



Fig. A1

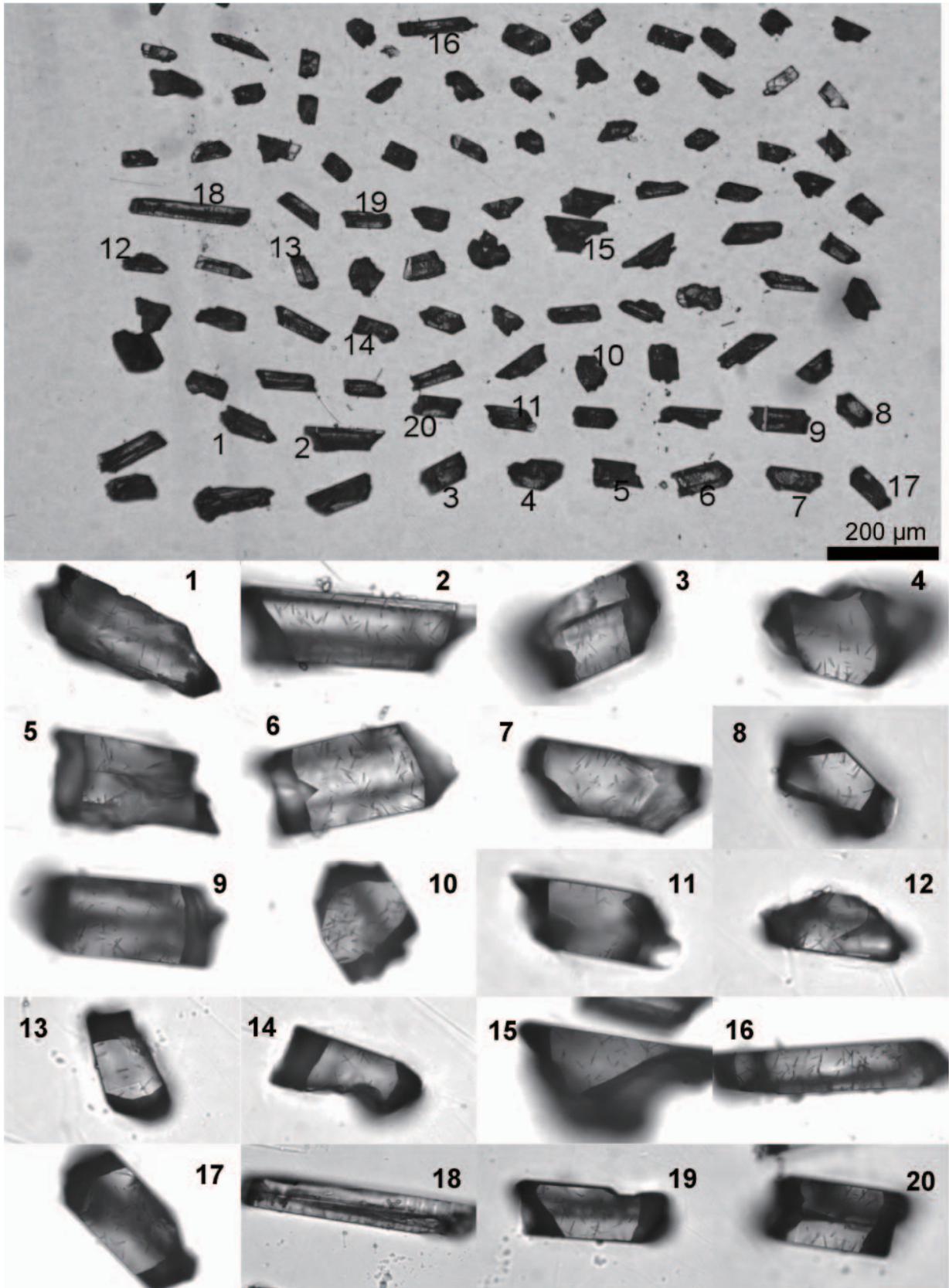


Fig. A2

Laser ablation		
Instrument	IFRIT (Cyber Laser Inc., Tokyo Japan)	
Laser type	Type-C Ti:S femtosecond laser	
Pulse duration	230 fs	
Wave length	260 nm (THG)	
Energy density	2–3 J/cm ²	
Crater size	15 μm	
Repetition rate	10 Hz	
Galvanometric optics	Used for two-spot analysis per grain	
Carrier gas	He	
ICP-MS		
Model	Thermo Fisher Scientific iCAP-Qc	
ICP-MS type	Quadrupole	
Forward power	1400 W	
Carrier gas	Ar	
Ar gas flow rate	0.9 L/min	
He gas flow rate	0.6 L/min	
Scanning mode	Standard mode (no collision gas was used)	
Data acquisition protocol	Time-resolved analysis	
Integration time	50 s (15 s for gas blank, 35s for ablation signal)	
Monitor isotopes	²⁹ Si, ²⁰² Hg, ²⁰⁴ Pb, ²⁰⁶ Pb, ²⁰⁷ Pb, ²⁰⁸ Pb, ²³² Th, ²³⁸ U	
Dwell time	0.2 s for ²⁰⁶ Pb, ²⁰⁷ Pb, 0.1 s for others	
Primary and secondary standards	Nancy 91500 * ¹ , OD-3 * ^{2,3,4} for U-Pb Fish Canyon Tuff * ⁵ , Buluk Member Tuff * ⁵ for FT Nancy 91500 * ^{1,6} for U-concentration	

