GSA Data Repository item 2002088, Apatite and zircon (U-Th)/He and apatite fission-track sample locations, data, and analytical methods

Analytical methods

Apatite and zircon were degassed by either CO_2 laser or resistance furnace heating (most by laser heating), and He was measured by (^{3}He) isotope dilution on a gas-source quadropole mass spectrometer, following cryogenic purification and concentration. U and Th contents of the same crystal aliquots used for He measurement were measured by (^{229}Th and ^{233}U) isotope dilution on an ICP-MS (HP-4500 quadropole and Finnigan Element sector). Analytical uncertainties on both He and U-Th contents of measured aliquots are about 1-2%. Alpha ejection corrections were applied using modified versions of Farley et al. (1996). Over the period of these analyses, Durango apatite age determinations averaged 32.7 ± 1.4 (2σ), and Fish Canyon tuff zircon averaged 27.5 ± 2.3 Ma (2σ). Based on reproducibility of these and other standard samples in the WSU and Yale He dating labs, we estimate two-sigma uncertainties for typical non-standard samples of about 6% for apatite, and 8% for zircon.

Apatite fission-track analyses were made at Union College, except for 011D samples, which were made at Donelick Analytical, Inc. Apatites were mounted, polished, and etched in 5 N HNO_3 for 20 seconds at room temperature (Union College) or 5.5 N HNO_3 for 20 seconds at 21°C (Donelick Analytical, Inc.). Mounts were covered with a low-U muscovite external detector and then irradiated at the Oregon State University (Union College) or Washington State University (Donelick Analytical, Inc.) nuclear reactor with a nominal fluence of 8 x 10^{15} neutrons/cm^2. The fluence gradients were calculated using a linear interpolation between track densities in mica detectors placed adjacent to U-doped glass monitors (CN-1) at the top and bottom of the irradiation packages. Induced tracks in mica were revealed by etching in 50% HF for 12-15 minutes at room temperature. Sample ages were calculated using zeta calibration factors of 104.8 ± 4.0 (± 1 se; wc95-series samples), 95.4 ± 3.9 (JV-series samples), and 113.8 ± 2.9 (011D series samples) based on determinations from both Fish Canyon tuff and Durango apatite age standards (Hurford and Green, 1983). All wc95-series samples were measured at 1562.5x using a dry 100x objective (12.5x oculars and 1.25x drawing tube) on an Olympus BH-2 microscope fitted with an automated stage and a Calcomp digitizing tablet. All JV-series samples were measured at 1250x using a dry 100x objective (10x oculars and 1.25x drawing tube) on an Olympus BMAX 60 microscope fitted with an automated stage and a Calcomp digitizing tablet. All 011D series samples were measured at 1562.5x using a dry 100x objective (125x oculars and 1.25x drawing tube) on a Nikon Optiphot-2 microscope fitted with a semi-automated stage and a Numonics digitizing tablet.

