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Mobilization of radiogenic Pb in zircon revealed by ion imaging: Implications for early Earth geochronology

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METHODOLOGY

Zircon grains were separated, mounted in epoxy resin along with the Geostandards 91500 zircon standard (Wiedenbeck et al., 1995) and polished to reveal their interiors. Back-scattered electron (BSE) and cathodoluminescence (CL) images were used to characterize the internal structure of the grains. A CAMECA IMS 1280 ion-microprobe at the Swedish Museum of Natural History, Stockholm (NordSIMS facility) was used both for zircon spot analysis and ion imaging. Spot analysis closely follows the method described by Whitehouse and Kamber (2005), using a ca. 15 µm, 6 nA O_2^- primary beam, and peak-hopping monocollection in an ion counting electron multiplier (EM) at a mass resolution of ca. 5400 (M/ΔM). Data reduction was performed using the NordSIMS-developed suite of software of M.J. Whitehouse. Common Pb was corrected using the ^{204}Pb counts assuming a present-day terrestrial Pb-isotope composition model (Stacey and Kramers, 1975) following the rationale of Zeck and Whitehouse (1999) that this is largely surface contamination introduced during sample preparation and not common Pb residing in zircon and/or micro-inclusions. Very low amounts of common Pb were detected during the spot analyses with f^{206}Pb <0.1%, in many cases below the detection limit for ^{204}Pb based on the electron multiplier background. Where common Pb corrections were deemed necessary on the basis of measurable ^{204}Pb, these were small and therefore insensitive to the precise composition of common Pb. For ion imaging, an aperture illuminated O_2^- primary beam with a spot size of ca. 2 µm and a beam current of ca. 100 pA was rastered over an area of 70 × 70 µm to obtain images of ^{48}Ti, ^{89}Y, ^{180}Hf^{16}O, ^{206}Pb, ^{232}Th (as ^{232}Th^{16}O) and ^{238}U (as ^{238}U^{16}O) in peak-hopping mode. Subsequent Pb-isotope imaging with the same primary beam set-up used four multicollector EMs to simultaneously detect the uranogenic Pb isotopes ^{206}Pb and ^{207}Pb, as well as ^{204}Pb and a matrix peak (^{180}Hf^{16}O at mass 196 was chosen because Hf was generally very uniform in the monocollection images), with the instrument set to a mass resolution of 4860, sufficient to separate Pb from molecular interferences. For spot analyses and multicollector Pb imaging, oxygen flooding in the sample chamber was used to enhance Pb secondary ion yields from ca. 10 cps/nA/ppm ^{206}Pb to ca. 20 cps/nA/ppm; oxygen flooding was not used for the monocollection trace element imaging. Detector backgrounds were assessed separately using long integrations with the secondary ion beam blanked and were typically <0.02 cps. Relative detector yields were measured using a peak-hopping routine putting the same species (e.g., HfO) sequentially into each detector and were within ±5% of each other. Secondary ion signals were sufficiently low that deadtime corrections were insignificant. Image analysis was performed using the CAMECA WinImage software. Following correction of all ratios for detector gains, ^{207}Pb/^{206}Pb ratios were, if necessary, further corrected for common

Pb using $^{204}Pb/^{206}Pb$ ratios, applying the same criterion used for spot analyses regarding ^{204}Pb detection limits to determine the significance of the correction.

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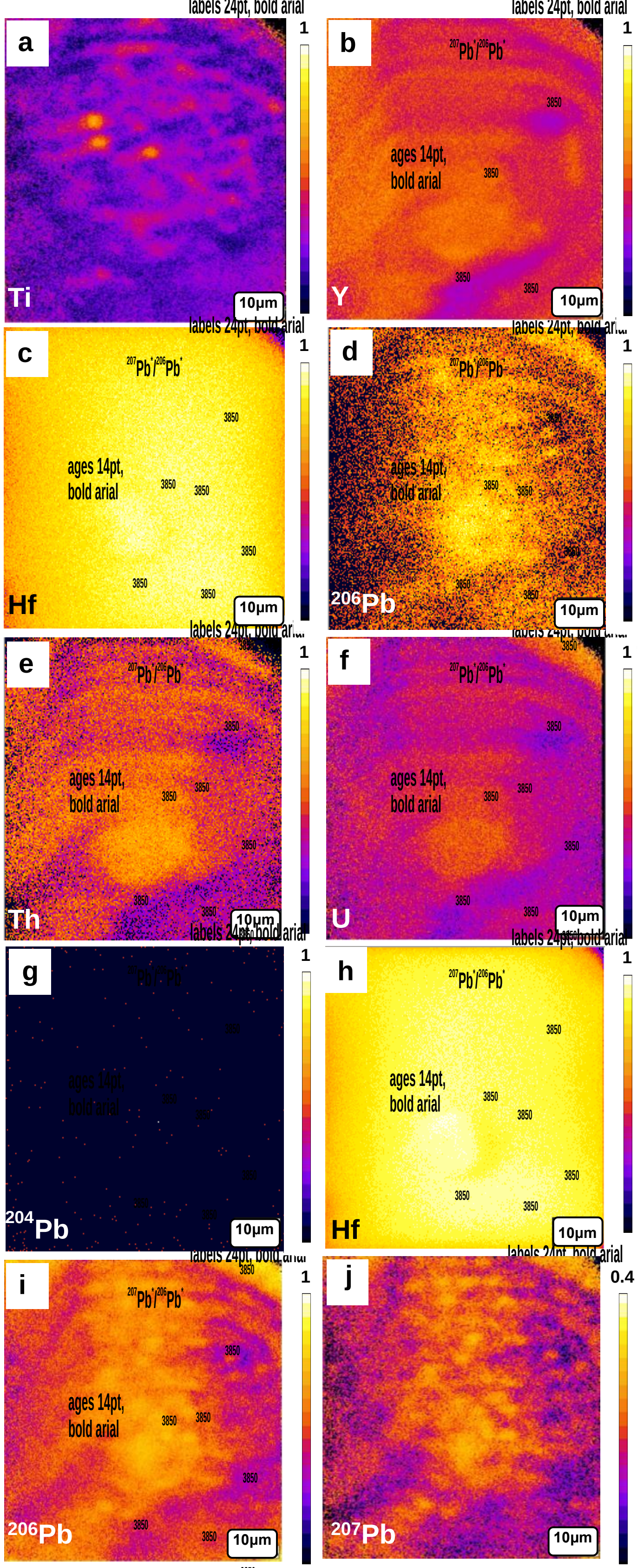