* 1, Wiedenbeck et al. (1995); * 2, Iwano et al. (2012); * 3, Iwano et al. (2013);
* 4, Lukács et al. (2015); * 5, Danhara and Iwano (2013); * 6, Iwano (unpublished)

Table. A1

Sample Spot no.	Isotopic ratios				U-Pb Age (Ma)				Th/U	Remarks		
	$\frac{^{207}\text{Pb}}{^{206}\text{Pb}}$	Error 2 σ	$\frac{^{206}\text{Pb}}{^{238}\text{U}}$	Error 2 σ	$\frac{^{207}\text{Pb}}{^{235}\text{U}}$	Error 2 σ	$\frac{^{206}\text{Pb}}{^{238}\text{U}}$	Error 2 σ			$\frac{^{207}\text{Pb}}{^{235}\text{U}}$	Error 2 σ
Tsukuriyama Laccolith												
no.1	0.2265 ±	0.1075	0.00302 ±	0.00070	0.0945 ±	0.0420	19.4 ±	4.5	91.7 ±	41.8	2.57	Discordant
no.2	0.0372 ±	0.0340	0.00281 ±	0.00064	0.0145 ±	0.0130	18.1 ±	4.1	14.6 ±	13.1	2.93	
no.3	0.0805 ±	0.0851	0.00244 ±	0.00081	0.0272 ±	0.0280	15.7 ±	5.2	27.3 ±	28.1	2.67	
no.4	0.1273 ±	0.0956	0.00235 ±	0.00068	0.0413 ±	0.0297	15.1 ±	4.4	41.1 ±	29.7	3.51	
no.5	0.0857 ±	0.0826	0.00298 ±	0.00093	0.0353 ±	0.0332	19.2 ±	6.0	35.2 ±	33.2	2.12	
no.6	0.1751 ±	0.0914	0.00427 ±	0.00100	0.1034 ±	0.0520	27.4 ±	6.4	99.9 ±	51.5	2.03	Discordant
no.7	0.0670 ±	0.0803	0.00226 ±	0.00077	0.0209 ±	0.0245	14.5 ±	5.0	21.0 ±	24.6	4.40	
no.8	0.2420 ±	0.0960	0.00643 ±	0.00129	0.2156 ±	0.0833	41.3 ±	8.3	198.2 ±	81.2	1.67	Discordant
no.9	0.0075 ±	0.0277	0.00275 ±	0.00101	0.0029 ±	0.0105	17.7 ±	6.5	2.9 ±	10.6	1.63	
no.10	0.0811 ±	0.0650	0.00254 ±	0.00067	0.0285 ±	0.0222	16.4 ±	4.3	28.6 ±	22.3	3.77	
no.11	0.3321 ±	0.1674	0.00304 ±	0.00082	0.1399 ±	0.0655	19.6 ±	5.3	132.9 ±	64.4	2.30	Discordant
no.12	0.0770 ±	0.0696	0.00222 ±	0.00063	0.0236 ±	0.0207	14.3 ±	4.1	23.7 ±	20.8	3.82	
no.13	0.2242 ±	0.1019	0.00370 ±	0.00082	0.1149 ±	0.0494	23.8 ±	5.3	110.4 ±	48.9	3.36	Discordant
no.14	0.6424 ±	0.2385	0.00557 ±	0.00127	0.4956 ±	0.1773	35.8 ±	8.2	408.7 ±	165.7	3.41	Discordant
no.15	0.1574 ±	0.0979	0.00254 ±	0.00067	0.0554 ±	0.0327	16.4 ±	4.3	54.7 ±	32.7	2.14	Discordant
no.16	0.1309 ±	0.0725	0.00258 ±	0.00058	0.0467 ±	0.0246	16.6 ±	3.8	46.3 ±	24.6	3.50	Discordant
no.17	0.0724 ±	0.1204	0.00168 ±	0.00080	0.0169 ±	0.0273	10.8 ±	5.2	17.0 ±	27.3	2.38	
no.18	0.0733 ±	0.0624	0.00254 ±	0.00068	0.0257 ±	0.0213	16.3 ±	4.4	25.8 ±	21.4	2.49	
no.19	0.0793 ±	0.0473	0.00285 ±	0.00060	0.0312 ±	0.0180	18.3 ±	3.8	31.2 ±	18.1	2.83	
no.20	0.1636 ±	0.0784	0.00366 ±	0.00079	0.0828 ±	0.0378	23.5 ±	5.1	80.8 ±	37.7	2.35	Discordant
weighted average for concordant data (n=11):							16.1 ±	1.4	17.9 ±	5.7		
OD-3 standard (33 Ma)												
OD3 5-1	0.0507 ±	0.0320	0.00512 ±	0.00100	0.0359 ±	0.0222	32.9 ±	6.4	35.8 ±	22.3	1.17	
OD3 5-2	0.0252 ±	0.0252	0.00529 ±	0.00114	0.0185 ±	0.0184	34.0 ±	7.3	18.6 ±	18.5	1.10	
OD3 5-3	0.0459 ±	0.0287	0.00508 ±	0.00096	0.0323 ±	0.0198	32.7 ±	6.2	32.3 ±	19.9	1.11	
OD3 6-1	0.0432 ±	0.0237	0.00491 ±	0.00086	0.0294 ±	0.0157	31.6 ±	5.6	29.4 ±	15.8	1.12	
OD3 6-2	0.0360 ±	0.0238	0.00483 ±	0.00090	0.0241 ±	0.0157	31.1 ±	5.8	24.1 ±	15.8	1.30	
OD3 6-3	0.0442 ±	0.0297	0.00495 ±	0.00097	0.0303 ±	0.0200	31.8 ±	6.2	30.3 ±	20.1	1.25	

