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SUPPLEMENTAL METHODS DETAILS

SIMS Zircon U-Th-Pb Geochronology and Trace Element Geochemistry

Zircon U-Pb ages were acquired using the SHRIMP-RG at the Stanford U.S.G.S. MicroAnalysis Center (SUMAC). Reflected light and SEM-CL and BSE imaging done at SUMAC were used to determine optimal sputter pit diameter and guide pit placement for analytical sessions. Larger pits were used for zircons with CL textures indicative of relatively homogenous Pb/U and trace element concentrations (e.g., zircons from plutons), whereas smaller pits were used for more complex grains requiring finer spatial resolution. The resultant pits were a fixed size for an analytical session and ranged from ~10 to 35 μm in diameter by ≤2 μm deep.

Run table acquisition parameters for masses of interest were calibrated on MAD-Green zircon (Barth and Wooden, 2010; Coble et al., 2018) before the analytical session. Acquisition of unknowns was interspersed with measurement of a primary age standard (either R33 or Temora2 zircon) every 3-4 analyses. Temora2 was the primary age standard used for mount ESG43 and all other mounts were standardized with R33. MAD-Green was analyzed 3-5 times during an analytical session to be used as a concentration standard. Immediately prior to data acquisition for a given spot, a 2- to 6-nA O_2^- primary beam was rastered for two minutes to remove gold from the intended analytical spot. Primary beam current varied on an inter-session basis, proportional to pit area. During geochronology analysis, five cycles of measurement of relevant masses for U-Th-Pb geochronology ($^{196}[Zr_2O]$, ^{204}Pb, ^{204}[background], ^{206}Pb, ^{207}Pb, ^{208}Pb, ^{232}Th, ^{238}U, ^{248}[ThO], ^{254}[UO], $^{270}[UO_2]$) and selected trace elements (see below) were made in ascending mass order. Care was taken to maintain reasonable distance between sputter pits to minimize secondary extraction field irregularities, especially in magmatic overgrowth

(i.e., "rim") domains. Thus, multiple analyses on a grain of interest involved multiple analytical sessions so the mount could be cleaned and re-coated with gold between sessions.

Ages (^{204}Pb corrected- ^{206}Pb/^{238}U, ^{207}Pb/^{206}Pb, and ^{208}Pb/^{232}Th, ^{207}Pb corrected- ^{206}Pb/^{238}U, and ^{208}Pb corrected- ^{206}Pb/^{238}U) were reduced with Squid2 (Ludwig, 2009) using published TIMS results for age standard Pb/U vs. UO/U calibrations (R33, 419 Ma; Temora2, 418 Ma, Black et al., 2004). The age results from 40 (of 425 total) analyses of unknowns are suspected due to various considerations discussed in results, but are included in the data table with strikethroughs over Best Age results[1]. Over twelve analytical sessions, the long-term reproducibility of the primary age standards (as indicated by 1s error in the weighted mean of the ^{207}Pb corrected ^{206}Pb/^{238}U calibration constant) ranged 0.25–0.86%. Zircon 91500 was run as a secondary age standard (Wiedenbeck et al., 2004) on mount ESG43, results from which are included in data table S1.

Weighted mean and concordia ages were calculated using *Isoplot 3.75* (Ludwig, 2012), with a systematic error of 0.86% (1s, based on poorest precision of calibration constant over all analytical sessions) propagated into final results of each age population. All uncertainties in text and figures are shown at the 95% confidence level, with total uncertainty including propagated systematic error shown in square brackets. Plots of the age results were generated using Isoplot 3.75 (Ludwig, 2012). For determination of crystallization ages, we used "Best age" results in bold from the datatable[1]. Because data were collected during multiple analytical sessions, we used two different methods for combining data from the sessions for each sample, and adopted the method that yielded the lowest MSWD for each sample. For samples 20-210, SCKG, NS3A, ELM89DM, and TUNG, the weighted average ages were calculated by combining the individual results from different analytical sessions into a single population of results, with systematic error

propagated into the weighted average result. For samples NS2A and SS1, weighted averages were calculated from each analytical session, and from those a final "intersession" weighted average for each sample was calculated, with systematic error propagated into the final result.