Figure DR2. Scanning ion images of grain n3847-44 from Dallwitz Nunatak sample 11178-1 using a monocollection routine: (a) ^{48}Ti, (b) ^{89}Y, (c) ^{180}Hf, (d) ^{206}Pb, (e) ^{232}Th and (f) ^{238}U; and a multicollection routine: (g) ^{204}Pb, (h) ^{180}Hf, (i) ^{206}Pb and (j) ^{207}Pb. All images (except ^{204}Pb and HfO) are normalized to the HfO image to minimize the effect of enhanced ion emission from the original spot analysis crater. The color-scale bars are relative intensity (i.e. do not correspond to ppm).

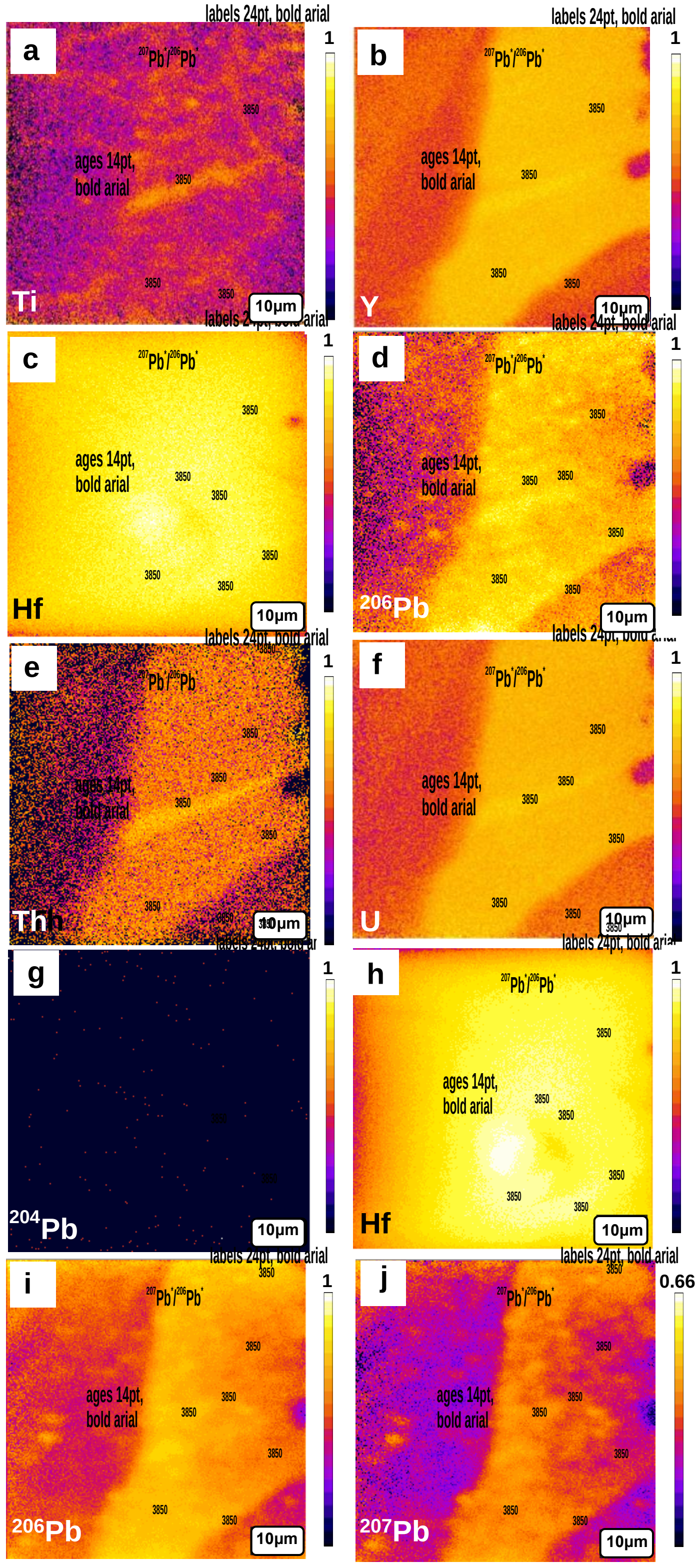

Figure DR3. Scanning ion images of grain n3850-47 from Gage Ridge sample 16178-2 using a monocollection routine: (a) ^{48}Ti, (b) ^{89}Y, (c) ^{180}Hf, (d) ^{206}Pb, (e) ^{232}Th and (f) ^{238}U; and a multicollection routine: (g) ^{204}Pb, (h) ^{180}Hf, (i) ^{206}Pb and (j) ^{207}Pb grain. All images (except ^{204}Pb and HfO) are normalized to the HfO image to minimize the effect of enhanced ion emission from the original spot analysis crater. The color-scale bars are relative intensity (i.e. do not correspond to ppm).

Table DR1. SIMS U-Th-Pb data from sample 11178-1 (Spot Height 945, Dallwitz Nunatak).

