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Supplemental Material

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Figure S1. Sulfides spatially associated with magnetite in ductilely deformed magnetite-quartz veins.

Figure S2. Microphotographs taken in reflected light, illustrating the intimate association between sulfides and magnetite, and the lack of typical deformation textures in the sulfides.

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Figure S6. Representative photomicrographs of titanite in the Gold Rock Ranch Granite.

Figure S7. Electron backscatter diffraction (EBSD) maps for representative titanite grains from sample OZ-053.

Figure S8. Tera-Wasserburg plots generated with IsoplotR (Vermeesch, 2018) showing titanite U-Pb data separately for each sample.

Figure S9. Cathodoluminescence (CL) and back scattered electron (BSE) images of zircons analyzed in this study, all obtained from pegmatites.

Figure S10. Concordia diagrams for zircon U-Pb reference materials.

Figure S11. Cathodoluminescence (CL) and back scattered electron (BSE) images of apatite analyzed in this study.

Figure S12. Concordia diagram for the apatite U-Pb secondary reference material (Durango apatite).

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Table S1: Sample Locations

Sample number	X-coordinate	Y-coordinate	Unit	Analysis
OZ-005	704397	3639726	Tumco Fm	sulfide Re-Os
OZ-036	704329	3639726	Tumco Fm	sulfide Re-Os
OZ-037	704329	3639726	Tumco Fm	sulfide Re-Os
OZ-038	704329	3639726	Tumco Fm	sulfide Re-Os
OZ-046	709269	3637927	Araz Wash Diorite	titanite U-Pb
OZ-049	709269	3637927	Araz Wash Diorite	titanite U-Pb
OZ-055	709535	3638412	Araz Wash Diorite	titanite U-Pb
OZ-057	709535	3638412	Araz Wash Diorite	titanite U-Pb
OZ-052	705231	3639531	GRR Granite	titanite U-Pb
OZ-053	705118	3639571	GRR Granite	titanite U-Pb
OZ-054	705073	3639804	GRR Granite	titanite U-Pb
OZ-015	704324	3639807	pegmatite	zircon U-Pb, apatite U-Pb
OZ-021	704324	3639798	pegmatite	zircon U-Pb
OZ-022	704470*	3639824*	pegmatite	zircon U-Pb, apatite U-Pb
OZ-024	704408*	3639912*	pegmatite	zircon U-Pb
OZ-002	705005*	3639995*	GRR Granite	apatite U-Pb

Location coordinates are in WGS 1984, UTM Zone 11N.

GRR: Gold Rock Ranch

*Approximate location

Table S2: Analytical Information for Sulfide Re-Os Analyses

Laboratory and Sample Preparation

Laboratory name	Yale University Metal Geochemistry and Geochronology Center
Sample type/mineral	pyrite, chalcopyrite
Sample preparation	crushing, hand-picking (no metal instruments)

Instruments

Re content	ThermoFisher iCAP-TQ ICP-MS
Re-Os isotopes	ThermoFisher TRITON-Plus TIMS

Measurements

Os isotopes	measured as OsO_3^- via ion counting using a secondary electron multiplier in peak hopping mode
Re isotopes	measured as ReO_4^- via static Faraday collection

Blanks

total procedural blanks	measured over course of this study: 0.1 ± 0.4 and 22.5 ± 2.0 pg, for Os and Re respectively, with a $^{187}\text{Os}/^{188}\text{Os}$ value of 0.25 ± 0.1 (2σ , $n = 2$)
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Standards

in-house Re standard solution	solution made from 0.137 g of zone-refined Re metal (99.999%, H-Cross company) in a 4N HNO_3 solution; yields an average $^{185}\text{Re}/^{187}\text{Re}$ ratio of 0.59931 ± 0.0008 (2 S.D., $n = 23$)
in-house Os standard solution	DROs; yields an average $^{187}\text{Os}/^{188}\text{Os}$ ratio of 0.16103 ± 0.00019 (2 S.D., $n = 13$)

Data Treatment

Uncertainties	determined by error propagation of uncertainties in Re and Os mass spectrometer measurements, blank abundances and isotopic compositions, spike calibrations, and reproducibility of standard Re and Os isotope values
$\lambda^{187}\text{Re}$ constant	$1.666 \times 10^{-11} \text{ a}^{-1}$

Other Information

inverse aqua regia	3 ml of 11N HCl and 6 ml of 15N HNO_3
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Several kilograms of sheared Tumco Formation gneiss with sulfide alteration were collected from the Oro Cruz open pit, and crushed by hammer between plastic sheets to avoid metal contamination. Sulfide grains were manually picked using plastic tweezers. Care was taken to select only the freshest sulfide grains, but contamination by minor amounts of oxidized material was unavoidable.

Fourteen aliquots of sulfide grains, from five samples, were tested for Re content on a ThermoFisher iCAP-TQ ICP-MS, to determine the optimum sample and spike weight to be used. The various aliquots yielded 5-41 ng/g Re, and accordingly 0.2-0.8 g of each sample was transferred to a Carius tube together with a mixed $^{185}\text{Re}+^{190}\text{Os}$ spike, and dissolved in inverse aqua-regia at 200°C for 48 hours. After cooling, the Os was extracted and purified by solvent extraction and microdistillation, and Re was separated by anion-exchange chromatography, following procedures outlined in Selby et al. (2009) and Cumming et al. (2013). Purified Os and Re were loaded onto Pt and Ni wire filaments, respectively, and measured in negative ionization mode on a ThermoFisher TRITON-Plus TIMS (Creaser et al., 1991).

Procedure

The Re–Os isotopic data including the 2σ calculated uncertainties for $^{187}\text{Re}/^{188}\text{Os}$ and $^{187}\text{Os}/^{188}\text{Os}$, and the associated error correlation function (ρ), were used to calculate a Re–Os isochron date using Isoplot V. 4.15 (Ludwig, 2003; Smoliar et al., 1996). Final age uncertainty includes the uncertainty in the decay constant, which permits a direct comparison with U-Pb dates. As a monitor of mass spectrometry reproducibility, two in-house Re and Os standard solutions were analyzed, both of which yield isotope ratios in agreement with previous studies (Nowell et al., 2008; Rooney et al., 2010).

Table S3: Re-Os Data for Sulfides from Sheared Tumco Formation Gneiss

Aliquot	Sample	Sulfide	Notes	Re (ng/g)	±2σ	Os (pg/g)	±2σ	¹⁹² Os (pg/g)	±2σ	¹⁸⁷ Re/ ¹⁸⁸ Os	±2σ	¹⁸⁷ Os/ ¹⁸⁸ Os	±2σ	rho	% Re Blank	% ¹⁸⁷ Os Blank	% ¹⁸⁸ Os Blank	Osi @ 65 myr	Osi ±2σ
OZ-005-1	OZ-005	py	all fresh	26.15	0.02	42.1	0.8	8.2	0.2	6342	139	8.69	0.229	0.831	0.17	0.03	0.97	1.82	0.27
OZ-005-3	OZ-005	py	minor ox	32.00	0.10	66.1	1.3	15.1	0.3	4222	79	6.33	0.196	0.591	0.14	0.02	0.52	1.76	0.21
OZ-036-4	OZ-036	cpy	tr ox	5.55	0.03	14.7	0.6	3.8	0.4	2935	308	4.87	0.521	0.979	1.98	0.27	5.20	1.69	0.62
OZ-037-1	OZ-037	py + tr cpy	mod ox	9.15	0.01	33.0	0.6	9.2	0.2	1988	38	3.86	0.128	0.569	0.25	0.03	0.44	1.70	0.13
OZ-038-1	OZ-038	py	all fresh	24.56	0.02	21.7	0.6	1.7	0.1	28140	1325	31.94	1.557	0.965	0.09	0.02	2.31	1.45	2.12
OZ-038-4	OZ-038	py	tr ox	41.04	0.02	35.2	0.9	2.5	0.1	32539	1100	36.91	1.388	0.899	0.05	0.01	1.60	1.66	1.83

cpy: chalcopyrite, Osi: initial ¹⁸⁷Os/¹⁸⁸Os ratio; ox: oxidized, py: pyrite, tr: trace

Table S4: Analytical Information for Titanite U-Pb Analyses

Laboratory and Sample Preparation

Laboratory name	University of Santa Barbara
Sample type/mineral	titanite
Sample preparation	in-situ in petrographic thin sections

Instruments

U-Pb isotopes	Nu Instruments Plasma HR-ES multi-collector inductively coupled plasma mass spectrometer
Trace elements	Agilent 7700x quadrupole inductively coupled plasma mass spectrometer

Laser Settings

Spot size	35 µm
Rep rate	4 Hz
Laser energy	100%
Energy setpoint	3.50 mJ
Pressure	6051 mbar
Voltage	0.91 kV

Standards

Primary U-Pb standard	MKED
Secondary U-Pb standards	BLR, Y17, Fish Canyon Tuff (FC)
Other information	Standards were analyzed every 8 unknown analyses (MKED every time, BLR every other time, rotate between Y-17 and Fish Canyon Tuff)

Data Treatment

Uncertainties	Uncertainties in U and Pb ratios propagated in quadrature based on how much uncertainty needs to be added to secondary standard BLR to make those data a single population. - For samples OZ-52, OZ-53, OZ-54, OZ-55 this was 2.7% in the 207/206 ratio and 4.4% in the 238/206 ratio. - For samples OZ-46, OZ-49, OZ-57 this was 3.4% in the 207/2067 ration and 3.0% in the 238/206 ratio.
Individual spot dates	Individual spot dates are common Pb corrected assuming a Stacey and Kramers common Pb value of 0.84 (a reasonable assumption based on how the data plot in Tera-Wasserburg concordia space).
Systematic error	Long-term reproducibility of standard analyses suggests a machine-specific uncertainty of ± 2% (Spencer et al., 2013).

Other Information

Cleaning	Two cleaning shots were fired to remove surface contamination prior to analyses.
Analysis duration	15-20 seconds
Washout time	15-20 seconds (between cleaning shots and analyses)

Procedure

Both euhedral crystals and anhedral aggregates were analyzed for U-Pb on a Nu Instruments Plasma HR-ES multi-collector ICP-MS, using a 35 µm spot size.

Table S5: U-Pb Data for Titanite from Jurassic Plutons in the Cargo Muchacho Mountains