Kernel density estimates of ages were plotted using *densityplotter* (Vermeesch, 2012) with bandwidth set at the mean (1s) uncertainty for the population. For inherited zircon domains that yielded older than Mesozoic age results, the Best Age results[1] were systematically picked from ^{207}Pb corrected $^{206}Pb/^{238}U$ (U/Pb, herein) and ^{204}Pb corrected $^{207}Pb/^{206}Pb$ (Pb/Pb, herein) results. For all Pb/Pb ages younger than 700 Ma, the U/Pb age is used. For ages over 700 Ma, the Pb/Pb ages are used unless the following combination of conditions are met, at which point U/Pb ages are substituted: Pb/Pb results yield >10% 1s error, Pb/Pb analytical error is double (or more) of U/Pb analytical error, U/Pb and Pb/Pb results overlap at 2s analytical uncertainty and discordance is ≤+5%. Discordance percentage values were calculated from ^{204}Pb corrected $^{207}Pb/^{206}Pb$ and ^{207}Pb corrected $^{206}Pb/^{238}U$ age results.

Concentrations and ratios of selected trace elements were measured in magmatic and inherited zircon domains. Trace element concentrations reported were calculated with SQUID 2 (Ludwig, 2009) using methods of Klemetti and Clynne (2014) ($^{196}Zr_2O^+$ normalized to MAD-Green; Barth and Wooden, 2010, or MADDER; Klemetti and Clynne, 2014). In magmatic domains, patterns of systematic variation in zircon trace element concentrations and ratios are assessed to understand fractionation trends captured by zircon populations in each sample. Most trace element measurements reported were made as part of the peak hopping cycle during geochronology analyses described above, and therefore document geochemistry of the same sputtered material that yielded the age results. This approach provides critical information when assessing age results that are suspected to represent mixtures between multiple age (and

geochemical) domains in a zircon. Grains TUNG–300 and TUNG–302 thru 355 were analyzed in a session that excluded most trace elements, only yielding Hf, Pb, Th, and U concentration data (in addition to the ages). Twenty-six trace element analyses without corresponding U–Pb geochronology (methodology of Klemetti and Clynne, 2014) collected on selected zircons from sample TUNG are labeled with suffix R in the datatable[1].

SIMS Zircon Oxygen Isotope Analyses

KIM-5 zircon standard grains (Valley, 2003, $\delta^{18}O$ = 5.09‰ VSMOW) were top-mounted in the center of polished grain mounts containing samples to be analyzed for oxygen. Positively charged ions from the Cs-source were tuned into a 10-μm diameter 2-nA $^{133}Cs^{+}$ beam spot. A normal incidence electron gun and gold coat were used for charge compensation. Peaks for $^{16}O^{-}$, $^{16}O^{1}H^{-}$, and $^{18}O^{-}$ were measured by FC detectors in multicollector mode. Unknowns were analyzed and corrected using eight standard analyses of KIM-5 bracketing (i.e., four before and four after) every 10-15 unknowns, as described by Valley and Kita (2009). The oxygen isotope data are reported in the standard δ notation in per mil (‰) relative to Vienna standard mean ocean water (VSMOW). Reproducibility of the bracketing standards ranged from ± 0.21 to ± 0.35 and averaged ± 0.25‰ (2SD). Zircon 91500 was measured as a secondary standard to monitor accuracy during the analytical session (Wiedenbeck et al., 2004). Ratios of $^{16}O^{1}H^{-}/^{16}O$ serve to monitor for accidental sputtering of hydrous phases or radiation damaged domains included within zircons (Wang et al., 2014). The full α-dosage for Precambrian age zircon domains were calculated from SHRIMP-RG determined U, Th and age results using the equation in Wang et al. (2014). Sample averages are reported as $\delta^{18}O$ mean values ± 2SD. Following

oxygen isotope analyses, secondary electron images of each sputter pit were obtained with a JEOL5600 scanning electron microscope to ensure pits were free of non-zircon inclusions.

Zircon Lu-Hf Isotopic Analyses (LA-ICP-MS)

Laser ablation Lu-Hf analyses were carried out on zircons in polished grain mounts from four samples (NS2A, NS3A, SS1, and TUNG). Zircon cathodoluminescence imagery and results of ion microprobe analyses were used to guide laser pit placement for Lu-Hf analyses, with consideration given to laser ablation analyte volumes being considerably deeper than ion microprobe analyses and the depth of investigation cathodoluminescence imaging. For analyses of samples NS2A, NS3A, and SS1, analytical work was done on previously dated domains. For analyses of sample TUNG, the laser ablation split stream (LASS) method (described below) was employed to simultaneously measure and monitor U–Pb geochronology isotopic ratios while measuring Hf isotopes in order to detect inadvertent analysis of different crystal domains. A few Mesozoic age zircon xenocrysts were also analyzed, three from sample TUNG and one from sample SS1. Hafnium isotopic analysis of Precambrian inheritance was predominantly focused on zircons from sample TUNG.