Sample/	U	Pb	Th/U[2]	$f^{206}Pb$[3]	Ratios[4]				Ages[4]				Conc.[5]
spot #[1]	ppm	ppm		%	$^{207}Pb/^{206}Pb$	±σ (%)	$^{206}Pb/^{238}U$	±σ (%)	$^{207}Pb/^{206}Pb$	±σ	$^{206}Pb/^{238}U$	±σ	%
n3847-01	100	91	0.40	[0.02]	0.2722	0.52	0.6555	0.72	3319	8	3250	18	97.4
n3847-02	36	43	0.69	0.05	0.3017	2.1	0.807	2.0	3479	32	3814	57	112.8
n3847-03	68	57	0.70	[0.02]	0.2234	2.9	0.5821	0.80	3005	47	2957	19	[98]
n3847-03r	510	370	0.33	0.01	0.2054	0.83	0.5630	1.1	2869	13	2878	26	[100.4]
n3847-04	130	140	0.43	0.02	0.3019	3.1	0.743	1.5	3480	46	3580	42	[103.7]
n3847-05	160	100	0.30	0.02	0.1766	1.8	0.4837	0.74	2621	30	2543	16	[96.4]
n3847-05r	1200	670	0.04	0.17	0.16236	0.41	0.4745	0.73	2480	7	2500	15	[100.9]
n3847-06	190	240	1.08	0.01	0.3053	1.3	0.7893	0.96	3497	20	3750	27	109.6
n3847-06r	130	140	0.68	[0.02]	0.2871	2.2	0.721	1.5	3402	34	3500	40	[103.7]
n3847-07	440	330	0.27	0.01	0.2357	1.2	0.5745	0.75	3091	20	2926	18	93.4
n3847-07r	480	350	0.22	0.01	0.2206	1.4	0.5648	1.1	2985	22	2886	26	[95.9]
n3847-08	330	210	0.29	0.01	0.1856	3.6	0.4945	0.73	2704	57	2590	16	[94.9]
n3847-09	160	120	0.38	0.02	0.20942	0.45	0.5490	0.74	2901	7	2821	17	96.6
n3847-09r	160	140	0.42	0.06	0.24573	0.35	0.6221	0.81	3157	5	3116	20	[98.4]
n3847-10	180	180	0.50	0.02	0.2835	2.0	0.725	2.4	3382	30	3514	66	[105.1]
n3847-12	150	92	0.18	0.03	0.1805	0.76	0.5003	0.75	2658	13	2615	16	[98]
n3847-13	210	230	0.43	0.02	0.2992	1.5	0.775	1.4	3466	24	3698	41	108.8
n3847-14	1100	790	0.28	0.03	0.2091	0.52	0.5437	0.75	2898	8	2798	17	95.7
n3847-15	88	88	0.67	[0.02]	0.2807	0.57	0.6905	0.82	3367	9	3385	22	[100.7]
n3847-16	190	180	0.76	0.12	0.25285	0.29	0.6423	0.73	3203	5	3195	18	[99.7]
n3847-16r	140	130	0.63	0.02	0.2597	0.54	0.6621	0.73	3245	9	3275	19	[101.2]
n3847-17	100	98	0.88	0.03	0.24536	0.39	0.6352	0.75	3155	6	3169	19	[100.6]
n3847-18	180	160	0.57	0.03	0.24045	0.29	0.6321	0.80	3123	5	3157	20	[101.4]
n3847-19	130	140	0.38	[0.01]	0.3021	2.8	0.761	1.4	3481	43	3647	39	[106.2]
n3847-19r	130	120	0.49	0.03	0.2647	1.8	0.668	1.6	3275	28	3297	41	[100.9]
n3847-20	59	43	0.32	[0.03]	0.2068	2.7	0.5616	1.1	2880	44	2873	25	[99.7]
n3847-21	190	130	0.25	[0.01]	0.2123	1.7	0.5376	0.90	2923	27	2774	20	[93.7]
n3847-21w	140	120	0.32	[0.02]	0.2491	1.1	0.6473	0.72	3179	17	3218	18	[101.5]
n3847-21r	830	480	0.10	0.01	0.1684	0.91	0.4849	0.72	2542	15	2548	15	[100.3]
n3847-22	640	630	0.43	0.01	0.2857	0.54	0.7073	0.76	3394	8	3448	20	[102.1]
n3847-23	32	27	0.52	[0.06]	0.2301	2.3	0.6116	1.2	3053	37	3077	28	[101]
n3847-24	710	740	0.39	0.01	0.3011	1.8	0.7382	1.3	3476	28	3564	37	[103.3]
n3847-25	88	56	0.73	0.11	0.1629	0.65	0.4657	0.74	2486	11	2462	15	[98.9]
n3847-26	230	140	0.24	0.04	0.1840	2.5	0.5044	0.89	2690	41	2632	19	[97.4]
n3847-27	690	440	0.31	0.00	0.1744	0.77	0.4977	0.72	2601	13	2604	15	[100.1]
n3847-28	180	180	0.42	[0.01]	0.2786	1.4	0.7343	0.94	3355	22	3549	26	107.5
n3847-28r	89	99	0.43	0.02	0.3035	2.7	0.7879	0.90	3488	41	3745	26	[109.7]
n3847-29	150	130	0.52	[0.01]	0.2513	1.8	0.6231	1.3	3193	28	3122	31	[97.2]
n3847-30	170	200	0.49	0.01	0.3217	1.5	0.852	1.5	3578	23	3972	44	114.8
n3847-30r	98	87	0.47	0.03	0.2573	2.7	0.6404	1.5	3230	42	3190	37	[98.4]
n3847-31	61	35	0.26	[0.04]	0.1604	0.73	0.4632	0.81	2460	12	2453	16	[99.7]
n3847-32	260	270	0.48	[0.01]	0.2979	2.0	0.740	1.5	3459	30	3571	40	[104.2]
n3847-33	210	160	0.26	0.04	0.2184	1.6	0.5738	0.74	2969	25	2922	18	[98]
n3847-33r	68	67	0.62	[0.03]	0.2667	2.2	0.6859	0.72	3287	35	3367	19	[103.1]
n3847-33w	100	97	0.29	[0.02]	0.2693	2.2	0.6920	0.92	3302	34	3390	24	[103.4]
n3847-34	95	110	1.69	[0.02]	0.2648	0.59	0.6660	0.76	3276	9	3291	20	[100.6]
n3847-34r	160	200	1.63	[0.01]	0.2761	0.74	0.7125	0.77	3341	12	3468	21	104.9
n3847-35	310	270	0.11	0.01	0.2579	1.8	0.6718	0.73	3234	28	3312	19	[103.1]
n3847-35w	22	16	0.57	[0.10]	0.2273	2.8	0.5383	0.78	3033	44	2776	18	[89.6]
n3847-35r	100	100	0.53	[0.02]	0.2777	1.5	0.7001	0.82	3350	23	3421	22	[102.7]
n3847-36	600	570	0.78	0.01	0.2627	1.0	0.6505	0.81	3263	16	3230	21	[98.7]
n3847-37	880	500	0.01	0.02	0.1687	0.83	0.4845	0.84	2545	14	2546	18	[100.1]
n3847-38	130	110	0.76	0.03	0.2455	2.9	0.6103	1.2	3156	45	3070	29	[96.6]
n3847-38r	230	230	0.73	[0.02]	0.2709	1.6	0.6829	0.72	3311	24	3355	19	[101.7]
n3847-39	430	510	1.42	0.02	0.2924	0.47	0.7090	0.72	3430	7	3454	19	[100.9]
n3847-40	68	65	1.37	0.13	0.2441	3.3	0.6027	1.4	3147	51	3038	35	[95.6]
n3847-40r	130	160	1.26	0.10	0.2976	0.97	0.7336	0.72	3458	15	3544	20	[103.3]
n3847-41	970	620	0.15	0.04	0.1782	0.61	0.5159	0.72	2636	10	2681	16	[102.1]
n3847-42	490	330	0.59	0.02	0.1955	1.0	0.4933	0.72	2789	16	2584	15	91.1
n3847-42r	270	300	0.46	0.03	0.3108	1.9	0.7824	0.79	3525	29	3725	22	107.5
n3847-43	310	350	0.68	[0.01]	0.3068	0.95	0.7403	0.84	3505	15	3572	23	[102.5]
n3847-44	680	680	0.71	0.01	0.2829	0.59	0.6759	0.68	3379	9	3329	18	[98.1]
n3847-45	1000	570	0.06	0.02	0.16536	0.34	0.4815	0.72	2511	6	2533	15	[101.1]
n3847-46	250	190	0.46	[0.01]	0.2216	2.0	0.5720	0.90	2992	33	2916	21	[96.8]
n3847-47	470	350	0.56	0.02	0.2055	1.3	0.5408	0.73	2870	21	2786	16	[96.4]
n3847-48	1100	720	0.09	0.06	0.1846	1.1	0.5172	0.70	2694	18	2686	15	[99.6]
n3847-49	330	240	0.38	0.02	0.2077	0.87	0.5429	0.66	2888	14	2795	15	96
n3847-50	40	53	0.94	[0.03]	0.329	3.3	0.849	2.4	3614	50	3964	70	[113]
n3847-51	250	260	0.17	[0.01]	0.3099	2.7	0.773	2.1	3520	41	3692	59	[106.4]
n3847-52	82	91	1.05	[0.01]	0.2915	0.85	0.7067	0.67	3426	13	3446	18	[100.8]
n3847-53	280	160	0.18	[0.01]	0.1660	0.85	0.4717	0.69	2517	14	2491	14	[98.7]
n3847-42c	310	340	0.68	[0.00]	0.2963	0.86	0.7397	0.73	3451	13	3570	20	104.5
n3847-54	300	280	0.64	0.01	0.25827	0.26	0.6518	0.73	3236	4	3235	19	[99.9]
n3847-55	72	61	0.37	[0.03]	0.2397	1.1	0.6291	0.68	3118	18	3146	17	[101.1]