U-Pb isotope data												Isotope ratios										Ages		Excluded from calculation of discordia age	Reason for exclusion
Analysis	U238_Eh	U238_Eh/Int2SE	Th232_H2	Th232_H2/Int2SE	Pb208_IC0	Pb208_IC0/Int2SE	Pb207_IC1	Pb207_IC1/Int2SE	Pb206_IC2	Pb206_IC2/Int2SE	Pb204_IC3	Pb204_IC3/Int2SE	207Pb/235U	±2σ*	206Pb/238U	±2σ*	238U/206Pb	±2σ*	207Pb/206Pb	±2σ*	207Pb-corrected 206Pb/238U age (Ma)†	±2σ* (Ma)			
OZ-055-7	-1.46E-03	6.50E-05	-1.72E-03	2.40E-05	1.70E-03	7.40E-05	6.69E-04	2.60E-05	7.79E-04	3.20E-05	6.23E-05	2.10E-06	190.000	268.880	1.600	1.602	0.625	0.626	0.850	0.850	-131	11208	x	huge uncertainty	
OZ-055-4	3.96E-02	5.00E-04	4.18E-03	1.40E-04	7.11E-05	1.20E-06	2.99E-05	6.00E-07	5.75E-04	8.40E-06	1.13E-06	9.50E-08	0.201	0.011	0.028	0.001	35.236	1.597	0.051	0.002	180	8	x	older group	
OZ-055-30	-4.28E-04	3.80E-05	8.05E-03	3.60E-04	1.10E-03	9.60E-06	4.03E-04	4.70E-06	4.84E-04	4.80E-06	3.75E-05	5.70E-07	58.900	3.254	0.516	0.025	1.938	0.093	0.833	0.023	31	103			
OZ-055-3	2.09E-02	4.20E-04	9.87E-03	7.10E-05	1.31E-04	1.70E-06	1.70E-05	4.40E-07	3.25E-04	3.60E-06	1.07E-06	8.00E-08	0.202	0.011	0.029	0.001	34.686	1.577	0.051	0.002	183	8	x	older group	
OZ-055-2	2.93E-02	3.90E-04	1.36E-02	1.40E-04	1.85E-04	4.40E-06	2.57E-05	1.10E-06	4.43E-04	4.10E-06	1.46E-06	1.70E-07	0.226	0.015	0.029	0.001	34.566	1.581	0.057	0.003	182	8	x	older group	
OZ-055-15	-1.10E-03	3.30E-05	9.71E-02	5.10E-03	2.49E-03	1.00E-04	7.47E-04	2.70E-05	8.71E-04	3.50E-05	6.92E-05	2.50E-06	174.300	11.340	1.490	0.088	0.671	0.039	0.852	0.024	-148	319			
OZ-055-14	-4.10E-04	3.40E-04	5.30E-04	5.10E-04	9.93E-04	9.80E-05	3.79E-04	3.70E-05	4.56E-04	4.60E-05	3.60E-05	3.30E-06	60.600	5.923	0.532	0.050	1.880	0.176	0.829	0.023	46	108			
OZ-055-1	5.00E-02	9.00E-04	1.50E-02	7.40E-04	2.03E-04	6.10E-06	3.93E-05	8.10E-07	7.07E-04	1.10E-05	1.50E-06	9.00E-08	0.211	0.011	0.028	0.001	35.907	1.670	0.055	0.002	176	8	x	older group	
OZ-054-2	5.52E-02	2.90E-03	2.80E-02	2.90E-04	3.35E-04	1.20E-05	6.35E-05	2.10E-06	8.22E-04	3.20E-05	3.14E-06	1.20E-07	0.301	0.017	0.029	0.001	34.662	1.550	0.076	0.002	177	8	x	older group	
OZ-054-4	1.93E-02	4.00E-04	3.42E-03	6.30E-05	8.78E-05	1.60E-06	2.20E-05	6.10E-07	3.00E-04	5.50E-06	1.88E-06	1.20E-07	0.279	0.017	0.028	0.001	35.511	1.704	0.072	0.003	174	8	x	older group	
OZ-054-16	8.05E-03	1.30E-04	5.01E-03	1.20E-04	1.23E-04	6.20E-06	2.47E-05	2.10E-06	1.57E-04	3.90E-06	2.65E-06	2.10E-07	0.654	0.056	0.031	0.001	32.531	1.579	0.154	0.011	170	9	x	older group	
OZ-054-15	5.54E-03	9.50E-05	3.20E-03	9.10E-05	9.16E-05	2.90E-06	1.82E-05	1.00E-06	1.16E-04	1.40E-06	2.36E-06	8.50E-08	0.644	0.047	0.030	0.001	33.212	1.489	0.155	0.009	166	8	x	older group	
OZ-054-28	1.58E-02	5.30E-04	7.20E-03	1.30E-03	1.79E-04	1.40E-05	5.94E-05	5.20E-06	2.65E-04	7.40E-06	5.73E-06	4.90E-07	0.910	0.079	0.030	0.002	33.852	1.832	0.226	0.015	146	9	x	older group	
OZ-054-7 1	1.01E-02	4.50E-04	1.60E-03	1.10E-04	1.48E-04	6.60E-06	4.82E-05	1.80E-06	1.75E-04	7.40E-06	4.88E-06	5.20E-07	1.114	0.070	0.029	0.002	33.979	1.745	0.275	0.010	134	7	x	older group	
OZ-054-7 2	1.08E-02	3.50E-04	2.30E-03	6.00E-04	2.50E-04	6.60E-06	8.70E-05	2.70E-06	2.18E-04	5.70E-06	8.64E-06	3.80E-07	1.822	0.122	0.033	0.002	30.030	1.766	0.397	0.013	119	8	x	older group	
OZ-054-23	9.94E-03	2.40E-04	2.19E-03	6.70E-05	6.83E-05	1.00E-06	1.74E-05	4.40E-07	1.22E-04	1.70E-06	2.31E-06	1.10E-07	0.389	0.022	0.020	0.001	49.068	2.262	0.140	0.005	115	5	x	older group	
OZ-054-14	1.08E-02	2.90E-04	1.89E-02	9.50E-04	1.92E-04	1.40E-05	5.53E-05	4.50E-06	1.71E-04	8.30E-06	5.46E-06	3.70E-07	1.175	0.085	0.027	0.001	37.580	2.103	0.319	0.015	112	7	x	older group	
OZ-054-19	6.24E-03	2.40E-04	3.76E-04	4.20E-05	7.44E-05	1.90E-06	2.50E-05	6.90E-07	9.38E-05	1.70E-06	3.08E-06	1.00E-07	0.817	0.053	0.023	0.001	43.783	2.359	0.260	0.009	107	6	x	older group	
OZ-054-17	1.01E-02	1.80E-04	3.00E-03	1.10E-04	7.89E-05	8.90E-07	1.91E-05	5.90E-07	1.15E-04	1.10E-06	2.47E-06	1.20E-07	0.423	0.027	0.019	0.001	52.826	2.419	0.164	0.007	103	5	x	older group	
OZ-054-27	6.63E-03	9.30E-05	3.80E-04	5.00E-05	5.32E-05	1.10E-06	1.48E-05	3.60E-07	8.47E-05	1.50E-06	2.26E-06	1.30E-07	0.446	0.026	0.019	0.001	52.521	2.428	0.172	0.006	103	5	x	older group	
OZ-054-5	1.07E-02	3.10E-04	2.80E-03	9.10E-04	1.17E-04	6.60E-06	3.53E-05	1.20E-06	1.21E-04	2.70E-06	4.04E-06	1.70E-07	0.737	0.042	0.019	0.001	53.248	2.432	0.289	0.010	84	4	x	older group	
OZ-054-1	1.26E-02	2.20E-04	2.03E-03	4.50E-04	9.23E-05	1.40E-06	3.22E-05	7.40E-07	1.29E-04	1.70E-06	3.43E-06	1.80E-07	0.593	0.035	0.017	0.001	57.438	2.621	0.246	0.009	84	4	x	older group	
OZ-054-26	6.44E-03	2.30E-04	4.67E-03	9.50E-05	9.24E-05	1.90E-06	2.10E-05	2.80E-07	7.34E-05	2.00E-06	2.83E-06	1.30E-07	0.667	0.041	0.017	0.001	57.770	2.573	0.280	0.012	78	4	x	older group	
OZ-054-8	1.54E-02	7.60E-04	1.26E-02	7.70E-04	1.90E-04	1.10E-05	4.34E-05	2.80E-06	1.52E-04	8.60E-06	4.71E-06	3.00E-07	0.678	0.039	0.017	0.001	57.937	2.753	0.284	0.009	78	4	x	older group	
OZ-054-22	8.37E-03	3.40E-04	3.12E-04	2.50E-05	9.61E-05	6.00E-06	3.30E-05	1.60E-06	9.67E-05	4.40E-06	4.09E-06	3.70E-07	0.885	0.054	0.019	0.001	53.220	2.601	0.344	0.012	75	4	x	older group	
OZ-054-18	1.25E-02	2.30E-04	1.19E-03	2.20E-05	6.21E-05	1.20E-06	2.12E-05	5.40E-07	1.06E-04	2.40E-06	3.01E-06	2.70E-07	0.387	0.022	0.014	0.001	69.735	3.319	0.195	0.006	75	4	x	older group	
OZ-054-9	7.84E-03	2.40E-04	-4.07E-04	3.50E-05	1.03E-04	2.80E-06	3.89E-05	9.90E-07	1.00E-04	2.10E-06	4.43E-06	2.00E-07	1.058	0.058	0.020	0.001	49.975	2.340	0.386	0.011	74	4			
OZ-054-21 2	6.69E-03	3.40E-04	-1.34E-03	2.80E-05	9.83E-05	3.50E-06	3.91E-05	7.10E-07	9.35E-05	3.10E-06	4.38E-06	3.30E-07	1.162	0.064	0.021	0.001	47.962	2.155	0.410	0.013	73	4			
OZ-054-13	8.11E-03	3.50E-04	-5.14E-04	4.00E-05	1.09E-04	2.60E-06	4.17E-05	1.00E-06	1.04E-04	2.50E-06	4.64														

BLR-3	1.64E-02	2.50E-04	1.47E-02	1.40E-04	1.28E-03	1.50E-05	1.81E-04	2.10E-06	1.69E-03	2.00E-05	6.42E-06	1.90E-07	2.722	0.144	0.185	0.008	5.420	0.246	0.107	0.003	1048				
BLR-4	1.67E-02	1.90E-04	1.54E-02	1.70E-04	1.33E-03	1.40E-05	1.87E-04	2.40E-06	1.87E-04	1.90E-05	6.33E-06	2.40E-07	2.709	0.142	0.186	0.008	5.379	0.239	0.106	0.003	1057				
BLR-5	1.32E-02	2.40E-04	1.24E-02	1.80E-04	1.11E-03	1.70E-05	1.56E-04	2.40E-06	1.42E-03	2.10E-05	5.84E-06	1.80E-07	2.815	0.149	0.187	0.008	5.342	0.241	0.108	0.003	1061				
BLR-6	1.31E-02	2.10E-04	1.22E-02	9.60E-05	1.10E-03	1.00E-05	1.54E-04	2.10E-06	1.41E-03	1.40E-05	5.95E-06	1.80E-07	2.814	0.151	0.187	0.009	5.362	0.246	0.109	0.003	1057				
BLR-7	1.33E-02	2.50E-04	1.24E-02	1.70E-04	1.16E-03	1.00E-05	1.62E-04	2.40E-06	1.47E-03	1.70E-05	5.92E-06	1.60E-07	2.910	0.154	0.193	0.009	5.189	0.231	0.109	0.003	1091				
BLR-8	1.33E-02	2.50E-04	1.25E-02	2.00E-04	1.14E-03	1.20E-05	1.58E-04	1.40E-06	1.45E-03	1.50E-05	5.71E-06	1.70E-07	2.854	0.155	0.191	0.009	5.238	0.245	0.108	0.003	1082				
BLR-9	1.31E-02	2.00E-04	1.22E-02	1.10E-04	1.14E-03	1.30E-05	1.60E-04	2.00E-06	1.44E-03	1.60E-05	5.91E-06	1.90E-07	2.950	0.158	0.194	0.009	5.168	0.238	0.111	0.003	1092				
FC-1	4.47E-03	8.70E-05	1.25E-02	1.10E-04	6.41E-05	6.30E-07	1.65E-05	3.50E-07	3.29E-05	5.90E-07	2.41E-06	1.20E-07	0.639	0.037	0.009	0.000	106.610	4.991	0.491	0.017	27				
FC-2	4.56E-03	1.10E-04	1.27E-02	1.50E-04	6.34E-05	9.20E-07	1.65E-05	3.20E-07	3.32E-05	6.80E-07	2.41E-06	6.90E-08	0.636	0.038	0.009	0.000	106.383	5.151	0.493	0.017	26				
FC-3	4.80E-03	9.10E-05	1.39E-02	1.60E-04	6.73E-05	7.70E-07	1.59E-05	3.30E-07	3.34E-05	5.10E-07	2.49E-06	6.60E-08	0.610	0.036	0.010	0.000	105.263	4.819	0.467	0.017	29				
FC-4	5.29E-03	8.30E-05	1.32E-02	1.80E-04	6.09E-05	7.50E-07	1.41E-05	2.80E-07	3.18E-05	4.50E-07	2.40E-06	1.10E-07	0.504	0.028	0.008	0.000	118.483	5.523	0.434	0.014	28				
FC-5	4.29E-03	8.30E-05	1.38E-02	4.90E-04	6.49E-05	9.80E-07	1.47E-05	3.30E-07	3.11E-05	5.50E-07	2.42E-06	1.30E-07	0.618	0.037	0.009	0.000	105.597	4.835	0.472	0.018	28				
FC-6	3.52E-03	1.00E-04	1.20E-02	3.30E-04	5.93E-05	8.60E-07	1.40E-05	2.50E-07	2.83E-05	6.60E-07	2.47E-06	1.20E-07	0.656	0.041	0.010	0.000	103.199	5.110	0.491	0.019	27				
Y17-1	2.78E-02	3.10E-04	8.46E-03	1.50E-04	3.35E-04	6.70E-06	8.33E-05	1.30E-06	9.99E-04	1.60E-05	3.53E-06	1.30E-07	0.747	0.040	0.065	0.003	15.430	0.697	0.083	0.002					
Y17-2	2.54E-02	4.80E-04	7.64E-03	7.90E-05	3.71E-04	8.30E-06	9.73E-05	2.40E-06	9.56E-04	1.10E-05	5.25E-06	2.50E-07	0.932	0.051	0.067	0.003	14.970	0.682	0.101	0.003					
Y17-3	2.90E-02	4.00E-04	8.68E-03	1.60E-04	3.44E-04	6.00E-06	8.58E-05	1.90E-06	1.02E-03	1.30E-05	3.94E-06	1.50E-07	0.770	0.041	0.067	0.003	15.002	0.678	0.084	0.002					
Y17-4	2.60E-02	4.00E-04	7.86E-03	9.60E-05	3.26E-04	3.90E-06	8.15E-05	1.80E-06	9.18E-04	1.00E-05	4.12E-06	2.60E-07	0.813	0.045	0.067	0.003	14.966	0.685	0.087	0.003					
Y17-5	2.52E-02	3.00E-04	7.52E-03	1.10E-04	3.01E-04	2.90E-06	7.23E-05	8.20E-07	8.79E-04	8.80E-06	3.49E-06	1.70E-07	0.740	0.040	0.065	0.003	15.277	0.690	0.082	0.002					
Y17-6	2.46E-02	3.20E-04	7.43E-03	1.10E-04	2.93E-04	4.30E-06	7.17E-05	1.30E-06	8.65E-04	1.30E-05	3.49E-06	1.50E-07	0.752	0.041	0.067	0.003	15.035	0.694	0.082	0.002					
Y17-7	2.58E-02	4.20E-04	7.69E-03	9.40E-05	3.09E-04	3.10E-06	7.56E-05	8.80E-07	9.14E-04	9.40E-06	3.38E-06	1.60E-07	0.743	0.040	0.067	0.003	14.966	0.680	0.082	0.002					
NIST612-1	1.22E-03	4.90E-05	-2.14E-04	2.20E-05	1.22E-03	1.50E-05	4.97E-04	6.30E-06	5.33E-04	6.00E-06	4.47E-05	4.60E-07	38.240	1.993	0.297	0.013	3.369	0.149	0.929	0.025					
NIST612-10	1.52E-03	7.10E-05	-1.53E-04	2.70E-05	1.29E-03	1.60E-05	5.14E-04	7.10E-06	5.58E-04	7.50E-06	4.81E-05	7.50E-07	37.470	2.008	0.295	0.014	3.390	0.156	0.919	0.025					
NIST612-11	1.56E-03	7.40E-05	-1.22E-04	2.10E-05	1.31E-03	2.20E-05	5.20E-04	8.70E-06	5.61E-04	9.60E-06	4.93E-05	7.50E-07	37.920	2.017	0.297	0.014	3.370	0.154	0.922	0.025					
NIST612-12	1.58E-03	5.40E-05	-8.60E-05	1.90E-05	1.33E-03	1.70E-05	5.31E-04	6.40E-06	5.70E-04	8.20E-06	4.92E-05	6.30E-07	38.320	2.058	0.302	0.014	3.308	0.153	0.923	0.025					
NIST612-13	1.58E-03	6.50E-05	-8.00E-05	2.60E-05	1.31E-03	1.90E-05	5.23E-04	7.10E-06	5.60E-04	8.60E-06	4.82E-05	9.20E-07	38.360	2.053	0.301	0.014	3.320	0.153	0.927	0.025					
NIST612-14	1.55E-03	6.50E-05	-8.70E-05	2.20E-05	1.29E-03	1.60E-05	5.17E-04	6.50E-06	5.57E-04	7.20E-06	4.79E-05	6.50E-07	38.040	2.022	0.300	0.014	3.336	0.152	0.924	0.025					
NIST612-15	1.53E-03	6.90E-05	-9.20E-05	1.40E-05	1.31E-03	1.90E-05	5.23E-04	7.60E-06	5.65E-04	8.50E-06	4.88E-05	1.10E-06	37.880	2.006	0.298	0.014	3.352	0.152	0.925	0.025					
NIST612-16	1.53E-03	4.80E-05	-8.70E-05	2.20E-05	1.30E-03	1.70E-05	5.19E-04	6.40E-06	5.61E-04	6.60E-06	4.88E-05	8.60E-07	38.110	2.008	0.300	0.014	3.332	0.150	0.922	0.025					
NIST612-17	1.60E-03	6.60E-05	-1.26E-04	2.10E-05	1.31E-03	1.60E-05	5.21E-04	7.50E-06	5.61E-04	7.50E-06	4.89E-05	9.30E-07	37.900	1.998	0.297	0.013	3.373	0.152	0.924	0.025					
NIST612-18	1.53E-03	6.70E-05	-1.15E-04	2.90E-05	1.30E-03	1.40E-05	5.16E-04	6.50E-06	5.56E-04	6.30E-06	4.80E-05	6.80E-07	37.840	2.009	0.297	0.014	3.370	0.154	0.924	0.025					
NIST612-2	1.22E-03	5.90E-05	-2.69E-04	2.40E-05	1.21E-03	1.50E-05	4.89E-04	5.50E-06	5.28E-04	6.10E-06	4.48E-05	7.20E-07	37.560	1.970	0.295	0.013	3.392	0.152	0.922	0.025					
NIST612-3	1.43E-03	6.90E-05	-1.24E-04	2.80E-05	1.27E-03	1.40E-05	5.12E-04	5.90E-06	5.48E-04	6.30E-06	4.67E-05	6.30E-07	38.590	2.027	0.301	0.014	3.320	0.149	0.932	0.025					
NIST612-4	1.49E-03	6.10E-05	-1.20E-04	2.90E-05	1.29E-03	1.50E-05	5.13E-04	7.80E-06	5.55E-04	7.40E-06	4.72E-05	1.00E-06	38.330	2.028	0.302	0.014	3.312	0.150	0.922	0.025					
NIST612-5	1.46E-03	6.50E-05	-1.19E-04	3.00E-05	1.29E-03	1.50E-05	5.14E-04	6.00E-06	5.53E-04	7.40E-06	4.75E-05	7.00E-07	37.480	1.990	0.297	0.014	3.367	0.153	0.927	0.025					
NIST612-6	1.46E-03	6.60E-05	-1.66E-04	2.70E-05	1.28E-03	1.40E-05	5.09E-04	6.30E-06	5.51E-04	6.70E-06	4.74E-05	7.60E-07	37.870	2.020	0.299	0.014	3.343	0.153	0.923	0.025					
NIST612-7	1.49E-03	9.80E-05	-1.19E-04	2.00E-05	1.29E-03	1.90E-05	5.13E-04	7.50E-06	5.51E-04	8.40E-06	4.82E-05	9.00E-07	38.520	2.052	0.300	0.014	3.331	0.152	0.927	0.025					
NIST612-8	1.54E-03	6.70E-05	-9.70E-05	3.20E-05	1.31E-03	1.60E-05	5.24E-04	5.60E-06	5.66E-04	7.10E-06	4.82E-05	8.10E-07	38.280	2.030	0.300	0.014	3.334	0.152	0.921	0.025					
NIST612-9	1.51E-03	6.20E-05	-1.25E-04	3.00E-05	1.29E-03	1.70E-05	5.15E-04	7.70E-06	5.55E-04	8.60E-06	4.91E-05	8.20E-07	38.500	2.033	0.301	0.014	3.321	0.150	0.924	0.025					
BHVO-1	-2.28E-03	2.30E-05	-1.71E-03	2.20E-05	4.48E-05	9.40E-07	1.87E-05	4.00E-07	2.19E-05	4.80E-07	2.66E-06	1.40E-07	no value	#DIV/0!	no value	#VALUE!		#DIV/0!	no value	#VALUE!					
BHVO-10	-2.29E-03	2.30E-05	-1.71E-03	2.20E-05	5.21E-05	6.30E-07	2.01E-05	5.70E-07	2.33E-05	4.80E-07	2.83E-06	1.60E-07	no value	#DIV/0!	no value	#VALUE!		#DIV/0!	no value	#VALUE!					
BHVO-11	-2.27E-03	2.70E-05	-1.68E-03	2.60E-05	5.15E-05	6.20E-07	1.99E-05	4.70E-07	2.36E-05	3.30E-07	2.94E-06	1.40E-07	no value	#DIV/0!	no value	#VALUE!		#DIV/0!	no value	#VALUE!					
BHVO-12	-2.27E-03	1.70E-05	-1.70E-03	2.30E-05	5.11E-05	7.30E-07	1.96E-05	3.70E-07	2.31E-05	5.30E-07	2.86E-06	1.40E-07	no value	#DIV/0!	no value	#VALUE!		#DIV/0!	no value	#VALUE!					
BHVO-13	-2.27E-03	2.10E-05	-1.70E-03	2.60E-05	5.14E-05	6.40E-07	1.97E-05	4.20E-07	2.29E-05	4.20E-07	3.00E-06	1.70E-07	no value	#DIV/0!	no value	#VALUE!		#DIV/0!	no value	#VALUE!					
BHVO-14	-2.26E-03	2.00E-05	-1.69E-03	2.10E-05	5.15E-05	6.40E-07	2.02E-05	4.90E-07	2.36E-05	4.50E-07	2.93E-06	9.20E-08	no value	#DIV/0!	no value	#VALUE!		#DIV/0!	no value	#VALUE!					
BHVO-2	-2.30E-03	2.20E-05	-1.71E-03	2.60E-05	4.53E-05	6.30E-07	1.85E-05	3.70E-07	2.20E-05	2.70E-07	2.52E-06	1.00E-07	no value	#DIV/0!	no value	#VALUE!		#DIV/0!	no value	#VALUE!					
BHVO-3	-2.30E-03	3.00E-05	-1.69E-03	1.80E-05	4.69E-05	7.60E-07	1.92E-05	3.60E-07	2.32E-05	3.70E-07	2.68E-06	1.10E-07	no value	#DIV/0!	no value	#VALUE!		#DIV/0!	no value	#VALUE!					
BHVO-4	-2.30E-03	1.80E-05	-1.69E-03	2.20E-0																					