Table DR1. Apatite and zircon (U-Th)/He data

Sample	Lat. N.	Long. W.	Elev. (m.a.s.l.)	multi or single xtal	MWAR[a] (μm)	mass (μg)	U (ppm)	Th (ppm)	He (ncc/mg)	F_T[b]	corrected age (Ma)	2σ err
North Cascades												
Spuzzum pluton												
WC95-11a	49.37	121.50	610	multi	65.7	33.1	89.9	77.3	81.6	0.81	7.72	0.46
WC95-11b (rep)	49.37	121.50	610	multi	37.4	23.1	95.0	70.2	68.6	0.70	7.20	0.43
WC95-15ab	49.35	121.57	80	multi	42.1	28.9	34.1	28.1	41.2	0.73	11.4	0.68
WC95-15ac (rep)	49.35	121.57	80	multi	62.3	92.9	29.0	21.0	33.8	0.81	10.1	0.61
WC95-15A (rep)	49.35	121.57	80	multi	41.8	34.2	30.6	22.4	31.8	0.69	10.6	0.64
WC95-16	49.50	121.50	762	multi	62.7	71.2	54.8	93.6	48.1	0.78	6.65	0.40
WC95-17	49.38	121.48	9	multi	56.9	39.4	5.66	8.26	4.19	0.75	6.09	0.37
WC95-14	49.32	121.43	274	multi	52.7	46.2	25.8	29.4	19.0	0.75	6.42	0.39
Custer gneiss												
WC95-12	49.22	121.42	671	multi	48.7	29.5	35.8	0.7	30.3	0.76	9.00	0.54
WC95-13	50.35	121.33	762	multi	77.9	13.1	3.22	1.61	3.62	0.82	10.2	0.61
Yellow Aster												
WC95-32	48.67	121.50	300*	multi	45.3	22.5	28.0	19.3	25.8	0.75	8.60	0.52
Lake Ann												
LA01A	48.835	121.641	1651	multi	49.1	30.4	8.15	16.7	1.44	0.72	1.37	0.08
LA01B (rep)	48.835	121.641	1651	multi	51.3	44.5	8.89	15.1	1.53	0.73	1.40	0.08
LA01C (rep)	48.835	121.641	1651	multi	58.4	41.2	9.18	18.2	1.54	0.76	1.24	0.07
LA02A	48.831	121.645	1471	multi	41.5	15.4	7.01	16.2	1.94	0.67	2.20	0.13
LA02B (rep)	48.831	121.645	1471	multi	54.4	24.0	6.70	15.3	1.86	0.74	2.00	0.12
LA03B			1310	multi	46.3	24.7	19.2	38.9	3.88	0.71	1.60	0.10
West flank of Cascades												
Index												
013D1A	47.808	121.552	229	multi	60.5	46.4	13.2	17.6	21.9	0.77	13.5	0.81
NE of Mt. Rainier												
00193	46.95	121.533	899	multi	66.7	54.7	4.93	16.0	7.34	0.78	8.96	0.54
00193b (rep)	46.95	121.533	899	multi	64.2	65.0	7.40	19.1	9.40	0.77	8.42	0.51
00198	46.932	121.530	1021	multi	38.2	18.8	52.1	65.2	38.8	0.66	7.24	0.43
97187	46.898	121.449	1315	multi	44.3	14.0	43.9	50.2	25.9	0.70	5.54	0.33
97216	46.896	121.469	1402	multi	52.3	44.9	20.4	26.7	14.9	0.74	6.24	0.37
97216b (rep)	46.896	121.469	1402	multi	33.1	13.5	28.8	41.0	13.5	0.61	4.78	0.29
Western Mt. Stuart batholith region												
JV-598	47.60	121.12	2024	multi	49.3	44.6	22.3	21.2	27.3	0.76	10.8	0.65
JV-598a (rep)	47.60	121.12	2024	multi	68.2	49.2	15.8	17.7	23.5	0.82	11.9	0.71
JV-640	47.71	121.10	975	multi	55.4	42.0	35.1	17.6	43.3	0.79	11.5	0.69
JV-683	47.72	121.28	378	multi	52.6	34.6	4.76	3.22	4.16	0.74	8.40	0.50
JV-728	47.72	121.20	594	multi	55.1	59.8	94.6	37.0	76.9	0.76	8.17	0.49
Granite Mtn.												
011D37B	47.417	121.583	493	single	46.0	2.64	23.4	50.1	31.3	0.71	10.3	0.62
011D37C (rep)	47.417	121.583	493	single	47.3	2.97	13.7	21.9	19.0	0.72	11.6	0.69
011D37D (rep)	47.417	121.583	493	multi	52.1	28.7	8.7	20.5	13.7	0.74	11.3	0.68
011D36A	47.383	121.517	660	multi	49.6	27.3	30.4	28.1	37.9	0.73	11.5	0.69
011D30A	47.403	121.483	853	multi	56.4	55.5	19.0	35.5	27.5	0.76	10.9	0.65
011D31A	47.409	121.480	1111	multi	40.5	18.5	17.9	32.2	22.1	0.67	10.7	0.64
011D32A	47.410	121.477	1268	multi	51.4	30.6	22.5	35.4	34.6	0.73	12.6	0.76
011D33A	47.413	121.469	1425	multi	45.7	33.5	39.9	42.1	46.3	0.71	10.8	0.65

