystallization temperatures (˚C) for zircons were calculated using the Ti-in-zircon thermometer, after Ferry and Watson (2007), assuming SiO_2 activity ($aSiO_2$) of 1.0 for silica saturated rocks; TiO_2 activity ($aTiO_2$) is assumed to be 0.7. Temperatures in Table[*sampleSummarySHRIMP-RGdata*] are calculated from representative median Ti concentrations of a sample population (i.e., they are not the mean of single-grain temperatures in Table[*SHRIMP-RGData*])

Every effort was made to select analytical points free of non-zircon inclusions. In some grains, though, nano-inclusions may have been encountered by the beam during analysis. Trace element median values in Table[*sampleSummarySHRIMP-RGdata*] exclude zircon grains with anomalous trace-element concentrations that were presumed to have been imparted on the signal by nano-inclusions (for example, apatite, feldspar, or ilmenite) in zircons that were not observable in CL images. Monitoring for inclusions relies on elevated Ca, Na, K, P, Ti, and REE concentrations relative to reasonably expected values for a zircon. Chondrite-normalized REE patterns and MREE and HREE concentrations are also compared in order to determine if zircon grains represent a single population. Spot analyses excluded from calculations of maximum, minimum and median trace element concentrations shown in

Table[*sampleSummarySHRIMP-RGdata*] are indicated in Table[*SHRIMP-RGData*] by "Yes" in the column "**Excluded_median**".

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