MKED-7	1.07E-02	1.20E-04	1.40E-02	2.60E-04	1.55E-03	1.50E-05	1.66E-04	1.90E-06	1.69E-03	2.10E-05	9.98E-07	8.90E-08	3.516	0.163	0.267	0.008	3.740	0.116	0.096	0.003				
MKED-8	1.07E-02	1.30E-04	1.42E-02	2.40E-04	1.56E-03	1.70E-05	1.65E-04	1.80E-06	1.71E-03	1.90E-05	9.90E-07	7.10E-08	3.530	0.165	0.268	0.008	3.727	0.117	0.096	0.003				
MKED-9	1.06E-02	1.30E-04	1.39E-02	2.30E-04	1.50E-03	1.80E-05	1.57E-04	1.90E-06	1.63E-03	1.50E-05	9.29E-07	6.40E-08	3.507	0.163	0.262	0.008	3.821	0.117	0.096	0.003				
BLR-1	1.19E-02	1.70E-04	1.17E-02	1.20E-04	1.02E-03	1.20E-05	1.49E-04	2.00E-06	1.34E-03	1.50E-05	5.49E-06	1.50E-07	2.846	0.131	0.187	0.006	5.353	0.163	0.111	0.004				
BLR-2	1.21E-02	1.70E-04	1.19E-02	1.30E-04	1.05E-03	1.30E-05	1.53E-04	2.20E-06	1.37E-03	1.40E-05	5.59E-06	1.90E-07	2.898	0.135	0.189	0.006	5.302	0.165	0.111	0.004				
BLR-3	1.26E-02	2.30E-04	1.25E-02	1.60E-04	1.09E-03	8.20E-06	1.53E-04	1.60E-06	1.39E-03	1.00E-05	5.59E-06	1.60E-07	2.903	0.134	0.190	0.006	5.277	0.162	0.110	0.004				
BLR-4	1.60E-02	1.80E-04	1.45E-02	2.00E-04	1.21E-03	1.20E-05	1.71E-04	1.40E-06	1.61E-03	1.60E-05	6.20E-06	1.90E-07	2.636	0.122	0.182	0.006	5.507	0.168	0.106	0.004				
BLR-5	1.64E-02	2.10E-04	1.51E-02	2.80E-04	1.24E-03	1.30E-05	1.76E-04	2.10E-06	1.64E-03	1.70E-05	6.21E-06	1.80E-07	2.635	0.122	0.180	0.006	5.543	0.172	0.107	0.004				
BLR-6	1.65E-02	1.50E-04	1.52E-02	2.60E-04	1.28E-03	1.40E-05	1.80E-04	1.80E-06	1.67E-03	2.00E-05	5.97E-06	2.50E-07	2.684	0.126	0.183	0.006	5.459	0.173	0.107	0.004				
BLR-7	1.28E-02	1.50E-04	1.21E-02	1.80E-04	1.05E-03	9.50E-06	1.47E-04	1.40E-06	1.35E-03	1.30E-05	5.24E-06	1.90E-07	2.779	0.129	0.187	0.006	5.359	0.166	0.108	0.004				
BLR-8	1.29E-02	1.60E-04	1.22E-02	2.20E-04	1.06E-03	1.20E-05	1.48E-04	1.90E-06	1.36E-03	1.50E-05	5.44E-06	1.80E-07	2.795	0.131	0.188	0.006	5.313	0.167	0.108	0.004				
BLR-9	1.28E-02	1.40E-04	1.22E-02	1.80E-04	1.05E-03	1.10E-05	1.48E-04	1.60E-06	1.35E-03	1.40E-05	5.50E-06	1.70E-07	2.805	0.131	0.187	0.006	5.339	0.168	0.109	0.004				
Y17-1	2.59E-02	2.80E-04	7.66E-03	1.10E-04	3.18E-04	5.10E-06	8.25E-05	1.60E-06	9.30E-04	1.70E-05	3.75E-06	1.30E-07	0.785	0.037	0.065	0.002	15.382	0.476	0.088	0.003				
Y17-2	2.51E-02	3.30E-04	7.42E-03	1.10E-04	2.94E-04	4.20E-06	7.41E-05	1.30E-06	8.91E-04	1.20E-05	3.34E-06	1.20E-07	0.738	0.035	0.065	0.002	15.499	0.481	0.083	0.003				
Y17-3	2.71E-02	4.70E-04	7.88E-03	1.20E-04	3.11E-04	3.90E-06	7.61E-05	9.00E-07	9.43E-04	9.80E-06	3.42E-06	1.40E-07	0.744	0.035	0.066	0.002	15.117	0.468	0.081	0.003				
Y17-4	2.50E-02	2.70E-04	6.64E-03	1.30E-04	2.80E-04	4.10E-06	7.34E-05	1.20E-06	8.74E-04	1.20E-05	3.49E-06	1.30E-07	0.762	0.037	0.066	0.002	15.221	0.496	0.083	0.003				
Y17-5	2.64E-02	2.90E-04	6.70E-03	1.50E-04	2.85E-04	2.90E-06	7.91E-05	1.10E-06	9.08E-04	1.00E-05	3.74E-06	1.60E-07	0.789	0.038	0.066	0.002	15.088	0.477	0.086	0.003				
Y17-6	2.33E-02	4.40E-04	6.47E-03	1.20E-04	2.75E-04	3.20E-06	6.85E-05	8.80E-07	8.10E-04	7.90E-06	3.23E-06	9.80E-08	0.768	0.038	0.067	0.002	14.919	0.498	0.084	0.003				
FC-1	3.55E-03	7.50E-05	1.16E-02	1.50E-04	6.53E-05	7.10E-07	1.73E-05	3.30E-07	3.23E-05	4.70E-07	2.53E-06	1.10E-07	0.806	0.041	0.011	0.000	90.744	3.061	0.535	0.021				
FC-2	2.93E-03	5.50E-05	9.31E-03	8.70E-05	6.35E-05	1.10E-06	1.80E-05	3.70E-07	3.20E-05	5.60E-07	2.59E-06	1.50E-07	0.929	0.049	0.012	0.000	82.645	2.831	0.552	0.022				
FC-3	3.13E-03	9.50E-05	1.02E-02	1.30E-04	6.50E-05	9.00E-07	1.80E-05	3.00E-07	3.23E-05	5.00E-07	2.62E-06	1.20E-07	0.909	0.049	0.012	0.000	82.988	2.879	0.550	0.023				
FC-4	4.96E-03	8.30E-05	1.39E-02	1.80E-04	6.51E-05	8.80E-07	1.58E-05	3.10E-07	3.33E-05	5.30E-07	2.28E-06	1.10E-07	0.600	0.031	0.009	0.000	106.270	3.510	0.470	0.019				
FC-5	4.26E-03	7.80E-05	1.25E-02	1.50E-04	6.33E-05	9.20E-07	1.55E-05	2.60E-07	3.19E-05	3.70E-07	2.30E-06	1.40E-07	0.659	0.034	0.010	0.000	98.912	3.502	0.479	0.018				
NIST612-1	1.28E-03	7.40E-05	-2.03E-04	1.90E-05	1.20E-03	1.80E-05	4.86E-04	7.70E-06	5.23E-04	7.90E-06	4.38E-05	7.90E-07	37.920	1.763	0.293	0.009	3.411	0.107	0.929	0.032				
NIST612-10	1.46E-03	7.80E-05	-1.44E-04	2.30E-05	1.24E-03	1.90E-05	4.94E-04	7.20E-06	5.35E-04	8.50E-06	4.59E-05	9.50E-07	36.580	1.732	0.292	0.010	3.425	0.112	0.918	0.032				
NIST612-11	1.46E-03	5.80E-05	-8.20E-05	2.30E-05	1.24E-03	1.80E-05	4.95E-04	6.70E-06	5.35E-04	7.30E-06	4.56E-05	5.60E-07	37.710	1.779	0.296	0.010	3.375	0.109	0.916	0.031				
NIST612-12	1.44E-03	7.70E-05	-9.90E-05	2.50E-05	1.23E-03	1.90E-05	4.93E-04	7.60E-06	5.27E-04	8.00E-06	4.66E-05	9.30E-07	37.780	1.765	0.293	0.009	3.408	0.108	0.926	0.032				
NIST612-13	1.45E-03	7.80E-05	-1.39E-04	2.30E-05	1.25E-03	1.80E-05	4.96E-04	7.10E-06	5.34E-04	8.90E-06	4.58E-05	7.90E-07	37.700	1.776	0.299	0.010	3.344	0.108	0.918	0.032				
NIST612-14	1.41E-03	8.10E-05	-1.14E-04	2.70E-05	1.24E-03	2.10E-05	4.96E-04	7.70E-06	5.32E-04	8.60E-06	4.66E-05	7.70E-07	38.050	1.802	0.302	0.010	3.311	0.107	0.927	0.032				
NIST612-2	1.30E-03	8.10E-05	-1.77E-04	2.50E-05	1.21E-03	1.80E-05	4.86E-04	8.00E-06	5.28E-04	8.70E-06	4.50E-05	8.60E-07	37.760	1.785	0.297	0.010	3.370	0.110	0.919	0.032				
NIST612-3	1.41E-03	6.10E-05	-1.30E-04	2.40E-05	1.23E-03	1.40E-05	4.90E-04	6.70E-06	5.33E-04	6.50E-06	4.57E-05	7.20E-07	37.630	1.757	0.294	0.009	3.399	0.108	0.927	0.032				
NIST612-4	1.39E-03	5.60E-05	-7.70E-05	3.00E-05	1.23E-03	1.60E-05	4.89E-04	6.10E-06	5.30E-04	7.10E-06	4.51E-05	6.50E-07	37.600	1.771	0.296	0.009	3.383	0.109	0.919	0.032				
NIST612-5	1.41E-03	5.00E-05	-1.64E-04	1.70E-05	1.21E-03	1.60E-05	4.83E-04	5.10E-06	5.23E-04	7.50E-06	4.50E-05	7.10E-07	36.420	1.702	0.291	0.009	3.435	0.109	0.914	0.031				
NIST612-6	1.42E-03	7.10E-05	-1.27E-04	2.80E-05	1.23E-03	1.50E-05	4.95E-04	6.10E-06	5.32E-04	7.40E-06	4.61E-05	9.30E-07	36.790	1.719	0.291	0.009	3.434	0.109	0.921	0.032				
NIST612-7	1.43E-03	8.10E-05	-1.03E-04	2.90E-05	1.23E-03	2.20E-05	4.91E-04	8.00E-06	5.30E-04	9.20E-06	4.64E-05	9.50E-07	37.100	1.738	0.291	0.009	3.432	0.110	0.925	0.032				
NIST612-8	1.40E-03	6.50E-05	-1.40E-04	2.30E-05	1.23E-03	1.70E-05	4.90E-04	7.10E-06	5.28E-04	7.80E-06	4.58E-05	7.50E-07	37.840	1.780	0.294	0.009	3.405	0.109	0.925	0.032				
NIST612-9	1.39E-03	5.00E-05	-1.56E-04	2.10E-05	1.23E-03	1.50E-05	4.91E-04	5.00E-06	5.30E-04	6.20E-06	4.65E-05	6.20E-07	37.180	1.756	0.295	0.010	3.392	0.109	0.922	0.032				
BHVO-1	-2.29E-03	1.80E-05	-1.65E-03	2.50E-05	4.44E-05	7.20E-07	1.80E-05	4.10E-07	2.11E-05	4.10E-07	2.46E-06	1.40E-07	no value	#DIV/0!	no value	#VALUE!		#DIV/0!	no value	#VALUE!				
BHVO-10	-2.27E-03	1.10E-05	-1.70E-03	2.40E-05	4.98E-05	7.70E-07	1.90E-05	3.80E-07	2.27E-05	3.90E-07	2.67E-06	1.50E-07	no value	#DIV/0!	no value	#VALUE!		#DIV/0!	no value	#VALUE!				
BHVO-11	-2.28E-03	2.00E-05	-1.75E-03	1.90E-05	4.89E-05	5.20E-07	1.91E-05	3.60E-07	2.19E-05	3.40E-07	2.65E-06	1.00E-07	no value	#DIV/0!	no value	#VALUE!		#DIV/0!	no value	#VALUE!				
BHVO-12	-2.25E-03	2.30E-05	-1.69E-03	2.30E-05	4.80E-05	5.80E-07	1.89E-05	4.90E-07	2.21E-05	2.80E-07	2.86E-06	8.70E-08	no value	#DIV/0!	no value	#VALUE!		#DIV/0!	no value	#VALUE!				
BHVO-2	-2.29E-03	2.00E-05	-1.66E-03	2.60E-05	4.60E-05	6.30E-07	1.84E-05	3.10E-07	2.17E-05	4.00E-07	2.66E-06	1.50E-07	no value	#DIV/0!	no value	#VALUE!		#DIV/0!	no value	#VALUE!				
BHVO-3	-2.27E-03	2.00E-05	-1.70E-03	2.30E-05	4.67E-05	7.00E-07	1.89E-05	3.80E-07	2.24E-05	2.40E-07	2.50E-06	1.40E-07	no value	#DIV/0!	no value	#VALUE!		#DIV/0!	no value	#VALUE!				
BHVO-4	-2.28E-03	1.80E-05	-1.68E-03	2.30E-05	4.73E-05	7.90E-07	1.88E-05	2.70E-07	2.27E-05	3.20E-07	2.57E-06	1.20E-07	no value	#DIV/0!	no value	#VALUE!		#DIV/0!	no value	#VALUE!				
BHVO-5	-2.28E-03	1.50E-05	-1.71E-03	2.80E-05	4.80E-05	5.10E-07	1.85E-05	3.60E-07	2.17E-05	3.10E-07	2.60E-06	1.20E-07	no value	#DIV/0!	no value	#VALUE!		#DIV/0!	no value	#VALUE!				
BHVO-6	-2.27E-03	2.50E-05	-1.72E-03	1.60E-05	4.73E-05	6.80E-07	1.86E-05	3.00E-07	2.23E-05	4.50E-07	2.60E-06	1.70E-07	no value	#DIV/0!	no value	#VALUE!		#DIV/0!	no value	#VALUE!				
BHVO-7	-2.26E-03	2.60E-05	-1.71E-03	1.90E-05	4.87E-05	6.30E-07	1.89E-05	3.90E-07	2.19E-05	3.40E-07	2.68E-06	1.00E-07	no value	#DIV/0!	no value	#VALUE!		#DIV/0!	no value	#VALUE!				
BHVO-8	-2.28E-03	1.90E-05	-1.71E-03	1.90E-05	4.84E-05	5.60E-07	1.83E-05	2.80E-																