011D34A	47.418	121.482	1716	multi	43.5	20.8	18.6	28.4	27.2	0.70	12.8	0.77
011D35A	47.415	121.473	1539	multi	52.1	39.7	49.9	55.6	70.8	0.74	12.6	0.76
East flank of Cascades												
Fourth of July Ridge												
010D19A	47.591	120.766	2142	multi	44.4	29.5	88.1	137	321	0.70	31.4	1.9
010D19D (rep)	47.591	120.766	2142	single	74.8	10.6	149	182	556	0.82	29.4	1.8
010D19E (rep)	47.591	120.766	2142	single	59.0	6.50	117	157	407	0.76	28.1	1.7
010D19B (rep)	47.591	120.766	2142	multi	45.2	28.1	109	155	388	0.71	31.0	1.9
010D18A	47.590	120.762	1984	multi	48.3	29.0	123	217	454	0.72	29.9	1.8
010D17A	47.588	120.767	1865	multi	45.9	25.4	122	161	405	0.71	29.3	1.8
010D17B (rep)	47.588	120.767	1865	single	58.0	5.70	90.0	144	379	0.77	32.9	2.0
010D17C (rep)	47.588	120.767	1865	single	59.0	5.40	147	189	489	0.77	27.4	1.6
010D17E (rep)	47.588	120.767	1865	single	52.3	3.17	138	179	453	0.74	28.2	1.7
012D16A	47.588	120.772	1695	multi	51.7	44.5	20.8	41.4	78.1	0.73	28.9	1.7
012D16B (rep)	47.588	120.772	1695	single	37.5	1.98	12.1	32.7	43.8	0.66	27.7	1.7
012D16C (rep)	47.588	120.772	1695	single	70.3	7.00	6.24	21.9	34.3	0.79	31.4	1.9
012D15A	47.588	120.779	1524	multi	50.7	28.0	14.8	28.5	48.8	0.73	25.8	1.6
012D14A	47.588	120.782	1375	multi	78.6	68.3	17.6	31.8	65.2	0.82	26.2	1.6
012D13A	47.587	120.786	1176	multi	47.8	35.8	13.3	28.1	37.9	0.72	21.9	1.3
012D11A	47.584	120.791	939	multi	65.7	66.6	15.6	26.9	39.9	0.79	19.1	1.1
013D10A	47.583	120.795	841	multi	55.7	39.6	20.2	36.0	56.1	0.75	21.5	1.3
013D20C	47.578	120.795	686	single	37.5	2.16	72.5	172	205	0.66	22.6	1.4
013D20D (rep)	47.578	120.795	686	single	44.5	2.70	57.3	169	196	0.70	23.8	1.4
013D21A	47.545	120.712	445	multi	51.7	34.3	57.1	124	159	0.73	20.8	1.2
013D21B (rep)	47.545	120.712	445	single	47.8	3.30	26.8	61.0	69.3	0.72	19.3	1.2
013D21C (rep)	47.545	120.712	445	single	43.3	2.44	44.4	116	147	0.69	24.4	1.5
JV-727	47.553	120.758	594	multi	51.5	47.5	187	132	365	0.74	18.9	1.1
JV-727C (rep)	47.553	120.758	594	single	41.5	2.34	45.1	104	117	0.69	20.2	1.2
JV-727D (rep)	47.553	120.758	594	single	47.0	2.65	117	83.3	281	0.72	23.7	1.4
Mt. David region												
013D6A	47.946	120.958	1231	multi	46.9	36.8	8.92	9.05	20.5	0.72	21.4	1.3
013D7A	47.946	120.954	1122	multi	43.4	37.9	34.6	37.0	98.9	0.70	27.2	1.6
013D7B (rep)	47.946	120.954	1122	multi	32.8	7.60	48.4	46.4	107	0.61	24.5	1.5
013D8A	47.948	120.943	759	multi	51.4	45.0	22.4	22.4	53.1	0.74	26.1	1.6
JV-596	47.88	121.17	1466	multi	53.4	40.7	26.6	3.90	56.5	0.77	22.1	1.3
JV-611b	47.81	121.07	1402	multi	51.1	53.1	37.2	21.9	99.9	0.75	26.1	1.6
Eastern Mt. Stuart batholith region												
JV-469	47.78	121.03	902	multi	59.9	53.0	27.3	14.8	54.5	0.81	17.9	1.1
JV-509a	47.54	120.82	1256	multi	52	38.0	91.8	60.8	245	0.76	25.1	1.5
JV-509b (rep)	47.54	120.82	1256	multi	51.3	21.3	90.8	58.0	216	0.75	22.8	1.4
JV-555a	47.65	120.83	2089	multi	47.5	17.8	85.0	10.1	456	0.74	58.0	3.5
JV-555b (rep)	47.65	120.83	2089	multi	43	29.3	98.3	9.06	533	0.71	62.0	3.7
JV-568b	47.56	120.85	2591	multi	56.3	31.1	169	143	831	0.78	43.4	2.6
JV-508	47.49	120.80	2694	multi	50.4	26.3	21.0	22.0	81.5	0.75	34.1	2.0
JV-561	47.42	120.90	2883	multi	53.6	49.4	52.3	61.3	191	0.78	30.0	1.8
Mt. Stuart zircons												
JV469ZRA	47.78	121.03	902	multi	53.8	36.1	343	45.6	1909	0.82	54.4	4.4
JV640ZRA	47.71	121.10	975	multi	57.7	38.6	335	45.6	2067	0.83	59.4	4.8
JV561ZRA	47.42	120.90	2883	multi	44.3	23.4	207	61.3	1558	0.78	74.4	5.9

Notes: [a]: MWAR is mass weighted average radius. [b]: F_T is fraction of total alphas retained (Farley et al., 1996). *The elevation of WC95-32 is not known and is assumed to be 300 m based on elevations at the approximate location.