Samples were ablated with a New Wave 213 nm Nd:YAG laser using a 40 μm diameter circular laser spot. Data acquisition and reduction protocol were as described in section 2.2.2 of Fisher et al. (2014a) using Mudtank zircon as the primary standard ($^{176}Hf/^{177}Hf = 0.282507$) and R33 (Fisher et al., 2014a,b), Plesovice (Sláma et al., 2008) and synthetic zircon MUNZirc-4 (Fisher et al., 2011) as secondary standards. Ratios of $^{176}Hf/^{177}Hf_{initial}$ and $\varepsilon Hf_{initial}$ values were calculated using U-Pb ages from this study, $\lambda = 1.867 \times 10^{-11}$/yr, present day $^{176}Lu/^{177}Hf_{CHUR} = 0.0336$ and present day $^{176}Hf/^{177}Hf_{CHUR} = 0.282785$ (CHUR=chondritic uniform reservoir;

Söderlund et al, 2004; Bouvier et al., 2008). Sample averages are reported as $\varepsilon Hf_{initial}$ mean values ± 2SD relative to CHUR. Of the total dataset of unknowns analyzed (n=32), 10 of the analyses required trimming of integration windows to exclude data collected after unintentionally ablating through zircon into underlying epoxy.

Zircon U-Pb Geochronology and Lu-Hf Isotopic Analyses (LASS)

Hf isotopic ratios and U-Pb ages of zircons from sample TUNG were measured simultaneously by the laser ablation split stream (LASS) method described by Fisher et al. (2014a). Using SEM-CL and BSE imagery, LASS analyses were targeted at either "core" or "rim" domains to gain insights regarding the Hf isotopic relationship between inherited and new zircon growth. Split stream work allowed monitoring of unintended ablation out of the targeted domain and provided verification of SIMS ages on previously dated grains and new ages on previously undated grains.

The laser cell configuration was identical to laser Hf analyses described above, with the exception of a branched flowline attached to the laser cell outflow so the analyte was split and delivered to both mass spectrometers. Configuration of instrumentation and data acquisition/reduction protocols are described in Fisher et al. (2014a) and Chang et al. (2006). For Hf isotopic analyses, Mudtank zircon was used as the primary standard and R33, Plesovice and FC1 (Fisher et al., 2014a,b) zircons were used as secondary standards (reported in Tables S4 and S5). Laser pit locations are indicated on CL images of polished zircon grains included as a Data Repository item.

For LASS U-Pb analyses, Plesovice zircon, FC1 zircon, and NIST 610 glass standards were used to calibrate Pb/U, Pb/Pb and Th/U ratios respectively. Ratios of $^{176}Hf/^{177}Hf_{initial}$ and

$\varepsilon Hf_{initial}$ values for magmatic zircon domains in sample TUNG were calculated using the SHRIMP-RG U-Pb pluton crystallization age obtained in this study, measured $^{176}Lu/^{177}Hf_{zircon}$ values, $\lambda = 1.867 \times 10^{-11}$/yr, present day $^{176}Lu/^{177}Hf_{CHUR} = 0.0336$, present day $^{176}Lu/^{177}Hf_{DM} = 0.038512$, present day $^{176}Hf/^{177}Hf_{CHUR} = 0.282785$, and present day $^{176}Hf/^{177}Hf_{DM} = 0.283225$ (DM=depleted mantle). For inherited zircon domains that gave LASS $^{206}Pb/^{238}U$ ages <200 Ma, SHRIMP $^{206}Pb/^{238}U$ ages were used to calculate $\varepsilon Hf_{initial}$ (with one exception addressed in LASS Results section). For inherited domains that gave LASS $^{206}Pb/^{238}U$ ages between 200 and 800 Ma, LASS $^{206}Pb/^{238}U$ ages were used to determine $\varepsilon Hf_{initial}$, and for LASS ages >800 Ma, LASS $^{207}Pb/^{206}Pb$ ages were used. A $^{176}Lu/^{177}Hf$ of 0.01832 from Rudnick and Gao (2003) was used to calculate a modeled lower crustal trajectory of $\varepsilon Hf_{initial}$ through time.