Table S6: Analytical Information for Zircon U-Pb Analyses at the Arizona LaserChron Center (Element 2 Single Collector)

Laboratory and Sample Preparation

Laboratory name	Arizona LaserChron Center
Sample type/mineral	Zircon
Sample preparation	Conventional mineral separation, 1 inch epoxy mount, polished to 1-micron finish
Imaging	Hitachi 3400N SEM with BSE and/or Cathodoluminescence

Laser ablation system

Make, Model, and type	Photon Machines Analyte G2 Excimer laser
Ablation cell and volume	HelEx ablation cell
Laser wavelength	193 nm
Pulse width	~8 ns
Energy density	~7 J/cm2
Repetition rate	7 Hz
Ablation duration	10 s
Ablation pit depth/ablation rate	~12 microns & 0.8 microns/sec
Spot diameter nominal/actual	20 microns
Sampling mode/pattern	Spot
Carrier gas	Helium
Cell carrier gas flow	0.11 L/min He in inner cup, 0.29 L/min He in cell

ICP-MS instrument

Make, Model, and type	Thermo Element2 HR ICPMS
Sample introduction	Ablation aerosol
RF power	1200 W
Make-up gas flow	0.8 L/min Ar
Detection system	Dual mode Secondary Electron Multiplier
Masses measured	202Hg, 204(Hg+Pb), 206Pb, 207Pb, 208Pb, 232Th, 235U, 238U
Dwell times (ms)	202=5.2, 204=7.8, 206=20.2, 207=28.4, 208=2.6, 232=2.6, 235=15.4, 238=10.4
Total integration time per output data point (sec)	202=1.5, 204=2.3, 206=5.9, 207=8.3, 208=0.7, 232=0.7, 235=4.5, 238=3.0
Sensitivity as useful yield	~5000 cps/ppm
IC dead time	22 ns

Data processing

Gas blank	8 sec on-peak zero subtracted
Calibration strategy	SLM zircon used as primary standard
Reference material information	Gehrels et al., 2008
Data processing package used/Correction for LIEF	E2agecalc
Mass discrimination	Normalized to primary standard
Common Pb correction, composition and uncertainty	Common Pb correction based on measured 206Pb/204Pb and the assumed composition of common Pb based on Stacey and Kramers (1975)
Uncertainty level and propagation	Uncertainties for individual analyses propagated at 1-sigma, and include only analytical (measurement) uncertainty. Uncertainty of pooled analyses (concordia and intercept ages) propagated at 2-sigma, and include both analytical and systematic uncertainties, added quadratically.
Quality control/validation	FC-1 (Schmitz & Bowring, 2001; Bachmann et al., 2007) & R33 (Black et al., 2004; Mattinson, 2010) analyzed as secondary standards

Systematic uncertainties	Systematic uncertainty includes: 1) ratio uncertainty in the primary reference material used for normalization, 2) long-term excess variance of the validation materials (typically 1-2%, Gehrels et al., 2008), 3) decay constant uncertainties, and 4) model Pb ratio uncertainty (Horstwood et al., 2016). Together, this is: - for sample OZ-021, this is 1.6% (2s) for the 206/238 ratio, 11.1% (2s) for the 206/207 ratio, and an average of 6.4% (2s) for both. - for sample OZ-022, this is 1.0% (2s) for the 206/238 ratio, 14.3% (2s) for the 206/207 ratio, and an average of 7.6% (2s) for both. - for sample OZ-015, this is 1.4% (2s) for the 206/238 ratio, 12.9% (2s) for the 206/207 ratio, and an average of 7.1% (2s) for both. - for sample OZ-024, this is 1.2% (2s) for the 206/238 ratio, 27.2% (2s) for the 206/207 ratio, and an average of 14.2% (2s) for both.
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Other information

Primary and secondary standards mounted together with unknowns.
Analytical methods described by Gehrels et al. (2008), Gehrels and Pecha (2014), and Pullen et al. (2018)

Procedure

Sample material was crushed and subjected to standard heavy mineral separation techniques, culminating in hand-picking of zircon and apatite and embedding in epoxy mounts. Cathodoluminescence (CL) images were used to identify zonations and core/rim relations in zircon grains, and select analytical spots. Zircons were analyzed on a Thermo Element 2 single-collector ICPMS, with a 25 µm spot, following Gehrels et al. (2008), Gehrels and Pecha (2014), and Pullen et al. (2018). Analyses were calibrated against the SLM zircon primary standard, and quality was monitored with the FC-1 and R33 secondary standards (Gehrels et al., 2008).