continued

Table DR1, continued

Sample/	U	Pb	Th/U[2]	$f\ ^{206}Pb$[3]	Ratios[4]				Ages[4]				Conc.[5]
spot #[1]	ppm	ppm		%	$^{207}Pb/^{206}Pb$	±σ (%)	$^{206}Pb/^{238}U$	±σ (%)	$^{207}Pb/^{206}Pb$	±σ	$^{206}Pb/^{238}U$	±σ	%
n3847-56	1200	690	0.11	0.01	0.17075	0.44	0.4951	0.70	2565	7	2592	15	[101.3]
n3847-57	220	230	0.56	[0.01]	0.2889	1.1	0.7184	0.73	3412	17	3490	20	[103]
n3847-58	840	470	0.05	0.01	0.1646	0.62	0.4765	0.72	2503	10	2512	15	[100.4]
n3847-59	900	660	0.04	[0.00]	0.2313	1.3	0.5871	0.69	3061	20	2978	17	[96.6]
n3847-60	75	84	0.61	[0.04]	0.3048	2.7	0.761	1.5	3495	41	3648	43	[105.7]
n3847-61	1200	700	0.05	0.01	0.16744	0.43	0.4832	0.71	2532	7	2541	15	[100.4]
n3847-62	310	260	0.50	0.02	0.2316	0.78	0.5990	0.81	3063	12	3025	20	[98.4]
n3847-63	650	370	0.13	0.01	0.1665	1.3	0.4753	0.68	2523	21	2507	14	[99.2]
n3847-64	150	100	0.12	[0.01]	0.2053	1.5	0.5543	0.83	2868	25	2843	19	[98.9]
n3847-65	600	380	0.34	0.03	0.1964	0.84	0.4917	0.81	2796	14	2578	17	90.5
n3847-66	130	120	0.65	0.03	0.2829	0.41	0.6768	0.72	3379	6	3331	19	[98.2]
n3847-67	320	220	0.47	0.03	0.1970	1.1	0.5326	0.68	2801	18	2752	15	[97.8]
n3847-68	140	110	0.80	0.03	0.2169	1.0	0.5564	0.68	2958	16	2851	16	95.5
n3847-69	260	220	0.48	0.02	0.2580	1.9	0.6206	0.89	3235	29	3112	22	[95.2]
n3847-70	350	340	1.03	0.03	0.2655	1.2	0.6319	0.73	3279	18	3157	18	95.3
n3847-71	770	540	0.06	0.02	0.2097	1.5	0.5702	0.84	2903	24	2908	20	[100.2]
n3847-72	330	260	0.24	0.02	0.2291	1.8	0.5984	1.2	3045	28	3023	28	[99.1]
n3847-73	760	480	0.14	0.01	0.1815	1.0	0.5110	0.67	2667	16	2661	15	[99.7]
n3847-74	560	590	0.80	0.01	0.2899	1.4	0.6978	0.97	3417	22	3412	26	[99.8]
n3847-75	690	800	2.16	0.01	0.24512	0.16	0.6400	0.67	3154	3	3189	17	[101.4]
n3847-76	930	560	0.10	0.27	0.1843	0.56	0.5005	0.67	2692	9	2610	14	96.3
n3847-77	31	23	0.48	[0.00]	0.2281	3.0	0.5572	0.66	3038	47	2855	15	[92.5]
n3847-78	440	330	0.22	0.03	0.2182	0.60	0.5790	0.93	2967	10	2944	22	[99]
n3847-79	160	100	0.26	0.05	0.1809	1.1	0.5130	0.71	2661	18	2668	16	[100.4]
n3847-81	190	130	0.55	[0.01]	0.1946	1.5	0.5354	0.67	2781	24	2764	15	[99.2]
n3847-80	830	500	0.06	0.01	0.1795	0.64	0.4991	0.67	2648	11	2610	14	[98.3]
n3847-82	240	210	0.76	[0.02]	0.2385	0.49	0.6062	0.66	3110	8	3055	16	[97.8]
n3847-83	480	420	0.10	[0.01]	0.2680	1.5	0.6800	1.2	3294	24	3345	32	[102]
n3847-84	3300	1900	0.19	0	0.15964	0.16	0.4802	0.66	2452	3	2528	14	103.8
n3847-85	300	200	0.09	0.03	0.2102	1.2	0.5520	0.67	2907	20	2833	15	[96.9]
n3847-86	590	370	0.14	0.02	0.1897	1.9	0.5096	1.1	2739	31	2654	24	[96.2]
n3847-87	720	460	0.25	0.02	0.1909	0.71	0.5133	0.69	2750	12	2670	15	96.5
n3847-88	380	280	0.30	0.02	0.2195	1.4	0.5595	0.73	2977	22	2864	17	[95.3]
n3847-89	490	390	0.31	[0.01]	0.2537	1.1	0.6078	0.71	3208	17	3061	17	94.3
n3847-90	570	540	0.59	0.01	0.2710	0.89	0.6657	0.80	3312	14	3289	21	[99.1]
n3847-91	340	220	0.37	0.05	0.1887	0.77	0.5062	0.70	2731	13	2639	15	95.9
n3847-92	320	240	0.02	0.03	0.2528	2.3	0.6173	0.71	3203	36	3099	17	[95.9]
n3847-93	410	800	4.14	0.03	0.2261	1.9	0.6765	1.5	3024	30	3330	38	113
n3847-94	390	330	0.48	[0.01]	0.2532	1.6	0.6051	0.74	3205	25	3050	18	[93.9]
n3847-95	1300	840	0.62	0.01	0.17364	0.40	0.4970	0.69	2593	7	2601	15	[100.4]
n3847-96	440	270	0.15	0.03	0.1839	1.3	0.4925	0.66	2688	21	2581	14	[95.1]
n3847-97	1200	840	0.49	0.01	0.1982	0.82	0.5379	0.73	2811	13	2774	16	[98.4]
n3847-98	240	260	0.68	[0.01]	0.3127	0.58	0.7309	0.66	3534	9	3537	18	[100.1]

[1]n3850 is the laboratory sample code corresponding to sample 11178-1.

[2]Th/U ratios presented are calculated from measured Th and U oxides.

[3]Percentage of common ^{206}Pb in measured ^{206}Pb, calculated from the ^{204}Pb signal assuming present-day Stacey & Kramers (1975) model terrestial Pb-isotope composition. Figures in parentheses indicate that ^{204}Pb was below detection limit.

[4]Values corrected for common Pb where ^{204}Pb exceeds detection limit.

[5]Concordance (in %); shown in parentheses if analysis is concordant within 2σ uncertainty.

Table DR2. SIMS U-Th-Pb data from sample 16178-2 (Gage Ridge).