Table DR2: Apatite fission track data

Sample	Elev(m)	ρ_s	N_s	ρ_i	N_i	ρ_d	N_d	n	$P(\chi^2)$	Age	-/+1σ	U ± 2se	MTL± 2se (n_t)
Mt Stuart Batholith													
JV-598	2125	3.49×10^5	156	1.57×10^6	701	3.70×10^6	4844	15	20.1	43.0 Ma	-4.0 +4.4	16.9±1.4	not measured
JV-596	1466	4.13×10^5	211	1.55×10^6	794	3.67×10^6	4797	15	76.3	50.8 Ma	-4.2 +4.6	16.9±1.3	not measured
JV-469	925	4.82×10^5	189	2.15×10^6	841	3.50×10^6	4585	15	97.4	41.1 Ma	-3.5 +3.8	24.4±1.8	not measured
JV-555	2100	1.76×10^6	836	5.18×10^6	2461	3.61×10^6	4726	15	50.8	64.0 Ma	-3.5 +3.7	57.1±2.7	not measured
JV-508	2750	6.98×10^5	355	1.54×10^6	784	3.54×10^6	4632	15	77.1	83.4 Ma	-6.0 +6.5	17.3±1.3	not measured
JV-509	1000	1.64×10^6	602	7.03×10^6	2587	3.56×10^6	4656	15	11.3	43.2 Ma	-2.5 +2.7	78.7±3.6	not measured
JV-561	2956	1.16×10^6	588	2.79×10^6	1417	3.63×10^6	4750	15	38.2	78.4 Ma	-4.8 +5.1	30.6±1.8	not measured
Spuzzum Pluton													
wc95-11	610	6.49×10^5	478	6.98×10^6	5143	4.19×10^6	2733	20	0.3	18.0 Ma	-1.1 +1,3	65.2±3.0	13.49+/-1.33 (76)
wc95-14	274	2.61×10^5	131	2.47×10^6	1241	4.23×10^6	2762	15	2.0	21.3 Ma	-1.9 +2.4	22.9 ±1.5	14.30+/-2.20 (15)
wc95-15	80	3.36×10^5	243	3.02×10^6	2182	4.27×10^6	2785	20	12.0	22.7 Ma	-1.7 +2.0	27.7±1.4	14.22+/-1.30 (53)
wc95-16	762	3.95×10^5	297	5.05×10^6	3799	4.20×10^6	2740	20	68.4	15.7 Ma	-1.2 +1.3	47.1±2.2	14.46+/-1.26 (21)
wc95-17	9	1.10×10^5	45	8.82×10^6	363	4.24×10^6	2766	13	44.9	25.0 Ma	-3.5 +4.8	8.1 ±0.9	none observed
Custer Gneiss													
wc95-10	1463	5.03×10^5	251	3.60×10^6	1797	4.36×10^6	2844	20	0.0	26.8 Ma	-2.1 +2.4	32.4 ±1.8	13.28+/-2.55 (27)
wc95-12	671	4.55×10^5	341	5.55×10^6	4158	4.26×10^6	2777	20	0.1	16.0 Ma	-1.2 +1.2	51.1±2.2	13.03+/-2.55 (42)
wc95-13	762	1.53×10^5	140	7.81×10^6	713	4.32×10^6	2818	20	2.6	40.3 Ma	-3.7 +4.5	7.1±0.6	none observed
Yellow Aster Complex													
wc95-32	300*	7.02×10^5	340	4.83×10^6	2340	4.30×10^6	2807	15	5.9	29.7 Ma	-2.0 +2.3	44.1±2.2	14.29+/-2.04 (32)
011D													
011D31	1111	1.42×10^5	58	1.97×10^6	808	3.90×10^6	4066	23	99.1	15.9 Ma	-2.2 +2.2	25	15.07+/-2.03 (56)
011D34	1716	1.42×10^5	35	1.99×10^6	490	3.89×10^6	4066	18	55.9	15.8 Ma	-2.8 +2.8	23	14.97+/-2.29 (41)
011D37	493	1.26×10^5	94	1.48×10^6	1106	3.88×10^6	4066	25	16.4	18.8 Ma	-2.1 +2.1	25	14.69+/-2.49 (103)

Notes: ρ_s = density (cm^{-2}) of spontaneous tracks; N_s = number of spontaneous tracks counted; ρ_i = density (cm^{-2}) of induced tracks; ρ; = density (cm^{-2}) of tracks on the neutron fluence monitor (CN-1); n_g = total number of grains counted; $P(\chi^2)$ = probability (%) of greater chi-squared; U = mean grain uranium concentration (ppm); MTL = mean track length (µm); n_t = total number of track lengths measured. Apatite fission track ages (± 1σ) were calculated using the computer program and equations in Brandon (1992); all ages with χ^2 > 1% are reported as pooled ages otherwise central ages are shown. *The elevation for this sample is only approximately known.

DR References:

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