Table S7: U-Pb Data for Zircons from Synkinematic Pegmatites

Analysis	U (ppm)	206Pb/204Pb	U/Th	206Pb*/207Pb*	± (%)	Isotope ratios					Apparent ages (Ma) [†]					Best age (Ma)	± 1s (Ma)	Conc. (%)	Discordance (%) [‡]	Excluded from calculation of discordia age	Reason for exclusion
						207Pb*/235U*	± 1s (%)	206Pb*/238U	± 1s (%)	rho	206Pb*/238U	± 1s (Ma)	207Pb*/235U	± 1s (Ma)	206Pb*/207Pb*						
OZ-021 Spot 0	7944	11379	3.1	19.5827	1.0	0.0728	1.7	0.0103	1.4	0.82	66.3	0.9	71.3	1.2	242.8	22.2	66.3	0.9	NA	85.8	
OZ-021 Spot 1	4983	1143	0.2	12.9646	10.0	0.0868	10.8	0.0082	4.2	0.38	52.4	2.2	84.5	8.8	1123.8	200.0	52.4	2.2	NA	90.6	x
OZ-021 Spot 4	37515	22900	12.5	19.8617	0.9	0.0682	2.1	0.0098	1.9	0.91	63.1	1.2	67.0	1.3	210.1	19.8	63.1	1.2	NA	85.6	
OZ-021 Spot 5	12058	2678	0.0	16.0261	2.8	0.0938	3.3	0.0109	1.7	0.51	69.9	1.2	91.0	2.9	686.9	60.4	69.9	1.2	NA	88.4	
OZ-021 Spot 6	20601	31381	20.8	20.5536	0.6	0.0676	1.6	0.0101	1.5	0.92	64.7	1.0	66.4	1.1	130.1	15.1	64.7	1.0	NA	85.1	
OZ-021 Spot 8	3669	2978	22.4	15.8023	5.8	0.0910	5.9	0.0104	1.2	0.20	66.9	0.8	88.4	5.0	716.8	123.2	66.9	0.8	NA	88.5	
OZ-021 Spot 10	6803	74991	29.3	20.9922	0.5	0.0651	1.1	0.0099	1.0	0.89	63.6	0.6	64.1	0.7	80.2	12.3	63.6	0.6	NA	84.8	
OZ-021 Spot 12	5198	1003	0.0	8.6595	12.3	0.1514	12.4	0.0095	1.5	0.12	61.0	0.9	143.1	16.6	1886.6	223.1	61.0	0.9	NA	93.7	x
OZ-021 Spot 14	10551	19303	30.0	19.9727	1.0	0.0250	8.7	0.0036	8.7	0.99	23.4	2.0	25.1	2.2	197.2	22.9	23.4	2.0	NA	85.5	x
OZ-021 Spot 15	5361	9977	0.5	19.9557	2.0	0.0683	3.0	0.0099	2.3	0.76	63.4	1.5	67.1	2.0	199.1	46.2	63.4	1.5	NA	85.5	
OZ-021 Spot 18	6103	4318	17.7	16.7809	2.9	0.0848	3.1	0.0103	1.1	0.34	66.2	0.7	82.7	2.5	587.9	63.7	66.2	0.7	NA	87.8	
OZ-021 Spot 19	7621	24734	28.0	20.3570	0.7	0.0679	1.1	0.0100	0.8	0.76	64.3	0.5	66.7	0.7	152.7	16.3	64.3	0.5	NA	85.2	
OZ-021 Spot 20	10147	12018	29.1	19.3816	1.0	0.0720	1.5	0.0101	1.1	0.76	65.0	0.7	70.6	1.0	266.5	22.1	65.0	0.7	NA	85.9	
OZ-021 Spot 21	5853	15006	41.1	19.9370	1.4	0.0722	2.2	0.0104	1.7	0.78	67.0	1.1	70.8	1.5	201.3	31.8	67.0	1.1	NA	85.5	
OZ-021 Spot 22	6144	27988	24.5	20.6638	0.7	0.0667	1.2	0.0100	1.0	0.80	64.1	0.6	65.5	0.8	117.5	17.4	64.1	0.6	NA	85.0	
OZ-021 Spot 23	4636	16144	22.3	20.0512	1.1	0.0774	3.2	0.0113	3.0	0.94	72.2	2.2	75.7	2.4	188.0	25.9	72.2	2.2	NA	85.5	x
OZ-021 Spot 24	6193	14185	14.5	20.1305	0.8	0.0685	1.3	0.0100	1.1	0.81	64.2	0.7	67.3	0.9	178.8	18.4	64.2	0.7	NA	85.4	
OZ-021 Spot 25	5960	5090	8.0	18.0186	1.6	0.0774	1.9	0.0101	1.1	0.57	64.9	0.7	75.7	1.4	431.4	35.7	64.9	0.7	NA	86.9	
OZ-021 Spot 26	2753	37390	52.5	20.7688	0.6	0.0671	1.1	0.0101	1.0	0.86	64.8	0.6	65.9	0.7	105.5	13.3	64.8	0.6	NA	84.9	
OZ-021 Spot 27	6354	2617	13.1	15.5579	5.0	0.0898	5.1	0.0101	1.0	0.20	65.0	0.7	87.3	4.3	749.8	106.6	65.0	0.7	NA	88.7	
OZ-021 Spot 28	6148	2105	19.7	14.9753	5.0	0.0948	5.3	0.0103	1.7	0.32	66.1	1.1	92.0	4.6	829.9	104.1	66.1	1.1	NA	89.1	
OZ-021 Spot 33	5473	6368	32.6	18.6105	0.7	0.0760	1.3	0.0103	1.1	0.83	65.8	0.7	74.3	0.9	358.9	15.8	65.8	0.7	NA	86.5	
OZ-021 Spot 34	3509	2035	2.4	14.2064	3.4	0.1008	3.7	0.0104	1.3	0.35	66.7	0.8	97.6	3.4	938.9	70.5	66.7	0.8	NA	89.7	
OZ-021 Spot 35	5098	5350	14.8	17.6012	1.5	0.0778	1.8	0.0099	0.9	0.50	63.8	0.6	76.1	1.3	483.4	33.5	63.8	0.6	NA	87.2	
OZ-021 Spot 36	4435	12249	24.8	19.3802	0.9	0.0728	1.4	0.0102	1.1	0.78	65.7	0.7	71.4	0.9	266.7	19.5	65.7	0.7	NA	85.9	
OZ-021 Spot 37	4345	2230	6.4	15.0504	3.0	0.1018	3.1	0.0111	0.9	0.28	71.3	0.6	98.4	3.0	819.5	63.1	71.3	0.6	NA	89.1	
OZ-021 Spot 38	3817	756	23.3	8.9594	4.5	0.1643	4.7	0.0107	1.3	0.28	68.5	0.9	154.5	6.7	1825.1	81.9	68.5	0.9	NA	93.5	
OZ-021 Spot 40	4696	3816	31.1	16.0288	2.7	0.0867	2.9	0.0101	1.2	0.39	64.7	0.7	84.4	2.4	686.5	57.7	64.7	0.7	NA	88.4	
OZ-021 Spot 42	5639	5892	11.2	18.7716	0.8	0.0767	1.2	0.0104	0.9	0.74	67.0	0.6	75.1	0.9	339.4	19.0	67.0	0.6	NA	86.4	
OZ-021 Spot 43	6233	2698	16.2	15.3728	2.3	0.0995	2.5	0.0111	1.1	0.43	71.2	0.8	96.3	2.3	775.0	47.6	71.2	0.8	NA	88.8	
OZ-021 Spot 44	5504	16516	27.5	19.6206	1.2	0.0744	1.6	0.0106	1.2	0.71	67.9	0.8	72.9	1.2	238.3	26.8	67.9	0.8	NA	85.8	
OZ-021 Spot 45	4827	4608	26.1	18.2206	1.6	0.0808	1.9	0.0107	1.0	0.50	68.5	0.7	78.9	1.4	406.5	36.7	68.5	0.7	NA	86.8	
OZ-021 Spot 46	5802	2469	4.5	14.6264	3.5	0.0997	3.8	0.0106	1.2	0.33	67.8	0.8	96.5	3.5	878.9	73.2	67.8	0.8	NA	89.4	
OZ-021 Spot 47	5616	1608	0.5	12.3418	5.0	0.1196	5.2	0.0107	1.3	0.25	68.7	0.9	114.7	5.6	1221.2	98.4	68.7	0.9	NA	91.0	
OZ-021 Spot 48	9669	2841	4.9	15.5423	3.1	0.0720	7.3	0.0081	6.6	0.90	52.1	3.4	70.6	5.0	751.9	66.3	52.1	3.4	NA	88.7	x
OZ-021 Spot 49	5945	1384	14.8	12.5296	1.8	0.1121	2.2	0.0102	1.3	0.60	65.4	0.9	107.9	2.3	1191.5	35.1	65.4	0.9	NA	90.9	
OZ-021 Spot 50	8482	29563	23.8	20.9512	0.8	0.0653	1.5	0.0099	1.3	0.86	63.6	0.8	64.2	0.9	84.9	18.4	63.6	0.8	NA	84.8	
OZ-021 Spot 51	3004	20292	51.1	20.5513	0.7	0.0705	1.2	0.0105	1.0	0.80	67.4	0.6	69.2	0.8	130.4	17.2	67.4	0.6	NA	85.1	
OZ-021 Spot 53	12309	30749	30.8	20.7290	0.7	0.0673	1.2	0.0101	1.0	0.80	65.0	0.6	66.2	0.8	110.1	17.5	65.0	0.6	NA	85.0	
OZ-021 Spot 56	4142	28471	35.8	20.5933	0.6	0.0676	1.2	0.0101	1.0	0.83	64.8	0.6	66.4	0.7	125.6	15.1	64.8	0.6	NA	85.1	
OZ-021 Spot 57	5822	5752	12.6	17.7707	2.3	0.0815	2.5	0.0105	1.1	0.43	67.4	0.7	79.5	1.9	462.2	50.1	67.4	0.7	NA	87.1	
OZ-021 Spot 58	8181	154647	27.5	21.0965	0.5	0.0675	1.0	0.0103	0.9	0.85	66.3	0.6	66.3	0.7	68.4	12.7	66.3	0.6	NA	84.7	
OZ-022 Spot 0	3003	79911	9.8	20.8876	0.6	0.0646	0.9	0.0098	0.7	0.77	62.8	0.4	63.5	0.6	92.1	13.6	62.8	0.4	NA	84.8	
OZ-022 Spot 1	3364	357																			

OZ-022 Spot 96	4541	22236	5.0	21.1588	0.7	0.0631	1.1	0.0097	0.9	0.75	62.1	0.5	62.1	0.7	61.5	17.8	62.1	0.5	NA	84.6			
OZ-022 Spot 97	5170	18306	25.0	18.9624	1.1	0.0736	1.4	0.0101	0.9	0.61	64.9	0.6	72.1	1.0	316.4	25.5	64.9	0.6	NA	86.2			
OZ-022 Spot 98	2884	162203	52.9	21.2200	0.7	0.0631	1.2	0.0097	1.0	0.83	62.4	0.6	62.2	0.7	54.5	16.5	62.4	0.6	NA	84.6			
OZ-022 Spot 99	3266	7341	46.3	18.2058	1.2	0.0753	1.5	0.0100	0.8	0.57	63.8	0.5	73.8	1.0	408.3	26.7	63.8	0.5	NA	86.8			
OZ-022 Spot 100	2409	5518	36.0	18.8626	1.0	0.0703	1.2	0.0096	0.7	0.59	61.7	0.4	69.0	0.8	328.4	22.3	61.7	0.4	NA	86.3			
OZ-022 Spot 101	3280	13380	36.4	19.7530	0.8	0.0715	1.0	0.0102	0.6	0.63	65.7	0.4	70.1	0.7	222.8	18.4	65.7	0.4	NA	85.7			
OZ-022 Spot 102	2943	24879	64.2	19.7475	0.9	0.0669	1.3	0.0096	0.9	0.69	61.5	0.5	65.7	0.8	223.4	21.2	61.5	0.5	NA	85.7			
OZ-022 Spot 103	2854	26561	25.2	20.3377	0.7	0.0675	1.2	0.0100	0.9	0.77	63.9	0.6	66.4	0.8	154.9	17.4	63.9	0.6	NA	85.2			
OZ-022 Spot 104	2896	59040	62.6	21.0449	0.5	0.0628	0.8	0.0096	0.6	0.77	61.6	0.4	61.9	0.5	74.3	12.7	61.6	0.4	NA	84.7			
OZ-022 Spot 105	4626	264129	49.8	20.8747	0.5	0.0656	1.0	0.0099	0.8	0.83	63.7	0.5	64.5	0.6	93.6	12.9	63.7	0.5	NA	84.9			
OZ-022 Spot 106	4332	1048	24.3	10.8810	13.2	0.1325	13.3	0.0105	1.5	0.11	67.1	1.0	126.3	15.8	1464.5	252.3	67.1	1.0	NA	92.1			
OZ-022 Spot 107	4220	2059	33.9	14.5869	5.8	0.0949	6.1	0.0100	1.7	0.28	64.5	1.1	92.1	5.3	884.5	120.2	64.5	1.1	NA	89.4			
OZ-022 Spot 108	4164	8715	10.5	19.7801	0.8	0.0697	1.3	0.0100	1.0	0.78	64.1	0.7	68.4	0.9	219.6	19.5	64.1	0.7	NA	85.6			
OZ-022 Spot 109	4923	40207	26.9	20.7822	0.5	0.0657	1.1	0.0099	0.9	0.86	63.5	0.6	64.6	0.7	104.1	12.8	63.5	0.6	NA	84.9			
OZ-022 Spot 110	2551	16336	57.5	21.1241	0.7	0.0639	1.1	0.0098	0.9	0.79	62.8	0.6	62.8	0.7	65.3	16.8	62.8	0.6	NA	84.7			
OZ-022 Spot 111	142	13931	1.4	19.5910	1.0	0.1884	1.4	0.0268	1.0	0.69	170.3	1.6	175.2	2.3	241.8	23.7	170.3	1.6	NA	85.8	x		bright & zoned in CL _u –169 Ma pop.
OZ-022 Spot 112	364	15940	1.3	20.0110	1.0	0.1787	1.6	0.0259	1.3	0.78	165.1	2.1	167.0	2.5	192.7	23.2	165.1	2.1	NA	85.5	x		bright & zoned in CL _u –169 Ma pop.
OZ-022 Spot 113	212	3576111	2.6	12.2933	0.6	2.3014	1.4	0.2053	1.3	0.90	1203.6	14.2	1212.7	10.1	1229.0	11.9	1229.0	11.9	97.9	91.1	x		bright & zoned in CL
OZ-022 Spot 114	3078	1440	69.1	13.3813	7.3	0.1052	7.6	0.0102	2.2	0.28	65.5	1.4	101.6	7.3	1060.4	146.1	65.5	1.4	NA	90.3			
OZ-022 Spot 115	3352	5131	24.1	17.4469	2.0	0.0795	2.3	0.0101	1.2	0.52	64.5	0.8	77.6	1.7	502.8	42.9	64.5	0.8	NA	87.3			
OZ-022 Spot 116	2515	90372	61.4	20.7136	0.5	0.0657	1.0	0.0099	0.9	0.85	63.3	0.6	64.6	0.7	111.9	12.7	63.3	0.6	NA	85.0			
OZ-022 Spot 117	3095	10285	59.6	17.8289	3.2	0.0801	3.3	0.0104	0.9	0.29	66.5	0.6	78.3	2.5	454.9	70.3	66.5	0.6	NA	87.1			
OZ-022 Spot 118	5952	14624	37.3	20.1352	1.5	0.0693	1.7	0.0101	0.9	0.52	64.9	0.6	68.0	1.1	178.3	33.9	64.9	0.6	NA	85.4			
OZ-022 Spot 119	3053	31684	52.4	21.2240	0.6	0.0634	1.0	0.0098	0.8	0.80	62.7	0.5	62.4	0.6	54.1	14.5	62.7	0.5	NA	84.6			
OZ-015 Spot 0	3038	43433	43.4	21.0687	0.8	0.0648	1.3	0.0099	1.1	0.79	63.6	0.7	63.8	0.8	71.6	19.5	63.6	0.7	NA	84.7			
OZ-015 Spot 1	5867	34748	68.7	20.4521	0.9	0.0690	1.6	0.0102	1.3	0.83	65.7	0.8	67.7	1.0	141.8	20.6	65.7	0.8	NA	85.2			
OZ-015 Spot 2	3156	5012	55.9	16.3022	2.3	0.0843	2.7	0.0100	1.4	0.52	64.0	0.9	82.2	2.1	650.3	48.7	64.0	0.9	NA	88.2			
OZ-015 Spot 5	3220	30990	57.4	20.6314	0.9	0.0673	1.8	0.0101	1.5	0.87	64.6	1.0	66.1	1.1	121.3	20.6	64.6	1.0	NA	85.0			
OZ-015 Spot 6	11202	36906	44.4	20.9163	0.7	0.0629	1.8	0.0095	1.6	0.93	61.2	1.0	61.9	1.1	88.9	15.9	61.2	1.0	NA	84.8			
OZ-015 Spot 8	38	179	37.5	3.0411	1.0	0.5977	1.8	0.0132	1.5	0.82	84.5	1.3	475.8	6.9	3611.0	16.0	84.5	1.3	NA	97.8			
OZ-015 Spot 9	5951	4602	35.2	16.8739	1.5	0.0812	1.9	0.0099	1.2	0.61	63.8	0.7	79.3	1.5	575.8	33.0	63.8	0.7	NA	87.8			
OZ-024 Spot 2	173	6243	3.2	21.1085	1.7	0.1394	2.1	0.0213	1.3	0.61	136.1	1.7	132.5	2.6	67.1	40.1	136.1	1.7	NA	84.7	x		bright & zoned in CL
OZ-024 Spot 5	78	9168	1.6	20.4453	1.6	0.1926	1.9	0.0286	1.1	0.56	181.6	1.9	178.8	3.1	142.5	37.1	181.6	1.9	NA	85.2	x		bright & zoned in CL
OZ-024 Spot 6	213	3408	1.6	16.6943	5.8	0.2297	6.0	0.0278	1.3	0.21	176.9	2.2	210.0	11.3	599.0	126.1	176.9	2.2	NA	87.9	x		bright & zoned in CL
OZ-024 Spot 7	203	13259	1.7	19.4272	1.4	0.1947	1.8	0.0274	1.1	0.63	174.5	2.0	180.6	3.0	261.1	32.2	174.5	2.0	NA	85.9	x		bright & zoned in CL
OZ-024 Spot 9	472	15763	1.6	20.3058	1.1	0.1740	1.8	0.0256	1.3	0.76	163.2	2.1	162.9	2.6	158.6	26.8	163.2	2.1	NA	85.3	x		bright & zoned in CL