Sample/	U	Pb	Th/U[2]	$f^{206}Pb^3$	Ratios[4]				Ages[4]				Conc.[5]
spot #[1]	ppm	ppm		%	$^{207}Pb/^{206}Pb$	±σ (%)	$^{206}Pb/^{238}U$	±σ (%)	$^{207}Pb/^{206}Pb$	±σ	$^{206}Pb/^{238}U$	±σ	%
n3850-01	2200	2800	0.15	[0]	0.3931	0.70	0.8644	0.92	3883	11	4016	27	104.6
n3850-02	4500	2700	0.07	[0]	0.1651	0.35	0.5084	0.98	2508	6	2650	21	106.9
n3850-03	2200	2000	0.07	[0]	0.2739	1.60	0.6801	0.97	3328	25	3345	25	[100.6]
n3850-04	1100	650	0.09	0.02	0.1695	0.64	0.4898	0.94	2553	11	2570	20	[100.8]
n3850-05	2800	1700	0.26	[0]	0.1622	0.10	0.4873	0.97	2479	2	2559	21	103.9
n3850-06	4900	2900	0.10	[0]	0.1619	0.06	0.4987	1.1	2476	1	2608	23	106.5
n3850-07	3600	3700	0.06	0.01	0.3282	0.85	0.7767	0.92	3609	13	3705	26	[103.5]
n3850-08	1700	1300	0.07	0.02	0.2522	0.85	0.6041	0.92	3199	13	3046	22	94
n3850-09	2400	1300	0.17	[0]	0.1577	0.18	0.4514	1.0	2431	3	2401	20	[98.5]
n3850-10	5100	3100	0.07	[0]	0.1674	0.10	0.5085	0.92	2531	2	2650	20	105.7
n3850-11	4900	2900	0.07	[0]	0.1642	0.20	0.4993	0.96	2500	3	2611	21	105.4
n3850-12	4500	2700	0.07	[0]	0.1655	0.12	0.4974	0.92	2513	2	2602	20	104.3
n3850-13	3900	2300	0.43	[0]	0.1616	0.10	0.4543	0.93	2473	2	2414	19	97.2
n3850-14	1800	1100	0.05	[0]	0.17070	0.37	0.5017	1.0	2565	6	2621	22	102.7
n3850-15	1900	1100	0.05	[0]	0.1727	0.48	0.4953	0.93	2584	8	2593	20	[100.5]
n3850-16	1300	910	0.07	[0]	0.2301	0.90	0.5492	0.92	3053	14	2822	21	90.7
n3850-17	3900	3200	0.10	0.01	0.2733	1.20	0.6297	0.96	3325	19	3148	24	93.3
n3850-18	5600	3300	0.08	[0]	0.1636	0.12	0.5046	0.92	2494	2	2634	20	106.8
n3850-19	2700	1500	0.18	[0]	0.1563	0.18	0.4533	0.95	2416	3	2410	19	[99.7]
n3850-20	3200	1900	0.06	[0]	0.1645	0.24	0.4972	0.92	2502	4	2602	20	104.8
n3850-21	320	250	0.16	0.81	0.2638	1.20	0.6035	0.93	3269	19	3044	23	91.4
n3850-21r	1500	980	0.04	0.02	0.1885	1.10	0.5328	0.93	2729	18	2753	21	[101.1]
n3850-22	4000	2400	0.06	[0]	0.1662	0.23	0.5011	0.94	2519	4	2618	20	104.8
n3850-23	2100	1200	0.21	[0]	0.1619	0.28	0.4800	0.97	2476	5	2527	20	102.5
n3850-24	2000	1200	0.05	0.02	0.1854	1.20	0.5228	0.94	2702	19	2711	21	[100.4]
n3850-25	1200	720	0.08	0.01	0.1783	0.98	0.4949	0.95	2637	16	2592	20	[97.9]
n3850-26	5700	3500	0.09	[0]	0.16490	0.30	0.5103	0.93	2507	5	2658	20	107.4
n3850-27	2400	1600	0.21	0.03	0.2068	0.82	0.5372	0.91	2881	13	2772	21	95.3
n3850-28	6600	4000	0.09	[0]	0.16540	0.26	0.5124	0.96	2512	4	2667	21	107.5
n3850-29	3900	2400	0.34	[0]	0.1600	0.45	0.4795	0.92	2456	8	2525	19	103.4
n3850-30	2700	2600	0.07	[0]	0.3104	1.10	0.7163	0.93	3523	17	3482	25	[98.5]
n3850-31	2700	1700	0.04	[0]	0.1873	0.74	0.5382	0.91	2719	12	2776	21	[102.6]
n3850-32	1900	1700	0.07	[0]	0.2970	2.0	0.7053	1.2	3454	31	3441	31	[99.5]
n3850-01b	2400	2800	0.17	[0]	0.3864	0.64	0.8264	0.92	3857	10	3883	27	[100.9]
n3850-33	5700	3400	0.07	[0]	0.1634	0.14	0.5044	0.94	2491	2	2633	20	106.9
n3850-34	1300	750	0.07	[0]	0.1677	0.34	0.4871	0.91	2535	6	2558	19	[101.1]
