Supplementary Text S3: Zircon Analytical Methods 2

U-Pb zircon geochronology: LA-ICP-MS at the University of Alberta

Zircon grains were separated from rocks as described above at ODM labs prior to being sent to the University of Alberta. Zircons were mounted and subsequently studied under cathodoluminescence (CL) for determination of analysis locations. A New Wave Research Nd: YAG laser ablation system (frequency-quintupled, $\lambda = 213$ nm) coupled with a Nu Plasma multiple collector (MC)-ICP-MS was used for in situ analysis.

Zircon Trace Element Analysis: LA-ICP-MS at Laurentian University:

Analytical setup: Zircon U-Th-Pb, trace element (TE), and Hf isotope analyses were conducted at the Mineral Exploration Research Centre isotope Geochemistry Lab (MERC-IGL), at Laurentian University. Laser ablation sampling was performed using a Photon Machines Analyte G2 ArF excimer laser, with 193 nm wavelength, <5 ns pulse width, and HelEx II cell. Hf isotope measurements were conducted using a Thermo Scientific Neptune Plus multicollector (MC) ICP-MS, equipped with Jet interface and nine Faraday cups. All MC-ICP-MS analyses were conducted in low resolution, static mode to ensure maximum sensitivity and stability. U-Pb and TE measurements were conducted using a Thermo Scientific iCap-TQ ICP-MS in single quad mode to ensure maximum sensitivity on the low to intermediate mass range.

U-Th-Pb and TE measurements were conducted simultaneously with Hf isotope analyses on the iCap-TQ and Neptune Plus, respectively, by splitting the ablated aerosol downstream of the sample cell (LASS; e.g. Kylander-Clark et al., 2013). Helium carrier gas flows through the ablation cell were 0.85 l/min (cup) and 0.15 l/min (cell), with 1.1 l/min Ar and 9 ml/min N2 makeup gas added downstream of the cell. Spots with diameter of 40 μm were ablated for 60 seconds, with laser fluence of 6 J/cm2 and 7 Hz repetition rate, leaving estimated ablation pit depths of ~15 μm. Sixty seconds of background were measured at the beginning and end of the analytical session, with 30 seconds of background measured between each ablation.

For U-Pb and trace element analysis on the iCap-TQ, masses measured and associated dwell times are shown in Supplementary Table S4. Cool gas, auxiliary gas, and RF power were set at 14 L/min, 0.8 L/min, and 1550 W, respectively, with Ar makeup gas flows between 0.15 l/min. Parameters associated with Hf isotope measurements on the Neptune Plus are shown in Supplementary Table S4. The cup configuration for Hf isotope analysis on the Neptune Plus is shown in Supplementary Table S4, and all cups were coupled with 1011 amplifiers. Daly ion beam drift is typically <0.05amu, with flat top peak width typically >0.175 amu, ensuring stable on-peak measurements throughout long-duration analytical sessions. Cool gas flows and RF power were set at 16 L/min and 1200 W, with Ar auxiliary gas flow of 0.8 L/min and makeup gas flow between 0.07 l/min.

Data Reduction: The raw data were synchronized in Iolite, along with the laser log file, prior to processing, so that the same timeslices (selections) for each analysis were used in the calculations. Baseline subtraction, instrumental drift, and other corrections were performed with the data reduction schemes (DRS) implemented within Iolite v3.6 (Paton et al., 2010, 2011), and reference materials (RM) shown in Table A-3.1. Reference materials were analyzed multiple times at the beginning and end of each session, and once every ten unknowns throughout the session. Three seconds at the beginning and two second at end of the ablation period were excluded from the selections in order to minimize potential fractionation effects, leaving ~55 seconds of signal for integration. Within run variance in the measured ratios for the primary RMs (i.e. the additional percent error required to achieve MSWD = 1) was propagated into the 2SE uncertainty for U-Pb and Hf isotope ratios of all unknowns. Verification RMs were analyzed during each session to ensure accuracy of the data, with values listed in Table A-3.1. For Hf isotope analyses, instrumental mass bias and interference correction factors were determined within each session through iterative calculation of the effective $^{176}Yb/^{173}Yb$ ratio required to yield identical $^{176}Hf/^{177}Hf$ ratios for MUN1 and MUN3. The effective (mass bias corrected) within session

$^{176}Yb/^{173}Yb$ was then applied in the interference correction for all analyses as part of the DRS.

Table A-3.1:

	L4	L3	L2	L1	C	H1	H2	H3	H4
U-Th-Pb	204Pb	206Pb	207Pb	208Pb	~220.65		232Th		238U
Hf	171Yb	173Yb	174Hf	175Lu	176Yb,Lu/Hf	177Hf	178Hf	179Hf	

References

Kylander-Clark, A.R.C., Hacker, B.R., and Cottle, J.M., 2013. Laser-ablation split stream ICP petrochronology: Chemical geology, v. 345, p. 99 – 112.

Patton, C., Woodhead, J.D., Hellstrom, J.C., Hergt, J.M., Greig, A., and Mass, R., 2010. Improved laser ablation U-Pb zircon geochronology through robust downhole fractionation correction: Geochemistry, Geophysics, Geosystems, v. 11, 36 p.

Patton, C., Hellstrom, J., Paul, B., Woodhead, J., and Hergt, J., 2011. Iolite: Freeware for the visualisation and processing of mass spectrometric data: Journal of Atomic Spectrometry, 11 p.