Standard Reference Materials

FC	355	58201	2.2	13.2054	0.6	1.9439	1.4	0.1863	1.2	0.91	1101.0	12.6	1096.3	9.1	1087.0	11.3	1087.0	11.3
FC	146	211738	2.1	13.0396	0.6	1.9704	1.2	0.1864	1.1	0.86	1102.0	10.9	1105.4	8.3	1112.2	12.4	1112.2	12.4
FC	159	33053	1.9	13.1183	0.8	1.9258	1.2	0.1833	0.8	0.71	1085.0	8.4	1090.1	7.9	1100.3	16.5	1100.3	16.5
SL	559	76853	6.5	16.9957	0.7	0.7256	1.3	0.0895	1.1	0.83	552.5	5.7	554.0	5.5	560.2	15.7	552.5	5.7
SL	525	475177	6.4	17.1256	0.8	0.7263	1.5	0.0902	1.3	0.85	557.0	6.8	554.4	6.4	543.6	17.3	557.0	6.8
SL	342	33689	7.4	17.1223	0.6	0.7158	1.2	0.0889	1.1	0.87	549.2	5.7	548.2	5.3	544.0	13.4	549.2	5.7
R33	145	11355	1.8	18.2572	0.8	0.5018	1.3	0.0665	1.0	0.78	414.9	4.1	412.9	4.4	402.0	18.0	414.9	4.1
R33	132	32553	1.8	17.9131	0.8	0.5176	1.2	0.0673	0.9	0.74	419.7	3.7	423.6	4.2	444.4	18.1	419.7	3.7
R33	1595	192886	1.5	18.0944	0.7	0.5187	1.2	0.0681	1.0	0.80	424.7	4.0	424.3	4.3	422.0	16.6	424.7	4.0
FC	86	24361	2.4	13.0516	0.5	2.0030	1.2	0.1897	1.1	0.91	1119.7	11.3	1116.5	8.2	1110.4	10.0	1110.4	10.0
FC	179	76250	2.8	13.1416	0.7	1.9189	1.1	0.1830	0.9	0.80	1083.2	9.1	1087.7	7.6	1096.7	13.7	1096.7	13.7
SL	485	71872	6.3	16.9584	0.8	0.7265	1.4	0.0894	1.1	0.82	552.0	6.0	554.5	5.9	564.9	17.1	552.0	6.0
FC	207	1125023	1.9	13.1256	0.6	1.9490	1.3	0.1856	1.2	0.90	1097.6	12.1	1098.1	8.9	1099.1	11.3	1099.1	11.3
R33	884	170451	1.3	18.0983	0.7	0.5201	1.3	0.0683	1.1	0.85	425.9	4.6	425.2	4.6	421.5	15.6	425.9	4.6
FC	433	921915	1.7	12.9850	0.8	2.0026	1.4	0.1887	1.2	0.83	1114.2	11.8	1116.4	9.4	1120.6	15.3	1120.6	15.3
SL	464	40890	6.4	17.0917	0.8	0.7276	1.4	0.0902	1.1	0.82	556.9	6.0	555.2	5.8	547.9	16.9	556.9	6.0
FC	59	32183	3.2	13.1699	0.8	1.9611	1.1	0.1874	0.7	0.67	1107.2	7.2	1102.2	7.1	1092.4	15.6	1092.4	15.6
FC	251	38786	1.1	13.1796	0.7	1.9592	1.3	0.1874	1.1	0.87	1107.0	11.4	1101.6	8.7	1090.9	13.0	1090.9	13.0
R33	887	94308	1.8	18.2857	0.7	0.5148	1.5	0.0683	1.3	0.89	426.0	5.3	421.7	5.0	398.5	15.1	426.0	5.3
SL	531	123715	6.3	16.3289	1.1	0.9152	8.6	0.1084	8.6	0.99	663.7	53.9	659.8	41.8	646.8	22.7	663.7	53.9
FC	114	286664	1.9	13.0534	0.7	1.9612	1.1	0.1858	0.8	0.74	1098.3	8.1	1102.3	7.3	1110.1	14.7	1110.1	14.7
FC	333	351334	1.8	13.2532	0.7	1.9755	1.2	0.1900	1.0	0.83	1121.2	10.5	1107.2	8.4	1079.7	14.0	1079.7	14.0
SL	602	66296	6.1	16.9968	0.6	0.7320	1.3	0.0903	1.2	0.88	557.1	6.2	557.7	5.6	560.0	13.7	557.1	6.2
FC	198	36512	1.9	13.2494	0.6	1.9312	1.2	0.1857	1.0	0.85	1097.8	10.6	1092.2	8.2	1080.3	12.8	1080.3	12.8
R33	33	76539	2.4	17.4392	1.2	0.5231	1.4	0.0662	0.8	0.57	413.1	3.2	427.2	5.0	503.8	25.8	413.1	3.2
FC	365	69410	1.7	13.1902	0.5	1.9451	1.2	0.1862	1.1	0.91	1100.5	10.7	1096.7	7.9	1089.3	9.9	1089.3	9.9
FC	329	141130	1.7	16.8843	0.7	0.7296	1.2	0.0892	1.0	0.84	550.8	5.5	556.3	5.3	579.1	14.8	550.8	5.5
FC	319	115972	1.7	13.0868	0.6	1.9507	1.3	0.1852	1.2	0.88	1095.5	11.9	1098.7	9.0	1105.0	12.6	1105.0	12.6
FC	104	60559	3.3	13.1624	0.6	1.9573	0.9	0.1870	0.6	0.72	1105.2	6.6	1101.0	6.0	1092.6	12.4	1092.6	12.4
R33	225	23965	2.8	18.3809	0.8	0.5235	1.5	0.0696	1.3	0.86	433.7	5.5	427.5	5.4	394.2	17.5	433.7	5.5
FC	479	389312	6.3	17.1331	0.8	0.7098	1.7	0.0882	1.5	0.87	545.1	7.7	544.6	7.1	542.6	18.0	545.1	7.7
FC	231	117717	2.5	13.1484	0.6	1.9385	1.5	0.1849	1.3	0.90	1093.9	13.2	1094.5	9.8	1095.6	13.0	1095.6	13.0
FC	261	163909	3.0	13.2296	0.7	1.9099	1.4	0.1833	1.2	0.88	1085.2	12.0	1084.6	9.1	1083.3	13.1	1083.3	13.1
SL	470	56964	6.2	17.0601	0.6	0.7358	1.5	0.0911	1.3	0.91	561.9	7.2	559.9	6.3	551.9	13.5	561.9	7.2
FC	429	126856	2.3	13.0974	0.7	1.9636	1.6	0.1866	1.4	0.89	1103.0	14.2	1103.1	10.6	1103.4	14.5	1103.4	14.5
R33	138	32681	1.5	18.4037	1.1	0.5062	1.5	0.0676	1.0	0.70	421.4	4.2	415.9	5.0	384.0	23.8	421.4	4.2
FC	1041	402244	2.3	12.9391	0.5	1.9433	1.3	0.1824	1.2	0.91	1080.3	12.0	1096.1	8.9	1127.7	10.9	1127.7	10.9
SL	476	353173	7.0	17.0058	0.8	0.7239	1.5	0.0893	1.3	0.85	558.6	6.8	553.0	6.5	558.9	17.7	551.6	6.8
FC	214	100728	1.8	13.1376	0.7	1.9463	1.3	0.1855	1.1	0.86	1097.1	11.3	1097.2	8.7	1097.3	13.3	1097.3	13.3
FC	308	260804	0.8	13.0783	0.7	2.0058	1.5	0.1903	1.3	0.87	1123.2	13.1	1117.5	9.9	1106.3	14.4	1106.3	14.4
R33	305	65366	1.8	18.0610	0.8	0.5172	1.6	0.0678	1.3	0.85	422.7	5.4	423.2	5.4	426.1	18.1	422.7	5.4
SL	561	267805	6.2	17.0065	0.7	0.7308	1.3	0.0902	1.1	0.82	556.7	5.7	557.0	5.6	558.6	16.2	556.7	5.7
FC	232	151856	2.0	13.0129	0.8	1.9357	1.6	0.1828	1.4	0.87	1082.1	13.8	1093.5	10.7	1116.4	15.7	1116.4	15.7
FC	193	46573	1.9	13.1251	0.8	1.9374	1.4	0.1845	1.1	0.79	1091.5	10.8	1094.1	9.1	1099.2	16.8	1099.2	16.8
SL	630	1207859	6.6	17.1053	0.7	0.7283	1.4	0.0904	1.2	0.84	557.8	6.2	555.5	5.9	546.1	16.3	557.8	6.2
FC	394	132487	1.7	13.1079	0.6	1.9770	1.4	0.1890	1.2	0.89	1110.7	12.6	1107.7	9.4	1101.8	13.0	1101.8	13.0
R33	653	33570	1.9	18.4621	0.5	0.5057	1.2	0.0677	1.1	0.90	422.5	4.5	415.5	4.2	376.9	12.2	422.5	4.5
FC	530	1155712	2.2	13.1369	0.6	1.9699	1.5	0.1878	1.4	0.91	1109.3	13.9	1105.3	10.1	1097.4	12.3	1097.4	12.3
SL	553	315125	6.3	17.0520	0.7	0.7379	1.2	0.0913	1.0	0.82	563.2	5.6	561.2	5.4	553.0	15.5	563.2	5.6
FC	103	21254	3.5	13.2343	0.7	1.9227	1.2	0.1846	1.0	0.83	1092.2	10.0	1089.0	8.1	1082.6	13.7	1082.6	13.7
FC	478	5698487	1.8	13.0733	0.5	1.9678	1.4	0.1867	1.3	0.92	1103.3	12.8	1104.6	9.2	1107.1	10.7	1107.1	10.7
R33	162	102016	1.8	18.0428	0.8	0.5093	1.1	0.0667	0.8	0.71	416.1	3.1	418.0	3.8	428.4	17.3	416.1	3.1
FC	478	59204	6.2	16.9080	0.8	0.7265	1.3	0.0891	1.1	0.82	550.4	5.8	554.5	5.8	571.4	16.8	550.4	5.8
FC	241	41543	1.8	13.2197	0.7	1.9279	1.7	0.1849	1.5	0.91	1093.8	15.3	1090.8	11.2	1084.8	13.6	1084.8	13.6
FC	606	141638	2.0	13.2780	0.6	1.9417	1.2	0.1871	1.1	0.88	1105.8	10.8	1096.6	8.1	1076.0	11.4	1076.0	11.4
SL	529	73122	7.0	16.8861	0.8	0.7214	1.3	0.0884	1.0	0.80	546.0	5.5	551.5	5.8	574.2	17.1	546.0	5.5
FC	345	737174	1.9	13.3044	0.6	1.9603	1.2	0.1892	1.0	0.86	1117.2	10.4	1102.0	8.0	1072.0	12.2	1072.0	12.2
R33	133	39261	1.8	17.8320	0.9	0.5176	1.2	0.0670	0.8	0.64	417.9	3.2	423.6	4.2	454.5	20.7	417.9	3.2
FC	285	467357	1.8	13.1236	0.7	1.9637	1.6	0.1870	1.4	0.91	1105.1	14.7	1103.2	10.7	1099.4	13.5	1099.4	13.5
FC	503	259545	6.5	17.0726	0.7	0.7198	1.2	0.0892	1.0	0.82	550.6	5.1	550.6	5.0	550.3	14.6	550.6	5.1
FC	1094	945762	1.9	12.8930	0.4	1.9900	1.3	0.1862	1.2	0.94	1100.6	11.9	1112.1	8.5	1134.8	8.8	1134.8	8.8
R33	197	441324	1.9	13.1245	0.6	1.9876	1.2	0.1864	1.0	0.85	1101.9	9.9	1110.0	7.8	1093.3	12.3	1093.3	12.3
FC	129	121378	1.9	18.3034	0.8	0.5086	1.3	0.0675	1.1	0.82	421.3	4.4	417.5	4.5	396.7	16.9	421.3	4.4
FC	630	95127	6.6	16.9109	0.6	0.7409	1.0	0.0909	0.9	0.84	551.1	4.7	552.9	4.7	550.4	17.7	550.4	17.7
SL	547	204262	2.3	13.0904	0.6	1.9501	1.3	0.1852	1.2	0.89	1095.9	11.7	1098.5	8.8	1104.5	12.5	1104.5	12.5
FC	434	475358	6.7	17.0374	0.6	1.9672	1.3	0.1867	1.1	0.87	1049.3	11.1	1043.3	8.5	1106.5	12.7	1106.5	12.7
FC	140	46434	6.3	16.9114	0.7	0.7250	1.4	0.0890	1.2	0.87	403.2	6.2	553.6	5.8	571.0	14.6	549.4	6.2
FC	141	44780	1.9	13.2494	0.8	1.9558	1.2	0.1890	0.9	0.77	1110.7	9.7	1100.5	8.3	1080.3	15.7	1080.3	15.7
R33	172	13585	1.4	18.3434	1.0	0.5007	1.4	0.0666	0.9	0.69	415.9	3.8	412.2	4.6	391.4			