n3850-35	1200	740	0.07	[0]	0.1760	0.85	0.4953	0.92	2616	14	2594	20	[99]
n3850-36	2500	1800	0.10	[0]	0.2146	1.20	0.5693	1.0	2941	19	2905	24	[98.5]
n3850-37	1400	1100	0.12	0.01	0.2480	1.10	0.5706	0.98	3172	18	2910	23	89.8
n3850-38	4400	5700	0.56	[0]	0.3832	0.29	0.8564	0.91	3844	4	3988	27	105
n3850-38b	2000	2200	0.30	[0]	0.3581	0.48	0.7640	0.95	3742	7	3659	27	97.1
n3850-39	1400	780	0.07	[0]	0.1648	0.22	0.4842	0.91	2506	4	2545	19	[101.9]
n3850-40	1500	1900	0.68	[0]	0.3741	0.49	0.8291	0.92	3808	7	3893	27	103
n3850-40r	2500	1600	0.07	0.01	0.1881	0.80	0.5289	0.91	2725	13	2737	20	[100.5]
n3850-41	2600	1800	0.06	0.02	0.2202	1.10	0.5530	0.94	2982	18	2837	22	94
n3850-42	7100	4400	0.10	[0]	0.1647	0.08	0.5174	0.91	2504	1	2688	20	109
n3850-43	4000	2300	0.08	[0]	0.1630	0.25	0.4949	0.92	2487	4	2592	20	105.1
n3850-44	3600	2000	0.11	[0]	0.1609	0.13	0.4812	0.91	2465	2	2533	19	103.3
n3850-45	1200	1000	0.03	[0]	0.2718	1.70	0.6468	1.1	3317	26	3216	27	[96.1]
n3850-46	3700	2200	0.07	[0]	0.1633	0.21	0.4920	0.92	2490	4	2580	20	104.3
n3850-47	4600	4300	0.08	[0]	0.2958	0.76	0.7124	0.92	3448	12	3468	25	[100.7]
n3850-48	2200	2200	0.10	[0]	0.3219	0.87	0.7342	0.97	3579	13	3549	26	[98.9]
n3850-49	280	340	0.66	0.01	0.3602	0.88	0.7820	0.94	3751	13	3724	27	[99.1]
n3850-49r	550	650	0.80	0.02	0.3438	0.27	0.7544	0.92	3680	4	3624	25	[98]
n3850-50	1900	1100	0.37	0.01	0.1620	0.11	0.4722	0.92	2477	2	2493	19	[100.8]
n3850-51	1800	1000	0.07	0.01	0.1673	0.47	0.4869	0.92	2531	8	2557	20	[101.3]
n3850-51r	3900	2300	0.09	[0]	0.1621	0.14	0.4893	0.92	2478	2	2567	19	104.4
n3850-52	1800	1500	0.07	[0]	0.2747	1.0	0.6213	0.93	3333	16	3115	23	91.8
n3850-53	3400	1900	0.06	[0]	0.1644	0.14	0.4925	0.91	2502	2	2581	19	103.9
n3850-53r	4900	2900	0.09	[0]	0.1638	0.11	0.5013	0.92	2496	2	2620	20	106.1
n3850-54	1100	660	0.08	0.01	0.1814	0.58	0.4971	0.93	2666	10	2601	20	[97.1]
n3850-54r	1200	750	0.07	0.02	0.2161	0.89	0.5263	0.96	2952	14	2726	21	90.6
n3850-55	980	550	0.06	0.01	0.1644	0.36	0.4792	0.91	2501	6	2524	19	[101.1]
n3850-56	1800	1100	0.09	0.04	0.1811	1.30	0.4820	0.96	2663	21	2536	20	94.2
n3850-56r	3400	2600	0.05	[0]	0.2614	2.30	0.600	1.7	3255	35	3030	42	[91.4]
n3850-57	1500	1000	0.05	0.01	0.2079	1.20	0.5349	1.0	2889	19	2762	24	94.6
n3850-57r	1900	1100	0.06	0.01	0.1787	1.50	0.5076	0.93	2641	24	2646	20	[100.2]
n3850-58	1400	1400	0.07	0.01	0.3312	1.10	0.7431	1.0	3623	17	3582	28	[98.5]
n3850-58r	2500	2400	0.07	[0]	0.3046	0.95	0.7226	1.0	3494	15	3506	28	[100.4]
n3850-59	1300	900	0.07	0.01	0.2176	0.59	0.5460	0.94	2963	10	2809	22	93.6
n3850-59r	1600	950	0.07	0.01	0.1812	0.84	0.4983	0.96	2664	14	2606	21	[97.4]
n3850-60	3600	1900	0.13	[0]	0.1528	0.17	0.4511	0.92	2377	3	2400	18	[101.2]
n3850-61	300	170	0.34	0.02	0.1619	0.30	0.4662	0.92	2475	5	2467	19	[99.6]
n3850-62	4100	2600	0.30	[0]	0.1728	0.29	0.5021	0.91	2585	5	2623	20	[101.8]