Whole Rock Elemental Geochemistry and Rb-Sr, Sm-Nd, and Pb Isotopic Analyses

Whole rock geochemical analyses of major and trace elements and Rb–Sr, Sm–Nd, and Pb isotopes were carried out on zircon geochronology samples NS2A, NS3A, SS1, and TUNG. In addition, two leucogranite samples from the northern Snake Range (NS3B and NS5), a Pole Canyon pluton sample from the southern Snake Range (SS4), and another sample of the Tungstonia pluton (K6) are also included in the study, but were not analyzed by zircon geochronology. NS5, a garnet bearing pegmatite sample from the lower part of Deadman Canyon (Fig. 3a), was the only of these that was not analyzed for isotope geochemistry. Sample NS3B was collected in the upper part of Deadman Canyon (Fig. 3a), and is a deformed equigranular two-mica granite with garnet. It crops out adjacent to the unit from which sample NS3A was collected, but cross-cutting relations were not seen. Sample SS4 was collected from an exposure of the Pole Canyon granite pluton that has 1–2 cm wide euhedral muscovite

phenocrysts (Fig. 3a). Sample K6 was collected from the western end of the Tungstonia pluton (Fig. 2) and has a more equigranular texture than sample TUNG, which has 3-4 cm wide euhedral muscovite phenocrysts with mm-scale biotite inclusions (Best et al., 1974). Published Sr-Nd and Pb results from Wright and Wooden (1991) are also used in this study for samples 20-210, ELM89DM (Nd only), and 12EGNS5 (Nd only).

Whole rock major and trace element geochemical analyses were determined at the Geoanalytical Lab at Washington State University using ThermoARL X-Ray Fluorescence spectrometer (Johnson et al., 1999) and Agilent 7700 ICP-MS instruments (Knaack et al., 1994). For isotopic analyses performed at the U.S. Geological Survey (USGS) in Denver, Rb, Sr, REE, and Pb were separated from ~ 200 mg subsamples of whole rock powders, loaded onto filaments and analyzed with a VG Isomass 54R thermal ionization mass spectrometer using methods described in Premo and Morton (2014). Concentration uncertainties for Rb and Sr are ~1.0 % and ~0.5 %, respectively. Isotopic ratios were corrected for blank and mass fractionation. Ratios of $^{87}Sr/^{86}Sr$ are normalized to $^{86}Sr/^{88}Sr = 0.1194$ and monitored for instrumental bias using NBS SRM 987 standard. The mean value of $^{87}Sr/^{86}Sr$ for over 30 analyses of the Sr standard was 0.710255 ± 10. Initial $^{87}Sr/^{86}Sr$ ratios were calculated using U-Pb zircon ages (Miller et al., 1988, this study; $\lambda = 1.42 \times 10^{-11}$/yr, present day $(^{87}Sr/^{86}Sr)_{UR} = 0.7045$, and $(^{87}Rb/^{86}Sr)_{UR} = 0.0824$, where UR = uniform reservoir). Concentration uncertainties for Sm and Nd are ~0.5 % and ~0.1 %, respectively. Isotopic ratios are corrected for blank and mass fractionation. $^{143}Nd/^{144}Nd$ data are normalized to $^{146}Nd/^{144}Nd = 0.7219$ and monitored for instrumental bias using the La Jolla Nd standard. The mean value of $^{143}Nd/^{144}Nd$ for 30 analyses of the La Jolla Nd standard was 0.511865 ±10. Initial $^{143}Nd/^{144}Nd$ ratios and εNd are calculated using U-Pb zircon ages (Miller et al., 1988, this volume; $\lambda = 6.54 \times 10^{-12}$/yr, present day $(^{143}Nd/^{144}Nd)_{CHUR} = 0.512636$, and

($^{147}Sm/^{144}Nd)_{CHUR}$ = 0.1967, where CHUR = chondritic uniform reservoir). U–Pb crystallization ages from this study were used to calculate initial isotopic ratios for all samples except SS4 and NS3B (neither dated in this study), for which ages from Wright and Wooden (1991) were used. The relative compatibility relationships of parent and daughter isotopes exhibited in both Sm-Nd and Lu-Hf systems (Vervoort et al., 1999) create an opportunity to evaluate the parallel evolution of these isotopic systems. Model $\varepsilon Hf_{initial}$ results were calculated from $\varepsilon Nd_{initial}$ results using best fit equations for mantle array and crustal array from Vervoort et al. (1999).

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