Table S8: Analytical Settings for U-Pb Geochronology of Apatite at the Arizona LaserChron Center (Nu multicollector, using Faraday Collectors)

Laboratory and Sample Preparation	
Laboratory name	Arizona LaserChron Center
Sample type/mineral	Apatite
Sample preparation	Conventional mineral separation, 1 inch epoxy mount, polished to finish
Imaging (If Applicable)	Hitachi 3400N SEM with BSE and cathodoluminescence
Laser ablation system	
Make, Model, and type	Photon Machines Analyte G2 Excimer laser
Ablation cell and volume	HelEx ablation cell
Laser wavelength	193 nm
Pulse width	~4-6 ns
Energy density	~6 J/cm2
Repetition rate	7 Hz
Alation duration	15 s (Faraday)
Ablation pit depth/ablation rate	~12 microns & 0.8 microns/sec
Spot diameter nominal/actual	65 microns (Faraday)
Sampling mode/pattern	Spot
Carrier gas	Helium
Cell carrier gas flow	0.10 L/min He in inner cup, 0.30 L/min He in cell
ICP-MS instrument	
Make, Model, and type	Nu Plasma multicollector HR ICPMS
Sample introduction	ablation aerosol
RF power	1300 W
Make-up gas flow	1.03 L/min Ar
Detection system	12 Faraday collectors with 3e11 ohm resistors, 4 ion counters
Masses measured	202Hg, 204(Hg+Pb), 206Pb, 207Pb, 208Pb, 232Th, 235U, 238U
Dwell times (ms)	one second for all masses
Total integration time per output data point (sec)	15 seconds (FAR)
Sensitivity as useful yield	~4000 cps/ppm
IC dead time	12, 10.8, 9.7, and 10 ns
Data processing	
Gas blank	15 sec on-peak zero subtracted
Calibration strategy	U/Pb and 206Pb/207Pb fractionation is calibrated relative to fragments of MAD Madagascar reference apatite of 486.6 ± 0.9 Ma (2 sigma)
Reference material information	Thomson et al. (2012); Gehrels et al. (2008)
Data processing package used/Correction for LIEF	NUagecalc
Mass discrimination	Normalized to primary standard
Common Pb correction, composition and uncertainty	Data uncorrected for common Pb (only corrected for fractionation) is used to create a Tera-Wassburg plot for each sample. Common Pb composition is then estimated for each sample from the y-axis intercept, and the corresponding date is obtained from the isochron (discordia) lower intercept. Individual spot and weighted mean 206Pb/238U ages are 207Pb corrected using a 20-step iteration, with the amount of common Pb based on measured 207Pb/206Pb, and the composition based on the Tera-Wasserburg y-axis intercept for that sample.
Uncertainty level and propagation	Uncertainties for individual analyses propagated at 1-sigma, and include only analytical (measurement) uncertainty. Uncertainty of pooled analyses (concordia, intercept, and weighted mean ages) propagated at 2-sigma, and include both analytical and systematic uncertainties, added quadratically.
Quality control/validation	Durango apatite (DUR) analyzed as secondary standard. Sources of systematic uncertainties include: 1) Uncertainty on the 206/238 elemental fractionation correction = 2.7% 1s 2) Uncertainty on the MAD reference 206Pb/238U ratio = 0.091% 1s 3) Uncertainty in 206Pb/238U and 207Pb/235U decay constant = 0.121% 1s 4) Uncertainty of Tera-Waserburg y-intercept 207Pb/206Pb common Pb value = varies for each grain dependent on its % common Pb.
Systematic and total uncertainties	Additional propagation of the reproducibility (uncertainty) of the secondary reference materials is not included in the systematic uncertainty. - For concordia and intercept ages: Only the first three sources are applicable. Quadratic addition of these sources is 2.71% 1s. This is added quadratically to the analytical uncertainty of the concordia and intercept ages, to find their total uncertainty. - For individual spot and weighted mean 206Pb/238U ages: All four sources are included in their stated systematic uncertainties, and added quadratically to their analytical uncertainty to find their total uncertainties.
U decay constants	28U/235U ratio: 137.818 ± 0.0225; 238U decay constant: 0.000155125 ± 8.3E-8 Myr-1; 235U decay constant: 0.00098485 ± 6.7E-7 Myr-1
Other information	
Primary and secondary standards mounted together with unknowns. Analytical methods described by Thomson et al. (2012)	

Table S9: U-Pb data for Apatite from Gold Rock Ranch Granite and Pegmatites

Analysis	U (ppm) ¹	Th/U	%Pb _c	Uncorrected for Common Pb ²					207Pb Common Pb Corrected ³						Excluded from calculation of discordia age	Reason for exclusion
				238U/206Pb _{lc}	± 1s (%)	207Pb/206Pb _m	± 1s (%)	rho	206Pb/238U	± 1s (%)	206Pb/238U Age (Ma)	±1s (Ma)	Systematic ± 1s % ⁴	Systematic ± 2s (Ma) ⁴		
OZ-002 spot1	2.7	0.14	96.65	3.8502	1.02	0.7972	0.71	-0.04	0.0082	23.06	52.6	12.1	10.8	41.2		
OZ-002 spot2	3.2	1.49	96.59	4.1850	0.54	0.7966	1.04	0.45	0.0077	33.13	49.6	16.4	10.6	43.0		
OZ-002 spot3	3.1	1.63	96.13	3.7741	0.55	0.7934	0.54	-0.02	0.0096	15.09	61.8	9.3	9.3	30.2		
OZ-002 spot4	3.6	1.46	95.09	4.8374	1.40	0.7852	0.52	0.02	0.0097	11.25	62.3	7.0	7.3	23.4		
OZ-002 spot5	3.3	1.46	96.94	3.7789	1.91	0.7993	0.75	-0.32	0.0076	27.14	48.9	13.2	11.9	48.7		
OZ-002 spot6	6.7	0.23	92.59	7.9415	0.46	0.7655	0.45	-0.13	0.0091	6.22	58.5	3.6	4.7	16.2		
OZ-002 spot7	5.5	1.65	94.33	4.7170	4.83	0.7797	0.51	-0.23	0.0115	10.61	73.6	7.8	6.3	17.1		
OZ-002 spot8	6.3	1.28	92.93	7.9302	0.91	0.7681	0.24	0.41	0.0087	3.52	55.9	2.0	5.0	17.8		
OZ-002 spot9	1.8	0.09	98.04	2.5710	1.00	0.8081	0.70	-0.17	0.0068	41.85	43.7	18.2	18.7	85.8		
OZ-002 spot10	5.1	1.30	94.54	6.3567	0.65	0.7806	0.28	-0.04	0.0083	5.40	53.5	2.9	6.5	24.4		
OZ-002 spot11	20.3	0.29	2.00	45.8173	1.14	0.0642	7.21	0.12	0.0214	1.29	136.4	1.7	0.7	1.0	x	~138 Ma pop.
OZ-002 spot12	28.9	0.30	0.78	47.0127	0.49	0.0548	7.17	0.58	0.0211	0.71	134.6	0.9	0.7	1.0	x	~138 Ma pop.
OZ-002 spot13	175.6	0.05	14.78	113.1535	0.26	0.1616	1.19	-0.66	0.0075	0.39	48.4	0.2	0.7	2.8	x	distinct pop. on T-W
OZ-002 spot14	3.2	1.75	96.47	3.8264	0.50	0.7959	0.60	0.34	0.0087	18.49	55.6	10.2	10.3	37.0		
OZ-002 spot15	70.6	0.37	22.34	44.8398	9.12	0.2215	12.33	-0.20	0.0173	10.20	110.6	11.2	0.7	1.2	x	distinct pop. on T-W
OZ-002 spot16	6.3	1.48	93.02	7.5199	0.75	0.7689	0.84	0.40	0.0091	12.30	58.1	7.1	5.0	17.4		
OZ-002 spot17	2.4	1.58	97.37	2.9086	0.68	0.8030	0.35	-0.58	0.0082	15.33	52.9	8.1	13.9	52.5		
OZ-002 spot18	7.6	1.26	92.11	6.5920	2.77	0.7622	2.00	-0.37	0.0116	25.79	74.6	19.1	4.4	11.9		
OZ-002 spot19	8.7	1.80	91.48	9.8683	0.64	0.7568	0.60	0.44	0.0085	7.07	54.5	3.8	4.1	15.0		
OZ-002 spot20	3.3	1.10	96.26	4.5558	0.62	0.7940	0.73	0.09	0.0078	20.94	50.2	10.5	9.7	38.5		
OZ-002 spot21	37.9	0.28	0.97	45.4263	0.50	0.0563	5.85	0.10	0.0218	0.66	139.0	0.9	0.2	0.2	x	~138 Ma pop.
OZ-015 spot22	5.4	0.76	96.68	3.2179	0.54	0.8133	0.35	0.11	0.0095	11.81	61.2	7.2	8.1	26.6		
OZ-015 spot23	15.5	0.33	91.43	9.2377	0.51	0.7711	0.49	-0.33	0.0091	5.73	58.5	3.3	3.0	10.3		
OZ-015 spot24	8.6	0.47	95.15	5.1077	0.52	0.8008	0.40	0.05	0.0091	8.68	58.5	5.1	5.5	18.8		
OZ-015 spot25	13.1	0.61	92.09	7.5160	0.33	0.7766	0.25	0.69	0.0103	3.22	65.9	2.1	3.3	9.9		
OZ-015 spot27	26.0	0.35	86.88	13.8361	3.53	0.7350	0.94	-0.04	0.0094	7.63	60.2	4.6	1.9	6.3		
OZ-015 spot29	27.1	0.40	85.08	14.7124	0.33	0.7209	0.39	-0.30	0.0100	2.41	64.4	1.5	1.6	5.1		
OZ-015 spot30	44.0	0.61	77.83	22.6932	0.48	0.6634	0.45	0.64	0.0097	1.77	62.3	1.1	1.1	3.4		
OZ-015 spot34	9.4	0.62	95.07	4.7876	9.74	0.8003	0.56	-0.31	0.0099	15.51	63.2	9.8	5.4	17.1		
OZ-015 spot33	160.9	0.24	25.42	95.7697	0.28	0.2488	0.84	-0.21	0.0078	0.45	50.0	0.2	1.0	3.9	x	anom. high U
OZ-022 spot2	3.5	1.33	96.20	3.1965	0.81	0.8124	0.43	0.45	0.0110	12.47	70.5	8.7	13.4	38.1		
OZ-022 spot4	3.5	1.18	95.32	4.1244	1.90	0.8052	0.41	-0.09	0.0107	9.66	68.9	6.6	10.8	31.4		
OZ-022 spot6	2.3	0.23	97.00	2.4037	11.25	0.8193	0.60	0.63	0.0110	26.09	70.6	18.3	17.2	48.7		
OZ-022 spot7	5.8	1.45	94.06	5.9944	0.63	0.7947	0.38	-0.09	0.0096	6.73	61.6	4.1	8.4	27.3		
OZ-022 spot15	6.2	0.95	92.05	5.7543	0.91	0.7794	0.47	-0.14	0.0134	6.10	85.6	5.2	6.2	14.4		
OZ-022 spot16	6.3	1.03	91.24	6.0671	1.29	0.7730	0.43	0.01	0.0140	5.09	89.6	4.5	5.6	12.4		
OZ-022 spot17	8.8	0.99	91.82	9.4724	1.74	0.7766	0.88	0.49	0.0085	10.81	54.5	5.9	6.0	21.9		
OZ-022 spot20	2.0	0.99	97.43	2.3529	3.38	0.8224	0.51	-0.43	0.0096	23.88	61.4	14.6	20.2	65.6		
Primary Reference Materials																
Cawood #2 MAD	15.9	10.75	9.26	11.6565	0.64	0.1334	0.72	0.61	0.0777	0.65	482.3	3.0	0.5	0.2		
Cawood #2 MAD	16.1	11.10	10.45	11.3507	0.47	0.1436	1.11	0.21	0.0787	0.52	488.4	2.4	0.5	0.2		
Cawood #2 MAD	16.1	10.35	10.46	11.3601	0.44	0.1436	0.66	0.09	0.0786	0.46	487.9	2.1	0.5	0.2		
Cawood #2 MAD	16.4	10.78	10.22	11.4553	0.46	0.1414	1.98	0.05	0.0782	0.60	485.4	2.8	0.5	0.2		
Cawood #2 MAD	15.6	10.35	10.47	11.4688	0.41	0.1435	2.25	-0.31	0.0779	0.61	483.4	2.8	0.5	0.2		
Cawood #2 MAD	15.9	11.37	9.66	11.4639	0.58	0.1370	9.14	-0.24	0.0786	1.80	487.9	8.5	0.5	0.2		
Cawood #3 MAD	16.2	10.31	9.83	11.6751	0.36	0.1380	2.03	0.27	0.0771	0.53	478.6	2.4	0.9	0.4		
Cawood #3 MAD	15.6	10.87	10.82	11.1629	0.26	0.1468	1.09	0.29	0.0797	0.34	494.2	1.6	0.9	0.4		
Cawood #3 MAD	16.0	10.32	10.09	11.3393	0.46	0.1406	1.27	-0.15	0.0791	0.52	490.8	2.5	0.9	0.4		
Cawood #3 MAD	16.6	10.50	11.72	11.5236	0.72	0.1536	4.27	-0.43	0.0764	1.16	474.6	5.3	1.0	0.4		
Cawood #3 MAD	15.5	10.30	10.66	11.3908	0.33	0.1451	5.67	0.00	0.0782	1.18	485.6	5.5	0.9	0.4		
Cawood #3 MAD	16.2	10.52	9.74	11.3969	0.45	0.1376	6.44	0.74	0.0790	1.29	490.3	6.1	0.9	0.4		
Cawood #3 MAD	16.1	10.41	10.86	11.2250	0.50	0.1470	4.90	0.25	0.0792	1.11	491.4	5.2	0.9	0.4		
Cawood #3 MAD	15.9	10.52	10.85	11.4478	0.50	0.1466	2.06	0.23	0.0777	0.65	482.3	3.0	0.9	0.4		
Secondary Reference Materials																
Cawood #2 DURANGO	10.9	8.33	20.01	146.4887	4.59	0.2053	29.56	0.10	0.0055	10.63	35.1	3.7	0.8	4.4		
Cawood #2 DURANGO	9.7	8.31	29.17	139.9200	8.83	0.2778	16.62	0.68	0.0051	12.07	32.5	3.9	1.2	7.1		
Cawood #2 DURANGO	10.9	10.09	13.08	153.5715	6.21	0.1503	37.04	0.23	0.0057	10.20	36.4	3.7	0.6	3.1		
Cawood #2 DURANGO	11.6	8.45	14.45	159.3090	5.53	0.1612	52.95	0.57	0.0054	13.77	34.5	4.7	0.6	3.4		
Cawood #2 DURANGO	9.0	8.29	8.05	128.3934	9.16	0.1108	66.85	0.57	0.0072	13.69	46.0	6.3	0.5	2.0		
Cawood #3 DURANGO	9.1	8.38	27.79	145.3418	7.87	0.2669	26.46	-0.07	0.0050	14.65	31.9	4.7	1.3	8.4		
Cawood #3 DURANGO	11.0	7.74	26.62	169.4350	5.56	0.2574	339.67	-0.08	0.0043	150.69	27.8	41.9	1.3	9.4		
Cawood #3 DURANGO	10.8	7.57	26.15	154.9279	3.52	0.2538	195.77	0.31	0.0048	85.09	30.6	26.0	1.3	8.4		
Cawood #3 DURANGO	3.4	17.78	56.70	112.1589	13.51	0.4963	73.39	0.46	0.0038	107.03	24.7	26.4	3.6	29.0		
Cawood #3 DURANGO	8.9	9.30	37.54	139.2551	13.85	0.3441	144.49	0.71	0.0045	101.50	28.8	29.2	1.8	12.7		
Cawood #3 DURANGO	9.7	8.26	23.84	156.6121	5.74	0.2355	44.46	0.03	0.0049	18.29	31.3	5.7	1.2	7.8		
Cawood #3 DURANGO	9.6	8.26	15.16	172.7531	5.94	0.1667	34.29	-0.09	0.0049	10.38	31.6	3.3	1.0	6.3		