continued

Table DR2, continued

Sample/ spot #[1]	U ppm	Pb ppm	Th/U[2]	f^{206}Pb[3] %	Ratios[4] ^{207}Pb/^{206}Pb	±σ (%)	^{206}Pb/^{238}U	±σ (%)	Ages[4] ^{207}Pb/^{206}Pb	±σ	^{206}Pb/^{238}U	±σ	Conc.[5] %
n3850-62r	1600	940	0.12	0.01	0.1658	0.64	0.4783	0.98	2516	11	2520	20	[100.2]
n3850-63	2500	1900	0.03	0.02	0.2472	1.40	0.6097	0.92	3167	22	3069	22	[96.1]
n3850-64	1200	760	0.07	0.09	0.2062	1.40	0.5153	0.96	2876	22	2679	21	91.6
n3850-65	530	290	0.13	0.02	0.16000	0.19	0.4659	0.64	2456	3	2465	13	[100.5]
n3850-66	2900	2400	0.05	0.03	0.2765	0.99	0.6331	0.62	3344	15	3162	15	93.1
n3850-67	2500	1600	0.06	0.04	0.2043	1.70	0.5106	0.62	2861	27	2659	14	91.4
n3850-68	3300	1900	0.03	[0]	0.1726	0.53	0.5001	0.61	2583	9	2614	13	[101.5]
n3850-69	1300	890	0.08	0.02	0.2317	1.40	0.5574	0.77	3064	22	2856	18	91.6
n3850-70	1600	940	0.15	0.01	0.1625	0.19	0.4819	0.64	2482	3	2535	13	102.6
n3850-71	4600	2700	0.08	[0]	0.1658	0.28	0.5009	0.66	2515	5	2618	14	105
n3850-73	1800	1500	0.19	0.02	0.2854	1.50	0.6189	0.85	3393	23	3105	21	89.4
n3850-74	3700	2100	0.02	[0]	0.1665	0.40	0.4974	0.63	2523	7	2602	13	103.9
n3850-75	2800	1600	0.31	[0.01]	0.1620	0.27	0.4741	0.62	2477	5	2502	13	[101.2]
n3850-76	1500	900	0.07	[0]	0.1833	0.56	0.5001	0.61	2683	9	2614	13	96.9
n3850-77	1800	1100	0.06	0.01	0.1964	0.91	0.5249	0.62	2796	15	2720	14	[96.7]
n3850-78	2000	1700	0.19	[0]	0.2965	0.52	0.6585	0.62	3452	8	3261	16	93
n3850-79	2100	1300	0.05	[0]	0.1804	0.45	0.5091	0.61	2656	8	2653	13	[99.9]
n3850-80	1600	1000	0.05	0.01	0.1958	1.20	0.5269	0.62	2792	20	2728	14	[97.2]
n3850-81	3400	1600	0.15	0.05	0.14940	0.17	0.3846	0.80	2339	3	2098	14	87.9
n3850-82	5300	3100	0.09	[0]	0.1635	0.42	0.4977	0.65	2492	7	2604	14	105.5
n3850-83	2200	1300	0.32	0.02	0.1555	0.11	0.4573	0.66	2408	2	2428	13	[101]
n3850-84	1500	930	0.07	1.03	0.1860	1.50	0.5080	0.83	2707	25	2648	18	[97.4]
n3850-85	1800	1100	0.06	[0]	0.1853	1.20	0.5011	0.64	2701	19	2619	14	[96.3]
n3850-86	930	560	0.08	[0]	0.1859	1.30	0.4947	0.67	2707	22	2591	14	[94.8]