Table. A2

Grain No	Fission Track Data			LA-ICPMS Data				Calculated			
	N _s	Area (10 ⁻⁶ cm ²)	ρ _s (10 ⁶ cm ⁻²)	Sample		91500 (74 ppm)		U _{ICP} (ppm)	Age (Ma)		
				n	Area-corrected N _{U-SP}	ρ _{U-SP} (10 ¹¹ cm ⁻²)	N _{U-STD}		ρ _{U-STD} (10 ¹⁰ cm ⁻²)	T	± 2σ
no.1	21	8.0	2.63	2	1349767	1.687	67620	1.914	652	14.2	6.4
no.2	36	14.0	2.57	2	2269553	1.621	67620	1.914	627	14.5	5.1
no.3	18	6.0	3.00	2	561388	0.936	67620	1.914	362	29.3	14.2
no.4	11	9.0	1.22	2	1015698	1.129	67620	1.914	436	9.9	6.1
no.5	12	4.0	3.00	2	464229	1.161	67620	1.914	449	23.6	13.9
no.6	44	20.0	2.20	2	2466895	1.233	67620	1.914	477	16.3	5.2
no.7	23	10.0	2.30	2	1120193	1.120	67620	1.914	433	18.8	8.1
no.8	9	6.0	1.50	2	781073	1.302	67620	1.914	503	10.6	7.1
no.9	29	15.0	1.93	2	1571422	1.048	67620	1.914	405	16.9	6.5
no.10	22	6.0	3.67	2	1232801	2.055	67620	1.914	794	16.3	7.2
no.11	4	6.0	0.67	2	711979	1.187	67620	1.914	459	5.1	5.2
no.12	9	3.0	3.00	2	430408	1.435	67620	1.914	555	19.1	12.9
no.13	6	4.0	1.50	2	591258	1.478	67620	1.914	571	9.3	7.7
no.14	5	4.0	1.25	2	298844	0.747	67620	1.914	289	15.3	13.8
no.15	7	6.0	1.17	2	645527	1.076	67620	1.914	416	9.9	7.6
no.16	32	7.0	4.57	2	1375317	1.965	67620	1.914	760	21.3	7.9
no.17	15	8.0	1.88	2	851872	1.065	67620	1.914	412	16.1	8.5
no.18	22	10.0	2.20	2	1138524	1.139	67620	1.914	440	17.7	7.8
no.19	23	8.0	2.88	2	1433847	1.792	67620	1.914	693	14.7	6.3
no.20	14	7.0	2.00	2	840981	1.201	67620	1.914	464	15.2	8.3
Pooled (n=20)	362	161	2.25		21151577	1.314	67620	1.914	508	15.7	2.4
N _s	Number of spontaneous fission tracks counted					λ _D	Total decay constant of ²³⁸ U (= 1.55125 x 10 ⁻¹⁰ y ⁻¹)				
A	Counting area					ζ _{MS}	Zeta calibration factor determined by LA-ICP-MS				
ρ _s	Spontaneous track density (= N _s /A)						ζ _λ	47.9 ± 2.6			
n	Number of spots analyzed					g	Geometry factor (=0.5)				
[U]	Uranium concentration in ppm					m _i	= (²³⁸ U/ ²⁹ Si) _{sample} / (²³⁸ U/ ²⁹ Si) _{U-standard} for zircon grain i				
FT age	t _{FT} = (1/λ _D)ln(1+λ _D ζ _{MS} gρ _s /m _i) = (1/λ _D)ln(1+λ _D ζ _{MS} gN _s ρ _{U-STD} /N _{U-SP})						Uranium stand Nancy 91500 (fraction A), 74 ppm U Age standard Fish Canyon Tuff (28.4 ± 0.2Ma: Danhara and Iwano, 2013) : Primary				
Error of FT age	σ = t _{FT} (1/N _s +1/N _{U-SP} +1/N _{U-STD} +σ _ζ ²) ⁻²										

Table. A3