¹U concentration calibrated relative to Madagascar (MAD) reference apatite and are accurate to ~10%

²Elemental fractionation corrected only

³Common Pb corrected with a 20 step iteration using Tera-Wasserberg upper (x=0, y-intercept) 207Pb/206Pb common Pb value (OZ-002: 0.822±0.003 = 0.35%, OZ-015: 0.838±0.002= 0.26%, OZ-022: 0.840±0.004 = 0.50%)

⁴Mean systematic uncertainty for included spots only, at 1s level (OZ-002: 8.67%, OZ-015: 3.73%, OZ-022: 10.96%)

⁵OZ-015 spot33: Common Pb corrected age calculated using Stacey & Kramers Model 207Pb/206Pb Value

lc = elemental fractionation corrected ratio

m = measured ratio

c = common Pb

T-W = Tera-Wasserburg plot

Sample OZ-002 is from the Gold Rock Ranch Granite (emplacement age 163 Ma, Tosdal & Wooden, 2015); OZ-015 and OZ-022 are pegmatites (emplacement age 63-66 Ma, this study).

Fig. S1. Sulfides spatially associated with magnetite in ductilely deformed magnetite-quartz veins. A) A full thin section microphotograph in plane polarized light (PPL) and crossed polarized light (XPL), showing a folded magnetite-quartz vein in Tumco Formation gneiss. Note the concentration of fine-grained magnetite along the borders of the vein, the dynamically recrystallized quartz within it, and the local concentrations of coarse-grained sulfides. B-D) Folded magnetite-quartz veins, with coarse blebs of sulfides locally associated with the magnetite, and narrow pegmatites that cross-cut the ductile foliation and the magnetite-quartz veins. E and F) Chalcopyrite concentrated along the magnetite-rich borders of highly deformed magnetite-quartz veins. Green malachite marks oxidation of the chalcopyrite. Cpy: chalcopyrite, mgt: magnetite, mlc: malachite, py: pyrite, qz: quartz.

Fig. S2. Microphotographs taken in reflected light, illustrating the intimate association between sulfides and magnetite, and the lack of typical deformation textures in the sulfides. A) Subhedral pyrite closely associated with magnetite in a deformed magnetite-quartz vein. This texture is interpreted as resulting from pyrite replacing or overgrowing magnetite, although it may also result from simultaneous precipitation of pyrite and magnetite. Note the texturally late partial oxidation of the magnetite to secondary hematite (paler grey). B) Intimately associated chalcopyrite and magnetite. The blue-grey rim on the chalcopyrite is likely covellite, or a similar secondary mineral resulting from chalcopyrite oxidation. C) Pyrite and magnetite, with small grains of pyrite occurring within the magnetite grains (marked by arrow). These may be inclusions of pyrite, which would suggest that magnetite formed simultaneously or after pyrite growth, or they may reflect local sulfidation/replacement of earlier magnetite by later pyrite. D) Anhedral chalcopyrite interstitial to magnetite grains, suggesting chalcopyrite precipitation after magnetite growth, or chalcopyrite remobilization around existing magnetite grains. We prefer the former interpretation, as chalcopyrite has not visibly mobilized along quartz or other mineral grain boundaries. E and F) Small round blebs of chalcopyrite and pyrite within magnetite, which has largely been oxidized to secondary hematite. The sulfide blebs may be inclusions, suggesting magnetite growth over pre-existing sulfides. However, we prefer the interpretation that they reflect local sulfidation of pre-existing magnetite, based on their small size and round forms, which are distinctly different to the size and shape of sulfide grains outside of magnetite. G) Co-existing pyrite, chalcopyrite, and magnetite. Note that chalcopyrite, which is typically considered the most ductile or easily remobilized of the minerals present, has not been remobilized into fractures in the adjacent magnetite, quartz, or pyrite. H) Coarse-grained, subhedral pyrite in quartz, with lesser chalcopyrite. Cpy: chalcopyrite, cv: covellite, hem: hematite, mgt: magnetite, py: pyrite, qz: quartz.

Fig. S3. Undeformed quartz veins with pyrite. A and B) Kinematically late quartz veins cross-cutting the ductile foliation and magnetite-quartz veins, with red-brown patches where pyrite in the veins has been oxidized. C) Broad (cm-scale), glassy, undeformed quartz veins with a coarse sugary or granular texture. Veins and patches of similar quartz are observed in sulfide-rich zones (note the abundant green malachite adjacent to this vein, indicative of oxidized chalcopyrite). D) Cubes of iron oxide, pseudomorphs after pyrite, within an undeformed quartz vein that cross-cuts the ductile foliation of Tumco Formation gneiss. Ccl: chrysocolla, cpy: chalcopyrite, mgt: magnetite, mlc: malachite, py: pyrite, qz: quartz.

A. OZ-052

B. OZ-053

D. OZ-055

Fig. S4. Titanite analytical spot locations, shown on photomicrographs taken in XPL. Spots are 30 μm , and serve as a scale for the images. A number of spots in sample OZ-053 are not included in the data table, as they are part of a different study.

Fig. S5. Concordia diagrams of titanite secondary reference materials

Fig. S6. Representative photomicrographs of titanite in the Gold Rock Ranch Granite. A) A large (~0.9mm long), prismatic, euhedral titanite crystal, interpreted as magmatic in origin, in a typical assemblage of quartz, feldspar, and biotite. Plane polarized light (PPL). B and C) Prismatic euhedral titanite crystals (labelled) and smaller, sub- to anhedral, round to oval titanite grains (indicated with arrows). The smaller grains are interpreted as the dynamically recrystallized remnants of larger, magmatic crystals. PPL. D) Prismatic euhedral titanite (lower left), similarly-sized subhedral titanite grains, and smaller, round, recrystallized grains (marked by arrows). PPL. E) A large (~0.7 mm) titanite grain comprising smaller (<100 μm) oval domains marked by different extinction angles (highlighted by arrows). These are interpreted as subgrains, and are indicative of internal strain and recovery, likely by subgrain rotation. Note the associated dynamically recrystallized quartz. Crossed polarized light (XPL). F) A large (>0.5 mm) titanite grain with broad domains with different extinction angles (undulose extinction). Oval-shaped subgrains are visible at the top right of the grain, and closely resemble the adjacent separate, smaller (~100 μm) titanite grains marked by arrows. Bt: biotite, fsp: feldspar, qz: quartz, ttn: titanite.

A. Dynamically recrystallized titanite

0 *misorientation* (°) 100

B. Euhedral magmatic titanite

0 *misorientation* (°) 5

Fig. S7. Electron backscatter diffraction (EBSD) maps for representative titanite grains from sample OZ-053. A) Titanite grain with distinct domains with different crystallographic orientations, interpreted as the result of dynamic recrystallization by subgrain rotation (SGR). B) Euhedral titanite grain with lesser, gradual misorientation, interpreted as an original magmatic grain.

Fig. S8. Tera-Wasserburg plots generated with IsoplotR (Vermeesch, 2018) showing titanite U-Pb data separately for each sample. Upper intercept ages are calculated for the younger group of analyses (shown in green), which in all samples except for OZ-055 define an isochron. All samples yield upper intercept ages for this younger group that are within error of 68 ± 1 Ma, which is the upper intercept age calculated for the younger group using the pooled data from all seven samples. A-D) Samples of the Araz Wash Diorite, E-G) samples of the Gold Rock Ranch Granite.

A. OZ-015 zircons: CL

OZ-015 zircons: BSE

B. OZ-021 zircons: CL

OZ-021 zircons: BSE

C. OZ-022 zircons: CL

D. OZ-024 zircons: CL

OZ-024 zircons: BSE

Fig. S9. Cathodoluminescence (CL) and back scattered electron (BSE) images of zircons analyzed in this study, all obtained from pegmatites. Analytical spots are shown at approximately actual size, and are labelled with the spot numbers as shown in Table S7. A) Sample OZ-015, B) sample OZ-021, C) sample OZ-022, and D) sample OZ-024. Note the distinctive appearance of the high-U, metamict zircons, all of which belong to the ~65 Ma population. Lower-U zircons with more typical features (CL-brighter, oscillatory zonations) are invariably older, and interpreted as inherited. Apatite grains are bright yellow-green in CL images.

Fig. S10. Concordia diagrams for zircon U-Pb reference materials. A) SLM zircon primary standard. B) FC-1 zircon secondary standard. C) R33 zircon secondary standard. IC: both U and Pb measured in counting mode; MI: Pb in counting mode, U in both analog and counting mode; AN: Pb in counting mode, all U in analog mode.

A. OZ-002 apatite: CL

OZ-002 apatite: BSE

Fig. S11. Cathodoluminescence (CL) and back scattered electron (BSE) images of apatite analyzed in this study. Analytical spots (not actual size) are labelled with the spot numbers, as shown in Table S9. A) Sample OZ-002, Gold Rock Ranch Granite; B) sample OZ-015, pegmatite; and C) sample OZ-022, pegmatite.

B. OZ-015 apatite: CL

OZ-015 apatite: BSE

C. OZ-022 apatite: CL

Fig. S12. Concordia diagram for the apatite U-Pb secondary reference material (Durango apatite).