[1]n3850 is the laboratory sample code corresponding to sample 16178-2.
[2]Th/U ratios presented are calculated from measured Th and U oxides.
[3]Percentage of common ^{206}Pb in measured ^{206}Pb, calculated from the ^{204}Pb signal assuming present-day Stacey & Kramers (1975) model terrestial Pb-isotope composition. Figures in parentheses indicate that ^{204}Pb was below detection limit.
[4]Values corrected for common Pb where ^{204}Pb exceeds detection limit.
[5]Concordance (in %); shown in parentheses if analysis is concordant within 2σ uncertainty.

Table DR3. Pb isotope and age data from defined areas of the ion images of zircons from samples 11178-1 and 16178-2

area ID[1]	area	equiv. dia.	^{206}Pb	measured ratios[2]				$f\,^{206}$Pb[3]	corrected ratios[4]		age[4] (Ma) ± 2σ		
	µm^2	µm	Σ counts	^{204}Pb/^{206}Pb	±σ (%)	^{207}Pb/^{206}Pb	±σ (%)	(%)	^{207}Pb/^{206}Pb	±σ (%)			
Sample 11178-2 (Spot Height 945, Dallwitz Nunatak)													
e-1	10	3.5	996	0	n/a	0.4701	5.59	[0]	0.4701	5.6	4150	±	166
e-2	23	5.4	10390	0.00009	100	0.3504	1.92	[0.16]	0.3496	1.9	3705	±	59
e-3	18	4.8	8698	0	n/a	0.3744	2.05	[0]	0.3744	2.0	3809	±	62
e-4	23	5.4	19110	0	n/a	0.3230	1.46	[0]	0.3230	1.5	3584	±	45
e-5	30	6.1	10760	0.00009	100	0.3036	1.99	[0.16]	0.3027	2.0	3484	±	63
e-6	36	6.7	5075	0.00036	71	0.1918	3.49	[0.67]	0.1874	4.0	2719	±	131
Sample 16178-2 (Gage Ridge)													
e-1	1269	40.2	4049500	0.00001	16	0.3135	0.10	<0.01	0.3135	0.10	3538	±	3
e-2	1439	42.8	684500	0.00006	14	0.2834	0.26	0.17	0.2825	0.27	3377	±	8
f-1	186	15.4	113800	0.00006	35	0.2731	0.64	0.12	0.2724	0.65	3320	±	20
f-2	206	16.2	64200	0.00009	41	0.3042	0.82	[0.16]	0.3034	0.83	3487	±	26
f-3	147	13.7	46640	0.00013	45	0.3668	0.97	[0.23]	0.3657	1.0	3774	±	30
f-4	209	16.3	71060	0.00009	38	0.2918	0.79	[0.17]	0.2908	0.80	3422	±	25
f-5	140	13.3	53530	0.00011	38	0.3267	0.78	[0.2]	0.3256	0.80	3597	±	24
f-6	200	16.0	533900	0.00002	33	0.3056	0.28	[0.03]	0.3054	0.28	3498	±	9
f-7	153	14.0	18610	0.000005	71	0.3273	0.31	0.01	0.3273	0.31	3604	±	10
f-8	201	16.0	862400	0.00001	35	0.3235	0.22	[0.02]	0.3234	0.22	3586	±	7
g-1	7.3	3.1	4320	0.00007	71	0.4855	2.66	[<0.01]	0.4855	2.7	4198	±	79
g-2	7.3	3.1	5133	0	n/a	0.4634	2.48	[0]	0.4634	2.5	4129	±	73
g-3	15	4.4	25990	0.00007	71	0.3818	1.18	[0.13]	0.3812	1.2	3836	±	36
g-4	13	4.0	34380	0.00003	100	0.3778	1.03	[0.05]	0.3775	1.0	3822	±	31
g-5	7.8	3.1	21600	0.00004	100	0.3968	1.27	[0.08]	0.3965	1.3	3896	±	38
g-6	7.1	3.0	16070	0	n/a	0.3861	1.49	[0]	0.3861	1.5	3856	±	45
g-7	9.0	3.4	5858	0	n/a	0.4022	2.43	[0]	0.4022	2.4	3917	±	73

[1]Area ID corresponds to areas used for calculation outlined in Figures 2e and 3e-g.

[2]Measured ratios are corrected for detector gains. Uncertainties are counting statistic (Poisson) errors, n/a = not applicable.

[3]Percentage of common ^{206}Pb in measured ^{206}Pb, calculated from the ^{204}Pb signal assuming present-day Stacey & Kramers (1975) model terrestial Pb-isotope composition. Figures in parentheses indicate that ^{204}Pb was below detection limit.

[4]Values corrected for common Pb where ^{204}Pb exceeds detection limit.